saturn history 3/3/67

PROPULSION AND VEHICLE
ENGINEERING LABORATORY

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MONTHLY PROGRESS REPORT

For Period

March 1, 1967, Through March 31, 1967

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 1262 (September 1961)

PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-67-3

MONTHLY PROGRESS REPORT

(March 1, 1967, Through March 31, 1967)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Concluded)

SATURN V

I. S-IC Stage

A. Investigation of the Failure of a Component of an S-IC Hold-down Arm

The two additional anchor studs that failed in the ball lock separator of an S-IC hold-down arm during assembly testing were subjected to chemical analysis. As was expected, the material was 17-4 PH stainless steel; whereas, the specified alloy is 1020 mild steel. The exact cause of failure was not determined; however, brittle characteristics of the fractured surfaces indicated that either notched tension or an impact failure occurred. No material changes were recommended since the wrong material was used.

B. Evaluation of Commercial Adhesives

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

1. Investigation of Polyurethane Adhesives

a. Study of Environmental Effects on Strength of Polyurethane Adhesives

The results of the first month of a long-term aging study of specimens prepared by the contractor under contract NAS8-11958 were reported in the previous monthly report. Specimens were bonded with Narmco 7343/7139 (100/12.5) to evaluate the following conditions: (1) unprimed adherends, (2) adherends primed with Z-6020 and 1 phr. Z-6040 added to the adhesive mix, (3) adherends primed with hydrolyzed Z-6040 and 1 phr. Z-6040 added to adhesive mix. The results seem to indicate general, though moderate, strength deteriorations during one-month exposure to the ambient outdoor environment. Exceptions are: (a) the -300°F (149°C) values throughout the three series, which reflect little or no deterioration, and (b) the room temperature values for Z-6040 primer with Z-6040 added, which exhibit about 30 percent strength loss (3367 psi initial; 2248 psi after one month). It is much too early in the program to ascertain any significant trends.

b. Reevaluation of Narmco 7343/7139 Cure Cycle

The currently standard cure cycle for the Narmco 7343/7139 adhesive system is 24 hours at room temperature followed by 24 hours at 160°F (71°C). Periodically, this cure cycle is compared with others which may offer savings in time and effort or which may give better bonds. The standard cure has been compared with a one-step, immediate 24 hours at 160°F (71°C) cure cycle for lapshear tensile specimens. Results were 3156 psi and 1876 psi at room temperature and +200°F (93°C), respectively for the

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-67-3

MONTHLY PROGRESS REPORT

MARCH 1, 1967 THROUGH MARCH 31, 1967

SATURN IB

I. S-IB Stage

A. Evaluation of Aging Treatment for 7075-T6 Aluminum Components in Reducing Susceptibility to Stress Corrosion

All tests initiated to determine the effectiveness of aging 7075-T6 to the -T73 condition for stress corrosion resistance have been terminated. The results of these tests will be reported on completion of data evaluation.

B. Corrosion Effects of MIL-H-5606 Hydraulic Oil

Tests comparing the corrosive effects of MIL-H-5606A hydraulic fluid to the B revision fluid have not shown any changes after 75 days of exposure.

II. H-1 Engine

Investigation of Cause of Leakage in an H-1 Engine Turbine Manifold

A leak was discovered in a weld area near the inlet duct of an H-1 turbine manifold that had been in service on the component test stand for approximately 2100 seconds. Metallographic and fractographic analysis of the leak area revealed a fracture on the Hastelloy B casting side of the manifold weld. Areas of darkened surface were present on the fracture surface in this area, indicating that the unit had been cracked for a period of time prior to major fracture. Fractographic study identified the presence of fatigue in this area. Penetrant examination of the remaining portion of the weldment revealed cracking approximately 180° from the leak area. Metallographic and fractographic studies are now being conducted in this area.

standard cure and 2882 psi and 1488 psi at the same temperatures for the abbreviated cure. These results appear to re-emphasize the desirability of retaining the preliminary 24 hours at room temperature in the cure process.

c. Evaluation of Curalon-L as Curative for Dupont's Adiprene L-100 and L-315

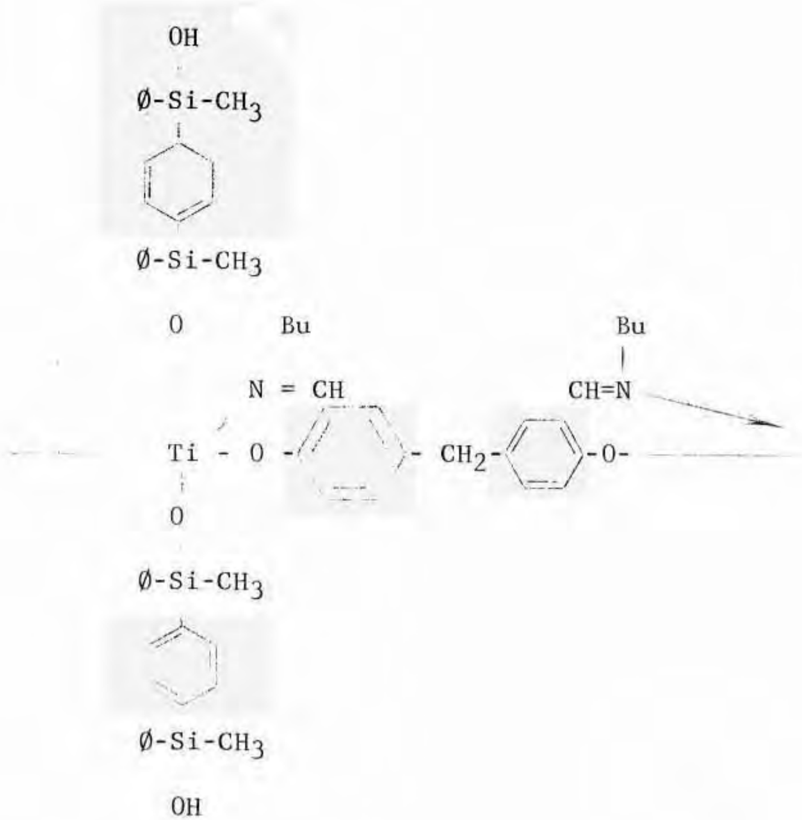
Dupont's polyurethane resin L-315 yields unusually high room temperature strength values when cured with MOCA, the standard curing agent used in conjunction with Adiprene L-100 to form the Narmco 7343 adhesive. This agent is not practical for use with Adiprene L-315 due to its extremely short pot life (4-5 minutes). It has been suggested that Naugatuck's Curalon-L is a curing agent that will afford a workable pot life on the order of five times that of MOCA. Curalon-L has been evaluated in lapshear tensile specimens with Adiprene L-100, Adiprene L-315, and blends of these two resins. Each adhesive mix contained Z-6040 silane coupling agent together with a stoichiometrically calculated amount of Curalon-L. Surprisingly, Curalon-L did not give outstanding lapshear strengths with either resin, but with certain mixtures of the two Adiprene products a great improvement in bond strength was noted. The pot life is also improved to a practical level. This phenomenon will receive further study as time permits.

2. Investigation of Surface Preparation for Bonding Stainless Steel Adherends

Four surface preparations were evaluated for type 316 stainless steel lapshear tensile specimens bonded with the Lefkoweld 109/LM-52 adhesive system. These were: (a) a two-step etch requiring treatment with dilute sulfuric acid at 160°F, followed by room temperature immersion in a dilute nitric-hydrofluoric acid solution, (b) a brief etch at 180°F (82°C) in a mixture of concentrated hydrofluoric acid, concentrated hydrochloric acid and concentrated hydrochloric acid and concentrated phosphoric acid, (c) sand blasting, and (d) no etch or other treatment (beyond the solvent degreasing and detergent wash given all specimens). The two-step etch yielded the highest bond strengths, though treatments (a), (b), and (c) gave nearly equivalent results. Surface preparation (d) gave 25 percent lower values.

3. Investigation of Semi-Organic Structural Adhesives

A 500-gram quantity of titanium chelate polymer has been received from Monsanto Research Corporation, under contract NAS8-20402, for in-house studies. The base polymer has the following structure:



This linear polymer has a molecular weight ($\bar{M}n$) greater than 20,000 and melts at 250-275°C. The melting range of the polymer in this form precludes its use with aluminum. The addition of the reactive plasticizer, 1,4-bis-(hydroxydimethylsilyl)phenyl ether, in a concentration of approximately 22 parts per hundred parts of base polymer lowers the melting range of the formulation to 90-100°C. This plasticized formulation has been treated with 10 percent by weight of tris(dimethylamino)-methylsilane in an attempt to effect crosslinking by way of silanol-amino silane condensation. The polymer-amino silane mix was dissolved in benzene and lyophilized to a fine powder. Preliminary experiments indicate that some of the expected condensation occurs at 100°C, but optimum cure conditions have not been determined.

C. Development and Evaluation of Potting Compounds and Conformal Coatings

The development of specially designed polymeric materials is continuing for application to the encapsulation of electronic circuitry. Embedment compounds of the epoxy siloxane type are being formulated for circuit embedment applications and hydrocarbon polymers are being modified for printed circuit board coating applications.

1. Development of Epoxy-Siloxane Embedment Materials

The synthesis scheme utilized to produce polyfunctional siloxane-containing epoxides has been described in previous reports. The remaining intermediate to be synthesized, p-allylphenyldimethyl-N,N-measurement. Since there was an immediate need for this instrumentation, a short term, high effort contract entitled "Feasibility Evaluation of a Nondestructive Inspection Technique for Saturn Hardware" was awarded to Southwest Research Institute for the modification (and subsequent application to this problem) of an existing current injection technique.

The contractor has nondestructively evaluated several fuel valve castings using the current injection method. Two of these castings have subsequently been received at this Center. These castings will be sectioned to destructively measure the depth of cold shuts. A subsequent comparison of the nondestructive with the respective destructive measurements will be made to reveal the true capability of the nondestructive testing (NDT) method.

II. Contract Research

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

A. Polymer Research, Development, and Testing

1. University of Florida, NAS8-20247
2. Narmco Research and Development, NAS8-11958
3. Peninsular ChemResearch, Incorporated, NAS8-5352
4. Battelle Memorial Institute, NAS8-11837
5. Bell Aerosystems Company, NASw-1317

B. Development of Cryogenic and High Temperature Insulation Material

Goodyear Aerospace Corporation, NAS8-11747

C. Analytical Methods Development

Beckman Instruments, Incorporated, NAS8-11510

D. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

E. Nondestructive Testing Techniques

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

III. S-II Stage

A. Investigation of S-II-F/D Stage LOX Vent Line Failure

The S-II-F/D LOX vent line (P/N ME 271-0022-0001) (S/N 08344220001) manufactured by Solar, Division of International Harvester Company, failed February 28, 1967, during the longitudinal axis phase of the primary dynamic dimethylaminosilane, has been prepared as a colorless oil boiling at 82-85°C/0.2 torr. The infrared and elemental analyses are consistent with the proposed structure.

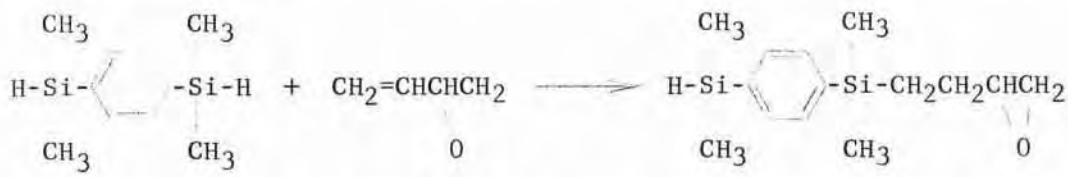
2. Implementation of Molecular Distillation Apparatus

An essential phase of the development of the siloxane-epoxide materials is the attainment of relatively pure polymer intermediates by molecular distillation. A mercury diffusion pump vacuum train has been connected to the molecular still to enable the system to distill high molecular weight liquids at pressures as low as 10^{-4} torr. A small portion of 1,5-bis(p-(2,3-epoxypropyl)-phenyl) hexamethyltrisiloxane from a previously described preparation has been distilled at a temperature of 120-130°C whereas the same material could not be distilled with conventional apparatus even at 200°C.

3. Development of Conformal Coating Materials

A 400-gram quantity of 1,4-bis(hydrogendimethylsilyl)benzene is being prepared for use in crosslinking the styrene-butadiene polymer. These crosslinked hydrocarbon polymer coatings have been developed to the point that application to simulated electronic hardware is desirable. A number of test printed circuit boards have been equipped with fragile diodes and resistors and have been connected to a terminal board by means of a wire harness. It is possible to monitor the electrical values of the various components while the coated board is undergoing environmental testing. The fabrication of the test boards was accomplished on request by R-ASTR-P.

The attempted preparation of 1-(3',4'-epoxybutyldimethylsilyl)-4-(hydrogendimethylsilyl)-benzene, for use in modifying the hydrocarbon polymer was unsuccessful in that both silicon-hydride groups reacted rather than giving the desired mono addition product. The desired reaction is illustrated below:



Further attempts will be made to favor mono addition in the above reaction by variation of stoichiometry and reaction temperature.

D. Nondestructive Examination of Fuel Valve Castings

Cracks or cold shuts have been found in A-356 aluminum castings which are component parts of fuel valves. Because the rejection or acceptance of the castings is dependent on the depth of these cracks, a program to develop a nondestructive method of determining crack depth was initiated. Preliminary investigations revealed that current radiographic, ultrasonic, and eddy-current methods were unsuitable for this type of

Center. In an agreement between the stage contractor and this Center, the torque was reduced to 170-inch pounds immediately and then will be increased to 250 $\pm$ 10-inch pounds shortly before launch. Based on available data, it was recommended that a maximum torque of 225-inch pounds be used. As a further recommendation, if service loads in the S-IVB/IU mating bolts are greater than 2.25 kips, then the torque value of 225-inch pounds cannot be used without a change of the nut plate. Effort is continuing to determine bolt lubricant, service load, service temperature range, vibration or fatigue environment and the relationship between induced preload and service load.

B. Developmental Welding

1. Studies are continuing in the determination of the repairability of 2014-T6 weldments. Enough panels have been prepared to complete the program. Welding of test specimens for evaluation should be completed during the next report period.

2. Studies have continued in the correlation of the effects of various welding energy inputs and natural aging with the performance characteristics of weldments in aluminum alloy 2014-T6. Weldments have been prepared utilizing approximately 25 percent excess energy input (1070 joules per linear inch). These weldments, upon completion of the specified aging periods, will be mechanically tested and metallurgically examined, and the results documented for comparison studies. Preliminary results indicate that a significant reduction in joint efficiency can be expected when excessive heat input is utilized.

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

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

A number of D-65 Scrim Cloth/3-D Insulation samples were evaluated to determine the effect of cure cycle on flammability in 5 psia oxygen. There does not appear to be an appreciable effect of cure cycle on the ignition of D-65 Scrim Cloth coated 3-D insulation. Additional studies are scheduled to determine the effect of 70 percent oxygen-30 percent nitrogen on the ignition of 3-D insulation by hypervelocity impact. Also, studies are scheduled to study shock and blast phenomena in a 3-foot diameter tank. A shock wave measuring system is being assembled for use at the Arnold Engineering Development Center. This system will measure the intensity of the shock waves produced under hypervelocity impact. Correlation of data recorded by this system and photographic data may elucidate the ignition process.

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

The permeation of helium through 3-D type insuation at liquid nitrogen temperature has been examined. Test specimens of 3-D insulation sealed only on one side with the normal polyurethane seal coat were evacuated testing of the Saturn V-D configuration. Examination of the line revealed a 16-inch fracture adjacent to weld 19, approximately midspan of the mounted line. The LOX vent line is a 10-inch diameter by 0.035-inch minimum wall thickness tube made of 321 CRES material. The failure, attributed to high cycle fatigue, initiated at the intersection of the longitudinal weld and the circumferential weld at a point approximately 25° from the top dead center of the tube in the installed position. Stress concentration factors including incomplete weld penetration, weld peaking, and the stiffening effect of repair weld reinforcement caused fracture progression from an area of lack of fusion under the load conditions created by dynamic testing of the Saturn V-D vehicle.

B. Evaluation of Fasteners

A program is currently in progress to establish the mechanical properties required for bolts used in the S-II stage thrust mount attachment. Tensile tests and hardness tests have been made on low strength (145-160 ksi) and high strength (180-200 ksi) A-286 bolts for comparison purposes. The use of160-180 ksi bolts was recommended to insure a minimum amount of cold work and better mechanical properties. It has been stated that the ultimate tensile strength is not an important design criteria in this application; the elongation properties are the determining factor. This philosophy has evolved from the Structures Division's experience with 3/8-inch diameter, low strength (145-160 ksi) and 7/16-inch diameter high strength (180-200 ksi) A-286 bolts. The weaker bolts with more elongation, deformed under load; however, the larger stronger bolts experienced a shear failure. It is considered that the torque induced tension load applied to these bolts is not adequate to overcome the actual service load. Effort is continuing to determine bolt lubricant, fastener service temperature range, mating joint materials, bolt length, maximum service loading, and the value of the applied torque induced preload.

C. S-II Stage Cryogenic Insulation

This division has continued to support the repair and test activities related to the S-II stage insulation at both the Mississippi Test Facility and the John F. Kennedy Space Flight Center. The effort to evaluate spray foaming has been hindered by a delayed foam shipment, but an attempt is underway to apply spray foam to a 70-inch diameter test tank locally. It is hoped that at least one fill and drain test of the foam insulated tank can be conducted in advance of a meeting to be held tentatively on April 7 with personnel of the stage contractor.

IV. S-IVB

A. Investigation of Fasteners

An analysis of torque requirements for NAS-625-4 bolts and NAS-675-A5 nut plates between the S-IVB stage and the Instrument Unit (IU) is being made. It was discovered that 335-inch pounds of torque was being applied to stage interface bolts being installed at the John F. Kennedy Space Flight on one side while maintaining one atmosphere of helium on the opposite side. Permeability was determined from the pressure rise in the evacuated chamber resulting from helium diffusion. Triplicate tests on each of five specimens at 28°C and one atmosphere differential pressure resulted in an average permeability of 5.6×10^{-4} cm^3/hr cm Hg $\Delta P/in^2$ for comparison to results obtained at -195°C. Testing the same five specimens at liquid nitrogen temperature resulted in gross mechanical failure of three of the specimens at the bond joints to the test fixture; however, the two specimens remaining intact showed no significant change in permeability from that obtained at 28°C.

Permeability determinations to ascertain the effect of perforated aluminum foil flame retardance coating are in progress. Additionally, a test program to determine the diffusion rate of helium from 3-D type insulation under pump-down conditions and to determine the absolute pressure rise within the insulation after prior evacuation is in progress. Unanticipated experimental difficulties have been eliminated and meaningful data should be forthcoming.

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

Determinations are continuing to ascertain the effects of helium diffused into the insulation on the thermal conductivity. In the present study, samples of 3-D insulation sealed with perforated aluminum foil flame retardance coating are being measured for thermal conductivity, according to the following cyclic program:

	Sequence	Atmosphere	Cold Plate	Action
	Precondition	Vacuum	LH_2	Measure, K
One Cycle	1	He 1 atm	LH_2	Measure, K
	2	He 1 atm	RT	Condition Sample

Eight cycles have been completed on one specimen. Uncorrected data indicate that the thermal conductivity of the sealed specimen approached the thermal conductivity of the specimens saturated with helium asymptotically with each subsequent cycle. Without removing the sample from the calorimeter, the sample chamber has been evacuated to less than 10^{-5} torr and the thermal conductivity determined as a function of time. This test will be continued until a minimum conductivity is obtained.

4. Study of Flammability of Materials

The burning characteristics of ten different polyurethanes are being evaluated as a function of oxygen pressure. The samples are being studied in 5 psia, 10 psia, 13 psia oxygen and air. A complete evaluation of these materials will be made when the testing is completed.

As a part of the flammability study, considerable time has been spent in searching for desirable criteria for selection of materials for use in gaseous oxygen systems. Specifically, what burning propagation rate should be selected? Also, should the sample be evaluated by ignition at top when samples are held in vertical position? Another possibility is ignition from bottom when the samples are held vertically or ignition of a sample in the horizontal position. A search of the literature reveals that the burn propagation rate of a sample ignited from the bottom is 10 times greater than a sample ignited from the top. Also, this same literature search indicated that the burning rate of specimens ignited from the top or in the horizontal position is approximately the same. The MSC Specification MSC-AD-66-3 specifies a vertical top method for evaluating materials in pure oxygen environments. The acceptable burning rate is 0.5 inch/sec (30 inches/min). It must be realized that this is a minimum burning rate not a maximum rate. The Underwriters Laboratory (UL) has issued a bulletin on a comprehensive program to determine flammability criteria for selection of plastics for use in electrical appliances in air. The end result of this study was the selection of a Plastic Performance Index (PPI) for selection of plastics for use in electrical appliances. A PPI of 50 was selected to correspond to acceptable magnitude for ordinary applications. This PPI has as a basis the performance of various plastics and plastic materials that have been used for years in electrical appliances. Each flammability property study (arcing, tracking, burning rate, etc.) of plastics were plotted against PPI scales of 0-100. When using PPI charts for high O_2 environments (similar to the UL Index), a burning rate (horizontal) corresponding to an index of 50 (in air) would be 1-inch/minute or 30 times more severe than the current 0.5 inch/sec. These charts were further broken down to indicate restricted burning, free burning, and spacing distances. It is recommended that consideration be given to adoption of the UL criteria using a PPI scale of 50 for most materials. The flammability tests would be made in gaseous oxygen.

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

A requirement for a thermal coating with an emissivity of 0.8 or greater on the interior of the liquid hydrogen tank of the S-IVB Workshop has resulted in a limited literature search as well as laboratory evaluation of available coatings. Since this coating must be insensitive to gaseous oxygen, only inorganic type coatings may be considered. Several coatings of the chemical conversion type are being evaluated. One coating which shows some promise and can be applied by manual techniques is being evaluated.

D. S-IVB Stage, Project Management, Materials

Efforts are continuing in the coordination and resolution of problem areas related to the materials aspects of the S-IVB stage of Saturn. During this report period, these activities have included the following:

1. Flutter Kit

DAC's proposal for bonding of the flutter kit on S-IVB stages was reviewed. Bonding and process specifications proposed for this application were found to be acceptable. Thus, no problems of a bonding or materials nature are expected.

2. Radiographic Inspection of Welds

A detailed review of radiographic inspection requirements of welds has been completed. Requirements of R-P&VE have been coordinated with those of R-ME and R-QUAL. An R&DO coordinated reply is being prepared by R-OM-V for forwarding to the S-IVB stage manager.

3. The following documents were reviewed:

a. DAC MRD 1P20031C, "Adhesive, Quick Set"

b. DAC PRD 1P0081D, "Insulation, Cryogenic, Installation (for non-oxidizing systems)"

c. DAC MRD 1P20075E, "Adhesive, Polyurethane, Flexible"

d. DAC MRD 1P20110, "Lubricant, Solid Film, Propellant Systems Compatible"

e. DAC ECP 2093, "LH_2 tank external surface finish"

f. DAC MRD 1P20121A, "Wire, Welding, Spooled Type, Aluminum Alloy, 4340"

g. DAC NS No. STM0-251, "Fabric, Glass, Finished, for Use as Scrim"

h. DAC MRD 1P20040B, "Primer, Silicone Resin Base"

i. DAC MRD 1P20014D, "Adhesive, Silicone Elastomer"

j. DAC MRD 1P20018D, "Resin, Epoxy, Low Temperature Resisting, Room Temperature Cure"

k. DAC MRD 1P20097B, "Adhesive, Edge, Epoxy, Thixotropic, Paper Honeycomb"

l. DAC PRD 1P00055A, "Bonding, Panel, Paper Honeycomb Core, Metal Faced."

V. J-2 Engine

A. Investigation of Cracking in a J-2 Engine Turbine Wheel Assembly

The quarter section of the first stage turbine wheel assembly from the oxidizer turbopump assembly of J-2 engine J2027 (S-IVB Program) was received for fracture analysis; however, only limited studies have been made due to scheduling problems. The section contains cracks near the hub-portion of the assembly.

B. J-2 Engine Project Management, Materials

1. After being directed to use Dynatherm, D-4327, to coat the cross-over duct on the J-2 engine, Rocketdyne claimed that they could not get any of this material which is LOX compatible. (It was recommended that the D-4327 be batch tested for acceptability.) One of the batches tested was previously tested by the Space and Information Systems Division of North American Aviation for use on the S-II stage and found acceptable. We have requested samples of the material tested by Rocketdyne to be sent to this Center for LOX impact testing. Apparently, there is some difference in Rocketdyne's testing techniques as compared to ours.

2. Failure of a brazed joint in an ASI instrumentation line (Pc line) on a J-2 engine on the S-II battleship stage recently, resulted in the necessity for inspection of this brazed joint on the same lines on the five engines installed on the S-II-2 stage at Mississippi Test Facility. It was determined by radiographic inspection of the joints, that two of the joints were inadequately brazed. These two lines, and subsequently, the lines on the other three engines were cut, removing the brazed joint, the ends crimped and welded shut. The lines are 347 stainless steel and 347 filler wire was used in welding the crimped ends.

VI. F-1 Engine

A. Study of Effect of Sea Water Immersion on F-1 Engines

The Advanced Systems Office (R-AS) has initiated a program to evaluate the F-1 engine's reusability after immersion in salt water. This program will be similar to a program conducted on an H-1 engine several years ago. This division has requested that we be included in the planning and initiation of this program. Presently, Rocketdyne has been requested to perform a study leading to recommendations as to special preparations and expected performance and reliability in sea water. A report of this study is due April 1, 1967. After a review of this report, further consideration as to the scope of the program will be given.

B. Study of F-1 Engine Primary LOX Seal Mating Ring

Metallographic analysis was continued on three F-1 engine primary LOX seal mating rings. Further evidence was found of cracking in the chrome plating; and by sectioning through various areas of one ring, it

Samples of four materials proposed for the insulation blanket for the ATM spar and experiment envelope were evaluated to 100°C at 10^{-8} torr. The materials were (1) 0.25 mil aluminized Mylar reflector film; (2) 35 mil polyurethane foam spacer material; (3) outer fiberglass laminate impregnated with polyurethane resin; and (4) outer fiberglass laminate impregnated with epoxy resin. The aluminized Mylar and the polyurethane foam had a weight loss of 1.3 and 3.1 percent, respectively. However, the weight loss of the Mylar is attributable to loss of surface adsorbed atmospheric gases, and the relatively high weight loss of the polyurethane foam was clearly identified as CO_2, probably the blowing material. Both of the fiberglass materials exhibited negligible weight loss.

Four other sample materials were tested for the Apollo Command Module. These were: (1) Kapton polyimide, aluminized on one side; (2) S-13 coating, RTV602 with titanium dioxide pigment, (3) Hypalon, a synthetic rubber; and (4) insulcork 2755, a cork bonded with phenolic resin. The Kapton sample was heated for 63 hours prior to a series of weight loss determinations involving 9 hours. The weight loss of 1.7 percent is all attributed to loss of surface gases.

The Hypalon and S-13 materials were tested for 8 hours each and had less than 1 percent total loss. The Insulcork 2755 was heated to 150°C over a period of 30 hours with a 18.0 percent weight loss. The sample lost 3.1 percent at 25°C, 0145 percent at 50°C, 9.4 percent at 100°C, and 5.0 percent at 150°C. The sample had visibly shrunk and discolored. Mass spectra indicate degradation of the phenolic resin binder and probable degradation of the cork. The presence of a large peak at M/e of 60 cannot be attributed to the binder and is probably an indication of degradation of the cork. A cork sample will be run separately to obtain a typical spectrum for this material.

One additional material was tested. This was the outer coating for the film heater proposed for the ATM spar. The material is an epoxy coating whose exact designation or composition is not known. The sample was tested to 100°C and lost a total of 2.7 percent.

B. Investigation of ATM Bearing Lubrication

To protect moving parts of the Apollo Telescope Mount lubricants will be required which will not break down or outgas in the environment of outer space. The problem areas to be considered are:

1. The gimbal pitch and yaw bearings
2. The gimbal roll bearings
3. The gimbal drive gears
4. The inertial platform bearings and gears, and
5. All drive motors.

was noted that the depth of overheating varied throughout the circumference of the ring.

VII. Instrument Unit

A. General Corrosion Studies

Corrosion tests on simulated beryllium cold plates have been concluded. This test was not conclusive; however, there were indications that alcohol water solution was high in copper ions which would cause corrosion of all aluminum components in the Environmental Control System (ECS). It will be necessary to test a regular cold plate made from beryllium before conclusive data can be obtained.

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

An investigation was initiated to determine if the reaction of the coolant with the metal components is the cause of the pressure build-up in the ECS. Approximately 30 ml of gas (50 percent H_2 by analysis) was evolved in 34 days by the action of 6061-LA141 couples in both inhibited and uninhibited methanol. Materials that have been tested previously for corrosion compatibility in 60 percent methanol are to be tested separately in uninhibited alcohol water solution for hydrogen evolution. There has been no measurable amount of gas evolution in the cylinders containing the Avco cold plate, LA141 specimens, and 6061 in either the uninhibited or inhibited methanol - water solution after 81 days of exposure.

C. Instrument Unit, Project Management, Materials

Because of a LVDA failure attributed to reaction of hydrogen (generated by the reaction of water and water/methanol with ECS components) with palladium-silver resistors, a review is being made of possible corrective actions, including replacement of the water/methanol coolant. At the present time replacement of the coolant does not appear feasible. The necessary corrective action is being pursued by Astrionics and IBM.

VIII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

The purpose of this project is to determine possible contamination of the ATM experiment, both direct deposition of contaminant materials on optical surfaces and degradation of the view area of the equipment.

Materials on the exterior of the Apollo Command Module, the Apollo Service Module, the Lunar Excursion Module, and the ATM package have been evaluated by determining weight loss as a function of time, temperature and pressure, and performing simultaneous mass spectral analysis.

approximately 10 hours for each of five separate exposures to produce a maximum total exposure of 1×10^{11} ergs-gm^{-1} (C). After irradiation and while still full of liquid hydrogen (LH_2), the valves will be checked for leaks across the valve seat. The tank then will be drained of LH_2, and a detailed inspection of the tank assembly will be made. The tank then will be filled with LH_2 and will be irradiated again. This sequence will be repeated for each of the five cycles. In addition, after each irradiation, the tank will be acoustically excited while it is still loaded with LH_2.

The tank to be used for these tests is the 108-inch diameter insulation test tank manufactured by Lockheed for the RIFT program. At the termination of this program, the tank was shipped to this Center and subsequently made available for the NGTM program. The test valves currently being considered are the 17-inch LOX prevalves manufactured by the Whittaker Corporation and the AiResearch Division of the Garrett Corporation. An 8-inch LH_2 fill and drain valve currently used on the S-II stage also is being considered. The valves selected for testing will be modified by replacing the presently used seal, lubricant, bearing retainer, etc. materials which are known to be susceptible to radiation with radiation resistant materials. Discussions are now underway with Whittaker and AiResearch concerning these modifications.

ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

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

A. Polymer Development and Characterization

1. Southern Research Institute, NAS8-20190
2. W. R. Grace Company, NASw-924
3. National Bureau of Standards, Government Order H-92120

B. Adhesive Development

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

C. Developmental Welding

The Boeing Company, NAS8-20156

D. Alloy Development

American Machine and Foundry Company, NAS8-11168

Tests are planned for a number of dry film lubricants under vacuum conditions and other possible simulated conditions. Preliminary testing has started to screen lubricants for the gimbal pitch and yaw bearings and a number of standard ball bearings have been ordered. These bearings will be modified with various composition retainers in order to test these retainer lubricants. During this period preliminary tests were made on number 203 ball bearings with Salox M, polyimide, and Rulon retainers. Bearings with a 10-pound thrust load, lubricated with molybdenum disulfide (MoS_2) powder and having Salox M cage retainers have operated under a vacuum of 3×10^{-9} torr for 1101.5 hours. This is the same bearing that had 560 hours running time as reported last month. Bearings with a 10-pound thrust load, lubricated with MoS_2 powders and having polyimide-bronze retainers have operated under a vacuum of 5×10^{-8} torr for 98 hours and 20 minutes before failing. Bearings with a 20-pound thrust load, with Rulon retainers which were run-in for one hour before test and under a vacuum of 3×10^{-8} torr during test ran for 95 hours. The test was terminated because of a malfunction in the driven cam. The balls and races showed some wear. Bearings with a 20-pound thrust load having Rulon retainers and races coated with MLF-9 which were run-in for one hour before test have operated under a vacuum of 1×10^{-8} torr for 315 hours with no noticeable damage. A device developed for measuring the torque on these bearings has been checked out and two more of these devices are being checked against the first for repeatability of results.

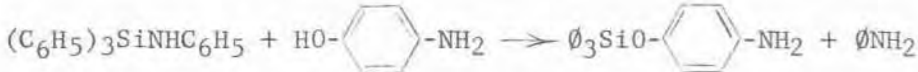
A computer program has been set up to calculate the Hertzian loads on bearing balls and races due to radial and thrust loads. This program is complete and has been checked out.

IX. Nuclear Ground Test Module

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

A contract (NAS8-18024) has been initated with the General Dynamics Corporation, Fort Worth, (GD/FW) Texas, to evaluate the effects of radiation and cryogenic temperature on the mechanical properties of selected cryogenic insulations, adhesives, and vapor barriers. In addition, the structural integrity of two insulation systems will be determined after exposure to acoustic, cryogenic temperature, and radiation stresses.

A modification to contract NAS8-18024 is being negotiated to incorporate the testing of (1) a thermal insulation system installed on a 108-inch diameter tank, (2) valve seal materials installed in modified Saturn valves contemplated for use on the NGTM, and (3) transducers of various types which will be required in the instrumentation system of the NGTM. The tank assembly consisting of the 108-inch insulated and instrumented tank with the test valves located in the vicinity of the tank bottom will be positioned above the GD/FW, 10 megawatt, ASTR reactor and will be irradiated for



This reaction has now been completed. From a mixture of triphenylanilinosilane and p-aminophenol in 10 mole percent excess, at 200°C, one mole of aniline was evolved. The residue was soluble in benzene save for a small portion that was found to be aniline hydrochloride which may have originated as an impurity in the p-aminophenol. The reaction product was recovered from the benzene solution by crystallization in 70 percent overall yield as light tan crystals melting sharply at 152-153°C. Elemental, infrared, and molecular weight analyses of the product gave strong support to the belief that it possesses the structure shown, namely that of p-aminophenoxytriphenylsilicon. The way seems to be clear for the preparation of Polymer A structures which contain occasional amino groups for reaction with crosslinking agents such as, for example, diisocyanates.

B. Development and Characterization of Phosphonitrilic Polymers

The accomplishment of the structural identification of the single somer obtained upon treatment of $(PNCl_2)_4$ with N-methylcyclohexylamine has given added impetus to the study of the various reactions of this derivative with reagents capable of forming suitable intermediates for ultimate conversion to ladder-type polymers.

To this end the partially aminated phosphonitrilic chloride tetramer, β-trans-$P_4N_4Cl_4(CH_3NC_6H_{11})_4$, has been treated with several compounds in an effort to produce these desired intermediates.

Initially, the -trans isomer was treated with phenylmagnesium bromide in refluxing anisole for an eight-hour period:

$$P_4N_4Cl_4(CH_3NC_6H_{11})_4 + 4\ \emptyset MgBr \longrightarrow P_4N_4\emptyset_4(CH_3NC_6H_{11})_4 + MgBrCl$$

Workup of the reaction mixture gave a 97 percent yield (13.8 g) of an oil which was chromatographed on activated alumina. Elution with benzene afforded 10.6 g of clear oil while continued elution with ether and methanol gave 1.0 and 1.4 g of oil respectively. Although there was separation of solid during the reaction, infrared spectra of all the oils showed no P-Ø absorption at 1440 cm^{-1} indicating that the desired type of ring substitution had not occurred.

In another approach, the β -trans isomer was treated with phenyl lithium which had been prepared <u>in situ</u>:

$$P_4N_4Cl_4(CH_3NC_6H_{11})_4 + 4\ \emptyset Li \longrightarrow P_4N_4\emptyset_4(CH_3NC_6H_{11})_4 + 4\ LiCl$$

Once again, workup of the reaction mixture gave an oil whose infrared spectrum showed no P-Ø absorption band.

E. Physical and Mechanical Metallurgy

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

F. Composite Material Development and Testing

1. Douglas Aircraft Company, NAS7-429
2. Mitron, Research and Development Corporation, NAS8-20609

G. Lubricants and Lubricity

Midwest Research Institute, NAS8-1540

H. Corrosion in Aluminum and Steel

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

I. Explosion Hazards and Sensitivity of Fuels

Stanford Research Institute, NAS8-20220

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

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

K. Instrument Development

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

II. General - In-House

A. Development of High Temperature Resistant Polymers

Work is continuing on the development of curing systems for polyaryloxysilanes of the Polymer A type. In an earlier report it was mentioned that a test was being prepared to determine whether free amino groups can survive the condensation process by which Polymer A is formed. The test was designed to allow equal competition between amino and hydroxyl groups in a reaction with an anilinosilane. If the hydroxyl groups react preferentially, the amino group will remain free as shown in the following condensation of model compounds:

water, alcohol or acetone was sufficient to provide reasonable adherence of the aluminum. However, there were still pinholes observable in the structure - mostly attributable to dust particles.

Two dielectric materials, silicon monoxide and titanium dioxide were deposited in varying thicknesses. A quartz crystal oscillator was used as a deposition thickness monitor. A film of the dielectric was also simultaneously deposited on a reference slide. Absolute thickness measurements will be made on these films with a multiple beam interferometer. However, several sets of the slides are well over 2,000 angstroms thick because colored interference reflections are clearly visible.

Measurements were made of the electrical characteristics of several of these experimental capacitors. Examination of the test data indicated that specimens having thinner dielectric films have a larger capacitance than the thicker films which would be expected from purely geometrical considerations. The variation with applied frequency, high capacitance and higher dissipation factor at the lower frequencies was not expected. Normally the change with frequency of capacitance is inverse to the change with frequency of dissipation factor. The probable reason for this anomalous effect is the fact that a driving voltage of 3 volts (rms) was needed at 500 hz and only 1 volt (rms) was required at 10 khz. This implies a non-linear voltage current relationship, and the test data revealed that these films were non-ohmic in character.

All specimens indicated a short upon initial measurement. However, some could be healed by passing a high momentary current through the film. The specimens which could not be heated exhibited conventional ohmic behavior, indicating contact between upper and lower aluminum films, or direct electron tunneling. It should be noted that all films less than 3,600 hz (measured difference) were shorted.

E. Lubricant Development and Evaluation

A major lubrication problem today concerns low temperature lubricants for use in a cryogenic environment. A test apparatus has been designed and fabricated for evaluating greases from +50°F to -100°F. The breakaway torque and the relaxation torque can be measured accurately at any specific temperature in this temperature range. No tests were made during this report period due to priority of ATM lubrication test problems.

F. Development and Evaluation of Metallic Composites

1. Development of a Technique for Wire Reinforcing Magnesium by Vacuum Infiltration

As discussed in last month's report, work is still continuing towards the development of a reinforced magnesium composite by vacuum infiltration. The procedure for preparing and producing this composite involves bundling 2000 strands of 0.004-inch diameter wires (NS355 alloy) and then inserting this bundle into a 3/8-inch stainless steel tube. The

The high degree of reactivity of the four chlorine atoms on the phosphonitrilic chloride ring led to the speculation that alkoxy derivatives might react in a more satisfactory manner to give the desired substituted derivatives.

Therefore, the β -trans isomer was treated with sodium ethoxide, prepared in situ, in refluxing ethanol:

$$P_4N_4Cl_4(CH_3NC_6H_{11})_4 + 4\ NaOEt \longrightarrow P_4N_4(EtO)_4(CH_3NC_6H_{11})_4 + 4\ NaCl$$

Although a theoretical amount of salt was isolated from the reaction, the product was an oil which could not be induced to crystallize.

A similar reaction with sodium phenoxide (C_6H_5ONa) yielded only unreacted starting material. The bulky $-N(CH_3)(C_6H_{11})$ group probably hindered reaction with the aryloxy group.

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

Development work and qualification testing have continued on low resistivity brush materials for possible application in the environment of space. An investigation of the molybdenum disulfide-tantalum (MoS_2-Ta) system has been initiated. Hot pressing at 1205°C of MoS_2 compositions containing 2.5 and 5.0 volume percent addition of Ta did not increase the density or hardness as compared to 100 percent MoS_2. A single sample containing 5 volume percent Ta hot pressed at 1370°C attained a fractional density (actual density/theoretical density) of 0.93 compared to a fractional density of 0.84 when hot pressed at 1205°C. The system will be investigated further, especially with regard to the effect of small metallic additions on electrical conductivity and mechanical properties.

Experimental hot pressing of compositions from the niobium diselenide-silver system has been suspended temporarily pending receipt of further information on the brush performance, electrical conductivity, differential thermal analysis (DTA), and thermogravimetric analysis (TGA) of these materials.

D. Investigation of Thin Films for Electronic Components

In order to fully define the parameters involved in depositing thin films of dielectric materials, eight sets of thin film capacitors were deposited on glass substrates. The capacitors were formed by (1) depositing a 1-inch by 2-inch film of pure aluminum; (2) depositing a 1-inch by 1-inch film of the dielectric; and (3) depositing a 3/4-inch diameter circle of aluminum on the dielectric. With this configuration the deposition parameters can be checked both by electrical capacitance and by electrical leakage measurements. In order to provide a uniform substrate, and eliminate nonunformity as a variable, careful attention was paid to the cleaning technique employed. Cleaning in a solution of sodium dichromate and sulfuric acid with a final rinse with distilled in all three grain directions and exposed in the alternate immersion tester for 90 days. This material was found to be susceptible to stress corrosion cracking in the short transverse direction (across the parting plane) and in the longitudinal grain direction (parallel to the parting plane). No failures occurred in the long transverse grain direction. Additional tests will be conducted to establish the threshold stress level for this alloy.

Studies have continued on the stress corrosion susceptibility of 7039-T61 and -T64 alloy. Failures of specimens from this alloy have occurred in the short transverse grain direction in both tempers. No failures have occurred to specimens stressed to 75 percent of the yield strength in either the long transverse or longitudinal grain directions after one year of exposure in the alternate immersion tester or the local atmosphere. The long range exposure of 7106-T6351 and 7139-T6351 aluminum alloys in the local atmosphere is continuing.

The investigation of the stress corrosion susceptibility of 2024 aluminum alloy in 3-1/2 percent sodium chloride solution (alternate immersion) has been terminated. It was found that this solution was too aggressive for reliable evaluation of the stress corrosion susceptibility of this alloy. This material is being evaluated in synthetic sea water.

The study of the stress corrosion susceptibility of Ti-6Al-4V in various solvents and other fluids is being continued. No failures have occurred in any of the various fluids except methanol in which specimens failed in 128 days. Flat Ti-6Al-4V welded specimens (automatic TIG) stressed to 115 ksi (75 percent of yield strength) also are being exposed to various fluids. The only failures encountered after three days of exposure were in absolute methanol. These failures occurred after one and two days of exposure. These two specimens are being studied metallographically to determine soundness of the joint and type of failure.

Flat short transverse specimens of 2219-T31 and -T81 were chemically milled to reduce any stresses on the surface of the specimens due to the machining. Approximately six mils per side were removed. Both stressed (75 percent of yield strength) and unstressed specimens were exposed in the alternate immersion tester (3-1/2 percent sodium chloride). The specimens are to be removed from test after three, five, seven, and nine days and submitted for nondestructive measurements. Flat annealed specimens of Ti-6Al-4V were stressed to 75 and 90 percent of the yield strength in absolute methanol. The specimens stressed to 90 percent of the yield strength will be removed after five, nine, and 14 days, and the specimens stressed to 75 percent of the yield strength will be removed after 19, 23, and 28 days. These specimens also will be submitted for various nondestructive measurements.

Specimens of X2021 and X7007 aluminum alloys were stressed in all three grain directions and exposed in the alternate immersion tester and the local atmosphere. The alternate immersion test has been terminated, and the results were reported previously. The only failures that have been encountered in the local atmosphere exposure tests were short transverse open end of the tube is immersed into a molten magnesium alloy bath (LA91) and a vacuum applied to the tube, causing the molten magnesium to be drawn up into the tube. Examination of sectioned portions of the composite indicated complete encapsulation of the steel wires by the magnesium. The center section of the composite rod was machined to 1/8-inch diameter in order to remove the stainless steel encapsulation tube and the mechanical properties of the composite rod were measured. The following results were obtained:

Volume of wire	19.3 percent
Tensile strength of composite (actual)	93,000 psi
Tensile strength of composite (theoretical)	110,000 psi
Modulus of elasticity of composite	26.8×10^6
Efficiency of composite	85.2 percent
Strength/density ratio	967,000

Mode of failure was ductile with moderate wire pull-out observed. Indications were that stress transmittal to the reinforcement wire through the magnesium matrix was essentially achieved. Although some degradation of wire strength was expected (due to infiltration temperature of 816°C), the strength to density ratio exceeded that of titanium (700,000).

2. Solid State Bonding of Boron

A program has been initiated to develop a boron composite. Initial efforts have been directed towards devising a practical and efficient way for winding the boron filament. However, first attempts were only partially successful. A new winding fixture has since been fabricated which allows the winding to be done with minimum handling. Magnesium sheets (0.010-inch thick) are being silver-plated and will be used subsequently as the matrix in the diffusion bonding of a boron filament reinforced magnesium composite.

3. Development of Tubular Transtion Joints

Efforts continued in the development of a diffusion bonded aluminum to stainless steel tubular joint in support of Project Thermo. Five 1-1/2-inch diameter aluminum-to-stainless steel transition joints were diffusion bonded, leak checked, and given a final machining. A total of six finished 1-1/2-inch joints and six finished 1/2-inch joints were submitted to the Manufacturing Engineering Laboratory for welding test flange assemblies to the joints prior to a mechanical test evaluation which is to be accomplished by the Experimental Mechanics Branch of this Laboratory. In addition, six stainless steel pressure diaphragm switch assemblies were diffusion bonded for the Experimental Mechanics Branch.

G. Investigation of Stress Corrosion Characteristics of Various Alloys

Current tests to determine the stress corrosion susceptibility of 7001-T75 aluminum forgings have been terminated. Specimens fabricated from "H" beam type forgings were stressed to 75 percent of the yield strength promising based on preliminary tests. A much broader test program has been undertaken involving the following alloys stressed in all three grain directions: 2024-T351 - T851, -T4, -T6; 2014-T6; 2017-T4, 2219-T37, -T87, -T62; 7075-T6; 7079-T651.

H. Developmental Welding

Tensile specimens of electron beam weldments of aluminum alloys 2014-T6, 2219-T87, and X7106-T6 have been fabricated and will be tested during the next report period. Electron beam weldments of these alloys also have been submitted for metallographic examination. The metallurgical structure of the weldments will be correlated to the mechanical properties in an effort to determine meaningful relationships between metallurgical structure and mechanical properties.

The investigation of the weldability of X7007 and X2021 aluminum alloys has been temporarily delayed because of a material shortage. Material in 1/2-inch and 1/8-inch thicknesses of both alloys has been ordered to provide for continuation of this study.

The program to compare the weld crack susceptibility of various aluminum alloys has been temporarily discontinued, awaiting procurement of required materials. No welding or weld evaluation was accomplished during this report period.

I. Investigation of Dielectric Properties of Materials

Determination of the conductivity of RJ-1 as a function of temperature and additive (ASA-3) concentration is continuing. Tests have been completed on samples at temperatures from 5 to 60°C with additive concentrations from 0 to 80 ppm.

The variation of conductivity with temperature appears to indicate that the ASA-3 is increasing conductivity by charge carrier addition. Conductivity of pure RJ-1 varied by a factor of 10 over the temperature range from 5 to 60°C (increasing with temperature) while the samples with additives varied from a factor of 3 to 5 over the same temperature span.

J. Development of Nondestructive Techniques for Evaluating Materials and Components

A project has been initiated to develop a suitable laboratory apparatus for measurement of the rate of crack propagation in metals subjected to stress corrosion environment. The apparatus is needed for experimental study of the influence of stress, reactive environments, temperature, etc. on the rate of crack propagation. Its eventual use is for the study of the mechanism of crack propagation in aluminum at the grain boundary level. The apparatus for this project has been designed, assembled and checked out for soundness of principle. Deficiencies have been discovered which would cause the apparatus to be unreliable for the extended operation required. A modification to the

X7007-T6E136 at stress loads as low as 10 ksi. The atmospheric test has been in progress for 13 months.

Alloy 321 stainless steel tubing welded and brazed to NAA, General Electric, and Aero type fitting has been removed from test after 180 days of exposure in the alternate immersion tester. Test results indicated that these fittings are resistant to stress corrosion cracking under the conditions of these tests.

Tests are continuing in the evaluation of the stress corrosion susceptibility of Almar 362, 15-7PH, 17-4PH, and PH14-8Mo (air and vacuum melt). The alloys are being tested in the following heat treat conditions:

1. Almar 362 - 1000°F for three hours
2. 15-7PH - RH950 and RH1050
3. 17-4PH - R900
4. PH-14-8Mo - SRH950 and SRH1050.

Flat, threaded-end tensile, and C-ring specimens stressed in the longitudinal, long transverse, and transverse grain directions to 75 and 100 percent of the yield strength are being tested in the alternate immersion tester. Alloy 15-7PH was found to be susceptible to stress corrosion cracking in all three grain directions as reported in the last progress report. The only other failures encountered have been threaded-end specimens of 17-4PH alloy stressed in the transverse grain direction to 100 percent of the yield strength (183 ksi) which failed in 50 to 90 days. The test has been in progress for 103 days.

The stress corrosion susceptibility of H-11 steel is being investigated. There has been no change in the test results since the last report except that one coated specimen stressed in the transverse grain direction to 90 percent of the yield strength failed in 67 days. Both the alternate immersion and local atmospheric exposure tests have been in progress for three months.

Specimens of Arde low silicon 301 stainless steel cryogenically stretched to nominal 240 ksi are being studied for stress corrosion susceptibility in the aged (20 hours at 421°C in air) and unaged conditions. The specimens were passivated according to an Arde specification (AE 8254 solution A). Longitudinal specimens stressed to 75 percent of the yield strength (unaged 184 ksi and aged 196 ksi) are being exposed in the alternate immersion tester. There have been no failures in 14 days of exposure.

Because of the excessive amount of general surface corrosion encountered in the stress corrosion testing of aluminum-copper alloys in 3.5 percent sodium chloride, a more suitable test medium for the alternate immersion tester is being investigated. Synthetic sea water appeared very

Again it was found that the slowest speed resulted in the largest crystallites. Several slow, single passes were made with some improvement evident, but not sufficient to warrant continuation. Finally, the system was placed on automatic, and 12 zone passes were made at the slowest speed. Etching and subsequent examination of the ingot revealed several large crystallites (approximately 1 cm x 1 cm x 4 cm). This indicated that spurious nucleation may be due to an impurity concentration. Further zone refining will be done before attempting crystal growth again.

Due to limitations on speed with the RF induction apparatus a third technique was tried. Bismuth is sealed in a pyrex tube and suspended vertically in a vertical, tubular resistance-heated furnace. The furnace is programmed to provide a temperature gradient down its length with the hottest zone at the top, a modified Bridgman technique. The temperature of the furnace is raised sufficiently to melt the ingot, and then lowered very slowly by means of an electronic control circuit and an automatic set point unit. The bottom tip of the ingot should crystallize first and produce a preferentially oriented crystal. The first attempt with this method produced spurious nucleation. Another attempt will be made with more highly purified bismuth.

L. Development and Evaluation of Lightweight Ceramic Foams

Efforts have continued to develop lightweight ceramic foams for use as cryogenic insulations. Hydrogen peroxide is being investigated as a foaming agent for sodium silicate-based foams. Initial attempts to use hydrogen peroxide as a foaming agent resulted in foams with very poor microstructures, indicating that the viscosity of the foam mix was not sufficient to control the foaming rate. Pyrex wool was dissolved in the sodium silicate, by boiling, to increase its viscosity. The resultant mix could be foamed at temperatures above 121°C (250°F), producing a comparatively strong foam with a relatively uniform microstructure and a density of approximately 12 pounds per cubic foot. This approach, with and without the use of hydrogen peroxide as a foaming agent, will be investigated further.

Small amounts of bentonite were added to the phosphate-bonded foams to control the foaming action during release of the carbon dioxide foaming gas. The bentonite additions appeared to stabilize the foaming rate; however, the structure of the foams still contained large bubbles. Small amounts of surface active agent (Triton X-100) were added to the foam mix to reduce the bubble size. The desired results were obtained partially; however, the Triton X-100 increased the setting time, allowing some collapsing of the foams.

Efforts were undertaken to produce a lightweight foam by bonding silica microballoons with monoaluminum phosphate (ALKAPHOS C). Foams with good mechanical strength and micropore structure were obtained; however, they had densities in the 16 to 17 pounds per cubic foot range, which is approximately twice the desired density.

recorded signals has been made. The method of bonding the ultrasonic crystals has proved unreliable, and a new method has been found.

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

Electromagnetic and ultrasonic measurements are being made on 2219-T31 and 2219-T81 aluminum specimens which previously had been stressed to 75 percent of yield and subjected to the alternate immersion in salt water for various lengths of time to induce stress corrosion. This series of measurements is being made on chemically milled specimens. Chemical milling was initiated to improve the surface finish and to remove surface stresses. Surface stresses caused by machining are known to be high and to be variable. The great variability in time requirements for stress corrosion cracking to occur is believed to be caused in large measure by these residual surface stresses.

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

K. Investigation of Thermoelectric Materials

The purpose of this project is to develop methods for zone refining materials to extreme purity and then develop techniques for growing large single crystals of metals and compounds for research on these materials. Single crystals with controlled defects and impurity gradient distribution will be grown.

In an attempt to produce large single crystals of bismuth, several methods were tried. The first method was the Bridgman technique, which involves melting the bismuth in a vertical cylindrical graphite susceptor by RF induction heating. The crucible is lowered slowly out of the heated zone and allowing the bismuth to begin crystallizing at the bottom in the conical tip. This method was tried several times with varying conical tip angles and various rates of withdrawal. However, even at the slowest speed possible (2 cm/hr) there was no indication that growth of a single crystal by this technique was possible. The second method tried was horizontal refining-zone leveling. Due to the relatively low thermal conductivity of bismuth, attainment of an approximately flat solid-liquid zonal interface is possible if the walls of the horizontal crucible are well insulated. For this reason a boron nitride crucible with asbestos tape on the sides and bottom was used. Cooling was accomplished by placing one end of the crucible on a steel bar which extended outside of the heated area.

M. Documentation Review

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

1. Revised eight TBC welding specifications.

2. NAS-536Hu - Insert threaded metal, self-locking, non self-locking.

3. S&ID - MA0608-001B, MD-1 and MD-1A, "Application of Organic Finisher to Saturn S-II Stage and GSE."

4. S&ID - MA0610-0016, MD-1A, "Methods of Cleaning and Cleanliness Requirements for Saturn S-II Fuel and Oxidizer Tanks."

N. 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

MARCH 1, 1967 THROUGH MARCH 31, 1967

I. Radiography

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

II. Photography

	Negatives	Prints	Others
Engineering Photography	91	413	
Metallography and Fractography	258	1033	
Miscellaneous Photography, processing, copywork, etc.	149	868	

III. Metallurgical and Metallographic Testing

A. An explosively bonded aluminum-titanium composite from Battelle Memorial Institute was studied metallographically. Diffusion bonding was accomplished along the bonded interface. A precipitate also was observed in the bond zone. Hardness traverses across the sample indicated decreased hardness in the 1100 aluminum portion of the composite and increased hardness in the titanium material.

B. Assistance was provided in the selection of material and heat treatment for a spring application at -423°F (-253°C). Inconel 718 (AMS 5664) was selected with a 1950°F (1066°C) solution anneal and a 1400°F (760°C) 10 hours to 1200°F (649°C) (total of 20 hours) age. Selection of machining of the spring in the age hardened or annealed condition will be up to the designer. A stress relief (850°F (454°C) for one hour) was recommended on completion of the spring fabrication.

C. ASME Boiler and Pressure Vessel Code, Section VIII was reviewed and comments were furnished relative to the fabrication of a liquid hydrogen heat exchanger.

D. In support of the John F. Kennedy Space Flight Center (KSC) molten steel slay spatter was simulated on stainless steel for corrosion studies.

E. Stainless steel caps were electron beam welded to nine pressure surge valves. Welding procedures were developed and satisfactory welds were made in every case.

IV. Spectrographic Analyses

Three hundred and thirty-nine determinations were made on forty-nine samples, and two hundred and thirty-two standard determinations were made.

V. Infrared Analyses

Thirteen qualitative analyses were made by infrared techniques specimens of Insulcork binder, Dynatherm 4327, air residue from vacuum system, and an experimental polymer.

VI. Chemical Analyses

	Determinations
methanol samples for water	6
metal samples for	
carbon	18
chromium	18
phosphorus	9
sulfur	8
nickel	8
hydrogen	20
oxygen	20
polymeric samples for	
carbon	3
hydrogen	3
chlorine	4
nitrogen	8
silicon	8
lithium triphenylmethylarsonium for	
lithium	2
carbon	5
hydrogen	5
nitrogen	5
gas samples for	
nitrogen	46
oxygen	41
argon	33
carbon dioxide	30
hydrogen	42
methane	3
helium	6

VII. Physico Chemical Analyses

	Determinations
density of	
RP-1 fuel	16
MIL-H-5606 oil	4

	Determinations
viscosity of	
MIL-H-5606 oil	5
RJ-1 fuel	12
heat of combustion of materials from Apollo capsule	11
pH of soil samples	2
molecular weight of experimental polymers	2

VIII. Rubber and Plastics

	Items
molded and extruded	29
cemented	54
potted	40
coated	22
fabricated	261

IX. Electroplating and Surface Treatment

	Items
cleaned	224
plated	73
chemically stripped	29
chemically milled	24
salt spray tested	6

X. Development Shop Production

A. A total of 4,972 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. One thousand four hundred and sixty-nine man-hours, approximately 29.5 percent of the total man-hours were devoted to productive effort of a non-routine nature and applied to the work orders listed below.

1. Six-Inch U.V. Camera Assembly

Design changes are being made in film mechanism of the 6-inch U.V. camera assembly.

2. Rack/Payload Module

Activity on the Rack/Payload module is still delayed pending design release.

3. Accumulator Assembly

Components of the accumulator assembly are being assembled.

4. X-Ray/Astronomy Assembly

The X-ray astronomy assembly is approximately 50 percent complete.

5. Telescoping Skirt Extension, J-2 Engine

Drawings have been released for the telescoping skirt for the J-2 Engine, and work has been started.

6. $LHe-LH_2$-Cryostat

Joints of the $LHe-LH_2$ cryostat are being welded and checked for leakage.

7. S-II Pre-Valves

Fabrication of S-II Pre-Valve components is in process, but the valves have not been received.

8. Test Fixture - Experiment #2

The test fixture for flight experiment #2 has been completed and delivered.

XI. Miscellaneous

A. One 20- x 36-inch Teflon sheet was surface treated for Manufacturing Engineering Laboratory.

B. MLF-9 dry film lubricant was applied to several components for Test Laboratory.

C. Twenty-eight items of steel and twenty items of titanium alloy were heat treated during this report period.

XII. Publications

Lovoy, C. V.: Considerations on Weldments in Two Precipitation Hardening Aluminum Alloys, IN-P&VE-M-67-2, March 10, 1967.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-67-3

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(March 1, 1967, through March 31, 1967)

SATURN IB

I. S-IVB Stage

A. Cold Helium Sphere Replacement

An investigation was started to determine what changes might be required to substitute an MSFC furnished steel sphere for the present titanium sphere inside the S-IVB stage LH_2 tank.

B. Propellant Dispersion System (PDS)

The basic concept for the S-IVB-209 PDS redesign was accepted. Vehicle breakup conditions are being studied and defined. Studies have been completed on the location of redundant primacord trains to ensure S-IVB stage destruction, and the maximum separation distance between the charge and the LO_2 tank bulkhead under a 50° per second relative tumble rate between the S-IVB and S-IB Stages.

II. General

A. Weight Status Reports

The following reports were completed and distributed:

The monthly weight status report for all Saturn IB vehicles.

The detail weight status report for the Saturn IB operational launch vehicle.

The quarterly detail weight status report for Saturn IB vehicles.

B. Predicted Mass Characteristics

The following documents were completed and distributed:

The preliminary predicted mass characteristics, guidance cutoff, for AS-208.

The preliminary predicted mass characteristics, guidance cutoff, for AS-207.

The preliminary predicted mass characteristics, depletion cutoff, for AS-209.

The final predicted mass characteristics, depletion cutoff, for AS-204/LM-1 configuration.

The final predicted mass characteristics, depletion cutoff, for AS-205.

SATURN V

I. S-IC Stage

A. Umbilicals

Testing was conducted at the MSFC service arm and umbilical test area on the tail service mast (TSM) for mobile launcher (ML) 3 utilizing aft umbilical test units. The tests were conducted in accordance with the revised test requirements stated in memorandum R-P&VE-VOU-67-33. These requirements are based on maximum TSM mislocation and the latest available vehicle drift curve information. All tests were successful.

B. S-IC Flush and Purge Servicer

1. Testing of the 35-gallon turbopump bearing preservative unit (TPBU) has identified a potential problem concerning the ability of the unit to perform its function under adverse weather conditions. Tests were accomplished, data reviewed, and determination made that more testing is needed. The following are examples of why more testing is necessary:

The unit was filled, exposed to ambient temperature at 38°F. and an attempt made to recirculate the preservation oil (MIL-C-14201). Flow could not be initiated. The unit was allowed to warm up to 40°F. at which time flow was obtained; however, amperage reading at the pump was noted to be 70 amperes.

The unit was exposed to varied temperature conditions to test the capability of the TPBU to retain the fluid temperature for an extended time (fluid temperature soak transients). Additional testing is necessary to further define unit capability and establish change requirements.

2. During turbopump preservation tests, the transformer supplying power to the 115 volts alternating current (v.a.c.) utility outlets was overloaded and burned out. Investigation revealed that there is no overload protection for this transformer. A request has been made that action be taken to prevent the use of 110 v.a.c. outlets on the flush and purge servicers until an engineering change proposal (ECP) to provide overload protection for the outlets is incorporated.

C. Acceptance Tests

Acceptance tests were completed on the following equipment:

Pneumatic checkout rack assembly 1.

Aft umbilical number 2.

The light weight manual actuator unit number 1.

The engine actuator power pack unit.

D. Integration Test Requirements and Specifications

The following integration test requirements and specifications were reviewed and evaluated for technical adequacy and approved for release:

D5-15401-1, for the S-IC pneumatic console.

D5-15401-2, for S-IC pneumatic checkout racks.

D5-15401-23, for S-IC forward umbilical service unit.

D5-15402-1, for S-IC pneumatics.

II. S-II Stage

A. Documentation Review

The S-II stage separation charge qualification test report was reviewed and found to be acceptable.

B. Isolator Mount Testing for the Safety and Arming (S&A) Device

Testing in all axes was completed on the four isolator mount configurations. The Barry mounts and the Firestone mounts failed structurally during vibration testing in the Z-axis. The Lord mount configuration was tested without any noticeable changes in the mount properties. The Robinson mount test resulted in destruction or "chewed up" condition of the resilient material by the top and bottom caps. Data is being reduced for each configuration tested.

C. LH_2 Exchanger

The 6 p.s.i. vacuum burst diaphragms for vacuum jacket protection will be installed in all A7-71 (S-II) heat exchangers as replacements for the existing 30 p.s.i. diaphragms. Interface revision notices (IRN's) are being prepared to vent the diaphragms to atmosphere. This is necessary due to the excessive back pressure in the hazardous gas vent system facility. The ML-1 heat exchanger diaphragm replacement for support of S-II-1 will be made only if the vent circuit is removed from the facility vent system. Otherwise, the 30 p.s.i. diaphragm will be retained in the system until after AS-501 launch.

D. Pneumatic Consoles

A considerable number of objections have been raised by Test Laboratory, Industrial Operations (IO), and North American Aviation (NAA) concerning the need for redundant regulation in the S7-41 (S-II) consoles to eliminate possible overpressurization of stage components. These objections stem from the NAA contention that a new console will be required. This Division generated ECR 114 which was signed by the S-II stage project engineer to fulfill a valid requirement. The need for an additional console is questioned but the requirement remains valid. Specific technical details were requested on the proposed console and console location to complete the technical evaluation of the NAA ECP.

E. Umbilicals

1. Due to the problem encountered in qualifying the ME144-0011-0016 disconnect for cryogenic service, NAA established a limited life requirement for the airborne half of the disconnect (mating seal only). During requalification of the coupling to the limited life requirements, the coupling failed to meet the leakage requirements of the cryogenic test phase. Testing was initiated on two new seal configurations on March 27, 1967. Should there be insufficient time to qualify a redesign, this Division is confident that the disconnect can be used for SA-501 with only one disconnect at cryogenic temperatures permitted.

Qualification Test of 1/2 inch 3200 PSI Check Valve, GTP item X-35G.

Qualification Test of the S-IVB Stage Environmental Protective Cover Kit, model DSV-4B-304.

Qualification Test of 3/4 inch Check Valve, GTP item X-36.

Qualification Test of 1/2 inch Variable Orifice Valve Assembly, GTP item X-109.

Qualification Test of 1/4 inch Variable Orifice Valve Assembly, GTP item X-110.

Qualification Test of the Auxiliary Propulsion System Oxidizer, model DSV-4B-322.

Pneumatic Regulator and Distributor Console Vibration Test, model DSV-4B-436.

Qualification Test of Pneumatic Console, model DSV-4B-436A.

Qualification and Acceptance Flow and Leak Tests of Pneumatic Console, model DSV-4B-436.

EMC Production Acceptance Test of the Pneumatic Console, model DSV-4B-436.

Qualification Test of the Automatic Stage Servicing and Checkout Pneumatic Console "A," model DSV-4B-436.

TM-DSV-4B-MS-R-5721, revision A, Qualification Test of the N_2O_4, Differential Pressure Gage, GTP item X-122.

Qualification Test of the N_2O_4 Pneumatic 3-way Valve, GTP item X-125.

IV. Instrument Unit (IU)

Reliability Analysis Model (RAM)

A meeting was held with International Business Machines (IBM) on March 15 and 16, 1967, to review and discuss the SA-501 reliability analysis data and additional guidelines and schedules of future analyses. IBM agreed to furnish some revised criticality data for the SA-501 IU. Such data will be included in the final issue of the SA-501 RAM.

V. General

A. Test Specifications and Criteria

Comments to the test and checkout specifications and criteria for each stage of the Saturn SA-501 launch vehicle were finalized. These comments when applied to the SA-501 documents will establish the baseline for SA-501 and subsequent vehicles against which future changes will be evaluated by this laboratory. These comments are contained in memorandum R-P&VE-DIR-67-187 which has concurrence from all divisions and is now awaiting signature by the laboratory director.

B. Saturn V Flight Mission Rules

A revision to the Saturn V data for flight mission rules was released to Mission Operations Office. The effectivity of this data is SA-501, SA-502, and SA-503. The data will be used by Missions Operations Office in generating the MSFC portion of the flight mission rules.

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

1. The recommended spare parts list (RSPL) for the damper redundant hoist system was prepared and forwarded to the Manufacturing Engineering Laboratory.

2. The criticality categories for the Saturn V DRRS, damper redundant hoist system, and auxiliary damping system was transmitted to the Saturn V Vehicle Ground Support Equipment (GSE) Project Office. The critical categories for the Saturn V damping system will be updated after release of the drawings.

D. Damper System

1. A review was made of the updated and revised criticality analysis on the Saturn V Damper System with the following results:

Several items that were previously in criticality category B were changed to category A.

Six new components were included because of the redundant system which was added to the Saturn V Damper System.

2. A revised list of the critical items on the Saturn V Damper System is being composed, listing the components that are required to be qualified. Some components that were on the previous list will be dropped and new components added. The revised list will be used for the procurement of necessary components for qualification testing.

3. A revised "warning" for the Saturn V Damping System O&M Manual was prepared and distributed. The clearance problem between the damper and swing arm number 9 was covered.

E. Weight Status Report

The following documents were completed and distributed:

The monthly weight status report for launch vehicles SA-501 through SA-506 and the Launch Escape Systems.

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

The final predicted operational mass characteristics, depletion cutoff, for Saturn V/AS-501.

ADVANCED TECHNOLOGY

I. Systems Design

A. S-IVB Orbital Workshop

1. The DAC test fixture for the Quick Release Manhole Cover program test was received. The fixture is being modified by the Manufacturing Engineering Laboratory to provide insulation according to SK10-9318. Considerable work will be required since the dome segment was not trimmed to mate with the fixture and did not include the mounting holes.

2. The design for the quick release manhole cover handling sling is 75% complete. SK10-9337, "Airlock to Quick Release Manhole Cover Physical Mating Requirements," was completed. This drawing defines the requirements for mating the airlock boot to the manhole cover adapter ring.

3. The information received from the principal investigators for experiments M-479 and M-488 was reviewed to determine the compatibility of the physical experiment and multiple docking adapter (MDA) interfaces. The necessary layouts were prepared to define the above interfaces and to request the experimenter to make necessary revisions.

4. The Lockheed proposal for experiment D-022 and the Goodyear proposal for experiment D-021 were reviewed. The resulting layout (SK10-9330) proposed a mounting location for experiment D-022 on the conical end of the MDA. The layout also defines interference problems encountered with experiment D-021.

5. The configuration integration layout (SK10-9317) was updated to incorporate latest information. The layout was expanded to include those experiments mounted within the IU/SLA and those mounted outside the MDA.

6. The following documentation involving the Orbital Workshop was completed:

SK10-9337, "MDA Experiment Space Allocation" (Defines the space allocation for all experiments mounted to the MDA).

SK10-9335, "Experiment Package Mounting Panel" (Defines the detail design requirements for the panel).

SK10-9327 (Defines the installation of the X-ray astronomy experiment on the MDA).

7. Layout SK10-9312 defining the protective net for the IU compartment was updated to include estimated rope tensions. In addition, a removable section was added to the net in the vicinity of the ST-124 in order to improve accessibility.

8. A sketch was prepared showing a crew quarters concept having roll-type doors leading into the waste management compartment and a swinging door leading into the food management compartment. This sketch is acceptable to MSC and is to be used to define the final crew quarters configuration for the Preliminary Design Review scheduled for May 2-4, 1967.

9. Sketch SK10-9322 was revised to show the crew quarters floor plan rotated 45° counterclockwise. A second access door in the floor structure was added; safety dictated these changes.

10. The MDA neutral buoyancy design is being accomplished in accordance with SK10-9317. In addition, a "hard" mockup of the MDA for show purposes will be documented. Design has been started on neutral buoyancy mockups of the experiment packages and the fan assemblies to be installed in the S-IVB workshop.

B. <u>Cluster</u>

1. Detail hardware design for the experiment mounting hardware in the MDA is in process. The design will be used for mockup and preliminary experiment design review.

2. SK10-7391 and SK10-7392 were completed defining the clearance between the MDA and nosecone/Spacecraft LEM Adapter (SLA) and the docking clearance between the Apollo Telescope Mount (ATM) and MDA, respectively.

3. The handling and auxiliary equipment (H&AE) requirements studies were completed on the following MSFC portions of the complete cluster mission:

Mapping and Survey System (M&SS) - SAA-207.

Orbital Workshop (OWS), Airlock Module (AM), and MDA - SAA-209.

ATM and Ascent Stage of the Lunar Module (LM) - SAA-210

Resupply Module (RM) - SAA-211.

C. Nuclear Ground Test Module (NGTM)

SK10-7293, "Nuclear Ground Test Module Systems Configuration Layout," was completed. This drawing defines the overall stage configuration and space envelopes for the pressurization, vent, fill and drain, and other associated engine systems. In addition to the space envelopes, all major structural "cutouts and feedthroughs" were located and sized. These included those requirements for servicing, access, and instrumentation as well as the propulsion systems.

D. Project Thermo

A layout defining existing access platforms on the S-IB and showing clearance and access capabilities of such platforms for the thermo project was completed. Studies have begun on the proposed additional platform and component dolly at MSFC station 1673.859. Mounting of batteries will require a track and dolly extending under the MSFC rack.

E. Pyrotechnic Window Experiment

Studies have been completed on various mounting configurations for a pyrotechnic window (SK10-9321). These studies include the packaging concept for mounting the experiment external to the MDA along with the required control systems. A request has been made to fabricate seals and foam material used in development testing of the window.

F. Apollo Applications Program (AAP) Payload

The monthly weight status report for AAP payloads was completed and distributed.

II. Systems Requirements

A. Design Criteria and Reference Data Handbooks

Revision 1 of the Design Criteria and Reference Data Handbooks for Lunar Surface Operations, volume I - General Criteria, and volume II - Lunar Shelter Payloads was released.

B. Orbital Workshop

1. Draft copies of Orbital Workshop Prelaunch Procedural and Functional Interface Control Documents were prepared.

2. Performance and Design Requirements for the Orbital Workshop Apollo Applications Program System for AAP-2, number SS025SA1000025, were delivered to the Laboratory Projects Office.

C. Electromagnetic Radiation Experiment (EMR)

Work is continuing on the EMR general test plan. Draft copies and comment were completed. The effort was coordinated with Research Projects Laboratory for technical inputs and general comments.

D. Voyager and Voyager Shroud

Based on the decision to write a general test plan (GTP) for the entire Voyager program rather than the Voyager shroud alone, an effort has been directed to obtaining technical information and general description of the Voyager systems and subsystems. It is anticipated that a draft of Voyager GTP will be completed in approximately 3 weeks.

John O. Aberg

John O. Aberg

PR-P&VE-A-67-3

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

SATURN V

Voyager Program

A. Spacecraft

1. 1973 Mission Description Document (Draft) --- Review and comments were made on a proposed baseline mission specification document prepared by JPL. In general, it was concluded that the document, which was based on VPE-14, expressed too limited a view for the 1973 overall mission. As an example, only a liquid engine propulsion system and cold gas attitude were considered. The document did not provide for alternative considerations which would achieve the same mission objectives.

2. Manpower --- A manpower estimate for the Advanced Studies Office was generated assuming number 3 priority (after Apollo and AAP as established in a memorandum from Mr. Weidner's Office) for the Voyager program. These data were forwarded to R-P&VE-RI for incorporation with other estimates from the Laboratory.

3. Inter-Center Working Group and Subpanels --- Comments on MSFC charter responsibilities (memorandum R-P&VE-AV-67-69, "Voyager Mission Design Subpanel Charters," dated March 17, 1967) were submitted to R-AS for inter-Center interface negotiations. These comments were used by MSFC Inter-Center Working Group members for discussions with other Centers in a meeting held at JPL on March 23-24, 1967.

Efforts to resolve Voyager interface problems have continued. Two basic Flight Capsule (F/C) interface problem areas exist: (1) Physical length of the F/C; (2) Weight of the F/C as defined in the Langley Research Center (LaRC) configuration. These problem areas were discussed with LaRC personnel on March 30, 1967, and an agreement was reached to reduce the F/C length 19 inches in order to be compatible with S/C dimensions. The weight allowance for the F/C has not been resolved since LaRC is studying weights up to 7000 pounds while MSFC is considering a F/C weight of 5000 pounds.

Work has been started on an inter-Center working paper which will evolve into a recognized Interface Control Document. The preliminary document was transmitted to MSFC by LaRC personnel with a request for comments and inputs. A meeting was held on March 30, 1967, between MSFC and LaRC personnel to discuss the format on the inter-Center working paper.

4. Configuration Control --- The latest drawings of the Voyager spacecraft configuration were released during March for both the liquid and solid propulsion system designs. These configurations are similar to the drawings issued in February except more design detail in areas such as the support structure is shown and greater system definition is included in the March drawings. Total planetary vehicle weight remains at 20,500 pounds for both the solid and liquid propulsion designs. Capsule weight is currently ground ruled at 5000 pounds.

To date, Voyager spacecraft designs have been the direct result of analyses conducted in the Advanced Studies Office; however, beginning with the configuration issuance in April, all designs are to be the responsibility of the P&VE Laboratory Spacecraft Design Working Group. This is made possible by the accelerated support of the spacecraft design by the various P&VE Laboratory Divisions. The designs issued in April are to be used as references for locating specific systems and subsystems and performing detailed loads, stress, vibrations, and thermal analyses by the appropriate organizations of the P&VE Laboratory.

A decision was reached March 23, 1967, at the regularly scheduled Spacecraft Design Working Group meeting concerning the design of the liquid propulsion spacecraft configuration to be issued in April. Primary features of the latest design are forward support of the planetary vehicle near the cg and stowing of the solar panels as a cone frustum around this support structure. The forward support structure allows separation of the nose cone over the nose and minimizes the weight of the structure supporting the planetary vehicle from the shroud.

A design of the solid propulsion system is currently being evaluated.

5. Advanced Studies Office Design --- As mentioned in the February progress report, this Office is conducting a cursory Voyager spacecraft design study which is similar to the P&VE Laboratory effort. All facets of design are being considered in this study, but each design aspect is being investigated in less depth. In this study, solid and liquid propulsion spacecraft designs with aft support structure have been selected as reference designs for more detailed analysis.

A preliminary weight comparison of the structure required to support the planetary vehicle at the forward end of the spacecraft versus aft support has been conducted with a result that aft support is heavier by about five per cent. However, analyses also show that if the support structure, which could weigh as much as 600 pounds, is left on the spacecraft, an increase of approximately 600 pounds of additional propellant would be required for a total of 1200 pounds or 6 per cent increase in the spacecraft weight. This is assuming the capsule weighs 5000 pounds. Therefore, since the primary P&VE Laboratory effort is to be conducted on concepts with forward support structure, which means the structure supporting the planetary vehicle in the shroud must continue on the entire mission, the effort in this Office is being concentrated on aft support, where support structure can be left in the shroud. Solar panel storage for designs to be evaluated by this Office will be similar to that selected for the reference designs being evaluated by the P&VE Laboratory.

A structural weight comparison of concave, flat, and convex structural support of the planetary vehicle from the shroud shows convex to be slightly lighter. With convex support (as viewed from the bottom), the structural support is in tension during launch to earth orbit.

For the solid motor propulsion concept, a preliminary evaluation was made of supporting the capsule on the spacecraft through the solid motor rather than through a cylindrical shell around the motor. This arrangement indicated a structural weight reduction of about 15 per cent.

6. Voyager Separation Study --- The computer program for evaluating the shroud separation clearance has been checked out and initial runs have been made with results being assembled and plotted in graphical form.

Mass characteristics data for the S-IVB/planetary vehicle/shroud configuration during the different phases of separation have been supplied to R-ASTR Laboratory for determining the control capability of the S-IVB auxiliary propulsion system and to R-P&VE-S and R-AERO Laboratory for use in separation analyses and spacecraft control studies. The total mass pitch rates as determined by R-ASTR will be incorporated into the computer program for evaluating the separation clearance of the Voyager shroud and planetary vehicles. The assumed values for S-IVB rotation of 0.1 deg/sec for the orbital shroud separation and 0.005 deg/sec for the separations after injection are now being used for separation studies.

7. Propulsion Analysis --- Several preliminary design concepts have been prepared for consideration in the selection of an all-liquid and a liquid/solid system for Voyager spacecraft propulsion. The liquid concepts utilize single and multi-engines with up to six engines per installation. The solid concepts also use single and multi-motor configurations with up to four motors per installation. Multi-engine configurations are generally lighter and shorter than the single engine configurations but are more complex. All configurations used available propulsion hardware.

B. Shroud Design

The following schedule for the Voyager Shroud Design study has been published in Memorandum R-P&VE-AV-67-2, dated March 7, 1967:

Oct. 14, 1966 to June 30, 1967	-	Preliminary Design (Part I)
July 1, 1967 to Dec. 31, 1968	-	Preliminary Design (Part II)
Jan. 1, 1969 to June 30, 1969	-	Final Design

A formal summary report of the conceptual design period (Preliminary Design, Part I) is to be compiled by this Office; target date for this documentation is June 2, 1967. Submission of rough drafts of all report material has been requested by May 19, 1967.

C. Science Packaging

The contractor Phase B study reports have been reviewed for considerations for Science Package location, packaging, and implications to the overall Voyager Spacecraft configuration. This information is currently being used to determine Science Packaging requirements for Voyager configurations being developed within P&VE Laboratory.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

LM Utilization

In the study of earth and lunar orbital utilization of the LM system as a propulsive maneuvering stage, primary analyses now being made are adaptation of 260- and 396-inch-diameter payloads to the LM ascent stage, adaptation of the LM ascent stage as a payload to the SM, and uprating of the SM with cryogenic or high-energy storable propellants. Work on the first two tasks is only 10 per cent complete so results from this part of the study cannot be reported yet. Results from the third task, which is approximately 70 per cent complete, show that the greatest ΔV advantage is to be gained by uprating the SM/LM system (the LM being payload on the SM) with a higher I_{sp} storable propellant. This is due to the higher density of the storable propellant over cryogenic hydrogen. (An upper limit on storable propellant I_{sp} of 360 seconds is being considered.) Approximately 60,000 pounds of storable propellant can be packaged in the SM, whereas only 20,700 pounds of cryogenic propellant can be packaged. A ground rule of the study is that the basic envelope of the SM will not be altered.

II. Lunar Surface

A. LSSM 1/6 g Flight Test

A report of the BECO-built LSSM Mock-up Flight Test at Wright-Patterson Air Force Base, Dayton, Ohio, has been prepared. The report summarizes the flight test results and indicates the desirability of additional flight tests with prototype LSSM configurations.

B. Mobility Test Article (MTA)

Data obtained during the MTA tests at Aberdeen and Yuma Proving Grounds are being normalized for application to an LSSM size vehicle. The task is scheduled for completion in mid-April.

C. Performance Studies of Augmented Lunar Vehicles

Investigations have been made of the feasibility of uprating lunar vehicles and to determine trade-offs between spacecraft systems and scientific equipment. The Lunar Module can be augmented to provide mission durations of up to 14 days at the cost of some scientific equipment. Extended stay time on the lunar surface requires an equal extension of time-in-orbit for the CSM. The major weight changes result from additional required expendables which include primarily food, oxygen, and fuel. For a 14-day stay time, the CSM weight increase is about 600 pounds. In the event that much larger payloads are contemplated, approximately 5100 pounds can be landed by using the ascent stage solely for cargo.

III. Integration

A. AAP Experiment Catalog

Work continued toward converting the experiments in the catalog to a new retrieval format. All additional work on the experiment catalog will be combined with the mission simulation program.

B. Earth Orbital Mission Simulation Program

The final report on the revised program is nearing completion. A technical paper abstract, defining this program, for the presentation to the AAS and Geology and Geophysics Conferences has been completed.

A trip was made to DAC to discuss their space station experiment programs relative to Advanced S-IVB Workshop studies. The DAC experiment catalog contains 1238 non-redundant experiments. Copies of their experiment reference list, "driver" selection rationale, experiment definition forms, and experiment/mission selection are being reviewed.

NUCLEAR VEHICLE PROGRAM

I. Nuclear Boiloff Sensitivity Study

A standard orbital launch configuration has been selected as a baseline for future study work. The configuration resembles the 1966 JAG configuration for the 1982 direct mission, but has higher propellant loadings. Total weight delivered to low orbit is approximately 3×10^6 lb, with a maximum payload requirement of 525,000 pounds.

This configuration requires five launches of the "660 K Launch Vehicle" to loft the nuclear modules, plus a spacecraft launch. With the latest LMSC module dimensional constraints, all five module stackups exceed the 416-foot VAB height limitation. Various methods of reducing both height and weight will be investigated.

A "standard" boiloff schedule is to be established for this vehicle and parametric variations will be performed around the standard.

II. Modular Nuclear Vehicle Study

The proposal for the Phase 3 safety effort has been received from Lockheed and evaluated. This is a further extension of the study contract NAS8-20007. Contracting action will begin shortly.

ADVANCED PROGRAMS

I. Launch Vehicle

A. Kick Stage Study

An investigation is continuing to check boiloff rates for various 260- and 396-inch-diameter kick stage designs which use cryogenic propellants. Other in-depth investigations of such parameters as interstage weight penalties, effects of propellant off-loading, length versus propellant loading for the 260- and 396-inch-diameter stages, etc., are continuing. The results of this study will permit a more rapid, versatile, and efficient response to requests for preliminary kick stage design.

B. Vehicle Design Handbook

Recently received abstracts of design programs from MSC are being reviewed and evaluated for inclusion in the handbook. The final selection of necessary design programs to be used in the handbook is approximately 80 per cent complete. Initial checkout and conversion of several on-hand programs is being accomplished in conjunction with the Computation Laboratory.

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

Documentation of Phase I of the 156-inch-diameter pod design (formerly 154-inch-diameter pod design) study is continuing. Phase II of this study is also continuing with emphasis on further refinements and innovations of the launch vehicle configuration chosen in the Phase I study.

II. Earth Orbital

A. Advanced S-IVB Workshop

The initial contract orientation meeting was held with the Douglas Aircraft Company on March 8, 1967, to discuss the details of the contractor study plan. Key guidelines on the configurations, subsystems, and experiments were presented and discussed.

A configuration matrix of the major variables of a Saturn V launched Early Orbital Space Station was completed and drawings were prepared for each configuration.

An orbital heat computer program and a three-dimensional transient heat transfer program have been developed for preliminary thermal analyses in support of the Advanced S-IVB Workshop efforts. Insulation requirements and wall temperatures for various configurations are being investigated. Also, an analytical procedure and computer program is being developed to investigate the location and area of radiators, heat exchangers, cold plates, pumps, and piping for active thermal control system concepts.

B. Five-year Space Station

Several concepts for a long-term space station have been developed. One of the more promising concepts, a multi-purpose module, has been chosen for some preliminary analyses. The analyses have been limited thus far to two principal areas: (1) mission responsiveness and flexibility; and (2) structural.

The proposed compartment (or "can") is 21.6 feet in diameter and 7 feet high. A flexibility investigation has shown that the proposed structural build-up can adequately accommodate a broad spectrum of activities in the experiment program envisioned for the late 1970 time period. With relatively small internal modifications, the "can" may also be used for living and crew accommodations.

A preliminary structural analysis has shown that one possible means of constructing the "cans" is through the use of four-inch honeycomb with 0.020-inch facing sheets and appropriate close-out members. The total weight of such a "can," equipped with airlocks and hatches, is approximately 3510 pounds.

C. Large Space Structure

A configuration layout was developed for a Saturn V launched communications antenna in support of study efforts being directed by R-ASTR-A. The configuration represents an operational system launched to synchronous orbit for direct home TV broadcast. Major components of the configuration are a 96-foot-diameter space-erectable parabolic antenna, based on contracted study results by General Dynamics/Convair, and a 5000-square-foot solar cell array based on study results by Boeing in a contract with JPL. The configuration was packaged in a 30-foot-long, 260-inch-diameter shroud and incorporated previous study efforts by this Office on an Uprated Saturn I launched communication antenna experiment.

III. Lunar

Lunar Backpack Jumper Augmenter

A presentation on the results of the Lunar Backpack Jumper Augmenter (LBJA) study was given to P&VE management on March 8, 1967. The LBJA study results are presently being reviewed by the Human Factors Engineering Section (R-P&VE-VAH) for technical accuracy and feasibility.

IV. Planetary

A. Manned Planetary Fly-by Joint Action Group (JAG)

A 10-man commitment has been made by this Office to support the effort required to update the Planetary JAG report published last October. This level of effort will last until approximately April 15, 1967, at which time MSFC will submit inputs to the report. The planned approach to the study is to review and check the DAC method of modifying the S-IVB to be an S-IVC stage. Present performance of the S-IVC stage, assuming a 180,000-pound spacecraft, indicates that an improved launch vehicle will be required for this mission.

Work has been initiated to size the booster needed to launch the various pieces of an Orbit Launch Vehicle which uses three S-IVC stages. Payload weight summaries for each of the four required launch vehicles will be prepared. Configuration drawings showing the earth launch vehicle configurations, the orbital assembly sequence of the orbit launch vehicle, the modification to the S-IVB stage to achieve the S-IVC, and the modifications to the standard Saturn V launch vehicle to achieve the required booster will also be prepared.

This Office is responsible for defining the planetary probes for the continued in-house JAG effort. The results of the effort are to be included in the final JAG report, due in May 1967. Efforts completed to date are the selections of probe complements for four selected missions in 1975, 1977, 1978, and 1979. Also, conceptual designs were initiated on these probes. Some results were presented during the JAG program review meeting on March 28, 1967, at MSFC.

B. Manned Mars Excursion Module

The effort to conceptually define a Mars Excursion Module (MEM) is being continued. The primary subsystems associated with the MEM have been defined in terms of weight, power requirements, and volume. Primary propulsion systems have also been defined.

Propulsion systems have been sized for various combinations of liquid propellants. Combinations selected for study were LO_2/LH_2, OF_2/MMH, N_2O_4/N_2H_4, and $N_2O_4/N_2O_4/N_2H_4\text{-}B_e$. The $N_2O_4/N_2H_4\text{-}B_e$ combination has tentatively been selected for additional study. A solid propulsion system, using a composite propellant with a Beryllium additive, was also evaluated; however, it did not appear to offer any significant advantages.

C. Mars/Venus Fly-by Study Programs

The two-stage studies for investigating the Orbital Launch Vehicle Application for the Mars/Venus Fly-by mission are complete and the final presentation is scheduled for April 5, 1967, at MSFC. Personnel from this Office have been working with the two contractors (NAA and DAC) finalizing stage data formats and reviewing drafts of the final report.

The Mars/Venus Fly-by Mission Study task schedule has been modified to provide information on scientific objectives, experiments, and probes. This will cover orbiter, atmospheric, and surface type probes and their supporting systems. This information will supplement the work being performed in-house for the Planetary JAG exercise.

D. Mars Surface Sample Return Probe (MSSR)

The effort to conceptually define a MSSR probe has been completed. The results of this effort are being compiled and will be published in a NASA-CR (Contractor Report).

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Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-67-3

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

March 1, 1967 through March 31, 1967

Saturn IB and Saturn V Component Qualification Test Program

Test reports are being reviewed of all critical propulsion components for each stage of the Saturn IB/V to determine if the components are qualified. Status of the review is:

STAGE	NO. OF COMPONENTS	REPORTS RECEIVED	REPORTS REVIEWED	REPORTS ACCEPTABLE
	To be Reviewed			
S-IC	73	65	31	31
S-IB	54	0	0	0
S-II	109	16	9	9
S-IVB	67	35	20	16
TOTAL	303	116	60	56

SATURN IB

I. S-IB Stage

A. H-1 ENGINE

1. Prevalve Operation for Saturn IB Analyzed

Analysis of data from the H-1 engine prevalve shutdown tests indicates that satisfactory prevalve shutdowns should be obtained using the LOX prevalve closing time range investigated.

2. S-IB Hydraulic Package Modified

Two S-IB hydraulic packages were modified to eliminate the accumulator sleeve. This modification reduces the path for nitrogen leakage into the hydraulic fluid. The units will be tested to determine if the one-piece dome design will solve the nitrogen leakage problem.

B. Thrusters and Panels for MSFC Experiment No. 2

Thrusters for MSFC Experiment No. 2 were received, all the equipment needed to assemble the experiment panels was acquired, and the assembly procedure for the Experiment No. 2 panel was prepared. From the electrical checkout of the thrusters, it was discovered that more than half failed the 50-megohm insulation resistance requirements. The thrusters were rejected and returned to the vendor. No schedule impact is expected.

II. S-IVB Stage

AS-206 Passivation Experiment

The feasibility of using the J-2 engine as a means of rapidly depleting residual propellants, is being proposed for AS-204 as a result of reassignment of the AS-206 launch vehicle. This experiment will provide valuable data for determining the applicability of dumping residual propellants through the J-2 engine for the Orbital Workshop mission, as well as for the S-IVB/IB and V.

SATURN V

I. S-IC Stage

A. F-1 ENGINE

1. R&D Engine Tests at EFL

Sixteen tests were conducted, and a total duration of 2185.9 seconds was accumulated. Ten of these tests were full-duration (150 seconds or more) runs. One test was terminated prematurely.

2. Production Engine Testing at EFL

Seven tests were conducted, and a total duration of 547.3 seconds was accumulated. Two of these tests were full-duration runs.

3. Component Qualification Test Reports

Revisions to eighteen F-1 Component Qualification Test Reports were reviewed. These revisions satisfactorily completed all of the changes requested to date, except the changes to the Main LOX Valve and Hydraulic Control Valve reports. The test report for the High Reliability Pressure Transducer is being reviewed at MSFC. The only

F-1 component which has not completed qualification testing is the High Reliability Temperature Transducer. This transducer is presently accumulating engine test time before qualification testing.

4. F-1 Engine Land Transport Test

F-1 Engine F-6049 was recently trucked from Canoga Park, California to MSFC to determine the effects of this type transportation on the engine. Upon arrival, the engine was subjected to receiving inspection prior to being fired in the single engine test stand. No significant discrepancies were found that could be attributed to the transportation. The engine was subjected to a 40-second static firing. Analysis of the data from this test indicates that the engine thrust was 1494K as compared to 1519K at Edwards AFB No specific cause for the thrust shift has been determined. The engine will be reorificed and fired again.

5. Engine Contamination S-IC-1

Inspection of the S-IC-1 engines following failure of three bellows sections in facility lines that supply nitrogen purges to the engine LOX systems revealed no contamination from the ruptured bellows sections. However, a small bolt was found on the top side of the injector plate of the center engine. Investigation indicated that the bolt entered into the LOX system from an external source downstream of the LOX tank screen. The extent of damage to the bolt indicated that no further inspection of the engine was necessary. The decision was made that no further inspection for contamination was required on the S-IC-1 stage and the engine system.

6. Gimbal System Flight Supply Line Test

The vibration portion of the qualification test for the gimbal system flight supply line, 20M55058, was successfully rerun. In the original qualification test, the specification vibration levels could not be obtained because of equipment limitations. The re-test was conducted using a larger vibration machine, and the specified vibration levels were obtained. The line was subjected to a burst test after the vibration. The burst pressure was 11,750 psig, which is substantially more than the specified minimum value of 8,800 psig.

B. Review of ECP 0183P (S-IC-2 and Subs)

An ECP concerning installation of improved anti-vortex plates in the S-IC fuel tanks, was reviewed and accepted, except a maximum liquid level slosh and surface inclination of 1.5 inches should be used in calculations rather than 4.6 inches. This would decrease fuel residual by an additional 3500 pounds.

C. Ordnance Testing

Twenty CDF initiators were exposed to a range of high temperatures for 2 hours, cooled and fired in an SPs 45C closed bomb. The results of this test showed that the maximum temperature at which the initiator will function within the specified limits is 275° for 2 hours.

II. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Twenty-four tests were conducted, and a total of 3419 seconds was accumulated. Two tests were terminated prematurely, because the ASI ignition was not detected (bent probe).

2. Production Engine Tests at SSFL

Eleven tests were conducted, and a total of 2130 seconds was accumulated. Two tests were full-duration runs.

3. Engine Testing at AEDC

Fourteen tests in four separate periods were conducted at AEDC. Three of these tests were S-IVB/501 first-burn simulations. These tests evaluated maximum build-up time and fuel prevalve opening sequence. Six tests were conducted after quick turn arounds to simulate a Saturn V restart with a hot turbine exhaust system from a previous test. Five of the tests had turbine exhaust system temperatures like those expected on S-IVB/501 and one had temperatures expected on S-IVB/504. Gas generator temperatures achieved were within the acceptable operating region of the engine in all cases. Five S-IVB/501 restart tests were conducted, evaluating hot thrust chambers on three tests, maximum build up time on one test, and ASI erosion on one test. A total time of 238.5 seconds, 175 seconds at 5.5 mixture ratio, were accumulated on J-2 Engine 2052 at AEDC. A total of 44 tests for 744 seconds has been accumulated on J-2052 at AEDC to date.

4. Component Qualification

Final test reports for thirty-four of the thirty-six J-2 engine components to be qualified have been received. Comments to 31 test reports have been submitted and test reports for the Oxidizer Turbine By-Pass Main LOX, and Main Fuel Valve are being reviewed. The PU Valve and the Start Tank Discharge Valve are presently being subjected to the qualification test series.

5. Ignition Detector Analysis

An analysis of the J-2 engine ignition detection system was conducted along with an analysis of the potential explosive hazard if ignition did not occur. The results indicate that a remote possibility of an explosion exists if ignition fails to occur or does not occur normally. Therefore, it is necessary that a reliable ignition detection system be used. The reliability of the current ignition detector is not adequate for flight and is in need of improvement before the first manned Saturn V flight.

6. J-2 Engine Analog Simulation

A J-2 analog computer model was developed for use with the J-2 engine altitude test program at Tullahoma. The model was checked out and compared with the available test data from the Tullahoma tests. This checkout shows that the analog model matches test data within 2 percent and reflects all engine trends during the start transient of the first or second burn. The analog model will be used to evaluate potential improvement of the J-2 engine to provide restart flexibility and eliminate present environmental restraints.

7. Engine Gimbal System Pump Tests

Design verification tests were continued on three S-II EGS main pumps. The first specimen has completed all tests except vibration and life cycle with no apparent deterioration of performance.

8. Engine Gimbal System ARMA Tests

Tests continued on the S-II ARMA with 5000 of a required 10,000 life cycles being completed.

9. Shear Test of J-2 Engine Quill Shafts

Torsional Shear tests at 800°F were completed on two J-2 Engine Quill Shafts. This shaft connects the LOX turbine with the main hydraulic pump. Results were the same for both shafts. Neither shaft failed when a torque (2640 in-lbs) 65 percent in excess of the 1600 in-lbs limit specified by the engine contractor.

10. Engine Precant Problem

The single outstanding problem, with regard to the established 1.8° outboard precant to be used on S-II-1, is the J-2 scissor-inlet bellows. Although the outboard corner command to 10.6° is not likely to occur on S-II-1, the possibility does exist both on the ground during checkout and in flight (at separation). Should this occur, the J-2 engine scissor bellows may be overstressed to the point of failure (due to the 10.6° being added to the 1.8° in the outboard direction). To preclude the possibility of this, the use of mechanical actuator stops is highly recommended. These mechanical stops are in the process of being designed/manufactured for S-II-1, which will limit the outboard corner travel to 8.3° for ground and flight operations.

B. LOX Vent Valves

The S-II LOX vent valves oscillated severely during S-II-1 operations at Mississippi Test Facility (MTF) and also on the battleship. Testing on the S-II battleship using LOX container ullage sensing for vent valve operation, rather than valve upstream pressure, proved successful in reducing the poppet chatter problem.

C. Verification Testing of S-II Accumulator Reservoir Manifold Assembly (ARMA)

The filter, proof pressure, functional, high and low temperature and vibration tests were completed with the assembly performing satisfactorily. The life cycle test is in process now. 3000 life cycles were completed, 12, 500 cycles are required.

D. LH_2 Stratification

The S-II-1 Acceptance Firing data were correlated with the fuel stratification prediction model used for S-IVB Net Positive Suction Head (NPSH) predictions and found to be in generally good agreement. The prediction technique was compared with the stage contractor correlation, and the two methods are generally agreeable except during terminal draining. The stage contractor has agreed to use the MSFC prediction for S-II-4 design criteria in conjunction with the S-II-4 tank pressure reduction. Additional data are required to improve the predictions for terminal draining, and the S-II-2 propellant loads were modified to obtain this data.

E. Ullage Motor Replacement

An investigation was made to determine the impact on propellant behavior of replacing the S-II ullage motors with the TX-280 (S-IVB) ullage motors. The present maximum predicted fluid motion amplification factor of 2.5 is increased to 6.0 when the TX-280 motors are used. The expected S-II slosh height at S-IC cutoff is 1 - 2 inches, and the increase in slosh amplification is not significant. From a fluid mechanics and thermodynamics standpoint, the TX-280 ullage motors are acceptable.

F. LH_2 Tank Venting Thrust During S-II/S-IVB Separation

A study was made to determine what influence the reaction of the S-II LH_2 residuals will have on the magnitude of the venting thrust during separation. The results indicate that the maximum thrust attainable before complete interstage separation is 180 lbf and is caused by the pressurization system. The bulk of the LH_2 tank residuals will impact the upper dome 1.5 seconds after retro rocket ignition and could cause an increase in the venting thrust. Since the J-2 engine bell clears the interstage in one second after retro rocket ignition, the influence of wetting the upper dome on vent thrust magnitude is irrelevant to stage orientation during S-II/S-IVB separation.

III. S-IVB Stage

A. Engine Gimbal System Arma Tests

Cycle tests at different temperatures were conducted on three accumulator reservoir manifold assemblies to aid in determining reasons for reservoir piston O-ring failures. Tests to date show that high temperatures (275°F and up) have a definite influence on the cycle life of the seal backup ring.

B. O_2/H_2 Burner Thermal Analysis

A thermal analysis to predict temperatures of the O_2/H_2 burner after 4 1/2 hours of orbital coast were completed. Average burner temperatures were -150°F. This is significantly lower than the minimum -85°F temperature currently specified for flight qualification of the O_2/H_2 burner. The use of thermal coatings to raise burner temperatures during orbital coast will be investigated. Preliminary estimates show that, with thermal coatings, the minimum burner temperature will be approximately -120°F.

C. O_2/H_2 Burner Testing

The performance inprovement test series was completed, and the modified, higher pressure burner was selected for production. This configuration has demonstrated reliable ignition and combustion with no injector icing problems. Due to schedule constraints, it will not be possible to use this burner for acceptance testing S-IVB 503 (new). Pre-QUAL testing will begin in April. A total of 92 firings with two burners is scheduled for a three-month program.

D. C-1 Engine (APS) Tests at MSFC

The single engine tests of the C-1 Engine at MSFC were concluded for the Block I design. During this period the engine was run with GHe saturated propellants at inlet temperature from 40°F to 100°F. The results of these tests indicated that there is no significant change in the pressure oscillations that were previously observed. Tests were also conducted to determine the effect of varying the chamber pressure from 80 psia up to 100 psia. The amplitude of the oscillation decreased as the pressure was increased and also damped out much faster. At a chamber pressure of 100 psia, the only oscillations observed were in the start transient. Three of the engines will be placed in a Saturn V S-IVB APS module and tested in the vacuum chamber. The purpose of these tests will be to determine the system effects on the performance of the engine and to compare the performance with that of the present Tapco engines.

E. The S-IVB/501 Continuous Vent Thrust Accuracy Requirements

The maximum average continuous vent thrust variation was determined to be 12 pounds. This limit assumes a failure of the spacecraft propulsion system, which results in a reentry acceleration of 20 g's. Steep reentry angles and high accelerations are the result of thrust predictions lower than the actual thrust. Vent thrust variations exceeding the allowable 12 pounds are not anticipated.

F. Acceptance Firing of Saturn V/S-IVB

The S-IVB-503 acceptance firing will be changed from the planned two-burn firing to a single-burn firing. The stage will be tanked to 100 percent less, approximately 4000 pounds of orbital boil-off LH_2, and fired for the full duration. J-2 engine gimbaling will be included in this test. The mainstage firing will be followed by a repressurization test of the O_2/H_2 burner with approximately 70 percent propellant loading. This change in the test plan will delay the acceptance firing of S-IVB-503 by one week; however, this delay is not expected to have an impact on the presently required delivery date.

G. Propellant Management System

A cracked weld on the bottom support mounting bracket of the S-IVB stage LH_2 probe was discovered by the probe vendor. Subsequent review of probes already installed in S-IVB vehicles indicated that all probes were susceptible to the cracked welds. These cracks resulted from an apparent deficiency in quality control. The stage contractor has decided to reinforce the welds on all probe mounts with rivets. All probes will be reworked and all future probes manufactured by the vendor will have the rivets installed. This rework will not affect the Propellant Utilization system in any way and the calibration will remain valid on all stages that have been static fired.

IV. Instrument Unit

A. Methanol/Water Corrosion Blamed for Failures

The presence of hydrogen within the Launch Vehicle Data Adapter (LVDA) has caused failures in the LVDA. The suspected source for the H_2 is the coolant passages, where H_2 is a by-product of corrosion. The H_2 leaks from the coolant passages into LVDA electronics section. Several possible solutions are under investigation:

1. Replacement of internal teflon flexible hose with stainless steel flexible hose.

2. Purge of LVDA/LVDC case with GN_2.

3. Use of different coolant.

4. Install H_2 absorbers in coolant line or LVDA/LVDC cases.

5. Change LVDA/LVDC coolant passage materials.

6. Coat H_2 susceptible components.

B. ST-124 Thermal-Vacuum Tests

Thermal-vacuum tests of the ST-124 indicate that temperature specifications will be exceeded only in hot orbits. Results of the tests also indicate that a drop in the Methanol/Water (M/W) average temperature will maintain the ST-124 within temperature specifications under all orbital thermal conditions. The desired temperature drop requires a change in the sublimator M/W and water control circuits. This change is being incorporated.

C. Sublimator Acceptance Test

Sublimator SN 019 completed the acceptance and production reliability tests. Sublimator SN 021 completed the acceptance test and should complete the production reliability test by March 30. Sublimator SN 014 and SN 020 are on hand for acceptance testing only.

SPECIAL STUDIES

I. Voyager Program

The conceptual design phase of the voyager program has started. Several designs are undergoing evaluation before a selection of two candidates each of the liquid and solid concepts.

II. Lunar Wheel and Drive Program

The harmonic drive and wire-frame wheel test articles were subjected to the planned thermal-vacuum tests by ACDRL. Two harmonic drives were tested; one went through approximately 13,000 cycles and the other about 45,000 cycles before the tests were terminated due to failures in the drive units. A common problem with both units was galling of the gear teeth in the flexspline and circular spline area. The first unit also developed a crack at the flexspline early in the test.

The thermal vacuum test on the nutator drive and metal-elastic wheel test articles was delayed due to a discrepancy that developed in the nutator drive during checkout tests. Spare parts are available; however, a redesign is required to alleviate the problem of high radial loads on the nutator diaphragm. To expedite the start of the test on the metal elastic wheel, ACDRL is also considering procuring another harmonic drive unit.

III. Apollo Telescope Mount (ATM)

The present Lunar Module (LM) Reaction Control System (RCS) engines impinge directly on the ATM rack and solar panels, causing intolerable heating and thrust loss. Investigation of various solutions have shown that:

A. Movement of RCS engines to the rack causes a large weight penalty and will not solve the impingement heating problem if the ATM experiment package is lowered another 22 inches, as presently planned. Also, this is a very expensive task that would require a lengthy qualification test program.

B. Casting the engines 20° does not significantly help the heating or thrust loss problem.

C. With the solar panels in the stowed position, 16-inch by 42-inch exhaust deflectors will solve the heating problems and cause only about five percent loss in thrust. Thrust deflectors will reduce the heating and thrust loss somewhat with the panels deployed. Heating is tolerable for an RCS firing time of 10 seconds, and probably for as long as 15 or 20 seconds. Thrust loss is 40 - 50 percent, as compared to 60 - 70 percent without deflectors. The LM/ATM control capability will be determined with panels deployed; exhaust deflectors will be used. Installation designs will be developed for LM and rack mounting and the best arrangement will be selected. The design for retractable solar panels will panels will be prepared but will not be implement unless it is determined that the LM/ATM is not controllable with panels deployed.

D. Panel retraction is more desirable than providing a hole in the panels.

E. A contamination shield between solar panels is not considered to be feasible if retraction capability is provided.

IV. Spar Thermal Deflection Test

This test is being run to determine the deflection in the spar caused by thermal gradients. All hardware has been designed for this test and fabrication is approximately 50 percent complete.

V. Thermal Control Systems Test of an Individual Quadrant

This test is being run to determine the adequacy of the thermal control system design. The quadrant being simulated contains the AS&E and NRL-A experiments and the PCS solar sensor. Design of the hardware is complete and fabrication is approximately 30 percent complete. Design of the insulation system has started.

VI. Project Thermo

A survey of literature was conducted to find another fluid with desirable properties to use with water in the two-fluid simulation experiment. It appears that Dow Oil No. 510 has desirable properties.

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

The break-in, calibration, pressure control, dynamic response, and pressure cycling tests at ambient conditions were completed on the Vickers Pump, SN MX71941. Although the recorded test data did not indicate any significant changes in pump performance during this test period, there were signs of pump wear as revealed by the filter patch tests. The test setup is now being modified for the low temperature test series.

VIII. Laser Velocimeter

The design of the discreet sampling circuitry was finalized and is being packaged. The system will have an operating range of up to 850 KH with interchangeable filter circuits. Additional data were obtained at the upper flow rates and is being processed.

IX. Fluid Transients in Low Gravity Fields

The interface test package and slosh-impulse test package was tested successfully. The problem previously experienced with the camera real time generator was corrected. The Dyna-tech test package is being modified for future testing.

X. Investigation of Brazed and Welded Tube Connectors

Twenty-four of the 1/4-inch tubing specimens have completed room temperature resonance dwell vibration tests. All 3/8-inch tubing specimens have completed post-impulse leakage tests. Thirty-six of the 3/4-inch tubing specimens were cut, flared, and fitted before proof and leak testing.

XI. Orbital Workshop

A. LH_2 Tank Thermal Control System

1. Fire Retardant Liner Emittance Value

Since internal radiant exchange is a significant mode of heat transfer that results in reduction of wall temperature gradients, a decision was made to incorporate an aluminum foil, fire retardant liner that has an emittance value of approximately .05. This will significantly affect the Orbital Workshop thermal control system performance, and studies are in progress to parametrically assess the effect of the lower emittance values.

2. Crew Comfort and Predicted Environment Compatibility

Studies to evaluate the Thermal Control System (TCS) performance for the anticipated mission A and B orientations are continuing. Preliminary results from these studies indicate that the TCS cannot accommodate crew comfort requirements (thermal and specific humidity) for both missions and yet provide the required heat rejection. This problem is further aggravated by the potential insulation conductivity variation that is caused by H_e/H_2 diffusion into and out of the insulation barrier. Further studies will be conducted to determine the magnitude of incompatibility with predicted and required values.

XII. Multiple Docking Adapter (MDA)

A study to predict MDA inner wall temperatures near the meteoroid shield and radiator supports was completed. The studies were conducted for a constant solar input of 3.7 Btu/ft^2 hr (deep space) or a radiator temperature of -30°F. These data show that the continuous support design results in temperatures significantly lower than the 50°F minimum allowable temperature, and to raise predicted wall temperatures above the allowable temperature by reducing contact area, the contact area must be less than 1/100 of the original area. A more refined analysis considering conduction along the inner wall is being conducted.

A thermal analysis of the MDA window design shows that predicted temperatures of the inner glass exceed the allowable limits of 50°F to 90°F. For a cabin wall temperature between 60° and 90°F, a cabin wall emissivity of 0.8, and a window shield emissivity of 0.2; the predicted inner glass temperatures were 55° to 110°F.

ADVANCED PROPULSION AND TECHNOLOGY

I. J-2X Engine Program

Testing of the J-2X 013 engine has increased the total accumulative firing time to over 1900 seconds during more than 40 tests. Salient features of the 013 engine system are parallel turbine drive and PU control of the fuel supply by a fuel pump recycle system. Primary objectives successfully demonstrated include deep throttling (8 percent of nominal thrust level), tank head start (starting transients of 5.4 seconds), and PU control at constant MR for the engine.

The supporting component development has progressed with emphasis on the MK 29 fuel pump (scheduled for immediate 013 engine installation), initiation of a subcontract for inflatable nozzle extension, wind tunnel analysis of nozzle extension concepts, and solid propellant turbine spinner technology.

II. Systems and Dynamics Investigation (AEA)

The fabrication and assembly of the aerospike solid wall thrust chamber and injector was completed and installed in the test stand. The fabrication of the stainless steel tube wall thrust chamber is nearly completed. The nickel tube wall thrust chamber is being fabricated.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-S-67-3

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(March 1, 1967 - March 31, 1967)

SATURN IB

Saturn IB System

A pull test was conducted on AS-204 to experimentally determine the strain to load relationship for the LOX studs located at Station 942. This constant is required for computing bending moment. The evaluation of the test results indicated the test was successful.

SATURN V

I. S-II Stage

A. SII/S-ICS Test Configuration

A design layout has been completed for joining the S-II and S-IC-S test sections.

B. LH_2 Feedline Elbow Test

The second S-II-5 feedline elbow was received and inspected. A small crack was found and removed and the fitting installed. Approximately forty bolts were waived for improper installation. The elbow was pressure tested during the week and successfully withstood 131 percent limit pressure (41.6 psig).

C. LH_2 Vent Line

A vibration analysis and a structural analysis were accomplished to determine if laboratory vibration qualification testing at S&ID on the S-II-4 configuration of the LH_2 vent line was satisfactory to qualify the S-II-1 configuration. The results of these analyses showed that vibration qualification of the S-II-4 configuration would satisfy the requirements of the S-II-1 configuration by dynamic similarity.

D. Cracked Lox Vent Line in the S-II-F/D Vehicle

The S-II stage facility vehicle Lox vent line, inside the Lox tank failed during dynamic testing. S&ID and MSFC dynamics groups are assessing the Lox vent line failure on the DTV. Visual inspection of the failure revealed a crack in the center part of the duct. This crack is in the circumferential direction about 16 inches long, which is approximately 180 degrees around the line. Metallurgical investigation revealed that the cause of failure was fatigue. It was recommended that the Lox vent line in the S-II-1 stage of the AS-501 vehicle at KSC and the S-II-2 stage at MTF be inspected.

E. S-II Lox Vent Line Stress Concentration Test

A tensile test was conducted on a segment of S-II Lox vent line, which contained several circumferential offset welds, to determine the stress concentrations resulting from the offset. The specimen was loaded to 45,000 pounds. Good welds and offset welds were instrumented to obtain a basis for comparison of stresses. Instrumentation included strain gages and "Photostress."

1. Evaluation of the test indicated that 100% offset or mismatch gives a stress concentration factor of 2.5 at operating stress levels. The 50% peaking was the worst defect, indicating a concentration factor of more than 3 at operating stress levels.

2. A stress analysis has been completed and the results indicated that the stress concentration due to offset and peaking is more than twice as high as the results of the concentration test.

3. Based on the analysis and the test, the Structures Division agreed to accept an offset of 70% of the minimum thickness and a 60% peaking for the center third of the line, and an offset

of 100% of the minimum thickness and a 80% peaking for the ends of the line.

F. S-II Simulated Ullage Motor Test

The S-II simulated ullage motor test was successfully completed at MSFC's Structural Test Laboratory March 16 and 17, 1967. The test specimen utilized for this program was the S-II high force test interstage specimen. Two loading conditions were simulated: (1) Eight motors firing, loaded in increments to 130% of maximum motor thrust during flight, and (2) seven motors firing, loaded in increments to 130% of maximum motor thrust during flight. This test structurally qualified the S-II interstage for AS-501 flight.

G. Safe and Arming Device Isolator Mount Evaluation Tests

Sine and random vibration tests were completed in the Vibration and Acoustics Branch test facility on four types of vibration isolators to evaluate their performance for use with the safety and arming device on the Saturn V, S-II stage. Isolators from Lord Manufacturing Company, Barry Controls, Robinson Vibrashock, and Firestone Rubber Company were subjected to pre-determined levels along the X, Y, and Z axes while supporting the safety and arming device. The Lord and Robinson mounts survived the tests although they showed some deterioration. The remaining two isolators failed during tests.

H. Instrumentation Requirements

Vibration and Acoustics Branch personnel met with North American Aviation personnel at Seal Beach, California to establish joint requirements for static firing instrumentation for stages S-II-504 and subs. The established requirements, containing a total of 90 vibration, acoustic, and strain measurements, will be implemented under existing change order 489.

I. Change Order 351 Testing

Seven tests were successfully completed during this reporting period. They are as follows:

1. SLTR-14, LOX inboard feedline completed March 2, 1967.

2. SLTR-4, LOX fill and drain line completed March 7, 1967.

3. SLTR-2, LOX tank pressure system completed March 8, 1967.

4. SLTR-9, recirculation actuation system completed March 8, 1967.

5. SLTR-24a, LOX destruct assembly completed March 10, 1967.

6. SLTR-7, LH_2 vent assembly, completed March 15, 1967.

7. SLTR-21, LH_2 recirculation lines completed March 18, 1967.

II. S-IVB Stage

A meeting was held with representatives of DAC, IBM, and Industrial Operations on March 23, 1967, to discuss interface joint tests on the S-IVB stage. The following decisions were made.

1. Station 3222: IBM and DAC will furnish hardware to MSFC for five joint tests.

2. Station 3100: DAC will test five specimens.

3. Station 2832: DAC will test five specimens.

4. Station 2746: The joint has been previously tested with both panels and full scale hardware. Results will be carefully reviewed to determine capability.

5. Station 2519: The bolt size will be increased to 3/8 inch diameter. Three specimens will be tested by DAC with new bolts. Bolts will be A-286 material with 200 ksi heat treat.

III. Saturn V System

Saturn V Damping System

The primary damper system for the Mobile Launcher I was shipped to Kennedy Space Center for installation. Design liaison support was furnished for one week. No major problems were encountered. The primary damper system has not been installed.

The auxiliary damper system has been tested and is presently being inspected by Quality Laboratory prior to shipment to KSC.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

A deflection analysis of the LEM Ascent Stage and SLA at the point of minimum clearance between the two has been completed. The results of the analysis indicate a total deflection of .62". The minimum clearance which is in the area of the Rendezvous Radar Antenna is believed to be 1.50" in the unloaded condition.

II. Rack/ATM

Detail design of the ATM Rack structure is being continued. At the request of the Astrionics Laboratory, a study was made of modifications to the rack structure to permit astronaut access to the experiment package. Two concepts were furnished for mock-up purposes.

Conceptual design layouts for the solar panel location relative to the rack were received from Astrionics. These layouts showed the hinge line located 11 inches below the base of the rack instead of the 8 inches previously agreed upon and a structural concept was devised for the relocated hinge line.

III. Rack/AS-504C

Documentation of the AS-504C Rack configuration was resumed and completed as requested by the Propulsion and Vehicle Engineering Laboratory Project Office. The structural parts providing attachment of the PM experiment have been revised to coincide with the drill fixtures provided by MSFC. The drawing release list (DRL)effectivity was changed from AS-504 to a special purpose DRL number.

IV. Cluster Concept

A. Multiple Docking Adapter (MDA)

Layouts of the pressure shell, axial docking port, and drogue mounted radial ports have been completed. The layouts were given a cursory stress check; however, the thermal analysis has not been completed and changes are anticipated as a result of this analysis. All changes resulting from the coordination meeting with McDonnell representatives on March 16 have been incorporated into these layouts.

B. MDA Loads Analysis

Final loads factors have tentatively been agreed upon. A loads analysis of the MDA was done for all launch and docking loads. Critical load cases were defined for various portions of the MDA.

ADVANCED PROJECTS

I. Nutator Drive Test Program

Contract NAS8-20378, Nutator Drive Experimental Test Program, was signed by MSFC on March 13, 1967. Bendix Corporation, Aerospace Systems Division, will be attempting to design, procure, and test a nutator drive unit within a four-month period.

II. Saturn V Voyager

A. Voyager Shroud

A discontinuity analysis of the upper bulkhead-cylindrical shroud joint and a second configuration of the payload support cone-cylindrical shroud joint has been completed. An analysis to determine the motion of the Voyager shroud during separation in space has been initiated. The theory is completed and is now being programmed for solution on a digital computer. A resizing effort has been completed for the shroud and nose cone utilizing the structural loads for the 45-foot shroud. Four preliminary design concepts for the shroud separation system have been completed. Work is continuing on the problem of shroud and spacecraft separation clearances. Detail design drawings of the frustum portion of the nose cone, utilizing honeycomb, to support the research and development effort on large shrouds have been completed.

B. Voyager Spacecraft

A concept of a liquid engine Voyager spacecraft has been prepared and presented at the Propulsion and Vehicle Engineering Laboratory status review meeting on March 23, 1967. This concept is for study purposes and will be modified as more design criteria and information become available.

III. Project Thermo

The preliminary design drawings of the rack structure for Project Thermo were completed. This rack design is similar to the ATM Rack instead of the PM Rack that was initially used as the base line configuration.

IV. Nuclear Ground Test Module

A design layout for the tail section was prepared. Coordination meetings were held with other design elements regarding umbilical locations, suction lines, fill and drain, etc. The support bracket for the emergency cool down line is being investigated. Preliminary strength studies indicate that the elliptical head rather than the conical head is better structurally. These head configurations are still being evaluated. An elliptical head indicates approximately 50 inches savings in the length of the flight vehicle.

V. Crew Motion Study

Laboratory testing is in progress in the vibration and acoustics testing facilities of Structures Division to determine the feasibility of measuring the forces exerted on the spacecraft by crew motion and to determine the possibility of reducing or eliminating these forces by isolating the crew from the spacecraft. Preliminary results indicate that crew motion forces can be measured in the laboratory and parametric studies are underway to evaluate various mechanisms of isolation.

VI. Lunar Wheel and Drive Test Program

A. Testing Status

1. Final test specification and schedule have been

received from General Motors.

2. AC Defense Research Laboratories' thermal/vacuum testing on the harmonic drive/wire wheel has been prematurely completed due to failure of the drive spline gear in both test units. Failure seems to be associated with a breakdown in lubrication with consequent excessive wearing of the spline teeth.

B. Program Approach

1. Because of the above failure in the Lunar Wheel and Drive Test Program, AC-DRL is following two courses in selecting a successful drive unit to couple with the metal elastic wheel for completion of the thermal/vacuum testing.

2. One approach is to procure a harmonic drive unit by March 27, 1967, from United Shoe Machinery Corporation. This unit will be modified from the two initial units in that there will be a larger tolerance existing on the spline gear assembly and a different method of lubrication will be tried.

3. The second approach lies in modifying the nutator drive unit to reduce its inefficiencies. Two proposed changes are as follows: (1) Replace the critical input shaft bearing with a double-row bearing, and (2) relocate the nutation center on the input shaft. The above two changes require a new input shaft, which has been manufactured. In the event that the above proposals do not prove successful, a chem milling of the diaphragm assembly to reduce its stiffness will be tried.

4. Both of the above approaches must be completed by March 25, 1967, when it will be decided which drive will be put in the vacuum chamber. Tentative plans call for completing all vacuum testing under the wheel and drive program by March 31, 1967.

G A Kroll

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Note: Reference to the Document Monthly Progress Report (March 1st 1967 through March 31st 1967) following are the missing pages.
Page Nos – 32, 44, & 56.