PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

FOR PERIOD

DECEMBER 1, 1967 THROUGH DECEMBER 31, 1967

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-67-12

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

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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MONTHLY PROGRESS REPORT

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SATURN V

I. S-IC Stage

A. Evaluation of Commercial Adhesives

Studies are continuing as outlined below to develop or modify high performance adhesive systems for use on the Saturn stages.

1. Polyurethane Adhesives

a. Aging Studies

Three series of lapshear and bell peel samples were exposed to ambient outdoor aging. In one series the aluminum adherends were primed with Z-6020 and bonded with an adhesive mix (7343/7139) containing 1.0 percent Z-6040 additive; in the second series the adherends were primed with hydrolyzed Z-6040 and bonded with the adhesive mix containing 1.0 percent Z-6040; in a third series both primer and additive were omitted. Test results after eleven months aging show a sharp drop in the lapshear room temperature strength of the third series (no primer, no additive). The first and second series showed little change from the previous month at any test temperature (-300°F (-184°C), ambient, and +200°F (93°C)). Several values are actually higher than those obtained on the original controls tested eleven months ago.

Arrangements have been made for the Terrestrial Environment Branch of the Aero-Astrodynamics Laboratory to provide daily humidity records for the period since January 1, 1967. An attempt will be made to correlate atmospheric moisture with monthly variations in bond strength.

b. Additive and Primer Studies

A 25-percent solution of Stafoam AA-1802 (parts R and T according to manufacturers' recommendations) in MEK (methyl ethyl ketone) has been shown to confer an increase in bond strength at room temperature and elevated temperature when used as a primer for aluminum adherends bonded with Narmco 7343/7139 (100 g/11.5 g). The upper and lower temperatures of these evaluations have now been extended. With a formulation using 0.2 percent Z-6040 in the Stafoam primer solution and 1.0 percent Z-6040 additive in the adhesive mix, the following strength values were obtained:

Temperature °F (°C)	Lapshear Strength, psi	T-peel Strength, piw
-423 (-253°	8360	-
-300 (-184)	6540	79
Ambient	3074	64
+200 (93)	1968	52
+250 (121)	1220	40
+300 (149)	1188	35

Although higher values than these have been observed in isolated cases, the above data represent a remarkable broadening of the temperature range over which this adhesive system may be used for bonding aluminum. Interestingly, this beneficial effect conferred by the Stafoam has not been matched by two other urethane foams, Nopco BX-250 and CPR 348-3. The study of this adhesive system will be continued.

2. Silicone Adhesives

Two silicones, Dow Corning Silastics 140 and 891 were evaluated routinely for lapshear and peel performance on aluminum adherends primed with Dow Corning A-4014 primer. These materials had similar lapshear strengths approximately 4,000 and 300 psi at -300°F (-184°C) and room temperature, respectively. The Silastic 891 had better peel strength at these two temperatures.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

Continued effort has been directed toward development of specialized polymeric materials for encapsulation of electronic hardware.

1. Development of Epoxysiloxane Embedment Materials

The preparation of 200-300 grams of crude p-allylphenyldimethylchlorosilane was accomplished during previous report periods, and the development of efficient reactions for converting this intermediate into the desired silanol, p-allylphenyldimethylsilanol, is currently being attempted. The previous report described the use of another intermediate, p-allylphenyldimethylaminodimethylsilane, to effect this conversion. Analytical data indicate that the dimethylamino-derivative can be recovered

in reasonably pure form. The conditions for hydrolysis of the dimethylamino-derivative to the silanol are being investigated with particular emphasis on the effect of temperature in order to optimize the recovery of silanol. Attempts are being made also to scale-up the process to prepare 1,4-bis-(hydroxydimethylsilyl)benzene, another key intermediate in the synthesis of these materials.

This phase of the program is designed to produce the various intermediates on a sufficiently large scale to allow comprehensive evaluation of the resulting epoxy-siloxane embedment polymers.

2. Development of Conformal Coating Materials

Evaluation studies have continued on the experimental polybutadiene-modified urethane conformal coating. Elevated temperature aging of coatings prepared from this polymer in a forced air oven for 24 hours at 100°C (212°F) has resulted in slight darkening of the samples as well as slight hardening of the surface of the coating which was exposed to air. Apparently, some oxidation of the double bonds along the butadiene moiety of the polymer has taken place. It was recently determined that a completely saturated version of the hydroxy-terminated polybutadiene is available in limited quantity as "Telagen-S" from General Tire and Rubber Company. This material, if obtainable, will be incorporated into a urethane polymer for subsequent evaluation as a conformal coating.

The silphenylenesiloxane polymer continues to be a candidate for a conformal coating application at temperatures above the capabilities of urethanes (>150°C (302°F)). Molecular weight data for a previously prepared vinyl-containing silphenylenesiloxane polymer indicated that low molecular weight was at least partially responsible for the low strength of vulcanizates of this polymer. The polymerization time has been increased from 4 to 20 hours in subsequent preparations of polymers of this type. One such polymer containing 5 mole percent of the vinyl-bearing substituent was cured through the silicon hydride crosslinking reaction to yield a tough, elastomeric product which was slightly tacky. Polymers of this type must apparently be of high molecular weight and have a vinyl group concentration between 5 and 25 percent in order to have desirable tensile and elongation properties.

The inherently poor adhesion of the dimethylsilicone polymers is also observed to a lesser degree in the silphenylenesiloxane polymers. While some improvement in adhesion to metal and glass over that of the conventional silicones is observed for these polymers, any conformal coating application will necessitate a primer coat to provide an adequate moisture seal for the printed circuit boards. Olefin-containing silane coupling agents have proved of some value in increasing the adhesion of non-polar polymer systems and are being more closely evaluated for these electrical applications.

3. Ceramic Potting Compounds

Because of desirable physical, electrical, and thermal properties and the stability of ceramic materials under conditions such as heat, vacuum, and radiation, a program has been initiated to develop ceramic potting compounds for protecting sensitive electronic components from the environments associated with launch vehicle operations and space exploration. A literature survey is being conducted to acquire information to the state-of-the-art of ceramic potting compounds.

Since the basic electrical characteristics of a potting compound are of prime importance and must be met before most of the other requisite properties have any significance, the initial efforts of this program will be directed toward developing ceramic potting compounds having the desired electrical properties. The greatest obstacle foreseen in the successful development of a ceramic potting compound is the difficulty of obtaining a non-porous material which can be processed at low temperatures; however, various processing techniques will be investigated for overcoming this problem.

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

Several Belleville springs were found to be broken in an S-IC LOX prevalve actuator which had been used for qualification test. These springs were made of 17-7 PH, RH950 material. Unbroken Belleville springs from this valve, failed in the humidity cabinet after 11 days exposure under very high stress. Additional springs of other designs from this same valve are being evaluated in the alternate immersion tester. There have been no failures of these springs after 60 days of exposure.

D. Stress Corrosion Studies of 17-7 PH Actuator Springs

Stress corrosion studies of the various springs used in both Moog and Hydraulic Research (HR) actuators are being continued. Except for specimens taken from clock spring (HR) which failed in service, no failures have occurred. All three specimens taken from the broken clock spring failed in the alternate immersion tester within 36 hours.

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 Rockwell, NAS8-20764
2. R. W. Benson and Associates, NAS8-20208

III. S-II Stage

A. Investigation of Failure of S-II Stage Interstage Fasteners

Studies were continued on 7075-T6 aluminum Hi-lok fasteners removed from the "High Forces Test" interstage. After more than 1000 hours of exposure to alternate immersion in salt water and 100 percent humidity environments, respectively, no failures have occurred in the two test panels containing 35 fasteners. These tests will be continued. Metallurgical studies were continued on fasteners removed from the interstage. Since the last report approximately 30 additional fasteners were selected randomly from the subject interstage. Four of the batch showed evidence of stress corrosion cracking in the threaded area of the fasteners. An additional failed fastener from the "C" interstage was received December 20, 1967, for failure analysis. This analysis is in progress.

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

Several combinations of materials were brushed or sprayed onto 14 x 14-inch spray foam panels for evaluation test in a simulated vacuum and heat environment for determining a coating suitable for the S-II stage spray foam insulation.

These materials consist of Narmco's 7343 adhesive with varying amounts of MOCA curing agent. Two each test panels using MOCA at 7, 15, and 20 parts per hundred (pph) in 7343 resin were prepared for testing. One each of the above panels were spray coated with one coat of Hypalon 2241 coating compound.

Four samples were prepared to simulate the bolting ring area on S-II-2 through 5. These consisted of 3/4-inch CPR pour foam covered with Tedlar and protected by 1/4-inch and 3/8-inch thick bonded-on spray foam and 1/8-inch and 1/4-inch thick cork.

Coatings thermally tested during this report period include Chem-Seal overcoated with Dyna-Therm V-455, Thermo Lag T-230, Adiprene, and Adiprene overcoated with Hypalon. The Chem-Seal overcoated with Dyna-Therm V-455 appears to be a promising coating and additional specimens of this combination of coatings will be tested as time permits.

Representatives of North American Rockwell, Corporation have reported satisfactory progress on the second spray foam test tank which has been shipped to the Sacramento test site. Barring unforeseen delays, the first test on this tank should begin early in January 1968.

C. Inspection of the S-II-F/D Liquid Hydrogen Tank

A cursory inspection of the S-II-F/D hydrogen tank has been made. Considerably more corrosion and corrosion products were observed than was noted in the liquid oxygen (LOX) tank, however, the depth of attack is not thought to be any more severe. Most of the upper bulkhead weld lands were corroded as well as several of the gore skin areas. Corrosion products were observed on several of the ring baffles with the upper two rings being more affected. Also, some of the upper portion of the aft facing sheet of the common bulkhead had corroded. This area and the J-ring groove was not closely evaluated because of the lack of proper personnel rigging.

D. Investigation of Cracking of 2014-T651 in S-II Stage Components

North American Rockwell (NAR) Corporation's Los Angeles Division has experienced cracking of the 2014-T651 material during brake forming of the S-II bolting ring and number one cylinder. The subject material was purchased under NR material specification MB0170-063 which calls for a preforging operation prior to rolling the plate stock. Previous material used for liquid hydrogen tank skin panels was purchased under NR material specification MB0170-021 which did not specify the preforged condition. The cause of cracking in the boss areas of cylinder No. 1 and the horizontal ribs of the bolting ring was attributed by NAR to abnormal localized stress concentrations caused by part design since all material property requirements were met. One of the cracked ribs removed from the bolting ring was forwarded to this division for failure analysis. Preliminary findings indicate an abnormally large grain size in the area of the crack; however, the effect of this large grain structure on the actual cracking is not known at this time. A complete investigation is being made of this failure.

E. Evaluation of Bolts for Use in the S-II Stage Thrust Stage Attachment

North American Rockwell Corporation has requested a reduction in the shear strength requirement to 90 ksi for the S-II stage thrust mount attachment bolts. We are in complete disagreement with this request because the subject bolts are shear bolts in the "criticality one" category. North American has stated that they have bolts which meet the 160-185 ksi ultimate strength but do not meet the 100 ksi shear strength requirement specified by this division in memorandum, R-P&VE-M-SII-67-32 to Colonel Yarchin, I-V-SII, June 6, 1967. Data obtained by this division substantiate the validity of the 100 ksi shear requirement and illustrate the possibility of error in the North American shear data for 160-186 ksi ultimate strength bolts. Our disapproval of the NAR request for use of a 90 ksi shear strength A-286 bolt requirement which permits low strength (145 ksi) bolts without a minimum of 20 percent cold work, is based on the following:

a. A bolt of this nature contains little or no cold work and can have a detrimental lamellar precipitate present in the microstructure. This precipitate can cause inconsistent hardness and mechanical properties in the bolt.

b. It is an unacceptable design practice to use A-286 bolts for shear application unless the bolts have been cold worked approximately 20 percent to increase yield strength, shear strength, and hardness values and to preclude the formation of a detrimental lamellar precipitate in the microstructure.

F. Investigation of Repair Used on the S-II Stage Thor Test Tank

NAR (Seal Beach) requested a review of their repair of the S-II Thor test tank. A 5/8-inch diameter 4140 alloy steel (160-180 ksi) plug was installed through the tank skin to repair localized damage. The damaged area was removed by reaming and a seal plug, washer, and nut were installed per Drawing No. IT11026 and torqued to 1200 inch-lbs. In evaluating this repair test assemblies were made from 0.051" thick 7075-T6 aluminum sheet, 3 washers, a 4140 machined thread plug and a 42FW-1018 nut. The plug was torqued to 1400 inch-lbs. An additional test set-up utilized 1200 inch-lbs of torque. The torqued assemblies were submerged in liquid hydrogen (LH_2) for 20 minutes, removed from the liquid, warmed to room temperature and examined for cracks and defects by visual and magnetic particle inspection techniques. Although the Manned Spacecraft Center (MSC) has used this same type of bolt repair for Thor tanks in the past with no reported problems, we do not approve of the use of 4140 alloy steel for cryogenic application (especially at LH_2 temperatures) due to its notch sensitivity and elongation at low temperature. Also, at -423°F (-253°C) the difference in contraction of the 2014 aluminum tank and the alloy steel plug could result in leakage due to the reduction in torque. Machined threads for such an application should not have been used.

G. Developmental Welding

Investigations have continued in an attempt to correlate the effects of various welding energy inputs and natural aging with the performance characteristics of fused joints in 2014-T6 aluminum.

The previous results obtained from weldments prepared in 1/8-inch thick and 3/8-inch thick aluminum alloy 2014-T6 indicated that, if welding energy input (joules per linear inch) is held constant, variations in heat affected zone width can be obtained by varying the voltage and/or amperage, without any apparent degradation of joint quality. To establish more firmly a correlation, if any, between heat affected zone width and joint strength, additional welds are being prepared using monitored and varied machine settings to permit evaluation of data by statistical analysis.

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

The objective of this project is standardization of nondestructive technology for inert gas welds of the Saturn S-II stage propellant tanks.

The most effective techniques are to be optimized and their performance is to be established.

An experimental study of the radiography of the 0.392 inch thickness of 2014-T6 aluminum alloy butt welded panels has been completed. The radiographic film presently is being read and analyzed. The preliminary results indicate that the actual radiographic sensitivity can vary widely within the limit set by the 2 percent penetrameter specification. By using optimum parameter values, the quality of the radiograph can be substantially improved over this minimum. Also, angle exposures were found to be necessary for the detection of lack of fusion.

Preparation of apparatus for the destructive analysis of the total defect content of weld panels is continuing. Also, more refined apparatus for development of advanced ultrasonic techniques is being assembled.

I. Investigation of Nondestructive Techniques for Composite Materials

Current emphasis in the nondestructive inspection of composites is directed toward the development of techniques required for the nondestructive evaluation of debonds and voids in spray foam-aluminum composite materials of the type and configuration used on the S-II stage.

To date, the most promising technique for the nondestructive detection of debonds in spray foam-aluminum composites combines the features of the resonant foam coupler method described in previous reports with an eddy current technique. Sonic waves are coupled into the composite and variations in wave characteristics caused by debonds are detected with a foam coupled microphone. Single side and through transmission transducers of this type have been designed, fabricated, and tested. The test results obtained on laboratory panels containing simulated areas of debond have shown that the method positively detects areas of debond. Work is continuing to characterize the sensitivity of the method to debond area and density.

The problem of detecting voids in low density foam materials has received little attention until recently. Of the several techniques which appear to be feasible for this application, the ones based on neutron radiography, X-ray radiography, and microwave methods have been investigated by this laboratory. Neutron radiographs have been made of foam samples containing various sizes of debonds and the method looks very promising. However, the equipment required for this technique is relatively complicated. Microwave methods have been used to some extent and the results are encouraging but there are several disadvantages to this technique which have to be overcome. The simplest and most satisfactory technique investigated to date employs ordinary X-ray radiographic methods and equipment. Foam samples containing 1/8-inch and 1/4-inch diameter voids were radiographed using low energy X-rays. The 1/8-inch voids were faintly visible on the radiographs whereas the 1/4-inch voids were very easily discernible. Because of these highly encouraging results, further work is being done to optimize the radiographic parameters for various foam-aluminum thicknesses.

J. Investigation of Dye Penetrants for Use in Inspection of S-II Stage Hardware

The dye penetrant (PGP-26BF) presently approved for use on the S-II stage consists of two fluorescent dyes dissolved in Kel-F-10 polymer oil, Freon TF, methylene chloride, and trichloroethylene. The present inventory of Kel-F-10 has been depleted. Minnesota Mining & Manufacturing Company (3M) has discontinued making Kel-F-10 oil for the present. North American Rockwell Corporation (NAR) substituted Halocarbon Oil 14-25E for Kel-F-10 and formulated the PGP-26BF-1 dye penetrant. The new formulation, PGP-26BF-1, was submitted to this Center for approval after passing LOX compatibility tests at NAR. Test evaluations of PGP-26BF-1 at this Center revealed that this dye penetrant was highly impact sensitive in liquid oxygen. This same sample had passed NAR/Downey's tests. A representative of this division visited NAR/Downey to determine the cause of this anomaly. An inspection of NAR facilities revealed the following differences and deficiencies:

1. NAR was using the 1-inch anvil as specified in their contractual document.

2. NAR is contractually bound to MSFC-SPEC-106, not MSFC-SPEC-106B.

3. NAR anodized discs were made by anodizing a sheet, then punching and hand deburring the discs. An inspection of the anodic coating revealed it was almost non-existent. Anodized discs are made at this Center by punching the discs, barrel deburring, and then anodizing.

4. The concrete base under the contractor's tester had powdered somewhat.

5. It was also learned that the first hint of trouble with the PGP-26BF-1 dye penetrant was observed in June of this year when NAR/Rocketdyne rejected a sample. It is also pertinent to note that most of the "batch testing" of production dye penetrant was done at the Los Angeles Division of NAR on a tester not certified by this Center. Most of the production testing was done on 0.050-inch thick samples, not on anodized discs as specified in their penetrant document.

This division is working on various formulations of the PGP in an attempt to make the penetrant LOX compatible.

K. S-II Stage, Project Management, Materials

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

1. Pulsed Arc MIG Welding (PAMIG)

The pulsed arc MIG welding study conducted by North American Rockwell, Space Division (NAR/SD) revealed that the opposed nugget technique, as employed in PAMIG welding, offers considerable promise for minimizing joint offset. Therefore, NAR/SD has proposed to conduct a study of the

opposed nugget technique using the TIG welding process. This program would not be as extensive as the PAMIG investigation. Initially, a feasibility study would be conducted on eight-foot long panels, and if successful, one 33-foot diameter cylinder would be welded. A very limited number of tensile specimens are proposed since the TIG process does not require a new qualification. The ECP for this program was approved.

2. Liquid Hydrogen Tank Stress Relief Areas

Efforts are continuing on the test program to investigate the structural integrity of the stress relief areas of the S-II-4 and S-II-7 stages. Programs being conducted at this Center and at North American Rockwell/Space Division are progressing satisfactorily to meet schedules.

3. Spray Foam Insulation

The McDonnell Douglas Corporation (MDC) tank has been insulated with NOPCO BX250 spray foam at North American Rockwell/Space Division facilities and has been delivered to the MDC test facilities in Sacramento, California. One of the primary objectives of this program is to resolve the problem of insulation spalling during liquid hydrogen (LH_2) detanking (warm-up) To preclude this problem, all close-out joints were given special attention in design and manufacturing. The most promising joint designs are employed on the close-outs and are capable of reconfiguration if the first LH_2 pressure again reveals spallation.

In Phase II of this study, several areas will be field repaired employing the best joint designs of Phase I. Subsequently, the field repairs will be evaluated by additional LH_2 pressure cycles.

IV. S-IVB Stage

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

1. Study of Flammability of Materials

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

A separate series of tests were made on various samples of 3-D polyurethane foam insulation to investigate the pressure-temperature profiles obtained when a particular size and weight of sample is burned in a known amount of pure oxygen. It is a characteristic of pure 3-D foam (no sealer or covering) that when ignited, the flame flashes over the entire exposed surface of the sample very quickly, and thus completely envelops the sample well before any appreciable inward burning can take place. Thus, within the first few seconds, peak tempersture and pressure are reached and then quickly drops off. However, when the exposed face of a 3-D foam sample is coated with Narmco 7343 sealer and ignited, the rate of flame propagation is reduced considerably and the temperature

increase and pressure rise are slowed. A number of samples of 3-D foam, coated with the above sealer and with known surface areas (from 0.8 to 16 in^2) were prepared, weighing from 2 to 30 grams. These specimens were ignited by hot wire at 25°C, in the 24-liter chamber at 6.2 psia pure oxygen. The results of these tests indicate the following:

a. No more than 6 grams of 3-D foam would burn in the amount of oxygen available, regardless of how much more sample weight was present.

b. Maximum temperature attained is directly proportional to both surface area and weight burned.

c. Maximum pressure depends entirely on the maximum temperature since the combustion molar relationship is a nearly 1:1 ratio of combustion products to original oxygen.

During this period, 12 samples were evaluated for flammability in accordance with the provisions of MSC-A-D-66-3, Revision A. These samples include samples of proposed thermal curtain material, various elastomers, and plastics. A cursory examination of the data on the thickness studies indicates that most plastics will pass the 0.3 inch/sec flame propagation rate when ignited at the bottom at a thickness of greater than 50 mils.

A program is in progress with support from Test Laboratory to further study the flammability hazard of covered S-IVB insulation and to compare 2, 3, 4, and 5 mil aluminum foil. In addition, the effect of the thermal control coating is being evaluated. Standard 3-foot diameter samples are used in all tests. The samples are flanged to a 3-foot diameter, 5-foot long test tank. The tank is placed in a vacuum chamber, evacuated, and backfilled with gaseous oxygen at a pressure of 5 to 5.7 choked flow. A fan is used to simulate S-IVB oxygen flow velocities. A nichrome wire is used to ignite the sample. The igniter is placed over the damaged area 1/8 to 1/16-inch away from the foam. The power used for the igniter is 20 volts at 9 amps.

During this period, a specimen was evaluated having a coating of 2-mil aluminum foil with thermal control coating and a simulated 6-inch diameter flaw (6-inch diameter area of bare foam exposed). The sample was ignited as above. The sample extinguished after burning an area of 9-1/2 inches. Additional tests are scheduled to determine the relationship between flow area and burn area.

An additional test program was started to determine the effect of burn area on tank temperature and pressure. Various sizes of foam are being bonded to the 3-foot diameter diaphragms. The samples are ignited and the pressure and temperature are monitored to obtain their relationship. The data from these evaluation tests will be compared with the theoretical data to ascertain the difference.

2. Study of the Outgassing Characteristics of Orbital Workshop Materials

Studies have continued in the determination of the rate of outgassing of hydrogen from the internal insulation of the Orbital Workshop.

At the request of MSC, materials for the Orbital Workshop are being evaluated under more stringent test conditions for potential hazard from outgas products. These materials are exposed to vacuum, 10^{-7} torr, at 70°C (155°F) for 72 hours, and the weight loss and outgassing products are evaluated.

This program has been completed and a data memorandum has been written. Therefore, no further reports will be made on this program.

B. S-IVB Stage, Project Management, Materials

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

1. Stress Corrosion of Belleville Springs

Belleville springs of 17-7 PH steel are used in the regulator of the liquid oxygen (LOX) tank pressurization module. These springs are susceptible to failure by stress corrosion cracking, and the risk of such failure increases with age of the springs. The springs on S-IVB-204 are about a year old; thus, it was decided to alleviate the problem by installing newer springs. Because of schedule restraints it is more appropriate to change the entire LOX tank pressurization module, not just the springs of concern.

A LOX tank pressurization module, Serial No. 40, was made available and will be installed on S-IVB-204. The 17-7 PH springs in this module were made on November 14, 1967, heat treated on November 17, 1967, stabilized on November 20, 1967, and installed in the module on November 29, 1967.

The stage contractor is working with the spring vendor on a non-stress corrosion susceptible Belleville spring material. Development testing will be conducted by the vendor to ensure material adequacy, and, upon completion of these tests, the stage contractor will submit an ECP to change to a new material, probably Inconel 718.

2. Stress Corrosion of Thrust Vector Control System Parts

The follower arm, part number 6B1423-2, of the cam follower assembly, part number 029-29870, of the Moog actuator, Model 17-189, is made of PH 15-7 Mo CRES steel, and this material is susceptible to failure by stress corrosion cracking. Thus, an Engineering Change Order has been issued to change the material of the follower arm to eliminate the probability of stress corrosion cracking.

3. Evaluation of MD-19 Thermal Control Coating

Cryogenic testing of the MD-19 coating in the 3-foot dome facility at Sacramento resulted in considerable spalling of the coating. Such spalling in the Orbital Workshop (OWS) would tend to clog the engine feedline screens and jeopardize performance of the engine. Thus, MD-19 has been disqualified for OWS applications.

Alodine 407-47 is being tested by the stage contractor as a back-up or alternate for the MD-19 coating. Emittance values in excess of 0.58 have been obtained. According to FED-STD-595, "Colors," the color of Alodined test specimens will vary from 24410 to 24325 as the emittance values vary from 0.58 to 0.77. Tests to date indicate that the Alodine 407-47 coating will satisfy the thermal requirements of the OWS; however, further testing is required to qualify this coating for OWS applications.

4. Penetration Sealing Devices

Two materials are being tested by the stage contractor for use in penetration sealing devices to reduce oxygen leakage during habitation of the OWS. These are PARCO Compound No. 1306-40 (based on General Electric SE-517) and STILLMAN Compound No. TH-1068 (based on General Electric SE-5401). Each of these materials complies with Category B of MSC-A-D-66-3A, "Procedures and Requirements for the Evaluation of Spacecraft Nonmetallic Materials;" however, flammability testing on a batch basis is required by this division for OWS applications.

5. Thermal Curtain Materials

The stage contractor submitted six candidate curtain materials for flammability testing by this division as follows:

a. TFE Teflon coated Nomex 98-101, 10 mils thick

b. Hi D5-50 Taconic Plastic, 0.50 lb/yd^2, TFE coated 116 glass fabric, 5 mils thick

c. Hi D10-77 Taconic Plastic, 0.77 lb/yd^2, TFE coated 128 glass fabric, 10 mils thick

d. Hi D5-37 Taconic Plastic, 0.37 lb/ft^2, TFE coated 116 glass fabric, 5 mils thick

e. Hi D10-98 Taconic Plastic, 0.98 lb/yd^2, TFE coated 128 glass fabric, 10 mils thick

f. 5-40B Taconic Plastic, 0.25 lb/yd^2, TFE coated 116 Beta cloth, 5 mils thick.

These materials were found to be unacceptable when tested in accordance with the requirements of Category A of MSC-A-D-66-3A.

The stage contractor has reported that other candidate curtain materials have passed the Category A flammability requirements of MSC-A-D-66-3A, and are identified as follows:

a. Carboxy Nitroso Rubber/Beta Cloth

b. Glass fabric reinforced aluminum foil

c. Teflon coated aluminum foil.

However, further testing is required to qualify any of these materials for OWS curtain applications.

6. Quick Opening Hatch Material

The stage contractor has proposed to make the quick opening hatch door and the adapter ring of 2014-T651 aluminum. This material is susceptible to stress corrosion cracking in the short transverse grain direction in the webs of these parts. Thus, this division has required that the door and adapter ring be shot peened and coated or plated after final machining to alleviate the problem of stress corrosion cracking.

V. F-1 Engine

F-1 Engine, Project Management, Materials

The clock and wave springs removed from the four Hydraulic Research servoactuators (S/N's 059, 063, 067 and 068) on SA-502 engines were forwarded to this division for visual and/or metallurgical examination. The eight springs were forwarded to this division for magnetic particle inspection. No cracks were detected with this procedure nor with subsequent visual examination. Two of the clock springs, SN's 059 and 063 contained considerable surface oxidation in the form of rust. Clock spring SN 059 was studied metallographically and no metallurgical irregularities were noted in the 17-7 PH stainless steel material.

VI. J-2 Engine

J-2 Engine, Project Management, Materials

Rocketdyne has requested MSFC approval on MR's to accept some thrust chamber shrouds with excessive microfissuring in welds and two titanium start bottles that have excessive grain sizes. Both of these problems are being studied by this division.

VII. Instrument Unit

Study of Possible Gas Evolution in the Environmental Control System

New hydrogen gas evolution tests are being investigated by exposing LA141 and Avco Products cold plate materials to inhibited methanol/water solution, individually and together (but not coupled). The sodium benzoate

inhibited solution is being studied for gas evolution and pH change. The solution containing 250 ppm sodium dichromate is being analyzed periodically for chromate breakdown and also for gas evolution. A combination of the two inhibitors using both the LA141 and cold plate material also is being studied. After 28 days of exposure very little gas has evolved in either of the inhibited solutions.

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

Twenty-three (23) materials were evaluated at 10^{-7} torr and to 100°C by making continuous weight loss determinations and periodic mass scans on each material.

Cat-A-Lac #67-10-20-1 black paint on polyurethane foam, Cat-A-Lac green primer #67-10-18-1, American Cyanimide Bonding Material Type II, Cho Seal No. 1215, PS 203, FFA-5 adhesive, Furane plastics MIL-A-8623, Cat-A-Lac flat white paint #463-1-500, and white nylon net #37K1012H have acceptable outgassing characteristics (<0.2 percent/cm^2/hr) for use on the ATM. However, it should be noted that the American Cyanimide Bonding Material Type II changed from a flexible to an unflexible material during the requested curing cycle of 350°F for 1.5 hours. The material that was originally gray became brown during curing.

The Lord BTR Elastomer and the phenolic-laminated rod L-P-509 Type 2 are marginal. The remainder of the materials tested were found to be unacceptable for use on the ATM based on weight loss criteria.

A complete, operational, digital command receiver (ATM) was subjected to a thermal/vacuum environment to determine the total outgassing load. This receiver was developed for the Saturn program and the materials used had not been checked previously for outgassing contamination potential. The purposes of this test were to determine the total outgassing load created by the receiver, determine the source of the outgassing, and find out if the component could be "cleaned up" by a vacuum bakeout, so that it would be usable without a major replacement of the constituent materials.

The receiver was placed in a vacuum chamber and pumped to a pressure of 2.1×10^{-6} torr. The temperature was raised to 45°C and the pressure increased to 3.2×10^{-6} torr and then began dropping. The temperature was increased to 85°C and the pressure increased to a maximum of 2.4×10^{-5}

torr, and then began an exponential decay to a value of 8×10^{-7} torr 18 hours later. At this point, the pressure began decreasing steadily to a final value of 8.7×10^{-8} torr, eight hours later. The outgassing ratio (the ratio of the outgassing from the sample to the system background gas load) went to 1422 at 45°C and a maximum of 9,600 at 85°C. At the end of the test, the outgassing ratio was down to 3.8. The specification for total outgassing (pending) allows a ratio of 1.5.

Periodic mass scans were made with a residual gas analyzer (RGA) during the test. Numerous peaks out to atomic mass unit (A.M.U.) 171 were recorded at 85°C, but the spectrum at the end of the test consisted only of system background peaks. Analysis of these data is now being done against the materials list for the command receiver, in order to identify the outgas sources.

A section of an ATM Solar Panel Module was subjected to a thermal/vacuum environment. An adhesive (Epibond 101) used in fabricating the modules, which has been ruled unacceptable for ATM has already been used in fabricating several modules. The purpose of this test was to determine the severity of outgassing from the adhesive, and find out if a vacuum bakeout would clean up this material.

In preparation for the test, the chamber was thoroughly cleaned, then baked out for 8 hours at 300°C. The chamber attained a pressure of 4.2×10^{-10} torr, with only hydrogen and nitrogen detectable at residual gases. The section of solar module was installed in the chamber, and the system was pumped to 5.0×10^{-9} torr. Temperature was increased to 50°C, and the pressure rose to 1.0×10^{-8} torr. The temperature was further increased to 100°C and the pressure increased to a maximum of 6.0×10^{-6} torr and then began decreasing. The pressure dropped to 1.1×10^{-7} torr in 2 hours, and to 5.5×10^{-8} torr in 6 hours. The pressure dropped to a value of 7.3×10^{-9} torr in the next 17 hours, still at 100°C, at which point the heat was turned off. The pressure dropped to 1.6×10^{-9} torr in one hour, to 7.0×10^{-10} torr in the next hour, and reached a final value of 4.7×10^{-10} torr 3.5 hours later.

The outgassing ratio at 50°C was 2.45, and the maximum ratio at 100°C was 1,260. However, at the end of the test the ratio was down to 1.12 (1.5 allowable), indicating a clean module condition.

Periodic mass scans were made and at 100°C peaks were noted to A.M.U. 284. However, at the end of the test the only peaks noted in the system corresponded to system background gases. Examination of the section after the test indicated that the Epibond 101 had run slightly, and yellow coloration could be seen on the edges of the module.

B. Evaluation of Direct Current Motors for Use on ATM

Evaluation testing has continued in the investigation and developmental activities related to the use of direct current torque motors in the ATM systems.

The 7 ft-lb high temperature Inland motors employing brushes of The Boeing Company material 046-45 were vacuum tested for 155 hours. The test was then stopped because of excessive outgassing from the motors. Although the test apparatus has not been disassembled, the brushes and bearings look good. More vacuum tests are planned for the motor assembly. Results from these tests will be compared to those of a similar system which is operating in air.

C. Investigation of ATM Bearing Lubrication

Studies are in process to provide lubricants for the Apollo Telescope Mount system which will not break down or outgas significantly in the environment of space.

A test on the torque drive test system for the Bendix Company was run in a vacuum of 10^{-7} torr and at temperatures of about 95°F (35°C) for 7 days. The Boeing Company compact material brushes designated 046-45 were employed in the motors. At the completion of the test, there was no measurable wear of the Inland drive motor brushes. Also, the Inland tachometer motor brushes exhibited a low wear rate as shown below:

Tachometer Brush Wear Rate for Seven Day Torque Tests

Brush Number	Wear Rate (inches/hour)
1	1.7×10^{-5}
2	3.4×10^{-5}
3	5.9×10^{-5}
4	4.1×10^{-5}

More tests are planned for the Bendix Company torque drive test system.

A universal bearing tester has been designed and is being fabricated to test, primarily, journal bearings (furnished by Perkin-Elmer for use in ATM systems)ranging in bore size from 3/8 inch to 1-1/2 inches. This tester has been so designed as to enable various sizes of journal and ball bearings to be tested with only minor changes in the test fixture.

D. Investigation of Thermal Control Materials for ATM

Continued support and consultation has been rendered in the selection and evaluation of insulation materials for the ATM. The major problem of concern is the selection of a spacer material for multilayer insulation on the sun end of the ATM canister. Two nylon net materials have been tested for outgassing characteristics. One was found to be satisfactory. However, the other material is preferred from a weight and thermal standpoint, but it did not meet outgassing requirements. Samples of this preferred netting material are being given a preliminary vacuum treatment to determine if the volatile materials can be removed without degrading the desired properties of the netting.

Efforts have continued in the evaluation of various commercial paints as thermal control coatings for application on Apollo Telescope Mount (ATM) components. As reported earlier, work has been undertaken to select white paints for use in stenciling connector designations on various ATM black boxes, which will be painted with Cat-A-Lac flat black paint No. 463-3-8. Two paints have been determined to be suitable for this application, namely, S-13G thermal control coating provided it is applied over a suitable primer, and Cat-A-Lac flat white paint No. 463-1-500, which has to be heat cured at 65°C (150°F) for 48 hours to obtain the requisite outgassing characteristics.

The 3M Company's black velvet coating No. 101-C10 is being evaluated as an alternate coating for Cat-A-Lac black paint No. 463-3-8. Samples of the paint have been prepared and submitted for optical property measurements and outgassing characteristics determinations.

The Astrionics Laboratory (R-ASTR) has coated a prototype of the Thermal Mechanical Unit of the S-054 telescope with Sherwin-Williams KEM LUSTRAL flat black paint No. F65B2, which does not have the requisite outgassing characteristics for ATM applications. At the request of R-ASTR, this laboratory is evaluating potential methods of making the F65B2 paint vacuum-compatible. Two methods presently being evaluated are heat curing the paint and overcoating the paint with Cat-A-Lac black paint No. 463-3-8 followed by heat curing.

Specifications were issued for Cat-A-Lac flat black paint No. 463-3-8 on December 12, 1967. The material specification is MSFC No. 10M01831, entitled "Paint, Flat Black, Temperature Control, Specification for." The process specification is MSFC No.10M01832, entitled "Application of Temperature Control Paint, Specification for."

IX. Nuclear Vehicle Technology

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

A. Investigation of Propellant Heating

Modification 2 to contract NAS8-18024 with the General Dynamics Corporation (GD/FW) provides for the design of an experiment to provide valid experimental data on the nuclear and thermodynamic effects of nuclear energy deposition in liquid hydrogen. These data are required for the analysis of the credibility of results predicted by existing analytical techniques.

A presentation on the status of this program was made to Mr. Kline (Director of the Space Nuclear Propulsion Office (SNPO) in Washington) and his staff on December 12, 1967. A series of questions resulting from this meeting and concerning the performance of the experiment has been received from SNPO. These questions have been reviewed and answers are being prepared.

The final presentation by the contractor on the design of the experiment has been scheduled for January 26, 1968 at this Center. A scope of work providing for the actual performance of the experiment has been written and forwarded to Procurement for processing as Modification 3 to the basic contract. Meetings were held with Mr. White of Astrionics Laboratory (R-ASTR) and Dr. Sieber of Test Laboratory (R-TEST) to discuss (a) the design and fabrication of a TV system to monitor the liquid hydrogen inside the test tank and (b) the availability of a fast response data acquisition system for these tests. Both Mr. White and Dr. Sieber agreed to support this program in these areas.

B. RIFT Tank Tests

Currently, tests are scheduled to be made under contract NAS8-18024 with GD/FW to evaluate various types of transducer, seal, and insulation materials in a radiation, liquid hydrogen, and acoustic environment. The tests will be made using the 108-inch diameter liquid hydrogen (LH_2) RIFT tank insulated with the test insulation. Valves and transducers containing the test materials will be installed on the tank for testing.

The detailed test plan for these tests has been written and distributed to all participating organizations. Structures Division has completed the modification drawings for the tank and Manufacturing Engineering Laboratory (R-ME) has initiated the necessary modifications. All of the test items have been procured with the exception of the 17-inch prevalve currently being modified by the Whittaker Corporation under contract NAS8-29784. The modification and checkout of the valve are scheduled to be completed late in January 1968. After checkout, the valve will be shipped to GD/FW for testing.

C. Activation Analyses

The computation of neutron activation of proposed Nuclear Rocket Vehicle materials is necessary for the establishment of stage operation criteria. Because of the complicated materials and difficult geometries comprising typical stage hardware, sophisticated computer programs must be used to calculate anticipated activation levels. One of these programs is the Neutron Activation Prediction Code (NAP) developed for this Center by Illinois Institute of Technology (IIT) under contract NAS8-11160.

Currently, efforts are directed toward the implementation of the NAP computer program at this Center. A good magnetic tape containing the program has been received from IIT and the program has been modified to run on the local computers. An initial run has been made on a sample problem previously run by IIT. The results obtained are not in agreement with the data output of the IIT computer, indicating that further debugging work is required.

ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

Supporting research activities have continued in the areas of technology and with the contractors 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

Battelle Memorial Institute, NAS8-11891

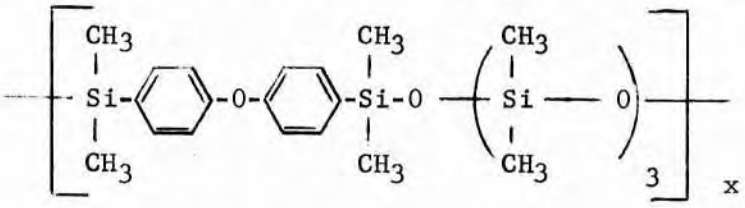
II. General - In-House

A. Development of High Temperature Resistant Polymers

Continued effort has been devoted to the development of improved crosslinking systems and procedures for the aryloxysilanes, silphenylenesiloxane and polymers of related structure.

Crosslinking studies involving the aryloxysilane polymers have been delayed during this report period in order to collect various analytical data on the linear polymers.

A promising ester exchange crosslinking technique for the silphenylene-siloxane polymers is being investigated in conjunction with personnel of Southern Research Institute under contract NAS8-20190. It was determined that the polymer having the structure below,

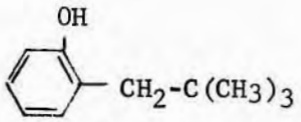


which was prepared under a previous contract with Midwest Research Institute, could be efficiently crosslinked by addition of tetraethoxysilane and dibutyltindiacetate. The optimum weight ratio of reactants required to produce a tough elastomeric polymer is 0.8 gram of polymer as a 40-percent solution in toluene, 0.7-0.8 gram of tetraethoxysilane and 0.1-0.15 gram of dibutyltindiacetate. The curing schedule consisted of 4 hours at 25°C, 16 hours at 60°C, 1 hour at 120°C, and 4 hours at 170°C. The films prepared in this fashion were equivalent or superior in terms of toughness, elasticity, and tear resistance to a commercially available silicone rubber, General Electric 615. Elevated temperature aging tests on the cured products are currently underway to determine if the inherent high thermal and oxidative stability of the silphenylenesiloxane linear polymer is retained in its crosslinked form.

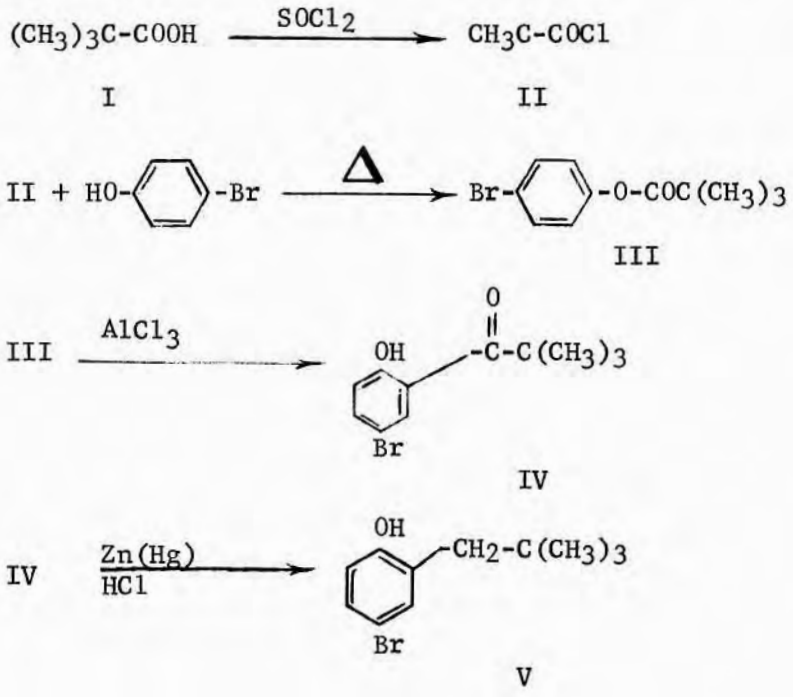
B. Development and Characterization of Phosphonitrilic Polymers

Additional studies have been directed toward the preparation of hindered phenols suitable for subsequent reaction with $(PNCl_2)_4$ to give non-geminally substituted derivatives. These derivatives would in turn be subjected to exhaustive aminolysis to obtain tetraamides capable of undergoing thermal deamination to polymers, hopefully, possessing ladder-type configurations.

Attempts to obtain a cryptophenol of the structure



were previously reported. Since these efforts did not succeed, the following sequence was tried:



Preparation of pivalic acid (I) was accomplished as described in the literature through carbonation/hydrolysis of the Grignard reagent of tert-butylchloride. The crude acid was treated directly with thionyl chloride and the pivoloyl chloride (II) was collected by fractional distillation as a clear liquid, boiling point 100-105°C. The p-bromophenyltrimethylacetate (III) was prepared through the reaction of the acid chloride and p-bromophenol at a reaction temperature of 128°C; copious evolution of HCl was observed at this temperature.

The crude ester was obtained in 93 percent yield as a white solid, melting point 58-59°C. The infrared spectrum showed strong carbonyl absorption at 1775 cm^{-1} and no hydroxyl absorption at 3400 cm^{-1}. The analytica sample was recrystallized from methanol-water as short white needles, melting point 60-61°C. Elemental analyses are pending. The selection of p-bromophenol was made for two reasons: (1) It was necessary to have a molecule with the para position blocked to prevent the formation of any para-hydroxy-substituted product in the subsequent Fries rearrangement reaction and (2) no p-cresol was available. The p-cresol would be the preferred intermediate in this case.

The Fries rearrangement of III to IV did not occur during a number of small scale reactions. Initial products were invariably intractable tars which defied attempts at purification and characterization. Employing the mildest possible conditions for the reaction, overnight stirring of equimolar quantities of the ester and anhydrous $AlCl_3$ in CH_2Cl_2, gave a moderate yield of oily product which showed strong hydroxyl absorption at 3400 cm^{-1}, but no carbonyl absorption. It can only be surmised that the ester was cleaved to give a phenolic derivative with no hydroxy-ketone being formed.

This continuing inability to synthesize any potentially useful phosphonitrilic chloride monomers or the desired ladder-type polymers, coupled with the expiration of an equally unsuccessful contracted effort, has necessitated a decision to suspend this effort until future developments warrant a resumption.

C. Development of Fluorinated Adhesives

Investigations have continued in the development of fluorinated polymers of potential use as liquid oxygen compatible adhesives.

The pyrolytic decomposition of disodium hexafluoroglutorate would normally be expected to proceed as follows:

$$NaOOC(CF_2)_3COONa \longrightarrow CF_2=CF-CF_2CF$$

Gas chromatography has previously shown at least three products among the gaseous pyrolysis products. A larger sample of disodium hexafluoroglutarate has now been pyrolyzed to yield a gaseous mixture of 300 torr pressure throughout the reaction system. Previous experiments had yielded only 100 mm Hg partial pressure of products.

The higher partial pressure of products permitted a measurement of number of moles of gas evolved, as well as a more accurate chromatographic analysis. Volume calibration of the pyrolysis system permitted calculations showing 2.4 moles of gas produced per mole of the disodium salt. Chromatographic analysis over a programmed range of temperatures showed that six separate components were present.

Work was initiated on preparation of p-diaminotetrafluorobenzene from hexafluorobenzene. The diamine is an intermediate in preparation of the corresponding diisocyanate to be used with fluorinated diols in polyurethane synthesis.

D. Development of Sealant Materials

Developmental activities have been initiated on materials of potential usefulness as sealants for fuel tanks and systems. The requisite sealants must be characterized by good adhesion to metals, thermal stability and solvent resistance. As a start toward preparation of a polymer having the requisite attributes synthesis has been initiated on a comonomer capable of providing p-styryl crosslinking sites in the backbone of a polysilphenylene-siloxane elastomer. The preparation of p-vinylphenylmethylbis(dimethylamino)-silane was attempted by a method similar to earlier work in which p-bromostyrene was used as the starting material. Several modifications were made, including the use of Et_2O rather than tetrahydrofuran (THF) as the reaction medium and the addition of the p-styrylmagnesium bromide to the Cl_3SiMe at 0°C to minimize di- and tri-substitution. However, attempted distillation of the crude product at a pot temperature of 125°C and 0.1 torr resulted in apparent decomposition of the material. Ultimately a moderate yield was obtained of distillate with a boiling point of 94-98°C/0.5 torr. This was presumed to be the desired comonomer, and tests are in process to confirm this.

E. Development and Evaluation of Metallic Composites

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

During this report period developmental activities were continued on the bonding of various metallic combinations by high explosive techniques. The following dissimilar high purity metal sheet combinations were successfully joined using the explosive nitroguanidine:

1. Copper to molybdenum
2. Zirconium to aluminum
3. Copper to titanium
4. Molybdenum to aluminum.

In addition, several multilayer aluminum sheet laminates reinforced with 0.009 inch diameter steel (NS355 stainless) wire were successfully bonded by the above explosive bonding technique. Metallographic specimens of the composite were examined microscopically and found to be uniform and completely bonded. Microhardness checks across the interfaces have been made in order to determine interface hardness conditions.

A filament reinforced composite was prepared by winding NS355 stainless steel wire of 0.009 inch diameter on to 3003 aluminum sheet. The aluminum and stainless wire were arranged such that there were five layers of aluminum with a layer of wire arranged between the aluminum sheets. This composite was successfully consolidated by means of explosive bonding techniques. Sections of this composite are being microanalyzed to

determine the quality of the diffusion bond. Preliminary observations indicate that the matrix bond and matrix to wire bond are excellent.

As mentioned in the preceding report new press platens, for use in diffusion bonding studies have been prepared to replace the defective platens formerly used. With these platens the optimum conditions were established for diffusion bonding several aluminum alloys.

Aluminum alloy 3003 produced a good bond by following the procedure described below:

1. Clean by wire brushing.
2. Static press to 10,000 psi.
3. Heat to 925°F for a period of 10 minutes.

F. Investigation of Stress Corrosion Characteristics of Various Alloys

The long-term exposure tests have continued on 7079-T61 and -T64 aluminum alloy in the local atmosphere. There has been no change in the test results since June. This atmosphere test has been in progress for a total of 22 months.

Investigations have continued in the evaluation of the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were exposed to inside and outside atmosphere. Failures to date have been confined to the outside atmosphere in all alloys with no changes since the October report. These tests have been in progress 8.5 months.

Specimens of aluminum alloy X2021 and X7007 were stressed in all three grain directions and exposed in the alternate immersion tester and to the local atmosphere. Both alloys were found to be susceptible in the alternat immersion tester as previously reported. Tests in the atmosphere have been in progress 22 months, and the only failures encountered were X7007-T6E136 specimens in the short transverse direction at loads as low as 10 ksi.

The test to determine the effect of overaging 7079-T651 (20 hours at 350°F (177°C), 10 hours at 350°F (177°C), and 5 hours at 375°F (191°C)) on the stress corrosion susceptibility of this alloy has been terminated after 90 days of exposure in the alternate immersion tester. The tests results indicate that 7079-T651 is susceptible to stress corrosion cracking in the short transverse grain direction at a stress level of 50 percent of the yield strength in all three aged conditions when tested in the alternate immersion tester using a 3.5-percent sodium chloride solution.

Round threaded end tensile specimens of 2014-T6 (short transverse) 2024-T4 (short transverse and longitudinal), 2219-T37 (short transverse and longitudin and 7079-T651 were to be studied for stress corrosion susceptibility by changing the water in the tanks periodically. This approach was taken in the belief that impurities deposited in the water from the corroding aluminum would affect the test results. However, failure of the specimens was so rapid with the exception of 7079-T651 that another approach will be investigated. The testing in synthetic water will be continued.

Aluminum alloy 7178-T651 is being evaluated for stress corrosion susceptibility. Round threaded-end tensile specimens stressed in the longitudinal and long transverse grain direction to 50 ksi (75 percent), and C-rings stressed to 30 ksi (45 percent) and 25 ksi (40 percent) in the short transverse direction are being exposed in the alternate immersion tester. Additional C-rings with similar tensile loads in the short transverse direction are being run in synthetic sea water. There have been no failures after 70 days of exposure.

The study of the stress corrosion susceptibility of Ti-6Al-4V alloy in various fluids is continuing. No failures have occurred to specimens exposed in any fluid except methyl alcohol. Failures are still occurring in the original flat specimens (with no shot peening). The most recent failure was of specimen in the annealed condition stressed to 50 percent of the yield strength which failed after 1 year of exposure in absolute methyl alcohol.

Initial tests have been terminated in the evaluation of the stress corrosion susceptibility of steels, Almar 362, PH15-7Mo, 17-4PH, 17-7PH, and PH14-8Mo (air melt and vacuum melt). Evaluation of the results show that the stress levels used were too high to predict threshold stress levels for both 17-7PH and PH15-7Mo sheet and bar stock. Additional tests have been planned and specimens have been fabricated and are being heat treated. Flat tensile specimens of 17-7PH steel in the CH900 condition were loaded to 50, 75, and 90 percent of the yield strength in both the longitudinal and transverse grain direction and exposed in the alternate immersion tester. There have been no failures after 76 days of exposure.

Welded and aged (20 hours at 790°F (421°C)) ARDE low silicon 301 stainless steel cryogenically stretched to a nominal 252.6 ksi is being tested for stress corrosion susceptibility. Longitudinal specimens stressed to 75 percent (190 ksi) and 90 percent (228 ksi) of the yield strength have been exposed in the alternate immersion tester for 140 days without failure.

Round tensile specimens made from 1/4 inch diameter music wire spring material were stressed in the longitudinal direction to 70 percent of the yield strength and exposed in the alternate immersion tester, humidity cabinet, outside atmosphere, and semi-controlled atmosphere. There have been no failures in any of the environments after 41 days exposure.

G. Investigation of Stress Corrosion Induced Property Changes in Metals

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

A series of flat 7075-T6 specimens were stressed to various percentages of the yield stress and subjected to an alternate immersion corrosion environment for various periods of time ranging from 4 to 48 hours. Electrical conductivity measurements were made at specific locations on each specimen before stressing, after stressing and before immersion, and after immersion. The conductivity data obtained presently are being analyzed and the specimens are being prepared for destructive tests.

Eighteen (18) round tensile specimens of 7075-T6 aluminum were subjected to a stress corrosion environment and then destructively tested. Subsequent to testing, high frequency electrical conductivity measurements were made using specially constructed transducers. The data are being analyzed to establish a correlation between high frequency conductivity, stress corrosion exposure time, and changes in mechanical strength.

H. Analysis of Retro Rocket Exhaust

The purpose of this program is to determine the composition of type TPE-240-2 rocket motor exhaust products and to evaluate the exhaust products as a potential contamination source to thermal control coatings.

An initial firing was made to determine the parameters required to ignite the rocket motor and to determine its effect on the test chamber. The vacuum chamber was pumped down to a pressure of 4×10^{-4} torr with two mechanical pumps and a blower. The pumps were then valved off from the chamber and firing initiated. The motor ignited when 30 volts d.c. was applied across the squib. The motor fired for 0.25 seconds and the final pressure in the chamber was greater than 1 torr. A thermocouple located at the base of the chamber in line with the rocket nozzle detected a temperature of 175°C 0.5 seconds after the motor ignited. A thermocouple was mounted behind the motor mount and detected a temperature rise to 75°C. Inspection of the chamber revealed a thick film of exhaust products on all surfaces within the chamber.

A specimen holder was fabricated to facilitate placement of thermal control coated discs for contamination testing. Discs coated with S-13, S-13G, Z-93, Cat-A-Lac Black and Hughes Surveyor white were spectrally evaluated and mounted on the holder.

In addition, five fritted glass plates were placed on the holder to absorb exhaust products. A gas cylinder was attached to the vacuum chamber to collect exhaust gases during firing. The test chamber was evacuated to a pressure of 3×10^{-7} torr with a liquid nitrogen cooled oil diffusion pump. The pumps were again valved off and the rocket motor ignited. Color motion pictures were taken at 5,000 frames per second. The final pressure in the chamber was approximately 300 torr. The temperature at the base of the chamber was 370°C. The rocket motor had been lowered 5 inches to facilitate motion picture coverage. The proximity of the motor to the base of the chamber caused the greater temperature increase. A thermocouple located midway on the sample holder monitored a temperature of 150°C. The chamber was bled back to atmospheric pressure and the sample holder removed. The samples are now being analyzed for contamination.

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

Electrical contacts in vacuum concerns any device for transferring electrical energy through moving contact surfaces, such as brushes, slip rings, and make-break switches. Standard brush-commutator type machines

suffer a severe degradation of performance at high altitudes, principally due to rapid wear of the graphitic carbon brushes. This results from failure of the normal process of lubrication of the contact surfaces. Therefore, this program was initiated to develop electrical brushes for use in a space environment.

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

A new test device capable of testing 18 brushes simultaneously in an inert atmosphere has been developed and is presently being used to evaluate the various materials against copper commutators. The compacted brush materials being tested presently, including the compaction pressures and temperatures, (where available) are:

1. 046-45 - Boeing proprietary composition prepared by The Carborundum Company

2. J-11 - 95.5 percent MoS_2, 4.5 percent Mo, 5,000 psi, 2,880°F

3. J-12 - 94.1 percent MoS_2, 5.9 percent Mo, 5,000 psi, 2,880°F

4. J-15 - Boeing proprietary composition prepared by this division.

These brushes are being tested in a gaseous nitrogen atmosphere at currents to 2 amperes. The results of these tests will be reported after a test duration of 100 hours.

J. Development of Low Density Ceramic Foams

Efforts have continued in the development of low density ceramic foams. Difficulties have been encountered in preparing large specimens of the Refrasil-reinforced sodium silicate foams; the larger specimens containing much larger and less uniform pores than the smaller specimens. These difficulties are attributed to the fact that the silicate foams are self-insulating as they develop when foamed by external heat, preventing the center of the foam from receiving adequate heat. Therefore, a heat source is needed that will heat the foam mix uniformly during foaming. One method of heating the foam mix uniformly is by micro-wave heating, and this technique will be investigated.

Efforts were undertaken to fabricate cylindrical specimens of Refrasil reinforced sodium silicate foams. A double-walled cylindrical form was fabricated and the foam mix poured in the form and heated. Problems were encountered in forming a complete cylinder of foam; however, half cylinders of the foams were easily formed.

K. Evaluation of Alloys

A bar of A-286 stainless steel (1 inch diameter) has been received from Armco Steel Company for acceptance and qualification testing per MSFC-SPEC-145. The alloy was received in the solution treated condition - cold worked approximately 50 percent. The material was age-hardened at 1200°F for 16 hours and air cooled. Longitudinal tensile specimens and transverse "C" ring specimens are being fabricated for stress corrosion evaluation. Tensile and charpy-V-notched impact specimens are being fabricated for testing at ambient and cryogenic temperatures. A bar of A-286 stainless steel (0.88 inch diameter) received from Carpenter Steel Company for qualification to MSFC-SPEC-145 which was cold worked approximately 40 percent, age hardened at 1200°F (649°C) for 16 hours, air cooled is being evaluated for stress corrosion susceptibility and suitability for cryogenic application. Tensile test results on 0.500 inch diameter specimens are as follows:

Temp. °F (°C)	Yield Strength 0.2 Percent Offset (ksi)	U.T.S. (ksi)	N.T.S. K_t=10 (ksi)	N/U Ratio	Elongation in 2.0 In. (Percent)	Modulus X 10^{-6} (psi)	No. of Tests
75 (24)	194.5	202.0	313.8	1.55	12.75	28.14	2
-320 (-196)	228.8	256.0	328.7	1.28	20.25	32.85	2
-423 (-253)	248.7	274.5	346.3	1.26	16.70	32.46	3

L. Developmental Welding

Progress has continued on the evaluation of the weldability of aluminum alloys X2021 and X7007. The base weldments of the weld repair portion of the program were completed for alloy-thickness combinations and were machined for the first repair (100 percent penetration). The weldments were cleaned chemically prior to making the repair weld. The first repairs were completed in weldments of 1/2 inch thick aluminum alloys X7007 and X2021. Three weld passes were required to complete each repair. The repair weldments were inspected radiographically and graded per MSFC-SPEC-259A. Acceptable repairs were selected for the determination of repair mechanical properties. The remainder of the weld panels were submitted to the machine shop for removal of the defective repair area. Subsequently, evaluations will be made on panels containing as many as five repeated repairs on the same area.

Additional Houldcroft tests were made to verify the initial results which showed inconsistent weld crack tendencies between sheet and plate in aluminum alloy 2219. Release of a summary report awaits the analysis of results from the additional Houldcroft tests.

The evaluation of the weldability of titanium alloys Ti-6Al-4V and Ti-5Al-2.5 Sn has continued. Welding parameters were established. Preliminary weld panels were obtained for each alloy. The weldments were inspected radiographically and those panels found to be acceptable were submitted to the machine shop for fabrication into tensile specimens.

The joint configuration of the 1/4 inch thick material was modified after it was found that suitable penetration could not be obtained with square butt joints. The joint configuration selected was a double bevel with a 1/16-inch land and a 60° included angle. It was noted that a helium shield produced welds with a more desirable appearance than welds using argon shield. The helium shield also permitted more favorable penetration characteristics than the argon shield during welding.

M. Investigation of Electroplating Procedures

Work was resumed on the evaluation of an electroplating solution produced by Technical Micronics Control, Inc. (TMC). In addition to the metals previously reported as being successfully polished by this solution, Invar, Rene' 41 and pure nickel were electropolished during this report period. Of the three metals studied, pure nickel was polished with the highest degree of luster. Also, this luster on pure nickel could be obtained under a wider range of operating conditions (current density, temperature, etc.). Only a fair polish was obtained on Rene' 41, but it also could be obtained using a wide range of operating conditions. On the other hand, a high degree of luster was obtained on Invar, but the conditions at which this high luster could be obtained were fairly narrow It was determined that the high luster rnage was around 12 to 14 volts at 150°F (66°C). However, the required voltage varied considerably with the temperature of the bath. Generally, the higher the temperature of the bath, the lower the voltage requirement. Several unsuccessful attempts were made to electroplate directly on electropolished surfaces of copper. It appeared that a passive film was retained on the polished surface which interfered with the bonding of an electroplate. However, it appeared that this film could be removed without dulling the polished surface, and once it was removed, good adhesion could be obtained. Fair adhesion was obtained using a subsequent hydrochloric acid dip, but more positive and consistent plate adhesion was obtained by the use of a short electro-clean treatment following the electropolishing operation. The type of polishing solution used was one containing chromic and phosphoric acid (type A). From previous experience using chromic acid as a pickling agent, it is believed that the chromic acid present in the solution is responsible for the retention of the passive film.

N. Documentation Review

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

1. Fastener Testing Development Group (FTDG) Test Procedures for; Double Shear, Definitions, Clamping Force.

2. R-QUAL-AV requested comment on North American ECP concerning the replacement of welded flex hose with flares and MS-208-19 fittings and sleeves. The ECP allows a choice of MS sleeves in stainless steel 302-303-304 - 304L-316-321-347. NAR proposes to use MC-124 "B" nuts with MS-208-19 sleeves. It was recommended that the MC sleeve be 40 percent cold worked A-286.

3. A proposed MSFC specification was reviewed and comments submitted to R-P&VE-NV on "Brazing of Steels, Copper, Copper Alloy, Nickel Alloy, Aluminum, and Aluminum Alloys."

4. NAR - MA0615-011 dated March 17, 1967, "Dimensional Control During Chemical Processing of Aluminum Alloy Components, Saturn S-II Stage."

5. NAR - MA0109-018 dated November 1, 1967, "Electroplated Lead on Corrosion Resistant Steel (CUS) Alloys for Sealing Application."

6. NAR - ST0110GA0002 C dated June 28, 1967, "Solvent Vapor Degreasing."

7. ST0210GB0002 dated May 25, 1967, "Trichloroethane, 1,1,1-Stabilized Vapor Degreasing and Solvent Flushing Grade."

8. MA0608-009 B dated November 20, 1967, "Application of Organic Coatings to Saturn S-II Stage Hydrogen Tank "J" Section Groove and Base."

O. Literature Survey

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

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

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

DECEMBER 1, 1967 THROUGH DECEMBER 31, 1967

I. Radiography

Fifty-one miscellaneous parts, components, and test specimens were inspected radiographically this period.

II. Photography

	Negatives	Prints	Other
Engineering photography	47	186	
Metallography and fractography	138	757	
Miscellaneous photography, processing, copywork, etc.			200

III. Metallurgical and Metallographic Testing and Evaluation

A. At the request of Propulsion Division, R-P&VE-P, photographic documentation was made of a cross section of an F-1 engine experimental zero leakage fitting.

B. Investigations have continued into materials and welding techniques appropriate for fabrication of metallic snap diaphragms. Electron beam techniques used to join the diaphragm to the test assembly have proved satisfactory. Subsequent work will involve establishing the feasibility of the snap diaphragm as a pneumatic control device. Other material, material thicknesses, and processing techniques will be investigated. This work is being done for the Propulsion Division, R-P&VE-PE.

C. Various components of the thruster engine assembly were joined together using the electron beam welder. Several seal welds and structural welds were required to complete the assembly. Seal welds on the titanium Ti-6Al-4V alloy were made at machine settings of 60 KV, 1.5 Ma, and 15 ipm travel speed while structural welds were made at machine settings of 90 KV, 7.5 Ma and 15 ipm travel speed. The engine sucessfully withstood hydrostatic pressure tests. To date, the thruster engine assembly has not been test fired. Further development work on the system awaits the results of test firing.

D. Consulation was provided to Manufacturing Engineering Laboratory (R-ME-M) on the evaluation approach for welded (circular patch) experimental panels subjected to sizing by the electromotive process.

E. As a result of the cracking problem which occurred in the S-II-7 stage hardware welds and the follow-on testing, a possible problem was uncovered in the relief design for the junction welds in S-II-4 hardware. Test specimen failures occurred in the radius of the relief sections at stresses and elongations significantly below the expected design requirements. Consequently, to resolve this problem within the assigned three-week period, Manufacturing Engineering Laboratory (R-ME-MW) is expediting fabrication of welds by methods simulating North American Rockwell Corporation production procedures and the subsequent machining of the welds into test specimens. It is anticipated that the test specimens fabrication will be completed in time for strain gauge installation, which Structures Division (R-P&VE-SVM) is expediting. The testing of the simulated S-II weldments will begin December 29. Thirty-five tests will be made at room, -250°F, -320°F, and -423°F (-156°C, -196°C, and -253°C) for 2014-T6 axial welds with two different weld bead widths. This program is scheduled for completion by January 8, 1968.

IV. Spectrographic Analyses

Two hundred and eight determinations were made on fourteen samples and one hundred and eighteen standard determinations were made.

V. Infrared Analyses

Thirty-five analyses were made by infrared techniques on a variety of materials including foam insulation, polymeric materials, greases, and two cleaner fluids from the NASA Medical Center.

VI. Chemical Analyses

	Determinations
Methanol-water mixture for	
trivalent chromium	4
Residue from electrical brushes for	
carbon	2
Rock-like substance for	
carbonates	2
magnesium	2
calcium	2
silicon	2
carbon	2
ignition loss	2
Metal samples for	
carbon	12
sulfur	12
chromium	8
nickel	6
tin	2
lead	2
beryllium oxide	2
hydrogen	10
Gas samples for	
hydrogen	21
nitrogen	8
RP-1 fuel, density	22

VII. Rubber and Plastics

	Items
Molded or extruded	136
Cemented	150
Coated	8
Fabricated	32

VIII. Electroplating and Surface Treatment

	Items
Acid cleaned	42
Degreased and cleaned	6
Alodine treated	45
Anodized	1,500
Electroplated	1

IX. Development Shop Production

A. A total of 6,068 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. Two thousand four hundred and ninety-seven man-hours approximately 41 percent of the total man-hours, were expended on work of a nonroutine nature and applied to the work orders listed below.

1. Saturn V Sled Test Module

The Saturn V sled module is completed and instrumentation is in process.

2. Models of ATM Experiment Package

The models of the ATM experiment package have been completed and delivered.

3. X-ray Astronomy Assembly Modification

Modification of the design of the X-ray astronomy assembly is in process.

4. GOX Impact Compression Tester

Work on the GOX impact compression tester is nearing completion.

5. Flange Assembly NGTM

Work on the flange assembly for the NGTM is 30 percent completed.

6. Bearing Test Assembly

The design of the bearing test assembly is completed and fabrication is in planning.

7. ATM Mock-Up Components

Work is in process on the ATM mock-up components.

8. Water Cooling Manifold

Fabrication has started on the water cooling manifold.

X. Miscellaneous

A. Eight parts were inspected by magnetic particle techniques during this report period.

B. Two hundred and sixty-eight items of stainless steel and items of Inconel alloy were heat treated during this report period.

C. Fifteen materials were evaluated for LOX sensitivity in accordance with the provisions of MSFC-SPEC-106B.

D. Made fifteen atomic absorption analyses on aluminum and steel specimens.

E. Made two hundred and sixty-eight chromatographic analyses on polymeric materials.

F. Made 16 reflectivity and eleven emissivity measurements.

G. One hundred and seven thermal property determinations were made including such tests as differential thermal analyses, differential scanning calorimetry, thermal gravimetric analyses, thermal conductivity, etc.

XI. Publications

None.

E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-67-12

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(December 1, 1967 - December 31, 1967)

SATURN IB

S-IVB Stage

Control Relay Assembly

A redesigned control relay assembly is to be qualified for 204 flight. The original relay assembly test specification consisted of sine sweep and sine dwell. The redesigned relay assembly failed during test. Astrionics Laboratory has requested that revised criteria be generated for this item. The data available from 201, 202, 203, and 501 were reviewed and a revised specification has been recommended.

SATURN V

I. S-II Stage

A. Interstage Recirculation and 207 Container Battery Environment

The North American Rockwell Corporation (NAR) has submitted for approval revised specifications for the interstage and 207 container mounted recirculation batteries. These levels were significantly lowered from the 501 and 502 flight worthiness environments to which the batteries were subjected and passed for use on 501 and 502. The Environmental Section, R-P&VE-SVE, recommended to NAR that the original flight worthiness levels be utilized in place of their recommended revised specifications for 503 and subs.

B. Acoustic Testing of Forward Skirt

One exposure of the S-II/MARL forward skirt has been accomplished. The acoustic source was a previously scheduled F-1 single engine firing. It has since been learned that no additional tests of the F-1 engine are scheduled, leaving the S-II/MARL forward skirt program incomplete and without an adequate acoustic source to complete the program. Efforts have been initiated to use static firings at places other than MSFC, Huntsville. Messrs. R. Jewell and G. Johnston met with personnel at MTF in an effort to determine the adequacy of the firings of the S-II and S-IC stages scheduled for that facility. The MTF people seem very interested in supporting this program.

C. S-II Weld Land Tests

Two long S-II LH_2 tank weld land specimens, containing crossover lands, were tested during the month. One panel contained milled down weld stress relief areas; the other contained no relief areas. The panel containing the weld reliefs failed at 200,000 pound load; the other at a load of 212,000 pounds. These tests completed the S-II LH_2 tank weld land panel test program. Further testing is presently being accomplished in Materials Division on small specimens, which includes longitudinally stressed welds along with adjacent parent metal. These are expected to produce the allowable strain capability of welds to compare with strain levels experienced in the panel tests. The small specimens will be tested at -423°F, -320°F, -250°F, and R. T. environments.

D. S-II Lightweight Structural Test Program

1. V7-21 ("A" Structure)

The transfer of the test specimen from ocean-to-river transportation was successfully accomplished November 25. The barge arrived at MSFC Sunday, December 3, 1967. The specimen was moved to Manufacturing Engineering Laboratory, Monday, December 4, 1967. R-ME is presently on the original schedule, but a readjustment will be necessary in the schedule to provide sufficient time to install the required strain instrumentation. The S-IC bulkhead was welded to the S-II #2 cylinder using the Pulsed Arc MIG process and the resulting weld was so clean no repairs were required. Presently R-ME is making the bulkhead-to-cylinder splices at each stringer in the LH_2 tank.

2. V7-22 ("B" Structure)

A combination of events has caused the first pneumostat test of the "B" structure at Santa Susana to be postponed until January 1968. Adverse weather conditions, electronic problems, and poor installation has resulted in a serious reduction in the number of operable strain channels. This problem has to be corrected before testing can begin. North American Rockwell and MSFC have an agreement as to how the problem will be solved to get the testing underway.

3. V7-23 ("C" Structure)

Four major tests were performed on the "C" structure aft skirt during the month of December. They were as follows:

a. Heat and cooling test on December 7.
b. S-IC cutoff engine influence test @ 70°F on December 12.
c. S-IC cutoff body influence test @ 70°F on December 12
d. Ultimate S-IC cutoff test at flight temperature on December 20.

The specimen was loaded to the planned maximum loading of 129 ±1% of the S-IC cutoff condition, including thermal environment, with no apparent damage. The data from the above tests are being evaluated by NASA and NAR. A summary stress report of the ultimate test will be published the first week of February by BECO. The test setup is being dismantled for conversion to the Phase II (Thrust Structure Test) portion of the "C" structure program. This Phase will be ready for testing in February.

II. S-IVB Stage

Acoustic Testing

Acoustic reverberation testing of the S-IVB forward skirt/instrument unit/SLA has been completed. Preliminary indications are that the data is of excellent form and quality and will be of significant engineering value in estimating the effects of various vibro-acoustic transfer functions and efficiency factors. Also evaluated will be the effects of static loads on the linearity or non-linearity of response amplitudes.

III. Saturn V System

A. AS-502 Pull Test

Revised pull test requirements were supplied to R-P&VE-V to be incorporated into the documentation for AS-502. This information reflected changes in going from specified targets to alignment targets in making deflection measurements.

B. Weld Evaluation Program

Strain gage locations have been selected for the Weld Verification Test Tank to be fabricated with the use of Titan tank bulkheads and skirts. A portion of the gages will be located on the weld seams to establish the relative stress between the weld material and parent metal. It is expected that with equal circumferential strain of the weld and parent metal materials, the stress will be higher in the less ductile weld materials. This condition would be evident from inspection of the stress-strain curves of the materials, if available, and should be verified by the selected strain gage locations.

Plans for a feasibility test of the foam insulation closeout arrangement to be used for inspecting weld seams on the Titan tank and on the S-II MSFC 402 ("A" structure) have been completed. Instead of the square five-foot tank being considered for use in the test, an existing foamed 70-inch cylindrical tank has been selected. The newly selected 70-inch tank is being prepared for the test and is expected to be completed by January 1, 1968. The test requirements for the closeout arrangement have been prepared and the Test Laboratory is making preparations for performing the test.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

A. Rack

Astrionics Laboratory has requested that the lower portion of the Rack structure be designed for attachment of support and handling equipment. Design work on this request has not started as the location of the solar panel modules must be located before the effects of the handling and support provisions can be defined.

A redesign effort has been started at the request of Astrionics for the -Z CMG support structure. A satisfactory redesign concept has not been achieved due to the requirement not to tie directly to the outrigger fitting.

A preliminary design layout has also been completed for adding "black box" support panels in three of the rack bays that presently have a diagonal strut. This new concept has been requested by Propulsion Division and is to improve the thermal environment of the Rack-mounted electrical equipment. However, firm locations of the electrical components have not been provided and this design investigation cannot be carried any further until this is done.

B. ATM Rack and ATM Shear Webs

The Environmental Section revised the vibration criteria for components mounted on the ATM rack and for components mounted on the ATM shear webs. The revised vibration criteria were zoned according to: (1) components mounted on equipment panels located in the diagonal segments of the rack, (2) rack mounted components on equipment panels located on the upper ring assembly, (3) the control moment gyros (CMG's) which are mounted above the shear webs on the short strut supports, and (4) components mounted to the ATM shear webs. This criteria supersedes that presented in memorandum R-P&VE-SV-67-101.

A meeting was held between MSFC/MSC personnel and AAP contractors in Houston to discuss philosophy and technique used by the various dynamics personnel to establish component vibration specifications and dynamic loads. Also discussed were external and internal SLA acoustic specifications and the merits of assembly level vibration and acoustic testing of the AM/MDA assembly as proposed by MSFC. Results of the meeting are as follows:

1. Reasonable agreement was reached on vibration specifications. Major differences were: 97 1/2% confidence level used by MSFC vs. the 90 - 95% confidence level used by the contractors and MSFC uses statistically averaged flight data vs. contractor use of one or two non-staticized pieces of data from dissimilar vehicles. Discussion did not indicate a need for revision or produce any action items.

2. Disagreement on internal SLA acoustic specification. MSFC and MSC will take action jointly to resolve the apparent discrepancy.

3. Agreement (almost total) was reached on assembly level test requirements. Of the eight groups represented, only McDonnell Douglas disagreed and they were not supported by MSC.

4. Action was placed on MSFC to supply MSC with assembly level test requirements for AM/MDA and LEM/ATM.

5. Action was placed on MSFC to supply MSC with vehicle loads.

II. Multiple Docking Adapter

MDA Docking Ports

A preliminary design layout for a fiberglas cylinder and associated rings to replace the existing thermal ring in all ports of the MDA has been completed.

A trip was made to the Goodyear Aerospace Corporation, Akron, Ohio, to discuss the fiberglas cylinders for the MDA. It was agreed that the selection of materials would be made by GAC and the materials selected would be covered by specifications recognized by MSFC. MSFC agreed to furnish the mandrel and the tool required to remove the fiberglas cylinders from the mandrel. GAC promised to deliver 8 fiberglas cylinders to MSFC three weeks after receipt of the mandrel.

An investigation of a flexible boot to cover the probe port has been initiated. Two concepts have been considered and preliminary layouts completed. Specifically, one concept is a flexible material that would fold back inside the port and then extend out for the probe installation. The second concept utilizes an extremely flexible bellows of welded construction along with a lightweight hard cover.

A trip was made to North American Rockwell, Downey, California, to discuss the MDA docking hardware requirements with the Apollo personnel. The docking hardware was identified by specific drawing numbers, including revisions, that MSFC requires to identify the docking hardware for AAP. A memorandum has been written to Manufacturing Engineering Laboratory concerning the part numbers and quantities that should be procured from NAR. An effort was made during this trip to locate surplus Apollo hardware for immediate use at MSFC. Five pressure hatches and one docking ring with latches were located and requested by an Apollo Surplus Hardware Utilization Request. This request will provide the hardware to MSFC at no cost. Expected delivery date at MSFC is January 15, 1968. Detail and assembly drawings for the MSFC-designed pressure hatches to be used on the structural test unit have been completed and information copies given to Manufacturing Engineering Laboratory.

III. Meteoroid Protection

Probability analyses were updated for the MDA, S-IVB Workshop, and the ATM canister. The MDA analysis now shows a 0.994 probability of no penetration during a one-year lifetime in orbit.

The Workshop solar panels were analyzed for effects of meteoroids on power production of the solar cells. A module was obtained from Astrionics Laboratory for hypervelocity impact tests using aluminum and glass projectiles.

IV. MSFC Flight Experiment #8

Detail design and documentation of the tension and indexing system, including the stress and engineering reports, will be completed on December 29, 1967. A revision to the technical directive was issued requesting formulation of a plan for functional and qualification testing of the experiment hardware. The completion date for the test plan is January 12, 1968.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-67-12

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(December 1, 1967, through December 31, 1967)

SATURN IB

I. S-IVB Stage

Pneumatic Consoles

Compatibility engineering change proposal (ECP), "Installation of a Relief Assembly to Pneumatic Console B" (DSV-4B-433) was proposed by the McDonnell Douglas Corporation (MDC). This change is necessary and results from the incorporation of ECP 2459 R1 which sealed the console to maintain a positive purge of two inches of water (H_2O). This results in excessive pressure buildup within the console whenever the warming purge is used during abnormal "hold" periods, and directs a flow on gaseous nitrogen (GN_2) to the temperature critical pneumatic and solenoid valves in the model 433 to prevent freeze up of these valves. The installation of a relief assembly to the console cabinet will provide pressure relief during the warming purge cycle. This relief assembly has been incorporated also in the Saturn V consoles (DSV-4B-433A).

II. General

A. Composite Mechanical Schematics

As a result of program redirection and extension by Industrial Operations (IO), Chrysler Corporation Space Division (CCSD) submitted a new work statement for the Saturn IB composite mechanical schematics, including manpower estimates. This is a task performed by CCSD under Schedule II, contract NAS8-4016. This division reviewed the submittal and recommend a small reduction in the CCSD manpower estimates.

B. Hazardous Gas Analyzer (HGA)

The tests performed in conjunction with ECP 1B-1044, "Modification to Sampling Valve Manifold," indicated that this change to the HGA would not reduce the sampling time as proposed while using the existing vacuum pump. The purge time doubled when pulling through all four sample lines simultaneously and the manifold pressure increased almost four times. The use of a larger vacuum pump was discussed but additional problems may be encountered, primarily where to locate the pump. This ECP was disapproved but further investigation into the sample time reduction will be conducted.

C. Weight Status Reports

The following weight status reports were completed and distributed:

Monthly weight status report for launch vehicles SA-201 through SA-212 and for Apollo Application Program (AAP) -1A through AAP-5.

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

Detail quarterly report for the SA-212 launch vehicle.

D. Engineering Criteria and Specifications

1. Specification Change Notices (SCN's) 10 and 14 of ECP 1340C revising the Instrument Unit (IU) System Test Specification (IBM-Dwg-7907967) were processed and recommended for approval.

2. Draft copies of the program specification addenda for SA-212 and 213 have been completed and distributed for center review.

3. An engineering change request (ECR), including a SCN, incorporating the S-IVB stage orbital safing requirements has been prepared and submitted to the level II change board.

3. The Apollo 5 (AS-204/LM-1), "Technical Information Summary," was completed and distributed.

I. S-IC Stage

A. Propellant Dispersion System (PDS)

1. A study of the debonding problems on the S-IC stage PDS cowling brackets has been completed and the recommended changes to the installation procedures have been compiled. An ECR was prepared which stipulates that a pull test shall be performed on all propellant dispersion system cowling support brackets on S-IC-2 through S-IC-4; that shims shall be installed between the cowling support straps and their respective brackets as necessary to relieve the preloading of support bracket bonds; and that adhesive shall be applied between the support straps and the cowling to prevent chattering in the event of cowling bond failure.

2. A study is being made on ways to redesign the existing PDS cowling to employ a total mechanical attachment to the stage. The design which was proposed in July 1965 is being investigated as a possible solution. The results of this study will provide data for a backup design should debonding of the present system of the stages continue.

3. A study is being made to define means of identifying the ordnance components of all stages as "explosives." This study is the result of a KSC request. One means under investigation is the use of identification tape similar to that used by the engine contractors for identifying system lines on the engine.

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

1. The system development facility (SDF) HSCU refurbishment effort has been completed. The filters have been cleaned and reinstalled in the unit. ECP-BO-215 (pump case drain modification) has been installed.

2. The ground hydraulic accumulator bank (GHAB) is being installed into the SDF HSCU system.

C. Ground Hydraulic Accumulator Bank (GHAB)

1. ECR 285, mandatory installation of GHAB for SA-502 and subsequent vehicles, was approved at level II Configuration Change Board (CCB) on December 8, 1967. In conjunction with the ECR, ECP-248, changeout of "Republic" valves and addition of the GHAB GN_2 interface, was partially approved to provide the GN_2 precharge capabilities.

2. The GHAB drawings have been corrected to conform to MSFC Class I drawing standards and are being processed for formal checking prior to release.

D. Pneumatic Consoles

1. The configuration of the S-IC pneumatic consoles at SDF was reviewed to determine what outstanding ECP's will be required for incorporation into the consoles to support a AS-502 system configuration verification test. A listing of all modification kits with delivery dates and modification numbers has been prepared and submitted for assignment of priorities.

E. Umbilicals

Lock blocks were installed in the intertank umbilical debris valve actuators by ECP 0889C for AS-501 to hold the valves open after umbilical disconnect. This was required because KSC could not provide assurance that the vent system would adequately vent pressure in the intertank lox lines.

II. S-II Stage

A. Electrical Harness

The final meeting of the S-II stage electrical harness working team "A" held at North American Rockwell (NAR), Seal Beach, California, was attended by Propulsion and Vehicle Engineering Laboratory personnel. All "A" team action items were closed out. The S-II-6 cable harness installations were inspected. This was the first stage built to the "J" revision of MA0313-1001, "Specification for Installation of Saturn S-II Wiring."

B. Fluid Requirements

Internal Revision Notices (IRN's) were submitted to change effectivity for the installation of the lox tank vent relief valves from SA-503 and subsequent vehicles to SA-502 and subsequent vehicles. The installation of these valves will preclude the possibility of damage occurring to the stage because of over pressurization.

C. S-II Pneumatic Consoles

1. The primary helium regulator (A8967 in the S7-41-A regulation and distribution console, located on mobile launcher (ML)-1, was disassembled and inspected by NAR after AS-501 launch. The condition of internal components was excellent. A series of photographs was made of the regulator poppet and seats. There was no evidence of erosion, deformation, or cracking.

D. Feedline and Regulator Requirements

1. The anticipated reduction in maximum LH_2 tank pressure in the S-II stage has resulted in a new mechanical ground support equipment (MGSE) requirement. Redesigned LH_2 vent valves will have their ambient sensing ports subjected to a vacuum during the countdown demonstration test (CDDT) to assure that their operation is within the prescribed band during flight. The vacuum will be supplied from drag-on lines tapped into the common bulkhead leak detection inlet circuit. A solenoid valve, mounted in the fluid distribution system, will provide vacuum or exhaust modes with exhaust being connected into the facility hazardous gas vent system. A pressure transducer near the stage vent valve sensing ports will monitor vacuum. The present effectivity is SA-503. Implementation on ML-2 to support SA-502 is being considered. However, due to the severe impact on facility plumbing, support of SA-502 without schedule impact is doubtful.

2. All of the relief valves which will be mounted in the ML-2 facility plumbing have been received by NAR. Installation began on December 11, 1967. Valve holddown bracketry will not be installed for SA-502 launch due to time restrictions.

3. NAR is still investigating the malfunction of the LH_2 feedline elbow flowmeter. A spare flowmeter was subjected to cold nitrogen flow tests. Output temperature was recorded at -90°F without turbine freeze up. The exact cause of failure is still unknown. NAR will continue the investigation until a satisfactory fix is found.

III. S-IVB Stage

Vent Disconnect

Additional testing was conducted at MDC on the GH_2 vent disconnect with a redesigned stronger bellows and the old seal configuation incorporated. Purpose of the tests was to give added confidence in this configuration for AS-204 and AS-502 because of the previous leakage problems. Tests were performed with the coupling in the offset position with satisfactory results. The leakage recorded was less than 10 SCCM. However, a new qualification test program will be conducted by MDC with a scheduled completion date of February 11, 1968.

IV. General

A. Vehicle Assembly Documentation (VAD)

1. The drafting of the AS-505 VAD and its related interface hardware torquing procedure has been completed.

2. A detailed study of the stage-to-stage mating hardware for SA-502 through SA-505 revealed that under extreme tolerance conditions the NAS625-8 bolts will be too short. It is being proposed that the contingency hardware kits, now at KSC, be expanded to include a set of NAS625-10 bolts for use as alternates to those currently specified by NAS5625-8.

B. Cable Installation Specification

Recommended changes to the S-IC stage cable installation specification have been completed. This completes the review of all stage installation specifications on the Saturn IB and V vehicles. Followup on incorporation of the proposed changes by the stage contractors will be taken.

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

The DRRS for ML-3 has been installed on the mobile launcher test structure at the swing arm test area. Considerable time has been spent acquainting the new test engineer with the system detailed test procedures. Several minor problems have been experienced which were attributed to procedural errors during the DRRS filling and bleeding operations. A major problem was encountered during the initial phase of the test program which is currently under investigation. This problem concerns the inability of the redundant retract cylinders to allow full extend (lower) or retract (raise) of the damper arm assembly. Full stroke of the cylinders is not being realized possibly due to excessive manufacturing tolerance buildups.

D. Flight Sequence

The division has completed updating of the Saturn V SA-504 flight sequence requirements of Propulsion and Vehicle Engineering Laboratory. This information has been transmitted to Astrionics Laboratory for incorporation into the vehicle flight sequence program.

E. Weight Status Reports

The following reports were completed and distributed:

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

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

I. Systems Design

A. Apollo Application Program (AAP)-2 Documentation

Revisions are being made to update the "Inboard Profile Space Envelope Layout," SK10-9317 (AAP-2) to conform to the latest changes in configuration requirements and handling and access equipment.

B. Apollo Telescope Mount (ATM) Documentation

1. SK10-7328, ATM Experiment Package Subassembly, is being revised to its M revision. The major revisions will be the relocation of H #2 telescope, addition of an active cooling system, details on cabling, and aperture door motor location.

2. SK10-7266, ATM Inboard Profile/Space Envelope Layout, is being revised to its AC revision. Major changes will include a new lunar module ascent stage outline, new solar panel configuration and active cooling of the ATM experiment package, and new locations of electrical components.

3. Lowered solar panel study (SK10-7452) has been completed. This study indicates that the panel package must be at least 14 1/2 inches below the lower rack centerline to clear MSC hardware.

4. ATM to Lunar Module (LM) ascent stage and Spacecraft/ Lunar Excursion Module (LEM) Adapter (SLA) clearance envelope (SK10-9921) is being revised to its C revision to show the current MSFC/MSC clearance envelope. The critical clearance items include latest solar panel envelope, component location on top of rack, and rack solar shield.

5. The conceptual design of the following end items is being accomplished:

ATM Ground Handling Fixture.

LM/ATM Assembly Covers for Transportation.

ATM Clean Room Scaffolding.

ATM/LM-AS Hoisting Adapter.

ATM Platform and Ladder Assembly.

6. A conceptual design for a rack to cable arch adapter has been initiated. The adapter will allow 18 cables each 5/8 inch in diameter to flex over a 215-degree rotation of the experiment package. This adapter will be supported from beams spanning the ATM rack upper ring. The approximate envelope of this adapter is 12 x 48 inches in diameter.

C. Nuclear Ground Test Module (NGTM) Documentation

Installation drawing for the Radiation Test Tank Assembly (SK10-9263, Revision A) is being accomplished. The following changes are being made: The method of thermocouple junction is being specified, six AN832-6D fittings are to be added to the base plate of the 10" NAR valve cover, and grommets are to be added on shipping covers to minimize stress on thermocouple leads.

II. Systems Operations

A. Cryogenic Quick Disconnect Coupling

This division met with representatives of Test Laboratory on December 4, 1967, to review the test requirements and procedure for the 3/4-inch cryogenic quick disconnect coupling and to discuss the status of the test facility. At present the test fixture is complete and build-up of the test facility is being accomplished. Testing is scheduled to begin January 2, 1968.

B. Orbital Workshop (OWS) Mechanical Ground Support Equipment (MGSE)

1. Preliminary ground support equipment (GSE) and special test equipment requirements, submitted by MDC have been reviewed which involved several GSE items over which the laboratory maintains design surveillance. The following new and modified equipment was included in the review:

BSV-4B-329, Checkout accessories kit

DSV-4B-1858, Propulsion checkout accessory kit

DSV-4B-1865, GN_2 preparation transportation stage purge kit

DSV-4B1896, Lox non-propulsive vent desiccator caps

TBD, OW leak test accessories kit

2. Volume I (specifications and description) and volume II (project plans) of the MDC S-IVB OWS (Delta) preliminary design review (PDR) package were reviewed in preparation for the PDR on December 12 through December 15, 1967.

3. The OWS thermal control system presented was a passive system, not requiring GSE servicing. However, an active system concept, utilizing a liquid coolant (FC75/H_2O) is still under consideration and preliminary design is continuing. This system would require new servicing GSE.

C. Multiple Docking Adapter (MDA) Purge

Information from Propulsion Division indicates that a ground insulation hot purge will be required for MDA. Purge gas flowrates, type, and temperature will be established through a test program utilizing a full size MDA insulation panel. This division, in conjunction with Propulsion Division, was requested to design a suitable purge gas system.

D. Apollo Telescope Mount (ATM) Fluid Requirements

Preliminary fluid requirements indicates the requirement of several purges probably requiring new and modified GSE. These requirements were established in a meeting with Astrionics Laboratory.

E. Design Reference Flight Sequence

An updated release of the AAP-2 Design Reference Flight Sequence, MSFC drawing 10M30381, was prepared and submitted as part of the data package for the OWS delta PDR.

III. Systems Engineering

A. Apollo Application Program (AAP)-2 Experiment Analysis

An analysis of the proposed AAP-2 experiments, to determine their compatibility with the MSC "Can Concept," was submitted to the Advanced Studies Office. Determination was made that AAP-2 experiments requiring a scientific airlock such as S069, S073, T025, and T027, may not be able to utilize the MSC concept because of unavailability of scientific airlock; that repeated reorientation from earth to sun, star, x-ray source, etc., could require considerable expenditure for propellant for the Reaction Control System (RCS); and that plume impingement could contaminate these experiments.

B. Astronaut Review

The Astronaut Review Outline is being updated for revision D in January 1968. This updating will be based on the delta PDR results and the latest available information on the mockup.

C. Neutral Buoyancy Simulation

The astronaut restraint locations for the forward dome penetration sealing task are undergoing additional neutral buoyancy simulation testing as a result of the reorientation of the LH_2 vent line seal suggested during the Astronaut Review on December 21, 1967.

D. Multiple Docking Adapter (MDA) Data Package

The Preliminary Design Review MDA Data Package was released on December 14, 1967. This document describes the MDA four wall internal configuration which will be presented at the MDA PDR.

E. Film End Work Station/Solar Panel Interface

1. A multiple degree of freedom simulation test of astronaut ingress/egress and film retrieval/replacement tasks in the LM end work station was performed at the Task Analysis Facility (TAF) on December 10, 1967, to identify potential astronaut/solar panel structure design interface problems. It has since been determined from MSC that the primary extravehicular activity (EVA) mode will now require the astronaut to have in addition to the umbilical, a Portable Life Support System (PLSS), PLSS control box, and an Oxygen Purge System (OPS) which sits on top of the PLSS. Therefore, the simulation run on December 20, 1967, will be rerun before design recommendations are made.

2. The training of test subjects has been completed in the Computation Laboratory for the ATM Pointing Control System Simulation, utilizing the hand controller in the cockpit of the LM simulator in Computation Laboratory. To date twelve subjects have completed this training.

IV. Systems Requirements

A. Orbital Workshop (OWS) General Test Plan

1. The OWS General Test Plan (10M05098) was submitted to the Projects Office of this laboratory for approval. The S-IVB OWS delta PDR document was reviewed for technical adequacy.

2. The division performed the accounting function for the OWS PDR. Review Item Discrepancies (RID) forms, RID flow diagrams, and a procedure for preparing a RID were made available at each subboard meeting.

B. Attitude Control System (ACS)

1. Final corrections to the ACS Systems Test Plan (10M32959) was completed; copies of the document were submitted to the project manager for review.

2. Preliminary copies of the ACS end item specification and R&D plan were completed and delivered to the laboratory Projects Office.

C. Solar Array System (SAS)

1. Final corrections to the SAS Systems Test Plan (10M32960) were completed and copies of the document were submitted to the project manager for review.

2. Preliminary copies of the SAS end item specification and the R&D plan were completed and delivered to the laboratory Projects Office.

D. Cluster Test Program

Documents summarizing specific portions of the Cluster Test Program were prepared and submitted to the Projects Office. These documents explain types of testing, test articles to be used, the sequence of testing, and the test objectives.

J. O. Abegg

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PR-P&VE-A-67-12

MONTHLY PROGRESS REPORT

ADVANCED STUDIES OFFICE

(December 1, 1967, Through December 31, 1967)

SATURN V

Voyager Studies

A. Baseline Spacecraft Design

1. R-P&VE Spacecraft Design Status --- The Phase I results of the spacecraft design study, formerly to be published in MSFC report IN-P&VE-A-67-8, will now be issued as Technical Memorandum X-53681. This change was made in order to allow wider distribution within NASA.

2. Spacecraft Structural Analysis --- This study has been completed and no follow-on effort is planned. Results from the latest phase of the study show the effect of longitudinal and lateral accelerations on the weight of the spacecraft. Results are shown for lateral accelerations from 1.0 to 2.5 g's and for longitudinal accelerations from 3 to 10 g's.

3. Miscellaneous Spacecraft Design Data Compilation --- This report has been reviewed by several cognizant personnel; the final manuscript is now being prepared prior to final management review.

B. Alternate Spacecraft Design Studies

The final draft of the 260-inch-diameter spacecraft concept report is being technically reviewed by personnel within this Office. This report will be published as Technical Memorandum X-53685.

C. Voyager Missions to Jupiter and Venus

The basic objectives of this study have been satisfied and the results documented. The last tasks completed were the evaluation of the mission requirements of a Venus swingby solar probe and a Saturn swingby to the planet Uranus. The final task scheduled for this study is documentation of a computer program, developed in the study, for evaluating mission requirements of parabolic, elliptic, and hyperbolic trajectories between planets of the solar system. With this program, target planet encounters may be either stop-over, flyby, or swingby; the latter may either be free or powered.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

A. Dry S-IVB Orbital Workshop

Several alternate configurations of the Dry S-IVB Orbital Workshop were developed, each considering a single Saturn V launch of a manned CSM, airlock module and shortened MDA, ground-fitted orbital workshop, and an experiment module located in the S-IVB/S-II interstage area. Variations in the experiment module included the ATM with and without the LM, and operated attached, detached and manned, and detached and unmanned; the EMR experiment module; and an earth resources module similar to the AAP-IA mission payload.

Two configuration approaches are currently being developed for study purposes, both considering a solar ATM without the LM and operated attached to the Dry Workshop. The primary variation in the two configurations is the orientation of the ATM, either colinear with the workshop longitudinal axis or perpendicular to it, as in Cluster I. The latter orientation is preferred as it implies an orbital attitude consistent with Cluster I and similar attitude control requirements and thermal environment. However, this orientation may present difficult design problems for supporting the ATM during launch and operation and could require a major redesign of the ATM. The alternate ATM orientation requires an orbital attitude of the end pointed toward the sun.

Other configurational aspects to be developed include provisions for locating corollary experiments and AM/MDA subsystems in the S-IVB LH_2 tank, relocation of the MDA thermal radiator, and location of ATM controls and displays in the S-IVB LOX tank. Preliminary weights and mass characteristics of each configuration are also being generated for use in studies to assess attitude control requirements.

Presentation charts were completed for defining structure, ECS, LSS, crew systems, and RCS evolution from the Spent Stage Workshop to the early Dry-launched Workshop.

The suggested experiments for the dry-launched workshop were analyzed and problems of physically incorporating these experiments into the workshop system defined.

An overall layout of the dry-launched workshop has been completed. This layout will be used as a "point of departure" for the in-house study.

A further assessment is being made of the basic components of the Cluster I Workshop Subsystems (EC/LSS, RCS, and crew systems) for possible utilization in the dry S-IVB austere workshop. A revised list of guidelines, assumptions, metabolic and atmospheric requirements, approaches, and weights is being compiled.

B. Independent Module Study

The first phase of the study which included experiment selection, requirements definition and conceptual design sketches was completed. This study provides a broad definition of the basic requirements for operation of an independent module in orbit.

C. Critique of Alternate AAP Approach

An alternate AAP approach consisting basically of a pressurized SLA area as the primary experiment and man support element was assessed from several aspects, including configuration, weights, experiment accommodation, launch vehicle impact, subsystem approach, program impact, operational approach, and growth flexibility. The approach was established as feasible with the exception of overall system weight. Each area investigated had several attractive aspects, but a multitude of potential problems. The basic experiments were not adequately accommodated; most of the

MSC proposed "warning flag" items were found to be applicable to alternate approach; the program implications were major; hardw changes from current AAP and between missions were substantial; selected subsystems were found to be inadequate; and the system weights are projected to be beyond the basic Saturn IB launch capab Results have been documented in memorandum R-P&VE-AA-67-163 dated December 6, 1967, and were presented to management.

II. Integration

A. Early Space Station Operational Analysis

Work has continued on developing parametric data for evaluating and understanding space station operational requirements. Manned tracking station coverage of 50- and 28.5-degree inclinations is being analyzed and compared. The percentage of the celestial sphere, both instantaneous and permanent, which can be viewed from a space station at an altitude of 260 miles is also being determined.

Additional ESCAPE runs are being made in an effort to establish experiment scheduling criteria on a multi-purpose one-yea duration station. Several runs have been made from the variables matrix previously developed, using the three sequencing schemes derived from the requirements of the different disciplines. Work continues on the analysis of the variables involved in these runs.

B. Experiment Integration Criteria

Comprehensive charts showing the available information on each of the EOSS baseline experiments have been constructed for each of the several disciplines. These data are intended to aid more effective experiment integration and operational characteristics analysis.

Work is now in progress to flag those experiment parameters which appear to be questionable (in accuracy and meaning) and to build a library of the most up-to-date information on the experiment program.

A preliminary experiment list for the Dry S-IVB Orbital Workshop (Cluster II) has been generated, and the integration criteria for this package are being developed.

III. Lunar Systems

A. MSFC Mobility Test Program

Test course preparation has been continued by Technical Services Office personnel; however, considerable drying is required before the work can be completed. Plans were made to extend the loan period of the soil shearograph until mid-July 1968. Covers for the plowed and sand course have been purchased, but are useless until the course has been completely prepared.

B. MTA Data Normalization

The evaluation of the MTA test data is continuing. Some problems have been encountered in attempting to match the data from Yuma Proving Ground (YPG) with the earlier Aberdeen Proving Ground (APG) data. The differences are quite significant and appear to be the result of specific test conditions and data recording techniques. Since the YPG testing duplicates most of the APG data and since there was much more testing at YPG, it has been agreed by representatives of ASO, YPG, and this Office to use only the YPG data. No problems are anticipated in normalizing the MTA data to the smaller, LSSM-sized vehicles.

C. Study of Mobility Power Systems

The study of specified power systems for lunar mobility vehicles has been completed. All battery systems considered were eliminated early in the study because of excessive weight-to-power ratio. The selected systems were very sensitive to mission duration and power requirements. The study indicated that fuel cells were most attractive for the one- and two-man vehicles having missions limited to 240 miles and a 14-day duration. For smaller vehicles such as the remote-controlled mini-vehicle, requiring a six-month stay time, the solar/photovoltaic was most attractive. The isotope system was less desirable because of low efficiency and large weight.

D. Mini-LSSM Programs

This Office is currently developing a work statement to perform a detailed investigation of a small lunar roving vehicle.

ADVANCED PROGRAMS

I. Launch Vehicles

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

Since the liquid strap-on pods for the "660k Launch Vehicle" are pressure fed, the information obtained from this study is also being used in support of the "Pressure-fed Launch Vehicle" study.

Preliminary base region environmental conditions have been determined (through R-AERO-AT) for the 660k launch vehicle first stage with the strap-on pods in place. Also, as a final effort, work is continuing on other aspects of the "660k Launch Vehicle." Some of these are as follows: (1) the evaluation of pod parametric structural data; (2) a layout of a specific pod configuration; (3) the evaluation of a pod pressurization system; and (4) a pod slosh analysis.

B. Pressure-fed Launch Vehicle

Preliminary analyses and layouts have been completed for a pressure-fed launch vehicle configuration based on a 75,000-pound payload capability to a 260-nautical-mile orbit. This configuration, intended primarily for reference purposes, was necessarily based on a number of preliminary, and sometimes arbitrary, ground rules and assumptions. Additional effort of a parametric and specialized nature is being planned in order to refine ground rules and to fully assess the many design options or trade-offs apparent from the initial effort to date.

Based on the results of discussions of the multi-nozzle concept with AEDC personnel at Tullahoma, interpretations of available test data have been made for application to pressure-fed launch vehicle trade-off studies. These studies are currently being conducted to determine if engine performance increases due to shrouding are worth the weight penalty associated with the longer interstage requirement.

A technical briefing was given on December 21, 1967, to apprise R-AS management of the analyses and configuration studies performed to date on the subject study.

C. Saturn Utilization Study

Representatives of Lockheed Missile and Space Company visited MSFC for presentations and discussions on the following study activities:

- Evaluation of common usage of solid rocket motors for NASA vehicles and their intermesh with USAF candidate solids
- Definition of KSC launch facility modifications for utilization of the above candidate vehicles
- A general "Launch Vehicle Utilization Study" which provides a summary of current and projected booster mission, performance, launch facility, and system cost data, for use in launch vehicle selection and improvement studies

These technical interchange visits are mutually advantageous in exchanging views on space launch vehicle uprating concepts and mission model composition.

II. Earth Orbital

Kick Stage Handbook

Other work commitments of higher priority have temporarily curtailed the effort to document the Kick Stage Summary Handbook into an MSFC Internal Note; however, it is expected that this report will be published sometime in the near future.

III. Planetary

A. Probe Module Definition Study

Effort was continued to define a probe module capable of housing a specified probe complement for a Mars mission. The probe module is being configured to structurally support, environmentally and biologically protect, and operationally deploy a proposed experimental complement.

B. Integrated Long-range Plan

This Office has completed an investigation to determine various manned spacecraft parameters for a 1982 Mars capture mission and a 1984 Mars landing mission. This information will be used to determine costs of various modules. Data were provided on the mission module, earth entry module, experiment module for both missions and the excursion module for the landing mission. These data will be documented and transmitted to the Advanced Systems Office for costing the overall mission program.

C. Command Post Definition Study

The study to define a command post and associated equipment for planetary missions has been completed and is being documented.

D. Common Mission Module

The presentation to the ASO Senior Staff on the Common Mission Module study, originally scheduled for December 15 and later for December 19, has been postponed indefinitely. The effort has been completed and results are being documented in an MSFC Internal Note.

E. Manned Planetary Flyby Studies

MSFC Internal Note IN-P&VE-A-67-11, "Identification of the Earth Launch and Orbital Launch Vehicle System for Manned Planetary Flyby Missions," has been prepared and submitted for publication. This report documents the results of studies in support of the 1967 NASA Joint Action Group to identify and define the preferred Earth Launch and Orbital Launch Vehicle system to perform planetary flyby missions in the 1975-1980 time frame. In these analyses, only chemical stages are considered.

F. Nuclear Vehicle Design Sensitivity Study

Final results of the nuclear vehicle design sensitivity studies have been obtained and are being evaluated prior to initiation of a nuclear stage/earth launch vehicle compatibility study.

Erich E. Goerner
Chief, Advanced Studies Offi

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PR-P&VE-P-67-12

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

December 1, 1967 through December 31, 1967

SATURN IB

I. S-IB Stage

A. H-1 ENGINE

Short Static Test Conducted on S-IB-11

Special stage instrumentation was installed for checkout prior to the anticipated stability test series. Performance was satisfactory on all engines except position 2, which will be reorificed because of high thrust.

B. Hydraulic Package GN_2 Leakage

Four hydraulic packages were replaced on S-IB-4 because of GN_2 leakage into the hydraulic fluid. Investigation of the cause of the leakage revealed excessive porosity in the Viton O-ring on the accumulator sleeve. As an interim fix, a permeation test will be performed to detect internal voids in the seal. A design change was requested to eliminate the seal.

C. Flight Critical Components

Fifty-eight of the eighty-one COQ's for AS-204 have been signed.

II. S-IVB Stage

A. Flight Critical Components

All COQ's for AS-204, S-IVB stage have been signed; however, 31 of the items are still considered conditionally qualified and require action or additional testing for AS-205 or AS-206.

B. AS-204 Propellant Loading

The updated propellant loading document for AS-204 was approved for release to Kennedy Space Center.

C. Orbital Workshop (OWS)

1. Qualified Hardware for Auxiliary Propulsion System

A search of existing qualified hardware for use on the APS was completed. All of the required components of the presently proposed system are available. Requalification will be required on most of the components due to the difference in the environmental requirements, such as vibration levels, pressure levels and the one-year vacuum storage.

2. Delta Preliminary Design Review (ΔPDR)

The Orbital Workshop environmental control system design concept and status were reviewed in the ΔPDR. The ECS performance data presented demonstrated that the system design was feasible to meet crew habitation requirements.

3. Storage Temperature

Additional analyses were performed to determine the storage temperatures, including the effects of Orbital transients, and solar and albedo heat flux variation. The minimum temperature was -40°F on the inside wall and -20°F on the curtain.

4. 45° Sidewall Test

Additional requirements for the initial test are listed below:

a. Additional instrumentation was installed at the entrance section of the thermal curtain to allow better determination of local heat transfer coefficient.

b. Due to the potential sudden compression or decompression of the test device, a diaphragm will be installed to insure against test article damage.

5. Heater Analysis

A preliminary thermal analysis was completed. The results of the analysis indicate that, with a power input of .86 watts/in.^{2}, the temperature of the heater surface is approximately 196°F. Due to heat conduction from the heater to the fan motor, the fan motor housing reaches 150°F. An insulative washer mounted between the heater and fan will probably alleviate this problem. Further analyses are in progress.

SATURN V

I. Apollo/Saturn Vehicles

A. AS-501 Flight Evaluation

The flight evaluation of AS-501 is proceeding satisfactorily. The basic effort should be concluded within the L+60 day time frame. Detailed analyses in a few areas where anomalies were observed will continue until they are resolved. Changes on AS-502, required as a result of AS-501, were identified and are being implemented.

B. Flight Critical Components

The number of critical items which still require action and/or additional testing for AS-502 or AS-503 are:

S-IVB - 28
S-II - 10

II. S-IC Stage

A. F-1 ENGINE

1. R&D Engine Tests at Edwards Field Laboratory (EFL)

Thirty-two tests were conducted, and a total duration of 3,395 seconds was accumulated. Seventeen of these tests were full-duration runs (150 seconds or more). Two tests were terminated prematurely due to a shorted facility wire and due to a low pressure indication caused by a loose "B" nut.

2. Production Engine Testing at EFL

Eleven tests were conducted, and a total duration of 965 seconds was accumulated. Three of these tests were full-duration runs, and all ran for the planned duration.

3. Production Support Program Reviewed

The dual thrust level capability will not be incorporated on the F-1 engine before vehicle 510. Any earlier retrofit of this capability would require replacement of the gas generator injector by an improved design (X-4). This replacement would require each engine to be hot-fired again.

Development of the "super cooled" baffle injector will be discontinued. Although adequate development experience has been gained to prove the design adequacy of the baffle design in preventing baffle erosion, a significant performance loss was indicated by the tests. Also, no problem has been encountered with the present injector.

B. Retro Motor

Results from evaluation of AS-501 data indicate that the chamber pressures for the S-IC retro motors were higher than expected. With the exception of the apparently high combustion pressures, the retro motors functioned normally and provided a successful S-IC/S-II stage separation. From a design standpoint, both the retro motors and stage attachment hardware are structurally adequate to withstand a higher thrust level; however, since the combination of motor-to-motor performance deviation and estimated telemetry measurement system error does not seem to account for the observed performance levels, additional investigation is required to resolve this discrepancy.

C. LOX Loading

A series of tests were performed to provide additional data on the S-IC LOX recirculation system during LOX loading and simulated abort and/or malfunction operation. Evaluation of test data from the first test in this series is currently in progress. Preliminary analyses indicate that a one-hour standby with the suction lines approximately half full of LOX to chilldown engine hardware will eliminate "negative" tank pressures when the recirculation system is started and may eliminate the requirement for ullage pressure regulation during LOX loading (used on S-IC 501). The LOX loading and geysering suppression sequence will be updated, based on the results of the test series.

D. LOX Tank Pressurization

S-IC-1 flight data revealed that the composite LOX heat exchanger performance was satisfactory; however, the pressurant flow rate demand to satisfy LOX tank pressure was much higher than anticipated. The engine contractor has requested that the bypass flow be reorificed for S-IC-2, so that lower flow rates and higher temperatures will result. The requested orifice sizes are being analyzed to determine their effect on performance.

III. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Nine tests were conducted, and a total of 1083 seconds was accumulated. One of the tests was a full-duration run. All of the tests ran for the planned duration.

2. Production Engine Tests at SSFL

Five tests were conducted, and a total duration of 626 seconds was accumulated. None of the tests were full-duration runs, and all of the tests ran for the planned duration.

3. J-2 Engine Tests at AEDC

During December, four test periods were conducted, and sixteen hot firings and four blowdown tests were run in support of the S-II fracture mechanics problem. Three of the four air-on periods were 225K configuration tests. The engine was changed to the 230K configuration for the last test. Thirteen of the sixteen hot fire tests simulated an engine start at 27.0 psia fuel tank pressure. The remaining three hot firings were high NPSH base case runs. The engine operated satisfactorily during these tests and no significant detrimental effects have been observed.

4. J-2S Testing at MSFC

The first programmed duration test of J-2S engine 108 was conducted on the MSFC battleship vehicle. This was the second attempt at the 15-second duration test. The first attempt was aborted by an instrumentation error. Preliminary review of the data indicates all objectives were met.

5. J-2X Experimental Engineering Program

Testing was concluded on J-2X 013-1 during the first few days of the report period. This engine test series evaluated throttling control by using the main propellant valves to vary main chamber mixture ratio and flow rate. In addition, cavitating venturi valves were procured and substituted for the standard main propellant valves to improve throttle control at the low flow rate/minimum valve opening condition. Throttling with cavitating venturi propellant valves produced a feed line instability downstream of the valves and into the thrust chamber. Throttling with the standard propellant valves was relatively successful, but low flow rate control is unpredictable. This engine test series concludes the hot testing activities under the 1967 J-2X Program.

6. J-2 Engine System Changes Required to Incorporate the J-2S Engine

A study was conducted to determine what major hydraulic system changes are required to accept the J-2S engine. Existing main pumps appear to be within the new envelope created by the 40:1 thrust chamber. Both the S-II and S-IVB main pumps have been tested for 8 hours at the higher LOX pump speed (11,500 rpm). These pumps will require requalification, because the present rated speed is only 8000 rpm. An alternate pump was selected that will meet the new requirements for both the S-II and S-IVB stages. The current system pressure of 3650 psi is adequate to meet the higher loads imposed by the J-2S engine. If the "majority voting" concept and the J-2S engine are both used on the S-IVB stage, an uprated auxiliary motor-pump will be required.

7. Increased J-2 Fuel Leakage

The engine contractor reported new data on H_2 leakage from the J-2 fuel turbopump into Saturn interstages. A study was made to determine allowable increases. The maximum H_2 leakages expected from the J-2 engines will increase interstage concentrations above the combustible limits during booster flight. Changes to the leakage vent system were recommended to reduce the quantity of H_2 vented into the interstages.

B. S-II Retro Motor

Evaluation of AS-501 data indicates that the four S-II retro rockets performed satisfactorily. The chamber pressure profiles for the four rocket motors were very similar, and the maximum difference

in burn times was 0.10 seconds. All performance parameters were close to their nominal values. The average chamber pressure was slightly higher and the average burn time slightly shorter than nominal. These parameters indicate slightly higher than nominal motor performance, but within specification.

C. S-II Ullage Motor

Evaluation of AS-501 data indicates that all eight S-II ullage motors functioned as predicted. A review of the chamber pressures shows the motor-to-motor variation was within plus or minus 3.5 percent. This variation is extremely low considering that the motors used on the AS-501 flight were from three different manufacturing lots. An ECP was submitted for removing four of the eight S-II ullage motors from future Saturn V flights. Studies indicate that four motors could ullage the S-II stage satisfactorily, and the removal would save cost and weight.

D. S-II LH_2 Tank Insulation

Evaluation of the internal purge pressure during the AS-501 flight was completed. The bursting pressure did not exceed 4 psid. For the AS-502 prelaunch operation, the purge line size from the umbilical to the insulation will be increased, and the inlet pressure control point will be relocated nearer the umbilical on the swing arms. This modification should provide approximately 50 percent more flow capacity to the stage at the same supply pressure.

E. LOX Tank

AS-501 data shows a significant LOX ullage pressure decay during S-IC boost (4.7 psi) resulting in marginal engine start pressures. Common bulkhead evacuation was proposed for AS-502 to circumvent the decay problem. A maximum decay of 2 psi is estimated, assuring engine start pressures of no lower than 35 psia. The LOX tank "hi-press" mode can be eliminated.

F. 1/8-Scale S-II LOX Tank Depletion Test

A 1/8-scale S-II LOX tank drainage test stand is being set up to determine the transient flow patterns through the sump and the liquid residuals resulting from liquid depletion. Primary interest will be breakthrough and the effect of anti-vortex configurations on LOX depletion.

G. S-II LOX Vent Valve Analytical Simulation

A mathematical model simulating the operation of the LOX vent valve was developed. The program appears to be working satisfactorily; however, additional design information is needed from the manufacturer before the program can be fully checked.

IV. S-IVB Stage

A. S-IVB Ullage Motor

Evaluation of AS-501 data indicates that the S-IVB ullage motors performed satisfactorily.

B. Pressure Switches

A failure of a pressure switch was reported during leak-check after static firing the 503N at SACTO. The calibration diaphragm failed. The corresponding switch on AS-502 at Cape Kennedy was checked, with the same results. A failure analysis is being conducted, and a report will be issued as soon as the investigation is completed. The calibration port of the pressure switch for AS-502 will be capped after calibration.

C. I-2 and I-3 Modules

Two of the I-2 Cold Helium Fill Modules and two of I-3 LOX Tank Pressurization Modules were added to the formal qualification test program. These new specimens reflect redesign of the belleville springs and poppet seals.

V. Instrument Unit

A. AS-204 LM-1/IU

The separation sequence and imposed environment of the AS-204 LM-1/IU interstage during the Reaction Control System (RCS) 100-pound thrust engine burn was investigated. The RCS engines are ignited to separate the LM-1 and the IU after the Spacecraft LEM Adapter (SLA) panels are deployed, and the RCS exhaust plume impingement creates a significant heating rate (≈ 1.5 Btu/ft^2-sec) on the electronics and cold plates. It was concluded that the aluminized mylar thermal curtains around the S-IVB cold plates would be destroyed, and the optical properties of the IU cold plate aluminum tape would be somewhat degraded; however, these effects are not considered detrimental to any of the experiments scheduled after LM-1/IU separation.

B. IU-204 Purge System Modified

The GN_2 purge duct system was modified to increase purge flow rate capacity of the system to ≈ 240 lb/min and to provide additional heating capacity to maintain the IU environment temperature. The change included eight one-inch orifices in the inlet "y" duct, and two two-inch diameter holes in the end caps of the purge duct. This change was made as a result of data from the AS-501 launch that indicated that the required environment could not be maintained for a launch on a cold day.

C. Gas Bearing Regulator

The Gas Bearing Regulator successfully completed the first 500 hours of the extended life test. The second 500-hour test was initiated.

D. Purge Duct Modified for S-IU-204 and S-IU-504

The purge duct was modified to allow more flow. The redline value was reduced to 55°F. The IU purge duct is being modified on S-IU-504 so that the Radioisotope Thermoelectric Generator (RTG) is properly thermally conditioned.

E. ECS Methanol/Water Separable Connections

The present lubricant hardens after several hours of cycling and causes sticking within the Quick Disconnects. A new lubricant is being tested.

SPECIAL STUDIES

I. Study of Filtration Mechanics and Sampling Techniques

The third phase of the Filtration Mechanics Project was completed. This project covered investigation of contamination and contamination control in fluid systems. Some of the major areas covered were:

Depth media filtration
Surface media filtration
Contaminant tolerance
Effects of vibration and filtration efficiency
Contamination measurements as related to "Silting Index"
Contamination measurements as related to servo-valve operation
Testing of a number of devices relating to contamination control and sampling techniques

II. Investigation of Brazed and Welded Connectors

Four Aeroquip and two GE 1/4-inch diameter connectors were vibrated at +500°F. One GE connector failed during vibration test after 133,000 cycles while under a peak stress of 15,000 psi. One Aeroquip connector, failed during vibration test after 98,000 cycles. Strain gages measured a peak stress of 12,000 psi on one side of the connector and 10,000 psi on the other side.

Two 1/4-inch diameter GE connectors successfully completed vibration at room temperature under 15,000 psi peak stress. Two 1/4-inch diameter thickwall GE, two thickwall Aeroquip, and four thickwall welded connectors were subjected to burst test. All completed the test satisfactorily.

III. Cryogenic Reliquefaction Compressor Performance Test

The mechanical set-up for the test at ambient temperature is complete, and electrical instrumentation is being installed.

IV. Optical Simulation of Fluid Flow Problems

Since experimental data, correlations, and analyses are readily available on drainage problems applicable to various flights and flight conditions, a drainage problem was chosen for the first simulation attempt. A laser beam was passed through an aperture into a large dark container. The intensity of the light was measured in a plane parallel to the aperture for several ratios of distances to aperture diameters. The values corresponded to the Fourier Transform of the surface of a fluid being drained from a cylindrical tank. The values were compared with those previously obtained experimentally and analytically and were found to agree within three to four digits. Other flow problems will be used to verify the general applicability of the technique. If the accuracy is good, a more general optical analog for flow problems will be designed and constructed. The technique has the inherent advantages of calculation speed, simplicity, and low cost.

V. Liquid Drop Dynamics

A report was submitted to the Experiments Review Board (ERB) for review. The purpose of the experiment is to study the dynamic behavior of liquid drops in a 2×10^{-5} g environment. In particular, the oscillatory modes of free drops and the interaction of colliding drops will be investigated. Controlled liquid dynamics experiments have never been conducted in a near zero-g environment over significant periods of time. Therefore, besides the fundamental scientific character of the

experiment, the investigations will provide a reasonable basis of understanding of liquid behavior applicable to engineering problems of fluid flow in a reduced gravity environment.

VI. Apollo Telescope Mount (ATM)

A. Thermal Testing of ATM System

1. A study was initiated to define facility thermal requirements for thermal/vacuum testing of the ATM thermal, prototype, and flight systems. The capabilities of various vacuum facilities will be compared with the identified requirements.

2. Quadrant IV Thermal Test

An infrared lamp calibration was conducted in both air at room temperature and a vacuum at - 300 °F. Heat flux intensities over the canister surface area were plotted at various lamp operating voltages.

The insulating and painting of the Quadrant IV test item was delayed due to higher priority assignments. Work on the test item will not start until after the first of the year, undoubtedly causing a delay in the scheduled completion date.

3. Quarter Rack Test

Design of the Thermal Background Simulator was completed, and insulation specifications were obtained. The interfacing status was updated; the Multiple Docking Adapter (MDA) will precede the Quarter Rack in testing.

Delayed receipt of Thermal Mechanical Units and the change of the TMU location configurations, as a result of the adoption of an active cooling system, are causing difficulty in maintaining scheduling. Also, redesign of the Control Moment Gyro mounting structures is delaying fabrication of the mounts. Efforts are being made to resolve these problems.

4. Experiment Package Thermal Test

The following hardware designs required for the thermal test are behind schedule:

a. The spar structural design (awaiting definition of experiment mount locations and configurations).

b. The ATM H_α telescope and the HCO H_α telescope (contracts are not signed. TMU documentation and hardware to be delivered 60 and 100 days after the contract is signed).

B. Gimbal System Design

The canister launch support struts, members supporting the canister during launch and docking, were designed using 6061-T6 aluminum. Cursory thermal analysis showed that the heat leak (from launch to docking), due to conduction between the canister and the rack through the launch support struts, would be prohibitive. Therefore, a change in the material from 6061-T6 aluminum to titanium was requested. The titanium struts should be wrapped with reflective (aluminum) tape to lower its overall emissive value. The change from aluminum to titanium lowers the conductive heat transfer by a factor of approximately 20.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Engine Aerospike Experimental Investigation

A series of four checkout tests was completed on the stainless steel tubewall thrust chamber. These tests evaluated design modifications toward improved hardware durability and reduction of combustion oscillations. The tests were conducted over a chamber pressure range of 500 to 800 psia and a mixture ratio range of 2.1-3.9. Test durations were the longest achieved to date, the longest being 7 seconds. Results indicate no hardware damage and a significant reduction in combustion oscillation amplitude. This hardware assembly was subjected to 9 tests for a total duration of 15.8 seconds. This program is being redirected to delete the planned thrust chamber performance tests to obtain performance data not achieved under the Air Force Advanced Development Program. The dynamics tests will be reinstated later subject to availability of test hardware and funding.

The first of four test series was completed on the gas/gas concentric orifice injector segment to evaluate combustion performance and chamber heat load. Preliminary data indicates high combustion performance. Chamber heat load data indicates that the combustion process is taking place very close to the injector face.

II. Small Engine Evaluation Program

Initial testing of the Walter Kidde 40-pound thrust engines was completed. A total run time of 2455 and 1695 seconds was accumulated on engines S/N 1 and 2, respectively. As expected, the chamber pressure roughness is increasing with run time, but both engines are still within the predetermined limits of ±10 percent Pc variation. The only

discrepancy noted during the testing was a valve failure that permitted leakage past the valve seat when closed. Disassembly of the valve revealed that a .002-inch shim beneath the valve seat had buckled, thus cocking the seat and preventing it from sealing. The shim was removed, and the valve was reassembled and tested. Subsequent testing indicated that the valve is working properly and no longer has a tendency to intermittently "hang up" during closing of the valve, as had been observed during earlier tests after the engine had heated up. Removal of the shim resulted in a slight increase in valve pressure drop but had no appreciable effect on engine performance or operation. Testing on one of the Hamilton Standard 25-pound thrust engines has started, and 864 seconds run time have been accumulated. Data reduction and evaluation of all the test data is underway. All engine hardware (22 sets) has been received and is scheduled for testing in early 1968.

III. C-1 Engine Acoustic Liner

Testing of the C-1 Engine, with and without the acoustic liner, was conducted during this period. All tests were conducted at run conditions designed to produce maximum combustion instability; i.e., the "most severe duty cycle" was used plus pre-heated, saturated propellants. Two series of firings were conducted using the standard engine with propellants heated to 120°F and 140°F, respectively. Instability occurred six times during the first series and nine times during the second series. Five of the instabilities in the first series were repeated on equivalent pulses during the second series. The two test series were repeated using the acoustic liner engine with slightly higher propellant temperatures, and no instability occurred.

PUBLICATIONS

"Experimental Study of Dynamic Characteristics of Turbopumps," Unclassified, TM X-53659, by Hideo Ohashi. Dated September 26, 1967; Published November 17, 1967.

"Thermodynamic Properties of Liquid-Solid Mixtures of Hydrogen (1 atm to 1400 psia)," Unclassified, IN-P&VE-P-67-8, by Charles D. Miller. Dated October 23, 1967; Published December 6, 1967.

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