XI.10
XI.11
XI.14

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

FOR PERIOD

September 1, 1968, Through September 30, 1968

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (Rev October 1967)

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-68-9

MONTHLY PROGRESS REPORT

(September 1, 1968, Through September 30, 1968)

By

Advanced Studies Office
Structures Division
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 (Concluded)

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-68-9

MONTHLY PROGRESS REPORT
ADVANCED STUDIES OFFICE

(September 1, 1968, Through September 30, 1968)

ADVANCED PROGRAMS

I. Launch Vehicles

A. Pressure-fed Launch Vehicle

The main program and the output format for evaluating PFLV stage weights have been completed and checked out on the computer. Subroutines to calculate tankage weight as a function of propellant loading and tank diameter have been incorporated. Subroutines for evaluating skirt, thrust structure, propulsion system, and instrumentation systems weights are currently being formulated.

B. Titan III Applications

Jettison weight summaries, configuration drawings, propulsion system summaries, and launch vehicle systems descriptions have been prepared for the following nine Titan III launch vehicles: -D (less SRM's); -M (less SRM's); -M (with Mark III CSM); -F (less SRM's); -F/LDC (less SRM's); -F/LDC(less transtage); -F/LDC (less SRM's and transtage); -G (with Mark III CSM); and -L (with Mark III CSM). Data on these launch vehicles supplement information previously compiled for 28 other Titan III configurations. Effort is being concentrated on familiarization with the Titan III M vehicle. As an initial step, a preliminary outline identifying the launch vehicle's major systems and subsystems has been prepared. In addition, first performance runs are underway to determine payload to low earth orbit for selected configurations using MSFC trajectory programs.

C. Nuclear Vehicle Studies

A document summarizing studies of the nuclear vehicle for the 1982 Mars stopover mission conducted during the period September 1966 - August 1968 was completed. Data excerpts from this report were presented in a review session on September 13, 1968. This concludes all work within our Office on manned planetary missions.

A "Phase-out" study with BECO in the nuclear vehicle area will continue until termination of BECO support to this Office in December 1968. This "Phase-out" study will examine the nuclear stage with the uprated NERVA I engine as a third stage on Saturn V for earth orbital and lunar applications, and will be a one-man level of effort. Specifically, the nuclear stage will be examined for the following applications: (1) changes in orbit plane angle; (2) changes in orbit altitude; (3) general maneuvers in earth orbit; (4) manned lunar transfer; (5) lunar orbital operations; and (6) unmanned planetary probes. Basic assumptions are that all missions will involve only a single launch of a standard Saturn V and that all missions will require a single nuclear stage (no clustering of stages in earth orbit). All performance will be based on the uprated NERVA I engine.

Analyses to date have been directed to examining possible maneuvers in earth orbit. The payload under consideration is the Apollo CSM that may be off-loaded as mission requirements dictate. Spacecraft weight has been determined as a function of available ΔV, ΔV as a function of orbit inclination angle, and spacecraft weight as a function of orbit inclination angle. Preliminary calculations indicate that a change in orbit inclination angle of 47.3° is possible, assuming no propellant losses through hydrogen boiloff. If a nominal loss through boiloff is assumed, the orbit angle change is reduced to 45.5°. All performance and nuclear stage sizing has been based on the payload capability of the SA-520 Saturn V launch vehicle.

D. Intermediate Launch Vehicle

Comments on the Boeing proposal to study the S-IC/S-IVB intermediate launch vehicle were made and subsequently reviewed with the NASA Contracting Officer's Representative in a general meeting of MSFC contract participants on September 9, 1968.

II. Earth Orbital

A. Earth Orbital Space Laboratory

1. B_o Workshop Study --- The overall conceptual design, floor layouts, experiment locations, and preliminary weight estimates for the B_o Workshop configuration design study were completed and documented in Memorandum for Record R-P&VE-AA-68-87. The results, which will be incorporated into an overall study report, include a sketch showing the general location of all of the selected experiments for the mission, a color illustration of the orbital configuration of the Workshop, an inboard profile drawing with floor layouts, a preliminary weight statement, and brief discussions.

Weight, mass characteristics, and structural loads data for the B_o configuration, and weight and definition data for the B_o CSM were compiled into Memorandum for Record R-P&VE-AV-68-127. All data are presented in viewgraph format, with descriptions, for incorporation into the overall B_o mission description document.

For the B_o design, the weight data presented are for a total payload weight of 63,500 pounds. Loads data presented are bending moment versus station, for a preliminary dynamic analysis, and are compared with Saturn V Apollo data. The CSM for the B_o Workshop is comparable with the AAP-3A CSM, which has a 56-day lifetime.

Five different vehicle/workshop combinations were investigated involving varying degrees of adaption of the original AS-210 S-IVB stage, Saturn V/S-IVB stage components, or newly fabricated components. All of the cases examined were feasible and have approximately the same degree of complexity involved in making the modifications. In all cases, the unnecessary propulsive equipment was removed and stored for later use.

The method selected involves utilizing the AS-210 tank and Saturn V/S-IVB stage skirts. All Workshop required modifications are made to the skirts, i.e., attaching the Workshop Attitude Control System and the solar cells. The residual Saturn V/S-IVB stage propellant tank is joined to the Saturn IB skirts to recover a propulsive stage that can be utilized on a Saturn IB launch vehicle for the logistics missions.

2. Space Lab Mockup --- Efforts are continuing on the Space Lab Mockup design. Preliminary structural analyses and structural layouts were completed, and the current primary task is to formulate, in detail, the internal floor arrangements. Many alternate configurations were considered for the crew quarters deck, the subsystems deck, and the experiments deck.

The first iteration of the crew quarters floor layout was completed, and the results are being evaluated. Among the ideas being considered are those presented by Mr. Fred Toerge of Loewy/Snaith, Inc., on September 25, 1968. Mr. Toerge showed drawings of various crew quarters deck floor arrangements, including several bunk concepts, restraint devices, and food and waste management compartment designs. He also displayed 1/20 scale cardboard mockups of four floor arrangements.

A survey was made to determine the overall subsystems and their respective components that will be installed on the subsystems floor of the Space Lab Mockup. The subsystems which will be installed either totally or partially in the mockup are the Environmental Control and Life Support, Electrical Power, Stabilization and Control, Communications and Data Management, and Instrumentation (Consoles, etc.). Elements of the Environmental Control and Life Support Systems, which will be installed either totally or partially, are Atmospheric Supply and Pressurization, Atmospheric Purification and Control, Thermal Control, Water Management, Waste Management, Suit Loop, and Crew Systems. A listing of the individual components (Black Boxes) of each subsystem was compiled along with their envelope sizes. A cross-sectional layout was made to illustrate the installation of these components with regard to location, volume occupied, and plumbing interfaces. A roll-out drawing was made to show the vertical installation of the components around the station wall. Additional sketches are being prepared to illustrate the maintainable components installed in cabinets. A standard shape has been selected for all the consoles to be installed on the subsystems floor. These consist of Remote Control-Astronomy, Remote Control-Earth Resources, Electrical Power, Station Monitoring and Control, and Communications and Data Management. Individual sketches for the manufacture of the individual components are being prepared.

Several meetings were held with R-AS to discuss experiments and experimental equipment which should be represented in the Life Sciences portion of the experiment deck. These meetings were most helpful in that much information from NASA Headquarters' sources was made available and a thorough critique was made of a preliminary layout already prepared. A second layout incorporating this new information is now being prepared. In coordination with R-AS, a preliminary list of experiment equipment for the maintenance and human engineering section of the experiment deck is being generated.

3. Space Lab Attitude Propulsion System --- A "quick-look" computer program has been developed for the purpose of analyzing APS environmental control requirements. The program computes temperatures, insulation thickness required, and amount of heat required to maintain

thermal equilibrium and prevent propellant freezing. Heat input requirements are then converted to power (watts) which must be supplied to the space station APS heater blankets. Further investigation is required to establish absorptivity/emissivity ratios and insulation conductance values applicable during the predicted 1975-80 Space Lab mission years.

4. Space Lab Experiment Compatibility Analysis --- A summary of results and conclusions from parametric crew scheduling studies of the Douglas Experiment Package A was documented in Memorandum R-P&VE-AA-68-86. The memorandum discusses all the trends and analyses that have been generated over the past twelve months using LaRC's Space Station Simulation Math Model. It also presents a summary of various individual analyses, in addition to a number of new trends and conclusions developed as a result of the overall consolidation.

B. Earth Orbital Experiments

Preparation of inputs to the Redshift Relativity Experiment Pre-PDP, requested by R-ASTR, is underway. Technical descriptions of the spacecraft configuration, structural design concept, and thermal control systems have been completed. Resources requirements and other data have been received from the Divisions and are being incorporated into a package for transmittal to R-ASTR.

III. Lunar

A. Mobility Test Article (MTA)

The mobility test of the two MTA's was delayed due to Test Laboratory telemetry problems, but these problems have now been corrected.

The BECO LSSM Mockup has completed the entire MSFC Mobility Test Program and the data gathered are being reduced by Computation Laboratory to a compatible format with the analog computer output for verification of the analog simulation of vehicle dynamics. After Computation Laboratory provides us with the reduced data there will be no further need for the BECO vehicle and it is to be handed over to the Space Orientation Center for display purposes.

B. Dual-mode LRV Study

The final revision of the work statement for the design and definition of a dual mode Lunar Surface Roving Vehicle (DMRV) was made and forwarded to NASA Headquarters. The $400,000 for the study is currently available and Headquarters' approval of the RFQ is expected in approximately one month.

Personnel from this Office, R-AS, and R-SSL attended a meeting on September 17 and 18, 1968, at the Bendix Systems Division in Ann Arbor, Michigan. The purpose of the meeting was to discuss potential experiments and mission science packages to be performed and delivered by a Lunar Roving Vehicle. The group also reviewed the work being performed in-house at Bendix on adapting their motorized LSSM mockup for remote control operation, which was demonstrated on September 18. This in-house task was undertaken in anticipation of obtaining SR&T funding for a test program in 1969. Bendix has proposed the possibility of using their vehicle for remote driving tests at MSFC; however, due to the climate in Alabama, the test course would have to be an indoor facility, such as a hangar. This might prove advantageous in that some type of suspension system could be developed to afford the vehicle approximately 1/6 g operation. The other alternative is to perform the tests in a dry location, similar to Arizona.

Personnel from this Office, Advanced Systems Office, MSC, and NASA Headquarters also attended a meeting at GAEC to review the contractor's recent work on lunar mobility. A demonstration was given of their motorized Lunar Roving Vehicle and remote controlled driving facility.

A meeting was held with representatives from R-AS and several R&DO Laboratories to discuss the LRV SR&T requirements. NASA Headquarters has allocated approximately $1.4M for these SR&T programs from FY-69 funds. This Office is drafting preliminary task descriptions, with coordination through line divisions and RMO, for submittal to Headquarters for funding in CY-69. The submissions are due October 1, 1968.

Charles L. Barker, Jr.

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-68-9

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(September 1, 1968, Through September 30, 1968)

SATURN IB

Saturn IB System

Flow induced vibration testing has been successfully completed on all six S-IB flexible lines that were determined by analysis to require additional flow testing.

SATURN V

I. S-IC Stage

A meeting was held at Boeing, New Orleans, on August 22, 1968, to discuss the solution to the LOX tank lower cantilevered ring baffle cracking problem on S-IC-3 and subsequent vehicles. This problem was first discovered on S-IC-4 during fill and static firing operations at R-TEST. The baffle web was only .032 inches thick and during fast fill a 4-inch by 8-inch plug was knocked out just above the fill line. The web was replaced with a .040-inch web, which is the same as S-IC-1, 2, and 3. During the fast fill of S-IC-6, a 17-inch by 24-inch plug of the same baffle was knocked out.

II. S-II Stage

A. S-II Eagle Picher Batteries

North American Rockwell recommended that the AS-503 specification exceedance vibro-acoustic test be expanded to include an interstage Eagle Picher battery assembly. This test would flight certify the batteries for AS-503. The reason for this recommendation was the previously reported battery failure during qualification maintenance testing.

After evaluation, NAR submitted an engineering change proposal to isolate the batteries for AS-503 and subsequents, with no schedule impact on AS-503.

A meeting was called at the local North American Rockwell Office September 10 to discuss the NAR position on the S-II battery installation and failures. It was determined from this meeting that the qualification times and levels utilized in the qual-maintenance test incorporated both the requirements of the interstage and the 207 container. Since the time requirements for the interstage were 1 minute of high level random and 4 minutes of low level random, and the vibration failure occurred after 8 minutes of low level random in the final axis, the interstage installation is qualified. As was pointed out in the meeting, the doubtful installation is the 207 container. The Vibration and Acoustics Branch received the action to develop with NAR a hard-mounted specification for the 207 container installation. This specification will be higher than the levels to which the batteries are qualified; therefore, a retest will be necessary.

B. "A" Structures Test (402)

1. The cryogenic temperature service life cycling test (phase VB) was run August 26, 1968. The foam insulation cracked extensively on the S-IC and S-II cylinders. Inspection of the specimen after Phase V testing revealed an additional 64 cracks in the S-IC baffle webs. Two of these cracks were 54 inches in length each; these baffles were replaced by ME Laboratory and the remaining cracks in the baffles were stop drilled. All foam insulation was repaired.

2. The limit flight max $q\alpha$ condition (Phase VIA) was run September 5, 1968. The foam insulation again cracked extensively on the S-IC and S-II cylinders. Post inspection of the specimen revealed additional cracks in the S-IC baffle webs and outside and inside ring caps cracked in one location. Several crack-like indications were found by dye-penetrant inspection in the vertical weld of the S-IC cylinder. Surface indications were ground out and blended.

All repairs on the foam insulation and cracked baffles were completed September 17, 1968.

C. "B" Structure Test (401)

1. Forward Skirt Panel Splice Tests

NR successfully completed panel tests of the S-II-4 forward skirt quarter panel lower splice using Inconel radius block reinforcements. All specimens were subjected to an axial compression of 29,000 pounds (1780 lbs/in) and failed by increasing the normal load simulating hoop tension.

2. The installation of the S-II-10 forward skirt on the "B" structure was initiated on September 4. Three 2020 hat stringers have been replaced (No. 42, 43, and 100) resulting from damage that occurred when the skirt was dropped.

D. "C" Structure Test (403)

An assessment of the structural failure repair requirements were presented to R-P&VE by North American Rockwell. NR has assessed that to rework the structure to the pretest condition, in every detail, would require 31 weeks. They further stated that a "battleship" type patch-up could be accomplished in 4 weeks.

The 31-week plan is completely unacceptable from a cost and schedule standpoint. The 4-week "battleship" approach appeared to be too great a deviation from the flight configuration. The approach being employed is to repair the local areas of damage as near to the flight configuration as possible, thus accepting minor configuration deviations.

III. Instrument Unit

A. ST-124

Mechanical Impedance Tests were performed in the Structures Division Test Laboratory to evaluate the effects of applying structural damping compound (X-306) to the exterior surface of the instrument unit in the region of the ST-124 in lieu of the steel channels. This is a recommended modification for Saturn AS-505 and subs in order to minimize the acoustically induced vibrations at lift-off and eliminate the load peaking effect on the I.U. and SLA caused by the steel channels.

A baseline was established by performing point impedance tests on the I.U. without the damping compound.

Damping characteristics of the X-306 damping compound have been evaluated when installed on the outside surface of the Instrument Unit, opposite the ST-124. The results of this evaluation indicate that the external application of the X-306 is generally better than the internal application. This is due to the fact that the external application was thicker and was applied over a larger area. The external application was installed by IBM as it would be in the flight configuration.

B. I.U. Interface Capability - Engine Out Case

Test specimen 5 of the Saturn V IU upper interface engine-out panel series failed at 102% loading. Three loadings in excess of 100% have now been achieved, resulting in qualification of the IU upper interface for the engine-out condition.

IV. Saturn V System

A. Vibration Exceedances

A review of the IBM recommended revisions to the QAST program was accomplished. We concurred with the general proposal for any items which had been exposed to significant specification exceedances during AS-501 and AS-502 flights. The determination of specific components to be rescheduled in the QAST program is the responsibility of the contractor and the cognizant design laboratory. This branch will support that effort in the definition of criteria and data evaluation and comparison.

B. Short Stack Static Test - Wyle (SSST)

1. Axial load calibration (influence) testing was completed September 21, 1968.

2. Side load and bending moment influence testing was completed Monday, September 23 at 5:45 a.m. 100% side load and aerodynamic load was applied successfully. Data received was good quality and the expected trends were seen.

3. The max "q α " 130% load test was started September 25 at 12:00 noon. 100% load level was reached with no structural problems. Several automatic aborts occurred at the 80% level due to tight tolerances on the service module load system. The tolerances were opened to ± 10% variation and testing continued. Another abort occurred between 100% and 110% due to pressure switch tolerances. All pressure switches were checked to assure proper tolerances to avoid further aborts. Testing was successfully completed about 1:30 a.m. September 26th. The data was of good quality and appeared to be nearly as predicted.

Presently the structure is being prepared for the 130% cut off case. The changeover from max q α to cut off requires removal of the air bags and reorientation of hydraulic cylinders and deflection indicator systems. Testing should resume approximately the 2nd of October.

C. AS-503 D-Mission

Critical peak wind velocities at the 60 foot level for the AS-503 D-mission vehicle have been determined for a variety of propellant loading conditions as specified by I-MO. Data contained in the two reports, although based upon the D-mission, is also applicable to the C prime mission as presently defined.

D. AS-505 through AS-510

Preliminary structural loads for maximum q and center engine cutoff conditions have been calculated for Saturn V vehicles AS-505 through AS-510. The data was generated as an aid in establishing guidelines for the S-II test program.

E. AS-511

Structural data was supplied to complete the definition of the AS-511 baseline vehicle and to enable the Boeing Company to continue the J-2S implementation contracts now in progress.

ENGINE

I. J-2 Engine

A. Start Bottles

The J-2 engine start bottles have been pointed out as a potential problem by the Boeing Company's fracture mechanics specialists in a review of pressure vessels installed on the Saturn vehicles. The J-2 engine start bottles on the S-II and S-IVB were manufactured by two suppliers: Airite and NR of Columbus, Ohio; the Airite bottles were proof pressurized to 1800 psi at room temperature and have the following fracture mechanics - guaranteed full pressure cycles remaining: S-II/503 - 12 cycles; S-IVB/205 - 20 cycles. Some on the NR Columbus bottles were proof pressurized to 1400 psi (The maximum operating pressure is also 1400 psi) and have a fracture mechanics-guaranteed life cycle of zero cycles. One of these NR Columbus bottles is installed on S-II/503. If the fracture mechanics considerations are to be met, the NR Columbus bottle must be removed from the vehicle.

B. J-2 Engine Vibration Measurements

As a result of data obtained during the static firing of S-II-5, it is necessary to lower the calibration ranges of the J-2 engine vibration measurements on the S-II and S-IVB stages. This change is considered mandatory.

On September 16, Mr. J. H. Farrow held a meeting at Los Angeles with personnel of North American Space Division and Rocketdyne. Agreement was reached that the ranges for measurements on the S-II engines specified in memorandum R-P&VE-DIR-68-614 to Colonel James were proper and should be implemented prior to AS-503 flight.

A meeting was held on September 17 at Los Angeles by Mr. Farrow with personnel of Rocketdyne and McDonnell Douglas Corporation to discuss J-2 engine vibration measurement ranges on the S-IVB. The MDC personnel insisted and Mr. Farrow concurred that establishment of new ranges should be delayed pending review of the S-IVB battleship static firing data. Instrumentation personnel at MDC assured Mr. Farrow that the range changes could be made on-board at KSC with no significant impact on manhours or schedules.

C. Flexible Lines

Personnel from the Vibration and Acoustics Branch visited Rocketdyne, Canoga Park, California to review with Rocketdyne engineers the flex line analyses which were used to determine which flex lines on the Saturn System engines required testing for flow induced vibration. It was determined from this review that Rocketdyne's method of analysis, although conservative, was acceptable.

I. Apollo Telescope Mount

A. ECS Pump Package

Testing and data analysis of the Apollo Block I ECS pump package assembly have been completed. The purpose of the test was to evaluate the effects of coolant pump operation on the ATM experiment by the use of dynamic force gages, and from published test information on the assembly. This pump has basic operational characteristics similar to the one being modified for use on the flight ATM, however, the position and number of motors are different. Therefore, the test setup was designed to secure representative pump data from the use of one pump motor. This data can then be extrapolated to the flight configuration, to obtain an estimation of the actual installation forces. Tests were accomplished in the Propulsion Division Test Facility, with support by the Vibration and Acoustics Branch. Preliminary results show a sinusoidal forcing function of 1 - $1\frac{1}{2}$ pounds peak at 340 cps caused by eccentricities in the pump assembly.

B. Rack Test Facility

A decision was made to forego modification of the experimental drive bar assembly and to perform additional designs for modifying all presently used drive bar assemblies for use on both horizontal and vertical test fixtures. The new designs will utilize as much of the existing hardware as possible to facilitate manufacture cost and test schedules.

Clearance studies of the Rack and test fixtures and design modifications to the test fixtures are being made. Manufacture of the fixture modifications are progressing satisfactorily.

II. Multiple Docking Adapater (MDA)

A. Test Article - Flight Configuration

The MDA structural test article and the new MDA flight configuration were modeled to determine peaking stress value and average stress differences. The new configuration shows a peaking value of 1.91 compared to 1.64 for the test article. The average stress in the new configuration is 13 percent higher than the average stress in the test article. Because of these differences, the test article could not be used to structurally qualify the new flight configuration.

B. Docking Ports

An updated layout of the clearance between the MDA docking port cover and the SLA was completed. The layout depicted a metallic cover deployed by the means of an expansion joint. A clearance of only 0.58 inches between the cover and the inside skin of the SLA was calculated at the closest point when the cover is fully retracted to the flight position.

An alternate MDA pressure hatch seal material, as recommended by the Materials Division, will be procured for use in the development phase of the MDA pressure hatch testing. Both the original silicone rubber seal and the alternate material will be tested.

III. Solar Array

Drawings have been prepared for a dynamic test specimen of the solar array. This specimen consists of 3 panels with the latest size modules. Testing will be conducted with the panels in the stowed position and the flight type cinching mechanism employed.

The reduction in the number of panels from 14 to 10, provided additional space near the S-IVB. With additional space available, a new concept was generated for the cinching mechanism. This concept employs 5 beams across the stacked array. Only one pyrotechnic device is needed per array for releasing the cinching device. Further study is being made to reduce the pyrotechnic devices from one per array to one per wing.

IV. Skin-Stringer Shroud

An acoustic transmission loss evaluation test utilizing a 36" X 36" cylinder has been completed. The objective of the test was to determine the noise reduction properties of a helium-purged cylinder as compared to the same cylinder containing air. The data has been partially evaluated and preliminary results indicate that as much as 12 dB overall noise reduction may be attainable. This amount of noise reduction is primarily in the frequency range where the internal acoustic level of the proposed MSFC skin-stringer shroud is predicted to exceed the internal acoustic levels of the present honeycomb SLA configuration, hence preliminary evaluations indicate that helium purging of the payload region may be a satisfactory partial solution to the problem.

The second phase of the experimental program to determine the noise reduction properties of a helium-purged/polyurethane foam lined cylinder began this week. The 36" X 36" cylindrical test specimen has been coated on the inside with polyuethane foam 1" thick, and will be subjected to acoustic tests in the Structures Division acoustic test facility.

V. Multi-Layer Insulation Test

A rocket sled test was successfully completed at Holloman Air Force Base September 19, 1968. The sled and insulation were visually inspected, as far as possible, after the test run with no apparent problems. The insulated tank specimen will be returned to ME Laboratory at MSFC for careful inspection. Preliminary evaluation of the data indicates that all test parameters (acceleration, vibration, acoustic SPL, and velocity) were met or slightly exceeded. Data slice times were chosen for a more detailed study. The results of this study should be available within 60 days.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-M-68-9

(September 1, 1968, Through September 30, 1968)

SATURN V

I. S-IC Stage

A. Evaluation of Commercial Adhesives

Investigations have continued as outlined below to develop, modify, or evaluate high performance adhesives, primers, and techniques for their use in fabrication of Saturn V stages.

1. Evaluation of Stafoam AA-1802 Primer Under High Humidity Conditions

As reported last month, Stafoam AA-1802 in a 25 percent solution in methyl ethyl ketone (MEK) is being evaluated under 100 percent relative humidity aging conditions as a primer for Narmco 7343 adhesive. The following five series of aluminum lapshear tensile specimens were prepared:

a. Primed with Stafoam and bonded with Narmco 7343 without additives.

b. Primed with Stafoam and bonded with Narmco 7343 containing 1 percent Z-6040.

c. Primed with Stafoam containing 0.2 percent Z-6040 and bonded with Narmco 7343 containing 1 percent Z-6040.

d. Unprimed adherends bonded with Narmco 7343 containing 1 percent Z-6040.

e. Unprimed adherends bonded with Narmco 7343 without additives. Test results at room temperature on samples stored at 100 percent relative humidity at 70°F (21°C) for 60 days indicated that specimens of series a, primed with Stafoam and employing no additive best withstood the effects of moisture. Specimens from series b and c maintained their strength during the second 30 day period after a large drop in strength during the first 30 days of exposure to elevated humidity. Specimens of series d and e, each unprimed, decreased drastically in bond strength during the sixty days of exposure to elevated humidity.

These results are compromised to some extent by the unexplicably low values obtained for the unprimed samples with Z-6040 in the adhesive mix; therefore, further samples have been prepared and are under investigation.

2. Evaluation of Effects of Methanol-Water on Bond Strength of AF-32 Adhesive

Aluminum lapshear tensile and T-peel specimens prepared from AF-32 nitrilephenolic film adhesive have been stored under methanol-water solution (80 percent by weight methanol) for a period of 16 weeks, with samples withdrawn for room temperature testing at selected intervals.

Strengths of AF-32 Bonded Aluminum Specimens Aged in Methanol-Water

	Zero Initial Control	Weeks Aging 1	2	4	6	8	10	12	16
Lapshear (psi)	2576	2344	2350	2402	2304	2152	1946	1628	1694
T-Peel (piw)		27.8	13.8	21.9	25.5	20.4	22.0	14.6	23.6

Control series stored 16 weeks under ambient laboratory conditions gave: Lapshear - 2602 psi; T-peel - 29.0 psi. Lapshear results indicate an apparent strength deterioration during 16 weeks aging under methanol-water. These tests are programmed for a total of 24 months.

3. Evaluation of Liquid FM-47 Phenolic Adhesive as a Primer for HT-424

Investigation of the manufacturing procedure employed by North American Rockwell (NR) on Spacecraft/LEM Adapter (SLA) panels verified that the contractor was using FM-47 adhesive as a primer for aluminum sheets and core that were bonded with HT-424. The adhesive manufacturer recommends using HT-424 over a temperature range of -423°F to +500°F (-253°C to 260°C) and for FM-47 a temperature range of -400°F to +225°F (-240°C to 107°C). Test data presented by the manufacturer show a drastic decrease in strength for the FM-47 adhesive at a temperature of around 200-225°F (93°C to 107°C). The NR specification for FM-47 primer - HT-424 adhesive systems states that the system is usable over a temperature range of -300°F to +500°F (-184°C to 260°C). To support this conclusion, NR presented a curve showing lapshear strengths over this temperature range that surprisingly compared favorably with that obtained with HT-424 primer - HT-424 adhesive.

A program was initiated to check the FM-47 primer - HT-424 adhesive combination. Three series of lapshear, flatwise tensile, and climbing drum peel samples were prepared. In one of the series the aluminum surfaces were primed with FM-47. In the second series, a double thickness of FM-47 was used, and in the third series HT-424 primer was employed. The samples were then bonded with HT-424 per the NR-SLA specification, MA0606-012C, "Adhesive Bonding, Apollo Space Vehicle Honeycomb Structure, for -300°F to 500°F Usage." Initial lapshear test results at -300°F (-184°C), room temperature, and +350°F (177°C) showed essentially the same strengths at room temperature, a slight preference for the HT-424 primer at -300°F (-184°C), and a marked decrease in strength for FM-47 primed samples at +350°F (177°C) (1910 psi, 1190 psi, and 620 psi for the HT-424, FM-47, and double coated FM-47 primed samples, respectively). These data do not agree with those furnished by NR. Additional tests are being run for verification.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

1. Development of Conformal Coatings

Efforts are continuing to develop the saturated, hydroxyl-terminated, hydrocarbon prepolymer precursors to urethane-type printed circuit board coatings. An assay has been obtained on the quality of hydrocarbon prepolymer supplied by General Tire and Rubber Company. The material is approximately 65 percent difunctional, with the remainder consisting of 30 percent monofunctional and 5 percent non-functional fractions. A sample of the polymer has been ordered which is to be purified by column chromatography to assay at least 96 percent difunctional product. Experiments can thus be carried out to determine if the prepolymer should be optimized with respect to functionality in order to reflect the most desirable conformal coating properties.

2. Development of Ceramic Potting Materials

Discussions concerning the requirements for ceramic potting materials were held with personnel of Astrionics Laboratory. There is considerable interest in ceramic potting compounds as materials capable of meeting the requirements of the proposed specification for materials in a gaseous oxygen environment and as a method of reducing cordwood module failures caused by the high coefficient of thermal expansion of organic potting materials.

A program to investigate the potential and problems of ceramic potting materials was arranged with Astrionics Laboratory (R-ASTR-PR). R-ASTR-PR will investigate the use of ceramic block potting using holes drilled in the block to accommodate the cordwood components. The components will be potted into the ceramic block with an organic potting compound during module assembly. This division will provide materials consultation and assist in the interpretation of test results and in failure analysis of these modules. Additional investigations will include the use of castable ceramic potting compounds in cordwood modules to be supplied by R-ASTR-PR. The evaluation of the modules using castable compounds will be a cooperative effort.

The initial experimental work has been directed toward the evaluation of the problems involved in casting appropriately sized pieces of the potting material, using the commercially available compounds previously evaluated for selected electrical properties. Casting in larger sections does not appear to cause any problems with the two Sauereisen materials tried. Casting in a cordwood module will be tried next. A limited amount of effort has been expended on the development of experimental magnesium oxychloride and magnesium oxysulfate bonded castable compounds.

C. Investigation of Cracking of S-IC Stage Ring Baffles

Failure analysis was completed of the fragments of 7079-T6 aluminum slosh baffle from S-IC-506. The failure is believed to have occurred during high rate LOX fill prior to static firing. Failure analysis revealed 5 initiation sites - precracks were found at each initiation site. Evidence of stress corrosion cracking was shown by both fractographic and metallographic examinations. The conclusion was made that the impinging LOX propagated fracture from each of the five precracks. The Boeing Company's fix is to use 0.063 inch thick 6061-T6 aluminum sheet with mechanical attached stiffeners for the baffles in the area of the LOX fill inlet.

II. Contract Research

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

A. Polymer Research, Development, and Testing

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

B. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

C. Nondestructive Testing Techniques

North American Rockwell, NAS8-20764

III. S-II Stage

A. Evaluation of Corrosion Characteristics of 2014-T651 Aluminum Tank Materials

The results of tests to determine the susceptibility of 2014-T651 (-021 and -063 material) to stress corrosion cracking in the alternate immersion tester have been reported previously. Outdoor exposure of both

-021 and -063 materials has been in process for 155 days. Specimens in this test are stressed to 40 ksi in the short transverse grain direction. To date one out of five specimens of the MB0170-021 material has failed while 28 of 30 specimens made from the MB0170-063 material have failed. In a re-test of various MB0170-021 plates, specimens were fabricated in the short transverse grain direction, stressed to 25 and 40 ksi and exposed to the outside environment. These tests have been in progress for 69 days with the following results: one specimen from Alcoa plate number 695-462, loaded to 40 ksi, failed in 14 days; one specimen from Reynolds plate number BG50305-2, loaded to 40 ksi failed in 42 days; two specimens from Reynolds plate number BG5036-01, one loaded at 25 ksi failed in four days and one loaded at 40 ksi failed in 52 days. No failures have been encountered on specimens made from Kaiser plate number 605581. The total test program consists of four plates, one each from Alcoa and Kaiser and two from Reynolds.

Because of the severe corrosion encountered in the alternate immersion tester and to verify the results obtained, stress corrosion tests were initiated in synthetic seawater and in a one percent NaCl - 2 percent $K_2Cr_2O_7$ solution at pH 4 and 140°F (60°C). Round tensile specimens (1/8 inch and 1/4 inch diameter) made from -021 , -063, original Reynolds material, and plate from Kaiser and Alcoa were stressed in the short transverse grain direction to 5 and 10 ksi and exposed to the two solutions. After three weeks of exposure, the NaCl - $K_2Cr_2O_7$ test was terminated. Expected results were not obtained and this solution does not appear to be effective for evaluating this alloy at the low stress levels of 5 and 10 ksi. Specimens exposed in synthetic seawater are continuing with the -021 being the only material not having failed after 31 days of exposure. An evaluation is also being made as to the effect of etching specimens in a 5 percent NaOH solution at 170°F for 30 seconds versus just solvent cleaning before stressing.

B. Investigation of Fracture Toughness

Investigations have continued on the study of the fracture toughness characteristics of aluminum alloys.

1. Techniques have been established to fly cut starter cracks for surface crack specimens with a root radius of 0.001 - 0.002 inch. Cutters of a 1 inch and 1-1/2 inch in diameter have been fabricated.

2. Larger surface crack specimens (6 inches wide) have been machined from the 5456 - H343/5356 - MIG repair welds representative of S-IB tank material. Compact-crackline-loaded specimens fabricated from 2014-T651, 2021-T8E31, and 7007-T6E136 have been precracked and are available for testing at room temperature, -320°F (-196°C), and -423°F (-253°C) temperatures.

3. The final report on the special studies program with The Boeing Company (TBC) to develop fracture toughness data on the 6Al-4V titanium J-2 engine gaseous hydrogen start bottle material has been received. The essential changes in this report include an appendix

defining the analysis procedure for a typical start bottle from the raw data and a life cycle change from 23 to 36 cycles for parent metal. An analysis of the TBC data indicates that the parent metal in either start bottle (Airite or NR Columbus) has 70 life cycles at 1400 psi and -200°F (93°C) temperature prior to failure.

4. Raw data have been received in tabular form from North American Rockwell personnel on their fracture toughness program to evaluate 2014-T6 welds representative of S-II tank material, proof, and operating conditions. However, establishment of the required proof factor from the data cannot be made until additional data are generated.

C. Investigation of Nondestructive Techniques for Inspection of Composite Materials

Methods and instrumentation required for the nondestructive evaluation of debonds and voids in spray foam aluminum composite insulation of the type and configuration used on the S-II stage have been developed. All of the single side and through transmission audio frequency methods developed are satisfactory for laboratory testing of Nopco BX-250 polyurethane foam aluminum composites. A through transmission eddy current technique is recommended for field type testing. This can be done by making as many spot checks of the insulation as required.

D. Investigation of Nondestructive Techniques for Inspection of Inert Gas Welds

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

Aluminum 2014-T6 weldments 0.392 inches thick have been nondestructively evaluated with radiography, several ultrasonic techniques, and with dye penetrants. Destructive tests have been made to determine details of the total defect content of the weldments. The welds have been dissected in ten mil increments, etched and examined under a fifteen power microscope. All of the data are being evaluated and subsequently will be described in a status report.

E. Investigation of Failure of S-II "C" Stage Structure

Failure analysis was completed on the latest "C" structure failed components (stringers 122 and 124 and the adjoining ring frame). No metallurgical irregularities were found. Failure was attributed to overload since mechanical tests indicated that the subject materials met specifications.

F. Investigation of Corrosion Under Insulation on Tank Walls of S-II Stages

Because of the discovery of debonded foam insulation blocks on S-II-503, 504, and 505 and the observation of corrosion on the aluminum skin under the debonded blocks a study was initiated to evaluate methods for bonding foam block to the bolting ring and number 1 cylinder of S-II stages. This study included an evaluation of primers for use with pour foam on the feedlines.

The following 8 primer systems were evaluated, with and without pour foam on the test specimens, for corrosion protection in salt spray.

1. Primer M (2 coats)
2. Diluted Lefkoweld 109 (2 coats)
3. Primer M (2 coats) plus thin coat 7343 adhesive (cured 2-4 hours)
4. Diluted 7343 with 1 percent Z-6040 (2 coats) cured 12-24 hours
5. Diluted C-1 epoxy/E hardener (2 coats)
6. Diluted Lefkoweld 109 (2 coats) plus primer M (2 coats)
7. Primer M (2 coats) plus thin coat 7343 adhesive (cured 12-24 hours)
8. Primer Z-6020 (2 coats).

In the instance of specimens without pour foam, heavy corrosion was encountered for the Z-6020 primed sample and medium corrosion for diluted Lefkoweld primed samples. The C-1 epoxy primed samples were sticky (apparently incompletely cured) and accordingly were not tested. The other five samples yielded acceptable corrosion protection. For the specimens with pour foam over the primers, corrosion was encountered on all specimens using 7343. Corrosion was also present on the C-1 epoxy-primed samples. One of four samples primed with both Lefkoweld 109 and Primer M showed corrosion. The Z-6020 primed sample showed corrosion only around the edges.

Pour foam blocks were bonded to aluminum surfaces that were cleaned both by abraiding and by acid etching. One set of the samples was primed with Primer M and the blocks were bonded on with 7343 plus scrim cloth. A second set of samples was primed with dilute Lefkoweld 109 and the blocks were bonded on with Lefkoweld 109 plus scrim cloth. The third set of samples was primed with Z-6020, and the blocks were bonded on with 7343 containing 1 percent Z-6040 plus scrim cloth. Salt spray tests on the above samples yielded no corrosion.

G. Investigation of Failure of S-II Stage "A" Structure

A 7079-T6 slosh baffle and the supporting inboard and outboard 7079-T6 ring caps in the S-II "A" structure were found fractured during post liquid hydrogen fill inspection at the Test Laboratory. Photographic documentation was made of the components in place. The slosh baffle was removed from the test structure which consists of portions of an S-II stage joined to a segment of an S-IC LOX tank. The fracture surfaces of the failed ring caps were not removed since doublers will be installed on the caps for subsequent testing. Visual inspection of the fractured cap indicated an overload mechanism. Preliminary investigation of the failed slosh baffle indicates that the fractures initiated in the area of the failed ring cap attachment. No known precracks existed near the failure initiation site at the outboard position; however, several precracks had been stop drilled near the inboard area of initiation. Further studies will be made on these parts. The latest slosh baffle received from the "A" structure makes a total of five removed from the test structure. All contained cracks ranging from 1/2 inch to about 3 feet.

H. S-II Stage Project Management, Materials

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

1. Investigation of Insulation Problems

a. Insulation Debonding at Bolting Ring and Cylinder No. 1

During a helium purge pressure check at the John F. Kennedy Space Center the S-II-503 stage sustained debonds at the tank sidewall of several pour foam insulation blocks at cylinder No. 1. The stage contractor (NR/SD) has initiated a program designed to define the source of the problem and to prove that the accepted fix will be structurally adequate to accomplish its function through launch.

Basically, the program entails testing of dog-bone specimens, prepared like the bolting ring/cylinder No. 1 insulation, and a proof pressure check of the stage fix. In the interim, this laboratory has recommended a repair procedure for replacing the previously removed insulation blocks.

b. Feedline Elbow Insulation/Corrosion

Investigations have continued by the stage contractors in an attempt to fully define the problem associated with corrosion observed under the insulation on feedline elbows and to develop means of preventing this corrosion on future stages. Preliminary results of these studies indicate that specimens coated with primer M on the bare aluminum and spray foam insulation corrode more than a pour foam insulated specimen. Also, humidity tests (95 percent relative humidity and 120°F (49°C)) cause more severe corrosion than standard salt spray tests.

Several primer materials other than the primer M are being evaluated. The criterion for acceptance of a primer is its corrosion resistance and adhesion to the aluminum as well as the foam insulation.

c. Investigation of Cork Insulation for Hot Spots on the S-II Stage

Sufficient information on the erosion of spray foam insulation at protuberances was not obtained with the limited number of flights on the X-15 aircraft to provide assurance that erosion would not be a problem on the S-II stage. Accordingly, this Center accepted the stage contractor's proposed cork insulation plan. Details of the design application have not been prepared, but it has been mutually agreed that the contractor and this Center would work closely on this phase of the work to resolve the matter in time to support S-II-506 at Mississippi Test Facility.

IV. S-IVB Stage

A. Evaluation of Korotherm 793-009 Insulation

The Korotherm insulation system presently used on the S-IVB stage is being subjected to vacuum compatibility evaluation. The materials of this system - zinc chromate and FR primers, Korotherm, white epoxy paint, Dow-Corning DC 92-009, and DC 93-044 - will be tested as individual materials and as materials in typical composite coating build-ups. The composite specimens will be tested after appropriate cure only and after cure plus exposure to the simulated aerodynamic environment of S-IVB ascent. Samples of certain of these individual materials have been prepared and submitted for vacuum compatibility evaluation.

B. S-IVB Stage, Project Management

Efforts have continued on 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. Korotherm Insulation

In a stage contractor presentation, it was concluded that the Korotherm insulation on S-IVB-503 is suitable for the flight regime provided that the feedline fairing is changed to reduce ascent heating downstream of the fairing. The configuration change was a minor one; thus, it was approved for S-IVB-503. This division concurred with the stage contractor that the Korotherm insulation problems have been solved for S-IVB-503.

2. Interface Bolts and Nuts

a. Bolts of H-11 alloy at 220 ksi having a cadmium fluoborate coating per NAS-672 were used at the interfaces of (1) aft interstage to aft skirt, (2) aft skirt to LH_2 tank, and (3) LH_2 tank to forward skirt. These bolts are susceptible to stress corrosion cracking; thus, they have been replaced with H-11 bolts at 220 ksi with a nickel-cadmium diffusion coating per AMS-2416. This change is effective with S-IVB-205 and subsequent stages and S-IVB-503 and subsequent stages.

b. Nuts of H-11 steel treated to a strength level of 220 ksi (identified as FN-22) are used with the bolts discussed above. The Navy has reported failures of the same nuts in a different size reportedly due to diffusion of cadmium into the parent metal. An investigation of the manufacturing process revealed that failures in the nuts used on the S-IVB stage could not be induced by this mechanism.

3. Investigation of Failure of LOX Vent and Relief Valve Bellows

High lead solder was being tested on a flight type bellows to qualify the high lead solder as a replacement for the 60/40 solder which is not compatible with liquid oxygen (LOX). One of the bellows failed during this testing program. An analysis of the failure attributed the cause to the soldering operation but not to the type of solder. The condition which caused this failure could possibly exist in any of the S-IVB stages. Thus, the stage manager was asked to require the stage contractor to certify that such a condition does not exist in any of the S-IVB stages.

4. Investigation of Vacuum Pump Oil Change

In ECP 3018, the McDonnell Douglas Corporation (MDC) proposed to change the oil in the pump used in evacuating the common bulkhead from the LOX incompatible Kinlube 220 oil which had been used since early in the S-IV program to a LOX compatible oil, "Hooker Chemical Company S-30," and to run pump tests with the new oil to ensure compatibility between the two. During AS-205 CDDT, the pump with the new oil malfunctioned; thus, it was replaced with a pump having the old oil and the CDDT was resumed.

Revision 1 to the stated ECP has been received from MDC rescinding the ECP 3018 proposal.

5. Investigation of Galvanic Corrosion of Ambient Helium Bottle Hardware

Corrosion was found on S-IVB-503 between the ambient helium bottle and the pad which separates the bottle from the hold-down strap. This division recommended a change of pad material from aluminum to stainless steel. An ECR, BC4M-082, was issued requesting this change. CCBD-304-8-0343 disapproved the ECR stating that, "KSC will be requested to direct MDC to inspect 205, 503, and 504 at KSC. Disposition for subsequent stages will be in accordance with the results of the galvanic corrosion survey to be conducted by MDC as required in P&VE memorandum R-P&VE-X-68-210, dated August 29, 1968."

6. Investigation of APS Engine Pressure Decay

The problem of engine pressure decay in the Auxiliary Propulsion System (APS) was caused by contamination of propellant orifices during burp firings under sea level conditions. This problem has been eliminated by deleting burp firing requirements of the engines at the John F. Kennedy Space Center.

7. The following documents were reviewed:

a. Marquardt Process and Materials Specifications for the WACS Propellant Isolation Valve

b. MSFC Drawing A20M042244, "Motor Driven Vaneaxial Fan, Specification for"

c. Bell Documents for WACS Applications (Drawing No. 8551-478001 and Specification No. 8551-947001)

d. MDC 1T10820A, "Development Test, Vacuum Valve Assembly, Saturn I Workshop"

e. Mission Requirements Document for AAP, MSC-KM-D-68-1.

V. Instrument Unit

Investigation of Corrosion Susceptibility of Instrument Unit Cooling System Materials

Tests are in process to determine the amount of hydrogen evolved from exposure of the various materials in the environmental control system of the Instrument Unit to the methanol-water coolant. The hydrogen evolution is monitored by means of a mass spectrometer. Due to the time related nature of these tests no conclusive data are available at this time.

VI. J-2 Engine, Project Management, Materials

Investigation of Failure of J-2 Engine Electrical Connector

A failure on an electrical connector on fuel and liquid oxygen (LOX) bleed valves was reported by Rocketdyne. It was determined that this failure was due to an improperly made electron beam weld joint. Rocketdyne concluded that the joint could be assessed visually for adequacy and subsequently an inspection was made on 205 and 503 J-2 engines. It is our understanding that no defective welds were found. An apparently poor weld from a spare part is currently being examined by this division.

VII. F-1 Engine, Project Management, Materials

As a follow-up on information received from the Navy Department on hydrogen embrittlement of H-11 steel nuts, a check was made at Rocketdyne to determine if some failures that had been reported on the F-1 engine could be related. It was found that the F-1 failures were the same type of nut as those with which the Navy experienced failures. A review of the particular application by Rocketdyne and the possible consequences of nut failures was made, and it was concluded that a number of nuts would have to fail before the joint (fuel volute to fuel inlet) would leak. These H-11 nuts are installed on 503 but an ECP was issued for the use of A-286 material on 504 and subs.

VIII. Saturn I Workshop

A. Study of Flammability of Materials

Investigations have continued in the determination of the ease of ignition and flammability of various materials proposed or considered for use in the Saturn IB Workshop.

Thirty-two materials were evaluated for flammability in 6.2 psia oxygen by the procedures outlined in MSFC-SPEC-101. Included were a number of samples from Raymond Loewy Associates. These specimens consisted of Acrylonitrile-Butadiene-Styrene copolymers, polyvinylchloride, and polypropylene materials currently used in aircraft. Most of them burned vigorously. In making these tests, it was noted that the vertical method (top ignition) currently used for flame propagation rates suffers from a serious drawback - flaming debris ignites the bottom of the sample making accurate measurement of flame propagation rates difficult. Studies will be made in the future to determine the effect of horizontal ignition.

A flammability test in 6.2 psia oxygen was made on the post landing ventilation (PLV) fan 97-179 from AiResearch, Incorporated. The test was made by stalling the fan blades with a mechanical locking device, thereby causing the fan to overheat. After four hours, the temperature stabilized at 390°C with maximum current of 19 amps. The test was ended and the system opened for inspection. The fan would not turn and parts of the potting compound had exuded from the power inlet plate. The fan is being disassembled and evaluated to ascertain whether there were other effects caused by overheating.

Work has continued on setting up the test articles for the new tests using the induced draft blower system rather than the forced draft blower system used on previous tests. Test Laboratory has experienced some difficulty in obtaining consistent flow velocities with the test equipment. These tests will not be resumed until reproducible, known, air flow velocities are attained.

B. Investigation of Thermal Control Coatings for the Saturn I Workshop

Investigations have continued on the development and evaluation of formulation and application techniques for the HXW coatings described in previous reports. Previously, the formulation of the HXW coatings specified sodium silicate as the gelling agent. However, recent investigations have indicated that use of potassium silicate as the gelling agent will yield a smoother coating. Thus, current formulations are compounded with potassium silicate. It has been found that there is an added benefit attendant to the change in gelling agents. Specimens coated with formulations containing potassium silicate have been submerged in water for five days with no evidence of solubility or softening.

C. Investigations of the Optical Properties of Teflon

A study has been made on the optical properties of two types of Teflon. These included three and ten-mil TFE and five-mil FEP Teflon. The three-mil TFE Teflon is the type proposed for use on the exterior of the Saturn I Workshop. In order to have meaningful data, it was necessary to back the partially transparent Teflon with the same materials as on the Workshop stage. These were "Lockspray" gold and 3M No. 101-C10 black paint. By backing the Teflon, an effective absorptivity and effective emissivity could be determined. Data from this study are as follows:

Sample	Effective Absorptivity
TFE, 3 mil (black backing)	0.74
TFE, 3 mil (gold backing)	0.20
TFE, 10 mil (black backing)	0.67
TFE, 10 mil (gold backing)	0.19
FEP, 5 mil (black backing)	0.93
FEP, 5 mil (gold backing)	0.26
Lockspray Gold	0.25
3M 101-C10 Black Paint	0.98

	Effective Emissivity
TFE, 3 mil (black backing)	0.74
TFE, 3 mil (gold backing)	0.57
Lockspray Gold	0.03
3M 101-C10 Black Paint	0.83

D. Study of the Effect of Oxygen in Non-Metallic Materials in the Saturn I Workshop

Samples of non-metallic materials that are presently planned for use in the orbital workshop have been exposed in a high humidity 100 percent oxygen atmosphere since May 15, 1968. During this time an equivalent of about 5000 volume changes of oxygen have been used in the test. To date there are no visual evidences of microbial attack or growth on any of the specimens.

E. Investigation of Saturn I Workshop Fans

Environmental evaluations of Saturn I Workshop thermal control fans are being made with particular emphasis on life tests of the fan bearings. Several additional types of fans have been ordered for evaluation as a back-up to the present AiResearch fan.

Inspection of the failed bearings from one of the first Workshop fans tested indicated that the failure was a result of poor lubrication. It appeared that the selection of a metal crown type retainer and a silicone grease was the probable cause of the bearing failure. The failed bearings were replaced with bearings having sacrificial retainers and again lubricated with D.C. 33 grease. The repaired fan was tested for 1,000 hours in a 5 psia oxygen environment in the high speed mode (5,000 rpm) then it was stopped and soaked in vacuum for 336 hours and then re-run at 5 psi for an additional 197 hours. This test cycle was the same as for the original test where the AiResearch bearings failed. The bearing noise remained low and the fan efficiency high. After tests the fan was disassembled and a visual inspection of the bearings indicated that they were still in good operating condition even though the counterbalance on the opposite end from blade of armature was debonded. This was repaired and the fan is now being run at the low speed mode (3,480 rpm) in a 5 psia oxygen environment.

Two additional AiResearch fans are being tested in a 5 psia oxygen environment in the high speed mode. One fan motor has the sacrificial retainer bearings with Krytox 240 AB grease and one fan motor has steel retainer bearings with DuPont's Krytox 240 AB grease.

In addition to these tests back-up tests have started on one other type fan. A Joy Company a.c. fan is now operating at 3,000 rpm in a 5 psia oxygen environment. Also, various other simulated bearing tests are continuing with steel and sacrificial type retainers using various lubricants.

F. Evaluation of Saturn I Workshop Meteoroid Bumpers

Meteoroid impact simulation tests are continuing to determine the effectiveness of external foam insulation with a bonded bumper. The target configuration being tested is a 0.125 inch aluminum wall with either 1.0 or 0.75 inch of spray-on S-II type foam insulation. A 0.020 inch aluminum bumper is bonded directly to the foam.

Several targets with each thickness of foam have been tested in an effort to determine the penetration threshold. Only the two tests closest to threshold will be discussed. A target with 1.0 inch of foam was just penetrated by a 0.125 inch diameter, 0.048 gram sphere of 1100-0 aluminum traveling at 6.44 km/sec (21,100 ft/sec) while at 0.75 inch foam target was not penetrated by an identical projectile traveling at a slightly lower velocity of 6.36 km/sec (20,900 ft/sec). This preliminary data indicates that the penetration threshold for this projectile is approximately 6.40 km/sec (21,000 ft/sec). Additionally, it appears that the thickness of the foam between the bumper and wall does not affect the penetration threshold appreciably. Further tests with this configuration and also with the bumper increased to a thickness of 0.025 inch are planned.

G. Investigation of the Effects of Ice on Deployment of Workshop Meteoroid Bumper

It is presently planned to hold the bumper wall on the tank side wall prior to and during flight, and then extend the bumper in outer space. The design does not prevent the possibility of water condensing or otherwise getting into the area between the tank wall and the bumper. When the tank is filled with liquid hydrogen, any water present will freeze and tend to bond the bumper to the tank wall. This will inhibit the deployment of the bumper wall in outer space for as long as the ice accumulation persists. To get some idea of the bond strengths that may be encountered, gold coated Kapton film was first bonded to aluminum adherends. Water was then frozen between the sandwiched gold coated surfaces. Tests at -300°F (-184°C) showed lapshear bond strengths of ice to aluminum of 208 psi and to the gold surfaces of 57 psi. The gold surfaces were very difficult to wet, and the 5 test samples varied in strength from 22 to 108 psi. It is concluded that ice could be a significant impairment to the shield deployment mechanism.

H. Study of Effect of Oxygen on Non-Metallic Materials in the Saturn IB Workshop

Corrosion studies of various aluminum alloys in gaseous oxygen and under high humidity have been discontinued after approximately five months of exposure. With the exception of bare 2014-T6 and 7075-T6 alloys, very little changes were noted on other bare alloys (6061, 1100), and both Alodine 1200 and Alodine 407-47 coatings on all alloys in a 100 percent oxygen environment at room temperature and approximately 100 percent humidity. Samples exposed to a 95 percent relative humidity and 100°F atmospheric test chamber for the same time have, in general, shown much more serious effects. The bare 2014-T6 and 7075-T6 are covered with heavy corrosion deposits and the coated 2014-T6 samples have several small corroded and pitted spots. Lesser effects were noted on the other samples. A test chamber has been ordered for evaluation of materials in an oxygen environment while under various temperature, humidity and reduced pressure conditions. This work will be continued when the test chamber is received.

IX. Multiple Docking Adapter (MDA)

Investigation of Resistance to Micrometeoroid Penetration of the Multiple Docking Adapter (MDA)

Meteoroid impact tests are continuing on the MDA bumper and super insulation configuration as supplied by the Structures Division. The penetration threshold velocity for a 0.190 gram spherical projectile of 7075-T6 aluminum has been determined. This projectile did not penetrate the target at 5.80 km/sec (19,000 ft/sec) but it did penetrate at 5.92 km/sec (19,400 ft/sec). This places the penetration threshold for a 0.190 gram projectile at approximately 5.85 km/sec (19,200 ft/sec). This data pinpoints one point on the velocity vs. mass curve for the penetration resistance of this target. To further specify this curve, tests are planned at higher velocities and lower masses. When this curve is determined extrapolation to the higher velocities associated with meteoroids will be possible.

The meteoroid impact simulation tests on possible design configurations for the MDA electrical cable tunnel as requested by R-P&VE-S are continuing. Testing is now devoted to determining the effectiveness of a double bumper configuration in protecting the cable. The specific design tested this month was an outer bumper of 0.020 inch aluminum separated from a second bumper of 0.070 inch aluminum by 2 inches. The projectile used was a 0.125 inch diameter 0.048 gram sphere of 1100-0 aluminum. It was found that this projectile traveling at 7.20 km/sec (23,600 ft/sec) would just penetrate the second bumper. However, even at a lower velocity of 6.65 km/sec (21,800 ft/sec) the back surface of the second bumper spalls considerably. A velocity of 6.44 km/sec (21,100 ft/sec) is the point of incipient spall. Further tests are planned in which the thickness of the second sheet will be reduced.

X. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

Evaluation of potential materials for use on the Apollo Telescope Mount (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°C (77°F) to 100°C (212°F) which does not exceed 0.2 percent/cm^2/hr.

1. Materials Test

The outgassing characteristics of fifteen materials were evaluated in vacuum, 10^{-7} torr, to 100°C (212°F) by making continuous weight loss determinations and periodic mass scans on each material. Test results are summarized in the following paragraphs.

The outgassing characteristics of three General Electric silicone rubbers, #5211, #525, and #517, were evaluated and found to be acceptable for use on the ATM.

Krytox 240 AB_2 fluorinated grease was examined and found to have a 0.76 percent/cm^2/hr maximum rate of weight loss at 50°C (122°F). The test was terminated after 30 hours with the material continuing to lose weight at a maximum temperature of 50°C (122°F). The steady rate of weight loss over a 4-hour period at 50°C (122°F) was 0.38 percent/cm^2/hr.

Two samples of vinyl chromate primer, #31-C-6, with different cure cycles were evaluated and showed a maximum rate of weight loss more than twice the acceptable value for ATM use. These materials also continued to lose weight when the test was terminated.

Korotherm, a subliming material, hexamethlene tetradenine in an epoxy binder, was heated to 100°C (212°F) in vacuum (10^{-6} torr) for 25 hours. This material is very unstable under these conditions as would be expected. It yielded maximum rates of weight loss of 1.17 percent/cm^2/hr at 50°C (122°F) and 1.25 percent/cm^2/hr at 100°C (212°F).

A sample of FR primer (epoxy base) was evaluated over an 8-hour period to 100°C (212°F). This material is unacceptable with maximum rate loss of 0.72 percent/cm^2/hr which occurred in going from 50°C (122°F) to 100°C (212°F).

Isochen Resin #1251 with #8 catalyst is very stable in vacuum at 100°C (212°F). This material only exhibited a maximum rate of weight loss of 0.14 percent/cm^2/hr and is therefore acceptable for ATM use.

A sample of Nopco polyurethane foam #54R46T, density 8 lbs/ft^3, was evaluated for outgassing characteristics at 100°C (212°F) and 150°C (302°F). This material is unacceptable with maximum rates of weight loss of 0.37 percent/cm^2/hr at 100°C (212°F) and 0.23 percent/cm^2/hr at 150°C (302°F). The decrease in rate of weight loss at the higher temperature can be attributed to most of the blowing agent being removed at a lower temperature.

Biggs epoxy adhesive #R-313, air cured for 5 days, is unacceptable for ATM use. The maximum rate of weight loss was 1.14 percent/cm^2/hr.

Dow Corning Silastic 882 was evaluated for outgassing after an air cure for 15 days. This material is unacceptable with a maximum rate of weight loss of 0.24 percent/cm^2/hr. Although the material is unacceptable according to the test criteria, the Silastic 882 is marginal and may find restricted application.

Three RTV silicone rubbers were tested and found to be unacceptable. RTV-757 air cured for 45 days, RTV with 0.1 percent T-12 catalyst air cured for 53 days and RTV-7 silicone foam rubber air cured for 45 days.

2. Component Test

a. Fafnir Bearings

Three types of Fafnir sleeve bearings for the ATM solar array panel were evaluated for outgassing in vacuum. These sleeve bearings were lined with a bonded plastic laminated sleeve. The test environment for these bearings was a reduced pressure of the order of 10^{-7} torr and temperature ranging from ambient to 100°C (212°F). Mass spectral scans were taken periodically of the outgassing products of these bearings. Test data indicated that products could be evolved from these bearings of atomic mass units as high as 216. However, the tests showed that the outgassing was attenuated with time under the conditions of test.

It is recommended that these three bearings be subjected to a thermal/vacuum bakeout of 24 hours at 100°C and 10^{-6} torr or less to be acceptable for ATM.

b. ATM Solar Panel Deployment Cable

A coil of ATM solar panel deployment cable was evaluated for outgassing characteristics since it has numerous swaged spheres which could entrap contaminants. The cable was heated on a temperature controlled aluminum plate to 60°C (140°F) at 10^{-7} torr in an organic free vacuum system. The cable was evaluated over a 165-hour test period.

Mass spectrographic data showed peaks to be present to 55 atomic mass units (AMU) at ambient temperature. At 40°C (104°F) and 60°C (140°F) peaks were present to 83 AMU. The peaks present at 60°C (140°F showed some reduction in amplitude over the same peaks present at 40°C (104°F). This indicates that the cable shows a tendency to cleanup at the higher temperature. Analysis of the results indicated large amounts of hydrocarbons.

A thermal vacuum bake cycle is recommended for this cable prior to its acceptance for ATM use. The deployment cable should be baked at 80°C (176°F) for 24 hours in a reduced pressure of 10^{-6} torr or less.

c. ATM Hydraulic Cylinders

Two hydraulic cylinders (door closers) were evaluated for outgassing. These cylinders were heated to 86°C (187°F) at 10^{-5} torr over a 46-hour period. The pressure was 10^{-7} torr at ambient temperature but increased to 10^{-5} torr as the temperature increased to 86°C (187°F).

Mass scan data showed numerous peaks beyond 100 AMU at 86°C (187°F). The cylinders continued to outgas and after several hours at 86°C (187°F) there was no indication that the mass range was being reduced or the peak heights being attenuated.

The results of this test indicate that these cylinders are not acceptable for use on the ATM. It is also indicated that a vacuum bakeout would not improve the outgassing characteristics of these components significantly.

d. CDF De-Cinching Manifold

The Mechanical Systems Branch of Propulsion Division has proposed that another test be made on the actuator mechanism and pyrotechnic cable. This test is to determine the source of the dust film that was noted over the entire test chamber subsequent to the two previous firings of the CDF de-cinching manifold.

Two samples of vinyl chromate primer, #31-C-6, with different cure cycles were evaluated and showed a maximum rate of weight loss more than twice the acceptable value for ATM use. These materials also continued to lose weight when the test was terminated.

Korotherm, a subliming material, hexamethlene tetradenine in an epoxy binder, was heated to 100°C (212°F) in vacuum (10^{-6} torr) for 25 hours. This material is very unstable under these conditions as would be expected. It yielded maximum rates of weight loss of 1.17 percent/cm^2/hr at 50°C (122°F) and 1.25 percent/cm^2/hr at 100°C (212°F).

A sample of FR primer (epoxy base) was evaluated over an 8-hour period to 100°C (212°F). This material is unacceptable with maximum rate loss of 0.72 percent/cm^2/hr which occurred in going from 50°C (122°F) to 100°C (212°F).

Isochen Resin #1251 with #8 catalyst is very stable in vacuum at 100°C (212°F). This material only exhibited a maximum rate of weight loss of 0.14 percent/cm^2/hr and is therefore acceptable for ATM use.

A sample of Nopco polyurethane foam #54R46T, density 8 lbs/ft^3, was evaluated for outgassing characteristics at 100°C (212°F) and 150°C (302°F). This material is unacceptable with maximum rates of weight loss of 0.37 percent/cm^2/hr at 100°C (212°F) and 0.23 percent/cm^2/hr at 150°C (302°F). The decrease in rate of weight loss at the higher temperature can be attributed to most of the blowing agent being removed at a lower temperature.

Biggs epoxy adhesive #R-313, air cured for 5 days, is unacceptable for ATM use. The maximum rate of weight loss was 1.14 percent/cm^2/hr.

Dow Corning Silastic 882 was evaluated for outgassing after an air cure for 15 days. This material is unacceptable with a maximum rate of weight loss of 0.24 percent/cm^2/hr. Although the material is unacceptable according to the test criteria, the Silastic 882 is marginal and may find restricted application.

Three RTV silicone rubbers were tested and found to be unacceptable. RTV-757 air cured for 45 days, RTV with 0.1 percent T-12 catalyst air cured for 53 days and RTV-7 silicone foam rubber air cured for 45 days.

2. Component Test

a. Fafnir Bearings

Three types of Fafnir sleeve bearings for the ATM solar array panel were evaluated for outgassing in vacuum. These sleeve bearings were lined with a bonded plastic laminated sleeve. The test environment for these bearings was a reduced pressure of the order of 10^{-7} torr and temperature ranging from ambient to 100°C (212°F). Mass spectral scans were taken periodically of the outgassing products of these bearings. Test data indicated that products could be evolved from these bearings of atomic mass units as high as 216. However, the tests showed that the outgassing was attenuated with time under the conditions of test.

It is recommended that these three bearings be subjected to a thermal/vacuum bakeout of 24 hours at 100°C and 10^{-6} torr or less to be acceptable for ATM.

b. ATM Solar Panel Deployment Cable

A coil of ATM solar panel deployment cable was evaluated for outgassing characteristics since it has numerous swaged spheres which could entrap contaminants. The cable was heated on a temperature controlled aluminum plate to 60°C (140°F) at 10^{-7} torr in an organic free vacuum system. The cable was evaluated over a 165-hour test period.

Mass spectrographic data showed peaks to be present to 55 atomic mass units (AMU) at ambient temperature. At 40°C (104°F) and 60°C (140°F) peaks were present to 83 AMU. The peaks present at 60°C (140°F showed some reduction in amplitude over the same peaks present at 40°C (104°F). This indicates that the cable shows a tendency to cleanup at the higher temperature. Analysis of the results indicated large amounts of hydrocarbons.

A thermal vacuum bake cycle is recommended for this cable prior to its acceptance for ATM use. The deployment cable should be baked at 80°C (176°F) for 24 hours in a reduced pressure of 10^{-6} torr or less.

c. ATM Hydraulic Cylinders

Two hydraulic cylinders (door closers) were evaluated for outgassing. These cylinders were heated to 86°C (187°F) at 10^{-5} torr over a 46-hour period. The pressure was 10^{-7} torr at ambient temperature but increased to 10^{-5} torr as the temperature increased to 86°C (187°F).

Mass scan data showed numerous peaks beyond 100 AMU at 86°C (187°F). The cylinders continued to outgas and after several hours at 86°C (187°F) there was no indication that the mass range was being reduced or the peak heights being attenuated.

The results of this test indicate that these cylinders are not acceptable for use on the ATM. It is also indicated that a vacuum bakeout would not improve the outgassing characteristics of these components significantly.

d. CDF De-Cinching Manifold

The Mechanical Systems Branch of Propulsion Division has proposed that another test be made on the actuator mechanism and pyrotechnic cable. This test is to determine the source of the dust film that was noted over the entire test chamber subsequent to the two previous firings of the CDF de-cinching manifold.

Preparations are now being made to employ a bag type technique to isolate the source of the dust particles.

B. Investigation of Lubricant and Lubricity Requirements for ATM

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.

DU type journal bearings have been selected for use by the Perkin-Elmer Company for use at several locations on the ATM pitch and yaw, and roll systems. These bearings have been reported previously. Low temperature (-40°C (-40°F)) tests are underway currently, and the data from these tests will be reported when testing is complete.

Because of extremely long life requirements on the ATM and other orbital spacecraft, it is questionable if dry film lubricated gears will successfully meet these requirements. A new gear design consisting of a sloped sandwich of alternate layers of steel and Teflon has been designed, and manufactured. One set of gears (4340 steel pinion and Salox M with 4340 gear) has run for 200 hours at a medium load with some wear noted. Additional sets of improved gears are being modified at the present time to decrease the wear rate.

C. Investigation of Corrosion of ATM P/L Boards for GSE Power Supplies

Several printed circuit boards for the ATM-GSE power supplies showed dark spotting at solder joints. These boards were fabricated by Spaco in May and loosely wrapped in a plastic blister type packing material. An evaluation as to the cause of this spotting indicates that moisture came into contact with the boards during the storage period. Many of the boards were fabricated using a flux to aid in the soldering. The flux material was not corrosive to joints tested without removing the residual flux from soldering. The discolored joints do not appear to further deteriorate in a dry atmosphere and should not degrade the electrical properties of the board. Recommendations to be made include "use as is" or if preferred, a light acid cleaning will remove the discoloration without harming the board.

XI. Nuclear Vehicle Technology

In-house and contractual studies are being pursued to develop the materials technology required to support a potential nuclear-propelled vehicle program. Specifically, the areas of cryogenic insulation, valve seals, transducer materials, gimbal and bearing lubricants, and induced neutron activation are being investigated.

A. Propellant Heating Experiment (PHX)

Contract NAS8-18024 with the General Dynamics Corporation provides for an experimental program to study the nuclear and thermodynamic effects caused by the deposition of nuclear energy in liquid hydrogen. The data obtained from this study is needed for the analysis of the credibility of results predicted by existing analytical techniques and for the design of future stage propellant systems.

The 17-inch LOX prevalve modified for use with liquid hydrogen (LH_2) in a nuclear radiation environment has been successfully tested for liquid nitrogen (LN_2) and LH_2 leak rates by Whittaker Corporation. The valve will be shipped to General Dynamics/Fort Worth (GD/FW) on September 30, 1968 for installation and radiation testing.

B. RIFT Tank Tests

The 108-inch diameter RIFT test tank was flown to GD/FW on a "Super-Guppy" airplane, and the tank is now being prepared for installation over the 10 megawatts Aerospace Test Reactor (ASTR) for the pending radiation environment tests.

C. Activation Analysis (439)

The computation of neutron activation of proposed Nuclear Rocket Vehicle materials is necessary for the establishment of stage operation criteria. Because of the complicated materials and difficult geometries comprising typical stage hardware, sophisticated computer programs must be used to calculate anticipated activation prediction code (NAP) developed for this Center by IIT under contract NAS8-11160. Currently, efforts are directed toward the implementation of NAP program at this Center.

1. A format error in the input data prevented completion of the neutrons activation prediction (NAP) code run on the IBM-7094 computer for 2219 aluminum alloy. The data is being rechecked and will be submitted to Computation Laboratory for another run.

2. A no-cost time extension to March 1969 has been recommended for contract NAS8-21031 in order that the data resulting from the RIFT tank test described above may be included in this work. It is anticipated that analysis of these data will require expenditure of all remaining funds allotted for this contract.

3. A set of four statistical analysis codes have been successfully implemented on the IBM-1130 computer to perform

a. linear regression,
b. factor analysis,
c. analysis of variance, and
d. polynomial curve fitting.

The linear regression code can fit up to 500 data points to a linear equation of up to 30 independent variables by a stepwise procedure that enables the code to determine which variable makes the greatest improvement in "fit", and to eliminate variables that make no significant improvement.

The factor analysis code can extract up to 10 significant factors from up to 500 measurements on up to 30 variables.

The analysis of variance code computes an analysis of variance for a complete factorial design for 2 to 4 factors of up to 10 levels each for up to 500 data points.

The polynomial curve fitting code can fit up to 150 data points to a polynomial of up to tenth degree.

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, NAS8-20402

C. Thermal Control Coatings

The Boeing Company, NAS8-21195

D. Physical and Mechanical Metallurgy

McDonnell Douglas Corporation, NAS8-21470

E. Composite Material Development and Testing

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

F. Lubricants and Lubricity

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

G. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-20396, NAS8-21487

2. Tyco Laboratories, NAS8-20297
3. Hercules, Inc., NAS8-21207

H. Explosion Hazards and Sensitivity of Fuels

Stanford Research Institute, NAS8-21316

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

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

J. Investigation of Sealant Materials

1. Monsanto Research Corporation, NAS8-21399, NAS8-21401
2. Battelle Memorial Institute, NAS8-21398

II. General - In-House

A. Development of High Temperature Resistant Polymers

Efforts have continued toward development of processing and cross-linking procedures for the aryloxysilane and silphenylenesiloxane polymers. The trifunctional silicon hydride recently prepared has been used to cure the aryloxysilane polymer in the form of adhesive lapshear joints using various curing procedures. Bond strength data at 78°F (25°C) and 500°F (260°C) are being obtained to evaluate these formulations.

Considerable effort has been spent in setting up and calibrating a gel permeation apparatus. This instrument is to be used initially to study the molecular weight distribution characteristics of the silphenylene-siloxane polymers. The various formulations of this polymer having equivalent inherent viscosities gave a wide range of mechanical properties in the cured state. This anomolous behavior is believed due to variations in molecular weight distribution which can easily occur even though the polymer appears from viscosity measurements to be reproducible. Weight average molecular weights ($\bar{M}_n$) of a series of silphenylenesiloxane polymers having viscosities from 0.15 to 0.6 are being determined from light scattering measurements. These data will allow calculation of a gel permeation calibration factor which is specific for these polymers.

Synthesis procedures employed to yield the experimental silphenyl-enesiloxane curative, 1,4-bis(triethoxysilyl)benzene, have not been successful to date. Until more promising procedures are developed, work on this compound will be stopped in favor of evaluation studies on the other silphenylene curative of interest, 1,4-bis(methyldiethoxysilyl)-benzene. This curative crosslinks the polymers efficiently in concentrations of 10 percent by weight but is slightly less reactive than tetra-ethoxysilane. Comparative isothermal aging studies at 500°F (260°C) and 600°F (316°C) are being carried out to determine if the silphenylene-based curative offers increased resistance to thermal degradation as compared with the conventional tetraethoxysilane.

B. Development of Fluorinated Adhesives

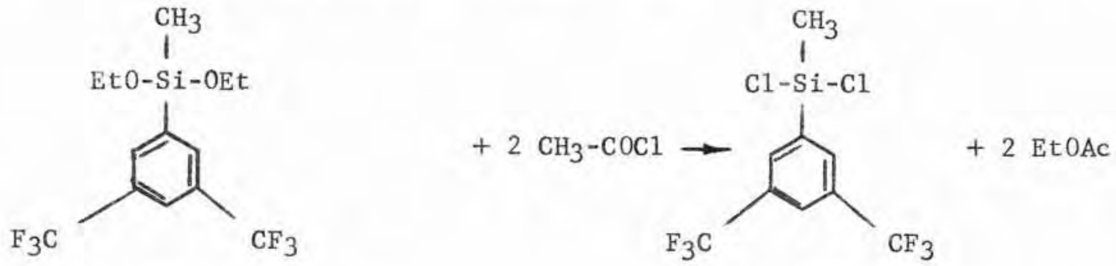
The viscous oil obtained when the dihydrazide of perfluoroglutaric acid was reacted with perfluoroglutaryl chloride could not be identified from infrared spectra as the desired polyhydrazide. The continuing uncertainties associated with this synthetic sequence led to a decision to repeat the synthesis with particular attention to purity of intermediates. Accordingly, the dimethyl ester of perfluoroglutaric acid has been prepared and purified by fractional distillation.

A procedure originated by Knunyants and Kroserskaya, (IZV. Akad Nauk, SSSR, Otd Khim Nauk 190, 1963) for conversion of perfluoroglutaric acid to the corresponding diacyl chloride has been attempted. Difficulties were encountered in fractionation of the product, which has been submitted for chromatographic analysis.

C. Development of Sealant Materials

Continued emphasis has been placed on the development of thermally stable sealant materials which will perform their sealant function when bonded to titanium alloy fuel tank configurations in the presence of hydrocarbon fuels to 500°F (260°C) in static air for extended periods of time (ultimate exposure of 20,000-25,000 hours). An additional critical requirement is that the sealants not enhance the stress corrosion susceptibility of titanium alloys chosen for fuel tank construction.

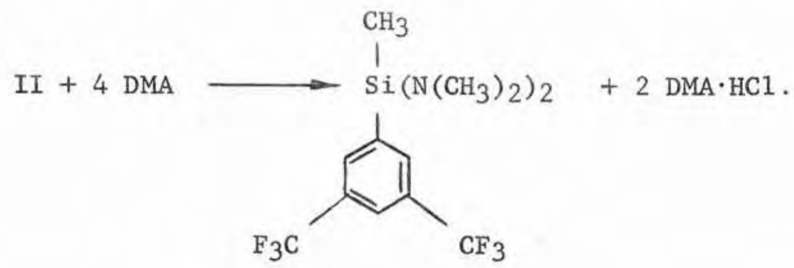
Continued studies are being carried out to modify the structure of the silphenylenesiloxane polymer for optimum sealant performance. As previously reported, the product of the reaction between methyltriethoxysilane and 3,5-di(trifluoromethyl)-phenylmagnesium bromide, methyl-3,5-di(trifluoromethyl)-phenyldiethoxysilane (I), was treated with excess acetyl chloride in an effort to convert the ethoxy groups to chlorine atoms:



(I) (II)

From this reaction a 64 percent distilled yield of (II) was isolated as a colorless oil, having a boiling range of 100-106°C (212-223°F) at 33 torr. The infrared spectrum of the product showed no absorption bands characteristic of Si-O. The amount of ethyl acetate formed during the reaction could not be determined because the ester co-distilled with the unreacted acetyl chloride.

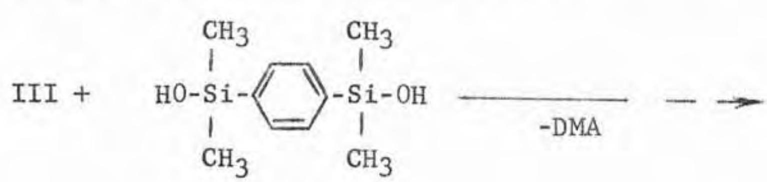
Methyl-3,5-di(trifluoromethyl)phenyldichlorosilane (II) was dimethylaminated in THF (tetrahydrofuran) at 0°C (32°F).



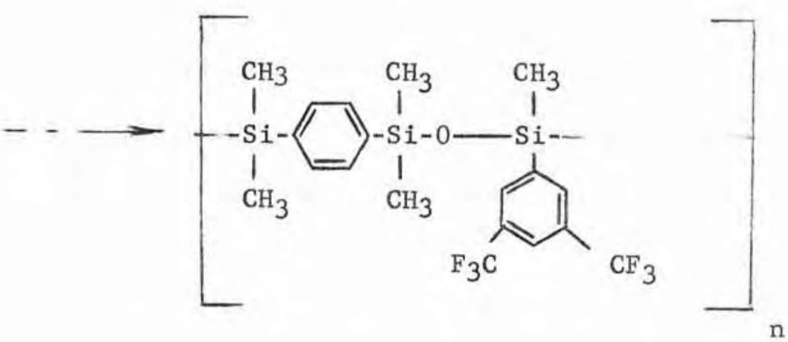
(III)

A 90 percent of amine salt was isolated and a 52 percent yield of (III) was obtained as a colorless oil, having a boiling range of 117-122°C (243-252°F) at 31 torr.

Methyl-3,5-di(trifluoromethyl)phenyl-bis(N,N'-dimethylamino)silane (III) was treated with 1,4-bis(dimethylhydroxysilyl)benzene (IV) in refluxing toluene to give the polysilphenylene ether:

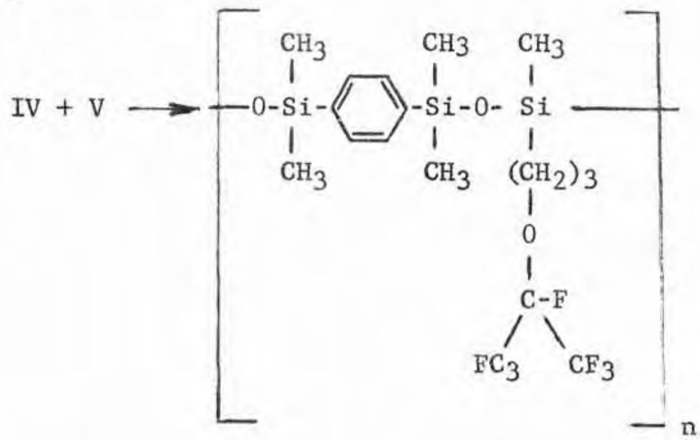


(IV)



The inherent viscosity of this polymer was 0.082, measured at 30°C (86°F) at a concentration of 10 grams per liter of tetrahydrofuran. Since the desired polymer molecular weight corresponds to a viscosity range of 0.4 - 0.6, this polymer will be treated with additional methyl-3,5-di(trifluoromethyl)phenyl-bis(dimethylamino)silane in an attempt to upgrade its molecular weight prior to initiation of curing studies.

In a similar synthetic sequential fashion, 3-(heptafluoroisopropoxy)-propylmethyldichlorosilane was dimethylaminated to the corresponding amino-silane (V), b.p. 103-105°C/30 mm Hg., which was then treated with (IV) in refluxing toluene:



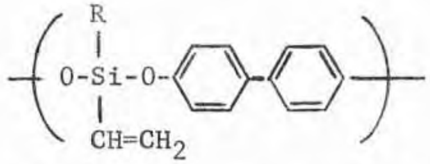
The inherent viscosity of this polymer was found to be 0.25. In an effort to achieve a molecular weight corresponding to a viscosity of 0.4 - 0.6, this polymer in toluene was treated with 14 drops of methyl-3-(heptafluoro-isopropoxy)propyl-bis(dimethylamino)silane and the solution was refluxed for 30-45 minutes. This chain extension polymerization was quenched by the addition of 5 milliliters (ml) of water, after which the mixture was refluxed 2 hours and the excess water was removed azeotropically. An additional viscosity measurement of this modified polymer will indicate if the desired molecular weight has been attained.

In a parallel synthetic effort, the preparation of phenyl-3,5-di(trifluoromethyl)phenyldiethoxysilane (VI) was attempted through the reaction of phenylchlorodiethoxysilane with 3,5-di(trifluoromethyl)-phenylmagnesium bromide. However, this reaction produced a heterogeneous mixture which was resolved only through repeated fractional distillations on a 15-inch Vigreux column. A very low yield of product, having a boiling range of 115-119°C (239-246°F) at 5 torr, was obtained which was deemed insufficient in quantity to use in further reactions.

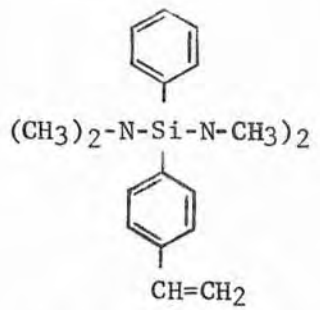
The preparation of (VI) is being attempted once more through use of phenyltriethoxysilane rather than phenylchlorodiethoxysilane. The preparation of more highly fluorinated aminosilane derivatives is also being investigated. Small quantities of both bis(3,5-di(trifluoromethyl)-phenyl)diethoxysilane (A) and bis(pentafluorophenyl)diethoxysilane (B) which are precursors of the desired aminosilanes, have been prepared by condensation of the respective fluoroaryl Grignard compounds with tetra-ethoxysilane. Both compounds must be prepared in larger quantities before the remaining sequence of steps leading to the polymer can be conducted.

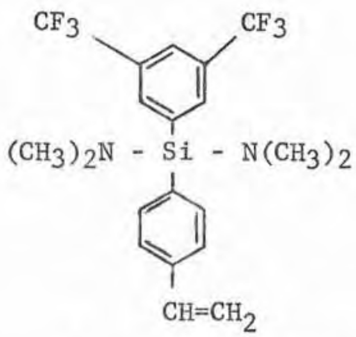
Continued effort has been directed toward development of siloxane-containing aromatic diamines for ultimate formation of polyimides for sealant application. The attempts to prepare these compounds in large quantities have been hampered by problems in purifying one of the intermediates, p-(N,N-di(trimethylsilyl)amino)phenyl bromide. This compound appears to be inseparable from its nomosubstituted analog by conventional distillation techniques and column chromatography may be required to recover the desired compound in pure form.

The sealant studies utilizing the aryloxysilane polymer system are awaiting preparation of the desired fluorinated aminosilane compounds analogous to those pursued within the polysilphenylene sealant effort. In an effort to reduce the hydrolytic instability of the particular structure shown below,



a synthesis is being initiated to prepare one or both of the following intermediates:





The phenyl substitution in other aryloxysilane polymer variants was observed to confer greater hydrolytic stability, apparently through greater steric shielding of the vulnerable Si-O bond. Preparation of the first of these compounds is being attempted by condenstion of the styryl magnesiumbromide with phenyltriethoxysilane to form the precursor diethoxy derivative.

D. Development and Evaluation of Metallic Composites

Investigations have continued on the development and evaluation of light weight high strength composites by means of various forming and bonding techniques.

As a part of a continuing search for high strength fibers for use in fabricating fiber or wire reinforced composites an evaluation was made of specimens silicon carbide coated boron fiber.

Samples of the fiber were exposed to a temperature of 1400°F (760°C) for two minutes (temperature of the molten magnesium) and then tested at room temperature. The results were quite gratifying since tensile strengths of approximately 250,000 psi were obtained. Comparing these results with those of an uncoated boron filament a decided increase is noted, i.e. 250,000 psi (Si coated boron) versus 50,000 psi (uncoated boron). It is anticipated that these fibers will be used in fabrication of reinforced magnesium-boron composites.

During this report period effort has been directed toward development of techniques for increasing the mechanical properties of explosively bonded steel wire-aluminum sheet composites. Experimental techniques under investigation include methods for rolling aluminum wire into heat treatable aluminum (6061), and subsequent operations including solution treatment quenching, re-rolling and aging. It is believed that by suitable selection of parameters for these operations wire aluminum composites may be formed and explosively bonded into multilayer composites which will have improved strength to weight characteristics.

E. Investigation of Stress Corrosion Characteristics

Tests have been terminated in the evaluation of stress corrosion susceptibility Almar 362, PH15-7Mo, 17-4PH, 17-7PH, PH14-8Mo (air and vacuum melt) and PH13-8Mo, and the results are being compiled for preparation of a technical report. Longitudinal round tensile specimens of 15-5PH steel were aged to the H900, H-925, and H-1025 conditions, stressed to 75 and 100 percent of their respective yield strengths and exposed in the alternate immersion tester. No results are available at this time. Specimens of 15-5PH-H925 are also being exposed in the ATM-DCS coolant, 80 percent methol-20 percent water.

F. Investigation of Stress Corrosion Induced Property Changes in Metals

Investigations have continued in the attempt to develop nondestructive methods of detecting incipient stress corrosion failure in launch and space vehicle hardware. Current project objectives are to improve experimental methods, to relate the magnitude of stress corrosion induced property changes to material failure time and to study stress corrosion mechanics.

Eighteen specimens are being processed through the examination and test sequences outlined below:

1. Check the surface finish of specimens.

2. Measure specimen uniformity with ultrasonic surface waves.

3. Carefully check specimen loading.

4. Replicate and study surface conditions before and after loading as well as after specimen degradation by stress corrosion.

5. Microhardness checks before and after specimen degradation.

6. Electrical conductivity measurements.

7. Tensile tests.

Additionally, time-to-failure tests were made on three parts of 7075-T6 specimens which had been carefully loaded to 75 percent of yield strength. These specimens failed in eleven days. Thus, the significance of careful loading procedures is obvious. However, other experimental factors require better control since other carefully loaded specimens have failed in different time periods. Efforts will be made to improve test conditions.

G. Evaluation of Ultrasonic Stress Measurement Methods

An in-house program designed to verify a contractor's claims for stress measuring instrumentation is being accomplished. Additionally, numerous electronic, acoustic, and mechanical factors which could affect the accuracy and the practicality of the system are being investigated.

During this reporting period efforts were made to determine the effect of surface finish on ultrasonic stress measurements. The null-frequency system was used with the bending bar apparatus to investigate surface stresses in 6061 aluminum alloy specimens having surface finishes of 8, 16, 32, and 64 microinches. Little or no change in accuracy was caused by changes in the surface finish.

H. Development of Low Density Ceramic Foams

Investigations have continued in the development of sodium-silicate-based foams. Calcium acetate treatment of the foam was previously shown to be an effective means of increasing the water resistance of the foam. Calcium chloride treatment of the foam appears to be as effective as the calcium acetate treatment. A sodium silicate foam ($Na_2O:SiO_2:1:3.25$) with borid acid addition at 1 gm H_3BO_2 per 30 gm sodium silicate solids failed the immersed load resistance test at 230 hours under a load of 30 psi. Samples from the same foam block, after calcium chloride treatment, withstood the immersed load resistance test for 847 hours before failure. The calcium chloride treatment has the further advantage of not involving an organic component; therefore, the LOX compatibility of the foam should not be impaired.

A limited investigation of an alternate method of producing sodium silicate foams has been initiated. Both conventional oven and microwave oven foaming methods require the induction of the foaming energy into the sodium silicate mass during the foaming process and both oven processes suffer because the energy cannot be induced uniformly into all parts of the mass. The method now under investigation, pressure extrusion foaming, allows the foaming energy to be stored within the mass prior to the start of the foaming process and may, therefore, allow production of more uniform foam structures than can be obtained with oven processes.

The pressure extrusion foaming process uses a closed pressure vessel heated to temperatures in the range of 190°C to 250°C (370 to 480°F). Under this processing, steam pressure develops within the vessel and, upon release of the orifice plug, the sodium silicate is steam expanded as it passes through the pressure drop at the orifice. The initial trials of this apparatus were conducted with a stainless steel orifice. The sodium silicate appeared to adhere to the walls of the orifice and uniform extrusion was not obtained. A single trial with a Teflon orifice resulted in uniform extrusion; however, the desired lateral expansion of the foam was not obtained. This lack of expansion is probably due to the large diameter ratio of the orifice. Further trials with this method of foam production will be conducted and the problem of proper orifice design will be investigated.

I. Developmental Welding

Activities have continued on the evaluation of the weldability of aluminum alloys X2021 and X7007. Analyses as well as graphic presentations of the tensile data are nearing completion. The tensile data for weldments in 1/16 inch thick alloy 7007 are being evaluated.

Welding operations have continued on the study of the weldability of aluminum alloy 7039. All welding has been completed in the flat position for one inch thick material. These panels have been submitted for radiographic inspection. Currently, material selections for fabrication into tensile specimens is progressing as weldments complete radiographic inspection. In addition, some selected panels are undergoing a 16-week natural aging period.

Progress has continued on the program to determine joint characteristics of aluminum alloys 2014-T6 and 2219-T87 welded in the flat position while passing a coolant (liquid nitrogen) through the back-up bar. Presently, an inert gas shielding fixture is being designed to prevent condensate from collecting on the nitrogen cooled abutting edges during the welding operation. Tentative plans will allow the fixture to move as the weld torch moves.

Studies have continued in the comparison of the mechanical properties and metallurgical characteristics of weldments in aluminum alloy 2014-T6 (1/8 inch thick sheet) made by using the TIG process with filler wire types 2319, 4043, and M-934. Mechanical testing of the vee notch specimens was completed during this report period. Currently, all the data are being tabulated and any significant trend will be reported during the next report period.

Studies have continued in the determination of the weldability of Armco stainless steel 21-6-9. Tensile testing has been completed and the results are being tabulated for presentation into graphic form. Weld samples have been submitted for metallographic examinations.

Activities have continued in the evaluation of the weldability of Inconel 718 alloy after subjection to various solution anneal/aging cycle combinations. Houldcroft test specimens were received, and heat treating of these specimens was completed. The heat treatment of the material consisted of five different solution anneal temperatures and four different artificial aging cycles. During the next report period the heat treated Houldcroft specimens will be cleaned (scale resulting from heat treatment removed) and weld test conducted as time permits. From the results of the Houldcroft tests, the most readily weldable material resulting from specific heat treat cycles will be selected for determination of the weld mechanical properties at ambient and cryogenic temperatures.

J. Porcelain Enamel Thermal Control Coatings

Efforts have continued to develop stable, white porcelain enamel thermal control coatings for application to 3-mil aluminum foil. The opacifying power of titanium dioxide (TiO_2) of differing particle size, from several commercial sources, was determined with a lead-based enamel frit. The TAM Titanox RA-10 pigment grade TiO_2 was found to give the best opacity. An enamel with a 20 percent TiO_2 pigment concentration was successfully applied and pigment concentrations up to 30 percent will be investigated.

A low lead frit is also being investigated. The high alkalinity of the enamel slip prepared from this frit results in corrosive attack on the foil during the drying period. This attack results in poor adherence and poor surface smoothness of the fired enamel. The effect of various mill additions on the rate of corrosive attack will be investigated.

K. Investigation of Dielectrics

1. Thermal Vacuum Degradation Study

Specimens of Kapton, CNR Nitroso Rubber, Armstrong Polyurethane Foam (2 lb/ft^3), and Napco Polyurethane Foam (8 lb/ft^3) have been evaluated to determine the dielectric stability of these materials when subjected to the combined effects of high temperature (to 150°C (302°F)) and intermediate vacuum (approximately 5×10^{-5} torr). Each of these materials was characterized stable capacitance and dissipation factor behavior up to 150°C (302°F) while conductivity decreased by factors ranging from 100 to 1,000. In the case of the Armstrong polyurethane foam tested in air, total dielectric degradation occurred at a temperature of 127°C (261°F).

2. High Voltage Foam Study

The corona behavior of the third specimen of 8 lb/ft^3 polyurethane foam tested proved very similar to that reported on in the last activity report. Corona inception voltages averaging about 2 KV were typical over the temperature range ambient to 110°C (230°F). The first phase of testing this material in vacuum of approximately 5×10^{-5} torr has begun.

L. Evaluation "TMC" Electropolishing Solution

The humidity tests, employing electropolished and mechanically polished panels of brass, were concluded during this report period. The specimens were exposed for a total of 4550 hours (approximately 189 days). The surfaces of the mechanically polished panels were dark brown to black. This tarnish has been present, to some extent, since the first few hours of exposure, but gradually increased as the exposure time was extended. However, the surface condition did not significantly change during the last several weeks of exposure time. The surfaces of the electropolished panels, for most part, were still semi-bright but not glossy. Several black spots were scattered over the surfaces. These panels did, however, retain their glossy appearance for several weeks after exposure to the humidity environment.

M. Literature Survey

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

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

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

SEPTEMBER 1, 1968 THROUGH SEPTEMBER 30, 1968

I. Radiography

Eighteen miscellaneous parts, components, and test specimens were inspected radiographically during this report period.

II. Photography

	Negatives	Prints	Other
Engineering Photography	91	498	
Metallography and Fractography	123	234	
Miscellaneous Photography processing, copywork, etc.			62

III. Metallurgical and Metallographic Testing and Evaluation

A. Metallographic studies were completed of two samples of 7079 aluminum alloy received from The Boeing Company, Michoud in support of the S-IC slosh baffle problem. Although one sample was supposed to be in the -T6 condition, both were annealed.

B. Metallographic studies were completed of an ATM wing deployment cable at the request of the Astrionics Laboratory. Photographic documentation was furnished of the cross sectioned swaged balls and inserted cable.

C. Metallographic studies were completed on seven brazed and welded connectors at the request of the Propulsion Division. No evidence of fatigue cracking was found after 300,000 cycles of testing.

D. Several H-11 steel nuts similar to those used in the F-1 engine and the S-IVB stage were received for metallographic studies. Various heat treatments and stressed conditions are being studied.

IV. Spectrographic Analyses

Two hundred and seventy-six determinations were made by spectrographic analyses and two hundred and seventy-two standard determinations were made.

V. Infrared Analyses

Twenty-two determinations were made by infrared techniques on a variety of materials including lubricants, packing material and paper.

VI. Chemical Analyses

	Determinations
Sulfuric acid anodize solution for	
sulfuric acid	2
Atmospheric samples for	
dichromates	2
sulfuric acid	1
Polymeric samples for	
carbon	2
hydrogen	2
nitrogen	2
silicon	2
neutralization equivalent	6

VII. Physico Chemical Analyses

Density of	
RP-1 fuel	4
Triphenyl methyl arsenium TCNQ crystals	2
Surface tension of sucrose solution	6
Chromatographic analyses of	
hydrogen for parahydrogen content	30
experimental polymers	12
Mass spectral analyses of gas for	
oxygen	57
hydrogen	78
nitrogen	42
Atomic absorption analyses for	
copper in methanol-water	12
zinc in methanol-water	12
cadmium in methanol-water	12
copper in seawater	4
calcium in water	5

VIII. Rubber and Plastics

	Items
molded and extruded	53
cemented	100
coated	2
fabricated	3

IX. Electroplating and Surface Treatment

	Items
acid cleaned	12
degreased and alkaline cleaned	40
electropolished	1
anodized	1680
Indium plated	1
gold plated	2

X. Development Shop Production

A. A total of 1,723 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. One thousand three hundred and forty-three man-hours, approximately 77 percent of the total man-hours, were expended on work orders listed below.

1. MSFC Experiment #8

Assembly of the components of experiment #8 is nearly completed. Modifications to the rotating mechanism are in process.

2. Pedal-Mode Ergometer

Assembly of the ergometer is complete.

3. Bearing Shaft-Pinion and Rack

The bearing shaft-pinion and rack test device is nearly completed.

4. Heater Tubes

The heater tubes were completed in September.

5. Thermal Contact Resistance Components

The contacts were delivered in September.

6. Specimen Frames

The specimen frames are completed and delivered.

7. Leed's Vacuum System Assembly

This system will be completed this month.

8. Liquid Nitrogen Trap Assembly

This assembly is not completed.

XI. Miscellaneous

A. Thirty-four items of stainless steel and two hundred and eight items of nickel base alloy were heat treated during this report period.

B. Sixteen rubber switch covers were fabricated for Manufacturing Engineering Laboratory.

C. Several O-ring seals of various sizes were provided for MDA proof pressure and leak testing at Quality and Reliability Assurance Laboratory.

D. At the request of Manufacturing Engineering Laboratory a microprobe analysis was made of aluminum alloy weld constituents.

E. At the request of Manufacturing Engineering Laboratory microprobe analyses were made of four braze metal specimens.

F. Twenty-two measurements of emissivity and thirteen measurements of reflectivity were made during this report period.

G. Thirty-two thermal property determinations were made including differential thermal analysis, thermal conductivity and thermo-gravimetric analysis.

XII. Publications

Lovoy, C. V.: Consideration of the Repairs of Weldments in Aluminum Alloy 2014-T6, IN-P&VE-M-68-4, September 17, 1968.

Lowery, J.; and Mitchell, G.: Investigation of the Alstan 70 Process for the Preparation of Aluminum and Aluminum Alloys for Plating, IN-P&VE-M-68-5, September 26, 1968.

Ruff, R. C.: Development of Materials Division Meteoroid Simulation Facility, NASA TM X-53787, September 26, 1968.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-V-68-9

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(September 1, 1968, Through September 30, 1968)

SATURN IB

I. S-IVB Stage

A. Explosive Device

The first test of the ejectable pancake-type explosive device, which will be used for the orbital workshop (OWS) configuration only, has been performed at McDonnell Douglas Astronautics Company (MDAC). The test was considered successful by MDAC; however, since the test did not simulate the common bulkhead as requested by this division, further testing has been halted until the test fixture is modified.

B. Vacuum Monitoring Console, DSV-4-303

1. During SA-205 countdown demonstration test (CDDT), the vacuum pump in the vacuum monitoring console had to be replaced due to malfunction. Tests on the replaced pump indicated that the new oil had a higher viscosity than the original oil and the pump motor was being overloaded, causing the circuit breakers to trip. The oil in the pump was changed by Engineering Change Proposal (ECP) 3018 because of a safety review requesting lox compatibility.

2. A waiver was approved to use the original oil in the pump on SA-205.

II. General

Saturn IB Launch Interlock Control Specification

After considering several methods, Industrial Operations (IO) decided that the way to document and control interlocks was to prepare a control specification; IO then requested General Electric Company (GE) to prepare the specification. The first draft for Saturn IB was found to be unacceptable because the scope of the document was limited to the automatic sequence portion of the countdown and no coverage was included for the propellant loading interlocks. In addition, the document contained additional unnecessary sections on logic diagrams, electrical schematics, bar charts, and a functional description. A memorandum was sent, therefore, to IO recommending that the missing interlocks be included and the unnecessary material be deleted from the document.

SATURN V

I. S-IC Stage

A. Hydraulic Supply and Checkout Unit (HSCU)

1. Testing of the system development facility (SDF) HSCU through 1000 hours of operations has been completed. Steps are being taken to effect a main pump removal and inspection. Plans have been made to have The Boeing Company (TBC) personnel remove the pumps and transport them to Test Laboratory where they will be disassembled and inspected in the presence of a Denison Engineering representative since the unit was manufactured by that company. The inspection will be scheduled when the Saturn V Vehicle Ground Support Equipment (GSE) Office can confirm the availability of the vendor representative.

2. A test was completed using the SDF HSCU to determine the temperature rise of RJ-1 in the event of loss of cooling water to the HSCU heat exchanger. The data (taken from the range of 80°F through 120°F) indicates that a linear increase in temperature of 2-21/2°F/minute can be expected under a "no water" condition. This information was verbally transmitted to Kennedy Space Center (KSC) operations personnel and will be further documented as backup information since it is presently planned by KSC operations to secure the facility chilled water at approximately T-5 minutes.

B. S-IC-3

1. A study was performed on S-IC-3 to determine the cant misalignment in two planes and the engine rotation caused by the thrust structure deflection. A memorandum transmitting information on S-IC-3 center engine misalignment was sent to aid Aero-Astrodynamics Laboratory in their vehicle-to-launch umbilical tower (LUT) clearance study for S-IC-3.

2. Reliability testing which failed S-IC helium pressurization line brackets was conducted at excessive levels and for the equivalent of eight S-IC launches. In light of our review of this test and reports, this division and the contractor consider the brackets flight qualified.

II. S-II Stage

A. Separation Charge

The dynamic testing of the first plane separation charge in the detonator area installation on S-II-3 has been successfully completed. No cracks in the charge were observed in the x-ray photographs. These results prove that the Engineering Change Proposal (ECP) 5898 is satisfactory. The test also proved that the vibration exceedances, as measured during the S-II-502 flight, will not be detrimental to the charge.

B. Recirculation Battery Test

A recent quality maintenance test performed by North American Rockwell (NAR) of the batteries used in the S-II-503 recirculation system showed that out of four randomly selected batteries, one failed (two batteries are needed for the system). The testing of those batteries was performed under simulated flight installation. However, the test specification required a dynamic envelope for two battery installations, one for the recirculation and one for the S-II container. Consequently, NAR proposed to shock mount the recirculation batteries on the S-II-503, requiring additional funding for these new designs. MSFC personnel found that the vibration levels (as they were used by NAR for testing these batteries) exceeded the flight levels. Since MSFC personnel want to save money and not impact a schedule, an investigation has been initiated to determine if the batteries are flight qualified for the flight dynamic levels, i.e., levels less than those in which the one failure occurred.

C. Stage LH_2

1. The S-II LH_2 tank entry kit, designed and manufactured by NAR, was tested by NAR's KSC technician and found to be satisfactory.

2. End item specification (CD 180M0007) for the LH_2 tank entry kit was reviewed and approved.

D. Tank Entry Test

Division personnel participated in the September operational review of the North American Rockwell (NAR) SDD-342 Tank Entry Kit and the SDD-343 Internal Access Kit. An S-II tank in the dynamic test stand simulated KSC stacked conditions. While the reviewer had several suggestions for increased safety and operability, the equipment was found well designed and usable.

III. General

A. Handling Equipment

The division is evaluating a cost proposal for redesign of the Saturn V handling equipment storage container mounted to the LUT. (These containers were heavily damaged during vehicle takeoff). A request to install temperature and pressure measurements on the LUT near the storage containers has been rejected. These measurements were to give the criteria needed for the modification of the storage containers. It is anticipated that the laboratory project engineers will resubmit these measurement requirements.

B. Safety and Arming Device

A preliminary report on the SA-505 (IB33735) improved safety and arming device was received. In summary, the report concluded that since the proposed design improvements caused the device to be susceptible to autorotation under specified dynamic environments, the contractor recommended the design improvements not be incorporated. We agree with this recommendation and will respond accordingly when the report is forwarded officially.

C. Reactor Thermonuclear Generator (RTG)

In a meeting at International Business Machines (IBM), it was decided by MSFC and Manned Spacecraft Center (MSC) personnel to accept the design of the RTG cooling system.

D. Environmental Control System (ECS) Checkout

The 500 Instrument Unit (IU) ECS will be operated in the closed-loop mode. The modifications which have been made are not proper and will be superseded by the closed-loop mode. Any future modifications will be determined later.

E. Cable Installation

This division is investigating a new cable connect installation for AS-503 at the IU/Spacecraft/Lunar Module (LM) Adapter (SLA) interface. This problem will be coordinated with MSC and KSC.

F. Reliability Analysis Model (RAM)

1. Personnel from this division, Reliability and Quality Management Office of IO, Systems Engineering Office of Astrionics Laboratory, and TBC met on September 12 and 13, 1968, to discuss updating the RAM data for SA-503 and subsequent vehicles. Agreement was reached on new ways to present the data to depict the true picture of the most critical single failure points (SFP's). The stage critical SFP's will be listed in numerical sequence, beginning with the most critical. This will replace the "Top 10" most critical components list and the list of critical components in each system or subsystem.

2. The Engine Reliability and Quality Management Office of IO notified this division that the criticality data determined for SA-503 by Rocketdyne, utilizing only F-1 and J-2 engine test data, may be incompatible and inadequate. They recommend a detailed review of the data by this laboratory and the Engine Program Office. In addition, IO recommended that:

Criticality data from Rocketdyne be implemented on SA-504 engines.

SA-502 engine criticalities determined by this laboratory in MSFC drawing 10M30792 be updated to the SA-503 configuration.

G. Propellant Replenish Mode

Laboratory coordination and review of S-II and S-IVB propellant replenish curves received from KSC was completed and the following conclusions reached:

The 100 percent propellant mass and pressurization plus 15 seconds interlock is redundant to and less useful than propellant loading redlines and can be deleted.

The redlines, as defined by this laboratory to Test Management Office, are based on pressurized mass. This practice must continue; however, if KSC is confident that, after extrapolating boiloff from T-187 seconds to lift-off, they can guarantee pressurized redlines from unpressurized cryogenics, there is no objection to termination of replenishing both S-II and S-IVB propellant tanks at start of automatic sequence (T-187).

To accomplish these changes in an orderly manner and to be consistent through all stages of Saturn V, KSC was requested to submit a change request to MSFC requesting the actions above and that S-IC lox replenishment also be terminated at start of automatic sequence.

APOLLO APPLICATION PROGRAM (AAP)

I. Cluster

A. Telecommunications System Criteria

The human factors cluster voice communications (CVC) criteria, developed among MDAC East, MDAC West, Martin Marietta Corporation, and this division, were published in a memorandum and later discussed at the September 17 Instrument and Communications (I&C) Panel Ad Hoc Working Group meeting at MSC. Additional requirements were added at this meeting and several action items were assigned. Ultimately, the working group hopes to gather all requirements and publish a specification.

B. Metabolic Loads

Metabolic load estimates, supplied to Propulsion Division, were transmitted for review to MSC at the September 26 Mechanical Panel meeting. MSC was requested to initiate a Crew Station Subpanel meeting in approximately 30 days to discuss the results of this review.

C. Man/Systems Design Requirements

The AAP-1/AAP-2 Man/Systems Design Requirements Document, MSFC drawing 10M32158, and a similar document for AAP-3/AAP-4, MSFC drawing 10M33205, were transmitted to MSC for comment at the above Mechanical Panel meeting. Results of this MSC review will also be discussed at the next Crew Station Subpanel meeting.

D. Weight and Performance Meeting

A representative from this division made a presentation at the AAP Weight and Performance meeting on September 26, 1968. The topic of the presentation was "Current Weights and Performance, Impacts of Performance Improvements, Weight Growth and Control Weights and Weight Management." This meeting was the second of its type, referred to as the 15-man committee (five from each center and MSF). The object of the meeting was to present the best weight data for each module and to arrive at means of improving the performance of each vehicle to assure a positive payload margin.

II. Orbital Workshop (OWS)

A. Aft Dome Penetration Seals

KC-135 zero gravity flight evaluation of the OWS aft dome penetration seals and installation procedures was conducted at Wright Patterson Air Force Base (WPAFB) on September 11 to 13, 1968. The Manned Systems Simulation Report (MSSR) is being written. The preliminary report has been written and transmitted to cognizant personnel. The test was a success.

B. Fan Containers

The boost flight criteria for the design of a flight container for the OWS fans have been identified. These special containers are necessary to isolate the fans from the MDA dynamic levels.

C. Schedules and Specifications

1. The design requirements portion of the Workshop Attitude Control System (WACS) Part I, End Item Specification, was submitted to the engineering manager for approval.

2. The WACS R&D schedule was updated and approved by the engineering manager.

3. A draft of the division WACS schedule was prepared.

4. The design requirements portion of the Workshop Thermal Conditioning System End Item, Part I, Specification was submitted to the laboratory Engineering Management Office for approval.

III. Multiple Docking Adapter (MDA)

A. Weight Allocation

An MDA weight allocation document was prepared for the laboratory Engineering Management Office which released it for comments at the last Configuration Control Board (CCB) meeting. The purpose is to have all design elements review the weights and the assumptions made to arrive at the weights and then baseline the document at the next CCB meeting. Coordination with design elements should assure that each element understands the document and concurs with the weights. The weight allocation document will be revised to reflect each element's comments and baselines.

B. Handrail Force Exertion

A test to determine the maximum force a pressure-suited crewman can exert on a handrail in zero-gravity was conducted September 13, 1968, aboard the KC-135 aircraft at WPAFB. Since insufficient test time could be allotted during this past flight to provide enough replications for a significant level of confidence, further test runs will be made when aircraft and test schedules will allow.

C. Proton Spectrometer

A memorandum has been sent to the laboratory Engineering Management Office identifying the priority and providing configuration and specification for the possible installation of the proton spectrometer on the MDA. This is the second time this organization has tried to get an official go-ahead to install this experiment in the MDA.

D. Window Cover

The MDA window cover opening mechanism has been tested and is unsatisfactory. New concepts are now being prepared.

E. Cable Support

Preliminary drawings of the internal electrical tunnel and cable support were reviewed. The method of cable support on the forward dome will result in cable installation and removal problems. A study will be made to determine if a better method is possible.

F. Electrical Connectors

A layout from North American Rockwell was reviewed which shows a new method for physical interface of electrical connectors between MDA and Command Service Module (CSM). This method was to satisfy a requirement that the power connector remain connected while the probe and drogue are being installed after which the connector would be removed. The reason for this is to conserve the CSM battery power. Since problems are arising, further studies will be made.

G. Schedules Requirements

1. The design requirements portion of the MDA, revision C, End Item, Part I, Specification was approved and submitted to the MDA Lead Laboratory Configuration Control Board (LLCCB).

2. Section 2 of the MDA R&D schedule has been updated on the basis of the latest schedule changes from the AAP Office. Revision 2 of the above schedule has been approved by the engineering manager and distributed to MDA laboratory project engineers.

IV. Apollo Telescope Mount (ATM)

A. Thermal Conditioning System (TCS) Mechanical Ground Support Equipment (MGSE)

The TCS MGSE design is being updated to eliminate the preflight heat exchanger for ATM. The Preliminary Design Review (PDR) for the ATM TCS MGSE was held September 19, 1968. A drawing package of schematics, CEI specifications, and layouts had been previously submitted for review. Minutes of the meeting indicated that only a few action items remained to be resolved. Discussion in the course of the review indicated no major problem areas other than resolution of requirement for ground cooling capability for the TCS.

B. Canister Purge

A meeting was held on September 21, 1968, within the laboratory to determine how to meet the particulate contamination requirements of the ATM canister purge medium. The following courses of action have been decided on and are being pursued:

The pneumatic console as supplied by this division will filter to 5 microns.

An investigation will be conducted to determine the feasibility of either a 0.5 micron at the end of the swing arm or a 1-2 micron filter on the umbilical disconnect.

Propulsion Division will incorporate a 0.5 micron filter onboard the vehicle as a final filter. If a 0.5 micron filter is installed on the swing arm, this type filter will be used for that purpose. The above decisions are being documented in a memorandum to Astrionics Laboratory. In addition, periods will exist when there will be no purge capability, i.e., during drop tests, filter changeouts, etc.

C. Translation Device

The KC-135 zero-G aircraft evaluation of the "trough" conceptual design by this division proposed for Extravehicular Activity (EVA) crew translation was conducted on September 13, 1968, at WPAFB. The "trough" which serves as both parallel handrails and a restraint for the feet and lower legs proved to be an effective translation aid for a pressure-suited crewman. The use of only one hand for translating and stability is capable of leaving the other hand free for package handling. A preliminary report of this test is forthcoming. Tests indicate that this is a useful item.

D. Preliminary Design Review (PDR) Control & Display Panel Static Simulator Review

1. As one part of the LM/ATM PDR Crew Station Working Group which met on September 25 and 26, 1968, MSC astronauts participated in a crew evaluation of the control and display panel systems operations and integrated experiment operations. Each astronaut (Garriott, Gibson, Weitz, and McCandless) spent 4 hours in the static control and display panel simulator at Computation Laboratory going through the procedures generated by personnel of this division. As a result of this review, the astronauts requested that they be provided with an additional 2 days to continue this work which is now tentatively scheduled for October 14 and 15, 1968.

2. Due to delays in the simulator fabrication, a dynamic simulation will not be available until January 1969 for the Crew Station Review. It is apparent from these requests by the astronauts, that extensive working sessions with control and display simulators are necessary to support both hardware and operational procedure development. The division is now initiating action to obtain a human factors procedures static simulator for use in the Task Analysis Facility to complement and reduce the demand on the Computation Laboratory dynamic simulator.

E. Rack

1. The proposed relocation of components on the equipment panels to facilitate cable installation has been reviewed by Propulsion Division. SK10-7266, revision AF, will reflect the proposed relocations.

2. Mounting requirements stipulated by contractual implications with American Science and Engineering (AS&E) dictated that AS&E equipment be relocated from the equipment panel to the top of the rack. The result is that AS&E's components, the main electronic assembly, and subcommutator

will be exchanged with the star tracker electronic assembly and measuring distributor #1. These changes are being reviewed by Astrionics Laboratory and Propulsion and Vehicle Engineering Laboratory personnel.

3. General design agreements were reached on the cable roll adapter support structure. A preliminary design of the structure is available for incorporation into SK10-7266.

4. Drawing SK10-9987, Sun End Aperture Door Mechanism, was released for information purposes to aid Structures Division in designing the solar end canister.

5. Alignment Control Drawing 10M03736 has been officially baselined. A draft of the Development Test Specification 10M13193, Cable Roll Adapter for the ATM, has been prepared and is being reviewed.

V. General

Mission Level Failure Effects Analysis (FEA)

1. Representatives of this division and Astrionics Laboratory attended a meeting at the Martin Marietta Corporation to review work that the company is performing on mission level FEA and single thread analysis for AAP-1 and AAP-2 and to update FEA for the ATM.

2. The following decisions and ground rules were agreed to for performing the analysis:

Failure Mode Effects Analysis (FMEA) will be performed on component-by-component basis through all events which comprise the mission.

Martin Marietta will define and recommend a common source of failure rates and modifying factors to be used.

Methods of Handling Redundancy.

Consideration of all Failure Modes.

Government Furnished Equipment (GFE) Document Transmittal Procedures.

MSFC will provide GFE and all experiment FMEA's for inclusion in the ATM FMEA.

Martin Marietta will receive component level analyses and will integrate these across interfaces for ATM FMECA.

A schedule for progress reviews and a document release schedule will be submitted.

The drawings of the rail translation system for the flight model have been completed. The "1g" model documentation was completed and the documents have been released to Manufacturing Engineering Laboratory for manufacturing.

ADVANCED TECHNOLOGY

Experiments

A. Experiment Packaging

Revision P, of SK10-7328, ATM Experiment Package Subassembly, is being revised to relocate the H alpha 1 experiment to make room for the Harvard College Observatory (HCO) A, modified, and to define the N_2 purge line routing for the Naval Research Laboratory (NRL) A and B experiments as well as the HCO-A, modified.

B. Experiment Photography

A feasibility study was completed replacing some of the experiment film photography with television photography on AAP-2. Video recorders with and without dumping capability and a real time were considered. It appears that a TV system with a dump capability could greatly benefit the mission.

C. Experiment Systems Definition Report

1. A preliminary review has been made of the Experiment System Definition Report. The Experiment Compatibility Status Report will be updated as soon as possible to show experiments and carrier systems compatibility.

2. The experiments action item status report has been updated. Of the 119 action items initiated to the present time, 94 have been closed. Work is continuing to solve and close the 25 remaining items at the earliest possible date.

D. Biomedical Experiments

1. Representatives of the division attended a discussion meeting at MSC with representatives of the Medical Directorate and Crew Systems Divisions. The meeting was held to obtain status and available documentation/criteria needed by MSFC for the design and implementation of experiments M-050, M-051, and the Experiment Support System (ESS). M-052, which is integrally tied to the M-487 experiment, was investigated in the light that MSFC may also assume responsibility for M-052. Data and criteria

was discussed on the metabolic analyzer, the bicycle ergometer, the lower body negative pressure device, the plethysmograph (a device to detect changes in lower leg volumes), and the requirements and provisions relating to the ESS. Sketches and ideas about the design of experiment M-052 (Ergometer) were discussed and shown on a viewgraph.

2. The following Biomedical Experiment documents were prepared:

A draft of the development plan for Experiment M-050.

A logic diagram for Experiment M-050.

A flow chart showing the interrelationship of Experiments M-050, M-051, M-052, ESS, and food management.

E. General

1. Interface Revision Notice (IRN) R-8 to 13M50303, Instrument Unit to SLA physical requirements Interface Control Document (ICD), was submitted to the Mechanical Panel for approval. This IRN adds a new electrical cable connector to the IU/SLA interface for AS-503 as the result of "Pogo" effect measurements to be taken on the payload area.

2. Engineering Bulletin 34A, Test Procedure and Test Report Identification Numbering System, was signed by the R&DO Director September 11, 1968. This bulletin will be distributed to all holders of the MSFC Engineering Drafting Manual (EDM).

3. As part of the updating action for CM 002 002 2H, Propulsion and Vehicle Engineering Lead Laboratory Configuration Management Manual, the MDA engineering manager was provided with a proposed procedure and associated documentation flow chart to cover actions involving "on the floor" modification for MDA articles and a proposed procedure for entering LLCCBD identification and numbers on drawing release lists (DRL's), engineering parts lists (EPL's), and engineering orders (EO's).

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-68-9

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

(September 1, 1968, Through September 30, 1968)

SATURN IB

I. S-IB Stage

AS-205 Longitudinal Structural Loads

Analysis of S-IB-12 stage static test data showed that the characteristic amplitudes and frequencies of the H-1 engine thrust oscillations were in close agreement with the values based on static test data from S-IB-211. Therefore, the POGO Working Group recommended that the AS-205 longitudinal structural loads induced by the H-1 engine thrust oscillations be used by MSC.

II. S-IVB Stage

A. AS-205 Countdown Demonstration Test

The only propulsion problem of consequence encountered during the test was low supply pressure to the J-2 engine start bottle. The low supply pressure was noted during the early phase of the bottle chill, and a hold was called to investigate the cause. The count was resumed and satisfactory conditions for launch were reached at simulated lift-off. Subsequent investigation revealed an orifice was installed in the supply line that should not have been there. Propulsion Division has reviewed the test data and has concluded that the removal is not mandatory.

B. ORBITAL WORKSHOP (OWS)

1. Solar Arrays

Steady-state "worse case" analyses show that the arrays will require purging after installation on the vehicle to prevent the panel temperature from exceeding the maximum limit. Since the current sequence reflects array installation 45 days prior to launch, the sizable purge flow rate (10 to 20 lb/min) required is considered prohibitive. Additional studies that consider the direction of the solar array tunnels and the solar vector are in process at Kennedy Space Center (KSC).

A thermal analysis of the solar arrays during boost was completed. This study shows that the array temperature limits will not be exceeded due to aerodynamic heating. Thermal analyses of the solar arrays during passivation prior to deployment are nearly complete. Preliminary results show that early first orbit deployment is required to prevent exceeding the minimum temperature limits.

2. Instrumentation Requirements

A priority listing of the OWS instrumentation was compiled for use as a guide in establishing weight and cost reduction figures. The OWS was divided into systems (Passivation, Workshop Attitude Control System (WACS) and TCS) and a priority listing was determined for each system except the TCS, which was withheld pending the probable acceptance of proposed modifications.

SATURN V

I. S-IC Stage

A. F-1 Engine

1. Thirty-three tests were conducted, and a total duration of 3489.4 seconds was accumulated. Three tests were terminated prematurely, two due to a ruptured LOX tank burst diaphragm and one because of a minor fire in the turbine area.

2. Production Engine Tests at EFL

Three tests were conducted for a total duration of 250.7 seconds. All of the tests ran for the planned duration.

3. Testing of Engine Flexible Lines

Testing of the F-1 high-pressure fuel bleed lines is in progress. Testing started with a resonant search test. The two Anaconda hoses showed no sign of flow resonance so they were flowed at the maximum flow rate for the remainder of the 2250 seconds.

The heat exchanger lines are being subjected to expanded limit flow testing on engine F-108-2 at EFL.

4. Theoretical Studies

A study to investigate the payload increase of the AS-506 vehicle when the present thrust profile of the F-1 engine is modified to include throttling capability was completed. Starting with a thrust of 1545 K lbs, a shift to 1602 K lbs was initiated 5 seconds after lift-off. At a flight time of 60 seconds, the thrust level was lowered to 1545 K, where it remained until an acceleration of 4.25 g was obtained. The center engine was shut down at this time while the remaining four engines operated until propellant depletion. The application of this thrust profile increased the vehicle's payload by 5921 lbs for a 100 n. mi. earth orbit, or 2729 lbs injected into the lunar trajectory, compared to a thrust level of 1522 K lbs throughout.

B. POGO-Baseline Pulse Tests

The first fuel feed system resonant frequency was established from the pulse tests on the F-1 engine facility. This data, which indicated that the frequency should be approximately 12 Hz throughout flight, will be verified by further testing. Baseline pulse testing was conducted to establish the compliance of the fuel pressure volume compensator (PVC) duct. The tests indicate that the PVC duct, rather than pump compliance, controls the system frequency. This result implies that the inboard line frequency may be higher ($\approx$ 2 Hz) than the outboard line frequency due to a shorter PVC duct. Additional tests will be conducted on the F-1 turbopump to evaluate the difference in compliance of the fuel PVC ducts. Baseline tests to determine the compliance of the LOX PVC duct are planned. The 12 Hz fuel system frequency is higher than that extraploated from the 1965 testing. Analysis of the two different configurations indicates that a 300-400 $in.^3$ gas volume in the 1965 prevalve configuration could account for the data difference.

C. Valves for Injection of Helium into LOX Prevalve for S-IC "POGO Fix"

Qualification tests were successfully performed on two types of valves for injection of helium into the S-IC LOX prevalves to eliminate the POGO effect, a 1/2 inch tube size, solenoid/pilot-operated, ball valve, and a 1/2 inch tube size, solenoid/pilot-operated, poppet valve.

D. Saturn V Payload Improvement Study

Payload improvements in minimum ullage volumes, propellant residuals, S-IVB first burn fuel lead, and S-II LH_2 propellant stratification were investigated. The minimum tank liquid residuals, based on initiation of suction line gas ingestion, are specified; however, these minimum values may not be achieved because of loading and vehicle operational constraints.

1. S-IC Stage

Total LOX residual should be 26,400 pounds in the tank and inboard and outboard suction lines. The fuel tank residual will be 8,560 pounds, contributing to a total fuel liquid residual of 21,926 pounds (tank, lines, and engine). The minimum allowable ullage volumes based on satisfying engine start transient NPSH will be 3 percent and 2 percent for LOX and fuel respectively.

2. S-II Stage

Minimum liquid residuals are estimated to be 1,524 and 3,828 pounds on the fuel and LOX systems, respectively. The minimum ullage volumes allowable for engine start transient NPSH considerations are 3 percent for the fuel tank and 5 percent for the LOX tank. The 5 percent LOX tank initial ullage volume requires a 13-inch extension to the LOX vent line to accommodate the additional liquid. Modifications to achieve the 5 percent LOX ullage volume will not be initiated until propellant management studies define the potential payload advantages. The S-II LH_2 temperature stratification analysis indicates no further reduction in stratification reserves is possible.

3. S-IVB Stage

The present ullage volumes of 5 percent for the fuel tank and 3 percent for the LOX tank are minimum. A fuel tank residual of 692 pounds is the predicted minimum based on S-IVB Battleship results. The tank, engine, and line liquid residuals at gas ingestion are 456 pounds for the LOX and 733 pounds for the fuel system. A reduction in S-IVB first burn lead is not recommended due to prevalve sequencing problems and redline changes required.

II. S-II Stage

A. J-2 Engine

1. Production Engine Tests at SSFL

Twenty-five tests were conducted, and a total of 3371 seconds was accumulated. All of the tests ran for the planned duration.

2. J-2 Engine Testing at AEDC

Fourteen hot firings were accomplished at AEDC. Four of the tests were simulated high-energy, eighty-minute S-IVB restart tests. Four tests were conducted with the start tank pressure decreased in steps to evaluate the S-IVB restart capability with low start tank pressure. Two tests were conducted using helium as the start tank pressurant to evaluate the feasibility of using stage helium as a backup pressurant. Two tests were conducted with the GG fuel valve forced to leak to evaluate this effect on an eighty-minute S-IVB restart. One six-hour S-IVB restart test and one S-IVB high-energy first burn were also conducted.

All tests were successful with the exception of one of the helium start pressurant tests, which was prematurely cut off by a facility timer. It was shown that helium can be used as a backup pressurant. The low start tank pressure tests demonstrated, on the basis of four tests and one engine sample, that the J-2 can start with a start tank pressure as low as 800 psia. The leaking GG fuel valve tests demonstrated that the engine can start satisfactorily with a high GG fuel leakage rate.

The GG LOX bootstrap line was replaced twice to evaluate the shift in GG temperature during the initial part of the start transient. It was concluded that the Avica GG LOX bootstrap lines will yield GG initial temperature spikes that are 400 to 600°F higher than the Anaconda lines. The Avica lines, therefore, are not satisfactory for S-IVB one or two orbit restarts. Further line tests will be conducted by the engine contractor.

3. J-2 Engine Flex Line Test Program

All flex lines that are required for the SA-205 flight satisfactorily completed all required testing. Testing was completed on 30 of the 46 specimens in the J-2 flex line test program.

4. J-2S Engine Program

Seven engine system tests were conducted on the J-2S-111 at test stand Delta-2A for a total of 207.6 seconds of idle mode and 383.8 seconds of mainstage operation. Test objectives included checkout and calibration, performance evaluation, start/cutoff sequence evaluation, and multiple start demonstrations. Three tests were terminated prematurely.

Test results indicated lower than predicted Isp in both mainstage and idle mode. Subsequent testing will optimize the film coolant flow to increase mainstage performance. An altitude idle mode test series at AEDC is required to obtain additional data on this performance degradation. An excessive thrust trend (approximately 5K increase in 200 seconds) was recorded during the tests, but a reduction in the turbine nozzle area should reduce this trend.

The modified Mark 29-F fuel turbopump suction performance testing was completed, and the data are being analyzed. Preliminary indications are that low NPSH performance was improved with the new inducer design.

Examination of the LOX post that split during recent testing revealed a hydro-carbon contamination. Further investigation is in progress.

Solid Propellant Turbine Spinner (SPTS) residue build-up was found in the fuel turbine 2nd stage on J-2S-111 during initial turbine disassembly. Future testing will be monitored for performance degredation.

To investigate the fatigue problems on the tapoff duct, ducts with increased wall thickness are being fabricated for evaluation during engine testing.

Testing is under way to investigate the hot-gas-tapoff valve thermal growth problems. It is expected that investigation will result in a redesign of the bearing container.

B. J-2 Engine Start Tank Pressurization

J-2 engine start tank pressurization criteria were revised to reduce flow rates through the purge and fill lines. The new criteria are based on avoiding flow-induced vibrations in the flexible bellows portion of the fill line. A program was initiated on the S-IVB Battleship stand to determine the best methods to reduce pressurization flow rates.

C. S-II-6 Cryogenic Proof Test

One long hold (approximately 3 hours) occurred during the testing due to a blocked screen in the LH_2 line that is used for fast fill. Trouble shooting and purging finally cleared this screen, and the test proceeded with a proof pressure of approximately 36.2 psig. Post-test evaluation is being performed.

D. S-II Prevalves

1. NR-Parker Prevalves

Qualification testing of four units was completed satisfactorily. Also, 10 valves were acceptance tested and delivered to NR for S-II-6 vehicle.

2. LAD Prevalves

Phase A and B sine and random vibrations were completed satisfactorily on the universal valves. Qualification testing is continuing.

E. Local Aerodynamic Protection for S-II-8 Spray Foam

The results of X-15 testing of the S-II-8 LH_2 tank spray foam and the predicted aero heating - wind shear forces of the S-II stage indicate a need for a thermal protective coating on top of the spray foam on the protuberance and ramp areas around the LH_2 feed line fairings, the cylinder 1-bolting ring transition, and the forward skirt. Tests and analyses show that without protective coating in these areas, serious erosion of the foam could occur, and due to the frangible nature of the foam, erosion depth would be variable (about 1 inch or more). The X-15 flights show that with 30 lb/ft^3 cork board (approximately 1/4 inch thickness) over these ramp and protuberance areas, the maximum temperature of the foam would remain below 150°F and no erosion would occur. Further effort is being made to define the specific coating details.

III. S-IVB Stage

A. SA-501 APS Anomaly Testing

A 150-lb thrust engine injector was detached from the engine and is undergoing a two-week exposure to the ambient atmospheric conditions. The injector was flow calibrated with an inert fluid before exposure to N_2O_4 and the hold period. The injector will be exposed to a vacuum environment following the exposure period and flow calibrated again to determine if restricting corrosion deposits have built up in the injector. The planned injector tests will conclude the testing related to the SA-501 APS anomalies.

B. S-IVB-503 C' Mission Studies

Failure to stage or terminate burn as programmed would result in eventual violation of engine NPSH requirements and possible catastrophic conditions. Ullage pressure requirements were based on 100 feet NPSH and estimated pump inlet temperatures. Ullage pressure requirements will be violated approximately 436 seconds after engine ignition if the burn is not terminated as programmed and approximately 472 seconds for an early staging case (step pressurization). Violation of ullage pressure requirements for second burn to depletion will occur approximately 317, 325, and 330 seconds after engine ignition for orbital coast tank pressures of 19, 20, and 21 psia, respectively. The thrust history subsequent to second burn was specified for mission planning and orbital operation analyses.

C. AS-503 C' Mission

The venting sequence after translunar injection for the 503 C' mission was defined, and performance predictions were completed. As a result of the programmed LOX engine dump after spacecraft separation, a ΔV of 31 ± 5 meter/sec will be imparted to the S-IVB stage. This ΔV will provide an adequate "slingshot" capability to preclude the S-IVB from impacting the earth or the moon.

D. S-IVB Flight Operation Analysis

Flight operation analyses were conducted to determine the minimum LH_2 prestart pressure required to assure that the 100 foot NPSH requirement is satisfied during mainstage. The study results indicate that the prestart pressure must be 1 psi greater than the mainstage minimum allowable ullage pressure to accommodate pressure decay during the ignition transient. The current prestart ullage pressure is 3 psi above minimum for 503 mainstage and 5 psi above minimum for 205 mainstage.

E. S-IVB LH_2 Tank Venting

Fracture mechanics constraints dictated a vent range of 31.0 to 34.0 psia on the S-IVB/IB and Saturn V fuel tanks. This range results in the possibility of GH_2 venting prior to liftoff on the IB and early into boost on the Saturn V flights. GH_2 venting below 10,000 feet (35-40 seconds boost) is undesirable because of the possible GH_2 combustion.

The most effective fix, requiring a minimum change, would be a delay in initiation of the Saturn IB/S-IVB fuel tank prepressurization from T_O - 113 seconds to T_O - 80 seconds and an increase in the vent valve range to 32.0 psia on the Saturn IB and 35.0 psia on the Saturn V. Relaxation of the fracture mechanics requirements during S-IC and S-IB terminal boost would be required. Estimated time of vent initiation would be T_O + 50 seconds on Saturn IB and T_O + 78 seconds on Saturn V.

An alternate recommendation would be a boost vent control switch with a range of 31.0 - 34.0 psia. This switch would control 33.0 - 36.0 psia vent valves from T_O + 50 seconds to S-IVB engine ignition. New or altered hardware would be necessary and vent switch "enable" and "disable" times would have to be added to the flight sequencer. Implementation of one of these changes can be accomplished in the event that the external insulation added for 205 and 503 is inadequate or undesirable for future stages.

F. Redline Backup Information

A review of MDC inputs for SA-503 redline backup information was completed. It was recommended that the recirculation pump differential pressure measurements be included as backup to the recirculation pump flow rate redlines.

G. Opening the Command Window for Saturn V Vehicles

A study was completed on opening the command window during powered flight phases of AS-503 and subs. The study considered possible or recognized failures that could occur during launch, i.e., inadequate S-IVB fuel and LOX pressurization or the failure of the S-IVB propellant utilization to activate low engine mixture ratio. Also, under consideration were recognized failures that could occur during second and third burns, i.e., inadequate S-IVB fuel and LOX pressurization, failure of S-IVB to cutoff, extended S-IVB first burn, or perigee below orbital conditions during second or third burn. The data are being evaluated.

SPECIAL STUDIES

I. Apollo Telescope Mount (ATM)

A. Rack Component Thermal Design

Transient analyses indicate that approximately 3000 watt hours of energy are required for the first 12 hours of the ATM mission. This energy requirement is compatible with the energy available from the Charger/Battery/Regulator (C/B/R). The ATM solar panels will be deployed not later than 12 hours after launch, and additional power will be available at this time, although the amount of power from the solar arrays is currently unknown. Several design studies are being investigated to reduce total power requirements during pre-operation.

B. Thermal Similitude Tests at MSC

A 1/10 scale model of the ATM is being constructed and painted with anticipated flight surface coating characteristics. This model will be integrated with 1/10 scale models of the other cluster modules to investigate the radiation heat transfer characteristics of this complex configuration.

C. Quadrant IV Thermal Test

Four tests were conducted in the Sunspot I chamber. The first two tests were to determine if stand-off heaters mounted on the simulated NRL-A experiment could maintain the experiment uniformly at 70 ± 1 °F and to evaluate the power required to do so. The external coating of the stand-off heaters had an emissivity of 0.3. A ten layer superinsulation blanket covered with one layer of black tedlar was then added to one side and the LM end of the NRL-A model. The first pair of tests were repeated to determine the influence of the insulation on NRL-A temperatures and power.

Preliminary NRL-A temperature data indicate a circumferential temperature gradient of 5 degrees during the first test (NRL-A internal power off) and of 3 degrees during the second (NRL-A power on). The insulation reduced these gradients to only 2.5 - 3.5 °F with power off and to 1.9 - 2.5 °F with power on. Data reduction for these and two previous tests is in progress.

II. Tensor Computer Program

The midcourse maneuver simulation was modified to calculate the firing time and the propellants consumed during this process. Polynomial coefficients used in the base drag calculation were modified for better accuracy. New, fast tapes were made for the final version, including the individual engine transients, standpipe simulation, midcourse maneuver correction, and base drag calculation. Gain tables used to calculate engine performance were established for J-2S engines operating at a thrust level of 230,000 lbs, or 265,000 lbs for a rated mixture ratio of MR = 5.5.

III. Slush Hydrogen

The evaluation of the slush manufacture and transfer test program was completed. Problems encountered included high heat leak through the lines, valves, and fittings and apparent instrumentation inaccuracy. The vacuum-jacketed transfer lines designed for liquid hydrogen service were not adequate for slush application due to inadequate line vacuum and thermal oscillations in the bayonet fittings and the shutoff valves. The excessive heat leak reduced the quantity of solid during transfer so that the desired concentration (50 percent) was not achieved in the test tank. The 20 percent solid concentration achieved, however, did demonstrate the feasibility of the recirculation technique. Tests subsequent to the completion of the slush program show that the apparent instrumentation errors were the results of a discontinuity in the calibration standard. The preliminary results of the test program indicate that a detailed thermal evaluation of the lines and valves is essential to future slush application.

IV. Low G Boiling Heat Transfer

Two tests were conducted with the heating surface in a horizontal position and at approximately .01 g/g_o. Initial analysis of data indicates that the tests were successful. However, the photographic data have not been reviewed.

V. Superinsulation

A thermal analysis was made on the 105-inch superinsulated tank to determine the heat load from the standpipe and the instrumentation feed-through to the LH_2. The results show that these heat loads can account for 2-3 percent of the total heat load and should not seriously degrade the test results.

VI. Inflatable Solar Shield Design Study

The second large-scale (15 foot diameter) deployment and structural test was performed. The shield was deployed from the canister, and inflation and rigidization were accomplished satisfactorily. The shield was mounted on a movable fixture that was designed to rotate the deployed shield to simulate loads encountered during flights for structural integrity evaluation. After the shield was allowed to chill to space operational temperatures, the motorized fixture would not rotate due to a motor failure, and the structural tests were not completed in the space environment.

VII. Investigation of Brazed and Welded Tube Connections

The investigation of brazed and welded tube connections for space vehicle use is continuing. One-half of the 3/8, 1/2, 1, and 1 1/2 inch specimens were removed from the corrosion test after completing 120 days. These specimens then underwent a leak test, proof test, and a a second leak test, with one failure occurring in the leak test. The samples are now in metallographic examination. The remaining half of the specimens will complete the 180-day corrosion test before removal. Twenty-seven outdoor storage specimens completed the two year storage test and are ready for further testing.

VIII. Cryogenic Reliquefaction Compressor

The testing of the Cryogenic Reliquefaction Compressor was terminated because of damage to the piston rod, retainers, piston rod seals and piston seals. A redesign, with modifications to the compressor, is expected before further tests are performed.

IX. Flex Lines - Flow Induced Vibration

The test setup for flowing air or other gases was developed and seven tests were conducted with air using ambient external environment and vacuum in the 20 to 70 micron range. Three tests using water as the flow medium and vacuum as the external environment were conducted during this period. Data are being evaluated from magnetic tapes on selected runs.

X. Boss Seal Leak Tests

Leak tests were made with silicone rubber O-rings in conjunction with indium and gold plated sealing surfaces. Results were inconclusive. Tests are being performed with methyl-phenyl-vinyl O-rings.

XI. Heat Pipe - Two analytical studies were completed employing the heat pipe as a radiator or fin. Testing was completed on a 3/4 inch heat pipe with water and Freon 113 as the working fluid.

XII. Thermal Similitude

A computer program for finding the nonlinear heat transfer and temperature distribution for a constant cross-sectional area fin was completed. A thermal similarity was also found that can be used for modeling.

ADVANCED PROPULSION AND TECHNOLOGY

I. Study of Filtration Mechanics and Sampling Techniques

The final report for 1967-8 has been released. This report covers the changes and modifications previously requested. Major topics covered by the report are: contaminant characteristics, cleanliness level chart, measurement of contamination level, establishing tolerance levels.

Oil samples from S-IB-8 were recently submitted for analysis and establishment of a standard method to classify contamination below 10 microns (silt). Silt has been a chronic problem in the S-IB engine gimbal system, and no effective control below 10 microns is specified.

II. Advanced Engine Aerospike Experimental Investigation

Installation of the nickel thrust chamber into the D-2 stand at the Nevada Field Laboratory is continuing. Delays in the Toroidal Thrust Chamber Program on the adjacent test stand caused further delays in starting the test series. The toroidal test series is not complete, and the first test of the nickel chamber is scheduled for the week of October 18.

PUBLICATIONS

"An Experimental Study of the Behavior of a Sloshing Liquid Subject to a Sudden Reduction in Acceleration," Unclassified, TM X-53755, by Louis E. Toole and Leon J. Hastings. Dated August 6, 1968; Published September 3, 1968.

H. G. PAUL
Chief, Propulsion Division