PROPULSION AND VEHICLE
ENGINEERING LABORATORY

XI.10
XI.11
XI.14

MONTHLY PROGRESS REPORT

For Period

July 1, 1966, Through July 31, 1966

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-66-7

MONTHLY PROGRESS REPORT

(July 1, 1966, Through July 31, 1966)

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

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Concluded)

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-66-7

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

SATURN V

I. S-IVB Stage Synchronous Orbit Study

Performance of the final synchronous orbit circularization maneuver with the J-2S engine operating in the idle mode at a reduced thrust level is being investigated as part of the synchronous orbit study. For some missions, operation of the J-2S in the idle mode on available tank pressure eliminates the requirement for repressurization of the propellant tanks prior to engine operation at full thrust and can eliminate all repressurization hardware and pressurant. This simplification greatly enhances the feasibility of modifying the S-IVB stage at KSC for the synchronous orbit mission. Some loss in payload capability may occur due to the lower idle mode specific impulse and mixture ratio of the J-2S; however, it is anticipated that the loss will not be significant.

II. Voyager Shroud Design

A study was initiated to define and perform a conceptual design of a shroud that will house and support the two planetary vehicles proposed for the Saturn V Voyager mission. Included in this study will be the design of the shroud cylindrical sections, nose fairing, encapsulation bulkheads, separation devices, and spacecraft mounting adapters. Also to be defined are mechanical and electrical interfaces, connections, shroud venting requirements, etc. Duration of the study will be approximately eight weeks, ending the latter part of September 1966.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

A. S-IVB Workshop

The S-IVB Spent Stage Experiment interim report, issued in draft form, has been reviewed by the S-IVB Workshop Technical Working Group members and comments incorporated. Several sections of the report, which present the current status of MSFC activities in the S-IVB Stage Experiments, were revised because of status changes, incompleteness, or the availability of very preliminary data in some areas. The report is being prepared for final publication.

Meetings were held with panel members to revise the work statement on the soon-to-be-funded FY-1966 study entitled "Utilization of Spent Saturn S-IVB Stage in Earth Orbit." Recent program changes on the AS-209 mission and other aspects have prompted this revision of the work statement.

A summary report is being prepared of several studies that define the evolution of the S-IVB Workshop. Included are possible AS-209 growth concepts, unmanned Saturn IB launched spent stage workshop concepts, resupplied workshop concepts, and ground-assembled Saturn V launched concepts. It is planned for this report to be revised later to include the results of the planetary evolution study which used the advanced ground-assembled workshop as a mission module.

B. Extra Vehicular Engineering Activity (EVEA)

The mid-term review of the Ling-Temco-Vought study on extra vehicular work platforms and space taxis was held at MSFC on July 6 and 7, 1966. Personnel from this Office participated in discussions with the contractor, the selection of a preferred concept, and the determination of future work activities.

C. Space Structures

Conceptual design of a space-assembled broadside dipole array antenna for earth orbital radio astronomy has been oriented toward integration of the antenna with a space assembly facility. The

space assembly facility will consist of an air lock, expendables, manned extra vehicular maneuvering units (MEMU), and structural support for the antenna, and will be used in conjunction with a CSM.

D. Electromagnetic Radiation Experiment

A presentation on the Electromagnetic Radiation Experiment (formerly Astronomy Experiment for Apollo), including laboratory responsibilities and resources required for support of the project, was made to P&VE Laboratory management on July 25, 1966. Briefings were given to personnel within each of the Divisions on July 21 and 22, 1966. Efforts are continuing in design of the experiment mock-up being built in the Manufacturing Engineering Laboratory.

II. Lunar Surface

A. LSSM Mock-up Suspension System

A preliminary study was initiated to investigate the feasibility of and resources requirements for incorporating a suspension system on the BECO LSSM motorized mock-up. This suspension system would, if possible, have a damping device in which the damping rate could be varied to provide different forces on men and equipment.

B. Mobility Test Article (MTA)

The Bendix MTA was shipped to Aberdeen Proving Ground (APG) and the planned test program was initiated. The General Motors MTA is now ahead of schedule and may arrive at APG for testing earlier than the scheduled mid-August date. This schedule change would permit an earlier test date at the Yuma Proving Ground (YPG). Several minor equipment malfunctions occurred in the Bendix vehicle; it is hoped that similar problems will not develop in the GM vehicle, since GM has completed more breadboard testing on their vehicle.

C. Lunar Gravity Simulation

A letter was forwarded to Wright-Patterson Air Force Base, from the Laboratory, to establish official recognition of the planned test, in August, of the LSSM mock-up in a KC-135 aircraft flying a 1/6-g trajectory. Letters were also written to both Bendix and General Motors requesting their comments. Preparations for the tests are proceeding on schedule. Two engineers in this Office are now qualified to fly in the KC-135 and accompany the LSSM during the four-day test, acting as monitors.

A preliminary investigation of a 1/6-g simulator concept, using an inclined platform (similar to the Langley Research Center simulator), was conducted. Work is presently being performed on a horizontal platform concept, using springs, pulleys, and counterweights.

D. Lunar Surface Activities Progress Report

Efforts have continued in preparing a film and documented progress report for the MSFC Director's presentation to the Management Council meeting on MSFC lunar surface activities. All filming is complete, but because of delays in film processing the report will not be ready until early August. The film will present scenes of the MTA, LSSM mock-up, Manned Flying System, and LEM shelter.

III. Integration

Revisions were made to the currently catalogued AAP experiments. Also, 84 new experiments have been added to the catalogue, and an additional 170 experiments are being prepared for inclusion. Several modifications were incorporated into the Mission Simulation/Experiment Grouping program, such as provisions for automatic plotting of data and determination of heavenly body locations. This program is now operational.

NUCLEAR ROCKET PROGRAM

I. Nuclear Ground Test Module Program

The Phase B study effort was completed and documented in a report entitled "Nuclear Ground Test Module Program Preliminary Definition," dated July 12, 1966.

A GTM supporting effort in radiation environment definition is still being conducted, but at a reduced effort. The purpose for the continuation is to maintain technical competence in readiness for the next phase of the GTM study. The possibility of transferring responsibility for this effort to a line organization is being explored.

II. Nuclear Flight Safety

The performance of in-house studies in this area is being temporarily deferred due to apparent lack of interest in Center and Headquarters management. Contractor effort in this area will continue to be monitored.

ADVANCED PROGRAMS

I. Launch Vehicle

A. Kick Stage Studies

Documentation of the kick stage sizing study was completed. Ten preliminary stage designs were investigated: six with a diameter of 260-inches, and four with a diameter of 396 inches. Storable propellants considered for the stages were 50/50 UDMH/Hydrazine and N_2O_4; cryogenic propellants were LOX and LH_2.

A study was initiated to develop four kick stage designs with assigned propellant loadings for use on Saturn V. Stage diameters will be 260 inches and 396 inches and propellants will be cryogenic and storable. Development of the structural and propulsion system designs will draw on the extensive MMM design work performed at MSFC; the KS/IU interface systems and APS requirements will be analyzed in detail and systems definitions will be prepared.

Two significant results obtained from the study are the following: (1) kick stages do not appear practical for missions requiring large velocity increments, namely, plane changes; (2) Saturn IB and Saturn V vehicle performance capabilities are improved in earth orbit rendezvous and maneuver operations with the use of kick stages.

B. Storable Pressure-fed Stage Study

The storable pressure-fed stage study was completed and documented. The first phase of this study was discussed in the preceding progress report. The latter part of the study consisted of developing equations for stage sizing and for computing stage weight for various propellant loadings.

C. Liquid Strap-on Pods

A parametric study was initiated to determine the maximum payload capability of the standard and uprated Saturn V vehicles using four liquid strap-on pods with diameters of 120, 135, and 156 inches. The 150-inch-diameter liquid strap-on pod analysis described in the preceding report is included in this study. An analysis is being performed to obtain the necessary weights for this study.

D. Advanced Engine Applications

A study was initiated to establish parametric vehicle performance data which can be used in the selection of high-performance bell and toroidal propulsion system configurations for Saturn V second and third stages. The stages will be employed interchangeably as either ground-launched Intermediate Saturn vehicles, or as upper stages on an improved Saturn V.

E. Saturn Improvement Studies

The 10-month program encompassing design, performance, and resource analyses for improved Saturn V, improved Saturn IB, and intermediate payload Saturn vehicles was initiated on December 6, 1965, and included a 3-month trade study phase to assess candidate vehicles followed by a design study period to evaluate selected configurations.

The mid-term review for the MLV-SAT-V and MLV-INT vehicles was held at MSFC on July 6, 1966, and was attended by NASA management and representatives of NAA, Boeing, Douglas, Martin, and United Technology. The major portions of the contractor presentations consisted of the performance and design study results obtained during the second phase of the contracts. As the resource analyses were being initiated at the time of these presentations, only the study guidelines were reviewed and preliminary results presented.

Major accomplishments to date have been the near-completion of all stage design studies, identification of resource requirements for the modified stages, and development of preliminary production schedules for all study vehicles.

A conference among MSFC, KSC, NAA/S&ID, DAC, UTC, TMC, TBC, and NAA/Rocketdyne personnel was held at the Douglas Huntington Beach facility on July 27 and 28. The meeting was convened by NASA/MSFC to satisfy contractual requirements under Exhibit C entitled "Vehicle/Stage Program Schedule Informal Review." Schedules were prepared by each stage contractor as well as The Martin Company (launch system changes), UTC (120-inch-diameter solid rocket motors) and Rocketdyne (uprated F-1 and toroidal engines). In all cases agreement was reached on an integrated stage-engine-launch system earliest availability date.

All studies are progressing satisfactorily except for the problem with Government-furnished computer services turn-around-time. The two-week slip in the CCSD study due to Slidell overload has been held, but

it has not been possible to absorb and its effect on critical path items has been noted. The change in support service contractors at R-COMP has resulted in a turn-around-time increase from approximately one day to approximately one week. Turn-around-time is particularly critical at this time point because alternate missions are being determined and the results of one run are needed before successive runs can be made. R-COMP has offered assurances that this problem will be alleviated and formal notification to MSFC Purchasing Office has been initiated.

F. Interstage, Shroud, and Nose Cone Design Procedures

Work was completed on the computer program for analyzing single-angle nose cones with skin, ring and stringer construction. The program and some parametric results have been submitted to management. Other parametric data are to be generated for further familiarization, checkout, and utilization of the program.

Development of two new programs to analyze double-angle nose cones, and cylindrical and cone frustum interstages has been initiated. For these programs, which are being written for skin, ring and stringer construction, the equations of analysis have been formulated, programmed, and the programs are being debugged.

G. Common Bulkhead Stage Design

Checkout of the integrated computer program for designing common-bulkhead-type stages is continuing. The only position of the program that has not been checked out is the mass characteristics subroutine.

H. 396-inch-diameter Payload Envelope

A study was initiated to define the various allowable 396-inch-diameter cylindrical sections that can be flown on the two-stage Saturn V launch vehicle. In the past it has been assumed that the two-stage

Saturn V vehicle was suitable for various applications in its "standard" condition. This study is to define the maximum allowable height without modifying the vehicle and to define the various modifications required for various lengths including 81 feet (present S-II length) and 115 feet (nuclear vehicle length). This study is similar to the recently-completed Saturn V/Voyager Payload Envelope study, and is scheduled for completion in November.

II. Earth Orbital

A. Film Return Capsule

A preliminary parametric study to determine the shielding requirements necessary to protect film from excessive radiation damage on a standard LOR trajectory was completed. Shielding materials considered for this study were aluminum, polyethylene, and a composite of the two materials.

B. Orbital Recovery Mission Profile

Part I of the Orbital Recovery Mission Profile was completed. This study involved the determination of the ΔV requirements for a chase vehicle to capture a target satellite(s), assuming coapsidal orbits. Part II of this study, which pertains to orbital transfer between non-coapsidal elliptical orbits, was initiated.

C. Recovery Capsule

A detailed study was initiated of a foldable capsule that will be used for satellite retrieval or astronaut rescue. The capsule consists of an assembled heat shield, a strap-on retro, a foldable afterbody, and subsystems. The heat shield is 58 inches in diameter and is divided into six equal slices, which is attached to a mid-piece for easy assembly. The afterbody may be fabricated from air mat structure fabricated by Goodyear Aircraft, Akron, Ohio. Some of the characteristics of this structure are as follows: (1) inflatable; (2) can be woven to specification of synthetic, fiberglass, stainless steel, and super alloy materials; (3) can be woven in many different shapes; (4) can be packed in a small space before deployment; (5) light in weight; (6) high strength-to-weight ratio; and (7) heat resistant up to 725°F.

D. Docking Structure Design

A study was initiated to investigate various docking structure configurations and to perform a conceptual design of a selected configuration. In addition, parametric weight data are to be generated for docking structure diameters, ranging from 120 inches to 600 inches, and for values of axial closing velocity of 0.5 fps to 6 fps. This study is scheduled to be completed the latter part of September.

III. Lunar

A. Super Mobile Exploration (MOBEX) Vehicle

A preliminary design study was performed to define an advanced mobility system concept capable of 180-day dormant storage prior to a three-man 90-day operation. This vehicle is delivered to the lunar surface by a Lunar Logistics Vehicle (LLV). This study was requested by R-AS in support of the Lunar Joint Action Group's effort in advanced planning for lunar exploration. Efforts included preparation of preliminary systems arrangement drawings, subsystems analysis, and determination of performance characteristics and detailed weights.

B. Lunar Systems Study for Apollo Direct-Flight Mission

In support of the R-AS Lunar Joint Action Group, a study was initiated to define a Lunar Logistics System (L-I and L-II stages) required to deliver a six-man spacecraft and earth-return stage (L-III) to the lunar surface. A six-month staytime on the lunar surface for the six-man spacecraft and L-III stage is assumed. In addition, an Earth Launch Vehicle (ELV) which is capable of injecting approximately 190K pounds into a translunar trajectory is assumed. The L-I and L-II stages utilize a cryogenic propulsion system; however, various propellant and engine concepts will be investigated for the L-III return stage, including advanced storable propellants. The study also considers application of the L-I and L-II stages to other Saturn launch vehicles.

C. Thrust-augmented LEM

A technical review is being made of BECO's final report on the "Thrust-augmented LEM Descent Stage" study performed under Technical Directive A-2-AVX-2-006. Also, data are being generated and compiled for publication in an MSFC Internal Note. The purpose of this report is to show how much additional payload can be landed on the lunar surface

by fully loading the Service Module propellant tanks and adding either liquid strap-on propellant tanks or solid strap-on rocket motors to the LEM. It appears that the liquid strap-on tankage provides the largest payload on the lunar surface; however, this configuration will require the most modification to the existing LEM descent stage. This study considers both the Block I and Block II Service Modules, the major difference in the two configurations being the additional propellant capacity of Block I. Two configurations will be analyzed for each Service Module: strap-on solid propellant motors and strap-on liquid propellant tanks.

D. Project Able

The Source Evaluation Board process for Project Able was completed. As a result of the SEB activity, Boeing and Westinghouse were selected to be recipients of the two parallel systems contracts for feasibility studies relating to Project Able. A summary of the Board's findings was presented to Dr. von Braun on July 13, 1966. Following additional presentations to Dr. Mueller and to Mr. Webb on July 14, 1966, during which the Source Selection Official (Mr. Webb) ratified the selections of Boeing and Westinghouse, contract negotiations were carried out for the 90-day study effort. A joint orientation meeting with the selected Project Able systems contractors was scheduled for August 4, 1966.

A meeting was held on July 26, 1966, to discuss plans for a proposed MSFC in-house study effort pursuant to Project Able. This meeting, under the chairmanship of Mr. von Tiesenhausen, R-AS, resulted in discussions of potential support within the R&DO Laboratories relative to the in-house study of Project Able. A meeting, internal to R-P&VE, was subsequently scheduled for August 1, 1966, to discuss the extent and nature of R-P&VE participation in the proposed study effort. A meeting to discuss the final course of action by the respective R&DO Laboratories relative to the proposed in-house study effort was scheduled by Mr. von Tiesenhausen for August 2, 1966.

IV. Planetary

A. NASA Advanced Planning Exercise

The Manned Planetary Missions studies, in support of the Joint Action Group, were completed. The results were presented to Dr. Mueller on July 27, 1966. A Preliminary Project Definition is being prepared by the Advanced Systems Office with inputs being furnished by the various participating organizations. The chemical injection

stage selected for the fly-by missions was a modified S-IVB stage. The technical problems involved with modifying the stage were defined. The problems of rendezvous and docking were described, and the development required to build a transtage was defined along with a description of the launch vehicle. The final weights and vehicle configurations were completed. These data will be published in a memorandum.

The data generated during the period of June 9-29, 1966, were documented in Memorandum R-P&VE-AV-66-101, "Selected Chemical and Nuclear Mission Modes for Manned Mars Fly-by," for presentation to the Joint Action Group.

B. Manned Mars/Venus Fly-by Contract Studies

Negotiations on the mission study were held with NAA/S&ID on July 7, 1966. The contractor will cost-share this study, boosting the minimum number of manhours from 22,000 to approximately 33,500. A meeting was held on July 20 and 21, 1966, with personnel from NAA and DAC representing all three contracts, to define a common data exchange schedule to be attached to each contract. During this meeting, a tentative start date on the mission study was set for August 1, 1966, with the contractors' orientation meeting planned for August 3, 1966; however, since the mission study contract is still unsigned, it appears both the start and orientation dates will slip into mid-August.

C. Scientific Mission Support Study for Mars Fly-by

This study was completed and the final report is being prepared. The objective of this study was to define specific scientific experiments which could be performed during a manned Mars fly-by mission and those which could be performed by jettisoning probes in the vicinity of the planet. The results of the study indicate that a substantial program of investigations can be carried out with probes and equipment weighing 12,000 pounds and that an extensive program is possible with approximately 25,000 pounds of probes and equipment.

D. Alternative Mission Modes Study

This contract was negotiated with TRW/STL and is expected to start in early August; the contractor orientation is tentatively scheduled for August 10, 1966.

V. General

Review of Air Force Systems Command (AFSC) Boost and Reentry Vehicles Forecast Document

The preliminary drafts of this document were reviewed by personnel of this Office at the request of Dr. Mrazek for the AFSC "Beyond the Horizon" Panel. In general, the contents were considered to consist primarily of an assessment of space flight state-of-the-art without correct resultant conclusions or hard definitions of future requirements; however, the summary document, "Director's Report - Beyond the Horizon," was considerably improved over the draft reports and the indications of USAF personnel awareness of the previously reported shortcomings were evidenced in discussions with Dr. Mrazek.

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Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-66-7

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(July 1, 1966, through July 31, 1966)

SATURN IB

I. S-IB Stage

S-IB Stage Launching Information

Amendment 2 to the S-IB-202 launching information was rejected by this division because of certain technical errors made by Chrysler Corporation Space Division (CCSD) involving specification quotations, redline values, and hydraulic system practices. The problems were resolved, however, as a result of a visit by a division representative to Michoud Operations.

II. S-IVB Stage

Critical Design Reviews (CDR's)

1. The ordnance CDR for the S-IVB-205/501 was completed. The Safety and Arming (S&A) device was determined not totally safe. Design modifications were made to assure that an unsafe condition does not exist on the Saturn IB device for AS-203 and AS-202, but the Air Force Eastern Test Range (AFETR) was satisfied with this modification for SA-204 and subsequent vehicles. Further testing must be accomplished simultaneously with the Saturn V devices.

2. The propulsion installation CDR for the S-IVB-205/501 was completed. Two important items are: (1) miscellaneous bonded supports and clips became detached from the S-IVB-201 stage during acceptance firing which indicates inadequacy in the method of adhesive application or the utilization of poor adhesive; (2) based on the latest Saturn IB maximum heating trajectory, the addition of insulation on the tunnel forward ramps will be required.

III. Instrument Unit (IU)

Acceptance Test

Acceptance tests on the IU water accumulator servicer, S-IB/V, S/N 3, were completed on July 13, 1966, except for the pump motor

pressure gage. The gage was defective and could not be calibrated. It was returned to the vendor for rework. The item will be installed when the reworked gage is delivered to CCSD.

IV. General

A. CALIPS Checkout Circuit Development Test

During test runs July 7, 1966, a possible error was discovered in the scaling factors associated with the CALIPS computer program. A test made July 16, 1966, on the analog to digital (A/D) converter indicated a definite problem does exist in the converter. CCSD was advised of the problem and was asked to take the necessary action to resolve it.

B. AS-206 Nose Cone

SK10-9206, AS-206 Nose Cone Assembly Layout, was completed. It defines the overall configuration of the nose cone, orientation and installation method for the jettison system, orientation of the separation rate measuring system, and stage to stage mating hardware requirements. The layout will be used by CCSD for preparation of the AS-206 vehicle assembly drawing. Work on the AS-206 nose cone paint pattern drawing was initiated.

C. Saturn IB/SA-204 Flight Sequence

Revision A to the Saturn IB/SA-204 Flight Sequence, drawing 10M30154, was prepared and released to Astrionics Laboratory. The document revised the lox and LH_2 venting sequence after cutoff to conform with Manned Spacecraft Center (MSC) constraints. Switching the S-IVB auxiliary pump to the thermal mode during orbital coast was added so that data could be obtained in the time required between cyclings of the pump during coast. Consideration is being given to programming the pump on and off for Saturn V since the thermal switches have been known to fail.

D. Saturn IB/SA-206 Flight Sequence

Engineering Order (EO) 2 to the Saturn IB/SA-206 Flight Sequence, drawing 10M30156, was prepared to revise the sequence of events for Experiment 2 to incorporate latest revised measurements and to provide the capability to reset the J-2 engine cutoff circuitry prior to S-IVB stage ignition command.

E. Servicing Requirements

A request was forwarded to Kennedy Space Center (KSC) for an IU purge test on SA-202 during prelaunch preparations. Indications are that larger flow will be required of SA-206, SA-208, and SA-210 to maintain an inert atmosphere in the compartment.

F. AS-203 Postflight Weights

Actual weights of the AS-203 stages, instrument unit, and nose cone were determined and distributed by memorandum in accordance with weight log books.

G. AS-204 Mass Characteristics

Final mass characteristics were completed and distributed by memorandum for use in updating operational trajectory.

H. Nose Cone Separation Analysis

The results of the nose cone separation analysis for AS-206, AS-208, and AS-210 were completed and distributed by memorandum.

SATURN V

I. S-IC Stage

A. Review of F-1 Engine Start Times

The latest F-1 engine starting times as determined by Propulsion Division were reviewed for sequence and functional interlock compatibility. Some slight differences were found in existing documented requirements. A request has been made that a mutually acceptable procedure be established by MSFC and The Boeing Company (TBC) for determining these times to alleviate further confusion.

B. Umbilicals

1. Several umbilical couplings and the locking mechanism were damaged on aft umbilical 3 during testing at the Saturn V ground support equipment (GSE) test facility on July 7, 1966. The damage occurred when the umbilical carrier unlocked and separated slightly from the vehicle plate, actuating the tail service mast prior to umbilical kickoff. A thorough evaluation of the failure was not possible because of the lack of instrumentation for the test run. Recommendations were made to Test Laboratory personnel to provide camera coverage for all tests and to install shear pins prior to umbilical disconnect test. Installation of the shear pins would prevent umbilical carrier separation until pneumatic or mechanical pushoff occurs.

2. A new aft umbilical carrier assembly 3 was installed to the tail service mast and the damaged carrier retained for refurbishment. A successful disconnect was conducted with the new carrier on July 9, 1966.

3. A retrofit kit for incoproration of modifications to the aft umbilicals per Engineering Change Proposal (ECP) 0041 is scheduled for shipment to MSFC on August 1, 1966. These modifications are required to support SA-501. Test Laboratory has agreed to perform the required modification to the aft umbilicals.

C. S-IC Hydraulic Supply and Checkout Unit

Checkout of unit 4 at KSC is again in progress after correction of the water problem previously encountered in early June 1966. The facility supply and return lines had been inadvertently plumbed together, thus bypassing the Greer Hydraulics, Inc., unit completely. The present fuel tanking schedules permit only limited and random access to the unit. The problem concerning the inability of pump 1 to switch from the "start" to the "run" mode, attributed to lacquer on the contacts of the timing relay reference designation TQ-3, has been resolved. The current problem under investigation involves the intermittent opening of circuit breaker CB1-1 (rated at 5 amps) in the supercharger pump circuit during initial startup of the pump. Preliminary investigation indicates that the initial surge at start is approximately 30 amps and that the pump requires 4.5 amps during the "run" mode.

D. S-IC Flush and Purge Servicer

Unit 1 of the S-IC Flush and Purge Servicer is progressing approximately two weeks behind schedule due to the slow delivery of parts from Walter Kidde and Company, Inc., vendors. This particular situation has been attributed to the high priority for parts placed on vendors, due to the Viet Nam effort. The tentative acceptance test schedule was established for commencement on July 20, 1966. The vendors experienced several problems during inhouse production testing which required minor redesign of some of the subassemblies in the unit. These problems, in brief, encompassed the Skyvalve solenoid valves, the suction stub, and the GN_2 regulator for the preservative oil system.

II. S-II Stage

A. S-II Automatic Sequence

The latest automatic sequence for Mississippi Test Facility (MTF) was reviewed to insure compatibility with KSC. Formulation of all of Propulsion and Vehicle Engineering Laboratory's comments on the sequence was completed and given to Test Laboratory. Test Laboratory is coordinating the review for MSFC.

B. Umbilicals

1. Failure of the lox fill and drain coupling to disconnect in the pneumatic mode of separation during qualification testing at

North American Aviation (NAA/S&ID) was determined to be caused by improper setting of the coupling support legs. Pneumatic disconnect of the lox fill and drain coupling was successfully conducted after the optimum support leg adjustment was established.

2. Leakage of liquid nitrogen from the hydrogen vent couplings occurred during testing of the S-II forward service arm and umbilical at the Saturn V GSE test area. The leakage occurred at 26 p.s.i.g. and during motion of the vehicle simulator. It was observed that excessive vehicle skin deflection was occurring during motion of the simulator. Action has been taken to resolve the problem.

C. Recirculation System Study

A stage to engine layout, SK10-9270, is being made to determine whether the J-2 engine LO_2 bleed line can be routed to eliminate a trap condition. Problems involved with removing engine components will probably necessitate a slightly different configuration being used on the MSFC J-2 engine stand; however, this configuration will approximate the proposed flight configuration close enough that valid data can be obtained.

III. S-IVB Stage

Data for the propulsion and electrical installation changes made at KSC in converting the S-IVB stage from the SA-200F to the S-IVB stage for the SA-500F are being compiled.

IV. Instrument Unit

Umbilicals

1. A new Saturn V skin panel was received at the MSFC GSE test facility from IBM on July 18, 1966. The new skin panel will more closely simulate the actual vehicle.

2. Tracking tests are scheduled to be conducted on the S-IVB forward/IU service arm/umbilical to determine whether there are any problems resulting from loads imposed on the vehicle skin by the service arm system. New Saturn V vehicle motion criteria received from Structures Division reflecting a reduction in vehicle motion amplitude for all frequencies will be used for the tracking test. The test will be conducted using service arm 7 of set 3 to avoid affecting schedules. The test will be completed by August 25, 1966, and any vehicle modifications if required will be made on the IU prior to 501 stacking.

3. A meeting was held July 22, 1966, by representatives from International Business Machines (IBM), TBC, Structures Division, and this division to correct the method of mounting the Saturn V S-IVB/IU vehicle skin panel to the vehicle simulator for the remaining test on service arm 7. It was agreed that all required design information will be submitted to TBC by IBM and Structures Division by July 27, 1966. TBC will then begin preparation of shop drawings.

V. General

A. Documentation

1. Thirty-nine Interface Revision Notices (IRN's) were reviewed and Engineering Change Requests (ECR's) were prepared and submitted for Configuration Control Board (CCB) action. Also, six IRN's were reviewed and approved without further action.

2. Eighteen design criteria sheets (DC's) with their accompanying ECR's have been reviewed and forwarded to the Vehicle GSE Project Office, I-V-G, with a request to purchase the concerned equipment. This equipment is required to satisfy maintenance requirements at KSC as set forth in the Human Engineering Design Criteria Study, MSFC-STD-267A and the Saturn V Bulkhead Protection Study D5-12802.

B. Reliability Analysis Model

Preliminary copies of the S-II stage and F-1 engine failure effects analysis and criticality determination reports have been received and are presently being reviewed. A completed Single Failure Point List will be published during the following month. Efforts are currently underway to prepare S-IC, S-IVB, and IU single failure point lists.

C. Operations Analysis

A list of Saturn V, SA-501 vehicle program baseline documentation produced by TBC has been officially released to the MSFC repository, KSC, and all concerned prime Saturn V contractors. The documentation depicts an operational analysis which shows the processing of the SA-501 vehicle from "on-dock" to lift-off at KSC from the vehicle design viewpoint. This analysis represents a consolidated MSFC approach toward the establishment on a timely basis of a common baseline of the Saturn V SA-501 launch vehicle field operations for use and validation of design definition, logistics planning, operational requirements and program assessments. Maximum use is made of the results of current and previous efforts.

D. Prelaunch Test Specifications and Criteria

The Saturn V Prelaunch Test Specifications and Criteria were revised by the stage contractors to reflect comments of recent redirection meetings. It is understood that these documents will be forwarded by Industrial Operations (IO) to KSC. This division has initiated a review and has requested review and comments by August 17, 1966, from Propulsion Division. These comments will be forwarded to the various stage officers for implementation in subsequent revisions.

E. Mobile Pneumatic Checkout Console

Several Investigation and Corrective Action Requests (ICAR's) are outstanding on the mobile pneumatic checkout console concerning reports on leaking check valves. A vendor representative is due to arrive at KSC on July 27, 1966, to further investigate the problems. Preparation of the ICAR's is then expected to be completed by August 13, 1966.

F. Wind Alleviation Damping System

1. A memorandum was prepared stating that the design of the retract-reconnect system would be for local (manual) control only. However, KSC has not agreed to this, so a meeting was held July 15, 1966, with Astrionics Laboratory to brief them on the overall system and coordinate their effort on a remote (automatic) retract-reconnect system. It is anticipated that this system will be available, on schedule, for the Saturn V flight vehicle damper system for AS-501.

2. A preliminary design review (PDR) of the hydraulic damping portion of the system was held July 15, 1966, at which time a list of parts required was presented. This list was given to Manufacturing Engineering Laboratory July 18, 1966. A PDR on the complete system (hydraulics, pneumatics, and electrical control) will be held on August 1, 1966. Additions to the parts list will be given to Manufacturing Engineering Laboratory at this meeting. The critical design review (CDR) will be held on August 31, 1966.

G. AS-501 Stage Weighing

Inventory of the S-IC-1 stage was begun in preparation for stage weighing to be conducted in August 1966.

H. AS-504 Mass Characteristics

Projected mass characteristics for AS-504, with a 98,000-pound and a 100,000-pound payload, were completed and distributed by memoranda.

I. S-II/S-IVB Early Staging Sequence

A study was begun to determine a satisfactory staging sequence in the event of premature shutdown of the complete S-II stage propulsion system. The present plan is to orbit the Command Service Module (CSM) by the S-IVB stage if this condition should occur.

J. RJ-1 Lubricity Test

Screening tests were made on samples of commercial RJ-1 lubricating additives. These tests were performed by means of the Shell Four Ball Wear Tester and the Falex Lubricant Tester. A report tabulating the results of these tests is being prepared. Four of the additives were selected for lubricity tests in the RJ-1 Hydraulic Pump Simulator. The first simulated S-IC Hydraulic Checkout and Supply Unit Hydraulic Pump was assembled with a redesigned piston loading mechanism. The new loading mechanism worked smoothly but other problems were noted.

ADVANCED TECHNOLOGY

I. Systems Design

A. Spent Stage Experiment (SSE)

1. The SSE assembly drawings are being prepared. SK10-9204, "Equipment Attach Orientation," was completed and is being transmitted to Douglas Aircraft Company (DAC). The latter drawing defines the installation of the fittings inside the S-IVB stage LH_2 tank. The fittings will be painted black to provide better visibility for the astronauts.

2. A layout is being prepared to define the latest configuration for the forward LH_2 tank bulkhead for AS-209. This layout will be used to define the possible interface areas between MSC support module and the S-IVB stage.

B. Apollo Telescope Mount (ATM) Program

SK10-7263, "Layout Apollo Telescope Mount (MSFC Rack Concept)," is being revised to include the power supply system (22 batteries) and two electronic support equipment containers. Also, the Lunar Excursion Module (LEM) descent stage portion of the environmental conditioning system is being incorporated into the layout.

C. Apollo Applications Program (AAP) Experiments

A review is being made of all the proposed MSFC experiments to determine the latest configurations and requirements. This review

includes some 42 MSFC experiments as well as the ATM Program and the Earth Orbital Mission #2 Program.

D. Low Amplification Bracket Development Test Program

Three low amplification brackets (SK10-1800, SK10-1994-1, and SK10-1995-1) have been fabricated and delivered to Structures Division. Vibration testing is scheduled to begin during August 1966.

II. Vehicle Systems Engineering

A. S-IVB Spent Stage Corollary Experiments

A meeting was attended July 22, 1966, at MSC by representatives of MSFC and MSC to discuss the status of corollary experiments on the S-IVB Spent Stage, AS-209. It was determined that a coordinated MSFC/MSC experiments package will be presented to the Manned Space Flight Experiment Board (MSFEB) in September.

B. MSFC Inflight Experiments

1. The nose cone Thermolag ablation problem affecting the measurement results of Experiment #2 on AS-206 was resolved. The decision to Thermolag the nose cone was rescinded; the gauge thickness of the nose cone will be increased, eliminating the Thermolag requirement.

2. Due to the delay in finalizing the experiment definition contract for Project THERMO (Experiments #3 through #7), the inhouse and out-of-house carrier studies are getting out of phase with the experiments requirements. As an alternative, the carrier studies schedule may be slipped.

3. Experiment #15 was cancelled from vehicle flights AS-504, AS-505, and AS-506, by Apollo Program Office, NASA Headquarters. This decision would not eliminate the experiment from being flown on other AAP flights (Saturn IB and V) or testing of the fairing and bracket being conducted by this division.

III. Human Factors Engineering

A. Human Factors Visual Simulation Study

The subject calibration utilizing the treadmill in building 4619 is approximately 80 percent complete. Procedures for standardization of the illumination level of the terrain belt and for the visual picture viewed by the subjects were completed.

B. Man-System Task Analysis for Lunar Surface Experiments

The Orbital Astronomy Package (OAP) was made fully operational and familiarization training (shirt sleeve) for the subjects was completed. The Statistical Program for evaluation of physiological data collected from test subjects is approximately 60 percent complete. All logic for assembly of data in matrix form was completed.

C. MSFC/MSC Human Factors Engineering and Crew Systems Technology Interface

A meeting between division personnel and a representative of the MSC Crew Systems Division, was held on July 22, 1966, at MSFC. Requirements were formulated and a draft of an inter-center mutual working arrangement in the areas of human factors design criteria and crew systems technology was prepared.

D. Task Analysis Simulation Facility

Neutral buoyancy facilities requirements and project schedules were formulated and submitted to the Manufacturing Engineering Laboratory to assist in development of building plans and schedules for a new, larger neutral buoyancy facility at MSFC.

John O. Aberg
Chief, Vehicle Systems Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-66-7

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

(July 1, 1966 Through July 31, 1966)

SATURN IB

I. S-IB Stage

A. S-IB-203 Propulsion Systems Perform Successfully

Engine performance was slightly high, but this was attributed to discrepancies in the engine gain tables used to predict performance.

B. Retro and Ullage Motors Perform Satisfactorily on AS-203

Preliminary evaluation of the data indicates all motors performed within specification, and no abnormalities were detected.

II. S-IVB Stage

A. Liquid Hydrogen Orbital Experiment Flown on AS-203 is Successful

The performance of the propellant control, venting and engine chilldown systems lends confidence to restart capability of the Saturn V, S-IVB stage. Besides confirming the Saturn V/S-IVB stage design, the flight also provided useful data on the operation of an intermittent orbital venting system.

B. AS-203 Simulated Restart Evaluated

Preliminary AS-203 flight data indicate that the engine hydrogen gas start bottle recharged satisfactorily to the conditions that would enable engine restart between the first and fourth orbits. During this time the hydrogen gas temperature and pressure were well within the required start conditions. The LH_2 lead before the simulated engine restart conditioned the thrust chamber to within the required limits. The effects of the ullage motor impingement need further investigation, because this additional heat-up effect was not determined on AS-203.

C. AS-203 Flight Base Heating Analyzed

A preliminary analysis indicates that the flame shield heating was less than the Block II of the 201 flights. This is probably due to the discharge of turbine exhaust gas in the flame shield region on 203. The heat shield heating rates and the gas temperatures were slightly higher than on previous flights, but none of the heat shield design limits were exceeded.

D. Inflight Temperatures of AS-206 Nose Cone Estimated

Thermal analyses were completed for the 1/8-inch thick aluminum skin of the nose cone. The maximum temperatures predicted for the nose cap ranged between 400 degrees F and 530 degrees F. The specified maximum nose cap temperature for 1/8-inch aluminum is 250 degrees F. Consequently, the nose cap thickness will be increased to 1/4-inch to eliminate structural problems. Thermal analyses are being made to verify that the 1/4-inch thick nose cap will maintain acceptable temperatures. Increasing the nose cap thickness, rather than utilizing thermal protection material, was selected so as not to impair the planned contamination experiment.

E. Engine Gimbal System Components Tested

Completion of the life cycle and vibration tests ended the planned test program on the main pump. The two static o-rings in the compensator housing failed during the vibration tests. The new auxiliary pump was subjected to electrical, proof pressure, functional, calibration, low temperature, high temperature and one axis of vibration tests. The only difficulty encountered was excessive oil leakage past the pump shaft seal during the low temperature test.

III. Instrument Unit

A. SA-203 Thermal Conditioning System Discrepancy Investigated

The control coolant (methanol/water) temperature was maintained for 2 3/4 hours after liftoff. However, the general control temperature trend was a steady downward drift, culminating in approximately a 50 degree F coolant temperature (85 degrees below nominal) at six hours into the flight. Detailed downrange flight data are not available, but indications are all IU and TCS systems (excepting thermal balance) were operating nominally during the flight. The vacuum flight simulation test program (S-IU-500F S) with similar flight conditions, however, has indicated that the apparent SA-203 overcooling problem does not exist. This obvious discrepancy is being investigated. Heater elements will be added to assure proper thermal balance for operational vehicles effective on SA-204.

B. I. U. Component Qualification Test Program

1. Pressure Switch - Qualification testing of the 3000 psi switch was completed successfully.

2. Sublimator Testing at AEDC - A series of functional performance tests was completed on sublimators SN 06', 11', 13', 10' and 12'. All of these units performed satisfactorily during flight simulated start tests. A low heat input test was performed using SN 02' sublimator. In the most adverse test, the methanol/water flow to SN 02' was stopped for 30 minutes with the water supply valve open. Methanol/water flow was started again after the 30 minute "freeze-up" period, and the sublimator restarted successfully with no apparent damage.

3. Thermal Capacity of Sublimator After Storage at Cape Kennedy - Testing revealed leakage from the methanol/water loop to the water loop of sublimator SN 05. This leakage prevented a good start with SN 05, even at low inlet water pressure (1.6 psia). Tentative plans at this time are to return SN 05 to Hamilton-Standard for investigation into the cause of failure.

C. Vibration Test of GBGS Heat Exchanger

Two heat exchangers (S/N 5 and S/N 9) were subjected to sinusoidal and random vibration in three axes and to proof pressure tests before and after vibration in each axis. There were no failures.

D. I. U. Coolant Pump Testing

Preflight Certification Testing of S/N 004 Coolant Pump was successfully completed. This included extended life tests to 1000 hours. S/N 004 was not subjected to corrosion environments (humidity, salt spray, etc.) because it did not have a sealed current limiter. S/N 005 completed acceleration, vibration, shock, and thermal vibration testing plus 500 hours of life testing during July.

SATURN V

I. S-IC Stage

A. F-1 Engine

1. R&D Engine Tests at EFL

Nineteen tests were conducted and a total duration of 2804.4 seconds was accumulated. Fourteen of these tests were full duration (150 seconds or more) and two were programmed short duration tests. Three tests were terminated prematurely due to a fire in the gas generator ball valve area, a fire of unknown origin, and a hot gas leak in the turbine manifold area.

2. Production Engine Tests at EFL

Ten tests were conducted and a total duration of 944.6 seconds was accumulated. Four tests were full duration runs (150 seconds or more). The total number of production engine tests conducted to date is 173 with a total duration of 13,480 seconds accumulated.

3. Engine Tests at MSFC

Approximately 2025 seconds of mainstage testing was conducted on engine F-5038. The slight baffle bulge noted after acceptance firing of the engine became a little more pronounced after each firing until the baffle finally eroded through in a spot approximately 1/16-inch in diameter. The damage will be repaired and tests will be continued to determine the adequacy of the repair procedure.

4. Engine Component Qualification Tests

Qualification tests were completed on all components except the "Hi-reliability" Pressure Transducers and the Turbine Exhaust and GG Igniters.

B. Hydraulic Return Line Successfully Vibration Tested

A S-IC Hydraulic Return Line successfully completed sinusoidal and random vibration test and proof pressure test without failure.

II. S-II Stage

A. J-2 Engine

1. R&D Engine Tests at SSFL

Fifty-five tests were conducted and a total duration of 6729 seconds were accumulated. Eight tests were terminated prematurely.

2. J-2 Engine Insulation Subjected to Environmental Tests

The engine insulation was subjected to combined environmental tests and the insulation and its application were approved. Heating of the J-2 engine components during operation with one outboard engine out was also studied. Several critical components overheat in the more severe engine out environment. The engine contractor will be funded to conduct a detailed study of engine-out operation for the S-II stage.

B. S-II Battleship Test Plan Revised

The three transition tests and the fifth full-duration firing were deleted. Two special short duration (20-second mainstage) firings, using 35 psia LOX pump inlet pressure for engine start, were added. These revisions were made for the following reasons:

1. Two short-duration firings are adequate to evaluate the problem in question. The earlier plan is not required.
2. The stage contractor had planned to change engines before the fifth full-duration firing; now the engine change can be eliminated.
3. The schedule will support completion of the three remaining full-duration firings and the two short tests requested above before September 1, 1966; thereby allowing all static firings in sequence before modifications are made for the boattail conditioning tests.
4. Since S-II-1 static firing program will be in progress after September 1, 1966, elimination of battleship firings after that date will simplify the stage contractor's problem of attempting to man two active static firing sites simultaneously.

C. S-II-F Test Plan Expanded

Additional test requirements were put into the S-II-F test plan to assure early S-II/S-IC interstage environmental conditioning system data from the early SA-500-F LOX tank loadings. These are required to insure representative results from the S-II Battleship. flight simulation test of the LOX recirculation system to be conducted in late September.

D. S-II LOX Recirculation System

The sensitivity of the LOX recirculation system was identified on the S-II-T vehicle. The S-II Battleship and S-II-T tests have indicated that the system may be marginal in the flight configuration. Several measures are now in progress to find the best solution to the problem. S&ID will conduct special LOX recirculation tests on the S-II Battleship with a simulated flight environment and flight-type hardware; proposed solutions and feasibility of vehicle modifications will be evaluated during the Battleship tests. Hardware changes and test plans are presently being formulated by S&ID. Re-routing of system lines and He injection locations will be investigated, and a modified J-2 LOX return line will be procured for testing on the MSFC S-IVB-Battleship.

E. Propellant Management System

A modification was made on the shock mount flange of the P. U. Computer, and the flange successfully passed the first two axes of random vibration. The other axis of vibration is being tested. With this fix the acoustics test was passed at 158 db.

F. S-II Stage Ullage Motor

The prime contractor, S&ID, has initiated a second source procurement for the S-II ullage motor with Thiokol. The original ullage motor subcontractor, Rocketdyne, is continuing with efforts to qualify the RS-V-601 motor design using their standard RDS 509 propellant system, and is also conducting a parallel effort to develop and qualify an RS-V-602 motor design using RDS-509J propellant system. This propellant system was proposed as a substitute for the RDS-509E propellant because of its superior physical properties and resistance to moisture degradation. The first RS-V-602 motor was successfully test fired on July 25, 1966. Preliminary data indicates that the motor performance was within the specification limits.

III. S-IVB Stage

A. Auxiliary Propulsion System (APS) Tested at MSFC

The APS module was subjected to a series of simulated altitude tests that verified its capability to operate in that environment. In addition, x-rays were made of the propellant tanks while loaded at various levels and after exposure to temperature cycles. The results indicate that a gas bubble forms within the bladder after a prolonged period of time when the propellant tanks are loaded and held under a blanket pressure of helium.

B. C-1 Engine (APS) Tests Reported

Testing of the prototype design was continued. The six prototype engines tested to date accumulated a total hot firing time of 26,741 seconds in 86,853 starts. These tests were run at the most severe duty cycle with propellant inlet temperatures ranging from 40 degrees to 130 degrees F. Both MMH (monomethylhydrazine) and Aerozine-50 (50% hydrazine - 50% UDMH) were used as the fuel in these tests. One of the engines was run for a total of 12,518 seconds and

44,747 starts. That engine employed a bi-propellant valve and a radiation-cooled nozzle extension. Another engine with a quadredundant valve and an ablative nozzle accumulated 2,059 seconds and 5,483 starts.

Another incident of the oxidizer spud being blown off the injector face occurred after 920 seconds. This failure was the first to occur with the engine in the horizontal position. The previous failures occurred when the engine was positioned to fire vertically upward. The test was conducted with a propellant inlet temperature of 45 degrees F and at an altitude of approximately 100,000 feet. In view of this and the three previous failures, a design change to the injector is being investigated.

C. LH_2 Chilldown Pump Helium Turbine Tested Successfully

Test duration was 2 1/2 minutes. The tests results indicate that the pump performed close to that expected, while the turbine exceeded its predicted performance. The turbine-pump speed ranged from 12,800 to 18,900 RPM during the test. Tests on the turbine and pump will continue.

D. O_2/H_2 Burner Tested Successfully

The first successful 4 1/2-hour burn of the oxygen-hydrogen burner was completed on July 1, 1966. Simulating mission profile, the burner operated in the thrusting mode for 270 minutes after which the LH_2 run tank pressure was ramped to simulate S-IVB Saturn V fuel tank repressurization. This was the third attempt at the 4 1/2-hour burn thrusting mode. The first two attempts resulted in unexplained flameouts.

An attempt was made to fire the LOX-hydrogen burner on July 22, 1966. No ignition occurred and cutoff command was given at T plus 17 seconds. Post-test investigation did not reveal any discrepancies that would account for the "no ignition" condition. The purpose of the test was to verify if relocating the inner LH_2 injector core holes closer to the LOX injector core holes would raise the temperature of the injector face significantly enough to eliminate ice buildup that has been the cause of the burner flameouts.

SPECIAL STUDIES

I. Cryogenic Tank Internal Insulation Analysis

An analysis is being performed to determine if heat leaks in the thin-walled cryogenic tank support structure can be reduced by using foam insulation on the tank inner surface in addition to optimum penetration exterior high performance insulation. Results thus far indicate that conical-type support heat leaks could be reduced approximately 25% with addition of internal foam insulation.

II. ATM Experiment

The ATM package will contain several solar experiments, that will acquire data on specific solar phenomena. Preliminary thermal analyses were made to furnish input for the MSFC program development plan. Results of these analyses indicate that the batteries and ATM package will require a combination of active and passive means for thermal control. More detailed analyses are presently underway to determine orbital temperatures for the batteries. Thermal studies for other components and ATM package will be initiated as required information becomes available.

III. Investigation of Freon E-3 as a Working Fluid in a T.V.C. System at Low Temperatures (-150 degrees F)

A characteristic curve of flow versus angular displacement for the control valve was determined. The flow characteristic of the valve is non-linear. The valve-heat exchanger combination will be checked with LN_2 to determine compatibility. The system is being modified to accomodate a water heat exchanger for the ambient temperature testing.

IV. Low-g Fluid Transients

A general computer program was developed that gives a detailed description of the motion of a confined liquid subjected to a near zero gravitational field. The fluid has a free surface and an unsteady source. The flow is assumed to be incompressible and irrotational. The tank is cylindrical.

V. Curve Fit of Low-g Surface Deflections in Cylindrical Tanks

A computer program was written to give a closed-form curve fit for the vertical displacement of the surface of a liquid in a tank as a function of the radius of the tank. Curve fits were obtained for the range of bond numbers between 10 and 100 and for contact angles as small as 3 degrees. Higher bond numbers are being investigated.

ADVANCED PROPULSION AND TECHNOLOGY

I. 350K High Pressure LH_2 Pump Tests

Four tests were conducted with the objective of achieving the 5500 psia design discharge pressure. During the last test, a catastrophic failure occurred that destroyed the pump and caused major damage to the test facility. The turbopump was operating at 4500 psia and 37,000 RPM at the time of failure. The cause of the failure was isolated to pump overspeed caused by a pressure surge and subsequent reverse flow in the system during shutdown. The failure was apparently initiated by non-synchronous system oscillations that caused a bearing failure and subsequent breakup of the pump during shutdown. Efforts to raise the non-synchronous frequency threshold outside the operating range are being continued in view of this failure.

II. Dynamic Seal Test Fixture

The initial checkout of the dynamic seal test fixture was completed. Three checkout tests using LN_2 and a standard F-1 primary LOX seal were conducted. Tests using liquid oxygen and F-1 seal materials are planned for the next test series to establish a life criteria for comparison of the results from new materials to be tested.

III. System and Dynamics Investigation

Quarter-scale models of the aerospike engine LOX manifold were built and two of three configurations were cold flow tested with water. Preliminary results indicate that priming of the manifold is accomplished relatively uniformly, but purges at cutoff do not adequately clear the manifold. Relocation of purge points is being considered. The full-size LOX manifold was completed and its phase will be initiated

early in August. Both the tube wall and solid wall full-size thrust chambers are being fabricated. The second tube wall chamber will use nickel tubes instead of stainless steel to increase the operating range of the chamber to include a full mixture ratio coverage from 5 to 7 and possibly an increase in chamber pressure operating limit (a test stand restriction) from the present 600 psia to 1000 psia at a mixture ratio of six.

IV. Advanced Engine Design Study, Aerospike

Various candidate engine cycles were examined in an effort directed toward defining a basic engine configuration. The candidates were reduced to nine and will be further reduced to about four early in August. Evaluation of the remaining candidates will be conducted with considerable care and thoroughness to determine the best candidate for the detailed design and operational analysis studies to be initiated in December. Preliminary parametric data are becoming available on these early candidates. The breadboard engine definition effort, which will begin early next year, was redirected from the 350K thrust level to the 250K thrust level in keeping with the decision of the Aeronautics and Astronautics Control Board (AACB).

PUBLICATIONS

I. "Motion Study of the Suction Ducting on the S-IC Stage of the Saturn V Vehicle," Unclassified, TMX-53471, by H. E. Fursdon, dated June 22, 1966; Published July 7, 1966.

II. "A New Concept to the General Understanding of the Effect of Longitudinal Conduction for Multistream Counterflow Heat Exchangers," Unclassified, TMX-53454, by C. L. Pan, N. E. Welch, and Robert R. Head, dated April 27, 1966; Published July 12, 1966.

III. "Evaluation of Flight Test Propulsion Systems and Associated Systems, Saturn S-IVB-201 (U)," Confidential, IN-P&VE-P-66-15 by the Performance Analysis Section of the Propulsion Evaluation Branch.

IV. "Applied Mechanical Research Facilities Handbook," by the Applied Mechanical Research Branch.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-66-7

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(July 1, 1966 Through July 31, 1966)

SATURN IB

I. S-IB Stage

The H-1 engine loads program, which is under development, has successfully computed loads for the outboard (gimbaled) engine case. Development of the program will continue so that nongimbaled engine loads may be computed. The program calculates loads and moments in three planes: at the gimbal point, and load components at the actuator attach points.

II. General

A. SA-203 Flight Evaluation

A preliminary review of SA-203 flight data indicated that the maximum acoustic levels attained along the instrument unit during flight ranged from about 154 to 158 dB. It appears that the oscillating shock environment did occur as predicted and was present over microphone B6-601 for about one-half second between 45 and 46 seconds of flight (referenced to range 0). However, the overall sound pressure level resulting from the oscillating shock was 6 to 10 dB below the predicted level. SA-203 acoustic data compared favorably to SA-201 acoustic data. Instrument unit vibration levels did not indicate a significant response and all composite Grms measurements were generally below SA-201 measurements.

Flight evaluation of the SA-203 vehicle for POGO instability was initiated. Preliminary analysis of flight data revealed no evidence of POGO.

B. AS-204

Vibratory bending moments through the critical loads period have been calculated for the AS-204 vehicle. These loads, based upon the operational control system, will be used as an aid in establishing the flight limits for structural capability of the vehicle.

The lateral vibration analysis of the Saturn IB, AS-204 (upper stage) was revised (Memo R-P&VE-SLA-66-18).

The torsion vibration analysis of the Saturn IB, AS-204 vehicle was revised (Memo R-P&VE-SLA-66-21).

Differential pressures on the AS-204 vehicle for the 150-square inch vent area were supplied to R-P&VE-SLS (Memo R-P&VE-SLL-66-41).

C. AS-206

A preliminary torsional vibration analysis of the Saturn IB, AS-206 vehicle with LEM and nose cone was published (Memo R-P&VE-SLA-66-20).

Differential pressures on the spherical cap, LEM, IU, and S-IVB forward skirt of the AS-206 vehicle were published (Memo R-P&VE-SLL-66-44).

D. AS-208

A lateral and torsional vibration analysis of the Saturn IB, AS-208 vehicle was published (Memo R-P&VE-SLA-66-22).

E. High Force Dynamic Test Program

Phases of the S-IVB high force test program that are applicable to the S-IB stage have been completed at Thiokol, Wasatch, Utah, with no noted structural discrepancies. Douglas Aircraft is preparing a report.

SATURN V

I. S-IC Stage

A. S-IC Vehicle Thrust Structure Bolts

The fix suggested by Boeing for the 1 3/8-inch diameter bolts connecting the lower caps of the crossbeam to center cruciform, has been accomplished on all existing vehicles. R-P&VE-MMA-66-47, "Failure of S-IC Vehicle Thrust Structure Bolts," dated June 14, 1966, published by Materials Division, summarizes their evaluation of the bolt failures and possible fixes. One of the possible fixes mentioned in this memorandum is the reduction of the heat treat of the bolts from 220 k. s. i. to some lower value. On June 23, another bolt head sheared off of AS-501 crossbeam subassembly. All of the corrective action had been incorporated into this assembly except the bolt heat treat reduction. A new loads study and evaluation of S-IC-S lower assembly test data indicated that the loads in this area are considerably lower than the original design loads. Therefore, as suggested in the preceding memorandum, the heat treat will be reduced to 160-180 k. s. i.

B. S-IC Upper Assembly (LOX Tank/Forward Skirt)

The upper assembly (LOX tank/forward skirt) was successfully tested to 140 per cent of condition I on July 12, 1966. This simulated the net axial load in the lower bay of the LOX tank for flight cutoff condition. This was performed with an empty tank and no ullage pressure. Condition II, performed July 13, 1966, simulated the net axial load in the lower bay of the LOX tank for flight cutoff, and included a full tank of water with maximum and minimum ullage pressures being applied. While attempting to qualify the forward skirt and forward panels of the LOX tank conditions III and IV, the intertank structure began to go into a failure mode at 120 per cent of design limit load. The test was aborted and additional "beef-up" is required on the intertank structure before testing can be continued. For this test the intertank is used as a test fixture only to simulate the proper end conditions. The intertank used for this test is of the early light design which was proven in test to be inadequate to sustain flight loads. The flight version of the intertank was redesigned. The Strength Analysis Branch recommended in April 1965, that a boiler plate "beef-up" be added to this intertank before testing was started. The beef-up is being installed at this time.

C. Prevalve Vibration Testing

The Boeing Company completed vibration tests on the S-IC (Whittaker) prevalves. After completion of the second axis random, the prevalves were opened and a bellows adjustment nut was found to have backed off and fallen into the valve cavity. The nut was screwed into place and re-crimped. The last axis test was run with no further problem. The Boeing Company is requesting that these adjustment nuts be backed up by a lock nut and safety-wired with an effectivity of 501. The valve had previously been qualified by MSFC, but not to a random environment. The fix as proposed by Boeing is acceptable and should be incorporated as soon as advantageous.

D. S-IC-T Measuring Program

The Structures Division measuring requirements for the next S-IC-T test program have been coordinated and submitted to the Laboratory Project Office. This program will complete the data requirements which were not met by the first S-IC-T series of tests.

II. S-II Stage

A. Measuring Program

The Structures Division revised measuring program for the S-II stage was finalized and submitted to the Laboratory Project Office and Mississippi Test Facility. This program established the vibration, acoustic, and strain measurements required for static test performance evaluation.

B. EDS Safe and Arm Device

An isolation system for the EDS safe and arm device was evaluated and recommended to reduce container 223 vibration levels to acceptable magnitudes. This isolation system is recommended for installation of the safe and arm device in container 223.

C. S-II Stage High Force Dynamic Test Program

Acoustic testing of the aft interstage, thrust complex assembly has been completed at Wyle Laboratories. Failures were experienced on three battery mounting brackets in the aft interstage. Modifications have been made and are being evaluated. The setup for mechanical vibration is scheduled to begin August 1.

D. S-II Recirculation Line

1. Reduction of strain data from the S-II recirculation line vibration test was completed. The resulting stresses indicated a significant reduction of stresses in the recirculation line boss when support brackets were added.

2. Inspection of S-II-F at KSC and S-II-3 at S&ID revealed cracks in the recirculation return line mounting pad.

3. Feasibility of using H7-17 fitup fixture as a spacer for the S-II stage was investigated for use in the VAB stackup of AS-501. Preliminary study indicates H7-17 can be used without additional beef-up.

4. Dye penetrant inspection of 29 selected areas of the S-II-F LH_2 tank revealed two surface cracks. One crack was located at ring frame No. 3 on the right side of splice weld No. 2 on the bottom radius of the rib. The crack was about 1/8-inch long and was parallel to the ring frame tab. The other crack was located in a "keyhole" slot in the circumferential stiffener at NAA Station 385 near stringer No. 77.

5. Both of these cracks appeared to be minor and were removed with a minimum amount of rework.

E. S-II LH_2 Tank Cracking Problem

The debris analysis of the S-II-T failure revealed the existence of a cracked area in the LH_2 tank cylinder adjacent to the bolting pad for the LH_2 recirculation return line. The discovery of this crack prompted an inspection of the other available vehicles to determine the existence of cracks. All other vehicles contain similar cracks in varying degrees. Additionally, it was discovered that the termination points of the ring frame tabs and stringers also contain cracks, some of which have propagated into the thin membrane of the tank skin. A summary of cracks follows:

S-II-F:

Vertical Stringers	0
Horizontal Frame Tabs	2
Bolting Pad	1

S-II-1:

Vertical Stringers	6
Horizontal Frame Tabs	17
Bolting Pad	1

S-II-2:

Vertical Stringers	0
Horizontal Frame Tabs	10
Bolting Pad	0

S-II-3:

Vertical Stringers	25
Horizontal Frame Tabs	17
Bolting Pad	2

CBTT:

Vertical Stringers	No Inspection
Horizontal Frame Tabs	1
Bolting Pad	0

There are nine areas in the S-II-3 where the cracks penetrate the membrane skin. All of these cracks have been ground out, and seven are being repaired with an adhesive patch which is applied to the external surface. S&ID is performing component tests to verify the structural adequacy of the patch design. All horizontal frame tabs are being scarfed to provide a more gentle slope of the frame tab at the termination point. The scarfing operation also removes the cracks at these points. All cracks are being ground out of the ends of stringers and bolting pads.

The cause of the cracking has not yet been determined; however, it appears that the forming of the panels and the hydrostatic test operations are the prime suspects.

One hundred per cent coverage of the cracking problem is being provided by the Strength Analysis Branch, requiring at least one engineer at the S&ID plant at all times.

III. S-IVB Stage

A. S-II/S-IVB Interface

S-II/S-IVB interface stack hardware was tested at DAC on June 27, 1966, for the following conditions:

1. Crush Pressure Differential (Mach 1.035)
2. Burst Pressure Differential (Mach 1.6)
3. Burst Pressure Differential (Mach 1.4)
4. Burst Pressure Differential (Mach 1.0)

All tests were successful.

B. S-IVB Stage Umbilical Connection

S-IVB stage aft umbilical connection was tested at MSFC on June 24, 1966. Because of excessive deflection of the test panel and connection hardware, the "harpoon gun" cylinder was pressurized to 100 p.s.i.g. to stabilize the connection. This test condition, which simulates vehicle oscillations of 0.66 cycles per second, dumps about 1,600 pounds of radial load into the vehicle, when the "harpoon gun" is pressurized to 100 p.s.i.g. Although it is recognized that the test panel does not simulate vehicle hardware, the S-IVB aft umbilical area for AS-501 will be stress-checked for a 1,600-pound radial load.

C. S-IVB Structural Qualification Test

The following structural qualification test conditions were completed at DAC, Huntington Beach:

S-IVB/S-II Interface Stack

Limit Max $q\alpha$, June 30, 1966

Forward Skirt, Saturn V, S-IVB Stage

Limit Max $q\alpha$ with 50 per cent and 100 per cent limit burst pressure

D. S-IVB Common Bulkhead

The common bulkhead of the S-IVB stage collapsed from excessive negative pressure causing failure of the entire stage near the end of the fourth orbit. The condition which resulted in the failure occurred, as would be expected, from the venting of the LOX tank while the LH_2 tank was being pressurized to its vent setting. The telemetered data showed the LH_2 ullage pressure to be 39.9 p.s.i.a. and the LOX ullage pressure to be 5 p.s.i.a. at failure. Thus the bulkhead failed at a negative pressure of 34.9 p.s.i.d. Since the common bulkhead tested at Sacto failed at 34.7 p.s.i.d., it is believed that the SA-203 test helps to firmly establish a reliable collapsing capability of the common bulkhead.

E. S-IVB Forward Skirt

Qualification testing of the forward skirt of the S-IVB stage of the Saturn V vehicle was successfully completed. As an additional test the axial load was held at limit and the bending moment was increased until failure occurred at 250 per cent of the design limit moment. The test results have proven that the Saturn V forward skirt design is more than adequate for manual flight.

F. Propulsion System

A stress analysis to determine the cause of failure and the pressure capability of the Parker 10-inch vent valve was completed. The analysis indicated that the valve should withstand over 80 p.s.i. without actual failure. The highest known operating pressure was 52 p.s.i. However, the valve did not meet the required 1.1 safety factor on yield strength at operating conditions.

G. Developmental LH_2 Pump

An analysis to determine stresses in the high pressure pump forward bearing area caused by thermal and rotational effects was completed. The stresses were very low, which seems to confirm the theory that failures result from unbalanced dynamic loads.

IV. Instrument Unit

A. ST-124M Fixture

ST-124M platform/bracket qualification test preliminary fixture evaluation was completed. Review of the data indicated that excessive cross-axis response was present in what is considered the critical frequency range of the platform. The fixture is being modified to eliminate the undesirable response. It is anticipated that Phase I (bracket qualification) tests will begin August 8.

B. ST-124-M4 Mounting Bracket

A vibration analysis of the redesigned ST-124-M4 mounting bracket to determine major resonant frequencies has been completed. These resonant frequencies were compared to the critical internal resonant frequencies of the ST-124. One resonant frequency, where the ST-124 acts as a rigid body with respect to the bracket as a spring in the radial axis, coincides with a critical internal frequency of the ST-124. A design change has been recommended to remove this frequency from the critical range.

C. SLA Petal Deployment

An investigation to determine the impact on the instrument unit structure and components resulting from the SLA petal deployment shock excitation has been completed, using the test data from the separation test of the SLA. It has been concluded from this investigation that the instrument unit structure and component installation are structurally adequate to withstand the shock transients induced by the SLA petal deployment.

D. S-IU-200/500S-3

All strain gages and photo stress were installed on the IU segments. The IU has been inserted in the test setup and the test stack configuration of the lower load ring of the S-IVB forward skirt.

V. General

A. Impedance Test Program

Phase I of the impedance test program is approximately 70 per cent complete. Excellent correlation has been established between test and analytical results indicating that the impedance trailer is operating properly and testing can proceed into Phase II (scale model structure).

B. Saturn V Damping System

The preliminary design has proceeded to the point where basic cross sections and portions of the material requirements have been defined. Information on steel angle shapes, spherical bearings, and a specification on the hydraulic cylinders has been given to Manufacturing Engineering Laboratory for procurement. Trips to KSC and the Manned Spacecraft Center are scheduled for coordination of the system.

C. AS-501

The POGO stability analysis of the Saturn V, AS-501 vehicle based upon the Langley 1/10-scale model has been completed.

Configuration 2 of the Langley 1/10-scale model, AS-501, is being analyzed for longitudinal dynamics.

D. AS-504

A longitudinal dynamic analysis of the AS-504 vehicle with a 100,000-pound payload has been completed and is being published. This analysis covers all main stage events and includes S-II stage ignition.

E. AS-500F

Reduction of camera sway data obtained during the Saturn V, AS-500F Ground Wind Test was requested. Request was for 30-second time slices from the runs (Memos R-P&VE-SLL-66-38 and R-P&VE-SLL-66-42).

A preliminary analysis of data obtained (May 23 through June 15, 1966) from the AS-500F Ground Wind Test was published. Analysis of AS-500F Ground Wind Test is continuing (Memo R-P&VE-SLL-66-39).

APOLLO APPLICATIONS PROGRAM

I. LFV Reusable Strut Test

A drop test of the original design for a reusable strut was conducted. The energy-absorbing characteristics of the strut were reported to vary during the testing operation. A further evaluation of the test is planned, and the test of an improved strut design is scheduled to begin in September.

II. LLV Landing Gear

A series of six crushing tests was performed on the LLV main strut. All tests were subjected to axial loads only, and the crushing forces ranged from 11,000 pounds to 40,000 pounds. The data obtained will be reduced and analyzed prior to beginning the next series which calls for an axial load and moment.

III. Apollo Telescope Mount

Manpower and schedule estimates required for stress analysis of the Apollo Telescope Mount experiment have been determined.

A preliminary vibration analysis has been completed on the Apollo Telescope Mount (ATM). In this analysis, the lowest natural frequency (20 cps) was determined. There appears to be no problem with the configuration analyzed. Further investigation of possible deflection problems is continuing.

IV. Lunar Module

Structural sizing of a docking structure, and two concepts of the Payload Module support structure have been completed.

Analysis and structural sizing of a shear panel LM carrier rack concept designed for both the cylindrical Payload Module and Project Thermo loads have been completed.

V. Project Thermo

Design investigation of the tank support structural systems required to carry the individual experiments of Project Thermo in a

LEM Descent Stage is continuing, and is about two-thirds complete. A manpower estimate and schedule for a Structures Division in-house effort for Phases B, C, and D have been made.

Analysis and structural sizing of the support structure for a 34-inch diameter tank (Experiment 6) and a 44-inch diameter tank (Experiment 7) using two penetration points have been completed.

ADVANCED TECHNOLOGY

I. Design Studies

A. Titanium Crossbeam

The titanium crossbeam developed several cracks along the upper cap and web. It was assumed the cracks were caused by hydrogen embrittlement. After discovery of the cracks, action was taken to stop-drill these. A meeting was held to discuss the methods of repairing the cracks. It was decided that NAA would attempt to repair the beam by welding. This was accomplished immediately and apparently was successful. A dye-penetrant check was made on all accessible welds to find any other defects. This check did not show any other cracks or defects on the beam.

B. Titanium Fuel Tank

Detailed drawings for the titanium fuel tank test specimen are being prepared. It is anticipated that the drawings will be available in late August.

C. Airlock Door

Analysis and structural sizing of an airlock door concept have been completed.

D. CPM Experiment Rack

The preliminary design of all machined fittings requiring outsized billets is near completion. It is anticipated that billet sizes will be released to Manufacturing Engineering Laboratory by August 1. Tooling points and mold lines have been determined and released to Tool Planning.

Vibration loads have been determined for the Payload Module (CPM) rack. These loads will be used to size the CPM support struts in the preliminary CPM rack design, which is to be released in mid-August.

II. Design Research

A. Biaxial Stress Tests of Aluminum Welded Joints

Tests have been conducted on a heavily instrumented cylinder. Test data have been sent to Advanced Methods Section for use as a basis in determining future instrumentation requirements.

B. 70-Inch Slosh Tank Tests

Tests of tank No. 2 have been completed. Required data, which included resonance frequencies, liquid level measurements, pressure distributions, forcing loads, damping curves, and slosh bearing loads have been collected. Test setup will now be moved to the original location, which is expected to be vacated soon, where the 200-inch multi-cell tank will be tested.

C. Semi-Toroidal Tank Study

The final reports for the semi-toroidal tank study were received and distributed. This completes the study effort.

D. Rocket Sled Testing

Rocket sled testing has resumed at Holloman Air Force Base and a firing was completed on July 19, 1966. A boundary layer rake and static pressure transducers placed along the test sled were added, for this and subsequent firings, in order to obtain information about the structural forcing function. The test is considered a failure because the velocity profile required was not attained. The sled reached an excessive velocity and failed to stop before it slammed into sand bags at the end of the track. Almost all channels of data were lost; however, little damage was sustained by the sled and the instrumentation was not damaged. Velocity profile control has been the principal problem with the Holloman track operations.

E. Honeycomb Cylinder Test Program

Liaison work was accomplished on a number of fabrication deviations. Engineering waivers were approved for four test specimens that were not within drawing tolerance.

F. Meteoroid Shielding

A conference with representatives of Research Projects Laboratory and Aero-Astrodynamics Laboratory was held and a meteoroid flux environment to be used for earth-orbiting spacecraft was adopted for use in MSFC analyses. This environment is based on Pegasus data and radar data fitted into a smooth curve and is considered conservative for current design studies.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-66-7

MONTHLY PROGRESS REPORT

JULY 1, 1966 THROUGH JULY 31, 1966

SATURN IB

I. S-IB Stage

A. Investigation of Materials for Thermal Insulation in the Aft Area of the S-IB Stage

Efforts have continued in the development of highly reflective thermal insulations having higher temperature capabilities than the recently developed FTA-442A and FTA-532A insulations. Compositions are being evaluated which consist of zirconium oxide (ZrO_2) fibers, ZrO_2 powders (-325 mesh), and asbestos fibers bonded with colloidal silica. The primary emphasis of the developmental work has been to maintain a low silica content so as not to compromise the refractoriness of the final composition. The most promising composition formulated to date is shown in the following table:

Batch Composition

Ingredient	Parts (dry weight basis)
ZrO_2 fibers	40
ZrO_2 powders	40
Asbestos fibers	20
Colloidal silica	63

Although, in this formulation, the colloidal silica is specified on a dry weight basis, it is added to the composition in the form of a silica sol and subsequently gelled to act as the insulation bonding agent.

The above insulation has been characterized as to bulk density, water absorption, flatwise tensile adhesion to an open-faced stainless steel honeycomb sandwich substrate, and refractoriness. The bulk density and water absorption were determined to be 78.5 lbs/ft^3 and 38.5 percent, respectively. The flatwise tensile adhesion was 37 psi when adhered to a

stainless steel honeycomb sandwich substrate, having a 1/4-inch high open-faced honeycomb core crushed to a height of 0.113-inch. The refractoriness was determined by placing bars (0.330 inch x 1 inch x 6 inches) in an electric furnace, with a 5-inch length of the bars cantilevered, and raising the furnace temperature at a rate of 110°C (230°F) per hour until the bars started to soften and bend. The bars softened at 1287°C (2350°F). This compares to 846°C (1550°F) for the FTA-442A insulation. Future work will include characterizing the new insulation as to reflectance, specific heat, thermal conductivity, mechanical strength, and insulating capabilities.

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

Activities have continued in the assembly, qualification and delivery of hazardous gas detection (HGD) systems for use at Saturn launch complexes at the John F. Kennedy Space Center (KSC). Delivery of the first HGD unit for Launch Complex 34 was made during this report period. Installation and final checkout of this unit is in progress and should be completed during this period. The second unit for Complex 34 will be completed and delivered during the month of August. Assembly is well within the scheduled time frame.

SATURN V

I. S-IC Stage

A. Developmental Welding

Studies have continued on the comparative weldability of several aluminum alloys in sheet and plate thicknesses. The alloys studied in these investigations were 6061, 5086, 2219, 7002 and 7006. Weldments of these alloys have been studied to determine crack susceptibility by a variety of testing techniques. Test results indicate that each of the alloys studied has a high resistance to cracking.

Work has continued on the investigation of porosity on 2219 aluminum alloy weldments and development of procedures for elimination of this defect from production weldments. Various methods of edge surface preparation are being evaluated to determine their effort on porosity.

Studies have been completed in the determination of the low temperature mechanical properties of weldments of aluminum alloy X7106. Weldments were made in two thicknesses, 1/8-inch sheet and one inch plate with weld filler metals X5180 and 5356. The welds were tested over the temperature range 80°F to -423°F (27°C to -253°C). Test data indicate that welds made with X5180 filler metal had better tensile properties than those made with 5356 alloy. Joint efficiencies for welds in 1-inch plate averaged 70 percent at room temperature and 44 percent at -423°F (-253°C). Joint

efficiencies for welds in 1/8-inch sheet was typically 89 percent at room temperature and 61 percent at -423°F (-253°C). Virtually, no improvement in tensile strength was observed with decrease in test temperature to -423°F (-253°C) for welds in 1/8-inch sheet. A moderate increase in strength was noted for the welds in 1-inch plate with decrease in test temperature to -320°F (-196°C). However, testing at -423°F (-253°C) revealed a tensile strength lower than that at -320°F (-196°C) but higher than the room temperature strength. Notched to unnotched tensile strength ratios exceeded 0.78 for all test temperatures and conditions with typical values exceeding a 0.9 ratio.

B. Study of Corrosion and Cleaning Procedures

1. Stress Corrosion Studies

Investigations have continued into the stress corrosion susceptibility of aluminum alloy 7039 in the -T61 and -T64 conditions. Alloy specimens of each heat treatment have been exposed for 135 and 113 days, respectively, in the alternate immersion tester and the local atmopshere. Three specimens of 7039-T64 stressed to 20 ksi and 1 specimen stressed to 10 ksi in the short transverse direction failed after 100 days exposure in the atmosphere. All specimens stressed at 10 ksi, 15 ksi, and 20 ksi in the short transverse grain direction have failed (with the exception of one specimen stressed at 20 ksi) within 78 days of exposure in the alternate immersion tester. There have been two failures each in the local atmosphere (57 and 92 days) and in the alternate immersion tester (101 and 104 days) of 7039-T61 stressed in the short transverse direction at 20 ksi and 15 ksi. No failures have been observed in either material (-T61 and -T64) stressed in the longitudinal or long transverse direction.

Specimens of Ti-8Al-1Mo-1V have been fabricated and are being fatigue cracked for precracked stress corrosion studies. No work was done this month on the corrosion aspects of Ti-6Al-4V in contact with nitrogen tetroxide.

Carpenter Custom 455 stainless steel alloy, aged at 1000°F (538°C) and 1100°F (593°C) was found to be resistant to stress corrosion cracking by testing in the alternate immersion tester. Specimens of this alloy aged at 1150°F (621°C) and stressed to various loads up to 100 percent have been exposed to the alternate immersion tester for 102 days with no failures.

An investigation is in process to determine the stress corrosion susceptibility of two new high strength weldable aluminum alloys (X2021-T831 and X7007-T6E13) being developed under contract NAS8-5452. These alloys are being tested in all three grain directions in the local atmosphere and the alternate immersion tester. Failures of X7006-T6E136 have occurred at stress loads of 10 ksi in the short transverse direction in the alternate immersion tester and 20 ksi in the local atmosphere.

Preliminary tests for the threshold stress levels indicate that the threshold stress level for the short transverse direction for this alloy is below 25 ksi (40 percent yield strength) and below 45 ksi (75 percent yield strength) in the long transverse and longitudinal grain direction. However, severe general surface corrosion may be interfering with the test results and additional tests will be made. No failures have occurred to specimens exposed to the local atmosphere.

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 fabricated from 7079-T6 has been exposed for 318 days without failure, and the actuator made from 7075-T73 has been exposed for 288 days without failure.

C. Investigation of Fasteners and Fastener Materials

Manufacturers of MC sleeves have expressed concern about the delivery problems encountered in obtaining AM-355 stainless steel to MSFC specification requirements. An alternate material, which has been under consideration since 1964, is type A-286 steel, cold worked approximately 40 percent to meet the 150 ksi minimum yield strength requirement. This material has been evaluated on the basis of stress corrosion susceptibility, chemical composition, microstructure, microhardness, tensile strength, elongation and cryogenic properties. In addition, qualification tests of A-286 sleeves have been made. The results of these tests indicate that the high strength A-286 alloy is acceptable for a sleeve material for -423°F (-253°C) application.

A review is underway on the use of H-11 alloy steel, heat treated to 260 ksi tensile strength for fastener applications. Several recent proposals have been made to use fasteners of this material and a study is in process on the stress corrosion and hydrogen embrittlement susceptibilities of the material. Waspaloy and Inconel 718 are being evaluated as substitute materials for use in 260 ksi fasteners.

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

Seventy 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.

Testing and data evaluations are continuing in the study of the reproducibility of impact testing as used by this division in determination of the sensitivity of materials to liquid oxygen.

E. Evaluation of Commercial Adhesives

Studies are continuing as outlined below in the development, evaluation, and qualification of adhesives for use in the Saturn program.

1. Investigation of Polyurethane Adhesives

Further studies are being made of Minnesota Mining and Manufacturing (3M) Company's 3515 B/A adhesive, which appears to be chemically and functionally similar to the Narmco 7343 adhesive. Reportedly, Douglas Aircraft Company has switched to the 3M material, claiming that it gives more consistent results. To evaluate the 3M adhesive, a series of shear tensile tests were run to compare the strength properties of this material with the Narmco adhesive. Both 3M and Dow Corning primers were evaluated for use with the 3M 3515 B/A adhesive, and recommended 3M bonding procedures were compared with standard processes used by this division. The results of this study indicate that the relatively simple procedure used by this division for mixing and applying the adhesive gives results comparable to those obtained with the more complicated 3M procedure. The results also indicate that Narmco 7343/7139 is equivalent to 3M 3515 B/A adhesive except perhaps at -300°F (-184°C) where the 3M product may be slightly stronger. Approximately the same scatter in test results was obtained with both adhesives. The Dow Corning Z-6020 primer appears to be equivalent to the 3M XD-3901 primer. These results continue to show an advantage for using primers on the adherends.

2. Evaluation of Furane Plastics Adhesive, Urlane 8361 B/A

The Furane Plastics Company furnished samples of a polyurethane adhesive, Urlane 8361 B/A and primer m-B/C. Shear tensile specimens were prepared with and without the use of the primer. The Furane adhesive with primer showed fairly good strength properties at room temperature and -300°F (-184°C) but was deficient at +180°F (82°C). The unprimed samples showed very low strengths, except at -300°F (-184°C). The low strength values may be due to only partial curing; however, the manufacturer's recommended procedure was followed rigorously.

3. Evaluation of Ironsides Resins Company High Temperature Adhesives

Samples of DPH-94 and 25-15A adhesives were supplied from the Ironsides Resin Company with the statement that the adhesives showed promising strengths at temperatures up to 1,000°F (537°C). Room temperature lapshear strengths were 2,000 psi and 900 psi respectively. The 25-15A adhesive had a strength of 220 psi at 1,000°F (537°C). No further work with these materials is contemplated.

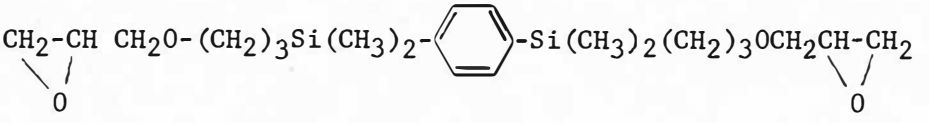
F. Development and Evaluation of Potting Compounds

Transparent, curable, elastomeric resin systems with good dielectric and adhesive properties are needed for encapsulation of delicate electronic circuitry. The flexibility criterion is not critical when, by the addition of inorganic filler, the thermal expansion coefficient of the composition approximates those of the ceramic and metallic components of the circuit. Of course, transparency is sacrificed by the addition of inorganic filler. For conformal coatings transparency, toughness, adhesion, and good dielectric properties are the prime qualifications. For both applications the requirements for improved insulation properties and chemical and thermal resistance continue to become more stringent.

Organic epoxy and urethane polymeric systems are representative of the materials available for these applications. The materials provide adhesion and ease of processing and moderately effective chemical resistance but they do not provide the desired dielectric properties. To achieve improvements in dielectric properties several chemical modifications of the epoxy and urethane systems are being explored, with emphasis directed toward the semi-organic types in which silicon atoms are introduced into the main chains or crosslinking agents, or into both. For example, the epoxy resin from the diepoxide containing the siloxane moiety, $-C_6H_4-Si(CH_3)_2OSi(CH_3)_2-C_6H_4-$, was characterized by a substantial reduction in dielectric constant from approximately 4 to 3, and additional improvements in thermal stability and water resistance, as compared with the standard epoxy resin. The current work comprises a continuation of this general approach with attention being given to epoxysilane, urethane-siloxane and urethanesilazane structures.

1. Investigation of Epoxysilane Polymers

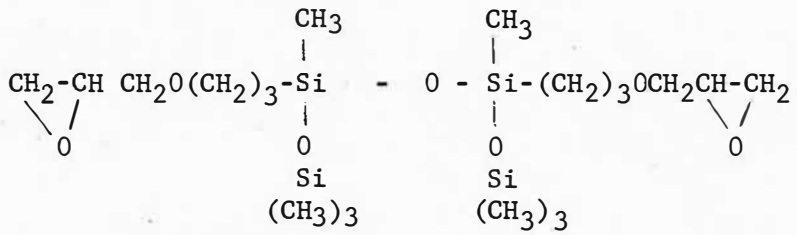
In the previous report it was noted that a one-gram sample of the silyldiepoxide,



1,4-bis(epoxypropylpropoxydimethylsilyl)benzene cured without difficulty in the presence of m-phenylene diamine to form an elastomeric dark resin. For the evaluation of the dielectric properties a larger sample is being synthesized. Approximately 100 grams of the intermediate, 1,4-bis(hydrogendimethylsilyl)benzene have been obtained by the reaction of the di-Grignard reagent from p-dibromobenzene with chlorodimethylhydrogensilane. The product will be added to allylglycidyl ether to yield the desired diepoxy silane.

2. Study of Urethanesiloxane Polymers

The completely aliphatic siloxane diepoxide



2,3-bis(2,3-epoxypropyl-propoxy)-1,1,1-trimethyl-2-methyl--4,4,4-trimethyltetrasiloxane

has become commercially available as Dow Corning XZ-8-5024. Attempts to prepare a strong, cured epoxy resin from the monomer have been unsuccessful, presumably because the molecular weight of product obtained in the prepolymer stage was not sufficiently high. Past efforts to directly cure all aliphatic structures of this general type have not been successful. Yet, the structure of the monomer is of interest since it is expected to impart flexibility to the derived polymer. The formation of a polyurethane resin by the reaction of the corresponding diol offered an immediately available scheme to evaluate the new Dow Corning structure.

The siloxane diepoxide was reduced to the corresponding diol in ether solution at 0-5°C by methylmagnesium bromide employed in small excess. The diol was isolated as an amber, viscous oil which could not be distilled in conventional vacuum distillation apparatus, whereas the diepoxide could be distilled.

The diol condensed with toluene-2,4-diisocyanate to yield a cured polyurethane resin which is indeed highly flexible. The process is being repeated on a large scale to produce sufficient material for dielectric measurements. The polymerization process comprised two steps: (a) reaction of the diol with the diisocyanate in 40 percent excess, catalyzed by triethyl amine, to form an oligomer of about four repeating units which were terminated by free isocyanate groups, and (b) curing for 4 hours at 90°C with Conap AH-8, a liquid polyamine.

3. Investigation of Urethanesilazane Polymers

The opportunity to incorporate silicon structures in amine curing agents arises from the previous work in this laboratory on the alkyl- and arylamino silanes. The curing of a conventional isocyanate-capped urethane prepolymer, Conap 2000, with C_6H_5-Si(N(H)C_3H_7)$_3$, phenyl tris(N-propylamino)silane, was too vigorous for proper control. The relatively bulky and sterically hindered, phenyl tris(n-cyclohexylamino) silane was selected as a potentially milder curing agent and was synthesized by the reaction of phenyltrichlorosilane with cyclohexylamine in ether at 0°C. The product, isolated in 42 percent yield as a clear viscous

liquid, with a boiling range of 177-180°C/0.1 torr, caused the Conap 2000 to cure to a strong, rubbery solid. The pot life of the mixture before curing was about 10 minutes. The dielectric properties of the polymer are being measured.

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 to operate for extended periods of time at low amplitude oscillations.

A new set of experimental slip rings has been installed in the test apparatus with rings composed of electro-plated gold and NEY-ORO 28A brushes. The purpose of this test series will be to determine the effects of changes in oscillatory amplitude on the long term noise and wear life of the slip rings. Oscillatory amplitude will be varied from 0.1 to 1.0 degrees with 25 milliamperes of brush current. The LVDT (linear variable differential transformer) unit for determining oscillatory displacement has been installed and calibrated, and is capable of determining amplitudes as small as 0.05 degrees.

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 GSE (Ground Support Equipment) hydraulic pump because of the poor lubricating properties of RJ-1. As a result, emphasis has been placed on evaluating RJ-1 lubricating additives. Screening tests have been made on commercial additives at constant temperature in the Shell Four Ball wear tester. The Shell Four Ball wear test is a relative measure of the lubricating ability of the fluids. The results of these screening tests of RJ-1 lubricant additives have been published in a report. Four of these additives have been selected for tests in the RJ-1 pump simulator.

Additional tests on some of the Esso additives have been made on the Falex lubricant tester. The Falex tester is another relative measure of the lubricating ability of the fluid. The 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. A decision was made to add the results of these additional tests to the report mentioned in the above paragraph resulting in a delay of publication. During this report period four Esso additives; WS-5412, LG-84, LG-85 and QA-201 were tested in the Falex lubricant tester in RJ-1 fuel in concentrations of 300 ppm and 1000 ppm. Although data from the Falex tests indicate that the LG-84 additive provides better lubricity than does WS-5412 the latter additive is still recommended since parts lubricated with LG-84 are corroded within 2 hours after completion of the test.

The simulated ground support hydraulic pump was reassembled and several trial runs were made to check the several new components designed to reduce the vibrations encountered previously. A successful run of 19 minutes duration was made using RJ-1 fuel. Some signs of wear were exhibited on the wear plate and shoes. Three test runs totaling approximately 2 hours duration were made using 1,000 ppm of Esso WS5412 additive in RJ-1 fuel. Very little wear was noted on the shoes and wear plate. Vibrations were noted in the first of these runs but this was corrected by more careful assembly of the pump. Difficulty was encountered with the Sanborn recorder (torque measurement) and the instrument is being repaired. Preparations are being made for additional tests.

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, NAS8-5053, NAS8-11958
3. Peninsular Chem Research, Inc., 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
3. United Aircraft Corporation, NAS8-20089

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, NAS8-5351

F. Nondestructive Testing Techniques

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

III. S-II Stage

A. Investigation of the S-II-T Vehicle Failure

The analysis of the S-II-T stage failure was completed; however, several samples of rib and stringer cracks were retrieved for study. Analyses will consist of inspection studies, metallographic studies, diffraction surface studies and fractographic studies. This work is being done in support of the S-II stage rib and stringer cracking problem.

B. Study of the S-II Stage Hydraulic System Pump

Metallographic studies were made on two sets of pistons removed from the S-II hydraulic pumps at the request of the Propulsion Division. The studies were made to evaluate the brazed joint between the silver ring and the leaded 4140 steel piston shoe. The piston shoes were received from pumps that had undergone qualification tests at Brown Engineering Company and S&ID (Space and Information Systems Division of North American Aviation), respectively. The evaluation indicated that poor brazing was evident in both sets of the piston shoes. Scratches on the silver rings, as well as erosion of the silver rings were noted. Some of the ball joints on certain piston shoes did not move freely; the type of contamination causing this condition was not determined. It was recommended that bronze plated 4140 (unleaded) steel piston shoes of the type being used presently on the hydraulic pump of S-IB stage be considered for replacement of the present design used in the S-II pumps. If use of the silver ring type is to be continued, it was recommended that unleaded 4140 steel be used in place of the leaded 4140, and also, these finished piston shoes be radiographed to insure good braze integrity.

Metallographic studies were also made on a pitted cylinder block from an S-II hydraulic pump. The studies did not reveal any material discontinuities in the Muller 603 bronze bar. The pitting attack, which occurred in the cylinder head and walls, was caused by erosion-corrosion after a long period of operation. The extent of damage was not believed to be great enough to impair the successful operation of the hydraulic pump.

C. S-II Stage, Project Management, Materials

As a result of the debris analysis from the failed S-II-T stage, it was determined that a recirculation return line mounting boss had been cracked prior to tank failure. The inspection of other S-II stages revealed cracking of the same boss. Continued inspections led to the discovery of cracks in horizontal ribs, vertical ribs, LOX tank waffle ribs, and common bulkhead evacuation plugs. The stage contractor (S&ID) has been directed to provide this Center with an analysis of the cause of cracking and a proposed plan of action early in August 1966.

IV. S-IVB Stage

A. Developmental Welding

Work is continuing on the development of weld repair data for welding 3/8-inch 2014-T6 aluminum alloy plate. Panels have been prepared using 2319 filler metal with repairs made also with 2319 filler. The welding procedures used are automatic GTA (gas tungsten arc). Approximately 90 percent of these welds have been repaired the required number of times and then radiographed. Additional studies will be made on 2319 virgin welds using 4043 filler wire for repair welding, and 4043 virgin welds repair welded with 4043 and 2319 aluminum alloy filler metal.

B. Study of Sealant Used in Repair of S-IVB-202 LOX Tank

A repaired area in the LOX tank of S-IVB-202 flight vehicle is coated with a sealant marketed by the Dynatherm Corporation identified as D-4327. Tests have indicated that the material used is marginal in LOX compatibility. If it is deemed to be incompatible with LOX, additional coats of LOX compatible D-4327 could either be applied over the incompatible coating, or the incompatible material could be removed before applying the compatible material. To insure that an adequate seal coat is applied, ten coats of D-4327 are used. A seal consisting of ten coats of D-4327 is not adversely affected by cryogenic temperatures. To obtain information on the effect of cryogenic temperatures on thicker coats of D-4327, two test panels with 10 and 20 coats of this material were prepared. After multiple layered coatings had been applied to sheet aluminum panels, the specimens were dried for approximately three and one-half days and then rapidly immersed in liquid nitrogen (LN_2). After attaining equilibrium temperature, the specimens were removed from the nitrogen and allowed to warm to room temperature and examined for cracks. The specimens were immersed three times in LN_2 without any obvious deterioration. It is concluded that either overcoating the present coating, or removing it and reapplying another batch of the coating that is certified LOX-compatible would be acceptable.

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

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 and the outgassing constituents will be identified for possible toxic products. This project has recently been expanded to include testing in a 5 psia atmosphere.

1. Materials Testing in Vacuum

Tests are continuing on Dynatherm D-65, the material chosen as the flame-retardant coating for the S-IVB insulation, and Dynatherm D-65A, the primer coat for D-65. Weight loss determinations were made on a sample of D-65 over the temperature range from 80°F to 170°F (27°C to

78°C). The sample lost 2.7 percent of its weight during pump down to 10^{-6} torr pressure. Heating to 170°F (78°C) caused an additional 1.7 percent loss in weight for a total of 4.5 percent weight loss.

Another sample of D-65 was placed in a dessicator for 4 weeks prior to making a weight loss determination. The sample lost 3.7 percent of its weight while in the dessicator and during the time the sample was exposed to air during installation in the balance it regained weight continually. When the system was pumped down the sample again lost weight immediately until it reached the same value as in the dessicator. The pressure was reduced to 5×10^{-6} torr at 82°F (28°C) and held for eight hours. No further weight loss occurred. The temperature was then raised to 200°F (93°C) and held for 28 hours. This resulted in a weight loss of an additional 3.4 percent.

A sample of D-65A (primer coat) was exposed to 82°F (28°C) and 10^{-6} torr for a period of six hours with a resultant weight loss of 5.7 percent. The sample was held at the same temperature and pressure for 18 additional hours which resulted in a further weight loss of an additional 3.3 percent. The sample was then heated to 120°F (49°C) for six hours with a weight loss of 1.3 percent.

Mass spectra were taken on gases evolved from both D-65 and D-65A primer both at ambient and at elevated temperature. The mass spectra of D-65 showed peaks at 2, 12, 15, 16, 18, 26, 28, 29 and 44 when the D-65 was heated to 150°F (66°C), but after 8 hours at 200°F (93°C) only mass 2, 28, and 44 were evident. D-65A was characterized by much the same behavior; at 150°F (66°C) peaks at 2, 12, 15, 18, 28, and 44 were observed, but after 6 hours at 200°F (93°C) only 2, 28, and 44 were observed.

The D-65 spectra showed peaks at M/e values of 29 and 44 which could indicate the presence of aldehyde residuals. However, these peaks also correspond to the methyl radical and carbon dioxide, respectively, both of which are normally present in residual gas spectra in vacuum systems. Additionally, the presence of spectra peaks corresponding to M/e ratios of 28 and 14 (corresponding to CO and CO++) tend to confirm the identification of M/e 44 as CO_2 since these mass numbers are normally produced in a hot ion source from CO_2. Efforts will continue in these investigations to identify the products which may be expected to be evolved from exposure of D-65 and D-65A to reduced pressure.

2. Study of the Effects of Exposure to 5 psia Oxygen

The Douglas Aircraft Company has reported that the S-IVB insulation coated with Dynatherm D-65, D-65A and 904, can yield, in the presence of 5 psia oxygen, significant quantities of propion aldehyde, acetyl aldehyde, and formaldehyde. An internal testing program has been initiated to check these reports.

Two samples of D-65, 0.020 inch by 3 inches by 5 inches, were placed in separate test chambers, evacuated to 1 torr and backfilled with oxygen three times, and then pressurized to 5 psia, 100 percent oxygen. The samples were held in the oxygen atmosphere for 24 and 72 hours respectively and the gases were drawn off and subjected to gas chromatographic analysis. The analyses indicated only the presence of oxygen and nitrogen. Tests on the D-65A primer are in progress.

D. Investigation of the Flammability of Materials in Gaseous Oxygen

Preliminary flammability studies in 5 psia oxygen have been made on several materials of interest in the S-IVB Workshop Program. The basis for these studies lies in the concern that materials within the hydrogen tank of the S-IVB stage may constitute flammable hazards and consequent sources of toxic gases when in contact with the life support atmosphere of 5 psia oxygen. These initial tests have been made with hot wire ignition sources. Polyurethane rubber melted and then burned rapidly; 3-D foam melted with considerable smoke and then burned, balsa wood evolved considerable smoke before combustion and Teflon burned slowly while in contact with the ignition source.

E. 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. Auxiliary Propulsion System Oxidizer Tankage

a. Testing of two APS (Auxiliary Propulsion Systems) peened tanks has been completed at the Langley Research Center and a third tank is being held pending our evaluation of test data developed on the first two tanks. Test data on these tanks have not been received but are expected within the coming report period.

b. An APS tank has been provided for use in the joint NASA-USAF contract with Thiokol for development of elastomeric bladders for N_2O_4 (nitrogen tetroxide) service. This tank was rejected for flight application but is considered quite adequate for use in the bladder development program.

2. Unbonded Bracketry

Unbonding of bracketry continues to be a problem, but contractor efforts are being made to alleviate the problem. Procedures are being upgraded, and implementation of approved procedures is being enforced more strictly than before. Improved bond strengths are being realized, especially when a scrim cloth is used in the bond.

3. Weld Problems

A comprehensive survey was made to identify the materials aspects of weld problems in the S-IVB program. Weld techniques, processes, etc. were considered, including acceptance criteria. The only deficiency recognized was relative to acceptance criteria; however, actions to correct this deficiency have been initiated.

4. High Strength Fasteners

Waspaloy bolts having an ultimate tensile strength of 260 ksi were recommended by this division for joining the S-II and S-IVB stages to each other. This recommendation was made on the basis of hole sizes already provided. Delivery of the Waspaloy bolts became a problem; thus, this division recommended larger diameter bolts of A-286 having an ultimate tensile strength of 200 ksi.

5. Spent Stage Experiments

D-65 was selected as a flame barrier for coating the interior surface of the insulated tank wall, and the stage contractor was directed to apply this coating to S-IVB-209. No problem is anticipated, except for probable damage of the coating caused by cleaning the coated tank with a detergent wash. This problem can be eliminated either by overcoating the D-65 with a waterproof seal coat or by eliminating the detergent wash following application of the D-65. Both candidate solutions are being investigated.

6. The following documents were reviewed:

a. DAC proposal for an automatic ultrasonic weld inspection.

b. S-IVB retrorocket installation redesign (Saturn IB).

c. Review of contract end item detail specification (prime equipment) performance/design requirements S-IVB stage for use with Saturn SA-213 through SA-219.

d. Unbonding of the aft skirt purge duct (S-IVB stage, Saturn IB/V).

e. S-IVB coolant system cleanliness requirements.

f. DAC 1P00119A, "leak test, system and subsystem."

g. S-IVB stage mechanical control drawings.

h. DAC PRD 1P00125, "radiographic inspection: soundness requirements for fusion welds in aluminum and magnesium alloys."

i. DAC PRD 1P00126, sensor, temperature, process for bonding for cryogenic and ambient temperatures."

j. DAC PRD 1P00061D, "sensor, temperature, process for bonding."

k. S-IVB forward skirt test fixture, stress relieving thermocycle.

l. S-IVB spent stage experiment interim report, June 1966.

m. Shot peening requirements for Saturn V/S-IVB APS tanks.

n. DAC PRD 1P00127, "bolt and screw, installation of."

o. Use of HL-20 and HL-21 series Hi-lok fasteners in the aft skirt separation ring, S-IVB vehicle.

p. S-II/S-IVB physical interface bolts.

q. S-IVB adhesive bonding techniques.

V. Instrument Unit

A. General Corrosion Studies

Testing has been completed in the determination of the corrosion resistance of brazed (82 percent gold and 18 percent nickel) joints of stainless steel tubing in inhibited methanol-water solution. No visual corrosion was evident after exposure of 90 days in the solution. Testing has continued in the study of the corrosion of magnesium-lithium alloys and protective coatings for these alloys.

B. Instrument Unit, Project Management, Materials

Studies have continued on the Environmental Control System Manifold weld cracking problem. After reviewing radiographs and making a metallographic study of one weld joint it appears that the manifolds presently made should perform satisfactorily. The primary problem is the high rework rate required to produce these manifolds. This aspect of the problem is being investigated by the Manufacturing Engineering Laboratory.

VI. F-1 Engine

Failure Analysis of an F-1 Engine Flight Supply Line

Failure analysis was completed on an F-1 engine flight supply line (part number R11620-1) that failed after 1150 seconds of testing by Rocketdyne Division personnel. The 321 stainless steel line, manufactured

by Resistoflex, Incorporated, is not a qualified part and is being used in ground tests until the flight configuration is available. Metallurgical analysis revealed that failure of the weldment resulted from fatigue. An identical failure of an F-1 engine supply line of the same configuration occurred in a local test facility on the 4T2 (single engine) block IV gimbal system. Recommendations were made that called for dye penetrant inspection of all components of this temporary design if they are to be used before flight hardware is received. If cracking is found, the defective component should be replaced.

VII. J-2 Engine

Investigation of Insulation for Use on the J-2 Engine

The thermal insulation system proposed for the J-2 engines of the S-II and S-IVB stages has been evaluated under specified conditions which simulate the environments the insulation must withstand on the respective stages during Saturn V and Saturn IB flights. The insulation system consists of a 0.280-inch thickness of Larodyne NA3310-23-4 insulator bonded with NA3310-23-11 adhesive and GE SS4155 primer to a sheet steel substrate. The insulation is overcoated with a 0.015-inch thickness of NA3310-23-7 vapor barrier. The results of the environmental tests indicated the insulation system is adequate for protecting the J-2 engines under conditions imposed by use on both S-IVB and S-II stages.

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. Hughes Aircraft Company, NAS8-5499
3. Goodyear Aerospace Corporation, NAS8-11070
4. W. R. Grace Company, NASw-924
5. 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

1. Southwest Research Institute, NAS8-20160
2. 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. North American Aviation, Incorporated, NAS8-11108
4. Melpar, Incorporated, NAS8-11322
5. Douglas Aircraft Company, NAS7-429
6. 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, NAS8-5340, NAS8-11226, 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

1. Stanford Research Institute, NAS8-20220
2. Air Reduction Company, NAS8-20078

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

1. General Dynamics Corporation, NAS8-2450
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

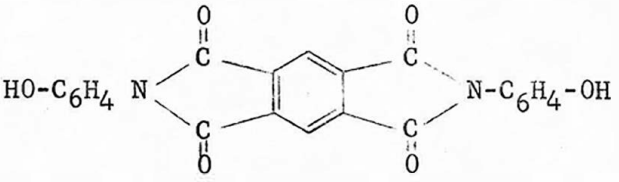
To obtain thermally resistant materials which are processable for applications as films, adhesives, coatings and structural shapes in space environment, condensation polymers of the semi-organic type are being studied. In present technology of addition polymerization, poly(tetrafluoroethylene) represents the most thermally resistant material obtained by the ethylene-type polymerization. Thus, the condensation type of polymerization seems to offer greater opportunity for producing materials of greater thermal stability. It has proven to be very difficult to produce processable materials of very high molecular weight by the condensation process in the laboratory and only a few systems, including that developed here, have been discovered. The ability to produce processable, semi-organic, condensation polymers of high molecular weight has been developed by this division, in significant part, from advances made here in the chemistry of the silazanes. Among the number of compositions of improved heat resistance which have been produced, Polymer A has been judged as the product possessing an optimum combination of properties for general use. The work is continuing to produce structures of still greater thermal resistance and greater utility for specific space applications. The recent efforts have been devoted largely to the polyarylsilanes and related compositions.

1. Monomer Preparation

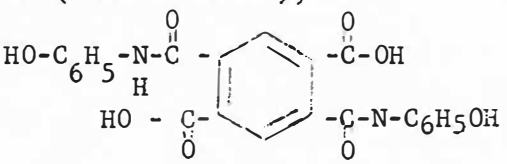
a. Additional preparations of phenyl(trianilino)silane and bis(anilino)diphenylsilane were made by methods described previously. The former is being employed as a crosslinking agent and the latter as an intermediate.

b. N,N'-p-hydroxyphenylpyromellitic Diimide

This pyromellitic diimide has been suggested for use as a



comonomer for the preparation of polyaryloxysilanes containing the highly stable pyromellitic group. In the June report it was noted that the diamide diacid ("diamic acid"),

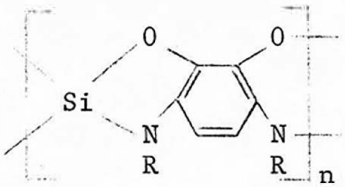


prepared by the condensation of pyromellitic dianhydride with p-aminophenol, exhibited an endothermic absorption at 500°C in differential thermal analysis Analysis with the gas chromatography unit showed that only water is evolved at 500°C. A sample of the diamic acid was heated overnight at 430°C. Infrared spectra of the product indicated that dehydration had taken place with the formation of the diimide. Elemental analysis was not possible with conventional combustion equipment since oxidation was incomplete under the conditions normally employed.

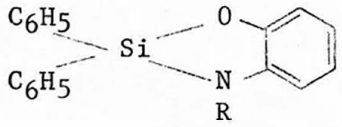
Preparations of the diester and the diacylchloride of the diamic acid were attempted, on the assumption that the diimide might be formed more readily by the elimination of ethanol or hydrogen chloride than by the elimination of the water. From the work completed it does not appear that either the acid chloride or the ester were formed by conventional reactions. Other means for effecting the cycloclization and confirmation of the diimide structure are being explored.

c. Diphenylanilinoethoxysilane

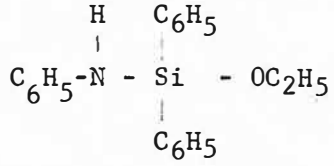
The following amino siloxane polymeric structure is of potential



interest. To establish the feasibility of the necessary synthetic reactions it was decided to prepare the monomeric structure,



by the reaction of o-aminophenol with diphenylethoxyanilinosilane,



The preparation of the compound by exchange reactions between diphenyldiethoxysilane and diphenyldianilinosilane and between diphenyldianilinosilane and ethanol are being studied. Among a number of sets of reaction conditions which have been explored, it appears that the former process in the presence of metallic sodium at 105°C and the latter without catalyst at 80°C offer promise.

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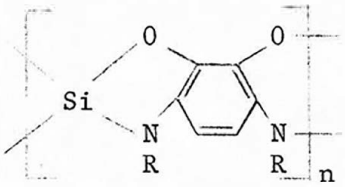

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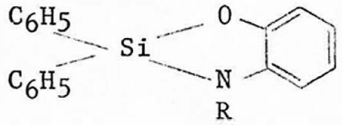

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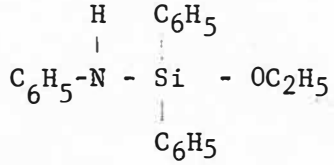

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2. Preparation of Polymers

a. Crosslinking Poly(4,4'-bisoxybiphenylenemethylvinylsilane)

In order to gain further information regarding the crosslinking of polyaryloxysilanes of the Polymer A type, some of the conditions for the curing of a prepolymer of the methyl vinyl counterpart of Polymer A were explored. A prepolymer of approximately eight repeating units was prepared by the melt condensation for 6 hours at 230°C of bis(anilino)methylvinylsilane with p,p'-biphenol. The product, dissolved in solvents such as the chlorobenzene was treated with several peroxides and free radical forming agents at 75-125°C. Examination of the treated products indicated that in each case some crosslinking or chain growth had taken place. It is apparent that the vinyl group in this system reacts sluggishly.

b. Preparation of Polymer A by Condensation in Solution

As mentioned above, Polymer A was discovered as a result of the developments in the chemistry of silazanes and has been prepared by the melt condensation of diphenyldianilinosilane with p,p'-dihydroxydiphenyl with the elimination of aniline. Upon establishing the structure and the promising properties of Polymer A it became obvious that the materials could be formed directly by the reaction of diphenyldichlorosilane and dihydroxydiphenyl thereby eliminating the necessity to prepare and purify the diphenyldianilinosilane,

$$(C_6G_5)_2\ SiCl_2 + HO\ C_6H_4 \cdot C_6H_4OH \xrightarrow[\text{catalyst}]{\text{solvent}} \left[(Si)(C_6H_5)_2(-O\cdot C_6H_4\cdot C_6H_4\cdot O)\right]_n + 2NH_4Cl$$

To establish the point, the equimolar quantities of diphenyldichlorosilane and p,p'-dihydroxydiphenyl were added to refluxing 1,2,4-trichlorobenzene (213°C) as diethylamine in nitrogen was bubbled through the solution. The polymerization took place smoothly.

B. Development and Characterization of Phosphonitrilic Polymer

The projected synthesis of substituted phenylphosphonitrilic chloride tetramers was continued with the study of the reaction of 2,4,6,8-tetrachloro-2,4,6,8-tetrakisdimethylaminophosphonitrilic tetramer with excess phenylmagnesium bromide:

$$P_4N_4Cl_4(N(CH_3)_2)_4 + 4\ \text{Ø}MgBr \longrightarrow P_4N_4\text{Ø}_4(N(CH_3)_2)_4 + 4\ MgBrCl$$

The tetrakisdimethylamide derivative was prepared in the previously described fashion through the reaction of stoichiometric amounts of $(PNCl_2)_4$ with dimethylamine. The isomeric mixture was recrystallized, in 40 percent yield, from petroleum ether-benzene as white crystals with a melting range of 130-140°C.

In a series of experiments it was determined that the most promising approach to Grignard arylation of the PN ring was through the use of dibutyl ether at 132°C.

In a typical run, the tetrakisdimethylamide was dissolved in chlorobenzene and added to a dibutyl ether solution of ØMgBr, from which the diethyl ether had been removed through distillation with noncommittant replacement by dibutyl ether and heated at reflux (132°C) for 7 hours. During this time solid material separated from the reaction mixture. The cooled mixture was poured into ice water containing hydrochloric acid and the resulting two phase system separated. The reaction solution was worked-up in the normal fashion. The organic layer was dried for 24 hours over anhydrous magnesium sulfate, filtered, and then concentrated <u>in vacuo</u> to a yellowish oil (89 percent yield).

All attempts to effect crystallization of the oil were unsuccessful. Although it was not desired to effect any isomer separation at this point, in an attempt to purify the crude material enough to allow crystallization to occur, the oil was dissolved in cyclohexane and chromotographed on activated alumina. Successive column elutions with mixtures of cyclohexane, benzene, and diethyl ether failed to give any solid derivative. Furthermore, only a 66 percent recovery from the column was realized.

Characterization, therefore, was limited to spectral examination of the original oil where the infrared spectrum was consistent with the proposed structure.

To further confirm the fact of complete replacement of the chlorine atoms with phenyl groups, the oil was dissolved in diethyl ether and treated with a large excess of gaseous dimethyl amine. No amine hydrochloride salt separated indicating complete prior replacement of the halogen atoms.

The semi-characterized arylated isomeric mixture was next subjected to the regeneration step in order to obtain $(ØPNCl)_4$ monomers:

$$P_4N_4Ø_4\left[(N(CH_3)_2\right]_4 + 8\ HCl \longrightarrow (ØPNCl)_4 + DMA\cdot HCl$$

To this end, the oil was dissolved in glacial acetic acid and the stirred solution treated with anhydrous hydrogen chloride (HCl). The temperature rose spontaneously to a maximum of 42°C. At this point the temperature was elevated through external heating to 55-60°C while continuing the introduction of the gaseous HCl. Solid material separated from the solution, and additional HCl was introduced at 55°C to 60°C for one hour. At the end of this time the excess HCl was removed through a nitrogen purge and the mixture was then concentrated <u>in vacuo.</u> The residue was treated with benzene and the mixture filtered. The weight of the dimethylamine hydrochloride salt corresponded to a yield of 65 percent.

Although it was realized that the product was contaminated with unregenerated tetrakisdimethylamides, the oil obtained upon concentration in vacuo of the filtrate was triturated with petroleum ether and the resulting mixture stored at sub-zero temperatures in an effort to obtain a solid derivative. If no solidification occurs, the oil will be re-treated with additional anhydrous HCl to effect quantitative regenerated $(\text{ØPNCl})_4$.

The results of these efforts mark the first successful nongeminal aryl substitution of the tetrameric PN ring through the Grignard reaction. If complete regeneration of the tetra chloro compounds can be achieved, then a number of reactions can be run in which alkyl substituted phenyl Grignards can be used to arylate the PN ring system.

C. Investigation of Materials for Electrical Contacts in Vacuum

Electrical contacts in vacuum concerns any device for transferring electrical energy through moving contact surfaces, such as brushes, slip rings, and make-break switches. Standard brush-commutator type machines suffer a severe degradation of performance at high altitudes, principally due to rapid wear of the graphitic carbon brushes. This results from failure of the normal process of lubrication of the contact surfaces. Therefore, this program was initiated to develop electrical brushes for use in a space environment.

During the reporting period, tests were made on brushes consisting of 80 percent niobium diselenide-20 percent molybdenum disulfide ($80NbSe_2$-$20MoS_2$) and 60 percent niobium diselenide - 40 percent molybdenum disulfide ($60\ NbSe_2$ - $40\ Mo\ S_2$). Results of these tests were as follows:

Brush Material	Test Duration	Negative Brush	Positive Brush
80% $NbSe_2$-20% MoS_2	285 hours	0.0000035	0.0000035
60% $NbSe_2$-40% MoS_2	117 hours	0.00017	0.000043

The constant pressure brush loading device was fabricated and checked out during this reporting period. Tests were made in air, using the new loading device, to determine the coefficient of friction of several brush materials. Tests were made with a brush pressure of 10 psi or about 0.48 pounds. Speed was maintained at 2,450 rpm, and the test duration was 1 1/2 hours. The results of these tests were as shown in the following tabulation.

Coefficient of Friction of Experimental Brush Materials in Air

Brush Material	Average Coefficient of Friction in Air
100% $NbSe_2$	0.67
85% MoS_2 - 15% Ag	0.12
60% $NbSe_2$ - 40% MoS_2	0.37
80% $NbSe_2$ - 20% MoS_2	0.44
80% $NbSe_2$ - 20% TaS_2	0.60

Further resistivity versus temperature determinations are being made on the molybdenum disulfide-silver composites to fully define the conduction mechanism and to resolve the apparent discrepancy in the resistivity of the two types of MoS_2. Determinations were also made on niobium diselenide and tantalum diselenide.

Sample A-130 (100 percent 2.5 micron MoS_2) has a negative temperature coefficient of resistivity and is semiconducting. In the higher temperature region it exhibits the definite break characteristic of a semiconductor entering the intrinsic conduction region. The energy band gap calculated for this is 0.54 electron volts. The relatively high resistivity of this material indicates that it is relatively pure. However, sample C-33 (100 percent 4 micron MoS_2) while possessing a negative temperature coefficient of resistivity has a resistivity lower than the A-130 sample by a factor of 400 indicating a high density of impurities which are contributing charge carriers to the conduction band. No energy band gap can be calculated for this material since the temperature required to reach the intrinsic region would destroy the materials.

Preliminary tests have begun on samples of (85 MoS_2-15 Ag) pressed at different pressing temperatures. Sample A-185, pressed at 1710°F (932°C) had a fairly high resistivity and a negative temperature coefficient characteristic of metallic conduction. This is probably due to a change in the diffusion rate of the silver atoms into the MoS_2 host lattice, since a dispersion of silver atoms is much easier to ionize than the same number of atoms bonded in a pellet.

D. Investigation of the Dielectric Properties of Materials

Testing is continuing in the evaluation of ability of selected additives to increase the conductivity of RJ-1 fuel. If a suitable additive can be found which, in low concentrations, can increase the conductivity of the RJ-1 fuel then use of the fuel in the hydraulic system of the S-1C stage will not result in an accumulated charge and electrical breakdown of the Teflon tubing of the hydraulic system will be avoided. Tests have been completed in the evaluation of Shell ASA-3 additive and the test data are being analyzed.

To more fully characterize the conductivity mechanism of RJ-1 both with and without additives, a Hall effect cell for use with liquids was designed and fabricated. The cell has been checked and preliminary tests on pure RJ-1 are in progress.

Because Mylar flat cables currently are used in launch vehicles and spacecraft, a study has been made to determine the changes in electrical properties produced by exposure to the environment of space. Mylar flat cables were exposed to equivalent solar ultraviolet radiation both at an environmental pressure of 10^{-9} torr and in air. Periodic measurements were made of the dielectric constant, dissipation factor, and conductivity throughout the tests. Test data indicate no appreciable change in any of the three parameters.

E. Investigation of Nuclear Environmental Effects on Materials

1. Study of the Effect of Radiation on Elastomers

A program has been initiated to study the effects of charged particle irradition of elastomeric materials. Much data has been obtained on the effect of gamma radiation but very little information is available on charged particle effects. The ultimate goal of the program is to obtain sufficient data to determine whether a correlation exists between radiation damage produced by electron and gamma radiation.

Twenty-four specimens each of natural rubber, Viton-A, silicone, and Buna-N have been tested to determine the effects of electron radiation on the tensile strength and ultimate elongation of these materials. Tests were made for exposures of 1.13×10^{14}, 1.13×10^{15}, and 1.13×10^{16} electrons/cm^2 using 1 Mev electrons. The Viton A shows a steady decrease in both tensile strength and elongation with increasing dose. The silicone shows a steady increase in tensile strength and a steady decrease in elongation with increasing dose. Both the natural rubber and the Buna-N specimens show a gradual increase followed by a rapid decrease of tensile strength; however, the shape of the elongation curve is similar to that of the tensile strength curve.

2. Application of Radiation Induced Defects to the Study of Stress Corrosion

The stress corrosion testing of the longitudinally cut 7079-T6 aluminum tensile specimens is being continued. Upon completion of these tests, the data will be analyzed to determine to what extent the proton bombardments influenced the stress corrosion mechanism and to establish the parameters for the next proton irradiation.

3. Vacuum Tensile Tests

A program has been initiated to determine in-situ the effects on the tensile properties of materials of 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.

Selected materials of films, foams, adhesives and elastomers make up the first initial test. Testing of the films is already underway and will take an estimated 10 weeks to complete.

New grips for testing foams are being designed. A new system for heating the specimens utilizing infrared strip heaters are also being designed.

F. Development of Materials for Direct Current Motors for Use in 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.

A series of torque-speed runs have been completed on the motor generator set. These tests were made at ambient temperature and at a pressure of 1×10^{-6} torr. The field currents of the motor and generator were maintained at 1.5 amperes by running both the motor and generator as separately excited machines. The motor characteristic curves of output torque and efficiency were determined for armature voltages of 40 and 50 volts.

G. Study of the Compatibility of Lubricants with MIL-H-5606 Hydraulic Fluid

Tests were started to determine if Dow Corning DC-4 (silicone compound) lubricant and technical petrolatum (VV-P-236) are compatible with hydraulic fluid. A testing device was designed and fabricated whereby four samples of the same lubricant could be tested at one time resulting in more reliable data. This is obtained by fastening 4 screened cups each containing approximately 4 grams of the lubricant to a four spoke wheel. All four cups are submerged in the hydraulic fluid and the 6 inch diameter wheel is rotated by a directly coupled 1 rpm motor. The hydraulic fluid can be heated by placing the container on an electric hot-plate. The samples are carefully weighed before and after test to check the weight loss or weight gain. Two tests have been run with DC-4 for one hour and 45 minutes duration each. The average temperature of the hydraulic fluid was 175°F (79°C). The results showed that the DC-4 under the conditions of the test undergoes an average increase in weight of 7 percent indicating some adsorption of hydraulic fluid. Additional tests will be made at various temperatures.

H. Determination of Physical Properties of Materials by Nondestructive Techniques

1. Internal Friction Measurements

Damping measurements have recently been made on about fifty 7079-T6 aluminum specimens in air and in a vacuum. Specimens of 1/8 inch and 3/16 inch diameter machined in the short transverse and longitudinal directions are included in this study. Very satisfactory results were obtained with the 3/16 inch diameter specimens. Material cut in the short transverse direction and subjected to both stress and the salt solution showed rapidly increasing energy losses with increasing exposure times. Material exposed only to the salt solution with no stress showed little energy loss. Specimens cut in the longitudinal direction followed the same general pattern, but the magnitude of the energy losses was much less.

Unsatisfactory results were obtained with the 1/8 inch diameter specimens. The difficulty of machining such small diameters without twisting appears to be the major problem. Therefore, all future work in this area will be done with 3/16 inch diameter specimens.

2. Electrical Conductivity

Electrical conductivity measurements have been made to determine the relationship between surface conductivity changes and stress corrosion damage. Conventional eddy current instruments can be used to measure these conductivity changes on flat specimens. However, special instruments and transducers are required for small cylindrical specimens. Conductivity measurements have been made with conventional equipment on about fifty flat specimens. Part of these specimens were cut in the short transverse direction and part in the longitudinal direction. Subsequent to being exposed to stress corrosion, only the specimens cut in the short transverse direction showed any appreciable change in specimen conductivity.

Specimens stressed to 75 percent of yield strength for as long as five hundred hours in air only, showed no appreciable change in electrical conductivity. Thus, it appears that the previously observed conductivity changes were produced by stress corrosion and were not caused by stress alone.

I. Investigation of the Materials Aspects of Joining Metallic Composites

Work has continued on the investigation of various techniques applicable in the development and joining of metallic composite materials. These investigations include diffusion bonding, and various solders and soldering techniques.

1. Study of Diffusion Bonding of Various Metals

Work has progressed in this program to the point that basic parameters and techniques for the solid state diffusion bonding of titanium, aluminum, and magnesium have been established. Therefore, steps are now being taken towards the development of a composite material. The composite being studied is beryllium wire in a magnesium matrix. Because of bonding difficulties with magnesium, silver plating is being studied as a means of improving the bonding characteristics.

2. Evaluation of Solders for Joining Materials

As reported last month, tests were made on previously soldered aluminum honeycomb composite samples. The test results were not as good as expected. Failed specimens showed considerable solder segregation occurring primarily in the center portion of the specimens, indicating either overheating or uneven heating. Additional samples will be made to further evaluate this problem.

3. Development and Evaluation of Methods for Laminating Various Light Weight Materials

A metallic laminate was prepared by diffusion bonding a machined grid of 6Al-4V-Ti alloy sheet, between 2024 aluminum facings. Test specimens cut from this laminate yielded an average tensile strength of 45,000 psi. Specimens taken from diffusion bonded aluminum sheets, minus the titanium grid, showed a tensile strength of 32,000 psi approximately 35 percent less than the reinforced laminate. However, specimens of both the aluminum to aluminum and the titanium reinforced laminate showed elongations of only 1.5 percent. It is anticipated that by experimentation with thermal treatment variations, significantly higher ulitmate tensile properties may be achieved.

J. Investigation of Inorganic Adhesives for Use in Contact With Oxidizers

Efforts have continued in the development of ceramic adhesives for bonding aluminum alloys. Compositions being investigated contain monoaluminum phosphate ($Al_2O_3 \cdot 3\ P_2O_5 \cdot 6\ H_2O$) as the binder, clay and powdered alumina (Al_2O_3) as filters, and chromium oxide (CrO_3) as an inhibitor to control the reaction rate between the binder and aluminum alloy adherends. Studies were made to determine the effects on the room temperature shear strength of the adhesive of aging the mix for 2, 24, 48, 72, 96, 168, 336, and 504 hours. The results indicated that pot life was not a factor of concern. In fact, the adhesive appeared to gain strength after the longer periods of aging.

A parallel series of test samples was made and tested for shear tensile strength at -300°F (-184°C). To date, typical strength values average approximately 75 and 150 psi at room and cryogenic temperatures, respectively. It is believed that these values can be improved significantly as time proceeds.

K. Development of Techniques for Growth of Large Single Crystals of Metals and Compounds

The purpose of this project is to develop methods for zone refining materials to extreme purity and then develop techniques for growing large single crystals of metals and compounds for research on these materials. Single crystals with controlled defects and impurity gradient distribution will be grown.

Since vertical float zone refining of aluminum using manual control proved impractical because of the low surface tension of the molten aluminum, an automatic temperature control system was required. A control system was designed and constructed which utilized a multiple range emissivity compensated optical pyrometer as the sensing element feeding a variable suppression type microvolt null detector. The output of the null detector was used to provide control current to a magnetic amplifier which in turn controlled a 10 KW polyphase saturable core reactor in series with the input of the RF generator. The apparatus provides smooth control, excellent repeatibility and uniform temperature ($\pm 2°C$) in the range from 400 to 1500°C.

The apparatus was utilized to produce titanium specimens in support of an investigation of the mechanical properties of titanium alloys through observation of the behaviour of individual crystals in the material. Samples of Ti-6Al alloy were prepared by the strain anneal method to take advantage of the fact that grain or crystallite size tends to increase when annealed while in a strained condition. A strain was produced in the titanium alloy by a large temperature gradient induced by a single turn induction coil operating at one megahertz. The high temperature region is then annealed by moving the zone. Thirty-two zone passes were made at a zone speed of 2 cm/min with the hot zone temperature at 850°C. The resulting grain structure was very prominent and the individual crystallites tended to be elongated in the direction of zone movement. Grain size was brought from sub micron levels prior to treatment to two centimeters in length by one centimeter wide (average) after strain-anneal.

L. Documentation Review

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

1. MSFC SPEC 471, "Solvent 1, 1, 1-Trichloroethane, High Purity, Inhibited"

2. NAA SPEC MA0104-017A "Processing of Photographic Etched anodized aluminum Name Plates"

3. MSFC SPEC - 341, "Cleaning, Testing, and Hnadling Hydraulic Components when RP-1 or RJ-1 Fuel is used as Hydraulic Fluid"

4. NAA SPEC MA0103-004 D, "Chem-Mill Processing of Wrought Aluminum Alloys"

5. NAA SPEC MA0109-004 D, "Electroless Nickel Plating"

6. Thiokol SPRC 7721, "Purge, Flush, and Cleaning Procedure TD - 345 Rocket Engine Spacecraft (RES), Process Specification for"

7. NAA SPEC MA0101-007, "Installation of Quick-Acting Fasteners"

8. MSFC-STD, 156 A (proposed), "Riveting, Fabricating, and Inspection"

9. Douglas Aircraft SPEC 1P00127, "Bolt and Screw, Installation of"

10. NAA SPEC MB0170-047E, "Aluminum Alloy 2020 Bar, Rod, and Shapes, Extruded"

M. Literature Survey

Surveys of the pertinent literature have been initiated or 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

JULY 1, 1966 THROUGH JULY 31, 1966

I. Radiographic Inspection

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

II. Photography

	Negatives	Prints	Other
Engineering Photography	61	158	
Metallography and Fractography	19	140	
Miscellaneous photography, processing, copywork, etc.	116	180	165

III. Metallurgical and Metallographic Testing and Support Services

A. Photomicrographs were made of a rotary seal surface of a rotating swivel joint at the request of the Research Projects Laboratory.

B. An evaluation was made of weld cracking problems associated with the Instrument Unit manifolds which are being built by Solar. Based on limited information available on the problem, the recommendation was made to modify the presently used welding technique from a three-pass weld to a one-pass weld using the appropriate filler wire.

IV. Spectrographic Analyses

Seven hundred and thirty-nine spectrographic determinations were made on forty-two samples and three hundred and seventy-two standard determinations were made.

V. Infrared Analyses

Samples of nine experimental polymers, two adhesives and Dynatherm D-65 and D-65-A and numerous fractions of these latter materials were analyzed qualitatively by infrared techniques during this report period. Quantitative determinations were made of contamination removed from an S-IVB LOX dome.

VI. Chemical Analyses

	Determinations
methanol water mixture for	
sodium benzoate	16
Freon for water	2
Gold plating solution for	
potassium cyanide	2
gold	2
metal samples for	
carbon	22
chromium	14
sulfur	14
RP-1 fuel for moisture	2
fluorinated polymers for	
carbon	6
hydrogen	6
gas samples for	
nitrogen	14
oxygen	43
hydrogen	4
carbon dioxide	12
chromatographic analyses	58

VII. Physico Chemical Analyses

	Determinations
Density of RP-1 fuel	34
pH of methanol water mixture	16
Specific resistance of methanol water	16
Heat of combustion of RP-1 fuel	2

VIII. Rubber and Plastics

	Items
molded or extruded	161
cemented	76
coated	1
fabricated	455

IX. Electroplating and Surface Treatment

	Items
cleaned	27

X. Development Shop Production

A. A total of 7,384 man-hours, direct labor, was utilized during this period for machine, fabricating, and welding.

B. One thousand six hundred and six man-hours, approximately 21.8 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. P&W Inducer Test Components

The P&W inducer test components have been completed and delivered.

2. 3,000 PSI Injector Body

Components for a 3000 psi injector body are being manufactured.

3. Box Cryostat

The Box Cryostat has been completed and delivered.

4. H-11 Specimen Components

Preparation of H-11 steel specimens is complete.

5. Chamber Section - Hydro Coil Lined

Components of the Chamber Section have been submitted for final machining.

6. Diaphragms-Dies

Machine work is in process on the diaphragm dies.

XI. Miscellaneous

A. Fifteen aluminum alloy items, four items of steel, and six items of titanium alloy were heat treated during this report period.

B. Ultrasonic velocity and acoustic impedance measurements were made on specimens of phosphor bronze, titanium, "K" Monel and stainless steel for Astrionics Laboratory.

C. The radiant energy output and radiant heat distribution of General Electric Model No. PLG 401W, 375-watt heat lamps (reflector type) were determined under specified conditions. Two lamps were tested to determine the variation in the heat output and distribution of the lamps. This work was done for Propulsion Division, R-P&VE-P.

D. Five water samples of known specific resistance were prepared for Test Laboratory.

E. Several component parts were bonded to an experimental structure for the Structures Division.

XII. Publications Issued

None.

J. E. Kingsbury