PROPULSION AND VEHICLE ENGINEERING LABORATORY

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MONTHLY PROGRESS REPORT

For Period

November 1, 1967, Through November 30, 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-67-11

MONTHLY PROGRESS REPORT

(November 1, 1967, Through November 30, 1967)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-67-11

MONTHLY PROGRESS REPORT

ADVANCED STUDIES OFFICE

(November 1, 1967, Through November 30, 1967)

SATURN V

Voyager Studies

A. Baseline Spacecraft Design

1. R-P&VE Spacecraft Design Status --- Phase I of the spacecraft design study has been documented and submitted to Laboratory management for review and approval. This study, which identifies the 140-inch-diameter baseline configuration, will be published as Internal Note IN-P&VE-A-67-8.

2. Spacecraft Structural Analysis --- Weight comparisons between three structural concepts for the Voyager-class spacecraft are being continued as a structural technology study. For these concepts, which were described in the October Progress Report, various structural members are being sized using the Structural Engineering System Solver, a computer program developed for the IBM 1130. Results of this study should be available during the second week in December.

3. Miscellaneous Spacecraft Design Data Compilation --- It is planned, for future reference, to compile pertinent spacecraft design data and memorandums that are not contained in other reports. All inputs have now been gathered and incorporated into a draft copy of the report, which has been circulated for management review. The final manuscript is now being prepared.

B. Alternate Spacecraft Design Studies

1. 260-inch-diameter Spacecraft Concept --- The first draft of a proposed Internal Note has been written and is being reviewed by the input originators. Publication of the report has been delayed until mid-December.

2. Shroud for Voyager-type Payloads --- The impact on the 140-inch-diameter "baseline" Voyager shroud, created by changing the diameter of the spacecraft from 140 inches to 260 inches, has been assessed and the results are being documented in a forthcoming MSFC Internal Note. Functionally, the shroud is unchanged and is characterized by the following: (1) shorter length; (2) the spacecraft external structure is an integral part of the shroud; and (3) conduits, umbilicals, and access are on the spacecraft. Launch vehicle loads are reduced since the 260-inch concept results in a length reduction of approximately four feet; separation is simplified. The cylindrical sections (including spacecraft) are of aluminum honeycomb sandwich construction and the double-angle nose cone is aluminum skin and stringer. Vent system requirements are unchanged.

3. Thermal Analyses of Shroud for Mars Missions --- The impact on payload shrouds created by utilizing radioisotope thermoelectric generators (RTGs) for power sources on enclosed payloads has been examined. As a baseline, four RTGs of 3000 thermal watts each were assumed. These units were located at different positions so that the "worst case" condition might be determined. The basic questions were the following: (1) is an active heat exchange device required to dissipate the thermal energy generated by the RTG, and, if so, (2) what is the nature of the device, i.e., its physical location(s) and design, and general impact on the structural and functional design of the shroud? This effort has been concluded, and the results documented in BECO Summary Report PVEL-28436-1, "Thermal Analyses of Enclosed Payload Containers," dated October 27, 1967. It was concluded that the spacecraft electronic bay and possibly the RTG radiators require cooling during prelaunch operations. Based on preliminary design data the critical components have been identified as the spacecraft batteries which have a maximum operating temperature of 86°F.

C. Program Status Review to Laboratory Management

A briefing to R-P&VE management has been prepared and will be presented as scheduling permits at the weekly P&VE Technical Seminar. This briefing will cover the previous 140-inch-diameter "baseline" spacecraft, the 260-inch-diameter spacecraft, shrouds for each, alternate planetary mission requirements (and the spacecraft's capabilities for performing them), and technology requirements for a 1975 mission.

D. Voyager Missions to Jupiter and Venus

Work is continuing on the preliminary design of a Voyager-type spacecraft for use in probing the outer planets and for use in a Venus swingby/solar probe mission. Completion of this study is presently scheduled for December 8, 1967.

APOLLO APPLICATIONS PROGRAM

I. Earth Orbital

A. Dry S-IVB Austere Workshop (Cluster II)

A conceptual design study of an early austere S-IVB Workshop that will be launched by the Saturn V for Cluster II has been initiated. This concept will make maximum use of the Cluster I Workshop components with minimum resupply. The mission time was assumed to be one year with a three-man crew. Several concept approaches are being developed.

A preliminary experiment program (consisting of experiments proposed, but not planned, for Cluster I, selected EOSS experiments, and several experiments which had been planned but not assigned between Cluster I and EOSS) was selected for initial guidance in the study.

Preliminary subsystems were also selected and a preliminary listing of guidelines and assumptions, functions, metabolic and atmospheric requirements, and recommended approaches has been compiled. A hybrid gaseous-supercritical storage system is being considered for atmospheric supply and pressurization. Cluster I environmental control systems components that might be used are molecular sieves, catalytic burners, debris traps, charcoal and chemisorbent beds, circulation fans, cold plates, etc. A one-year supply of water will be stored in either new or LEM-type tanks. Cluster I solar cell panels and batteries and ATM Control Moment Gyros with the Cluster I auxiliary attitude control system are being considered as the principal power and attitude control systems, respectively. The Communications and Data Management Systems and Instrumentation for Cluster I will be used as a point of departure.

An overall configuration sketch was developed for R-AS which represented a Saturn V-launched non-propulsive S-IVB Workshop/CSM/ MDA/ and ATM proposed as a candidate for a longer lifetime Cluster II mission. In this concept, the MDA would be shortened to provide space in the SLA to accommodate the CSM. The ATM module would be located in the S-IVB/S-II interstage, interfaced with the S-IVB LOX tank and could operate attached to the S-IVB either remotely and manned or remotely and unmanned. Mechanical interface problems associated with these alternate modes of operating the ATM, and, particularly, modifications required to the S-IVB LOX tank, aft skirt, and aft interstage are being investigated.

B. Independent Module Study

The experiments (from the EOSS baseline experiment package) for the independent module study were selected. Both an astronomy and a general-purpose module are being defined. The basic requirements for the selected modules have been outlined and conceptual design sketches are being developed.

C. Earth Orbital Thermal Analysis

Parametric analyses of the primary loop of candidate thermal control systems are being continued with emphasis placed on definition of radiator characteristics and location as affected by alternate attitude orientations and heat rejection requirements. The study is being conducted such that the results would be applicable to requirements of the proposed dry launched S-IVB Workshop for Cluster II.

II. Integration

A. Early Space Station Operational Analysis

Efforts during this reporting period have been concentrated on establishing the tradeoffs that can and should be conducted in investigating a space station's operational requirements. The programmed efforts are being channeled in two principal directions: (1) defining and presenting constraints imposed by orbital and celestial mechanics, and (2) developing the requirements placed on a station by simultaneously conducting a multi-discipline experiment program. In the mechanics portion of the effort the percentage of time a space station is over major land masses and bodies of water versus orbital inclinations was determined. The percentage of time in the South Atlantic Anomaly versus orbital inclination was completed.

Reaction control firing time, coast time, and propellant consumption for various reorientations of a baseline space station (EOSS) were completed. ESCAPE runs were made to evaluate the effects of stellar, solar, and earth pointing constraints on the experiment programs. Also, four experiment sequencing modes have been defined to evaluate the efficiencies of proposed operational options. Rather than scheduling experiments in random order, it may be more logical to group certain disciplines or types of experiments together during each launch interval.

B. Experiment Integration Criteria

Considerable effort has been expended to delineate the detailed requirements and characteristics of discrete experiments in the EOSS baseline experiment package. Comprehensive charts showing the available information on each experiment are being constructed. These data are intended to allow more effective integration of the experiment system into the station system and analysis of the operational characteristics.

III. Lunar Systems

MSFC Mobility Test Program

As a result of meetings between the Technical Services Office, Test Laboratory, and P&VE Laboratory, Technical Services has agreed to prepare three test courses and provide sand for the soft soil course. The three test courses are a scraped, packed soil course, a plowed soil course, and the sand course. Also, existing paved gravel courses will be used. The prepared courses will be located in the Test Laboratory GSE area. Since the prepared courses require dry soil, the course preparation has been delayed because of recent rains. It is anticipated that all courses should be prepared and ready for testing by December 4, 1967.

The three test vehicles, both MTAs and the BECO Mock-up, are ready for testing and the proposed test plan has been submitted to the Test Laboratory. The chase vehicle and data telemetry system are also ready for operation.

At the request of Public Affairs Office, personnel from this Office assisted in the preparation of a short filmed sequence on lunar surface vehicles for the British Television Network, ITV. The BECO Mock-up was driven and films were taken of both MTAs at rest in the Test Laboratory area. Films from our earlier flight test at 1/6 g with the BECO Mock-up were provided and excerpts were included in the eight-minute film.

ADVANCED PROGRAMS

I. Launch Vehicles

A. 660k/Nuclear Vehicle Report

The results of the first phase of the "660k Launch Vehicle" study and the nuclear launch vehicle study have been documented and are now being published in MSFC Internal Note IN-P&VE-A-67-9. This report identifies the concept of the "660k Launch Vehicle" which has a two-stage payload capability of over 660,000 pounds to a 185-km circular orbit and is designed to carry a nuclear stage as the payload. The nuclear vehicle study, which employs the 660k launch vehicle, was to investigate the preferred nuclear orbital launch vehicle configuration and the earth launch vehicle system to support an early Manned Mars Landing Mission, based on the LMSC Phase I nuclear stage design.

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

In a joint effort with R-AERO-X, control, aerodynamic, and separation parameters are being determined for this vehicle. Presently, Nitrogen Tetroxide and Alumizine (N_2O_4/N_2H_4-A143G) has been chosen as the baseline propellant for the pods of the "660k Launch Vehicle." However, the evaluation of other propellants is being continued. Study examinations are to be made to identify the effects of using HY-150 metal for the pod propellant tanks. The pod pressurization system design analysis is continuing and the propellant slosh analysis is also being investigated.

C. Stage Design for Personnel Transfer

A memorandum, R-P&VE-AV-67-293, summarizing current results from this study has been completed and distributed to key study personnel. Results of this effort identify the usability of storable and cryogenic propellants in employing a transfer stage that is based on the

Voyager spacecraft bus system as a transfer stage for earth orbital operations. The effect of stage diameter on the payload configuration and the effect of boil-off and off-loading in the cryogenic stage are described.

D. Low-cost Launch Vehicle

A summary progress review on the subject study effort was given to members of the Advanced Systems Activity on November 7, 1967. This review was given by members of the study group on the Conceptual Design and Analysis portion of the "Low-cost Launch Vehicle" effort, currently being managed and technically supported by members of this Office. In addition to a delineation of the overall managerial aspects of the study, this Office presented the results of supporting study efforts resulting from specific tasks identified as follows:

(1) Scaling and parametric sensitivity studies

(2) Configuration analyses

(3) Shrouded multi-nozzle rocket engine theoretical performance analyses

(4) Performance analyses for exponentially-scaled launch vehicle concepts

Results to date on the latter two of these tasks are summarized in memorandum R-P&VE-AV-67-303, dated November 16, 1967. Effort in these two task areas is continuing with emphasis on thrust augmentation description, stage commonality concepts, and more sophisticated performance analyses.

In response to managerial direction, primary study emphasis is currently being directed toward a vehicle of the 75 k payload class. Two cases under investigation within this Office, involving definition of this vehicle and its conceptual extrapolation to other payload classes, are the following:

(1) 75 k "optimized" performance vehicle system

(2) Exponentially-scaled building-block vehicle/vehicle spectrum concept

Ground rules, individual tasks and a tentative schedule have been formulated and agreed upon for this effort.

E. Saturn Launch Vehicle Uprating Studies

1. Saturn V SA-520 Definition --- The SA-520 definition report is in the final stages of documentation. Publication of the report is scheduled for mid-December.

2. Saturn IB SA-217 Definition --- The SA-217 definition report is in the final stages of documentation. Publication of the report is scheduled for the end of December.

F. Saturn Utilization Study

The first progress review on the Saturn Utilization Study was presented to the Advanced Systems Activity Senior Staff by Mr. William L. Corcoran, Study Manager, and covered activities and accomplishments for the period September 24 through October 31. The study is on schedule and operating within present manpower commitments. A discussion on sensitivity factors within the low-cost fleet generator computer program for determination of configuration evolutions led to a request for a formal presentation on the methodology techniques utilized.

The basic data sheets for a "Saturn Vehicle Shopping List" have been prepared. These sheets give physical characteristics of each vehicle by stage, and also present performance characteristics. The candidate vehicles have been selected; data sheets are currently being prepared for each vehicle.

G. Saturn Improvement Studies

R-AERO and R-TEST presented informal status reviews of their base heating and launch facilities tests, respectively, for selected Saturn V models with strap-on solid rocket motors. The base heating tests are being conducted at Cornell Aeronautical Laboratories, Buffalo, New York. The simulated launch tests, performed at MSFC under direction of KSC, have indicated (1) flame bucket redesign is required to eliminate exhaust spill over the flame trench and (2) mobile launcher exhaust opening increase of approximately 2 1/2 feet on all sides. These findings effectively substantiate the conclusions and recommendations of the recently conducted study of launch facilities for improved Saturn vehicles conducted by The Martin Company for KSC in conjunction with MSFC. Total non-recurring costs for the fully modified mobile launcher and the new flame deflector are estimated at $12.1 M and $3.8 M, respectively.

The complete testing program was reviewed and film coverage of recent tests shown. One of the primary program objectives is the determination of the environment of the vehicle base and facility elements during holddown and initial lift-off. Although Phase III (basic Saturn V with 120-inch-diameter SRM) is not scheduled for completion until February 1968, preliminary results indicate no appreciable change in base environment problems for 120-inch-diameter SRM strap-ons when utilizing the redesigned flame deflector.

II. Earth Orbital

A. Common Mission Module

A conceptual design of the CMM has been developed, including structural configuration, systems definition, subsystem integration, and internal layout and arrangement. Current efforts involve weight analysis, design review, and preparation of the final report. A final presentation on the study results has been scheduled for December 15, 1967.

B. Three-burn S-IVB Stage

An Internal Note concerning the utilization of a three-burn S-IVB stage for advanced earth and lunar orbital missions is being prepared for publication. In the report, advanced Saturn V missions, such as the synchronous orbit mission, the S-IVB in lunar orbit mission, and others, are discussed. The S-IVB stage and IU capabilities and changes required for each mission are also covered.

III. Planetary

A. Probe Module Definition Study

A study was initiated to conceptually define a probe module or probe compartment configured to structurally support, environmentally and biologically protect, and operationally deploy a proposed experimental package for a manned planetary encounter mission. This study will establish the interface requirements with other spacecraft subsystems and define the functional requirements imposed on the mission module by the onboard scientific experiment program.

B. Mars Soft-lander Probe Definition

The study to conceptually define the soft-lander probe is continuing. The experiments and experiment payloads were established and a baseline probe configuration has been defined. The baseline probe weighs 5,000 pounds, is 16 feet in diameter, and has a cone half-angle of 60 degrees.

C. Command Post Definition for Planetary Spacecraft

Command and control center functions pertaining to the mission module of a Mars planetary mission have been established. The type equipment and equipment characteristics necessary to perform these functions are now being defined. Expected results include a layout of equipment with corresponding volumes, areas, weights, etc.

D. Nuclear Vehicle Design Sensitivity Study

Based on the results documented in BECO Report PVEL-27013-2, "Nuclear Vehicle Design Sensitivity Study," dated September 29, 1967, and LMSC Report A830246, "Nuclear Propulsion Module Reference Design, Phase II," dated February 24, 1967, efforts were initiated to produce the following engineering analyses: (1) establish new "nominal" or reference baseline configurations under consideration; (2) verify velocity increments for earth departure, Mars braking, and Mars departure, and compare with LMSC Phase II data; and (3) define the sensitivity of the nuclear module weight for various mission parameter changes. (Examples are variations in engine thrust and I_{sp}, propellant boiloff, etc.)

Preliminary results have been received from BECO and are presently being reviewed. A follow-on effort to determine nuclear stage/earth launch vehicle compatibility is being prepared.

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~~Erich E. Goerner~~
Chief, Advanced Studies Office

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-67-11

MONTHLY PROGRESS REPORT

NOVEMBER 1, 1967 THROUGH NOVEMBER 30, 1967

SATURN V

I. S-IC Stage

A. 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 the Effects of Aging on Polyurethane Adhesive Bond Strength

Two series of silane-primed specimens and one series of unprimed controls have now been exposed to an outdoor aging environment for ten months. In one series the aluminum adherends were primed with Dow Corning Z-6020 and bonded with an adhesive mix (Narmco 7343/7139) containing 1.0 percent Dow Corning Z-6040, in another series the adherends were primed with hydrolyzed Z-6040 and bonded with the adhesive mix containing 1.0 percent Z-6040; and in the last series the adherends were unprimed and no additive was included in the adhesive mix. In general, lapshear and bell peel tests at -300°F (-184°C), room temperature, and 200°F (93°C), indicate that aging for ten months resulted in higher bond strengths than were observed with specimens aged for only one month. These data continue to indicate that humidity has a reversible effect on bond strength. Both the humidity and temperature during the last two months have been lower than in the preceding months. An attempt will be made to correlate strength values with prevailing humidity and temperature conditions.

2. Study of Effects of Additives and Primers on Polyurethane Bond Strength

1, 1-Dihydroxymethyl ferrocene was compared with an equivalent percentage of the silane additive Z-6040 in the standard Narmco 7343 formulation. Test data indicate that the ferrocene compound is not as effective as the silane additive and therefore deserves no further study.

A series of experiments is in progress to evaluate the efficiency of hot water as a means of removing excess silane primer from aluminum surfaces. Preliminary indications suggest that treatments of less than one half hour duration will be effective.

A study has been completed on various parameters affecting the strength of urethane adhesive bonds formed with Alodine 1200-coated aluminum adherends. Despite several variations in cleaning and surface preparation, inferior strength at cryogenic temperatures was consistently obtained with Alodine adherends. Strengths at room temperature and above were not adversely affected by the Alodine treatment.

Further studies have been made of the Stafoam AA-1802 primer. Several permutations and combinations of the following are being investigated.

a. The effects of silane pre-primers

b. Silane additives to the Stafoam solution

c. Silane additives to the bulk urethane resin.

One set of specimens incorporating all three of these innovations gave lapshear and T-peel values at +250°F (121°C) of 2380 psi and 48 pounds per inch of width (piw), respectively. These are extremely high values for the Narmco material under these conditions and further work on these compositions is indicated.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

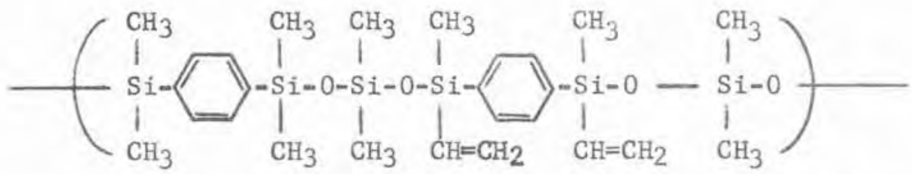
Continued effort has been directed toward development of specialized polymeric materials for encapsulation of electronic hardware. Various methods have been studied for increasing the yields of large scale laboratory preparations of epoxy-siloxane polymer intermediates. These polymers are useful as embedment compounds for cordwood modules. Continued attempts have been made to crosslink the silphenylenesiloxane polymers as part of the conformal coating program.

1. Development of Epoxysiloxane Embedment Materials

The preparation of a 100-200 gram quantity of _p_-allylphenyldimethylsilanol has been continued with emphasis on optimization of the yields of the multistep synthesis. The intermediate, p-allylphenyldimethylchlorosilane, is recovered in poor yield by distillation of the crude product of the reaction of p-allylphenyl magnesium bromide and dichlorodimethylsilane. However, the corresponding dimethylamino derivative, formed by treatment of the crude reaction product with dimethylamine, can be isolated in higher yield. The subsequent hydrolysis of the dimethylamino derivative at 0°C - 5°C (32°F - 41°C) provides the monosilanol in good yield. The sequence of reactions involving the dimethylamino derivative offers several advantages in the preparation of the desired monosilanol, p-allylphenyldimethylsilanol, and it will be appraised in a larger scale process.

2. Development of Conformal Coatings

The silphenylenesiloxane polymer,



which was prepared previously, has not been crosslinked as successfully as the polymer system containing larger percentages of double bonds. The polymer illustrated above was crosslinked with 1,4-bis(dimethylsilyl)benzene in Si-H/C=C ratios ranging from 1/3 to 3/3. The crosslinked polymer in each case was a low-strength, "cheesy" solid. Various analytical data necessary for optimization of this process are being obtained.

C. Investigation of Spring Failures in Hydraulic Engine Actuators

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

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

Several Belleville springs were found to be broken in an S-IC LOX prevalve which had been used for qualification test. These springs were made of 17-7 PH, RH950 material. Unbroken Belleville springs from this valve failed in the humidity cabinet after 11 days exposure under very high stress. Additional springs from the same valve are being evaluated in the alternate immersion tester. There have been no failures of these springs after 30 days of exposure.

E. Investigation of the Failure of S-IC Stage Servoactuator Boot Fitting

Failure analysis was completed on the failed servoactuator boot fittings removed from SA502. Cracks in the 7075-T6 fittings were found by The Boeing Company personnel during routine inspection. The cause of the failure was determined by both metallographic and fractographic means to be stress corrosion cracking. This finding was verified by The Boeing Company on similar fittings. The increased susceptibility of these parts to stress corrosion resulted from high stressing due to misalignment due to distortion in the part fitup. The "fix" adopted by The Boeing Company was to shim the fittings to very close tolerances.

F. Investigation of Seal Failure in a 6-Inch LOX Fill and Drain Valve

A Teflon seal failure in a 6-inch LOX fill and drain valve has been investigated in response to a request from Propulsion Division. The seal is essentially a flat disc with a round cutout in the center. It is held in place by serrations which are pressed into the seal during valve assembly with considerable local deformation of the seal material. These serrations are near the outer periphery of the seal. It was concluded that this seal was made from a Teflon billet of poor quality having a tensile strength only slightly more than half of the minimum value stipulated in the vendor's material specification. A seal of this quality could have conceivably failed in tension due to thermal stressing alone. Recommendations are being made to appropriate personnel for avoiding this difficulty in future values.

II. Contract Research

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

A. Polymer Research, Development, and Testing

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

B. Development of Cryogenic and High Temperature Insulation Material

Goodyear Aerospace Corporation, NAS8-11747

C. Analytical Methods Development

Beckman Instruments, Incorporated, NAS8-11510

D. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

E. Nondestructive Testing Techniques

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

III. S-II Stage

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

Failure analysis was completed on two failed fasteners removed from the S-II "C" interstage. Fractographic studies verified the failure mode to be intergranular stress corrosion cracking followed by overload shear due to reduction in effective cross section. As a result of the above failures, twelve fasteners were removed from a cracked stringer in the "C" interstage and were studied both visually and metallographically to determine if early stages of stress corrosion was evident. No evidence of cracking was found; however, the metallographic study revealed that the threaded areas and fastener heads consisted of recrystallized grain structure. The high temperature solution heat treatment following theading and heading operations causes the recrystallization of the cold worked areas.

Approximately 75 fasteners were removed from the "high forces test" interstage located in the storage area south of building 4619. A three-foot long section of a stringer was removed also so that test panels could be made for testing some of the fasteners in stress corrosion environments. Eighteen fasteners were torqued with new collars in a one-foot long section of the stringer and exposed to alternate immersion in sodium chloride. A similar panel was prepared and exposed in a humidity cabinet. After more than 400 hours of exposure in these environments, no failures have occurred. The remainder of the 75 fasteners was studied visually and metallographically with no evidence found of stress corrosion cracking. The stress corrosion studies will be continued.

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

1. Evaluation of Coatings for Spray Foam Insulation

Efforts are continuing to find a coating for the Nopco BX-250 foam which will afford some measure of mechanical protection and impermeability to moisture, and which will not undergo gross failure during the thermal-vacuum ascent environment. To date, no coating has been found that does not separate from the foam in large blisters that are progressively enlarged by the outgassing products of the foam. The Chem-Seal product recommended by the stage contractor is prone to catastrophic failure during the ascent profile, with or without an overcoat of Hypalon. There have been reports that this coating shows better high temperature performance after aging and this is under study.

In addition to several Chem-Seal-coated panels, samples coated with SR-529 silicone, PV-100 white coating and white Tedlar film were evaluated for this application with variably poor results. These investigations will be continued in an attempt to locate or develop a coating which will seal the Nopco BX-250 foam against the rigors of test, prelaunch and launch environments.

2. Investigation of Surface Preparation Required for Bonding Foam Insulation to the "Mini-Stage"

A number of samples having various pretreatments to the alodine coating was prepared and spray foamed with the Nopco BX-250A foam, as described in the previous report. Subsequent testing of these first samples yielded flatwise tensile strengths averaging about 55 and 35 psi at room temperature and -300°F (-184°C), respectively. Only foam breaks were obtained at these temperatures. However, at liquid hydrogen temperature, adhesive failures were obtained. This peculiar failure pattern prompted a repetition of the tests with other foam specimens. Testing at liquid hydrogen temperatures has not yet started, but the latest samples have given results comparable to the first series at -300°F (-184°C) and room temperature.

3. Evaluation of the Effects of Heat and Vacuum on CPR-348-3 Foam

The CPR-348-3 pour foam is used around the feed lines and in the bolting ring area of initial S-II vehicles. Tests described in the previous report corroborated reports from North American Rockwell (NAR) that this material disintegrates and ejects fragments similar to popcorn under heat and vacuum conditions. During this period, identical behavior was observed in a sample of this foam prepared locally by Manufacturing Engineering Laboratory. Efforts are continuing in an attempt to identify the attribute or constituent of this foam contributing to this unusual behavior. The possibility of minimizing or controlling this effect by use of ablative or intumescent overcoats is also being studied.

C. Removal of Corrosion from S-II-F/D Vehicle Tanks

Work is in progress to remove the light corrosion and pitting found in the S-II-F/D liquid oxygen (LOX) tank. This corrosion was observed on the dollar weld of the aft facing sheet of the common bulkhead and the upper meridian weld lands. The depth of pitting in these areas ranged from 0.001 to 0.010 inch. These areas have been chemically etched and realodined and will be reworked further when a firm use for the stage has been established. An examination will be made of the liquid hydrogen (LH_2) tank when the stage has been placed in a horizontal position.

D. Developmental Welding

Investigations have continued in an attempt to correlate the effects of various welding energy inputs and natural aging with the performance characteristics of fused joints in 2014-T6 aluminum. During this report period test weldments were made using optimum welding energy input (as has been previously established) to determine the effects of varying voltage and/or amperage upon the quality of the fused joint. Preliminary results obtained from weldments prepared of 3/8 inch thick aluminum alloy 2014-T6 indicate that limited variations in voltage and/or amperage produces welds having a varying heat affected zone width. However, all welds were satisfactory in appearance and radiographic quality with no apparent differences in joint strength. Statistical methods are being used to evaluate the data in order to establish optimum methods of procedure.

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

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

The effect of variations in radiographic parameters on the quality of radiographs of a typical S-II propellant tank weld has been studied through experimental radiography. Numerous exposures of three 0.382-inch 2014-T6 aluminum alloy test weld panels have been made. These panels have been programmed to contain porosity, cracks, and lack of fusion. A certain amount of analysis has been performed on the films with much more to follow. The data show exposures longer than are normally used in production and angle exposures which are normally used in production for diagnostic purposes only to increase the detection capability of radiography of these welds. Complete analysis will show the degree of improvement.

F. S-II Stage, Project Management, Materials

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

1. Pulsed Arc MIG Welding (PAMIG)

The Space Division of North American Rockwell, Inc. (NAR/SD) has completed the study of pulsed arc MIG welding (PAMIG) which was requested by this Center.

On November 15-16, 1967, a joint meeting between the contractor and this Center was held to review the results of the program and to access the continued program proposed by NAR/SD. In brief, the conclusions reached on the PAMIG study were:

a. The ultimate tensile strength of PAMIG welded joints is less than TIG at RT and -423°F and approximately equal at -250°F.

b. Transverse elongation values of PAMIG welds is approximately one-half the value of TIG welds except at -423 where the PAMIG welds are approximately 80 percent of the TIG elongation values.

c. Repair of PAMIG welds results in more loss in strength than does repair of TIG welds.

d. Weld offset in PAMIG welds is greatly reduced over that encountered in TIG welds.

e. Equipment reliability of both processes is about equal.

f. The weld quality of both processes is approximately equal since the surface flaws (cracks and undercut) in PAMIG equals the internal quality encountered in TIG.

Based on the above conclusions it was recommended by NAR/SD to continue the PAMIG study on a laboratory basis in an attempt to improve elongation and external quality.

2. Liquid Hydrogen Tank Stress Relief Areas

Tests are being made to determine the design adequacy of the doubler structure as well as the insulation design for S-II-7. An extensive program is in process to determine the stress magnification resulting from the stress relief geometry. The latter is a joint program between the stage contractor (NAR/SD) and this Center and will be completed prior to S-II-4 launch, with certain phases of the study to be completed to support a decision for a doubler on S-II-4 prior to static firing. The weld defects in S-II-3 have been accepted by materials review board action, and thus will not require a doubler. (R-P&VE-M and R-P&VE-S have concurred in the MR action.)

3. Weld Cracks at Weld Crossovers

The S-II-9 aft LOX bulkhead experienced cracks at the weld crossovers (at the juncture of the thick to thin weld) after hydrostatic proof pressure. One crack was internal and has caused considerable concern. A review of the X-rays by this division has disclosed that the cracks occurring in bulkhead weld crossovers coincide with "twinning" in the weld. ("Twinning" is a particular metallurgical structure encountered as a result of the heat and stress of welding and is readily evident by radiography. It is also interesting to note that this cracking is identical to the crack in the LH_2 tank crossover weld that occurred in S-II-6 (post pneumostat) having the same degree of twinning. Studies completed in this division some years ago indicated that as weld speed is increased twinning becomes apparent in the structure and further increases of speed induce weld cracks. While twinning itself has not been considered detrimental, it is an indication that the weld speed is approaching a limit beyond which cracks will result. By reducing the speed to eliminate twinning, it may be possible to eliminate the crossover cracking problem. The stage contractor has been so advised and will investigate this solution.

4. Spray Foam Insulation

The stage contractor has shown considerable progress in manufacturing improvements on spray foam insulation. The tooling and spray equipment together with personnel experience has reduced the number of MR's per cylinder by approximately 75 percent and in some cylinders there are no MR actions. The most recent attempt to qualify the Binks spray gun was not successful but with the Lemco spray gun performing so well there is no major concern.

Because of the in-flight shedding problem with present pour foam (type 348) NAR/SD has explored pouring the Nopco BX250 spray foam. Technical problems in maintaining a proper density at the metal surface have precluded its qualification for immediate use. However, the Nopco 249 pour foam has shown considerable promise. Tests have indicated that the latter pour foam will not shed in flight and will pass structural qualification.

The most recent insulation coating composite (3 coats of Chemseal and one coat of Hypalon) has failed to pass the altitude heat profile after having passed several times before. The recent failures have been unexplained by NAR/SD. However, contractor personnel believe it may be related to differences in coating thickness as applied at different manufacturing times. Within the past two weeks, NAR/SD has developed a seemingly better composite consisting of the 3 coats of Chemseal and two coats of Dynatherm. Tests (altitude and heat) conducted at both NAR/SD and this Center have indicated that this composite has promise. It has been agreed that both parties would assist in evaluating this in order to support an early decision date for application to S-II-8 and S-II-9.

IV. S-IVB Stage

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

1. Study of Flammability of Materials

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

An autoignition test chamber and all supporting components including a spark ignition source have been fabricated, assembled, and qualified for operation. A test program has been initiated to describe combustion characteristics of materials proposed for spacecraft environment applications. Data that are to be determined experimentally for each material are: (a) combustion products, (b) flash point, (c) fire point, (d) autoignition temperature, (e) flame temperature, and (f) pressure and temperature profiles within test chamber. The listed tests normally will be conducted in an atmosphere of oxygen at 6.2 psia. Additionally, thermal analyses of each material are being made as follows:

a. DTA, differential thermal analysis - reaction versus temperature.

b. TGA, thermogravimetric analysis - weight loss versus temperature.

c. TMA, thermomechanical analysis - glass transition temperature, softening point.

In the initial phase of this program, over 25 samples of materials have been obtained for testing. The thermal analyses have been completed on eight specimens and are continuing on the remaining samples. Ignition temperatures, flame temperatures, combustion products, etc. are being determined for one material at a time on a daily basis. These data combined with flame rate data should well define the combustion characteristics of each material.

Eleven samples were evaluated for flammability in accordance with the provisions of MSC-A-D-66-3, Revision A. These samples were silicon rubber type GE SE-517 and "Penton" (chlorinated polyethylene) in 10 different thicknesses (between 0.005-inch to 0.10-inch).

During this period, a test series was started to determine the flammability of 60 percent methyl alcohol-40 percent water solutions. Tests conducted on the bulk liquid indicates that this solution will ignite and continue to burn in air.

2. Study of the Outgassing Characteristics of Orbital Workshop Materials

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

A sample of the 3-D insulation was punctured just through the seal coat to continue the study of diffusion into the insulation. When the vacuum apparatus was set up it was found that the ionization gauge controller did not function properly. The unit has been sent to the Calibration Lab for repairs. The design of the test chamber for the study of permeation-diffusion of hydrogen into the 3-D insulation has been completed. We will modify the existing chamber to conduct these tests. It is planned that the chamber will be insulated externally to slow down the boil-off of liquid hydrogen. The chamber is to be inverted so that the Orbital Workshop insulation will be at the bottom of the tank (internally) to provide for liquid hydrogen soak.

B. S-IVB Stage, Project Management, Materials

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

1. Korotherm Insulation on S-IVB Stages

The defective Korotherm insulation on S-IVB-204 will be refurbished in a manner similar to that formerly reported for S-IVB-501 and S-IVB-502. For S-IVB-205 and subs and for S-IVB-503 and subs, however, all of the Korotherm will be removed and replaced, and an appropriate sealer will be applied to preclude further damage of the Korotherm insulation by water through the seal coat.

2. Defective Liquid Hydrogen Tank Insulation

The S-IVB Stage Manager has been requested to obtain, for review by this division, a written contractor report on the complete story of defective 3-D insulation in the liquid hydrogen tank of S-IVB stages, including a mapping of defects in all stages involved, an explanation of the basis upon which the contractor judged affected areas to be acceptable or nonacceptable, for flight applications, and detailed descriptions of the actions taken by the contractor to correct unacceptable conditions of the 3-D foam. Upon receipt of the requested report, a decision will be made as to the technical adequacy of the contractor's recommendations relative to the defective insulation.

3. Stress Corrosion of Belleville Spring

A failure has occurred in the Belleville spring in the regulator of the 1B42290 liquid oxygen (LOX) tank pressurization module. This failure was attributed to stress corrosion.

The stage contractor is working with the spring vendor on a non-stress corrosion susceptible Belleville spring material for use in the LOX tank pressurization module, 1B42290, and the cold helium dump module, 1B57781. Development testing will be conducted by the vendor to ensure material adequacy, and, upon completion of these tests, the stage contractor will submit an ECP to change to a new spring material, probably Inconel 718. Submission of this ECP is expected early in December.

The stage contractor considers this an improvement change not requiring retrofit for delivered stages. The same type of spring failure on a flight stage would result in a slight pressure decay in the LOX tank during start transient. The stage contractor has determined analytically that such pressure decay is acceptable for both captive firing and launch of the stage.

4. Reinforcement of Main and Auxiliary Tunnel Clips

The method of bonding tunnel supports to the liquid hydrogen tank has been revised to add a fiberglass doubler across each tunnel support and onto the LH_2 tank. This should eliminate unbonding of support fingers as experienced on S-IVB-501.

5. Review of Materials Compatibility in S-IVB Stage Oxygen Systems

The S-IVB stage contractor has been requested to review all oxygen systems of the stage, including storage and transfer systems, for which the contractor is responsible, and to report to this division the utilization of any and all materials that are not compatible with liquid oxygen as defined by MSFC-SPEC-106B. In response to this request, the contractor proposed to conduct this investigation at an estimated cost of $84,000 and to submit a report of findings by February 5, 1968.

6. Preparation of Welds for Dye Penetrant Inspection

As a result of detailed investigations by this division, the S-IVB stage contractor has been requested to machine welds to a 25-40 RMS finish and to etch the machined surface for 15 minutes prior to dye penetrant inspection of the weld. The stage contractor has proposed to comply with this requirement at an estimated recurring cost of $28,000 per stage.

7. Liquid Hydrogen Tank Internal Mounting Brackets

There are 92 epoxy-glass mounting brackets in the LH_2 tank of each S-IVB stage. Flammability testing of these brackets revealed them to be unacceptable for OWS applications. Thus, action has been taken to have the glass-epoxy brackets replaced with metal brackets, perhaps aluminum.

8. Evaluation of MD-19 Thermal Control Coating

Flammability tests of typical S-IVB stage liquid hydrogen tank insulation specimens having a fire retardant liner of 2-mil aluminum foil and a thermal control coating of MD-19 reveal that the fire retardant liner is enhanced by the MD-19 coating. However, final acceptance of the MD-19 coating for Orbital Workshop applications is awaiting receipt and approval of material and process specifications and cryogenic testing in the 3-foot dome facility at Sacramento.

9. The following documents were reviewed:

a. AAP-2 General Test Plan, Revision A

b. OWS Delta PDR Data Package, Document No. 208-07-00011C

c. MDC MS STM0375, "Lubricant, Solid Film, Extreme Environment"

d. PCP-9040, "Study of GOX and LOX Systems in Stage and GSE"

e. ECP-2597C, "Reinforcement of Main and Auxiliary Tunnel Clips"

f. ECP-2584, "Improvement of Korotherm Primer"

g. Martin Marietta Corporation Contract NAS8-21004, Phase C Extension.

V. F-1 Engine

A. Investigation of Insulations for Use on F-1 Engine Components

A sample of F-1 engine insulation has remained exposed to outside humidity since the last reporting period without any measurable change in weight. This verifies earlier experiments which indicated that gross contact by liquid water is necessary to totally saturate the Refrasil material on the interior of the insulation. The measures being taken to alleviate this problem appear adequate.

B. F-1 Engine, Project Management, Materials

The F-1 engine contractor has completed a special research funded program on Rene' 41 alloy. It was determined that significant improvements can be made with respect to strain age cracking of this material in the F-1 engine through the use of improved heat treatment procedures. Efforts are being made to introduce these procedures into the F-1 production schedule as soon as possible. One important aspect noted in the study was the greatly improved ductility of Rene' 41 when heat treated in an argon atmosphere rather than in air.

VI. J-2 Engine, Project Management, Materials

In conjunction with the Propulsion Division, efforts are being made to minimize the use of materials incompatible with liquid oxygen for J-2 insulation. Additionally, the contractor has been requested to evaluate the flammability characteristics of these materials in accordance with established procedures.

VII. Instrument Unit

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

Tubular joints made by silver diffusing aluminum (6061) to stainless steel (300 series) are being evaluated for resistance to corrosion in inhibited and uninhibited methanol/water solution. Tests have been completed in this evaluation by exposing specimens for 120 hours to both uninhibited and inhibited methanol/water solution. These specimens are being examined metallurgically to determine the depth of attack and also to see if the joint has been adversely affected by the methanol/water solutions.

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

Exposure of LA141 and 2024 aluminum in distilled water containing 250 ppm and 1000 ppm of sodium dichromate ($Na_2Cr_2O_7$) was discontinued after 90 days. The hydrogen gas produced in most tests was negligible with the exception of 2024 in 250 ppm $Na_2Cr_2O_7$ which produced 28 milliliters of gas, and the coupled LA141 - 2024 in 1000 ppm $Na_2Cr_2O_7$ which produced 44 milliliters of gas. New tests are being planned using LA141, 6061 aluminum, and sections of Avco cold plate to verify the previous data and to investigate inhibitor concentration, hydrogen evolution, pH and solution decomposition.

VIII. Apollo Telescope Mount (ATM)

A. Investigation of Contamination and Contamination Sources

Investigations have continued in the determination of possible contamination of the optical environment of the ATM experiment, both by direct deposition of contaminant materials on optical surfaces and by degradation of the view area of the equipment. All materials are tested in accordance with the Materials Property Criteria established in the Materials Management Plan for ATM contamination. To be acceptable, a material must have a maximum rate of weight loss during temperature cycling from 25° to 100°C which does not exceed 0.2 percent/cm^2/hr.

Fourteen materials were evaluated in vacuum (10^{-7} torr) to 100°C by making continuous weight loss determinations and periodic mass scans on each material. Materials of particular interest with test results are as follows:

Epoxy-coated glass #2525, Z-93 paint #67-7-26-3, nylon ribbon EM46, Type K-1, Ball Brothers' Paint, Type D8B #67-8-3-3, Armstrong X-300 and RTV 60 have acceptable outgassing characteristics for use on ATM. Dacron lacing tape Stur D, Lace H, Style 20 and Mylar Scotch with backing #56 were stable to 50°C but as the temperature increased above 80°C the materials outgassed excessively. The large outgassing rate for the Mylar Scotch is attributed mainly to the adhesive backing. Glass laminate base EM-88 CL-4 sheet and Nylon rod MIL-P-20693 Type I are marginal with respect to vacuum temperature stability.

The application of these materials will be determined by the ATM Materials Control Board. RTV-577 silicone adhesive does not meet the weight loss criteria as established for the ATM and is acceptable. The material can be made acceptable from the view of outgassing contamination by baking the material in vacuum at 100°C for 72 hours at 1 X 10^{-6} torr, however, the material becomes tacky during this treatment and, therefore, is still unacceptable.

Epibond 101 adhesive also was found to be unacceptable at 100°C. This material is used in the solar cell assembly to bond Micoply to the honeycomb substrate. The ATM Materials Control Board has expressed a desire to use this material if possible because of its adhesive properties and the contractor's favorable experience in applying the material. Therefore, a section of a solar array will be placed in a vacuum chamber and the outgassed material from this array will be monitored with a residual gas analyzer to determine the contamination potential.

A preliminary list was made of 17 materials that exhibited acceptable weight loss in Phase I tests. These materials will be subjected to a redeposition test. RTV 118 was tested for redeposition characteristics. The sample was heated to 50°C and 100°C at 10^{-7} torr. No visible film was deposited on the glass slide in the test chamber and no significant change in electrical resistance between two electrodes on the slide was noted. Therefore, RTV 118 is also acceptable in accordance with Phase II of the Materials Property Criteria.

B. Evaluation of Direct Current Motors for Use on ATM

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

The brush system for the Inland Motor Company 7 ft/lb high temperature motor that was reported last month has been redesigned to provide a brush load of approximately 6 psi on The Boeing Company brush material, 046-45. The motor is now driving a generator through a direct spur gear system in a vacuum environment that ranges from 10^{-6} torr to 10^{-7} torr. The motor is operating with 20 volts and approximately 1.5 ampere input. The generator field amperage is 0.5, the output amperage is approximately 1.0 and the output voltage is 0.35. The driver gear and the driven gear are made of alternate laminated sheets of 316 stainless steel and Teflon. A molybdenum disulfide (MoS_2) spray lubricant was applied to the gear teeth before assembly. This system has now been operating for approximately

78 hours and the components appear to be functioning satisfactorily. Testing will continue until a modified system has been completed whereby another Inland motor can be used as a loading device to replace the bulky generator. This should be completed in a few days. A system similar to this is operating at ambient conditions at present and a comparison will be available with the one in vacuum.

C. Investigation of ATM Bearing Lubrication

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

The test on the torque drive test system from the Bendix Company that was running in a vacuum of 10^{-7} torr and at temperatures of about 95°F (35°C) was stopped because of excessive brush wear on the 7 ft/lb Inland drive motor and the Inland tachometer motor. The test lasted for approximately 30 days instead of the intended 60 days. The system was disassembled and the Inland motors were replaced with new motors containing The Boeing Company compact material brushes designated 046-45. This material is expected to last longer than the niobium diselenide and silver brushes in the old motors. The system is now reassembled and pumpdown has started on the vacuum system.

D. Investigation of Thermal Control Materials for the ATM

Efforts have continued in the evaluation of thermal control coatings for application on Apollo Telescope Mount (ATM) components. Work has been undertaken to select white paints suitable for stenciling connector designations on various ATM black boxes. White paints selected for this application must have the desired outgassing characteristics and must be capable of application over the Cat-A-Lac flat black paint No. 463-3-8, which is used for painting the black boxes to provide the requisite optical properties. S-13G thermal control coating is suitable for this application provided a primer is used. Other white paints being evaluated include Cat-A-Lac flat white paint No. 463-1-500 and Carroll white No. 1013 manufactured by the Finch Paint and Chemical Company and Carroll Products, Incorporated, respectively.

Preformed blocks of Nopco BX-250-A foam were coated with Cat-A-Lac flat black paint No. 463-3-8. There were no problems encountered in applying the paint to the foam, and the paint appeared to be well bonded to the foam. Samples of the painted foam have been submitted to the Chemistry Branch for solar absorptance and total normal emittance determinations. This work is being done in support of the quarter spar thermal tests.

IX. Nuclear Vehicle Technology

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

Because of the uncertainties with respect to funding thus far in this fiscal year planning for continuing activities, both contractually and in-house, has been limited. However, reasonably firm guidelines have been received concerning FY-68 funding under this program and action has been initiated to continue the supporting research effort at General Dynamics/ Fort Worth.

In-house activities have continued in the development and evaluation of lubricant systems insensitive to radiation. Due to the time related nature of these tests there are no new data to report at this time.

ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

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

A. Polymer Development and Characterization

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

B. Adhesive Development

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

C. Developmental Welding

The Boeing Company, NAS8-20156

D. Thermal Control Coatings

The Boeing Company, NAS8-21195

E. Physical and Mechanical Metallurgy

Battelle Memorial Institute, NAS8-20029

F. Composite Material Development and Testing

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

G. Lubricants and Lubricity

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

H. Corrosion in Aluminum and Steel

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

I. Explosion Hazards and Sensitivity of Fuels

Standard Research Institute, NAS8-20220

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

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

K. Instrument Development

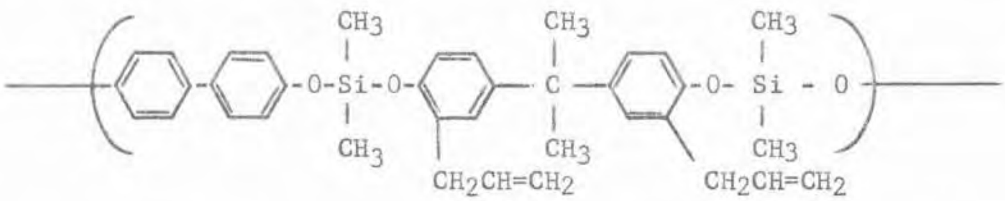
1. Battelle Memorial Institute, NAS8-11891
2. Canadian Commercial Corporation, NAS8-20529

II. General - In-House

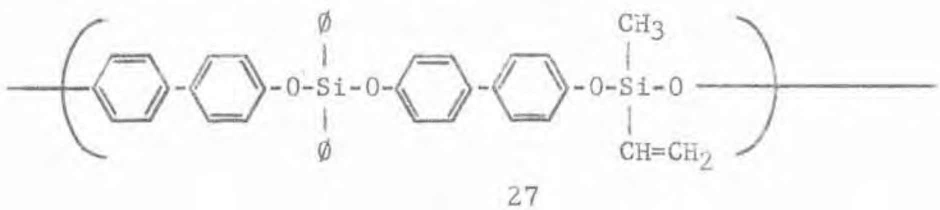
A. Development of High Temperature Resistant Polymers

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

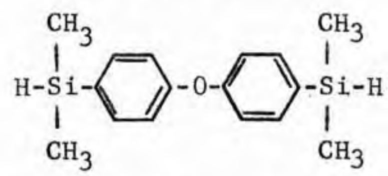
The previous crosslinking studies of an aryloxysilane polymer modified by incorporation of an allyl-containing diol,

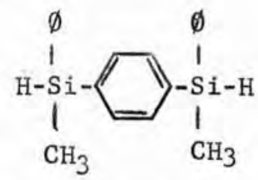


showed that 25 mole percent of the olefin-bearing monomer is sufficient to yield a crosslinked polymer which is infusible at 250°C. A modified aryloxysilane polymer illustrated below,

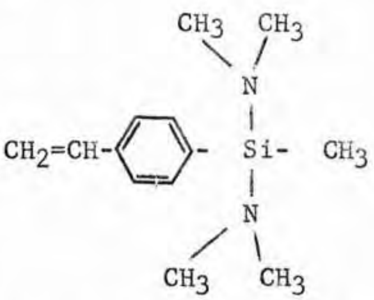


has been prepared which contains 25 mole percent of a vinyl-bearing moiety. This polymer together with the silphenylene hydride crosslinking system can be freeze-dried to yield a powdered, catalyzed mix which can be molded and cured in a single operation. A very small amount of the dihydride crosslinking agent has been observed in the benzene recovered after the freeze-drying process. The use of hydrides with lower vapor pressures is being investigated, since loss of even a small amount of dihydride from the polymer formulation would result in a serious imbalance in the crosslinking stoichiometry. Two compounds which are being investigated for this purpose are illustrated below:





Current attempts to vulcanize or crosslink the polysilphenylenesiloxane elastomer by way of a millable formulation have been directed toward incorporation of a small number of p-styryl groups along the polymer chain. The preparation of a suitable comonomer, p-vinylphenylmethyl-bis-(dimethylamino)silane,



has been attempted by condensation of the Grignard reagent of p-bromostyrene with excess trichloromethylsilane and subsequent treatment of this condensation product with dimethylamine. A pale yellow oil, boiling at 94-98°C/0.5 torr, has been recovered and is presently being characterized. The styryl group has a considerably higher reactivity toward peroxide initiated addition polymerization than the $-Si-CH=CH_2$ or $-C_6H_5-CH_2CH=CH_2$ groups, and silphenyl-enesiloxane polymers containing the styryl configuration should be more readily crosslinked with standard peroxide catalysts.

B. Development and Characterization of Phosphonitrilic Polymers

The product obtained from the reaction of 2,4,6,8-tetrachloro-2,4,6,8-tetra(2',4'-di-*tert*-butylphenoxy)tetraphosphazine with excess monomethylamine, was induced to crystallize through trituration with cold water. After being dried *in vacuo* over sodium hydroxide pellets, the white solid had a melting range of 70-75°C. No satisfactory solvent or combination of solvents could be found that was suitable for recrystallization of this material. The infrared spectrum and elemental analyses confirmed the identity of the compound as $P_4N_4(HNCH_3)_4(OR)_4$.

The compound was also submitted for ^{31}P magnetic resonance data to the Chemistry Branch in order to obtain spectra for determination of the number of phosphorous environments present in the molecule. Absolute geminal or non-geminal structural assignment of the molecule cannot be made until these data are received and analyzed.

In a parallel effort to prepare non-geminally substituted tetraphosphazines, the highly hindered alcohol, triphenylcarbinol, was prepared through the reaction of phenylmagnesium bromide with ethylbenzoate:

$$2\ \emptyset MgBr + C_6H_5CO_2C_2H_5 \longrightarrow (C_6H_5)_3\ COMgBr + MgBrOC_2H_5$$

$$(C_6H_5)_3\ COMgBr \xrightarrow{H_2O} (C_6H_5)_3COH + MgBrOH$$

It was anticipated that the molecular size of the alcohol would be sufficiently bulky to permit only non-geminal substitution to occur. However, all attempts to prepare the sodium salt of the carbinol in refluxing tetrahydrofuran with metallic sodium were futile. This particular approach does not appear to merit further investigation.

C. Development of Fluorinated Adhesives

Certain highly fluorinated materials are shown to be compatible with liquid oxygen when tested in accordance with MSFC-SPEC-106B. The objective of this program is the preparation of highly fluorinated monomers and prepolymers for incorporation into LOX compatible adhesive formulations. Such adhesives would eliminate some of the risks involved in making adhesive bonded repairs in areas subject to contact with liquid oxygen.

The pyrolytic decomposition of disodium hexafluoroglytarate was expected to yield the difunctional monomer, perfluorovinylglutaryl fluoride:

$$NaOOC(CF_2)_3COONa \xrightarrow{\Delta} CF_2{=}CF{-}CF_2{-}\overset{\overset{\large O}{\|}}{C}{-}F$$

Gas chromatography has shown at least three components among the gaseous pyrolysis products. Each component contains a trifluorovinyl group and one component contains acyl fluoride. Mass spectroscopy reveals a molecular weight of at least 240 for one of the gaseous components. (M.W. of perfluorovinylglutaryl fluoride is 178.) No satisfactory interpretation of these enigmatic data is yet available.

D. Developmental and Evaluation of Metallic Composites

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

Activities have continued in the evaluation of the efficiency of various types of explosives to produce successful bonds between metallic sheets.

The explosives explored were C-3, C-4, "Prima sheet", and nitroguanidine, with the greatest success being attained with nitroguanidine. Utilizing this information, several metal combinations were explosively joined during this reporting period with nitroguanidine. Distribution loading of the explosive varied from 0.55 g/cm^2 to 2.7 g/cm^2 in the 21 tests completed this month. Employing the established detonating requirements, the following metal sheet combinations were successfully bonded: aluminum to aluminum, copper to copper, magnesium to magnesium, tantalum to nickel, tantalum to aluminum, tantalum to copper, and tantalum to silver. Various other metal combinations are planned for explosive joining during the coming months and will be reported accordingly.

As discussed previously tests are being conducted to determine the optimum time, temperature, and pressure necessary to diffusion bond selected aluminum alloys. Data from these tests will be used to determine fabrication procedures for composites having aluminum matrices with reinforcements of boron, stainless steel, and beryllium filaments. During this report period, it was determined that an uneven pressure was being applied to the sample during the diffusion bonding process. An examination of the heated pressure platens revealed a depressed area just above the heating elements. Additional platens to replace the defective ones have been produced and are presently being faced.

E. Investigation of Stress Corrosion Characteristics of Various Alloys

Testing and evaluation have been completed in the determination of the threshold stress level in the short transverse and long transverse grain direction of alloy 7001-T75. Test results indicate that the threshold stress level for the short transverse is below 25 ksi (37 percent of yield strength) and 60 ksi (70 percent of the yield strength) for the long transverse. Additional tests will be run to more accurately determine the threshold stress level. There have been no failures of specimens exposed to synthetic sea water for 106 days.

The long-term exposure tests have continued on 7079-T61 and -T64 aluminum alloy in the local atmosphere. There has been no change in the test results since June. This atmosphere exposure test has been in progress for a total of 21 months.

This investigation was undertaken to evaluate the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7079-T6, and 7079-T651 were exposed to inside and outside atmosphere. Failures to date have been confined to specimens exposed to the outside atmosphere with no changes since the October report. These tests have been in progress 7.5 months.

Specimens of aluminum alloys X2021 and X7007 were stressed in all three grain directions and exposed in the alternate immersion tester and to the local atmosphere. Both alloys have been found to be susceptible to stress corrosion in the alternate immersion tester. Tests in the atmosphere have been in progress 21 months and the only failures encountered were X7007-TE136 specimens in the short transverse direction at loads as low as 10 ksi.

Testing has been completed in the study of the effect of overaging 7079-T651 (20 hours at 350°F, 10 hours at 350°F, and 5 hours at 375°F) on the stress corrosion susceptibility of this alloy. The results of the test will be reported when the data evaluation is completed.

Aluminum alloy 7178-T651 is being evaluated for stress corrosion susceptibility. Round threaded-end tensile specimens stressed in the longitudinal and long transverse grain direction to 50 ksi (75 percent), and C-rings stressed to 25 ksi (40 percent) in the short transverse direction are being exposed in the alternate immersion tester. Additional C-rings with similar tensile loads in the short transverse direction are being run in synthetic sea water. There have been no failures after 43 days of exposure.

Studies have continued in the determination of the stress corrosion susceptibility of Ti-6Al-4V alloy in various fluids. No failures have occurred to specimens exposed in any fluid other than methyl alcohol. Failures are still occurring in short peened specimens exposed to methyl alcohol; solution treated and aged specimens stressed to 80 percent of the yield strength failed in 278 days; annealed specimens stressed to 70 percent of the yield strength failed in 316 days, and specimens annealed and stressed to 60 percent of the yield strength failed in 349 days.

Initial tests have been terminated in the evaluation of the stress corrosion susceptibility of Almar 362, PH15-7Mo, 17-7PH, and PH14-8Mo (air melt and vacuum melt). Evaluation of the results shows that the stress levels used were too high to predict threshold stress levels for both 17-7PH and PH15-7Mo sheet and bar stock. Additional tests have been planned and specimens are being fabricated. Flat tensile specimens of 17-7Ph steel in the CH900 condition were loaded to 50, 75, and 90 percent of yield in both the longitudinal and transverse grain direction and exposed in the alternate immersion tester. There have been no failures after 46 days of exposure.

Welded and aged (20 hours at 790°F) ARDE low silicon 301 stainless steel cryogenically stretched to a nominal 252.6 ksi is being tested for stress corrosion susceptibility. Longitudinal specimens stressed to 75 percent (190 ksi) and 90 percent (228 ksi) of the yield strength have been exposed in the alternate immersion tester for 110 days without failure.

In a program to evaluate the stress corrosion susceptibility of various spring materials, round tensile specimens made from 1/4 inch diameter music wire material were stressed in the longitudinal direction to 70 percent of the material yield strength and exposed in the alternate immersion tester, humidity cabinet, local Center atmosphere, and semi-controlled inside atmosphere. There have been no failures in any of the environments after 10 days of exposure.

F. Investigation of Thin Film Dielectrics

The developmental Teflon thin capacitor program is continuing. Fifty-seven capacitors with dielectric thickness ranging from 800 Å to 11,500 Å have been prepared for electrical evaluation during this reporting period. Significant results of the evaluation tests of these capacitors were as follows. Dielectric constant is relatively independent of temperature from +24°C through -137°C. On the other hand, dissipation factor varies directly with temperature and changes by almost 75 percent in some cases. The most significant changes in these specimens is depicted in breakdown strength values with dielectric thickness as the primary influencing parameter. The thinner Teflon specimens (1,500 Å) had breakdown strengths greater by a factor of 10 than did the thicker (15,000 Å) specimens. This effect is quite significant in view of the possible use of Teflon thin films in micro-miniature circuitry employing relatively high voltage. The thermal resistance of Teflon further enhances its potential in these applications in that thermal degradation of electrical insulation is a specific cause of high voltage insulation breakdown.

A representative Teflon thin film capacitor was subjected to microprobe analysis. The purpose of this analysis was to determine the nature of penetrations through both the electrodes and the dielectric substance resulting from high voltage breakdown of the capacitor. Results indicate a considerable difference in behavior of these specimens in the immediate area of breakdown when contrasted to behavior of previously investigated CeO capacitors. In the case of Teflon dielectric, no fusion of either the Al electrode or the Teflon was evident, the path of electrical discharge appearing to consist more of a mechanical displacement of material, i.e., as if punched, rather than having been fused. This suggests a very rapid vaporization of materials along the path of discharge with equally rapid thermal quenching in the area immediately surrounding the path of discharge. Discharge cavity size as determined by the microprobe range from a minimum of 6 microns to a maximum of 48 microns with an average of 32 micron diameter over the 2 frames sampled.

G. Development and Evaluation of Techniques for Nondestructively Determining Lack of Penetration in an Aluminum Alloy Weldment

There has always been difficulty in nondestructively detecing lack of penetration (LOP) in aluminum weldments. The objective of this program is to develop a technique to facilitate the detection of lack of penetration. Aluminum weldments have been made with copper foil between the two aluminum sample plates. Lack of weld penetration leaves a certain amount of unfused copper foil which can be easily seen on a radiograph. The amount of unfused foil bears a direct relationship to the lack of penetration. Weldments so prepared have been evaluated with ultrasonic shear waves to confirm radiographic results. Tensile tests have been made on the weldments to determine whether or not copper foil or electroplated copper has any deleterious effects. The percentage of elongation and the average tensile strength decreased for the specimens containing copper foil and electroplated copper. The following statements and recommendations can be made with respect to the nondestructive tests and future investigations.

1. Lack of penetration was detected by radiography when copper foil or electroplated copper was in the weldment. LOP would have been undetected without the foil.

2. LOP was, with few exceptions, detected with ultrasonic shear waves whether or not the weldment contained copper foil.

3. There was good correlation between ultrasonic reflections and destructive strength values.

4. With very few exceptions, ultrasonic indications could be directly correlated with visual observations of LOP in the broken weldments.

5. Pulse echo ultrasonics do not show porosity very well.

6. Critical weldments should be evaluated with X-ray and ultrasonic techniques.

7. It appears that limited, uniform LOP, has little effect on the strength of weldments. This type of LOP accounts for some of the exceptions noted above.

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

1. Development of Electrical Brush Materials

The composition and processing procedures for the proprietary brush material developed by The Boeing Company have been received. Raw materials with the specified particle size have been ordered. While awaiting these materials, an investigation of the composite materials system utilized in the Boeing process is being made with materials already available. A specimen prepared from the Boeing compositions and procedures using these available materials was hard and dense and similar in appearance to the Boeing material. Brushes will be prepared from this material for comparison with the Boeing brushes. In addition, this basic reaction occurring during the Boeing process is being investigated individually.

2. Evaluation of Brush Materials

Testing and evaluation are continuing on several selected brush materials operating against a copper commutator in an inert atmosphere. The brush materials being evaluated are listed below with processing pressure and temperature indicated.

A-194 - 100 percent molybdenum disulfide (MoS_2), (McGee) 4,000 psi, 2,500°F, (1371°C)

C-49 - 100 percent molybdenum disulfide (MoS_2), (Bemol) 4,000 psi, 2,500°F, (1371°C)

A-91 - 76.3 percent tungsten disulfide (WS_2), 23.7 percent silver (Ag), 4,000 psi, 2,500°F, (1371°C)

C-50 - 85 percent molybdenum disulfide (MoS_2), 15 percent silver (Ag), 4,000 psi, 1,730°F, (943°C)

C-51 - 85 percent molybdenum disulfide (MoS_2), 15 percent silver (Ag), (91.88 Vol. percent) and 8.11 Vol. percent silicon carbide (SiC), 4,000 psi, 1730°F (943°C)

A-195 - 95 percent molybdenum disulfide (MoS_2), 5 percent tantalum (Ta), 4,000 psi, 2,500°F (1371°C).

I. Development of Low Density Ceramic Foams

Efforts have continued in the development of low density ceramic foams. The basic composition which has shown the most promise and which is presently being optimized is composed of 92.2 percent "D" sodium silicate and 7.8 percent Refrasil fibers (weight percent basis). Present studies include optimizing the compressive strength of foams prepared from the basic composition. A series of foams was prepared by pre-drying for 2, 4, 6, and 8 hours at 74°C (165°F) prior to foaming at 188°C (370°F). A control sample was prepared without any pre-drying. Compressive strength was determined on specimens cut from foamed samples to minimize skin effects. The specimens pre-dried for 8 hours were the strongest, having an average compressive strength of 42.8 psi. The control sample had an average compressive strength of 34.1 psi, whereas the strength of all other specimens was below 30 psi. For comparison, samples foamed from "D" sodium silicate only, i.e., without the Refrasil fiber addition, had an average compressive strength of 9.3 psi.

To determine the problems associated with preparing larger specimens of the foams, the thickness of the specimens was increased from 1-1/4 to 2-1/2 inches. The thicker specimens contained larger and less uniform pores, and their compressive strength averaged only 9.2 psi. These results were not entirely unexpected since the foams are produced in an enclosed mold. Additional efforts in scaling up the size of the specimens will be directed toward increasing the length and width of the specimens while maintaining the thickness at 1-1/4 inches.

A sample of the basic "D" sodium silicate-Refrasil fibers foam was determined to be nonflammable when evaluated for flammability in a 6.2 psia oxygen atmosphere.

J. 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

NOVEMBER 1, 1967 THROUGH NOVEMBER 30, 1967

I. Radiography

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

II. Photography

	Negatives	Prints
Engineering Photography	47	186
Metallography and fractography	100	377
Miscellaneous photography, processing, copywork, etc.	75	516

III. Metallurgical and Metallographic Testing and Evaluation

A. Twelve 1-inch diameter stainless steel connectors (brazed and welded) were studied metallographically at the request of the Propulsion Division. Visual examination of these specimens, which had been exposed for 180 days to alternate immersion testing, revealed no corrosion on the General Electric and Aeroquip type brazed connectors nor the North American Rockwell welded connectors. However, severe corrosion attack was found along the interface cross-section of both brazed type connectors. No defects were found on the welded connectors.

B. Metallographic studies were completed of 7-1/2 inch diameter stainless steel connectors at the request of the Propulsion Division. North American Rockwell type welded connectors and Aeroquip type brazed connectors comprised the samples. A 300,000 cycle vibration test at room temperature was completed on the unfailed specimens, whereas, the cracked connectors were removed from test upon detection of leakage. All connectors were cooled at -320°F (-196°C) for 1-1/2 hours after fabrication, heated to 500°F (260°C) for 1-1/2 hours, cooled to room temperature and tested. The metallographic examination revealed that both welded and brazed connectors sustained complete or partial failure during the 300,000 cycle test. At this point in the study, it is believed that the calculated load exceeds the threshold load for the connector configuration and materials used. All failures resulted from fatigue.

C. Two welded 2014-T651 aluminum specimens from North American Rockwell Corporation (NARC) were studied metallographically. One sample was a MIG pulsed arc bend sample containing several cracks in the cover pass of the weld (tensile side of bend). A bent TIG weld specimen (uncracked) was examined for comparison. The metallographic study revealed a large grained parent metal microstructure in the MIG pulsed arc weldment and a very small grained structure in the parent metal of the TIG specimen. The material for the MIG weldment was machined from 1-3/4 inch plate whereas the material for the TIG weldment was as rolled 0.300 inch plate. Cracking of the MIG pulsed arc specimen was attributed to intergranular fracturing of the brittle network in the weldment of large grained material. It must be noted also that the bend test used by NARC exceeded the specified bend requirements for this thickness material.

D. At the request of Test Laboratory five samples of plate stock including titanium, stainless steel, T-1 steel, plain carbon steel and aluminum, were polished and etched to determine rolling direction.

E. A GSE microswitch was received from the Vehicle Systems Division for determination of corrosion product between potting compound and the metal switch case. The switch was disassembled and studied visually; only slight surface pitting was observed. Samples of the corrosion products were removed and studied by X-ray diffraction techniques. The corrosion product was determined to be basic lead carbonate ($Pb_3(CO_3)_2(OH)_2$).

F. Failure analysis was completed of two failed Ti-6Al-4V struts removed from a 105-inch diameter test tank. The aluminum tank was used to test super insulation materials at high "G" force loads. These titanium struts were welded to a flanged base by the Manufacturing Engineering Laboratory (R-ME) then bolted to the tank for use as stabilizers while undergoing test on a rocket sled at Holloman Air Force Base (AFB), New Mexico. The failed struts were found by R-ME personnel following successful testing of the insulation at the Holloman AFB and after return by truck to this Center. Visual examination of the fracture indicated that both failures initiated at point on the strut to base plate weldment where only one side of the strut section was welded and this area had very shallow weld penetration. The analysis indicated that the fracture initiation was caused by overload tension and final failure of one strut resulted from low cycle fatigue probably during the trip from New Mexico to this Center. Fatigue indications were found during visual examination and were verified by fractographic studies.

G. Material changes from AISI type 301 stainless steel to Inconel X resulted in the successful fabrication of a snap diaphragm fixture. The electron beam weld settings required to join the 0.015-inch thick diaphragm to the test assembly were 60 KV, 3Ma, and a welding speed of 26 ipm. The diaphragm was subsequently stress relieved, and contour formed to 0.050 inch concavity. A diaphragm was welded to each of two assemblies during this report period. This work is being done at the request of the Propulsion Division.

H. Various components of the thruster engine assembly were joined using electron beam welding. Several seal welds and structural welds were required to complete the assembly. Seal welds on the titanium Ti-6Al-4V alloy were made at machine settings of 60 KV, 1.5 Ma, and 15 ipm travel speed while structural welds were made at machine settings of 90 KV, 7.5 Ma and 15 ipm travel speed. The engine successfully withstood hydrostatic pressure tests and will be test fired at a later date.

IV. Spectrographic Analyses

Three hundred and eighteen determinations were made on thirty samples and three hundred and sixteen standard determinations were made.

V. Infrared Analyses

Twenty-four analyses were made by infrared techniques on a variety of materials including experimental and commercial polymers.

VI. Chemical Analyses

	Determinations
Dow 17 Anodize solution for	
sodium dichromate	2
ammonium acid fluoride	2
phosphoric acid	2
Corrosion products from switch for	
chlorides	2
nitrates	2
sulfates	2
phosphates	2
Metal samples for	
carbon	21
silicon	4
Metal nitrides for	
nitrogen	4
Polymeric samples for	
carbon	8
hydrogen	8
silicon	8
phosphorus	2
nitrogen	2
fluorine	2
Gas samples for	
hydrogen	24
nitrogen	23
oxygen	11
helium	5
para hydrogen content	36
Atomic absorption analysis of	
aluminum for copper	4
stainless steel for copper	2
tin-lead solder	2

	Determinations
National Bureau of Standards standards for	
chromium	36
nickel	36

VII. Physico Chemical Analyses

	Determinations
Density of	
RP-1 fuel	8
Teflon seal	9
Viscosity of methanol-water (80/20)	7
Heat of combustion of materials for S-IVB Workshop	22
Molecular weight of polymers	2

VIII. Rubber and Plastics

	Items
molded and extruded	79
cemented	106
coated	13
fabricated	22

IX. Electroplating and Surface Treatment

	Items
acid cleaned	29
degreased and cleaned	25
gold plated	10
alodine treated	63
salt spray tested	50

X. Development Shop Production

A. A total of 5,453 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. Two thousand, eight hundred and fifty-three man-hours, approximately 52.3 percent of the total man-hours, were expended on work of a non-routine nature and applied to the work orders listed below.

1. Coupling Assembly

These couplings have been completed and delivered.

2. Saturn V Sled Test Module

The Saturn V sled test module is in the final stage of assembly.

3. Hydrazine Engine Mock-Up and Fixture

The hydrazine engine mock-up and fixture has been completed and delivered.

4. Models of ATM Experiment Package

One ATM experiment has been delivered and the remaining four units are being assembled.

5. C-1 Engine Modification

Work on the C-1 engine modification has been completed.

6. ATM Contamination Test Fixture and Parts

The ATM contamination test fixture and components have been delivered.

7. ATM Model Payload

The ATM model payload has been delivered.

8. ATM Rack

The ATM rack is completed and delivered.

9. X-Ray Astronomy Assembly Modifications

Modifications to the X-ray astronomy assembly are in process.

10. GOX Impact Compression Tester

Work has started on the GOX impact compression tester.

XI. A. Seven materials were evaluated for LOX sensitivity in accordance with the provisions of MSFC-SPEC-106B. Data generated from these evaluations were forwarded to requesting groups and will appear later in applicable reports.

B. Heat treated six items of maraging steel and three Inconel X diaphragm assemblies.

C. Inspected two aircraft strut brackets by magnetic particle techniques.

XII. Publications

Demorest, K.; and Whitaker, A.: Evaluation of Direct Current Motors in Vacuum, TM X-53675, November 24, 1967

Thompson, L.; and Hill, W.: A Preliminary Evaluation of Silane Coupling Agents as Primers and Additives in Polyurethane Bonding Procedures, TM X-53676, November 28, 1967.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-67-11

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(November 1, 1967, through November 30, 1967)

SATURN IB

I. S-IB Stage

Cable Installation Review

A review was completed on the S-IB-5 discrepancies noted by Quality and Reliability Assurance Laboratory personnel at Michoud. A status report of the review and action to be taken by Chrysler Corporation Space Division (CCSD) has been submitted to the S-IB Stage Project Office.

II. Instrument Unit (IU)

Engineering Change Proposal (ECP)

ECP 1463, a proposal to revise the IBM Systems Test Specification, Saturn IB, IU, was evaluated and recommended for approval.

III. General

A. Technical Checklist

Revision 15 to the Saturn IB Technical Checklist was completed and distributed.

B. Program Specifications

Revision A to the SA-204 through SA-212 Program Specification Baseline was approved by the Level II Board. The approval documents were sent to the Repository for distribution and filing.

C. Technical Information Summary

Final review of the Technical Information Summary for SA-204 was completed; the document will be released 30 days prior to launch.

D. Weight Status Reports

The monthly weight status reports for launch vehicles SA-201 through SA-212 and for AAP-1A through AAP-5 and the detail monthly weight status report for the SA-212 launch vehicle were completed and distributed.

E. Mass Characteristics

Revised launch vehicle weight data for AAP reference trajectories were distributed. Mass characteristics for AS-217 were calculated and furnished to the Advanced Studies Office of this laboratory.

SATURN V

I. S-IC Stage

A. Ordnance Bonding Problems

A study is being made to define possible changes to the S-IC ordnance cowling installation to prevent bracket failures similar to those experienced on AS-501. A comparison of S-IVB to S-IC installation procedures and bracket design is being made to determine if design changes are required. A summary of all known bracket bonding failures on the S-IVB program has been completed. In most cases, the failures can be attributed to failure to follow installation procedures.

B. Aft Umbilical/Tail Service Mast (TSM) Test

In support of the AS-501 launch, an aft umbilical/TSM test program was conducted at the MSFC Service Arm Umbilical Test Facility (SAUTF) to determine if umbilical separation and TSM retraction could be accomplished in the event the TSM were prematurely actuated prior to vehicle liftoff. One test was performed on each of the 3 umbilical/TSM systems. All tests were successful with umbilical separation occurring in the shear out mode.

C. Stage Umbilical Hardware

A memorandum was sent to IO stating that the S-IC stage umbilical/service arm systems compatibility testing at MSFC had been completed and that the umbilical hardware utilized as test units during the test program should be reprogrammed into the S-IC system. In addition, a request was made that the intertank umbilical for Mobile Launcher (ML)-3 presently at MSFC be returned to The Boeing Company (TBC)/Michoud Assembly Facility (MAF) for incorporation of all outstanding Engineering Change Proposals (ECP's) and reacceptance testing prior to shipment to Kennedy Space Center (KSC). Request for contractual action to implement the above was initiated.

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

1. HSCU S/N DSV-339 successfully supported the flight readiness test (FRT) and subsequent launch of vehicle AS-501 conducted at KSC.

2. The spare servo drawer, which was refurbished by TBC was tested at the Systems Development Facility (SDF) and shipped to KSC to support the HSCU during AS-501 launch activities.

3. During post FRT on spot maintenance inspections of HSCU S/N DSV-339 at Launch Umbilical Tower (LUT) 1, it was noted that the flowmeter for main pump number 1 was erratic in operation. The problem was corrected by replacement of the flowmeter pickup coil.

4. During the launch of AS-501 the fire system in room 4A of the LUT was energized and sprayed the HSCU with foam. The reason for the activation has not been determined at this time; however, two possibilities are being explored which concern excessive vibration (sufficient to trigger control relays) and extreme heat during launch. Information will be forwarded from KSC as it becomes available. Subsequent cleanup procedures have indicated that no obvious external damage was evidenced in the HSCU.

5. The SDF HSCU is undergoing refurbishment and modification. The new RJ-1 fluid was delivered on November 28, 1967. The emulsified fluid has been drained and all filters sent out for cleaning. The modification effort will consist of installation of the accumulator bank (10M32051) into the SDF HSCU system in preparation for test. An effort is being made to complete the installation of this equipment so that the tests can be run to support the launch of AS-502.

E. Inert Prefill Unit (IPU)

During the countdown for AS-501, at approximately T-40 hours, a minor problem occurred on S-IC IPU S/N 003. The pump shaft coupling bolts had worked loose and required retorquing which corrected the problem.

F. Test Specifications and Criteria

1. Revision D of TBC document, D5-13251, "Prelaunch Test and Checkout Requirements for S-IC Stages at KSC," was reviewed for technical accuracy and found to be acceptable.

2. Advanced Document Revision Notices (ADRN's) M-38 through M-44 of the "Specifications and Criteria for S-IC stage prelaunch checkout and launch operations at KSC," D5-13618, are now being reviewed for technical accuracy.

3. IRN R-45 to 13M50096 was released and reflects new changes to the stage/GSE interface pressure tolerances and regulator settings for the S-IC helium storage bottles and control pressure spheres. These were changed following a comparative review of red-lines and regulator settings following SA-501 Countdown Demonstration Test (CDDT).

G. Qualification Test Procedures

The following qualification test procedures for S-IC stage were reviewed and comments made recommending revisions to meet the minimum acceptance criteria:

D5-13814, Qualification Test Procedure, Flodyne Manual Ball Valve, 65B235331-103C.

QTP IN-66-67, Qualification Test Procedure, Model 2302, Pressure Sensor Assembly, Modified Design, Bourns Incorporated, dated September 21, 1967.

3A180A, Qualification Test Procedure for Manual Ball Valve, Flodyne, 65B23531-41.

QTR IN-66-67, Evaluation and Qualification Test of a Model 2302, Pressure Assembly, Modified Design, Bourns Incorporated, dated July 25, 1967.

QTP IN-66-67, Revision B, Evaluation and Qualification Test Procedure for a Model 2302, Pressure Sensor Assembly, Bourns Incorporated, dated October 11, 1967.

QTR IN-66-67, Revision A, Evaluation and Qualification Test of a Model 2302, Pressure Sensor Assembly, Modified Design, Bourns Incorporated, dated October 11, 1967.

Partial Qualification Test Procedure, Servo-Dome Pressure Regulator, 1351-1001-1, Boeing part number 65B23421-3B

H. Engineering Change Proposal (ECP)

ECP 2305, Reconfiguration of Cold He Control Valve and Re-pressure Control Module Assembly, was reviewed and recommended for approval.

I. Integration Test Requirements Specifications

D5-15402-1, Integration Test Requirements Specifications for S-IC Pneumatics Subsystem Checkout Local Control, KSC, proposed revision "C," was reviewed and processed prior to release for KSC use. The document is periodically updated for KSC reflecting the latest fluid requirements.

II. S-II Stage

A. S-II Pneumatic Console Set (S7-41)

An internal circuit modification was made to the S7-41C console that separates the turbine start bottle GN_2 vent control pressure circuit from the LOX and LH_2 disconnect shroud purge circuit. This modificaton was made to improve the flow of the purge circuit.

B. Insulation Purge Pneumatic Control Console (S7-45)

1. Relocation of the LH_2 feedline elbow return line flowmeter preamplifier into the S7-45C filter bank was implemented at ML-1 to support AS-501 only. This change, which was made at ML-1 as a result of return line flowrate readout malfunction during the AS-501 CDDT, is not considered the complete answer by all responsible parties: i.e., North American Rockwell (NAR) at Mississippi Test Facility (MTF) and this division. However, for lack of sufficient data, preamplifier relocation was approved at ML-1 for AS-501 launch. A series of tests are now being performed by NAR to accurately determine a permanent fix.

2. The S-II LH_2 tank sidewall purge inlet pressure was reduced from 4.0 p.s.i.g. to 3.0 p.s.i.g. of GH_e. Pressure was reduced to the possibility of overpressurizing the sidewall insulation at 4 p.s.i.g. During AS-501 countdown the sidewall pressure dropped to zero and back purge was initiated.

3. An Interface Revision Notice (IRN) was submitted by KSC to delete the ΔP and flow rate values of IRN-R-25 to 65ICD9775 (function 2.70) and revised the maximum operating pressure from 4.0 p.s.i.g. to 3.0 p.s.i.g., effective with AS-501 only. A general note on the KSC IRN stipulated that the ΔP and flow, obtained from KSC as-built hardware, was acceptable for AS-501 launch. IRN R-25 will be revised to reflect a AS-502 and subsequent vehicle effectivity. The division has concurred in this change for the following reasons:

The AS-501 CDDT verified that a lower pressure and flow was required to protect the sidewall insulation from overpressurization. However, the reduced inlet pressure resulted in a sidewall outlet pressure which rapidly approached zero during AS-501 LH_2 loading prior to launch. Consequently, back purge was initiated with the accompaning loss of sidewall leak detection capability.

Full flow relief valve installation into ML-3 fluid distribution system is being withheld as a result of the approval of spray-on foam insulation for S-II-8 and subsequent stages. Spray-on foam will delete certain leak detection functions and corresponding relief valves. Changes to the ML-3 fluid distribution system will be defined at a later date.

III. S-IVB Stage

A. Pneumatic Console

Emergency ECP 0955 was processed, removing failed relief valve, A12275 P/N 1A66984-503 1/4", from pneumatic console, DSV-4B-433A. The relief valve is used to provide vent relief capability for the cold helium supply (oxidizer tank pressurization). This valve has failed several times during the past month, and is being replaced with a 3/4 inch relief valve, P/N 1A66984-1. In the event the relief valve fails in the closed position during liftoff, no venting of high pressure helium can occur. This will cause pressure buildup within the system and result in serious damage to the console and piping.

B. Electrical Housing Purge

An Engineering Change Request (ECR) and IRN R-34 to 13M50098 and IRN R-30 to 65ICD9402 were prepared to document a reduction in flow rate for the electrical housing purge for compatability with hardware configuration for SA-501.

C. Deletion of the 436 Console

An IRN to 65ICD7469 was prepared reflecting the deletion of the 436 console by KSC. Instead of the 436, KSC is using portable regulators to supply the pressure to the Auxiliary Propulsion System (APS) hypergol loading equipment. This system is less complex and allows better communication between personnel accomplishing the loading on the Mobile Service Structure (MSS). A number of interfaces and flex lines between the MSS and ML are also eliminated. These IRN's have been transmitted to KSC for concurrence.

IV. General

A. Vehicle Assembly Documentation

1. Documentation was prepared to change the interface for SA-503 and SA-504 sealant material requirements. This change was initiated in response to a request by the Saturn V Systems Engineering Management Office to reduce their logistics problems by changing to a sealant with a longer shelf life. An ECR was also prepared to submit the proposed change to the Configuration Control Board (CCB) for approval.

2. Documentation was prepared to add markings to the S-IC stages to aid in stage identification while in storage.

3. A review has been completed on the final draft of the AS-505 Ordnance Systems Document supplement and approval has been given to TBC.

4. The vehicle assembly documentation release schedule for AS-505 through AS-515 has been completed and distributed. The schedule is based on arrival of the S-IC stage at KSC.

B. J-2 Engine LO_2 Pump Seal Bleed Overboard Drain

Results of the studies of the Rocketdyne-proposed redesign of the overboard drain system have been submitted to the Saturn V Project Office. It was pointed out that this division does not recommend changing the present system configuration from a 1-inch to a 1 1/2-inch line. This is contrary to information supplied by Propulsion Division.

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

Information is being compiled in the form of a written report for a design certification review (DCR) in accordance with Program Directive I-V-ED number 2. This report includes a system description, function, and subsystem breakdown of the primary and auxiliary damping systems to include major problems evidenced during research and development of both systems.

D. Cable Installation Specifications

Cable installation specifications for all stages have been reviewed. All prime contractors will be notified of MSFC-required revisions pertaining to installation and inspection.

E. Cable Installation Test Program

Studies are being made to establish the test fixture and cable configurations required to evaluate maximum acceptable cable bundle sizes for vehicle installation.

F. Weight Status Reports

The monthly weight status reports for launch vehicles SA-501 through SA-506 and the detail monthly weight status report for the SA-506 launch vehicle were completed and distributed.

G. Mass Characteristics

Revised AS-502 final predicted operational mass characteristics were distributed.

ADVANCED TECHNOLOGY

I. Systems Design

A. Cluster Documentation

1. The "Inboard Profile/Space Envelope Layout," SK10-9317, is being revised considerably in order to define the complete configuration for the AAP-2 vehicle for the Preliminary Design Review (PDR). The changes involved are described as follows:

The Multiple Docking Adapter (MDA) display and control panel and the S-069 display unit have been removed from the MDA. Astrionics Laboratory states that these components will be located in the Structural Transition Section (STS). A new design for the electrical feed through plate was initiated. This new design will comply with the display and control panel being located in the STS.

The engineering layout defining the external system on the MDA is 60 percent complete. A decision was made not to rotate the windows in the conical bulkhead but, instead, to rotate the docking target. This rotation was necessary to prevent interference between the target and window cover.

2. The documentation on the MDA hoist and track assembly and the airlock module hoist and track assembly was completed.

3. The MDA platform and ladder assembly concept will require the addition of brackets on the four inner walls for attaching and supporting the platform segments.

4. The first concept for the MDA handling fixture and slings was undesirable from a structural standpoint. The present concept is to provide a structural box or ring section which will hard mount to the hoist on the MDA.

5. Test program requirements for the MDA window cover mechanism have been coordinated with Structures Division of this laboratory and are being established in detail. A decision was reached to test the mechanism without the window.

6. The preliminary configuration of the four mobility poles and the continuous dutch shoe has been completed. Class I documentation will begin as soon as a suitable method for manufacturing the continuous dutch shoe can be obtained from Manufacturing Engineering Laboratory. The processes which are being considered are spinning, hammer forming, and explosive forming.

7. The coordinate systems for the MDA orientation have been changed from the launch vehicle axes to the Apollo payload axes. The layouts are being revised to reflect this change.

8. A sketch, SK10-1998, was prepared to show details of providing a window emplacement experiment in the S-IVB spent stage. The window experiment will be ground tested by Manufacturing Engineering Laboratory and the documentation will be furnished by this laboratory.

9. The Contract End Item (CEI) specifications on the MDA handling and auxiliary equipment (H&AE) are being updated as the requirements are finalized. Layouts from Structures Division on the wall installation are being modified by this division for fabrication of hardware for the MDA 1 g trainer. A design and assembly plan for the 1 g trainer is being prepared.

10. A study of the MSFC quick release fastener design (SK10-9264) resulted in a 50 percent weight and space reduction from the original design. A new concept also incorporates a standard self-locking insert to prevent torque relaxation.

11. A review has been completed on the equipment changes in the forward and aft skirt for installation of the solar panels for the orbital workshop mission. Five equipment panels will possibly require relocation along with numerous cable routings.

B. Apollo Telescope Mount (ATM) Documentation

1. SK10-7266, "ATM Inboard Profile Space Envelope Layout," was revised to its AA revision. The solar array configuration was changed to a 7-panel, 16-module per panel array, resulting in a decrease in the width and an overall increase in the depth of the panels. Because of enlargement of the control computers, two batteries, a remote digital multiplexer, and the fine sun sensor conditioner assembly were relocated.

2. SK10-7328, "ATM Experiment Package Subassembly," was revised to its K revision. Some of the major revisions were as follows:

Added Goddard Space Flight Center proportional counter.

Added detail on spar ring attachment and cable routing.

Defined flat to round cable transition.

3. Drawing 10M03736, "Apollo Telescope Mount Alignment Control Drawing," was revised according to information received from Structures Division, Astrionics Laboratory, and Manufacturing Engineering Laboratory. The drawing was released for signatures and checking.

4. The preliminary CEI specifications for the following end items were prepared:

Lunar Module (LM)/ATM Assembly Covers for Transportation.

ATM Clean Room Scaffolding.

ATM Ground Handling Fixture.

ATM Platform and Ladder Assembly.

5. The investigation on the transporter and pallet for Apollo Applications Program (AAP)-4 payload was completed. The investigation produced the following results:

The mainstream Apollo payload transporter can be used with no modification if the ATM ground handling fixture is designed to adapt to the regular spacecraft/LM adapter interface on the transporter. (The loads will have to be coordinated as soon as they are defined for the AAP-4 program.)

The pallet which is the ATM ground handling fixture will be required. This fixture will provide transportation adaptation to the payload transporter, environmental protection, and clean room requirements maintenance by allowing a purge of the enclosed area.

6. SK10-7452, "Lowered Solar Panel Study," was completed. This study showed that lowering the solar panel units 8 inches eliminated the interference with the LM/ascent stage umbilical support arm and the 603 level work platform supports. Based on a decision between the Propulsion and Vehicle Engineering and Astrionics Laboratories, another study was made to determine the feasibility of lowering the solar panels 12 inches. Lowering the solar panels 12 inches would cause redesign of the astronaut work station.

7. Requirements for an ATM/LM ascent stage hoisting adapter were defined at meetings with representatives from Astrionics Laboratory and the Layout and Packaging Section of Propulsion and Vehicle Engineering Laboratory. A CEI specification input was prepared.

8. SK10-7453, "ATM Experiment Package Access Study," was completed. The study shows that the present ATM configuration (LM/ascent stage, solar panels, and lower spacecraft/LM adapter in place) does not provide access to all experiment package film retrieval doors. Access can be gained to the astronaut work station with some degree of difficulty.

9. A new configuration layout for the ATM was initiated to define the requirements for an active cooling system.

10. Drawing SK10-9940, "ATM Electrical Equipment Relocation Study," was completed. This drawing shows the relocation of electrical equipment from the upper ring and quarter panel areas of the rack to areas within the rack bays and solar shield substructure. This study proposes a rack structure extending from the lunar module ascent stage to the rack solar shield. The conclusion of this study is that the present rack design does not allow the enclosed mounting for all components. However, a rack structure that extends from the lunar module ascent stage to the rack solar shield will permit proper component mounting.

11. Conceptual design is in progress on a rack to cable arch adapter such that an experiment package rotation of 215 degrees (total) can be accommodated.

C. Nuclear Ground Test Module (NGTM) Testing

1. The Insulation Radiation Test Tank Assembly Drawing, SK10-9263, was released for signature. Some missing information will have to be added to the drawing later.

2. Studies are underway to determine whether an AS-203 manhole cover can be adapted to the NGTM propellant heating test tank for visual monitoring during testing. Initial results indicate that the location and viewing angle of the cameras will limit the viewing.

II. Systems Operations

A. Apollo Telescope Mount (ATM) Mechanical Ground Support Equipment (MGSE)

Concurrence was obtained from NASA headquarters regarding an active fluid thermal control subsystem for ATM in lieu of a passive heater system. Based on previous studies, existing MGSE may require modification and new MGSE will be required to support this system.

B. Cluster/Operations Analysis

1. The operations analyses for two operations have been completed for the MDA prelaunch sequence of operations. A tentative milestone completion date for the entire ground sequence of May 1, 1968, has been established. A similar effort is required for the ATM prelaunch sequence of operations with an expected completion date of July 1, 1968. Preliminary data will be made available as generated.

2. Preliminary work is continuing to establish backup information for the AAP-2 ground sequence of operations. Operation summary sheets for two tasks have been completed for the purpose of validating and demonstrating an analysis technique. This technique will delineate event functional flows which will be used to identify and extract test requirements, necessary handling equipment requirements, and related facility requirements for launch operations at KSC.

C. Automatic Umbilical Reconnect System

The Critical Design Review (CDR) was held on November 17, 1967, in building 4610. The CDR consisted of a presentation by BECO of the final concept and the sequence of operations for the system. An informal discussion of the detailed design followed utilizing the detail drawings. All drawings will be completed and ready for MSFC by December 4, 1967.

III. Systems Engineering

A. Orbital Workshop (OWS) Simulation

1. The requirement for a package transfer device for the OWS and MDA Crew Station Reviews was established by an Engineering Information Data (EID) sheet to the laboratory Projects Office on November 3, 1967. Design criteria for the package transfer device were included with the EID.

2. Lighting requirements for the OWS and MDA were released November 1, 1967, to Astrionics Laboratory.

3. Human factors considerations for the OWS Pressure Relief System were forwarded to Propulsion Division. Experimental data indicates that a pressure rise rate of 1 p.s.i./minute in the OWS is tolerable to the crew. Estimated astronaut emergency egress times from 5 locations and under 7 conditions within the OWS were provided.

4. A review of simulation testing of workshop activation equipment and procedures in the Aft dome area was held with MSC personnel on November 14 and 15, 1967. A discussion of the test program and the preliminary results was held November 14, 1967, and an astronaut review of the Aft penetration sealing task was completed November 15, 1967. Astronauts Cooper, Lousma, and McCandless participated in neutral buoyancy evaluations of the penetration sealing task. Astronaut comments paralleled and verified laboratory findings.

5. Simulation of crew quarters ceiling deployment and the crew quarters door evaluation was completed November 28, 1967. The present concept of ceiling deployment appears acceptable. One door concept was damaged, apparently during installation and some delay in testing was necessary to repair the door. A second concept, which was delivered late by MDC, had to be installed underwater. The mechanism could not be made to function properly, therefore, this design was not tested. Both tests were delayed due to incomplete assembly of the mock-up prior to installation in the Neutral Buoyancy Facility. Procedures in progress to provide for mockup inspeciton by the division prior to installation will eliminate this problem.

B. Lunar Module (LM)/Apollo Telescope Mount (ATM) Mockups

1. Five mockup concepts (2 MSFC and 3 MSC) of the ATM control and display panel integration into the LM were evaluated on November 15, 1967, in a joint review by MSC and MSFC held at the center. The MSFC alternate concept developed by this division with fixed panels located in the aft right midsection of the LM was established as the baseline concept. The human factors considerations included astronaut safety, operability, translation, and access. Astronauts Cooper, Garriott, Gibson, and Michel participated in the review.

2. Problems with the pointing and control simulation (PCS) were discussed with a representative of Computation Laboratory on November 20, 1967. The digital programs for Star Tracker mode and Canopus Acquisition are being checked out. If all goes well, the PCS simulation test runs will begin on November 27, 1967, instead of the November 13, 1967, previous commitment.

C. Multiple Docking Adapter (MDA) Mockups and Reviews

1. The following is a summary of crew station results of the MDA design systems reviews held on November 14 to 17, 1967:

Provide a "control station" in the Aft MDA/STS.

When possible, locate other MDA and fixed experiment controls in the "control room."

Reconfigure the forward MDA to provide stowage for equipment displaced form the Aft MDA/STS.

Route the gaseous oxygen supply line from the CSM to the AM externally on the MDA.

2. The astronaut interface with the Structural Transition Section (STS) and MDA was discussed by division personnel with a representative of MDC St. Louis, Missouri, on October 30 to 31, 1967. The company representative assisted in preparing an updated MDA initial pressurization sequence and briefed division personnel on the present MDA concept for servicing the liquid cooled undergarment support system. The MDA engineering mockup was reviewed and the MDA/STS crew station interface and potential STS window and panel access problems were discussed. It appears that STS access is unaffected by MDA internal configuration, i.e., eight mounting surfaces present as much of an obstruction on initial activation as do four walls, but STS initial activation access can nevertheless be achieved.

3. The AAP-2 Astronaut Review Outline, Revision C, was distributed on November 8, 1967. Revision D of this document will be available December 15, 1967, and Revision E (final revision) will be published immediately prior to the MDA and OWS Crew Station Review in late January.

4. The astronaut metabolic load profile for AAP-2 mission, orbital phase, was prepared and released by drawing 10M32154. This initial profile identifies and locates major activities of the astronauts and provides estimates of both individual and cumulative heat generated. The first seven days of the AAP-2 mission were analyzed with inputs from the man system timeline.

5. Manned Spacecraft Center (MSC) and MSFC are working together for establishing and controlling the stowage configuration for AAP-1 and AAP-2. The current list, dated October 30, 1967, contains MSFC inputs derived from layout drawings, experiment interface, requirement documents, experiment implementation plans and from individual contributions in addition to the MSC inputs.

D. Human Factors Experiments

1. Urine dumping from experiment M052 (Bones and Muscle Changes) could present a significant contamination problem to the S-IVB solar array panels. During each 24 hour period of AAP-2 mission, approximately 1.3 gallons of liquid urine will be dumped overboard from the OWS. If this liquid impinges on the solar array panels before they crystalize, the efficiency of the panels will be significantly affected. Propulsion Division is currently evaluating this problem area and will make their recommendations when the study is concluded.

2. An experiment integration meeting for M053, "Human Vestibular Function," was held on November 15, 1967, under the direction of this division. It was established that M053 will now utilize MSFC furnished multiplexers in the OWS for telemetry instead of the Experiment Data Acquisition System. Physical data to be returned was reduced from seventeen pounds to one pound. A new four box package concept for M053 will replace the old single box concept.

3. An experiment integration meeting for T013, "Crew-Vehicle Disturbances," was held on November 21, 1967, under the direction of this division. Some of the more significant actions that resulted from the meeting were as follows:

Physical return data were reduced from 20 pounds to 5 pounds.

Langley Research Center (LRC) will study the feasibility of locking the experiment gyros and eliminate power requirements during the prelaunch and launch phases.

MSFC will determine the optimum package size and the number of packages for translation into the OWS.

During the operation of experiment T013, the astronaut will wear a lycra suit containing the necessary potentiometers and a belt pack transmitter. Other experiments will have to be mechanically inactive for approximately 80 minutes while T013 is in operation to prevent vehicle disturbances.

4. An investigation was made to determine the experiment requirement for the MDA bulkhead windows. Originally, the MDA windows were incorporated to satisfy the observation requirements of several experiments, some of which required ultraviolet and x-ray measurements. However, only one experiment, Multi-Band Terrain Photography (S065), from the present baseline list now requires the use of the MDA windows. It was recommended that fused silica glass MBO 115-005 Type I (equivalent to Corning 7940) be used for the MDA bulkhead windows. This will also provide the observation capability to meet any contingency.

5. Evaluation of MSFC experiment number 28 (leak detector) was completed. Various experiment locations were proposed and a recommended leak source configuration was given. Gross astronaut functions were identified and human factors guidelines and requirements related to the work station were presented.

6. Evaluation of experiment M507, Gravity Substitute Workbench, was completed. The evaluation included preliminary identification of human operator and equipment design requirements, preliminary identification of human operator and equipment design requirements, preliminary identification of potential safety hazards, and discussion of the workbench as a general repair support device.

E. Contract Activities

1. The final draft analysis for General Electric (GE) contract NAS8-18117, "Human Engineering Data for Maintenance & Repair of Advance Space Systems," was completed and transmitted to GE (Valley Forge) on November 6, 1967. The completion of these analyses was ten days late. It is not yet known whether this additional delay will affect the final report completion dates.

2. The first group of subjects was run under contract NAS8-21118, "Man-System Locomation Control and Display Criteria for Extraterrestrial Vehicles, Phase II" on Wednesday, November 28, 1967. This is approximately two months behind schedule. A number of equipment and data collection problems have interfered with the progress of the program.

F. Weight Status Report

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

IV. Systems Requirements

Test Plans and Specifications

1. Preliminary drafts of the Auxiliary Altitude Control System (AACS) specification, AACS R&D Plan, and the AACS Systems Test Plan were completed for the Apollo Application Program (AAP).

2. Preliminary drafts of the Solar Array R&D Plan, end item specification and the System Test Plan were completed and distributed for review.

3. Data was assembled for preparation of the AM/MDA Integrated Test Plan. This document will contain test information for the combined AM/MDA integrated testing to be conducted at MSFC, MSC, and MDC.

4. Assembly of all available information necessary for writing the ATM Systems Test Plan continued during this reporting period. It was tentatively agreed that this document would not be a true systems plan in that the main body would outline laboratory policies, guidelines, schedules, etc., with test efforts covered by appendixes. Each appendix will cover a specific phase of testing, i.e.; structural, vibration, acoustics, thermal/vacuum, and will be added to the test plan as they become available from the responsible activity.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-67-11

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

November 1, 1967 through November 30, 1967

SATURN IB

I. S-IB Stage

A. S-IB-4 Engine Thrust Chamber Corrosion

An inspection of H-1 engine thrust chambers revealed surface corrosion forming on all engines. This corrosion is caused by the long exposure of the thrust chambers to the highly corrosive salt spray atmosphere; however, it has not progressed to a point where it will be detrimental to thrust chamber operation or performance. The corrosion deposits were removed, and the thrust chambers of all engines were completely repainted.

B. S-IB-4 Gimbal System Sampling

Hydraulic fluid samples were taken from the gimbal systems on positions one and three. Analysis of the samples revealed no trace of the silt that was previously seen in the systems. Apparently the hydraulic system purge and fill procedure is effective in removing the small particle contamination. No further fluid sampling is planned unless component malfunctions are encountered.

II. S-IVB Stage

ORBITAL WORKSHOP

1. Storage Analysis

Preliminary analyses indicate that curtain temperature variations will be between a maximum of approximately 58°F and a minimum of approximately 9°F. The temperatures cannot be predicted until vehicle roll rates are established.

2. Meteoroid Shield Close-Outs

Analysis indicates that 900 Btu/hr of internal heat will be required to offset heat leakage out the ends of the 5-inch gap between the meteoroid shield and the tank wall. This analysis was performed for a gravity gradient mode with a 53°β angle. The perpendicular to Orbital Plane (POP) mode should have a significantly larger heat leak. A flexible curtain with an inner surface emissivity of .05 and an outer surface emissivity of .9 is recommended to close out this gap. Such a curtain would reduce the heat leak to negligible proportions.

3. Penetration Heat Leaks

Analysis of eleven metal insulation penetrations indicates that in some places the astronaut touch limits of 55°F to 105°F will be exceeded; however, many of the penetrations are behind the thermal curtain and are not apt to be touched. Also, all the aft end penetrations are out of reach of the astronauts. Exceeding the touch criteria in local areas is not expected to be of concern.

4. Increase Duct Flow Rates

By increasing duct flow rates to 675 cfm and adjusting the coating emissivities, the minimum wall temperatures for the coldest sun-oriented case can be increased from 40 to 57°F. For the coldest POP mode case, the wall temperature increases from 20 to 34°F. For hottest case conditions, the wall temperatures do not increase significantly. These changes reduce internal heat requirements about 3000 Btu/hr for Mission "A".

5. Environmental Control System Heater

A heater for the OWS environmental control system is being designed. Preliminary design of the heater was completed, and sketches were submitted for thermal analysis. A procurement specification for the heater assembly is being prepared.

SATURN V

I. Apollo/Saturn Vehicles

A. AS-501 Engineering Film Evaluation (All Stages)

The evaluation of the film is approximately 90 percent complete. Film evaluation difficulties occurred, because a control power and timing loss during the period of 0.6 to 1.0 second made it impossible to project a time curve for this period. In addition, the ground support equipment holddown arms were released during this power failure. As a result the time of vehicle first motion cannot be established from the film, and disconnect times of the holddown arms, the tail service masts, and the swing arm umbilicals (except S-IC intertank, swing arm No. 1) cannot be shown. All the following items have time/data loss during power failure:

1. Retraction ratio of tail service masts and swing arms.
2. Vehicle motion (first 5 meters).
3. Horizontal motion of the base of the S-IC stage.
4. Vehicle/LUT relationship lift-off to tower clearance.

The two on-board cameras were recovered. The quality of this film was excellent.

B. Evaluation of Flight AS-501 Data on Retro and Ullage Motors

Data obtained from flight AS-501 on the retro and ullage motors indicates all solid motors fired; however, some of the data was blanked-out due to telemetry attenuation. More complete data taken from the on-board tape recorder will be obtained from the prime contractors.

C. Saturn V Flight Critical Components Review

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

S-IVB	-	29
S-II	-	14

In addition, there are 6 items in formal qualification testing for the AS-503 S-IVB Stage, oxygen-hydrogen burner system.

II. S-IC Stage

A. F-1 ENGINE

1. S-IC-1 Flight Data Analysis Indicates No F-1 Engine Problems

Analysis of the flight data received to date indicates that there were no F-1 engine-related problems during the flight of S-IC-1.

2. S-IC-1 Engine Gimbal System Flight Data Evaluation

All gimbal system parameters were in the range that was expected. Five system measurements were lost; the filter manifold differential pressure transducers were faulty, and the return fluid temperature measurement on position 4 also failed to provide useful data. The filter manifold differential pressure transducer problem will be corrected for S-IC-2 and subsequent stages. The maximum gimbal angle during the flight was 0.6 degrees. This is only a fraction of the maximum capability of 5.2 degrees.

3. Outboard Engine Depletion Sensor

The effect of dry indication of the outboard engine depletion sensor was investigated. It was found that prior to lift-off one (of two) fuel or two (of four) LOX sensor dry indications will inhibit the beginning of the automatic start sequence and result in a no-go condition. After lift-off, the above indication will cause all outboard engines to shut down subsequent to "outboard engines cutoff enable" signal (145.1 seconds after lift-off for SA-501).

B. S-IC-1 Stage Pressurization System Performance

1. Fuel Tank

The helium pressurization system performance was satisfactory, and the helium heat exchanger performance was within specification limits.

2. LOX Tank

The pressurization system maintained the ullage pressure within the flight control limits. The GOX flow control valve fully opened at 120 seconds because of the large pressurant demand that resulted from heat exchanger performance being greatly off-design. The cause for the off-design performance is being investigated.

C. S-IC-1 Stage Base and Impingement Heating

The base region environment agreed fairly well with predictions in regard to total heating and base pressures. Therefore, it does not appear likely that a substantial amount of insulation can be removed from the F-1 engines.

D. Subscale 120-inch Diameter Solid Motor Model Tests

Four tests have been conducted to date using subscale 120-inch diameter solid motors strapped on to a subscale S-IC stage to evaluate the effects of solid motor exhaust on a scale model of launch complex 39. Test results indicated there would be no significant adverse effects on the launch complex by the solid motor exhaust. All tests were conducted with a zero drift condition on the vehicle and a zero degree nozzle cant angle on the solid motors. The next series of tests will be conducted with maximum drift on the vehicle followed by tests using solid motors with a six degree nozzle cant angle.

III. S-II Stage

A. J-2 ENGINE

1. SA-501 Flight Data Analysis

Preliminary analysis of the flight data indicates that there were no J-2 engine related problems during the flight. As a result of the analysis the J-2 start tank refill capability will be eliminated for S-II/502 since restart is not required.

2. R&D Testing at SSFL

Seventeen tests were conducted, and a total of 1225 seconds were accumulated. None of the tests were full-duration runs. One test was terminated prematurely by a faulty safety cutoff device.

3. Production Engine Tests at SSFL

Nine tests were conducted, and a total of 765 seconds was accumulated. None of the tests were full-duration runs. One test was terminated prematurely due to a fire at a loose fitting on the thrust chamber.

4. J-2 Engine Test at AEDC

Eight hot firings and two blowdown stall tests were run in support of the S-II fracture mechanics problem. Seven of the eight hot firings were conducted with a simulated S-II fuel tank pressure of 27.0 psia. The remaining hot fire test was conducted to establish base data at maximum fuel pump NPSH. The engine operated satisfactorily during these tests, and no significant detrimental effects were observed. Further low fuel pump NPSH tests with the present configuration engine and fuel ducts are scheduled for December.

5. J-2X Turbopump Hot LH_2 Cavitation Evaluation

The Rocketdyne cavitation testing of the J-2 fuel pump with hot LH_2 was completed. Results indicate that the minimum bulk saturation pressure for nominal engine operation of the S-IVB stage will be very close to the tank pressure limit. It may, therefore, be possible to operate the S-IVB stage with zero tank NPSH and no orbital prestart repressurization system.

6. J-2X Experimental Engineering Program

Testing continues on the J-2X 013-1 Engine to investigate propellant valve throttling on J-2S configuration hardware. Thirteen (13) tests were conducted for a total duration of 929 seconds. Standard main propellant valves were incorporated for thrust control during the early tests with marginal success. Later tests have used special cavitating venturi valves to control main propellant flow. Problems have been encountered with flow instabilities and valve control.

7. J-2S Engine

The study to adapt the J-2S to S-II and S-IVB stages of 213 and 513 was completed. The pressurization system hardware must be requalified if the present J-2 pressurization interface requirements cannot be met.

B. S-II-501 Stage

1. Evaluation of Engine Gimbal System Flight Data for AS-501

All four systems performed as predicted. Some system-to-system variation was probably due to instrumentation shifts, since ground system calibrations were not performed at KSC. During the CDDT, low reservoir levels were observed on two systems. This was subsequently corrected by bringing up the accumulator precharge to specification levels. The countdown EGS sequence recommended by MSFC was employed for this launch. Very few hardware replacements or modifications were required for the four S-II systems, because they were built up on the stage.

2. Pressurization System Performance

Liftoff tank pressure was lower than expected due to low LOX vent valve seating pressures (out of specification). This caused the engine start pressures to be at the required minimum of 35 psia. The decay rate of 1.6 psi/min was greater than the 1.4 psi/min expected decay. The 2 psi ullage decay following engine start and 16 seconds recovery time was as expected. Engine 4 LOX heat exchanger exit temperature was 150° hotter than the other four. The cause of this anomaly was attributed to a plugged heat exchanger inlet. The GOX flow control valve fully opened at 350 seconds into burn. This was attributed to the large flow demand created by the low temperature and pressure of the pressurant medium at the flow control valve inlet.

3. Base and Impingement Heating

The Base environment appears to be substantially less severe than the design environment. The J-2 insulation appears adequate; all insulated components stayed well below their allowable temperatures.

4. LH_2 Stratification

The stratification data are being evaluated. It appears that heat loads to the LH_2 tank were significantly reduced by ice/frost formations. The propellant temperature and stratification were lower than predicted, but they agree well with the analytical model when reduced heating is superimposed.

5. LH_2 Tank Insulation

During the countdown and launch, the previously determined procedures performed acceptably. TV inspection just prior to launch showed no insulation problems of concern. During flight, the internal bursting pressure in the insulation did not exceed 4 psig, which was slightly below predicted pressures. Insulation surface temperatures were also below predicted values, and tentatively, this is attributed to frost on the outer surface. The flight data are still being analyzed.

C. S-II-2 Flight LOX Pump Inlet Pressure Profile During Start Transient

The pressure profile during start transient was predicted for a given flow rate transient and tank pressure history. The results, which will be used for simulation at the Arnold Engineering Development Center (AEDC), reveal a momentum pressure loss of 2 psi for a LOX outboard suction duct length of 7.34 feet. A recovery time of 16-18 seconds will be needed to reach the control pressure range (36-37.5 psia) with a 35 psia initial pump inlet pressure.

IV. S-IVB Stage

A. S-IVB-501 Stage

1. Evaluation of Engine Gimbal System Flight Data

All gimbal system parameters were within specifications for both burns, and all redline criteria were met prior to liftoff. No auxiliary pump-motor thermal cycles were required during orbital coast. The reservoir level was lower than nominal during liftoff and first burn due to a low system oil level and temperature of accumulator precharge. The level did go up to 32 percent during the second burn due to the heat input to the system. Also, only 30 percent of the actuator force capability was employed, and 1.2° engine deflection was observed during the course of both burns.

2. APS Flight Evaluation Summary

This evaluation was based on flight data available for the periods from T + 240 seconds to T + 700 seconds and from T + 11,300 seconds to T + 11,800 seconds. The APS performance during these periods was satisfactory. The performance parameters of the systems were generally well within their normal values. Deviations from the predicted values were noted on the helium tank pressure, which indicated corresponding deviations from the predicted propellants consumed. The total amount of propellants consumed by modules I and III throughout the flight until T + 11,800 seconds was estimated to be approximately 69 percent and 65 percent (respectively) of the predicted values. This indicates that the altitude control demands during the flight were not as much as was anticipated.

3. Actuation Pressure Loss During Flight

The exact location of the leakage is unknown. Based on the data available, it appears that the leak was downstream of the regulator and probably from one of the actuation control modules. The modules in question will be replaced with newly designed modules on S-IVB-205, -502, and subs.

4. Base and Impingement Heating

The S-IVB/J-2 orbital temperatures and impingement heating rates are being investigated in detail. Preliminary information indicates cool orbital temperatures and little impingement heating.

5. Low Gravity Propellant Control

A preliminary review of the data was made to determine the measurement locations in the propellant tank ullage regions that sensed liquid during the low gravity periods of orbit insertion and J-2 engine restart preparations. Since the S-IVB gas temperature and liquid-vapor sensors are not suitable for operation in low gravity, only limited conclusions can be derived from the data. The following observations were made:

a. Orbital Insertion

(1) LH_2 Tank - Measurements on the instrumentation probe indicated no significant liquid motion. Liquid was indicated by the six internal skin temperatures distributed on Position I between the slosh baffle and deflector.

(2) LOX Tank - No liquid motion was detected, but all instrumentation was located on the instrumentation probe, and therefore, liquid motion at the tank walls could not have been detected.

b. Restart Sequence (Initiated at flight time = 11,160 sec.)

(1) LH_2 Tank - The presence of liquid was indicated by most of the sensors, both on the instrumentation probe and internal skin, between the slosh baffle and deflector prior to 11,160 seconds (beginning of pitch and yaw maneuvers, repressurization, and ullage engine thrust). It cannot be determined when this liquid impinged on the sensors until additional data are received. The sensors above the deflector detected liquid at random times and locations after 11,160 seconds.

(2) LOX Tank - All liquid-vapor sensors indicated liquid prior to and during engine restart preparation; however, the gas temperature measurements seem to indicate the presence of vapor.

B. Redesign of the S-IVB Engine Gimbal System for Majority Voting Actuators

The gimbal system will undergo a major redesign in order to incorporate the majority voting actuators. The following system changes are also being made:

1. Reduction of system pressure from 3650 to 3000 psi.

2. Resetting and requalification of the engine-driven main pump, low pressure relief valves, and high pressure relief valve.

3. Design and development of a higher flow, lower pressure auxiliary pump that will match the present dc motor characteristics.

4. Installation of springs in the reservoir that will create a positive inlet pressure for both pumps in the event that the accumulator precharge is lost.

5. Rerouting of tubing and flexible hoses will be compatible with the above changes.

C. Cryogenic Valve Electrical Connectors

It was recommended that all cryogenic valve electrical connectors on the S-IVB stage be reworked to debond the connector interfacial seals. Experience has shown that the silicon wafer-to-glass insert bond induces cracking of the glass at cryogenic temperatures.

V. Instrument Unit

A. Instrument Unit Purge Test

Hardware is being collected for flow tests to determine the availability of IU purge gas for cooling the Radioisotope Thermal Generator (RTG) on the Lunar Module descent stage. Testing will be completed by January 15, 1968. Changes required will be incorporated on AS-505 to accommodate the RIG.

B. Regulator Life Tests

The Gas Bearing Regulator is being subjected to the extended life test. The external leakage of the regulator was slightly above the specified limits. The regulator now has 300 hours of test time and is operating satisfactorily. A 2000-hour life test will begin on the S-IC stage regulator in December.

C. Sublimator

Acceptance testing was completed successfully on Sublimator S/N 24 and S/N 26. A production reliability test was successfully completed on S/N 26. S/N 27 and S/N 29 are awaiting test.

SPECIAL STUDIES

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

The final test report for the Vickers Pump was issued. An American Brake Shoe Pump was installed in the Freon E-3 test setup. The pump was operated for 22 minutes when the input shaft of the torque transducer (part of the test equipment) sheared, interrupting the tests. The transducer is being repaired.

II. Gas Bearing Regulator (20M42012) Extended Life Test

Approximately 350 of the 1500 hour extended life test were completed satisfactorily. Tests are continuing.

III. AAP-2 S-IVB Stage Passivation

The passivation of the S-IVB stage was revised, based on a Command and Service Module (CSM) docking time of 30 hours. The basic passivation concepts previously established are still employed. The only difference lies in dumping the cold helium bottles directly into the LOX nonpropulsive vent downstream of the vent valves. This mode is accomplished by the addition of a new line and squib valves. It offers the advantage of continuously venting the cold helium and eliminates the possibility of pressure buildup in this system during habitation.

IV. Apollo Telescope Mount (ATM)

A. ATM Thermal Control

1. Experiment Canister

A decision was made to use active liquid cooling of the experiment canister. A preliminary design study was completed. A two-loop system, which uses a CSM pump and glycol/water in the canister cooling loop and a Gemini pump and Coolanol 15 fluid in the radiator loop, is being considered. This system will allow maximum use of off-the-shelf hardware and compatible fluids.

2. Rack-Mounted Components

Thermal analyses show that all but three of the rack-mounted components will operate within design limits during ATM active operation, but that many of the components located on the rack ring will get too cold during the pre-operational period between orbital insertion and ATM activation (~ 75 hours). The preoperational problem can be solved by orientating the ATM side-toward-sun and slow roll. An alternate solution is the use of a thermal cover, such as mylar, over the rack components; however, this is not desirable, and probably not feasible, from the standpoint of the Extra Vehicular Activity (EVA) required for cover removal prior to operation. Another approach is being analyzed wherein all components, except the star tracker, are mounted on the rack sides, so they will receive thermal protection from the folded solar panels during the preoperational mode. Since the star tracker's location is fixed, it may require a heater or insulation.

3. ATM Spar Thermal Deflection Test

The final test report was released.

4. Quadrant IV Thermal Test

The change in the ATM thermal control concept, from a passive to an active system, required a change in test objectives. A series of tests are being planned to determine the thermal characteristics of the experiment packages (temperature gradients and stabilization times) and to check out test facilities (vacuum chamber, solar simulation, data acquisition system, etc.) in preparation for the Experiment Package Thermal Test. Hardware fabricated for the original test program is being modified to accomplish these objectives. The solar and electrical heat simulators on the experiment packages were reworked to meet the latest specifications. Deflective heater blankets on the experiment packages were reworked and checked out. The experiments are ready to be installed on the spar. It is expected that these objectives can be accomplished within the schedule of the original test program.

5. Quarter Rack Test

Fabrication of the quarter rack structural parts was completed, and the parts were received. Assembly of the structure is now in process. Design of the rack end-plates, Lunar Module (LM) simulator, and lower rack shroud to provide thermal background simulation was started. Delivery of all rack-mounted Thermal Mechanical Units (TMU's). It may be necessary to fabricate some TMU's in-house. The provision of Control Moment Gyro (CMG) mounting hardware has been requested. The full impact of the change in ATM thermal control concept on this test program is not known at this time.

6. Optical Correlation Techniques for Fluid Flow Simulation

It was demonstrated that the Fourier Transform of the wave equation and associated boundary conditions can be obtained with less than 1 percent error by optical correlation techniques using a coherent light source suppled by the He-Ne CGW Laser. The boundary conditions are varied by merely changing aperture shapes in a punched card. The advantage of this technique for solving fluid flow problems is in the speed and ease with which problems can be set up. Of course, the computation is virtually instantaneous, and a direct analogue of the fluid system is used rather than numerical techniques.

B. Environmental Control System

Design of the test sections for the canisters and radiators for the ECS system depicting several different types of flow patterns were completed. Specifications are being written for a diverter valve, check valve, hand valve, vent valve, heater system and a coolant flow proportioning temperature control subsystem.

V. Multiple Docking Adapter (MDA)

A. Thermal Analyses

The MDA thermal status was summarized for the Preliminary Design Review (PDR). Current analyses show that the Mission B heat losses are already 50 percent above design specifications, which will necessitate heater power (150-200 watts) for satisfactory thermal operation. Major heat loss contributors are windows, docking ports, radiator, scientific airlock and the numerous insulation penetrations required to support the radiator and meteoroid shield.

Analyses were performed for the MDA storage mode that indicate internal wall temperatures stabilize at approximately - 15°F. Approximately 500 watts of heater power will be required to increase the wall temperatures prior to activation of the MDA after storage.

The thermal performance of the MDA insulation system is being determined experimentally. These test programs cover investigation of insulation thermal conductivity and outgassing characteristics.

B. Multiple Docking Adapter Insulation Test

The Aluminum foil and Plexiglas insulation is being tested. Tests of the perforated and unperforated aluminized mylar and polyurethane foam insulation are completed and results are being documented.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Engine Aero Spike Experimental Investigation

The gas/gas impinging jet injector performance characterization test was completed. As expected with gas/gas propellants, the chamber heat load data indicated that the combination process takes place very near the injector face. The concentric orifice injector is being tested. The first injector heat exchanger element for gasifying LOX is also being tested. Thrust chamber tests will resume early in December.

II. Small Engine Evaluation Program

Testing of the Walter Kidde 40-pound thrust engine is continuing. Approximately 50 minutes total run time was accumulated. Tests have included cold and hot pulsing and steady-state operation without any appreciable change in engine performance.

III. C-1 Engine

The baseline engine testing was started. The first test of the series was run with a propellant inlet temperature of 100°F, and the engine accumulated a total of 1,145 starts for a total burn time of 100 seconds. There were no instabilities encountered during this series. Approximately three minutes after the test was shutdown, an explosion occurred in the cell. The oxidizer inlet line was ruptured and the Moog valve cover was bulged. The engine was not damaged below the valve. The valve was replaced and the damaged valve is being inspected. The explosion probably occurred in the oxidizer line upstream of the engine inlet, because the oxidizer line was completely ruptured, and its design burst pressure was 4,000 psi.

PUBLICATIONS

1. "Apollo Telescope Mount Spar Thermal Deflection Test," Unclassified, IN-P&VE-P-67-7, by Jack D. Loose, dated October 4, 1967; published November 14, 1967.

2. "Thermodynamic Properties of Liquid-Solid Mixtures of Hydrogen (1 atm to 1400 psia)," Unclassified, IN-P&VE-P-67-8, by Charles D. Miller, dated October 23, 1967; published November 7, 1967.

3. "An Investigation of the Use of Acoustic Energy Absorbers to Damp LOX/RP-1 Combustion Oscillations," Unclassified, NASA TN D-4210, by Curtis R. Bailey, dated and published in November 1967.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-S-67-11

MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(November 1, 1967 - November 30, 1967)

SATURN IB

Saturn IB System

Updated ground wind loads for the AS-204 vehicle were furnished to R-P&VE-SS as an aid in determining ground wind restrictions. The loads were revised because results from tests showed that the lower portion of the vehicle is stiffer than originally computed. This change in stiffness necessitated a revision of dynamic characteristics.

Lift-off dynamic loads analyses have been initiated for the Saturn IB, AS-204 vehicle, using the latest vehicle deflections due to ground winds. Longitudinal and lateral lift-off loads will be computed.

SATURN V

I. S-IC Stage

A. AS-501 Slow Release Mechanism

Slow-release mechanism strain gage data for AS-501 flight has been evaluated for four of the mechanisms. The data indicates that the preload in the rods increased to a range of 50-60 kips during engine ignition, just prior to lift-off. This is in the range that was expected and as a result the mechanisms functioned successfully. This is a preliminary evaluation based on data from only four mechanisms. Data on all sixteen mechanisms have not been received from KSC.

B. Pyrotechnic Separation Device

An investigation into the use of a pyrotechnic separation device for the slow release device has been made. The investigation revealed that a standard, off-the-shelf device is not available which could be incorporated into the existing design. A method of cutting the die with a shaped charge looks feasible, but would require a long lead time for procurement and tests. An additional problem with this method would be controlling the fragments. It is estimated that a charge size of 300 grains per foot or greater would be required to cut the die.

II. S-II Stage

A. Recirculation Batteries

The vibration criteria for the 501 flight worthiness of the interstage mounted recirculation batteries were reviewed to evaluate appropriateness for qualification of the Eagle Picher batteries for use in the 207 container. The evaluation indicates that the interstage environment is more severe than the 207 container installation; therefore, the use of the Eagle Picher batteries in the 207 container was approved contingent upon an analysis to determine that the 207 container loads would not be significantly increased to jeopardize the qualification status of the supporting bracketry.

B. Forward Skirt Acoustic Testing

The S-II forward skirt which was tested in Wyle's reverberation chamber has been installed on the Mobile Acoustic Research Laboratory (MARL) and instrumented with 82 vibration and acoustic measurements. The MARL is in position at the F-1 engine test stand. The specimen will be subjected to three static firings. The purpose of the tests is to determine vibro-acoustic transfer functions obtained in a free field exposure, and correlate them with those obtained during reverberation testing.

C. LH_2 Redesigned Center Engine Feed Line

The LH_2 redesigned center engine feed line is being subjected to vibration tests at Wyle Norco. The following tests have been completed:

1.	Inlet	longitudinal axis
2.	Inlet	radial axis
3.	Thrust structure supported section	longitudinal axis
4.	Thrust structure supported section	radial axis
5.	Thrust structure supported section	tangential axis

Inspection after test five indicated bracket failures at the inlet and the thrust structure support section. North American Rockwell (NAR) has proposed that the line be subjected to tests other than vibration that are required in the qualification sequence. During this period the brackets will be redesigned, fabricated, and then the vibration sequence will be continued from the point of failure. After completion of all required tests the line will be considered qualified. The line and new brackets will then be subjected to repeat tests of 1, 2, 3, 4, and 5 to qualify the brackets. This program is predicated on the rationale that the initial brackets would be 'softer' and therefore subject the line to more conservative responses than the redesigned brackets. Structures Division agrees with continuing the test from the point of failure but disagrees with qualification of the to be determined only after adequate proof of the relative conservativeness of the redesigned versus original brackets is obtained. This proof can be obtained by comparative test results of the redesigned versus original brackets in the original failure test mode.

D. <u>402 Testing - "A" Structure</u>

Sometime during the ground handling operations of the S-IC portion of the S-II 402 "A" structure, it was discovered that a longitudinal stringer had been completely sheared off the specimen. The stringer was sheared at approximately 0.25 inches above the cylindrical skin and extended about 11.0 inches up the stringer from the S-II/S-IC interface. This specimen has been ground handled three times since it was removed from the S-IC-S Lox tank. It is not known which ground handling operation caused the failure or whether other stringers were possibly damaged in the same manner at the same time. All stringers on the S-IC portion of the S-II "A" structure have been visually and dye-penetrant inspected. Five additional stringers were found to be damaged. These stringers have cracks located at approximately .25 inches above the cylindrical skin and range from about .10 to 2.0 inches up the stringer from the S-II/S-IC interface. These stringers are located approximately 45° around the tank from the damaged stringer. The mechanical splice is being evaluated to determine the structural impact, if any, that will result from these discrepancies. Preliminary evaluation indicates that the stringers can be trimmed enough to eliminate the cracks without significantly affecting the structural integrity of the splice.

E. <u>MSFC Test 403 ("C" Structure)</u>

Structural preparation and modification of the specimen was completed on November 14. A cracked stringer was found on the aft skirt which was apparently caused by a prying action at some time. approximately one inch was removed from the end of the stringer in order to remove the cracks.

Due to discovery of mismatched holes in an alignment fitting at the second separation plane the start of testing was delayed until November 28, 1967. Boeing completed their final checkout of gages, thermocouples, and heat system by this date and Phase I testing was initiated. The Phase I test will be conducted at ambient temperature. Testing with temperature environment is scheduled to begin during the first part of December.

F. Weld Land Relief Tests

Two panels of a series of panel tests to determine the load distribution in the thinned down area of the S-II LH_2 tank circumferential weld land were tested this month. Both tests were carried to failure. The first specimen was nonwelded with weld relief - 224, 500 pounds failure load. The second was a welded specimen with weld relief - 202, 000 pounds failure. A third panel will be ready for test early in December. Two more panels are being fabricated by Manufacturing Engineering. These panels are longer and will contain the crossover land. The test data indicate that considerable load redistribution actually does take place and that local yielding occurs in the thinned down weld land at less than the pneumostatic test pressure.

III. S-IVB Stage

Forward Skirt/Instrument Unit/SLA Acoustic Test

The S-IVB forward skirt/instrument unit/SLA acoustic test specimen was mounted on its test fixtures in the reverberation chamber at Wyle. The specimen was instrumented, calibration of the instrumentation completed, and a 'live' ST-124 was installed in the instrument unit. The first phase of testing was completed November 20, 1967. This phase of testing included three runs at sound pressure levels of 144, 150, and 153 dB, and a static load of approximately 25, 000 pounds. The static load is presently being increased to approximately 75, 000 pounds. The second phase of testing will consist of three runs at sound pressure levels of 144, 150, and 153 dB with the increased static load. To date there are no major problem areas and testing should be completed well ahead of schedule.

IV. Instrument Unit

A. Water Dilution of Hypergols

Efforts have been initiated to determine the structural effects of a water dilution of hypergols in the S-IVB/IU compartment. Conditions to be examined include shell loads during free-standing, water line loadings on the IU shell from both the umbilical plate and a diffuser inside the compartment, and pressure loadings on the S-IVB bulkhead and forward skirt. Evaluation of the IU for three loadings caused by pumping water into the IU/S-IVB compartment has been completed. Results show that the expected loads are higher than those required to yield the umbilical plate.

B. Interface Panels

Panel 4 of a series of five IU upper interface specimens failed at approximately 90% engine-out loadings. Because of this premature failure, attempts are being made to determine the cause. No conclusions have been made to date. Another panel has been instrumented preparatory to testing. Presently spring clip deflection gages are being made to acquire the numerous deflection measurements requested for this panel test.

C. Cold Plate Attach Points

Several load conditions defining the capability of the cold plate attach points have been forwarded to R-P&VE-VS for use in their design of a work platform to be installed in the IU spacer structure on the ATM vehicle.

D. Umbilical Separation/Service Arm

Analysis of the IU for the loadings resulting from umbilical separation/service arm testing in the VAB has been completed and documented by memorandum. This study shows that the IU can successfully withstand the loads arising from the above condition with the access door removed.

V. Saturn V System

A. Damper System

Design studies are continuing to increase reliability of switches in the hook actuation cylinders. The present design (vendor furnished) allows only .045 inches of movement for switch actuation. This makes adjustment of the switch very critical. It is desirable to have .125 inches movement available.

B. AS-501

The relative deflection between the umbilical tower and the AS-501 vehicle was determined for the 63.2 knot wind condition (60 foot level) with the vehicle empty and the damper attached. This information was furnished to Mr. Aberg, R-P&VE-V, as an aid in determining the tracking capability of the umbilical arms.

C. AS-501 Launch Monitoring and Evaluation

The bending moment and axial load at station 790 were monitored in real time during the prelaunch activity and the first six minutes of AS-501 flight.

The peak bending moment recorded during the prelaunch activity was 33 million inch-pounds. The bending moment and axial load immediately before S-IC ignition were 24 million inch-pounds and 4.5 million pounds respectively. The axial load jumped to 5.5 million pounds at lift-off and increased to a maximum of 7.0 million pounds at inboard engine cutoff. Ignition of the S-II stage caused a 1-second transient compressive force of 1.9 million pounds in the S-IC intertank. The bending moment reached a maximum of 56 million inch-pounds adjusted at 78 seconds. The real time display functioned smoothly throughout the period being monitored. The results obtained from this display were in good agreement with preliminary flight data.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

A. Rack

A preliminary design was completed for the additional structure required for supporting the solar panel modules 15.5 inches below the lower frame of the Rack. An estimate of the weight based on this preliminary design was also made. However, the final location of these panels has not been decided. Detail design has continued for the addition of Rack-stiffening shear webs surrounding each control moment gyro (CMG). Detail design was also started for the Star tracker support structure. A layout was started to develop the structural concept for the cable tray system required to carry the electrical cables across the gimbals between the Rack and Experiment Package. A preliminary design was completed for the support beam required in the Rack by the cable tray system. Conceptual layouts were also initiated for a structural system to support the CMG inverters in the Rack outrigger areas.

B. Experiment Package Insulation

The insulation material for the experiment package has once again returned to a multilayer high performance insulation due to a decision to utilize a fluid system for thermal control. The complete insulation system has not been defined at this time.

C. Spar

A wing of the ATM spar has been fabricated for the purpose of obtaining data on tolerances expected on the flight spar configuration. This wing bowed slightly (approximately 0.10 inch over its length) and received a considerable amount of interest during a tour of Manufacturing Engineering Laboratory by Dr. von Braun. As a result, a brief description of the spar design status has been written giving the design, testing, and manufacturing planning accomplished and planned for the ATM spar.

D. Gimbal System

A monthly design review was held with representatives from Astrionics, Perkin-Elmer Corporation, and P&VE. Discussions on MSFC weld requirements and the latest configurations of the launch lock mechanism were main areas of interest to Structures personnel.

Perkin-Elmer was reluctant to specify the required Class I weld as defined by MSFC-SPEC-135. Failure to understand the requirements of a Class I weld was apparently the cause of this reluctance, since Perkin-Elmer appears willing to use the specification following an explanation by personnel of this Division.

Perkin-Elmer is redesigning the launch lock mechanism since the latest concept, as pointed out by Structures Division personnel, was in reality a four-bar linkage and as such was unstable.

Following the review, Perkin-Elmer was given a task assignment to study operation of the gimbal system in a 1 G checkout, including checkout in the stacked launch vehicle, where accessibility seems to be the major problem.

II. Multiple Docking Adapter (MDA)

A. Structural System

Preliminary layouts of the equipment mounting walls and astronaut floor have been completed and delivered to the Strength Analysis Branch for final check. The bulkhead, previously reported in release was recalled to incorporate late change requests from Vehicle Systems Division and Manufacturing Engineering Laboratory. These changes have been incorporated and the drawing package is again in the formal release process. A preliminary layout of the new skin panel cutouts (information received November 15) in the upper cylinder assembly has been completed. Detailing has been held up until cutout sizes and locations have been confirmed, since these changes will affect hardware already fabricated and ready for subassembly.

The MDA window construction has been changed from a double to a single pane installation. This option, provided in memo from Mr. G. B. Hardy to Mr. R. G. Eudy, dated May 1, 1967, has been coordinated with strength and thermal analysis representatives who agree that a simpler window installation can be had with no compromise to structural or thermal efficiency. Meteoroid analysis indicates there is no problem with a single pane installation.

B. Structural Test Article

Due to a myriad of design changes which has been requested, recommended, and proposed, it is no longer possible to release the necessary documentation for the structural test article by December 1, 1967. Particularly involved are the docking ports and the provisions for equipment mounting; both are currently under revision.

C. Docking Ports

A design change is underway to incorporate a revised thermal barrier in all docking ports for both the static structural and thermal tests. A dummy hatch will also be designed for static test use where pressurization is required. These design requirements have been imposed by the unavailability of Apollo hardware for early use in the MDA program.

III. Nuclear Ground Test Module

The status report and viewgraphs for the Laboratory weekly seminar meeting were completed. The nine-foot insulation test tank drawings were revised for shop requested changes. Detail parts for the tank modification are being manufactured. The 105-inch insulation test tank drawings have been completed except for the vacuum jacketed drain line. The design of the vacuum jacketed drain line is in progress. No expected completion date can be given because of lack of interface requirements.

Work is continuing on the Nuclear Ground Test Module. The status of the drawings is as follows:

Forward Head Assembly	
Apex and Base Gore Segments	Complete
Apex Gore Segment with Fittings	90% Complete
Aft Head Assembly	
Base Gore Segments	Complete
Y-Ring - Forward Head	Complete
Tanks Assembly	Complete
Skin Segments	Complete
Skin Section Assembly	Complete

Aft Skirt Assembly	
Skin Segment	95% Complete
Aft Skirt Weldment	80% Complete
Lower Ring	25% Complete
Forward Skirt Assembly	10% Complete

IV. Experiments

MSFC Flight Experiment #8

Detail design of the tension and indexing system is essentially complete. The film and specimen retrieval container is approximately 60% complete. Documentation is approximately 95% complete and checking has been initiated. Detail design is expected to be completed on December 4, 1967. Checked drawings and the stress and engineering reports are scheduled for completion on December 29, 1967. Design of the data acquisition system is essentially complete. Component selections have been made and their installations defined.

G. A. Kroll
Chief, Structures Division

Note: Following are the missing pages.
Page Nos. – ii, 42, 74.