PROPULSION AND VEHICLE
ENGINEERING LABORATORY

X1.10
X1.11
X1.14

MONTHLY PROGRESS REPORT

For Period

May 1, 1966, Through May 31, 1966

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (September 1961)

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-66-5

MONTHLY PROGRESS REPORT

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

Advanced Studies Office
Vehicle Systems Division
Structures Division
Materials Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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-66-5

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

SATURN V

S-IVB Stage Synchronous Orbit Study

A Center-wide kickoff meeting was held initiating a "second-look" effort directed toward doing a synchronous orbit mission using the S-IVB stage for the terminal maneuver. The primary goal for this effort is to determine the least expensive and simplest ways to accomplish the mission by careful analysis of the mission to eliminate as many stage modifications as possible. The modifications that are required will be kit-on type installable at KSC. This effort is expected to end about August 1, 1966, at which time a formal report will be published.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

A. S-IVB Workshop

Design studies for the S-IVB Spent Stage Experiment Support Module (SSESM) are continuing in several areas, including stage modifications, overall configuration, experiment integration and meteoroid protection analysis. The S-IVB stage internal attachments, fittings, and coating have now been defined. Criteria are being developed for the passivation cable and the hydrogen hand valve with design studies continuing on the helium sphere covers and the installation of ropes for

the astronauts. A current configuration of the SSESM has been prepared and will be revised as definitions of spent stage experiment equipment become available. Engineering data are also being consolidated and developed for the MSFC version of the experiment support module.

Efforts are continuing to determine a logical evolutionary approach to the utilization of the S-IVB stage and to develop conceptual designs of selected points within the framework of the evolution program. Initial growth versions have considered the proposed 30-day AS-209 S-IVB Workshop with the present available payload and no resupply. Later versions will consider resupply and multiple Saturn IB launches. Investigations are being made to define feasible and desirable experiment groupings for these later-version S-IVB Workshops.

B. Extra Vehicular Engineering Activity (EVEA)

Two initial concepts of an extra vehicular platform in earth orbit for men and materials have been developed. These concepts will be further defined until one can be selected for preliminary design. In addition to the platform concepts, preliminary requirements have been developed for EVEA equipment.

C. Space Structures

Design requirements and a definition of available design trade-offs are being developed for various types of earth orbital radio telescopes and antennas which operate at wavelengths of radio emission not observable on earth. Potential mission applications and the effects upon design requirements are being identified. After selection of specific antenna and radio telescope types and configurations, the conceptual designs will be initiated. A preliminary configuration of a space assembly facility, to be used for space assembly of radio telescopes and antennas, and a definition of required supporting equipment are also being prepared.

D. Apollo Telescope Mount (ATM)

Support has been given to Industrial Operations, I-SC-E, in the preparation of a statement of work for Grumman supporting analysis of LEM/ATM integration. The contract, which will be an addendum to the present study contract that MSC has with Grumman, is expected to begin the first part of June 1966. Present efforts include formulating the contract management panel and defining the required in-house study efforts.

E. Astronomy Experiment for Apollo

At the request of Research Projects Laboratory, supporting efforts have been initiated to prepare drawings for construction of a mock-up of the Astronomy Experiment for Apollo, including preliminary design efforts for integration of the astronomical instruments on the LEM. Completion of construction of the mock-up and presentation of the program proposal to MSFC management are scheduled for August 1, 1966. Planned instruments for the experiment include ultraviolet cameras, ultraviolet spectrographs, X-ray detector, and gamma ray detector. It is presently anticipated that fabrication of the instruments for the experiments would be a joint effort between MSFC, Naval Research Laboratory, Oak Ridge National Laboratory, and the University of Arizona - Steward Observatory. Present efforts are involved with preliminary definition of configuration and support requirements of the instruments and integration of these instruments with the LEM.

II. Lunar Surface

A. Local Scientific Survey Module (LSSM)

The BECO-built LSSM Mock-up was demonstrated to Dr. Lucas and other P&VE management personnel. After the demonstration the steering mechanism was damaged; however, the vehicle has since been repaired and the steering rate performance improved.

B. Mobility Test Article (MTA)

Personnel from this Office assisted in the negotiations concerning the current overrun of the General Motors MTA. An ad hoc task group was assembled to visit the GM Santa Barbara facility to inventory the MTA. A detailed cost-to-complete estimate was made by the task group on a part-by-part basis. The vehicle is about 90 percent complete. The majority of remaining work is on electrical systems and instrumentation, with some machining required on rear unit suspension.

Personnel from this Office briefed Messrs. Gorman, Neubert, and Shepherd (DIR) on the Bendix MTA, which is located in building 4650. A formal demonstration of the vehicle will be conducted on June 1, 1966, for all interested Center personnel. During the briefing, Mr. Shepherd requested that a five-minute film of MSFC's activity toward lunar surface exploration be prepared and shown at the next OMSF Council meeting.

Personnel from this Office met with the Chiefs of Structures Division and Vehicle Systems Division to discuss the possibilities of their Divisions assisting or assuming direction responsibility in MTA project activity areas. Both Division Chiefs agreed to support these efforts.

C. Lunar Backpack Jumper

Work is continuing in the preliminary definition and conceptual design of a propulsive unit to enable an astronaut to jump longer distances on the lunar surface. Work performed this month includes a nozzle exhaust plume study to determine effects on the space suit, evaluation of canted versus uncanted nozzle configurations, and further definition of mechanical controls and system simplifications. It is presently planned to build a full-scale model of the Lunar Backpack Jumper.

NUCLEAR ROCKET PROGRAM

I. Nuclear Ground Test Module Program

All technical effort on the past study program has been completed. Writeups describing technical effort accomplished by Task Force participants are being collected. A final report on this effort will be prepared shortly. Effort to prepare guidelines for the future study has been delayed due to the absence of any definite study organization or study plan.

II. Nuclear Flight Safety

Errors have been discovered in the technical approach being followed in the in-house launch azimuth study, resulting in an interruption in the effort until an alternate approach may be implemented. This alternate approach will require participation by R-AERO. A study plan for the R-AERO effort is being prepared.

The LMSC Safety Study has finally reached publication. The reports are due to be distributed shortly. The follow-on effort has passed the proposal evaluation status and is awaiting negotiation.

ADVANCED PROGRAMS

I. Launch Vehicle

A. Reusable Orbital Transport (ROT) Studies

Characteristics of the slipper and rail concepts that have been investigated to date are materials, number of slippers required on the sled, and track bearing medium between slippers and rails. Six different rail design configurations and different concepts of height placement and arrangements of the tracks have been investigated. Track bearing mediums include air-bearing, metal-to-metal, and hydrofoil systems.

B. Advanced Stage Design Study

The initial phase of this study has been completed. Results have been documented and presented to management. In this phase of the study, a comparison has been made between S-IVB, S-IVA, and the Lewis kickstage concept. Also, a typical kickstage concept with toroidal tanks and bell and toroidal engines has been analyzed. Future work on advanced stage designs will be a more detailed analysis of specific tank location and structural support arrangements.

C. Kickstage Study

A study of storable and cryogenic kickstages for maneuvering Saturn IB, Saturn V and uprated Saturn V payloads in earth orbit has been initiated. Results to be produced in the study are stage gross weights, propellant loadings, configurations, mass fractions, system locations and descriptions. Results of the study will be applicable to the Advanced Planning Planetary Mission Exercise. Completion of the study is scheduled for mid-July.

D. Storable, Pressure-fed Stage Study

In direct support of the Advanced Planning Planetary Mission Exercise, a short-term analysis is being conducted of the storable pressure-fed stage. Results of this study are to be a preliminary design of the stage which will include nozzle and nozzle skirt weights and dimensions, tank weights and sizes, and stage system weights and performance. Data thus generated will be coordinated with a comparable R-AERO study to provide an overall preliminary evaluation of the storable, pressure-fed stage concept for the Mars Fly-by mission.

II. Earth Orbital

A. De-Orbit Capsule Study

The Phase I study of the De-Orbit Capsule (DOC) which can be used for astronaut rescue and satellite retrieval is continuing. This month's effort consisted of producing several conceptual designs of folding and telescoping capsules, and determining the minimum number of subsystems required inside the DOC for rescue and retrieval missions.

B. Film Return Capsule

A study has been initiated to determine the shielding requirements necessary to protect film from excessive radiation damage on a standard LOR trajectory. Materials investigated for shielding thus far include aluminum, polyethelene, and a composite of the two materials. No conclusion can be made at this time on the type material which would be best for shielding. This effort is scheduled for completion in June 1966.

C. Orbital Recovery Mission Profile

Effort is continuing on the Orbital Recovery Mission Profile study. This study is to determine the velocity requirements (ΔV) for a chase vehicle required to capture a target satellite(s). A computer program has been written which calculates the ΔV's required to transfer from one orbit to another and also the ΔV requirements to change orbital planes. This program assumes proper phasing of the chase and target vehicle prior to transfer initiation. An attempt is presently being made to determine orbital transfers when the phasing is not proper for a minimum energy transfer. This effort is scheduled for completion in June 1966.

III. Lunar

Lunar Logistics Payload Study

This study was continued to investigate and define potential lunar shelters, scientific experiments, and other scientific mission support equipment which may be considered as a payload for the lunar logistics vehicle (LLV). Preliminary drawings and weights have been generated for one concept utilizing the Apollo Command Module as the shelter. Scientific support equipment and subsystem requirements for the shelter concept are currently being defined.

IV. Planetary

A. Manned Mars Fly-by

In support of the NASA Advanced Planning Exercise, data were generated and presented to the Planetary Mission Planning Committee on the orbit and earth launch vehicles required to deliver a 120,000-pound spacecraft to Mars injection for a Manned Mars Fly-by mission. Stages evaluated for the orbit launch vehicle were the S-IIB, MS-IIC, S-IVB, S-IVC, nuclear and storable, pressure-fed stages. The types of data provided on these stages were stage weight, length, configuration, and stage structural and system modification. For the earth launch vehicles, standard Saturn V and uprated Saturn V vehicles with payloads of up to 735,000 pounds to orbit were evaluated. The large upratings were required for the single launch mission modes.

Data generated were presented on May 19, 1966, to the Planning Committee at their first formal meeting at MSFC. As a result of decisions reached at and subsequent to this meeting, similar OLV and ELV data are being evaluated for a 180,000-pound spacecraft. Launch vehicles resulting from this evaluation are being compared with those required for the Manned Mars Landing Mission. Results of the evaluation for the 180,000-pound spacecraft are to be presented to MSFC management on June 8, 1966, and to the Planning Committee in Washington on June 9, 1966.

A study has been initiated to determine the feasibility of utilizing storable propellant stages to perform a Manned Mars Fly-by in 1975. Studies are also being performed to investigate the feasibility of utilizing storable propellant stages in conjunction with nuclear stages to perform a manned Mars landing in 1982. The configurations being analyzed are the following:

	Depart Earth	Brake to Mars	Depart Mars
Stage	Nuclear	Nuclear	Nuclear
Stage	Nuclear	Nuclear	Storable
Stage	Nuclear	Storable	Storable

Studies are also being performed to determine transtage size required to transfer stage from a 185-km orbit to a 485-km orbit in conjunction with the Mars Fly-by and Landing missions.

B. Manned Mars/Venus Spacecraft Configurations

A study was initiated to determine the feasibility of a spacecraft configuration which is capable of performing a planetary fly-by mission and later evolve (with minimum modification to subsystems) into the spacecraft for a Mars Landing mission. The study will establish the proper evolution of subsystems and the spacecraft concept. It is also intended to define modifications to the current MSFC fly-by concept to adapt it for the Mars Landing mission. The feasibility of using the ground-assembled S-IVB Workshop or the Manned Orbital Research Laboratory (MORL) will also be considered, assuming these are orbital development modules with subsequent planetary applications.

C. Scientific Equipment for Planetary Missions

An investigation of the scientific equipment or experiments which would be required for planetary fly-by, capture, and landing missions is continuing. A literature survey was made for the selection of scientific experiments. These data were compiled and are to be used in defining the associated equipment and requirements for scientific investigations during either a Mars or Venus Fly-by mission.

Charles Barkley, Jr.
for Erich E. Goerner
Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-66-5

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(May 1, 1966, through May 31, 1966)

SATURN IB

I. S-IB Stage

CALIPS Checkout Console

The cleaning and final assembly of the CALIPS checkout console were completed. The expected delivery date is June 6, 1966.

II. S-IVB Stage

A. Engineering Change Proposals (ECP'S)

The following ECP's were reviewed and recommended for approval:

ECP 388C (to modify the model DSV-4B-438A gas heat exchanger so that gaseous helium could be used to set the gaseous hydrogen regulator).

ECP 904-1E (to modify valves in the DSV-4B-438 to prevent stem leakage).

ECP 904-2E (to modify valves in the DSV-4B-438A).

ECP 363E (to add a vent port to the vent stack of the gas heat exchanger).

B. Umbilicals

The S-IVB forward/Instrument Unit (IU) umbilical carrier was installed on the SA-203 vehicle at complex 34.

III. Instrument Unit

A. IU Pneumatic Console

ECP 2028-1, which implements installation of a servo amplifier to complement the high accuracy transducer, was reviewed and recommended for approval to the Vehicle GSE Manager, I-I/IB-G.

B. Ground Support Cooling Unit (GSCU)

1. A consolidated modification plan which proposed to incorporate all outstanding modifications for each GSCU simultaneously at the Chrysler Corporation Space Division (CCSD) plant in Huntsville was reviewed. Implementation of this plan was recommended to the Vehicle GSE Manager, I-I/IB-G.

2. Contract end item (CEI) 09R102A, specification CP09RA-100002A, IU GSE cooling unit, was reviewed and approved.

C. Servicing Requirements

A request for a change in orifice sizes for the S-IB lox tank prepressurization system was forwarded to Kennedy Space Center (KSC). The change was requested by CCSD to provide better assurance that lox tank prepressurization will be completed in the time allowed and to bring launch complex (LC) 37 to the same configuration as LC 34. The change is effective for vehicles SA-202, SA-203, and subsequent vehicles.

D. Operations Analysis

The program plan for the operations and reliability analysis of the Saturn IB launch vehicle prepared by CCSD at Michoud has been reviewed and recommended for usage by CCSD in conducting the studies and analyses with outputs depicted in the plan. The plan with specific review comments and with the recommendation of its usage has been transmitted to the MSFC Saturn IB Program Office for implementation into the Saturn IB analysis effort.

IV. General

A. AS-206 Nose Cone Assembly

A layout of the 25° nose cone was made for the SA-206 vehicle. This layout defines the present structural configurations for the nose cone and mating Spacecraft Lunar Excursion Module (LEM) Adapter (SLA) ring.

B. Mechanical Support Equipment

1. An intercenter meeting was held to decide action to be taken by responsible organizations to provide access for servicing the LEM on flight SA-206 and subsequent LEM flights.

2. MSFC will provide tiedown points on the XA 477 platform level for the landing radar checkout unit and a fixture for handling the unit utilizing the IU cart.

3. MSFC will also provide a new cart fixture for handling the ST-124 platform and a bracket on the model DSV-4B-402 (lower level) platform for supporting the SHe (supercritical helium) box.

C. SA-203 Nose Cone

The critical design review (CDR) for the SA-203 nose cone access kit was approved. The design was such that the design package was also approved as a CDR. This access kit will be provided by CCSD.

D. Saturn Technical Information Handbook

The SA-203 Handbook, Volume III, S-IVB Stage, was distributed.

E. Saturn Vehicle Data Book

The following data book supplements and revisions were distributed:

The preliminary flight report supplement for SA-201 Data Book.

SA-203 Data Book, Revision 1, S-IVB Stage.

SA-204 Data Book, Revision 1.

F. Project Specifications

1. The SA-202 project specifications were distributed.

2. The Standard Launch Vehicle Project Specification (SA-213 through 228) was submitted to Technical Systems Office, R-TO, for approval.

G. Saturn IB Launch Vehicle Design Reference Mission Sequence

A revised release of the Saturn IB Design Reference Mission Sequence (DRMS) Drawing number 10M30401, Revision A, was released for analysis and planning purposes. The document presents a design reference mission sequence covering the time period from stages arrival at KSC through end of launch vehicle mission.

H. SA-203 Flight Sequence

A revised Saturn IB/SA-203 flight sequence was released to Astrionics Laboratory to incorporate results of recent analysis of venting sequence and other LH_2 experiment requirements received by MSFC from Douglas Aircraft Company (DAC).

I. Saturn IB/SA-206 Flight Sequence

The Saturn IB/SA-206 vehicle flight sequence requirements of the laboratory (drawing number 10M30156) were completed. These requirements will be incorporated in the flight sequence program prepared by Astrionics Laboratory. The sequence includes all events from liftoff through S-IVB stage burn, including the shutdown sequence after S-IVB engine cutoff.

SATURN V

I. S-IC Stage

A. Monitor and Control System

The Boeing Company (TBC) has been requested to change the quick disconnect fittings on the monitor and control system of the fuel and lox tank pressurization system of the S-IC stage. The Aeroquip fittings, part numbers 75M51371, 75M51372, and 75M51374, have been selected because of a unique twist lock feature which prevents undue strain from causing the fitting to leak. The present quick disconnect fittings leak under some operating conditions.

B. F-1 Engine Interference Study

The interference study between the F-1 engine and the LUT (launch umbilical tower) level platform has been completed. The layout and supporting calculations indicate that there is interference between the F-1 engine and platform when the engine is gimballed full inboard by the servoactuators. Follow up action on this problem will continue.

C. Integration Test Requirements

The integration test requirements and specification for the S-IC ground hydraulic system checkout unit, TBC document D5-15403-2, was approved.

D. S-IC Hydraulic Supply and Checkout Unit

Initial checkout of unit 3 was begun at the mechanical automation breadboard (MAB) on May 10, 1966.

E. Forward Umbilical Service Unit

Acceptance testing of the S-IC forward umbilical service units intended for the Test Laboratory and for KSC ML-1 was completed on April 1, 1966.

F. Servicing Requirements

The Saturn V/S-IC stage fluid requirements 13M50096 were approved by Research and Development Operations (R&DO) and the Configuration Control Board (CCB) and forwarded to the MSFC repository. The functional interface control document (ICD) identifies the fluid requirements required to satisfy the stage at the ground support equipment (GSE) and vehicle interface.

G. S-IC Documentation

The following documents were approved:

I-V-GTS 1-05-1400, Saturn V installation checkout test specification.

I-V-GTS 2-01-1400, Saturn V operability and calibration test specification.

I-V-GTS 2-05-1400, Saturn V operability and calibration test specification.

D5-15403, Integration test requirements and specifications, S-IC engine inerting systems checkout.

D5-15401-1, Integration test requirements and specifications for the S-IC pneumatic consoles.

II. S-II Stage

A. Mechanical Support Equipment

1. The following design criteria sheets have been approved:

DC 1082(N) Handling Device, Submultiplexer.

DC 1086(N) Handling Device, Lox Prevalve.

DC 1077(N) Hoisting Unit, Universal, Internal Stage.

DC 1084(N) Handling Device, Lox Fill and Drain Valve.

2. The preliminary design review approved the S-II battery carrier design.

B. Ordnance Handling Containers

Engineering drawings and CEI specifications are being prepared for manufacture of ordnance handling containers for the S-II stage. Manufacturing Engineering Laboratory will manufacture the containers.

C. Integration Test Requirements

The integration test requirements and specifications for the following equipment were approved:

S-II pneumatic console test set (TBC document D5-15411-17).

S-II pneumatic systems checkout with S-II simulator (TBC document D5-15413-4).

D. Propellant Utilization Calibration Unit Test Set

The acceptance tests were completed for the S-II propellant utilization calibration unit test set (C7-85) for use at the vertical assembly building (VAB) high bay.

E. Integration Test Requirements and Specifications

Integration Test Requirements and Specifications for S-II Pneumatic Console Test Set, End Item Checkout (D5-15411-17) were approved.

F. Servicing Requirements

A comparison of S-II-T loading at Mississippi Test Facility (MTF) and planned S-II loading at KSC was initiated. A memorandum was prepared requesting data from MTF to provide KSC with knowledge of the loading conditions prior to loading of SA-500F at KSC.

III. S-IVB Stage

Pneumatic Ground Support Equipment (MGSE)

1. Modifications to the Systems Development Facility (SDF) S-IVB pneumatic consoles (DSV-4B-432 and DSV-4B-433) and the portable test set (DSV-4B-286) were completed.

2. The pneumatic console, DSV-4B-432, was shipped to the SDF on May 3, 1966. The test set, DSV-4B-286, and the pneumatic console DSV-4B-433, were shipped to SDF on May 6, 1966.

3. Deviation approval request CSD-0040, pertaining in the S-IVB pneumatic consoles for the Saturn V SDF was approved.

4. Cleaning and testing of the S-IVB space flight simulator auxiliary console was completed. Delivery was made to the SDF on May 26, 1966.

IV. Instrument Unit

IU Cooling Equipment

Unit 14 successfully completed acceptance tests at Chrysler Airtemp and was then shipped to International Business Machine (IBM) in Huntsville for Saturn V IU checkout.

V. General

A. Project Specifications

1. Revision "A" to the SA-501 project specification was submitted to the Level II CCB for approval.

2. The project specification for SA-501 through SA-515 has been prepared and distributed for center review.

B. Integration Test Requirements and Specifications

Saturn V Installation Checkout Test Specification VABH Launch Vehicle MGSE (I-V-GTS 1-18-2400) was approved.

C. Spent Stage

Design ground rules for the S-IVB spent stage effort were released.

D. Operations Analysis

The following list of Saturn V program baseline documentation prepared by TBC has been released to the MSFC Saturn V Program Office for implementation with the stage contractors and KSC:

TBC document D5-16001-910, volumes 1 and 3, revision "C", Sequence of Events.

TBC document D5-16001-012, volumes 1, 2, and 3, Event Operations Summary Sheets.

TBC document D5-16001-122, revision "C", Low Bay Operations.

TBC document D5-16001-120, revision "B", Operations.

TBC documents D5-16002-120 through D5-16002-124, Operations.

E. Umbilicals

1. All umbilical hardware required for SA-500F has been delivered and installed on the vehicle at Merritt Island Launch Area (MILA).

2. A revised manual, Reliability Analysis Model Report (RAM), for SA-501 was distributed.

F. Saturn V Mass Measuring Properties Program

A report entitled "Level of Confidence Computer Program for the Saturn V Mass Measuring Properties Program," was completed. Methods developed for reducing the number of measurements for effective results in the Saturn V Mass Measuring Properties Program were described in this report.

ADVANCED TECHNOLOGY

I. Systems Design

A. Orbital Mission Number 2

A layout has been prepared defining 13 experiments located on the LEM laboratory for orbital mission number 2. This layout will be used for presentation purposes to Advanced Studies Branch and NASA Headquarters personnel.

B. Experiment Number 2

1. A total of ten detailed installation drawings for Experiment number 2 were released to Manufacturing Engineering Laboratory.

2. The new aft fairing has been incorporated on the sensor panels ICD drawing.

C. MSFC Experiment Number 3 through 7

The pressurization and fill and drain systems are being integrated into the LEM structural stage support layout.

D. MSFC Experiment Number 15

The mechanical assembly drawing, 10M22550, for MSFC Experiment Number 15 was released.

E. Development Programs and Test Procedures

The following development programs and test procedures have been completed:

VSA-T-66-1, "Test Procedure for the Evaluation of Low Amplification Bracketry."

VSA-T-66-2, "Low Amplification Bracket Development Program."

VSA-T-66-2, "Evaluation and Qualification Program for Electrical Cable Ties and Clamps."

F. Replacement of IU Coolant Lines

The feasibility study report and layouts for the utilization of brazed fitting on the IU Environmental Control System (ECS) were completed. The study recommends the incorporation of brazed fittings in the IU ECS for increase in reliability, weight savings, elimination of leakage problems, and reduction of contamination problems.

G. Liquid Ordnance Propellant Dispersion System

The comparison study of the new Aerojet General liquid explosive and the Aerex L-1 has been completed. The heat requirements for maintaining the Aerex L-1 above 20°F. have been established, while the heat requirements for maintaining the Aerojet General liquid explosive above freezing are being investigated. An investigation to determine the feasibility of replacing the B-nut fittings with brazed fittings is being made.

H. Ordnance Camera Ejection System

The feasibility test phase on the ordnance camera ejection was completed and the Qualification Testing Program is being prepared. Several more firings will be made to obtain better definition of the velocity versus initial volume curves prior to entering qualification testing. An increase in cost of R&D cartridges and later delivery impact will be reflected in the new qualification testing technical directive.

I. IU Cold Plates

The physical interface control document, 13M20720, has been completed which reserves IU cold plates 13 and 24 for future MSFC experiment equipment.

J. Spent Stage Experiment

1. The "inboard profile" layout for the spent stage experiment, SK10-7284, is being updated to include the latest structural configurations. A sketch has been made of the tubing layout for the airlock and LH_2 tank pressurization system.

2. A layout defining major cable routings was made.

3. A concept for a micrometeoroid shield around the airlock, SK-7283, was completed and given to Structures Division for analysis.

4. Another layout has been initiated to define the components located inside the airlock. This will be presented to Structures Division to aid in defining the attach points inside the airlock.

K. Mechanical Support Equipment

1. A layout is being prepared showing the airlock hoisting fixture and the airlock hoisting clamp. The hoisting fixture and clamp design is such that the horizontal tube structure is used as the pickup points. The hoisting fixture is designed to give equal load distribution to each of the four pickup points. The use of this type fixture and clamp will necessitate the notching of the meteoroid shield at each of the four hard-point positions. The cutouts will be approximately 9" wide x 15" long and should not decrease the meteoroid protection provided below the acceptable level.

2. Five preliminary information packages, utilizing the present airlock concept, have been prepared on the following:

Handling sequence for KSC activities.

Preliminary design (conceptual) of airlock handling equipment.

Preliminary design (conceptual) of necessary access platforms.

Analyses and preliminary design (conceptual) of the necessary component and handling equipment.

Determination of the necessary modifications to existing access and handling equipment.

L. Saturn V Vehicle Assembly Documentation and Hardware

The responsibility for the preparation and maintenance of the Saturn V final assembly documentation will be retained by this division;

the contract with TBC for this documentation will be cancelled. The contract with TBC for the mating hardware will also be cancelled except for the AS-501 vehicle. These cancellations were agreed on after arrangements had been made with the Manufacturing Engineering Laboratory for the procurement of mating hardware.

M. Auxiliary Propulsion System

A dimensional sketch on the S-IVB/V auxiliary propulsion system structure was prepared for Aero-Astrodynamics Laboratory. The information will be used to manufacture a 4 percent model for wind tunnel test.

N. Safety and Arming (S&A) Device Explosive Testing

Testing conducted on the Saturn V S&A device (1B33735) indicated that performance in the safe position was marginal. Since the S&A device used on the Saturn V vehicle is similar to the one used on Saturn IB, additional testing on the Saturn IB device was made. Modifications were made to the device and tests clearly showed that the modifications were successful. A complete test analysis is being made.

O. Human Factors Engineering

Phase I of the non-system task analysis for lunar experiments was completed.

P. Human Engineering Design Criteria Study

Document MSFC-STD-267A, "Human Factors Engineering Design Criteria, Standard for," developed under contract with the Douglas Aircraft Company, was reviewed and approved as a MSFC standard. Minor editorial comments are being incorporated into the document prior to official release.

MISCELLANEOUS EFFORTS

I. Configuration Management

Accounting System

1. All DAC S-IVB contract end item base data have been put into the configuration management accounting system.

2. New forms for MSFC-PROC-466 configuration management accounting subsystem have been developed to allow for submitting one ECP against multiple CEI. This was a result of a change in NPC 500-1 philosophy by the Configuration Management Office, I-RM-C. MSFC-PROC-466 is being revised to reflect these changes.

3. A new configuration management accounting report was completed.

II. Interface Control Document System

ICD Status Reporting

Mr. Dannenberg, R-S, requested a computer generated "memorandum" to notify panels and working groups of delinquent ICD's and of ICD's scheduled to be released within the next month. This has been accomplished and samples have been furnished.

III. Engineering Documentation

Corrections

The laboratory IU Project Office requested that conflicting engineering documentation releases between this laboratory and IBM be corrected. Computer programs have been written to assist in this effort. Approximately 400 documents were identified for correction.

IV. Engineering Parts and Release Records (EPRR)

Reporting Changes

A change was made in TBC engineering reporting. The Engineering Master Parts List (EMPL) and Engineering Assembly Parts List (EAPL), and release record were combined into one report. The new report is now labeled the EPRR. New abstracts and format explanations were received and distributed to all users at MSFC.

John O. Aberg
Acting Chief, Vehicle
Systems Division

PROPULSION AND VEHICLE
ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

May 1, 1966, Through May 31, 1966

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (September 1961)

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-66-5

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(May 1, 1966, through May 31, 1966)

SATURN IB

I. S-IB Stage

A. Fuel Vent Line Support Bracket

The Vibration and Acoustics Branch was requested to investigate the Chrysler proposed modification to the support bracket of the S-IB fuel vent line. The bracket had failed, along with the fuel vent line, during qualification tests. This line was included in the approved waiver list for 201 flight. Chrysler maintains that the line failure was a result of the bracket failure. The Vibration and Acoustics Branch has recommended that the modification be applied to SA-203 if, and only if, it can be qualified by test prior to stage installation. A possibility exists that the bracket modification could transmit a higher vibration environment during flight than the current bracket. Therefore, unless this bracket-line installation can be qualified before installation, a higher confidence would exist with the current bracket design.

B. Pressure Equalizing Tube Assembly and GOX Expansion Joint

Qualification tests were attempted on the S-IB pressure equalizing tube assembly and GOX expansion joint. A failure occurred during sine test in the first axis (flight). Chrysler has decided to change the test setup to eliminate the outer LOX tank dome, and re-run the test using current qualification levels. The current test setup is the best

simulation of the actual operating condition and is the most applicable for the specifications used. The Vibration and Acoustics Branch recommends that the current setup be used, but that Chrysler review the test specifications and submit for approval a mass attenuated specification.

II. S-IVB Stage

A. Model Fabrication

The S-IVB stage panel flutter model fabrication schedule has been revised. The pressure survey model will be completed by June 20, 1966, and the flutter model will be completed by July 5, 1966. The pressure survey model wind tunnel test is now scheduled to begin July 18, 1966. The flutter model wind tunnel test remains as previously scheduled. The final stress report, prepared by BECO, was released during this period.

B. Model Specimen

A deflection analysis has been completed for the S-IVB panel flutter model specimen. Results show that the desired buckling stresses in the panels are assured.

C. Angular Velocities

Critical angular velocities for the Saturn IB during S-IVB burn were published using gimbal angles of 7 to 10 degrees (memorandum R-P&VE-SLL-66-30).

D. Weld Investigation

On April 29, 1966, a meeting was held with Douglas to discuss the status of the common bulkhead/LOX bulkhead joint, fillet weld investigation. MSFC analysis, along with an evaluation of the S-IVB and S-IV test failures, indicates that the joint is structurally deficient and that structural reinforcement should be incorporated. The decision from the meeting was that AS-203 and AS-501 could be flown without beef-up, being unmanned flights. AS-202 will be reinspected for possible problems. Further testing is in progress to prove the adequacy of design for impact or manned vehicles.

III. General

A. SA-201

Results of flight evaluation of low frequency acceleration levels on the Saturn IB, AS-201 flight was sent to R-AERO-F for transmittal to MSC (memorandum R-P&VE-SLR-66-20).

B. SA-202

A lateral vibration analysis of the Saturn IB, SA-202 vehicle during first stage burning was completed (memorandum R-P&VE-SLA-66-12).

C. SA-204 and Subs Forward Skirt Ring Frames

Further analysis found the ring frames in the forward skirt of the SA-204 and subs stages above the frame to be structurally adequate to carry the negative differential pressure imposed by aerodynamic loads. This determination resulted from using more refined pressure distributions and flexible ring frame analysis methods.

D. SA-207

A lateral vibration analysis of the Saturn IB, AS-207 vehicle during first stage burning was completed (memorandum R-P&VE-SLA-66-10).

A torsional vibration analysis of the Saturn IB, AS-207 vehicle during first stage burning and for all stages empty was completed (memorandum R-P&VE-SLA-66-11).

A lateral vibration analysis of the Saturn IB, SA-207 vehicle during S-IVB stage burning was completed (memorandum R-P&VE-SLA-66-13).

E. Saturn IB Improvement Studies

The midterm review by Douglas and Chrysler on May 18, 1966, was attended. Conceptual drawings relating to the structural changes were requested for review. Monthly progress reports were reviewed.

I. S-IC Stage

A. S-IC-17

An analysis of test data from static test S-IC-17 was initiated for longitudinal loads and vibrations.

B. SA-505/S-IC Fuel Tank

The SA-505/S-IC fuel tank upper bulkhead was severely buckled during testing on April 29, 1966. This was caused by a negative pressure imposed on the bulkhead while draining the tank after a successful proof test. The buckles were two or three feet deep in some areas and the bulkhead was considered unrepairable and will be replaced.

C. Forward Skirt Panel

Another developmental bonded forward skirt panel was successfully tested by Rohr Corporation on May 12, 1966. Prior to and during application of axial load, one end of the panel was subjected to -250°F and the other to +180°F. The failure load was approximately 210 kips, and the panel was designed for an ultimate load of 204 kips. The failure appeared to be caused by debonding of the stringers from the skin.

D. Loads

The S-IC stage was evaluated for the loads presented in memorandum R-P&VE-SLR-66-27, "Dynamic loads for Saturn V, AS-504 vehicle during first stage cutoff and separation," dated May 9, 1966. No structural impact was indicated and factor of safety of 1.4 was maintained.

The S-IC stage was structurally evaluated for the loads presented in R-P&VE-SLL-66-22, "Longitudinal dynamic loads Saturn V/Voyager with 22.7-foot shroud," dated April 14, 1966. No structural impact was indicated and a factor of safety of 1.4 was maintained.

The S-IC stage was structurally evaluated for the loads presented in R-P&VE-SLL-66-23, "Longitudinal force distribution for AS-504 with early CECO times," dated April 20, 1966. This memorandum supersedes R-P&VE-SLL-66-18. No structural impact was indicated for the early CECO time cases and a factor of safety of 1.4 was maintained. For the nominal case (0.0 sec CECO), the margin of safety is still minus 4.5 per cent.

E. General

An evaluation of the 1-3/8-inch diameter bolt head failure of the splice on the lower caps of the crossbeam-to-center cruciform of the SA-501/S-IC vehicle indicated that an installation/material finish problem exists. Boeing is taking the following action:

1. Discontinue the use of a water-cooled drilling tool for drilling the splice bolt holes.

2. Cadmium plate the radius between bolt head and shank.

3. Install bolts in splice with a wet zinc chromate compound.

4. Replace the 1/8-inch thick washer used in this splice with 1/4-inch thick washers.

5. Replace the bolts in the splice area on all fabricated S-IC flight stages with new bolts.

6. Conduct an environmental test program on the bolts.

II. S-II Stage

A. 2020-T6 Stringers

Acoustic test results, given cursory review by the Vibration and Acoustics Branch, indicate that little confidence in the integrity of the stringer installation in the S-IC/S-II interstage area has been attained. Specifically, testing deficiencies existed in: the test specimen used; instrumentation employed; and inadequate facility and levels attained. In addition, North American was not able to clearly state their reasons for originally activating acoustic testing when failures had occurred under impact loading.

The conclusions gathered were that: S&ID does not have a clear position as to what the original testing was supposed to attain; P&VE and S&ID agree, with some reservations by S&ID, that the test results do not provide a significant level of confidence; S&ID feels there is nothing more that they can do by way of testing, short of a research program, to increase the confidence; and S&ID management will review the test data again and will consider the views and position of P&VE technical consultation. S&ID will prepare a letter stating their exact position and future plans.

B. Instrument Container Acoustic Tests

Review of acoustic data from the S-II battleship firings and transmission loss curves from acoustic tests completed on container 208 revealed that the external and internal acoustic environments of the instrumentation containers are severe. The containers are mounted to the S-II stage thrust structure and in the forward skirt region. Because the severe acoustic levels can cause a malfunction of critical electrical components mounted in the containers, a letter was written to Colonel Yarchin requesting that CCN-13 test program be modified to include acoustical testing on containers 207 (hard mounted) and 209 (isolation mounted).

C. S-II Stage General

The S-II-3 forward LH_2 bulkhead was severely buckled in hydrostat May 5, 1966. The insulation in the upper one-third of the bulkhead was heavily damaged and debonded. Cause of the failure was an improperly installed bellows counter weight attachment bracket. The bulkhead has been dye-penetrant inspected on the inner surface and along the weld lands on the outer surface. An X-ray inspection was made at 10 locations which has previous history of weld repairs. No cracking was detected by the inspections. The S-II-3 forward bulkhead has been hyrostatically tested again after it was buckled during its original hydrostat. Inspection of the bulkhead indicated no weld cracks or flaws resulting from the buckling. Some residual deformations remain, particularly at weld lands. A foamed in-place type insulation has been proposed for the bulkhead without detrimental grinding.

Boeing and S&ID have submitted proposed beef-ups and peaking load distributions at the S-IC/S-II interface. Boeing and S&ID analyses are in close agreement. Direction to incorporate the fixes have been made.

Investigations have been initiated on the S-II stage discontinuity weldment incorporating a plastic hinge in the aft LOX bulkhead. A similar type juncture on the S-IVB stage has been encountering failures in hydrostat. It is believed that the design of this juncture on the S-II stage is adequate; however, no test verification above 80 per cent of its design limit load has been planned. Ultimate test verification is highly recommended in the discontinuity area to verify the design.

The S-II-3 stage LOX sump bolts failed in proof hydrostat. A redesign has been proposed using 7/16-inch diameter straight insert bolts in lieu of the stepped insert bolts. This redesign would require a three-week schedule slip if incorporated on S-II-1. Since the cause of the bolt failure cannot be clearly identified, it is strongly recommended that the revision be made on S-II-1. The bolt redesign should be requalified on the structural test of the LOX bulkhead.

The Propulsion Division has requested studies of structural modifications required to install an off-the-shelf Genie ullage motor in lieu of the current Rocketdyne-developed motors for the S-II stage. The studies indicate that the Genie motor can be adapted to the S-II stage with modifications to the attachment brackets and to the aerodynamic fairings. These modifications would appear to have a minimum structural impact; however, it would require retrofit at MTF or KSC for S-II-1 and S-II-2.

D. S-II Semitoroidal Stage

Brown Engineering's preliminary report on the S-II semitoroidal stage optimization study is being reviewed.

III. S-IVB Stage

A. Hydrostat II

A meeting was held with Douglas at Huntington Beach to discuss the testing to be performed on the new hydrostatic test tank. The tankage originally to be used in the AS-503 vehicle was removed from the assembly line and provided as a test vehicle. Since the primary problem is to prove the integrity of the lower fillet seal weld at the common bulkhead/LOX bulkhead joint, it was decided to perform a cyclic test series followed by an ultimate test of this joint as Phase I. This test will start May 28 and the completion date is June 4, 1966. Phase II will be an ultimate test of the remaining portions of the tank assembly. The following phases will include systems failure loadings, and a loading to intentionally produce structural failure.

B. Forward Skirt Test

Structural testing of the forward skirt of the S-IVB stage will begin on May 31, with testing to continue for approximately one month.

IV. Instrument Unit

A. Dynamic Testing

Dynamic evaluation testing of the North American-built instrument unit structure (500V-2) was completed during May at Wyle Laboratories under the direction of IBM. There were no apparent structural discrepancies. Response data is presently being reviewed by IBM, and localized environments established for comparison with previous test results and anticipated flight environments.

B. General

The instrument unit was structurally evaluated and can successfully withstand the loads given in R-P&VE-SLT-66-27, "Dynamic loads for Saturn V, AS-504 vehicle during first stage cutoff and separation," May 9, 1966.

IBM's proposal for the instrument post-flight evaluation has been reviewed and the comments forwarded to R-P&VE-SJ.

S-IV 200/500S-3 instrumentation requirements have been determined in conjunction with IBM and have been forwarded to R-P&VE-SE.

V. General

A. F-1 Engine

Strain gage data from the load ratio test on the F-1 engine, left turbopump, support structure were reduced. The data showed much more bending in the struts than was anticipated. The tests have been completed and the support structure was loaded to 180 per cent of limit load before failure. The purpose of this test was to determine the structural capability of the outboard outrigger during cyclic, yield tension and compression, and ultimate compression load tests.

B. Reverse Pressure Tests of Model Bulkheads

The data system has been repaired and is presently being connected to bulkhead instrumentation. Tests are scheduled to begin June 15, 1966.

C. 3 Per Cent Model of Mobile Service Structure (MSS)

A 3 per cent model of the MSS was proof-loaded to 20,000 pounds. Upon completion of the proof loading, which the structure successfully withstood, the MSS was shipped to Langley where it will be used in wind tunnel tests.

D. S-IVB Common Bulkhead LOX Joint Specimens

Fourteen two-inch wide specimens have been tested. The objective of the test program was to provide data which will be used to evaluate the structural adequacy of the actual joint.

E. 70-Inch Diameter Test Tank

Stress analysis of the 70-inch diameter test tank support structure has been completed and the drawings signed.

F. AS-209 Spent Stage Experiment

Work has been initiated on the analysis of the AS-209 Spent Stage Experiment.

G. AS-501

An analysis to determine the dynamic loads for an engine-out condition just prior to S-IC cutoff has been initiated for the AS-501 vehicle.

The trajectory of a point in the release plane of the AS-501 was determined for release in a 99 per cent ground wind (memorandum R-P&VE-SLR-66-30).

Differential pressures on the Saturn V spacecraft, instrument unit, and S-IVB forward skirt of the SA-501, 502, and 503 vehicles were published with 100 and 150 square inches of vent area (memorandum R-P&VE-SLL-66-24).

Equations have been derived for representing the Saturn V feed-lines as a continuous system instead of a spring mass representation. These new equations are being added to the current POGO stability programs.

H. SA-504

A longitudinal dynamic loads analysis was performed for the AS-504 vehicle during first stage cutoff and separation. This study was made because of recent F-1 engine thrust decay changes (memorandum R-P&VE-SLR-66-27).

Equations have been derived for representing the Saturn V feed-lines as a continuous system instead of a spring mass representation. These new equations are being added to the current POGO stability programs.

I. Saturn V Improvement Studies

The monthly progress reports were reviewed. A meeting with Boeing personnel was attended to discuss base heating environment and base heat sheild design concepts.

APOLLO APPLICATIONS PROGRAM

I. Orbital Experiment Compartment

Design investigations of the tank, tank support, and insulation system combination were started for the LEM Descent Stage Carrier configuration. Design investigations into the structural joints of the MSFC Experiment Rack were also started. A meeting with Propulsion Division personnel (the experiment designers) revealed that the total number of penetrations for the tanks with the present configurations seriously affect the technical value for conducting the experiments. Therefore, the technical directives for the support contractor are currently being revised to allow a determination of the structural penalties involved in designing for a maximum of three penetrations. Rack configurations were investigated for the Cylindrical Payload Module (CPM). Two Division level meetings were called to determine the Division recommendations as to concepts, manpower, and schedule estimates. Results of the meetings were sent to the Propulsion and Vehicle Engineering project manager.

II. LEM Experiment Compartment

A tank support concept for the 20-inch diameter tanks to be used in the Grumman LEM of the LEM experiment compartment has been sized.

Manpower estimated for the LEM experiment rack, docking structure, CPM support structure study were determined in conjunction with R-P&VE-SA.

III. Manned Flying System

The progress of Bendix's development of a reusable lunar landing strut was discussed by telephone, and further possible improvements were conceived. Because of the stringent schedule requirements, however, no further changes were recommended. A copy of Volume I of the Bell Aerosystem's final MFS draft report was received and reviewed.

IV. LLV Strut Impact Tests

Test specimen modifications, which include larger vacuum fittings and a plate which will allow a better core fit, have been completed. Next test is scheduled for the week of June 13 through 17.

V. LFV Reusable Strut

The inside diameter of the reusable strut's upper tube was rehoned and the variation in the force resisted during the stroke was rechecked on a tensile test machine. The stroke force variation was improved considerably, but still varies by about 40 per cent. It is possible that strut force variation can be further improved by additional chrome plating and rehoning. It is evident, however, that an improved design would be required for a constant stroke-force relationship. Presently it is planned to drop-test the strut before further improvements are implemented.

VI. Lunar Shelter Study

Layouts for two shelter concepts were made and are currently undergoing a preliminary stress analysis. These two shelters are both rigid structures. Their purpose is to evaluate ways by which the meteoroid shielding weights may be reduced.

One expandable structure concept was selected on the basis of the summary report prepared last month. Improvements to the selected concept were recommended to the support contractor, and a new lay-out was started.

VII. Reusable Structures

A survey of technical literature is being accomplished to determine the state-of-the-art and current activities in the field of reusable aerospace structures. Four control surface and nose shroud test panels designed and manufactured under Contract NAS8-11739 have been received at MSFC for thermal cycling tests and evaluation. Materials are being procured for the manufacture of four additional panels for testing under a combined environment.

VIII. LLV Landing Gear

All hardware for the modification has been fabricated and is now being installed in the strut. Testing is expected to resume during the week of June 13 through 17.

ADVANCED TECHNOLOGY

I. Design Studies

A. Nuclear Ground Test Module

The preliminary concepts have been completed and presented to MSFC management. Presently, no further work is being done on the project.

B. Clustered Spherical Tank Study

A clustered spherical tank configuration has been established and feasible means of supporting the tank are being investigated. Preliminary sizing of the major components has been accomplished, and the calculations presently indicate that the clustered spherical tank will be slightly heavier than an equal volume, single sphere.

C. Titanium Structures Investigation

An assembly to make a test specimen of the titanium Y-ring and skin segments, which are the final products of contracts NAS8-20533 and NAS8-20530, is being investigated. The test specimen will be the same size and have the same attach point locations as the present T-stiffened aluminum test segment, so that the existing test fixture can be used with only minor modification. Several assembly problems and specimen/fixture incompatibilities are being studied. Information gained from this test will be beneficial in future titanium designs.

D. Utilization of Spent Stages

Work is continuing on a final design for the airlock structure. Considerable coordination with Manufacturing personnel has been required. A complete design layout is about 50 per cent complete.

E. MLV-3

Studies were initiated to determine the dynamic response of the NERVA-2 engine in the Modular Nuclear Stage on top of the S-II stage of the Saturn MLB-3 vehicle during main stage buildup and liftoff.

F. Titanium Crossbeam

Modification of the crossbeam in Manufacturing Engineering Laboratory was started but was not completed. Work was stopped on the modification because of higher priority work. No estimate can be made on the completion date of this modification.

II. Design Research

A. Meteoroid Shielding

Four degrees of meteoroid protection for the spent stage experiment were studied and their probabilities of success determined:

1. No external add-on protection - no penetration in the internal insulation allowed.

2. Use of the SLA panels for partial protection - no penetration in the insulation allowed.

3. No external protection, but with consideration given to the protective value of the internal insulation.

4. Use of a deployable meteoroid bumper over the exposed tank surface.

B. Oxygen-Rich Environments

Additional tests are urgently needed to investigate more thoroughly the possible bumper materials and the effects of hypervelocity impact in oxygen-rich environments.

C. Improved Heat Shield

Material procurement on the advanced heat shield test panels is being accomplished. The test requirements and drawings will be distributed in June.

D. 500F Damper System

The beams of the 500F damper system were delivered for testing the week of May 2. Testing was completed by May 7; however, required modifications to the control panels and the hydraulic tubing delayed shipment to KSC. Modifications to both panels and beams were completed and the parts were shipped from building 4619 on May 17.

Calibration of the hydraulic system was completed to the extent that the orifice size and valve settings for each control panel were established prior to 500F "roll-out." It was determined that at higher amplitudes, the hydraulic system will heat up more than the recommended maximum operating temperature (190°F) of the hydraulic cylinders. Methods for dissipating the heat to lower the operating temperature are being evaluated. Copper fins attached to the lines between the cylinder and slush manifold lowered the temperature approximately 10°F for identical runs using a 3/8-inch orifice.

Also, attempts are being made to lower the damping to values that will permit a more complete ground winds test program.

The installation of the stage fittings to the S-IVB-D aft interstage was completed May 27. The test setup for proof loading these fixtures was started. Testing should start Friday, June 3. Although these tests could not be conducted prior to 500F "roll-out," as was desired, the test measurements, such as ring frame deflections, will be beneficial to the stress group should a similar system be required for 501.

III. Structural Experiments

Cryogenic Test Tank #2 (105-inch diameter)

The pressure level recorded in the jacket is presently 900 microns. The target pressure level of 200 microns originally established may be revised upwards based on recently obtained insulation test data.

for G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-66-5

MONTHLY PROGRESS REPORT

MATERIALS DIVISION

MAY 1, 1966 THROUGH MAY 31, 1966

SATURN IB

I. S-IB Stage

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

The original objective of this program was to develop a replacement for M-31, the material presently used for insulation on the horizontal heat shield of the S-IB stage. Based upon laboratory results, this objective has been attained. Two materials, designated FTA-442A and FTA-532A insulations, have been developed and are suitable replacements for M-31, FTA-442A being superior with respect to both insulating efficiency and adhesion to the heat shield substrate. Recently, the objective was extended to the development of insulations having higher temperature capabilities than the FTA insulations.

One approach to the development of an insulation for higher heat fluxes has been to substitute refractory oxide opacifiers for pigmentary potassium titanate (PKT) in the FTA-442A formulation. As reported previously, two opacifiers, zirconium oxide (ZrO_2) and the anatase form of titanium dioxide (TiO_2), are being evaluated individually as substitutes for PKT. During this report period, the insulations were evaluated with respect to thermal-shock resistance, refractoriness, and insulating efficiency as applied to the S-IB stage type heat shield substrate. There was no sign of thermal-shock failure of either insulation when exposed to a radiant heat flux of 24 Btu/ft^2-sec for 180 seconds and quenched immediately in water. The refractoriness was characterized by exposing bar specimens (0.300 inch x 1 inch x 6 inches), supported at one end only, in an electric furnace and raising the furnace temperature until the bars started to soften and bend. The bars containing the TiO_2 and ZrO_2 softened at 1900°F (1038°C) and 1950°F (1066°C), respectively, as compared to 1550°F (843°C) for FTA-442A. The insulating efficiency of equal thicknesses of the

insulations was determined in radiant heat fluxes of 24 and 40 Btu/ft^2-sec. After 145 seconds exposure to 24 Btu/ft^2-sec, the back face temperature increases for the insulations containing TiO_2 and ZrO_2 were 107°F (42°C) and 137°F (58°C), respectively, as compared to 115°F (46°C) for FTA-442A. When exposed to 40 Btu/ft^2-sec, the back face temperature increases at 145 seconds were 266°F (130°C) and 298°F (148°C) for the insulations containing TiO_2 and ZrO_2, respectively, and 404°F (207°C) for FTA-442A. The results clearly demonstrate that both TiO_2 and ZrO_2 increase the refractoriness of the insulations and improve their insulating efficiency at the higher heat flux.

Efforts have continued in the development of an all-zirconia (ZrO_2) thermal insulation, however results to date have not been satisfactory. The primary difficulty encountered was in gelling the colloidal zirconia sol binder, which should occur by raising its pH above 5.5. Attempts were made to raise the pH through use of an ion exchange column, however this approach proved unsuccessful. Additions of ammonium hydroxide (NH_4OH) coagulated the sol at a pH of 3.5. This coagulated sol was used in formulating an insulation with zirconium oxide and zirconia fibers. Although the composite material hardened during drying, it lacked mechanical strength and moisture resistance. These initial results are not promising and indicate strongly that another binder other than zirconia sol should be investigated.

B. Monitoring of Gas Leaks in the S-IB/S-IVB Interstage Compartments

Activities have continued in the assembly, qualification, and delivery of the three hazardous gas detection systems for use at launch complexes 34 and 37B and for use with the AS-V 500F facilities vehicle.

The hazardous gas detector (HGD) scheduled for use in conjunction with the 500F facilities vehicle was delivered on May 24, 1966, and installation was completed on May 25. Installation of this system was completed one week ahead of schedule.

The prototype HGD system was moved from launch complex 34 to launch complex 37B for use during tanking tests on AS-203. The first permanent HGD unit for Saturn IB, launch complex 34, is being fabricated. All fabrication of parts for the vacuum system is complete and assembly of the vacuum system will be completed and tested in two weeks. Modifications to the Gas Analyzer, Peak Selector, and other electrical panels are in progress and should be complete within three weeks. Rack cabinets have been delivered to the John F. Kennedy Space Center (KSC) and the analyzer will be installed in these racks at KSC.

The permanent HGD for launch complex 37B is in the early stages of fabrication. All mounting frames are complete. Some modification is required on the diffusion pump and liquid nitrogen trap. It is anticipated

that delivery of this unit will be ahead of schedule; however this will depend on the launch schedule of AS-203 which is being serviced by the prototype unit.

C. Investigation of the Failure of MF Fitting Springs

Investigations have continued into the failure of 17-7 PH wave springs used on MF flared tube fittings. Annealed springs, heat treated to RH950, RH1050, RH1100, TH1050, and TH1100, conditions have failed in periods ranging from 1 to 32 days when subjected to alternate immersion in salt water and exposure to the atmosphere. The springs heat treated to TH1100 exhibited the best resistance to stress corrosion cracking since only two failures occurred during the three months test period. This test was terminated after three months because of severe crater corrosion at the mating surfaces. Inconel 718 springs have been recommended as replacement components for the 17-7PH springs. Test springs of Inconel 718 annealed at temperatures of 1900°F (1038°C) and 1800°F (982°C) have been exposed to alternate immersion in salt water and exposure to the atmosphere for 49 and 85 days, respectively, with no failures.

SATURN V

I. S-IC Stage

A. Developmental Welding

Specimen preparation and evaluation have continued in an attempt to establish the susceptibility to cracking of welds in various aluminum alloys. Specimens cut from cruciform weldments of one-inch thick 2219-T87 and 2014-T6 aluminum alloys have been naturally aged for sixty days with no evidence of cracking. These results support the previous conclusion that the cruciform weld specimen is not characterized by a high enough restraint to induce cracking.

Other tests are being made in which relatively thin sheet or plate aluminum specimens are joined to a heavy aluminum slab by a peripheral weld. The concept involved is that the heavy slab will not deform appreciably, thus, the weldment will be severely restrained and highly susceptible to cracking. This procedure is known as the "Reeve" test.

All welding has been completed in the study of the weldability of experimental aluminum alloys X2021 and X7007. Radiographs of the welded panels were inspected, and the welds were classified as meeting the Class I requirements of MSFC-SPEC-259A. The weldments are being fabricated into test specimens for use in determining the mechanical properties.

Investigations are continuing in an attempt to identify the cause of porosity in aluminum alloy weldments. Several bead-on-plate specimens were prepared with varying degrees of weld bead penetration as controlled by heat input. However, no effect on porosity was observed with variations in penetration. Tests with butt weldments made in various thickness indicate strongly that the observed porosity is related through some factor associated with the butt joint configuration. Studies are being directed toward methods of joint preparation prior to welding.

B. Study of Corrosion and Cleaning Procedures

1. Stress Corrosion Studies

Studies have continued in the determination of the threshold stress levels of 7106-T6351, 7139-T6351, 7039-T61, and 7039-T64 aluminum alloys. Specimens of alloy 7039 in the -T61 and -T64 conditions have been exposed for 72 and 50 days, respectively, in the alternate immersion tester and to the local atmosphere. Three specimens of 7039-T64 stressed at 20 ksi in the short transverse direction failed after 50 days of exposure in the atmosphere and two specimens each, stressed to 20 and 15 ksi, failed from 29 to 42 days of exposure in the alternate immersion tester. There has been only one failure of 7039-T61, and this specimen failed after 57 days in the atmosphere under a stress of 20 ksi in the short transverse direction.

Stress corrosion tests using round and flat tensile specimens of extra low interstitial (ELI) grade Ti-6Al-4V titanium alloy have been terminated after one year of exposure in the alternate immersion tester. No failures were encountered, and final mechanical properties are being measured. Specimens have been fabricated and are being fatigue cracked for pre-cracked stress corrosion tests on Ti-8Al-1Mo-1V alloy. Studies are continuing on the stress corrosion susceptibility of Ti-6Al-4V alloy in nitrogen tetroxide (N_2O_4).

An investigation is in process to determine the stress corrosion susceptibility of two new high strength weldable aluminum alloys (X2021-T8E31 and X7007-T6E136) being developed under contract NAS8-5452. These alloys are being studied in all three grain directions in the alternate immersion tester and in the local atmosphere. The threshold stress level of alloy X7007-T6E136 alloy was found to be less than 10 ksi in the short transverse direction in that failures occurred in from 27 to 90 days in the alternate immersion tester at loads of 10, 15, and 20 ksi. Failure on exposure to the local atmosphere has been limited to one specimen stressed in the short transverse grain direction at 20 ksi after 62 days of exposure. These atmospheric exposures have been in process for 97 days.

Failures of alloy X2021-T8E31 have been encountered in all three grain directions as a result of exposure in the alternate immersion tester. All specimens stressed in the short transverse grain direction to levels of 35 ksi, 39 ksi, and 25 ksi failed in a period ranging from

24 to 50 days. All specimens stressed in the long transverse grain direction to a level of 75 percent of the yield strength failed in a period ranging from 34 to 73 days and one of three specimens stressed in the longitudinal grain direction to the same level failed in 73 days. No failures have occurred to specimens exposed to the local atmosphere. This test has been in progress for 77 days.

Carpenter Custom 455 alloy, aged at 1000°F (538°C) and 1100°F (593°C) was found to be resistant to stress corrosion cracking in a 3-1/2 percent sodium chloride solution. Specimens were stressed to loads up to 100 percent of the yield strength and exposed in the alternate immersion tester for 180 days without failure. Tests are continuing on specimens of this alloy aged at 1150°F (621°C). No failures have occurred after 41 days exposure in the alternate immersion tester.

2. Study of Corrosion Susceptibility of Hydraulic Actuators

Exposure to a salt spray environment has continued on representative specimens of two different designs of S-IC stage hydraulic actuators. The actuator fabricated from 7079-T6 aluminum alloy has been exposed for 261 days and the actuator fabricated from 7075-T73 alloy has been exposed for 231 days. There is no evidence of cracks on either actuator at this time.

3. Study of the Corrosive Aspects of the Atmosphere at the Michoud Assembly Facility

Testing of the electrical conductors which were exposed to the Michoud atmosphere for approximately 3-1/2 years is almost completed. Results to date show no appreciable change due to this exposure.

C. Investigation of Fasteners and Fastener Materials

Materials testing and evaluation are continuing in the study and characterization of various fasteners and fastener materials used, or of potential use, in Saturn V vehicles. During this report period, activities under this project were directed toward an evaluation of Carpenter Custom 455 stainless steel. Present studies are being made on specimens of Carpenter Custom 455 steel aged in vacuum at 1150°F (621°C) for four hours and vacuum/argon cooled. Mechanical properties of sheet material in the longitudinal direction ranged from 253 ksi ultimate tensile strength (U.T.S.) and 177 ksi yield strength (Y.S.) at -320°F (196°C) to 233 ksi U.T.S. and 201 ksi Y.S. at -423°F (-253°C). The notched-to-unnotched tensile ratio ranged from 1.03 at room temperature to 0.46 at -423°F (-253°C). These studies show that the mechanical properties (U.T.S. and Y.S.) of the custom 455 stainless steel material were reduced by the 1150°F (621°C) aging temperature; however, the elongation and charpy impact strength values were improved considerably. The 1150°F (621°C) aging treatment

also has affected the corrosion resistance of the alloy. The material rusts at an accelerated rate, possibly due to the retained austenite and the martensitic structure.

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

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

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

E. Evaluation of Commercial Adhesives

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

1. Evaluation of Lefkoweld 211

Aluminum specimens bonded with Lefkoweld 211 adhesive were evaluated in a lapshear configuration. The adhesive was mixed as recommended by the manufacturer and cured for seven days at room temperature (R.T.). The test results confirm previous conclusions to the effect that this adhesive yields favorable strength at room and moderately elevated temperatures but at low temperature the strength is degraded markedly.

2. Evaluation of Stycast CP-16

Stycast CP-16 was evaluated using aluminum adherends in lapshear tensile configurations. Average lapshear tensile strength values obtained were 1854 psi, 7086 psi, and 6112 psi at room temperature, -300°F (-186°C) and -423°F (-253°C), respectively. Stycast CP-16 is a polyurethane adhesive with a liquid catalyst which preliminary analysis has shown to be a solution of MOCA in dibutyl phthalate.

3. Evaluation of Dow Corning (DC) 93-046 Adhesive

Dow Corning 93-046 adhesive is a new material with improved strength compared to previous silicone materials. Since it is cured with a catalyst at room temperature, this material was considered as a candidate adhesive for insulation close-outs and similar uses. A composite film was made from 3-mil aluminum foil and polyurethane-impregnated nylon cloth. Flatwise tensile specimens were made by bonding the polyurethane face of the composite film to the test block with DC 93-046 and the aluminum side with Lefkoweld 109. DC-1200 was used to prime the aluminum adherends.

Shear tensile tests, T-Peel tests and flatwise tensile tests were made on these specimens at temperatures ranging from -100°F (-73°C) to 400°F (204°C). The results of these tests were comparable to, but somewhat lower than those of similar tests made during the preceding month. These data indicate that DC 93-046 adhesive is marginal in acceptability for use in conjunction with cryogenic insulation.

F. Development and Evaluation of Potting Compounds

The objective of this program is the development of a transparent, curable resin system characterized by good dielectric properties and which is either inherently flexible or may be filled to yield a coefficient of thermal expansion approaching that of ceramics and other materials used in electronic circuitry. Urethane-siloxane and epoxy-silane copolymers are being investigated as possible materials for this application.

1. Epoxy Silane Polymers

The projected synthesis of polymer precursors containing the silphenylene bridging group and terminal epoxy groups has continued with optimization of epoxidation reaction conditions using trifluoroperacetic acid. 1,4-Bis(vinyldimethylsilyl)-benzene was epoxidized by the trifluoroperacetic acid method utilizing trifluoroacetic anhydride and 90 percent hydrogen peroxide. Freshly generated potassium carbonate was used to neutralize the acid reaction by-product. The peracid addition was carried out at 5°C, followed by continuous stirring at 25°C with periodic monitoring of the pH of the reaction liquid. Fresh portions of potassium carbonate were added until a pH of 6-7 was attained. Subsequent workup of the reaction mixture afforded a 75 percent yield of colorless oil. The infrared spectrum showed an intense absorption at 885 cm^{-1} attributable to the epoxy ring. The absorptions generally attributable to hydroxyl and carbonyl groups were absent, which suggests that the diepoxide did not undergo esterification. This method can now be used to prepare relatively pure epoxy resin precursors for polymerization studies.

2. Study of Failure of Potting Compound in an H-1 Engine Connector

As a result of a recent failure of the potting compound, Scotchcast XR-5038, currently specified for use on H-1 engine electrical connectors, tests were initiated on specimens of Products Research PR-905, potting compound in an attempt to qualify an alternate material for this potting application.

A sample of uncured PR-905 was obtained from the engine manufacturer, Rocketdyne, and used in the potting of 5 connectors which were allowed to cure 24 hours at ambient temperature. Additionally, 4 dielectric test specimens were potted. The potted connectors were placed in a humidity chamber at 70°C and 80-90 percent relative humidity. One connector was removed after each 24-hour period and examined for any possible corrosion of the connector pins by the potting material. At

the end of 120 hours the fifth connector showed no evidence of pin corrosion. The potting material had darkened significantly during the test. This darkening was attributable in part to the elevated temperature of the test which promoted further cure of the resin. Dielectric constant and dissipation factor values for the PR-905 were determined after exposure to 70°C and 90 percent humidity for 24 hours. The results indicated some hydrolysis or moisture degradation of the polymer as shown by the increase in values:

Sample	Dielectric Constant	Dissipation Factor
Control	4.24	0.013
Humidity conditioned	5.39	0.041

It should be noted, however, that the dielectric test configuration exposed more surface area for moisture penetration than does the H-1 engine connector configuration, thus, the hydrolysis effect would be somewhat smaller in the latter configuration. On the basis of these test results, and since the electrical connector configurations do not expose a large surface of potting compound it is believed that PR-905 can be used as an interim "fix" pending the qualification of a fully satisfactory potting material for this application.

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

The engine fuel, RJ-1, will be used as the hydraulic fluid for the servo-actuators of the S-IC stage. Concern has arisen over the life of the ground system equipment (GSE) 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. On the basis of these tests, four lubricant additives have been selected for testing in a simulated ground support hydraulic pump. These lubricant additives have been subjected to additional tests in the Falex lubricant tester.

The first simulated ground support hydraulic pump was assembled with the redesigned piston loading mechanism. This new loading mechanism worked smoothly but other problem areas were noted. There is considerable leakage of the RJ-1 lubricant between the shoes and the wear plate. There also appeared to be too much scratching on the wear plate and on the shoes. To correct this, the wear plates have been hardened and the shoes and wear plates have been ground and lapped to a much closer tolerance. The pump is being re-assembled for checkout.

H. Investigation of the Failure of Saturn S-IC Stage Thrust Structure Bolts

The analysis has been completed on the four H-11 steel bolts that failed in the lower center splice plate of vehicles 501 and 502. The study identified two possible causes of failure, bolt head bending loads and corrosion induced hydrogen embrittlement or stress corrosion cracking. The Boeing Company's proposed corrective action includes replacing the bolts with units that have been coated with vacuum deposited cadmium and zinc chromate primer and modifying bolt installation and torquing procedures. Both The Boeing Company and this division have initiated stress corrosion tests on specimens of H-11 steel.

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, NAS8-5251

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. Evaluation of Heat Shield Insulation Materials for Use in the S-II Stage

The effect of heat and vacuum on the insulating capabilities of highly reflective insulations is being studied indirectly by determining the change in the reflectance of the insulation materials resulting from subjection to various heat-vacuum treatments.

As reported earlier, contamination of the insulation samples by the furnace atmosphere has been a factor in determining the effect of heat and vacuum on the reflectance of the insulations. Furnace contamination factors have been determined and applied in calculating the effect of heat and vacuum on the reflectance of M-31, FTA-442A, and FTA-532A insulations. Preliminary results indicate that exposure to elevated temperatures and a reduced pressure of 6×10^{-5} torr reduce the reflectance of M-31 at all test temperatures ranging from 500 to 1000°C, (932 to 1832°F). There was very little change in the reflectance of the FTA insulations at temperatures of 900°C (1652°F) and below; however, at 1000°C (1832°F), a decrease in reflectance was noted. The changes in reflection of all three insulations appeared to result from sintering of the insulations rather than reduction of the titanate component to its sub-oxides. Future work will include additional tests to verify the above results and the testing of other, more refractory, insulations.

B. Development and Evaluation of Materials of Potential Use in S-II Stage Tank Wall Insulations

Activities have continued in the development and evaluation of insulation materials for the liquid hydrogen tank of the S-II stage. During this report period these activities have included the following:

1. Evaluation of Lefkoweld Adhesive for Attaching Close-Out Strips to Insulation

Lefkoweld adhesive 109/LN-52 is being used by NAA/S&ID (Space and Information Systems Division of North American Aviation) to attach close-out insulation strips in the weld areas. In a study of the capabilities of this adhesive, 20-mil aluminum face sheets were bonded to both 3/8-inch and 3/4-inch cell HRP (heat resistant phenolic) core using the procedure outlined in NAA/S&ID Specification MA0606-027A. Tests have been completed on these specimens at room temperature, -300°F (-184°C) and -423°F (-253°C). Data from these tests indicate that the Lefkoweld 109/LN-52 adhesive is satisfactory for use in bonding the close out strips of S-II stage tank insulation.

2. Dual Seal Insulation

A test tank seventy inches in diameter has been insulated with the dual seal insulation system for use in developing and evaluating application techniques for the insulation and in evaluating the insulating capability of the concept. The insulation on this tank was nondestructively inspected by ultrasonic techniques and four areas were identified as containing debonds. Sections of the insulation containing these suspect areas were removed and examined destructively to determine the exact location of the "debonds." All the debonds were found to be nonbonds resulting from air trapped between the inner seal and the tank wall. The cutout areas are being repaired with pre-cut insulation sections.

C. Development of Nondestructive Inspection Techniques for Common Bulkheads

Activities have continued in the development of techniques for nondestructively inspecting S-II stage common bulkhead.

Impedance methods are effective for evaluating many types of composite materials from a single side, and are the best available for locating debonds in composites of the type in use in common bulkheads. However, the necessity of having a liquid couplant limits the evaluation of a large bulkhead and faster techniques are highly desirable. Air coupled techniques have shown considerable promise using sonic and lower ultrasonic frequencies, and work in this area has been resumed. A loud speaker was used as the source of sound and a microphone served as a receiver. Maximum penetration of a one-inch thick honeycomb panel was obtained with sound frequencies near three kH_z. However, debonds could be detected only when frequencies near 21 kH_z were used. This would be expected since the lower frequencies penetrate too deeply. The major difficulty in air coupled honeycomb testing appears to be the establishment of uniform sound fields. Activities are continuing in an attempt to establish and qualify a satisfactory technique for nondestructively inspecting common bulkhead materials.

D. Investigation of the Failure of X-2020 Aluminum Alloy Stringers

An analysis of 2020-T6 aluminum alloy stringers representative of batches that were found to be susceptible to cracking during machining and installation as well as batches that were termed "acceptable" by the S-II Stage Contractor (S&ID) revealed that the only differentiating feature between the representative specimens was the superior transverse ductility of the "acceptable" stringers. Thus, it was recommended to the S-II Stage Manager that S&ID continue to use the 2020 alloy stringers to minimize schedule impact but that S&ID sample each extrusion lot of stringers to insure that the transverse properties met certain minimum values (ultimate strength 75,000 psi; yield strength 70,000 psi; and

elongation 4 percent), that S&ID etch and dye penetrant inspect each stringer subsequent to all machining operations and prior to installation, and that S&ID use the modified installation scheme which was recommended as a result of a company-initiated investigation. Since the 2020 alloy has some undesirable features, it was recommended, further, that S&ID initiate a redesign utilizing 7075-T73 aluminum alloy.

An investigation also was initiated into the stress corrosion susceptibility of the stringers. Flat sheet type and round threaded end specimens were cut from stringers and stressed in the longitudinal direction to 75 percent of the yield strength. Sections from selected stringers were loaded as cantilever beams to 75 percent of the yield strength in such a manner that the maximum stress was at the base of the flange normal to the direction where the stringers have cracked. There have been no failures after 12 days of exposure to alternate immersion in salt water and exposure to the atmosphere. Additional specimens are being fabricated in the transverse direction and will be stressed to 75 percent of the yield strength and similarly exposed in the alternate immersion tester.

E. S-II 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. S-II-3

During rehydrostatic testing of the S-II-3 aft LOX bulkhead, failures were experienced in some of the LOX sump simulator attachment bolts. Since the same type of bolts is used on flight stages, the stage contractor (S&ID) initiated several redesign studies. Based upon an evaluation of the sparse data available, it seemed reasonable to personnel of this division to continue to use the A-286 steel alloy bolts but to change the design from the current stepped-shank configuration to a straight-shank configuration to reduce stress-risers. This Center has instructed S&ID to evaluate the straight-shank bolts under hydrostatic test using the "test bulkhead."

During a hydrostatic test of the S-II-3 LH_2 bulkhead, the bulkhead was collapsed because of procedural errors. After certain inspections, the bulkhead was repressurized to limit load (35 psi). As a result of the repressurization, the bulkhead deformation, with one possible exception, was removed. Since the insulation on the apex half of the bulkhead was damaged beyond repair, S&ID currently has hopes of spray foaming an insulation blanket onto the bulkhead. Considerable work remains to be done in developing application and inspection procedures for the spray foam as well as in qualification of the insulation blanket.

2. S-II-501

In conjunction with an insulation review meeting at S&ID, it was observed that while the insulation on S-II-501 and 502 appears better than the insulation on S-II-T and -F, in many respects, there are numerous examples of poor workmanship and poor quality control. As a result of the experience with S-II-T, S&ID has introduced several insulation design changes including foam-in-place around all of the LH_2 feed lines and the LH_2 fill and drain line. Since the foam-in-place material is very flammable, S&ID was asked to evaluate the fire hazard associated with the design change that was made effective on S-II-501. Also, since there will be little or no accessibility to the S-II insulation once the stage is "stacked" in the Saturn V configuration at the launch site, S&ID was asked to reevaluate all operational requirements and repair procedures in the light of this inaccessibility.

IV. S-IVB Stage

A. Development of Expulsion Bladders for the S-IVB Auxiliary Propulsion System

Activities have continued in this division on the development of molding techniques and designs for hemispherical bladders of potential use in the expulsion of the oxidizer and fuel from the tanks of the S-IVB auxiliary propulsion system.

On the basis of the results of tests made on a "handmade" experimental bladder configuration a new mold configuration was designed. This mold is being fabricated and when finished will be used to form hemispherical bladders from fluorocarbon resins for evaluation. It is believed that the new design will result in an improved folding pattern as the bladder is collapsed which will contribute to longer cyclic lifetime of the bladder.

B. Developmental Welding

Tests are in process on weld specimens whose configurations simulate the joint of the common bulkhead to the LOX bulkhead of the S-IVB stage. The tests are designed to determine the amount of membrane stress plus bending that the joint can withstand. Test results to date are inconclusive.

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

Activities have continued in the study of materials problems attendant to the use of the hydrogen tanks of spent S-IVB stages as manned chambers in space. This work includes theoretical considerations and experimental testing in each of the following areas:

1. Investigation of the Effects of Reduced Pressure on Internal Tank Materials

The purpose of this project is to determine the vacuum compatibility of materials contained within the liquid hydrogen (LH_2) tank of the S-IVB stage. Materials will be evaluated as to weight loss and the outgassing constituents will be identified for potential toxic components.

Determinations were made of the vacuum compatibility of Dynatherm D-65, the material selected as the passivating coating on the S-IVB LH_2 tank insulation. D-65 is a sprayed coating containing phosphate and boron flame-retardant compounds dispersed in a flexible polyurethane binder. A specimen of this material was subjected to a reduced pressure of 10^{-5} torr and the specimen weight loss observed, and the products evolved were analyzed by mass spectral techniques. The total weight loss to the point of stabilization was 9.4 percent. Mass spectral data indicated that this lost material was predominately hydrogen, nitrogen, and benzene. The high weight loss observed was due, largely, to evolution of gases trapped during spraying and it does not preclude the use of this material for passivating the S-IVB insulation.

2. Investigation of the Effects of Simulated Micrometeoroid Impacts on S-IVB Stage Tanks

Previous tests on tank materials and insulation at the Arnold Engineering Development Center (AEDC) high velocity test facility have indicated that high velocity particle impacts can induce burning of the internal tank insulation in the presence of 5 psia oxygen. Arrangements have been made for additional tests at AEDC. Thirty additional samples have been prepared for simulated micrometeoroid penetration tests. Several insulations specimens have been coated with silicone materials to determine the potential fire retardant or inhibiting effects of the silicones. The coatings used were products of Dow Corning; DC 93-046, DC 93-027, and DC 92-009. Specimens of several flexible materials have been prepared for evaluation as micrometeoroid bumpers. It is anticipated that tests will be initiated on these insulations and bumpers during the first week in June.

D. 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. S-IVB-202

The stage contractor removed what was believed to be a crater crack in the LOX tank toe weld of the common bulkhead. Existence of a crack was verified during removal operations. Minimum thickness of metal after grinding at this location was 0.114 inch (original thickness was $0.191 \pm .005$); thus, a doubler patch was required.

2. APS Oxidizer Tankage

Testing of two APS tanks filled with nitrogen tetroxide (N_2O_4) was initiated at Langley Research Center on April 14, 1966. The N_2O_4 conforming to specification MSC-PPD-2 was pressurized to give a tank skin stress of 90 KIPS and held at 110°F (43°C) for a 30-day period. No problems were encountered. Thus, it was decided to continue testing one of these tanks for another 30-day period and to pressurize the remaining tank to failure.

3. The following documents were reviewed:

a. Preliminary S-IVB Spent Stage Experiment Development Plan, dated April 22, 1966

b. DAC PRD 1P00108, "Heat Treatment of Aluminum Alloys, Process for

c. High Strength Bolts for Joining S-IVB and S-II Stages

d. Relaxation of Time Restrictions on Burp Firings of Saturn IB/S-IVB APS

e. S-IVB-501 through -515 Maximum Aerodynamic Heating Trajectory.

V. Instrument Unit

A. Corrosion Studies of Magnesium Lithium Alloys

All general corrosion and protective coating studies on magnesium lithium alloys has continued. To date, AZ31B magnesium alloy appears to be more susceptible to galvanic type corrosion than either LA141 or LAZ-933 alloys. Additional tests are being made to determine the effectiveness of IBM fluoride anodize and Dow 17 protective coatings for reducing the susceptibility to stress crackingof re-solution heat treated LA141 alloy. Neither coating appears to give satisfactory protection to the re-solution heat treated alloy. Potential measurements of the three test alloys with other metals in several electrolytes are continuing.

B. Study of Corrosion Resistance of Brazed Joints in Stainless Steel Tubing

Investigations are in process to determine the corrosion resistance of brazed joints in stainless steel tubing used in contact with the inhibited methanol-water cooling solution specified for the instrument unit cold plates. The tubing joints are brazed with a gold brazing compound. No corrosion has been observed on any of the joint specimens being tested after approximately 50 days of exposure to the inhibited water-methanol solution.

C. Instrument Unit, Project Management, Materials

Efforts are continuing on the coordination and resolution of problem areas related to the materials aspects of the instrument unit of Saturn V. During this report period, these activities have included the following:

1. Study of Failure of Cap Screws Used on Environmental Control Panels

Several 1/4-inch socket head cap screws used on the Instrument Unit Environmental Control Plates failed during vibration testing. Fractographic analysis indicated that the fractures initiated in an embrittled area which could have been caused by hydrogen embrittlement, and the resulting cracks were propagated by fatigue. It was suggested that an MSFC Document 10419960 be used as a cover document for Federal Specification QQ-P-416A when cadmium plated fasteners were purchased. As a result of this analysis, several bolts are being removed from SA-202 and SA-203, and also from a test unit which was vibration tested, to determine the extent of this problem prior to making a decision on changing these bolts.

2. Study of the Quality of the Weld in the Water Accumulator

A problem has developed relative to the quality of the weld in the water accumulator used in the environmental control system. The accumulators, manufactured by Hamilton Standard are not required to be inspected radiographically. However, radiographs made on several of the units after they were accepted indicate that the weld quality does not meet the present specification requirements. Radiographs are now being made of all available accumulators in order to select a possible unit for use on SA-203 and SA-202.

VI. F-1 Engine

A. Study of the Failure of F-1 Engine Fluid Power System Flight Supply Duct Assembly

A fluid power system flight supply duct assembly (Resistoflex PN R-11620-1, MSFC Drawing 20M55058) failed after a total of approximately 600 seconds firing time on 4T2 (single engine) Block IV gimbal system. Failure of the 321 stainless steel component occurred in the tube-to-flange fillet weldment. This line was not a qualified part and was used for ground test until the new flight configuration is received. The flight configuration incorporates a butt weld to join the tube to the flange. The subject failure resulted from fatigue. Although failure occurred in the weld, secondary cracking was noted in the heat affected zone of the tube. No metallurgical irregularities that could have influenced the failure were identified.

B. Study of Main LOX Valve Control Line Failure on F-1 Engine

A 321 stainless steel flange-to-tube fillet weldment on the main LOX valve control line (Rocketdyne PN 601914) of an F-1 engine failed after a total of approximately 2500 seconds firing time on engine F4T2. The failed line segment furnished hydraulic fluid (RP-1) to the opening control port which operated the number two LOX valve. The failure resulted from fatigue. The stress riser created at the flange-to-tube fillet weld junction is a natural pivot point for fatigue. No metallurgical irregularities were detected that could have influenced the failure. No change in design was recommended at this time since the line had undergone 2500 seconds firing time.

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

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

G. Lubricants and Lubricity

Midwest Research Institute, NAS8-1540

H. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-5340, NAS8-11226, NAS8-20285
2. National Bureau of Standards, GO-H2151A
3. Northrop Corporation, NAS8-20333

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

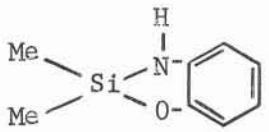
II. General - In-House

A. Study of Silicon-Nitrogen Polymers

Experimental work has continued on the preparation and characterization of polymeric materials based on recurrent silicon-nitrogen linkages. During this report period emphasis was directed toward preparation of dimethylethoxyanilinosilane which has been accomplished by the following reaction:

$$\begin{array}{l} \text{Me} \\ | \\ \text{EtO-Si-Cl} \\ | \\ \text{Me} \end{array} + \text{H}_2\text{N-}\emptyset \xrightarrow[\text{Benzene}]{\text{N(Et)}_3} \begin{array}{l} \text{Me} \\ | \\ \text{EtO-Si-N-}\emptyset \\ | \\ \text{Me} \end{array} + \text{HCl}\cdot\text{N(Et)}_3$$

The crude product was obtained in a 86.1 percent yield. This was obtained by removal of the benzene solvent through distillation. The crude product had a purity of 77 percent as indicated by gas chromatography analysis. The hydrochloride salt was recovered and dried and represented a yield of 99.6 percent of theory. This material will be distilled and subsequently used in an attempted preparation of the following model compound:



B. Development of High Temperature Resistant Polymers

Activities have continued on the development of high temperature resistant polymers. During this report period these activities included the following:

1. Model Compounds

Attempts were made to obtain X-ray diffraction data on some aryloxysilane compounds. Preliminary results on the initial compounds studied indicated that these materials were largely amorphous and the Bragg reflectance was not clear and well defined. Thus, no d-spacings could be determined.

2. Monomer Preparation

Elemental analyses have been completed on the new hetrocyclic diol compound, N,N'-(p-hydroxyphenyl) pyromellitic dimide, which was prepared last month. These analyses yielded values for percent carbon which were at variance from the theoretical value of the carbon content. Further attempts will be made to prepare this compound.

A method for the preparation of phenyltrianilinosilane was reported previously. An additional batch of this compound has been made. It was noted that this material has a poor shelf life so that it will be necessary to prepare it as it is needed. The analysis of a sample prepared earlier was in only fair agreement with theory. This is believed due to decomposition on standing, prior to analysis.

The work done at Battelle Memorial Institute, Contract NAS8-11837, on the pilot-plant preparation of Polymer A has indicated that the aniline obtained as a bi-product of the polymerization causes coloration in the polymer. In an effort to avoid color forming bodies, work has been done on the preparation of two silane monomers, bis(dimethylamino)-diphenylsilane and bis(dimethylamino)dimethylsilane. It is proposed that these materials be used instead of the dianilinosilane in the preparation of Polymer A, thus avoiding the aniline induced coloration. Since bis-(dimethylamino)diphenylsilane has not been reported in the literature, a

method had to be developed for its preparation. In the first run the silane was added to benzene, chilled, and excess dimethyl amine was added as a gas.

$$\underset{}{\phi_2SiCl_2} + \underset{\text{excess}}{HN(CH_3)_2} \xrightarrow[\text{benzene}]{\text{cold}} \phi_2Si(N(CH_3)_2)_2 + HCl\cdot\overset{H}{\overset{|}{N}}(CH_3)_2$$

This procedure resulted in an 84 percent yield of a product of 60 percent purity. In a second attempt chilled liquid dimethylamine was used. In this case the product was 91.4 percent pure according to gas chromatography. Infrared analysis indicated that the desired compound had been obtained. However, because of the presence of 8.6 percent impurities, the elemental analysis and molecular weight analysis were rather poor. It was concluded that this material was not of sufficient purity for use in polymerization.

Attempts were then made to prepare bis(dimethylamino) dimethylsilane. It was believed that this material could be more easily purified by distillation because of its lower volatility. The liquid amine procedure described above for the diphenyl compound was used and a 50 percent yield of product having a purity of 98.9 percent was obtained. A total 82 percent of theory of the hydrochloride salts were obtained. A second preparation gave a poor yield of a product which was 99 percent pure. This material will be used in polymerization studies.

3. Polymerization Studies

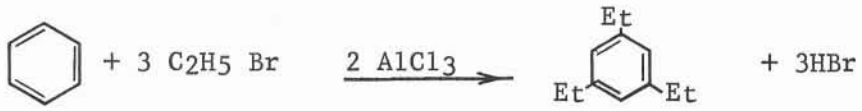
Investigations have continued into methods appropriate for crosslinking Polymer A. Initial attempts to crosslink a specimen of the polymer with trianilinophenylsilane were unsuccessful, however, a specimen of the polymer having a degree of polymerization (DP) of 10 was crosslinked successfully with trianilinosilane as indicated by increased hardness and decreased solubility of the cured polymer.

Activities have continued in the determination of the chemical, physical, and electrical properties of Polymer A. The specific heat of Polymer A ranges from 0.312 to 0.335 cal./gm./°C at 50 to 100°C. Thermogravimetric analyses in air nitrogen, and in vacuum have been completed on specimens of Polymer A and these data indicate the material has good thermal stability in vacuum and nitrogen but is only fair in air. Differential thermal analyses indicate that no significant molecular transitions or rearrangements occur in Polymer A at temperatures below 542°C.

C. Development and Characterization of Phosphonitrilic Polymers

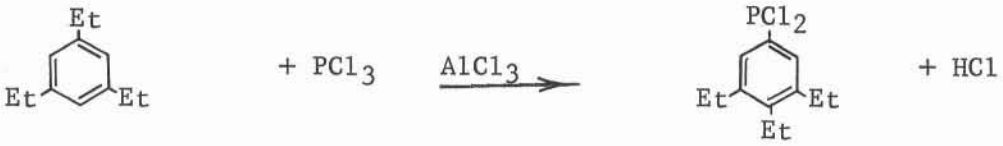
The projected synthesis of aryl-phosphonitrilic chloride tetramers was continued with the investigation of 1,3,5-trimethylbenzene as the starting material.

The sym-triethylbenzene was prepared through the Friedel-Crafts reaction of benzene with ethyl bromide:



The hydrocarbon was obtained in 82 percent yield having a boiling range of 67.5-69°C/5 torr. Examination of the infrared spectrum of the compound showed absorption bands at 710 and 870 cm^{-1}, indicative of 1,3,5- substitution.

The preparation of 1,3,5-triethylphenylphosphorus dichloride was attempted through the reaction of the hydrocarbon with excess phosphorus trichloride in the presence of anhydrous aluminum chloride:



Work-up of the reaction mixture gave a low yield of product as a pale yellow oil, having a boiling range of 100-109°C/0.15 torr. This material has been characterized only to the extent of obtaining its infrared spectrum which showed that the 1,3,5-configuration was no longer present.

This reaction is being repeated in order to increase the yield of product through a longer time of reaction with increased amounts of catalyst present. Also, complete characterization of the product will be attempted.

D. Investigation of Materials for Electrical Contacts in Vacuum

Activities have continued in the development and evaluation of materials suitable for use as electrical brushes in the environment of space.

One test was completed during this reporting period in the study of wear rate as a function of brush pressure for the composition 85 percent molybdenum disulfide (MoS_2) and 15 percent silver (Ag), pressed at 3,500 psi. The test was operated at 2,000 rpm and 1 ampere of brush current for 264 hours with 10.8 psi springs installed. The wear rate was 1.7×10^{-5} inches/hour. The wear rate obtained on this brush material under the same operating conditions but with 12.8 psi springs was 1.8×10^{-6} inches/hour. This test series is continuing.

The brush test apparatus is being modified to allow the measurement of brush friction while maintaining constant spring pressure on the brushes. The drive motor will be unrestrained in bearing supports and the reaction torque produced will be measured. The pressure on the brushes will be kept constant by the use of a weight-lever arm arrangement. These modifications

require new test chambers which are being designed. Brush materials of various percentages of niobium diselenide ($NbSe_2$) and molybdenum disulfide (MoS_2) will be tested in this test system.

The equipment developed to measure resistivity and Hall coefficient at low temperatures was used to measure the resistivity of a series of electrical brush materials. The use of this equipment was dictated because of the wide range of resistivity values (10 to 10^{-6} ohm-cm) and because it utilizes the four probe method which eliminates the effects of contact potentials normally associated with these types of materials. The results of these tests are summarized as follows:

Tests were made on specimens of hot pressed $NbSe_2$ of two different particle sizes, i.e. 40 microns and 2 microns, and specimens hot pressed from composite compositions of $NbSe_2$ and MoS_2 (4 microns). The processing temperature ranged from 1400°F (760°C) to 1850°F (1010°C) and the pressure ranged from 3000 psi to 5500 psi.

The test data indicate no apparent difference in resistivity of $NbSe_2$ material as a result of variations in either pressing temperature or pressure. Similarly there was no noticeable difference in resistivity between specimens of $NbSe_2$ prepared from 40 micron and 2 micron raw material. As expected, the system composed of MoS_2 and $NbSe_2$ showed an increase in resistivity as the MoS_2 content was increased.

Similar studies were made on composite specimens formed from MoS_2-Ag. In this system the variables were particle size of the MoS_2, pressing temperature and pressure, and variations in silver content. Significant differences in resistivity were noted in the instance of specimens formed for MoS_2 of different particle sizes.

Four micron particle size MoS_2 is about 2 orders of magnitude lower in resistivity than the 2.5 micron MoS_2, varying from a factor of 3.5 for 100 percent MoS_2 to about 0.8 for 70 percent MoS_2 - 30 percent Ag. This variation would be expected with increasing Ag content, since the silver is furnishing the majority of the current carriers. Also noted was a sharp variation in resistivity of the 2.5 micron MoS_2 with pressing temperature. Specimens of 85 percent MoS_2 - 15 percent Ag pressed at 1,700°F (927°C) had a resistivity of 2.5 ohms-cm, while the same material pressed at 1,740°F (949°C) had a resistivity of 0.055 ohm-cm. Thus, a variation in resistivity of two orders of magnitude was obtained by varying the pressing temperature by only 40°F (22°C). Since the melting point of silver is 1765°F (961°C), it appears likely that better diffusion of silver is being accomplished with increased probability of interstitial substitution.

The marked difference in resistivity between the 2.5 micron MoS_2 and 4 micron MoS_2 would be expected to be due to higher impurity content in the 4 micron MoS_2. This would present no problem unless the impurities

would be harmful to the lubricating properties of the MoS_2. Some observable differences were noted in the operation of brushes compacted from the two types of MoS_2, and a difference in lubricity probably does exist.

E. Investigation of the Dielectric Properties of Materials

1. Study of Effects of Additives on Dielectric Properties of RJ-1 Fuel and Teflon Tubing in Hydraulic Systems

Teflon tubing used in the hydraulic system of the S-IC stage accumulates an electrostatic charge due to the high velocity flow of fluid through the filter system. The charge is great enough to cause electrical breakdown of the unfilled Teflon high pressure tubing. Therefore, a study was initiated to determine the effect of high conductivity tubing and additives to the hydraulic fluid. If the additives increase sufficiently the conductivity of either the Teflon or the RJ-1 fluid, it is believed that the accumulated charge will be eliminated or reduced to a low level so that electrical breakdown of the tubing will not occur.

A definitive program to determine the effectiveness of various conductivity additives to RJ-1 has been initiated. Additionally, work is in progress to determine the effects on conductivity of various lubricity additives which are being considered for RJ-1.

2. Study of Static Electrical Charge Effects on Passive Thermal Control Coatings

Thermal control coatings on the Saturn vehicle have degraded in flight, apparently due to surface deposition of particles from the retro rocket exhaust. Adherence of the particles is enhanced by the static electrical charge on the vehicle skin.

To determine the magnitude of the problem a rudimentary apparatus was assembled in a vacuum chamber which would permit dropping ultra-fine AL_2O_3 powder past the surface of a thermal control coating sample which was electrically charged. Preliminary runs were made on an S-13 coated disc, with and without an electrical charge. The test results are tabulated below.

DEPOSITION OF AL_2O_3 ON S-13

State of Disc	Mass of Powder Attracted - gms.
Uncharged	0.00045
Charged to +630 Volts	0.00355

3. Development of Technique for Determining Impurities in Nitrogen Tetroxide (N_2O_4)

The compatibility of nitrogen tetroxide (N_2O_4) with titanium tanks of Auxiliary Propulsion Systems is dependent on the amount of impurities contained in the N_2O_4. The possibility that the change in impurity content would result in a change in dielectric properties was investigated as a means of determining the impurity content of N_2O_4. Significant changes were observed in both dielectric constant and dissipation factor when impurities were added to the N_2O_4, but differences were also noted between samples of supposedly pure N_2O_4 from different cylinders. Since the exact analyses of the N_2O_4 used in these tests were not known, the experimental results are difficult to assess, however, it is considered probable that a correlation could be obtained between dielectric characteristics and impurity content if N_2O_4 samples of known purity could be obtained.

F. Investigation of Nuclear Environmental Effects on Materials

1. Study of the Effects of Radiation on Thermal Control Coatings

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

The initial optical measurements on specimens of S-13 and Z-93 thermal control coatings have been completed by Hughes Aircraft Corporation, on a service contract basis and these specimens have been delivered to this Center. Irradiations of these specimens are scheduled after completion of the electron beam pattern measurements on the accelerator. Preliminary optical measurements are being made by the Research Projects Laboratory (RP) on some specimens of bright anodized aluminum. When these specimens are received, they will be irradiated and returned to RP for further analysis.

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

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

3. Study of Effects of Charged Particle Irradiation of Elastomers

A program has been initiated to study the effects of charged particle irradiation of elastomeric materials. Much data have 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 of neoprene rubber have been tested to determine the effects of electron radiation on the tensile strength and ultimate elongation of this material. Tests were made for fluences of 1.2×10^{13}, 1.04×10^{14}, and 1.22×10^{15} electrons-cm^2 using 1 mev electrons. The data obtained were statistically analyzed to determine whether the observed property changes were significant or within the experimental error of the tests. The results obtained are shown in the following tabulation:

1 MEV ELECTRON IRRADIATION OF NEOPRENE RUBBER

Condition	Tensile Str. (psi)*	Change (%)	Ult. Elong (%)*	Change (%)
Controls	3272	-	367	-
I-1 (1.2×10^{13} e/cm^2)	3074	6.5	344	6.3
I-2 (1.04×10^{14} e/cm^2)	3023	13.1**	333	9.3**
I-3 (1.2×10^{15} e/cm^2)	2728	16.6**	242	34.0**

*Average of 6 specimens
**Statistically significant at a 95 percent confidence level

As can be seen in the table, significant reductions in tensile strength and ultimate elongation were observed for irradiations of 1.04×10^{14} and 1.2×10^{15} cure on the radiation stability of this material.

4. Vacuum Tensile Tests

The apparatus for determining, in-situ, the tensile properties of materials after prolonged exposure to vacuum and temperature has been received from the development shop where several major modifications were made. The apparatus is now being checked for vacuum integrity. The first tests which are scheduled for the first week in June will be made on structural adhesives and laminates. The feasibility of using this apparatus for vacuum-radiation tests is being studied currently. The concept being considered is that of placing a cobalt 60 gamma ray source or a strontium 90 beta source in close proximity to the tensile specimens to determine the in-vacuo effects of the radiations on the tensile properties of various polymeric materials.

G. 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.

During this reporting period the motor in which the experimental materials are evaluated was run with separate excitation to the field as opposed to the d.c. shunt arrangement with the field and armature circuits in parallel. This was done to obtain more meaningful torque-speed curves as a function of field current, armature current, and applied voltage. Tests also were initiated to obtain the field and armature resistance to enable the calculation of the efficiency of the motor and generator by the method of system losses. In addition, a series wound high torque motor has been received and is being prepared for testing. A loading device for directly coupling to this motor is being designed. Tests on this motor (which will be run in air) will furnish information on the operating characteristics of series (high torque) d.c. motors.

H. Investigation of Lubricant Materials

One of the major lubrication problems today concerns low temperature lubricants for use in contact with oxidizers. A test apparatus has been designed and manufactured for evaluating greases from +50°F to -100°F (10°C to 73°C).

During this reporting period, a new test fixture having improved sensitivity in measuring the break-away torque of the greases was put into service to test low temperature, LOX compatible lubricants for use on liquid oxygen valves.

Two commercial lubricants and three lubricants developed by this division were tested for break-away torque and relaxation torque over the temperature range 0°C to -80°C. A preliminary comparison of the observed break-away and relaxation torque data indicates that at least one of the lubricants developed by this division is superior to the currently used commercial lubricants.

I. Study of Materials for In-Flight Experiment No. 1

In support of proposed in-flight experiment, No. 1, tests are being made to determine the effects on dielectric constant, dissipation factor, and conductivity of dielectric samples measured with several configurations of flat screen electrodes, both in air and in vacuum.

All test determinations have been made. However, due to the large number of parameters involved, data reduction is a lengthy process, and rather than presenting inconclusive preliminary results, no information will be presented until all data tabulations are complete.

J. Determination of Physical Properties of Materials by Nondestructive Techniques

1. Internal Friction Measurements

A study is being made to determine whether the internal friction of aluminum changes after the metal is exposed to a stress corrosion environment.

Damping measurements have previously been made on aluminum specimens subsequent to an exposure to stress corrosion. Material damage caused rather large energy losses. Damping measurements have been made on fifty 7079 aluminum alloy specimens in air, and about half of these have also been measured in a vacuum. Specimens 1/8 inch and 3/16 inch in diameter machined in the short transverse and longitudinal directions were included in this study to minimize experimental variations by selecting an ideal specimen size. The data obtained are being analyzed.

2. Electrical Conductivity

Electrical conductivity measurements are being made in an effort to correlate changes in surface conductivity with stress corrosion damage. Measurements to date have been made on flat specimens using conventional eddy current instrumentation. However, for measurements involving cylindrical specimens, conventional instrumentation is not applicable and special instrumentation is required. Consequently, several new transducers currently are being designed and fabricated which will enable conductivity measurements to be made on cylindrical stress corrosion 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 specimen cut in the short transverse direction showed any appreciable change in conductivity.

K. Investigation of the Materials Aspects of Joining Metallic Composites

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

1. Study of Diffusion Bonding Studies of Various Metals

Eight 6Al-4V titanium specimens were diffusion bonded to determine the bonding time/temperature parameters necessary for producing an acceptable bond without loss of strength in the material. Four of these specimens were subjected to a three-hour cycle at 1750°F (954°C) and the remaining four specimens for five hours at temperature. Subsequent to bonding and after solution treatment and aging, the specimens were cleaned in a HF and HNO_3 solution. After bonding, the specimens were tested in shear. Lapshear strengths ranged from 8,560 psi for the specimens bonded for three hours to 22,000 psi when bonded for five hours. While these values appear low, the lap area was reduced in order to cause failure to occur in the lap area rather than in the parent material. It was noted also that with increase in the bonding time, an increase in lapshear strength resulted without significant loss in parent material strength.

Subsequent heat treatment improved the lapshear strength of the specimens which were bonded at temperature for three hours, but little effect was noted on the specimens bonded for five hours. Further tests will be done to verify these results.

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

In an effort to develop techniques for producing laminates of various sheet materials, a dissimilar metal diffusion bond (aluminum to titanium sheet) was attempted. In this instance, the aluminum outer sheets (which were used also as the retort closures) were wrapped around the titanium center sheet and welded together forming the completed retort. Cleaning fluids were introduced through an orifice welded in the retort. This approach was utilized in an attempt to accomplish the cleaning operation within the retort in an effort to preclude usual surface reoxidation prior to bonding. The laminate retort was heated to 900°F (482°C) under a recorded pressure of 4,400 psi for 1-1/2 hours. The low temperature and contaminates (smut on the aluminum faces which did not wash out during the cleaning operation) were believed to have contributed to poor bonding of the dissimilar laminates. The second bonding attempt was accomplished by first cleaning the respective aluminum and titanium sheets and then subjecting them to a temperature of 950°F (510°C) and 4,400 psi for approximately 40 minutes. The bonded sample was then sectioned and both photomicrographs and mechanical evaluation indicated complete diffusion of the laminates over the majority of the sample. Further bonding tests will be done to verify and substantiate previous results.

3. Evaluation of Solders for Joining Composite Materials

Soldered aluminum honeycomb composites prepared during the previous report period were found to have an unacceptably low flatwise tensile strength. A detailed examination of failed specimens revealed that only the outer border of the honeycomb was wetting properly. Since non-perforated core material was being used, it was thought that possibly the entrapped air in the cells, upon heating and expanding, forced the liquid solder from these cells to the outer edges of the specimen. Two more specimens were then prepared with notches made across each cell at the top portion of the core, and all the soldering parameters were applied as done previously, that is, use of 0.006-inch thick solder foil and soldering temperature of 635°F (335°C) for six minutes. These flatwise tension specimens, upon testing, showed results of approximately twice the properties as previously indicated. Furthermore, the failed specimens, upon examination, indicated uniform wetting of the solder at the face sheet and honeycomb interfaces. These results compare favorably with adhesively bonded aluminum honeycomb flatwise tensile properties.

4. Evaluation of an Explosively Bonded Bimetallic Sheet Material

An explosively bonded bimetallic sheet material (1100 aluminum alloy bonded to pure titanium), submitted by Battelle Memorial Institute, was subjected to room temperature mechanical tests. The composite consisted

of 33 percent by volume of titanium and 66 percent by volume of aluminum. A tensile strength of 59,000 psi with a ductility of approximately 12 percent elongation was obtained when these specimens were tested. A study of the interface bond, after the specimens were subjected to the tensile, bend, and thermal tests, indicated the interface to be of acceptable quality. A micro-examination across the laminate interface showed continuous bond throughout, with intermittent oxide buildup and partial diffusion noted in the bond line.

L. Investigation of Inorganic Adhesives for Use in Contact with Oxidizers

The objective of this program is the development of a ceramic adhesive or family of ceramic adhesives for application in liquid oxygen systems and that are useful for structural application at liquid oxygen temperatures. The resultant adhesives must be applicable to 2014-T6 aluminum alloy at temperatures not to exceed 350°F (177°C).

Adhesive systems being investigated contain various inert materials such as silica (SiO_2), alumina (Al_2O_3), zirconia (ZrO_2), and clay ($Al_2O_3 \cdot 2\ SiO_2 \cdot 2\ H_2O$) as the filler, monaluminum phosphate ($Al_2O_3 \cdot 3\ P_2O_5 \cdot 6\ H_2O$), phosphoric acid ($H_3P_4$), and monofluorophosphoric acid (H_2PO_3F) as the binder, and chromium oxide (CrO_3) to inhibit reaction between binder and substrate. Several adhesive systems have been formulated using various combinations of the above ingredients and evaluated for compatibility with the 2014-T6 aluminum alloy adherends. To date, the most promising adhesives evaluated contain either clay or Al_2O_3 as the filler, monaluminum phosphate as the binder, and CrO_3 as the inhibitor. Adhesives containing either H_3PO_4 or H_2PO_3F react vigorously with the adherend material resulting in poor adhesion. Future work will consist of optimizing the most promising adhesive systems with respect to composition and application techniques.

M. 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 cyrstals with controlled defects and impurity gradient distribution will be grown.

Five zone passes were made on an ingot of aluminum under varying conditions of pressure and helium purge gas in the RF induction furnace. The ingot was imbedded in aluminum oxide powder with only the top surface exposed to allow visual examination of the zone movement. The LN_2 trap was found to be unsatisfactory since the change in color and thickening of the surface layer on the ingot indicated backstreaming was being permitted. To circumvent this problem helium gas was pumped through the system continuously at a pressure in the viscous flow region and the color of the RF glow discharge was observed to determine the presence of contaminants. At one torr, the RF plasma was blue-green indicating high oxygen concentration.

When the helium flow was increased to the point where the plasma consisted only of the reddish-pink color characteristic of helium, the oxide formation was considerably reduced. However, the heat losses associated with this flow rate are prohibitive and it is barely possible to sustain the molten zone.

A new helium supply system is being fabricated in order to eliminate the in-leakage of air and enable operation at lower helium flow rates.

N. Documentation Review

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

1. Boeing Change Request PRR 1089S, "Modify Airsearch prevalves to correct corrosion problems and replace nuts which are susceptible to cracking"

2. Thiokol RMD Spec. 4085, "Water Specification for General Purpose Rinse and Dilution"

3. Thiokol RMD Spec. 7706, "Method of Pickling Tantalum and Columbium Alloys"

4. Thiokol RMD Spec. 7705, "Method of Pickling Titanium Alloys"

5. Thiokol RMD Spec. 7708, "Cleaning Procedure for Semi-Finished and Finished Titanium Alloy Parts"

6. Thiokol RMD Spec. 7709, "Cleaning Procedure for Semi-Finished and Finished Refractory Metal Parts"

7. Thiokol RMD Spec. 7711, "Cleaning Procedure for Silica Reinforced Plastic"

8. Thiokol RMD Spec. 7712, "Gold Plating"

9. Thiokol RMD Spec 7713, "Anodic Coating Black Dyed, Process Specification for"

10. Thiokol RMD Spec. 7029, "Anodic Oxidation Processes for Aluminum Alloy"

11. Thiokol RMD Spec. 4125, "Resin Impregnated High Silica Fabric Tape"

12. Thiokol RMD Spec. 7674, "Electron Beam Welding"

13. Thiokol RMD Spec. 7703, "Method of Cleaning Aluminum Alloys for Electron Beam Welding"

14. Thiokol RMD Spec. 7716, "Welding Quality for Extension Nozzle, Rocket"

15. Thiokol RMD Spec. 7044, "Welding and Allied Processes"

16. Thiokol RMD Spec. 4120, "Columbium, Oxidation Resistant Coating"

17. Thiokol RMD Spec. 4121, "Refractory Alloy: Oxidation Resistant Coating (Sylcor R508C)"

18. S&ID Spec. MA0110-010 Rev. D "Solvent Cleaning, Methods including list of General Chemical Processing Specifications"

19. S&ID Spec. MA0109-010 Rev. A and B, "Hard Chrome Plating Copper, Nickel, and Ferrous Alloys"

20. S&ID Spec. MA0610-024B, "Contamination Control During Installation, Testing, and Assembly of Saturn II Parts, Sub-Assemblies, and Assemblies (Stage and GSE)."

L. 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
6. Measurement of residual stresses
7. Ultrasonic inspection techniques
8. Refractory metals
9. Metallic fracture surfaces
10. Weld defects in aluminum.

L. K. Zoller
for J. E. Kingsbury

MONTHLY PRODUCTION REPORT
MATERIALS DIVISION
MAY 1, 1966 THROUGH MAY 31, 1966

I. Radiographic Inspection

One hundred and seventy-one miscellaneous parts, components and test specimens were inspected radiographically during this report period.

II. Photography

	Negatives	Prints	Other
engineering photography	103	427	
metallography and fractography	101	523	
miscellaneous photography, processing, copywork, etc.	38	57	256

III. Metallurgical and Metallographic Testing and Support Services

A. Two gold-plated brass specimens were examined metallographically to determine the plating thickness. Measurements showed that the average plate thickness was 0.000125-inch.

B. Metallurgical studies were completed on several LOX container relief switch diaphragms. These studies indicated that three out of the eight diaphragms examined were not bonded (soldered) securely. It was recommended that an investigation be made to determine the soundness of the solder bond after the thermal cycling operation and that other methods of joining be considered for these components. A study to determine the corrosion resistance of Kirkson No. 20 solder presently being used to join the diaphragms to the pick-up plate on the LOX side of this switch was also made. Results of this study indicated that the solder is susceptible to corrosion in high humidity and that the solder can be protected by plating 0.3 mil of gold over the solder.

C. A metallurgical study was made of an Allis Chalmers fuel cell hydrogen electrode seal at the request of the Astrionics Laboratory, R-ASTR-E. The seal consisted of gold-plated nickel mesh covered with a platinum impregnated teflon. Examination indicated that the platinum particles were uniformly dispersed in the teflon. The maximum thickness of the gold plating was 0.000031-inch.

D. A plating and corrosion problem associated with magnesium plates used on an oxygen fuel cell and water recovery system on the Apollo vehicle was discussed with Astrionics personnel. The protective coatings used on the magnesium plates are electroless nickel plus gold plating.

Considerable corrosion has occurred after extensive exposure to a potassium hydroxide-water environment. Suggestions were made for improving the plated coatings and the possibilities of using other types of coatings. IBM anodize and Dow 17 coatings were applied to samples of magnesium for preliminary studies. Detailed plating procedures were not available, but an attempt will be made to obtain them.

E. It was recommended to the Propulsion Division that the 20 cu. ft. helium pressure bottles, formerly used on S-I/IB vehicles, could be used for gaseous oxygen storage without an internal coating, provided some corrosion could be tolerated and that the relative humidity could be maintained at 30 percent or below.

F. Examination of a redesigned Moog actuator rod end fitting was completed at the request of the Astrionics Laboratory. The rod end fitting had endured a total of 130,000 cycles of various modes during testing. Microscopic and dye penetrant examinations revealed no cracking. Redesign of the component consisted of increasing the radius between the "eye" and the threaded area with subsequent "peening" of the critical surface. The component was returned to the Astrionics Laboratory for further testing.

G. Metallurgical studies were completed on a failed J-2 engine gas generator combustion body received from the Test Laboratory. Since information received on the failure indicated that an explosion occurred in the generator rather than a material failure, the studies were concentrated on small cracks found in the Hastaloy C and 347 stainless steel material. The studies indicated that the cracks were surface tears probably resulting from the high deformation caused by the explosion.

H. A prototype injector was electron beam welded for the Propulsion Division. Extensive preproduction development was required to establish an optimum welding schedule.

IV. Spectrographic Analyses

Four hundred and eighty spectrographic determinations were made on thirty samples and seven hundred and sixty-two standard determinations were made.

V. Infrared Analyses

Three monomer specimens and two samples of contamination from liquid oxygen systems were analyzed by infrared techniques during this report period.

VI. Chemical Analyses

	Determinations
methanol water mixture	
for sodium benzoate	1
freon for water content	15
RJ-1 fuel for water content	2
detergent samples for	
moisture	6
ash	4
saponification number	4
nitrogen	2
phosphorus	2
sulfur	2
chlorides	4
gold plating solution for	
gold	2
potassium cyanide	4
fluorocarbon sample for	
free acid	3
metal samples for	
copper	35
carbon	24
sulfur	26
nickel	11
chromium	12
phosphorus	16
silicon	4
nitrogen	3
silver	4
polymeric samples for	
carbon	10
hydrogen	10
nitrogen	10
silicon	2
phosphorus	4
nitrogen tetroxide for	
purity	4
nitric oxide	2
moisture	2
chloride	2
residue	2
gas samples for	
oxygen	66
nitrogen	54
hydrogen	33
butane	9

VII. Physico Chemical Analyses

	Determinations
Density of	
RP-1 fuel	37
Beryllium specimens	4
pH of	
methanol water solution	1
detergents	2
specific resistance of methanol water	1
heat of combustion of dicyclopropyl-methane	3
viscosity of oil sample	6

VIII. Rubber and Plastics

	Items
molded or extruded	286
cemented	1
coated	27
fabricated	27

IX. Electroplating and Surface Treatment

	Items
Electroless nickel plated	1
gold plated	12
cleaned	50
tested under salt spray	8

X. Development Shop Production

A. A total of 7,588 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. One thousand three hundred and sewen man-hours, approximately 17 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. Impact Tester

Components of the impact tester have been completed and used to rebuild existing test facilities.

2. P&W Inducer Test Components

Further work on the Pratt and Whitney Inducer Components is pending design data on inner contour dimensions.

3. Ultrasonic Specimen Goniometer

Components of the ultrasonic specimen goniometer are complete and delivered.

4. Frame Weldment; Gas Analyzer

The frames for the gas analyzers have been completed and delivered.

5. Cyclone Chamber

The cyclone chamber is complete and delivered.

6. Vortex Suppressor

The vortex suppressor has been completed and delivered.

7. Low Temperature Drift Mobility Apparatus

The low temperature drift mobility apparatus is scheduled for completion on June 15, 1966.

8. Parts Turbopump Failure

The components for the turbopump have been completed and delivered.

XI. Miscellaneous

A. Fifty aluminum alloy items and forty-three items of stainless steel were heat treated during this report period.

B. Liquified three hundred and fifty liters of helium for the Research Projects Laboratory.

C. Eighteen chromatographic analyses were made on four experimental monomers and other miscellaneous compounds.

D. Specimens of contaminant from our Instrument Unit Sublimator were analyzed for the Astrionics Laboratory.

E. Specimens of contaminant from a cryogenic storage tank at Michoud were analyzed at the request of I-PL.

XII. Publications Issued

None

L. K. Zoller
for J. E. Kingsbury