PROPULSION AND VEHICLE
ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

May 1, 1967, Through May 31, 1967

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (September 1961)

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-67-5

X1.10
X1.11
X1.14

MONTHLY PROGRESS REPORT

(May 1, 1967, Through May 31, 1967)

By

Structures Division
Advanced Studies Office
Materials Division
Vehicle Systems 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 (Concluded)

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-67-5

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(May 1, 1967 - May 31, 1967)

SATURN IB

I. Saturn IB System

Nose Cone

The ring for the SA-204 pull test has been modified as requested by Kennedy Space Center. Design drawings of the brackets and scale to be used in conjunction with the pull test have been delivered to Manufacturing Engineering Laboratory for fabrication. Documentation effectivities of the nose cone have been changed to SA-204, 206, 208, and 210.

II. S-IVB Stage

Vibration and Acoustics Branch personnel visited Douglas Aircraft Company in Huntington Beach, California, to review the propulsion components attached to panels H-1, I-1, and J-10 mounted on the S-IVB thrust structure and to review vibro-acoustic flight, laboratory test, and flight test data associated with these components to determine if the deletion of the acoustic test requirements for these components could be justified. The acoustic test requirements were waived for the following reasons. (1) The components have successfully passed vibration qualification testing at levels higher than those measured during acceptance firings; (2) none of the components are functioning during S-IC lift-off, and; (3) inspection of the components indicates that they are not susceptible to acoustic excitation.

SATURN V

I. S-II Stage

A. Test Program

The design of the tank splice and S-IC modification are proceeding

for the 402 test structure. Present plans are to use two different foams on the structure during test in order to gain additional experience with foam insulation.

Design studies to increase the capability of the interstage for use in the S-II-4 configuration thrust structure/aft skirt have been made. Preliminary studies indicate additional stringers and reinforced ring frames will be necessary.

B. V7-22 Test Structure ("B" Structure)

Discussions with North American have revealed the forward bulkhead of V7-22 test structure is undersized. A total circumferential mismatch of 1.5 inches includes the bulkhead circumferential undersize measurement of 1.25 inches, and the No. 6 cylinder circumferential oversize measurement of 0.25 inches. This condition is not acceptable and three alternatives exist: (1) Obtain a new flight bulkhead, (2) obtain three new gores to be installed in the presently available bulkhead (one gore must be replaced because of corrosion), and (3) shrink cylinder No. 6 and associated structure to fit presently available bulkhead. NAA is now in the process of conducting a schedule impact study to determine which approach is the most feasible.

C. S-II Weld Mismatch

S&ID has reviewed with Strength Analysis Branch personnel the results of a study to establish a method of evaluating weld mismatch in portions of the S-II stage which may be exposed to bending and direct stress combinations. After a thorough discussion, the Strength Analysis Branch sees no reason to restrict the use of this new evaluation criteria. Subsequent to this review, contact with Dr. Hoff of Stanford University indicates that there is no effect of mismatch at the S-II forward dome to No. 6 cylinder weld joint. Dr. Hoff has tested model specimens with up to three times the wall thickness over one-twentieth of the circumference with no degradation in failing pressure. Use of the new criteria will allow the acceptance of the S-II-6 forward dome to No. 6 cylinder mismatch which is measured at 0.068 inches.

D. S-II Outboard Thrust Mount

An S-II outboard thrust mount was incrementally loaded to a compressive load of 390,500 pounds. The objective of the test was to provide data which will be used in determining thrust mount strains and deflections which occur in static firings and structural tests for both S-II-1 and S-II-4 types of thrust structure. The data is presently being evaluated.

E. S-II Thrust Structure

The test setup for testing the S-II-1 thrust structure configuration was started. The thrust structure modification was completed and the thrust

structure was inverted into the test position. Layout of the strain gage locations has begun. Part of the test fixtures have been fabricated. Test setup drawings are being prepared for the S-II-4 thrust structure configuration tests.

F. LOX Vent Line

Laboratory vibration testing has been completed on the LOX vent line which was installed in the S-II-2 and removed. The line was cut to obtain seven test specimens, five of which were subjected to vibration testing. The vibration levels and test times represented the design criteria for the LOX vent line. The results and conclusions of the testing are as follows. (1) All specimens passed the desired design criteria without failure. (2) When the specimens were tested to failure at stress levels higher than design, three of the specimens failed in the parent material at the fixture-specimen interface because of the stress concentration associated with the internal-external collar method of attachment. One specimen failed in the weld and testing was discontinued on the other after a large number of cycles was accumulated with no failure. (3) Since failure in the weld was forced in only one specimen only one fatigue data point was obtained; however, this division is studying the feasibility of additional testing with improved techniques for providing better fatigue data.

II. S-IVB Stage

The S-IV stage research bonded common bulkhead was tested to failure at Sacramento on May 17, 1967. The bulkhead failed in general instability at a reverse pressure of -48 psid. This pressure is 203 percent of the limit design pressure of 23.6 psid.

This research program had demonstrated the feasibility of bonded, rather than welded, forward face sheets on common bulkheads. The test also demonstrated that the higher load capabilities associated with the general instability mode of failure can be achieved if the bulkhead to tank wall juncture is reinforced locally. A bonded patch on the forward face sheet was also qualified, since a crack caused by the instability failure propagated through the face sheet and patch with no evidence of debonding. This patch technique could be used with confidence on the hydrogen side of future S-II and S-IVB stage common bulkheads that need repairs.

Based on this test result and the much lower manufacturing costs associated with bonded bulkheads, this method of fabrication appears very desirable for future vehicles.

III. Saturn V System

A. Saturn V Damping System

Testing on the ML-2 system with the redundant hoist is essentially complete. The primary and redundant hoist systems performed satisfactorily.

B. BP-30 Boilerplate

Refurbishment of the BP-30 boilerplate for the 501 mission is progressing. Modification kit for the escape tower fittings on the CM has been installed and checked out. Support bracketry for mounting ballast weight inside the Command Module has been fabricated. Preliminary installation drawings have been submitted for coordination. Reinforced support rings for propulsion tanks have been fabricated and will be installed after tank pressure tests are performed. Cover plates for the Service Module doors are being fabricated.

C. AS-501

A comparison of measured deflections with theoretical predicted values was made for the AS-501 pull test. Comparison showed good agreement.

A lateral dynamic loads analysis for the AS-501 vehicle has been initiated to determine the bending moment due to simultaneous ignition of adjacent outboard F-1 engines. Also a longitudinal buildup rebound loads study is underway assuming all four outboard engines ignite simultaneously. Either of these conditions could exist if a single point failure occurs in the Terminal Countdown Sequencer.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

A. Rack/ATM

In response to a request from the lead Laboratory, the Rack structure is being redesigned to provide capability for carrying a 10,500 pound LM Ascent Stage. New weight estimates for the Rack structure reflecting the revised loads were also made. A preliminary design layout of the aft LM Ascent Stage support fitting modification incorporating the LM electroexplosive separation device was completed. Detail design drawings of the lower ring assembly and the outrigger components are in the process of final check prior to release.

B. Experiment Package

Insulation drawings have been prepared for the quarter-spar thermal control system test and the half-scale shroud structural test items. However, insulation material (aluminized mylar) is not currently available.

II. Multiple Docking Adapter

Preliminary drawings (layouts) of the MDA are essentially complete except for the high performance insulation, which will be complete June 1, and the upper bulkhead, which will be available June 15. Final detail drawings are being prepared. Pressure shell details above the ring (Station 1962) are being held up by lack of definitive information on mountings of the nuclear emulsion, X-ray astronomy, and scientific airlock experiments; umbilical booms; foot restraints; window covers; navigation lights; and docking targets.

III. Rack/PM

A design effort was initiated to utilize the ATM Rack design for the PM project. This effort will investigate the modifications required to convert the ATM Rack to a PM Rack and define the PM interface ring and support structure. Detail drawings are scheduled for completion by June 19, 1967.

ADVANCED PROJECTS

I. Voyager

A. Voyager Shroud

A preliminary design concept, investigating an eight-point support system for the spacecraft, was completed. This concept depicted a system utilizing a bolt and separation nut for attaching the spacecraft support structure to the shroud and compression springs as an ejecting mechanism. An estimated 400 pounds of shroud weight is saved when using the eight-point support in lieu of the continuous conical frustum support.

B. Voyager Spacecraft

Major emphasis has been placed on the liquid engine concept. A tentative study version has been prepared by R-P&VE-AV based on the design prepared by Structures Division. Advanced Studies Office has integrated the science packages and other Laboratories' requirements. This concept shows the use of forward mounted outrigger supports for spacecraft to shroud attachment. This method of attachment appears to be the most feasible approach at this time. The weight of the bus structure has been estimated at 1390 pounds. This weight is comparable to the guideline weight given by JPL plus necessary meteoroid protection. Detail design of the bus structure is continuing.

II. Modular Nuclear Vehicle, Flight Configuration

The study to establish the optimum thrust structure arrangement for the Modular Nuclear Vehicle has resulted in a plan to revise the engine gimbal

mechanism. The revised concept has been presented to SNPO-Cleveland and the Aerojet Corporation. A further effort to establish its impact on the thrust structure is being conducted in-house. The effects of flight dynamics on the thrust structure arrangement are also being evaluated.

RESEARCH

I. Superinsulation

105-Inch Diameter Test Tank

A design study is underway to determine the feasibility of modifying the 105.00 diameter tank for high performance insulation evaluation without tank support losses (the tank will be supported by a structural vent line). This tank would become the calorimeter tank for determining thermal performance of very thick insulations such as those for a nuclear stage.

GENERAL

I. At the request of Mr. C. L. Adams of the Facilities and Design Office, F&D-DS, personnel from the Vibration and Acoustics Branch made a visit to Astrionics Laboratory's linear accelerator test facility to determine the cause and effects of extreme vibration on the walls housing the facility when testing was in progress. The first and second floor cinder block walls are deflecting as much as a quarter of an inch when testing is in progress. This severe motion on the cinder block structure is causing large cracks which might eventually cause the walls to collapse. It has been determined that the vibration of the walls is caused by a severe shock wave produced by the accelerator capsule striking the air cylinder. A measurement program has been initiated to determine the magnitude and frequency content of the shock wave. Recommendations to the Facilities and Design Branch will be made when the measured data has been evaluated.

II. NERVA Ground Test Module

A lateral dynamic loads analyses was performed for the Nerva ground test stage, engine gimbaling. It was concluded from this study that no stabilizing support will be needed at top of stage.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-67-5

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

SATURN V

Voyager Program

A. Spacecraft Design

1. Propulsion Type Selection --- Mr. Hearth, OSSA, directed MSFC to select by July 1, 1967, the type propulsion system (liquid versus solid) to be used for the Voyager spacecraft. Early action within MSFC is required to allow commitment of affected FY-67 funds in support of the program.

The all-liquid system concept was selected as the spacecraft primary propulsion system, the baseline concept using the Lunar Module Descent Stage Engine (LMDE). This selection was based on recommendations by R-P&VE. The selection and reasons for the selection were discussed with Center Management in a meeting on May 18, 1967. At the end of the meeting, Dr. von Braun expressed his full agreement with the selection proposed by R&DO.

As a backup to the baseline configuration, studies will continue utilizing the higher-performance Titan IIIC Transtage and Agena engines as alternate propulsion systems. This will assure flexibility in the spacecraft design should performance requirement problems arise.

2. Configuration Control --- Due to the management decision to utilize liquid propulsion for the Voyager spacecraft, only a liquid propulsion spacecraft configuration was issued under this task assignment. (As stated in last month's progress report, the issue of both liquid and solid propulsion configurations was planned.) The configuration issued on May 26, 1967, is to be used for the conclusion of the conceptual system design studies by P&VE and other Laboratories. The results of the design studies will be presented to P&VE management on June 21, 1967.

3. Alternate Propulsion System Evaluation ---As a result of the decision to consider only liquid propulsion systems for Voyager, work on the alternate solid motor concepts and all-liquid engine concepts with the exception of two alternates to the LMDE is being discontinued and will be documented in the near future.

Future effort will be concerned only with the two chosen alternates to the LMDE baseline system which are (1) a modified Agena engine and (2) the Titan III transtage engine. The Transtage engine work was previously carried by Propulsion Division but was dropped to allow concentration of effort on LMDE configurations. Funds have been requested for contractor studies which will determine the modifications necessary to adapt these alternate engine systems to the Voyager mission and verify expected engine operational and performance data.

Weight estimates have been made for Voyager spacecraft designs utilizing the Agena engine. For a 5000-pound capsule weight, these estimates show a planetary vehicle weight of 18,600 pounds; with a 7000-pound capsule the PV weight is 23,300 pounds. Spacecraft conceptual configuration drawings utilizing the Agena propulsion system are currently being made.

4. Evaluation of 7000-pound Capsule Concept --- Spacecraft configurations and weight estimates have been made for a Mars Voyager mission utilizing a 7000-pound capsule weight. For the Mars orbit insertion maneuver two propulsion systems, the LMDE and the Minuteman Wing VI, were investigated. For the midcourse and orbit trim maneuvers, both the liquid and solid propulsion spacecraft designs utilize C-1 engines.

Planetary vehicle gross weight with a liquid propulsion system is 25,500 pounds total and 25,560 pounds total with a solid propulsion system. These planetary vehicle gross weights compare with the 20,500-pound gross baseline weight (5000-pound capsule).

Both of the above planetary vehicles are sized for the dynamic envelope presently assigned to the baseline spacecraft design. Therefore, no length change is necessary in the launch vehicle payload shroud for a 7000-pound capsule weight.

The information generated in this study was presented to Mr. Newby on May 22, 1967. The results of the study are currently being documented.

5. Evaluation of "TRW Advanced Mission Definition" Concept --- An evaluation of the TRW concept of using the LM descent stage as the Voyager spacecraft has been completed. A presentation was made to Mr. Dave Newby on May 17, 1967, concerning the results of the evaluation. The conclusion was that although the TRW concept was feasible, it was not practical. The necessary modifications to the LM descent stage were so extensive that it appeared as though only the basic cruciform structure and propellant tanks would be usable. Because of the extensive modifications, a completely new qualification program would be required. The recommendation was made and accepted that no further effort be put into the TRW concept. A report will be published showing the results of the evaluation.

6. Analysis of Alternate Voyager Missions --- A cursory study of Voyager type missions to Venus and Jupiter has been made for the purpose of comparing the spacecraft for these missions with that for the Mars mission. The approach taken in the study was to design a spacecraft specifically for each mission which would utilize the entire injection capability of the Saturn V launch vehicle. For the Venus mission, the concept of two planetary vehicles was maintained. For the Jupiter mission only one planetary vehicle could be injected with the Saturn V.

The study considered spacecraft designs utilizing both LMDE and Minuteman Wing VI propulsion systems. Mass fractions for these liquid and solid propulsion spacecraft designs were assumed to be 0.720 and 0.725, respectively. These mass fractions are approximately the spacecraft mass fractions being obtained in current design analyses for the Mars Voyager mission.

Results of the study for the Venus mission show the spacecraft gross weights to be 28,245 pounds and 29,120 pounds, respectively, for liquid and solid propulsion spacecraft. For the Jupiter mission, the spacecraft gross weights for liquid and solid propulsion are 12,943 pounds and 13,303 pounds, respectively. These spacecraft gross weights compare with liquid and solid propulsion spacecraft gross weights of 15,470 pounds and 14,835 pounds, respectively, for a typical Mars mission design with a 5000-pound capsule weight.

For the Venus mission, the payload which could be injected by the Saturn V resulted in two planetary vehicles with a gross weight of 31,850 pounds each. This payload corresponds to a C_3 of 14 km^2/sec^2. The Venus orbit considered was elliptic with periapsis being 1000 km and apoapsis being 10,000 km.

For the Jupiter mission, the payload which could be injected by the Saturn V launch vehicle resulted in a single planetary vehicle having a gross weight of 14,000 pounds. This payload corresponds to a C_3 of 94 km^2/sec^2. The Jupiter orbit considered was elliptic with periapsis 1,000,000 km and apoapsis 5,000,000 km.

The results of this study are currently being documented in an internal memorandum.

7. Service Module for Voyager Spacecraft --- A study to evaluate NAA-S&ID's proposal to use the Service Module for the Voyager spacecraft has been completed. In general, S&ID was found to be optimistic in their spacecraft weight estimates and in their estimates of shroud length and weight. S&ID's spacecraft weight estimates did not include spacecraft science or an adequate weight allowance for spacecraft subsystems. Their shroud design lacked provisions for planetary vehicle encapsulation. Based on the above, the Laboratory does not recommend the use of the Apollo Service Module for this application.

Mr. Newby was briefed on May 17, 1967, on the results of the evaluation. A summary of the evaluation results is contained in memorandum R-P&VE-AV-67-159, dated May 22, 1967.

8. Single Spacecraft Study --- Single spacecraft conceptual configurations and detailed weight statements have been generated for both 5000-pound and 7000-pound capsule weights. The single spacecraft concept utilizes a planetary vehicle having a single spacecraft and two capsules. For this concept, the gross payload (planetary vehicle and shroud) required above the Saturn V Instrument Unit at ground ignition for LMDE propulsion varies from 44,400 pounds to 53,400 pounds, respectively, for 5000-pound and 7000-pound capsule weights. Comparable payloads for the Minuteman Wing VI propulsion spacecraft design vary from 48,100 pounds to 58,200 pounds, respectively, for 5000-pound and 7000-pound capsule weights. Gross payload with the Minuteman Wing VI spacecraft design is greater mainly because two solid propellant motors are used to obtain the required propellant loading. The gross payload weights presented compare with 53,400 pounds for the baseline two-planetary vehicle concept utilizing a 5000-pound capsule weight.

9. Liquid/Solid Stage Commonality and Alternate Mission Study --- A preliminary short-term study to determine feasibility and penalties involved in designing a spacecraft that would allow the use of either a liquid or solid propulsion system has been completed. The baseline configurations were (1) the LMDE propulsion system and (2) the Minuteman Wing VI motor sized for the 1973 and 1975 Mars missions, respectively. Missions to Venus and Jupiter were also considered for various configurations. The study shows that in all the solid planetary vehicle configurations into which a liquid propulsion system was substituted, a net saving in weight or gain in ΔV occurred. This is due to the liquid propulsion systems lighter weight and higher I_{sp}. In all cases where a solid propulsion system was substituted into a liquid planetary vehicle configuration a substantial weight penalty or ΔV loss occurred.

10. Voyager Spacecraft/Capsule Interface --- A meeting was held with LaRC on May 9, 1967, to discuss flight spacecraft/flight capsule interface problems. LaRC personnel could not define their flight capsule concept at that time. MSFC was informed that LaRC had stopped all work on the interface working document supposedly by unofficial direction of OSSA. However, after a telecon between Mr. Newby and Mr. Stone, the interface working document is now being reviewed by LaRC and will be discussed at a meeting to be held at LaRC on June 1, 1967.

B. Shroud Design

1. General --- Rough draft inputs to the "Summary Report, MSFC Voyager Shroud Design, Preliminary Design, Part I" are presently being received for documentation early in June. This report documents the conceptual phase of the shroud design study performed during the period October 14, 1966, to May 31, 1967.

2. Shroud Separation Study --- Work is continuing on the second phase of this study, which is the evaluation of planetary vehicle separation from the shroud. However, no interim results are available to present at this time.

APOLLO APPLICATIONS PROGRAM

I. Lunar Surface

A. LSSM Program

As a result of discussions with NASA Headquarters and contractor personnel, and because of delays in the LSSM program, the LSSM flight test requirements have been reexamined and an alternate test program will be submitted. The feasibility and economics of a flight test model program, utilizing a 1/4 scale model of each contractor's vehicle, have been investigated. A model test program would produce the same type results as the motorized mockup test with twice the amount of data; however, this program cannot provide onboard driver tests. Based on this preliminary study it is anticipated that each model would cost approximately $25,000 and would require from six to eight months to develop.

The results of the BECO LSSM Mockup 1/6 g flight test program have been documented in an MSFC Internal Note (IN-P&VE-A-67-3).

Comments have been prepared and submitted to the committee chairman concerning the procurement specification for the LSSM. The specification was written to fulfill the requirements based upon a single-astronaut capability. Currently, MSC is maintaining that the LSSM should have dual astronaut capability. Further refinement of the specification is pending an evaluation of the MSC recommendation.

B. Lunar Wheel and Drive Study

The lunar wheel and drive system test program being conducted by General Motors Research Laboratories, Goleta, California, has been completed and the final presentation was given to MSFC personnel on May 14, 1967. During the test program two types of wheels and transmissions were tested; however, neither met the design goal of 100,000 cycles. The test program did show that current designs of the wheels and drives are adequate for ranges to approximately 100 miles. Additional

work is being performed on the nutator drive system by the Bendix Corporation and should be available next month.

C. Mobility Testing

Both MTAs have been returned to MSFC for refurbishment and further testing. The Bendix MTA has been refurbished and delivered to R-P&VE-S for measurement of vehicle parameters such as spring rate, weight, moment of inertia, etc. The General Motors MTA is being equipped with new stiffer wheels and is scheduled to be delivered to P&VE on June 7, 1967. Parameter measurements have also been made on the BECO LSSM. All three vehicles should be ready for testing to begin the first of August. A detailed test plan and schedule are being prepared for submission to the Test Laboratory.

The normalization of the MTA test data, obtained from test programs at Yuma and Aberdeen Proving Grounds, for application to an LSSM-sized vehicle is proceeding; however, the Army report on the YPG test data has still not been received.

II. Integration

A. AAP Experiment Catalog

All experiments now in the catalog have been converted to the retrieval format. In addition, the retrieval system has been modified considerably to allow multiple-parameter call-up.

All experiments for AAP flights 1 and 2 are now included in the catalog and work continues toward inclusion of those for flights 3 and 4.

B. Experiment Scheduling and Compatibility Program (ESCAPE)

The program has been debugged with the exception of the automatic plotting routine. Work is continuing to incorporate the following program modifications: multiple equipment number, variable power levels during experiment duration, experiment carry-over across day boundary, and astronaut shifts on any experiment. The report (NASA Technical Memorandum) describing the first generation ESCAPE program is nearing completion.

The first-cut experiment scheduling analysis of AAP flight 2 has been completed and the results presented on May 26, 1967. Work has now begun on the second iteration of this mission.

NUCLEAR VEHICLE PROGRAM

Nuclear Boiloff Sensitivity Study

The analysis of the LMSC Phase I nuclear module design is essentially complete. Both OLV and ELV configurations requiring from 5 to 10 earth launches have been studied. Assuming a "nominal" boiloff schedule, a 10-launch system which will accomplish the 1982 manned Mars landing can be earth launched by the two-stage MLV-Saturn V-4(S)B vehicle. The 5-launch system cannot be earth launched by any presently identified improved Saturn V launch vehicle. The proposed configuration requires 6 launches of a "660K" class launch vehicle.

Draft copies of the LMSC Volume II, Nuclear Propulsion Module Systems Analysis,and Volume III, Nuclear Propulsion Module Vehicle Design, have been received from R-AS-VP with the request that this Office review and comment as soon as practicable. Volume V, Nuclear Propulsion Module Flight Safety Studies, was reviewed previously.

Studies are now being initiated to investigate the effects of using LMSC Phase II nuclear module design. The results of this study will be compared to the Phase I study results.

The results of the Phase I study effort to date are being summarized for presentation to P&VE management.

ADVANCED PROGRAMS

I. Launch Vehicle

A. Kick Stage Study

An investigation is continuing to determine methods, parametric curves, tables, charts, drawings, etc., which will provide the information necessary to respond quickly and accurately to a requirement for design information concerning kick stages. The study of varying propellant loading in a kick stage to meet the requirements of various missions has been completed and the conclusion drawn that in the majority of cases it is desirable to off-load rather than try to add sections to the tanks or design each stage for a particular mission. Most of the technical effort concerning such in-depth investigations as boiloff rates for cryogenic propellants, kick stage length versus propellant loading, and interstage weights for the 260 and 296-inch-diameter kick stages has been completed. This study is to be completed about the end of July 1967.

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

Documentation (MSFC Internal Note) of Phase I of the 156-inch-diameter pod design study is scheduled for completion in early June 1967. A presentation to P&VE management on this vehicle concept is scheduled for June 1967. Phase II of the study is continuing. It will consider several other refinements and innovations of the launch vehicle configuration chosen in the Phase I study. Portions of the Phase II study which have been completed concern pressurization simplification, gathering of detailed information on alumizine characteristics, and other refinements of the launch vehicle configuration chosen in the Phase I study. A comparison of the pressure-fed strap-on pod with the pump-fed pod will also be made during Phase II.

II. Earth Orbital

A. Advanced S-IVB Workshop

The first briefing by McDonnell Douglas Corporation (MDC) on their Advanced S-IVB Workshop study was held at MSFC on May 17, 1967. This briefing concentrated primarily on the synchronous orbit application of the early type workshop system. Major changes in workshop design for this application would be relocation and redesign of radiators and the thermal control system, and possible shifting of the crew quarters floor to the upper part of the LH_2 tank for ease of radiation shielding. A final report draft submitted by the contractor has been reviewed and comments forwarded to R-AS.

Configuration study categories and appropriate levels of effort for MDC were discussed with R-AS. MDC was recently directed to concentrate on relatively unsophisticated versions (early and intermediate designs) of the ground-equipped S-IVB Workshops. The Advanced Spent Stage Analysis by MDC will be terminated July 1, 1967.

B. In-house Workshop Configuration Study

The results of a recently completed Workshop-configuration-matrix in-house study were presented to personnel of the Advanced Studies Office on May 26, 1967. This study defined the most feasible variables of a ground-equipped and advanced spent stage workshop. These variables and their multiple combinations, along with the evaluation results of the 39 configurations considered, were presented with some recommendations. An MSFC Internal Note is being prepared which defines the concepts considered and the resulting evaluation.

The initial in-house effort on the subsystem definition for the Early Orbital Space Station (EOSS) has been completed and is currently being documented in an MSFC Internal Note. A progress report on the in-house Advanced Workshop designs and subsystems will be presented on June 9, 1967, to R-AS and other interested organizations. A subsystems definition study for an Advanced Spent Stage Workshop (AWS) has been initiated.

C. Five-year Space Station

The bulk of the effort on the Five-year Space Station Study during this reporting period has been on evaluating a 9-man station concept with previously generated requirements and constraints. The general compartment arrangement has been completed and the installation of the various subsystems is now in process.

D. TV Broadcast Satellite Study

Proposals are being evaluated for selection of a contractor for the 9-month duration "TV Broadcast Satellite Study" which will be directed by R-ASTR-A. The study will investigate technological and cost factors of the spacecraft systems for TV Broadcast in the 1970 to 1975 time frame. The study will consider a Saturn V launch to synchronous orbit in a manned or unmanned configuration.

III. Planetary Systems

A. Mars/Venus Flyby Studies

The third interim presentation on the manned Mars Flyby study was made the first week in May at MSFC by North American Aviation. NAA has finalized all the scientific experiments for both the spacecraft and the probes. The probe design work has also been completed by AVCO. Several vehicle concepts were presented with the preferred NAA mode being an artificial gravity spacecraft, injected by a LOX tanked S-IIB stage. NAA stated the preferred mode costs were the same as those where S-IVB C stages are utilized, but provided much better growth capability. The remainder of the study will cover costing the more detailed subsystems and preparing RDT&E programs.

The study contract with MDC (NAS8-18032) has been extended for approximately four and one-half months. The purpose of the extension is to develop the performance, design characteristics, tradeoffs, and the approximate cost and development schedule for a new propulsive stage which is suitable for manned planetary exploration. This stage(s) is based on extension of the S-IV and S-IVB technology. It would be used as an injection stage for missions to Venus and Mars, as a braking stage for orbital capture, and as a return stage from the planet. The study is scheduled for completion about September 8, 1967.

B. Mars Excursion Module

The study to conceptually define a Mars excursion module has been completed. The study showed that a 77,000-pound MEM was required to transport and contain the four-man crew on the Mars surface for a period of 40 days (maximum). The results of the study are being documented for publication.

C. Mars Orbiter Probe

This study is being continued and sizing of the orbiter propulsion system has been completed using storable liquid propellant. A first-cut approximation indicates the probe will weigh approximately 11,000 pounds, of which 700 pounds is scientific payload.

Erich E. Goerner
Chief, Advanced Studies Office

I. S-IB Stage

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

Testing has continued in the comparison of the corrosive effects of MIL-H-5606A revision hydraulic fluid to the B revision fluid. Neither fluid has caused any corrosion of various metal coupons after 136 days of exposure.

B. Evaluation of Horizontal Heat Shield Insulation

As reported previously, Chrysler Corporation Space Division (CCSD) is evaluating FTA-442A insulation as a replacement material for M-31 on the base heat shield of the S-IB stage. CCSD has insulated a full-sized heat shield panel with FTA-442A insulation. This panel was mounted on the S-IB-10 stage and tested during the short and full duration static firings of the vehicle. The insulation capably withstood both static firings and was in good condition after the full duration firing.

II. H-1 Engine

Investigation of Corrosion in LOX Seal Cavity of H-1 Engine

During inspection of several H-1 engines a leak detection solution (Shurlock) was allowed to get into the LOX seal cavity and remain for several months. This occurred on about 15 engines at Michoud. Although the corrosion is insignificant as far as structural damage is concerned, the corrosion products could get under the LOX seal and cause leakage; and any liquid that remains could form ice which would contribute to further leakage. A test procedure has been set up to remove any liquid by heat and vacuum and check for corrosion products with a boroscope and small vacuum cleaner. If either liquid or corrosion products are found, the seal cavity will be opened and examined visually.

I. S-IC Stage

A. Evaluation of Commercial Adhesives

Aluminum specimens bonded with Narmco 7343 adhesive under contract NAS8-11958 for long term aging show excellent strength retention after four months, although control specimens (unprimed adherends, with no silane coupling agent in the adhesive mix) appear to show a gradual strength loss. Significant trends are not discernible this early in the program.

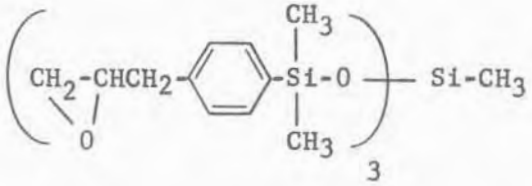
Additional humidity tests at 80°F (27°C) and 80 percent relative humidity have been made on control samples of this adhesive and on other samples incorporating silane coupling agents as primers or bulk resin additives. It appears that silane agent Z-6040 promotes somewhat better lapshear strength retention under these conditions when used as a bulk additive rather than as a primer. Also, it appears that part of the temperature-humidity strength degradation may be offset by post-exposure drying of the bondline. Fractional strength recovery of silane-primed samples was higher than the control specimens.

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. Emphasis during this reporting period has been directed toward (1) synthesis of a series of epoxy-siloxane polymer intermediates for ultimate conversion into polymeric embedment materials, and on (2) formulation of hydrocarbon polymers and various proprietary materials as conformal coatings.

1. Development of Epoxy-Siloxane Embedment Materials

The synthesis of the last epoxide intermediate in a series of four compounds described in recent reports, has been partially completed. The desired structure, methyltris(p-2,3-epoxypropyl)phenyldimethylsiloxy)-silane, is illustrated below:



The triallyl analog of this material was prepared by condensation of three mole-equivalents of p-allylphenyldimethylsilanol with one mole-equivalent of methyltris(dimethylamino)silane. Titration of the dimethylamine evolved during the condensation indicated that the reaction was 94 percent complete. Molecular distillation provided three fractions with the following boiling ranges:

a. 100-165°C (212-329°F) /10^{-4} torr, 1.3 grams

b. 165-170°C (329-338°F) /10^{-4} torr, 8.2 grams

c. 170-200°C (338-392°F) /10^{-4} torr, 2.4 grams

Fraction b. was a pale yellow oil whose infrared spectrum contained the expected absorption peaks. Elemental analyses are being obtained for this compound.

Additional molecular distillations were carried out on previously prepared quantities of 1,5-bis(p-allylphenyl)hexamethyltrisiloxane (1), and 1,4-bis((p-allylphenyldimethylsiloxy)dimethylsilyl)benzene (2). Compound (1) was recovered as a pale yellow oil, boiling at 150-155°C (302-311°F) /5 x 10^{-4} torr. Satisfactory elemental analyses were obtained for these compounds to confirm the expected structures.

Epoxidation studies of the two above mentioned compounds, methyltris(p-allylphenyldimethylsiloxy)silane and 1,5-bis(p-allylphenyl)hexamethyltrisiloxane, have been carried out in an effort to optimize the yield of pure epoxide and minimize the undesirable ester formation. A molar ratio of sodium carbonate to trifluoroperacetic acid of 1.5 in the epoxidation reaction produced the desired epoxide analog of the two above compounds, with faint carbonyl and hydroxyl bonds evident in the infrared spectra. Subsequent epoxidations will utilize a carbonate/peracid ratio of 1.75-2.0.

2. Development of Conformal Coating Materials

Additional formulation studies have been carried out on the styrene-butadiene copolymer in an effort to further improve the marginal adhesive properties of this material as a cured coating. Three formulations were prepared using 1,4-bis(hydrogendimethylsilyl)benzene as the curing agent and chloroplatinic acid as the catalyst and cured for 16 hours at 110°C (230°F) as aluminum lapshear tensile specimens.

(1) 100 grams polymer
100 grams curing agent
0.1 gram catalyst
Bond strength: 88 psi

(2) 100 grams polymer
12 grams curing agent
2 grams vinyl triethoxysilane
0.1 gram catalyst
Bond strength: 90 psi

(3) 100 grams polymer
12 grams curing agent
2 grams allyltriethoxysilane
0.1 gram catalyst
Bond strength: 122 psi.

The unexpected low value obtained with formulation (2) is subject to reexamination, as the adhesive strength of (2) should approximate that of (3).

Coating formulation studies have been carried out using a commercial C_{36} dibasic acid, Empol 1010, Emery Industries, Incorporated, and a diaziridine, HX-740, 3M Company. These materials were polymerized in molar ratios varying from 0.75/1.0 to 1.0/1.0 of diaziridine/acid. The products cured to a considerable degree after 24 hours at 100°C (212°F) but were still tacky. Efforts will be made to obtain or synthesize a trifunctional aziridine in order to increase the crosslink density of the cured polymer.

C. Investigation of Foams Used in Electrical Distributor Boxes

Slow expansion of Stafoam AA-1802 in S-IC distributor boxes continued to create concern for the reliability of the electrical components in contact with the foam, although no failures attributable to foam expansion have been reported. This phenomenon is being studied to determine the cause, determine the rate of expansion, and, if possible, to recommend corrective actions.

Foamed boxes of Stafoam AA-1802 have been prepared using the recommended amount of catalyst, 90 percent of the recommended amount and 10 percent excess catalyst. Some preparations were treated to the standard cure of 24 hours at room temperature, while others were subjected to a cure cycle culminating in 24 hours at 195°F (91°C). Accelerated foam growth was induced by heating in ovens and in an environmental chamber with controlled humidity. There is apparently little difference in post cure behavior of Stafoam AA-1802 when cured with excess catalyst, stoichiometric catalyst, or 90 percent stiochiometric catalyst. Increase in humidity results in increased foam growth; the higher temperature cure decreases post cure growth to some extent. Exposure to water vapor at 200°F (93°C) inside a sealed plastic bag for three hours caused drastic growth which destroyed the structural integrity of the foam. A proposed replacement material, Nopco foam B-610-RT was undamaged after identical treatment and underwent only 1 percent linear expansion. The use of this particular Nopco foam is objectionable because it is not fire retardant. A related flame-retardant foam formulation has been ordered from Nopco and will be evaluated for this application.

II. Contract Research

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

A. Polymer Research, Development, and Testing

1. University of Florida, NAS8-20247
2. Peninsular ChemResearch, Incorporated, NAS8-5352
3. Battelle Memorial Institute, NAS8-11837

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. R. W. Benson and Associates, NAS8-20208
2. Southwest Research Institute, NAS8-20731

III. S-II Stage

A. Investigation of Fracture Toughness of 2014-T6 Weldments

Studies have continued in the determination of the fracture toughness of weldments of 2014-T6 aluminum alloy in Saturn S-II stage propellant tanks.

Program objectives and outlines have been established for the evaluation of weldments made by the MIG pulsed-arc process and the TIG procedure presently used in fabricating S-II stage tanks. The objectives of this study are as follows:

1. Determine K_{IC} values (0.296 inch, S-II-T, pulsed-arc 0.266, and 0.500 inch) for weldments at room temperature, -196°C (-320°F), and -253°C (-423°F).

2. Determine influence of filler metal (4043 and 2319) on K_{IC} for the same temperatures.

3. Determine K_{IC} degradation due to the HT424 cure cycle.

4. Determine K_{IC} degradation due to repair welding.

5. Establish K_{IC} range for best and worst case weldment condition.

6. Determine for room temperature the low cycle fatigue crack growth characteristics for best and worst case weldment condition. Test equipment has been assembled for this program and test specimens are being fabricated. A variety of sizes of compact-tension edge crack specimens and weldment types, and thickness have been tested to establish testing background, specimen size influence, and tentative range of K_{IC} values at room temperature. Test results which were determined from data meeting linearity requirements but not crack length and thickness requirements are as follows:

Type	Thickness (inch)	K_{IC} Values (ksi-in 1/2) Room Temperature	-196°C (-320°F)
TIG 4043 Lab.	0.375		27.4
TIG 4043 Lab.	0.250		27.2
TIG 4043 Lab.	0.625	20.8	
TIG 4043 Lab.	0.250	23.9 - 28.2	
TIG 4043 Lab.	0.375	24.3	
Cure Cycle TIG 4043	0.375	20.6	
Cure Cycle TIG 4043	0.250	21.3 - 21.5	
S-II-T (TIG 4043)	0.296	19.1 - 22.9	

In addition to the above in-house studies, supporting studies are also being made by Lewis Research Center and The Boeing Company. Material for these studies will be supplied by the Space Division of NAA.

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

During a meeting at Seal Beach, California between representatives of this Center, the Space Division of North American Aviation (SD) and Douglas Aircraft Company (DAC) plans were made for applying spray foam insulation to an 8-foot diameter Thor LOX tank. The planned program provides for DAC to clean, inspect, certify, and deliver the tank to SC. The S-II stage contractor (SD) will apply CPR 369-3 spray foam to the lower half of the tank and Nopco BX 250A spray foam to the upper half. The insulated tank will be delivered to DAC at Sacramento for eight liquid hydrogen (LH_2) fill and drain tests. The first six tests will duplicate the pressure and/or strain expected in the S-II stage LH_2 tank, i.e., normal ground pressure tests, 130 percent of normal ground pressure test, pressure test to achieve tank strain levels equivalent to 90,000 feet of altitude, and maximum flight pressure tests. In the last two LH_2 tests, cracks, debonded areas, and standard repairs will be introduced in the foam prior to testing. Due to unforeseen delays in obtaining the tank and other items, the initial schedule has been delayed approximately two weeks. DAC is presently planning to deliver the tank to SD by May 29 rather than May 15. Assuming no other delays, testing should be initiated on or about July 15 at Sacramento, California. The results of the tests will be evaluated by a Special Review Board consisting of representatives from SD and this Center. DAC will be invited to participate with the Special Review Board.

Ten test plugs were pulled by SD on the foam insulation applied locally to the 70-inch tank. In three of the tests the foam broke prior to obtaining a strength value; these tests were in areas where inadequate repairs had been made. Strength values for the other 7 plugs varied from 36 to 75 psi. The dogbone samples made for testing by SD all passed when tested.

The first attempt to make repairs to the foam insulation on the 70-inch tank was unsuccessful. The foam was full of cracks and did not bond to itself. Later, it was shown that an improper application technique was employed, and that the equipment was operating improperly. It was reported that the foam turned green within a few seconds in direct sunlight. However, the part that sunlight may have contributed to the failure of the foam repair has not been completely ascertained as yet.

C. Evaluation of Nondestructive Techniques for Examining Composite Materials

Several very effective methods of evaluating complex honeycomb composite materials (such as are used in the common bulkhead of the S-II stage) have been developed. However, further work is required to develop better coupling techniques (e.g. air coupling) and to establish better and more meaningful standards.

Recent work in this area has been directed toward the nondestructive evaluation of aluminum-foam composite materials which are to be used for the S-II stage.

Single side and through transmission techniques of low and of ultrasonic frequencies have been applied to a foam-aluminum composite panel with little success. These techniques involve inducing vibrations into the metal and observing amplitude, phase or impedance modification of the induced signal by debonds. The major reason for the difficulty in detecting debonds in this composite is simply that low density foam (3 lbs. per cu. ft.) has very little damping capacity. The metal plate will vibrate almost as well with foam attached as it will without the foam. Therefore, a new approach is being considered. Plans involve inducing transverse vibrations into the foam, rather than into the metal. There is little doubt that a bond to metal will modify foam vibrations. The efficient introduction of sound into foam constitutes the major problem of this approach. Basic acoustic properties of 3 lb. foam are being measured so required transducer design calculations can be made. These transducers must be capable of vibrating the foam directly in the transverse direction.

IV. S-IVB Stage

A. Developmental Welding

1. The study to determine repairability of aluminum alloy 2014-T6 weldments is approximately 95 percent complete. Currently, specimens are being prepared for tensile testing.

2. Studies have continued in the correlation of the effects of various welding energy inputs and natural aging with the performance characteristics of weldments in aluminum alloy 2014-T6. During this report period, 3/8 inch thick plate material was received and is being machined into the desired configurations for subsequent weld evaluations in accordance with the program plan. During the next report period, welding of this material will be accomplished as time permits.

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

1. Study of the Effects of Hypervelocity Particle Penetration of Internal Tank Insulation

Additional tests have been made to ascertain the effect of hypervelocity particle penetration on aluminum foil coated 3-D insulation when impacted after having been soaked in gaseous oxygen. Test results to date indicate that specimens impacted with 1/8 inch diameter projectiles at 25,000 feet /second after soak periods of up to 70 hours in 15 psia oxygen are ignited and suffer a burned area of approximately 9 inches in diameter before self extinguishment.

2. Study of Permeation - Diffusion of Helium into 3-D Insulation

a. Permeation

Studies to determine the permeability of 3-D type insulation are continuing. Results from the helium gas phase were reviewed in the previous monthly report. A test program is now in progress to determine the permeability of the insulation to hydrogen gas following the test schedule described in the review for helium. The hydrogen flow rate is being determined by a barometric technique. Permeability results for hydrogen are anticipated within the next 30 days.

b. Diffusion

An apparatus has been designed and fabricated which permits the determination of the flow rate of helium resulting from diffusion from a known surface area of 3-D insulation exposed to high vacuum. The pressure change within the insulation resulting from helium diffusion is recorded concurrently with the flow rate as a function of time. Studies are in progress to determine time-pressure parameters necessary for complete removal of helium from within the 3-D insulation by the diffusion process. This program is continuing on a high priority basis.

3. Investigation of the Effect of Helium Diffused into the Insulation on Insulation Conductivity

An experimental test has been completed to determine helium diffusion into and out of the S-IVB tank insulation as reflected by the thermal conductivity of the insulation system. Maximum and minimum thermal conductivity values corresponding to complete helium saturation and removal were confirmed by repeating the testing schedule using the same sample with the surface seal coat perforated with eight 1/8-inch diameter holes to insure complete helium saturation and removal. These K values are 0.5 and 0.058 $(Btu\text{-}in)/(hr\text{-}ft^2{}^\circ F)$ which compares favorably with maximum-minimum K values of 0.4 and 0.062 resulting from simple diffusion of helium through the seal coat. Considering the 0.5 and 0.058 K to be infinite time values for simple diffusion conditions, these data are quite compatible with the previously reported test results.

4. Study of Flammability of Materials

A program has been initiated with support from Test Laboratory to study further the flammability hazard of aluminum foil covered S-IVB insulation. Standard 3-foot diameter samples are used in all tests. The samples are flanged to a 3-foot diameter by five 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 was used to ignite the samples. The igniter was placed over the damaged area 1/8 inch to 1/16 inch away from the foam. The power used for the igniter was 21 volts at 9 amps.

A preliminary review of the data obtained on 2 mil aluminum foil covered S-IVB insulation indicates the following:

a. No ignition in 15 minutes on an undamaged aluminum foil liner.

b. No ignition in 20 minutes on an aluminum foil liner having a damaged area of 1 inch x 1/4 inch.

c. Ignition and burning, approximately 5 inch diameter, on a sample with damaged area of 2 inch diameter with oxygen flowing past the ignition point at a rate of 25 ft^3/min.

All of the tests conducted to date used a 5 psia flowing system. However, the velocity of the oxygen across the face of the sample was not to Orbital Workshop specifications.

The test tank is being modified to permit flowing of oxygen over the face of the test specimen at the same rate as that proposed for the S-IVB Workshop. The burning characteristic of 2 and 5 mil aluminum foil covered S-IVB insulation will be evaluated using this system.

5. Study of Combustion Products of S-IVB Insulation Materials

A study has been initiated to analyze the combustion products of insulations which are used in the S-IVB Workshop. All combustion tests will be made in an oxygen atmosphere at 5 psia of pressure. A new chamber has been assembled and has been found to contain virtually no leaks during evacuation. The chamber consists of an aluminum base and glass bell jar. The base is octagon-shaped on outer walls with ports that contain valves and electrical wires which are used for hot wire ignition. Sufficient valves are available to accommodate purging, back filling, and evacuating the chamber. The entire chamber has a volume capacity of 48 liters at atmospheric pressure. The combustion tests are being made in two series. The first series consists of burning samples with an excess amount of oxygen and the second series of tests will be made by simulating the quantities of materials aboard the spent stage in regards to the weight of insulation to the volume of available oxygen.

6. Investigation of Thermal Control Coatings for Use in the S-IVB Workshop

Work continues in the search for a thermal control coating to be used in the S-IVB Workshop. The coating should have an emissivity value of 0.8 or better and must be compatible with liquid oxygen (LOX). Current efforts are being concentrated on a modified alodine coating (MTL-3). Test results indicate that this green coating has an emissivity of 0.7 or better. Results of other tests indicate that it provides a good base for adhesive bonding and has a dielectric surface comparable to chromic acid anodize. LOX compatibility tests are being made on specimens of this coating. Corrosion resistance in high humidity and salt spray is being determined and after 60 hours of exposure, no appreciable corrosion is evident. Salt spray and humidity tests are also being made on two other candidate coatings (K_2SiO_4/ZnO and Black Magic). The K_2SiO_4/ZnO gray coating has prevented corrosion, but the Black Magic coating has allowed some corrosion on the aluminum foil after 60 hours of exposure.

C. S-IVB Stage Project Management - Materials

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

1. S-IVB-IU Interface Bolt Torque Requirements

The problem of interface bolt torque requirements has been resolved by Materials Division approval of ECR No. R-P&VE-VSA-67-5, dated March 31, 1967, and ECR No. R-P&VE-VSA-67-6, dated April 4, 1967. This approval is based upon the fittings being lubricated and experiencing a maximum service load of 3016 pounds.

2. Flutter Kit

The problem of inadequate bonding of flutter kit hat sections on S-IVB-501 was investigated. It was found that the voids in the bond were not unbonds but were caused by an inadequate quantity of adhesive to fill the space between the faying surfaces of the adherends involved. The contractor's proposal to correct the problem was reviewed and found acceptable; thus, no problems of flutter kit bonding on S-IVB-501 are anticipated.

3. Radiographic Inspection of Welds

A detailed review of radiographic inspection requirements of welds has been completed, and our recommended changes have been appropriately coordinated with the R&DO elements involved and forwarded to the S-IVB stage manager. The stage contractor (DAC) has been asked for a QRE (Quick Response Estimate) to incorporate our recommended changes in the stage contract, and we are awaiting DAC's response to this request.

4. J-18 Valve

a. The J-18 valve, which is a part of the liquid hydrogen (LH_2) repress control module, had seats of Mylar, failing, reportedly because of high temperature to which the seats were exposed. Our investigation into the matter revealed that temperature was not the problem. Further investigations revealed that the problem was due to poor design application of the Mylar.

The J-18 valve with Mylar seats will be flown on S-IVB-501, because (1) a leak-free valve can be ensured during countdown for flight and one operation of the valve during flight is all that is required, and (2) there is not time to qualify an alternate material in time for -501.

b. Polyimide seats are being tested as a replacement for the Mylar, and these seats are performing quite well. Upon satisfactory completion of the QUAL test program, polyimide will replace the Mylar for seats in the J-18 valve.

5. The following documents were reviewed:

a. DAC DPS STP0135, "Nicropress Sleeves, Installation and Inspection of"

b. Spec No. SS02SA1000025, "Performance and Design Requirements for the Orbital Workshop Apollo Applications Program System for AAP-2"

c. DAC MRD 1P20087A, "Filler, Edge, Epoxy"

d. ECP No. 2183, "Modification of Fuel Recirculation Pipe Bellows"

e. DAC STP0130, "Leak Test, Systems and Subsystems"

f. DAC STM0051A, "Mat, Surface, Glass Filament, Continuous"

g. DAC MRD 1P0111A, "Primer, Structural Bonding, Cryogenic"

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

i. DAC F-289, Revision AG, "Finish Specification"

j. DAC STP0193, "Cryogenic Insulation Liner, Fire Retardant Aluminum Foil Film, Installation of"

k. DAC STM0174, "Adhesive, Silicone, Elevated Temperature."

V. J-2 Engine

Investigation of J-2 Engine Start Tank Discharge Valve Failures

Two failed J-2 engine start tank discharge valves failed while undergoing vibration qualification tests. The nature of the failure was that the shaft

stuck in the cylinders. Visual observation of the chrome plated 347 stainless steel shaft indicated that flaking of the chrome was evident. This finding was verified by cross sectioning and studying on the metallograph. Evidence found with the latter method indicated that wearing of the chrome had occurred. This study is continuing.

VI. F-1 Engine

A. Study of the Effect of Sea Water Immersion on F-1 Engine Tests

The Advanced Systems Office (R-AS) has proposed a test program to evaluate the reusability of the F-1 engines after immersion in sea water. A report has been received from Rocketdyne giving a proposed test program. This report is being evaluated.

B. Investigation of Insulations for Use on F-1 Engine Injector Face Baffles

Copper samples simulating the F-1 engine injector face baffles have been fabricated. These samples will be coated with various flame-sprayed ceramic coatings, and the insulating efficiency of the coatings determined by exposing the coated specimens to an oxygen-acetylene-gas flame adjusted to simulate the F-1 engine thermal environment. To standardize the test procedure and to determine the heat input required to raise the temperature of the copper samples to the operating temperature of the injector face baffles, which is approximately 648°C (1200°F) at equilibrium, thermocouples were accurately placed on one of the copper samples and the sample heated until the equilibrium temperature was reached. The coated samples will be thermocoupled in the same manner and subjected to the same heat input as the uncoated sample. The difference between 648°C (1200°F) and the equilibrium temperature of the coated samples will indicate the insulating efficiency of the coatings.

Performance of the flame-sprayed ceramic coatings for the intended application is dependent upon the adherence of the coatings to the copper substrates. Techniques have been developed which will provide optimum adherence. These techniques consist of vacuum blasting the copper substrates with G-25 angular steel grit followed by the application of a prime coat of flame-sprayed nickel aluminide. At present, the candidate ceramic coatings are being applied to the copper test specimens.

VII. Instrument Unit

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

An investigation was initiated to determine if the reaction of the coolant with the metal components is the cause of the pressure build-up in the environmental control system (ECS). No measurable amount of gas has been evolved from specimens of cold plate, LA141 magnesium alloy, or 606i aluminum. However, dissimilar metal couples exposed to the methanol/

water solution have produced some hydrogen gas after 27 days of exposure. Stainless steel 316 coupled to anodized 6061 aluminum produced seven mls; LA141 magnesium coupled to 2024 anodized aluminum produced 103 milliliters (mls); LA141 to 6061 aluminum (anodized) produced 49 mls, and 356 aluminum casting alloy coupled to 316 stainless steel produced 7 mls. LA141 magnesium is being tested in distilled water. This alloy has produced 11 mls of gas after eight days of exposure.

Plans are being formulated to conduct tests on a full production unit of the ECS in an attempt to find the cause of the pressure build-up that has occurred two or three times on units at KSC.

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) and stainless steel (300 series) are being evaluated for resistance to corrosion in inhibited methanol/water solution. This type of joint is being considered for use in the Environmental Control System. Joints are being tested with no surface protection and some have been given an alodine 1200 treatment. The joints have not been in test long enough to provide definitive data at this time.

C. Investigation of Failure of an Instrument Unit Relief Valve Seat

An Instrument Unit relief valve, P.N. 800-3-005, had withstood successfully a series of vibration tests, had been removed from the test fixture and was being reinstalled in the fixture for post vibration functional tests when failure occurred in the relief valve seat, P.N. 800-3-122. The 2024-T6 aluminum part, manufactured by Aerodyne Controls Corporation, was forwarded to this division for failure analysis. The failure resulted from bending or torsion overload. The design of the relief valve seat permitted an overlap of the poppet bore and the threaded section reducing the cross sectional area sufficiently to preclude ample load carrying capacity. No evidence of fatigue was found by fractographic analysis. A redesign of the relief valve seat was recommended.

VIII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

The purpose of this project is to determine possible contamination of the optical environment of the ATM experiment, both direct deposition of contaminant materials on optical surfaces and 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 Property Criteria established in 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 (77° to 212°F) which does not exceed 0.2 percent/cm^2/hr.

Six materials were evaluated during this reporting period. Only two of the materials tested proved acceptable for use on the ATM. Cat-a-lac 463-3-8 heat cured to 300°F (149°C), and DuPont polyvinyl fluoride 380X RB113BK. It should be noted that all of the other materials tested were air dried, including another sample of Cat-a-lac 463-3-8, which was not acceptable. Numerous inquiries have been received concerning the compatibility of specific materials with the anticipated ATM environment. All inquiries are being handled with the procedure outlined in the Materials Management Plan.

B. Investigation of the Effects of Vacuum on ATM Photographic Film

Due to the configuration of the experiments on the ATM, it will be necessary for the photographic film to be exposed to the vacuum environment of space for an appreciable length of time. Since the effect of prolonged vacuum exposure on the emulsion and backing of the film was not known, a brief test program was undertaken to determine if a problem did exist in this area.

Two samples each of unexposed Kodak Pan-x and 103-0 were placed in a vacuum chamber and evacuated to 10^{-6} torr at ambient temperature for 50 hours. These samples were then exposed to a standard Kodak reflection density guide and processed as recommended by the manufacturer. Density measurements were made on the films and compared with the same type of film that had been exposed and processed in the same manner but had not been exposed to a vacuum environment. The density of the Pan-x film negative not exposed to vacuum was greater than the film negative exposed to vacuum. The density values ranged from 1.6 percent to 53 percent greater, which means that the light area on a print from a Pan-x negative not exposed to vacuum will be 1.6 percent lighter and the dark area will be 53 percent lighter. Density measurements on 103-0 film negatives not exposed to vacuum were less than the film exposed to vacuum. These density values ranged from 1.4 percent to 23 percent. This means that the dark area on a print from 103-0 negatives not exposed to vacuum will be 1.4 percent darker and the light area will be 23 percent darker.

C. Evaluation of the Outgassing Characteristics of the ATM Torque Motor Sub-Assembly

A contact ring assembly for an ATM torque motor assembly consisting of gold plated contacts mounted on a fiberglass laminate ring was tested by mounting the assembly on a heated aluminum plate in a vacuum chamber. A background scan was made with the mass spectrometer, and then the temperature of assembly was raised to 100°C in steps. Mass scans were made periodically during the heating process to determine the outgas products. The results of these runs are being analyzed.

D. Investigation of Thermal Control Coatings for ATM

A program is underway to evaluate thermal control coatings for the Apollo Telescope Mount. A variety of white and black coatings are

being evaluated for both outgassing and optical performance. The requisite black coatings are required to have a solar absorptivity and emissivity of 0.9 or greater. The required white coating must have an initial solar absorptivity of 0.2 or less, and its absorptivity must not increase to greater than 0.4 upon exposure to approximately 5,000 sun-hours. The emissivity of the white coatings must be approximately 0.9.

The outgassing of four black coatings, i.e., Lowe Brothers No. 47865 Black Enamel, Midland Industrial Finishes Company No. L6X958 Dull Black Mocobond and No. 3X923 Sicon Black, and Finch Paint and Chemical Company Cat-a-lac Flat Black No. 463-3-8, were determined after the coatings had air dried only. The outgassing of all four paints was above an acceptable level. The four coatings were then heat cured. The optical properties (emissivity and absorptivity) of the four coatings were measured after the heat cure, and determined to be acceptable except for the emissivity of the No. 3X923 Sicon Black, which had degraded to an acceptable level during curing. Therefore, the Sicon Black will not be further evaluated. Outgassing of the outer three coatings is presently being determined.

Samples of Boeing Company B-1060 paint have been obtained and samples of IIT Research Institute S-13G paint have been prepared. These paints are presently being air dried prior to determination of their outgassing properties. Outgassing of IIT Research Institute Z-93 paint has been determined to be satisfactory.

A sample of black Tedlar PVF film, identified as 38OXRB113BK, was obtained from DuPont and evaluated. This film has an absorptivity of 0.92 and an emissivity of 0.84. These values are considered satisfactory for use on the spar of the ATM. This film was also evaluated for vacuum compatibility and is considered satisfactory for ATM usage. An order has been placed for 200-250 pounds of this film. This provides 6000-7000 square feet of film which would be adequate for the ATM program.

E. Investigation of Candidate Coolant Fluids for the ATM Active Thermal Control System

An investigation has been initiated to select a candidate coolant fluid for possible use in an active Environmental Control System (ECS) for the ATM. The heat exchange fluids investigated were methanol/water in various concentrations, Ethylene glycol-water (60/40), "Freon" 21, Coolonol 15, various "Freon" ethers, Halocarbon fluids, and Hydrotherm 700-130. These coolant fluids were studied on the basis of the following physical and chemical properties:

1. Freezing, pour, and boiling points
2. Operating pressure (pressure versus boiling point)
3. Density
4. Viscosity
5. Specific heat
6. Thermal conductivity
7. Relative pumping power

8. Flammability characteristics
9. Materials compatibility
10. Leakage potential
11. Lubricity

On the basis of this interim investigation, three coolant fluids, in descending order of applicability, have been suggested. They are as follows:

1. "Freon" E1
2. "Freon" E2
3. Methanol/water (60/40)

However, additional work must be done to determine the compatibility of the "Freon" fluids in contact with materials and their radiation stability. The other coolant fluids are not considered acceptable because they failed to meet one or more of the necessary criteria.

At this time, "Freon" E1 is considered to be the best coolant fluid choice in that it appears to meet the acceptance criteria more closely than the others. Based upon data supplied by E. I. du Pont de Nemours and Company, Incorporated, Freon Products Division, Wilmington, Delaware, it appears that this fluid is well suited to the constraints placed on it by an ECS environment. Its low pumping power requirements, between water and methanol/water (60/40), coupled with a high density range and low viscosity should provide an adequate convective and/or evaporative heat transfer medium. While "Freon" E1 has a boiling point of 102.2°F which is below the 140°F acceptance criteria, a pressure of 45 psia will raise the boiling point to 170°F. In addition, "Freon" E1 is reported to have excellent stability with respects to thermal and chemical degradation. Also, the "Freon" E fluorocarbons exhibit a high degree of compatibility with most plastics and elastomers. These fluids were found to have a slight effect on polyvinyl, cellulose, "Hypalon," and butyl polymers. It has also been reported that the "Freon" E fluorocarbons are moderately good lubricants. The non-flammability and low toxicity of these fluids commend their use from a safety standpoint.

"Freon" E2 is also a possible candidate; however, its heat transfer properties do not appear to be as good as "Freon" E1. On the basis of the data we have at this time, the "Freon" E2 coolant still may be a possible choice.

While methanol/water (60/40) was found to meet the acceptance criteria, it is believed that this is not the best possible choice. Due to the possible long-term operation of the ATM, the corrosion problem may be quite severe. Since there is no ATM-ECS interface with the LEM, MDA, or S-IVB Orbital Workshop, the use of flammable fluids is not considered to be a critical hazard to personnel; however, every possible effort should be made to eliminate the use of flammable fluids and materials. In addition, when one considers the possibility of a system leak, the high volatility of methanol/water will result in a much more rapid loss of coolant fluid than if a much less volatile heat transfer media were selected.

In order to further substantiate our findings and to develop in depth data on the subject coolants, sufficient quantities of "Freon" E1 and E2 have been ordered on an emergency basis to provide for corrosion, flammability, physical, and chemical properties experiments.

Due to the orbital radiation flux environment of 3×10^{10} electrons/cm^2/day at 250 nautical miles, radiation effect experiments will be run to determine the stability of the three candidate coolant fluids.

Based upon information received from the various interested divisions within P&VE, as a result of our interim report, "Freon" E1 appears to be an acceptable coolant fluid for the ATM-ECS. This program will continue as materials and additional data are obtained.

F. Investigation of Possible Contamination on Damage to ATM Surfaces as a Result of LM RCS Exhaust Gas Impingement

A literature survey of available information has been completed on the LM RCS contamination of thermal control coatings and surfaces on the ATM. Based upon this information, it appears that major damage to the ATM thermal control surfaces will be due primarily to thermal and pressure loading. Computer data indicate that the thermal environment on the solar cell panels will vary between 310°F (154°C) to 80°F (27°C) from an RCS engine nozzle center line to 95 percent of the plume envelope depending on firing duration. The heating rates will vary between 10 Btu/ft^2 sec. to 0.1 Btu/ft^2 sec. from plume center line to 95 percent mass boundary depending on firing duration. The pressure loading can be as high as 1.2 lbs/ft^2. Based on the possible thermal environment, it does not appear that present thermal control coatings can be used, short of a ceramic, unless some method can be found to baffle the solar panels or retract them during altitude control maneuvers.

From a partial analysis of the propellant reaction products, it appears that contamination will be very slight. However, studies will be required to corroborate these data since tramp metal contaminants normally found in nitrogen tetroxide (N_2O_4) and monomethyl hydrazine (MMH) may adhere to the control surfaces.

Engine leakage from RCS motors or problems from unreacted hypergols is not expected to present a serious problem since they would be in the form of ice particles which would be melted from the control surfaces during RCS operation.

A preliminary report will be written shortly to cover this part of the investigation. In addition, an experimental program will be defined to resolve some of the possible contamination problems.

G. Investigation of ATM Bearing Lubrication

To protect moving parts of the Apollo Telescope Mount lubricants will be required which will not break down or outgas in the environment of outer space. During this period tests were made on number 203 ball

bearings with Salox-M retainers. Bearings with a 30-pound thrust load, having MLR-2 coated races were tested under a vacuum of 3×10^{-8} torr for 100 hours. The lubricating film on the races wore through during test. This could have resulted from having no run-in time before test. Bearings with a 30-pound thrust load, having MLF-5 coated races ran under a vacuum of 5×10^{-8} torr for 113 hours. These bearings appeared in much better condition after test than the bearings that were not run-in before test. Bearings with a 30-pound thrust load, having MLF-5 coated races, which were run-in for 1 hour in air ran under a vacuum of 7×10^{-8} torr for 113 hours. It appears that the MLF-5 lubricant is superior to the MLR-2 under these test conditions.

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 actively investigated.

Under contract NAS8-18024 with General Dynamics/Fort Worth (GD/FW), data are being collected to provide for an evaluation of the effects of radiation and cryogenic temperature on the mechanical properties of selected cryogenic insulations, adhesives, and vapor barriers. In addition, the structural integrity of two insulation systems will be determined after exposure to acoustic, cryogenic temperature, and radiation stresses.

Investigations to determine the cause of the detonations which occurred in the corkboard insulation on the cryogenic insulation test dewar (CITD) during radiation testing at the General Dynamics reactor facility in Fort Worth, Texas, are continuing. The contractor has been directed to make a detailed theoretical study of the radiation chemistry of corkboard insulation in order to formulate theories which will explain the detonations and to design and conduct experiments to investigate the validity of each theory. This study will include the foam insulation, also, to predict whether or not similar detonations would have occurred in the foam if it had been irradiated to the same exposure which the corkboard received. To date, the following two theories have been proposed:

1. Hydrogen/Oxygen - This theory postulates that a detonation could have occurred as the result of a reaction between the hydrogen gas which was produced by the radiation-induced chemical degradation of the corkboard and oxygen which was available in the air trapped in the corkboard. (Theoretical calculations show that for the amount of radiation which had been absorbed at the time of the detonation and the subsequent amount of H_2 which would have been evolved, a detonable mixture of H_2 and O_2 could have been obtained.)

2. Liquid Oxygen/Liquid Ozone - According to this theory, a detonation could have resulted from the reaction between the corkboard and the liquid ozone that was produced by the irradiation of the oxygen which condensed in the layer of the corkboard insulation that was adjacent

to the wall of the LH_2 tank. Some testing to check these theories has been done in-house and by the contractor, and further tests are planned. Briefly, these tests, in which a mass spectrometer was used to analyze the evolved gases, have shown that a significant amount of hydrogen gas indeed is evolved from corkboard when it is irradiated. Similar tests with foam have shown that only about one-fourth as much H_2 is evolved from the foam as is evolved from the corkboard for the same radiation exposure. In one in-house test involving the electron irradiation of corkboard, a detonation was obtained which resembled the detonations that occurred during the CITD tests. No such detonations occurred when the foam was tested under the same conditions. LOX compatibility tests have been made on samples of the foam and corkboard. These tests show that the corkboard is much more sensitive to LOX than is the foam. Since it is known that liquid ozone is more reactive than LOX, it is postulated that very little energy would have been required to obtain a reaction between the corkboard and the liquid ozone. In summary, these tests have shown that both of the proposed theories have some merit and that further investigations are required. Two additional reactor tests have been scheduled. The first run is for the purpose of evaluating these and any other theories which may be forthcoming and will include experiments with the two current insulation materials in addition to two other types to obtain data at both ambient and cryogenic temperatures and in air and inert gas atmospheres. The second run is for the purpose of repeating the cryogenic insulation test dewar experiment using the foam insulation. The successful testing of the insulation on this dewar sill serve as a qualification of the insulation for use in the model tank tests.

A meeting was held with representatives of R-ME, R-ASTR, R-P&VE-V, R-P&VE-S, and R-P&VE-P to review the model tank radiation tests. The procurement status of the various major test items was discussed in addition to the scheduling of the various tasks required for the modification and instrumentation of the test tank (RIFT 108 inch diameter tank). The Astrionics Laboratory will furnish a capacitance-type liquid level gauge for testing and the contractor (under the terms of the contract) will procure several additional types of transducers for evaluation.

In collaboration with the Propulsion Division and the Advanced Studies Office, a scope of work has been written and submitted as a modification to contract NAS8-18024 for the detailed design of an experiment to provide comprehensive experimental data on nuclear energy deposition in liquid hydrogen and the effects of this energy deposition on the thermodynamic state of the fluid. Some of the factors to be considered in the design of the experiment include neutron to gamma ratio, reactor power level, reactor-tank geometry, energy spectra, tank pressure, and angular distribution of radiation. The tank to be used for this experiment is a shortened S-IB 105 inch diameter LOX tank obtained from the Michoud Facility. It will be modified and instrumented at this Center and shipped to the contractor for testing. It is desirable that the modifications,

instrumentation, and testing of this tank follow these operations on the RIFT tank as close as possible.

A preliminary run has been made using the NAP code to predict the activation dose rates from the model tank assembly after radiation testing at GD/FW. These data will be compared with experimentally determined activation data to determine the accuracy of these predictions. Currently, calculations of the NGTM activation dose rates are being made to compare with those obtained by R-AS. Spectrographic analyses have been completed on samples of 304 and 321 stainless steel. Analyses of other alloys contemplated for use on the NGTM are in progress. Because of the influence of trace quantities of zinc on the activation of 2219 aluminum, (the material to be used in the fabrication of the NGTM tank) the Aluminum Company of America (ALCOA) was contacted to ascertain the lowest level to which the zinc content of this alloy could be controlled without significantly increasing the cost of the material. Normally, the amount of zinc present in this alloy is about 0.06 percent by weight. ALCOA stated that for an additional 10 percent increase in cost, it could provide this material with a guaranteed maximum of 0.03 percent zinc. In terms of dollars, this means that it would cost approximately $6,000 more to fabricate an NGTM using the low zinc content 2219 alloy than it would cost using the regular 2219 material.

The question of the desirability of using the low zinc content material will be answered when more definitive information on the activation dose rates from the NGTM relative to those from the test stand and shield becomes available.

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. Alloy Development

American Machine and Foundry Company, NAS8-11168

E. Physical and Mechanical Metallurgy

1. Aluminum Company of America, NAS8-5452
2. Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

Mitron, Research and Development Corporation, NAS8-20609

G. Lubricants and Lubricity

Midwest Research Institute, NAS8-1540

H. Corrosion in Aluminum and Steel

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

I. Explosion Hazards and Sensitivity of Fuels

Stanford Research Institute, NAS8-20220

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

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

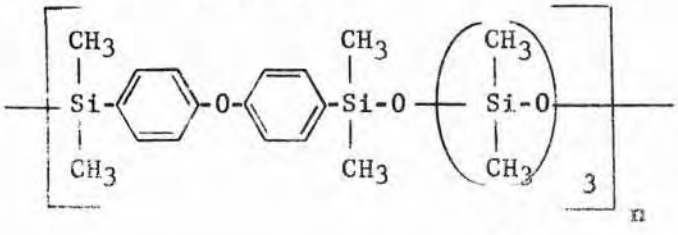
K. Instrument Development

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

II. General - In-House

A. Development of High Temperature Resistant Polymers

In the Spring of 1966, the Midwest Research Institute prepared coatings of the polymer,



with and without zinc oxide, on aluminum and on ceramic coated steel for evaluation of the optical properties in simulated space environment at this Center. The compositions had been cured by the action of two percent t-butylperoxybenzoate and one percent stannous octoate during one hour at 135°C (275°F). On arrival at this Center the coatings appeared to be coherent and the surfaces were firm and smooth. After standing for about nine months (in a succession of three or four laboratories) the surfaces of the coatings became sticky and somewhat rough. On reheating, the coatings did not harden or remain completely coherent. This is now the third observation in recent months of a significant change having taken place in the properties of resins in the polysiloxane series during storage in a laboratory environment. While the nature of these decompositions is not understood, it should be noted that the vast majority of commercial and experimental polysiloxanes, which contain no obvious impurities or highly reactive groups, are stable to the conditions of storage. Further study of this effect is indicated.

B. Development and Characterization of Phosphonitrilic Polymers

The reaction of $(PNCl_2)_4$ with N-methylaniline was reinvestigated in hopes that a resonance stabilized tetra-substituted derivative could be obtained which would lend itself to further reaction with Grignard type reagents to form alkyl/aryl substituted products. Treatment of phosphonitrilic chloride tetramer with excess N-methylaniline in refluxing cyclohexane gave an uncrystallizable oil which was used directly in the next step without any attempt at purification. The infrared spectrum of the oil was consistent with the expected product.

The oil was dissolved in toluene and treated with a slight excess of a 3-molar solution of phenylmagnesium bromide. The resulting solution was heated to reflux and maintained at this temperature for eight hours during which time the separation of solid occurred. The reaction mixture was hydrolyzed with a saturated solution of ammonium chloride and the separated organic phase was processed in the usual manner. The resulting product was an oil whose infrared spectrum showed no P-Ø absorption band at 1440 cm^{-1} indicating that the desired type of ring substitution had not taken place.

$$P_4N_4Cl_4(CH_3NC_6H_5)_4 + 4\ \text{ØMgBr} \not\longrightarrow P_4N_4Ø_4(CH_3NC_6H_5)_4 + 4\ \text{MgBrCl}.$$

Further studies were then shifted to the reaction of $(PNCl_2)_4$ with substituted phenols to give non-geminally substituted derivatives. p-tert-Butylphenol was prepared from the Friedel-Crafts reaction of phenol and tert-butyl alcohol and converted to the corresponding sodium salt *via* metallic sodium. The salt was dried *in vacuo* at 60°C/20 torr overnight prior to use. The sodium salt was dissolved in hot tetrahydrafuran (THF), and the solution was treated in separate portions with tetramer (salt to tetramer, 1:0.125).

$$(PNCl_2)_4 + 4\ RONa \longrightarrow P_4N_4(OR)_4Cl_4 + 4\ NaCl.$$

The weight of recovered salt indicated that approximately 0.15 mole of sodium-p-tert-butylphenolate had reacted with the tetramer. This corresponds to six equivalents of the phenolate and indicates that some geminal substitution occurred in addition to the anticipated non-geminal substitution. The product was isolated as off-colored solid which was recrystallized from petroleum ether as white crystals, having a melting range of 177°-181°C (351°-358°F). Elemental analysis for chlorine will be obtained in order to determine the degree of substitution.

C. Lubricant Development and Evaluation

A major lubrication problem today concerns low temperature lubricants for use in a cryogenic environment. A test apparatus has been designed and fabricated for evaluating greases from +50°F to -100°F (10°C to -73°C). The breakaway torque and the relaxation torque can be measured accurately at any specific temperature in this temperature range. During this period tests were run on a Chapman/Chrysler processed oil and on Halocarbon 11-21E oil. Because of the corrosive effect of the Halocarbon 11-21E lubricant which is presently used in the bearings of LOX transfer system pumps at the John F. Kennedy Space Center, this Chrysler processed oil is being considered as a possible substitute. The results of one test on each oil indicated that the Chrysler oil has about the same low temperature properties as the Halocarbon oil. A breakaway torque of approximately 500 gm cms was measured at -80°F (-62°C) and approximately 4.0 gm cms at +40°F (4°C) for both oils. Both lubricants appear to be good down to approximately -40°F (-40°C). Testing is continuing on both lubricants.

D. Development and Evaluation of Methods for Laminating Various Light Weight Metals

Five magnesium laminate composites were diffusion bonded during this reporting period. The first experiment consisted of producing a diffusion bonded lapshear joint. The specimens were chemically cleaned and subjected to a temperature of 900°F (482°C) and a pressure of 10,000 psi for three hours. Lapshear specimens cut from the composite failed outboard of the lap joint, thus precluding the establishment of the shear strength. The peel test was not satisfactory. The next sample was bonded at a higher temperature (930°F (499°C)) and a pressure of 10,000 psi; however, this time a titanium modular filament sheet was sandwiched between two magnesium sheets (AZ31B). Some deformation of the filament sheet and excessive lateral flow of the matrix material was noted. In this instance, the peel strength was much greater than the previous test. Three subsequent experimental laminates were fabricated. In these instances the individual magnesium sheets were chemically cleaned and then mechanically brushed before bonding was attempted. Very good interface bonding was achieved by using this method of oxide removal. Other diffusion bonding experiments included bonding alternate layers of titanium and aluminum, and a silicon carbide whisker reinforced aluminum composite.

E. Investigation of Stress Corrosion Characteristics of Various Alloys

Testing has continued in the study of the corrosive effects of the local atmosphere on specimens of 7039-T61 and -T64 aluminum alloy. During this report period, a specimen fabricated from 7039-T61 failed after 408 days exposure in the local atmosphere. All three of these specimens have now failed in this environment. The failure times were 57, 391, and 408 days. These specimens were stressed to 20 ksi in the short transverse grain direction.

An investigation was undertaken to evaluate the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were stressed in the short transverse grain direction to 75 percent of their yield strengths. Three bare unprotected and three anodized specimens of each alloy are being exposed to inside and outside atmospheres. Failures to date have been confined to specimens exposed to the outside environment. All three bare 7079-T651 specimens failed in eight days and two anodized specimens made from this alloy failed in 21 and 30 days. Two of three bare 2014-T6 specimens also failed in 21 and 30 days. All specimens have been in test for 40 days.

Specimens of aluminum alloys X2021 and X7007 were stressed in all three grain directions and exposed in the alternate immersion tester and the local atmosphere. Both alloys were found to be susceptible in the alternate immersion tester as previously reported. Tests in the atmosphere have been in progress for 15 months, and the only failure encountered was with specimens made from X7007-T6E136 stressed in the short transverse direction. Failures in these specimens have occurred at loads as low as 10 ksi.

Because of the excessive amount of general surface corrosion encountered in stress corrosion testing of aluminum-copper alloys in 3.5 percent sodium chloride, a more suitable test medium for the alternate immersion tester is being investigated. Synthetic sea water appeared very promising based on preliminary tests. A much broader test program has been undertaken involving threshold stress levels in all three grain directions of the following alloys: 2014-T6; 2017-T6; 2024-T351, -T851, -T4, and -T6; 2219-T37, -T87, and -T62; 7075-T6, and 7079-T651. The specimens have been exposed to synthetic sea water for 64 days, and the test will be terminated at the end of 90 days.

Studies have continued into the stress corrosion susceptibility of Ti-6Al-4V alloy exposed to various fluids. No failures have occurred in any of the fluids except absolute methanol. Specimens that had not failed in methanol containing 0.25 and 0.50 percent of water for 176 days failed in one and two days after the addition of 0.013 grams of sodium chloride (10 ppm Cl). Specimens exposed to methanol containing 3.0 percent water for 176 days have not failed after the addition of 0.039 grams of sodium chloride (30 ppm Cl). These specimens have been exposed to the chloride four days.

Additional specimens to evaluate the stress corrosion resistance of NAA, General Electric, and Aero Quip type stainless steel fittings welded and brazed to 321 stainless steel tubing have been exposed in the alternate immersion tester for 56 days without any failures. These fittings will be exposed for 180 days.

Tests are being continued to evaluate the stress corrosion susceptibility of Almar 362, 15-7PH, 17-4PH, and PH14-8Mo (air and vacuum melt) stainless steels. Alloy 15-7PH was found to be susceptible to stress corrosion in all three grain directions as reported in a previous progress report. The only other failures encountered have been threaded-end specimens of 17-4PH alloy stressed in the transverse grain direction to 100 percent of the yield strength (183 ksi) which failed in 50 to 90 days. The test has been in progress 164 days.

The study of the stress corrosion susceptibility of H-11 is continuing. The only change in the test results since the last report is one failure of a bare longitudinal specimen stressed to 90 percent of the yield strength in 141 days of exposure to the local atmosphere. The alternate immersion and atmospheric tests have been in progress five months.

Arde low silicon 301 stainless steel, cryogenically stretched to nominal 240 ksi, is being studied for stress corrosion susceptibility in the aged (20 hours at 790°F (421°C) in air) and unaged conditions. The specimens were passivated according to an Arde specification (AE8354 solution A). Longitudinal specimens stressed to 75 percent of the yield strength (unaged 184 ksi and aged 196 ksi) are being exposed in the alternate immersion tester. There have been no failures in 67 days of exposure.

Specimens of 21-6-9 stainless steel sensitized and unsensitized (1250°F (677°C)) for one hour, air cooled) are being studied for stress corrosion susceptibility. Flat, round threaded-end, and C-ring specimens, stressed to 75 and 100 percent of the respective yield strength of both conditions, are being exposed in the alternate immersion tester. No failures have been encountered after 35 days of exposure.

F. Developmental Welding

Studies have continued in the determination of mechanical properties of electron beam weldments in 1/8 inch thick sheets of aluminum alloys 2014-T6 and 2219-T87 have continued. The weldment quality of both alloys was affected by pre-weld joint surface preparation, as indicated by the resultant mechanical properties. Weldments prepared with a pre-weld joint surface preparation of either chemical cleaning or mechanical surface scraping with a sharp triangular hard steel tool displayed strength levels 5 to 10 ksi (10 to 20 percent) greater than weldments prepared from material in the as-received condition with no pre-weld joint surface preparation. Whereas, weldments of both alloys prepared by the pre-weld joint surface wire brushing displayed strength levels less favorable than those of weldments prepared from material in the as-received condition.

Macroscopic examination of the fracture surface of the weldments revealed an intermittent lack of fusion in the lower 1/2 of the weld bead. In some cases, heavy porosity was evident in the same area. The presence of this porosity was attributed to the surface condition of the back-up bar used in making the weldment, as well as the pre-weld joint surface condition. Also, some lack of fusion was evident in the weldments that displayed the most favorable strength levels. At present, efforts are being made to determine the cause or causes of this lack of fusion. These efforts will include beam pulsation and beam oscillation welding techniques as well as variations of other welding parameters.

G. Investigation of Dielectric Properties of Materials

The use of polymeric foams, both closed and open cell types, for high voltage insulation of space craft components has been questioned. Their ease of fabrication, ability to flow into small spaces, and light weight may be offset by undesirable outgassing effects as well as thermal stability in vacuum. This project is designed to determine the high voltage breakdown behavior of polyurethane foam under the combined effects of vacuum, temperature, and time under pre-breakdown electrical stress.

Test specimens have been procured and tests have been made to determine the temperature profile of the specimen since high voltage will preclude the use of an active thermocouple during actual tests.

RJ-1 used as the hydraulic fluid in the S-IC stage produces an electrostatic charge due to its dielectric nature and its high velocity of flow. Studies are continuing to determine the basic conduction mechanism of RJ-1 with and without anti-static additives. In preparation for making dipole moment measurements on RJ-1 it was necessary to calibrate the dipolmeter. This was accomplished using specimens of spectrographic grade cyclohexane, carbon tetrachloride and benzene, for which the dipole moments are well known. The maximum error noted in these calibrations was 0.03 percent, and indicates the extreme accuracy that may be attained with this instrument. However, much of the accuracy is also dependent upon the care which is exercised in preparing and cleaning the test cell and the test specimen.

H. Development of Nondestructive Techniques for Evaluating Materials and Components

Stress corrosion cracking of high strength alloys is a major problem in the aerospace industry and with several Saturn components in particular. A current in-house program involves the nondestructive measurement of changes in material properties caused by stress corrosion.

Electromagnetic and ultrasonic measurements have been made on 2219-T31 and 2219-T81 aluminum specimens which previously had been stressed to 75 percent of the yield strength and subjected to alternate immersion in salt water for various lengths of time. Both types of measurements showed

increasing degradation with increasing time of exposure. However, there was not enough difference between the specimens exposed to corrosion only and those exposed to stress and corrosion. In future tests, 2219 specimens will be exposed to a simulated sea coast environment. Less of the purely electro-chemical type of corrosion is expected to occur in this case.

Alternate immersion of metal in a salt solution and in air is an effective means of obtaining rapid stress corrosion cracking; however, it is not realistic. Therefore, several specimen have been stressed to 75 percent of the yield strength and exposed to the local environment. Initial electrical conductivity measurements were made and recorded. These conductivity measurements will be repeated at one-week intervals until cracking occurs. No change in the conductivity of these specimens has occurred to date.

Stress corrosion studies involving Ti-6Al-4V material have been initiated. These are preliminary tests designed to determine the feasibility of nondestructively detecting stress corrosion "damage" in titanium.

Ti-6Al-4V specimens have been stressed and exposed to methyl alcohol several weeks. Two stressed specimens and an unstressed sample were removed from the alcohol after five, nine, fourteen, and nineteen days exposure. Subsequent electrical conductivity and ultrasonic surface wave measurements did not indicate any significant property changes in the titanium. The remaining specimens will be exposed to the corrosive environment for several additional weeks or until cracking occurs before any more measurements are made. No cracks have occurred to date.

I. Investigation of Organic Semi-conductor Materials

During the reporting period electrical conductivity measurements were made on single crystals of an organic semi-conductor, chrysene ($C_{12}H_{18}$). The single crystals, which were obtained from saturated solutions, range from approximately 2 to 5 millimeters on a side and have thicknesses of 100 to 250 microns. The conductivity measurements are being made perpendicular to the ab plane of the crystals and over a temperature range of 45°F to 125°F (7°C to 52°C). These measurements are being made in order to obtain molecular activation energy from a plot of the natural logarithm of the conductivity as a function of $10^3/T$, where T is temperature in degrees Kelvin. A guard ring is being employed to eliminate surface conduction from the measurement. A listing of the data will be given in the next report. Also it is anticipated that photoconductivity measurements will be made during the reporting period.

J. Development and Evaluation of Lightweight Ceramic Foams

Efforts have continued to develop lightweight ceramic foams. Sodium silicates of various sodium oxide: silicon dioxide ($Na_2O:SiO_2$) ratios are being evaluated with respect to their foaming characteristics. Sodium silicates having $Na_2O:SiO_2$ ratios ranging from 1:2.90 to 1:3.75 have been investigated.

The general procedure for producing the foams is to pour the sodium silicate into an aluminum foil pan and place the pan into an oven preheated to 177-188°C (350-370°F). Foaming and drying is completed in approximately 5 hours. The density of these foams varies with the $Na_2O:SiO_2$ ratio, ranging from 6.5 lbs/ft^3 for $Na_2O:SiO_2$ ratio of 1:2.90 to 14.8 lbs/ft^3 for a $Na_2O:SiO_2$ ratio of 1:3.75. Pore structure varies in the foamed body, with the bottom portion containing somewhat smaller pores than the top portion. However, it is believed that the pore structure can be controlled by use of additives to inhibit the foaming action or by restricting the volume of the foam produced from a given quantity of sodium silicate.

In the area of phosphate bonded ceramic foams, lightweight raw materials are being investigated in an effort to produce low density foams. Presently, a series of foams containing Fiberfrax fibers, calcium silicate, and silica as the matrix materials, monoaluminum phosphate as the binder, and calcium carbonate as the foaming agent are being investigated. The density of the foams evaluated to date ranged from 12 to 14 lbs/ft^3. Some of the foams exhibited good pore structure and moderate strength.

K. Documentation Review

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

1. 60C66001 - "Procedures for Cleaning and Painting Engine Servoactuators, P/N 60C66001 on Saturn Vehicles"

2. MA0616-016B Amend. MD-1, March 22, 1967, "Clean Packaging Requirements for Saturn S-II Liquid and Gaseous Oxygen System Components"

3. MA0111-015E Amend. MD-1, March 22, 1967, "Clean Packaging Requirements and Procedures."

L. Literature Survey

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

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

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

MAY 1, 1967 THROUGH MAY 31, 1967

I. Radiography

One hundred and eighty-five miscellaneous parts, components, and test specimens were inspected by radiographic techniques during this report period.

II. Photography

	Negatives	Prints	Others
Engineering photography	37	192	
Metallography and fractography	264	1,336	
Miscellaneous photography, processing, copywork, etc.	9		18

III. Metallurgical and Metallographic Testing and Evaluation

A. Fourteen 7039 aluminum torus tank weldments were evaluated metallurgically. These specimens were selected to compare the as welded condition with one to five weld repairs. Both initial and repair welding was done with X5180 filler wire. Two tensile specimens, numbers 118 and 146 were examined also. Specimen 118, repaired four times, had an ultimate strength of 38,800 psi and 2 percent elongation. The other specimen, repaired five times had an ultimate strength of 47,800 psi and 6 percent elongation; yield strength was 29,500 psi for both specimens. The metallographic studies did not reveal a reasonable explanation for the low strength and elongation of specimen 118. Although the hardness of specimen 146 increased from the fourth to fifth weld repair, no plausible explanation was found to account for the increase in elongation. No defects were found in as welded or repair welded sections of the 7039 aluminum alloy.

B. Failure analysis was completed of a type 316 stainless steel rupture disc that failed during LOX loading in preparation for a static firing at Mississippi Test Facility (MTF). The 8 inch diameter disc had been used in the vent systems on a LOX barge at MTF for the past two years. A review of service records by MTF personnel indicated that a pressure spike of 105 psig was experienced; the disc was rated at 64 psig at 70°F (21°C). No metallurgical irregularities were found that would have caused the failure. The fracture at the probable failure initiation site was somewhat brittle in nature; however, no evidence of corrosion or fatigue was detected by fractographic methods.

IV. Spectrographic Analyses

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

V. Infrared Analyses

Thirty-seven qualitative analyses were made by infrared techniques on a variety of materials including metallic oxides, experimental polyurethane formulations, fluorocarbons, black paints, and breathing line contamination.

Quantitative analyses, for total hydrocarbon content, were made on specimens of activated charcoal and swabs from LOX pump seal cavities on H-1 engines.

VI. Chemical Analyses

	Determinations
Polyurethane synthesis components for	
isocyanate content	4
hydroxyl content	4
nitrogen content	24
carbon content	1
3-D foam for	
carbon	3
hydrogen	3
nitrogen	2
glass	5
Cured Lefkoweld 109 for	
carbon	2
hydrogen	2
nitrogen	2
Cured Narmco sealant 7343 for	
carbon	2
hydrogen	2
nitrogen	2
Experimental polymers for	
carbon	4
hydrogen	2
fluorine	2
Gas samples for	
nitrogen	29
oxygen	33
argon	15
carbon dioxide	19
hydrogen	23
Compressed air breathing samples for	
moisture	1
carbon monoxide	1
methane	3
ethane	3

	Determinations
acetylene	3
nitrogen	3
oxygen	3
argon	3
carbon dioxide	3
Contamination from engine for	
water	2
dissolved solids	1
isopropanol	2

VII. Physico Chemical Analyses

	Determinations
Density of	
RP-1 fuel	10
cured Lefkoweld 109	2
cured Narmco sealant 7343	2
Boiling point of methanol-water mixture	3
Freezing point of methanol-water mixture	3
Flash point of methanol-water mixture	6
Molecular weight of polyurethane synthesis components	2
Refractive index of polyurethane synthesis components	4
Surface tension of polyurethane synthesis components	4
Heat of combustion of	
cured Lefkoweld 109	2
cured Narmco sealant 7343	2

VIII. Rubber and Plastics

	Items
molded and extruded	99
cemented	3
coated	2
fabricated	29

IX. Electroplating and Surface Treatment

	Items
cleaned	2,063
anodized	14
plated	10
penetrant inspected H-11 steel bolts	16

X. Development Shop Production

A. A total of 6,875 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. Two thousand three hundred and forty-nine man-hours, approximately thirty-four percent of the total man-hours, were devoted to productive effort of a non-routine nature and applied to the work orders listed below.

1. Six-inch UV Camera Assembly

Changes in electrical wiring are in process on the six-inch UV camera assembly.

2. X-ray Astronomy Assembly

The X-ray astronomy assembly is approximately 70 percent complete.

3. Telescoping Skirt Assembly for J-2 Engine

The telescoping skirt assembly for the J-2 engine has been completed and tested.

4. LHe-LH_2 Cryostat

A redesign was required on the liquid helium-liquid hydrogen cryostat and this redesign is partially complete.

5. LH_2 Tank Outlet Sealing Device

The liquid hydrogen tank outlet sealing device has been completed and delivered.

6. Pressure Vacuum Furnace Assembly

The pressure vacuum furnace assembly is approximately 50 percent complete.

7. LOX Impact Tester

Approximately forty hours additional labor are needed to complete assembly of the LOX impact tester and prepare for testing.

8. Cryogenic Test Tank Assembly

Fabrication of the cryogenic test tank assembly is approximately 40 percent complete.

9. Ice Calorimeter Stand and Support

Fabrication of the ice calorimeter stand and support is 50 percent complete.

10. Spherical and Roller Bearing Components

Design work has been completed in experimental spherical and roller bearing components for the ATM and fabrication of these items has started.

XI. Miscellaneous

A. One thousand and seventy items of aluminum alloy, three items of titanium alloy, and three items of stainless steel were heat treated during this report period.

B. Fifty-two determinations of emissivity were made during this report period.

C. Nineteen determinations of reflectance were made during this report period.

D. Sixty five chromatographic analyses were made during this report period.

E. Seventeen miscellaneous materials were tested for sensitivity in contact with liquid oxygen in accordance with MSFC-SPEC-106B.

XII. Publications

Lovoy, C. V.: The Influence of Filler Wire and Specimen Width on the Transverse Weldment Mechanical Properties of Aluminum Alloy 2014-T6, IN-P&VE-M-67-3, May 17, 1967.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-67-5

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(May 1, 1967, through May 31, 1967)

SATURN IB

I. General

A. Launch Mission (LM) Rules

Data for the SA-204/LM-1 Launch Mission Rules was transmitted through the laboratory Projects Office to Mission Operations Office, Industrial Operations, for inclusion in the final SA-204/LM-1 Launch Mission Rules document for publication at Kennedy Space Center (KSC).

B. Weight Status Report

The detail weight status report for the Saturn IB operational launch vehicle was completed and distributed.

C. Predicted Mass Characteristics

The preliminary predicted mass characteristics, guidance cutoff, for AS-204/LM-1 configuration were completed and distributed.

D. Program Specification

SA-205 through SA-211 Launch Vehicle Program Specification addenda were reworked to conform with the new mission assignments.

SATURN V

I. S-IC Stage

A. Integration Test Requirements and Specifications

Revision C of the integration test requirements and specifications for the S-IC pneumatic checkout racks (phase I) and the S-IC forward umbilical service unit (phase I) (for use on mobile launcher No. 1) were accepted for release.

B. Umbilicals

1. Testing of the aft umbilical/tail service mast (TSM) systems 3-4 and 1-2 with the new KSC RJ-1 return line and redesigned lox dome purge line was completed May 19, 1967, at the MSFC test facility. Purpose of the tests was to verify that adequate umbilical retract could be obtained with the stiff lines installed in the TSM's prior to installation of the lines at KSC for SA-501 launch.

2. A problem was encountered at KSC in evacuating and maintaining the required micron level in the upper lox line vacuum jacket of the intertank umbilical reconnect assembly (65B80191-1). All attempts to detect and isolate any leakage in the vacuum jacket have failed. The difficulty appeared to result from evaporation of moisture accumulated in the jacket. KSC is evaluating this problem. Recommendation has been made to the Saturn V Program Office that an intertank umbilical reconnect assembly at Michoud Assembly Facility (MAF) be updated to support SA-501 in the event a new unit is required.

3. A retrofit kit for incorporation of Engineering Change Proposal (ECP) 212 was delivered to KSC on May 17, 1967. This ECP provided a redundant switch for the intertank umbilical to indicate retract accomplished. The change was requested by KSC and is considered mandatory for SA-501.

4. TBC was issued a Configuration Control Board (CCB) directive to incorporate ECP 211C. The ECP will be incorporated for SA-501 and includes the following changes:

Provide new lock pin and lock pin bracket to eliminate hydrogen embrittlement.

Add 90° swivel elbow to lox line purge system to eliminate interference.

Rework lock mechanisms to reduce corrosion.

C. ASA-3 Additive for RJ-1

As a result of tests performed by Materials Division on Engineering Change Request (ECR) an Interface Revision Notice (IRN) to 13M50096 was prepared and released requesting that the ASA-3 antistatic additive in the RJ-1 hydraulic fluid be increased from 3 p.p.m. to 6 to 10 p.p.m. This is necessary to prevent the buildup of static electricity in the fluid. A memorandum reflecting this change has been prepared and is being held pending approval of the IRN by the CCB.

II. S-II Stage

A. Servicing Requirements

An agreement was reached regarding the method to be used to assure removal of residual lox from the S-II airborne fill and drain line. Consideration was originally given to the use of an interlock; however, this was determined to be infeasible. Instead of an interlock, a measurement will be provided in the 1-inch drain line to monitor the temperature increase and hence assure complete removal of the residual lox. This parameter will not be redlined during countdown demonstration test (CDDT) but will be monitored to validate the results of the KSC studies which indicated a purge time of 67 to 111 seconds. A decision will be made on the need for a launch countdown redline following an evaluation of the CDDT data.

B. S-II Prelaunch Sequence, Interlocks, and Redlines Drawing

The division completed a review of the latest revision to the S-II prelaunch sequence, interlocks, and redlines drawing prepared by North American Aviation (NAA) for inclusion in the S-II stage test specifications and criteria document. The review indicated most of the earlier comments had been incorporated by NAA and that the drawing was generally complete and accurate. The S-II Stage Manager's Office was notified that the documents were acceptable.

C. Acceptance Tests

Acceptance tests were completed on the following S-II stage equipment:

Leak detector propellant tank and insulation, models C7-55, C7-56, and C7-57.

LH_2 propellant coupling A7-64, unit 9.

Lox propellant coupling A7-65, unit 9.

Insulation purge console model S7-45, section C.

III. Instrument Unit (IU)

A. General Test Program

1. NPC 500-10 impact study on the Saturn IB/V IU, dated February 28, 1967, (International Business Machines (IBM) number 67-257-0002, MSFC number I-1-103-5) was reviewed and accepted without change.

2. The preliminary AS-502 test program specifications for Saturn V Launch Computer Complex, IBM document number 67-F11-0003, dated March 17, 1967, was accepted.

B. Integration Test Requirements and Specifications

The updated revision A of the integration test requirements and specifications for IU ground cooling subsystem checkout local control for ML 1 incorporated corrections and revised fluid requirements. The document was accepted.

C. Umbilicals

The LH_2 and lox fill and drain couplings, serial numbers (S/N's) 9, and modification kits for the 1-inch H_2/O_2 disconnects were delivered to KSC for SA-501 launch. Detail procedures for installation and checkout were included with the modification kits.

IV. General

A. Critical Component and Installation Qualification Status Lists

1. Lists of critical components, component mounting installations or bracketry, and the qualification testing status of the components and brackets are being prepared for S-IVB and S-IC stages. A similar list was completed for the S-II stage.

2. The AS-501 critical component listing was updated and will be sent to the laboratory Projects Office.

B. Safety and Arming (S&A) Device

An informal Douglas Aircraft Company (DAC) report on the S-II installation test results for the S&A device was reviewed. Comments were made which requested more observations along with an ECP for replacing inert checkout units.

C. Contingency Payload Modifications

1. Drawing SK10-9436, AS-501 Contingency Payload Modifications, was finished and delivered to Manufacturing Engineering Laboratory and to the laboratory Projects Office on May 15, 1967. The drawing defines the installation of a tower jettison system and the H_2O fill and drain system to the AS-501 boilerplate spacecraft.

2. Bracketry details for cable support and for fill, drain, and vent system support were included.

D. Stage Ordnance Component Flight Certification

Certificate of component qualification sheets for the linear shaped charge, lox tank, and S&A device were prepared for S-IVB-501 vehicle and submitted to the laboratory Projects Office.

E. Saturn V Damper Arm Systems Design Analysis (SDA)

The SDA for the damper arm system (MSFC drawing 10M30762) was published. The following conclusions were made after consideration of the analysis:

Any component failure effect which can lead to structural damage to the launch escape system (LES) tower must be monitored regardless of its criticality.

Effective implementation of a continuous monitoring of the damper arm damping cylinder pressure and cylinder position to assure that excessive forces are not transmitted to the vehicle without discovery will eliminate all category A items. (A continuous monitoring system is now under investigation.)

F. Hazardous Gas Analyzer (HGA)

1. The final acceptance testing of the first HGA unit was satisfactorily completed. Chrysler Corporation Space Division (CCSD) released this unit for shipment to KSC.

2. Modification for the second HGA unit by CCSD is complete and preparations are underway to perform the acceptance tests.

G. Launch Mission Rules

1. An investigation was completed to determine mandatory requirements for the single sideband (SSB) telemetry channels in the S-IC and S-II stages of the AS-501 vehicle. As a result of the investigation, discovery was made that vibration and acoustics measurements are dispersed throughout the two channels involved on each stage to such an extent that the loss of either channel on either stage would leave large voids in the data obtained. Since one of the primary mission objectives for SA-501 is to demonstrate structural integrity of the launch vehicle throughout powered and coasting flight, it was determined that both channels must be categorized as mandatory for the flight phase of the mission.

2. This division completed preparation of initial input data submittal for the AS-502 launch mission rules. This data was transmitted to Industrial Operations (IO) through the laboratory project engineer for inclusion in the AS-502 Launch Mission Rules document to be published by KSC.

H. Damper System

1. The Saturn V damper system test plan on ML-2 was revised.

2. During tests on the ML-3, excessive leakage was evidenced around pistons on the redundant system. The design activity is correcting this problem by changing piston seals.

I. Technical Checklist

The Saturn V Technical Checklist, revision 10, was completed and distributed.

J. Ordnance Systems Manual

The SA-503 and SA-504 Saturn V Ordnance Systems Manual was updated and distributed.

K. Weight Status Report

The monthly weight status report for launch vehicles SA-501 through SA-506 and the launch escape system (LES) was completed and distributed.

L. Mass Characteristics

Saturn V/AS-501 S-IVB stage mass characteristics reflecting an open propellant utilization (PU) valve restart (depletion cutoff) were completed and distributed.

ADVANCED TECHNOLOGY

I. Systems Design

A. Nuclear Ground Test Module (NGTM)

1. The studies of the engine chilldown line geometry were completed. The studies included engine gimballing during ambient conditions with an empty propellant tank and with a 3-inch upward deflection to allow for engine thrust. A way to mount the chilldown line to the facility and engine without attaching to the stage was defined.

2. The following motion study drawings were prepared to define the problems associated with the ground test peculiar engine chilldown line:

SK10-9459, "Centerline Motion Study, Engine Chilldown Line, NGTM Layout No. 1."

SK10-9560, "Centerline Motion Study, Engine Chilldown Line, NGTM Layout No. 2."

SK10-9561, "Centerline Motion Study, Engine Chilldown Line, NGTM Layout No. 3."

3. Conceptual layouts were completed on a new sump and thrust structural configuration. This layout defined the sump configuration, prevalve location, and bellows, and proposed that the gimbal system be a part of the engine. The actuators will be mounted on the stage side as well as the screw jacks that attach the engine to the stage.

4. Layout studies are being made for routing fluid services and electrical lines in the aft skirt-engine area. This routing is proving to be a problem area due to limited available space and increasing number of lines.

B. Saturn V Payload

1. The following tasks were completed:

Initial, and revised, mission configuration layout for Voyager payload (SK10-7394).

Inboard profile layouts for both solid and liquid propulsion concepts (SK10-7395).

Identification of access requirements for servicing and stacking.

Preliminary spacecraft and flight capsule physical interface control drawings.

2. A study was completed which defined the handling requirements for the Voyager planetary vehicle.

3. A stowage and deployment scheme layout for the high gain antenna was generated. This resulted from new size requirements for the antenna which call for the maximum possible size.

C. Multiple Docking Adapter (MDA)

1. The following MDA layouts were completed:

SK10-9466, "X-ray Sensor Unit (S016) Location Proposal."

SK10-9431, "Nuclear Emulsion S-009, Experiment Package Internal Mounting Provision."

SK10-9426, SK10-9438, SK10-9458, and SK10-9464, "Experiment Mounting Panels."

SK10-9463, "Four Pole Concept for Mobility Aids MDA."

SK10-9429, "Typical Hard Mounted Experiment," and SK10-9430, "Typical Quick Release Mounting Assembly."

2. A layout is being prepared to reflect all windows, handling and auxiliary equipment (H&AE), mobility aids, and experiment vents in the forward conical section of the MDA. This will be incorporated into SK10-9317.

3. The MDA structural requirements to support the upper MDA experiment handling and hoisting equipment were determined. These requirements were requested to be added to the structural assembly documentation.

4. Conceptual design of the H&AE is in process. This conceptual design will be used to prepare the detail design. A detail layout has been prepared which defines the relationship of the H&AE attach points in the conical portion of the MDA to the optical windows and structure.

5. The existing handling and access equipment that can be used to satisfy the handling and access requirements of the MDA was documented.

6. A preliminary schedule and the man-hour requirements for the design of the access platforms and component handling equipment (excluding the handling fixtures) for the MDA were completed.

7. The following MDA mockup documents were completed:

Design of the MDA neutral buoyancy mockup. Preliminary prints of the unsigned mockup drawing will be delivered for Manned Spacecraft Center's (MSC's) review and comments.

Modification to the Airlock Module (AM) forward compartment neutral buoyancy mockup to include the McDonnell Aircraft Company Structural Transition Section (STS).

The hard mockup of the McDonnell Aircraft Company STS structure.

A drawing of the workshop fan assembly neutral buoyancy mockup.

8. A mockup was designed for the interior of the MDA which defines the space envelopes required for all protuberances and experiments. All experiment packages in this mockup were designed to be compatible with the Orbital Workshop mockup mounting privisions.

9. The first two level "A" physical ICD's for the MDA were prepared and submitted to the chairman of the Apollo Applications Program (AAP) Mechanical Panel for signature by MSC and MSFC.

D. Apollo Telescope Mount (ATM)

1. ATM layout drawings SK10-7266, "ATM Proposal, MSFC Rack," and SK10-7328, "Experiment Package Subassembly," are being revised to define all "A" level interface areas and envelopes of all major components.

2. A test plan for the ATM equipment is being prepared.

3. Three configuration layouts were completed which proposed locations of solid propellant rocket motors on the S-IVB stage. These motors would be ignited after the J-2 engine cutoff and an approximate 40-minute coast period to increase the payload capability of the AAP-2 and AAP-4 missions. The J-2 engine burn of the S-IVB stage would place the payload into an 81 x 260 nautical mile elliptical trajectory. The solid motors would fire at the 260-mile apogee and circularize the payload in that attitude.

4. The design of vibration dummy "black boxes" as required on the Astrionics Dummy Component Equipment List 50M73427 is in process.

5. H&AE requirements for the ATM program were updated based on the information available on the project and project components.

E. Orbital Workshop

1. Status of the quick release manhole cover project is as follows:

The McDonnell Douglas Corporation test fixture for LH_2 testing was delivered to Test Laboratory. The quick release manhole cover was instrumented and installed on the test fixture. The test fixture is being instrumented and installed in the test setup.

The test procedure for turnbuckle torque, leakage, vibration, and shock testing was approved.

An interface definition drawing, S-IVB hatch/AM Boot, SK10-9471, was prepared and forwarded to McDonnell Aircraft and DAC for their review. These companies were requested to provide comments on or before June 4, 1967.

II. Systems Operation

A. Orbital Maintenance Concept Plan for S-IVB Workshop

1. An orbital maintenance concept plan for the S-IVB Orbital Workshop mission was prepared for the Preliminary Design Review. The plan included a general discussion of the need for the consideration of possible maintenance activities during the orbital mission. A basic assumption was made that in-flight maintenance is complementary to component redundancy in reliability and that in-flight maintenance performed by the crew can bridge the gap between the required and achieved reliability of the workshop mission, thereby, increasing the probability of success.

2. A general approach for the development of a maintenance plan was discussed. This approach consisted of the following phases:

Generation of required input data.

Performing the analysis.

Preparing the necessary outputs for implementation.

3. Elements of each of these phases were discussed and ground rules and problems were enumerated.

4. Conclusion was made from this study that numerous maintenance factors and considerations are necessary for the Orbital Workshop mission even though the design will be as maintenance free as possible and maximum redundancy will be utilized. As this study represented only a framework from which to proceed, it was recommended that this effort continue with the ultimate objective of developing a complete maintenance package. Finally, a list of potential in-flight tasks was presented with supplementary data to illustrate the factors and considerations necessary in the performance of the tasks.

B. Concept Plan for Contingency Alternate Sequences for S-IVB Workshop

A conceptual plan for contingency alternate sequences for the S-IVB Orbital Workshop mission was prepared for the Preliminary Design Review. The purpose of this study was to provide a plan for the consideration of alternate actions which can be accomplished within the design capabilities of the Orbital Workshop to produce acceptable conditions for mission continuance should a contingency develop which prevents accomplishments of the normal sequence of events.

III. Systems Engineering

A. Apollo Applications Program (AAP)

1. The monthly weight status report for AAP payloads was completed and distributed. Mass characteristics for the Cluster mission were revised and distributed (memorandum R-P&VE-VAW-67-66, dated May 8, 1967).

2. An Orbital Workshop (OWS) Astronaut Walkthrough and Preliminary Design Review was held from May 2 to May 10, 1967. The walkthrough began on May 2, 1967, with an astronaut orientation briefing on S-IVB passivation, thermal control, penetration sealing, crew quarters installation, corollary experiments, and workshop deactivation. Immediately after the briefing, the astronauts visually inspected the workshop mockup in its fully activated flight configuration with all internal equipment installed and corollary experiment boxes mounted. On May 3, 1967, astronauts Alan Bean and Jack Lousma, wearing pressure suits, simulated initial LH_2 tank entry, inspection, and pressurization; installation of lights, fans, and sensors, and sealing of the six tank penetrations. Crew quarters installation procedures were performed in shirt sleeve conditions. On May 4, 1967, the astronauts walked through the deployment of the corollary experiments. Several teams of astronauts reviewed the shirt sleeve portions of these experiments; astronauts Engle and Weitz performed the spacesuited portions of the experiments in pressurized suits. The astronauts performed individual tasks on the part task mockups surrounding the S-IVB, including the use of the 5-degree of freedom simulator and the partial IU mockup in building 4755 to review the M467 (ST-124 Removal) experiment. During the course of the walkthrough, a total of 205 origianl Review Item Discrepancy (RID) forms were received and processed by the Crew Station Subboard (No. 5). The number of RID's were reduced to 68.

3. Corollary Experiments

Studies were completed leading to design specification information for film storage volumes within the Cluster, restricted to the MDA, the AM, and the OWS. Such information includes environmental envelopes, volume requirements, and optimal location of film storage volumes for film used in all AAP-2 corollary experiments during the 28-day mission. An analysis was made to determine whether or not sighting restrictions existed in the Cluster configuration for corollary experiments S009 (Nuclear Emulsion) and S069 (X-Ray Astronomy). The analysis proved that current design permits sightings within stated experiment specifications.

B. Voyager

Baseline Saturn V vehicle weights for determining Voyager payload capability commitment were completed and distributed.

IV. Systems Requirements

A. Nuclear Ground Test Module (NGTM)

1. NGTM program planning was completed for the cold flow test unit. Planning will be expanded to include the two hot flow test units.

2. The final review draft of the NGTM program specification was completed and distributed. Final comments are due June 26, 1967.

3. A final draft of the tank assembly to engine functional ICD was completed.

B. Cluster

The Cluster mission schedule for AAP-1, 2, 3, and 4 was completed.

C. Voyager

The laboratory implementation plan for the Voyager project was prepared.

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-67-5

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

May 1, 1967 through May 30, 1967

SATURN IB

I. S-IB Stage

A. S-IB-10 Static Tests Completed

S-IB-10 was successfully static fired. No engine hardware problems were reported. The engine in position 8 was out of specification performance (209.6K versus 208K maximum allowable) on the short test and performed satisfactorily after reorificing.

B. Turbopump Contamination

Leak-detection solution was found in the turbopump LOX seal cavities. Further disassembly revealed solid products of corrosion. All suspected engines are being inspected, and engines with evidence of corrosion will be returned to Neosho for reworking.

C. S-IB-10 Engine Gimbal System Contamination

Fluid samples taken from the S-IB-10 hydraulic systems before static firing contained an excessive number of particles below 10 microns in size. As a result of these findings, it was assumed that the contamination was introduced by the ground hydraulic servicers at Michoud. The problem was aggravated by the presence of excessive water in the hydraulic fluid. The stage contractor is attempting to solve the problem by using water strippers with the ground servicers, installing better filters in the ground units, using a corrosion inhibitor in the hydraulic fluid, and eliminating mild steel components in the service equipment. If it is determined that the S-IB-10 stage was contaminated by the Michoud ground equipment, stages S-IB-4 through S-IB-9 may be in a similiar condition since they were also serviced with the same ground equipment. Sampling will be necessary to determine their condition.

ORBITAL WORKSHOP

1. Orbital Restart Study Completed

The primary study areas were associated with propellant management and control, repressurization and recirculation pump flow parameters. The minimum payload improvement with a continuous vent system or O_2/H_2 burner for propellant control was approximately 3000-3500 lb. Larger payload advantages are indicated based on low LOX residual. Previous experience shows that a satisfactory engine chill-down or start can not be achieved with low residuals.

2. External Insulation Study

An external insulation system consisting of foam on the forward and aft skirts, purged cells (foam-filled honeycomb) on the LH_2 tank sidewall, and foam or high performance insulation on the bulkheads is being analized. Preliminary results indicate that an external insulation can satisfactorily reduce the heat load for an Orbital Workshop mission; and provide design and operational flexibility for appropriate integration with the environmental control system. The external insulation would also avoid combustible materials within the tank, facilitate passivation, and could reduce the micrometeoroid impact.

3. Thermal Control System Temperature Performance

The thermal control system performance capability and the need for heating the Workshop internal atmosphere at worst case orbit inclination, vehicle attitudes, insulation conductivity and optical property degradation is being investigated. The feasibility of eliminating the need for heater power by controlling the daily launch window is being studied.

4. Solar Array Panel Impact

Studies were performed to evaluate the effect of the side-mounted solar array panels upon the Orbital Workshop thermal control system. The Mission A orientation will result in colder inside wall temperatures (by 5 to 20 °F) than temperatures without panels. Atmosphere temperatures were colder by as much as 10 °F. For Mission B orientation, the solar array results in warmer temperatures. The solar array concept is considered compatible with the S-IVB thermal control system. A detailed study to define the available mission time for habitation, attitude control restraints, and atmosphere heater power was recommended to be a portion of a design effort.

5. Simplified Condensation Test

Results of the initial test of the liner model showed 20 to 40 percent greater condensation than expected. Tests using chemical smoke and tufts showed that the flow was turbulent with eddies of reverse flow in addition to flow separation at the duct entrance. Additional tests indicated that the test section expansion portion was responsible for these flow patterns. As a result, relocating the fans or reversing the flow direction is being considered. The fan will be relocated on the test model to duplicate the flight article flow direction and to allow measurement of condensation without recirculation.

6. Solid Motor Survey

A survey was conducted to determine the availability of solid propellant rocket motors that deliver 100,000 lb/sec to 350,000 lb/sec total impulse. Two motor designs were selected as the most promising candidates. They were the UTC FW-4S (fourth stage Blue Scout) motor and the 23 KS-11000 (Alcor) motor, which deliver 172,000 lb/sec and 257,900 lb/sec, respectively. Both motors have had flight experience and are currently in a production status. The Orbital Workshop S-IVB application will require four FW-4S motors or three 23 KS-11000 (Alcor) motors. The anticipated modifications, qualification requirements, schedules, and costs are being evaluated.

SATURN V

SA-501 FLIGHT-CRITICAL COMPONENTS REVIEW

The review of all data and documentation of the Saturn V stages to determine the flight worthiness of propulsion system flight components is 95 percent complete.

I. S-IC Stage

A. F-1 ENGINE

1. R&D Engine Tests at EFL

Nineteen tests were conducted, and a total duration of 2079.8 seconds was accumulated. Eleven of these tests were full duration runs (150 seconds or more). Two tests were terminated prematurely; one was due to the LOX pump bearing pressure exceeding the redline value, and the other was due to a facility malfunction.

2. Production Engine Testing at EFL

Eight tests were conducted and a total duration of 713.7 seconds was accumulated. All of the tests ran for the intended duration. Three of the tests were full-duration runs.

3. Component Qualification

The Qualification Test Report for the High Reliability Temperature Transducer is being reviewed. This will complete qualification of all of the F-1 engine components on the original component qualification list. Qualification test procedures for the new redundant shutdown system were reviewed.

4. F-1 Engine Ready for 501 Flight

The Program Managers preflight review meeting was held on May 17, 1967. It was determined that the engine is ready for flight use on SA-501.

5. Performance of Helium Heat Exchanger Increased

The increased S-IC-504 burn time has resulted in the requirement to increase the performance (outlet temperature) of the F-1 helium heat exchanger. This is necessary, because the fuel tank pressurant capacity is fixed. The engine model specification will be revised.

B. Helium Bottles Inspected

Bottle S/N 3 was inspected after four years of use and found to be in good condition. No indication of stress corrosion was found. This bottle will be subjected to a burst test.

C. S-IC-4 Successfully Acceptance Fired

The S-IC-4 stage was successfully acceptance fired at the Mississippi Test Facility (MTF) on May 16, 1967. Mainstage duration was 125 seconds. This was the first flight stage acceptance test at MTF. No major problems occurred during the firing. All systems appeared to function satisfactorily. The acceptance test for S-IC-5 is tentatively scheduled for July 11, 1967.

D. Retromotor Criticality

According to the stage contractor's predicted criticality, the S-IC retromotor is one of the most critical items on the Saturn V vehicle. Some of the values of parameters used in the criticality calculation appeared to be unrealistic and will be investigated.

E. Retromotors Being Investigated

All S-IC retromotors manufactured to date were placed on hold status pending the outcome of an alleged report that substandard graphite was used in manufacturing the nozzle insert. This report is being investigated.

F. S-IC-504 Propulsion System Evaluation

Although calculations based on chamber pressure indicated that the S-IC-504 engines were performing over the engine specification limits during static testing, engine performance based on turbopump speed was within specification limits. An investigation revealed that the chamber pressure measurements were mis-calculated by approximately 1 percent.

G. Ordnance Testing

An EBW detonator failed during lot acceptance testing. The failure occurred during a room temperature test and is being investigated. So far only some quality control and inspection deficiencies were discovered.

II. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Four tests were conducted, and a total of 710 seconds was accumulated. All of the tests ran for the intended duration.

2. Production Engine Tests at SSFL

Thirteen tests were conducted and s total of 1290 seconds was accumulated. Two of the tests were terminated prematurely prior to mainstage due to erroneous hydrogen flow indication.

3. J-2 Ready for SA-501 Flight

It has been determined that the J-2 engine is ready for flight on SA-501.

4. J-2 Engine Tests at AEDC

Seven tests in two separate test periods were conducted. All seven tests were S-II-501 simulation tests. One more test period of four engine tests will be devoted to S-II-501 verification to complete the SA-501 verification program at AEDC. A total time of 85 seconds was accumulated at 5.0 mixture ratio on J-2052 during this report period. Fifty-nine tests have been conducted, and a total of 919 seconds have been accumulated on engine J-2052 at AEDC to date.

5. Engine Gimbal System Main Pump Test

Design verification tests on three S-II EGS main pumps were continued. Two of these pumps were subjected to 60 out of an intended 100-hour endurance test. Both pumps have high pressure spikes when going from a full flow to zero flow condition.

6. Verification Testing of Accumulator Reservoir Manifold Assembly

The filter, proof pressure, functional, high and low temperature and vibration tests have been completed satisfactorily. 10,000 life cycles were completed on the accumulator and reservoir pistons using 100 ± 20°F oil. Failure occurred when the reservoir piston O-ring broke after 300 life cycles using 225 ± 25°F oil. This portion of the test required that 2500 life cycles be completed on both pistons using hot oil. Disassembly of the S-II ARMA revealed that one of the GN_2 accumulator piston seals was protruding below the piston. This failure caused sporadic GN_2 leakage during the life cycle test. All testing has been completed.

7. Failure of Engine J-2052 Investigated

The functional failure of engine J-2052 was caused by scrap safety wire in the Electrical Control Assembly (ECA) shorting between two circuit paths which burned out a transistor. Disassembly and inspection of 14 ECAs revealed similar irregularities. ECAs on engines J-2080 and J-2093 were partially disassembled and inspected. Additional contaminants were found so all ECAs were returned to the engine contractor for inspection, removal of contamination, and programmed electrical-functional check.

B. Verification Tests of Three Main Pumps

The test setup for simultaneous endurance testing of the first and second S-II main pumps was completed and both pumps have undergone 60 hours of endurance testing.

C. Evaluation Testing of Propellant Pre-Valves

Vibration tests (sine and random) at LN_2 temperature were completed on the first valve. The hydrogen test setup is being constructed.

III. S-IVB Stage

A. S-IVB-503N Successfully Acceptance Fired

The S-IVB-503N stage was successfully acceptance fired. Mainstage duration was 444 seconds. This was the first Saturn V/S-IVB stage that was acceptance tested with a single burn. There were no major problems during the countdown or firing. All systems appeared to function normally. The next stage acceptance test is S-IVB-504 tentatively scheduled for June 15, 1967.

B. Propulsion Performance Predictions

A final propulsion performance prediction on S-IVB-501 incorporating the "open PU valve" restart was completed by the stage contractor. Data tapes of the S-IVB-503N firing were distributed and the final performance prediction is progressing satisfactorily. A flight-type dry run on processing data, reconstructing the firing and producing the final prediction, is being performed simultaneously by DAC and Boeing. The two procedures and results will be studied and compared.

C. PU System Calibration

A detail review of the volumetric method recommended by the stage contractor for calibrating the propellant utilization system was completed. The method was approved for use on stages that will not be acceptance fired; however, it was recommended that the flow integral method of calibration be used as the method for all S-IVB stages that have been or will be acceptance fired.

D. O_2/H_2 Burner Restartable Feasibility Tests

Feasibility tests using a new ignitor configuration, are being conducted on the O_2/H_2 burner by the stage contractor at Sacromento Test Facility. All starts have been successful. Multiple starts were completed with no changes to the burner between starts. All tests simulated the mission duty cycle expected of the burner in orbit (approximately 265 seconds burn time). The extremes of the expected start box of the burner were tested. Approximately 20 more tests will be conducted before a decision will be made as to whether the restartable ignitor configuration will be qualified and flown.

E. S-IVB Bulkhead ΔP Investigated

The affect of single-point failures on the S-II and S-IVB common bulkhead differential pressures is being investigated. No single point failure has been identified prior to second burn cutoff. Vehicle time response for vent valve failures is being determined, based on the ultimate structural limit, to define the abort conditions.

F. Liquid Level Sensors

Malfunctions occurred in the LH_2 depletion sensor system during the S-IVB-503N loading and static firings. The cause of these malfunctions has not been identified or corrected. The stage contractor will initiate second source procurement for a system that will reliably perform the assigned depletion, overfill, and fastfill functions.

G. S-IB/S-II Retromotor

Qualification testing of the retromotor redesign was completed. No problem areas were encountered during the qualification test.

IV. Instrument Unit

A. First Stage Regulator

During installation of a relief valve, the mounting stud broke off. A metallurgical investigation of the mounting stud revealed that the failure was a result of a design deficiency. A design improvement is being implemented.

B. Replacement of Heat Transport Fluid for IU

A study of various heat transport fluids was made to determine if the present Methanol/Water (M/W) fluid could be replaced by another fluid that is compatible for use in the IU Thermal Control System (TCS). The study was initiated because M/W reacts with Magnesium-Lithium to generate H_2 gas, which is believed to have caused failures in the Launch Vehicle Digital Computer and Launch Vehicle Data Adapter. Over-pressurization of the M/W coolant circuit is also believed to be caused from H_2 generation. The study indicated that the pumping power for the fluids under consideration was higher than that of M/W. Therefore, compatible substitute fluid could not be used in the IU without a major hardware change and subsystem testing to determine the effect of lower heat transfer on the temperature critical electronic boxes.

C. Pressure Switch Qualification Testing Completed

Qualification testing was completed on the pressure switch for the IU Methanol/Water ECS. The results of the qualification testing indicate that the deactuation pressure setting can shift outside specification limits under the specified vibrational environment. It was recommended that this switch be deemed as unqualified until the problem of deactuation pressure shift is eliminated or until the specification is revised.

SPECIAL STUDIES

I. Voyager Spacecraft Program

A. Propulsion System Studies

Studies were conducted to aid in the selection of the type of propulsion system (liquid or solid) used for the Voyager spacecraft.

In addition, the following series of special studies were completed:
(1) a review of a NAA proposal to use the Service Module for Voyager,
(2) a conceptual study of a propulsion system for a 7,000 lb capsule,
(3) a review of a TRW report on advanced missions.

B. Voyager Solid Motor Liquid Injection Thrust Vector Control Analysis

Systems that could be used in the Voyager Program for thrust vector control of the Solid Motor were analyzed and recommendations were made as to design improvements in terms of mission reliability.

C. Voyager Pressurization Module Configuration Analysis

Mission reliability analyses were performed on possible Voyager propulsion system pressurization control modules to determine best module in terms of mission reliability.

D. Propellant Management

A preliminary survey was made of low-gravity propellant management problems that may be incurred during various phases of the Voyager mission to Mars. It appears that propellant motion can be adequately controlled at all times in flight with a simple arrangement of capillary screens. The major advantages in using screens are the elimination of propellant settling requirements and simplicity - screens are passive control devices in contrast to complicated expulsion systems such as bellows.

E. Thermal Investigations

The radiant heat fluxes for the spacecraft and LEMDE engine in the Mars orbit were completed. The spacecraft heat fluxes were determined for an emissivity of 0.90 and absorptivities from 0.1 to 0.9. The wide variation in radiant fluxes with orbit position and spacecraft location indicates that insulation will be required for the area shaded by the solar array.

A preliminary investigation of the capsule/spacecraft interface relative to heat dissipation from the capsule and the change in heat gain at the capsule/spacecraft separation indicate that a near adiabatic interface should be maintained.

F. Voyager Shroud

A parametric flow analysis was conducted to assist in sizing the umbilical connections for the environmental control system. Final selection is dependent on spacecraft prelaunch requirements.

II. Multiple Docking Adapter (MDA) Thermal Control

Preliminary studies assuming conservative boundary conditions were performed to establish the best thermal concepts for use in design of the insulation system, docking ports, meteoroid shield supports and radiator supports. These studies indicate that one inch of Goodyear high performance insulation will provide adequate MDA thermal protection.

III. Apollo Telescope Mount

A. Spar Thermal Deflection Test

Fabrication and installation of test hardware is complete. Installation of instrumentation is 60 percent complete. Tests will be started June 5, 1967.

B. Quadrant IV Thermal Control System Test

Fabrication and instrumentation of hardware is 95 percent complete. Due to a delay in the receipt of insulation material, the start of this test will slip to July 1, 1967.

C. Cannister Insulation, Acceleration and Vibration Test

Fabrication of the support adapter for the centrifuge is 85 percent complete. The cannister is awaiting insulation.

D. ATM Experiment Package Thermal System Test

Design of a thermal model of the Naval Research Laboratory Experiment "B" was started. A thermal model of the Goddard Space Flight Center Experiment (GSFC) was received.

E. Radiation Flux Cycles Studies

The analytical study of maximum and minimum radiation flux cycles that will be seen by the external surfaces of the ATM experiment package was completed. Work was started on programming the infrared system in the Quadrant IV Thermal Control Systems Test, preparing a general test plan for this test, and preparing a mathematical model of the Quadrant IV Thermal Control System Test hardware to be used in making insulation thickness modifications.

IV. Nuclear Ground Test Module

The vent system blow down study is 40 percent complete. Work has started on tank drainage studies that will be conducted in-house to investigate drain, vortex, and destratification. The tank pressurization computer program is being revised to meet system parameters. A nuclear propellant heating computer program is being implimented to meet system parameters.

The diffuser design for the NGTM fill, drain, and replenish system was completed. This design reduces the inlet fluid velocity from 65 ft/sec to 10 ft/sec and will prevent internal container damage and degradation of pump and engine performance while operating in the replenish mode.

A layout of the proposed fill and drain system was completed. To install this system, a 10-inch extension to the skirt is required.

V. Zero Leakage Projects - Investigation of Brazed and Welded Tube Connectors

Twelve 1/4-inch tubing test specimens were subjected to tensile tests, and 24 are undergoing metallographic examination. Burst tests were conducted on eleven 1/4-inch tubing test specimens. Liquid nitrogen soak tests were conducted on eighteen 1/2-inch test specimens. Test setups are being investigated for 3/4-inch tubing at ambient temperature and 1/4-inch tubing at +500 °F temperature.

VI. Sunspot I Vacuum Chamber

Installation of this vacuum chamber is 90 percent complete. Installation remains on the Ion/Titanium pumping system and the liquid nitrogen shroud. The chamber is being leak checked. After shroud installation, performance tests will be made using the diffusion and Ion/Titanium pumping systems, individually. It is estimated that setup of the first thermal vacuum test in the vacuum chamber can begin on June 19, 1967.

VII. Investigation of Freon E-3 as a Low Temperature Hydraulic Fluid

The calibration, pressure control, dynamic response, and pressure cycling tests at -30 °F and -60 °F were successfully completed on the Vickers Pump. The preliminary test data agree with corresponding data obtained during the 0 °F and ambient temperature test series. However, as should be expected, the system pressure drops and fluid contractions are becoming more evident as the temperature is decreased.

VIII. Drop Tower Telemetry and Instrumentation

Fabrication and check out was completed on a new 8-channel telemetry control box for the terminal drain test package in preparation for a new series of tests. A new pulse generator for camera time was fabricated and checked out. Three optional units are now available that give 1000 and 10 pps simultaneously. The slosh-impulse package was recalibrated, balanced, and sent back to the tower for additional testing. Design was started on a mixer amplifier for the telemetry transmitter input in an effort to obtain full 125 kc deviation. Data from the slosh-impulse tests were processed, evaluated, and delivered.

IX. Cryogenic Container Thermodynamics During Propellant Transfer

The objectives of this program are to provide analytical and empirical descriptions of the transient phenomena occurring in cryogenic transfer lines and receiver tanks during initial propellant transfer and establish conditions leading to and methods of eliminating implosion. The computer programs developed for predicting these transients were completed and testing is currently in progress to obtain data to verify the analytical techniques. The transfer line chilldown program was successfully correlated with National Bureau of Standards experimental data.

X. High Performance Insulation Thermal Design Criteria

Work was completed, and two handbooks containing useful thermal data on materials were developed as a result of this study, "Thermal Design Data for Multilayer Insulation Systems" and "Optical Properties for Thermal Control Surfaces." Diffusion coefficients were obtained for two insulation systems with various gases and temperatures. The resultant data compared favorably with the kinetic theory predictions of the effect of molecular weight on the diffusion coefficient.

ADVANCED PROPULSION AND TECHNOLOGY

I. J-2X Thrust Chamber Test Program

Test facility activation firings were started. Three ignition firings and three low level main stage firings were conducted successfully. The longest duration was 15 seconds with mainstage chamber pressure of 300 psi. Firings will progressively approach full mainstage operation conditions, at which time the stand activation chamber - a standard J-2 model - will be replaced with the test program chamber of the J-2X configuration.

II. System and Dynamics Investigation

Four hot firing tests of an aerospike solid wall thrust chamber were conducted. The objective of these tests was to verify injector integrity, checkout test stand operation, and exercise the programmed throttle and dump valve units which are used to simulate pump head-flow slopes. The first three tests accomplished facility and injector checkout. The fourth test was intended to exercise the programmed throttle and dump valve units which can be set to simulate various pump head-flow slopes. A defective programmer electrical switch prevented the LOX dump valve from receiving its signal thereby causing it to remain closed.

The injector is being pressure and leak checked and will be cleaned for assembly in the stainless steel tubewall thrust chamber. The

programmed valve control circuitry is being extensively checked and is having new safety circuits installed. Further checkout runs will be conducted on this valve system prior to the tube wall tests.

III. Large Booster Sub-Scale Experimental Program

The hot firing test program on the eighteen-engine plug multi-chamber model was successfully completed. The last series of firings employed a 10 percent length plug with a porous base plate. Several different gases were used as base bleed, and flow rates were varied. Preliminary results indicate good correlation with the previous cold flow tests. Engineering analysis of all the test data is under way.

H. G. Paul
Chief, Propulsion Division

Note: Reference to the Document Monthly Progress Report (May 1st 1967 through May 31st 1967) following are the missing pages.
Page No – 50.