PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

July 1, 1967 Through July 31, 1967

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-67-7

MONTHLY PROGRESS REPORT
(July 1, 1967 Through July 31, 1967)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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MONTHLY PROGRESS REPORT

JULY 1, 1967 THROUGH JULY 31, 1967

SATURN IB

I. S-IB Stage

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

Testing has continued in the comparison of the corrosive effects MIL-H-5606 A revision hydraulic fluid to the B revision fluid. No visibl effects have been noted after 197 days of exposure.

B. Development and Evaluation of Horizontal Heat Shield Insulation

A report has been written describing the development, properties, and insulating characteristics of FTA-442A insulation, which has been recommended as the replacement material for M-31 insulation on the base heat shield of the S-IB stage. Issuance of this report completes the planned activities under this project, and it is not anticipated that future progress reports will reference this project.

II. H-1 Engine

Examination of H-1 Engine H-2038

H-1 Engine H-2038 was stored approximately four years, removed from storage and static fired, and then shipped to this Center for a complete tear-down. All components but the turbopump have been examined and no corrosion was evident on any of the parts.

The soft goods from this engine were routed to this division for inspection. Mr. R. Ciernak of Rocketdyne was present and assisted in the examination of the items. No serious defects or anomalies were found.

I. S-IC Stage

A. Evaluation of Commercial Adhesives

Aging studies have been in progress for eighteen months to determine the effect of outdoor ambient conditions on aluminum lapshear tensile specimens bonded with Narmco 7343/7139 polyurethane adhesive. Three series of aluminum adherends were used: (a) primed with 3M Company's 3901 silane primer; (b) primed with Goodyear's G-207 primer; (3) unprimed. Specimens are protected during aging from direct precipitation and are tested at room temperature, +180°F (82°C), and -300°F (-184°C). The most obvious conclusions from the data collected to date are:

1. For the XC-3901 primed and G-207 primed specimens, only minor strength deteriorations were observed during the 18-month period.

2. For the unprimed specimens, room temperature tests show an almost 50 percent decline during 18 months, while the decline at +180°F (82°C) and -200°F (-129°C) remained minor.

The compound α-glycidoxypropyltrimethoxysilane is commonly used at this Center as an additive to the Narmco 7343/7139 polyurethane adhesive system. Specifically the material used is marketed as Dow Z-6040, however, it has been learned that this material is also available as Union Carbide A-187. A practical test was made to determine the adequacy of the Union Carbide product as an alternate material. Aluminum lapshear tensile specimens and T-peel specimens were fabricated using 7343/7139 (100 g/11.5 g) with 1.0 g A-187 or 1.0 g Z-6040. Comparative lapshear and peel strengths for formulations containing each additive are shown below.

Temperature °F (°C)	Peel Strength, piw		Lapshear Strength	
	A-187	Z-6040	A-187	Z-6040
-300 (-184)	68.3		8793	9012
70 (21)	45.3		2314	2180
+200 (93)	25.8		1339	1350

Tabulated peel strength values are actually for the A-187 additive; the peel strengths of adhesive with the Z-6040 additive were within 1 piw of these values at each test temperature.

It is concluded that Union Carbide's A-187 product is comparable to Dow Corning Z-6040.

In bonding operations with the Narmco 7343/7139 adhesive system this division has used a materials ratio of 100/11.5 (100 parts by weight 7343 and 11.5 parts by weight 7139). The cure cycle consists of 24 hours at room temperature (R.T.) followed by 24 hours at 160°F (71°C). However, other users of this adhesive system use different materials ratios and different cure cycles.

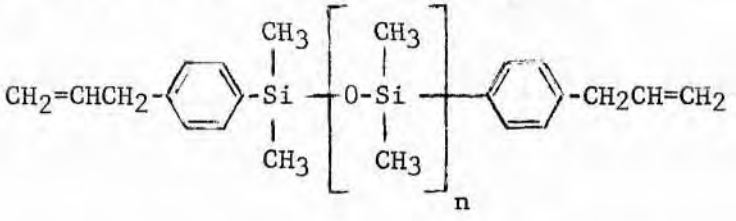
Tests were made to assess the effects of three cure variations and two materials ratios on lapshear tensile strength attained by specimens bonded with 7343/7139 adhesive system. The materials ratios evaluated were 100/11.5 and 100/11.0. The cure cycles used were (1) 24 hours at room temperature followed by 24 hours at 160°F (71°C); (2) 24 hours at room temperature followed by 6 hours at 120°F (49°C); and (3) two days at room temperature in a vacuum bag followed by 8 days at room temperature in a dry atmosphere. The test data indicated no significant differences in bond strength with either the different materials ratios or cure cycles.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

Continued effort has been devoted to the development of specialized polymeric materials for the encapsulation of electronic hardware. Two siloxane polymer intermediates were prepared for conversion into embedment compounds and several polymer systems have been investigated as potential conformal coatings.

1. Development of Epoxy-Siloxane Embedment Materials

The preparation of two allyl-siloxanes was completed. These compounds are represented by the structure below,



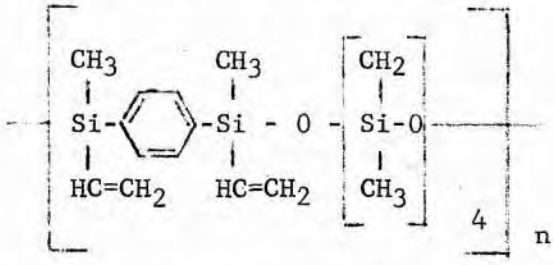
in the cases where n is either 3 or 4. The tetrasiloxane and pentasiloxane were prepared by the condensation of p-allylphenyldimethylsilanol with 1,3-bis(dimethylamino)-tetramethyldisiloxane and 1,3-bis(dimethylamino)-hexamethyltrisiloxane, respectively. The synthesis of the amino silane derivatives was described in the previous report. The yields of the desired compounds were essentially quantitative. These materials are being purified and characterized prior to epoxidation. The epoxides thus formed will be employed to form solid embedment polymers.

2. Development of Conformal Coating Materials

Investigation of the commercial hydroxyl-terminated polybutadiene (Sinclair Petrochemicals Company) has continued with emphasis on formulations of this product with toluene diisocyanate. Two polymerization catalysts, dibutyltindilaurate and triethylenediamine, were evaluated in this formulation It was found that the tin derivative resulted in a prohibitively short pot life, whereas the amine was less active and allowed the formulation to be degassed and molded.

Specimens of the urethane polymer resulting from stoichiometric proportions of polyol and diisocyanate have been prepared and will be evaluated for dielectric constant and dissipation factor.

Selected silphenylene-siloxane polymers developed by Midwest Research Institute under contract NAS8-11338 are being investigated as improved dielectric materials. In the case where the degree of polymerization of the siloxane moiety is 3-4 these polymers have the form of elastomeric gums with glass transition temperatures as low as -80°C. Therefore, it was of interest to develop these materials as conformal coating polymers. In order to provide this polymer structure with reactive groups capable of crosslinking the polymer chains, a modified polymer was prepared from 1-aza-3,5,7-trioxa-2,4,6,8-tetrasilacyclooctane and 1,4-bis(hydroxymethylvinylsilyl)-benzene, as illustrated in the formula below.



The cyclic monomer was prepared as a liquid, boiling at 88-89°C/8-9 torr by the method of L. H. Breed (Summary Report, Contract NAS8-11338, November 2, 1966). The diol monomer was prepared as a white solid, melting at 94.5-96°C, by previously described methods.

In different polymerizations the form of the polymer ranged from a viscous oil to a gum. Characterization of this material is in progress. The vinyl groups pendant to the polymer chain will be crosslinked by silicon hydride compounds in an effort to obtain cured elastomeric coatings.

C. Investigation of Foams Used in Electrical Distribution Boxes

The slow expansion of Stafoam AA-1802 used in S-IC distributor boxes has created concern for the integrity of electrical components embedded in the foam, although no failures attributable to foam expansion have been reported. An investigation into the behavior of Stafoam AA-1802 during cure and post cure periods has been completed.

Although accelerated growth of foamed boxes is probably a very imperfect simulation of foam growth under actual use conditions, the acceleration technique is the only one available for a rapid survey of conditions and parameters which contribute to the phenomenon. Accelerated growth was accomplished by heating foamed boxes for 1 to 4 days at 225°F (107°C), by heating at 140°F (60°C) in an environmental chamber at varying humidities for varying lengths of time, and by exposure to water vapor at 200°F (93°C) inside a sealed plastic bag. Foam growth, measured as linear expansion above the top of the box, reached a maximum of nine percent during exposure to 140°F (60°C) and 75 percent humidity for 4 days, and showed no

additional expansion during 18 days of the same treatment. Extended exposure to dry heat (225°F (107°C)) resulted in no more than 5 percent growth. Water vapor at 200°F (93°C) destroyed the structural integrity of the foam in less than three hours.

Attempts to suppress growth by a combination of heat and pressure were not successful. Incorporation of small amounts of water during mixing did not appear to affect post cure behavior. All tests included foam cured with excess catalyst, stoichiometric catalyst or 90 percent stoichiometric catalyst. The most effective procedureal change was to substitute for the standard room temperature cure a cure cycle recommended by Boeing Company, requiring 8 hours at 150°F (66°C), 24 hours at room temperature, and 24 hours at 195°F (91°C). This elevated temperature cure cut post cure foam growth by 50 percent but did nothing to improve structural stability in the admittedly drastic 200°F (93°C) water vapor environment.

A proposed replacement material, Nopcofoam B-610-RT, was formulated both with and without a fire retardant agent and showed less than one percent expansion under any of the previously described conditions, including the sealed bag, 200°F (93°C) water vapor exposure. If the density of Nopcofoam (2 to 3 times that of Stafoam) is not an unfavorable factor, then the greater stability of Nopcofoam will favor it over Stafoam for this application.

D. Investigation of Cleaning Procedures

The Rocketdyne Division of North American Aviation has planned a development period for converting their vapor degreasers from trichloroethylene to 1,1,1-trichloroethane. During this period, extensive control and record keeping procedures are being established in an effort to determine the minimum controls necessary to maintain a satisfactory operating solution.

E. Investigation of the Failure of the S-IC-S Fuel Tank

Failure analysis was completed on a dollar section weldment from the S-IC-S fuel tank aft bulkhead that failed during hydrostatic pressure test on April 28, 1967. Hydrostatic pressure at the time of failure was 62.8 psig or approximately 140 percent of flight pressure. Several other hydrostatic tests of the tank had been completed since the initial test on January 9, 1967, at which time a proof pressure of 51.2 psig was reached. All interim tests were made at pressures below 51.2 psig. The original 8-inch dollar section was removed from the tank during fabrication because of several weld defects. It was replaced with a 9-1/2-inch oversize dollar section. Calculated stress in the weldment at time of failure was approximately 20,000 psi, which was considered to be below the normal yield strength of the weldment. The entire dollar section and weldment was removed from the tank and forwarded to this division for failure analysis on July 3, 1967. The failure consisted of two cracks, one about

4-1/2 inches long and the other about 3 inches long, overlapping at one end but not intersecting. An area containing small cracks was removed and forwarded to Boeing, Michoud, for analysis. Fracture originated (in the 4-1/2-inch crack) in an area of the weldment containing lined-up oxide inclusions and a heavy distribution of porosity which apparently lowered the mechanical properties of the weldment.

F. Evaluation of O-rings for S-IC GOX Flow Control Valve

The Boeing Company (TBC) was directed by MSFC to change out the fluorosilicone O-ring material in the GOX flow control valve to Viton A which had been batch tested to the requirements of MSFC-SPEC-106B. The Boeing Company ordered sets of O-rings from Precision Rubber Products Company and Parker Seal Company. Testing of these O-rings by TBC resulted in rejection of all sizes of O-rings from both manufacturers. Subsequent testing of these O-rings by this Center revealed that seven sizes met the requirements of MSFC-SPEC-106B. The O-rings (sizes) that failed were then vacuum treated at 300°F (149°C) for 72 hours and tested. Four sizes of O-rings met the specified LOX compatibility requirements after this treatment. A representative of this division visited Boeing, Michoud, to observe their LOX impact procedures and noted a number of discrepancies between Boeing's and MSFC's testing procedure. All LOX impact batch testing at Boeing has been halted until the noted discrepancies have been corrected and results of O-ring testing are comparable.

II. Contract Research

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

A. Polymer Research, Development, and Testing

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

B. Development of Cryogenic and High Temperature Insulation Material

Goodyear Aerospace Corporation, NAS8-11747

C. Analytical Methods Development

Beckman Instruments, Incorporated, NAS8-11510

D. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

E. Nondestructive Testing Techniques

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

III. S-II Stage

A. Investigation of Fracture Toughness of 2014-T6 Weldments

Studies have continued into the fracture toughness of S-II stage weldments at temperatures down to -423°F (-253°C). Tests are being made on specimens taken from actual S-II weldments (S-II-T) and also on test weldments simulating S-II conditions. This includes weld repairs and MIG-pulsed arc weldments. In order to obtain the required test parameters necessary for valid fracture toughness testing, specimens from material thicknesses of 0.625 and 1.0 inch were added to the program. Results to date indicate that a compact K_{IC} range exists for all the weld types and thicknesses studied for weld metal at -423°F (-253°C).

B. Investigation of Failure of S-II Stage GSE LOX Fill and Drain Line

Failure analysis was completed on the S-II stage GSE LOX fill and drain line that failed after 5 hours and 25 minutes of flow testing at the Test Laboratory. The water flow rate was 5700 gallons per minute with an inlet pressure of 170 psig. This line had been used previously for LOX fill and drain tests on the Saturn 500-F vehicle at Kennedy Space Center. Failure occurred in the seventh outside diameter convolute at the top side of the inside diameter bellows section adjacent to the line outlet. The failure resulted from shear stress and fatigue. The gimbal pin, which was rubbing the failed convolute, served as a stress raiser plus a pivot point for fatigue crack propagation of the failed convolution.

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

A review was made of spray foam problems encountered recently in the Manufacturing Engineering Laboratory when abnormally low foam to metal bond strengths were obtained. In one case the flatwise tensile strength of five specimens averaged only 11 psi whereas normal bond strength of the foam to metal is approximately 70 psi. No abnormalities were noted in the material, and it is believed that the extremely high ambient humidity at the time these samples were sprayed contributed to their low strength. It is understood that processing procedures are being modified to provide for application of the spray foam under carefully controlled environmental conditions.

Efforts are continuing to develop or specify a non-blistering coating for the exterior surface of the spray foam insulation. Thermolag T-230 appears to offer some promise for this application and will be studied further . The stage contractor reportedly has obtained good results with Chem-Seal, another proprietary coating, and panels coated with this product by the contractor have been obtained for local thermal testing. An emergency order has been placed for additional quantities of the Chem-Seal coating.

D. S-II Stage, Project Management, Materials

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

1. S-II-1 Stage

Studies have continued in-house at this Center and in the stage contractor's facilities to determine the critical flaw size for 1.6-inch insulation under aerodynamic conditions (wind tunnel tests). The in-house test results have indicated that a 6-inch crack together with a debond will not propagate during flight. This is better than expected since early calculation indicated a 3-inch crack would be the maximum tolerable length.

In conjunction with these studies, personnel of this laboratory visited the John F. Kennedy Space Center to determine if existing television coverage of the stage would be adequate for detecting the critical flaw. Simulated demonstrations indicated a 3-inch crack could be detected from a distance of 80 feet. The existing television coverage on the LUT is believed to give adequate coverage over 2/3 of the sidewall. Additional facilities may be necessary for the remaining 1/3 of the sidewall.

2. S-II-2 Stage

Dye penetrant inspection of the tank welds has been completed at the John F. Kennedy Space Center. There were no crack-like indications disclosed during this inspection.

3. S-II-3 Stage

This vehicle is presently in route to Mississippi Test Facility (MTF). Prior to shipment from Seal Beach, the dye penetrant inspection of tank welds revealed 29 crack-like indications, the largest of which was 0.075 inch deep and 0.110 inch long.

4. S-II-4 Stage

Rework of the sidewall insulation is in progress at station IX. This involves routine insulation repair and installation of rubber doublers. Propulsion system lines are being inspected and reworked.

5. S-II-5 Stage

Currently systems installation is in process together with insulation closeouts on the sidewall.

6. S-II-6 Stage

All crack-like indications in the liquid oxygen (LOX) and liquid hydrogen (LH_2) tank have been removed and repaired where necessary. Presently, installation of the organic edge seal is in process.

7. S-II-7 Stage

The cylinder 6 to bulkhead weld was completed using TIG welding from one side. A rigid back-up bar was employed to prevent excessive offset. The resulting weld required 3 weld repairs because of internal defects and had a maximum offset of 0.020 inch.

8. S-II-8 Stage

Cylinder No. 3 has been spray foamed using NOPCO and the Lemco gun. An 8-inch wide band along the top of the cylinder (completely around) required repair because of the gun location in the production fixture. This fixture has 3 guns which are adequate to cover a complete cylinder. The test run was performed on paper and because of the heat sink difference there was a much higher rise. Based on this test, the guns were positioned to cover the cylinder sidewall. However, the lower rise of the foam on the cylinder caused a shallow defective area at the top. This has now been repaired and the machining operation completed. Test specimens taken from the completed cylinder average approximately 73 psi.

IV. S-IVB Stage

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

1. Study of Flammability of Materials

Testing has continued with support from Test Laboratory in the study of the flammability hazard of aluminum foil covered S-IVB insulation and a comparison of the relative protection offered by 2 and 5 mil aluminum foil. Standard 3-foot diameter samples are used in all tests. The samples are flanged to a 3-foot diameter by 5-foot test tank. The tank is placed in a vacuum chamber, evacuated, and back-filled with gaseous oxygen to 5 to 5.7 psia flowing oxygen. A nichrome wire is used to ignite the samples The igniter is placed over a damaged area of the foil and at a standoff distance 1/8 to 1/16 inch from the foam. The power used for the igniter is 21 volts at 9 amps. Additional tests have been made using the 5-mil aluminum foil. The results of 5 tests with 5-mil aluminum foil indicate that the maximum burn diameter with the 5-mil aluminum foil is approximately 5 inches under the conditions of this test procedure. This study will be

expanded to include an assessment of the protection afforded by 3-mil aluminum foil and compare it with the 2 and 5 mil.

B. Study of Combustion Products of S-IVB Stage Materials

Analyses of combustion products of materials in 5 psia oxygen were continued during this period. Materials investigated were, Teflon FEP, Teflon TFE and proposed thermal curtain material which is a Teflon-coated glass fabric. Based on the volume of the test chamber and the weight of sample used, sufficient oxygen was present for complete combustion. The materials tested during this report period were compounds containing fluorine whereas materials reported previously were compounds containing nitrogen. As expected the test data reveal that the materials containing fluorine have been more difficult to combust than the materials containing nitrogen and the combustion products from the materials containing fluorine are more toxic. This investigation will continue on other types of materials when they become available.

C. Evaluation of Sensitivity of Materials to Impact When in Contact with Gaseous Oxygen

The current flammability specification from MSC, "Procedures and Requirements for the Evaluation of Spacecraft Non-Metallic Materials MSC-A-D-66-3, Revision A, has a requirement for impact/friction testing of materials in high pressure oxygen. This division has received drawings of the proposed tester. It is our opinion that this tester is not designed for routine testing. Therefore, the GOX tester described in last month's activity report is being redesigned to permit operation at higher pressures. Upon fabrication, a study will be made using both the adiabatic compression tester and the GOX impact tester. The results of this study will be evaluated to determine if these testers can be used to test materials per MSC-A-D-66-3.

D. Study of Outgassing Characteristics of Orbital Workshop Materials

At the request of the Manned Spacecraft Center (MSC), materials for the Orbital Workshop are being subjected to a more severe test environment to evaluate the potential hazard of outgassed products. The 3-D foam insulation was tested to 160°F (71°C) at 10^{-7} torr for 72 hours. The test sample was prepared with the Adiprene L-100 and aluminum foil on one surface with a single hole in the foil. The remaining surfaces were covered with aluminum foil which was bonded to the foam with Lefkoweld. The results of this test indicated a weight loss of orders of magnitude higher than that of previous tests. It is believed that this is an indicated weight loss due to gas issuing from the orifice in the aluminum foil rather than a true weight loss. This material will be investigated further to substantiate this result.

V. J-2 Engine

Investigation of a Corroded Quill Shaft from a J-2 Engine

A corroded quill shaft P/N 458168, S.N. 8309401, was removed from J-2 engine J-2044 on S-II-502 and forwarded to this division for evaluation regarding mechanical properties, hardness of core and surface, and the effects, if any, of corrosion on these properties. The ultimate strength, yield strength and hardness of the nitrided Vascojet 1000 material met specifications. The corrosion was restricted to surface pitting and did not appear very severe.

VI. F-1 Engine

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

As reported previously, seven candidate ceramic oxide coatings were selected and test specimens prepared for evaluation as insulations for the F-1 engine injector face baffles. Each of the seven specimens was tested under a thermal environment which simulates the F-1 engine operating environment. Each specimen was tested a total of five times or until the coating failed. Coatings which withstood the five test cycles were zirconium oxide (ZrO_2) applied by the "Rokide" process, and two types of aluminum oxide (Al_2O_3) and the ZrO_2 applied by the "Metco" process. Coatings which did not withstand the five test cycles were zirconium silicate ($ZrSiO_4$), chromium oxide (Cr_2O_3) and (Al_2O_3) applied by the "Rokide" process.

To determine the insulation efficiency of the coatings, thermocouples were attached at selected places on the test specimens to measure temperature rise during testing. Although the test data have not been completely analyzed, preliminary evaluations indicate that the ZrO_2 coating applied by the "Metco" process is a better insulator than the outer three coatings which withstood the five test cycles. Although the ZrO_2 coating applied by the "Rokide" process was a good insulator, its adherence was only fair.

VII. Instrument Unit

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

The investigation was continued to determine if the reaction of the coolant with the metal components is the cause of the pressure build-up in the environmental control system (ECS). Dissimilar metal couples, which are in the system, when exposed to inhibited methanol/water solution have produced hydrogen gas after 72 days of exposure.

Additional tests are being conducted using these dissimilar metal couples in methanol/water inhibited with sodium dichromate and sodium benzoate separately and in combination. These inhibited solutions are being evaluated as a possible substitute for the methanol/water in the ECS. The effect of pH on the corrosion of LA141 and 6061 aluminum in methanol/water also is being evaluated by exposing panels of LA141 and 6061 (coupled and uncoupled) in methanol/water. The pH in one test is being controlled by periodic solution changes for comparison with a second test with no pH control (no change of solution).

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

Tubular joints made by silver diffusing aluminum (6061) to stainless steel (300 series), are being evaluated for resistance to corrosion in inhibited and uninhibited methanol/water solution. Joints are being tested with no surface protection and with an alodine 1200 treatment. This type of joint is being considered for use in the Environmental Control System. The joints in the inhibited methanol have less corrosion than those in the uninhibited solution, and the alodine 1200 treatment is affording additional protection to joints in both solutions after 58 days of exposure.

VIII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

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

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

During this report period several additional materials were tested in vacuum (10^{-7} torr) to 100°C with periodic mass spectrographic determinations being made. Materials of particular interest with test results are as follows. PR-1538 is stable to 100°C but when raised to 135°C momentarily the materials begin to degrade rapidly and continued to do so even when the temperature is lowered back to 100°C. Nylon lacing cord, type 18B, is also stable to 100°C and indicates only an initial weight loss of water at 25°C. Lockfoam B-610 is very stable with the maximum rate of loss occurring during the first hour at 100°C. Sylgard 182 is also stable to 100°C with the maximum rate of weight loss at the interval from 50 to 100°C. HT-424 has been reevaluated under a different cure cycle and now qualifies as an acceptable material for use to 100°C when properly cured.

A supplement to the preliminary list of materials evaluated according to the Materials Management Plan for ATM has been published. Forthcoming supplements to the current list of acceptable and unacceptable materials for use on the ATM will be published bimonthly.

Testing has been initiated in the determination of the redeposition characteristics of materials. Tests are in progress on a sample of Epon 828 epoxy resin to determine its redeposition characteristics. Deposited film thickness is being monitored constantly. A glass slide with deposited film electrodes is included to provide an absolute film thickness and electrical resistivity measurement.

Selection of the test methods and techniques for determining the cleanliness level of the Houston Space Simulation chambers has been accomplished. Selection of the test samples has also been done. Three separate techniques will be employed: (1) samples of typical ATM coating materials will be exposed in the chambers and examined for surface contamination, (2) a nude source type Residual Gas Analyzer will be used to continually monitor the gases present in the chambers, (3) a crystal oscillator will be employed as a film deposit thickness monitor.

The material samples to be used are:

1. S-13g thermal control coating
2. Cat-A-Lac black control coating
3. Electropolished 304 stainless steel
4. Optically flat quartz
5. Glass slides
6. Front surface mirrors
7. Gratings (probably)

The two thermal control coatings will be checked for spectral properties. The stainless steel will be checked by laser interferometer. The glass slides will first be checked by standard interferometry for a total film thickness measurement and then have the film stripped for Infra-Red Analysis. The mirror and the grating will be checked for changes in optical characteristics.

B. Study of Thermal Control Surfaces and Materials for ATM

Two rolls of black Tedlar film identified as Dupont Number 380XRB113BK were received from the manufacturer. This film will be used as a cover for the insulation on the experiments and on the cannister. The optical properties of this film were determined by this division. In the unsupported, as received condition, the absorptivity α=0.96 and the emissivity ϵ was 0.77. Other samples were bonded onto 1/8 inch aluminum sheet with conductive adhesive before measuring. Values of α = 0.94 and ϵ = 0.91 were obtained using this technique. These values are considered satisfactory. One roll of the film was delivered to the Manufacturing Engineering Laboratory for use in insulating the quarter spar.

The outgassing characteristics of three black paints, namely, Lowe Brothers, No. 47865 black enamel and Midland Industrial Finishes Company No. L6X958 dull black microbond and No. L5X923 Microweld black paint, were determined. Although these paints were heat cured in addition to air drying, their outgassing characteristics were determined to be unacceptable for ATM applications.

IIT Research Institute S-13G paint, which had been air dried for nine weeks was evaluated for outgassing. Based upon these results, S-13G is acceptable for ATM applications.

C. Investigation of ATM Bearing Lubrication

To protect moving parts of the Apollo Telescope Mount, lubricants will be required which will not break down or outgas in the environment of outer space. Work being done on the inertial system control gimbals at Midwest Research Institute under contract NAS8-21165 indicates that the bearings and gears for this system can be successfully lubricated with dry film lubricants. A torque drive test fixture for this system was delivered to this laboratory for vacuum testing; however, checkout tests indicated that the bearings in the fixture were misaligned and the system was returned to the Bendix Company for repair.

IX. Nuclear Ground Test Module

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

Tensile, compression, and lapshear specimens of four types of spray foam (CPR 368-2, COR 385-2, Nopco BX250-A, and Cook 977) were fabricated and shipped to General Dynamics/Fort Worth (GD/FW) for testing under contract NAS8-18024. In addition, special sealed specimens of Insulcork and foam were prepared to obtain data on radiation induced hydrogen gas evolution at ambient and cryogenic temperatures. The new liquid hydrogen cryogenic insulation test dewar (CITD) has been fabricated by GD/FW and was shipped to this Center for application of the spray foam insulation by the Manufacturing Engineering Laboratory. The insulation of this tank has been completed and the tank was returned to GD/FW for irradiation and acoustic testing during the reactor run scheduled for August 30, 1967.

The RIFT 108-inch diameter tank currently is in the Manufacturing Engineering Laboratory for removal of the internal insulation. After this operation is completed, it will be returned to the Materials Division for radiographic inspection of the welds. A coordinating meeting has been held between representatives of this division, the Structures Division, and General Dynamics/Fort Worth to insure that modifications being made to the test tank and the contractor's test facility will be compatible.

Spectroscopic analyses are being made of the alloy of the 108-inch diameter model tank, and the engineering drawings of the tank are being procured. These data will be used to predict the neutron activation of the tank in the GD/FW tests. The computer results will be compared with the experimental measurements that will be made after the test.

The 17-inch Whittaker LOX prevalve to be evaluated in conjunction with the 108-inch RIFT tank has been returned to the Whittaker Corporation for modification. Several of the candidate valve seals fabricated by the Narmco Division of the Whittaker Corporation have been irradiated by exposure to the 24,000 Curie Cobalt 60 source. To date, the laminated E-glass/Kynar seals appear to be the most promising of the types tested. Additional seals have been fabricated by Narmco for testing in a combined cryogenic temperature-nuclear radiation environment at General Dynamics/ Fort Worth.

ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

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

A. Polymer Development and Characterization

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

B. Adhesive Development

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

C. Developmental Welding

The Boeing Company, NAS8-20156

D. Thermal Control Coatings

The Boeing Company, NAS8-21195

E. Physical and Mechanical Metallurgy

Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

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

G. Lubricants and Lubricity

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

H. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-20396
2. National Bureau of Standards, GO-H2151A
3. Northrop Corporation, NAS8-20333
4. Tyco Laboratories, Inc., NAS8-20297
5. Kaiser Aluminum and Chemical Company, NAS8-20285
6. North American Aviation, Inc., NAS8-20471
7. Hercules, Inc., NAS8-21207

I. Explosion Hazards and Sensitivity of Fuels

Standard Research Institute, NAS8-20220

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

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

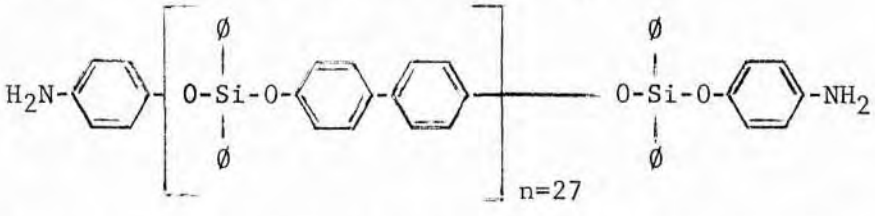
K. Instrument Development

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

II. General - In-House

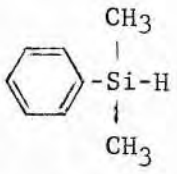
A. Development of High Temperature Resistant Polymers

Continued effort has been devoted to the development of improved crosslinking systems for the polyaryloxysilanes. An amine-terminated structure of the Polymer A type has been prepared:

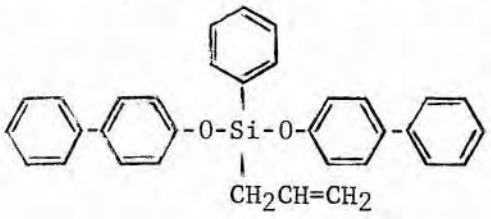


While the product has not been fully characterized, the molecular weight is expected to be about 10,000. The crosslinking of this material of intermediate molecular weight will be examined by reaction of the amino groups with diepoxides and other agents.

To facilitate the crosslinking studies of the Polymer A structures mentioned above and polysilphenylene ether structures the reactions of various mono-functional model compounds are being considered. For example, the two compounds,



and



b.p. 157-159°C/760 mm

(I) (II)

have been prepared. Examination of the ease and extent of addition of the silicon hydride group in (I) to the silicon allyl group in (II) will give an indication of the potential utility of the reaction for crosslinking silicon-containing resins.

B. Development and Characterization of Phosphonitrilic Polymers

The projected synthesis of derivatives of $(PNCl2)_4$ suitable for subsequent conversion to ladder-type linear polymers was continued along two different lines of approach. The facile preparation and structural identification of the product obtained from the reaction of $(PNCl_2)_4$ with N-methylcyclohexylamine, namely, β-trans-$P_4N_4Cl_4(CH_3NC_6H_{11})_4$, gave impetus to utilization of this derivative as a monomeric intermediate in the projected polymeric synthesis. When this substituted amide was treated with phenylmagnesium bromide in a number of experiments in which the solvents and temperatures of reactions were varied, the product invariably was an oil from which the desired compound (I) could not be isolated.

$$P_4N_4Cl_4(CH_3NC_6H_{11})_4 + 4\ \text{Ø}MgBr \longrightarrow P_4N_4\text{Ø}_4(CH_3NC_6H_{11})_4 + 4\ MgBrCl.$$

(I)

The possibility of isomerization occurring during the Grignard reaction could account for up to four different geometrical configurations being present with subsequent inability of the gross mixture to crystallize. However, the isolated product had always been rejected as being the desired product because the infrared spectrum consistently showed no strong P-Ø absorption band at 1440 cm^{-1} which would be indicative that the desired type of ring substitution had occurred.

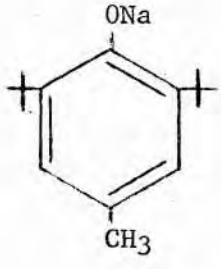
Subsequent studies have shown that this lack of absorption at 1440 cm^{-1} may not have been a valid criterion for rejecting the reaction product as being the tetraphenyl substituted derivative. A sample of β-trans$(\emptyset PNCl)_4$ was obtained from the W. R. Grace and Company, Clarksville, Maryland, and treated with an excess of N-methylcyclohexylamine in tetrahydrafuran (THF) at room temperature:

$$(\emptyset PNCl)_4 + 4\ CH_3NHC_6H_{11} \longrightarrow P_4N_4\emptyset_4(CH_3NC_6H_{11})_4 + 4\ \text{amine}\cdot HCl. \qquad \text{(II)}$$

A theoretical amount of amine salt and crude solid product was separated from the reaction mixture. The latter was recrystallized from CH_3CN-$\emptyset H$ as white coarse crystals having a melting range of 148-150°C (298°F-302°F). An infrared spectrum of this compound, whose structure and geometrical configuration was already established, showed no P-$\emptyset$ absorption band at 1440 cm^{-1} which certainly would have been anticipated. (The compound from which it was derived shows a strong P-$\emptyset$ band at 1440 cm^{-1}.) Furthermore, the infrared spectrum of this derivative is nearly identical to the infrared spectrum of the oil which is obtained in the Grignard phenylation of $P_4N_4Cl_4(CH_3NC_6H_{11})_4$ mentioned earlier. The major difference in the two spectra is the presence of a medium intensity absorption band at 1070 cm^{-1} in the spectrum of the oil which appears as a very weak absorption band in the spectrum of the solid. Otherwise, the two spectra contain common absorption bands consistent with the proposed structure, i.e., phenyl absorption at 695 cm^{-1}, tetrameric PN ring absorption at 1260 cm^{-1}, C=C absorption at 1600 cm^{-1}, and PNR_2 absorption at 980 cm^{-1}. It can only be surmised that the presence of the bulky $-CH_3NC_6H_{11}$ in the molecule is of such shielding force that excitation of the atoms of the P-$\emptyset$ group cannot be realized to give rise to infrared absorption. This is only conjecture at the present time.

The attempted preparation of (I) has been repeated and the oily product purified by column chromatography (alumina/benzene). An 86-percent recovery of product was achieved. The product was light yellow and gave a negative Beilstein test for halogen. A complete elemental analysis is being made on this material including Cl, Mg, and ash.

In a second approach to the preparation of suitably substituted monomeric derivatives, the use of hindered phenols to give non-geminally substituted derivatives of $(PNCl_2)_4$ has been investigated. Initially, an excess of the sodium salt of 2,6-di-tert-butyl-p-cresol was treated with $(PNCl_2)_4$ in refluxing THF for a 24-hour period.



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

where + = tertiary butyl group

Attempted purification of the reaction mixture yielded only unreacted starting materials.

In a subsequent repetition of this reaction, bis(2-methoxyethyl) ether (diglyme) was employed as the solvent instead of THF, because of its much higher boiling point, and the fact that the sodium salt of the hindered phenol is also soluble in it. A diglyme solution of the phenol was treated with an equivalent quantity of metallic sodium and the resulting solution treated with 0.025 mole of $(PNCl_2)_4$. At a reaction temperature of 135°C (275°F), separation of solid was noted and the temperature of the reaction mixture was maintained there overnight. The reaction mixture was concentrated *in vacuo* and the residue exhaustively extracted with benzene in a Soxhlet apparatus. This experiment is in progress at this time.

A portion of $P_4N_4Cl_4(CH_3NC_6H_{11})_4$ was dissolved in THF and treated with anhydrous ammonia. A quantitative yield of NH_4Cl and an oil which solidified upon trituration with acetonitrile were obtained from the reaction mixture. The solid $(P_4N_4(NH_2)_4\ (CH_3NC_6H_{11})_4$ was recrystallized from CH_3CN-ØH as short white needles, having a melting range of 158-160°C (316-320°F). Realizing that this derivative would be hydrolytically unstable, as would be any polymers prepared from it, a portion of the product was placed in a test tube and slowly heated by means of an oil bath to a maximum temperature of 290°C (554°F). At 160°C (320°F evolution of ammonia accompanied melting of the solid and continued throughout the heating cycle until the maximum temperature was reached. At this point evolution of ammonia ceased and the liquid changed to an olive-colored granular powder (m.p. 350°C (662°F)). The polymer was mostly soluble in benzene and chloroform. No additional characterization of the product is contemplated.

C. Investigation of Metallic Composites

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

Developmental activities have continued in the area of metallic composites. During this report period emphasis was directed toward the development of a titanium modular filament cylinder composite. This Al-Ti-Al cylinder composite section is being fabricated to simulate launch vehicle ducting-tankage applications. The inner and outer sleeves are being fabricated by the seam welding tube technique. The techniques for joining or bonding the three components will be either by diffusion bonding or explosive bonding.

Also, under investigation is a special stainless steel alloy, Custom 455, which, if found to be acceptable, will be used in the fabrication of modular sheets for composite development. This alloy has a yield strength in excess of 250,000 psi when cold-worked and aged at

900°F (482°C). The aging temperature and time cycle coincides quite conveniently with the diffusion bonding temperatures of aluminum and magnesium. Consequently, the use of this alloy for diffusion bonding composite applications appears interesting. A 0.32 inch thick sheet of this material has been reduced in thickness to 0.015 and 0.020 inch thick sheet for use in the modular project.

2. Development and Evaluation of Wire Reinforced Composites

In earlier investigations with wire reinforced magnesium composites, it was observed that the strength of the composite formed was less than that anticipated based on the reported strength of the wire. This loss in strength was believed to be due to the temperature to which the wire was exposed during forming of the composite, i.e., 1400°F (760°C). Tests were made to determine the effects of exposure to elevated temperatures on wire specimens of boron, stainless steel (NS 355) and beryllium.

These tests consisted of wrapping the wire on a stainless steel core and subsequently heating the assemblies to temperatures of 700°F, 1000°F, and 1400°F (371°C, 538°C, and 760°C) for five minutes and then cooling in air. The greatest percent loss in strength was found to be in the boron wire, in which the strength was decreased from 446,000 psi at room temperature to about 50,700 at 1400°F (760°C). Also, the room temperature ultimate properties of beryllium wire was noted to be approximately 40,000 psi less than reported in the vendors test report (202,600 psi). These tests will be continued in order to develop adequate base line data to provide a basis for evaluation of wire reinforced composites.

D. Investigation of Stress Corrosion Characteristics of Various Alloys

Studies have continued in the evaluation of the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were stressed in the short transverse grain direction to 75 percent of their yield strengths and are being exposed to inside and outside atmospheres. Specimen failures to date have been confined to those exposed to the outside atmosphere. These tests have been in progress for 98 days.

Specimens of aluminum alloys X2021 and X7007 were stressed in all three grain directions and exposed in the alternate immersion tester and the local atmosphere. Both alloys were found to be susceptible to stress corrosion in the alternate immersion tester. Tests in the atmosphere have been in progress 17 months, and the only failures encountered were X7007-T6E136 specimens stressed in the short transverse direction. Failures of these specimens have occurred at loads as low as 10 ksi.

Because of the excessive amount of general surface corrosion encountered in stress corrosion testing of aluminum - copper alloys in 3.5 percent sodium chloride, a more suitable test medium is being investigated. Synthetic sea water appeared very promising based on preliminary tests and a broad program has been undertaken involving threshold stress levels in all three grain directions of alloys 2014-T6; 2024-T351; -T851, -T4 and -T6; 2219-T37, -T87 and -T62; 7075-T6, and 7079-T651. The only changes in the test results since the June progress report is one 2024-T6 (plate),50 ksi long transverse specimen, failed in 120 days; one 2024-T6 (bar), 43 ksi transverse specimen, failed in 120 days, and one 2024-T851, 43 ksi short transverse specimen, failed in 122 days. This test is being extended beyond the usual 90 days.

Studies are continuing into the stress corrosion susceptibility of Ti-6Al-4V alloy in various fluids. No failures have occurred in any of the fluids except methyl alcohol. Specimens that had not failed in methanol containing 0.50 and 1.0 percent water for 176 days failed within two days after the addition of 16.5 ppm sodium chloride (10 ppm Cl). Specimens exposed to methanol containing 3.0 percent water for 176 days have not failed in 49 days after the addition of 66 ppm sodium chloride.

Additional tests to evaluate the stress corrosion resistance of NAA, General Electric, and Aero Quip type stainless steel fittings welded and brazed to 321 stainless steel tubing have been exposed in the alternate immersion tester for 113 days without any failures.

Arde low silicon 301 stainless steel, cryogenically stretched to a nominal 240 ksi, is being studied for stress corrosion susceptibility in the aged (20 hours at 790°F (421°C) in air) and unaged conditions. The specimens were passivated according to an Arde specification (AE8354 Solution A). Longitudinal specimens stressed to 75 percent of the yield strength (unaged 184 ksi and aged 196 ksi) have not failed after 135 days in the alternate immersion tester.

Specimens of Armco 21-6-9 stainless steel unsensitized and sensitized (1250°F (677°C) for one hour, air cooled) are being studied for stress corrosion susceptibility. Flat, round threaded-end, and C-ring specimens stressed to 75 percent and 100 percent of the yield strength of both conditions are being exposed in the alternate immersion tester. No failures have been encountered after 93 days of exposure.

E. Investigation of Dielectric Properties of Materials

Studies have continued in the determination of the high voltage breakdown behavior of polyurethane foam under the combined effects of vacuum, temperature, and time under pre-breakdown electrical stress.

Base line characteristics on polyurethane breakdown characteristics as a function of temperature at atmospheric pressure were reported last month. In contrast to these data, polyurethane breakdown characteristics in vacuum are currently being investigated. Premature discharges within the vacuum chamber has created experimental problems; however, these problems have been resolved and no further delays in experimentation are expected.

Experimental data obtained in vacuum agree qualitatively with the behavioral trend of the 'in air' data reported last month in that polyurethan breakdown values vary directly with temperature. Examination of the inter-electrode space at the point of breakdown shows much less carbonizing of the foam than do the specimens broken down 'in air'. Unlike the 'in air' tested specimens, the specimens tested in vacuum show little change in dielectric structure (from the amorphous state) in the area immediately adjacent to the carbonized pit.

A high voltage breakdown test cell to accommodate various electrode configurations and various sample thicknesses is being designed for use in the high voltage vacuum chamber with both the 50 KV a.c. corona machine and also the 150 KV d.c. machine. This test cell will accommodate point to point, point to plane, point to ball, plane to plane, and ball to plane configurations and test specimens up to 5 inches in diameter and ranging from 1 mil to 3 inches in thickness.

F. Development of Nondestructive Techniques for Evaluating Materials and Components

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

Numerous electromagnetic, ultrasonic and internal friction measurements have demonstrated that early stages of stress corrosion cracking can be detected in 7079-T6 aluminum; furthermore, there is a very significant difference in the magnitude of materials property changes caused by corrosion only and those changes measured when the specimen is stressed and exposed to a corrosive environment. A current objective of these studies is to relate the magnitude of these property changes to the mechanical strength of the specimens. The Charpy impact test was selected as most appropriate for this purpose. Three small impact specimens were machined from the center of each stress corrosion specimen and placed in the impact tester so that the falling weight would strike the side opposite the stress-corroded surface; thus, small cracks should cause large losses in the impact strength of the material. Specimens exposed to stress corrosion for 48 hours lost approximately two thirds of their impact strength as compared to uncorroded material. With the exception of two or three points, there was excellent correlation of impact tests results with electrical conductivity changes. Detailed results will be reported when fifty additional specimens are tested.

The magnitude of residual stresses are of major significance in space vehicle components. This is especially true near weldments and in components susceptible to stress corrosion. Thus, a broad program has been initiated to develop nondestructive techniques for measuring residual stress in metals.

Since the "I" beam loading table and the required fixtures have been received from the Development Shop, R-P&VE-MED, a limited number of stress measurements or indications have been made on steel with a magnetic reaction analyzer. Small differences were observed in the analyzer indications as increasing stress was applied to the steel; however, the degree of significance of these differences is yet to be determined.

A project has been initiated to develop a suitable laboratory apparatus for measurement of the rate of crack propagation in metals. The apparatus is needed for experimental study of the influence of stress, reactive environments, temperature, etc., on the rate of crack propagation. Its eventual use is for the study of the mechanism of crack propagation in aluminum at the grain boundary level.

Experiments are underway to determine the optimum stress monitoring point; monitoring the stress across a notch stress riser yielded unsatisfactory results.

G. Investigation of Organic Semi-Conductor Materials

Studies have continued in the establishment of the characteristics of the semi-conductor chrysene. Data from electrical conductivity measurements made on large crystals of known purity have been prepared for and released to the Computation Laboratory for data reduction. The results of this analysis will yield the molecular activation energy for this crystal along the "ab" plane of the crystal. Photo-conductivity measurements are being made on this material.

H. Development and Evaluation of Light Weight Ceramic Foams

Efforts have continued to evaluate "Refrasil" fibers as an additive for improving the strength of the sodium silicate based foams. The amount of "Refrasil" fibers (1/4-inch length) that could be added to various sodium silicates prior to foaming was investigated. This amount appeared to be related to the viscosity of the sodium silicate. The strongest foam produced to date was prepared from a low viscosity sodium silicate having a sodium oxide:silicon dioxide ratio ($Na0:Si0_2$) of 1:2.00. This foam was prepared from a mixture containing 12.5 grams of "Refrasil" fibers per 100 cc of sodium silicate. The foam had good mechanical strength, reasonably uniform pore structure, and a density of 5.0 pounds per cubic foot. Previously, all foams produced have been prepared in containers that restricted the foaming action in only two directions. This technique

has resulted in foams with non-uniform densities - the top of the foams being lighter than the bottom. Studies are presently underway to investigate techniques of restricting the foam growth in all three dimensions. The first technique investigated was to cover the container with heavy aluminum foil. This technique only slightly restrained the growth of the foam during foaming and the foams produced had pore structures similar to those produced in a container without a cover. Work will continue to develop stronger and more uniform foams in containers designed to restrict foam growth.

I. Investigation of Electroplating Processes

1. Electroplating on Anodized Aluminum

Several test panels of alloys 6061, 2024, and 7075 have been nickel plated after receiving an anodize for a short period of time in a mixture of sulfuric and phosphoric acids. Adhesion appears to be extremely good on occasion, but some inconsistency has occurred. It is believed that some process details can be altered to overcome this fault. The process is more critical than conventional procedures. Nickel has been more successfully plated than other metals. Panels are being prepared with a nickel plating to determine the corrosion protection afforded by this method of application.

2. Electroplating on Magnesium-Lithium Alloys

Previous attempts to electroplate magnesium-lithium alloys indicated fair adhesion of subsequent metals could be obtained by using a modified "Dow" zincate pretreatment following a five percent nitric acid pickle. Additional studies with this alloy have been initiated in an effort to improve the adhesion of the plated coatings. Various pretreatments and acid pickles have been employed; however, the nitric acid pickle still provides the best surface for subsequent coatings. Various concentrations of nitric acid have been used with a six-percent concentration being the best thus far. Panels have been plated using this six percent nitric acid pickle and the modified "Dow" zincate pretreatment with adhesion which withstood a 40-minute 350°F (177°C) bake without blistering and a back and forth bend until fracture occurred in the basic metal without flaking.

J. Investigation of Gamma Ray Absorption and Determination of Resultant "G" Values of Materials

A program has been initiated to measure the outgassing of insulation materials under gamma irradiation with initial emphasis directed toward cork and polyurethane foams. The test results are reported in "G" values, which is the number of gas molecules produced per 100 ev of radiation absorbed.

Two-gas cylinders measuring 6 inches high and 5 inches in diameter were constructed from aluminum for the purpose of irradiating samples of cork and polyurethane foams. The tops of the cylinders, fitted with an O-ring, are removable for access to the material inside.

The proposed method of testing will be as follows: About 60 grams of foam or cork are installed in the cylinder after which the cylinder is connected to a vacuum pump and the pressure reduced to 100 μ. The cylinder and contents are then irradiated in the Gammacell (flux 2 x 10^6 R/hr.) for a period of 6 to 20 hours. After irradiation the gases are analyzed by mass spectroscopy and gas chromatography for H_2, CO_2, CH_4, C_2H_6, C_3H_8, and C_4H_{10}. Three cork samples and one foam sample have been tested to date, and an approximate "G" value for cork (Armstrong 7326) of 0.4 has been found. Further analysis of the data is in progress.

K. Documentation Review

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

1. MDC STP0205, "Titanium and Titanium Alloys, Heat Treatment of."

2. 1P20118, "Gas Shielding, Helium, Argon Mixture for Welding," dated January 25, 1967.

3. 1P20114, "Gas Shielding, Argon For Welding," dated January 25, 1967.

4. STM0308, "Wire, Welding, Titanium Alloy, High Purity," dated March 28, 1967.

5. 1P00128, "Mechanized Fusion Welding of Titanium Alloys," dated June 7, 1967.

6. 1P20115, "Gas Shielding, Helium for Welding," dated January 18, 1967

7. STP0102, "Welding, Butt, Gas Pressure, Titanium Alloy Pressure Vessels," dated June 28, 1967.

8. DAC STP0176, dated March 17, 1967, "Titanium Alloys, Surface Treatment."

9. DAC STP0191, "Leak Test, Aft Dome Joint Welds and Fasteners."

10. DAC STM0334, "Leak Test Solution."

11. NAA MA0110-011J, dated April 24, 1967, "Cleaning of Aluminum and Aluminum Alloys."

L. Literature Survey

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

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

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

JULY 1, 1967 THROUGH JULY 31, 1967

I. Radiography

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

II. Photography

	Negatives	Prints	Other
Engineering photography	139	1236	
Metallography and fractography	86	191	
Miscellaneous photography, processing, copywork, etc.	38	42	2

III. Metallurgical and Mechanical Testing and Evaluation

A. Twelve experimental stainless steel tube connectors were studied metallographically at the request of the Propulsion Division, R-P&VE-PE. The twelve connector specimens consisted of four General Electric (GE) Corporation brazed connectors, four Aeroquip brazed connectors and four North American Aviation (NAA) welded connectors. All twelve connectors had completed successfully 300,000 cycles of vibration testing. Although the GE connectors had the best braze integrity, three of this type connector failed from fatigue during qualification testing; whereas, no failures were observed in the Aeroquip brazed or NAA welded connectors. The main concern with the NAA welded connector is that weld drop-through on the I.D. will act as a flow restrictor.

B. At the request of Test Laboratory determinations were made of the rolling direction of two pieces of material (aluminum and steel). The pieces were removed from large plates that did not have visible rolling direction indications.

C. R-ME-MMP has requested assistance in the selection of fastener materials to be evaluated under contract NAS9-20779. The alloys included in the contract are A-286 stainless steel, H-11 alloy steel, 5 Al-2.5 tin titanium alloy, 6Al-4V titanium alloy, 2014-T4 aluminum alloy, AISI 8740 and AMS 6304 alloy steels, and L-605 (cold-rolled) cobalt base alloy. The new alloys under consideration are: Inconel 718, Waspaloy, AF-1753, Dupont alloy MP-35 and Custom 455 stainless steel.

D. We have been requested by R-P&VE-PMS to evaluate a specification for an "Exploding Bridgement Detonator." The materials used in the detonator are being examined for material compatibility and suitability for use at -300°F. The types of materials included in the detonator are: 4140 steel alloy, 52 percent nickel + iron driver-harris alloy number 52, alumina, alloy steel per MIL-S-7742 (B-1213, case steel, mica, RTV silicone rubber, Phenolic-Plastic rod - Form R-type FBE procured to MIL-P-79.)

IV. Spectrographic Analyses

One hundred and fifty-four determinations were made on fourteen samples and one hundred standard determinations were made.

V. Infrared Analyses

Fifty qualitative analyses were made by infrared techniques on a variety of materials including experimental and commercial polymers, silicone oil, combustion products, and Freon materials.

VI. Chemical Analyses

	Determinations
RJ-4 fuel for	
sulfide	4
lead	1
tetracyanoquinonedimethane for	
carbon	33
hydrogen	33
nitrogen	33
water for copper content	2
metal samples for	
copper	4
carbon	5
phosphorus	4
sulfur	2
nitrogen	5
manganese	2
chromium	4
nickel	4
experimental polymers for	
carbon	3
hydrogen	3
nitrogen	3
phosphorus	2
chlorine	1
fluorine	4

gas samples for	
nitrogen	49
oxygen	77
hydrogen	72
argon	66
carbon dioxide	87
helium	6
carbonyl fluoride	35
carbon tetrafluoride	47
methane	16
ethane	16
acetylene	6
propane	10
butane	10

VII. Physico Chemical Analyses

	Determinations
Density of RJ-1 Fuel	4
Acid number of lube oil	4

VIII. Rubber and Plastics

	Items
molded and extruded	128
coated	228
fabricated	40

IX. Electroplating and Surface Treatment

	Items
electropolished	22
painted	6
conversion coated	39
anodized	34
acid cleaned	63
degreased	9

X. Development Shop Production

A. A total of 7,484 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. One thousand seven hundred and ninety-six man-hours, approximately 24 percent of the total man-hours, were expended on work of a non-routine nature and applied to the work orders listed below.

1. Six-Inch U.V. Camera Assembly

Approximately 140 man-hours are needed to complete the six-inch U.V. camera assembly.

2. X-ray Astronomy Assembly

The X-ray astronomy assembly is 90 percent complete.

3. Pressure Vacuum Furnace Assembly

The pressure vacuum furnace assembly is completed and delivered.

4. Cryogenic Test Tank Assembly

The cryogenic test tank assembly is completed and delivered.

5. Ice Calorimeter Stand and Support

The ice calorimeter stand and support have been delivered.

6. Dolly-Vacuum Pump Chamber

The Dolly-Vacuum pump chamber is completed and delivered.

7. Coupling Assembly

Work has started on the coupling assembly and the material for seals is purchased.

8. Saturn V Sled Test Module

Work on the mock-up is in process but modifications to the sled have not been started.

9. Spherical and Roller Bearing Assemblies

Work is progressing satisfactorily on the spherical and roller bearing assemblies and should be completed by August 4, 1967.

XI. Miscellaneous

A. Eight reflectance determinations were made during this report period.

B. Thirteen specimens were tested for emissivity during this report period.

C. Forty-one materials were evaluated in accordance with the provisions of MSFC-SPEC-106B. Data generated from these evaluations were forwarded to requesting groups and will appear later in applicable technical reports.

XII. Publications

Mathur, Satish C.: Conduction Mechanism in Organic Semiconductors, TMX-53638, July 26, 1967.

Lovoy, C. V.: An Investigation of the Behavior of Restrained Weldments in Aluminum Alloy 2219, IN-P&VE-M-67-4, July 3, 1967.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-67-7

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

SATURN V

Voyager Program

A. Spacecraft Design

1. Current Spacecraft Preliminary Weights --- Recent guidelines issued by the Voyager Interim Project Office (VIPO) state requirements for a 7000-pound capsule for the 1975, 1977, and 1979 missions and a 6000-pound capsule for the 1973 mission. In addition, the VIPO designated a gross weight allocation of 18,200 pounds for the spacecraft for the 1973 mission. The spacecraft, like the capsule, is to be designed for a 7000-pound capsule weight capability and off-loaded for the 1973 mission. Also, the ΔV requirement for all missions has been reduced from 2.12 km/sec to 1.95 km/sec.

From these new requirements, the current spacecraft weight is about 143 pounds less than the allocated 18,200 pounds for the 1973 mission, giving a 143-pound weight contingency at present. For the 1975 to 1979 mission with the heavier capsule, the spacecraft weight would be approximately 18,844 pounds with no contingency. Since the spacecraft weight allotment for the later missions has not been identified, the weights will be adjusted with design iterations without assigning a contingency.

2. In-house Efforts Presentations --- An informal technical review of the in-house R-P&VE Phase I study and design efforts during the period ending June 30, 1967, was given on July 20, 1967, to Messrs. D. Newby, Dick Smith, et al.

3. Additional Missions Definition for Planetary Vehicle --- Effort is continuing to define additional missions for the Planetary Vehicle (P/V) utilizing the Saturn IB/Centaur and Saturn V launch vehicles. Modifications required to the P/V to enhance alternate missions are also being defined.

A computer program which will size the planetary vehicles and determine ΔV capability has been written and checked out and will be used to generate a portion of the data required for this study. Completion date is scheduled for mid-August 1967.

4. Agena Engine for Voyager --- Several versions of a modified Agena engine (model 8517) designed for the Voyager mission are being studied. Spacecraft propulsion system designs employing the model 8517 are being investigated for four cases as follows:

Case 1. For orbit insertion maneuvers the primary mode of operation will be pump-fed; pressure-fed operation will be used for backup at a reduced thrust level. Midcourse and orbit trim maneuvers will be performed by an auxiliary propulsion system.

Case 2. Same as Case 1 except that changes to the standard Agena engine required to achieve the pressure-fed operation capability will be minimized and will not compromise pump-fed performance. Pressure-fed performance will be degraded in this case.

Case 3. The Agena engine will perform all maneuvers including midcourse, orbit insertion, and orbit trim. Mixture ratio for all modes of operation will be constant.

Case 4. This case is similar to Case 3 except that mixture ratio for each mode will be adjusted for optimum engine performance.

5. Voyager Spacecraft with 260-inch-diameter --- Preliminary configurations of this spacecraft design concept have been drawn for structural analyses and for location of systems. Because the effort is in the initial phase of study, no conclusions can be stated at this time.

6. Personnel Transportation to Synchronous Orbit --- Results from this study of launch vehicles and space stages for transporting personnel to synchronous orbit show that neither the Apollo nor the Gemini capsules can be transported by the Saturn IB launch vehicle, with an optimized third stage, to synchronous orbit and returned. The 260-inch-diameter space stage design, used for circularizing and deorbiting the

payload at synchronous orbit, adapts well with the advanced Apollo (180-inch-diameter) and with the standard Apollo capsule (154-inch-diameter), but requires a very long and heavy adapter with the Gemini capsule.

The study plan is to evaluate the 260-inch-diameter space stage in the first phase of the study and a 140-inch-diameter stage in the second phase of study. Reports on these stage designs are to be completed by September 1 and November 20, 1967, respectively.

7. S-IVB Staging Study --- A study has been made of increasing Voyager payload capability by using the Voyager spacecraft as fourth stages on the Saturn V launch vehicle. In this mission mode, following burnout of the S-IVB stage, each Voyager spacecraft will provide an additional velocity increment to obtain the required transmartian injection velocity. Data evaluated on this concept show that by increasing the propellant loading of each spacecraft by approximately 75 per cent, the capsule weight delivered to Mars orbit can be increased by 6 to 8 per cent. The optimum velocity with respect to the earth for staging the S-IVB, to obtain this maximum capsule weight in Mars orbit, was found to be 3.6 km/sec. The ratio of inert to propellant weight used for scaling the spacecraft weight for this study was 0.1 lb/lb. Results of the study are currently being summarized and will be issued August 4, 1967.

B. Shroud Design

The conceptual phase of the Voyager shroud design effort (October 1966-June 1967) has been documented in MSFC Internal Note IN-P&VE-A-67-6, "Summary Report, MSFC Voyager Shroud Preliminary Design - Part I." A significant result is the proposed recommended baseline shroud system, as follows: skin/stringer nose cone; honeycomb sandwich cylindrical planetary vehicle compartments; honeycomb sandwich cylindrical spacer section; circumferential separation joints with encapsulated mild detonating fuse (MDF); over-the-nose separation; external cable troughs; and separate umbilicals to each planetary vehicle compartment. Total system weight is 12,400 pounds. It is anticipated that this recommended system will be finalized before the end of the year; however, an earlier decision is being sought on the honeycomb construction of the cylindrical sections.

Beginning July 1, the design effort moved into Part II of the Preliminary Design; the first official meeting was held July 14, 1967.

C. Voyager Spacecraft Science

A memorandum, "Voyager Spacecraft/Spacecraft Science Interface Summary," R-P&VE-AA-67-111, has been prepared presenting the study results of activities of the P&VE Voyager Working Group representative for Spacecraft Science during Part I of the MSFC Voyager in-house study. The memorandum presents a discussion of the procedure and management being evolved for selection of the scientific instrumentation for the Voyager Spacecraft, a definition of the Hypothetical Spacecraft Science Payload being used for preliminary design purposes, and an assessment of spacecraft accommodation of the science payload in the areas of instrumentation location and packaging. The information presented in the memorandum is intended for use as a guide for more detailed studies in this area during Part II of the MSFC Voyager in-house study.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

Advanced S-IVB Workshop

A visit was made to the McDonnell/Douglas Aircraft Corporation, Huntington Beach, California, July 10 - 14, 1967, to clarify the status and logic of configurations and subsystem work accomplished to date, to determine the extent to which configurations can be narrowed down at this time, to resolve any guideline differences, and to reach accord on future efforts. The subjects discussed were configurations, design and experiment integration, EC/LSS, human factors and crew systems, structures, RCS propulsion and gas storage, with the major effort on configurations. After reviewing these areas, recommendations were made, through the study COR, for additional configuration and subsystem effort during the remainder of the contract. The recommendations are documented in memorandum R-P&VE-AA-67-114.

The in-house effort has concentrated primarily on the preparation of MSFC Internal Notes covering the design and subsystem definition of the EOSS and AWS. The effort of defining the applicability of EOSS-type subsystems to an Advanced Spent Stage was completed. The subsystem effort is being broadened to properly assess the adequacy of the EOSS and AWS subsystems to perform under various potential operational conditions; to further define these subsystems where gaps exist; to perform a limited failure mode analysis; and to define necessary crew displays, crew movements, and equipment access.

II. Integration

A. AAP Experiment Catalog

The cataloging of experiments for AAP flights 3 and 4 has been completed and about half of the total catalog has been updated with the latest information.

An effort has been initiated to include the EOSS experiment data, which have been received recently from the McDonnell/Douglas Aircraft Corporation.

B. Experiment Scheduling and Compatibility Program (ESCAPE)

The following modifications have been made to ESCAPE and are being checked out:

(1) Multiple equipment number capacity

(2) Assignment of weights to corresponding equipment numbers

(3) Detailed power profile routine

Five modes of operations for AAP flights 3 and 4 have been defined and are ready for ESCAPE analysis.

A summary of EOSS experiment requirements is being prepared.

III. Lunar Systems

A. Mobility Test Program

The delivery of the GM/MTA wheels was delayed until the week of July 17, thus creating approximately a 6-week delay in start of the MSFC mobility test program. It appears now that the test program cannot be started prior to mid-September 1967. An attempt was made to secure the Bendix four-wheel motorized mockup for this test program; however, even with program delay, sufficient time is not available to check out and instrument the Bendix vehicle. Although current plans do not include testing of the Bendix motorized mockup, it will be possible to perform the test with this vehicle at a later date. The current test program will include both MTA vehicles and the BECO-built LSSM mockup.

The BECO-built LSSM motorized mockup is presently undergoing tests, on the Army test course, for purposes of calibration and checkout of vehicle instrumentation. This calibration and shakedown program should continue through mid-August.

A proposed detail test plan is currently being prepared to include such items as number of runs, size of obstacles, vehicle speed, etc.

B. LSSM Program

At the request of I-S/AA, three possible programs for testing the LSSM were developed. These test programs recommend the 1/6-g flight test and ground-simulator testing of either full-scale or 1/4-scale models of the LSSM. Preliminary cost data were also developed for each of the three test programs.

NUCLEAR STUDY PROGRAM

I. Nuclear Vehicle Design Sensitivity Study

Evaluation of the LMSC Phase II results has begun. Contractor documentation is being reviewed in order to establish the mission/vehicle definitions for the study. Preliminary weight estimates have been made for OLV configurations similar to configurations B and D of the Phase I study and utilizing the same ground rules. Results indicate substantial weight reductions and/or payload increases may be achieved utilizing Phase II structural and weight-staging assumptions.

Results achieved to date in the study of the LMSC Phase I concept are being documented. The report will be released in mid-August.

II. ATM Film Fogging

A brief technical review of ATM film fogging and conceptual remedies was prepared for presentation to P&VE management in early August.

ADVANCED PROGRAMS

I. Launch Vehicles

A. Kick Stage Study

The technical effort on the Kick Stage study was completed and results were documented.

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

The Phase I and Phase II efforts of this study will be combined into one report. A new effort has been initiated which will involve an in-depth look at both pressure-fed and pump-fed systems. Hydrogen peroxide/alumizine propellant is being considered as well as nitrogen/tetroxide/alumizine for each system.

C. Launch Vehicle Handbook

Selected material is being taken from past studies to aid in the definition of the handbook contents. Applicable computer programs are being converted and checked out. A control study being initiated for the "660K" vehicle will be applicable to this study.

II. Earth Orbital

Five-year Space Station

A report covering the last six months' effort on the definition of a five-year station was completed on July 21, 1967. The report shows the various concepts developed, along with limited investigation in structures, subsystem layout, and weight statements.

III. Planetary Systems

A. Mars/Venus Fly-by Mission Study

The NAA study of Mars/Venus missions using Saturn/Apollo hardware is scheduled to terminate on August 3, 1967. Draft copies of the final report were reviewed and comments were forwarded to the contractor. The final presentation is scheduled for August 2, 1967.

B. Mars Orbital Probe

Work has continued in this area to conceptually design a Mars probe which will be launched from a fly-by spacecraft, orbit the planet, and collect and transmit data pertaining to the surface, atmosphere and environment of the planet Mars. The study is approximately two-thirds complete. Two probe concepts will evolve from this effort: a probe capable of packaging and satisfying the maximum scientific objectives and one which will satisfy the minimum or higher priority scientific objective.

IV. Common Mission Module Study (CMM)

A. Configuration and Systems

The study of a common mission module which would satisfy the requirements for both a long-term space station and a Mars fly-by or Mars capture mission is continuing. The initial work involves investigating the design and functional requirements, design criteria, parametric and tradeoff studies of configuration approaches and subsystems for selected missions. Parametric analysis has been initiated in the areas of structural design approaches and thermal environment and control, and preliminary layouts are being developed for interior design and arrangement. The subsystem areas to be investigated are Environmental Control and Life Support, Electrical Power, Crew Systems, Reaction and Control, Stabilization and Control, Communications and Data Management, and Instrumentation. A preliminary layout has been initiated to determine equipment and subsystem locations.

B. Radiation Requirements

A preliminary analysis has been made to determine the radiation levels which must be endured by a flight crew for two-year earth orbital or interplanetary missions. The approach taken for this analysis was to evaluate solar radiation (1) based on the maximum activity (1959-1960) period and (2) that actually predicted to occur during the expected mission time (approximate levels of 1957 and 1958). Shielding and solar shelter requirements were determined for each case.

C. Command Post Definition

A study has been initiated to determine the common associated with the functions of a Command and Control Cente mission module which will satisfy the requirements of long-te orbital space stations and manned interplanetary flights. The of this study are (1) to determine the specific function of the co post as it pertains to a common mission module approach; (2) t data to assess the types and characteristics of equipment requi perform the command post functions; and (3) to provide concept out and packaging schemes of the equipment integrated with the Mission Module (CMM). The results of this study will provide i concept selection, definition, and evaluation of a CMM conceptua

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-67-7

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(July 1, 1967 - July 31, 1967)

SATURN IB

I. S-IVB Stage

A. SA-211

During an internal manufacturing operation at Huntington Beach, McDonnell Douglas Corporation (MDC) was demating the SA-211 structural assembly at the separation plane by lifting the upper portion off the interstage, when it was discovered that one interface bolt had not been removed. Inspection revealed a circumferential crack in the horizontal flange of the aft skirt interface angle. This area will be repaired by splicing the area with an inside backup angle. The structural integrity of the S-IVB/211 stage should not be impaired by this situation.

B. S-IVB/IU

IBM has informed Structures Division that a fix proposed by MDC (Tension straps or plates across the S-IVB/IU interface in the event that the panel structural tests do not show the S-IC engine-out loading capability) has been altered, to the agreement of both contractors, to include radius blocks in only local areas to increase the strength. This modification has not been explained in detail yet, so no position has been taken by MSFC.

II. Saturn IB System

AS-204 Pull Test

The second pull test on AS-204 was run on July 17, 1967. The real time display of bending moment at the HOSC was partially successful. The problems were due to the breakdown of the analog-to-digital (A/D) converter. In the effort to bypass the A/D converter, several problems developed that had not been previously encountered. However, enough strain data was received to verify that the strain to load relationship obtained from the first pull test was satisfactory.

In essence, both pull tests on AS-204 yielded the same results which indicates the vehicle is stiffer than previously expected. Also, the tests indicate that the internal loads analysis is in error for the ground wind case. The effect of the pull test on the internal loads analysis is being investigated.

SATURN V

I. S-IC Stage

A. Heat Shield

The use of the flight type heat shields was investigated for use on S-IC-T stage. The investigation revealed that either one-quarter inch plate or the flight type heat shield is satisfactory for ground test firings of the S-IC stage.

B. S-IC-8 Fuel Tank

The S-IC-8 fuel tank has successfully completed the second hydrostat test and the 10 cycles of operating pressure. The reinspection of all welds on the S-IC-8 fuel tank has been completed. No further crack growth was detected. All of the "cracks" had been ground out and five of these areas rewelded. The maximum depth of crack was 0.15 inches on the upper bulkhead to Y-ring weld. The tank will now be hydrostatically tested and put back in the flight schedule.

II. S-II Stage

A. MSFC Test 404

During fabrication of test fixture for MSFC Test 404, a crossbeam honeycomb panel of the S-II configuration thrust structure was damaged. A

hole of about one inch in diameter will be repaired. The hole will be reinforced with a doubler between the upper and lower chord members of the crossbeam.

B. LH_2 Feedline Evaluation

North American Aviation, Space Division has completed evaluation tests on a wrinkled LH_2 center engine feedline to determine if a wrinkled line will withstand S-IC boost random vibration conditions. A failure occurred at the turbopump attachment end in the gimbal pin and gimbal convolutions. Since this test specimen had already completed Change Order 351 vibration tests the failure at the gimbal was not considered valid, however, it does point out a potentially weak area. The wrinkled section itself did not fail during this test, which would tend to increase the confidence in the ability of the line to withstand imposed flight environments. However, the successful completion of the test does not qualify the line.

C. Component Flight Certification

As a result of discussions among personnel of the Structures Division, Propulsion Division, and North American Aviation, the following programs are being drafted by North American to develop sufficient confidence in the S-II stage for flight of S-II-1 and subs.

1. Outboard LH_2 feedline assembly ME271-0011-0007. The thrust structure-attached section of this line will be subjected to IN-P&VE-S-63-2 vibration test requirements prior to 501 VAB rollout. This requirement was imposed for the following reasons: (a) Lack of an adequate qualification test in the original North American qualification program, and (b) lack of similarity between this line and the inboard line in the thrust structure region.

2. Inboard LH_2 feedline assembly. North American has been unable to determine the cause of the pressure carrier wrinkles (i.e., all analyses indicate that the line should not have wrinkled). Therefore, the following test programs have been proposed: (a) Subject a wrinkled line to full flow test to determine whether the flow will induce pressure carrier fracture, (b) subject a wrinkled line to launch vibration simulation to determine whether the wrinkle will propagate or the pressure carrier fracture, and (c) subject an unwrinkled line to a vibration development test with adequate instrumentation to determine the loads required to wrinkle the line.

3. LH_2 recirculation duct 901-0237-0087 and -0088. North American will procure and subject to IN-P&VE-S-63-2 tests, the noted line assemblies prior to 502 VAB rollout. These tests have been required by MSFC because of inadequate qualification in the original qualification program.

4. Flex hose assembly ME271-0017-0075. This flex hose assembly will be vibration tested to IN-P&VE-S-63-2 levels and philosophy prior to 502 VAB rollout. Successful completion of this test and other representative tests will provide adequate confidence in S-II flex hose installations.

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

The MDC interstage has been completed and will be stored at MDC until NAA is prepared to receive it at Santa Susana. The welding of the forward bulkhead gores has been a unique and difficult problem and has resulted in oversize weld beads widths. The difficulty of evaluating these welds has been a major, time consuming effort. All hardware items are nearing completion and ready for assembly.

E. V7-23 Test ("C" Structure)

The 1/16 thrust cone panel was crated and shipped out of Tulsa July 19 and received July 21, 1967. This panel will be utilized to prove out the heater strip installation and controls.

The crossbeam and lower ring of the thrust structure were cleaned with tap water to reduce corrosion assumed to be caused by salt water exposure during shipment from NAA/SD. R-QUAL and R-P&VE-M inspected the structure and stated that the indications of corrosion would not be detrimental to the structure if cleaned.

F. Camera Coverage for S-II

A meeting was held Tuesday, July 18, to discuss camera coverage during testing of S-II structure. For test 404, it was requested that five video tape T. V. cameras be available for complete coverage of all limit load and ultimate load tests. High speed camera coverage was requested in seven locations during the ultimate load test.

G. V7-21, 22, and 23 Test Evaluation

Work has been initiated to define the data evaluation objectives for each of the three major tests to aid in preparing an Evaluation Plan document which would define in detail the work statement for test evaluation.

III. S-IVB Stage

A. Component Flight Certification

1. As a result of discussion among personnel of Structures Division, Propulsion Division, and MDC, the following flex hose assemblies will be

subjected to qualification test per IN-P&VE-S-63-2 as amended by Change Orders 250 and 251: 1B52444, 1B44237, 1B56439, and 1B59187. These flex hoses are considered representative samples and when coupled with other hoses currently scheduled for test in systems, these tests will give a representative sampling of S-IVB flex hose assemblies.

2. Redesign of an F-4 line item (LH_2 feed duct) support bracket which failed during vibration test was checked and found to be effective on 501.

3. Redesign of the F-8 LH_2 recirculation line was determined to have been effected on 501.

B. S-IVB/AS-509

After welding of the sump into the apex region of the AS-509 lox bulkhead, a 7" x 10" x 0.3" buckle was discovered in one panel of the adjacent gore assembly. This is a "stiff" buckle which involves the circumferential weld land. MDC plans to strain gage the area and force the buckle out by mechanical forming. This problem may compromise the acceptability of this item.

C. S-IVB/AS-502

After the restacking of the S-IVB stage onto the AS-502 vehicle, an attempt was made to remove the upper handling ring. However, as the ring was lifted it was discovered that one mating bolt had not been removed. The operation was stopped and corrective action taken. Subsequent inspection of the vehicle interface ring revealed no degradation.

D. S-IVB Flutter Panel Testing

A new panel was installed in the S-IVB flutter panel load fixture and instrumented with strain gages and deflection potentiometers. Several load conditions that cause panel buckling have been run to a maximum load of 64,000 pounds. After completion of the static load conditions, the panel will be reinstrumented with dynamic strain gages and will be further readied for the wind tunnel tests scheduled to begin the latter part of September.

E. IU/S-IVB Tension Panels

The test specimen was received for evaluating the tension capability of the IU lower interface (IU/S-IVB). The forward ring of the S-IVB panels is out of tolerance and must be machined to tolerance prior to the tests. The test fixture was completed except for that portion that must be accomplished at the time of panel installation. Instrumentation of the first IU panel has been completed. Instrumentation of the S-IVB panels cannot begin until the machining operation has been completed.

IV. Damper System

Testing of the ML-3 damper system is in progress. In testing the hook mechanism assembly, failure of one of the centering cables was experienced. A design investigation revealed that the cables required resizing. Redesign of the cable assembly is in progress. A semi-permanent fix has been released with a permanent fix in progress. Load test to the breaking strength of the cable assembly is being performed.

APOLLO APPLICATION PROGRAM

I. MSFC Flight Experiment #8

The proposed mounting location for the testing apparatus is at position III (between ports 2 and 3) on the exterior of the MDA. The current goal is to have Experiment #8 included on the AAP-2 flight. Clamshell doors, actuated by the indexing mechanism, have been added to aid in thermal conditioning and the design also allows for retrieval of four preselected broken specimens. Camera requirements have been specified by Vehicle Systems Division. It is recommended that the camera be mounted on the inside of the airlock and photograph through a view port by means of a fiber optics bundle.

II. Multiple Docking Adapter

The MDA bulkhead assembly and detail drawings will be late by approximately five weeks. Information required to complete the bulkhead was received July 21. Approximately three weeks will be required to incorporate this information and define the milling patterns in the skin details.

III. S-IVB Orbital Workshop

A. Internal Acoustic Environment

The Vibration and Acoustics Branch is investigating the internal acoustic environment of the S-IVB Workshop. The AiResearch ventilation fans have a particularly unique spectrum in which the speech interference level (SIL) is too high for normal voice communications. It appears that a decrease of about 20 dB in SIL is necessary to optimize the internal acoustic environments for communication purposes. This must be accomplished, however, without adversely affecting the ventilation system's flow properties. Representatives of the Vibration and Acoustics Branch demonstrated the operation of a single fan to three acoustic consultants in the New York and Boston areas. The general consensus was that the fan was not of particularly good design from the standpoint of noise generation. Assuming that the design of the fan is frozen each of the acoustic consultants believed that effective silencing methods could be employed which would afford a considerable noise

reduction. A three phase program was discussed and plans for implementing this program are currently in progress.

B. Vibration and Shock Criteria

The vibration and shock criteria were developed for the Multiple Docking Adapter, Apollo Telescope Module, and Payload Module assemblies. These criteria are applicable for the design and testing of the entire payload assemblies. In addition, vibration and shock criteria were developed for the MDA equipment mounting panels. These criteria will be applicable both to the structural mounting panels and the installed components.

IV. Apollo Telescope Mount (ATM)

A. Gimbal Support System Static Testing Specification

Discussion of the ATM Gimbal Support System Static Testing Specification with Perkin-Elmer Electro-Optical Division revealed that they knew nothing of MSFC structural testing philosophy at the time of writing their test specification. Perkin-Elmer was told that they must qualify the structure to ultimate loading condition (s), which were not included in their plans. In addition, it was recommended that they neither yield nor fail the structure but make it available to MSFC for possible inclusion in the rack test program. It was also recommended that they obtain from Structures Division a complete load history to use in their design and test program. The recommendations were accepted and Perkin-Elmer proposed a meeting in the near future to discuss in more depth our design and testing philosophy and procedures.

B. Rack/ATM

All detail and subassembly drawings for the Rack have been released as Class I documentation, or will be advance released by August 1. The Rack assembly drawing, 30M14501, will be advance released on schedule by August 1.

Discussions with personnel of Materials Division, Manufacturing Engineering and Astrionics Laboratories on the subject of electrical bonding of the Rack structure resulted in a decision to place an alodyne finish on the detail parts, and apply a zinc chromate coating, which is nonconductive, to the structural assembly. A coat of paint will be applied over the zinc chromate.

C. Experiment Package/ATM

A decision to fabricate a single wing of a flight configuration spar has been made. Drawings will be started as soon as experiment mounting information is received from Vehicle Systems Division. The purpose in

fabricating this wing of the spar is to check stability of the material subsequent to rough machining, heat treating, and finish machining. The data obtained will then be used in experiment alignment studies.

ADVANCED PROJECTS

Nutator Drive Test Program

Personnel from R-P&VE-SSV, R-AS, and NASA Headquarters visited the Bendix Corporation at their facility in Ann Arbor, Michigan, on June 28-30, 1967, to review the Nutator Drive Experimental Test Program, contract NAS8-20378.

During this time, the test article was run through its speed range under small loadings in an ambient environment and partially disassembled for inspection. After some 20 hours of operation on the gears and 40 hours of operation on the remainder of the unit, no visible signs of wear were evident. Also, while operating, the unit ran relatively smooth; however, it exhibited a resonant condition in the 4000-5000 input rpm range. This did not seem particularly critical but could be undesirable in the vehicle since it does represent an energy loss.

RESEARCH

I. Rocket Sled Test Program

The operational documentation of the Saturn V model rocket sled test program has been completed and signed by both Holloman AFB and MSFC personnel. The design and detailed drawings for the 1/10 scale model and its support are also completed. The model is currently being fabricated by the Engineering Physics Branch of Materials Division.

II. Mobile Acoustic Research Laboratory (MARL)

The MARL was moved into the Structures Division facility and the platform removed. Adapters were made for the Block I instrument unit, installed on the IU, and the unit secured to the test platform. Both the IU and the MARL were instrumented with 21 microphones and 26 accelerometers and moved to the test site on July 18, which is approximately 100° east of the flame deflector centerline and 300 feet out from the center of the S-IC test stand. Test Laboratory will monitor the instrumentation during the firing.

III. Impedance Research Program

Phase II testing on the Republic shells was completed on July 8. The data are being reduced and the data report formulated. The data report for Phase I (analytically determinate beams and plates) is being analyzed. The computer program for predicting impedance on shell structures has been completed and is being checked out with data from the Phase II test specimens. The impedance trailer was reactivated and Phase III tests on the 1/10 scale model Saturn V started the 3rd week of July. The steady state noise level of 100 - 110 dB in Building 4619 may create an insurmountable problem for taking data during first shift. The severeness of the problems is being investigated and solutions will be recommended prior to testing.

Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-67-7

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

July 1, 1967 through July 31, 1967

SATURN IB

I. S-IB Stage

S-IB Hydraulic Package Modification

To eliminate GN_2 leakage past the S-IB accumulator sleeve into the hydraulic fluid, three hydraulic packages were modified and tested successfully. One package is being subjected to single engine testing to further prove the redesign.

II. S-IVB Stage

A. Nominal Two-burn S-IVB-206 Propulsion Flight Prediction Completed

Propulsion dispersions for the second burn will be supplied following receipt of the dispersions in first burn velocity cutoff time. A report containing revised S-IVB loading data was received from the systems contractor for use in loading AS-204.

B. Orbital Workshop Attitude Control

A proposed attitude control system for the Orbital Workshop would provide for the present boost and passivation requirements as well as the 22,500 lb/sec of impulse required for docking and gravity gradient stabilization. The modules would consist of two S-IVB propellant tanks and six 25 lb thrust engines. The entire module would be insulated with high-performance insulation to reduce the power consumption during the storage period.

C. Simplified Condensation Test

The condensation test program was started. The last 12 tests were made with the fan located at the exit, the location selected to assure laminar flow. Preliminary results indicate that both the Martin and Brown Engineering mathematical models predict more condensation than actually occurs with the experimental setup. However, both models predict values that are within the expected range of experimental and calculation error.

D. Meteoroid Shield Closeouts

When deployed, the meteoroid shield stands approximately five inches from the outer skin of the LH_2 tank. The stand-off distance provides a "tunnel" between the meteoroid shield and outer tank skin through which a significant amount of heat will be transferred (approximately 2000 Btu/hr). It was requested that the annulus at each end of the meteoroid shield be covered.

E. Incident Radiant Heat Flux

Studies were made of the effect of the Cluster configuration upon the Orbital Workshop sidewall incident energy. These results, when compared to the simplified Cluster deletion of the LEM-ATM and CSM, have shown heat flux agreement within 5%. Therefore, all off-design attitude heat flux data are being generated using the simplified Cluster model to reduce machine and setup time.

F. Penetration Heat Leaks

Additional studies of penetration heat leaks were completed on the LH_2 feed line, LH_2 fill line, instrument probe, helium bottles, and thermal curtain support bolts. With the determined values, the total penetration heat leaks (exclusive of bulkheads) were estimated by scaling the non-analyzed penetrations with the particular penetrations in accordance to size. With a solar-fixed attitude, the total heat loss is estimated to be less than 100 Btu/hr. With a gravity gradient orientation and the worst roll attitude, the total heat loss is estimated to be in the range of 300 to 500 Btu/hr.

G. Bulkhead Heat Loss

Studies of the forward and aft bulkhead show the need for insulation to minimize the heat leaks. The aft LOX bulkhead insulation will not be sufficient due to the fin effect of the thrust cone. Internal radiation baffles and thrust cone insulation are being evaluated.

SATURN V

I. S-IC Stage

A. F-1 Engine

1. Solution for Hydraulic Control Line Problem

Damping devices and newly designed brackets have exhibited reduced strain levels during engine and vibration tests at Rocketdyne. It is believed that these devices will eliminate fatigue failures in the hydraulic control lines. Retrofit of the No. 2 Main LOX Valve opening control line is being recommended for the S-IC-502 and subsequent stages.

2. R&D Engine Tests at EFL

Twenty-four tests were conducted and a total duration of 2747.5 seconds was accumulated. Sixteen of these tests were full-duration runs (150 seconds or more). One test was terminated prematurely due to a self-induced instability while testing a new injector configuration.

3. Production Engine Testing at EFL

Seven tests were conducted and a total duration of 546.4 seconds was accumulated. Two of these tests were full-duration runs.

B. S-IC-T Pressure Switch Failures

Two pressure switches failed on the S-IC-T vehicle at Michoud. The system port operating pressure and the calibration port operating pressure were outside the specification limit. Investigation and Corrective Action Requests were prepared.

C. Saturn V-501 Flight Critical Components Review Completed

The review of all available data and documentation of the Saturn V stages to determine the flight worthiness of the propulsion system flight components is complete. All "Certification of Component Qualification" (COCQ) sheets are signed except for those items which require action just before the Saturn V-501 roll-out.

D. LOX Turbopump Seal Purge at KSC

A loading sequence similar to that used for static firing was recommended, based on the premise that RP-1 would be tanked one week

prior to launch. Since it would be necessary to purge the LOX turbopump seal for the entire week, the RP-1 will be drained below the prevalves to eliminate the need for the purge.

E. S-IC-504 Type Flight Predictions Completed Using Dual Thrust System and 1550K Uprated Engines

These predictions were made as part of a study to determine the impact of the above modifications on the payload gain, trajectory, and the Saturn V structure.

II. S-II Stage

A. J-2 Engine

1. R&D Testing at SSFL

Six tests were conducted and a total of 2565 seconds was accumulated. Five of these tests were full-duration runs.

2. Production Engine Tests at SSFL

Five tests were conducted and a total of 760 seconds was accumulated. One test was terminated prematurely due to a faulty cutoff device.

3. J-2S Testing

Engine J108, which is the engine scheduled for delivery to MSFC, completed two checkout and calibration tests at Rocketdyne. The first test was aborted because of tapoff temperature redline after approximately 40 seconds of mainstage when the engine mixture ratio was changed to 5.5. The engine was recalibrated before the second test, and a 165-second mainstage run was accomplished.

4. Restart Testing at AEDC

The J-4 test cell at AEDC was reactivated after undergoing facility maintenance. A total of nine tests for a duration of 145 seconds in three separate test periods were conducted. The first four tests were S-II/501 simulation tests completing the S-II/501 verification test series. All 501 testing was completed, and modifications required were incorporated into the flight vehicle. The remaining five tests were S-IVB/500

simulations, with two of the tests conducted to simulate a one-orbit turbine hardware condition. One test was aborted because of gas generator overtemperature; however, review of the data disclosed that the main LOX valve was improperly conditioned. Further review of the data is continuing.

5. J-2X Experimental Engine Program

Firings on the redesigned thrust chamber contour of engine J-2X 012 were completed and indicate no reduction in side loads. This chamber was designed and constructed to eliminate side loads associated with the sea level testing of the standard J-2 thrust chamber contour. A secondary objective of the test series was the hot firing demonstration of pneumatic logic engine control. The results were successful for this secondary objective and for the ASI liner investigated during the firings. Engine 015 is being prepared for its test series, which will be a preliminary evaluation of a 40:1 expansion ratio chamber of the J-2S configuration.

B. Verification Testing of Three Main Pumps

Simultaneous endurance testing of the first and second main pumps is complete. Each pump was disassembled and examined. Results indicated considerable wear on the original and little wear on the modified pump. The third pump has undergone transient pressure, dynamic response, and high temperature testing and is undergoing low temperature testing.

C. S-II-1 Sidewall Insulation Television Test

A test was conducted at KSC (high bay - VAB) to determine the capability of existing LUT television cameras to detect small defects in the sidewall insulation. Ten or more simulated defects were located and visually evaluated by television. The HOSC received the television and audio during the test. Preliminary results indicate excellent visual coverage with capability to evaluate defects approximately 1 to 3 inches in length. Some additional camera locations will be required on the LUT, and on the ground for 100 percent coverage.

D. S-II-502 Flight Prediction

Final S-II-502 stage flight prediction was received from the stage contractor.

E. LH_2 Tank Slow Pre-Chill

Because of the high rate of S-II LH_2 tank insulation failures, a sequence change was proposed to reduce the chilldown rate used for the initial preconditioning and to extend the chilldown up to LH_2 loading so that the tank is approaching LH_2 temperature. This change will reduce thermal stresses within the sidewall insulation and should reduce the insulation failures. KSC is evaluating the proposed sequence to determine if any major facility modifications will be required.

F. LOX Residual Evaluation

The S-II-501 and S-II-502 static testing at Mississippi Test Facility (MTF) has indicated that LOX pump cavitation occurs earlier than anticipated. This early cavitation results in a minimum payload loss of 180 pounds. A multi-phased program to minimize the LOX residuals was recommended.

G. LOX Ullage Pressure Decay for S-II-504 and S-II-505

The LOX tank pressure decay for S-II-504 and S-II-505 was predicted based on the effective bulkhead thermal conductivity data obtained from static test and a laboratory test sample. The prediction uses the available data and indicates the best estimate and worst case margins of 4.1 and 0.6 psi, respectively. Since the impact of the flight environment cannot be accurately assessed and the reduced prestart requirement has not been accepted for S-II-506 and subs, a feasibility study of two backup approaches will be undertaken. A special bulkhead evacuation test is recommended in conjunction with the first static firing of S-II-503. Procurement of hardware kit and implementation plans will be based on the results of the feasibility study and the flight of S-II-501.

III. S-IVB Stage

A. APS Gas Formation Tests at MSFC

Tests were conducted on an S-IVB/V APS module to determine the effects of various levels of blanket pressure on gas permeation through the oxidizer tank bladder during hold at ambient temperatures. X-ray photographs indicate that gas had formed inside the bladder with blanket pressures of 80, 100, and 150 psig. The ambient temperature variations ranged from 56°F to 120°F during hold periods of as much as six days. Gas formation tests at 50 psig blanket pressure will be followed by the gas removal test. The gas removal test will be conducted to verify the stage contractor's procedures and portable GSE and to familiarize personnel with the procedures and operations involved.

B. Flight Predictions

The S-IVB-502 final propulsion performance prediction was completed and distributed. Since the S-IVB-503 mission ground rules were changed shortly after acceptance firing and the new mission configuration has not been finalized, the final prediction was delayed until September 15. The S-IVB-504 preliminary prediction with dispersion was completed and distributed.

SPECIAL STUDIES

I. Voyager Spacecraft Program

A. Voyager Spacecraft Propulsion Conceptual Design Report Completed

The requirements for the spacecraft propulsion system specification are being defined, and the propulsion system is being refined to reflect recent changes in mission ground rules.

B. 100 lb Thrust Engine Gimbal Test Stand

A test stand was designed to evaluate the performance of electromechanical actuators and to provide gimbal capability for a series of 100 lb thrust static firings.

C. LMDE Verification Program

Work was started on the LMDE for the Voyager Demonstration Program. Primary emphasis was placed on refurbishing two injectors and element assemblies for use in Phase I and Phase II testing. This program is progressing on schedule. Work was started on the Voyager Spacecraft Engine Mock-up and the Voyager Spacecraft Engine Data Manual. The Phase II space environmental vacuum storage facility is being ordered for a nine-month space storage test with the LMDE. Phase I Life and Performance testing are scheduled to begin in late August or early September.

D. Effects of Sudden Feed Line Valve Closures

A study was conducted to determine the pressure surge and backflow created by the rapid closure of the propellant shutoff valves. The maximum pressure rises and back flow volumes occur in the oxidizer (N_2O_4)

feed system. It is believed that the back flow at shutdown will not significantly affect propellant within the main tanks because of dissipating effects of the sump and screens over the sumps. However, the effects of the high-pressure rises on the design and operation of the feed system must be evaluated.

E. Thermal Control

Thermal control guidelines were established to aid in determining the feasibility and limitations of the louver concept for thermal control of the electronic assemblies. The louver assemblies could be supplemented by heat addition and dissipating area variation. A mathematical model is being developed to determine the view factors and the effective emissivity between the louvers and the solar panels and/or capsule bioshield. The thermal radiation absorbed by a sun-oriented, Mars-orbiting spacecraft/capsule vehicle was determined. The analysis indicates that the spacecraft heat loads are not significantly affected by the capsule due to shading by the solar array. This result indicates that the spacecraft should not be significantly affected by the capsule separation if the near-adiabatic interface is maintained. A steady-state analysis was used to determine the temperature of an uninsulated spacecraft orbiting Mars. This analysis confirms the preliminary conclusion that high-performance insulation will be required for most of the spacecraft. The operating temperature of a solar array, constructed similar to the ATM array, was determined to be approximately 340 °R.

F. Fill & Drain

Filling and draining the propellant and pressurant tankage by evacuating the storage volume was analyzed. This method reduces problems such as trapped gases in the small lines and the series tankage. The spherical tankage can withstand the internal vacuum, but elongated tankage must be evaluated.

II. Nuclear Ground Test Module (NGTM)

A. Analog Simulation

The NGTM Analog Simulation Program was completed and is being used to determine optimum propellant loading, fill, drain, replenish, and pressurization sequences.

B. Propellant Management and Liquid Level System

The volumetric analysis of the NGTM container was completed and is being used to determine the location of instrumentation for the propellant management and liquid level systems.

III. Payload Gains for LOR Missions

Studies were performed to determine the payload gains for LOR missions when modified engines were used on all stages of the Saturn V vehicle. A thrust level of 1522-1570K was used, and a payload gain of 1800 lb was obtained. A chi curve of the S-IC stage was calculated. A throttleable F-1 engine with a thrust level of 1522-1800K was time tailored so as to not exceed the structural limits imposed on the Saturn V vehicle. This resulted in a payload gain of 10,000 lb. The 265 K J-2S engines with an expansion ratio of 40:1 were used on the S-II and S-IVB stages and resulted in an 8000 lb payload gain. The S-IVB stage was also "flown" using the 265 K J-2S engine with an expansion ratio of 50, 60, 70, and 80, which resulted in payload gains of 1200 lb, 2000 lb, 2700 lb, and 3300 lb, respectively, when compared to the 265 K J-2S engine with an expansion ratio of 40.

IV. Investigation of Brazed and Welded Connectors

Impulse tests were conducted on four 3/4-inch and six 1-inch thickwall tube specimens. Thirteen 1 1/4-inch thinwall and twelve 1 1/2-inch thickwall specimens had fittings welded to both ends and were proof tested. Two 1/4-inch specimens were vibrated at +500°F; however, the specimens were not able to complete 300,000 cycles due to strain gage failures. The leadout wire configuration is being changed, and the vibration test setup is being modified to correct this problem.

V. Thermal and Hydrodynamic Research

Ultrasonic inspection of the diffusion bonded joints was successfully completed.

VI. Apollo Telescope Mount

A. Spar Thermal Deflection Test

The object of this test is to thermally verify the design of the ATM spar as an optical bench for mounting the ATM telescopes. Preliminary results indicate that the spar is thermally adequate.

B. Quadrant IV Thermal Systems Test

The purpose of this test is to demonstrate that the ATM experiment package can be thermally controlled using the passive thermal control system with heaters. A model of Quadrant IV was built with simulated geometries, solar and electrical heats and heater blankets. Insulation is being installed on the test hardware.

C. Insulation Vibration and Acceleration Test

This test is being conducted to prove that the ATM insulation scheme will remain structurally intact during boost. A half-scale ATM cannister was built which will be insulated, then, simultaneously, it will be vibrated and accelerated. The cannister was mated to the centrifuge and is being mated to the acoustical vibration facility.

VII. Spin Cooler

Performance tests were continued to determine the effect of length-to-diameter ratio. Tests to date indicate an optimum design point for maximum sub-cooling of the liquid nitrogen to be L/D = 1.5.

VIII. Laser Velocimeter

The laser and power supply was received, installed, and aligned. The signal was greatly improved over the previous laser. The first series of test runs in the transition region were completed using the phase-lock loop. The data are being evaluated. A frequency discriminator and voltage bucking circuit were designed and fabricated. Preparations are being made for additional test runs in the transition region using different sized pipes.

IX. Multiple Docking Adapter (MDA)

A. Insulation

The MDA, a non-cryogenic stage, will use multi-layer insulation for thermal protection and control. Until recently, thermal conductivity as a function of temperature was not available. Lockheed has developed a unique thermal conductivity apparatus wrapped with a sample of alternate layers of aluminized Mylar and sliced foam, and obtained data between 0 °F and 150 °F with a temperature difference across the insulation of 10 °F at each data point. Work is continuing to extend this data to cover -50 °F to +200 °F temperature range.

B. Thermal Design

The need for active thermal control of experiment S-009 was identified. For the 14-day experiment, a temperature tolerance of ± 5 °F was established. This requires a cold plate on the experiment package controlled by a fluid loop from the Environmental Control System. Investigation of the problem is continuing.

C. Testing

It was recommended that the integrated test plan include thermal vacuum testing. A thermal vacuum test of the MDA docking port configuration to be conducted in the MSFC 15-ft vacuum chamber is currently planned.

X. BP-30 Service Module Valve Manifold Vibration Tests

Reinforced mounting brackets were received, and vibration testing in the flight direction was successfully completed on the forward section. The aft section is being prepared for testing.

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

The calibration, pressure control, pressure cycling, and response tests were completed at -80°F and -100°F on Vickers Pump S/N MX71941. No failure occurred.

ADVANCED PROPULSION AND TECHNOLOGY

Advanced Engine Aerospike Experimental Investigation

The first two aerospike thrust tube wall chamber tests were conducted by Rocketdyne at the VTS-1 test stand, Santa Susana Test Facility. The first test was successful at a chamber pressure of 550 psia, mixture ratio of 2.2, and a duration of 200 milliseconds. The second test was scheduled for 600 psia chamber pressure, 2.5 mixture ratio, and a duration of 700 milliseconds. Data from the second test is being examined to determine actual run conditions, and the outer shroud is being removed for a planned hardware inspection.

PUBLICATIONS

"Nonlinear Heat Transfer and Temperature Distribution Through Fins and Electric Filaments of Arbitrary Geometry with Temperature-Dependent Properties and Heat Generation", Unclassified, TMX-53621 by A. R. Shouman, Dated June 14, 1967. Published July 12, 1967.

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PR-R-P&VE-V-67-7

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(July 1, 1967 through July 31, 1967)

SATURN IB

I. S-IB Stage

Umbilicals

All Saturn IB interface control documents (ICD's) were reviewed by Chrysler/Michoud and this division and then forwarded to Kennedy Space Center (KSC) on July 25, 1967 for concurrence. Upon approval by KSC, the ICD's will be incorporated into the Chrysler IB stage contract beginning with the SA-207 vehicle.

II. S-IVB Stage

S-IVB/AS-206 Restart Mission

A review of the documentation submitted by McDonnell Douglas Corporation (MDC) for the AS-206 restart mission was completed. The results of the review were discussed in a meeting at Huntington Beach, California on July 11 and 12, 1967.

The helium spheres and associated bracketry to be located in the spacecraft lunar module adapter and a list of components for the AS-206 restart mission kit to be submitted by MDC, were discussed also.

III. General

A. Operations Analysis

1. The Saturn IB Launch Vehicle Design Reference Ground Sequence (DRGS), MSFC drawing 10M30576, was released. The document which presents a launch vehicle DRGS covering the time period from stages arrival at KSC until the vehicle is launched, is intended to be used for analysis and planning purposes. Major launch site operations to be performed on the vehicle as currently identified are presented for the prelaunch period.

2. While the current information is basedon the SA-204 mission, future releases will be expanded to include subsequent vehicles as data becomes available.

B. Weight Status Reports

The following reports were completed and distributed:

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

The detail monthly weight status report for the SA-212 launch vehicle.

C. Mass Characteristics

The final predicted mass characteristics (depletion cutoff) for AS-205 were distributed.

D. Saturn IB Mission Plan and Technical Checklist

Revision 14 of the Saturn IB Mission Plan and Technical Checklist was completed.

E. Flight Readiness Review Report

The vehicle description portion of the Flight Readiness Review Report was rewritten for AS-204 and sent to Aero-Astrodynamics Laboratory for inclusion in the completed report.

SATURN V

I. S-IC Stage

A. Test Specifications and Criteria

After coordination with the other laboratory divisions, revision B to the S-IC Specification and Criteria document, D5-13618, was sent to the Saturn V Program Office with laboratory comments by the division. A request was made that all corrections be included in the next revision to the document.

B. Cable Installation Discrepancies

Cable installation discrepancies in the tail area of the S-IC Stage were reviewed at KSC. Disposition of the discrepancies will be documented.

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

1. Tests of the HSCU to determine the magnitude of the return line pressure transients were conducted at KSC. Recorded data from Mobile Launcher (ML)-1 indicated that a maximum pressure transient of 420 p.s.i.g. is being experienced at the umbilical disconnect during 1°, 2°, and 3° step response gimbal exercises with four actuators, which is attenuated to a pressure of 320 - 380 p.s.i.g.

at the base of the tail service mast ("0" level). HSCU start transients reached a magnitude of 340 - 345 p.s.i.g. at the umbilical and were attenuated to a magnitude of 80 - 82 p.s.i.g. at the HSCU return filter. HSCU stop transients attained a 310 - 320 p.s.i.g. value at the umbilical and were attenuated to 300 - 318 p.s.i.g. respectively, at the return filter.

2. An advance drawing change notice (ADCN) to perform the intent of Engineering Change Proposal (ECP) BO-215 was initiated by KSC personnel. This task involves rerouting of the main pump case drains from the return line manifold directly to the HSCU reservoir. Incorporation of this change is tentatively scheduled for August 10, 1967.

D. Flush and Purge Servicer (F&PS)

1. Testing of the S-IC F&PS, serial number (S/N) 002, was completed by Test Laboratory with the exception of the turbo pump bearing preservative units (TPBU). The 5.5 gallon TPBU is presently undergoing tests to determine whether the problem (inability of the unit to automatically reduce the purge pressure to 37 $\pm$ 12 p. has been induced by operational error or whether a design deffi exists. Further testing of the 35-gallon TPBU was delayed until such time as an environmental test chamber can be located and ut

2. An ADCN to effectively perform the intent of ECP BO-213 was ini by KSC personnel. This task involves interchanging certain qui disconnects and nameplates of the ML and changing the hypergol regulator of the F&PS to ensure compliance with the S-IC stage requirements.

3. A post-test critique was conducted July 21, 1967, concerning t qualification/verification testing of F&PS S/N 002. Pending t view of all data, it was concluded that the F&PS has successfu demonstrated the capability to meet all fluid flow and pressu requirements dictated by the S-IC fluid requirements document (13M50096) except for incomplete testing of 35-gallon TPBU ar condition in the GN_2 manifold. Tests for the TPBU are set fo month; a forecast for correction of the leak has not been ma

E. Acceptance Tests

Acceptance tests on the Aft No. 1 Umbilical Carrier (65B80271-1 refurbished unit were completed.

F. Qualification Test Procedures

Qualification test procedures for the S-IC aft umbilical retai ing collar(65B80773-1) and the intertank umbilical (65B80762-1 reviewed for correctness and technical accuracy. Both documer accepted.

G. Integration Test Requirements/Specifications

Revision "C" of the Integration Test Requirements/Specifications for the S-IC flush and purge truck, the S-IC flush and purge subsystem checkout (local control), and the S-IC ground hydraulic supply system and checkout unit (MILA, LC 39, ML No. 1) were accepted for release after minor corrections are made.

II. S-II Stage

A. S-II-6 Cable Rework Review

A review was completed on North American Aviation (NAA) ECP's 4704E and 4704E-1 for the rework and rerouting of S-II-6 aft skirt cabling due to initial inadequate installation.

B. Acceptance Tests

Acceptance tests on the Insulation Purge Console Model S7-45, Section A were completed.

III. General

A. AS-501 Critical Component Status Charts

1. The critical components status list was revised for the S-IC and S-II stages (AS-501 vehicle). This revision updated the status of the S-II helium receiver and the range safety command antenna testing.

2. The AS-501 flight critical items list was reviewed. A matrix was prepared which compared the flight critical components and part numbers with those called for on the vehicle control drawings and the component installation drawings.

B. Damping, Retract & Reconnect System (DRRS)

1. The ML-1 redundant hoist system for the DRRS was installed at KSC. Tubing interference problems are being resolved by rerouting.

2. The ML-2 redundant hoist system was shipped to the swing arm area for testing. No major problems were encountered.

3. The ML-3 redundant hoist system is being fabricated at the Manufacturing Engineering Laboratory. Present schedule calls for installation on the test tower during the week of August 6, 1967.

4. Plumbing routing problems in the auxiliary damping system at KSC are being resolved; new plumbing is being fabricated.

5. Redesign of the damper drip pan was completed. Drawings were released on July 31, 1967.

6. Several pilot operated check valves for the primary damper system

were returned to the vendor for rework. The valves (drawing number 11M00798) require machining and seal installation.

7. Change in criteria of static loading of the primary damper on the launch escape tower was effected. The allowable loading was raised from 5,000 to 7,000 pounds.

C. AS-501 Flight Sequence

Engineering Orders (EO's) 10M30631-5 and 10M30631-6 were released against the SA-501 flight sequence to Astrionics Laboratory. EO 10M30631-5 contained highly desirable changes to the S-IVB restart sequence to give the flight controllers capability to take action in case of failure of the continuous vent valves to close and failure of the propellant utilization (PU) valve to go to the hardover position when commanded; these changes were disapproved, however, by the Level II Configuration Control Board (CCB) on July 14, 1967, because they were not considered mandatory. EO 10M30631-6 was a mandatory change to increase the time for lox repressurization during the restart sequence; this change was approved.

D. Mechanical Ground Support Equipment (MGSE) Launch Mission Rules

1. An investigation of input data for MGSE launch mission rules was completed. As a result of this investigation recommendation was made that the facility launch mission rules be expanded to include stage peculiar equipment. This was considered to be the best and most efficient approach to this problem since the facility contractor already would have a thorough knowledge of this equipment and its operation once it was integrated into the other launch facility equipment. This approach to the problem was approved by KSC, Mission Operations Office, and Saturn V Program Office representatives.

E. Weight Status Reports

The following documents were completed and distributed:

The monthly weight status report for launch vehicles SA-501 through SA-506.

The detail monthly weight status report for the SA-506 launch vehicle.

F. Mass Characteristics

Mass characteristics for the J-2 restart test on AS-503 were completed and distributed.

G. Maintenance Analyses

The Boeing Company (TBC) tasks for maintenance analyses and operations analysis were combined into a single follow-on task effective July 1, 1967.

H. Saturn V Damping, Retract and Reconnect System (DRRS)

1. The test monitoring effort on the qualification of critical components

for the Saturn V Damper System was continued. Incoming EO's were reviewed and incorporated into the qualification test specifications, as applicable, to keep qualification test program up-to-date.

2. The Projects Engineer, Manufacturing Engineering Laboratory, was authorized to supply two modified, pilot operated check valves, (P/N 11M00798), for the damper system. Failure of these valves during qualification tests requires that they be modified and requalified prior to the flight of AS-503.

3. Work is continuing on the change to the Saturn V Damping System O&M Manual which is now scheduled for reproduction on August 16, 1967.

ADVANCED TECHNOLOGY

I. Systems Design

A. Multiple Docking Adapter (MDA)

1. Interface drawings were initiated for experiments M492 and M493, "Electron Beam Welding and Tube Joining," respectively.

2. The designs of the 525 level hoist and track assembly, the upper MDA hoist and track assembly, and the 1968 level platforms were reviewed; comments were prepared on these items.

3. The following concept layouts were completed to show different configurations for the MDA docking parts:

SK10-7441, "ATM/MDA Port No. 1 SLA Fairing Proposal."

SK10-7442, "ATM/MDA Port No. 1 Flush Port Proposal."

SK10-7443, "ATM/MDA Port No. 1 Port Lowering Proposal."

4. The hard mounted and soft mounted experiments, located in the conical section, as well as both interior and exterior of the MDA were reviewed. One major change was recommended, however, The configuration of the soft mounted experiments should be revised to eliminate the large packages from behind the four walls.

5. The window cover deployment mechanism is being redesigned to incorporate a better sealing method.

6. A layout was initiated defining a new configuration for the nose fairing. This fairing will replace the Spacecraft/Lunar Excursion Module (LEM) Adapter (SLA) panels and allow the probe to be installed on the MDA prior to lift-off.

B. Apollo Telescope Mount (ATM)

1. The following layouts were completed:

   SK10-7445, "ATM Docking Port," defining the clearance between a probe mounted in the MDA and the spacecraft lunar module adapter panels. (The probe was flush mounted and extended 17.25 inches beyond the docking ring contact surface).

   SK10-7444, "Cable Routing Proposal" (ATM rack to experiment package), defining a method of routing all the electrical cables from the experiment package to the rack. (This proposal accounted for all the gimbal requirements of the experiment packages).

   SK10-9921, "ATM Rack to Experiment Package Clearance Envelope," defining the clearances required around the lunar module ascent stage for equipment installed on the top of the rack.

   SK10-9921, "Rack Assembly to LM/AS Clearance Envelope," and SK10-7444, "Cable Routing Proposal."

2. Work was started on an ATM neutral buoyancy mockup design. One of the most important questions to be answered is where the mockup should be separated into segments. A sketch showing a proposed mockup configuration with splice locations (SK10-9820) was given to the contractor for analysis. Mockup design is being based on the assumption that all areas on the ATM, with which the astronaut is in proximity during film retrieval, requires envelope mockup and that all astronaut/hardware interfaces require flight configuration mockup. Firm criteria are not presently available.

3. Design is proceeding on the basic rack structure and the ATM canister envelopes. The canister mockup will simulate all astronaut visual and motor obstructions and provide for maximum visual observations of the astronaut operations from vantage points other than that of the astronaut.

C. Cluster Mission Concept Mockups

The following were completed:

Design changes to the S-IVB Tank, Instrument Unit (IU), and SLA Neutral Buoyancy Mockups to meet MSC requirements.

Design and documentation on handling fixtures required by MSC for segments of the S-IVB tank, IU, and SLA neutral buoyancy mockups.

Shop documentation on the support dolly for the MDA neutral buoyancy trainer.

D. Payload Module (PM)/Rack

1. Work is in progress on the Handling and Auxiliary Equipment (H&AE) for the PM Program. The designs will include access platforms, dolly

track assembly, and dolly track support assembly.

II. Systems Operations

A. Automatic Umbilical Reconnect System

A preliminary design review (PDR) was conducted on the automatic umbilical reconnect prototype development program on July 18, 1967, by Brown Engineering Company (BECO), the mission support contractor.

B. Nuclear Ground Test Module (NGTM)

Fabrication of the upper and lower tank pneumatic complexes was coordinated with Manufacturing Engineering Laboratory. The necessary preliminary sketches, schematics, physical ICD's and frame weldments were transmitted for this work. Also, Manufacturing Engineering Laboratory was requested to review this material and prepare a detailed manufacturing schedule for inclusion in the division schedule. Completion of this schedule is expected by August 11, 1967.

III. Systems Engineering

A. Apollo Applications Program (AAP)

The monthly payload weight status report for Cluster was completed and distributed.

B. Orbital Workshop (OWS)

1. Division personnel participated in a review of the defined crew quarters (CQ) floor plan held at MSC on July 25, 1967. The location of the food management/waste management (FM/WM) equipment and the position of the FM/WM compartment walls were reviewed. A configuration was selected for the 1-level CQ design. Requirements were defined for urine dump, fecal dryer and lower body negative pressure (LBNP) vacuum vent lines.

2. A human factors engineering review of the 2-level CQ concept revealed that the only major problem would be moving the plenum chamber to the "Crotch area" of the hydrogen tank, which may impose operational problems in sealing the four tank penetrations in that area. Investigation of the operational impact to the penetration sealing is underway. Minor changes to the handrail requirements will also be necessary.

3. Neutral buoyancy simulation mockup requirements were identified for the internal CQ equipment and S-IVB stage modification hardware. MDC was requested to provide this simulation equipment beginning September 1, 1967.

4. Revision B of the OWS Astronaut Review Outline was completed in all areas except OWS deactivation. The document is now scheduled for release on August 4, 1967.

5. Package/pallet transfer was simulated using the Martin "jump rig" six-degree of freedom simulator in conjunction with a mockup of the fireman's pole from the workshop access hatch to the CQ's area. Preliminary verification of package size limitations, preferred handle location, tether requirements and techniques for translation along the pole were obtained to complete this phase of the simulation verification. Preparation for the next planned phase of zero-g simulation on the KC-135 aircraft included the following activities:

   Initiation of mockup drawings for KC-135 test hardware.

   Coordination with MSC and Wright-Patterson Air Force Base for a mid-September initial flight.

   Participation in preflight training and orientation flight at Wright-Patterson, July 17 to 21, 1967, by MSFC test subjects and other test personnel.

C. Multiple Docking Adapter (MDA)

1. The Martin-Marietta Corporation presented the results of a limited contingency analysis for the MDA which included the following:

   Failure mode and effects analysis.

   Deployment concepts.

   Experiment prioritization.

   Additional systems requirements.

   These outputs were further reviewed in a subsequent series of meetings among various MSFC organizations. The Martin Company was directed to continue the activity during a 60-day period concentrating specific and quantitative recommendations on the problem of contingent habitability. As a result, the division will recommend that a partial 4-wall internal MDA configuration be used.

2. The MDA mockup construction is being completed and should be ready for testing by August 3, 1967. The test plan for the four pole sliding platform concept was completed and will be a guideline for the simulation.

D. Apollo Telescope Mount (ATM)

1. Simulation test plan for the LM/ATM Pointing and Control System (PCS) simulation was prepared. Steps were taken to implement this plan with initial checkouts and tests estimated to begin in early September, 1967.

2. Tasks to be accomplished by Lockheed Missile and Space Company (LMSC) during a 60-day period were defined during a meeting on July 17, 1967 with respect to PCS and experiment panels simulation. LMSC will concentrate their efforts toward the generation of a conceptual design and implementation schedule for conducting the total ATM PCS and experiment operation simulation. This design effort will be based on a survey of available MSFC resources including computers, hardware, software, and facilities. It is planned that the generation of this total ATM simulation concept would serve eventually as an astronaut simulation trainer.

E. Voyager

1. Preliminary mass characteristics for the Voyager payload were completed and distributed.

2. A review of an existing spring separation computer program was completed. The purpose of this review was to ascertain if the computer program was valid for the Voyager shroud separation scheme. Since this program only computes vertical separation distances, it was concluded that a more sophisticated computer program is required. Action has been taken to generate the math model for this program requirement.

3. Specifications to be issued with the Request for Quotation (RFQ) for the phase C and D contractor design effort were reviewed and comments forwarded. In addition, scopes of work to be incorporated into the RFQ covering weight engineering, maintenance analyses, and maintainability trade studies were generated.

F. Extraterrestrial Vehicle

Contractual arrangements have been entered into with Man Factors, Inc., San Diego, California, for a research study to derive human factors crew station design criteria for a lunar roving vehicle, to validate the fixed base simulation results, and to determine the applicability of the simulation technique for astronaut training.

IV. Systems Requirements

A. Nuclear Ground Test Module (NGTM)

The preliminary draft of the NGTM General Test Plan is being prepared.

B. Multiple Docking Adapter (MDA)

Airlock Module (AM)/MDA Test Plan was completed. This document reflects the agreements and arrangements between MSFC, MSC, and MDC for the joint test program on the combined AM and the MDA.

C. Orbital Workshop (OWS)

The S-IVB Stage Orbital Workshop General Test Plan is being developed. Additional test information has been requested of the division offices of the Propulsion and Vehicle Engineering Laboratory.

D. Voyager

1. Work continued in the research and study of information in preparation of the Voyager Test Plan.

2. The Voyager Shroud R&D Plan was prepared.

E. Apollo Applications Program (AAP)

1. A statement of work was prepared for the study contract to coordinate and prepare AAP-2 experiment interface control documents.

2. An Engineering Change Request (ECR) containing 20 Specification Change Notices (SCN's) for updating the MDA Contract End Item (CEI) specification CP114A10000026A, was completed.

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