PROPULSION AND VEHICLE ENGINEERING LABORATORY

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MONTHLY PROGRESS REPORT

For Period

October 1, 1966, Through October 31, 1966

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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-66-10

MONTHLY PROGRESS REPORT

(October 1, 1966, Through October 31, 1966)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

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MONTHLY PROGRESS REPORT
ADVANCED STUDIES OFFICE
(October 1, 1966, Through October 31, 1966)

SATURN V

I. S-IVB Stage Synchronous Orbit Study

A two-day meeting, attended by MSFC and DAC personnel, was convened at MSFC on October 4 and 5, 1966, for the purpose of discussing S-IVB modifications required to accomplish a synchronous orbit mission. Agreements reached and ground rules established are contained in Memorandum R-P&VE-AV-66-169. DAC is proceeding with additional studies to affirm the required long-lead modifications previously defined and will submit an Engineering Change Procedure (ECP) defining all modifications required and modification costs. Information contained in the DAC ECP, data from IBM concerning the IU, and Memorandum R-P&VE-AV-66-176, which contains a justification and general description of a three-burn synchronous orbit mission mode, will supply IO with the necessary background data to seek NASA Headquarters' approval for implementation of the long-lead modifications on AS-507, and subsequent vehicles, which are necessary to prepare the S-IVB stage for acceptance of the modification kits.

II. Voyager Program

In support of the Voyager program, MSFC has initiated a six-month in-house preliminary design study for the Voyager planetary vehicle shroud. The shroud configuration consists of a 45-foot-long 260-inch-diameter cylindrical section and an MSFC standard double-angle nose

cone envelope. MSFC design responsibility terminates at a payload mounting ring interface within the shroud. The Advanced Studies Office is coordinating this in-house effort with the following study objectives:

(1) To establish a preliminary design of the Voyager encapsulation shroud and nose cone.

(2) To establish weights, separation scheme, and systems definition.

(3) To determine test requirements.

(4) To define long-lead-time items.

(5) To determine the manpower, costs, and schedules to design, develop, manufacture, test, and transport the shroud and nose cone.

The results of the conceptual design study on a Voyager shroud were presented to the MSFC/JPL Engineering Implementation Panel on October 20, 1966. These study results will be distributed in Memorandum R-P&VE-AV-66-179.

Data were assembed for a presentation by Dr. von Braun to Dr. Seamans, et. al., at NASA Headquarters on November 3, 1966, in response to their query of the "Impact of Option B on MSFC." This option delegates responsibility for the Voyager spacecraft and propulsion system to MSFC, in addition to the shroud.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

A. Early Synchronous Orbit Mission (SA-510)

At the request of IO, a preliminary mission analysis study was initiated by R-AS to determine a group of primary and secondary experiments to be flown on flight vehicle SA-510. A preliminary mission analysis coordination group was established to coordinate the study with the experiment investigators. The first cut list of experiments consists of Laser Communications, LEM Relay Experiment, Synchronous Orbit Radio Beacon, Navigation and Traffic Control, Radiation Measurements, Thermal Measurements, and Ultraviolet Astronomy. The CSM/LEM/RACK will be used for mounting the experiments, and use of the Apollo

Telescope Mount subsystems will be investigated. This Office is responsible for configuration design and selected aspects of experiment integration.

B. Large Space Structures

A report entitled "Analysis of Orbital Radio Telescopes," dated September 1966, was prepared by BECO to serve as a basis for conceptual design of large space-erectable structures currently under study by this Office. This report presents alternate configurations and system requirements of long-wave radio telescopes for potential use in orbital radio astronomy observatories. Current study consists of conceptual design of a typical radio telescope system with emphasis on structural design and packaging to facilitate space assembly, and assembly techniques, procedures, and support equipment. This effort is scheduled for completion by December 1, 1966.

A representative of this Office is serving as a member of the technical management panel for the contracted study entitled "Large Space Structures Experiment for AAP," which was initiated October 5, 1966. The study, being performed by General Dynamics, Convair Division (GDC), and directed by R-AS, is to analyze and derive conceptual designs of three potential large space structure experiments for flight during the AAP time-frame. A representative of this Office has also participated in the contracted study entitled "Feasibility Study of Large Space Erectable Antenna," which is being directed by R-ASTR-A. This study, also being performed by GDC, is to analyze and derive conceptual designs of large space-erectable antennas having potential application to communication systems.

C. Project Thermo

A study has been initiated to investigate and compare alternate mission profiles to accomplish the Project Thermo mission. Consideration is being given to a single improved Saturn I launch, a dual improved Saturn I launch, and integration of Project Thermo with the ATM and S-IVB Orbital Workshop missions. This study is expected to be completed by November 17, 1966.

II. Lunar Surface

A. Local Scientific Survey Module (LSSM)

Personnel from this Office attended the LSSM presentations at Boeing in Seattle, Washington, and Bendix in Ann Arbor, Michigan. A driving and ingress/egress demonstration by a hard-suited subject of the Bendix LSSM powered mock-up was most impressive. Personnel from this Office were also allowed to drive the vehicle. Some difficulties with the single-hand controller were noted.

B. Mobility Test Article (MTA)

The General Motors MTA has been transferred from Aberdeen Proving Grounds to the Yuma Proving Grounds, arriving there on October 17, 1966. The testing of the Bendix MTA has been suspended to allow the General Motors MTA test program to catch up, at which time the two vehicle tests will continue with parallel schedules. The current test schedule shows both vehicles as being finished at Yuma Proving Grounds prior to December 24, 1966, and shipped to the Danny Boy Crater in Nevada for natural terrain testing. This phase of the MTA test is scheduled for early 1967. The schedule now indicates that the entire test program will be completed by early April of 1967.

C. Lunar Gravity Simulation

The final briefing by LMSC/HREC on the contracted study "Preliminary Design Study of a Lunar Gravity Simulator" was held October 27, 1966. Completion date for the contract is November 14, 1966; the final report is due at MSFC on November 4, 1966.

In-house effort is continuing on the design of a simple, easily-assembled 1/6-g simulator for advanced studies of lunar operations. This effort is scheduled for completion on November 10, 1966.

As a result of a slippage in the Apollo test program schedule and higher priority test commitments, the MSFC LSSM mock-up 1/6-g flight test has again been delayed. The new tentative test date is November 27, 1966. The earlier delay allowed several improvements to be made in the test equipment and instrumentation: the pulley system was modified to mount directly to the cabin floor; a fast-response braking system was designed and built; and a single-hand controller, for speed and steering, was developed. The pulley and brake were developed at MSFC and shipped to WPAFB; the vehicle controller was built at WPAFB.

At the October LSSM interim presentation, the Bendix Systems Division demonstrated their LSSM motorized mock-up. They have tentatively agreed to lend this mock-up to MSFC for flight testing onboard the KC-135; however, this would not take place until early 1967 since they have plans to show the vehicle at various places throughout November and several modifications to the vehicle are required before it can be flight tested. A list of minor modifications and a cost estimate are being prepared for adapting the Bendix LSSM mock-up for KC-135 testing.

III. Integration

A. AAP Experiment Catalog

The writing of the new cataloging program, which has various retrieval capabilities for selected categories of experiments, is approximately 25 per cent complete. One hundred and ten experiments have been referenced by the eight-digit category-numbering code. Test runs of the new system are being prepared.

B. Earth Orbital Mission Simulation Program

The draft of a Technical Memorandum documenting the Earth Orbital Mission Simulation Program is nearing completion. Consideration is currently being given to adding several improvements to the computer program.

NUCLEAR ROCKET PROGRAM

I. Radiation Environment

Experience accumulated to date in the operation of the QAD-P5 program is being documented in an operating manual. This manual is designed to supplement the existing literature on the program. It contains a listing, input card identification and explanation, and sample problem results. The manual is presently in final typing and will be distributed as soon as possible.

II. Stage System Studies

A. Nuclear Vehicle Boil-off Sensitivity Study

This study is concerned with the performance effects of various rates of propellant boil-off on a typical nuclear vehicle performing a planetary mission. The primary objective is to establish first-order sensitivity effects assuming a fixed design concept. The principal accomplishment to date is the definition of a complete mission and preliminary sizing of all nuclear stages, assuming nominal boil-off. In addition, propellant-dependent structural weight scaling laws have been defined for each flight stage. Study results are being documented and will be distributed within two weeks.

B. Nuclear Vehicle Heat Penetration Analysis

The purpose of this study is to analyze the magnitude and effects of heat penetration into the liquid hydrogen tanks of the assembled nuclear vehicle for a manned Mars landing mission. The study is based on (1) broadside orientation to the sun, (2) two inches of superinsulation, and (3) an average solar constant for the mission. Phase I, which included mission time from earth departure to Mars arrival, has been completed. Results were compared with previous studies to gain a deeper understanding of the problems of modular nuclear vehicle design. Phase II, which has been initiated, will extend the analysis to include total Mars mission time from earth launch to Mars departure. The scope of interest will include the transient heating problems associated with both earth and Mars orbit.

III. Nuclear GTM Requirements

This Office has prepared a preliminary plan for a study leading to the establishment of a "typical" nuclear vehicle preliminary design. This effort is in response to a request for information from R-P&VE-X for flight vehicle design characteristics which could affect the GTM program. The study schedule is being examined as to resources and management implications.

ADVANCED PROGRAMS

I. Launch Vehicle

A. Kick Stage

1. 260-inch Cryogenic Kick Stage Design. - A preliminary design for a 260-inch-diameter cryogenic kick stage, with a propellant capacity of 25,000 pounds, has been developed. Orbit transfer payload capability is about 475K pounds from a 185-km orbit to a 485-km orbit. The structural and propulsion system concepts used were based on the multi-mission module configuration developed at MSFC. Attitude control and IU/stage interface problems were examined in detail. Results will be published in an MSFC Internal Note.

2. Cryogenic Kick Stage for Logistics Study. - A study was performed to size a cryogenic kick stage to be used for transferring cargo from a 185-km circular orbit, at inclinations of 28.5° and 55°, to a space station in a 485-km circular orbit, at the respective inclinations. The earth launch vehicles used in this study consisted of a full-length and a three-quarter-length 260-inch-diameter solid rocket motor first stage, with an S-IVB second stage. Both manned and unmanned cases were considered. The unmanned full-length 260-inch solid rocket motor at an orbit inclination of 28.5° required the largest kick stage. The kick stage designed for this payload was off-loaded for the other mission profiles.

3. Computer Program for Sizing a Kick Stage. - A computer program is being written which will size a kick stage (propellant and structural weights) for various earth orbital maneuvers, i.e., orbit transfer, circularization, plane change, rendezvous and docking, deorbit, etc. The program will have the capability to size a kick stage to propel any selected weight and to determine the propellant weight required using a constant kick stage structure, i.e., a Service Module and off-loading to suit the particular mission.

B. Pump-fed Stage Study

A study has been initiated to investigate the preliminary design of pump-fed, storable stages for the OLV of the manned Mars fly-by mission. The primary purpose of the study is to evaluate stage weights and injection payloads to be used in comparing pump-fed and pressure-fed

storable stage designs. (The pressure-fed stage design data were generated in July 1966.) Equations for determining tank dimensions from propellant loading and stage weights for a specific propellant loading have been generated.

C. Docking Structure Design

A study has been initiated to determine design variables and to design docking structures for the spacecraft and stages to be used in either the manned Mars fly-by or landing missions. Primary tasks of the study, which is to be completed in approximately three months, are to develop and compile from the literature docking structure design concepts and to structurally analyze and weigh a particular concept. At the completion of one month's effort, approximately ten docking structure concepts have been identified and their advantages and disadvantages defined. Also, a preliminary structural analysis has been made on a cone-frustum docking structure design. Future activity is to consist primarily of refinement of this cone-frustum design.

D. Advanced Engine Applications to Intermediate Saturn Vehicles

A study concerning the performance of two-stage Intermediate Saturn vehicles using advanced high-pressure bell nozzle engines and toroidal aerospike engines has been completed. It was found that the high-pressure bell engine with interchangeable nozzles optimized for sea level and vacuum operation provided the best payload gains. The results of the study will be published as an MSFC Internal Note. Performance of a standard Saturn V using advanced bell nozzle engines with interchangeable nozzles will be analyzed in the near future.

E. Liquid Strap-on Pods

A study is underway to determine the payload capability of both standard and uprated Saturn V vehicles using four pressure-fed liquid strap-on pods. Pod diameters of 120 inches, 135 inches, and 156 inches with one and two engines per pod are being studied. Analysis is complete on six of the twelve basic Saturn V core vehicle configurations. The payload increase to a 185-km orbit, compared with the standard Saturn V, ranges from 75,000 pounds to 298,000 pounds for the six completed configurations.

II. Earth Orbital

A. Advanced S-IVB Workshop

Studies were initiated to better define the configuration of an advanced S-IVB orbital workshop with emphasis on the one-year ground-assembled S-IVB workshop. Structural arrangements and subsystems will be defined.

Contractor proposals for "A Study of Spent Saturn S-IVB Stage Utilization for Support of Early Orbital Mission" are due at MSFC on November 8, 1966.

B. Orbital Recovery Mission Profile Computer Program

The orbital recovery mission profile computer program is presently operational at the Computation Laboratory. Computer runs are being made to checkout the program. When checkout is completed, the program will be used to determine minimum energy requirements for capturing and returning spent satellites to earth.

III. Lunar

A. Mobility Evolution Study (MOBEV)

Personnel from this Office met with the Bendix MOBEV study manager and other representatives to discuss the program status and establish plans for the final reports and presentation. Bendix was asked to improve their quality of presentation through the use of illustrations in discussing the program methodology. The current study ends on December 7, 1966, with the tentative date for the final presentation being November 17, 1966, at MSFC. Plans are being made to possibly continue the study if funding can be obtained. A Bendix programmer is due here the first of November to brief MSFC personnel on the program operation and to adapt it to MSFC computers.

B. Early Lunar Shelter Study

The mid-term review for the Early Lunar Shelter (ELS) study was held at AiResearch Division, Los Angeles, California, October 25, 1966. A full-scale mock-up of the selected shelter configuration was shown. This shelter was derived from a horizontal cylinder and has a total volume of 715 cubic feet, including an air lock volume of 122 cubic feet. The ELS is a small lunar base which provides all equipment,

accommodations, and supplies needed by a two- or three-man crew for extended lunar missions. The study is scheduled for completion in February 1967.

C. Mission Modes and Systems Analysis (MIMOSA)

The second interim presentation on the Mission Modes and Systems Analysis for Lunar Exploration was held on October 28, 1966. The contractor has established three exploration programs which were discussed. The study is scheduled to terminate in January 1967, with no plans for continuing the effort.

IV. Planetary

A. NASA Advanced Planning Exercise

The J-2S engine and core stage I of the Titan III-C vehicle have been studied for possible use in the manned fly-by Orbit Launch Vehicle (OLV). Use of the J-2S engine in the MS-IVB stages of the OLV deletes the requirement of a kick stage for transferring the MS-IVB from parking orbit (100 n.mi.) to assembly orbit (262 n.mi.). The J-2S engine is burned twice to perform the orbit change and then is restarted for injection of the fly-by spacecraft. Use of the J-2S engine results in savings both in total OLV weight and mission development cost.

The Titan III-C stage in the OLV was compared with a previously-studied pressure-fed storable stage. Because of the lower specific impulse of the Titan III-C stage (288 seconds versus 312 seconds for the pressure-fed stage), 25,000 pounds of additional propellant was required for each of the five OLV Titan III-C stages. This increase in required propellant necessitated a change of Earth Launch Vehicles from the standard Saturn V, which was used for the pressure-fed stage, to an improved Saturn V launch vehicle (5 × 1800K-pound-thrust F-1 engine and extended tanks on the S-IC stage).

B. Manned Planetary Fly-by Studies

Discussions were held between DAC, NAA, and MSFC personnel to determine the status of the program and to make plans for the first interim presentation and second contractor data exchange, which are to be held at MSFC on November 2 and 3, 1966. The mission contractor's

first progress report indicated several changes to the baseline concept, which they will be asked to comment on during the two-day session. Other meetings were held with MSC and NASA Headquarters to discuss the program, the possibility of injecting the Planetary JAG study results into the fly-by program, and the feasibility of using these data as the concept baseline.

C. Mission Module Evolution Study

The analytical effort for this study has been completed and the results are being documented. Two Mars landing spacecraft concepts were defined: a 396-inch module and a 260-inch module. These concepts were then evolved into fly-by configurations, using as many subsystems from the landing concepts as possible.

D. Mars Soil Sample Probe Study (MSSR)

A study was initiated to determine the practicality and to establish a conceptual design of an unmanned surface probe, launched prior to arrival of a manned Mars fly-by spacecraft at the target planet. The probe is envisioned as being capable of landing on the Mars surface, collecting a soil sample, and then rendezvousing with the fly-by spacecraft. Major effort is being directed toward the following areas:

1. Definition of major problem areas associated with storage and ejection of large probes.

2. Description of the probe/spacecraft interface requirements during the terminal phase of the mission (rendezvous, docking, soil sample, retrieval, storage, etc.)

3. Comparison of solid and liquid propulsion systems.

4. Development of a design concept and techniques for obtaining and packaging a soil sample.

5. Determine the number of stages for the ascent vehicle.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-66-10

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(October 1, 1966, through October 31, 1966)

SATURN IB

I. Instrument Unit (IU)

A. IU Ground Support Cooling Unit (GSCU)

1. IU GSCU units 3 and 4 were received by Chrysler Corporation Space Division (CCSD) from launch complex (LC) 34 and are currently undergoing modification. It is anticipated that modifications will be completed by November 7, 1966. Upon completion, these units will be shipped to Kennedy Space Center (KSC) for use on LC 37B.

2. GSCU 9, previously modified, will be shipped to International Business Machines (IBM) for use on Saturn IB IU checkout.

3. Unit 2 was received by CCSD from IBM for modification. This unit is scheduled to be returned to IBM for Saturn IB IU checkout on November 28, 1966.

B. Documentation

The final revision and modification of the IU mechanical assembly, cable installation, and cable length drawings for S-IU-202 (10M22202, 10M23202, and 10M23212; respectively) were completed.

II. General

A. Sequential Operations Plan

Volume III of Saturn IB Launch Operations Sequential Operations Plan, SDES 66-477, was released. This volume establishes the electrical components repair or replace sequence for SA-206 and LC 37B.

B. Mission Rules

An investigation was performed to determine whether the AS-204 vehicle can safely be allowed to lift-off with one or more of the four fire

detection circuits malfunctioning. No fires have occurred at launch on Saturn I or IB; therefore, the system has not been triggered. The AS-202 vehicle flew with one circuit malfunctioning. It was recommended that the mission status of the system be retained such that two circuits are mandatory and three circuits highly desirable for launch commit. Mission Operations Office was requested to add these requirements to the launch mission rules for AS-204.

C. Acceptance Tests

Final acceptance tests were completed on the Hazardous Gas Analyzer (HGA), unit 2, for LC 37.

D. Launch Vehicle Program Specifications

Addenda's for the SA-205, SA-206, SA-207, SA-208, and SA-209 launch vehicle program specifications were prepared and released to the Configuration Control Board for baselining.

E. Monthly Weight Status Report

The weight status report for all Saturn IB vehicles was completed and distributed.

F. Monthly Operational Mass Characteristics

Projected operational mass characteristics for AS-206 were completed and distributed.

SATURN V

I. S-IC Stage

A. Flush and Purge Servicer

1. A Roper pump seal static leakage problem was noted subsequent to filling the trichloroethylene tank of S-IC Flush and Purge Servicer (unit 001) at KSC. Copies of the unsatisfactory condition reports (UCR's) when available, will be sent to Roper Pump Company and Walter Kidde and Company, Inc., for their information and action.

B. Servicing Requirements

The problem concerning the S-IC stage fuel tank prepressurization system inadequacy has been resolved for SA-501, SA-502, and SA-503. MSFC will allow the increase in the facility line pressure drop requested by KSC since those stages have a large ullage and the "makeup" during engine start is not as critical as SA-504 and subsequent vehicles which have a small ullage.

C. Functional Interlock Requirements

Engineering Order (EO) 7 for the S-IC functional interlock requirements, drawing 10M30551, was prepared. This EO revised the SA-501

F-1 engine start sequence as necessitated by a change in the procedure for determining engine starting and incorporated the required F-1 engine start sequence for vehicle SA-502.

D. RJ-1 Lubricity Tests

The RJ-1 lubricity tests were successfully completed on the simulated S-IC hydraulic and supply unit hydraulic pump; the preliminary test report is being prepared.

E. Acceptance Tests

1. The acceptance tests on the following contract end items (CEI) were completed:

S-IC Forward Umbilical Servicing Unit for Mobile Launcher (ML) 2.

S-IC Pneumatic Checkout Rack Assembly 4, part number (P/N) 65B24093-1, for ML 3.

2. Acceptance tests for the S-IC forward umbilical servicer unit (FUSU) for ML 3 were rescheduled for November 20, 1966, due to a shortage of components.

II. S-II Stage

A. Vent and Pressurization System

1. The division performed an operational and reliability study of the lox and LH_2 tanks vent and pressurization system for the first static firing of S-II-1 at Mississippi Test Facility (MTF). It was concluded from the study that the systems concerned are acceptable for the first static firing test from an operational and reliability standpoint.

2. As a result of the application design review of the S-II LH_2 heat exchanger and subsequent failure effect analysis (FEA), it was found that the collapse pressure of the intertank (LH_2) was significantly lower than that stipulated by North American Aviation (NAA) (15 p.s.i.g. versus 30 p.s.i.g.). Subsequent investigation by NAA confirmed the lower value. An Engineering Change Request (ECR) is being prepared to correct this deficiency.

B. Acceptance Tests

1. Acceptance tests on the S-II Heat Exchanger (A7-71), unit 6, were suspended because of leakage of the upper helium coil assembly. NAA was directed to seal the leak prior to acceptance.

2. Acceptance tests on the Stationary Vacuum Pump, model S7-29, were completed.

III. S-IVB Stage

A. Pneumatic Ground Support Equipment (GSE)

The mechanical GSE successfully completed the loading tests of the AS-500F vehicle; however, facility failures prevented an extended series of tests to determine the integrity of the cold circuits of the gas heat exchanger, DSV-4B-438A, and the pneumatic console, DSV-4B-433A. A complete test of the pneumatic support system would be possible only if the facility were capable of supporting an extended "hold" after loading. Since this was impossible during the AS-500F loading tests, efforts to stop valve freezing of the heat exchanger and console must await further loading tests for evaluation.

B. Qualification Tests

Qualification test reports on the following General Test Plan (GTP) line items were reviewed for technical adequacy and compliance with requirements stipulated, in SM 41412, GTP, Saturn S-IVB System, dated October 1964, and approved:

AB-55, SM 51892. Model DSV-4B-402, Vertical Forward Interstage Access Kit, DAC P/N 1B40669-1.

AB-25, DAC 56310, Umbilical Separation Cylinder Assembly, P/N 1A77112-1 for Model DSV-4B-315 and Model DSV-4B-355, Aft Umbilical Launch Kits.

X-52, SM 53185, "400 p.s.i.g. 1/4-inch Relief Valve, DAC specification control 1B151360-505, Vacco Valve Company, P/N RVA 30832.

X-54C, SM 47513, 1/2-inch Monothylhydrazine Check Valve, DAC specification control 1A19348-501, W.M. Lanagan P/N 90158.

IV. Instrument Unit

Acceptance Tests

Acceptance tests were completed on IU Ground Support Cooling Units 12 and 13 for ML 2.

V. General

A. Vehicle Assembly Drawing

The revision A of the SA-501 vehicle assembly drawing was completed; the drawing includes changes in the S-II/S-IVB and S-II/S-IC stage to stage mating hardware, changes in several reference callouts, and addition of the Lunar Excursion Module (LEM) test article to the payload.

B. Torque Sequence Procedure

Test data was analyzed and the correct torque value selected for the respective SA-501 stage to stage mating hardware. Document 10M14503, specifying these values, was completed and submitted to Structures Division.

C. Saturn V Damping System Interface Control Document (ICD)

Changes requested by Manned Spacecraft Center (MSC) to the damping system ICD were made. The significant change defined the alignment of the hook to the cross-head assembly.

D. Safety and Arming (S&A) Device Test Report

The report for simulated S&A device testing at MSFC was completed. Test results show evidence of low order burning of the rotor explosive lead; consequently, the Naval Ordnance Laboratory will be requested to perform Vari-Comp (various explosive compositions) testing to obtain a solution to the problem.

E. Identification of Confined Detonating Fuse (CDF) Assemblies

The Boeing Company (TBC) was requested to identify all S-IC CDF assemblies by adding electrical cable harness identification tags. This change will prevent the possibility of interchanging Apollo spacecraft CDF with the retromotor or jettison system CDF.

F. S-IC Hydraulic Performance Tester

An extensive review of TBC's cost termination proposal, pertaining to the deletion of four S-IC hydraulic performance testers, was completed. The review indicates that approximately 53 to 60 percent of the original contract funds have been utilized by TBC during fabrication of two existing units.

G. Monthly Weight Status Report

The weight status report for all Saturn V vehicles was completed and distributed.

H. Mass Characteristics

1. Mass characteristics for AS-501 revised operational trajectory based on nominal propulsion data were completed and distributed.

2. Projected mass characteristics for AS-503 were completed and distributed.

I. Monthly Operational Mass Characteristics

Operational mass characteristics for AS-506 was completed and distributed.

J. Integration Test Requirements and Specifications

Integration test requirements and specifications for the following CEI's were reviewed for technical adequacy and compliance with MSFC drawing 10M01811, "Saturn IB and Saturn V Mechanical Ground Support Equipment General Test and Documentation Plan, Procedure for" and approved:

D5-15401-8, S-IVB Gas Heat Exchanger, model DSC-4B-438A, for ML 1.

D5-15401-10, S-IVB Pneumatic Console, model DSV-4B-433A, for ML 1.

D5-15402-3, S-IVB Pneumatics Subsystem Checkout, Local Control for ML 1.

D5-15401-25, S-IC Pneumatic Console Test Assemblies for ML 1.

D5-15401-26, S-IC Pneumatic Checkout Racks Test Assemblies for ML 1.

D5-15401-9, S-IVB Pneumatic Console, model DSV-4B-432A, for ML 1.

K. Test Activities

1. Efforts are continuing for establishing requirements for the Saturn V Damping System component qualification program. A list of components required for qualification tests was completed except for final approval. Criticalities were established for each of the components comprising the system. From a total of 52 components, 2 were classified criticalities "A", 31 were classified criticalities "B", and 19 were rated criticalities "C". Criticality "C" components will not require qualification testing.

2. The Saturn V Damping System General Test Plan was revised to include the Auxiliary Damping System. The revision will include test requirements for component qualification and identify those components that were previously qualified. No requirements exist for strain gages or instrumentation during the structural testing of the Saturn V Damping System for ML 1. A redline copy of the system test plan, deleting all requirements for strain gage measurements, was delivered to the Test Laboratory for concurrence.

3. The test on the Ingersol-Rand winch motor was completed. Preliminary reports from the test agency indicated the motor performed satisfactorily.

L. Launch Vehicle Program Specification

Addenda's to SA-505, SA-506, SA-507, SA-508, and SA-509 launch vehicle program specifications were prepared.

Systems Design

A. Low Profile Flange Development

1. The stress versus pressure curves were completed for all flanges tested under project 162 and flanges tested under Contract NAS8-20148.

2. A draft of the development test procedure was completed for the testing of the 25" low profile flange of the sump manifold assembly SK10-1428. The test procedure is a comprehensive delineation of testing required to determine actual internal flange stresses.

B. Nuclear Ground Test Module (GTM)

A preliminary design analysis was made to define the auxiliary and handling equipment required for mechanical GSE on the GTM. Also, a flowchart for this equipment was prepared. The flowchart will be needed during transportation of the GTM to and from the test stand for coldflow tests.

C. Experiment #2

The final test report, #496 for Phase I, "Vibration and Shock Test Report of Thermal Sensor Panel, MSFC Experiment #2," and the flight qualification test plan was completed.

D. X-Ray Astronomy Experiment

The latest concept drawing of the X-ray astronomy experiment (S-027) container casting and operating mechanism was completed.

E. Laser Communication Satellite Experiment

Drawing SK10-7321 was prepared to define the envelope of the laser communication satellite experiment in the MSFC rack. The layout will be used by Astrionics Laboratory for further study and power supply definition.

F. Electromagnetic Radiation Detection Experiment (EMR)

1. The EMR experiment layout drawing SK10-7320 was revised to define the latest design configuration which includes a change in the power supply from 66 batteries to four fuel cells.

2. A drawing (SK10-7323) was completed which defines the EMR envelope in the Saturn IB vehicle with a 25° nose cap.

G. Project Thermo

Drawing SK10-9222, "Project Thermo Integration Layout," was completed. The document will be used as the conceptual design for the

experiments. The experiment tanks, camera, and associated electrical equipment were integrated into the MSFC rack.

H. Synchronous Orbit Mission

Drawing SK10-9223 was completed defining the location of the mounting studs inside the S-IVB LH_2 tank required for relocation of the deflector and baffle. Also, provisions for mounting two more cold helium bottles were defined. This drawing will be used to define the modifications Douglas Aircraft Company (DAC) will make during tank fabrication.

I. Apollo Telescope Mount (ATM) Program Documentation

Layouts on the ATM were revised to remount the solar monitoring camera inside the experiment package to the cannister spar.

J. Payload Module (PM)

The physical ICD's for the PM are 50 percent complete. The rack to spacecraft LEM adapter (SLA) drawing 13M50449 was completed. ICD's are being prepared for the PM withdrawal envelope, PM to rack, and the docking ring to PM.

K. S-IVB Orbital Workshop

1. The design concepts are in process on the LH_2 tank initial entry aid, environmental control system sleeve, internal padding, mobility aids, equipment attachment, instrument unit protective netting, and LH_2 tank crew quarters design. Access studies were completed on those portions of the S-IVB stage propulsion system inside the LH_2 tank. These studies will be used to define the sealing requirements.

2. A three-phase test program was completed for the quick release manhole cover.

3. To support workshop designs, an experiment is to be flown on GT-12 (Gemini-Titan) which will test the ability of an astronaut to attach a box to a panel.

L. Aquatic Neutral Buoyancy Program

Fabrication of the volumetric calibration tank used to measure human anatomical components and positive buoyancy forces was completed on October 21, 1966.

MISCELLANEOUS EFFORTS

I. Systems Design

Ordnance Test and Reviews

Five tests were completed on the S&A device test hardware. Five inert pieces of hardware were fired with the rotor in the safe condition. All five tests were completed without rupture of the primacord end fitting diaphragm. It is concluded from these tests that the exploding bridgewire (EBW) detonator does not produce sufficient gas to detonate the end fitting.

II. Systems Requirements

A. Engineering Change Coordination

The final draft of MSFC-PROC-455, "Preparation of Input for the Configuration Management Accounting and the Reporting System," was forwarded to Operations Management Office and the Industrial Operations Configuration Management Office.

B. Research and Development (R&D) Plans

Preliminary drafts 4 and 5 for the orbital workshop R&D plan were completed and submitted to the project engineer.

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-66-10

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

October 1, 1966 through October 31, 1966

SATURN IB

I. S-IB Stage

Engine Gimbal System Auxiliary Pump Motor Qualification

Bearing failures and corrosion of the rotor have been encountered in the auxiliary pump motor. In an attempt to obtain better components, several motors were procured and tested. One of the motors tested is superior to the others. In addition to more than satisfying the test conditions, this motor has 33 percent more horsepower, which would permit operation of the auxiliary hydraulic pump at a higher flow rate. The stage contractor was notified that the new motor is available for possible use in the S-IB hydraulic system.

II. S-IVB Stage

A. S-IVB-207 Stage Acceptance Firing

The S-IVB-207 stage was successfully acceptance fired for a mainstage duration of 447 seconds on October 19, 1966. Two minor problems were noted during the countdown, but they did not delay the test. The LH_2 recirculation shutoff valve "talkback" was erratic until the start of automatic sequence. The other problem was concerned with sporadic operation of one of the fuel depletion cutoff sensors, which has happened on several other stages.

B. Engine Gimbal System Tests at MSFC

Due to the failures occurring during system testing, a new system was assembled and subjected to environmental and endurance

tests. The auxiliary pump failed after approximately 12 hours of testing. Investigation revealed the pump's valve plate return spring had broken. The spring is presently being studied for metallurgy.

C. Main Pump Compensator Leakage Investigated

Leakage past the static seals between the compensator and pump housing was discovered in two pumps at MSFC. The stage contractor was notified and was requested to conduct a design analysis on that area of the main pump. The contractor found similiar failures in the formal qualification program and is presently evaluating the problem for a fix that will affect S-IVB-204. There are supposed to be three pumps in the formal qualification program. Six of eight pumps have been rejected in the attempt to get three good pumps. The pumps appear to be plagued by quality control problems.

D. Liquid-Vapor Sensors Tested in Low Gravity Drop Tower

A series of drop tower tests was completed on a liquid-vapor sensor to determine its reliability in a low gravity environment. Two sensors of this type were used in the S-IVB-203 liquid hydrogen tank. Preliminary results from the drop tests indicated that the sensor is reliable for certain positions of the sensor relative to the acceleration direction of a vehicle, but is not reliable for the mounting position used on the S-IVB-203.

E. Component Qualification Test Program

Mandatory environmental tests that must be performed on critical components before the AS-204 flight were agreed upon. Tests are being performed on an emergency basis. One item (the fill and drain valve) completed the required environmental tests. Twenty-nine other items are currently in test and are scheduled to be completed before the AS-204 flight.

Two hundred and twenty-nine components are scheduled for design evaluation and qualification (DE/Q) testing. Testing is complete on one hundred and ninety-two components. Review of DE/Q test reports was completed on forty-four components.

Thirty-one components are scheduled for formal qualification testing. Testing is complete on ten components. Fourteen components are presently undergoing tests and seven components are being held for engineering.

F. S-IVB Stage Final Flight Predictions Revised

Revised S-IVB Final Predictions for AS-204 and AS-205 were received from the stage contractor. These predictions were revised due to required changes in hydrogen loading as a result of the S-IVB-206 acceptance test. The revised final AS-204 prediction was released for analysis. The revised AS-205 prediction is presently being reviewed.

III. Instrument Unit

Relief Valve on IU First Stage Regulator Successfully Vibration Tested

There was no leakage from the relief valve.

SATURN V

I. S-IC Stage

A. F-1 ENGINE

1. R&D Engine Tests at EFL

Ten tests were conducted and a total duration of 1510 seconds was accumulated. Seven of these tests were full duration (150 seconds or more). One test was terminated prematurely due to a failure at a drain boss on the No. 1 high pressure fuel duct.

2. Production Engine Tests at EFL

Six tests were conducted and a total duration of 500.6 seconds was accumulated. Two of these tests were full duration (150 seconds or more). One test was terminated prematurely due to a facility malfunction.

3. Engine Test at MSFC

A prevalve shutdown test conducted at MSFC on engine F-1002-3 resulted in extensive damage to the turbopump and engine. This was the first of a planned series of tests to investigate the effects of using the prevalves for emergency engine shutdown. The incident is still under investigation, but several corrective actions were effected as a result of the test. It was decided that the S-IB and S-IC Thrust OK pressure switches shall be interlocked in the prevalve-close signal

circuitry in such a way that the Thrust OK pressure switches must drop out before the prevalve-close signal is initiated.

4. Engine Gimbal System Back-up Lines Qualified

Qualification tests of the flight supply line were successfully completed. This line is back-up for the stage contractor flight supply line, which must be replaced because of the excessive loads it transmits to the F-1 engine high pressure fuel duct.

Another line was qualified as a back-up ground supply line. The line is available for use. The stage contractor's ground supply line recently failed on F-1 engine 4017 at the single engine test stand. The failure was attributed to poor welds in the assembly. If further failures of the presently used ground supply line are encountered, use of the back-up line should be considered.

5. Results of Transducer Testing

Sixteen NA5-27440 transducers have been tested on F-1 engines during static firing for a total of 418 test exposures and 49,336 accumulated mainstage seconds. There has been only one failure during these tests and that was a broken component lead due to soft potting material. This occurred early in the test program, and the design was corrected by epoxy bonding the resistor to the board before potting. There have been no failures since this change. Two of these NA5-27440 transducers have completed the component qualification test series. Approval has been granted for incorporation of the NA5-27440 high reliability pressure transducers on the F-1 engines.

B. S-IC-501 Propellant Loading Tables Completed

The tables were generated for the S-IC-501 based on the latest flight predictions. However, the tables will not be distributed until it appears certain that there will be no changes to require a revised prediction.

C. Propellant Loading Curves Completed

KSC personnel requested curves to provide manual back-up adjustments for the fuel loading computer settings to compensate between real time fuel density and predicted lift-off fuel density. (These are normally determined by the RCA 110 Propellant Loading Monitor Program.) Manual adjustment curves were computed to accomplish the above function and, in addition, to provide adjustments for overloading the fuel tank up to 102 percent. (Excess fuel will be drained

during the final level adjustment.) These curves will be included with the propellant loading tables for each vehicle.

D. Temperatures of Acoustic Environment Measuring Devices Predicted

Transient temperatures were predicted for high intensity microphones used to measure the S-IC fuel and LOX tank static test acoustic environment. Predicted peak sensor element temperatures of microphones mounted on or near the fuel tank were 185°F. Microphones mounted on or near the LOX tank were below 32°F and resulting frost formation could invalidate test measurements. Undesirable low temperature can be prevented by attaching small thermostatically controlled heating elements to each microphone or by mounting the microphones a radial distance of two feet from the LOX tank.

II. S-II Stage

A. J-2 ENGINE

1. R&D Tests at SSFL

Seventy-six hot firing tests were conducted, and a total of approximately 8,474 seconds was accumulated. Six of these tests were terminated prematurely.

2. Engine Deliveries

Engines J-2084, J-2085 and J-2088 for SA-505 and J-2086 for spare were delivered to the second stage contractor. Engines J-2083 and J-2087 were delivered to the third stage contractor SA-209 and SA-210.

3. Engine Tests at AEDC

Three successful programmed duration tests were conducted. Abnormal gas generator temperature spikes were observed on all three tests and higher than normal vibration counts were picked up on the first and third tests. The abnormalities are being investigated.

B. S-II-1 Suction Line Leakage

A purge and collector manifold was installed around each LH_2 suction line-tank sidewall interface. These manifolds are purged with helium from a facility source and exhausted into the GSE contaminant detector system. During the first tanking of S-II-1, no

hydrogen leakage was detected.

C. S-II-1 LN_2/LH_2 Tanking Test

The S-II-1 LN_2/LH_2 tanking test was completed. Although no major problems were noted, various difficulties did prevent the accomplishment of all test objectives. The A7-71 heat exchanger did not operate properly, and prevented successful demonstration of start bottle chill and pressurization, thrust chamber chill, and tank prepressurization. LH_2 vent valve crack and reseat pressures were obtained during a special six-minute self-pressurization test; however, LOX vent valve crack and reseat pressures were not obtained due to an electrical problem in the GSE. The recirculation valve actuation bottle pressure decayed rapidly during the test, and this is attributed to prevalve solenoid leakage. The first static firing is scheduled for October 28, 1966.

D. S-II Battleship Boattail Environmental Tests on LOX Recirculation System

A series of tests were started to evaluate the LOX recirculation system performance in a boattail environment. Baseline tests revealed the present system was not satisfactory to meet NPSH or LOX pump discharge temperatures. Tests were performed to evaluate proposed solutions. None of the above proposed solutions were satisfactory for LOX recirculation with a warm GN_2 purge blowing into the boattail. A test was conducted without the GN_2 purge and system performance was satisfactory. These results indicate the most adverse effect on the LOX recirculation system is caused by the GN_2 purge being blown directly onto the recirculation components producing excessive heating. Additional tests on the Battleship will include evaluating the effects of the boattail environment on the J-2 engine start bottle.

E. Simulated Altitude Testing of J-2 Engine Start Tank

Leakage, caused by cryogenic temperature, high vacuum, and high pressure was eliminated by changing materials. Preliminary testing with GN_2 is being conducted. Testing with LH_2 will begin soon.

F. RS-U-602 Motor Casted Successfully

The four RS-U-602 motors cast on October 15 will be used in the PFRT program scheduled for mid November.

G. Component Qualification Testing

Two LH_2 valves were successfully vibrated in the vehicle longitudinal axis to verify the structural integrity of the valve and bracketry for the static firing of S-II-1. The valves leaked excessively during the test. It was determined, that the primary pilots would not stand-up to the vibrational environment and need to be modified by incorporation of a teflon sleeve in the pilot assembly or electrolizing the pilot assembly parts.

H. Verification Testing of Accumulator Reservoir Manifold Assembly

The filter test and proof pressure test were completed satisfactorily. The test program was temporarily delayed to conduct a vibration test on the S-IVB accumulator reservoir assembly.

III. S-IVB Stage

A. Status of S-IVB-501 Components Reviewed

Of the remaining 30 unqualified S-IVB-501 propulsion systems components, 20 are in formal qual, and 10 in design evaluation qualification. Twenty-five items are classed as flight critical, and five as noncritical.

B. Operational Procedure Completed for Saturn V/S-IVB-502 and 503

The recommended operational procedure for Saturn V/S-IVB-502 and -503 and the associated constraints for these vehicles were established.

C. Saturn V and IB Payload Loss Due to Increase in Unavailable Residuals

During the acceptance tests of S-IVB-206 and -502, the depletion level sensors were uncovered and started the timer that actuates J-2 cutoff. However, before the timer expired, cutoff was initiated by an observer who was monitoring the available NPSH. Evaluation of the test data indicates that something is occurring so that the level of the propellant on the tank outlet side is lower than the level across the tank. There is also an apparent "pull-through" problem, because at this low level the upper layers, or stratified layers, are being taken into the engine sooner than expected, and the

available NPSH is lower than expected. As a result, the timer between the cutoff sensors and engine cutoff is being removed, and the unavailable residual propellant is being increased by 562 pounds on Saturn IB and 567 pounds on Saturn V. This is a direct trade-off on payload of one-to-one.

D. Auxiliary Propulsion System (APS) Tests at MSFC

A series of tests to determine the effect of gas bubbles passing through an attitude control engine was conducted in the vacuum test cell at MSFC. Helium gas was injected into the propellant feed manifold a few inches from the engine valve inlets at various times of engine start and operation. The bubbles caused a decrease in engine chamber pressure, and it was possible to shut the engine off by injecting a much larger volume of gas. No further gas bubble testing is planned at MSFC.

E. C-1 Engine (APS) Tests

The development testing of the C-1 engine is continuing. To date, 200,850 starts have been conducted, and a hot firing time of 85,015 seconds has been accumulated. Engine S/N 728 accumulated a total of 6,866 seconds as compared to the specification requirement of 2,000 seconds.

IV. Instrument Unit

A. Cold Plate Heater Tests Completed

First indications are that the initial design of the heater with insulation has a low efficiency and that an uninsulated heater with an aluminum foil cover is more efficient than the initial design with insulation.

B. IU/S-IVB Forward Skirt Vent Area

The vent area in the S-IVB forward skirt was relaxed to 100 $in.^2$ for vehicles SA-204 and -205. Vent area for vehicle -501 is currently being studied to determine if it could be relaxed to 100 $in.^2$.

C. Methanol/Water Temperature Requirements for AS-204/205 Changed

The minimum Methanol/Water (M/W) temperature

requirements were relaxed to 49°F for AS-204. A further relaxation to 45°F is also expected for AS-205. It is not expected that 204 requirements will be exceeded; however, since vehicle -205 heat dissipation load is reduced considerably and since it faces deep space for 2 1/2 hours, the M/W temperature could drop as low as 30°F at the end of the -205 4 1/2 hour mission. Investigations are being conducted to incorporate changes to allow the M/W temperature to be maintained within acceptable limits.

D. AEDC Sublimator Test Data Analyzed

The first of the series of computer programs has been completed and can be used to fine test parameter distributions, standard deviations, and means. A follow-on program for calculation of distributions of sublimator starting times has been written and is being checked out. Data correlations have not yet been started.

E. First Stage Regulator Passed Vibration Testing

The new relief valve for methanol/water first stage regulator passed vibration testing.

F. M/W Coolant Pressure Buildup

An investigation is being conducted to determine the cause for pressure buildup in the ECS when the system is nonoperative. The pressure buildup has occurred on AS-202 and -204 at Cape Kennedy.

SPECIAL STUDIES

I. Thermal Protection Systems for Cryogenic Propellants on Interplanetary Space Vehicles

Mission analyses were performed for interplanetary vehicles (chemical and nuclear) considering active and passive thermal protection systems. Vehicle masses were optimized considering propellant evaporation losses associated with various combinations of active and passive thermal protection systems. Significant conclusions of the study are:

A. Liquid hydrogen storage system mass (amounting to about 8 percent of the usable propellant mass) can be reduced 60 percent through use of triple-point hydrogen. Reductions are based on .

non-vented tanks with ideal de-stratification.

B. Solar shields can reduce propellant storage penalties of the Mars braking stages 40 percent.

C. With increasing thermal severity of the mission, vented propellant storage systems inproved relative to non-vented storage.

D. Use of the large ullage space available in non-vented storage systems for temporary storage of propellant to be vented during earth orbit assembly operation may eliminate the need for an orbital tanker.

II. Investigation of Freon E-3 as a working Fluid in a TVC System At Low Temperature

Break-in, partial calibration, proof pressure load cycle, and functional tests were completed on the second Vickers Co. pump. These tests were conducted at room temperature. Problems were noted in compensator stability. Data collected during these tests are being evaluated.

III. Performance Test of Hydraulic Pumps

Tests were completed on three hydraulic pumps to determine their condition and suitability for use in future test programs. The data are being evaluated and the report is being written.

IV. Laser Velocimeter

An electronic system was developed that will determine the velocity distribution resulting from turbulence. The system employs discrete sampling of the time base of the heterodyne signal. This system has eliminated a complex data reduction procedure that was previously required.

V. Lateral Heat Transfer in Superinsulation

The temperature gradient in a sheet of superinsulation caused by cold retaining pins was predicted using variable thermal conductivity and three complex transformations to map the insulation segment into a shape for which a solution would be obtained. The analysis was experimentally verified using LH_2. The correlation between the predicted and experimental results was good.

VI. Drop Tower Telemetry System

The telemetry system on the terminal drain test package was successfully tested at the drop tower. All measured parameters including flow, temperature, pressure and acceleration were transmitted from the drop tower and received and recorded at the West Area blockhouse. There was no loss of signal or significant noise problem. The results were conclusive enough to justify a complete change of the data acquisition system in the drop tower from trailing wire to telemetry. Two test packages, the terminal drain and the impulse-slosh packages, are being modified to accommodate on-board controls and telemetry. The on-board control timers, the main battery power supply, and the transducer battery packs were redesigned and are being standardized on all test packages. This should eliminate many of the delays in the low gravity test program.

ADVANCED PROPULSION AND TECHNOLOGY

I. High Pressure LOX Pump Study

The first set of hardware was assembled and is now being installed in the test facility. The first test which is expected to be conducted on or about the first week of November, will be a 22 second run involving slow acceleration to full rpm and a slow, stepped deceleration. The pump will be disassembled and completely inspected after this run.

II. Helium Turbine Tests

The S-IVB LH_2 chilldown pump helium turbine was successfully tested twice for a total duration of over 900 seconds. No indication of impending bearing failure was observed. One more test is scheduled before the program is completed.

III. High Pressure LH_2 Pump Development

The high pressure liquid hydrogen pump was tested to a discharge pressure of 5130 psia. At this pressure the second stage discharge diffuser inserts collapsed causing the pump casing to split. This insert will be eliminated in future pumps without resulting in performance degradation. Two significant goals were achieved in

this test, namely the highest pressure LH_2 has been pumped with a rocket propellant pump and the elimination of hydro-mechanical system oscillations that have previously caused bearing failures by using roller bearings instead of ball bearings.

PUBLICATIONS

I. "Analysis of Oscillating Flow Through Cascades," Unclassified, IN-P&VE-P-66-19, by H. Ohashi, dated September 26, 1966; Published October 25, 1966.

II. "Analytical Study of Dynamic Characteristics of Turbopumps," Unclassified, In-P&VE-P-66-20 by H. Ohashi, dated September 26, 1966; Published October 25, 1966.

III. "Gas-Liquid Interface Dynamics Resulting from the Bubbling of Inert Gas Through a Stagnant Liquid," Unclassified, IN-P&VE-P-66-21, by Hugh M. Campbell, Jr., Dated September 26, 1966; Published October 25, 1966.

for H. G. PAUL
Chief, Propulsion Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-S-66-10

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(October 1, 1966 - October 31, 1966)

SATURN IB

I. S-IB Stage

A. The CCSD ECP EP30886, which increases the thickness of panel 10, panel 9, and panel 1 and modifies stiffeners in the forward and aft skirts of the 70-inch LOX tanks of S-IB-12 to S-IB-26, has been approved. This ECP will increase the capability of the 70-inch LOX tanks for all flight and ground wind conditions based on R-P&VE-SL-212-63 contractural loads.

B. The Vibration and Acoustics Branch evaluated vibration failures in the propulsion distributor resulting from testing of the emergency destruct system. Analysis indicated that the failures were a result of accumulated test time during the reliability program. Retrofit of the specimens with new hardware and re-test is now being carried out.

II. S-IVB Stage

A. The panel flutter tests at the AEDC 16-foot transonic wind tunnel (16T) facility were satisfactorily completed on October 11, 1966. No destructive flutter occurred under severe dynamic pressures and loading; however, tunnel limitations due to a previous compressor stage failure restricted higher dynamic pressure and Mach number testing. The tests were performed by varying the following four parameters:

1. Mach number 1.1 through 1.4

2. Dynamic pressures of 300 through 700 psf

3. Differential pressure across the test specimen of .3 to 1.0 psi.

The following conclusions were made from the test results:

1. The test was conservative because the boundary layer thickness was less than that predicted for the flight vehicles.

2. Limited amplitude flutter was indicated by the test data, but the levels of response were so low that the test specimen was in no danger of failure.

3. The test panels sustained a considerable accumulation of test time with limited amplitude flutter indications as compared to a critical flight time of twenty (20) seconds.

4. There were no indications of panel fatigue or overstressing problems.

5. Catastrophic panel flutter will not occur on typical S-IVB skirt panels.

6. The AS-204 flight trajectory was proven not critical.

B. The S-IVB hydrostatic test vehicle was pressurized to failure on September 26, 1966. The liquid hydrogen tank had previously been tested to ultimate pressure loads in all areas on September 21, 1966. Failure occurred at 68 psig at the LOX sump area and 61.4 psig at the low point of the hydrogen tank. The failure area includes the forward hydrogen tank dome meridional weld and parent material, hydrogen cylinder parent material, and hydrogen tank aft dome. Failure origin is not known at this time.

C. S-IVB thrust structure measurements from acceptance firings and flight were reviewed to evaluate a Douglas Aircraft Company requested specification revision. A revision was granted to the major and sub-zone specifications for the thrust structure which consisted of raising the high frequency random specification and lowering the low frequency sine specification. This specification change will be effective on all forthcoming formal qualification tests.

III. Saturn IB System

Flight evaluation of the first three Uprated Saturn vehicles revealed no evidence of POGO instability. Low frequency acceleration investigation revealed levels well below MSF crew limits.

SATURN V

I. S-IC Stage

A. Phase I of the S-IC LOX tank (AS-504 Configuration) testing was successfully completed October 6, 1966. This included hydrostatic pressure, cut-off, Max Q α, and rebound conditions. The results are being compared with the S-IC-S upper assembly (AS-501 Configuration) test data. Phase II, inertia load test on the lower bulkhead, is scheduled for January 1967.

B. The S-IC-C tank is being modified to incorporate an S-II stage LH_2 elbow (Fuel feed line fitting) for hydrostatic pressure testing. Preliminary design and stress analysis have been completed and actual tank modifications began October 28, 1966. The ultimate pressure for this test at the centerline of the fitting will be 48 psig. This testing will be done as a back-up for the 22-bolt repaired elbow which is to be tested concurrently on the common bulkhead test tank.

C. The test preparation continued with the following being accomplished: (1) The upper load ring was installed, (2) A portion of the upper load beams were moved into place and some of the load straps were attached, and (3) Cables were run to the strain gages and check-out was begun.

II. S-II Stage

A. The P&VE Test Program on the S-II stage patch configuration tension specimens has been completed. Fourteen specimens were

tested to failure.

4 Control Specimens - Avg. Failure Load = 159, 750 lbs.

5 Bolted Patch Specimens - Avg. Failure Load = 141, 100 lbs.

5 Bolted & Bonded Patch Specimens - Avg. Failure Load = 139, 350 lbs.

Although there was no appreciable difference in strength of the two configurations at ultimate load (Failure), strain gage data indicate the bolted and bonded patch configuration reduced the stress in area under the patch approximately 10% more than the bolted patch configuration prior to failure.

B. The S-II-3 stage was pneumostatic-tested at the Seal Beach facility. The LH_2 tank was pressurized to 35 psig and the LOX tank to 20 psig: these pressures were held for 10 minutes. After testing, the tanks were inspected and the following information was reported:

1. No cracks were found at the rib ends in the LH_2 tank.

2. No cracks were found in the inside welds of the LH_2 feed elbows.

3. The outside welds on all 5 LH_2 feed elbows had cracks.

C. The S-II-4 LOX Bulkhead girth weld eccentricity and porosity problems were solved when it was decided by the Primary Board to cut the girth weld and replace the aft bulkhead with the S-II-5 LOX aft bulkhead. The bulkhead was cut October 12.

D. The flow test of the LH_2 feed elbow was conducted at Santa Susana test facility. The test was run in three phases, and the elbow inspected after each phase. No leakage was detected and the foil seal was still intact after 30 minutes of LH_2 flow. A few small flakes of adhesive (about .125 dia.) were found in the downstream screen.

E. On October 14, 1966, in the structural certification test of the S-II-1 stage, just prior to propellant loading, a structural failure of the external insulation on cylinder 5 occurred. A section of outer face sheet (approximately 4.5 ft. x 2.5 ft.) debonded from the

core just above the insulation close out at the circumferential seam weld between cylinder 4 and 5. A rip in the face sheet at the close out seam relieved internal pressure. Pressure at failure was approximately 4.3 psig in the insulation purge system. Recommendations were made to repair the debond area, proof pressure check the insulation to 7 psig., and continue with the propellant loading test.

F. The S-II-4 common bulkhead to LH_2 tank J-ring weldment has 9 noted flaws appraised as porosity with tails in a region undergoing 4 hand weld repairs. The MRD was sent to the Primary Board for decision on October 20, 1966. The decision of the board was that the weldment was suitable for flight usage with the provision that the weldment be re-inspected after the first static firing. The inspection will be as complete as if a repair were required.

G. A .020 inch deep gouge in No. 5 cylinder assembly of S-II-5 was discovered approximately one inch below a circumferential rib and adjacent to a meridional weld land. A "Strong Back" will be attached to the circumferential rib for reinforcement.

H. A major milestone was passed on October 16 with completion of the first axis of testing (sine and random) on the forward skirt. The sine run marked the initial use of the new control system on the 8 shaker facility and was completely successful from the test point of view. However, a failure occurred during the low level sine run in container #224. Inserts were pulled from the honeycomb panel where a 60 pound component is mounted. Preliminary indications are that the failure was a result of marginal design for inserts carrying dynamic loads in a honeycomb panel. This is a situation similar to problems experienced by MSFC during the developmental testing of cold plates for the instrument units. A quick fix is being made to the high force specimen and analysis is underway to determine the effect on flight stages (including As-501).

I. A successful longitudinal axis high level random vibrational test was accomplished on the S-II thrust complex. Since the thrust complex is the most complicated specimen to be tested, this mechanically induced vibrational test was considered more likely to produce failures in the mode simulating flight conditions than other vibration tests. Completion of this test without failure greatly increases confidence in the structural integrity of the thrust structure and is directly relatable to the launch of AS-501.

However, insert failures noted in container #224 on the forward skirt. have also shown up in container #206 during low level sine testing on the thrust complex. Parallel failure evaluations are being carried out by North American Aviation and Vibration and Acoustics Branch dynamic personnel. A failure was also noted in a thrust cone ring frame splice plate after completion of the low level sine tests. The 3-inch crack was stop drilled and testing resumed with no additional propagation noted. The problem is not felt to be critical; however, the plate will be replaced and a materials evaluation made on the part that failed.

III. S-IVB Stage

The S-IVB/V aft skirt was tested to failure October 19, 1966, at Huntington Beach. The skirt sustained 100% limit axial load and 225% of the limit bending moment. Two modes of failure were noted. The skirt failed in tension at the interface angle and compression failure in the aft interstage simulated structure. Which failure occurred first is being investigated. The testing indicates the skirt meets its design requirements.

IV. Instrument Unit

The **Saturn** V instrument unit self-contained actuator was random vibration tested in the extended position. Closure time before and after each test was between 3.5 and 4.0 seconds. This adequately meets vehicle vibration test requirements. No visible oil leaks were detected.

V. Saturn V System

The critical design review for the auxiliary damping system was held October 17 and drawings have been released. Fabrication of the primary damping system is proceeding.

APOLLO APPLICATIONS PROGRAM

I. PM RACK

Drawings for the PM RACK have been released to checking. Advanced released drawings have been given to Manufacturing Engineering Laboratory.

II. Electromagnetic Radiation Experiment (EMR)

A. Three concepts for mounting the ultraviolet experiments on the MSFC rack have been prepared. These concepts are: (1) An X-type cross beam which attaches to the four corners of one of the eight sides of the rack, (2) honeycomb sandwich panel which attaches to two of the eight vertical members of the rack, and (3) a waffle stiffened panel which attaches to two of the eight vertical rack members. The waffle type was evaluated and discarded.

B. Two concepts for mounting the X-ray units on a panel which will in turn be attached to the MSFC Carrier Rack have been prepared. The two concepts are: (1) a grid type network of beams, and (2) a honeycomb sandwich type panel. Presently the honeycomb panel is considered to be the most feasible because of the higher stiffness. Deflections and rotations of the X-ray units are very critical.

III. Apollo Telescope Mount (ATM)

New information from the principal investigators on the ATM experiment sizes and camera locations and inputs from the Propulsion Division on thermal conditioning requirements have made all concepts prepared to date obsolete.

The thermal control problem appears now to govern the basic structural concept in order to satisfy the extremely close pointing accuracies of some experiments (within arc seconds). Through liaison with Propulsion Division, a test "spar" configuration simulating the mounting structure for the experiments was agreed upon for thermal distortion tests. The structure is principally bonded honeycomb sandwich and will be suitable for testing either a passive or active system (standard I. U. cold plates will be used).

ADVANCED RESEARCH

I. Voyager Shroud

An orientation meeting was attended at which ground rules, study schedules and data requirements were established for a six-month preliminary design study. Three design concepts, honeycomb sandwich, skin stringer, and a honeycomb sandwich skin stringer combination are being investigated for the cylindrical shroud and nose

cone. Initial study efforts are centering on the separation concepts for the recommended over-the-nose separation scheme.

II. Nuclear Ground Test Module

Preliminary design of the dewar assembly to be used as a test fixture for evaluating various types of insulation, when subjected to combined radiation, cryogenics and acoustic loading, has been completed.

Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-66-10

MONTHLY PROGRESS REPORT
MATERIALS DIVISION
OCTOBER 1, 1966 THROUGH OCTOBER 31, 1966

SATURN IB

I. S-IB Stage

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

Assembly, qualification, and delivery of hazardous gas detection systems (HGD) for use at Saturn launch complexes at the John F. Kennedy Space Center (KSC) has continued.

The HGD unit for launch complex 37B has been completed and checked out; in addition, the first article inspection was completed by the Quality and Reliability Assurance Laboratory (R-QUAL). Delivery and installation of this unit at KSC has been completed. This completes the HGD assembly program for KSC. A technical report was written on the development of the HGD during this period.

The 500-F tanking tests at KSC were completed during this period. The HGD system was successfully computer operated during the entire test program without failure or a malfunction.

The HGD system being assembled for in-house use is near completion.

B. S-IB Stage, Project Management, Materials

Efforts are continuing in the coordination and resolution of problem areas related to the materials aspects of the S-IB stage of Saturn. During this report period, these activities have included the following:

Stress corrosion cracking has been found in three control piston cylinders on the fill-and-drain valves and pre-valves. The cylinders for vehicle AS-204 will be replaced with new cylinders of the same material (7075-T6) and the k-seals will be replaced with O-rings. Later, cylinders will be made of 7075-T73 material and will use a k-seal for minimum leakage.

It has been learned that the housings of the servo-actuators are made from forgings of 2014-T6 aluminum. Activities are in progress to establish protective measures until a new alloy can be specified and incorporated into the vehicle schedule.

The stage contractor submitted a proposal (MD-141) providing for evaluation and complete qualification testing of FTA-442A, a replacement for M-31. With certain modifications the proposal was acceptable.

SATURN V

I. S-IC Stage

A. Developmental Welding

Investigations are complete on the determination of the weldability of two new aluminum alloys, X2021 and X7007. The report covering the findings is now being prepared. Significant findings for each of the alloys are as follows:

1. Aluminum Alloy X2021-T8E31

a. The toxicity level of the cadmium vapor emitted during welding aluminum alloy X2021-T8E31 is high enough to be hazardous to operator safety unless specific precautions are taken.

b. Mechanical properties of two-pass weldments of X2021 alloy are superior to those made with one welding pass.

c. Weldments of X2021 alloy made in the flat welding position have superior mechanical properties to those made in the horizontal welding position.

d. Weldments made in 1/8-inch thick X2021 alloy have 10 to 15 percent higher strength properties than those made in 1/2-inch thick material.

e. Weldments in the X2021 alloy can be repaired at least five times without experiencing a significant loss in mechanical properties.

f. The mean crack length in the 1/8-inch thickness, as determined by the Houldcroft weld restraint cracking test, was 1.15 inches for specimens of welded X2021 alloy.

g. Preliminary results from the corrosion susceptibility evaluation indicate that the welded X2021 aluminum alloy is susceptible to stress corrosion cracking.

2. Aluminum Alloy X7007-T6E136

a. The mechanical properties of weldments of alloy X7007-T6E136 were determined after completion of a natural aging period of 16 weeks.

b. Preliminary results of the stress corrosion evaluation of weldments of X7007 alloy indicate that failure due to stress corrosion cracking may occur in a relatively short time.

c. Metallographic analysis of X7007 weldments revealed the presence of a brittle intermetallic compound at the toe of the weld crown. This brittle compound is often the initiation point of fracture.

d. Analysis of the fracture surfaces of failed tensile specimens of weldments of X7007 alloy indicate the presence of an overaged zone in the weldments, which, in some cases, invites failure.

3. Materials are being procured for the new program to determine the electron beam weldability of X7106, 2219, and 2014 aluminum alloys in 1/8-inch thickness. In addition to establishing optimum electron beam welding techniques, this program is directed toward determining nondestructive techniques and standards by which weldments may be accepted. Thus far, electron beam welding techniques have been developed for the three aluminum alloys. These techniques include one-pass welds with and without filler metal addition and two-pass welds with and without filler metal addition. Specimens welded by these techniques are now being evaluated nondestructively and by mechanical property tests.

B. Study of Corrosion and Cleaning Procedures

1. Stress Corrosion Studies

Stress corrosion studies are continuing on aluminum alloys 7002, 7006 and 7039. Specimens of aluminum alloy 7039 in the -T61 and -T64 tempers have been exposed for 237 and 215 days, respectively, both in the alternate immersion tester and to the local atmosphere. Several failures have occurred both in the alternate immersion tester and in specimens exposed to local atmosphere when stressed in the short transverse grain direction. No additional failures have occurred, and no failures have occurred to specimens stressed in the long transverse or longitudinal grain direction.

Studies of the stress corrosion susceptibility of 2024 alloys are being made, using a synthetic ocean water. This type of corrodent shows considerable promise as a test for the aluminum-copper (Al-Cu) alloys, because the surface corrosion is greatly reduced over the standard 3-1/2 percent salt (NaCl) solution.

Specimens of Carpenter Custom 455, aged at 1000°F, 1100°F, and at 1150°F (538°C, 593°C, and 621°C) were tested to determine the susceptibility of this material to stress corrosion. Both sheet and round bar were tested using flat tensile and "C" ring specimens stressed at various loads up to 100 percent of the yield strength and exposed for six months in the alternate immersion tester. No failures were encountered.

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 to the local atmosphere. Test results have not changed since the last progress report. There have been no failures of specimens of the X2021-T8E31 alloy after 231 days of exposure to the local atmosphere.

Specimens of alloys X2021 (0.5 inch thick) and X7007 (0.125 inch thick), welded with number 5180 wire and stressed to 50 percent of the weld ultimate strength, using "H" beam fixtures, are being tested for stress corrosion susceptibility and susceptibility to general surface corrosion in the alternate immersion tester. One specimen of X7007 failed after two days of exposure. Other specimens have been exposed for 57 days without additional failures.

2. 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 412 days without failure, and the actuator made from 7075-T73 has been exposed for 382 days without failure. Recommendations to paint all actuators with an epoxy primer and topcoat to reduce the possibility of stress corrosion cracking are, apparently, being followed by the responsible personnel of this Center. Some guidance has been offered to the Manufacturing Engineering Laboratory personnel who are to apply the coatings to actuators on the 501, 502, and Test Vehicles.

3. Study of the Susceptibility to Stress Corrosion of Steel Fittings

Specimens of stainless steel tubing (321 alloy) welded and brazed to North American Aviation, General Electric and Aero Quip type fittings are being evaluated for stress corrosion susceptibility in the alternate immersion tester. There have been no visible failures after 57 days of exposure.

C. Investigation of Various Paints and Paint Primers

Two clear lacquers are being evaluated to determine the protection that they afford to highly polished surfaces. One of the lacquers is air drying and the other requires baking.

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

Twenty 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.

E. Evaluation of Commercial Adhesives

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

1. Evaluation of Narmco 7344

Additional evaluation tests were run with Narmco 7344 adhesive due to the interest in this material by the Manufacturing Engineering Laboratory. Acid-etched 2014-T6 aluminum adherends were bonded with Narmco 7344 adhesive and were cured with Narmco 7119 agent for seven days at room temperature. Shear tensile test data show good strength properties at room temperature, but the strength falls off rapidly as the temperature is increased. At cryogenic temperature, the adhesive strength is not outstanding, and no immediate advantage over other products is indicated for this material.

2. Study of Polyurethane Adhesives

It has been reported that exceptional strength can be attained in bonds of Narmco 7343 by exposure of the adhesive coated adherends, prior to bonding to atmosphere humidity; subsequent to exposure to the humidity, the adherends are brought together and cured for three days at room temperature followed by a 6 hour cure at 140°F (60°C). Attempts to duplicate these results have indicated that the converse is true; exposure to atmospheric humidity results in decrease in bond strength as time of exposure is increased. Although moisture is known to "cure" some polyurethanes in a chemical sense, the resulting structures do not have the mechanical strengths obtainable by other curing agents.

Dow Corning Z-6040 primer when mixed in polyurethane resins has tended to enhance the properties of the final product. To check the effect that this primer might have, 0.25 parts, 0.50 parts and 1.00 parts were blended into 100 parts of Narmco 7343, and these blended materials were used to bond acid-etched unprimed 2014-T6 aluminum adherends with catalyst 7139. The following data were obtained by testing the various compositions at 200°F (93°C):

Z-6040 content, Parts per Hundred (Phr)	Shear Tensile Strength at 200°F (93°C) psi
0.25	1040
0.50	1690
1.00	1910

These are exceptionally high values for this temperature.

Additional studies were made with this primer using three different operators working independently but using the same adhesive mix. In these tests 1.2 parts of Z-6040 primer were added to both a sample of Narmco 7343 and Adiprene L-100. MOCA (11.5 parts) was added after the addition of the primer. The samples tested at room temperature were cured 5 days at room temperature; those tested at 200°F (93°C) were cured 7 days at room temperature. Essentially the same results were obtained with the Narmco 7343 samples as with the Adiprene L-100 samples:

Primer Content	Shear Tensile Strength, psi	
	75°F (24°C)	200°F (93°C)
Without Z-6040	1490	460
With 1.2 Phr Z-6040	1840	1710

Although the advantage of this additive at cryogenic temperatures is not yet defined, it appears to give dramatic improvements in elevated temperature strength of this adhesive.

Investigations are continuing in an attempt to determine the effects of aging on polyurethane adhesive bonded joints. In these studies, shear tensile specimens bonded with Narmco 7343 are being exposed to an accelerated aging environment of 93-100°F (37-38°C) and 100 percent relative humidity. In addition to unprimed control specimens, this study includes specimens primed with 3M Company's XC-3901 primer and Goodyear Aerospace Company's G207 primer. Aging effects are assessed by periodically subjecting samples of each series to shear tensile tests at -300, 75, and +180°F (-184, 24, and 82°C). The following conclusions are based upon observations after nine months:

a. Strength values obtained with XC-3901 primed specimens were higher than values obtained with other specimens.

b. Progressive deterioration in strength of specimens tested at room temperature and a +180°F (82°C) is marked in the first 7 to 14 days, but is scarcely observed after that time.

c. Relatively little deterioration is reflected in specimens tested at -300°F (184°C). This remarkable result is not new but is still enigmatic.

A parallel long-term aging study to determine the effect of actual outdoor ambient conditions on aluminum lapshear specimens bonded with Narmco 7343/7139 polyurethane adhesive has been in progress for eight months. Specimens are protected during aging from direct precipitation and are tested at room temperature, +180°F (82°C), and -300°F (-184°C). As in the accelerated laboratory studies described above, the only samples showing serious adverse strength changes are the unprimed control specimens.

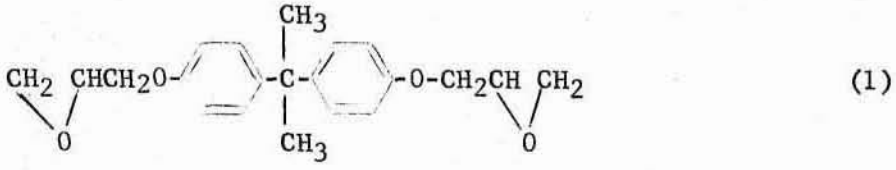
F. Development and Evaluation of Potting Compounds

Efforts are continuing to develop and adapt improved curable resin systems for application in the encapsulation of electronic circuitry. The polymeric siloxanes and silazanes containing the Si-O and Si-N linkages, respectively, have shown promise as materials possessing a desirable combination of dielectric and adhesive properties. The bulk of the current work comprises incorporation of siloxane or silazane groupings in epoxy and urethane resin systems. Subsequent application and cure processes can then be accomplished by standard urethane and epoxy technology. Also, attempts are being made to take advantage of the excellent dielectric properties of hydrocarbon and fluorocarbon polymers in encapsulating systems. This promises to be difficult because of processing difficulties and because of the very poor adhesion of these materials to ceramics and metals. With the increasing availability of low molecular weight curable, liquid, "prepolymer" forms of these products, there is opportunity to utilize the resins in conformal coatings. The initial approach involves development of curing systems which enhance the adhesion, without serious degradation of the dielectric properties of the resin. The work reported below on the curing of a styrene-butadiene prepolymer and a new fluorocarbon nitroso rubber represents this alternative approach to the conformal coating problem which was initiated during this period.

1. Potting Compounds

a. Epoxysilane Polymers

Measurements of the dielectric properties of cured resins prepared from the following diepoxides are in progress:



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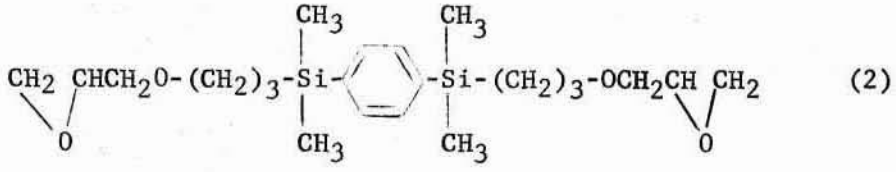

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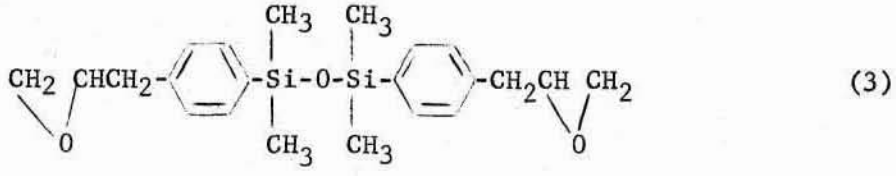
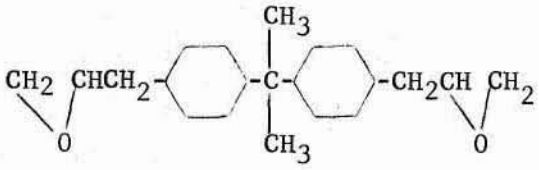


(3)



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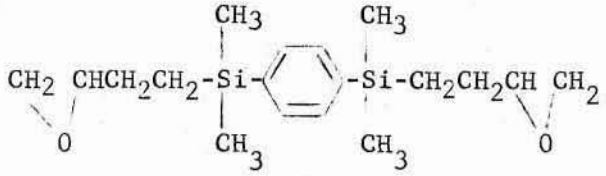
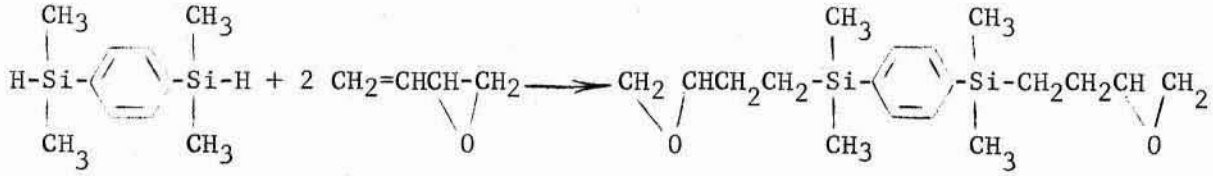


(5)

The diepoxides were cured by reaction with 10 weight percent triethylenetetraamine. The preparation of compounds 1, 2, and 3 were reported previously. Compound 4 was supplied by the Epoxylite Corporation. The structure 4 is assumed from various reports and is being verified by analysis. Compound 5 has been prepared recently by the addition of 1,4-bis(hydrogendimethylsilyl)benzene to 3,4-epoxy-1-butene in the presence of chloroplatinic acid as the catalyst.



The addition of the silicon hydride group to the olefinic group takes place smoothly, and the process may be employed, as reported below, for effecting crosslinking of unsaturated hydrocarbon polymers.

b. Epoxy Resins Cured with Silazanes

In a previous report, it was noted that a sample of a standard epoxy resin cured with tris(N-propylamino)phenylsilane became soft in its outer portions on standing in air for three months. Experimentation is in progress to establish whether the action of moisture in the atmosphere is the cause of the degradation, and to incorporate chemical groups within the resin that will effectively shield the Si-N linkage from chemical attack.

c. Siloxaneurethane Polymers

Additional quantities of bis(N,N-dimethylamino)dimethylsilane are being prepared for use in the polymerization of a siloxane diol.

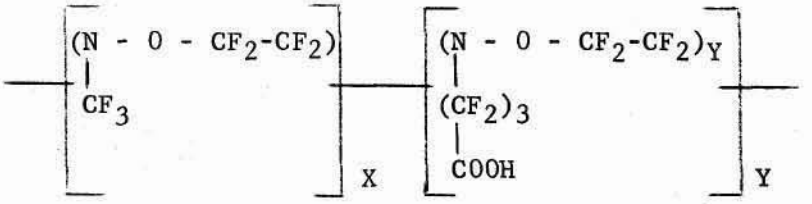
2. Conformal Coating Materials

a. Styrene-Butadiene Prepolymer

A liquid copolymer of styrene and butadiene of molecular weight of about 10,000, "Buton-100," produced by the Enjay Company, has been cured to a clear, tough, highly flexible film by the addition of approximately 17 weight percent of 1,4-bis(hydrogendimethylsilyl)benzene in the presence of approximately 1 weight percent of chloroplatinic acid hexahydrate as the catalyst. While important questions remain to be answered regarding the use of a solvent in a conformal coating system, and the poor adhesive qualities of this hydrocarbon resin, the other physical properties and the dielectric properties appear to be quite attractive.

b. Nitroso Rubber

Samples of a new nitroso rubber have recently been made available by the Thiokol Corporation. The material is in the form of a curable, millable gum and is said to possess the following structure:



where X >>Y. The supplier has indicated the potential availability of the material in the form of a low molecular weight, curable, liquid "prepolymer." The cured elastomeric sheets of the gum rubber are fairly transparent, highly flexible, and moderately strong. The dielectric constant is reported to be quite low, about 2.4. The physical, electrical, and adhesive properties of the cured elastomer are being appraised.

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

The purpose of this project is to develop or locate materials of low wear and noise characteristics for slip rings designed to operate for extended periods of time at low amplitude oscillations.

A set of experimental slip rings consisting of 24K electroplated gold rings and NEY-ORO 28A brushes was operated with 25 milliamps brush current while oscillating at 7.1 hertz with 0.0134 degrees double amplitude (DA). Initial noise level was 20 microvolts, RMS. At the end of 400 hours operation, the noise level was still at 20 microvolts. The noise waveform coincided quite well with the excursions of the driving oscillator. The low noise is definite proof that with small amplitude oscillators, only rolling contact is produced.

H. Investigation of the Lubricating Characteristics of Fuels and Hydraulic Oils

The engine fuel, RJ-1, will be used as the hydraulic fluid for the servo-actuators of the S-IC stage. Concern has arisen over the life of the ground support equipment (GSE) hydraulic pump because of the poor lubricating properties of RJ-1. As a result, emphasis has been directed toward evaluating RJ-1 lubricating additives. Screening tests have been made on commercial additives in the Shell Four Ball wear tester and the Falex lubricant tester. The Shell Four Ball wear test is a relative measure of the lubricating ability of the fluids. The Falex tester is also a relative measure of the lubricating ability of the fluid. The Falex test measures bearing load and resulting wear produced by forces on a rotating pin and set of vee-blocks. A successful test is 3.0 hours in duration with wear measured in the number of loading gear teeth required to maintain the 100-pound load. Five of the best additives found in these screening tests were tested in the simulated GSE pump. The pump consists of nine steel cylinders in a bronze cylindrical housing. These cylinders have swivel bronze shoes which are attached to one end and rest against a wobble wear plate. This plate is driven by an electric motor at 1,750 rpm. The fluid being tested (RJ-1 or RJ-1 and additive) is forced by a low pressure through the pistons and small openings in the center of the wear shoes forming a lubricating film between the shoe surfaces and the wear plate surface. A static load is applied to the center of the shoes (on a holding plate). This load can be varied manually during the test. The motor torque (reaction torque of the shoes against the wear plate) and static load are measured on load cells and recorded on a Sanborn instrument. Of those lubricant additives evaluated a material marketed by Esso designated WS-5412 has proven superior. A final report on the results of these tests is being written in which it is recommended that WS-5412 be used as an additive in the RJ-1 fuel in the GSE hydraulic system. This project is complete and will no longer be reported.

I. Investigation of the Low Temperature Mechanical Properties of Engineering Alloys

Studies have continued in the evaluation of the low temperature mechanical properties of structural alloys. The status of this program is as follows:

1. Evaluation of PH 14-8Mo Stainless Steel

Tensile testing at cryogenic temperatures has continued on specimens of PH 14-8Mo stainless steel heat treated to the SRH 950 and SRH 1050 conditions.

2. Evaluation of Titanium Alloy 8Al-1Mo-1V Duplex Anneal

Smooth and notch specimens of the 0.050-inch and 0.10-inch thick sheet have been tested at low temperature. However, additional tests are required at various temperatures before the data can be evaluated.

3. Evaluation of Aluminum Alloys X2021 and X7007

All tests scheduled are complete for the evaluation of aluminum alloys X2021 and X7007. Data from these tests are being reduced and evaluated.

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. Development of Materials for Special Purpose Electrical Equipment

IIT Research Institute, NAS8-5251

F. 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 Pistons from an S-II Stage Variable Delivery (Actuator) Hydraulic Pump

Two sets of pistons removed from S-II hydraulic pumps were received for evaluation of the braze joint between the silver ring and the leaded

4140 steel piston shoe. The first set of pistons was removed from a pump which had undergone qualification tests at Brown Engineering Company. The second set of pistons (received with the cylinder block) was removed from a pump which had undergone 1150 seconds running time prior to an "O" ring failure. This failure, caused by overpressurization of the systems, occurred during testing at Mississippi Test Facility (MTF). The braze joints in both sets of pistons contained an excessive amount of voids. Lack of process control was also demonstrated by differences in the pistons. Metal removal was noted on the exit side of the cylinder block and in the cylinder walls of the unit received from MTF. The cause of this condition could not be determined; however, the removal could be the result of erosion and/or fretting corrosion.

A piston shoe which failed during the break-in run portion of acceptance testing of the main S-II variable delivery (actuator) hydraulic pump also was received for failure analysis. This failure analysis request was prompted by the poor quality found in the brazed joints of the silver ring to leaded 4140 piston shoes in two sets of pistons evaluated previously. This was the third piston shoe to fail during the break-in run portion of acceptance testing. The fractured surface on the failed silver ring was smeared; therefore, the exact mode of failure could not be determined; however, inadequate braze "wetting" of the leaded 4140 steel was observed under the missing portion of the silver ring.

It was recommended that bronze-plated 4140 (not leaded) steel piston shoes be used. If this change cannot be effected, the use of unleaded 4140 steel piston shoes and good braze process control should improve the quality of the braze joining the silver ring to piston shoe.

B. Evaluation of Adhesive Used in the Repair of S-II Stage Insulation

The stage contractor reportedly is using Lefkoweld 211 adhesive for repair work in the insulation of the liquid hydrogen tank of the S-II stage. The Lefkoweld 211 adhesive is a three-component adhesive, and based on 100 parts of resin, only one part of one of the components is used, thus, making it difficult to obtain a uniformly mixed material. Additional tests of this adhesive have been made. Representative shear tensile data from acid-etched 2014-T6 aluminum adherends bonded with Lefkoweld 211 are summarized as follows:

Temperature, °F (°C)	Shear Tensile Strength, psi
-300 (-184)	1380
75 (24)	2130
300 (149)	510
400 (204)	400

The above data, and all previous results continue to show that this adhesive does not have outstanding properties at cryogenic temperatures.

C. Evaluation of Adhesive Used In S-II Stage Fuel Tank Repair

Initially, HT-424 adhesive was used to bond reinforcing doublers over those areas of the liquid hydrogen tank where cracks had been discovered. The cure employed was 3 hours at 290°F (143°C). In order to obtain additional data on this adhesive, various primer treatments and pressure-temperature cure conditions were investigated. Vacuum bagging was compared with various press cures, since the former route represents the most probable means of applying bonding pressure under actual conditions. Strength values obtained on vacuum bagged samples were lower than press cured where attainment of higher adherend contact pressures is possible. As expected, this study indicated that Narmco 7343 would be preferable for this application if an added margin of cryogenic strength is needed. The HT-424 would be preferred if higher strength above room temperature is needed.

IV. S-IVB Stage

A. Developmental Welding

During this report period, all welding operations have been completed in the evaluation of the weld repairability of 3/8-inch thick 2014-T6 aluminum plate. More than half of the tensile specimens have been machined, and approximately 1/3 of the specimens for metallographic examination have been completed. Preliminary results from the metallographic examination indicate that the problem of precipitated $CuAl_2$ does not appear to be as critical as it was with the 1/8 inch thick 2014 repair weld.

Studies have continued into the effects of weld heat input on weld strength in 2014-T6 aluminum alloy. Test material has been obtained and is being prepared in the appropriate configuration for welding. It is anticipated that various weldments with controlled heat input can be prepared during the coming report period.

B. 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 liquid hydrogen tank of the S-IVB stage. Materials will be evaluated as to weight loss as a function of time of exposure to reduced pressure, and the outgassing constituents will be identified for possible toxic products.

Testing has continued in the determination of the type and amount of toxic products which may be evolved from D-65 coating. Three tests were completed which involved exposure of D-65 to 5 psia oxygen at 100°F (38°C) for 48 hours. In one of these tests the D-65 yielded 39 ppm tetrahydrofuran; in the remaining two tests, the tetrahydrofuran yield was only 10 ppm. In all three cases, the tetrahydrofuran yield was well below the toxic level reported in "Dangerous Properties of Industrial Materials" edited by N. Irving Sax.

Six additional specimens of D-65 are being prepared for long-term testing. These samples will be prepared according to the same procedure used for all previous samples. The samples will be air-cured for 72 hours followed by exposure to a vacuum of 10^{-6} torr for 72 hours. They will then be placed in a 5 psia oxygen atmosphere at 120°F (49°C) for 14 days, and analyzed for toxic constituents.

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.

All specimens for hypervelocity impact testing have consisted of 6-inch discs of the Douglas Aircraft Company (DAC) 3-D foam internal insulation bonded to 12-inch diameter 1/8 inch thick aluminum plates. The foam was covered with the standard Narmco 7343 impregnated glass fabric and the coatings to be evaluated were applied to this surface. Aluminum foil (1-1/2-mil) was applied to six specimens. Three of these six foil covers had 1/32 inch holes spaced on one-inch centers. An analogous series of samples was prepared using 2-mil Kapton film.

Studies completed to date indicate that the 3-D insulation will burn in the presence of 5 psia oxygen when punctured with a 3/32-inch diameter (mass 0.0196 gm) aluminum pellet at velocities of 22,700 feet per second.

Tests have been made to evaluate the fire-retardant characteristics of several types of coatings or seal materials over the 3-D insulation. Preliminary results indicate that the seal coat is barely penetrated at velocities below 14,800 ft/sec using the 3/32-inch diameter projectile. Detailed analyses of tests made with the various coated samples of D-65 are still in progress.

C. S-IVB Stage, Project Management (Materials)

Efforts are continuing in the coordination and resolution of problem areas related to the materials aspects of the S-IVB stage of Saturn. During this report period, these activities have included the following:

1. Bolts for S-II/S-IVB Interface Joint Tests

The stage contractor, Douglas Aircraft Company (DAC), proposes to use nuts and bolts of H-11 steel of the 220-240 KSI class for the S-II/S-IVB interface joint tests; however, because of the unreliable performance of H-11 bolts in this application, it is intended to use A-286 alloy fasteners in the flight hardware. If, during the tests, the H-11 fittings should break before reaching the design ultimate line load of 814 pounds/inch, the contractor proposes to change to H-11 fittings having an ultimate tensile strength of 260 KSI. The contractor

was advised that A-286 fittings of the 200 KSI class should be used for the S-II/S-IVB interface joint tests.

The Douglas Aircraft Company has stated that H-11 fasteners were used throughout the stage but that the exact locations of such fittings were not known at that time. Thus, an action item was placed upon DAC to identify the location of each H-11 fastener in the stage and specify its operating environment.

2. Investigation of Dynatherm D-4327 for Applications in Contact with Liquid Oxygen

A coating designated D-4327 marketed by the Dynatherm Corporation has been used successfully in several applications in liquid oxygen (LOX) tankage to seal sensitive materials from contact with LOX. However, recently some difficulty has been encountered in qualifying D-4327 for use with LOX per MSFC-SPEC-106B. The stage contractor (DAC) suspected that the problem was related to the drying procedures used for the LOX compatibility test specimens. Thus, investigations were made to determine the effects of the solid content of the coating solution and of the thickness of applied coatings on LOX sensitivity. By thinning the solution with methyl-iso-butyl ketone to a solids content of 10 percent, maximum coverage was obtained and "pin holing" was minimized. Investigation of coating thickness suggested that each coat of material should be applied with a maximum thickness of 0.7 mil with at least one-half hour drying time between coats. All D-4327 tested by DAC since January 1966, utilizing the aforementioned procedure, has met the requirements of MSFC-SPEC-106.

3. Evaluation of Dynatherm D-65 Coating Material for Orbital Workshop Applications

Testing continues at Douglas Aircraft Company (DAC) to further qualify D-65 which was recommended by this division as a flame-retardant coating for the S-IVB Orbital Workshop. Preliminary testing by DAC resulted in the selection of four candidate coating systems. These include (1) Dynatherm D-65 applied to XD-3901 primed liner, (2) Dynatherm D-65 reinforced with two plies of 1562 glass fabric applied to XD-3901 primed liner, (3) aluminum foil, 0.002-inch thick, bonded over liner with polyurethane adhesive (XD-3901 primer was applied to liner and foil), and (4) DAC flame-retardant coating No. 21 reinforced with one ply of 1533 glass fabric applied to XD-3901 primed liner.

Candidate coatings were tested by thermal cycling on three-foot domes and considerable damage was encountered by each. It was determined that the test domes were improperly designed and that test conditions were much more severe than those expected during flight; thus, all data on three-foot dome tests were invalidated.

The three-foot dome was redesigned and prepared for testing an aluminum foil liner. This dome also failed prematurely, thus, invalidating data developed in the test.

4. Bonding of Clips and Sensors

Debonding of temperature sensors initially presented somewhat of a problem on S-IVB-203 at cryogenic temperatures. An improved bonding process was developed, resulting in bonding the ceramic-type sensors with 1P20075 polyurethane adhesive and covering each sensor with one ply of MIL-C-9084, Type 2 glass fabric impregnated with 1P20075 adhesive per PRD 1P00126. All temperature sensors bonded with this newly developed process performed satisfactorily during flight of the S-IVB-203 stage.

Considerable problems have been encountered with debonding of attachments; however, the bonding process has been improved. Stages incorporating the improved process are not expected to have attachment debond problems as a result of cryogenic loadings and captive firings.

5. Prevention of Corrosion in S-IVB LOX Tank

Problems with corrosion in the LOX tank have been resolved by upgrading cleaning procedures and changing fitting alloys. However, during a discussion of the corrosion problem, DAC mentioned the use of silver-plated nuts. Since this division disapproved the use of silver-plated nuts on the S-IVB stage, DAC was asked where such nuts are being used. Because DAC could not answer at that time, an action item was placed upon DAC to identify each silver-plated nut and the material of the bolts on which silver-plated nuts are used.

6. Welding Allowables, Including Strength Allowables for Repaired and Unrepaired Welds

Considerable discussion with the stage contractor (DAC) was devoted to definition of a weld repair and to DAC's justification of their design allowables. The contractor stated that the data were available to this Center in work-sheet form but discouraged our accepting copies of the data on the basis that it would be meaningless to this Center. We insisted that the requested data were necessary to improvement of the S-IVB weld program. Thus, two action items were assigned to DAC as follows:

a. DAC will provide this Center with data upon which design allowables are based for each structural weld of the S-IVB stage.

b. DAC will document in writing their statement that a maximum of two weld repairs are allowed for each defect in structural welds of the stage. This will include a written definition of a weld repair.

The stage contractor objects in principle to the preparation of a weld repair procedure because of the many variances that can occur requiring repair welds. This division concurred with DAC in this matter and suggested that, where weld defects occur frequently, emphasis should be placed upon improving procedures to eliminate the defect initially.

7. Common Bulkhead of S-IVB-210

A considerable quantity of water entered the common bulkhead during hydrostatic testing of the stage because of a drain plug which was inadvertently omitted during preparation of the stage for testing. About 8,000 cc of water have been removed. The current removal rate is about 3 cc per hour. An unwetted common bulkhead was found to yield water at the rate of about 1 cc per hour. Thus, DAC considers that a common bulkhead yielding no more than 1 cc of water per hour is dry, and efforts are directed toward getting the water yield of the S-IVB-210 bulkhead below 1 cc per hour as collected by warming and vacuum pumping the bulkhead.

Nondestructive tests of the common bulkhead have been made to ascertain the extent of damage caused by water in the bulkhead, and both destructive and nondestructive tests of laboratory specimens are being made to support this investigation. To date, no evidence of damage has been found; however, testing is being continued to verify the extent of damage incurred.

8. The following documents have been reviewed:

a. DAC proposal, "S-IVB insulation improvement study for spent stage applications

b. DAC PRD 1P00103A, "Coating for Heat Sinks, Dielectrics, Process for"

c. DAC PRD 1P00084B, "Heat Treatment of Steels (Aircraft Practice), Process for"

d. DAC PRD 1P00085D, "Bonding Structural, Multicomponent Adhesive"

e. DAC PRD 1P20075D, "Adhesive Polyurethane, Cryogenic, Flexible"

f. DAC PRD 1P20112, "Lubricant Grease Consistency, Propellant Systems Compatible"

g. DAC PRD 1P00097A, "Bonding, Structural, Film Adhesive"

h. DAC PRD 1P00098A, "Bonding, Low Stress"

i. DAC MRD 1P20107, "Foam, Polyurethane, Yarn Reinforced"

V. Instrument Unit

1. Investigation of Corrosion of Magnesium-Lithium Alloys

A review of the data collected during this study of the corrosion susceptibility of magnesium lithium alloys revealed a considerable contrast

between the corrosion resistance of the magnesium-lithium and AZ31 magnesium alloys. The magnesium-lithium alloys were considerably more susceptible to general corrosion and were not protected sufficiently by coatings normally used for the common magnesium alloys. The most effective inorganic coatings found to protect these alloys were the Dow 17 and IBM anodic coatings. These coatings, when followed by an epoxy paint system, provide satisfactory protection except in extremely corrosive environments. As with all magnesium alloys, galvanic corrosion from dissimilar metals should be avoided.

Electrochemical measurements show that the lithium containing magnesium alloys are slightly more reactive than the commonly used magnesium alloys. Stress corrosion studies conducted in a 100 ppm sodium chloride solution and in the outside environment showed the two magnesium-lithium alloys to be resistant to this type of failure even when stressed to a load of 100 percent of the yield strength. Electroplating techniques also were evaluated. Satisfactory metallic coatings were obtained by using slight modifications of the zinc immersion process. Chemical bond strengths of the plated coatings exceeded those that had been previously reported by other investigators. Although the work on this program is essentially completed, data from some long-term tests will continue to be recorded, and any changes or additions to the above results will be reported at a later date.

2. General Corrosion Tests

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.

3. Instrument Unit, Project Management (Materials)

A problem has arisen on the adhesive used on the honeycomb structural panels of the Instrument Unit (I.U.). The adhesive manufacturer (Narmco) has experienced difficulty in supplying material to the present specification requirements (climbing drum peel test). It has been reported by IBM that, after consulting with Narmco, steps will be taken to upgrade the adhesive to meet specification requirements.

VI. F-1 Engine

Analysis of Failed Section of Fuel Pump Balance Cavity Supply Line on F-1 Engine F-5038

A high pressure flex hose failed on the fuel pump balance supply line after 2025.4 seconds total firing time and 17 starts on F-1 engine F-5038. Failure of the 347 stainless steel bellows was attributed to fatigue. Failure occurred in the fifth I.D. convolution with a secondary crack in the fifth O.D. convolution. Galling and scoring of the bellows O.D. surface

were noted in the area of secondary cracking. No metallurgical irregularities were found in the material. Fractographic studies verified the presence of fatigue striations at the origin of the fracture. Because of fatigue problems associated with this type of line, a design change has been made which replaces the 347 stainless steel flex hose with an impregnated teflon hose.

VII. J-2 Engine

A. Analysis of Oxidizer Line Weldment Failure on J-2 Engine (2048) Augmented Spark Ignition Assembly

Failure occurred in the weldment between the oxidizer line and the orifice valve of the augmented spark ignition assembly on J-2 engine 2048 after 1965 seconds total running time and 16 engine ignitions. The failure, resulting from fatigue, occurred in the heat-affected zone of the oxidizer line adjacent to the weld interface. No metallurgical irregularities were found that could have caused failure. Weld under-bead drop through, which could constitute a flow restrictor, was noted on the I.D. surface of the oxidizer tube. Fractographic studies verified that the failure resulted from fatigue.

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

A repair procedure which is being used to reclaim some defective Tens-50 aluminum alloy castings was discussed with Rocketdyne personnel. Apparently, Rocketdyne received approximately twenty turbopump volute castings in which a core shift caused the wall thickness of the castings to be thinner than the drawing requirement. The repair procedure, in this case, is to build up the thickness by laying on weld beads using Tens-50 filler wire. The repair zone on these particular castings was as large as 1-1/2-inches in width by 14 inches in length, built up in thicknesses from 0.100 inch to 0.300 inch. Rocketdyne developed the repair technique several years ago, and has been using it regularly on castings for other engines also. All welding is done prior to heat treatment, and all repairs are thoroughly inspected. The repair procedure is apparently rigidly controlled and thoroughly documented. Rocketdyne will furnish data on the procedure, with test results showing properties of repaired castings.

C. C-1 Engine

Standardization of Nondestructive Techniques for Examining Electron Beam Welds

At the request of the Quality and Reliability Assurance Laboratory, a study was initiated and directed toward development of techniques and establishment of specifications for inspection of electron beam welds on the C-1 engine.

A quantity of tantalum-10 tungsten (Ta-10W) alloy, one of the C-1 motor component materials of interest, has been ordered.

The 2014-T6, Ti-6Al-4V and Ta-10W test blocks on hand could not be machined to a sufficiently high accuracy for sound velocity measurements by comparative measurement techniques. Astrionics Laboratory has been requested to machine these blocks to the required accuracy. These blocks also will be used for attenuation measurements. Specimens have been ordered for velocity and attenuation measurements utilizing the resonant technique.

Apparatus is being assembled and designed for sound beam geometry measurement. Characteristic curves will be semi-automatically plotted using an x-y scanner and x-y recorder mechanically coupled together.

Components for precise dimensional definition of ultrasonic test beams have been ordered and delivered. However, failure to meet tolerances on a key item is necessitating rework of the item.

Radiographic techniques also will be evaluated for use in examination of electron beam welds in C-1 engine components.

The work will entail fabrication of penetrameters and thickness step blocks, determination of radiographic sensitivity as a function of thickness and technique and developmental radiography of electron beam welds in 2014-T6, Ti-6Al-4V and Ta-10W alloys.

VIII. Apollo Telescope Mount (ATM)

A study was initiated to determine the possible sources of contaminant deposition which could adversely affect the operation of the 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 products of the RCS system. Results of the preliminary study indicate that the RCS system may well be the largest source of potential contaminant material. A complete study of all possible contaminant sources is in progress.

IX. 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 Module Program. Specifically, the areas of cryogenic insulation, valve seals, transducer materials, gimbal and bearing lubricants, and induced neutron activation are being actively investigated.

A contract (NAS8-18024) has been initiated with the General Dynamics Corporation, Fort Worth, Texas to evaluate the effects of radiation and cryogenic temperature on the mechanical properties of selected cryogenic insulations, adhesives, and vapor barriers. In addition, the structural integrity of two insulation systems will be determined after exposure to

acoustic, cryogenic temperature, and radiation stresses. The 900 test specimens required for this program are being fabricated.

A contract is being negotiated for the computation of neutron induced activation of proposed GTM structural materials. This information is necessary for the establishment of stage operation criteria. The computations performed will utilize the computer program initiated by this division and validated by the Illinois Institute of Technology under contract NAS8-11160.

Work is in progress to determine the coefficient of thermal conductivity from room temperature to 20°F (-7°C) for a specimen of laminated corkboard which is a candidate insulation system for the GTM. 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. Specimens of several foam insulations are being prepared for testing in the vacuum tensile tester for evaluation as potential insulation systems. Drawings of two valves currently used on Saturn launch vehicles have been received from Propulsion Division and, the materials used in these existing 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 personnel of the Propulsion Division and the Quality and Reliability Assurance Laboratory.

ADVANCED RESEARCH AND TECHNOLOGY

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, GO-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

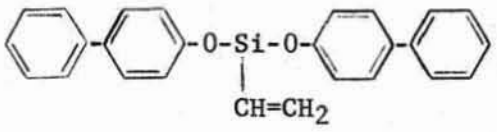
1. Battelle Memorial Institute, NAS8-11891
2. Canadian Commercial Corporation, NAS8-20529

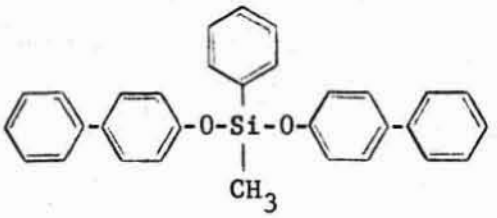
II. General - In-House

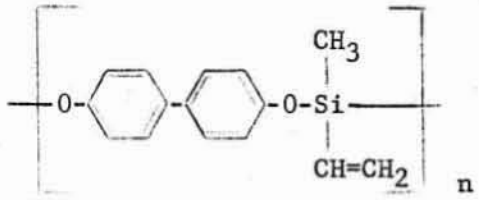
A. Development of High Temperature Resistant Polymers

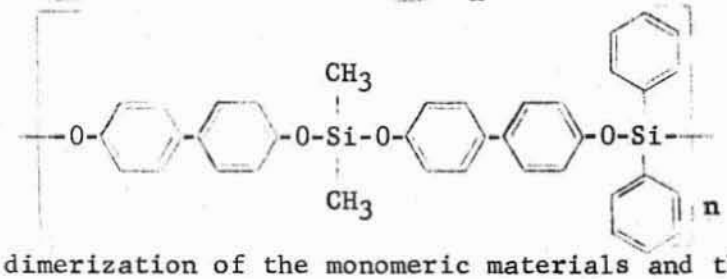
1. Curing Studies

Studies of potential curing reactions for Polymer A type structures are continuing. These investigations have utilized monomeric and polymeric structures including the following:

a. 

b. 

c. 

d. 

The dimerization of the monomeric materials and the crosslinking of the polymeric products by conventional methods, such as treatment with peroxides and other catalysts have proven unsuccessful. The vinyl group attached to Si is very sluggish in polymerization with itself and in copolymerization with other vinyl compounds. The commercial methyl silicone polymers can be crosslinked by reaction of methyl groups with peroxides, but in the aryloxysilanes the methyl group is unreactive.

The most effective means of curing Polymer A which has been found to date consists of treatment with trianilinophenylsilane (TAPS). Volan A-1500 treated glass fabric was used in conjunction with Polymer A to make a series of fiberglass laminates. The separate samples of Polymer A used in this study contained varying proportions of TAPS. The lay-ups were pressed at 492°F (250°C) for two hours and subjected to flexural tests per ASTM D-790-63 with the following results:

TAPS Content, Based Upon Polymer A, Percent	Flexural Strength of Laminate, psi
2.5	10,150
5	20,150
10	32,450
15	33,500

Although the practicality of this curing method is subject to question, it does prove that crosslinked Polymer A structures have potentially desirable properties. Consequently, efforts to achieve these structures under more controllable and less stringent conditions will continue.

2. Characterization of Polymer A

The ArRo Laboratories, Incorporated, Joliet, Illinois, has reported gel permeation chromatographic (GPC) analyses of samples of Polymer A in toluene solution. The values of the observed molecular weight and molecular weight distribution appear to be comparable to those found by other methods. These data confirm the utility of this very convenient measurement for resins of the Polymer A type.

Evaluation of the purity of 1,2,4-trichlorobenzene ("Superior Grade," Matheson, Coleman and Bell) indicated that the product is suitable as a solvent for use in the determination of the molecular weight of dissolved polymers by the light scattering technique.

Differential thermal analysis of a sample of Polymer A (21 987-79-1) showed evidence of decomposition at 560-600°C (1040-1112°F) but no recognizable glass transition point between -118°C and +980°C (-180°F and 1796°F).

B. Development and Characterization of Phosphonitrilic Polymers

The synthesis of substituted phenyl-phosphonitrilic chloride tetramers was continued with a characterization of the product obtained from the anhydrous HCl treatment of 2,4,6,8-tetraphenyl-2,4,6,8-tetrakis-N-methylcyclohexylaminophosphonitrile:

$$P_4N_4\emptyset_4\left[N(CH_3)(C_6H_{11})\right]_4 + 8\ HCl \longrightarrow (\emptyset PNCl)_4 + 4\ \text{amine}\cdot HCl$$

Unfortunately, the product isolated from this reaction was shown, through comparison of infrared spectra, not to be one (or a mixture) of the geometric isomers of $(\emptyset PNCl)_4$. The identity of the material is unknown, but is definitely some other tetrameric phosphonitrile since its infrared spectrum shows P-N ring absorption at 1280 cm^{-1}.

Optimum conditions will certainly have to be established for this regeneration. However, immediate attention will be directed toward a more thorough characterization of the product assumed to be $P_4N_4\emptyset_4(N(CH_3)(C_6H_{11}))_4$. In all of the reactions leading to the formation of this material, the product has always been obtained as an oil. Characterization of this oil has been limited to infrared spectral examination which has been consistent with the proposed structure. More purification of this oil may be required prior to its treatment with anhydrous hydrogen chloride (HCl) in order to regenerate the tetrachloro derivative.

The starting material in the three-step synthesis, $P_4N_4Cl_4(N(CH_3)(C_6H_{11})_4$ has been fully characterized both chemically and spectrally. Elemental analyses are in agreement with the emperical formula while nuclear magnetic resonance (n.m.r.) spectra of the amide shows it to be non-geminally substituted and to be either the beta-trans, gamma-trans, or cis-isomer. Furthermore, its n.m.r. spectra and narrow melting point range suggests that the product is a single isomer and not a mixture.

Future work will be concentrated on fully characterizing the phenyllated derivative.

Considering all factors, it would appear that this system, i.e., the N-methylcyclohexylamino derivative, is the best one to continue further studies. The basicity of the $-N(CH_3)(C_6H_{11})$ group is approximately the same as the $-N(-CH_3)_2$ group. Other workers have reported that this group can be replaced through nucleophilic displacement by halogen atoms.

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. As reported earlier, the niobium diselenide ($NbSe_2$) based brush materials have shown more promise for the projected applications than the previously developed molybdenum disulfide (MoS_2) based materials; therefore, the $NbSe_2$ based materials are being investigated thoroughly.

The results of the electrical conductivity measurements on a variety of $NbSe_2$ based materials have been made. The conductivity of the tantalum diselenide ($TaSe_2$) composites, and of the $TaSe_2$ alone lies in the 10^3 ohm^{-1} cm^{-1} range; for the $NbSe_2$-MoS_2 composites the conductivity is in the 10^2 to 10^3 ohm^{-1} cm^{-1} range. The $NbSe_2$-Ag composite material also has a conductivity in the 10^3 ohm^{-1} cm^{-1} range. No consistent trend of conductivity as a function of composition has been observed in any of these three systems.

Tungsten diselenide (WSe_2) based materials also are being investigated as brush materials. Two compositions have been prepared. The first was 86.1 WSe_2-13.9 Ag hot-pressed at 760°C (1400°F) with 5500 psi mold pressure, and the second was 100 WSe_2 hot-pressed at 927°C (1700°F) with the same mold pressure. Fractional density (actual density/theoretical density) for both compositions was approximately 0.81, and neither sample was particularly strong.

The literature indicates WSe_2 to be a good conductor (though not as good as $NbSe_2$). Further work will be done to determine if a dense, strong material can be obtained by increasing the hot-pressing temperature and/or pressure.

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 program has been initiated which provides for an experimental investigation of materials and thin film technology as applicable to microminiaturized electronic components such as capacitors and transformers.

Thin films of silicon monoxide were deposited on glass substrates. A light brown discoloration of the film is evident, and is the result of oxidized tungsten originating at the evaporation filament. The silicon monoxide film was observed under a microscope and was found to be homogeneous and uniform.

An electron beam gun, incorporated in the vacuum deposition apparatus has been activated to allow "in-situ" cleaning of metallic substrates for deposition of both silicon mono- and dioxide films. The necessary shields, shutters and substrate holders have been designed, fabricated, and installed, and deposition is in progress.

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 two tests were made on a mechanically coupled motor-generator set incorporating experimental brushes, bearings, and dielectrics. While both tests were made at a pressure of 1×10^{-6} torr, one test was conducted at room temperature and the other at elevated temperatures. Average speed for both tests was 670 rpm with applied motor armature voltage of 40 volts and with field currents maintained at 1.5 amperes.

In the ambient temperature test the average motor efficiency was 80 percent while in the elevated temperature test the efficiency was only 75 percent.

F. Determination of Physical Properties of Materials by Nondestructive Techniques

1. Electrical Conductivity

Electrical conductivity studies are being made to determine if surface conductivity changes can be used to indicate the progress of the stress corrosion process in aluminum.

Current efforts have been directed toward the use of a commercial eddy current instrument for determining the initiation of stress corrosion in aluminum specimens. However, this instrument is not entirely satisfactory, therefore, specifications have been written for a specialized eddy current instrument for this application.

2. Ultrasonic Measurement of Crack Propagation

A project was initiated during this reporting period to develop a suitable laboratory apparatus for measurement of the rate of crack propagation. The apparatus is needed for experimental study of the influence of stress, reactive environments, temperature, etc. on the rate of crack propagation. Its initial use is to be the determination of the mechanism of crack propagation in aluminum at the grain boundary level.

A project plan has been written and ultrasonic instrumentation has been located which appears suitable for ultrasonic signal generation, amplification and processing. In addition, a pen recorder and corrosion resistant tanks have been ordered and a schematic of the proposed apparatus has been drawn.

G. Lubricant Development and Evaluation

1. Study of Lubricants for Low Temperature Applications

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 from +50°F to -100°F. The breakaway torque and the relaxation torque can be measured accurately at any specific temperature in this temperature range. During this period tests were made on DuPont PR-240 AB and PR-240 AC fluorocarbon grease. Test results indicate that at all test temperatures from -80°C to 0°C, the relaxation torque and breakaway torque are significantly lower for the PR-240 AB grease than for the PR-240 AC grease.

2. Compatibility of Lubricants with MIL-H-5606 Hydraulic Fluid

Tests to determine if Dow Corning DC-4 (silicone compound) lubricant and technical petrolatum (VV-P-236) are compatible with hydraulic fluid are completed. The testing device used for these tests was designed and fabricated so that four samples of the same lubricant could be tested simultaneously resulting in more reliable data. This was obtained by fastening four screened cups, each containing approximately four grams of the lubricant to a four spoke wheel. All four cups were submerged in the hydraulic fluid and the six-inch diameter wheel was rotated by a directly coupled 1 rpm motor. The hydraulic fluid is heated by placing the container on an electric hot-plate. The samples were carefully weighed before and after test to check the weight loss or weight gain. Three test runs of 1 hour and 45 minutes duration were made at each temperature setting for each lubricant. The lubricant DC-4 seemed to hold up well up to 175°F (79°C), but the petrolatum dissolved rapidly at approximately 120°F (49°C).

3. Lubrication of Ball Bearings for Use in Vacuum

Small instrument ball bearings are being tested at low pressures for a variety of applications in spacecraft and moon-based equipment. Various dry films and self-lubricating retainers are furnishing lubrication for the bearings.

Two bearing life tests were completed during the reporting period. These data will be reported after several more tests have been made.

4. Radiation Lubrication Tests

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 gamma radiation in the linear accelerator and tested in the Falex lubrication tester.

During this reporting period the lubricant MLR-2 (MoS_2, Sb_2O_3 in a polyimide binder) was applied to Falex test specimens, irradiated and tested in the Falex tester. Ten specimens were used as control samples, ten specimens were irradiated at 1.8×10^{17} electrons per square inch and ten specimens were irradiated with 3×10^6 R. gamma radiation. In general, a wear life of 1 to 2 hours is considered acceptable for dry film lubricants being operated under a 1,000 pound jaw load on the Falex machine; therefore, it appears from these results that the MLR-2 provides exceptional wear life and is substantially unaffected by radiation in the ranges tested.

H. Investigation of Nuclear Environmental Effects in Materials

1. Thermal Control Coatings

A test program has been initiated to determine electron and proton induced changes in the optical properties of various thermal control coatings in order to evaluate their suitability for use on spacecraft and launch vehicles. Irradiations in air and vacuum with electrons and in vacuum only with protons are planned. Equipment will be developed to permit in-situ optical property measurements.

2. Vacuum Tensile Tests

A program has been initiated to determine in-situ the effects on the tensile properties of materials after prolonged exposure to vacuum and temperature. It is necessary that the vacuum-temperature effects on the tensile properties be isolated in order to determine the effects of radiation on the tensile properties of materials in a space simulated pressure-temperature environment. Mechanical property tests

were made in vacuum on Mylar, Tedlar, and H-Film after exposure to reduced pressures of 3×10^{-7} to 5×10^{-8} torr for periods of 24, 48, and 96 hours at room temperature. Two gauges of each material were evaluated to determine if specimens of different thicknesses behave the same in a vacuum environment. There appears to be no change in the mechanical properties of these materials in this environment.

I. Investigation of Ceramic Fiber Reinforced Composites

The objective of this program is to investigate the possibility of incorporating whisker materials into a drawn glass fiber to improve its strength and modulus of elasticity. Several trial melts of E-glass and silicon carbide (SiC) whiskers have been made by heating the melts to 1343°C (2450°F) and holding at this temperature for 5 minutes. SiC whiskers were observed in the glass with the petrographic microscope. It appears, therefore, that the SiC whiskers are more stable in the E-glass than either the bulk or fiber SiC crystals tested previously. Attempts to produce a glass fiber containing the whiskers have not been successful, but the experiments will be continued. The equipment for the fiber tensile tester and for the fiber drawing drum has been received.

J. Study of Ceramic Adhesives for Use in Contact with LOX

Efforts have continued to develop LOX compatible ceramic adhesives for bonding aluminum alloys. Several adhesives were prepared and evaluated using either potassium or sodium silicate as the binder and alumina and clay as the inert ingredients. Three formulations were prepared using sodium silicate and two using potassium silicate. The average shear tensile strengths of the sodium silicate-bonded adhesives were less than 50 psi at room temperature, whereas, the potassium silicate-bonded adhesives had shear strengths of approximately 100 psi at room temperature. All silicate-bonded adhesives show improved shear strengths at liquid nitrogen (LN_2) temperature as do the phosphate-bonded adhesives.

A commercial adhesive consisting of molybdenum disulfide, colloidal silica, and phosphoric acid was evaluated as an adhesive. Although adhesion to the metal was very good, its shear was very low. Its poor shear strength is attributed to reaction of the phosphoric acid with the aluminum adherends resulting in voids in the joints.

K. Development and Evaluation of Metallic Composites

Investigations have continued in the development of a beryllium wire reinforced magnesium composite by means of diffusion bonding techniques. Silver-plated magnesium sheet wound with NS 355 stainless steel wire (NS 355 is being used in place of beryllium wire initially for cost reasons) has been placed between two other silver-plated magnesium sheets (0.020 inch thick) and diffusion bonded. Tensile tests were made on specimens cut

from the composite, and the results were close to theoretical values. An X-ray analysis of the composite revealed that, generally, a good alignment of the steel wire in the magnesium matrix was established. Additional studies are in progress to establish optimum bonding conditions before attempting to incorporate beryllium wire into a similar matrix.

Experiments are continuing toward producing a beryllium reinforced aluminum composite. During this period a composite was produced by placing a chemically milled beryllium grid sheet between two 2024-T3 aluminum sheets. The package was then subjected to a pressure of 4025 psi while at a temperature of 900°F (482°C). The resultant composite laminate did not attain the predicted mechanical properties, even though the yield strength was approximately 11.25 percent higher than that of the 2024-0 sheet. The composite modulus also was found to be greater than the non-reinforced 2024-0 sheet. Experiments are in progress to find a suitable stop-off which will prevent the composite specimens from adhering to the pressure plate or platen.

Activities have continued on the study of explosive techniques for producing laminated composites. During this reporting period, laminate specimens explosively bonded (2024-T4 to 6Al-4V) were mechanically tested with the following results:

Sample	Yield psi	Ultimate psi	Modulus psi x 106	Percent Elongation
Al-Ti	121,300	139,742	14.79	2.5
Al-Ti	118,400	136,000	14.37	2.5
Al	54,100	67,500	10.6	7.0
Ti	126,000	133,000	16.5	12.0

As can be seen, an increase in strength was noted with a decrease in ductility, apparently due to cold work as a result of the high energy joining process. Microscopic examinations revealed a presence of an extraneous intermediate layer at the bond interface. Electron-probe analysis of this extraneous layer revealed it to be primarily aluminum and aluminum oxide. Several other metallic laminates have been explosively bonded successfully. These are 2024-T4 bonded to 2024-T4, 2024-T4 bonded to 6Al-4V, 6Al-4V sandwiched between 2024-T4 (alclad), and 6Al-4V sandwiched between Mg Li 933 (clad). Macro and micro analysis and mechanical property evaluation are being accomplished.

L. Documentation Review

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

1. MA0610-001C, dated 8-18-66, "Methods of Cleaning and Cleanliness Requirements for S-II Fuel and Oxidizer Tanks"

2. MA0110-012 C 7-26-66, "Cleaning Ferrous Alloys"

3. MA0109-003 G, 6-23-66, "Application of Chemical Films to Aluminum and Aluminum Alloys"

4. CEI #243261A, "Prevalve Ground Pressure Accumulator Assembly for S-IC Project Apollo"

5. 60B32086B, September 66, "Cleaning, Testing and Handling of Hydraulic Systems, Component and Fluids"

6. NAA-S&ID, Spec. GOP-M-Z-018A, dated 7-11-66, "General Operating Procedure for Level 1 and Level 2 Field Cleaning at MTF"

7. MSFC-SPEC-441, dated 7-18-66, "Cleanliness Levels and Inspection of Materials Used for Clean Packaging"

8. MSFC-SPEC-468, "Nickel and Cobalt Base Alloys, Heat Treatment of"

9. MSFC-SPEC-469, "Titanium and Titanium Alloys, Heat Treatment of"

10. DAC Specification 1P00084B, "Heat Treatment of Steel, Process for"

11. NAA-S&ID Specification, "Fusion Welding of Iron, Nickel, and Cobalt Base Alloys for the Saturn S-II Vehicle," Revision D.

M. 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

OCTOBER 1, THROUGH OCTOBER 31, 1966

I. Radiographic Inspection

Two hundred and thirty miscellaneous parts, components and test specimens were inspected radiographically during this report period.

II. Photography

	Negatives	Prints
Engineering Photography	136	709
Metallography and Fractography	112	850
Miscellaneous Photography Processing, Copy Work, etc.	54	75

III. Metallurgical and Metallographic Testing and Support Services

A. A sample of cracked C-1 Engine material was studied to determine the cause of failure. Metallographic examination revealed brittle intergranular cracks in the Ta-10 percent W material. Surface cracking and corrosion pitting of the plated zones were evident. The hardness ranged from R_b 93 to R_c 20, which is below the maximum hardness of R_c 25 for the base material. The large grain size, the oxidation corrosion attack and cracking of the plating lead to the conclusion that the material was overheated in service. Cracks that originated in the surface plating propagated during the operation of the engine and caused failure of the component.

B. A metallurgical investigation of several stainless steel and aluminum fittings was completed at the request of the Propulsion Division, R-P&VE-PE. The fittings were torqued, pressure tested and leak checked at the beginning of the test program and, subsequently, after each six months of exposure to the exterior environment of this Center for a total period of 18 months. AM 355 stainless steel sleeves were used on the hardened 304L stainless steel tubing and 7075-T3 aluminum sleeves on the 6061-T6 aluminum tubing. Metallographic examination did not reveal any corrosion on the stainless steel assemblies; however, the 6061 aluminum tubing did sustain surface corrosion on the tip of the flare and along the surface of the tubing. One flare was cracked as a result of over torquing. No evidence of corrosion was found on the aluminum sleeves.

C. Metallographic studies were completed on several welded and brazed tube fittings at the request of the Propulsion Division, R-P&VE-PE. Samples consisted of three different joint designs fabricated by three manufacturers. The joints were made up of slip fittings welded or brazed to two lengths of tubing. Each sample had been subjected to 180 days of exposure to alternate immersion in salt water and exposure to the atmosphere. The examination did not reveal any corrosion attack on the samples nor were any metallurgical defects found in the brazed and welded joints or stainless steel tubing.

D. Two swaged Resistoflex fittings were studied metallographically at the request of the Propulsion Division, R-P&VE-PAE. The two AM 355 stainless steel fittings cracked after 6 and 12 days, respectively, of exposure in the alternate immersion tester. The examination revealed a good swaged fit between the 17-4 PH stainless steel tubing and the AM 355 shoulder. Both specimens displayed segregated areas of carbide networks and partial carbide networks. One specimen contained areas of excessive carbide developed delta ferrite. This specimen displayed a deep, pitting type corrosion on the I.D. of the AM 355 stainless steel fitting. The hardness ranged from R_c 37 to R_c 40 which is the recommended hardness range. No defects were found in the 17-4 PH stainless steel tubing.

E. Several panels coated with Vita-Var Aluminum Paint were evaluated to determine minimum thickness requirements for achieving the desired low emissivity requirement of the I.U. (0.30 or less). The results indicated that this requirement could be met with a coating thickness of 0.001 inch, provided it was properly applied (several cross-passes with the spray gun). Permission was given to IBM (Huntsville) to change the 0.002-inch requirements to 80 percent of the surface between 0.001 and 0.002-inch with 0.001 inch being the minimum acceptable thickness.

F. A request was made by the Structures Division to examine the "C" tank for corrosion. This tank may be used for an S-II experiment. The tank was fabricated in June 1963 and has been used for many tests. The tank had been open to the atmosphere outdoors, and a manhole cover had been left off allowing rain water to enter the tank. There was surprisingly little corrosion in the tank. The lower bulkhead of the tank was full of water, but there appeared to be an oily residue on the surface which came from test cable that had been used in the tank. This residue probably prevented corrosion.

G. At the request of the Manufacturing Engineering Laboratory, a study was made of the relative merits of Turco 4009 and Octagon Descaler cleaning materials for removing carbon, heat scale and rust from both stainless and alloy steels. Test data indicated that the Turco accomplished the cleaning better than the Octagon Descaler.

H. Consulting services were provided to personnel of the Kennedy Space Center in determining the type of material used in a pinion gear. Teeth of the pinion gear had failed during operation. Examination of the fractured surface indicated the material was gray cast iron in lieu of the specified modular cast iron.

I. Services were provided in the welding of a proto-type IU cold plate which had been designed in accordance with the recommendations of this division. Upon satisfactory completion of the weld, radiographic inspection was performed and the weld was found to be sound. It was, therefore, recommended that this radiograph be used as a standard for acceptance of the components built by a contractor.

J. In support of the Astrionics Laboratory, electron beam welding techniques were developed for welding a cryostat valve.

K. Consulting services were provided to the Structures Division, R-P&VE-S, relative to the weldability of M-45 casting material, weldability of joints between the dissimilar materials 6061 and 2014, and the weldability of 4340 steels for ground support equipment.

IV. Spectrographic Analyses

Eight hundred and thirty determinations were made on fifty-five samples and fourteen hundred and twenty-six standard determinations were made.

V. Infrared Analyses

A. Qualitative Analyses

Specimens of an organo-silicon, Dyna Therm D-65, Cryo-Mastic, a plasticizer and nine experimental polymers were analyzed qualitatively by infrared techniques during this report period.

B. Quantitative Analyses

Nonvolatile residue and hydrocarbon contamination on steel ballast material were analyzed quantitatively by infrared techniques.

VI. Chemical Analyses

	Determinations
experimental polymers for	
carbon	14
hydrogen	14
nitrogen	3
silicon	4

	Determinations
metal samples for	
carbon	34
nickel	14
chromium	20
sulfur	20
phosphorous	12
manganese	7
gas samples for	
helium	6
nitrogen	14
oxygen	15
hydrogen	10
hydrocarbon content	8
chromatographic analyses	26
vacuum fusion analyses of metals for	
hydrogen	9
oxygen	9

VII. Physico Chemical Analyses

	Determinations
density of RP-1 fuel	18
molecular weight of experimental polymers	1
refractive index of experimental polymers	2

VIII. Rubber and Plastics

	Items
molded and extruded	12
cemented	5
potted	31
fabricated	37
coated	57

IX. Electroplating and Surface Treatment

	Items
cleaned	205
salt spray tested	26
electroplated	251

X. Development Shop Production

A. A total of 8,122 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. Three thousand six hundred and ninety-one man-hours, approximately 45.4 percent of the total man-hours, were devoted to productive effort of a non-routine nature and applied to the work orders listed below.

1. 3000 psi - Injector body

The 3000 psi injector body has been completed and delivered.

2. Chamber Section - Hydro Coil Lined

The first Hydro Coil Lined chamber was completed but failed in hydrostatic test. A new design is in process.

3. Rack/Payload Module

The Rack/Payload Module was completed and delivered.

4. Ejector Assembly

The Ejector Assembly was completed and delivered.

5. Cyclone Chamber

Work on the cyclone chamber is approximately 83 percent complete.

6. Quick Release Umbilical Carrier

The quick release umbilical carrier is approximately 63 percent complete.

7. Micro Balance Fixture and Heater Covers

The micro balance fixture and heater covers are completed and delivered.

8. Tee - 10 Inch Vacuum System

The "T" fitting for the 10-inch vacuum system is complete and delivered.

XI. Miscellaneous

A. Eighty-seven aluminum alloy items, thirty items of stainless steel, seven items of 1018 low carbon steel, and four items of 718 Inconel alloy were heat treated during this report period.

B. Fabricated two 1.6-inch S-II insulation panels 20 inches x 48 inches for use in developing procedures for cutting out for stud bonding at the John F. Kennedy Space Center.

C. Poured approximately 42 feet of liquid hydrogen (LH_2) pipe insulation from urethane foam for Test Laboratory.

D. Fabricated a reinforced plastic transformer box for use in the drop test tower.

E. Twenty-four differential thermal analyses, thirty-six thermogravimetric analyses, and sixty-nine differential scanning calorimetric tests were made on various materials during this report period.

F. Absorptance measurements were made on fifty-seven specimens.

G. Four samples of experimental electrical brush materials and one sample of titanium oxide were analyzed by X-ray spectroscopy.

H. Examined five specimens by electron microscopic techniques.

I. Determined compatibility with liquid oxygen of specimens from thirty-three jars of FS-1281 lubricant.

XII. Publications

A. C. Krupnick and W. M. Zittle: Evaluation Report on the Nephlometric Method of Nonvolatile Residue (NVR) Analysis, TM X-53520, September 19, 1966.

J. E. Kingsbury