PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

October 1, 1967, Through October 31, 1967

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-67-10

MONTHLY PROGRESS REPORT

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By

Advanced Studies Office
Vehicle Systems Division
Structures Division
Materials Division
Propulsion 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 (Continued)

TABLE OF CONTENTS (Concluded)

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-67-10

MONTHLY PROGRESS REPORT
ADVANCED STUDIES OFFICE
(October 1, 1967, Through October 31, 1967)

SATURN V

Voyager Program

A. Baseline Spacecraft Design

1. R-P&VE Spacecraft Design Status --- The final draft of the proposed Internal Note on Phase I design study has been technically evaluated by all Advanced Systems Office personnel and is being editorially reviewed by R-P&VE Technical Documents Group. It will be published upon return from that Office.

A memorandum is being prepared which describes the current status of the Langley Research Center effort on the Voyager Flight Capsule. This memorandum includes a description of the latest design of the Flight Capsule, along with a brief discussion of the interface between the Flight Capsule and the Spacecraft.

2. Phase B, Task D Contractor Oral Reports --- The three contractors, TRW, GE and Boeing, presented the final results of their efforts to MSFC personnel on October 18-19, 1967.

3. Voyager Weight History Documentation --- The various Voyager weight statements that have been generated in the in-house Voyager spacecraft design study, as a result of ground rule changes in the Voyager program, are being documented chronologically in a memorandum

entitled "Voyager Weight History." Included are spacecraft weight comparisons for capsule weights of 5000, 5600, 6000, and 7000 pounds, ΔV variations of 2.12, 1.95, 1.92, and 2.37 km/sec, and for both the LMD and Agena engine propulsion systems. Detailed spacecraft weight breakdowns are presented for the initial baseline spacecraft which considered a 5000-pound capsule and a ΔV = 2.12 km/sec and for the current baseline spacecraft which was designed for a 7000-pound capsule and a ΔV = 1.92 km/sec (1975 mission).

4. Spacecraft Structural Analysis --- A weight comparison has been made between the basic structure of the 140-inch baseline Voyager spacecraft and two alternate structural concepts. The baseline, concept 1, consists primarily of a 140-inch-diameter honeycomb shell to which eight outrigger supports are attached. The engine, propellant tanks, and other systems within this cylindrical shell are supported on a truss attached to the shell lower portion. In concept 2, the propellant tanks are supported from the cylindrical shell with tubular structure, instead of from the truss. A beam from the lower part of the cylindrical shell is used to support the engine. In concept 3, the propellant tanks are supported by a tubular structure which extends through the center of the spacecraft and provides a direct path for thrust loads from the engine to the spacecraft/capsule interface.

In comparison, concept 2 has a 17-per cent higher weight than concept 1; by contrast, concept 3 has a 6-per cent lower weight than concept 1.

Work is underway to evaluate the weight of these three concepts more precisely, using a computer program. The program uses unit deflection theory to calculate the sizes of the various structural members.

B. Alternate Spacecraft Design Studies

All current work being expended on the 260-inch-diameter spacecraft concept is devoted to documenting results of previous efforts. This information is scheduled to be published the end of November 1967.

A study to investigate the utilization of a modified Agena engine in the 260-inch-diameter spacecraft design has been completed. The summary results of the study show the following: (1) a weight saving of about 600 pounds over a similar LMDE configuration (using the 7000-pound capsule) is possible with the Agena configuration; (2) no increase in

planetary vehicle envelope size is required; and (3) the modified Agena engine has the capability to operate in the pressure-fed mode as a back-up to the primary pump-fed mode of operation.

C. Voyager 1973 Orbiter Study

All data generated in the consideration of alternatives to the "currently-conceived" Voyager program were forwarded to R-TO-Voyager for presentation to OSSA. The results of this study, as presented in last month's progress report, have been documented in memorandum R-P&VE-AV-67-267, "Voyager 1973 Orbiter Configurations and Weights," dated October 9, 1967. Presented in this memorandum were 13 different mission concepts, with each concept consisting of both a 1973 and a 1975 Voyager payload configuration. Supporting weight tables and figures were also included.

Pending receipt of guidance from Center management, this work is considered to be terminated.

D. Voyager Missions to Jupiter and Venus

In support of the in-house study of Voyager-type missions to other planets, an investigation has been made of missions to Mercury, Jupiter, and Venus.

Results from the Mercury mission evaluation show an orbiter mission to be unfeasible with present spacecraft design technologies and existing launch vehicle performance capability. Results from a fly-by mission appear to be meager due to the short time in the planet's vicinity. Both conclusions derive from the high approach velocities of the spacecraft with respect to the target planet which resulted from all mission modes considered.

For Jupiter and Venus, spacecraft have been sized for typical missions. For the Jupiter mission, resulting spacecraft data are (1) a gross weight of 17,900 pounds, (2) a propellant loading of 9,015 pounds, and (3) a science payload of 1,541 pounds. For Jupiter, only one spacecraft can be injected by each Saturn V launch due to the high velocity requirements of the mission. In the Jupiter mission analysis, only a planet orbiter without a landing capsule was considered. For Venus, the resulting spacecraft data are (1) a gross weight of 39,360 pounds, (2) a propellant loading of 18,547 pounds, (3) a science payload of 671 pounds, and (4) 13,927 pounds which can be divided between a landing capsule and additional science. Two spacecraft can be launched on a single Saturn V for the Venus mission.

For the Jupiter and Venus missions, a list of experiments critical to planet exploration has been compiled showing approximate size, power requirements, weight, and experiment purpose. These experiments are reflected in the spacecraft weight data presented above.

Although the above data are for spacecraft designed for uniquely exploring each planet, a study has been initiated to assess the capability of the Mars Voyager spacecraft when used for Venus and Jupiter missions. Also, the use of Voyager-type spacecraft for solar probes and outer planet fly-bys will be studied.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

A. Advanced S-IVB Workshop

A considerable amount of in-house concept and configuration and subsystem design for a ground-equipped S-IVB Workshop has been accomplished. Among the design items that have been defined are the major design variables and requirements, concept approaches for zero and artificial g systems, interior layouts, systems and equipment integration, selected supporting analysis and weights. In the subsystems area the requirements, approaches, comparisons, and recommendations for most major subsystems have been determined. The most desirable ground-equipped S-IVB Workshop did not require major S-IVB stage structural modification and mainly utilized current subsystems. The feasibility was established for a one-year no resupply station with a crew of six and 40,000 pounds of experimental equipment.

On October 16, 1967, MDC presented the final briefing of a six-month advanced S-IVB Workshop study to MSFC. The briefing concentrated on the ground-equipped S-IVB Workshop and recommended an approach wherein some experiments are integrated into the basic configuration and others are packaged in modules that can operate attached or detached from the basic station. Considerable information was also presented relative to experiment program requirements. The final reports will be available in late November 1967.

Parametric preliminary design data for an active thermal control system of the advanced S-IVB Workshop (EOSS) are being

developed. Being determined are the heat rejection capabilities and modulation requirements, for different candidate locations of the space radiator and possible attitude orientations as indicated by mission requirements.

B. Independent Module Study

A study has been initiated to determine the feasibility of operating independent modules in conjunction with an EOSS. The objectives of the study are to select the experiments for the independent module, determine the basic requirements for operating the independent module, and determine the requirements of the station to support the independent modules.

C. Early Space Station Operational Analysis

Recently, work began on defining the operational requirements of an early space station to be launched in the 1973-1975 time frame. The concept developed by this Office and the experiment package defined by MDC under the S-IVB Space Station contract are being used as departure points. The types of operational problems to be investigated are experiment requirements, pointing requirements, gravity requirements, and solar cells and antenna orientation requirements. The main question to be answered is how many and to what extent can multiple experiments be simultaneously conducted on a manned space station.

D. Earth Resources Mission Forecast

A preliminary forecast was made in the area of Earth Resources for the Integrated Long-range Plan being developed by R-AS. This prediction for the years 1968-1987 involved mission objectives and requirements, mode of operation, manned or unmanned, and flight systems definition.

II. Integration

A. Experiment Catalog

Forty copies of an updated experiment catalog have been distributed. The updated revision includes a revised format, a new indexing, and updated data on the 411 experiments. Work is continuing on a supplementary volume containing the 283 advanced experiments proposed for flight on an early orbital space station (EOSS) in the 1971-1975 time period.

B. Experiment Compatibility and Operations Analysis

Work is in process delineating detailed experiment descriptions and operational characteristics for proposed orbital experiments in the mid-seventies time period.

Proposed experiment matrices for the LaRC mat[illegible]del and ESCAPE computer program are very near completion. These matrices are intended to establish the sensitivity of the mission accomplishments to crew skills, manhours available, time for astronomy, time over land, etc.

A NASA Technical Memorandum, NASA TM X-53626, entitled "An Analytical Experiment Compatibility Procedure for Earth Orbital Missions," has been printed and distributed.

III. Lunar Systems

A. MSFC Mobility Test Program

Personnel from this Office met with representatives from Test Laboratory in an effort to expedite the Mobility Test Program. By lowering test course requirements to a minimum, it appears that the program can take place in early November. All three vehicles, both MTAs and the BECO-built Mock-up, are in running condition. Only a small amount of instrumentation remains to be installed on the MTAs. The chase vehicle has also been completed.

B. LSSM Program

In response to a NASA Headquarters request through R-AS, this Office is providing preliminary design data on a Small Manned Roving Vehicle (SMRV) for a single-launch extended LM mission. Data include configuration analysis, mobility performance, and layouts. The effort will culminate in a presentation to MSFC management personnel on November 2, 1967, and to NASA Headquarters on November 9, 1967.

ADVANCED PROGRAMS

I. Launch Vehicles

A. Liquid Strap-on Pods, "660 K Launch Vehicle"

Effort is being continued by R-AERO-X to determine control, aerodynamic, and separation parameters for this vehicle. An initial preliminary performance trajectory has been completed. The use of alumizine as a mono-propellant is still under consideration. Additional computer runs are still being determined to aid in this evaluation. Preliminary pod pressurization systems and feedline pressure drop evaluations have been completed.

B. Launch Vehicle Handbook

Documentation of the computer programs under this effort is being continued and is expected to be completed by November 15, 1967. One method for rapid estimation of vehicle performance has been completed and released in a memorandum for record. A second, more complex method is currently being evaluated.

C. Stage Design for Personnel Transfer

In this study, the evaluation of spacecraft weights for various synchronous orbit mission modes has continued, although no conclusions can be firmly drawn from study results, yet. Due to cut-backs in the Voyager program, an analysis of the 140-inch-diameter Voyager Spacecraft, originally plamed for this synchronous orbit mission application, has been dropped. Now, only the 260-inch-diameter spacecraft design is being evaluated in this study.

D. Low-cost Launch Vehicle

Effort is continuing to develop mathematical equations which describe the thrust augmentation obtainable from shrouding multi-nozzle rocket vehicle configurations. A literature survey and evaluation on previous work performed of this type is approximately 50 per cent complete and is scheduled for completion on November 10, 1967. A major problem encountered to date in this study is the development of equations to theoretically determine base pressure on the vehicle.

One low-cost launch vehicle concept being considered utilizes stage commonality for three launch vehicle generations as an approach to low cost. These vehicle generations differ in payload capability by a factor of e. This low-cost concept utilizes the first and second stages of a first-generation, three-stage launch vehicle as the second and third stages of a second generation launch vehicle, and utilizes the first stage of the first generation launch vehicle as the third stage of a third generation launch vehicle. This conceptual approach, which may be repeated for generations as desired, always provides two developed stages for the next launch vehicle generation to be developed. However, it requires that one stage from the preceding vehicle generation be dropped from use on the succeeding generation of launch vehicle. Also, it requires that stages developed for the first launch vehicle generation of a three-generation series be used only for this series.

Analysis of the concept to date shows that fixed capacity stages may be used for three launch vehicle generations without undue vehicle performance loss in any one generation. Analysis also shows that a simple logarithmic relation exists for the propellant capacity of each launch vehicle stage. Future analyses are to determine vehicle configurations and stage thrust levels which result from this launch vehicle concept and are to determine whether commonality in these characteristics is reasonable for three launch vehicle generations differing in payload capability by a factor of e.

A summary review of study progress to date will be presented to the Advanced Systems Activity Senior Staff on November 7, 1967. This review will be given by members of the Study Group on the Conceptual Design and Analysis (CDA) portion of the "Low-cost Launch Vehicle" effort, under study management of this Office. Studies performed in context with the Initial Phase of the study will be summarized by the R-AS and co-located Laboratory members of the CDA Study Group.

E. Saturn Utilization Study

The first progress review on the Saturn Utilization Study was presented to the Advanced Systems Activity Senior Staff on Tuesday, October 31, 1967, by Mr. William L. Corcoran (R-P&VE-AP), Study Manager. The review covered activities and accomplishments for the period September 24 through October. The study is on schedule and operating within present manpower commitments. A discussion on sensitivity factors within the low-cost fleet generator computer program

for determination of configuration evolutions led to a request for a formal presentation on the methodology techniques used. Mr. Huber, R-AS-S, has the action for this meeting, tentatively scheduled for mid-November. The initial selection of Saturn configuration candidates to be considered in this study has been distributed to all participants.

II. Earth Orbital

Common Mission Module

A status report was presented to the Advanced Systems Activity Senior Staff on October 24, 1967, on the CMM study. Material presented included current work being performed, manhours being expended, schedule, and the approaches being pursued in the commonality assessment. Efforts continued on the CMM study with emphasis in the configuration development and subsystems selection areas.

III. Planetary

A. Mars Soft-lander Probe Definition Study

A study has been initiated to provide a conceptual design and analysis for a soft-lander probe deployed during the encounter phase of a manned Mars fly-by mission. The study effort will include the design and analysis of critical probe subsystems, the development of a scientific experiment program, description of the complete probe mission operations and evaluation of the role of man.

B. Command Post Definition for Fly-by Spacecraft

A study has been initiated to determine specific functions of a command and control center as it pertains to a mission module for a Mars planetary mission. The study will provide data to assess the types and characteristics of the equipment required to perform the command post functions as well as provide conceptual layout and packaging schemes of equipment integration.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-67-10

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(October 1, 1967, through October 31, 1967)

SATURN IB

I. S-IVB Stage

A. LO_2 Pump Seal Bleed Overboard Drain System

An overboard drain system for the S-IVB-204 J-2 engine LO_2 pump seal bleed system was documented. The configuration of the system will be similar to that provided on the S-IVB-501 stage except that a hard line will be required for S-IVB-204 and subsequent stages.

B. S-IVB-206 Restart Mission

1. Documentation was completed which redefines the interface envelope through the Instrument Unit (IU) for the repressurization supply lines. A relocation of components on the S-IU-206 by International Business Machines Company (IBM) required this action.

2. Routing two proposed stainless steel 1-inch repressurization system lines through the IU interferes with the water accumulator located at position I in the IU. A recommendation was made to use flex hose instead of hard lines and to support them in the IU at a maximum of every 15 inches. The above recommendation and the envelope for the flex lines were documented.

II. General

A. AS-204/LM-1 Launch Mission Rules

Review of a preliminary release of the AS-204/LM-1 Launch Mission Rules by the division revealed that the single sideband channels which contain approximately 80 to 90 percent of all vibration measurements are classified as highly desirable. Industrial Operations (IO) has been requested to change the classification to mandatory.

B. Saturn IB/SA-204 Flight Sequence

An Engineering Order (EO) was prepared against the Saturn IB/SA-204 flight sequence drawing 10M30154-11 to change burn time prediction for the S-IB stage caused by change in launch date. This change impacts backup events in the flight program and is mandatory if the launch occurs during the first quarter of 1968.

C. Countdown Observer Redlines (SA-204/LM-1)

The SA-204/LM-1 countdown observer redlines, revision 1, dated June 16, 1967, was revised and updated. The resulting revision 2, dated October 16, 1967 was forwarded to Kennedy Space Center (KSC) for official use for the Countdown Demonstration Test (CDDT) and launch countdown.

D. Weight Status Reports

1. The monthly weight status report for launch vehicles SA-201 through SA-212 and for AAP-1A through AAP-5 was completed and distributed.

2. The detail monthly weight status report for the SA-212 launch vehicle was completed and distributed.

E. Mass Characteristics

Mass characteristics for AS-204 for a first quarter launch were calculated and distributed.

F. Spacecraft/Lunar Excursion Module (SLA) Cutter

An MSC device proposed for cutting emergency launch pad egress openings in the SLA was reviewed at MSC by a representative from this division. Manned Spacecraft Center is attempting to have this pneumatic cutter installed on the SA-204 SLA during ground operations. It is expected that use of this device, which appears feasible, will help reduce the hazard to personnel resulting from payload hypergol leakage. This division will continue to monitor and, as necessary, support this development.

G. Technical Checklist

Revision 15 to the Saturn IB Technical Checklist is being coordinated for publication.

I. S-IC Stage

A. S-IC-501 Component Recovery

A list of recoverable components and documentation on each component, including a procedure for safing the propellant dispersion system (PDS), was prepared. Representatives of Propulsion and Vehicle Engineering Laboratory established the safe and arm (S&A) device as priority #1 for component recovery since its safing is necessary to render the PDS inoperable. Complete photo coverage of the operation is planned.

B. Qualification Test of Command Destruct Container

Sinusoidal and random vibration tests were performed on electrical container 60B70747 for the tangential and radial axes. Preliminary data indicate that the bracket design and shock mounts are sufficient to dampen the vibration inputs in order to subject the exploding bridgewire firing units and S&A device to levels below that for which the components are qualified. The thrust axes vibration tests will be performed at the Michoud Assembly Facility (MAF) by TBC.

C. S-IC Hydraulic Supply and Checkout Unit (HSCU)

1. KSC reported that an operating procedure, that will effect a "work-around" for the 800 cycle per second (cps) noise problem presently being evidenced on the umbilical transducer output signal, will be implemented during AS-501 vehicle launch activities. The method employed will provide a communications network between the F-1 engine hydraulics panel operator and the HSCU panel operator, whereby, if the engine hydraulic system should deviate from the normal pressure during launch activities, the information will be transmitted to the HSCU panel operator for corrective action.

2. Test procedures were prepared to include additional testing of the System Development Facility (SDF) HSCU in conjunction with the S-IC hydraulic accumulator bank (HAB). The test procedure will include installation of the HAB into the SDF hydraulic system to establish total system capabilities; i.e., to determine precharge pressure required to meet S-IC stage maximum fluid requirements, and to analyze the total effect of the HAB on the HSCU return line pressure transients.

3. HSCU performance, during the recent countdown demonstrations tests (CDDT) at KSC, demonstrated the capabilities of the unit under extended operational conditions. No major problems were experienced through approximately 120 hours (accumulative for three tests); however, a few minor problems were noted and corrected without delaying the test.

4. During the CDDT, the facility chilled water valve for the HSCU heat exchanger was partially closed to restrict the flow of water to the heat exchanger and increase the temperature of the HSCU RJ-1. The results proved satisfactory since the temperature of the RJ-1 delivered to the engine was increased to the 70°F range required by the F-1 engine under cryogenic conditions. An increase in temperature was noted (as high as 122°F) in the HSCU servo control system. However, no problems are created since the maximum operating temperature of this system is 152°F.

D. S-IC Flush and Purge Servicer (F&PS)

1. Reports were received from KSC that both F&PS units (located at KSC) were contaminated with water, oil, and rust particles. To date, all components of F&PS unit S/N 001 have been cleaned and the unit has been restored to serviceable condition. Back-up for unit S/N 001 to be used during AS-501 launch activities was provided by securing an Air Force flush and purge servicer (Rocketdyne P/N C-2000) from General Dynamics at KSC.

2. Subsequent to receipt of unit S/N 002 at KSC, an inspection of the trichloroethylene system revealed the same basic condition as noted in unit S/A 001. In addition, the hoses and quick disconnects (QD's) were found contaminated with water and dirt. This condition was attributed to damage (during shipment to KSC) of the material used to seal the hoses and QD's subsequent to cleaning at MSFC.

E. Separation of Umbilicals with Lines Pressurized

Test of the aft umbilicals, as requested by this division, was accomplished by Test Laboratory. The testing demonstrated that the umbilical carriers would separate successfully with the umbilical lines pressurized during launch at umbilical disconnect. The emergency shear out mode of disconnect, ECP 0213, was also successfully tested.

F. Intertank Umbilical Lock Mechanism

1. Failure analysis of the intertank umbilical lock mechanism which malfunctioned on Mobile Launcher (ML) -1 was accomplished at MAF. As a result of this failure analysis Engineering Change Proposal (ECP) 0328 was initiated by TBC/MAF to effect a design change to the lock mechanism.

2. A lock mechanism for the intertank umbilical carrier assembly 65B80191 was modified by TBC/MAF. The lock mechanism was successfully tested and shipped to KSC for installation on ML-1. Full incorporation of ECP 0328 is planned for AS-502 and subsequent vehicles. Requalification of a lock mechanism fully updated is in progress at MAF by TBC.

G. S-IC Lox and Fuel Tank Prepress Circuit Capabilities

Interface Revision Notices (IRN's) reflecting the results of the S-IC lox and fuel tank prepress circuits test at KSC were released. These tests established the flow and pressure capabilities of these circuits for SA-501 and 502 and confirmed the deficiency anticipated for SA-501. The deficiency in flow and pressure is caused by high pressure drop in the circuit. No problem exists for SA-501, SA-502, and SA-503. A decision will be made soon on the approach to be used to overcome the deficiency for SA-504 configuration.

II. S-II Stage

A. LO_2 Pump Seal Bleed Overboard Drain Lines

The overboard drain line exit nozzle is being redesigned to prevent water entry during rain storms.

B. Installation Purge Pneumatic Control Console (S7-45)

The pressure loss, which was experienced in the S-II stage LH_2 tank sidewall purge circuit during the first S-II-3 stage static firing at Mississippi Test Facility (MTF), resulted from a choking condition in the stage upper purge manifold. The S7-45 console sidewall purge circuit flow capacity is sufficient to meet the maximum flow capacity of the stage sidewall inlet manifold.

C. Pneumatic Console Set (S7-41)

A check valve was installed in ML-1 S7-41-C console LOX and LH_2 debris valve actuation circuit vent manifold. The check valve was required to prevent moisture from being cryopumped into the debris valves of the S-II stage during hold conditions with propellants on board.

D. S7-41 Pneumatic Console Tests

Tests on S7-41 equipment were completed at MTF on October 3, 1967. The test report will be available in the near future.

III. S-IVB Stage

Vacuum Monitoring Console

During sealing tests of the vacuum monitoring console, DSV-4-303, for the S-IVB stage it was found that the GN_2 flow from the pneumatic console DSV-4B-433A was inadequate to properly purge the cabinet. MDC has initiated preliminary interface revision notices (PIRN's) to correct this deficiency by changing the source of GN_2 supply from the DSV-4B-433A to the facility GN_2 supply.

IV. General

A. J-2 Engine LO_2 Pump Seal Bleed Overboard Drain System

MSFC testing on the teflon duct material for the J-2 engine LO_2 pump seal bleed system overboard drain line was completed. The teflon ducting successfully withstood a combination of worst case S-II and S-IVB stages vibration environments while being pressurized at 10 p.s.i.g. and -300°F. Based on these test results, the duct material is considered acceptable for AS-501. A complete test report is being prepared and will be submitted. AS-502 and subsequent vehicles will utilize metal lines.

B. Propellant Dispersion System (PDS) Installation Problems

Documentation was prepared to revise the PDS systems on the S-IVB and S-II stages to prevent recurrence of the installation problems experienced on AS-501. The changes will consist of better tolerance control on bracket installations and control of tolerances on PDS components.

C. Status of Systems Tunnel Seals

1. TBC has submitted an informal ECP (0299) concerning sealing of tunnels (electrical and pressurization) to prevent rain or moisture from entering. The ECP was reviewed and approved and a recommendation was made to use a boot in lieu of potting compound.

2. Engineering Change Request (ECR), BB-2M-064, was initiated to direct North American Aviation (NAA) to seal the openings on the electrical tunnel covers.

3. Documentation was generated requesting McDonnell Douglas Corporation (MDC) to perform a study on the probability of rain or moisture entering their tunnels and the possibility of damage if this condition occurs.

D. AS-505 Ordnance Systems Document

1. The Saturn V Ordnance Systems Document for AS-505 was reviewed and requested changes were submitted to TBC for incorporation in the final document.

2. Relief devices, which were added to the fluid distribution systems at ML-1 and MTF test stand A-1, are now scheduled to be installed in ML-2 and MTF test stand A-2. The permanent fix, which would have incorporated relief devices within the S7-41 and S7-45 consoles, was rejected by IO because of anticipated schedule impact resulting from installation lead time plus the cost of the system ($40,000). The IO decision to accept the ML-1 fix, as a final fix, has been judged by this division as a trade-off of ground support equipment (GSE) circuit overpressure protection in return for a stage oriented, lower cost, quick fix.

E. Saturn V Composite Mechanical Systems Schematic

This division reviewed and evaluated a TBC proposal for extending the Saturn V composite mechanical systems schematic task. The proposal was considered acceptable as submitted including the manpower estimate for accomplishing the effort. The first release under the extended effort was made August 15, 1967, for SA-501. Subsequent releases to be updated on a quarterly basis shall be on a block basis for all Saturn V configurations with functional differences noted.

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

1. The DRRS has been operating satisfactorily during the Saturn V countdown demonstration.

2. Two mandatory changes, effective with AS-501, were submitted to the Level II Change Board at KSC; both changes were approved. The changes involved replacement of the end plate screws on 11M00567 flow control valves and changing of the relief valve setting on the 11M00681 valves. Also, a change involving a drip pan installation on the auxiliary damper system was disapproved for AS-501, but will be effective for AS-502.

G. Hazardous Gas Analyzer (HGA)

1. The HGA on ML-1 successfully supported launch vehicle SA-501 CDDT, which were recently conducted at KSC.

2. ECP BO-253, prepared by TBC was approved for launch vehicle SA-503. This ECP incorporates two items (modification of pump fitting and LH_2 fill line extension) that were incorporated on S/N 003.

H. Environmental Control System Moisture Content

A KSC IRN was received requesting an increase in the moisture content of the GN_2 purge gas provided to the vehicle by the facility Environmental Control System (ECS) system from 1 gr/# D.A. to 5 gr/# D.A. This action was due to moisture entering the system through the joints of the duct and moisture in the insulation. Any increase was rejected for all areas except the instrument cannisters on the S-II and S-IC stages, which was increased to 3 gr/# D.A. An IRN reflecting this has been forwarded to KSC and should be released along with the corresponding Level B IRN's (fluid requirements) by October 9, 1967.

I. Operations Analysis

1. Saturn V Launch Vehicle Design Reference Ground Sequence (DRGS) document, MSFC drawing 10M30577, was released. The document presenting a launch vehicle DRGS covering the time period from stages arrival at KSC until the vehicle is launched, is intended to be used for analysis and planning purposes. Major site operations to be performed on the vehicle as currently identified are presented for the prelaunch period.

2. While the current operations analysis information is based upon the SA-501, SA-502, SA-503, and SA-504 countdown, future releases will be expanded to include additional vehicles as the data become available.

J. Weight Status Reports

1. The monthly weight status report for launch vehicles SA-501 through SA-506 was completed and distributed.

2. The detail monthly weight status report for the SA-506 launch vehicle was completed and distributed.

K. Mass Characteristics

Revised AS-501 final predicted operational mass characteristics were distributed.

L. Mechanical Ground Support Equipment (MGSE) Instrumentation Data

A plan for processing MGSE instrumentation data was approved. A processed data requirements document form is presently being prepared for submittal to Computation Laboratory for requesting KSC data. Requests will be completed and submitted by November 10, 1967. Indications are hat KSC cannot satisfy all data requirements.

M. Ordnance System Specification

The second draft of the Saturn V Ordnance System Specification was sent out to appropriate organizations for comment and review. This division will assist in the preparation of an MSFC ordnance specification.

N. Technical Information Summary

The Saturn V (AS-501) Technical Information Summary was completed and distributed.

ADVANCED TECHNOLOGY

I. Systems Operations

A. Multiple Docking Adapter (MDA) Functional Requirements

This division completed and forwarded to Astrionics Laboratory a block diagram which presents the design concept of the MDA as presently envisioned by Propulsion and Vehicle Engineering Laboratory. Astrionics Laboratory was requested to verify that the present design concept of the MDA electrical system, instrumentation, data management, electrical support equipment, and other Astrionics Laboratory systems are compatible with the Propulsion and Vehicle Engineering Laboratory design.

B. Mechanical Ground Support Equipment/Purge Requirements

A preliminary copy of the AAP-2 fluid requirements was reviewed for MGSE impact. It was concluded that the MGSE functions involve only the MDA and nose cone ambient GN_2 purges. These purges are so uncomplicated that KSC may supply them, without impact, from a convenient source, such as existing MGSE or facilities. Further coordination is in progress to more clearly define the purge responsibility.

II. Systems Design

A. Cluster

1. The Inboard Profile/Space Envelope Layout, SK10-9317, was revised to include the latest system design requirements for the following:

Radiator Installation to the MDA.

Electrical Fluid Tunnel.

External and Internal Mobility Aids.

Experiment Package Mounting Walls.

Hard Mounted Experiments.

Environmental Conditioning System Duct.

Internal Docking Port.

Docking Target Configuration.

External S069 Experiment

Experiment T-023 Surface Absorbed Material

Pressure drop sensor, LO_2 sensor, Fire Detector Sensor, and a total Compartment Pressure Sensor.

2. Drawings were completed for Preliminary Design Review (PDR) mockup of all hard mounted experiment packages which are not on hand at MSFC, except for S-070 and probe stowage.

3. The MDA engineering mockup, SK10-9394, was revised to show the addition of handling and trunnion blocks.

B. Orbital Workshop (OWS) Reviews

1. A review was completed on the exploding bridgewire (EBW) firing unit installation layout for the meteoroid shield ignition system. Two engineering ignition systems were accepted tentatively by MSFC.

2. The dynamic mass simulator for the MDA quick release fasteners could not be completely tested because of improper fit between the mass simulator and the dynamic shaker head. This condition was caused by the improper dimensioning of the attaching feet sent to MSFC by MDC. Also, the MDC grid failed which will require a base plate modification. A rework is in progress so the test can be completed.

3. A list of operational equipment and habitability equipment was prepared for a status review to IO. The list was divided into two categories: those package envelopes which are known; and those which are assumed.

4. SK10-9532, "Dynamic Test Article Quick Release MDC Fastener," was completed and delivered to the Manufacturing Engineering Laboratory.

C. Multiple Docking Adapter (MDA) General Test Plan

1. Inputs on MSFC Form 1839 to the MDA General Test Plan were completed for 23 system component and auxiliary handling equipment items. These inputs will be incorporated into the MDA General Test Plan.

2. To date, a requirement for eight items of handling and auxiliary equipment (H&AE) has been defined. The items are as follows:

MDA Handling Fixture and Slings.

MDA Internal Access Platform and Ladder Assembly.

MDA Component Hoist and Track Assembly.

AM/MDA Component Hoist and Track Assembly.

MDA Docking Port Adapter for Transporter.

MDA Experiment Handling Fixture Kit.

MDA Docking Port Protective Covers.

MDA/AM Protective Cover, Launch Complex.

Inputs for the preliminary Contract End Item (CEI) specifications for the listed equipment were completed.

3. The MDA component hoist and track assembly and the airlock module (AM)/MDA component hoist and track assembly have been designed and will be ready for checking by October 31, 1967.

4. Two flow charts were prepared showing the integrated handling and auxiliary equipment for transportation, assembly, checkout, and maintenance on the AM/MDA. One flow chart shows the MDA being shipped from MSFC directly to KSC and the other shows the MDA being shipped to MDC, St. Louis, Mo., for mating and altitude testing with the AM.

D. Apollo Telescope Mount (ATM) Documentation

1. A detailed layout of an active cooling system for the ATM experiment package was completed.

2. Drafts for the CEI specification inputs were prepared for: Handling and fixture slings; and the ATM ladder and platform assembly.

3. SK10-7266, "ATM Inboard Profile Space Envelope Layout," was revised to its W revision. Some of the major revisions were as follows:

Defined astronaut work station guard rail mounting requirements to structural rack.

Revised the entire layout where required to agree with the latest electrical equipment list.

Defined interface between cable arch and roll ring.

Acquisition sun sensor was relocated to the -Y bay of the rack to minimize radiation view interference.

A view was added to show the location of the N_2 line disconnect interface between the lunar module ascent stage and the rack.

The SLA umbilical plate was relocated to conform to latest NAA drawings.

The cannister control box design and foot restraint mounting on astronaut work station.

Orientation of antenna panel on solar array wing number 710 was provided.

Clearance envelope for service loops and support bracket were added.

GN_2 purge line routing was defined.

4. SK10-7328, "ATM Experiment Package Subassembly," was revised to its J revision. Some of the major revisions were as follows:

The envelope for the telescope aperture doors was defined.

The camera door sizes and locations were changed according to latest information.

The envelopes of Experiments H #1, and Naval Research Laboratory (NRL) A&B telescopes were revised according to latest information from the experimenter.

Harvard College Observatory (HCO) -B telescope was replaced with HCO-C.

5. Drawing 10M03736, "Apollo Telescope Mount Alignment Control Drawing," was revised to add alignment relaxations and requirements to several experiments.

E. Nuclear Ground Test Module (NGTM) Documentation

1. A layout study of the flight half of the proposed electrical disconnect for NGTM showed that the mounting flange is not suitable for sealing in the aft skirt penetration. Astrionics Laboratory was advised of the problem and was requested to investigate the possibility of providing the connector with 3-inch flanges with a machined sealing surface.

2. The pneumatic schematic diagram received from Propulsion Division shows that the lower umbilical must have more pneumatic lines than are presently provided.

3. The first estimate of the quantities, sizes, and weights of the electrical equipment received from Astrionics Laboratory shows that there will be 36 packages of electrical gear not including cold plates, pneumatic purge system, propellant loading and replenish system controls, and "flight" batteries.

4. The penetration layout drawing was completed except for details of the 4-inch propellant bypass line and the pressurization regulator sensing line.

5. The insulation radiation test tank assembly drawing was completed and is being checked. Some detail information such as thermocouple wire size and solder requirements is being coordinated and will be added to the drawing.

III. Systems Engineering

A. Cluster

1. The AAP monthly payload weight status report was completed and distributed.

2. An updated version of the man/system timeline (10M32151) was completed.

3. A system engineering evaluation of Lockheed Task-24, "Cluster B Mission Studies," was completed and documented. Lockheed Task 24 consisted of evaluating potential solar array design concepts, documenting the advantages and disadvantages, and selecting one design concept for further detail analysis. Another objective of this task was to analyze the selected concept to establish possibility of the design, compatibility with Cluster B requirements, and provide sufficient detail to permit a launch vehicle and mission impact analysis.

B. Orbital Workshop (OWS) Simulations

1. Package transfer and package mount/dismount KC-135 zero "g" simulations initiated September 20-22, 1967, at Wright-Patterson Air Force Base (WPAFB) were completed at MSC on Ocotber 19, 1967. Astronauts Lousma, Kerwin, Garriott, McCandless, and Col. Tom McElmurry, Asst. Director of Flight Planning, MSC, served as test subjects. A total of 101 parabolas were flown, and subjects operated both suited and in shirt-sleeves. A number of evaluations were performed, including a mechanical package transfer device, various modes of translation along the pole,

various package sizes, shapes, and handle configurations, and both translation to and operations at the mount/dismount station. A complete report of work at both WPAFB and MSC is in preparation.

2. Division personnel participated in the OWS Electrical System Interim Design Review at Astrionics Laboratory, October 16 and 17, 1967. The location, number and intensities of ambient lights and initial entry lights were tentatively approved pending evaluation in the PDR mockup.

3. Planning for the OWS Crew Station Review (CSR) is continuing. A preliminary CSR organization chart was completed and the duties of each participant are being formulated. Revision "B" of the Astronaut Review Outline (ARO) was issued. This ARO will incorporate MDA, OWS, and contingency model.

4. Two additional neutral buoyancy simulations of workshop door concepts were identified during the Workshop Interim Design Review Meeting, October 10, 1967. Simulation testing of orbital workshop S-IVB stage hardware scheduled to begin on October 16, 1967, has been delayed due to late delivery of mockup from MDC. The simulation schedule will have to be significantly compressed to allow completion of all workshop simulation prior to December 12, 1967.

C. Multiple Docking Adapter (MDA) Review and Simulation

1. Inputs for the crew station group PDR data package were received and are undergoing review and editing. The goal is to have this package available in draft form at the subsystem review scheduled November 13 and 14, 1967.

2. Neutral buoyancy simulation evaluation of package fastening device concepts proposed by MDC, Huntington Beach; MDC, St. Louis; Martin-Marietta Corporation; and MSFC was completed on October 6, 1967. An interim report was completed, containing the results of the simulation evaluation. The simulation results indicated that the concept proposed by MDC, Huntington Beach, was the best concept in terms of speed and ease of operation and reliability.

D. LM/Apollo Telescope Mount Mockup

1. The LM/ATM neutral buoyancy mockup was placed in the ME Laboratory neutral buoyancy tank on October 2, 1967. Final assembly of the solar panels and the translation rail to be evaluated in the simulations was completed. Simulation of translation from the EVA LM end workstation to the sun end workstation was conducted during the period of October 9-20, 1967. The following were investigated:

Verification of a typical translation route.

Analysis of extravehicular body movement during translation.

Determination of translation aid requirements.

Verification of design approach for a typical translation aid and handrail.

2. A computer availability problem caused a schedule slippage in the Pointing and Control Simulation (PCS) effort at Computation Laboratory. However, an agreement was reached on October 24, 1967, that ATM simulation testing would begin on November 13, 1967.

E. Experiments

Experiment D018, Integrated Maintenance, has been withdrawn from AAP-2 flight consideration by the Air Force due to increasing cost requirements for hardware development. As a consequence of the D018 removal, Alternate Restraints Experiment D020, which was to have been an integral part of D018 , will not be expanded to independent status. Fluid requirements for the AAP-2 corollary experiments were revised to incorporate the latest information and to reflect the position of the ECS/Thermal sub-panel.

IV. Systems Requirements

A. Multiple Docking Adapter (MDA) Requirements

1. The MDA R&D Plan is being coordinated within the division.

2. The MDA Functional Systems Checklist, revision 1, was completed.

B. Orbital Workshop (OWS) Requirements

1. The top level visibility schedule chart for the OWS Delta PDR was completed. The document was approved by the laboratory Projects Office.

2. Drafts of the Delta PDR Procedure and Data Package List were completed, subject to the necessary review and comment.

C. Voyager Specifications

1. The final drafts of Voyager Spacecraft Systems Specifications and the Voyager Spacecraft Systems Description were completed.

V. General

A. Stage Systems Tunnel Seals

1. The study and layouts were completed on a permanent method of sealing the S-IC-3 system tunnel against water entry.

2. Studies are in progress on permanent methods of sealing the tunnels on the S-IVB-2 and S-II-2 stages. All prime contractors will be contacted for proper documentation follow-through.

B. Cable Installation Specification Review

A review was completed comparing S-IB, S-IVB, S-II, and S-IC stage contractor cable installation specifications as well as the military cable installation specification. The results will be used to determine a standardized cable installation specification to be applied to each stage contractor.

C. Seat Simulator

A hydraulic driven seat simulator developed under the "Lunar Flying Vehicle" study contract by Bell Aerosystems was received by this division. The seat simulator will be placed in the Computation Laboratory for man-in-the-loop simulation.

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-67-10

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(October 1, 1967 - October 31, 1967)

SATURN V

I. S-IC Stage

AS-501 Slow-Release Mechanism

The final AS-501 countdown demonstration test (CDDT) was performed on October 12-13, 1967. The 16 channels of information on the slow-release mechanism were recorded throughout the test and four of the channels were recorded in real time on strip charts. This data was finally received by MSFC October 20, and is now being evaluated.

The 16 slow-release mechanisms were untorqued on October 16, and the strain gages indicated that an average load of 6.0 kips still existed after untorquing. KSC is still evaluating the system to determine what caused this amount of error. The four channels of data that are available show an average of 9 kips after Lox loading. Making a correction of 6.0 kips would still indicate that a preload of 3.0 kips exists in each mechanism.

KSC stated on October 18, 1967, that 16 channels of data on the slow-release mechanisms will be recorded on digital tape throughout the final launch countdown and lift-off. However, four channels of data to be recorded on strip charts in real time has been rejected by KSC. This means that MSFC will not have any data to evaluate prior to launch. This data is requested in order to assure that the new AS-501 slow-release mechanisms function in the same manner as those on the CDDT tests.

A work order to manufacture 18 slow-release pins for SA-501 replacement was released. Material certification was required for the pins.

II. S-II Stage

A. 501 Flight Worthiness Criteria Evaluation

Four major zone areas of the S-II stage were evaluated to determine if recent high force data would impact the 501 S-II stage with additional re-qualification. The areas evaluated were the forward skirt, aft skirt, thrust structure, and interstage. In all areas it was determined and mutually agreed by North American and the Vibration and Acoustics Branch that no additional retest will be required of any components that have successfully been tested to either IN-P&VE-S-63-2 revised or SID-62-199.

B. 402 Tests (A Structure)

Repair and buyoff of the Lox girth weld was completed October 25, 1967. Remaining tension load strips will be installed, and mating to the aft skirt will be completed in early November. The on-dock date at MSFC is November 30, 1967.

The foam insulation drawing is estimated to be 80 percent complete. Specifications for the foam material and application are still not available. It is understood that development of the specification is being accomplished by Materials Division and Manufacturing Engineering Laboratory.

C. 403 Tests (C Structure)

Mechanical setup for Phase I testing of the 403 test specimen has been completed. The checkout of the cryogenic load ring was performed and these tests indicated that the desired radial deflection can be obtained within acceptable limits. Work on Phase II test fixtures was continued and is approximately 75% complete. All Phase II fixtures and parts are scheduled to be completed by mid November. This checkout was made without heat applied to the thrust structure. When heat is applied during 403 tests more cooling of the ring will be required to maintain the deflections.

Documentation was released for installation of tension ties at the separation plane. The parts have been fabricated and installation of the tension ties is being accomplished.

D. 404 Tests (High Force)

"Beef-up" of the 404 test fixture was completed. All preparations, with the exception of final checkout, have been completed.

E. S-II-7 LH_2 Tank

During post pneumostatic inspection of S-II-7, two transverse weld cracks were discovered in the LH_2 tank. The cracks occurred in the milled

down circumferential weld land section. All stages with the exception of S-II-1 will be reinspected in the weld crossover areas. An apparent structural deficiency exists at these milled areas. This deficiency may be eliminated in several ways as listed below:

1. Reduction in flight LH_2 tank pressure.
2. Scarfing the ends of the machined areas.
3. Mechanical doublers.
4. Combinations of the above.

Joints of this configuration have not been tested in the full stage configuration.

III. S-IVB Stage

A. S-IVB/AS-501 Interstage Insulation

The insulation on the vertical side walls of the aft interstage stringers on S-IVB/AS-501 is flaking off over most of the interstage. This condition appears to be caused by improper preparation of the surface prior to application of the insulation. MDC strength engineers have determined that the vehicle would meet the required 1.25 factor of safety for the AS-501 mission without replacement of the insulation in the "clean areas." However, insulation will be required in the air-flow wake region aft of the LH_2 feedline fairing and in the retrorocket plume impingement region forward of the S-II retrorockets. The recommendation of MDC is to add a portion of aerodynamic fairing to the aft end of the existing LH_2 feedline fairing to provide a "blunt-end condition." This addition will reduce the temperatures in the wake region to an acceptable level. In the retrorocket plume impingement region, the plan is to add a protective channel over the affected stringers to prevent melting of the structural elements.

B. Interstage Insulation - S-IVB/AS-502 and Subs

At the request of the Strength Analysis Branch, R-P&VE-SS, MDC has reevaluated the need for insulation to cover the entire area of the S-IVB conical interstage. At present, a large portion of that structure is uninsulated. The reanalysis resulted in a determination by MDC that the complete interstage should be insulated beginning with AS-502. Complete insulation is not necessary for AS-501 since the anticipated flight loading is reduced.

C. S-IVB Flutter Panel

All work to be accomplished at MSFC on the S-IVB flutter panel test fixtures was completed. The panel, fixtures, and equipment have been delivered to AEDC. Tests are scheduled for the first week of November.

D. Thin Stringers

MDC has discovered that improper machining procedures used in the shaping of stringers to be used on S-IVB/Saturn IB and S-IVB/Saturn V skirts and interstages has resulted in possible strength degradation on many of the forward skirts, aft skirts, and interstages of each of the aforementioned vehicles. MDC strength engineers have checked the "projected" capability of AS-501 based on all stringers being reduced to the strength of the poorest stringer discovered to date. The MDC analysis shows a factor of safety in excess of the required 1.25. To date 2664 stringers have been inspected with 82 found to be under tolerance. Both skirts of S-IVB/AS-502 have been inspected and two of the forward skirt stringers were found to be below tolerance Analysis shows the S-IVB/AS-502 forward skirt to be acceptable. The aft skirt of S-IVB/AS-501 has been inspected with no defects found. The forward skirt will not be looked at on S-IVB/AS-501 until after completion of the CDDT.

IV. Instrument Unit

IU/S-IVB Compartment

An astronaut safety netting concept proposed by IBM for the IU/S-IVB compartment has been structurally evaluated with results showing no deleterious effects on either stage.

An evaluation of an 8 x 19 x 0.053-inch bulge on one segment of an IU has been completed with the principal recommendation being that the segment not be used on a Saturn vehicle. Results were documented by memorandum R-P&VE-SSV-67-123.

V. Saturn V System

A. Damper System

A design investigation to employ redundant switches is being made for the purpose of achieving greater reliability of damper hooks open and closed indications. While an improvement to the existing pneumatic cylinder design will be made, the use of externally mounted switches will be investigated. The investigation will be completed, if possible, in order that improvements may be tested on the Mobile Launcher 3 system now being tested at MSFC.

An unsatisfactory certification report which outlined a possible load problem during connect operation of the damper during checkout at the VAB was reviewed. The U. C. R. reported a 3-inch vehicle deflection at the damper station. This deflection was observed from movies of the operation. A review of the deflections by the Dynamics and Loads Branch indicated an approximate load of 4700 pounds which is under the maximum design load of 7, 000 pounds. At the request of the Vehicle Systems Division, redundant switches were added to the damper design for pitch control.

B. Saturn V Sled Test

The missile model has been through surface treatment and final assembly has started. The sled and support structure has been assembled and is ready for painting. A minor delay was caused due to the lack of tools to install several blind fasteners in the sled. This problem has been resolved. The expected completion date is mid November.

C. AS-501

An evaluation of AS-501 predicted loads due to a single point failure in the terminal countdown sequencer has been completed. It was concluded that this type of failure causes no structural problems on the launch vehicle.

APOLLO APPLICATION PROGRAM

I. ATM

A. Caging Mechanism

The latest concept of the Perkin-Elmer caging mechanism was checked for stability when subjected to design loads. The results of the analysis indicate that the system is stable only when the ATM-Spar is attached. If the spar is not attached the loading block will rotate. This might present a problem during structural test if a simulated ATM-Spar is unavailable.

B. Rack/ATM

At the request of the ATM Engineering Office, investigations were started to determine the impact on the released Rack structure of solar panel module support points located 15. 5 inches below the lower frame of the Rack. This is 12 inches below the points previously specified. Cognizance is also being taken in the design investigations of the Acquisition Sun Sensor support structure, the sun shield structure, and support and handling requirements, although firm definitions of any of these latter items are not available. A minimum change in existing tools and fixtures is also a design ground rule.

The Control Moment Gyro support structure loads during the boost launch phase were reviewed with personnel of the Strength Analysis Branch, and a decision was made to stiffen the Rack in the CMG bays. Designs were initiated for adding shear webs that would surround each of the CMG's. Manufacturing Engineering Laboratory planning and tooling personnel were notified (verbally) of the scope of these changes.

C. Experiment Package Insulation

A low density foam, with a thick (approximate 0.1 in.) canister skin appears to be the most favorable insulation due to difficulties with high density foam. The thick skin is required for a proper thermal capacitance value of the skin-insulation system. Preliminary studies show the weights of the two systems to be essentially identical.

II. Experiments

MSFC Flight Experiment #8

Detail drawings of the tension test package is approximately 50 percent complete. Design data on the camera has not been received from MSC but is expected in the very near future. A new design concept for mounting the experiment package on the MDA has been completed and is undergoing strength analysis. Checking of the design drawings will be initiated in the near future. Manhours for this task have not been allocated by the Vehicle Systems Division at this time.

III. Multiple Docking Adapter

A design study has been initiated to determine the feasibility of installing a probe in the MDA after cabin pressurization. A concept employing a collapsible bladder is presently being investigated.

Preliminary equipment wall loads induced by wall mounted components were received from the Vibration and Acoustics Branch.

GENERAL

I. Superinsulation Material Test

The first rocket sled test run for the final phase of evaluation testing of the aluminized mylar superinsulation material was successfully completed at Holloman Air Force Base, New Mexico on October 12, 1967. The material was mounted on a simulated fuel tank (105 inches in diameter and 120 inches long) and subjected to the combined environments of vibration, acoustic, steady

state acceleration and cryogenic temperatures on board a rocket sled. The test environments were designed (except for acoustics) to exceed those anticipated during any typical Saturn vehicle flight. Inspection of the material after the test showed no insulation degradation. One additional test run is scheduled, however, it may not be necessary.

II. Structures Division Acoustic Facility

The acoustic facility in Building 4619 shut down because the safe working pressure for the storage bottle air supply is far below an effective facility operating air pressure. An evaluation by the Strength Analysis Branch indicates that according to the ASME Boiler Code for unfired pressure vessels a working pressure of 217 psi is permissible, hence the present working pressure of 850 psi (nominal) represents a severely hazardous condition. A pressure of 217 psi is not adequate for effective acoustic testing. Several projects are impacted as a result of the facility shutdown.

G. A. Kroll
Chief, Structures Division

SATURN IB

Investigation of the Corrosive Effects of MIL-H-5606 Hydraulic Oil

Testing has continued in the comparison of the corrosive effects of MIL-H-5606 A revision hydraulic fluid to two types of the B revision fluid. Due to the time related nature of these tests there are no significant results to report at this time.

H-1 Engine, Project Management, Materials

During an inspection of the AS 204 vehicle which has been exposed at the Cape for over a year, light rusting was found on the stainless steel thrust chamber tubing of the H-1 engines. The tubing is protected by a coat of zinc chromate primer and one coat of aluminum lacquer. An analysis by the stage contractor indicated a quantity of chlorides in the rusty areas. Since there was some danger of fluid entrapment behind the reinforcing bands, recommendations by Rocketdyne were to wire brush (using stainless steel) the corroded areas, dust by blowing with dry nitrogen, wipe with Freon and dry with dry nitrogen, followed by reapplying the zinc chromate primer and then spraying the entire engine with the aluminum lacquer. Although a damp wipe with distilled water would have increased the assurance that the chlorides were removed, Rocketdyne objected to this step and their procedure for the repair was approved.

SATURN V

I. S-IC Stage

A. Evaluation of Commercial Adhesives

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

1. Investigation of the Effects of Aging on Polyurethane Adhesive Bond Strength

Specimens bonded with 7343/MOCA for long term aging tests were evaluated after nine months of ambient outdoor storage. These evaluations indicate no appreciable bond strength deterioration in either of the two series which employed silane primer and additive. In the control series no bond strength deterioration is evident at 200°F (93°C) or -300°F (-184°C). However, specimens from the control series tested at room temperature, have shown a gradual decline in bond strength throughout the nine-month aging period. Also, it is noted that the test results appear to be responsive to the humidity at the time of testing or during the period immediately preceding the test.

2. Study of Effects of Additives and Primers on Polyurethane Bond Strength

Experiments were run to determine the effect of adding Z-6040 silane coupling agent to 7343 resin several hours before the adhesive mix is completed. It was believed that possible reaction between the uncatalyzed resin and the silane coupling agent might benefit the bonding properties of the adhesive. In one case 1.0 g Z-6040 was added to 100 g 7343 and placed in a vacuum desicator for 16 hours before addition of MOCA; in the second case an identical sample was kept for 16 hours in a vacuum oven at 160°F (71°C).

The test data show that addition of Z-6040 in the usual manner, just prior to mixing with catalyst, gave strength values equal to or better than either of the above procedures (although lapshear strength at 200°F (93°C) appears unusually low for all three formulations). Storage at 160°F (71°C) is markedly detrimental.

Two adhesive formulations were made utilizing 1,1-dihydroxylmethyl ferrocene (DHF) as a replacement for half of the MOCA normally required in the Narmco 7343/MOCA adhesive system. Solid DHF was added to heated (160°F (71°C)) resin in one instance. A third formulation utilized DHF as a 1.0 percent additive to the 7343 resin, while retaining the normal amount of MOCA. Test data indicate that only the 1.0 percent additive technique has any promise; substitution of DHF for MOCA was unsuccessful. In additional experiments DHF and Z-6040 will be combined as additives in the 7343/MOCA system.

Stafoam AA-1802 polyurethane formulation has been evaluated as a primer for aluminum adherends bonded with the Narmco 7343/MOCA (100 g/11.5 g) adhesive system. Two primer solutions were prepared for brush application: (1) 5 percent Stafoam AA-1802 (resin and catalyst mixed according to manufacturers recommendations) in methyl ethyl ketone (MEK) and (2) 25 percent Stafoam AA-1802 in MEK. The primer was allowed to air dry for two hours before bonding. Adhesive cure was 24 hours at room temperature, 24 hours at 160°F (71°C).

Preliminary data indicate that treatment with the higher concentration promotes substantially increased lapshear strength values. This study will continue with an evaluation of other priming concentrations and temperatures, and a study of the effects of inclusion of silane derivatives.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

Continued effort has been devoted to the development of specialized polymeric materials for the encapsulation of electronic hardware. Large scale laboratory preparation of several intermediates for the epoxysiloxane polymers has been partially completed during this reporting period. These polymers are useful as embedment compounds for cordwood modules. Crosslinking studies on silphenylenesiloxane polymers have been carried out as part of the conformal coating program.

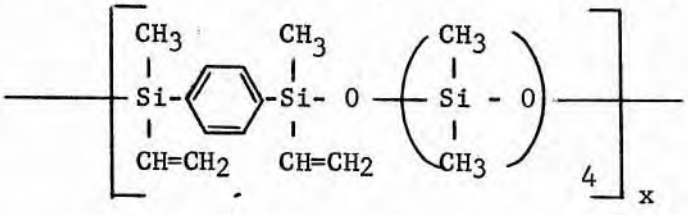
1. Development of Epoxysiloxane Embedment Materials

The preparation of a 100-200 gram quantity of p-allylphenyldimethylsilanol has been partially completed. This intermediate is common to the synthesis of four of the epoxysiloxane polymer precursors of interest within the program. Preparation of the silanol has been attempted from two different starting materials, p-allylphenyldimethylethoxysilane and 1,3-bis-(p-allylphenyl)tetramethyldisiloxane, in an effort to improve the yield. Experimental quantities of the epoxysiloxane polymers which have been prepared to date are not adequate to allow fabrication of the numerous test configurations necessary to qualify the materials as embedment compounds. Thus, since studies of model reactions and polymerization processes are essentially complete, future efforts will be devoted to the preparation of large batches of the necessary polymer intermediates.

2. Development of Conformal Coating Materials

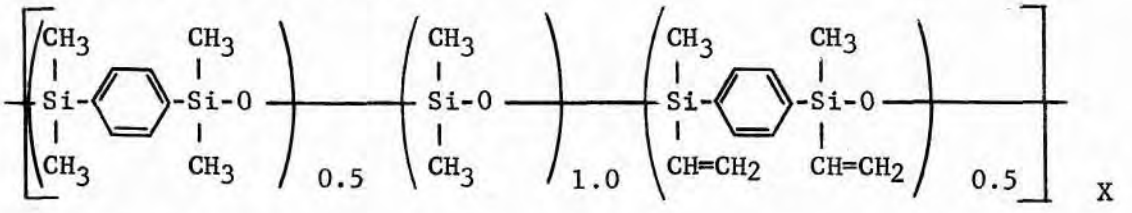
Evaluation studies of the butadiene-modified urethane polymer as a potential conformal coating have been deferred to allow completion of pending electrical and mechanical tests.

Crosslinking studies have been directed toward a previously prepared vinyl-modified silphenylenesiloxane polymer,



in an effort to adapt this type of material to meet the requirements of the conformal coating program. A crosslinked, elastomeric film was prepared by

dissolving the polymer in tetrahydrofuran and mixing with a sufficient amount of 1,4-bis(hydrogendimethylsilyl)benzene to result in a Si-H/C=C ratio of 1/3. The reaction was catalyzed by a trace of chloroplatinic acid. The THF was slowly evaporated at room temperature, leaving a thin film of the catalyzed polymer which has an appreciable shelf-life in this form. The polymer film, on aluminum, was cured at 100°C (212°F) for 24 hours, followed by a post cure at 150°C (302°F) for three hours. The resulting polymer was a very resilient elastomer having low tensile strength but excellent elastic recovery. The coating could be heated to 250°C (482°F) with no tackiness or loss of dimensional stability. Another polymer of this type has been prepared more recently in which the dimethylsiloxy group concentration, as well as the vinyl group concentration is reduced:



This polymer is being characterized. The reduction in dimethylsiloxy group concentration has been shown from previous experiments to result in elastomers which retain sufficiently low brittle points to be of interest to the coating program. The synthesis procedures for preparing this type of polymer are significantly more straight forward than other approaches which require higher degrees of polymerization of the dimethylsiloxy group.

C. Investigation of Spring Failures in Hydraulic Engine Actuators

Metallurgical and stress corrosion tests were continued on several 17-7 PH stainless steel clock and wave washer springs removed from actual hardware and from production lots. Analysis of springs removed from Hydraulic Research (HR) thrust vector control servoactuators on SA-501 indicated that no springs were broken or cracked; however, several showed evidence of surface oxidation. No failures have occurred in "C" rings made from a clock spring removed from an actuator at this Center and exposed to alternate immersion in a NaCl solution for more than 1400 hours. There have been no failures in coiled wire springs (CH900 condition) removed from both HR and Moog actuators and subjected to over 1000 hours in alternate immersion. Similar tests on controlled processed springs have also produced no failures after several hundred hours of exposure. These tests are being continued.

D. Investigation of Spring Failure in the S-IC Stage LOX Prevalve

During the recent stress corrosion survey of spring materials used in the Saturn vehicle, it was found that Belleville washer springs used in the S-IC LOX prevalve are made of 17-7 PH stainless steel in the

RH950 condition. Since this material, in the RH950 condition, is known to be susceptible to stress corrosion cracking, a decision was made to inspect all available S-IC LOX prevalves for spring failures. One of the several prevalves inspected showed evidence of severe corrosion. Upon dismantling the spring unit, 26 of the 54 washer springs comprising the unit, were either cracked or broken. Information received from the Propulsion Division indicate that the subject prevalve was subjected to severe qualification testing including at least one water pressurization test. The prevalve was stored in the as-tested condition for about 1-1/2 years prior to the recent inspection. Preliminary analyses indicate that the failures resulted from stress corrosion cracking. One of the unbroken springs was stressed and subjected to a humidity chamber for approximately 17 days before it also failed. Stress corrosion cracking of this spring was verified by both metallographic and fractographic analysis. Studies are being continued on these springs.

E. Evaluation of Stainless Steel Passivation Procedures

Studies are in process to determine the extent of iron particle removal from 321 stainless steel surfaces when cleaned by various industry accepted removal (passivation) procedures. Stainless steel surfaces which have been brushed or machined with steel tools contain embedded iron particles on the stainless surfaces. These particles must be removed to prevent rust from staining the surfaces. Removal procedures include various treatments with nitric and hydrofluoric acids and electro-polishing baths. Studies to date have included only deeply embedded particles on samples power brushed with a mild steel brush. Thus far the results indicate that a simple nitric acid treatment will not remove these particles.

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. Thiokol Chemical Corporation, NAS8-21197, NAS8-21149
2. University of Florida, NAS8-20247
3. Peninsular ChemResearch, Incorporated, NAS8-5352

B. Development of Cryogenic and High Temperature Insulation Material

Goodyear Aerospace Corporation, NAS8-11747

C. Analytical Methods Development

Beckman Instruments, Incorporated, NAS8-11510

D. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

E. Nondestructive Testing Techniques

1. North American Aviation, NAS8-20764
2. R. W. Benson and Associates, NAS8-20208

III. S-II Stage

A. Investigation of Fracture Toughness of 2014-T6 Aluminum Alloy Weldments

Studies have continued on the determination of the fracture toughness of S-II stage weldments at temperatures down to -423°F (-253°C). Tests were made at -320°F (-196°C) and -423°F (-253°C) on 1 inch thick 2014-T6/TIG-2319 material for determination of the trend of toughness with test temperature. The yield strengths at room temperature, -320°F (-196°C), and -423°F (-253°C) were considerably lower than previous tests. Consequently, all tests to determine K_{IC} values were invalid. Efforts are being made to procure additional equipment to improve our test capability in this area.

B. Evaluation of Spray Foams for Applicability as S-II Liquid Hydrogen Tank Insulation

1. Study of In-Flight Structural Integrity of Nopco BX-250 Foam

The evaluation of the structural integrity of the Nopco BX-250 foam insulation has been hampered due to lack of a suitable test environment simulating the combined environments of vacuum, aerodynamic heating, and aerodynamic shear that would be experienced by the foam during flight of the S-II stage. It has been determined that the X-15 experimental aircraft in some tests essentially duplicates the Saturn V environment. To evaluate the spray foam insulation structural integrity, permission has been obtained to install test panels on the X-15 aircraft for flight tests. The first foam specimen will be bonded on the upper speed brake for testing tentatively scheduled for October 31. The sample will have minimum instrumentation (2 to 4 thermocouples) and no camera coverage. It is expected that this sample will be used only as necessary to simulate the S-II environment on the specimen. Only half of the foam surface will have a seal coat applied. On the second flight scheduled for some two to three weeks after the first flight, foam specimens will be attached to both the upper and lower speed brakes. It is planned to have camera coverage on one panel attached to the lower speed brake and a highly instrumented sample on the opposite side. The panels

on the lower speed brake are not expected to be intact after flight. The panels on the upper speed brake will again be available for inspection after flight. It is anticipated that a few additional tests can be carried out on later flights probably in the Spring of 1968.

2. Investigation of Seal Coat Materials for Spray Foam Insulation in the S-II Stage

Presently available information indicates that a protective seal coat will be needed on the spray foam insulation to insure that the foam on lift-off is still structurally sound and that thermal performance has not been appreciably degraded. A sample of the Nopco BX-250 spray foam was coated with a high-temperature resistant polyester paint by Manufacturing Engineering Laboratory, and was subjected to simulated aerodynamic heating to 600°F (316°C) while being evacuated. The paint formed small bubbles that ruptured promptly and did not burn. Inspection of the sample after the test showed that the paint had degraded into a relatively hard material still adhering to the foam that probably would have been blown off by aerodynamic shear forces. Additional tests are planned with this paint.

3. Investigation of Surface Preparation Required for Bonding Foam Insulation to the "Mini-stage"

A shortened version of the S-II stage designated as the "mini-stage" is being shipped to this Center for use as a structural test vehicle. It has been learned that this stage will have an alodine coating when it arrives at this Center.

For test purposes the tank will be highly instrumented, and it will be difficult to remove the alodine coating and paste acid-etch the surface in preparation for insulating with spray foam. Test panels with alodine coating were coated with spray foam after the following surface treatments: (1) the alodine coating was sanded, solvent wiped with Freon, and then primed with Primer M, (2) the alodine coating was solvent wiped with Freon, and then primed with Primer M, (3) the alodine coating was removed, and the surface was then paste acid-etched and then primed with Primer M, and (4) the alodine coating was only solvent wiped with Freon. Flatwise tensile specimens from each of the panels were tested at room temperature, -300°F (-196°C), and -423°F (-253°C). In all cases, highest strength values were obtained on samples where the alodine coating was solvent wiped only, and this set showed practically all adhesive failures at the foam to the metal surface. In the other three sets, foam failures were encountered thus showing that the test evaluated foam specimen preparation rather than surface preparation. More realistic specimens are being prepared for additional testing.

4. Evaluation of Surface Preparations of Aluminum Required for Bonding of Spray Foam

In this study, aluminum surfaces that were "jitterbug" sanded and primed with Primer M and/or Z-6020 before being coated with spray foam were compared with other samples that had been paste acid-etched and primed. The sanded samples were stored for 3, 7, and 14 days and reprimed after 14 days before spray foam was applied. Paste acid-etched control samples

were spray foamed at the same time. Test results indicate that quality control of the foam is the controlling factor rather than surface preparation There was no trend in the test data that favored any of the individual processes studied.

5. Evaluation of Effects of Vacuum and Simulated Aerodynamic Heating on CPR 348-3 Foam

The CPR 348-3 pour foam is used as an insulation on the bolting ring and around "hard-spots" on S-II-1-5 flight vehicles. Tests at the Space Division of North American Rockwell Corporation indicated that under the combined effects of vacuum and simulated aerodynamic heating this foam tends to pop off in small pieces. Samples of this foam were tested locally, and the same behavior was noted. Efforts are underway to evaluate ablative coatings, whose application may minimize this behavior. Attempts are being made also to identify the constituent(s) causing this behavior and insure their exclusion from all foam products contemplated for future applications of this type.

C. Evaluation of Nondestructive Techniques for Examining Composite Materials

Investigations have continued in the development of nondestructive means of assessing the integrity of bonded foam insulation such as that used on the S-II stage hydrogen tank. A new technique is being investigated for the examination of the S-II insulation. This technique combines features of the resonant foam coupler and eddy current methods. Vibration is induced into the metal and variations in vibration caused by debonds are detected with a foam coupled microphone. Two types of this transducer have been tested. Large coils are required for the "single side type" transducer. Core materials for these coils were obtained from the Astrionics Laboratory.

D. Development of Standard Nondestructive Techniques for Inspection of Inert Gas Welds of the S-II Stage

The objective of this project is the development of standardized nondestructive techniques for inspection of inert gas welds of the Saturn S-II stage propellant tanks. The most effective techniques are to be optimized and their performance is to be established.

The details of the S-II propellant tank welds have been determined. Material has been ordered, machined, and welded to produce panels simulating S-II welds. The welds were made to contain defective areas and the weld bead was shaved and dressed as is done with S-II welds. A medium thickness common to the stage was selected for initial work.

The panels were marked such that all data may be later correlated. All panels were visually inspected with a low power microscope and defect data were taken relative to the orientation system.

The welded panels are being subjected to radiographic parameter tests. All major parameters relating to radiography are being varied about those values representing good commercial practice. The effects of these variations will be analyzed.

Apparatus has been constructed for application of advanced ultrasonic tests. Also weld dissection equipment is being prepared for detailed destructive analysis of the weld defect content.

E. Investigation of Failure of S-II Interstage Fasteners

Additional failed Hy-lock 7075-T6 aluminum fasteners were received for failure analysis. These fasteners were removed from an S-II interstage test structure undergoing tests by the Structures Division. Preliminary findings indicate stress corrosion cracking in the recently received fasteners. Fractographic studies are being conducted on fracture faces to verify these findings.

F. S-II Stage, Project Management, Materials

Efforts have continued in the coordination and resolution of problem areas of a materials nature related to the S-II stage. During this report period these efforts have included the following.

1. Investigation of the Applicability of MIG Pulsed-Arc Welding Processes for the S-II Stage

The Space Division of the North American/Rockwell Corporation (NAR/SD) has continued the study of the MIG pulsed-arc weld process. Results of this study to date have been unfavorable because of cracking problems in the weld cast structure. The cracks are detected during dye penetrant inspection but are not visible in the weld radiographs. Metallurgical studies reveal that the indications are really cracks and that they originate in eutectic phases. Efforts are being devoted to the study of process parameters which may be inducing these cracks. It appears that in order to eliminate the cracks, the eutectic phase precipitates must be reduced considerably. This gross amount of eutectic phase has not been observed in TIG welds unless there have been several repairs.

2. Spray Foam Insulation Test Tank

The McDonnell Douglas Corporation (MDC) delivered the second Thor tank to NAR/SD on October 30, 1967, which was 12 days later than required by schedule. The late delivery was caused by a compilation of several minor problems, not one specific problem. NAR/SD is putting the hardware into the production line immediately so that their manufacturing operations should be complete in approximately 28 days. To effect this 28-day schedule,

it was necessary to divert the spray foam coating operation to MDC, Sacramento, where it can be accomplished concurrently with facilities check-out operations. The McDonnell Douglas Corporation, Sacramento, has been alerted to the scheduled arrival date and has advised that all facilities will be ready.

IV. S-IVB Stage

A. Developmental Welding

Investigations have continued into the effects of various welding energy inputs and natural aging on the quality of fused joints on aluminum alloy 2014-T6. Evaluations of weldments prepared using optimum heat input and 25 percent excess heat input were completed for two thicknesses (1/8 inch and 3/8 inch). The results show a 5-8 percent increase in both ultimate tensile and yield strengths after natural aging 10 days. Increasing the weld energy input 25 percent over optimum resulted in weld joints having approximately 10 percent higher ultimate tensile and yield strengths with no apparent degradation of other weldment characteristics. Energy inputs greater than 25 percent of optimum proved detrimental to joint quality. Where weldments proved acceptable, it can be concluded that establishing optimum welding parameters is necessary to obtain maximum joint efficiency. The final phase of this program will consist of investigations which will utilize corrected weld energy inputs to determine the effects of varying voltage and/or amperage upon the quality of the fused joint.

B. Investigation of Failure of S-IVB Hydraulic Auxiliary Pump Spring

During testing of the S-IVB engine gimbal system at Brown Engineering Company, a Ni-Span-C helical compression spring failed in the hydraulic system auxiliary pump. The spring maintains a pump outlet pressure of 3650 psi during operation. Failure occurred after a total operation time of 223.7 hours; whereas, quality requirements specify 200 hours minimum operating time. Failure of the spring resulted from fatigue which was probably enhanced by an oxide scale on the surface of the spring.

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

1. Study of Flammability of Materials

Investigations have continued with support from Test Laboratory in the study of the flammability hazard of aluminum foil covered S-IVB insulation and to compare 2, 3, and 5 mil aluminum foil. Standard 3-foot diameter samples are used in all tests. The samples are flanged to a 3-foot diameter by 5-foot test tank. The tank is placed in a vacuum chamber, evacuated, and back filled with gaseous oxygen to 5 to 5.7 psia flowing oxygen. A nichrome wire is used to ignite the samples. The igniter is placed over a damaged area in the foil 1/8 to 1/16 inch away from the

foam. The power used for the igniter is 21 volts at 9 amps. Additional tests have been made using the 5- and 3-mil aluminum foil covering over the insulation as a fire retarding medium.

In general these tests confirmed previous results, however, one specimen coated with 3-mil foil sustained a burned area over approximately one full quadrant of the sample surface. A thorough review of the motion picture film of this test revealed that this anomaly was most likely caused by excessive adhesive on the foil surface. Additional tests are planned to further study this problem.

During this period, seventeen materials were evaluated for flammability in accordance with the provisions of MSC-A-D-66-3, Revision A, "Procedures and Requirements for the Evaluation of Spacecraft Non-Metallic Materials," for major and minor exposed materials. The requirement for major exposed materials (Category A) is self-extinguishment in 6.2 psia oxygen when ignited at the bottom. The requirement for minor exposed materials (Category B) is a flame propagation rate of less than 0.3 inch/second in 6.2 psia oxygen when ignited at the top. The materials evaluated during this period included a Huntsville Phone Directory (August 28, 1966) in a thickness of 3/4 inch. The Huntsville Phone Directory met the requirements of minor exposed materials with a flame propagation rate of 0.10 inch per second. This illustrates that the requirements of minor exposed materials is such that very few materials will fail this category.

Testing was initiated to establish a semi-quantitative relationship between thickness and flame propagation rate in materials.

Tenite I (cellulose acetate) was chosen as the first material for this study because it is classified as slow burning in air by Underwriters Laboratories. A number of thicknesses (5 mil to 250 mil) will be evaluated to ascertain the variation in flame propagation rate with thickness. The results of this study should be of considerable value to the designer in that knowledge will be gained relative to what minimum thickness of a material is required for minor or major exposed materials to meet the flammability requirements. It is interesting to note that the flame propagation rate of the Tenite I tends to stabilize at 0.3 inch/second in thicknesses greater than 20 mils.

Work has been initiated to evaluate techniques of applying the McDonnell Douglas Corporation's MD-19 thermal control coating to samples of the workshop insulation. Initially, five specimens (12 inches x 12 inches) will be prepared and coated with the MD-19 coating. Upon successfully coating these specimens, 14 three-foot diameter specimens will be coated. These specimens will be used to determine the effects of the coating and other factors on the flammability behavior of the workshop insulation.

2. Study of the Outgassing Characteristics of Orbital Workshop Materials

Activities have continued in the determination of the outgassing rate of helium from within the S-IVB fuel tank insulation. A sample of 3-D insulation was first evacuated to 6.5×10^{-6} torr at room temperature until the residual gas analysis indicated that the outgassing rate was in equilibrium with the pump speed. The chamber was back filled with one atmosphere of helium and the insulation specimen was allowed to soak in the environment for 24 hours. The chamber was then flushed with nitrogen to allow faster start up of the "Vac Ion Pump." Initial data indicate that the helium entrapped in the insulation is removed within 24 hours at room temperature. Due to the poor efficiency of the "Vac Ion Pump" to remove helium, it was decided to employ a diffusion pumped system. The test system was modified accordingly and tests have been completed on an initial sample. Data from these tests indicate that the partial pressure of helium will decrease from 1 atmosphere to 1.3×10^{-7} torr within 10 hours. After 72 hours of pumping, the helium pressure was 0.9×10^{-8} torr as effected by the total system pressure of 1×10^{-5} torr. Further data reduction is required before this can be put into meaningful information. Tests also are being initiated to determine the effect of holes located on 9-inch centers through the aluminum foil and seal coat on the outgassing rate.

D. S-IVB Stage, Project Management, Materials

Efforts have continued on the coordination and resolution of problem areas of a materials nature related to the S-II stage. During this report period these efforts have included the following:

1. Use of Incompatible Materials in LOX Vent and Relief Valves

An engineering change proposal has been received from the stage contractor on gold plating of the incompatible 60-40 tin-lead solder in the LOX vent and relief valves to inert the solder against the GOX environment. No other work was proposed to eliminate the problem, not even qualification testing of the gold-plated components; thus, disapproval of the proposal was recommended. The corrective action recommended by this division was to eliminate the incompatible solder altogether by redesign of the components involved. As an interim solution, however, plating of the incompatible solder with a compatible material such as gold, electroless nickel, etc. was recommended.

2. Korotherm Insulation of S-IVB-501 and 502

a. The Korotherm insulation of S-IVB-501 was wetted by rainwater through pinholes in the insulation sealcoat, and the insulation came loose. Refurbishment of the damaged areas included:

(1) Removal of loosened Korotherm insulation with a plastic scraper.

(2) Coating of affected areas with RTV-1200 primer.

(3) Application of DC 93-044 in appropriate thicknesses to replace damaged insulation and to further seal the undamaged Korotherm.

b. Stage contractor laboratory tests have verified acceptability of the above stated procedure, and Materials Division agrees with the stage contractor that the stated fix is acceptable.

c. Actions are being taken by the stage contractor to preclude a reoccurrence of the Korotherm insulation unbonding on S-IVB-502. This activity will include inspection and mapping of the areas involved, refurbishment of the Korotherm as required, and sealing of the Korotherm with brush-on applications of DC 92-009 (the same sealer used initially but with improved application techniques). This work will be done in the Vertical Assembly Building (VAB) to preclude the possibility of schedule slip on the launching pad.

3. Under Tolerance Fabrication of S-IVB-501 Stringers

Under tolerance fabrication of several S-IVB-501 stringers resulted in a requirement for additional protection against ascent heating. This requirement was satisfied by applying metal jackets over the undersized stringers and sealing with the same materials and techniques used for the refurbishment of Korotherm insulation on S-IVB-501.

4. Rebonding of S-IVB-501 Tunnel Brackets

Three brackets in the auxiliary tunnel were unbonded completely and fifteen brackets in the main tunnel were unbonded, at the tip of the bracket fingers. These were all rebonded with approved materials and procedure and the rebonded brackets are considered to be in as-good-as-new condition.

5. Defective Liquid Hydrogen Tank Insulation

Liquid hydrogen tank insulation tiles were made of uncured 3-D foam and installed in several of the stages, including at least S-IVB-212, -507, and -508. After installation, the uncured tiles continued to grow, thus creating an unsatisfactory condition which was detected after insulation of the tanks was completed. Correction of the problem will require reworking the affected areas by removing the insulation liner, cutting away the excessive foam thickness, and restoring the liner to good-as-new condition. Up to about 20 percent of the 3-D insulation is affected in each of these stages.

Based upon laboratory investigations and tests, the stage contracto has issued the following acceptance criteria:

a. Swelled foam is acceptable if Z threads are bonded to the insulation liner (Z threads are the foam reinforcing threads normal to the insulation liner).

b. Swelled foam is acceptable if unbonded Z threads do not extend beyond a single insulation tile.

c. Swelled foam is acceptable if the total area of Z thread unbond does not exceed the area of the largest tile involved.

d. Insulation liner blisters up to 2 inches diameter are acceptable.

The above stated acceptance criteria are being reviewed by this division for technical adequacy.

6. Materials for Flammability Testing

The S-IVB stage manager was requested to order from the stage contractor certain orbital workshop typical insulation specimens, 3 feet in diameter, for our flammability testing. This order is being processed; however, the probability of obtaining authority to purchase the specimens looks rather slim at this time because no change orders requiring additional cost against the stage contract are being processed at this time.

7. The following documents were reviewed:

a. MDC STP0191, "Leak Test, Aft Dome Joint Welds and Fasteners"

b. MDC Response to OWS PDR Action Item 2-32, "Fuel Tank Bleed Capability for Experimental Accommodation"

c. MDC STP0193, "Cryogenic Insulation Liner, Fire Retardant Aluminum Foil Film, Installation of"

d. MDC MRD 1P20110, "Lubricant, Solid Film, Propellant System Compatible"

e. MDC Response to OWS PDR Action Item No. 2-30, "Minimum Flight Instrumentation Requirements"

f. APS Recycle Capability Tests

g. MDC Response to OWS PDR Action Item 2-74, "Materials for OWS"

h. Sealing of S-IVB-501 Stringer Jackets, Feed Line Fairings, and Korotherm Insulation"

i. MDC Response to OWS PDR Action Item No. 2-56b, "Design Concept for Visible Index Markings for Connectors"

j. MDC ECP 2506, "Low Pressure Relief Valve, Grease Packing"

V. F-1 Engine

A. Investigation of Insulations for Use on F-1 Engine Components

Efforts have continued in the study of the effect water would have on the insulating qualities and integrity of the metal foil enclosed Refrasil insulation which is being used for insulating the F-1 engine components. Pre-dried Refrasil samples were aged isothermally (25°C) in a 100-percent humidity environment without a measurable weight change. When contacted by bulk liquid water the material retains water which is equivalent to more than seven times its own weight. This suggests that the affinity of this material for water is due solely to a surface wetting action. The insensitivity of the material to high humidities, in the absence of bulk liquid water, rules out a capillary absorption mechanism and retention of water solely by this wetting action permits its rapid evolution as steam under the heat flux conditions that would prevail during firing.

A section of this insulation (4 x 6 feet) previously exposed to a water sprinkler during a test by Propulsion Division has been dried in a forced draft oven at (250-300°F (93°C-149°C)) to constant weight. Approximately 4.5 pounds of moisture were removed by drying overnight. This panel has been suspended vertically under a shed that is protected only from direct rainfall. There has been no measurable weight change due to absorbed or adsorbed water from the atmosphere.

B. F-1 Engine, Project Management, Materials

As a result of the overall review of the use of spring materials on Saturn V mechanical components, the Rocketdyne Division of North American Rockwell Corporation was requested to make such a review on the F-1 and J-2 engines. A list of components which have 17-7 PH RH 950 springs was submitted, and action was taken to eliminate these springs in those components where their operation is critical.

VI. J-2 Engine

Investigation of Corrosion of Quill Shaft for J-2 Engine

An evaluation of corrosion found on a quill shaft of a J-2 engine resulted in a proposal by the Rocketdyne Division of North American Rockwell Corporation to chrome plate this part. This proposal was concurred in provided it could be demonstrated that no hydrogen embrittlement would occur. It was also recommended that adequacy of the drying procedures following

cryogenic loading be reviewed and amended if necessary to eliminate the moist conditions which caused the quill shaft to corrode.

VII. Instrument Unit

A. Study of Possible Gas Evolution in the Environmental Control System

With minor exceptions tests have been terminated in the study of gas evolution from within the environmental control system of the Instrument Unit, and data are being analyzed. Tests are continuing on dissimilar metal couples in distilled water inhibited with sodium dichromate. When this phase of the program is completed a complete evaluation will be made and reported.

B. Evaluation of Diffusion-Bonded Tube Joints for Use in the Environmental Control System of the Instrument Unit

Tubular joints made by silver diffusing aluminum (6061) to stainless steel (300 series) are being evaluated for resistance to corrosion in inhibited and unhibited methanol/water solution. All testing has been terminated after 120 days of exposure. Visual inspection of the joints shows blistering and pitting around the mating surface. These specimens will be examined metallurgically to determine the depth of attack and also to determine whether the joint strength has been adversely affected by this attack.

C. Investigation of "B" Nut Failures in the Instrument Unit

Three failed MC124D8 (7075-T73) "B" nuts were discovered in Advanced Saturn Instrument Units at the IBM Huntsville facility. Analysis of the parts at IBM and by this division revealed the failures to be the result of stress corrosion cracking. Conductivity tests of the failed nuts established the heat treat condition at -T6 rather than the specified -T73. Both -T6 and -T73 nuts have been found in stock supplies. An investigation is underway to determine the extent and the cause of the stock mix.

D. Instrument Unit, Program Management, Materials

A corrosion problem has been found on the first stage Pressure Regulator of the Instrument Unit. The 2024 aluminum body was corroded on 11 of 13 regulators. Initially it appeared that poor anodizing was responsible, but since other components from the same vendor have not corroded this does not now appear to be the reason. IBM requested that a material change to 6061 aluminum or stainless steel be made. Because of the severity of the corrosion and since a 6061 aluminum identification tag exposed to the same environment also corroded to the same degree, a more positive assessment of the cause of the problem will be required before a satifactory solution can be developed. IBM was requested to investigate the processing of this housing and to better identify possible causes of this problem so that a satisfactory resolution can be made.

VIII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

Investigations have continued in the determination of possible contamination of the optical environment of the ATM experiment, both by direct deposition of contaminant materials on optical surfaces and by degradation of the view area of the equipment.

Evaluation of potential materials for use on the ATM is continuing. All materials are tested in accordance with the Materials Management Plan for ATM contamination. To be acceptable a material must have a maximum rate of weight loss during temperature cycling from 25 to 100°C which does not exceed 0.2 percent/cm^2/hr.

Twelve materials were tested in vacuum (10^{-7} torr) to 100°C with periodic weight loss measurements. Materials of particular interest with test results are as follows:

Epoxy PS-269, Hitemp fiberglass insulation, CPR 738-7 polyurethane foam, and S-13G white paint #67-7-14-5, are acceptable materials for use on the ATM. These materials all show excellent thermal stability in vacuum and have a maximum rate of weight loss less than 0.2 percent/cm^2/hr. CPR 738-7 polyurethane foam was evaluated to 150°C but found to be unacceptable above 100°C. Armstrong cork #9520 was also found to be unacceptable even though it was vacuum baked at 100°C in vacuum prior to testing. RTV-615, Cat-a-lac black paint #67-7-14-3 and Z-93 white paint #67-7-26-1 were marginal with respect to weight loss. These materials may find limited application in their present form depending on the surface area involved and their proximity to the ATM optics.

The winding on the Inland Motors Company's 7 ft-lb torque motor which is potted with Epon 828 epoxy and rated by Inland to be stable in vacuum to 155°C was tested at 10^{-7} torr at 100°C. The potted material was heated internally by applying current to the winding. The potted winding was tested for 31 hours and showed extensive outgassing with mass spectra peaks to 242 atomic mass units (AMU).

A block of Epon 828 with curing agent Z and flexibilizer 871 was heated to 100°C and 10^{-8} torr for 54 hours. This sample outgassed initially but was free of dibutyl phthalate and relatively clean of other peaks at the end of the test. The data from this sample and the potted winding indicate that the epoxy in the bulk form is not adequately cured. The potted winding will be tested again for a period of 72 hours at 100°C to determine if an extended vacuum bake will make this formulation of Epon 828 acceptable.

Mass spectrometer data on potential ATM materials is being reduced and analyzed based on a background scan made at 25°C at a pressure of approximately 5 x 10^{-7} torr. The major peak of the background scan is assigned a relative intensity of 100. For all other peaks, a ratio of the peak height to the major peak height is computed, this being the relative intensity of that mass constituent. When this ratio is less than 1.0, the constituent is considered insignificant. To date the tabulation of data on 19 materials that exhibited some weight loss has been completed. Analysis of the reduced data is in progress. A new vacuum system has been assembled for making weight loss and mass spectra determinations simultaneously. The system is designed to assume routine sample testing in order to free the larger chamber for component type tests.

B. Investigation of the Cleanliness of the Space Environment Simulation Chamber

One of the requirements of the ATM program is that the completed ATM undergo systems checkout in a simulated space environment prior to flight. In order to assure that the test environment does not adversely effect the ATM, tests must be made to assure the cleanliness of the test chamber.

All in-house and contractor samples to be used in the chamber A cleanliness test at the MSC Space Environment Simulation Laboratory have been received. Fabrication of all apparatus for the test is complete. The samples will not be mounted on the sample test fixtures until shortly before the test. It is desired to make certain optical measurements on the paint samples just prior to the test to minimize the effect of aging.

The shutter assembly and the 7 ft-lb torque motor are being mounted on one of the sample test fixtures. The unit will then be checked for mechanical and electrical operation.

The General Electric monopole residual gas analyzer (RGA) purchased with 37.5 foot cables for the tests at the Manned Spacecraft Center (MSC) has been delivered. General Electric Company representatives have checked out the RGA at this Center with the special cables and the unit scans satisfactorily to 600 AMU with a sensitivity 5 amp/torr.

C. Evaluation of Direct Current Motors for Use on ATM

Direct current torque motors will be used extensively on the Apollo Telescope Mount. Materials and motor evaluations are being made to ascertain the suitability of selected motors and materials for the ATM project.

During this reporting period an Inland Motor Company 7-ft-lb. high temperature motor was operated for 200 hours at 10^{-7} torr. The motor was operated unloaded at 200 rpm; with 40 volts and approximately 0.2 ampere

input. Post test evaluation of this motor indicated a slight lubricant build-up on the commutator from The Boeing Company 046-45 brush material. It is believed that the motor, as designed, does not have sufficient brush pressure to prevent this build-up. The brush system has been redesigned to provide a brush load of approximately 6 psi.

D. Investigations of ATM Bearing Lubrication

In order to lubricate adequately the Apollo Telescope Mount systems lubricants are required which will not break down or outgas in the environment of outer space.

A torque drive test system has been received from the Bendix Company and has been installed in a vacuum system for test. This test system includes a 7 ft-lb. Inland motor, a tachometer and a magnetrol for loading the drive motor. This system has been in operation for 15 days of a 60-day test at the loads and speeds set up by the Bendix Company. Environmental pressures are being maintained at 10^{-7} torr and temperatures at about 95°F. No major problems have developed to date.

E. Thermal Control Materials for the ATM

Evaluation of thermal control coatings for application on ATM components has continued. As reported earlier, Cat-a-lac flat black paint No. 463-3-8 has acceptable outgassing characteristics when cured at various temperatures ranging from 65°C (150°F) to 140°C (300°F). During these studies, the curing time used at 65°C (150°F) was 48 hours. Although the long curing time is not objectionable, it would be desirable to shorten the curing cycle for some applications. However, when the paint was cured for only 24 hours at 65°C (150°F), it did not have acceptable outgassing characteristics. The solar absorptance (α) and total normal emittance (ϵ) values reported previously for the Cat-a-lac paint were measured on specimens cured at 149°C (300°F). During this report period, α and ϵ values were measured on paint specimens cured at 65°C (150°F) and at 93°C (200°F). All values obtained were greater than 0.9, indicating that the curing temperature has no apparent effect on the optical properties of the paint.

Fabrication of heater blankets for the quarter spar canister was completed during this report period.

Installation of the heater blankets on two segments of the quarter spar was accomplished using Narmco 7343 adhesive.

Preformed blocks of 7.0 ± 1.0 lb/ft^3 density CO_2 blown polyurethane foam were ordered to insulate the quarter spar for thermal tests. This material was tested for outgassing under vacuum, and was acceptable for use over the expected temperature range.

Tests were run on bonding the foam over the heater blankets for the quarter spar tests. The heater blankets consist of heater wire embedde in fiberglass reinforced polyurethane resin. Polyurethane foam of approximately 12 lb/ft^3 density was bonded to fiberglass reinforced polyurethane, and this in turn was bonded to an aluminum surface using Lefkoweld 109/LM-5 and/or Narmco 7343/7139 adhesive. Flatwise tensile tests showed strength of 290 psi for the Lefkoweld samples and 250 psi for the Narmco samples witl all failures occurring within the foam.

IX. Nuclear Ground Test Module

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

As reported previously, the Narmco Division of the Whittaker Corporation is modifying a 17-inch Whittaker (S-IC) prevalve for use in a liquid hydrogen radiation environment. After modification the valve will be shipped to General Dynamics/Fort Worth (GD/FW) where it will be tested as a component of the RIFT tank. The lubrication of critical parts of this valve will be done by Midwest Research Institute under contract NAS8-21165.

The design of the liquid hydrogen nuclear heating experiment is well underway by GD/FW. NERVA radiation environment data generated by Lockheed, Westinghouse, and Aerojet were obtained from this Center to provide design baseline information.

To protect moving parts in the Nuclear Ground Test Module and in nuclear-powered spacecraft, lubricants will be required which will not be degraded by operation in hard radiation. In connection with this requirement a second series of tests is being made in which various dry film lubricants are irradiated with gamma radiation to a dose of 10^8 and 10^{10} ergs per gm carbon and subsequently tested in the Falex lubrication tester. Fifty specimens coated with each of the lubricants of interest are to be tested, twenty specimens irradiated to 10^8 ergs per gm carbon (gammas), twenty specimens irradiated to 10^{10} ergs per gm carbon (gammas), and ten control specimens. Testing of the dry film lubricant MLF-9 (MoS_2, graphite, Bi, $AlPO_4$) was started during this period and is continuing.

Sliding seals for pneumatic actuators are usually made of Teflon or grease lubricated elastomers. The high radiation field on the NGTM requires the selection of materials which will fulfill the basic requirements of a sliding seal and be relatively unaffected by radiation to 1×10^{10} ergs per gm (C). A series of tests were made on polyurethane O-rings sliding against aluminum. In general the polyurethane O-rings were characterized by very high coefficients of friction in the range of 0.6 to 0.9, as compared with

0.1 for Teflon. Polyurethane irradiated to 1 x 10^{10} ergs per gm (C) wore more rapidly than the unirradiated O-rings. Operation of the O-rings against the dry film lubricants MLF-5 and MLF-9 improved the frictional properties but not sufficiently to recommend these combinations for a sliding O-ring seal.

ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

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

A. Polymer Development and Characterization

1. Southern Research Institute, NAS8-20190
2. National Bureau of Standards, Government Order H-92120

B. Adhesive Development

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

C. Developmental Welding

The Boeing Company, NAS8-20156

D. Thermal Control Coatings

The Boeing Company, NAS8-21195

E. Physical and Mechanical Metallurgy

Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

1. Solar, Division of International Harvester, Inc., NAS8-21215
2. Mitron, Research and Development Corporation, NAS8-20609
3. McDonnell Douglas Corporation, NAS8-21083
4. Babcock and Wilcox Company, NAS8-21186

G. Lubricants and Lubricity

1. Midwest Research Institute, NAS8-21165
2. The Boeing Company, NAS8-21121

H. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-20396
2. National Bureau of Standards, GO-H2151A

3. Northrop Corporation, NAS8-20333
4. Tyco Laboratories, Inc., NAS8-20297
5. Kaiser Aluminum and Chemical Company, NAS8-20285
6. North American Aviation, Inc., NAS8-20471
7. Hercules, Inc., NAS8-21207

I. Explosion Hazards and Sensitivity of Fuels

Standard Research Institute, NAS8-20220

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

1. General Dynamics Corporation, NAS8-18024
2. Hughes Aircraft Company, NAS8-21087
3. IIT Research Institute, NAS8-21031

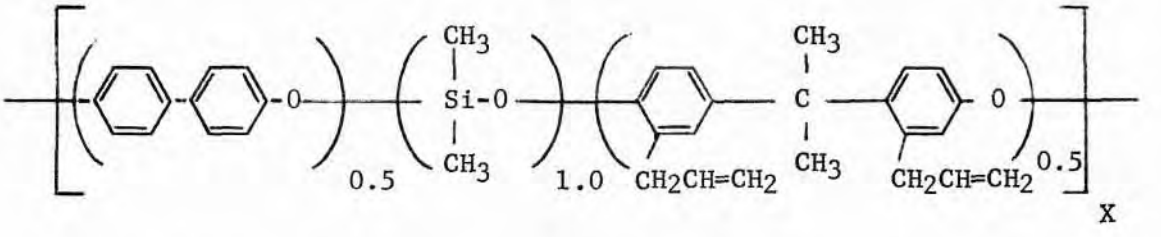
K. Instrument Development

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

II. General - In-House

A. Development of High Temperature Resistant Polymers

Continued effort has been devoted to the development of improved crosslinking systems for the polyaryloxysilanes, polysilphenylenesiloxanes, and polymers of related structure. Additional curing studies have been carried out on the previously prepared allyl-modified aryloxysilane polymer,



which melts at 90-100°C (194-212°F). This polymer was dissolved in tetrahydrofuran and treated with a sufficient amount of 1,4-bis(hydrogendimethylsilyl)benzene to theoretically react with all of the double bonds. The polymer was cast as a film on aluminum and cured for 24 hours at 100°C (212°F) followed by a post-cure of 4 hours at 130°C (266°F). The resulting film was semiflexible and tough at room temperature, was unaffected by rubbing with a cloth dampened with tetrahydrofuran, and remained non-tacky and dimensionally stable to 250°C (482°F). The freeze-dry process is being investigated as a possible processing technique for this polymer system to result in a catalyzed, uncured one-part system which is crosslinked by

application of heat. This process consists of dissolving both polymer and crosslinking agents in benzene and freezing the solution on the sides of a flask by rotating the flask in an alcohol-dry ice bath. The benzene is then sublimed out at reduced pressure, leaving an intimate mixture of the polymer and the curing agent which is in the form of a fine powder. The polymer described earlier was not processible by this technique, as it appeared to coalesce during the sublimation step. Several structural modifications of the polymer will be prepared in an attempt to obtain a system which can be freeze-dried efficiently.

B. Development and Characterization of Phosphonitrilic Polymers

The product obtained from the reaction of 2,4,6,8-tetraphenyl-1,2,4,6,8-tetra-N-methylcyclohexylaminophosphazine (I) with anhydrous HCl in a pressure reaction vessel (100°C (212°F)/8 hours) has been analyzed for both ionizable and total chloride content. Based upon these results and observations previously described, it can be assumed that the reaction leads to the formation of an addition type compound (II) and does not proceed via a nucleophilic displacement mechanism to give the tetrachloro-substituted derivative, $(\text{ØPNCl})_4$:

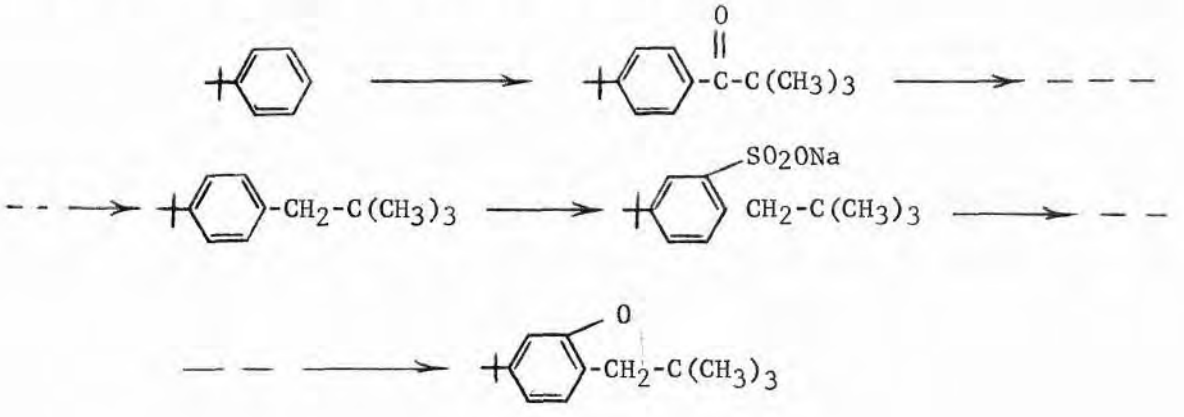
$$\text{I} + n\text{HCl} \longrightarrow \text{II}\cdot n\text{HCl}$$

$$\text{I} + 8\ \text{HCl} \longrightarrow (\text{ØPNCl})_4 + 4\ \text{amine}\cdot\text{HCl}$$

Analyses for II: Ionizable Cl - 65.14 percent
Total Cl - 66.29 percent

Theoretical Cl for $(\text{ØPNCl})_4$ = 22.50 percent

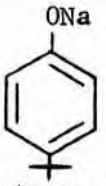
Subsequent studies were directed toward the preparation of a non-geminally substituted $(\text{PNClR})_4$ through the use of hindered phenols. Initial efforts consisted of the attempted preparation of a phenol substituted in the ortho position with a side chain of the configuration $-CH_2-C(CH_3)_3$. The synthetic procedure was envisioned as follows:



However, all attempts to effect a Friedel-Crafts reaction between tertbutylbenzene and pivaloylchloride (and pivalic anhydride) were unsuccessful and no ketone compound was isolated. A previous search of the literature failed to yield any information on the preparation or existance of this compound. It was hoped that a phenol of this configuration would be sufficiently hindered to permit only non-geminal substitution, but not bulky enough to prevent any reaction at all from occurring with $(PNCl_2)_4$.

2,4,di-tert-Butylphenol was prepared from the reaction of tert-butylphenol and tert-butylchloride in about 40 percent yield. The crude product was distilled twice through a 45 cm Vigreaux column and the fraction collected with a boiling point of 75-77°C/2 torr. The distillate solidified to a white solid, melting range 52-53°C.

The sodium salt of this hindered phenol was prepared through the treatment of its tetrahydrofuran (THF) solution with metallic sodium. The resultant violet-blue solution was then added to a THF solution of tetrameric phosphonitrilic chloride and the system heated at reflux (65°C) overnight. At the end of this time, the reaction mixture gave a neutral reaction to moist alkacid test paper and the mixture was white and turbid from separated salt:



$$(PNCl_2)_4 + 4 \longrightarrow P_4N_4Cl_4(OR)_4 + 4\ NaCl.$$

The reaction mixture was processed to give a near quantitative yield of product as a yellowish viscous oil. The infrared spectrum (5 percent CCl_4 solution) showed a strong absorption band at 1190 cm^{-1} which can be attributed to the presence of P-O-C. The spectrum also showed PN ring absorption at 1260 cm^{-1}. The oil could not be induced to crystallize. Therefore, half of the product (0.0125 mole) was dissolved in THF and treated with excess monomethylamine:

$$P_4N_4Cl_4(OR)_4 + 8\ H_2NCH_3 \longrightarrow P_4N_4(HNCH_3)_4(OR)_4 + 4\ amine\cdot HCl.$$

From the reaction mixture was obtained 3.1 g of amine salt (theoretical yield, 3.4 g). The filtrate was evaporated to dryness leaving a near solid residue. Every effort will be made to effect crystallization of this product in order that both phosphorous and proton magnetic resonance data can be obtained. This should permit determination of the number of P environments present, and the J_{PNCH} coupling constants. These data will enable structural assignments to be made which will clarify the non-geminal (or geminal) configuration of the molecule.

C. Development and Evaluation of Metallic Composites

Investigations are continuing in the development and evaluation of both explosive bonded and diffusion bonded metallic composites.

During this report period, 22 explosive bonding tests were completed. Tests were run using constant and varying explosive loads of Prima sheet in bonding aluminum to aluminum. Tests also were made using constant density nitroguanidine as the explosive. In the varying load tests, the Prima sheet was varied in load along the sheet from one gram/in^2 to eight grams/in^2. A good bond was obtained in the area where the explosive density was from 2 to 3 grams/in^2. In future bonding tests the explosives C-3 Deta sheet, C-4 composition, and nitroguanidine will be employed. The explosive material that appears to have the most promise is nitroguanidine which has a detonation velocity within optimum joining parameters. Results to date indicate that a continuous acceptable bond can be obtained in an aluminum to aluminum laminate when nitroguanidine with a density of eight grams/in^2 is employed.

Investigations were initiated during this period to develop methods for producing composite materials using aluminum as the matrix and filaments of boron, beryllium and stainless steel as the reinforcement agent. Initial efforts are directed toward the determination of optimum temperature, pressure and time parameters necessary to bond an aluminum-to-aluminum (3003 alloy) joint. All experiments have been run in air. As a result of the five experiments completed, one process appears promising. The procedure for producing the bond, in this case, consisted of degreasing and wire brushing followed by subjecting the parts to a pressure of 100,000 psi for 20 minutes at a temperature of 930°F (499°C). Diffusion bonded specimens have been sectioned and are presently being examined to determine interfacial characteristics.

D. Investigation of Stress Corrosion Characteristics of Various Alloys

Tests are continuing on aluminum alloy 7001-T75 to determine the threshold stress level in the short transverse and long transverse grain direction. Round threaded-end tensile specimens stressed in the long transverse grain direction to 70 percent of the yield strength (60 ksi) failed in 45 days. In the short transverse three specimens out of three tested (3/3) failed in 73 days when stressed to 44 percent (30 ksi) and 2/3 failed in 25 and 45 days when stressed to 37 percent (25 ksi) in the alternate immersion tester using 3.5 percent sodium chloride solution. There have been no failures in synthetic sea water after 76 days of exposure.

The long-term exposure tests have continued on 7079-T61 and -T64 aluminum alloy in the local atmosphere. There has been no change in the test results since June. This atmosphere exposure test has been in progress for a total of 20 months.

Investigations have continued in the evaluation of the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens 2014-T6, 2024-T4, 7079-T6, and 7079-T651 were stressed in the short transverse grain direction to 75 percent of their strength and exposed to inside and outside atmosphere. Failures to date have been confined to the outside atmosphere.

Specimens of aluminum alloys X2021 and X7007 were stressed in all three grain directions and exposed in the alternate immersion tester and to the local atmosphere. Both alloys have been found to be susceptible to stress corrosion in the alternate immersion tester. Tests in the atmosphere have been in progress 20 months and the only failures encountered were X7007-TE136 specimens in the short transverse direction at loads as low as 10 ksi.

Aluminum alloy 7183-T651 is being evaluated for stress corrosion susceptibility. Round threaded-end tensile specimens stressed in the longitudinal and long transverse grain direction to 50 ksi (75 percent) and C-rings in the short transverse grain direction stressed to 30 ksi (45 percent) and 25 ksi (40 percent) are being exposed in the alternate immersion tester. Additional C-rings in the short transverse having the same stress levels are being exposed in synthetic sea water.

An evaluation is being made to determine the effect on stress corrosion susceptibility of 7079-T651 three overaging conditions, i.e. (20 hours at 350°F (177°C), 10 hours at 350°F (177°C), and 5 hours at 375°F (191°C)). Round threaded-end tensile specimens stressed in all three grain directions to 50 and 75 percent of the directional yield strength are being exposed in the alternate immersion tester. The only failures encountered have been in the short transverse grain direction after 71 days of exposure. Three specimens failed of five exposed (3/5) at 75 percent and 3/4 at 50 percent aged 20 hours at 350°F (177°C); 3/3 at 75 percent and 3/3 at 50 percent aged 10 hours at 350°F (177°C); and 2/3 at 75 percent and 2/3 at 50 percent aged 5 hours at 375°F (191°C).

Studies were made to determine the stress corrosion susceptibility of SS21-6-9 stainless steel unsensitized and sensitized (1250°F (677°C) for one hour, air cooled). Flat, round threaded-end, and C-ring specimens stressed to 75 and 100 percent of the yield strength in both conditions have been terminated after 180 days of exposure in the alternate immersion tester. The results of this test indicate that SS21-6-9 both unsensitized and sensitized is resistant to stress corrosion cracking when exposed in the alternate immersion tester for 180 days.

Stress corrosion susceptibility tests are being made on specimens of welded and aged (20 hours at 790°F (421°C)) ARDE low silicon 301 stainless steel cryogenically stretched to a nominal 252.6 ksi. Longitudinal specimens stressed to 75 percent (190 ksi) and 90 percent (228 ksi) of the yield strength have been exposed in the alternate immersion tester for 80 days without failure.

Initial tests have been terminated in the evaluation of the stress corrosion susceptibility of Almar 362, PH15-7Mo, 17-4PH, and PH14-8Mo (air melt and vacuum melt) stainless steels. Evaluation of the results show that the stress levels at which these tests were conducted on the 17-7PH and PH15-7Mo steels in both sheet and bar are much too high to predict stress levels. Additional tests for these alloys in several aged conditions and stress levels have been planned and specimens are being prepared.

Tests have been terminated in the evaluation of the stress corrosion resistance of NAA, General Electric, and Aero-Quip type stainless steel fittings welded and brazed to 321 stainless steel tubing. After 180 days of exposure in the alternate immersion tester no visual evidence of stress corrosion cracking could be detected.

Investigations have continued into the stress corrosion susceptibility of Ti-6Al-4V alloy in various fluids. No failures have occurred in any of the fluids except methyl alcohol. Specimens that had not failed in 6 months when exposed to methanol containing 0.50 and 1.0 percent water failed within two days after the addition of 16.3 ppm sodium chloride (10 ppm Cl). Specimens exposed to methanol containing 3.0 percent water for 6 months have not failed in 4 months after the addition of 66 ppm sodium chloride. Failures are still occurring in shot peened specimens in methyl alochol after over 300 days exposure.

E. Investigation of Organic Semi-Conductor Materials

Experimental studies have continued in the establishment of the characteristics of the semi-conductor, chrysene. During this report period emphasis in this study was directed toward measurement of photoconductivity and dark conductivity.

Dark conductivity and photoconductivity perpendicular to the a-b plane of chrysene single crystals have been investigated over the temperature region from 5°C to 60°C.

Dark conductivity was studied as a function of temperature and voltage. Plots of equilibrium conductivity yield activation energies of 1.6 ev $\pm$ 0.2 ev below 31°C and 0.98 ev $\pm$ 0.07 above 31°C with a conductivity of $(8.0 \pm 1.0) \times 10^{-14}$ ohm cm^{-1} at room temperature.

The photocurrent was studied as a function of voltage, temperature, intensity of illumination and wavelength of excitation. The current-voltage characteristics and the variation of the photocurrent with light intensity were generally linear. The photoconduction action spectrum contains more structure than the corresponding absorption spectrum of the compound. Considerable space charge effects were observed at all wavelengths studied. Activation energies for photoconductivity were determined to be 0.155 $\pm$ 0.012 ev for wavelengths of 260, 310, and 410 millimicrons.

F. Evaluation of Electroplating Processes

1. Electroplating on Magnesium - Lithium Alloys

Several panels of LA141, LAZ933 and AZ31B magnesium alloys were plated with 0.0005 inch of nickel, 0.0005 inch of cadmium and 0.0001 inch of gold and exposed to the local outdoor atmosphere for eighteen months. Cadmium plated AZ31B withstood the environment with no adverse effects,

however, none of the other plated samples were satisfactory. From these results, it appears that much thicker coatings will be required to afford any degree of protection to the magnesium.

2. Evaluation of "Technical Micronics Control" Electropolishing Solutions

Studies have continued in the evaluation of a proprietary electropolishing solution developed by "Technical Micronics Control, Inc." Experimental results to date indicate that a high degree of luster can be obtained on copper, brass, stainless steel (300 series) and certain nickel alloys. Also, a less lustrous, but a good shiny finish was obtained on aluminum (sheet stock) alloys 2024-T6, 6061-T6, and 7075-T6. On one alloy tested, 7075-T6, which was cut from plate stock, results showed that a shiny surface could be obtained but the surface was covered with minute pits. This difference was attributed to the difference in the grain structure of the sheet and plate material. Specimens of mild steel also were satisfactorily polished with this solution, but were less lustrous than the stainless steel specimens.

G. Investigation of Thin Film Dielectrics

A series of thin film capacitors utilizing Teflon as the dielectric have been prepared and electrically tested. As in the case of the cerium oxide capacitors preceding this study, the Teflon dielectric was sputtered in an argon atmosphere to thicknesses ranging from 3,000 Å to 12,000 Å. An aluminum electrode of rectangular geometry and 1,000 Å thick was deposited on a 1 x 3 inch microscope slide by conventional vacuum deposition. After the aluminum deposition was completed, the slide was placed in the sputtering chamber and the Teflon dielectric was deposited. This was accomplished through conventional argon ion bombardment at an RF field frequency of 2.5 megahertz. Teflon was sputtered on the aluminum substrate at the rate of 4,000 Å/hour producing a homogeneous thin film of Teflon. A second aluminum electrode was then deposited over the Teflon to complete the capacitor assembly. Wire leads were attached to prepare the capacitor for electrical evaluation. The completed determinations were then made of capacitance, dissipation factor, and breakdown strength to liquid nitrogen temperature.

Capacitance and dissipation factor measurements made over the temperature range +30°C to -178°C and over 20 different capacitors show very little change indicating practically no alteration of the dielectric constant. Breakdown strength increased with decreasing temperature with values comparable to those of 1 mil thick Teflon and highly superior to those of Teflon in thicknesses of 0.250 inch. Analysis of these data are continuing to determine the full significance of the electrical behavior of Teflon in thin film form.

H. Development and Evaluation of Nondestructive Techniques for Assessing Stress Corrosion Damage

Stress corrosion cracking of high strength alloys is a major problem in the aerospace industry and with several Saturn components in particular.

Activities are continuing in an attempt to adapt nondestructive testing techniques to the early detection of incipient stress corrosion failure.

Numerous electromagnetic, ultrasonic, and internal friction measurements have demonstrated that early stages of stress corrosion cracking can be detected in 7079-T6 aluminum. Also, it has been shown that there is a very significant difference in the magnitude of materials property changes caused by corrosion only and those changes measured when the specimen is stressed and exposed to a corrosive environment. Attempts are being made to relate the magnitude of these property changes to the mechanical strength of the specimen. A modified Charpy impact test was selected as appropriate for this purpose. A total of seventy-eight 7079-T6 Al specimens have been tested. Twelve specimens were uncorroded stock material. The remaining specimens were exposed to a corrosive environment and then to stress corrosion for periods of time up to forty-eight hours. Specimens exposed to stress corrosion for forty-eight hours lost approximately two-thirds of their impact strength compared to specimens of uncorroded material. However, the large spread in the date and the variation in strength values obtained for the uncorroded material made the validity of these initial test results somewhat questionable. Both tensile and impact tests will be made until the more appropriate method is determined. A tensile specimen has been designed for the stressing fixtures.

Present plans include nondestructive, metallographic, and destructive mechanical tests on stress corroded 7075-T6 Al specimens. A detailed program has been prepared and the specimens have been machined. Considerable difficulty has been experienced in obtaining the high finish required for electron microscope studies. Due to difficulties with stress corrosion mechanism studies, a parallel program has been planned. A second group of specimens will be stress corroded and electrical conductivity measurements will be made. A tensile test will then be performed in order to obtain a correlation of mechanical property changes with electrical property changes.

I. Development and Evaluation of Materials for Electrical Contacts in Vacuum

1. Development of Electrical Brush Materials

As part of the program to investigate additions to the molybdenum disulfide-silver (MoS_2-Ag) brush materials which would be useful incontrolling the commutator film thickness, samples of MoS_2-Ag-molybdenum disilicide ($MoSi_2$) and MoS2-Ag-carbon fiber have been hot

pressed. These compositions present no great difficulties in hot pressing of the carbon fiber does prevent the attainment of high density in the compact. Brush specimens are being prepared from these materials.

Two samples of MoS_2-tantalum (Ta)-carbon fiber have also been hot pressed. A sample hot pressed at 1370°C (2500°F) appears satisfactory; the material hot pressed at 1480°C (2700°F) appears to have a center delamination, probably due to the rate of pressure release at the end of the run. The effect has been observed previously in the MoS_2-Ta materials.

2. Evaluation of Brush Materials

One of the characteristics required in a good brush is the ability of the brush to furnish a lubricating film so as to minimize wear of the commutator and at the same time remove any substantial film buildup. Plans are being made to test some of the earlier brush compositions with minute addition of particles such as diamond dust which may serve as polishing compounds.

A new test device capable of testing 18 brushes simultaneously in an inert atmosphere has been developed and used to evaluate the Boeing Compact 046-45 against copper, beryllium copper, and gold-plated commutators. These tests were made at 1,800 rpm and at unit brush loads varying from 3 psi to 15 psi. Tests to date have not included current flow through the brushes. In general, it appeared that brushes loaded to 10 to 15 psi unit load chattered and vibrated badly during operation. Brushes loaded to 3 psi tended to deposit a lubricant film on the commutators while the brushes loaded between 5 and 7 psi unit load operated satisfactorily. The copper and gold-plated commutators wore slightly while the harder beryllium copper exhibited almost no wear.

J. Documentation Review

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

1. NAA MA0104-003B dated August 1, 1967, "Markings, Etched, Application of"

2. MA0610-023A dated August 30, 1967, "Contamination Control at Field Sites for Saturn S-II"

3. MA0610-023B dated May 3, 1967, "Surface Preparation of Metals and Non-Metals for Adhesive Bonding, Saturn S-II Program"

4. MA0190-018A dated July 6, 1967, "Electroplated Lead on Corrosion Resistant (Cres) Alloys for Sealing Applications"

K. Literature Survey

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

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

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

OCTOBER 1, 1967 THROUGH OCTOBER 31, 1967

I. Radiography

Fifty-three miscellaneous parts, components, and test specimens were inspected by radiographic techniques during this report period.

II. Photography

	Negatives	Prints
Engineering Photography	56	118
Metallography and Fractography	143	469
Miscellaneous Photography, Processing, Copywork, etc.	72	525

III. Metallurgical and Metallographic Testing and Evaluation

A. Twelve experimental stainless steel connectors were studied metallographically at the request of the Propulsion Division, R-P&VE-PE. Both Aeroquip and General Electric type brazed connectors failed before completion of 300,000 cycles vibration at 500°F (260°C). The North American/Rockwell welded connectors completed successfully the 300,000 cycles at 500°F (260°F). The metallographic studies indicated that complete or partial failure occurred in all tubing connectors. Although no leaks developed in the weld connectors, partial cracking was found in each welded connector that was studied. Hardness studies of the tube cross-sections showed that cracking followed the weakest zone adjacent to welded or brazed joints. Published data show that 321 stainless steel has a yield strength of about 19,000 psi at 500°F (260°C) which is slightly below the stress level used in testing the connectors. This fact accounts for the fatigue failures that occurred in the annealed areas of the tubing adjacent to the welded and brazed connectors.

B. Activities have continued in the development of electron beam welding techniques for fabrication of snap diaphragms for the Propulsion Division. During this report period an Inconel X diaphragm was electron beam welded to an Inconel X test assembly. Previously, AISI type 301 stainless steel had been used. Joining of a 0.015 inch thick diaphragm to the test assembly consisted of two welds made at power settings of 60 KV, 3ma, and a travel speed of 26 ipm. To complete the joint, special tooling was required to position and hold the diaphragm. The assembly will be stress relieved after the joining operation.

C. Metallographic studies on samples prepared by means of preliminary electron beam welding schedules indicated that suitable welds are obtained in 6Al-4V titanium alloy when welded at machine settings of 60 KV, 1.5ma, and at a speed of 15 ipm. Seal type welds were made on the injector assembly and the ring assembly using the noted power settings. Currently the component are being machined into the desired configurations prior to subsequent electro beam welding to the engine assembly.

IV. Spectrographic Analyses

Two hundred and eighty-three determinations were made on twenty-nine samples and four hundred and one standard determinations were made.

V. Infrared Analyses

Twenty-six analyses were made by infrared techniques on a variety of materials including water from an engine test stand sump, cellulose specimens, corrosion specimens, and fluorine samples.

VI. Chemical Analyses

	Determinations
Residue from cutting oil for carbon	2
Vanadium and Niobium nitride for nitrogen content	6
Liquid from Whittaker LOX prevalve for	
water	2
sulfates	1
chlorides	1
Metal samples for	
silicon	6
copper	7
carbon	15
Polymeric samples for	
carbon	4
hydrogen	4
silicon	2
ionic chloride	2
total chloride	2
water	2
epoxide equivalent	12
Gas samples for	
hydrogen	20
Combustion products from materials considered for S-IVB Workshop for	
nitrogen	12
oxygen	50
carbon dioxide	50
Atomic absorption analyses of	
aluminum for copper and zinc	24
steel for zinc	8
Inconel for zinc	4

VII. Physico Chemical Analysis

	Determinations
Density of	10
RP-1 fuel	5
oil samples, SAE 30	5
Viscosity of SAE 30 oil	2
Molecular weight of polymers	

VIII. Rubber and Plastics

	Items
molded and extruded	61
cemented	152
coated	3
fabricated	26

IX. Electroplating and Surface Treatment

	Items
acid cleaned	77
degreased and cleaned	2
gold plated	12

X. Development Shop Production

A. A total of 8,667 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. Three thousand one hundred and eighty-five man-hours, approximately 36.8 percent of the total man-hours, were expended on work of a non-routine nature and applied to the work orders listed below.

1. Six-Inch UV Camera Assembly

Work on the second six-inch camera assembly has been halted for an indefinite period until design problems are solved.

2. Coupling Assembly

The coupling assemblies are being assembled.

3. Saturn V Sled Test Module

The final assembly of the Saturn V sled test module is now in progress.

4. Models of ATM Experiment Package

The models of the ATM experiment package are approximately 60 percent complete.

5. C-1 Engine Modification

Components for the C-1 engine modification have been completed and are ready for welding.

6. ATM Contamination Test Fixture and Parts

Fabrication of the ATM contamination test fixture is approximately thirty percent complete.

7. ATM Model Payload

The model payload for the ATM is being manufactured.

8. ATM Rack

The ATM rack is approximately 60 percent complete.

XI. Miscellaneous

A. Fifteen materials were evaluated for LOX sensitivity in accordance with the provisions of MSFC-SPEC-106B. Data generated from these evaluations were forwarded to requesting groups and will appear later in applicable reports.

B. Twenty-two analyses were made by chromatographic techniques.

C. Heat treated six furnace braze assemblies.

XII. Publications

Montano, J. W.: Low Temperature Mechanical Properties and Ambient Temperature Stress Corrosion Properties of Custom 455 Stainless Steel Alloy, TM X-53665, October 20, 1967.

Cassidy, J.; Hill, W.; and Thompson, L.: Expansion of Foam Used in S-IC Electrical Distributors, IN-P&VE-M-67-5, October 26, 1967.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-67-10

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

October 1, 1967 through October 31, 1967

SATURN IB

I. S-IB Stage

A. Updated Performance Prediction

An updated Performance Prediction for the AS-204 LM-1 Mission was provided by the stage contractor, and was approved for use in analysis of trajectory and weight.

B. S-IB Fuel Fill and Drain Valve Acceptance Tests

Acceptance and closure tests of the fuel fill and drain valve were performed to determine if the valve liner could be dislodged by closing the valve against a flow rate of 630 gpm. Eleven tests were performed without damage to the liner.

II. S-IVB Stage

A. S-IVB-205 Propulsion Prediction

A revised propulsion prediction tape was received from the stage contractor and is being verified for adequacy. A detailed write-up of the S-IVB/IB prediction program (MARK 10) was also received from the systems contractor.

B. Orbital Workshop

1. Auxiliary Propulsion System

Work was initiated on design for the Orbital Workshop Auxiliary Propulsion System. Inhouse development of the APS is being investigated.

2. Thermal Control System Design

Design of the OWS thermal control system was postponed until baseline orientation and vehicle configuration are established.

3. Emergency Vent System

Requirements for an emergency vent system were analyzed, and the feasibility of a proposed system is being established. The stage contractor provided a new design for the vacuum valve assembly. The concept was accepted and the stage contractor will proceed with development.

SATURN V

I. AS-501 Vehicle

A. Flight Critical Components Reviewed

All "Certifications of Component Qualification" (COCQ) have been signed; however, a number of items were conditionally accepted and require further action or additional testing for AS-502 or AS-503. The number of components in this category are as follows:

S-IVB Stage - 29

S-II Stage - 14

B. Auxiliary Propulsion System (APS)

The following changes were incorporated on the AS-501 APS hardware and operational procedures:

1. The oxidizer tank assembly in Module I was replaced. Excessive bladder leakage resulted from bladder expansion during system leak checks at the pad in preparation for propellant loading. Action is being taken to prevent reoccurrence of the incident.

2. A new orifice will be installed at each of the vent ports of the low pressure helium module dump valves after propellant tanking is completed. The orifice will further restrict the flow thru the dump valve, assuring proper differential pressure across the propellant tank bladder during depressurization of the system.

3. As a precautionary measure against excessive expansion of the oxidizer tank bladder when the system is depressurized to hold-

pressure after burp firing of the engines, the gas, formed in the oxidizer bladder will be removed 10 hours before burp firing. A similar procedure will be followed if a launch is aborted after pressurization.

4. The low pressure helium system will be purged every three days after propellant loading to expel propellant vapors that have migrated in the pressurization system. This will prevent exposure of the helium regulator to the propellant vapors.

C. Flight Readiness Test Completed

The propulsion console in HOSC was manned at approximately 6:00 a. m. at T-4 hours. The test was concluded at approximately 10:15 p.m. after simulated restart of the S-IVB. Although the FRT is primarily an electrical test, many propulsion systems items are cycled during the test. No propulsion problems were noted.

II. S-IC Stage

A. F-1 Engine

1. R&D Engine Tests at EFL

Eighteen tests were conducted, and a total duration of 1665 seconds was accumulated. Seven of these tests were full-duration runs (150 seconds or more). Two tests were terminated prematurely because the fuel pump balance cavity pressure was below the redline and due to a fire in the turbine area which was caused by a cracked turbine manifold.

2. Production Engine Testing at EFL

Six tests were conducted, and a total duration of 503 seconds was accumulated. Two of these tests were full-duration runs.

3. F-1 Engine Thermal Insulation on S-IC-1

To prevent damage to the thermal insulation by steam generated from moisture entrained within the insulation panels,5/8 inch diameter vent holes will be drilled through the doublers on the outside foil of the insulation panels.

B. Countdown Demonstration Test (CDDT)

1. F-1 Engine Data Reviewed

The data indicated that all conditions were met for the F-1 engine. No hardware changes were necessary.

2. Fill and Drain Valves Replaced After CDDT

One LOX fill and drain valve was replaced because of apparent leakage. The helium fill valve was replaced because of a faulty microswitch indication. The LOX prepressurization switch was also replaced when it checked out high through the CALIPS port.

3. LOX Recirculation System Performance

No problems were encountered with the system during CDDT. The temperatures in all outboard suction lines fell within their predicted ranges during loading, standby, and countdown. Temperatures in the inboard suction line were 6-8 °F warmer than expected. Investigation of this discrepancy is continuing; however, the warm temperature is not a problem because the LOX is 6.5 °F below the engine redline temperature at ignition.

4. Tank Pressurization

The CDDT results show that prepressurization flowrates were close to nominal.

C. Terminal Draining of Center Engine Standpipe

Terminal draining studies were completed on the 1/8-scale S-IC LOX tank to determine the flow transient into the center engine suction line. The transient data were taken by high-speed photography. The flowrate history will be provided to update the analysis of the F-1 engine cutoff transient and determine the adequacy of the thrust OK pressure switch as a backup cutoff system.

D. LOX Prevalve

Tests to determine the effects of acceleration on visor closure with reduced spring force were completed. The test conditions simulated the failure of belleville springs due to stress corrosion. It was determined that up to 22 of the 54 belleville springs could fail completely without adverse effects.

III. S-II Stage

A. J-2 Engine

1. R&D Testing at SSFL

Nine tests were conducted, and a total of 1146 seconds was accumulated. One test was a full-duration run. Three tests were terminated prematurely due to facility problems.

2. Production Engine Tests at SSFL

Four tests were conducted, and a total of 348 seconds was accumulated. None of the tests were full-duration runs. One test was terminated prematurely due to a facility problem.

3. Countdown Demonstration Test Data Reviewed

The data indicated that all conditions were met for the J-2 engine. No hardware changes were necessary.

4. Tests at AEDC

Engine J-2052 was removed from the test cell and was replaced by engine J-2047. Three test periods and four hot firings were completed. GG temperatures and LOX pump spin-up speeds were high during the first test, because the oxidizer turbine by-pass orifice retainer was left in the duct. The second test established a baseline on the engine. The third and fourth tests were low NPSH tests.

5. J-2X Experimental Engine Program

Testing was completed on engine J-2X 015, which is the first R&D engine with a 40:1 thrust chamber. Evaluation of altitude tank head start, main stage operation, and "powered idle mode" were the major test objectives. A turbine exhaust aspirator was employed with the LOX and LH_2 turbopumps arranged in series simulating an altitude turbine back pressure during the tank head starts. All objectives were accomplished with 38 engine runs for a total duration of 390.9 seconds of mainstage operation.

Engine J-2X 013-1 was installed, and two firings were conducted. This engine is a rebuild of a previously tested "shorty" chamber (= 16.5:1). Current test objectives include evaluation of cavitating venturi propellant valves, additional tank head start evaluation with a turbine exhaust aspirator, and mainpropellant valve throttling.

B. Countdown Demonstration Test (CDDT)

1. J-2 Engine Start Tank Chilldown

Start tank chilldown was extended from T_o-14 1/2 to -18 minutes on the S-IVB stage and from T_o-18 to -22 minutes on the S-II stage following CDDT to reduce heatup rates. This change will be incorporated for the launch of AS-501.

2. LH_2 Tank Insulation

The previously determined pressure/television criteria performed adequately. Post-test inspection of the insulation revealed large leaks which caused abnormally low pressures during cryogenic operation. These leaks are being repaired. The inlet pressure was lowered from 4 to 2 psi to reduce the strain on the insulation.

3. LOX Tank Loading

The LOX loading procedure was modified to eliminate baffle damage caused by slugging in the fast-fill line. The loading will be accomplished by the slow-fill and replenish systems for launch on AS-501. Remedial action will be taken to prevent baffle damage to the S-II-502 system.

4. H_2 Tank Slow Chill

The H_2 tank (J-ring) slow chilldown procedure was satisfactory, except for the countdown revert procedure. A severe thermal shock occurred at start of LH_2 loading, and procedures were revised. Due to the changes in LOX loading duration, the LH_2 tank chill (for the -501 launch only) will be started at the beginning of the fast-fill of the S-IVB H_2 tank instead of at the beginning of the S-IVB LOX tank chill.

5. S-II/S-IVB LH_2 Tank Vent System Back Pressure

Evaluation of pressure in the tank vent system shows that cyclic back pressures exist. This may be caused by ice formation at the burn pond. Vehicle conditions were acceptable during both CDDT tests for vehicle launch, but interface criteria were slightly modified to alleviate the problem. Maximum tank ullage pressures were 17.1 psia, with 17.7 allowed for the -501 launch.

6. S-IVB/S-II Propellant Conditioning System

The propellant recirculation systems functioned normally for both S-IVB and S-II propellant systems. However, S-II fuel pump inlet instrumentation was incorrectly calibrated and indicated a failure to meet the redline, although performance was satisfactory. The LOX pump discharge redline temperature was established as -286°F, based on the CDDT data in conjunction with previous Battleship tests and analytical studies.

7. Interstage Environmental Control System

A cursory evaluation of interstage conditioning systems indicated satisfactory environmental control in the S-II/S-IC and S-IVB/S-II interstages. The Instrument Unit environmental temperatures were slightly colder than desired, but within specified tolerance. This could mean that temperatures might be below redline on a cold launch day. Efforts are underway to further define potential problems and identify solutions.

8. Tank Pressurization

LOX tank prepressurization required the 60 seconds allotted in the automatic sequence. The flowrate was determined to be approximately 1.4 lb/sec, which is 0.2 lb/sec below that desired. As expected, three makeup cycles were required prior to liftoff. The fuel tank prepressurization flowrate was nominal at 1.1.

C. Verification Tests of Three Main Pumps

Endurance tests of the third pump was successfully completed during this reporting period. All testing is complete.

D. Propellant Prevalve

The following tests were successfully completed on the modified prevalve; valve actuation, operational leakage, valve actuation, sine and random vibration.

E. Flight LH_2 Pump Inlet Pressure Profile During Engine Start Transient

The total pressure available at the LH_2 pump inlet during start transient was predicted for a given flowrate and tank pressure history. The results will be used for simulations at Arnold Engineering Development Center (AEDC). Major emphasis was placed on the suction duct momentum loss (4 psi) and the recovery time associated with low engine start pressures (~ 28 psia).

F. LH_2 Pressure Schedule, S-II-3 and Subs

Modification LH_2 tank pressure schedule for S-II-3 and subsequent was proposed because of fracture mechanics considerations. The propulsion system modification, with the dual sensing vent valve set at 27.5 to 29.5 psig during S-IC boost and 30.5 to 33.0 psi during S-II burn, was evaluated. The valve maximum pressure at S-IC cutoff is 0.3 psi above that required to proof the most critical weld against the most conservative fracture mechanic criteria. The proposed changes were approved and the valve will be reset at 27.0 to 29.0 psig if the AEDC tests show that the engine will start satisfactorily at this condition.

G. Pressure Switches

A design change was made in the Frebank pressure switches. The goldplating from the diaphragm was removed, except for a thin rim around the edge, to eliminate a corrosion problem.

IV. S-IVB Stage

A. S-IVB-505 Acceptance Firing Successful

An acceptance firing of the S-IVB-505 stage was conducted. Preliminary information indicates that all primary test objectives were satisfied.

B. Countdown Demonstration Test

The expected prepressurization flowrates of 0.6 and 0.2 lb/sec on the fuel and LOX tank, respectively, were met during the CDDT. Although the prepressurant temperature was higher than anticipated, no changes are recommended.

C. Fill and Drain System

A potential problem was identified relative to the Fill and Drain System. An electrical or pneumatic power failure can cause inadvertent closure of the fill and drain valve during high flow conditions. A test program is being established to determine valve closure times and the accompanying line pressure surges. This program will consider both fill and drain high flow conditions.

D. Valve Position Sensors

The prevalve qualification test report was reviewed. Problems with the valve position sensors are being investigated.

V. Instrument Unit

Environmental Control Systems Projects

A. Sublimator Acceptance Test

Acceptance testing of Sublimator S/N 024 and S/N 026 (the twelfth sublimator tested) was completed. Preliminary results indicate that both sublimators met the acceptance test requirements. No additional sublimators are on hand for testing.

B. Sublimator Production Reliability Test

Sublimator S/N 026 is being tested in the Sunspot I vacuum chamber at MSFC. Testing should be completed by November 15, 1967.

C. AS-501 IU-ECS

Cracked B-nuts were found in the IU. Investigation revealed that the B-nuts were improperly heat-treated. The faulty nuts were replaced.

SPECIAL STUDIES

I. Voyager Spacecraft

A. Spacecraft Propulsion System

All work was stopped on the design of the Voyager Spacecraft Propulsion System. A summary report describing the selection of the liquid propulsion system was prepared.

B. LMDE Verification Program

The Phase II LMDE vacuum storage program was started. The Phase I LMDE Head End Assembly acceptance tests were completed successfully. The Phase I Life and Performance Test Series was scheduled to begin on October 23, 1967. Work was continued on the engine mock-up and data manual.

C. Breadboard Propulsion Module

Cost estimates were received from TRW for a LMDE engine and from Hamilton Standard for sixteen one-pound thrust monopropellant engines. These or similar engines would be required for testing of the Voyager breadboard configuration.

D. Small Engine Evaluation Program

A checkout run of the Walter Kidde 40-pound thrust monopropellant engine indicates that the unstable chamber pressure noted during the original tests with this engine has been corrected. Testing to the planned test duty cycle is expected to start the first week in November.

E. Hydraulic System Storage

A draft of a standard for closed-loop hydraulic system storage was completed. This standard presents the approved method of preparing hydraulic systems for long-term storage and for subsequent retrieval.

II. Apollo Telescope Mount (ATM)

A. Quadrant IV Thermal Control System Test

Changes were made in the solar and electrical heat loads on the experiments. The thermocouple ice junctions are about 75 percent complete. The thermal temperature controllers were checked out and mounted under the chamber in preparation for the test. The eight heater blankets for the outside of the canister were installed. Testing is scheduled to start February 1, 1968.

B. ATM Thermal Control

1. Test Plans for Thermal Vacuum Tests

Plans for the thermal vacuum tests of the Thermal Systems Unit (Prototype and Flight Unit) were completed.

2. Fluid-Cooled Thermal Control System

Preliminary studies were completed on a fluid-cooled canister wall versus the spar-mounted cold plates. The fluid-cooled canister wall appears to offer greater heat removal and control capability, easier installation, and less experiment impact than the spar-mounted cold plates.

3. Rack Component Qualification Tests

Environments for the qualification tests of the rack components are being defined, and will be incorporated in the work proposal.

III. Nuclear Ground Test Module

The insulation study for the replenishment line was completed.

IV. Laser Applications

The study of aperture size and shape using diffraction theory was extended to small cylinders and irregular surfaces. Aperture sizes and cylinder diameters were measured within ±0.000025 inches. This tolerance is within that theoretically anticipated. However, additional theory must be developed to obtain precision interpretation of diffraction patterns produced by surface roughness. All three measurements are expected to produce order of magnitude improvements in quality control of these machine operations.

V. Zero Leakage Projects

A. Investigation of Brazed and Welded Connectors

Twelve 1/2-inch thinwall and twelve 1/2-inch thickwall test specimens were subjected to vibration tests at room temperature. Four 1/2-inch Aeroquip Brazed Specimens and one 1/2-inch welded specimen failed.

B. Thermal and Hydrodynamic Research

The last four welded connector test specimens passed the LH_2 thermal shock test successfully. The twelve diffusive-bonded specimens and six welded specimens were all leak-checked successfully after the

LH_2 thermal shock tests. The end of actual testing was achieved by four diffusive-bonded and two welded specimens passing the burst pressure test successfully.

VI. Drop Tower Telemetry and Instrumentation

The LOX Interface and Slosh Package was dropped six times. Testing should be complete within a week. The Vapor Sensor Package was damaged on its first drop and is being repaired; the pressure regulator malfunctioned. The Dynatech test package is being prepared for a series of tests.

VII. Boilerplate 30

Three specimens of the BP-30 Water Ballast Relief Valve have undergone and passed in-house qualification testing.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Engine Aerospike Experimental Investigation

Thrust Chamber modifications are continuing. The modifications are intended to help suppress flow oscillations noted in test firing. No thrust chamber activity was conducted this month. Segment test firings were started to evaluate injector performance using gaseous oxygen and gaseous hydrogen.

II. C-1 Engine

Fabrication of the C-1 acoustic liner is nearly complete. A checkout firing of the standard engine was conducted. Ambient temperature propellants were used, and there was no combustion instability. Base instability firings using pre-heated propellants are scheduled.

H. G. PAUL
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