PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

November 1, 1966, Through November 30, 1966

FOR INTERNAL USE ONLY

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-66-11

MONTHLY PROGRESS REPORT

(November 1, 1966, Through November 30, 1966)

By

Advanced Studies Office
Vehicle Systems Division
Structures Division
Materials Division
Propulsion Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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R-P&VE-A-66-11

MONTHLY PROGRESS REPORT
ADVANCED STUDIES OFFICE
(November 1, 1966, Through November 30, 1966)

SATURN V

I. Voyager Program

A. Shroud Design Study

On November 18, 1966, a status review was held on the MSFC in-house Voyager shroud design study. The following items of progress were noted:

1. Voyager Planetary Vehicle dynamic envelopes have been defined by MSFC and JPL and published.

2. The Voyager/Saturn V launch vehicle configuration has been defined and published.

3. The Voyager/Saturn V launch vehicle weight summary has been compiled and published.

4. Launch vehicle flight trajectory has been calculated and vehicle aerodynamics largely determined.

5. Shroud separation study has been initiated.

6. Shroud venting analysis has been initiated.

7. Structural design study has been initiated.

8. KSC contacts have been established.

The midterm review to MSFC management, recently rescheduled for December 20, 1966, now will be a presentation to Dr. von Braun and other MSFC management officials; however, this presentation is now planned for December 22, 1966, or possibly later, and a dry run for the presentation is scheduled for December 20. Consequently, the midterm review with JPL will be delayed another one or two weeks.

B. Shroud Separation Study

A study is underway of various design parameters influencing the Voyager shroud separation from the S-IVB stage after planetary injection. Some of the parameters being investigated are vehicle rotation, separation thrust misalignment, and center of gravity misalignment to the shroud and, thus, to the clearance between the shroud and the Voyager vehicle during shroud separation. This effort is scheduled to be completed by December 21.

C. Spacecraft Design

It has been decided by the Director of P&VE Laboratory that all efforts required of P&VE on this study will, at the present time, be channeled through Mr. Goerner (876-8976), and he will represent the Director in arranging appropriate participation of the various disciplines of the Laboratory. Mr. Orillion (876-1688), of this Office, will be the point of contact if Mr. Goerner should not be available.

II. S-IC Thrust Tailoring

A study has been initiated to determine the feasibility of reducing critical structural loading in the Saturn V vehicle by tailoring the thrust trace during S-IC burn. Sea level thrust versus S-IC burning time was developed for thrust variations of 5, 10, 15, and 20 per cent of nominal thrust. These data, along with the propellant flow rates for each thrust variation, were supplied to R-AERO-X for performance evaluation. The resulting trajectory data will be given to R-P&VE-S for structural analyses.

III. Three-burn S-IVB

A preliminary performance study has been initiated to determine the payload capability to various orbits ranging from 100 n. mi. to an inclined synchronous orbit of the Saturn V launch vehicle utilizing a three-burn S-IVB stage. The study is essentially complete and results will be published shortly.

Another study, utilizing a three-burn S-IVB, has been initiated to determine the feasibility of injecting an S-IVB into lunar orbit. The third burn of the S-IVB would be used to brake the stage to a lunar orbit.

An in-house study has been initiated concerning the identification of future missions which utilize a three-burn S-IVB stage on the Saturn V vehicle. The objectives of phase I of the study are (1) to identify as many three-burn missions as possible, and (2) to select, from these, several for specific investigation. This will include trajectory, payload, experiment packaging, and vehicle and stage performance requirements. It is expected that the results of the study will add significantly to the list of known uses for a three-burn S-IVB stage and will assist MSFC in future planning concerning this capability. Phase II of the study will concentrate on detailed definition of two or three missions selected from Phase I.

As a result of a meeting held in early November and attended by IO and R-P&VE personnel, Douglas Aircraft Company has been asked to quote their cost and schedule requirements in ECP format for only the long lead modifications to the S-IVB stage required for a three-burn capability. The cost estimates will be quoted by fiscal year beginning in FY-67 with vehicle AS-509. This new ECP will be handled through normal channels. The justification for its approval is based on adding versatility to the stage in accordance with Apollo Program Directive 18.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

A. Early Synchronous Orbit Mission Study (SA-510)

In support of the SA-510 Synchronous Orbit Mission study, this Office has generated preliminary payload weights and layouts to evaluate compatibility of the selected experiments and support systems with the existing Saturn V/Apollo vehicle. The payload consists of a CSM, LM ascent stage, RACK, and ten selected synchronous orbit experiments with supporting systems. Based on available information, the selected experiments and required support systems appear within the Saturn V/Apollo weight and volume constraints.

B. Project THERMO

The mission profile analyses are continuing and will be completed in early December 1966. Primary emphasis is being given to a cluster mission mode where the Project THERMO payload is launched unmanned and operated in conjunction with the Orbital Workshop/ATM/Resupply Module Cluster. A single launch configuration is also being considered which

involves, because of weight limitations, the use of a two-man air lock rather than the LM Ascent Stage. Related studies have been initiated with R-AERO and R-ASTR concerning astronaut timeline analyses, orbital mechanics, and a dynamic analysis of the THERMO/cluster, based on the cluster mission mode.

C. LEM Orbital Operations Applications

A study of LEM performance capability for lunar and earth orbital operations missions was initiated. LEM payloads are being evaluated for rendezvous, low/high orbit transfer, plane change, and docking missions. In the analysis, both the two-stage and the LEM ascent stage are being considered for the mission evaluations. For extending mission capability of the LEM, a maximum propellant capacity increase of 50 per cent is being considered.

II. Lunar Surface

A. LSSM 1/6-g Flight Test

The 1/6-g flight test of the LSSM mock-up was postponed from November 28, 1966, to December 5, 1966. The delay was caused by necessary maintenance on the KC-135 aircraft. The LSSM will be installed in the KC-135 during overhaul and the flight test will be completed by December 9, 1966.

B. Augmented Lunar Module (ALM)

A study has been initiated to assess certain problem areas associated with the proposed Augmented Lunar Module (ALM) program and to determine the impact on the present Saturn V/Apollo program. Engineering requirements imposed upon the CSM as a result of the ALM vehicle will be investigated in addition to determining what portion of the injected lunar payload must be allocated to the CSM. Since the current ALM concepts require increased payload, the Saturn V launch vehicle will be investigated to determine what degree of uprating can be accomplished by product-type improvements. Also, in the event growth potential is required on the ALM program, approaches will be investigated for increasing the injected lunar payload to 105,000 pounds.

III. Integration

A. AAP Experiment Catalog

A new data retrieval program has now been completed and checked out using five sample experiments from the catalog data bank. Approximately 80 experiments have been converted to the new format and are ready for input into the data bank.

B. Earth Orbit Mission Simulation Program

A draft report on the Earth Orbit Mission Simulation program has been completed and is being edited. In addition, a study has begun to generate a new Mission Simulation Program incorporating a considerable number of improvements suggested by experience with the present program. Some of the more important improvements are an automatic data plotting routine, a graduated priority scale, a power check, and an orbit selection routine. The data plotting routine has now been completed and checked out. This revised program will be operational in late January 1967.

NUCLEAR ROCKET PROGRAM

I. Radiation Environment

Final documentation on this effort has been prepared and distributed. No extension of this effort is planned at present.

II. Stage System Studies

A. Nuclear Vehicle Boil-off Sensitivity Study

The initial phase of this study, which established a reference configuration and weights, has been completed, documented, and distributed. A follow-on effort is presently underway. In this phase, vehicle weights will be refined somewhat and boil-off effects will be established. The effects of boil-off on individual stage size and weight and on total assembled weight in earth orbit (IMIEO)* will be shown as a function of per cent boil-off. Documentation is scheduled to begin in early January 1967.

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* IMIEO = Initial Mass In Earth Orbit

B. Earth and Orbital Operations

A study is underway to determine for the Mars landing mission (a) the impact on earth launch vehicle height of nuclear stage diameter, engine length, and thrust structure geometry; and (b) the details of a scheme for rendezvous of nuclear stages and the mission spacecraft in earth orbit. The primary objective of part (a) of the study is to determine the diameter required for the nuclear stage to be consistent with the 416-foot launch vehicle height limitation imposed by KSC. The propellant loading of the nuclear stage is fixed by the mission spacecraft weight of 332,300 pounds and a two-module, earth-escape orbit launch vehicle configuration. In part (b) of the study the rendezvous sequence of orbital assembly is to be investigated fully, considering rendezvous by a kick stage, LEM configuration, or Service Module. Devices for docking the stages, such as television cameras, as well as devices for rotating the two modules of the earth escape stage are to be considered.

III. Nuclear GTM Requirements

A program outline has been prepared and submitted to R-P&VE management; however, the study efforts cannot commence until R-AS submits their GTM criteria evaluation report.

ADVANCED PROGRAMS

I. Launch Vehicle

A. Pump-fed Stage Study

The study of pump-fed storable stages for the Mars fly-by mission and the comparison of these stages with pressure-fed stages has been completed. Study results show that pump-fed stages designed around the second stage Titan engines have higher mass fractions than pressure-fed stages. The pump-fed stage orbit launch vehicles therefore show a higher payload per pound of propellant. The mass fraction advantage for the pump-fed stage is primarily due to the lighter tankage weight which is possible with the lower tank pressure and the aluminum material. The pressure-fed stage concept requires high tank pressure (to allow for engine pressure drop) and steel construction.

B. Kick Stage Engine Sizing

A joint study effort between the R-P&VE and R-AERO Advanced Studies Offices to evaluate the engine size required for Hohmann transfers between earth orbits has been completed. A primary conclusion from the study is that thrust level has an insignificant effect on ΔV for the Hohmann transfer mission; therefore, engine thrust level selection must be made only on allowable engine burn time. A final conclusion is that adequate vehicle performance calculations can be made from the simple orbital mechanics calculations for ΔV.

C. Docking Structure Design

The first phase of a study of docking structure designs for mating orbit launch vehicle stages was completed. In this phase of the study, ten concepts were evaluated from which two concepts were selected for detailed analysis. The cone and ring concept proposed by LMSC was structurally evaluated in detail in this phase of the study for a diameter of 260 inches and a scaling relation for docking structure weight defined for diameters from 120 to 396 inches. A significant conclusion from the structural analysis for designing the 260-inch docking structure was that closing velocity has a profound effect on docking structure weight.

In the second phase of the study a bumper and ring docking structure concept proposed by NAA for reducing docking structure weight is to be evaluated. This phase is scheduled for completion in January 1967.

D. Liquid Strap-on Pods

The study to determine the payload capability of pressure-fed liquid strap-on pods for the S-IC stage is continuing. The optimum chamber pressure, mixture ratio, and specific impulse are being determined in order to deliver 660,000 pounds of payload to a 100-n. mi. orbit, using standard or improved Saturn V vehicles.

II. Earth Orbital

A. Advanced S-IVB Workshop

An MSFC-wide in-house system study on the advanced S-IVB spent stage and one-year workshop has been proposed by R-AS; however, the manner of implementing this study has not been agreed upon. A significant effort is being expended by this Office in preparation of the

new S-IVB Workshop advanced study contract. Presentations were given to the P&VE weekly Technical Seminar and the Study Management Panel for this contract on November 2 and 7, 1966, respectively, covering the evolution of S-IVB workshop designs from AS-209 through a ground-fitted five-year space station.

Several concepts have been developed in-house for the one-year S-IVB ground-fitted space station. The location of the subsystem module, number of floors required, and the possible addition of a pressurized compartment enclosing the IU are the major variables in these concepts. Several concepts of internal structure arrangements and methods of attaching this structure and equipment to the S-IVB tank wall have also been developed, since this is one of the major problems encountered in the design of the one-year ground-assembled workshop. This problem, along with the estimated structural testing requirements, has been discussed with representatives of the Structures Division. These discussions will continue until specific designs are selected.

The type of environmental control, passive or active, will have considerable effect on the selected concept for the one-year station. This problem was discussed with representatives of Propulsion Division and it was recommended that an active system with additional insulation to the stage be the preferred method until further thermal analysis is conducted.

Definitions of the various subsystem requirements for the Advanced Spent Stage and One-year Ground-fitted Workshop are in progress. A matrix of requirements and feasible approaches has been developed for each of the subsystems, primarily utilizing the Saturn/Apollo systems. Power, communications, and data handling requirements for the evolution study are also being investigated by R-ASTR. A preliminary weight statement of the environmental control and power system expendables and resupply requirements for the advanced spent stage and one-year station have been developed.

The proposals for the S-IVB Workshop Advanced Study Contract have been received and the evaluation is scheduled to be completed by December 2, 1966, with a projected contract initiation date of January 10, 1967. The seven-month study ($400 - $500 K) is intended to design an advanced S-IVB spent stage and a one-year ground-fitted S-IVB space station. R-AS is initiating an activity through IO with the AAP integration contractors covering some aspects of the advanced S-IVB spent stage.

B. Five-year Space Station Study

The design activity under this study was essentially curtailed in October; however, the final reports and presentations have just been completed. Presentation material on the one-year workshop was prepared for Mr. Williams' November 22 briefing to Dr. Seamans and the compilation of data on the S-IVB workshop station for the final report (Workshop Evolution from AS-209, One-year Workshop, and Five-year Workshop) was just completed. No further activity is anticipated.

III. Lunar

The final presentation on the Mobility Evolution and Comparison study by Bendix Systems Division was held at MSFC on November 17, 1966. Final copies of the Design Point Vehicle (DPV) data books have been delivered to MSFC and the final report is due by December 3, 1966. At present, there are no funds available to continue the study; however, Bendix has proposed two schemes for a follow-on effort.

A computer program developed by Bendix in MOBEV is being adapted to MSFC computers by a Bendix programmer. The program will be available for MSFC use by mid-December 1966.

IV. Planetary

A. Mars/Venus Fly-by Studies

The first interim presentation on the study of Manned Mars/Venus Fly-by Missions was held at MSFC on November 2 and 3, 1966. A meeting was held in Washington on November 22, 1966, to discuss how the MSFC in-house planetary JAG results would be used in the current study and to agree on some intermediate objectives and guidelines. At this meeting it was agreed to give the contractors (NAA and DAC) a copy of the JAG concept which would be evaluated along with the other concepts established in Phase III of the mission study. NASA Headquarters also mentioned that IBM had been contacted and had agreed to perform work on the IU in support of the fly-by studies. Therefore, on November 23, 1966, a briefing was held for personnel from IBM and R-ASTR on the Mars/Venus Fly-by Studies.

B. Double Fly-by of Mars

A task has been initiated to determine the feasibility of making a double fly-by of the planet Mars with a manned spacecraft. A probe would be ejected and landed on Mars during the first pass (outbound leg) and would rendezvous with the spacecraft on the second pass (inbound leg). Task completion is scheduled for December 21, 1966.

C. Mars Soil Sample Return Probe

Effort has continued to conceptually define an unmanned surface probe capable of landing on the Mars surface, collecting a soil sample, and returning to the fly-by spacecraft. Methods of collecting the sample and retrieving the return module have been evaluated. The descent and ascent propulsion stages are presently being evaluated. This involves defining the number of stages and determining the type propulsion system which would best satisfy the mission objectives. Spin stabilization is being considered for the ascent phase of the flight. This could result in a considerable reduction of the probe weight. Final results, or concept definition, are expected by December 30, 1966.

Erich E. Goerner
Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-66-11

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(November 1, 1966, through November 30, 1966)

SATURN IB

General

A. Data for AS-205 Launch Mission Rules

Data for AS-205 launch mission rules was released to Industrial Operations (IO) for the laboratory.

B. Interlock Requirements

The Saturn IB functional interlocks document was revised to incorporate recent engineering orders (EO's). Other major changes included in the revision were format change, the purpose of each interlock, and an alternative control center indication for each interlock.

C. Monthly Weight Status Report

The weight status report for all Saturn IB vehicles was completed and distributed. Also, an operational detail weight status report for AS-206 was completed and distributed.

SATURN V

I. S-IC

A. Umbilicals

1. During functional checkout of the aft umbilicals at Merritt Island Launch Area (MILA), a problem was encountered with aft umbilicals 1 and 2 when adequate clearance was not obtained between the umbilical carriers and vehicle plates at pneumatic kickoff. System testing at Kennedy Space Center (KSC) of the tail service mast and aft umbilicals requires umbilical separation and tail service mast retraction. To permit

system testing to be accomplished without possible damage to the vehicle, this division recommended increasing the pneumatic kickoff pressure for aft umbilicals 1 and 2 from 500 to 750 p.s.i.g. A nonconformance event record was prepared by KSC and the change effected. Subsequent umbilical disconnects were accomplished successfully.

2. The aft umbilicals for set 3 tail service mast will be tested at MSFC to the increased umbilical kickoff pressure to evaluate performance of the umbilical carriers with vehicle lift-off. Testing of set 3 umbilical and tail service mast is scheduled for December 15, 1966.

B. S-IC Flush and Purge Servicer

1. Final acceptance tests of the 5.5-gallon turbopump bearing units were delayed due to a design problem in the unit bleed valve system. A redesign of the poppet and cage assembly, deleting the poppet and adding a diffuser and baffle assembly was accomplished. Drawings and test procedures were updated and transmitted to MSFC.

2. Two quick disconnects and the electrical cable extension box, which are the documented shortages for unit 002, were received. These components will be turned over to the Test Laboratory for installation on the servicer.

C. Acceptance Tests

Acceptance tests were completed on the S-IC aft #3 Umbilical Carrier, P/N 65B80271-5 and the S-IC Pneumatic Checkout Rack Assembly, P/N 65B240093-1, for ML 3.

II. S-II Stage

A. Environmental Control System Study

A study was completed and submitted to the Propulsion Division on redesign of the engine compartment conditioning system manifold for S-II-501. Recommendations were made on relocation of the manifold to prevent hot gas impingement on the J-2 engine lox turbopump.

B. Destruct Assembly Qualification Test Report

The liquid hydrogen (LH_2) destruct assembly qualification test report was reviewed. The destruct assembly S-II stage is considered unqualified until successful testing is completed according to Change Order (CO) 351. Comments were submitted, according to these findings.

C. Electrical Container Loads Study

A study is being conducted to compare the high force test loads to those expected on the S-II flight stage electrical components. The study is concentrating on the loads applied to the mounting inserts in the container base. The results of this study will be used to determine the proper type of inserts to be installed on the flight stage.

D. Servicing Requirements

1. Action was initiated to change the S-II LH_2 coupling disconnect supply from nitrogen to helium. This change was necessitated to assure proper disconnect. There was concern that the cryogenic temperature of the LH_2 coupling would result in freezing of the gaseous nitrogen (GN_2) and thereby cause improper disconnect.

2. Two major propellant loading problems, revealed during SA-500F loading, were investigated. The possibility of baffle damage to future S-II liquid oxygen (lox) tanks was eliminated by performing the bulkhead leak check when the tank was 100 percent full instead of at the 40 percent level. Since the condition could also result during a "revert" condition, KSC is taking the necessary actions to minimize the gas bubbles in the lox transfer line prior to reinitiation of fast fill. The LH_2 vent system excessive back pressure problem has not been resolved and is still being investigated.

E. S-II Pneumatic Consoles

The lowered helium bottle pressurization requirement to 1500 p.s.i. for S-II stage tanks, has caused the S7-41 performance margin to become questionable. A test is now in progress at Mississippi Test Facility (MTF) to determine whether the S7-41 consoles can deliver the required helium flow to the stage at the reduced pressure. Nonconformance could require regulator resetting and possible orifice changes.

F. Leak Detection

A meeting was held at KSC on November 3, 1966, to discuss S-II-1 propellant loading at that facility. No requirement was placed on KSC to leak check the ducts since KSC officials were of the opinion that this would severely impact the present launch schedule. The leak detection equipment performed satisfactorily during AS-500F wet tests.

G. Umbilicals

Fabrication and testing of the modified A7-64 and A7-65 propellant fill and drain coupling debris valve is on schedule; the expected completion date is December 9, 1966.

H. Acceptance Tests

Acceptance tests were completed on Forward Umbilical Carrier, ML A7-42, unit 7, and Heat Exchanger, ML A7-71 for the S-II stage.

III. S-IVB Stage

Umbilicals

1. The third ball-lock vehicle half retainer failed during tracking test on the S-IVB aft service arm and umbilical system at the MSFC ground

support equipment (GSE) test facility on November 8, 1966. The failure occurred after tracking for 30 minutes at maximum amplitude and frequency.

2. A new vehicle support assembly for the third ball-lock was installed on the Saturn V S-IVB aft test panel at MSFC on November 17, 1966, and subjected to 1 hour and 20 minutes of vehicle oscillation at 99.9 percent wind condition with no failures.

IV. Instrument Unit (IU)

Acceptance Test

1. SE 100154, Acceptance Test Procedure for Fixture Assembly, IU Cart, Lem Servicing CEI AM 1072A, was reviewed for technical adequacy and compliance with the applicable MSFC directives. The document was approved.

2. The qualification certifications covering the critical IU mechanical components for the Saturn IB/V were completed.

V. General

A. Damping, Retract, and Reconnect System (DRRS)

1. The new component flowrates and operating pressure of the hydraulic-system, resulting from an analysis of the actual DRRS system, were prepared for use during the component qualification program.

2. IRN 17B to 65ICD9200A, "MSFC/KSC LC-39 Facility Cables," was prepared to incorporate the new cabling requirements of the DRRS.

B. Mobile Service Structure (MSS) Auxiliary Damping System

Test requirements for the MSS auxiliary damping system were established.

C. SA-501 Flight Sequence

EO 3 to the SA-501 flight sequence requirements was released to Astrionics Laboratory. This EO incorporated latest burn times for the S-IC and S-II stages, increasing the time between S-II cutoff and S-II/S-IVB separation by 0.5 seconds to improve the probability of successful separation with one retrorocket out. Also, the arming time for the S-II propellant depletion sensors were changed to 35 seconds before expected depletion to compensate for possible early depletion in the event of a failure of the mixture ratio shift to occur as scheduled.

D. Vehicle Assembly Documentation

1. The Revision A to the AS-501 vehicle assembly drawing 10M15000 was completed and released. This revision updated the S-II/S-IVB interface hardware callouts and effected several documentation type changes.

2. The vehicle assembly drawing, 10M15002, for AS-502 was completed and released.

3. Documentation was released against the torque sequence drawing, 10M14503, to lower the torque valve for the S-IVB interface hardware as requested by Structures Division.

E. Saturn V Design Reference Mission Sequence

Revision B to the Saturn V Design Reference Mission Sequence was forwarded to Astrionics Laboratory for concurrence. Changes were made in format extending the effectivity to SA-505 and SA-506, adding the latest precountdown information, included a mission description for each vehicle. The technical contents of the complete document were updated also.

F. Monthly Weight Status Report

The weight status report for all Saturn V vehicles was completed and distributed. In addition an operational detail weight status report for AS-506 was completed and distributed.

G. AS-504C Projected Weights

The revised projected weights for AS-504C with PM/RACK payload were completed and distributed.

H. AS-504 Mass Characteristics

The revised projected mass characteristics for AS-504 with a 98 K capability were completed and distributed.

I. Saturn V DRRS

A maintenance analysis report was completed on November 17, 1966. This report contained maintenance analysis and spares summary for DRRS and the auxiliary damping system.

J. Q-Ball Alignment Ring

The Q-Ball alignment ring for Saturn IB and Saturn V was furnished to KSC by this division.

K. Saturn V Damping System

1. The vibration requirements were received for the components which are being qualified for the Saturn V Damping System. These requirements are being incorporated in the test specifications; the final documents are being prepared for release. Test specification requirements for the winch and kick-off system have not been determined because criticality classifications have not been received. Work on the test specification for the systems will begin when criticalities are established.

2. Changes were completed on the Saturn V Damping System general test plan to include the Auxiliary Damping System. The revision also included test requirements for component qualification and identification components previously qualified.

L. Hazardous Gas Analyzer (HGA)

Acceptance tests were completed on the HGA, P/N 11100350, for ML 3.

ADVANCED TECHNOLOGY

I. System Design

A. Payload Module (PM)

1. Preliminary drawings of the PM/RACK access platforms were completed and given to Manufacturing Engineering Laboratory to start fabrication of the platforms for use on the PM/RACK mockup. The mockup will be used in the preliminary design review and access equipment.

2. A preliminary study is underway to determine if the Pegasus container handling sling can be modified to use as the handling sling for the MSFC rack.

3. The PM/RACK Access Review was rescheduled for November 30, 1966. Rescheduling of the meeting, to be used as the preliminary design review, has created a delay of more than 2 weeks in the start of final documentation on the access okatfirns.

4. Some requirement changes have accentuated the need for design changes. Modifications must be made to both the support assembly and the mockup of the Model DSV-4B-402 forward vertical access kit so they will conform to the flight configuration. The mockup is not to the flight configuration.

B. S-IVB Orbital Workshop

1. The quick release manhole cover development and qualification schedule was completed for the S-IVB orbital workshop

2. The configuration of the thermal control sleeve for the LH_2 tank was confirmed and the design concept completed (SK10-9242). An experiment package latching mechanism proposal (SK10-9245) was completed.

3. A configuration drawing was made which shows how the neutral buoyancy mockup will be segmented for use in the facility pool.

4. A layout was started which will define a TV system to be used in both the Spacecraft Lunar Excursion Module Adapter (SLA) and workshop areas to view and record the experiments.

5. Work continues on the layouts which describe the astronaut installation of the crew quarters' ceiling and partitions. Work on the partition structure was halted pending an agreement between this division and Structures Division as to which has responsibility for the design.

6. A layout describing the installation of experiment packages onto the Spent Stage Experiment Support Module (SSESM) truss assembly was completed. The electron beam welding experiment (MSFC M-492) was reviewed to determine its compatibility with current installation proposals. The layouts describing the protuberance pads are being revised to eliminate the Velcro fasteners which have been ruled incompatible.

C. Project Thermo

1. Form 1138 was sent to NASA Headquarters with cutdown copies of proposed tank arrangement for Project Thermo. Tank rack configuration was presented at the Project Thermo third contract interface meeting with Manned Spacecraft Center (MSC), Grumman Aircraft and Engineering Corporation (GAEC), Douglas Aircraft Company (DAC), and the Garret Corporation. The MSFC tank arrangement was chosen as being the best to carry out the 14-day mission.

2. Structural support for tanks is being designed. The MSFC rack design is being modified to accept the experiment packages. Camera Field of View (FOV) layouts are being drawn so that maximum tank viewing is possible. A 12-inch diameter sphere is being added to the interface stability experiment at the experimenter's request.

3. The proposed configuration (SK10-9222, Revision A) was approved. Experiment analysis is now being carried out on the propellant storage tank (Experiment #7) before tank length can be determined. The tank diameter is frozen 40 inches.

4. A new design study is in process to determine optimum location on the rack for thruster fuel tanks, thrusters, Astrionics Panel No. 1, tanks for Experiment #7, and water bottles. Although thrusters will be required on each of the four outriggers, the thruster fuel tanks will be located approximately 180 degrees apart in order to balance the weight more evenly.

5. In order to accommodate two additional experiments, all the batteries were relocated and are now mounted under the octagonal ring. The addition of two new experiments will require an overall payload weight analysis.

D. Electro-Magnetic Radiation (EMR) Detection Experiment

Seven detail drawings of the Far-UV Camera Cartridge were completed for the EMR Detection Experiment.

E. Low Amplification Bracket Development Test Program

Sinusoidal testing of the low amplification bracketry was completed. Tests were performed on 37 simple "Hat-section" brackets fabricated of various materials. Data has been received for about two-thirds of the tests performed. This data is being analyzed.

F. Apollo Telescope Mount (ATM)

1. An overall schedule for the ATM design integration was completed.

2. The following layout studies were completed:

Maximum experiment envelopes, hard points for experiment mounting, and the location of the passive thermal control insulation with respect to the experiment envelopes (SK10-7325).

The required enlargement of the experiment canister in order to accommodate the present experiment telescope configurations (SK10-7326).

3. The following layout studies are being made:

A compatibility study between the canister hard points and the proposed experiment mounting points.

The clearance envelope for the experiment canister when the canister is gimballed $+5^{\circ}$ in pitch and yaw and rotated 90° longitudinally.

G. Nuclear Ground Test Module (NGTM)

1. Drawing SK10-7296 was initiated which will be an inboard profile of the NGTM. All of the systems and subsystems have not been located on the drawing at this date but will be added as coordinated information becomes available.

2. Information was prepared which stipulates handling equipment required for the Ground Test Module (GTM) at Jackass Flats. This information will be given to Kaiser Corporation to aid them in making a cost estimate to MSFC for this equipment.

II. Systems Operations

Fluid Requirements for NGTM

Analysis of preliminary fluid requirements and other available data for the NGTM is continuing in order to complete preliminary piping criteria and physical Interface Control Documents (ICD's) by December 1, 1966. Flow calculations indicate many current lines described on Kaiser drawings are grossly undersized to handle the flow specified in the preliminary fluid requirements. These discrepancies are being coordinated within the division.

III. Systems Engineering

A. Aquatic Neutral Buoyancy Program

Volumetric error analysis test of the 125-cubic foot neutral buoyancy tank, a recently fabricated 4-cubic foot segment tank, and a 1/4-cubic foot appendage tank were completed. All tests verified that volumetric accuracies of better than plus or minus 3 percent can be obtained with present set-up and procedures.

B. Project THERMO

Two documents, "Project THERMO Apollo Earth Orbital Scientific Experiment Proposal," and "Appendices to Project THERMO Apollo Earth Orbital Scientific Experiment Proposal," dated November 10, 1966, were completed, documented, and published. The Experiments Office has proposed to use these documents as models for future experiments proposals.

C. Human Engineering Data for Maintenance and Repair of Orbital Systems

An Apollo state-of-the-art suit was prepared for use during neutral buoyancy operations in the Manufacturing Engineering Laboratory test facility. Initial tests are being conducted to evaluate water pressurized and air pressurized conditions.

IV. Systems Requirements

Configuration Management

Technical review of MSFC-PROC-485, "Preparation of Input for Configuration Management Accounting and Reporting System," was completed.

MISCELLANEOUS EFFORTS

Systems Design

A. Safety and Arming (S&A) Device Improvement

Additional effort is required for further improvement of the S&A device. Explosive gases are to be vented within the body of the S&A device and several tests must be accomplished to qualify this design.

B. SA-501 Staging

The division furnished technical support to KSC during the staging (stacking) of the SA-501 vehicle. No significant problems were encountered during the stacking operations and no apparent problems occurred with the handling and distribution of the stage to stage mating hardware.

C. Common Ordnance Comparison

The differences between the exploding bridgeware (EBW) detonators and the S&A devices for AS-204 and AS-501 vehicles were documented.

John O. Aberg

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-66-11

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(November 1, 1966 - November 30, 1966)

SATURN IB

I. S-IB Stage

On November 7, 1966, the S-IB 70-inch LOX test tank II was tested at CCSD/Michoud for the max fin load condition (64.6 seconds after liftoff) with max internal pressure. A failure occurred in the forward skirt just above 120 percent of limit loads. The rivets in the aft portion of the main longerons around the cutout per CCSD ECP ET-30867 failed in shear and caused the panels on both sides of the cutout to buckle. This failure was not severe. Up to 120 percent of limit loads, all strain and deflection data in the critical panel 10 were linear. Also, the peaking value was less than the peaking value experienced in test tank I. There is no indication that a failure will occur before 140 percent of limit loads in the pressurized section of the tank. Structures Division has forwarded recommendation for the repair of this tank to I-I/IB-SI/IB.

II. S-IVB Stage

S-IVB Flutter Panel

The additional tests that were required to obtain data that will be used to determine the stressed condition of the panel when it was tested in the wind tunnel were completed. The test setup has been dismantled and the test specimen has been moved to another position on the test floor. The data from these tests are presently being analyzed.

III. Instrument Unit

A. ST-124 Platform

A vibration investigation test was accomplished on the live ST-124 platform. The purpose of this test was to determine the source of bending in the outer gimbal at the critical 90 - 150 cps range. Acceleration measurements were made on the gimbal, the bearing block, and the platform frame. A preliminary review of the data revealed that very little frame and bearing block vibration was being experienced at the maximum gimbal response. It was concluded that most of the outer gimbal response was due to a lack of gimbal 'pivot area' stiffness and not to the compliance of the frame or bearing block assembly.

B. Impedance Testing

ST-124 impedance testing in the S-IU-500V-2 configuration with and without the long and short channels installed has been completed. Testing in the S-IU-200/500S-3 configuration without the channels installed has also been completed. The results of this testing are as follows:

1. The rigid body mode shapes extend 50 inches beyond the IU rings into the SLA and S-IVB forward skirt and 30 inches circumferentially beyond the mounting pads.

2. The rigid body resonant frequency in the longitudinal axis was shifted upwards 10 percent. There was no shift of the rigid body resonant frequencies in the radial or tangential axes. The reason for this was the large area of the structure participating in the rigid body mode shapes. No feasible localized structural modifications to the IU structure alone will raise these frequencies significantly.

3. The addition of the long or short channels did, however, reduce the vibratory response of the ST-124 by approximately 50% for a given vibro-acoustic input.

Impedance testing of the ST-124 in the S-IU-500V-2 configuration with the mass damping material (X306) installed is being evaluated now.

SATURN V

I. S-IC Stage

A. Fin Acoustic Testing

The structural test (S) fin was acoustically tested on November 17 and 18, 1966. The sequence of testing was as follows: 163 dB for 2.5 minutes, thence 171 dB for 2 minutes, thence 163 dB for 20 minutes. During the first 4.5 minutes of testing the fin was inspected every half minute for failure, then less frequently thereafter. Upon completion of the testing, one side of the skin was stripped off for a more thorough inspection of the spar and ribs. No structural failures were detected during the detailed visual inspection. Dye penetrant tests will be accomplished as a final check. The facilities (F) fin is presently undergoing modification so it can also be acoustically tested.

B. Short LOX Tank

The internal support structure that will react the air bags to be used in applying the simulated inertial loads on the aft bulkhead of the lox tank containing the sculptured Y-ring is approximately 40% complete. The fabricated parts, which must be small enough to pass through one of the bulkhead openings, are being installed inside the tank concurrently with fabrication of the parts out on the test floor.

II. S-II Stage

A. S-II-4 Aft LOX Bulkhead/Cylinder Weld

The aft lox bulkhead has been cut off because of an unacceptable weld. The S-II-5 aft lox bulkhead is being moved up as a replacement. Measurement of the S-II-5 bulkhead shows it to be undersize with respect to the cylinder. This problem is under consideration at S&ID.

B. LOX Tank Foil Seal on S-II-1

An inspection revealed that the lox tank foil seal covering the 111 in. dollar weld area was torn beyond repair. Present plans are to remove the foil and the Narmco adhesive filler. The area will be coated with Dynatherm and then tested by loading with LN_2 and pressure for leak checking.

C. Aft LOX Bulkhead Test

The aft lox bulkhead was hydrostatically tested to failure on October 28, 1966. Failure occurred at 97.5 psig, measured at the sump. Testing was done with the dome oriented in the inverted position. Due to the hydrostatic head the pressure varied from 97.5 at the sump to 102.3 at the equator. Failure appeared to have initiated near the circumferential weld which joins the waffle portion to the membrane portion. The required pressure capability at the sump is 96.3 psig. The failure test was performed without the structural doublers at the 111 inch dollar weld. S&ID has determined that the following factors of safety were demonstrated:

sump	1.42
dollar weld	1.28
waffle/membrane circumferential weld	1.38

D. CBTT Testing

(a) On Wednesday, November 14, 1966, the CBTT successfully withstood the pneumostatic proof pressure cycle testing (Phase I). This test involved cycling the LH_2 tank to 35 psig, a total of five times with GN_2.

(b) On Saturday and Sunday, November 19 - 20, 1966, the CBTT successfully withstood LN_2 fill and drain test and the LH_2 cycle test (Phases II and III). The LH_2 test involved cycling the tank to 21.4 psig, a total of twenty times and finally taking pressure to 42.2 psig to simulate.

E. S-II Feed Line

The S-II feed line fitting was instrumented with strain gages prior to its installation on the "C"-Tank. All the work that could be accomplished prior to the tank being moved into hydrostat position was completed. Work was done in preparing the data link between the hydrostat facility and the computer room in Building 4619. This linkage will permit more expedient testing than was experienced during an earlier hydrostatic test of the "C"-Tank.

F. Containers 207 and 209

Container 207 was acoustically tested on November 11, 1966, for North American Aviation by Wyle Laboratories at Huntsville. All electrical equipment mounted in the container was monitored during the test. Functional checks were also made before and after the acoustic test. There were no functional failures detected, before, during, or after the acoustic test program. Container 209 was acoustically tested on November 15, 1966, at the same facility. Electrical equipment mounted in this container was functionally checked before and after the acoustic test and monitored during the test. The output signals from the 209 container were recorded on magnetic tapes, and the tapes need to be analyzed before any malfunctions can be detected.

G. High Force Testing

The S-II aft interstage was subjected to random vibration testing in the first lateral axis. An inspection following testing revealed a crack in the redesigned recirculation battery bracket. Evaluation of the failure has started and a resolution is expected presently. The aft interstage sinusoidal vibration test has been delayed due to problems with the data acquisition and analyzing equipment.

H. S-II/S-IC Interface

All the heating blankets were bonded in place and were checked to ascertain if any were shorted to the structure. Some of the blankets have been connected to the power cables. The loading fixtures are in place and all hydraulic lines are corrected to the load control console.

III. S-IVB Stage

Longitudinal dynamic loads analyses were conducted to determine the structural impact in the event of a LOX depletion shutdown during the S-IVB flight. The results of the investigation showed no severe vehicle loads due to engine shutdown using the J-2 engine cutoff characteristics.

IV. Saturn V System

A. AS-501 Damper System

The two hydraulic cylinders that will be installed in the AS-501

damper system were calibrated for load vs. pressure. This information will be supplied by Mr. Arnts, R-P&VE-SJ, who will make it available to personnel of R-TEST to be used during the tests at the "Swing Arm Farm." The cylinders required for the damper calibration have not arrived so these tests will be delayed.

B. AS-504

A time response in g's for the PM/Rack interface has been calculated. This study includes the longitudinal response versus time for the interface at liftoff and first stage separation, and the lateral response versus time for this interface for liftoff, and maximum dynamic pressure during flight.

ENGINES

I. F-1 Engine

The Rocketdyne F-1 engine electrical post which failed at 297,000 cycles during qualification testing has been accepted as qualified and posts of this design are qualified for flight.

II. J-2 Engine

A. Component Qualification Program

The J-2 engine component qualification program was reviewed during a meeting with Rocketdyne at Canoga Park, California. Ten components have experienced problems during the component qualification program. Of these ten problem areas nine are related to the vibration test program and involve the following components: (1) main LOX valve, (2) start tank discharge valve, (3) start tank vent and relief valve, (4) helium regulator, (5) P.U. valve, (6) amin fuel valve, (7) primary instrumentation package, (8) auxiliary instrumentation package, and (9) LOX dome purge check valve. Agreement was reached with Rocketdyne on disposition of action required on all items except the PU valve. On this item it has been proposed that R&DO request retrofit of this valve on all flight engines.

B. Mainstage Thrust OK Pressure Switch

EDS vibration qualification testing of one non-calips type

pressure switch has been completed. Preliminary results indicate possible switch contact chatter proved to be the result of faulty recording equipment. A re-evaluation of test results showed satisfactory completion of testing with no malfunctions. An additional two switches are to be tested.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount (ATM)

A decision to incorporate the fine-pointing gimbals into the experiment package support has greatly impacted the ATM Rack structure. The principal support ring must be moved from the bottom of the Rack to approximately the middle. Provisions for low-friction gimbals in pitch, yaw, and roll must be added, including caging capability. The gimbal approach recommended by Lockheed (under their AAP support contract) is being investigated.

II. Electromagnetic Radiation Experiment (EMR)

A structural concept was selected for the Gamma Ray experiment, and a structure for the X-ray experiment was tentatively selected, pending a thermal analysis. A structural concept for the ultraviolet camera location and support has not been selected as additional operational requirements have not been fully evaluated.

III. Voyager Shroud

Studies have been initiated for testing of potential contaminant free separation joints and for the preliminary design of the shroud structure. A meeting was held with representatives of Manufacturing Engineering Laboratory to discuss structure/manufacturing development work necessary for the Voyager shroud program.

IV. S-IVB Workshop Lunar Floor

A design concept for integrating the lunar floor and compartment wall structure was released to the Vehicle Systems Division for investigation.

Chief, Structures Division

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-66-11

MONTHLY PROGRESS REPORT

NOVEMBER 1, 1966 THROUGH NOVEMBER 30, 1966

SATURN IB

I. S-IB Stage

A. Development of Hazardous Gas Detection (HGD) Systems for Saturn Launch Complexes

A copy of the configuration audit report for the HGD delivered to Launch Complex 37B has been received. Discrepancies noted between the documentation and the actual hardware configuration were resolved by making the requisite corrections to the documentation.

Preliminary information has been received relative to problems encountered during operation of the HGD system at Launch Complex 39. Reportedly difficulties were encountered which involved compatibility of pump fluids and instability of calibration gas. These reported difficulties were ill defined; however, this division will investigate further and take appropriate corrective action as required.

B. Evaluation of Aging Treatment of 7075-T6 Aluminum Components for Reducing Susceptibility to Stress Corrosion

Because of failures of control piston cylinders used on the fill and drain and pre-valves (S-IB stage) due to stress corrosion cracking, studies were initiated to determine the effectiveness of overaging 7075-T6 aluminum components to reduce the susceptibility to stress corrosion. Five cylinders were available for study; three were made from 7075-T6 alloy, and two were aged to give the 7075-T73 temper of this alloy. C-Ring type specimens were fabricated from these cylinders, stressed to 40 ksi, and exposed in the alternate immersion tester. Two out of the three -T6 rings failed in six days. There have been no failures in the overaged rings after 30 days of exposure. In order to confirm the advantages of the -T73 aging used on the 7075-T6 cylinders, threaded-end, round tensile specimens were fabricated from 7075-T6 plate in the short transverse grain direction. Part of these specimens were aged to obtain the -T73 temper. The 7075-T6 specimens were stressed to 75 percent of the yield strength (45 ksi), and the overaged specimens were stressed to 75 percent (36 ksi)

and 50 percent (24 ksi) of the yield strength. All of the 7075-T6 specimens failed within three days, while the overaged specimens have not failed after 16 days. Both types of specimens are being exposed in the alternate immersion tester.

C. S-IB Stage, Project Management, Materials

As reported previously, the servoactuator housings used on the S-IB stage are made from a stress corrosion susceptible material, 2014-T6 aluminum. The stage contractor has been directed to paint the actuator housings on AS-204. Additionally, the contractor is to submit a schedule illustrating when other protective measures will be employed.

The stage contractor, Chrysler Corporation Space Division, has submitted a revised proposal for evaluation and qualification of FTA-442A and FTA-532A as replacements for M-31 horizontal heat shield insulation. However, the proposal included an ablative material which cannot be evaluated in conjunction with the FTA ceramic insulations since the ablative products would constitute a "dirty" contaminant which could interfere with the reflective properties of the ceramic.

Two of the fuel valve housings on the S-IB stage of AS-204 leaked during pressure testing. Radiographic examination of five of the eight valves revealed gross porosity (4-F rating). All of the fuel valves on AS-204 are to be removed and pressure tested.

SATURN V

I. S-IC Stage

A. Study of the Corrosion Susceptibility of Hydraulic Actuators

Exposure to a salt spray environment has continued on representative specimens of two different designs of the S-IC stage hydraulic actuators. The actuator made from 7079-T6 alloy has been exposed for 440 days without failure, and the actuator made from 7075-T73 has been exposed for 410 days without failure.

B. Study of the Compatibility of Various Engineering Materials with Propellants

Thirty miscellaneous materials were evaluated for compatibility with liquid oxygen in accordance with MSFC-SPEC-106B. Data generated from these tests were forwarded to cognizant design groups and other interested personnel.

C. Evaluation of Commercial Adhesives

Studies are continuing as outlined below to evaluate, develop, or qualify new adhesives for use in the Saturn program.

1. Study of the Effect of Z-6040 Silane Coupling Agent Additions to Narmco 7343

Additional tests were run to determine the effect of adding various quantities of Dow Corning Z-6040 silane coupling agent directly to Narmco 7343/7139. Previous tests had been limited to 0.25 percent to 1.00 percent Z-6040 concentrations and to tests at room temperature and +200°F (93°C). The aluminum adherends were acid etched, but were not primed. Catalyst concentration was 11.5 parts/100 parts resin, and the adhesive was cured for one day at room temperature followed by one day at 160°F (71°C). Lapshear tensile strength data from these tests are given in the following tabulation:

Z-6040 Percent (Based on Resin)	Lapshear Tensile - psi		
	-300°F (-184°C)	Room Temperature	+200°F (93°C)
0.05	9210	3060	1320
0.50	9070	3400	1530
1.00	9480	3350	1470
1.50	9570	2920	1690
2.00	8190	2520	1240

These results continue to show an advantage for using Z-6040 in a concentration range of about 1 ± 0.5 percent based on resin, particularly at the +200°F (93°C) test temperature.

2. Study of Effect of Using Hydrolyzed Z-6040 Silane Coupling Agent as a Primer for Narmco 7343

Dow Corning Z-6040 coupling agent was hydrolyzed with acetic acid, and was then used as a primer for aluminum adherends. The hydrolyzed Z-6040 was applied as an approximate 0.2 percent solution in methanol-water and was allowed to air dry about an hour before applying Narmco 7343/7139 adhesive. The samples were cured for a minimum of seven days at room temperature. Test data on these specimens indicate excellent strength over the temperature range from -423°F (-253°C) to +200°F (93°C), with useful strength up to 250°F (121°C).

3. Study of the Effect of Curing Agent Concentration on the Bond Strength of Narmco 7343

Another series of tests were run to further evaluate the effect of curing agent concentration on bond strength. In these tests the curing agent Narmco 7139, was varied from 9 to 14 parts/100 parts of Narmco 7343 resin. The aluminum adherends were primed with 3M XC-3901 silane primer. The samples were cured for two days at ambient temperature followed by 1 day at 160°F (71°C). Test results are presented in the following table:

7139 Concentration Parts/100 Part 7343	Lapshear Strength - psi		T-Peel Strength - PIW	
	Room Temperature	-300°F	Room Temperature	-300°F
9	2590	9670	16.6	47.9
10	1680	9010	16.1	35.9
11	2150	8530	18.1	43.5
12	2210	7360	22.8	52.0
13	2350	6850	21.5	31.3
14	1860	4820	32.9	4.5

The most clearly discernible trend shown by these results is a decrease in lapshear strength at -300°F (184°C) with increasing concentrations of Narmco 7139 curing agent. In general, results tend to indicate that the 7139 concentration should not exceed 12 to 12.5 parts/100 parts of 7343.

4. Investigation of the Effect of Residual Acid Etched Aluminum Adherends

In order to study the effect of residual acid on the bond strength attained with acid etched aluminum adherend surfaces, half of a batch of aluminum panels were thoroughly rinsed with water after acid etching, dipped into diluted ammonium hydroxide (NH_4OH), and then thoroughly rinsed again. After drying, half of the panels (with and without the NH_4OH rinse) were primed with 3M XC-3901 silane primer. Primed and unprimed samples were then bonded with Narmco 7343/7139, and the adhesive was cured for 2 days at room temperature followed by 1 day at 160°F (71°C). Lapshear strengths were essentially the same at room temperature for all primed samples with or without the ammonia rinse. On unprimed samples, there is a slight beneficial effect of the ammonia rinse, but generally, trace quantities of the acid remaining after a thorough water rinse do not appear to affect the bond strength significantly.

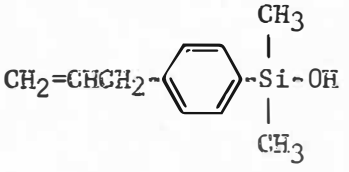
D. Development and Evaluation of Potting Compounds and Conformal Coatings

Efforts are continuing to develop and adapt curable resin systems for encapsulation of electronic circuitry. The introduction of siloxane and silazane moieties into conventional polymers has enhanced the dielectric properties, toughness, and adhesion, properties which are critical in encapsulating materials. A preliminary examination of a new Thiokol nitroso rubber has been made, and chemically modified hydrocarbon prepolymers are being considered for the Saturn conformal coating requirements.

1. Development of Epoxy Silane Encapsulating Materials

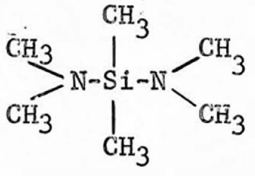
The cured epoxy polymer prepared from 1,3-bis(p-2,3-epoxypropyl)-phenyl)tetramethyldisiloxane showed improved dielectric properties as compared with those of conventional epoxy resins. Measurements of the dielectric properties of the resins of four additional diepoxydisiloxanes, previously described, are in progress.

In order to appraise the contribution of trisiloxane groupings to the toughness, flexibility and dielectric properties of epoxy resins, it is planned to produce Monomers I and II by the reaction of Compound A with Compounds B and C, respectively, as shown below:

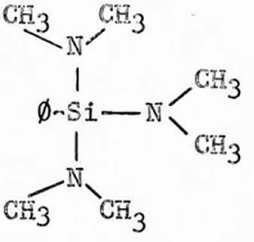


Compound A

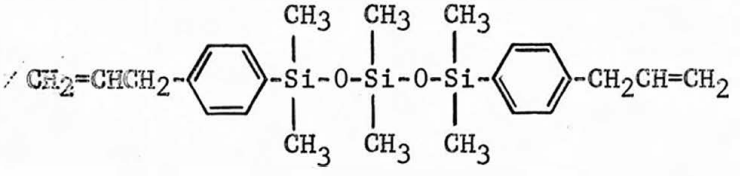
+



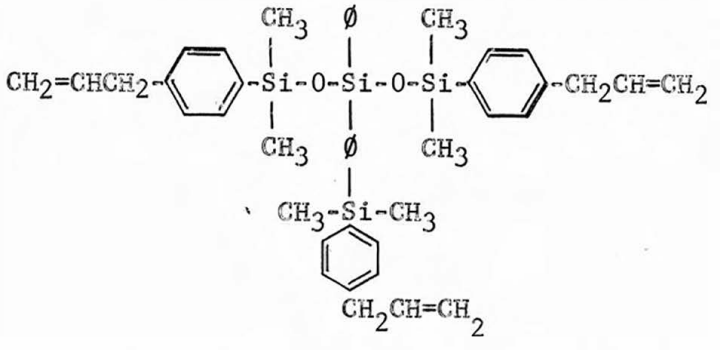
Compound B



Compound C



Monomer I



Monomer II

Monomers I and II will be epoxidized and cured by conventional processes.

The preparation of Compound A, p-allylphenyldimethylsilanol, is in progress. The intermediate, p-allylphenyldimethylchlorosilane, boiling at 70-71°C/0.08 torr, has been produced in pure form by reaction of the mono-Grignard reagent of 1,4-dibromobenzene with allyl bromide, followed by reaction of the Grignard reagent of the product with dichlorodimethylsilane. Hydrolysis of the chlorosilane to the desired product Compound A, is in progress. A molecular still is being assembled for use in the purification of Monomers I and II.

2. Evaluation of Conformal Coating Materials

Interest in the examination of the dielectric and physical properties of the new Nitroso elastomers being developed by the Thiokol Corporation was mentioned in the last report. An epoxy-cured elastomeric terpolymer has been subjected to preliminary evaluation. The low dielectric constant, about 2.3, of the composition indicated that the incorporation of an epoxy curing system did not seriously degrade the dielectric properties. Samples of a liquid Nitroso rubber prepolymer are expected, and will be of considerable interest for evaluation as prepolymers for the preparation of conformal coatings.

E. Investigation of Materials for Low Noise, Miniature Slip Rings

The purpose of this project is to determine the wear and noise characteristics of slip rings operating for extended periods of time at low amplitude oscillations.

The results of the last test indicated the appearance of a d.c. bias at the noise waveform output terminals of the electrical network which was designed to isolate the slip ring current from the slip ring noise. The appearance of the bias was traced to a faulty capacitor. Other key components of the isolation network are also being checked. Tests will resume upon completion of the checkout.

II. Contract Research

During this report period, Saturn-related supporting research activities have continued in the fields of technology with the contractors and under contract numbers listed below:

A. Polymer Research, Development, and Testing

1. University of Florida, NAS8-20247
2. Narmco Research and Development, NAS8-11958
3. Peninsular ChemResearch, Incorporated, NAS8-5352
4. Midwest Research Institute, NAS8-11338
5. Battelle Memorial Institute, NAS8-11837
6. Bell Aerosystems Company, NASw-1317

B. Development of Cryogenic and High Temperature Insulation Material

1. Goodyear Aerospace Corporation, NAS8-11747
2. IIT Research Institute, NAS8-11333

C. Analytical Methods Development

Beckman Instruments, Incorporated, NAS8-11510

D. Assessment and Evaluation of Blast Hazards

1. Edwards Air Force Base, Government Order H-61465
2. National Bureau of Mines, Government Order H-76708

E. Nondestructive Testing Techniques

1. North American Aviation, Incorporated, NAS8-11733
2. R. W. Benson and Associates, NAS8-20208

III. S-II Stage

A. Evaluation of S-II Stage "J" Ring Protection

Examination of the "J" ring on the S-II F/D vehicle prior to hydrostatic testing revealed that the epoxy coating which had been applied for stress corrosion protection had lost all adhesion and was coming off in large pieces. Recommendations were made for reapplying this coating.

B. Repair of the "Dollar Weld" Area of Vehicle S-II-501

Considerable support was provided the stage contractor at the Mississippi Test Facility (MTF) in making repairs in the "Dollar Weld" area of S-II-501 stage. An employee of this division has been in residence at MTF throughout this effort.

Evaluation of Dynatherm 4327 for Use in the Repair of the "Dollar Weld" Area

Studies were made to verify the utility of the PR-1732 primer for Dynatherm 4327 in making the repairs in the S-II-501 "Dollar Weld" area. Although the test samples did not precisely conform to the test configurations used by NAA, the surface treatments and bonding procedures proposed for the vehicle repair were followed rigorously. To evaluate the strength properties of D-4327 with and without the primer, lapshear and T-peel specimens were prepared. After acid etching the adherends, half of the plates were primed with PR-1732 using a brush coat, and the primer was dried at room temperature for a minimum of 30 minutes. Three coats of D-4327 were brushed on each surface with a 20-minute drying time between each coat. A fourth coat was applied to each surface just before contacting the mating surfaces for bonding. The samples were cured under a vacuum for approximately 24 hours before determining bond strength on a part of the

specimens. The rest of the samples were allowed to continue curing at room temperature while other specimens were tested periodically. The results of these tests confirmed that the primer promotes stronger bonds with higher peel strength at room temperature, but no significant advantage was indicated by tests at -300°F (-184°C). About 24 hours additional room temperature aging beyond the initial 24-hour vacuum cure was required before the primed samples developed significantly greater lapshear strengths than the unprimed samples. A longer time, between 1 and 2 additional days, was required for the primed samples to develop higher room temperature T-peel strengths. Both T-peel and lapshear values were still increasing after 10 days.

It was concluded that this primer is definitely beneficial at room temperature and also provides adequate strength at cryogenic temperature.

IV. S-IVB Stage

A. Investigation of Weld Etching Procedures

The Douglas Aircraft Company (DAC) has requested that a review be made of the prescribed weld etching procedure to be used prior to penetrant inspection. It has been reported that the specified etching times result in intergranular attack which reacts as a crack under dye penetrant inspection. A report of the contractor's work and recommendations has been received. As soon as a supply of the contractor's etchant (Turco 4366) is received, additional work will be done to further evaluate the dye penetrant procedure used in investigating welds on the S-IVB stage.

B. Investigation of Failure of S-IVB Hydraulic Valve

Failure analysis was initiated on a S-IVB auxiliary hydraulic pump valve assembly that failed during test. Failure occurred in a 17-7 spring and in a high carbon steel stop pin.

C. Investigation of Stress Corrosion in Titanium Alloys

Initial studies have indicated that Ti-6Al-4V is susceptible to some form of stress corrosion cracking when highly stressed in the presence of absolute methyl alcohol. U-Bend and threaded-end type tensile specimens fail in four to five days in the presence of absolute alcohol. Notched-type tensile specimens, stressed to 120 ksi, fail within 17 to 96 minutes in the same environment. Tests also indicated that Ti-8Al-1V-1Mo and Ti-5Al-2 1/2Sn failed as quickly as the Ti-6Al-4V in this environment. Tests have been initiated to determine if Ti-6Al-4V will crack in other fluids. Fluids now being tested include RP-1 fuel, acetone, MIL-H-5606 hydraulic oil, trichloroethylene, ethyl and isopropyl alcohols, distilled water, monomethylhydrazine, Aerozine 50, Freon PCA, and methyl alcohol with various amounts of water added (0.25 percent to 3.0 percent). These tests have been in progress for eight days, and no failures have occurred. Additional tests will be initiated when specimens can be fabricated.

D. Study of the Effect of Water on Components of the S-IVB Stage Common Bulkhead

Since water leakage into the common bulkhead of S-IVB 210 was reported, the pH of water was investigated under various conditions of exposure to the bulkhead materials. Distilled water was boiled before immersing the samples. The water at that point had a pH of 5.8, and during standing for five days the pH changed to 6.4. In one day, water in which cured HT-424 was immersed changed to a pH of 7.0 and remained at this pH over the rest of the 5-day soak. In another sample, the water with the cured HT-424 was boiled for 30 minutes. This changed the pH from 6.7 to 7.9. Tests with the HRP core showed that this material had very little effect on the pH of the water and the change in pH usually did not exceed 0.2-0.3 units. It is therefore conceivable that water in contact with the normally cured adhesive materials could become moderately alkaline on the pH scale over a period of time. DAC representatives attributed this effect to "activator-rich" adhesive, but these results indicate that the normally-cured adhesive can create moderately basic pH values. Since this is a single component film adhesive, there is no way to study rigorously the contractor's explanation of the pH value observed during attempts to dry out the actual bulkhead unless some samples of the specific HT-424 adhesive batch(s) used for the bulkhead fabrication are still on hand.

E. Study of Materials Problems Attendant to the S-IVB Workshop Program

1. Materials Testing in Vacuum

The purpose of this project is to determine the vacuum compatibility of materials contained within the LH_2 tank of the S-IVB stage. Materials will be identified for potential toxic constituents. This project has been expanded to include testing in a 5 psia oxygen atmosphere.

Tests to determine the type and amount of volatile constituents evolving from the D-65 coating are continuing. Three long-term tests were conducted at a temperature of 120°F in oxygen atmosphere. The samples were air cured for 72 hours followed by exposure to a vacuum of 10^{-6} torr for 72 hours. The samples were then exposed to 5 psia oxygen at 120°F (49°C); one sample was exposed for 14 days and two were exposed for 16 days. Analytical results indicate that all samples contained less than 10 ppm of cyclohexanone at the end of the test which is well below the toxic level.

2. Simulated Micrometeoroid Tests of S-IVB Materials

Testing and materials evaluation have continued in the study of the effects of simulated micrometeoroid impacts on materials used in the S-IVB stage. The major emphasis in these studies is directed toward qualifying a material to act as a flame suppressant or inhibitor for the 3D insulation.

Over thirty different specimens were prepared for hypervelocity impact testing in support of this program. These specimens consisted of conventional Douglas 3D foam panels overcoated with various films and coatings. Dow Corning coatings 93-046 and Q92-009 are under study and Kapton film and aluminum foil are being evaluated as flame-retarding surface films. Scrim cloth layers are being investigated for use in conjunction with Dynatherm D-65. These samples ranged in size from 6 inches in diameter to three feet; the larger size incorporated a waffle pattern simulating the S-IVB tank wall.

Simulated micrometeoroid impact tests have been completed on specimens of 3D insulation coated with either Kapton H Film, Aluminum Foil or D-65 scrim cloth. The coated insulation specimens were bonded on the inner surface of small aluminum tanks which were pressurized with 5 psia oxygen. The test specimens were punctured by simulated micrometeorites and the time from puncture until burning was complete was recorded. A preliminary evaluation of the burning time data clearly illustrates the superior fire suppressant qualities of the D-65 coating over the other two materials.

3. Study of Permeation - Diffusion of Hydrogen into 3D Insulation

The Propulsion Division has reported a problem with apparent changes in thermal conductivity of a tank insulated with internal 3D insulation. The changing boil-off rates indicate that repeated fill and drain cycles have produced at least partial saturation of the insulation with gaseous hydrogen. In order to investigate the permeation of the 3D insulation, a test program has been planned in which helium will be used as the cryogen for safety reasons. Permeation rates of gaseous helium through the insulation and seal coat will be determined. The thermal conductivity of the insulation evacuated and saturated with gaseous helium will be determined. Based on results of these tests, other tests will be made.

V. Instrument Unit

Corrosion tests have been initiated on beryllium specimens to simulate the environmental exposure anticipated for beryllium cold plates. These tests are being done in a methanol-water solution. Due to the time-related nature of these tests, there are no significant data to report at this time.

VI. F-1 Engine, Project Management, (Materials)

A Scope of Work was prepared for a research study on Reme' 41 steel used extensively in the turbopump of the F-1 engine. The number of cracks in finished engine components has decreased drastically in the past nine months, but the engine contractor continues to report considerable fabrication problems with this material. Efforts will be made in the first week of December to negotiate this contract, and it will be funded by F-1 special study funds. Technical direction will be provided by personnel of this division.

In a recent check with Rocketdyne to verify appropriate QUAL testing of dry film lubricants in the turbopumps, it was learned that batch tests on molybdenum disulfide dry film (RB0140-007) materials were not being made as required in the specifications. Rocketdyne uses almost exclusively Oxylube 701 for the turbopump shaft splines. Although this material has functioned very well and is LOX compatible, past experience with such compounds has prompted the use of batch tests to insure that no changes have been made by the vendor to render the material incompatible. Action is being taken to insure compliance with the batch testing requirement.

VII. J-2 Engine

A. Investigation of Solder Joint Cracking

Studies are continuing in an attempt to characterize and determine the cause of the solder joint cracking in the J-2 Engine ECA. Chemical analysis of five solders is being made along with solder joint strength tests. Metallographic examination of soldered terminals has disclosed evidence that partial refusion of the solder joint opposite the side soldered last is frequently a contributing factor to joint cracking.

B. J-2 Engine, Project Management (Materials)

A meeting was attended with personnel of the Propulsion Division (R-P&VE-PA) and their engineering support contractor employees to discuss a J-2 Engine thrust chamber nozzle extension study being conducted by the Propulsion Division. The proposed nozzle extension would be approximately 51 inches in length and would result in an expansion ratio of 46:1. The design of the nozzle extension would be such that it could be retracted to some position around the thrust chamber and, after separation of the S-IVB stage, would be deployed to act as an extension. We have been asked to assist in making the material selection for such a nozzle extension. The only criteria we have been given upon which to base the selection are that the extension be the radiation cooled type and that wall temperatures would be in the range of 2700°R - 3200°R (2240°F - 2740°F). Activities are currently directed toward screening the literature to determine the best material (refractory alloy and coating) available for the application.

VIII. C-1 Engine

Standardization of Non-Destructive Technology for Electron Beam Welds

Work has continued on the development of techniques and specifications for the inspection of electron beam welds in components of the C-1 engine. Test blocks of 2014-T6, Ti-6Al-4V, and Ta-10W have been prepared for sound velocity and attenuation measurements by comparative methods. Velocity and attenuation data have been taken using the Sperry Products Company Attenuation Comparator. Also, a second method of velocity measurements is being applied using the Sperry Products Company Velocity Comparator. Test specimens have been prepared for velocity and attenuation measurements utilizing the resonant technique.

Apparatus has been obtained for sound beam geometry measurements. Beam geometry characteristic curves will be plotted using a mechanically coupled x-y scanner and recorder apparatus. Apparatus for precise dimensional definition of ultrasonic test beams is ready for use.

An effort has been initiated to develop special calibration blocks of general applicability for use in this investigation. It is planned to develop spherical bottom hole blocks as opposed to the flat bottom hole; blocks presently in use in ultrasonic testing. The advantage of such blocks will be that they will be highly adaptable to ultrasonic angle beam testing as well as straight beam testing since a uniform spherical bottom hole may be used over a range of angles. Also, in general, precise alignment will not be required.

IX. Advanced Manned Missions

A. Apollo Telescope Mount (ATM)

A program was initiated to determine the possible sources of contaminant deposition which could adversely affect the operations of the Apollo Telescope Mount (ATM). This study will include all substances vented overboard from the various spacecraft elements, as well as potential outgassing from structural or instrumentation materials and exhaust of the RCS system. A complete study of all possible contaminant sources is continuing.

B. Nuclear Ground Test Module (GTM)

In-house and contractual studies are being pursued to develop the materials technology required to support the Nuclear Ground Test (GTM) Program. Specifically, the areas of cryogenic insulation, valve seals, transducer materials, gimbal and bearing lubricants, and induced neutron activation are being actively investigated.

As a back-up for the spray foam insulation proposed for the ground test module, a 20-inch diameter aluminum tank was insulated with Armstrong No. 9520 cork. Four layers of 1/4-inch thick cork were bonded to the tank using Lefkoweld 109/LM-52 adhesive. Each layer of cork had a 2-mil Tedlar film bonded on as a vapor barrier using the same adhesive.

The first test of this tank with liquid hydrogen was run, and oral reports indicated that the surface temperatures were all well above 0°F (-18°C) and that the insulation functioned satisfactorily. After warming up, the tank was examined, and no cracks were found on the sidewall. There was one 2/3 "moon" type crack about 2.5 inch diameter on the lower dome essentially at the junction with the vertical secion. Two cracks about 1-1/4 and 1-1/2 inches long were found at the junction of the neck tube to the upper dome. These cracks were in the vertical direction approximately 180° apart. It was impossible to tell how deep the cracks were. The insulation was repaired by bonding 2-mil Tedlar film over the defective area using the Lefkoweld adhesive, and tests will continue.

Work has continued in the determination of the coefficient of thermal conductivity from room temperature to 20°F (-7°C) of a specimen of laminated corkboard which is a candidate insulation system for the GIM. In addition, the coefficient of linear thermal expansion is being determined at cryogenic temperatures for corkboard. These data will be used in the analysis of the thermal and structural performance of this insulation system.

Drawings of two valves currently used on Saturn launch vehicles have been received from Propulsion Division and the materials used in these valves are being evaluated for use in a radiation environment, and, when appropriate, replacement materials will be specified. Qualification testing of these components will be conducted under contract NAS8-18024 and will be coordinated with R-QUAL and R-PGVE-P personnel.

To protect moving parts in the Nuclear Ground Test Module and in nuclear-powered spacecraft, lubricants will be required which will not be degraded by operation in hard radiation. In connection with this requirement a series of tests are planned on various dry film lubricants irradiated with electrons and gammas in the linear accelerator and tested in the Falex lubrication tester.

During this reporting period the lubricants Electrofilm - 2306, Electrofilm - 5396, and MLF-9 (Molybdenum disulfide, Graphite, Bismuth, Aluminum phosphate)were applied to Falex test specimens. Some of these specimens were irradiated at 2.8×10^{16} electrons per square inch and a number are scheduled for gamma irradiation. Testing has started on the electron irradiated specimens as well as the control specimens for all three lubricants.

X. Project Able

Creep Properties of Metallized Films

Apparatus has been constructed for measurements of the creep of 0.5 and 1.0 mil aluminized Kapton film at 250°F (121°C), 75°F (24°C), (50 percent relative humidity), and -300°F (-184°C) at constant loads. With this equipment the creep values of three samples of each film can be measured simultaneously at 50 and 200 psi, at each of the two higher temperatures. The measurements at 75°F (24°C) and at +250°F (121°C) are in progress. The Instron machine with its constant temperature cabinet will be employed for the measurements at -300°F (-184°C). It is planned to begin the measurements at -300°F (184°C) early in December. The amount of creep at -300°F (-184°C) is expected to be quite small and difficult to measure accurately with the cathetometer available, however, the experiment will provide the opportunity to measure both the degree and the forces of contraction which result from decreasing the temperature of the films from +250 (121°C), or +75°F (24°C), to -300°F (-184°C).

I. Contract Research

Supporting research contract activities have continued in the areas of technology and with the contractors as specified below:

A. Polymer Development and Characterization

1. Southern Research Institute, NAS8-20190
2. W. R. Grace Company, NASw-924
3. National Bureau of Standards, Government Order H-92120

B. Adhesives Development

1. Narmco Research and Development, NAS8-11068
2. Monsanto Research Corporation, NAS8-11371, NAS8-20402, NAS8-20406

C. Developmental Welding

The Boeing Company, NAS8-20156

D. Alloy Development

American Machine and Foundry Company, NAS8-11168

E. Physical and Mechanical Metallurgy

1. Aluminum Company of America, NAS8-5452
2. Syracuse University, NAS8-11345
3. Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

1. Harvey Aluminum, Incorporated, NAS8-11508
2. Aeronca Manufacturing Company, NAS8-5445
3. Douglas Aircraft Company, NAS7-429
4. Mitron, Research and Development Corporation, NAS8-20609

G. Lubricants and Lubricity

Midwest Research Institute, NAS8-1540

H. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-20396
2. National Bureau of Standards, CO-H2151A
3. Northrop Corporation, NAS8-20333
4. Tyco Laboratories, Inc., NAS8-20297
5. Kaiser Aluminum and Chemical Company, NAS8-20285

I. Explosion Hazards and Sensitivity of Fuels

Stanford Research Institute, NAS8-20220

J. Synergistic Effects of Nuclear Radiation, Vacuum, and Temperature on Materials

1. General Dynamics Corporation, NAS8-18024
2. Hughes Aircraft Company, NAS8-20210

K. Instrument Development

1. Battelle Memorial Institute, NAS8-11891
2. Canadian Commercial Corporation, NAS8-20529

II. General - In-House

A. Development of High Temperature Resistant Polymers

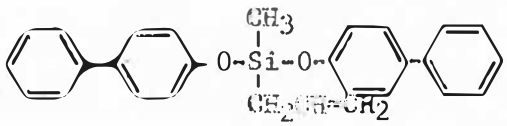
Work is continuing on the development of curing systems for polyaryloxysilanes of the Polymer A type along two lines; (1) condensation of the polymer end groups with polyfunctional silanes such as trianilinophenylsilane (TAPS) with the elimination of aniline, and (2) formation and curing of copolymers of Polymer A containing chemically active side chain groups, without the elimination of small molecules.

1. Curing of Polymer A

Aluminum lapshear specimens were bonded by application of a molten mixture of Polymer A and 7.5 weight percent trianilinophenylsilane (TAPS), the melt being held at about 200°C. Additional specimens were bonded with Polymer A alone. After heating the specimens for one hour at 260°C in a compression molding press at contact pressure, the samples bonded with the TAPS mixture were characterized by a tensile strength of about 2400 psi whereas those bonded with Polymer A alone had tensile strengths averaging about 850 psi. Unfortunately, the pot life of the Polymer A-TAPS mixture at 200°C was only 2-3 minutes. Application by dipping the metal in solution of the mixture followed by evaporation of solvent and curing, yielded weaker bonds, i.e., 1560 psi and 813 psi for the samples with and without TAPS, respectively. It is possible that the solvent was not completely removed before the curing process. A new experiment is in progress in which the mixture is applied in the form of thin films which have been cast from solution and thoroughly freed of solvent.

2. Synthesis of Bis(p-Phenylphenoxy)allylmethylsilane

A new monomeric model compound,



has been prepared for use in the appraisal of the reactivity of allyl groups connected to silicon in structures of the Polymer A type. The material was formed by the condensation of p-phenylphenol and allylmethyldichlorosilane in benzene solution containing triethylamine as the acid acceptor. Recrystallization of the crude product from a mixture of benzene and petroleum ether yielded a white crystalline compound, with the expected elemental composition.

Thermogravimetric analyses (TGA) have been made on the group of monomeric aryloxysilanes described in a recent publication (Inorganic Chemistry 5 2042 (1966)). In that publication the differential thermal analyses (DTA) of the compounds were reported. The availability of the two accurate analyses of a group of carefully purified materials affords some clarification of the meaning of the analyses at temperatures below those at which decomposition takes place: (a) TGA weight losses were directly proportional to the volalitity and inversely proportional to the molecular weight of the materials, and (b) energy absorption in the DTA measurement took place only at the melting points of the compounds.

Previous work has indicated the possibility that the solvent, tetrahydrofuran (THF) may react chemically with the polyaryloxysilanes. However, a quantity of triphenylphenoxysilane was prepared and was found to be stable in boiling THF for a period of 7.5 hours.

An unsuccessful attempt to cure an aryloxysilane polymer containing Si-CH_3 groups by treatment with methylethyl ketone peroxide gave an opportunity to check the increase of absolute molecular weight as determined by light scattering against the increase in relative molecular weights as determined by gel permeation chromatographic analysis (GPC). The two methods agreed and showed that a small increase in molecular weight of the polymer resulted from the peroxide treatment.

B. Development and Characterization of Phosphonitrilic Polymers

The product obtained from the reaction of 2,4,6,8-tetraphenyl-2,4,6,8-tetrakis-N-methylcyclohexylaminophosphonitrile and anhydrous HCl, and which was assumed to be an isomeric mixture of phenylphosphonitrilic chlorides, was subjected to elemental analyses and found to contain approximately 30 percent ash as MgO. Furthermore, the product contained only a negligible amount of chlorine which was probably present as a contaminant and not a part of the molecule.

Therefore, the intermediate assumed to be $P_4N_4\emptyset_4(N(CH_3)(C_6H_{11}))_4$ as obtained from the Grignard phenylation of the corresponding tetrachloro derivative is undoubtedly some type of phosphonitrilic-magnesium complex arising from attack by the $\emptyset MgBr$ on the ring nitrogens with concommittant attachment of the Mg to the lone pair of electrons on the nitrogen atom. Unfortunately, these results parallel unsuccessful efforts by other workers to effect tetrameric ring substitution with Grignard reagents.

At the present time efforts are being devoted to a characterization of the $P_4N_4Cl_4(N(CH_3)(C_6H_{11})_4$ obtained from the reaction of $(PNCl_2)_4$ with N-methylcyclohexylamine. This amide is obtained in quantitative yield through the treatment of $(PNCl_2)_4$ with the amine at 0°C in THF. More significant, however, is the fact that the nuclear magnetic resonance (n.m.r.) spectrum of the amide shows it to be a non-geminally substituted single isomer. This is very unusual because the formation of four isomers is possible from the reaction; and, to date, no literature references report the isolation of a single isomer in quantitative yield from the numerous reactions studied involving amination of $(PNCl_2)_4$. Moreover, n.m.r. data show that the amide is either of the α-trans, γ-trans, or cis configuration.

To establish the configuration of the $P_4N_4Cl_4(N(CH_3)(C_6H_{11}))_4$, a series of reactions are being undertaken to prepare appropriate derivatives suitable for n.m.r. study. The amide has been treated at 0°C in THF with excess monomethylamine to form a completely substituted derivative:

$$P_4N_4Cl_4(N(CH_3)(C_6H_{11}))_4 + 8\ H_2NCH_3 \longrightarrow P_4N_4(HNCH_3)_4(N(CH_3)(C_6H_{11}))_4 + 4\ \text{amine}\cdot HCl.$$

The product was obtained in quantitative yield as a coarse crystalline solid which had m.p. 174-176°C after recrystallization from THF. Elemental analyses are pending.

The next step will be treatment of this amide with one equivalent of phenyl isocyanate.

$$P_4N_4(HNCH_3)_4(N(CH_3(C_6H_{11}))_4 + C_6H_5NCO \longrightarrow$$

$$\longrightarrow P_4N_4(HNCH_3)_3(N(CH_3)CONHC_6H_5)(N(CH_3)(C_6H_{11}))_4$$

The proton n.m.r. spectrum of this derivative will be examined after deuterium exchange of the amido protons. If the spectrum of the compound shows four doublets indicating that the methyl-amido groups are in four different environments, the only configuration that satisfies this requirement is the α-trans. However, if the spectrum shows three methyl doublets with an area ratio of 1:2:1, the only geometrical configurations possible are the cis and γ-trans. If the latter possibility is the case, then treatment of $P_4N_4Cl_4(N(CH_3)(C_6H_{11}))_4$ with anhydrous $FeCl_3$ in benzene will be performed to effect isomerization to another geometrical configuration. Subsequent work as outlined above coupled with dielectric constant measurements will enable final characterization of the original isomer.

C. Investigation of Materials for Use as Electrical Contacts in the Vacuum of Space

Development work and qualification testing have continued on low resistivity brush materials for possible application in the environment of space. Present work is concerned with the development of niobium diselenide ($NbSe_2$) based brush materials. As reported previously, difficulties have

been experienced in hot pressing the $NbSe_2$-silver (Ag) brush materials. The hot pressed density of a 90 $NbSe_2$-10 Ag composition has varied from 99.4 percent of theoretical using one batch of $NbSe_2$ to 83.3 percent of theoretical using another batch of $NbSe_2$. Preliminary findings indicated that reaction between the $NbSe_2$ and Ag during hot pressing, forming a new compound, may be responsible for the density variations. X-ray diffraction techniques are being used to study the reaction and analyze the new compound.

X-ray diffraction analysis of the latest shipment of $NbSe_2$ shows that this material is identical with previous batches of $NbSe_2$. The hot pressed density of this material was also identical with the hot pressed density of the previous shipment with the same particle size. The 90 $NbSe_2$ - 10 Ag composition was hot pressed again with the same results obtained - a fractional density (actual density/theoretical density) of 0.83. During the rerun of this composition, samples of the powder were taken after hand mixing with a spatula, after mixing for 2 hours with steel balls in a tumbler, and after hot pressing. The sample taken after hand mixing shows the diffraction patterns of $NbSe_2$ and Ag, as expected. The samples taken after ball mixing and after hot pressing both show reaction of the components. After ball mixing, the pattern shows $NbSe_2$, Ag, and 5 unidentifiable lines; after hot pressing, the pattern shows only $NbSe_2$ and 5 unidentifiable lines. A sample of 95 $NbSe_2$-Ag, made from the previous shipment of $NbSe_2$, showed only $NbSe_2$, and a sample of 80 $NbSe_2$-20 Ag, also made from the previous shipment of $NbSe_2$, shows an apparent new compound. The nature of the reaction and characterization of this new compound will be investigated further.

Tests are continuing in which a variety of experimental brush materials including various selenides, sulfides, mixtures of these, and sulfides and selenides with added silver are being tested in air and in a reduced pressure environment to determine the coefficient of friction of the brush materials in the stated environments when operated against a slotted copper commutator rotating at 2,200 rpm.

D. Investigation of Thin Film Materials for Electronic Components

A thin film of SiO was deposited on a polished brass plate 3-1/2 inches indiameter. The thickness of the film was approximately 420 angstroms. The thickness measurement was made on a reference glass slide using a double beam interferometric technique. The film was determined to have zero resistance with standard dielectric measurement apparatus. A small probe with a 1-1/2 volt source also showed zero resistance. These results are as expected. At this film thickness the voltage gradient is above 5×10^5 volts per cm and is sufficiently high for onset of electron tunneling and dielectric breakdown. Special low voltage measuring techniques will be developed to resolve the question of the conduction mechanism through the film.

Variations in the ratio of film thickness to mass of the source have been found to exist. Further depositions are planned to isolate the nonreproducible factor.

E. Development of Direct Current Motors for Use in the Environment of Space

Materials are being evaluated at extreme temperatures and low pressures for use in direct current (d.c.) motors designed for operation in the space environment.

During the reporting period one test was made on the motor-generator set at a pressure of 1×10^{-6} torr. Average speed was 670 rpm with applied motor armature voltage of 40 volts and with field currents maintained at 1.5 amperes. This test was ended after 313 hours with little wear of the brushes and with no bearing or insulation problems. Wear rate determined for these brushes averaged 2.0×10^{-5} inch/hour.

F. Determination of Physical Properties of Materials by Nondestructive Techniques

1. Acoustic Emission Studies

A project is being conducted to determine the correlation between acoustic emission and stress corrosion propagation.

Due to the very low level of acoustic emission resulting from stress corrosion phenomena, difficulty in separation of these signals from background emissions has necessitated acquisition of an acoustically insulated chamber. The chamber has been designed, constructed and delivered.

Transducer holders have been reduced in size to present a smaller receiving aperture to minimize damping and distortions.

2. Ultrasonic Measurement of Crack Propagation

A project has been initiated to develop a suitable laboratory apparatus for measurement of the rate of crack propagation in structural alloys. The apparatus is needed for experimental study of the influence of stress, reactive environments, temperature, etc. on the rate of crack propagation.

C. Lubricant Development and Evaluation

A major lubrication problem today concerns low temperature lubricants for use in a cryogenic environment. A test apparatus has been designed and fabricated for evaluating greases over the temperature range from +50°F to -100°F (10°C to -73°C) breakaway torque and the relaxation torque can be measured accurately at any specific temperature in this temperature range. During this period several repeat tests were made on lubricants previously tested as well as several new greases. The lubricants tested were as follows:

Dow Corning	FS-1281	(fluorosilicone)
Halocarbon	25-5S	(fluorocarbon)
3M Company	Kel-F-90	(fluorocarbon)
MSFC	AC 4-2-4	(fluorosilicone)
MSFC	AC 8-3	(fluorosilicone and fluorocarbon)
MSFC	QF 10065 (75)	(fluorosilicone and fluorocarbon)

The results of these tests will be tabulated when tests are complete and the data will be included in the next monthly report.

H. Investigation of Ceramic Fiber Reinforced Composites

Efforts have continued to develop ceramic whisker reinforced drawn glass fibers. A few short lengths of glass fiber containing silicon carbide (SiC) whiskers have been prepared by filling a glass tube with a mixture of 90 percent E-glass and 10 percent SiC whiskers, melting the end of the tube in an induction heated graphite tube and drawing the fiber by hand. The fibers are weak and large and have a very poor surface. The presence of the whiskers appears to reduce markedly the ability to draw the fibers. Some experimental trials in melting E-glass alone have been made. Thin-walled platinum crucibles were used initially as containers for melting the glass in the induction furnace; however, platinum is not a satisfactory susceptor for the RF power. Crucibles of SiC have been ordered to use as the susceptor material and the glass melt will be contained in a platinum crucible within the SiC crucible.

The design of the fiber tensile tester is complete and detailed drawings of the individual parts are being prepared.

I. Development and Evaluation of Metallic Composites

Efforts are continuing to develop LOX compatible ceramic adhesives. A series of mixes were investigated in which monoaluminum phosphate and 25 percent colloidal silica were used as bonding agents and zirconium silicate ($ZrSiO_4$), zirconium oxide (ZrO_2), and aluminum oxide (Al_2O_3) as inert ingredients was investigated. The best composition consisted of 10 grams Al_2O_3, 10 grams ZrO_2, 5 cc monoaluminum phosphate and 4 cc colloidal silica; however, it did not have a satisfactory pot life, nor was its shear tensile strength comparable to that of the previously developed 114 mix.

Future work will continue on the in-house development of ceramic adhesives, and the evaluation of commercial ceramic adhesives.

J. Development and Evaluation of Metallic Composites

Several specimens of steel wire reinforced magnesium composite material were prepared during this report period. Previously prepared wire reinforced magnesium composites contained wire volumes of only four percent; however, recent experimental composites contained eight and

twelve volume percent of steel wire reinforcement. The materials used in these composites were AZ-31 magnesium alloy foil and NS 355 steel alloy wire of 0.004-inch diameter. Matrices of alternating layers of magnesium alloy foil and steel wire were heated to 700°F (371°C) for five hours under a reduced pressure environment of 2×10^{-2} torr and under a clamping pressure of 10,000 psi. An average tensile strength of 57.5 ksi was obtained for an 8.5 percent wire composite and 72.4 ksi for an 11.7 percent wire composite. Other tests will be made to verify the above data; and, if found valid, experiments with beryllium wire will be attempted.

Work has continued on the development of techniques and concepts for utilizing modular filament sheets, as a method of producing low density, high strength composite metallic materials. A patent application has been completed except for necessary drawings of the potential application and will be submitted upon receipt of these drawings. The modular filament concept has been extended to include filament reinforced cast aluminum and magnesium composite. Assembly of stacked beryllium modular filaments are being accomplished. Also, preliminary casting techniques have been discussed and established for producing aluminum and magnesium cast panels reinforced with the above mentioned beryllium modular filament.

Three types of explosively-bonded composite sheet materials were prepared and tested with results indicated in the following tabulation:

	Composite	Ultimate Tensile Strength, psi	Yield Strength psi	Percent Elongation (2in)
1.	2024-T4 aluminum (0.015-inch thick) bonded to 6Al-4V titanium 0.051-inch thick	148,000	130,000	5.5
2.	2024-T4 aluminum (0.060-inch thick) bonded to a second sheet of same material	73,000	61,000	10
3.	6Al-4V titanium, Alclad (0.047-inch thick) bonded to 2024-T4 aluminum (0.024-inch thick)	109,000	-	-

It should be noted that in the number 1 combination there was an increase of 16 percent in the ultimate and 15 percent in the yield strength compared to the theoretical calculated mechanical properties of the alloy combination prior to joining. In the number 2 combination there was an increase of 7.2 percent in ultimate and 28 percent in the yield compared with typical mechanical properties of 2024-T4. Finally, in the number 3

combination there was an increase of 7.0 percent in the ultimate compared to the theoretical calculated mechanical properties of the alloy combination prior to joining. Explosively joined panels 10 inches by 24 inches are planned for the next reporting period in the combinations, aluminum-titanium-aluminum and magnesium-titanium-magnesium.

K. Evaluation of "Alstan 70" Process for Plating on Aluminum

Activities have continued on the evaluation of the "Alstan 70" process for plating aluminum alloys. The Alstan process employs an initial alloy strike (tin and copper) in the plating sequence instead of the zinc immersion coating which is used in the conventional process. Two alloys, 6061 and 7075 are being used in the evaluation of this process. Results of the work thus far indicate that the 6061 alloy may be satisfactorily plated with nickel and gold using this process; however, difficulty in plating 7075, as well as 2024 and 5052 alloys, has been encountered. The main problem is poor adhesion in the area of electrical contact. Several types of electrical contacts have been used and all result in numerous small blisters around the contact area. This problem is not encountered when plating these alloys using the conventional zincate method.

L. Investigation of Stress Corrosion Characteristics of Various Alloys

Tensile specimens have been fabricated and a test program formulated to evaluate the stress corrosion characteristics of 7001-T75 aluminum alloy. The properties of this alloy have been obtained, and tests will be started as soon as possible.

Stress corrosion studies have continued on alloy 7039 in the -T61 and -T64 tempers. Failures have occurred to specimens stressed in the short transverse direction; however, no failures have occurred to specimens stressed in the long transverse and longitudinal directions after approximately eight months exposure in the alternate immersion tester and in the local atmosphere.

The stress corrosion resistance of X2021 and X7007 aluminum alloys is being investigated. These alloys were stressed in all three grain directions and exposed in the alternate immersion tester and in the local atmosphere. There have been no failures of these alloys since those listed in the August progress report. Alloy X2021-T8E31 specimens have been exposed to the local environment for 262 days without any failures.

Weldments of aluminum alloys X2021 and X7007 welded with number 5180 wire are being evaluated for susceptibility to stress corrosion cracking. Specimens are stressed to 50 percent of the ultimate weld strength using a bend type specimen. No failure has occurred to specimens of either alloy that can be attributed to stress corrosion. The specimens made from X7007 have been exposed in the alternate immersion tester for 100 days, and exposure is being continued. The specimens fabricated from X2021 alloy have been removed from the test environment, and the properties are being obtained.

Stainless steel tubing (321 alloy) welded and brazed to fittings marketed by General Electric, Aero Quip, and North American Aviation are being evaluated for susceptibility to stress corrosion cracking. The alternate immersion tester is being used in this work. There have been no visible failures after 66 days of exposure.

M. Investigation of Various Paints and Paint Primers

Two clear lacquers have been evaluated for the protection of highly polished surfaces. An air-drying lacquer produced a fair surface appearance which was improved by baking at a low temperature (175°F). The baking lacquer gave the best results and provided a harder, more durable finish. This finish is extremely difficult to remove after it has been cured and could not be considered for strippable purposes.

N. Synthesis of Fluorocarbon Monomers (SWO 426)

1. The preparation of fluorocarbon intermediates of potential adhesive interest is continuing.

Trifluorovinyl lithium is commonly prepared by reaction of trifluorovinyl iodide with methyl lithium. Since analytical data on one of the reactants, methyl lithium, is quite uncertain, an attempt was made to prepare trifluorovinyl lithium by reaction of trifluorovinyl iodide and butyl lithium, a much more easily characterized material.

In the reaction sequence to prepare the unsaturated alcohol, $CF_2=CFCH(CF_3)OH$, butyl lithium was substituted for methyl lithium in the first stage of the sequence described above. If this substitution can be made directly, then the final product should be identical to that prepared using methyl lithium in preparation of vinyl lithium. The product, however, appears to be different, showing different distillation properties. The reaction was run once in ethyl ether and once in hexane, and in each case, the product formed azeotropic mixtures which have not yet been resolved.

2. Investigations have continued in the study of fluorocarbon materials as potential lubricants for use in contact with liquid oxygen. Several variations of the synthesis of 1,1,2,2,tetrafluoroethyl polysiloxane by the photo chemical reaction of methyl dichlorosilane with tetrafluoroethylene have been tried in order to study this reaction. High yields of a high boiling product have been obtained and an analysis for functional groups (SiF) both before and after hydrolysis indicated that (SiF) was not present. A new synthesis was started using a more intense UV source in an attempt to solve this problem.

O. Documentation Review

The following specifications, documents, or reports were reviewed and comments were forwarded, where appropriate, to responsible individuals or organizations:

1. Thiokol Spec. 7220 B, dated 9/4/63, "Protective Treatment, Aluminum Alloys, Touchup"

2. Thiokol Spec. 7695 B, dated 8-2-66, "Heat Treatment, Cleaning, and Pickling Requirements for Semi-Finished and Finished Refractory Metal Parts"

3. Thiokol Spec. 7703 B, dated 8/2/66, "Method of Cleaning Aluminum Alloys for Electron Beam Welding"

4. Thiokol Spec. 7704, February 66, "Cleaning and Pickling Requirements for Semi-Finished and Finished Molybdenum Parts"

5. Thiokol Spec. 7705 C, dated 8/2/66, "Method of Pickling Titanium Alloys"

6. Thiokol Spec. 7706 A, dated 8/2/66, "Method of Pickling Tantalum and Columbium Alloys"

7. Thiokol Spec. 7708 B, dated 8/2/66, "Cleaning Procedure for Semi-Finished and Finished Refractory Metal Parts"

8. Thiokol Spec. 7709 A, dated 8/2/66, "Cleaning Procedure for Semi-Finished and Finished Refractory Metal Parts"

9. Thiokol Spec. 7712 A, dated 8/2/66, "Gold Plating"

10. Thiokol Spec. 7736, dated August 66, "Oval Thrust Chamber Cooling Jacket Passivation"

11. NAA Spec. MAD616-016 B, dated 8/23/66, "Cleaning Packaging Requirement for Saturn S-II Liquid and Gaseous Oxygen System Components"

12. NAA Spec. MAD116-015 E, dated 8/8/66, "Clean Packaging Requirements and Procedures"

13. Thiokol Spec. 7703, "Method of Cleaning Aluminum Alloys for Electron Beam Welding," dated August 2, 1966

14. Thiokol Spec. 7716, "Welding Quality for Extension Nozzle, Rocket," dated August 2, 1966

15. Thiokol Spec. 7676, "Certification, Electron Beam Welding Machine Operators," dated September 29, 1965

16. Thiokol Spec. 7675, "Certification, Electron Beam Welding Machine," dated November 8, 1965

17. A review was made of the draft entitled, "Casting Procurement Specification for Ferritic Steel Castings for Valves and Pumps," submitted by I-MT-EQ.

P. Literature Survey

Surveys of the pertinent literature have been initiated as are continuing on the following subjects:

1. Radiation effects on engineering materials
2. Vacuum effects on engineering materials
3. Lubricants and lubricity
4. High and low temperature resistant polymers
5. Stress corrosion on structural alloys.

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

NOVEMBER 1 THROUGH NOVEMBER 30, 1966

I. Photography

	Negatives	Prints	Slides
Engineering Photography	18	71	8
Metallography and Fractography	185	324	
Miscellaneous Photography Processing, Copywork, etc.	87	602	

II. Metallurgical and Metallographic Testing and Support Services

A. At the request of the Test Laboratory, several gold and tin-plated electrical terminals were exposed to the five percent spray and 100 percent relative humidity for comparison of corrosion susceptibility. Salt spray exposure for 216 hours and exposure to a 100 percent relative humidity for 30 days did not result in serious deterioration based on a visual examination. It was recommended that electrical measurements be made for a complete evaluation and comparison.

B. A metallurgical evaluation of a 302 stainless steel snap diaphragm was completed at the request of the Propulsion Division, R-P&VE-PEM. The 302 stainless steel snap diaphragm was shaped by magnetic hammer forming. The evaluation did not reveal any adverse effects as a result of the magnetic forming operation. No increase in hardness was noted in the formed section; however, it must be understood that the 302 stainless material was in the fully work hardened condition.

C. At the request of the Structures Division, R-P&VE-SVT, metallographic studies were made on an Alclad 2024-T3 dynamic test specimen. The sample had been exposed to random cycling with loads ranging from 1800 psi to 54,000 psi. The test lasted for nine hours before specimen failure. Since the test lasted for this extended period, a study of the microstructure and hardness was requested. The metallographic study did not reveal any metallurgical irregularities nor was the hardness out of the range for 2024-T3.

III. Spectrographic Analyses

Two hundred nineteen determinations were made on twenty-one samples and two hundred nineteen standard determinations were made.

IV. Infrared Analyses

Twenty-four determinations were made by infrared techniques on a variety of materials including residue from a CEC leak detector, residue from an air dryer, Arochlor 1254 from S-II-501 LOX tank, an ink from Test Laboratory, and a variety of polymer and monomer specimens.

V. Chemical Analyses

	Determinations
experimental polymers for	
carbon	3
hydrogen	3
nitrogen	3
phosphorus	2
total chloride	2
ionizable chloride	2
ash content	2
metal samples for	
carbon	24
chromium	24
nickel	24
sulfur	24
methanol water mixture for	
sodium benzoate	3
caustic solution for	
NaOH	4
residue from solid propellant rocket for	
carbon	4
gas samples for	
hydrogen	7
oxygen	20
nitrogen	20
toxic contaminants	8

VI. Physico Chemical Analyses

	Determinations
Density of RP-1 fuel	24
Heat of combustion of RP-1 fuel	2
pH of methanol-water solution	3
specific resistance of methanol-water	3

VII. Rubber and Plastics

	Items
molded and extruded	33
cemented	50
potted	19
fabricated	63

VIII. Electroplating and Surface Treatment

	Items
cleaned box assemblies for liquid hydrogen and liquid oxygen use	2
plated	132

IX. Development Shop Production

A. A total of 5,015 man-hours, direct labor, was utilized during this test period for machining, fabricating, and welding.

B. One thousand two hundred and seventy-five man-hours, approximately 25.4 percent of the total man-hours, were devoted to productive effort of a nonroutine nature and applied to the work orders listed below.

1. Cyclone Chamber

The cyclone chamber has been completed and delivered.

2. Quick Release Umbilical Carrier

The quick release umbilical carrier is approximately 80 percent complete.

3. 6-Inch UV Camera Assembly

Hardware is ordered and design prints are nearly complete for the 6-inch UV camera assembly.

4. Rack/Payload Module

The first rack, built for access study, was satisfactory. This rack will be used for buoyancy tests.

5. Rack/PM Battery Dolly and Track

Numerous test components are in various stages of manufacture.

X. Miscellaneous

A. Six steel items, one hundred items of titanium alloy, and five items Inconel 718 alloy were heat treated during this report period.

B. Prepared several ceramic insulators from Grade A Lava for Test Laboratory.

C. Prepared over thirty foam insulation specimens coated with various flame-retardant coatings.

D. Made forty-six chromatographic analyses of various organic materials.

E. Determined compatibility with liquid oxygen of specimens from eighteen jars of FS-1281 lubricant.

F. Fifteen differential thermal analyses, two thermogravimetric analyses, and thirty differential scanning calorimetric tests were made during this report period.

G. Reflectance determinations were made on two specimens.

H. Sixteen samples were examined by X-ray spectroscopy during this report period.

XI. Publications

Key, C. F.: Compatibility of Materials with Liquid Oxygen, III, TM X-53533, November 3, 1966.

Fowler, M. V.: Effect of Molecular Structure on Physical Characteristics of Polyaryloxysilanes and Related Compounds, TM X-53536, November 14, 1966.

Olsen, M. G.; Davis, R. A.; and Worden, S. W.: A Study on the Effects of Various Heat Input Rates on T-1 and T-1A Steel Welds, TM X-53537, November 14, 1966.

Key, C. F.: Compatibility of Dye Penetrants and Penetrant System Components with Liquid Oxygen, IN-P&VE-M-66-5, November 3, 1966.

Morgan, W. R.: Low Temperature Mechanical Properties of Aluminum Alloy 7039-T6 Sheet and Plate, IN-P&VE-M-66-6, November 14, 1966.

J. E. Kingsbury

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-66-11

MONTHLY PROGRESS REPORT

November 1, 1966 through November 30, 1966

SATURN IB

I. S-IC Stage

A. H-1 Engine

1. Engine Gimbal System Auxiliary Pump Problem

The auxiliary hydraulic pump on position 4 of S-IB-4 was making periodic "pinging" noises. It was suspected that the pressure compensator was sticking since the noises were accompanied by small pressure oscillations. Consequently, the entire hydraulic package was removed and sent to Michoud for investigation.

2. Servicing and Inspection of Engines on S-IB-4 Completed

All outstanding work items were completed on H-1 engines of S-IB-4 at KSC. The LOX domes were flushed for decontamination, the turbopump shaft lock tabs were inspected with satisfactory results, and the thrust chamber walls were cleaned.

3. Engine on S-IB-7 Stage Replaced

Engine H7080 on position No. 4 was replaced with spare engine H7074 because teflon pieces were found in the LOX system during poststatic test. Investigations indicated that neither the engine nor the stage use this type of material. Also, no possible external source could be suggested by the engine and stage contractors.

4. Engine on S-IB-8 Stage Replaced

Engine H4078 on position No. 6 was replaced with engine H4071 after the short static test because of turbine blade damage. The

damage possibly resulted from entrance of a foreign object, although other failure modes (such as blade cracking) cannot be ruled out at this time.

B. S-IB/S-II Retro and S-IVB Ullage Motor Programs

The short burn time of the retro motor on SA-202 was caused by a "burn-through" of the motor case. An ECP is being prepared describing the changes to the motor that are required to prevent this malfunction.

C. S-IB-3 Stage Successfully Static Tested at MSFC

Test duration was 35 seconds. All stage systems performed satisfactorily with the exception of one engine. Engine No. 6 (H-4078) performed at a sea level thrust of 185.9 K. An inspection of the turbine revealed that 25 percent of the blades on the first stage were knocked out, and the second stage blades were badly dented. This engine was removed and replaced with a spare. The next test is scheduled for a duration of 143 seconds.

II. S-IVB Stage

A. S-IVB-204 LH_2 Pump Meets Inlet Total Pressure Requirements

Predicted data previously showed an NPSH problem at 300 seconds of burn time. A review of the pump inlet requirements showed that the suction line ΔP is expected to be less than the predicted 1.69 psi, that the pressure switch lower limit is 27 psi instead of 26.5 psi, andthat the probability of the tank pressure being at the lower limit of the pressure switch setting is remote.

B. Qualification Status of S-IVB Propulsion Components

Seventeen additional propulsion components have fulfilled the requirements of mandatory testing relative to the launch of S-IVB-204. There are now only four components that must pass mandatory qualification for the 204 launch.

C. Orbital Workshop Thermal Control

Studies to establish the adequacy of the passive control concept have continued.

1. Number of Fans for the 16-compartment Liner - The number of fans is contingent upon that necessary to establish an acceptable film coefficient and to flow sufficient air for energy rejection requirements. Studies show eight Apollo Post Lunar Landing ventilation fans are sufficient to satisfy film coefficient needs.

2. Moisture Condensation on Wall - With the no spin orientation restraints necessary for clustered OWS, portions of the internal wall will be below the dew point at the minimum relative humidity of 30 percent. Preliminary studies indicate that sufficient "drying" of the atmosphere will occur to reduce the relative humidity of the atmosphere below the minimum of 30 percent. This problem is being investigated.

3. Meteoroid Shield Effect on Thermal Control - Preliminary studies show that the addition of a meteoroid shield can have little effect on the thermal control concept. This conclusion applies to meteoroid shields consisting of an aluminum skin without or with very little insulating material. Thicker layers of insulation affect this conclusion and demonstrate the need for a coordinated structural/thermal design.

SATURN V

I. S-IC Stage

A. F-1 Engine

1. R & D Engine Tests at EFL

Six tests were conducted for a total duration of 781.4 seconds. Four of these tests were for full duration (150 seconds or more). All the tests were successful.

2. Production Engine Tests at EFL

Three tests were successfully conducted, and a total duration of 261.1 seconds were accumulated. One test was for full duration (150 seconds or more).

3. Engine Performance Analysis of S-IC-3 Test

Analysis of test data indicates that the performance of all the engines was satisfactory. Engine F-4024, which was found to be contaminated during the pre-test preparations, was replaced with engine F-4027 before the test.

B. LOX Tank Center Engine Riser Line Extension Vortex Study Results

The results of an investigation of the draining characteristics of the proposed S-IC LOX tank riser line extension indicated there are no surface distortions. Model flow rates, determined from Froude number simulation, were increased by 50 percent for the flow tests. It was recommended that no change in the height of the cross-baffles be made if the riser line is extended as proposed.

C. Redesign of Forward Skirt Compartment Hardware to New Prelaunch Environment Proposed

The proposal provides for modification (orifice change and manifold insulation) of the canister environmental control system; addition of heater blankets to measurements that exceed qualification temperatures, requalification of various equipment, and modification of temperature sensor ranges as necessary. All the modifications were approved with the exception of the increased temperature range of the canister transducers since the current range is below allowable equipment operating temperature. The addition of the heater blankets was approved contingent upon the measurement need and effect upon accuracy of the low temperature.

D. Revised S-IC-501 Flight Prediction

A revised final S-IC-501 flight prediction was necessary due to revised trajectory data and other revised input data. The data tape should be available within two weeks.

E. Preliminary S-IC-502 flight prediction data tape was verified, The 18 dispersion cases were completed but have not been verified.

F. Evaluation of S-IC Filter Elements

Construction on the test set up for the dirt holding capacity test was completed. Filtration efficiency tests of one element from each to the six vendors was completed. A media migration test was run on one element, but because of the wear observed in the filter manifold after vibration, it was impossible to determine whether the metallic particles came from the filter or the filter manifold. The filter manifold is being investigated further.

G. Status of Propulsion Component Qualification

All components are now qualified. The 10-inch LOX vent and relief valve is the only remaining item of concern. Because of its past qualification failure history, the S-IC Stage Project Office (I-V-S-IC) was requested to consider using the backup valve as soon as the schedule permits.

II. S-II Stage

A. J-2 Engine Tests at AEDC

Two test series were conducted, each with several objectives. The first test series consisted of a successful 5-second test firing employing a one-second fuel lead. The test was followed by a 30-second duration test employing a 4.5-second fuel lead after 90 minutes simulated coast period. This was the first hot firing test at AEDC with an extended fuel lead.

The second test series consisted of a 40-second test firing employing a one-second fuel lead. This test was followed by a simulated Saturn V restart with the thrust chamber at ambient temperature and employing a fuel lead of 8 seconds after a 90-minute simulated coast. The test was terminated by the GG over-temperature device at 0.93 seconds after STDV open. Indications are that, an 8.0-second fuel lead may be too long for a restart. The investigation is continuing.

B. Battleship Test - LOX Recirculation System

Testing of the S-II LOX recirculation system indicated that the Engine Compartment Control System (ECCS) provides excessive turbulence in the engine compartment area, and that the LOX recirculation system will not perform properly as designed. J-2 LOX system insulation and/or redesign of the ECCS are required. Tests indicate that a re-orificed ECCS, LOX system insulation and in-flight helium injection in the LOX recirculation return lines will provide proper LOX conditions for engine engine start. These modifications are being proposed for S-II-I. Tests using an ECCS distribution manifold external to the thrust cone indicate that the required engine insulation would be less than for the above configuration, but thrust cone insulation would be required.

C. J-2 Start Tank

Slight leakage is still occurring from seals on the tank. A helium leak detector was used to pinpoint the actual leakage areas.

Polyurethane was applied to the seals, and further leakage checks are scheduled.

D. Status of Unqualified Propulsion Components

1. Calmec LOX Vent Valves - The LOX qual valves completed acceptance, Phase A&B vibration, high temperature and salt spray testing. Remaining tests to be made are low temperature, sand and dust, salt spray, shock, and cycling. The phase A&B vibration results were not conclusive enough for 100 percent qualification status (high leakage and crack problems were experienced irregularly). These problems may be due to test set up conditions. It was recommended that the phase C random vibration program, which is scheduled for 72 minutes in each axis, be modified.

2. Calmec LH_2 Vent Valves - The LH_2 qual valves completed acceptance and Phase A&B vibration testing. Remaining tests to be made are cycling, high temperature, low temperature, internal and external GH_2 leakage, humidity, and acceleration.

E. Verification Testing of S-II Accumulator Reservoir Manifold Assembly (ARMA)

The filter test, proof pressure test and a portion of the functional test have been completed satisfactorily. Work is continuing on the test program.

F. RS-U-601 Ullage Motors

Of the 16 motors cast four motors were rejected due to voids within the propellant grain. The voids were caused by the leakage of air through the aft insulation strip into the motor during the vacuum casting operations. The tooling modifications have to date been ineffective. The qualification program completion date is now scheduled for February 12, 1967. The stage contractor has proposed that the ullage motors be x-rayed prior to installation on the S-II stage at KSC.

G. RS-U-602 Ullage Motors

Five RS-U-602 ullage motors were cast. These motors have subsequently been x-rayed and found to be acceptable for the RS-U-602 PFRT program. The PFRT program is scheduled for completion in early December. The stage contractor does not recommend the

continuation of the RS-U-602 program into qualification. The stage contractor has presented the results of a study to determine the minimum acceleration levels required for S-II stage engine ignition and propellant settling. The study indicates that no ullage motors are required for first and second stage separations above 175,000 feet. A final decision on the proposed deletion of the S-II stage ullage motors is expected late this year. In the meantime, work will continue through RS-U-601 qualification and delivery of motors to KSC for S-II-501 assembly.

III. S-IVB Stage

A. C-1 Engine (APS) Tests at Reaction Motors

The C-1 engine was started 63,325 times and accumulated a total firing time of 13,224 seconds. The program overall totals are now 264,175 starts with an accumulated hot firing time of 98,240 seconds. Reaction Motors is presently performing durability tests on the Block I engines in demonstration of the 2000 second life requirement. The results of these tests thus far are satisfactory. The burst test on the moog bipropellant valve was successfully completed using three specimens.

B. Auxiliary Propulsion System (APS)

An analog model was developed to simulate the Saturn V/S-IVB APS oxidizer feed system and evaluate various pressure oscillation damping devices. A two-directional gas pressurized bellows type accumulator was designed using various configuration parameters on the analog computer to measure the effects on the overall oxidizer feed system performance. The new design accumulator eliminates pressure oscillations due to valve opening and closing as simulated by the analog computer. Hardware verification tests are scheduled for the first quarter 1967.

C. LH_2 Tank Heat Leak

As a result of continued evaluation of the AS-203/S-IVB stage flight data, it was determined that helium and/or GN_2 predominantly influences the S-IVB stage LH_2 tank insulation thermal conductivity, and the LH_2 wetted area is increased due to the low-g acceleration. Preliminary evaluation indicates the total heat inputs to the LH_2 to be approximately 30 percent higher ($\approx$ 1000 lb additional boiloff for 4 1/2 hour orbit) than the maximum orbital heating values currently being used.

D. Vibration Testing of S-IVB Accumulator Reservoir Assembly (ARA)

The S-IVB ARA was subjected to a vibration test to evaluate the design of the vent tube. A small accelerometer was mounted inside the end of the vent tube to measure g-levels developed by the tube. During the sinusoidal sweep, high vent tube g-levels (up to 370 g's) were measured at several frequencies, but the vent tube completed the vibrating test without failure.

E. Battleship Test Reported

During the Battleship test firing, the number one fuel depletion sensor malfunctioned at the end of the replenish cycle and remained inoperative for the remainder of the firing. All other depletion sensors functioned properly throughout the loading and firing. The depletion sensor malfunctions appear to have been caused by oversize sockets in the vehicle feed-thru connectors. All S-IVB stages will be reworked to insure that no oversize sockets exist in the electrical feed-thru connectors. This solution to the depletion sensor problem is currently under study, and at least one successful static firing is mandatory to verify the fix.

F. Thrust Chamber Chill and Hold Duration

Current launch ground rules for the S-IVB/Saturn IB limit the J-2 engine thrust chamber chill duration to a total of 20 minutes. The basis for this limit is concern about excessive component and subsystem cooling for longer chilldown periods. Present launch countdown sequences provide for thrust chamber chilldown initiation at T-15 minutes. Consistent with the 20-minute chill time limit, the present sequence only allows a 5-minute hold capability during chilldown. To prevent this limit from inpacting the launch, it is recommended that the thrust chamber chilldown be started at T-10 minutes. This can be accomplished by increasing supply flow rate for a more rapid chilldown and will provide a maximum of 10 minutes hold once this operation is started. This relaxation on hold periods applies to both Saturn IB and Saturn V. The stage contractor was directed to evaluate this recommendation and to submit a feasibility report on the sequence change.

G. O_2/H_2 Burner Stage Acceptance Firing Test Requirements

The S-IVB-503 stage acceptance firing test plans, the propellant loading and PMR profiles, and the detailed O_2/H_2 burner acceptance

firing test requirements (the present flight sequence of operations for the burner) were reviewed. Successful operation of the burner on each stage during acceptance firing is mandatory, and a detailed definition of the requirements for successful operation of the burner on each stage has been defined.

H. Instrumentation Requirements for Synchronous Orbit Missions During Hohmann Transfer

Propulsion instrumentation requirements for monitoring during the synchronous orbit Hohmann transfer were determined. The requirements tabulated the S-IVB stage and Instrument Unit instrumentation, present operational telemetry system sampling rates, and the minimum allowable sampling rates.

I. Component Qualification Test Program

1. Design evaluation and qualification - Of two hundred and thirty-three components scheduled for DE/Q testing, testing is complete on two hundred and two. Review of DE/Q test reports was completed on forty-six components.

2. Formal Qualification - Thirty-one components are scheduled for formal qualification testing. Testing is complete on 13 components. Thirteen components are presently undergoing tests. Five components are being held for engineering modification or part purchase.

IV. Instrument Unit

A. Instrument Unit - Cold Plate Heater Test

Results of this test were published for two insulation schemes, a heater element with phenolic block insulation and a bare heater element shielded with an aluminum cover. The heat input to the heater element was 140 watts for both heater configurations. The heat gained by the cold plate Methanol/Water (M/W) for the insulated heater was approximately 60 watts for a cold test and 120 watts for a hot test. For the bare heater, the heat gained by the M/W was approximately 10 watts higher for either test. It was concluded from the tests that either heater configuration could be used, but to obtain maximum gain, the entire cold plate on which heaters are mounted should be shielded with a highly reflective material.

B. Cold Plate/IU Skin Thermal Resistance Tests

One test was conducted to determine the heat leakage and thermal resistance between the cold plate and IU skin. Results of the test indicate a possible malfunction with the skin heater. The test was temporarily discontinued to repair leaks in the vacuum chamber.

C. Beryllium Cold Plates

Testing was completed. Since one of the cold plates was damaged near the mounting holes on the structural side prior to testing, the vibration test was omitted. Test data indicates that the pressure drop was extremely excessive; for a flow rate of 100 lb/hr, the pressure drop was 19 psi as compared to 6 psi at 200 lb/hr for the AVCO plate.

SPECIAL STUDIES

I. Project Thermo

Condensing Heat Transfer Experiment (MSFC No. 20)

The program is on schedule; the analytical and preliminary design and evaluation studies were completed. Present effort is directed toward the detail system design. The condensing test section will consist of three straight quartz tubes, which are capable of single and multiple tube operation, one tapered glass tube, and one straight steel tube that will be instrumented along its length so that local pressure drop and heat transfer data can be obtained. The contractor is presently determining astronaut participation requirements for the experiment.

II. Apollo Telescope Mount (ATM)

Studies of active and passive thermal conditioning systems were delayed by the decision to incorporate the ATM into the Cluster, requiring modification of existing thermal models.

III. Nuclear Ground Test Module (NGTM)

A preliminary study of the nuclear stage weight penalty resulting from using a non-zero NPSH pump was completed. The advantage of

utilizing a non-zero design requirement are maximum use of Saturn components, and development of the 36-inch PSOV and the low speed inducer are not required. A decision to forego development of the large PSOV and low speed inducer would decrease the engine development time and decrease the cost.

IV. High-Performance Insulation

A. ADL Calorimeter Testing - The ADL 30-inch diameter calorimeter was insulated with 48 layers of NRC insulation, installed in the vacuum chamber and instrumented for cryogenic testing. A base line heat leak will be established and subsequent testing of penetration heat leaks pursued.

B. Vacuum Chamber Modification - Rapid ascent equipment is being obtained for the 15-foot diameter vacuum facility that will be used to simulate a Saturn pressure decay rate for the first 100 seconds. The installation of the main connecting line and one accumulator tank will complete this facility.

V. Study of Electronic Packages, Environmental Control Systems, and Vehicle Thermal Systems Integration

The study objective is to establish the optimum environmental control concepts for thermally conditioning individual electronic packages for missions of durations varying from 4 1/2 hours to 180 days. Heat load profiles and astrionic equipment thermal design and expendable cooling methods were studied. Other parametric studies included the application of thermoelectric cooling, utilization of H_2 boiloff, and space radiator design and analysis. Based on the analyses, it appears that use of H_2 boiloff is feasible, and that appreciable weight savings are possible by use of a hydrogen-gas-fluid cooler and a space radiator.

VI. 110 Second Failure Analysis

An approximate 1/4 scale model of the F-1 engine feed system at Edwards AFB was built to determine the cause of the turbo-pump failures at 110 seconds. Six tests were conducted using procedures similar to those at Edwards AFB. Results of these tests are being evaluated.

VII. Spin Cooler

A new experimental apparatus was built to more accurately test the spin cooler for cryogens, which uses a variable area cavitating

venturi for flow control. A complete set of data were gathered. Additionally, an air ejector was built and calibrated to give a lower receiver pressure for the spin cooler.

VIII. Solid Propellant Motor Malfunction Detection and Combustion Termination System

The sixth quench verification test (QV-6) was performed using the Mod-4 version of the water injector. The injector was modified by drilling additional holes in the row 6 plenum and make the slide valve cylinder shorter to permit row 1 to reopen at the end of the injector sweep cycle. These changes were made to direct additional water at the entire grain surface to keep it cool after the initial sweep had extinguished the motor. For test QV-6, the quench system was actuated at ignition plus 0.493 seconds, at which time the chamber pressure was reduced to zero immediately. However, shortly after 3.0 seconds the pressure began to rise gradually and the motor came up to full thrust. Detailed analysis of the data indicate that mechanical problems with the quench system occurred, and the injector ball did not travel the full distance, thus water never reached the plenum of row 6 and a sweep of the total grain surface was never accomplished. In addition, secondary water coverage of the quenched grain was not accomplished because row 1 did not reopen. The data obtained from the six quench verification tests and the design of the quench system, which has had mechanical problems throughout the test series, will be reviewed.

ADVANCED PROPULSION AND TECHNOLOGY

Systems and Dynamics Investigation

Fabrication of the first tube wall thrust chamber is continuing. All stainless steel tubes are on hand with 50 percent completed through the final forming. The injector is being assembled for the furnace braze operation. Nickel tubes for the second tube wall chamber are on order.

T. P. Isbell

for H. G. PAUL
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