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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MONTHLY PROGRESS REPORT

For Period

April 1, 1968, Through April 30, 1968

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-68-4

MONTHLY PROGRESS REPORT

(April 1, 1968 through April 30, 1968)

By

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

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

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MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(April 1, 1968 through April 30, 1968)

SATURN IB

Saturn IB System

AS-205 Hypergol Spillage Problem at KSC

The hypergol spillage occurred when the diaphragm burst in the pump supplying N_2O_4 liquid to the spacecraft in a scheduled hot flow test. A combination of hydraulic pump oil and N_2O_4 was discharged from a 1/16-inch diameter hole in the pump housing until an estimated one-two pints puddled on the work platform floor approximately six to eight feet from the spacecraft cylinder wall. Spacecraft technicians sprayed the platform with a two-inch diameter fire hose for an estimated five to twelve minutes to prevent fire. As a result of the spraying, contaminated water ran down and into the S-IVB/IU Spacecraft compartment, as well as all down the entire 205 vehicle. Collections of liquids were found in the IU, S-IVB forward skirt, and S-IB fuel and LOX tank forward skirt, and S-IB engine compartment. Examination of all the known affected areas showed either the paint or zinc chromate coatings removed or discolored. No etching, corrosion, or other structural degradations were found by the investigating team or by the stage contractors. Also, no apparent damage was done to electrical cabling. Since seepage of the contaminated liquid has continued at several locations and since litmus paper checks of the liquid shows an acid, probably nitric, is present, specific recommendations have been requested from the contractors as to what cleansing, neutralization, dilution, or other actions should be taken to prevent long term corrosion on the vehicle.

SATURN V

I. S-IC Stage

S-IC Controlled Release AS-502

AS-502 control release mechanism flight data has been evaluated and the average peak load for the six mechanisms that were monitored during lift-off was 80.0 kips. This value is only preliminary and could be high because a reliable zero has not been established on the oscillographs received from KSC. Further data clarification has been requested. The data also indicates that .52 seconds was required to complete the mechanism operation.

II. S-II Stage

A. "B" Structure Test (401)

Thursday, March 28, 1968, the phase VB (cryogenic cycling) testing was completed on the "B" specimen. Phase V consisted of 45 room temperature cycles and 30 cryogenic cycles. Inspections after each period of testing have indicated no defects. Phase VIA (max $Q\alpha$) testing, the first limit loading was completed Friday, April 5, 1968. All requirements were met with the exception of the high increment (6.8 psig) of skirt pressure. Excessive leakage of the helium pressurant limited the skirt pressure achievement to 3.7 psig. Additional sealing efforts will be made, and also a larger pump and alternate pressurizing gas will be utilized so the required skirt pressure can be achieved during the rerun condition. The second run of Max $Q\alpha$ limit condition was completed on the "B" structure at Santa Susana, California, April 12. This rerun allowed the alternate 1300 channels of gaging to be installed and utilized. No structural problems were encountered during the test phase. Apparent instrumentation problems have slowed the "B" structure testing. There is a considerable discrepancy between strain data at ambient and cryogenic temperatures in the tank regions (10% - 40%). NR has run some dogbone tests to recheck their original data which showed a discrepancy of 10%. This value was checked. NR has developed a plan of action to assess the situation and attempt to solve the problems.

Test Phase VIII (limit S-II boost) was performed on the V7-22 (401B) on Thursday, April 18, 1968. During testing resistance measurements were taken of 35 gage circuits which had indicated the greatest discrepancies from predicted strains at cryogenic. These measurements indicated the temperature compensating gage circuits had unusually high resistance measurements. Friday, April 20, 1968, five of these

circuits were removed from the stage and tested. It was verified that the wrong gage had been installed in all cases checked. The contractor has been directed to stop testing until resolution of the problem has been made. To determine which channels give erratic readings, the resistance of all strain circuits will have to be made at room temperature and at cryogenics. Effect of these discrepancies on data obtained to date is under investigation.

B. "A" Structure Test (402)

Manufacturing Laboratory has completed the foaming of the S-IC bulkhead. Five local areas were repaired. Trimming around cut-outs and Y-ring was accomplished before installation of forward skirt. On April 1, as the forward skirt was being lowered over the S-IC lox bulkhead, the clutch slipped on the overhead crane, dropping the skirt onto the "Y" ring. The forward skirt skin was torn in three locations requiring doublers to be added. The "Y" ring damage was limited to scratches that could be removed. No schedule slippage was caused by this accident. The installation of the fix was completed April 6, 1968. Foaming operations on the tank cylinder began April 8, 1968. While the skirt was being installed, the installation of the aft skirt doublers was completed.

The forward skirt has been mated to the specimen and a large portion of the spray foam insulation completed. Damaged areas were discovered in the common bulkhead and design of repairs is in progress. This damage was apparently caused by objects being dropped and in two cases the forward facing sheet was penetrated. Numerous cracks have also occurred in the S-IC baffle portion of the specimen.

C. "C" Structure Test (403)

The following limit load tests were conducted on the S-II "C" structure:

Load Condition	Sequence	Description	Date
1	3	5 engines, 0° gimbal	March 27
2	1	Eng. #5 out, 6° gimbal	March 28
3	1	5 engines, 6° gimbal	March 28
2	2	Eng. 5 out, 6° gimbal w/actuators	April 1
3	2	5 engines, 6° gimbal w/actuators	April 1
4	2	Eng. 3 out, 7.7° gimbal	April 1
4	3-A	Eng. 3 out, 7.7° gimbal w/actuators	April 2
4	3	Eng. 3 out, 7.7° gimbal w/actuators	April 2

(Note: Gimbal angle applies only to four outboard engines)

This series of limit load tests was concluded five work days ahead of schedule.

On April 2, two limit tests for one engine out condition were run on the "C" structure. During these tests, high strain gage readings were observed in the outboard cap of the ring frame at NR station 112 (Engine position 1). After completion of these tests, a slightly buckled area was found in the lower flange of the outer ring frame cap. Back to back axial strain gages were added to this area at five locations, and the test condition was rerun on April 4. The high stresses recorded during this test left little doubt that the deformation of the ring frame cap was caused by test loadings. A design fix was prepared by NR. Installation of the Station 112 ring frame doublers at the outboard engine locations started April 24, 1968.

On April 11, 1968, the ultimate load testing was initiated. The first in this series was the zero degree gimbal five engine thrust load condition with heating. Testing was halted because the center engine crossbeam buckled at 110% and 115% loadings on this first ultimate test. NR is designing fixes for the crossbeam and plans to install the additional structural hardware on the "C" structure this month. If the "C" structure successfully withstands the planned ultimate tests with the additional structural hardware, it will be installed on S-II-4 through S-II-10 vehicles. The fixes will be of two types: 1. to make the test hardware suitable for continuing the tests, based on a battleship approach for those areas that were damaged, and 2. to make those areas not damaged into a flight hardware fix configuration for qualification.

Forty-four additional strain channels and nineteen additional deflection channels have been requested for installation on the "C" structure during the third week of April.

III. S-IVB Stage

At the insistance of MSFC, MDC subjected 3 isolators representative of the worst debonded case on 501 and 502 to a repeat vibration qualification test. This test was on the same configuration as the overstress test, which was the maximum isolator loading condition. The isolators successfully passed the test.

IV. Instrument Unit

A preliminary analysis has revealed that the Saturn V IU can withstand an additional pressure of approximately seven psi burst resulting from a spillage of oxygen in the S-IVB/IU/SLA compartment during flight.

Two additional exposures, to the F-1 engine acoustic environment, are planned for the IU/ST-124M. These acoustical exposures will take place at the MSFC F-1 engine test stand on the 7th and 14th of May, and are expected to conclude the testing program.

V. Saturn V System

A. AS-502

An analysis of ground wind bending moment during the Saturn V, AS-502 rollout was performed for the peak winds of 34.18 knots which were measured at the 60 foot level. Data from strain gages at vehicle station 790 was compared with bending moment predictions generated from wind tunnel analysis. Results showed that peak winds of short duration do not affect the bending moment.

A lift-off study was performed on the AS-502 using slow release rods (reduced from 16 rods). The results of this study revealed that 12 rods could be used and the dynamic loads would not be excessive.

B. AS-503

An analysis has been completed on AS-503 terminal countdown sequencer single point digit failure. It was determined that a terminal countdown sequencer failure will not produce loads that exceed vehicle design loads.

C. POGO

AS-502 flight evaluation revealed the pressure of structural feedback to the propulsion system. This apparently forced the five F-1 engines to get in phase starting about 90 seconds flight time, resulting in abnormally high longitudinal and lateral loads in the spacecraft at about t = 126 seconds. These were approximately 0.6 "g" at 5.3 cps. Appropriate action has been initiated in Structures and Propulsion Divisions and the contractors involved towards accomplishing the appropriate analysis and engine tests required to insure an adequate fix on AS-503.

D. AS-502 Flight - Data Acquisition

The vibration and acoustic data acquisition assessment for the AS-502 flight has been made. Of the 55 measurements on the S-IC stage 75% yielded useful data, of the 63 measurements on the S-II stage 68% yielded useful data, of the 39 measurements on the S-IVB stage 98% yielded useful data, and all the measurements on the S-IU yielded useful data. The overall vehicle percentages are 81% yielding useful data for AS-502 as compared to 87% for AS-501. There were 10 invalid engine measurements on the S-IC stage, 15 invalid engine measurements on the S-II stage, and 1 invalid engine measurement on the S-IVB stage.

E. Data Evaluation

The following summarizes the results of the AS-502 data evaluation review:

1. No anomalies in the vibration condition were apparent on the J-2 engines during S-IC boost.

2. Although the data on the S-II stage J-2 engines are invalid, no trends can be identified that correlate with the engine failures.

3. Two anomalies occurred in the S-IVB data which correspond to other stage environmental changes or engine performance changes at 700 seconds. The combustion chamber dome accelerometer went dead and an anomalis change occurred on the LH_2 turbopump accelerometer. The LH_2 turbopump accelerometer was invalid from a standpoint of absolute measurement but could adequately define changes.

4. The 5 cps vibration levels measured and extrapolated on the 502 S-II and S-IVB stages is adequately covered by engine assembly test therefore, the 5 cps levels are not considered contributory to flight anomalies.

5. In summary, no evidence exists of an anomalis vibration condition on the J-2 engines which would correlate to the engine failures. This does not mean the engine induced vibration environment did not or could not have contributed to the failures. It means that if the self induced vibration environment did contribute to the failures, it was a nominal environment and must have been supported by some other type of significant deviation.

APOLLO APPLICATION PROGRAM

I. Apollo Telescope Mount

A. Rack

Considerable difficulty is being experienced in arriving at a satisfactory fastener selection for use in the ATM structure. Materials Division recommendations rule out all NAS fasteners due to loose manufacturing controls, all cadmium plated fasteners because of excessive outgassing, and most CRES fasteners due to stress corrosion. In view of the closely controlled environments specified for the ATM hardware, the best choice appears to be placing the least importance on corrosion.

B. Experiment Package

Class I documentation of the spar structural details and the spar assembly have been completed and sent to Vehicle Systems Division for checking. Completion of the drawings was delayed two weeks to incorporate a relocation of two major instruments.

II. Multiple Docking Adapter

A. Docking Ports

Investigations of a hatch restraining device and a rigid metal handle to replace the flexible handle on the proposed pressure hatch for the MDA have been completed.

The design of a new pressure hatch is under consideration. Concepts have been completed and reviewed. Due to the time required to design and manufacture a new hatch the Apollo Block II hatch is being contemplated for use on both the vibration test unit and the One-G trainer for the crew station review.

B. MDA/Airlock Structural Test Program

The following has been or is presently being accomplished on the combined MDA/Airlock Test Program:

Load systems have been defined and submitted to BECO for incorporation into a test setup artist's concept drawing and a layout drawing. A list defining presently known materials and equipment requirements has been developed. Available items are being tagged for this test program. Other items have either been ordered or are in the process of being ordered.

Verbal approval has been obtained from the MSFC Safety Office to conduct these tests under the 30,000,000-pound test tower providing the test specimen is properly shielded; tests are conducted remotely; and applicable MSFC safety procedures are complied with. No difficulties in complying with these requirements are anticipated. Availability of a SLA for the test program has not been resolved. Test setup planning includes a SLA in addition to the IU and lower load ring that was utilized during the S-IU/500 S-II IU structural test program. Test fixtures are presently being designed to experimentally determine the stiffeners of the Saturn V dynamic test SLA, including the effects of the upper SLA. This information will be used to aid in the analytical determination of the stiffness of the flight SLA.

Preliminary analysis has been completed on the glass windows and frame. Preliminary analysis of pressure hatch for test model has been completed.

III. Orbital Workshop

Development of silencers for the Orbital Workshop ventilation fans has been accomplished. Starting with an internal acoustic environment which would allow normal speech communication at no greater than one-foot separation it was mandatory that the speech interference level be decreased to reasonable conversation levels. Utilizing external end silencers and a shrouded motor case it was possible to effect the needed decrease in speech interference without compromising the flow characteristics of the ventilation fans. The size and weight of the completed silencer (fan) diffuser system is excessive with regard to the criteria recently suggested by the Vehicle Systems Division. No criteria was available at the start of the development program, and even now the question of acceptable internal noise level has not been given consideration from a speech interference standpoint. Physiologically acceptable noise levels are considerably above the speech interference criteria. Work is continuing to determine if a smaller and lighter overall package can be attained by modification of the inherant noise generation properties of the fan. Meetings with fan manufacturers and Propulsion Division have been held in regard to this type of solution. It appears that certain improvement may be possible through the use of redesigned flow straightener vanes.

IV. Electron Beam Welding Experiment

New design criteria necessitated cancelling manufacture of the acoustical covers for the electron beam welder. The susceptability of the beta cloth to abrasion and the requirement to design for a vacuum environment prohibited the use of beta insulbatte. Perforating the beta cloth cover would release insulbatte fibers. A redesign is pending acoustical test data justifying the requirement.

V. BP-30

Tank skirt modifications were accomplished by adding a doubler around the lower skirt of the four tanks. Due to weld crack found after modification at KSC, it is evident that additional modification will be necessary. Until the tanks are returned to MSFC and inspected, the additional modification cannot be defined.

RESEARCH

I. Biaxial Weld Test

Three 2219-T87 aluminum 40-inch diameter cylinders of the biaxial weld test program were tested on March 28, April 5, and April 18. The stress ratios were 2 to 1 and the walls were 0.1 inch thick. The cylinders failed at internal pressures of 205 psig, and 165 psig, respectively. The predicted failure pressures were calculated as 220 psig.

Three possible causes of these early failures could be (1) extended fine porosity in the weld, (2) embrittlement in the domain of the weld, or (3) an undetected undercut in the weld. Final determination will be made after specimen examination by Materials Division.

II. 105-Inch Diameter Test Tank

Preliminary analysis required for structural sizing of steel struts for a 105-inch diameter test tank has been completed.

III. 120-Inch Cylinder Test

The first 120-inch diameter honeycomb research cylinder was tested to failure under axial compression April 2, 1968. This cylinder was 60 inches high and had a total thickness of 0.52 inches. The 70 75-T6 face sheets were 0.02 inches thick. The failure was not due to general instability but due to an ultimate compressive strength failure caused by the high axial load plus the high end bending moment. The predicted general instability load based on the small deflection theory was 896,000 pounds. The large deflection theory given in MIL-HDBK-23 predicted an instability failure at 556,000 pounds. The actual failure was 912,000 pounds. There are 26 more 120-inch honeycomb research cylinders of various L/R and R/T values to test.

G. A. Kroll
Chief, Structures Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-68-4

MONTHLY PROGRESS REPORT
ADVANCED STUDIES OFFICE
(April 1, 1968, Through April 30, 1968)

ADVANCED PROGRAMS

I. Launch Vehicles

A. Pressure-fed Launch Vehicle (PFLV)

A cursory evaluation of the four-module first-stage pressure-fed launch vehicle concept was made and shows that the original estimates of stage mass fraction were within 1 to 1.5 percent of the preliminary design values. Some other rather significant conclusions could also be drawn from the evaluation. First, the four-module first-stage cluster, as compared with a single-module stage, does not seem to present a significant weight penalty, since module wall thickness decreases proportionally with diameter. Second, the interstage of the second stage has a significant effect on the mass fraction of this stage. Third, making all module side walls and all module bulkheads of equal thickness has a relatively small impact on overall stage weight.

The basic structural weight evaluation of the Parametric Analysis Task (Task 2.0) of the Phase II PFLV study was completed for a module L/D of 2.7; a similar evaluation for module L/D's of 3.5, 4.5, and 7.0 has been initiated. These parametric data will provide a module weight comparison for different tankage materials, configurations, diameters, and internal pressures. Using these data in conjunction with propulsion system and stage integration data, a complete stage weight optimization of chamber pressure for each stage L/D or other parameter can be made.

Preliminary data to determine thrust gain were generated for a four-engine shrouded configuration (upper stage application) with a primary nozzle expansion ratio of 8:1. Thrust gain attributed to the shroud is approximately 3.6 percent.

Initial study definition and literature survey efforts are underway to determine the feasibility of using gas generators for pressurization of mainstage propellant tanks of a pressure-fed vehicle. Preliminary objectives of the effort are to determine upper temperature and pressure limits for storable propellants, pressurization system and temperature compatibility of the propellants and/or structural materials. Secondary objectives are verification of design for high-pressure propellant tanks, and verification of high-strength structural alloy mechanical properties. It is anticipated that this study will involve an in-house MSFC effort of four to six months during which analytical studies will be performed. If, at the end of this time, the results are favorable, a test program might be proposed to demonstrate the feasibility of this concept.

Informal technical discussions relating to the possible pressurization test program were held with R-P&VE-PT and R-P&VE-SJ personnel concerning test objectives, concepts, and requirements as currently postulated for the program. In support of the related literature survey, a RSIC computer search printout was reviewed for unclassified and classified articles which will potentially furnish data of value to this program. Pertinent articles and/or reports were ordered.

A brief discussion was held on April 11, 1968, with Mr. W. McAllister of The Boeing Company (Huntsville Research Center) on the subject of company-funded work in progress at Boeing pursuant to the design and fabrication of propellant tanks and pressurization subsystems to be conjunctively used with the TRW pressure-fed engine. Believing that this joint Boeing/TRW effort to develop a demonstration pressure-fed stage would be of probable across-the-board interest to the P&VE Laboratory and to the in-house PFLV study effort, an agreement was reached to have a presentation by Boeing on this subject on May 15, 1968. An announcement pertaining to this presentation has been distributed (Ref. Memorandum R-P&VE-AP-68-24, dated April 24, 1968).

A status review of the in-house PFLV study effort was given at the P&VE Technical Seminar on Wednesday, April 3, 1968, and action pursuant to the directions and/or suggestions which were advanced at the review has been initiated.

An internal project management review was given on the PFLV study, along with other Advanced Systems in-house studies, on April 17, 1968. Emphasis was directed primarily to the resources and scheduling aspects of the study.

B. Launch Vehicle Utilization Studies

A meeting was held with Boeing Company personnel on April 9, 1968, at Research Park, for the purpose of discussing their in-house Mission Analysis effort. The result of their interpretation of the future NASA space program is a mission model which is essentially an updated version of the "optimistic" model presently utilized in our own study. An updated version of the mission model that evolved from the MSFC forecast effort is available in Internal Note IN-ASO-68-2, entitled "Space Program Forecasting," dated March 15, 1968.

The supporting effort (mission analysis and computer programming operations) of Advanced Systems Office, R-AS, personnel was discontinued as a result of their recent reorganization. Continuance of the in-house Saturn Utilization study is questionable, especially if priority is given to MSFC involvement in the Chrysler-proposed million dollar "National Space Booster" study -- essentially another launch vehicle utilization study.

During this report period, Mr. W. L. Corcoran, R-P&VE-AP, visited McDonnell Douglas, Huntington Beach, California; North American, Downey, California; General Dynamics, San Diego, California; and Lockheed Missiles and Space Company, Sunnyvale, California. The purpose of the visits was to evaluate and assess contractor efforts with respect to launch vehicle utilization studies, including computerized mission modeling and candidate launch vehicle design considerations, and to determine the contractors' proposed degree of participation, if any, in MSFC launch vehicle utilization studies.

Work is continuing on the in-house Titan III Launch Vehicle Application study. An initial set of launch vehicle configurations has been selected for examination. Jettison weight summaries, configuration drawings, propulsion system summaries, and overall launch vehicle systems descriptions are being compiled for each vehicle. Subsequently, mission aspects and operational constraints are to be examined with the ultimate purpose of producing a consistent data package which will enable mission planners to identify the most practical Titan III configuration for any given mission and which will allow comparison with other launch vehicle systems.

C. Nuclear Vehicle Studies

A three-phase in-house study has been initiated to (1) generate design sensitivity data for certain selected configurations using the uprated NERVA I engine; (2) study additional concepts of modular nuclear vehicles

for manned planetary missions; and (3) analyze certain concepts to determine if they lend themselves for application to additional manned and unmanned missions. Study duration is anticipated to be 12 months. During Phase I, three specific stage concepts are to be examined. The first is a "propellant module concept" which is similar to the LMSC Phase II concept with jettisonable shrouds and insulation. The second is a "propellant transfer concept" where propellant transfer takes place between modules during stage burn. In this case all modules are propulsion modules; no propellant-only modules are used. The third concept is an "engine restart concept" which assumes that the nuclear engine is restartable. As with the "propellant transfer" concept, all modules are propulsion modules and no propellant-only modules are used. The initial step in this effort is to produce a nominal mission model for each of the three basic stage concepts under consideration. After the nominal cases are described, parametric analyses and design sensitivity studies will be performed to examine the impact of changing engine thrust, engine I_{sp}, launch window reserves, propellant boiloff losses, etc.

Work to be accomplished under Phases II and III has been proposed as follows: Phase II will examine the "propellant transfer" and "engine restart" concepts using the NERVA II engine instead of the NERVA I. The primary goal of examining these concepts is to produce standard modules of uniform propellant capacity. Phase III is concerned with mission analyses of nuclear stage concepts for selected applications other than the Mars manned stopover missions previously examined in Phases I and II. Typical lunar and planetary missions will be examined and the advantages of using nuclear stages determined. Both manned and unmanned missions will be considered.

Initial work on a Nuclear Stage Thermodynamic analysis is nearly completed. The analysis assumes the LMSC Phase II nuclear stage module concept and is based on the 1982 manned Mars landing mission. The primary objectives are to identify all major heat leaks associated with the nuclear stage, establish stage thermal models, and to determine propellant boiloff during earth orbit, Mars transfer, and Mars orbit. Two basic thermal models have been assumed, differing primarily in the assumption of a continuous vapor film in one case, and a wholly wetted tank wall surface in the other. The first case is expected to result in less propellant loss from boiloff than the second due to the thermal conductance characteristics of the hydrogen vapor film between the tank wall surface and the propellant mass.

II. Earth Orbital

A. Saturn V Workshop: Configuration

The current major activity this month was the preparation of a consolidated R-P&VE, R-AERO, and R-ASTR report covering the past two months' study activity on mission analysis, configurations, subsystems and experiment integration. The final draft of the report is now being prepared. The report describes the range of approaches considered for Saturn V Workshops, using modified S-IVB stages, and describes a representative early baseline. The early baseline selected is a three-man station with the following characteristics: unmanned, 1971-72 launch, 1 1/2-year mission duration, side-pointing ATM, and a "three-man" size multi-discipline experiment grouping.

In developing the early three-man baseline design, several revisions have been made relative to habitation and atmospheric expendable accommodations. One entire floor is now devoted to habitation, including three revised crew sleeping compartments and a food preparation/wardroom exercise area which occupies approximately one-half of the floor. A small partial waste management facility is incorporated on the subsystems control floor. The station interior is shown in Figures 1 and 2. On Figure 1, a layout is shown of the waste management area, command center, experiment control consoles, and storage areas. Figure 2 represents the crew quarters floor which contains living, food management, exercise, and recreation areas.

Atmospheric circulation system criteria and design requirements have been compiled and are being reviewed for Saturn V Workshop configurations which incorporate closed floors and partitions. Alternate circulation schemes are currently being developed and analyzed. A Martin-Marietta study on the application of a heat pipe thermal control system for the Saturn V Workshop has been received and reviewed. The concept, as proposed by Martin-Marietta, consists of heat pipes located circumferentially around the Workshop LH_2 tank, with additional heat pipes placed longitudinally and leading to a radiator at the S-IVB forward skirt. The Martin Company maintains that this concept, which is completely passive, eliminates the need for tank insulation and equipment cold plates while maintaining thermal control of the atmosphere, equipment, and tank wall within small temperature excursions.

An in-house investigation of the expected traffic pattern aboard an orbiting Saturn V Workshop was initiated. A typical day's activity for three crewmen is being plotted and tabulated in an effort to identify critical

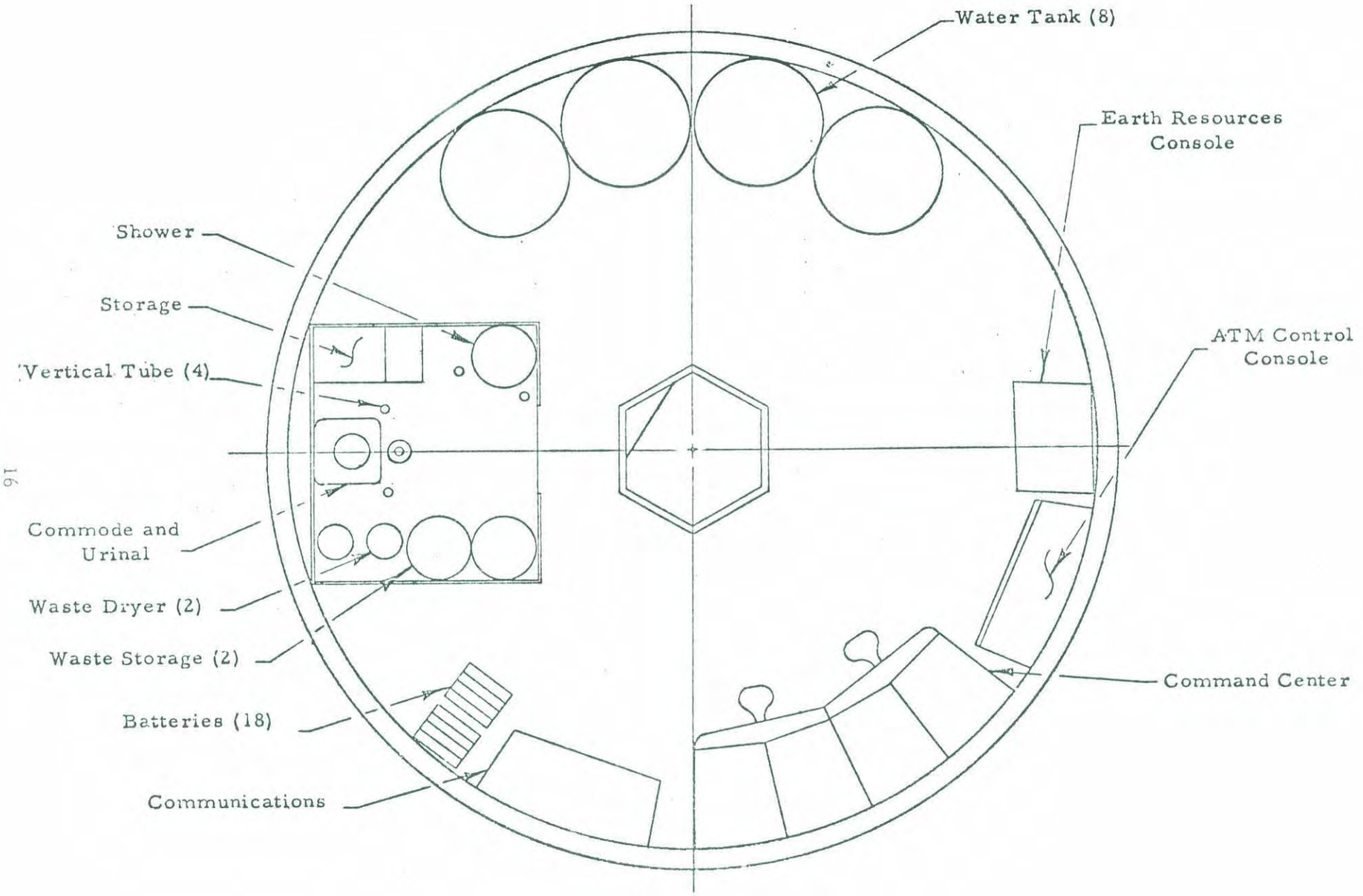


FIGURE 1. WASTE MANAGEMENT, STATION AND EXPERIMENT CONTROL AND STORAGE

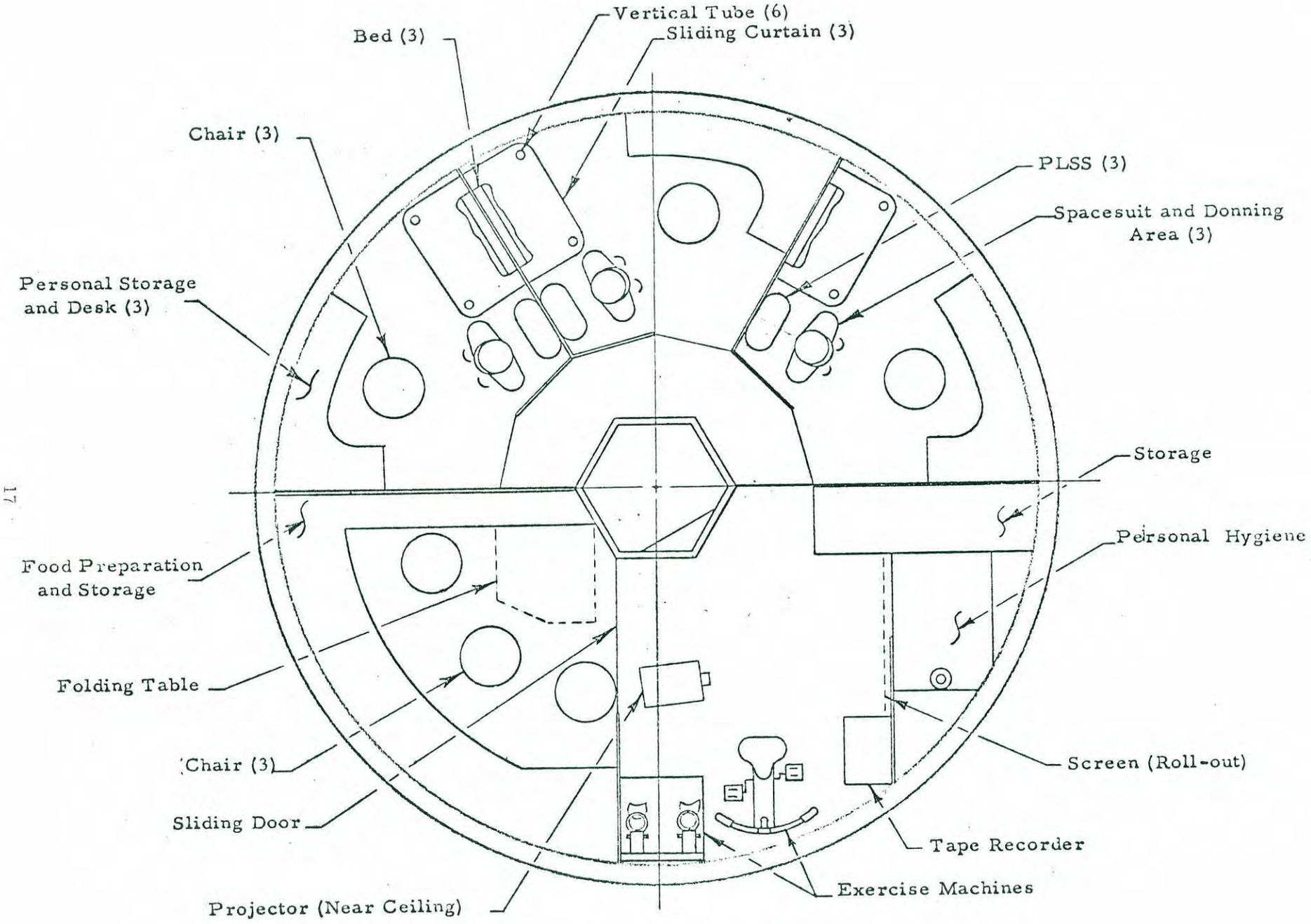


FIGURE 2. CREW QUARTERS

congestion points inside the station. Subsequently, the conceptual internal layouts will reflect possible means of eliminating the identified over-crowded areas. The traffic analysis may also indicate a need for changing the basic crew schedules which, in turn, may perturbate the experiment scheduling.

The baseline configuration is also being investigated with respect to possible logistics CSM configurations. A "hybrid" CSM is now being considered for the baseline early Saturn V Workshop B. The hybrid CSM would resupply atmospheric O_2 and N_2 to the Workshop at 90-day intervals and would be dependent upon the Workshop for electrical power. Also, design activities at a reasonable low level for the next three months are being initiated to further study interior structural concepts, explore conversion of a spent stage to a dry launch, and to determine configuration changes for updated experiment and subsystems inputs. The interior structural investigation will attempt to further compare attachment of floor directly to the LH_2 tank wall versus attachment to an internal "cage" structure, equipment support methods, and factors associated with retaining the common dome bulkhead.

Information describing Saturn V Workshop experiments and subsystems equipment was sent to Mr. Charles Sprinkle, I-S/AA, in memorandum R-P&VE-AA-68-31, dated April 12, 1968. These data are part of an information package forwarded to Loewy/Snaith, Inc., for use as a guide in their layouts of Saturn V stations.

Visits were made by Mr. H. B. Wells to McDonnell Douglas (Santa Monica), Lockheed (Sunnyvale), and Boeing (Seattle) Aircraft Companies during the week of April 22-27, 1968. The purpose of the visits was to attend the technical debriefing of Douglas' 60-day Manned Life Support System test and to discuss advanced life support systems. The Douglas test, which was conducted with a four-man crew, was completed on April 19, 1968. The life support facilities of Lockheed and Boeing were visited to obtain more general knowledge of their advanced life support development work.

B. Saturn V Workshop: Experiments

Preliminary experiment integration studies on the Saturn V Workshop B configuration were completed. These studies included laboratory designs, aft interstage experiment placement and operational concepts, and detailed descriptions of the experiment objectives and equipment. In addition, experiment compatibility and scheduling analyses were made using the ESCAPE computer program. A number of different mission periods were analyzed for both three- and six-man crews and two experiment groupings. Outputs of the program included schedules, power

profiles, and effects of system variables, such as power, crew schedule, ground and celestial targets, discipline sequence, attitude, and inclination. Similar studies have been completed for the EOSS concept, and a catalog of EOSS experiment data has been published.

In addition to selected scheduling analyses for three-man early stations and a six-man early station, a three-month study of experiment integration has been initiated to develop extended experiment scheduling for a long-duration early Saturn V Workshop mission. A 3/6-man hybrid mission is being considered as the baseline. From this baseline, schedule sensitivity will be established for parameters such as power, crew skill, crew schedule, and experiment priority.

Mr. Llewellyn and Miss Brender of LaRC were at MSFC on April 18, 1968, for a working session relative to studies on the Early Saturn V Workshop using the Langley Space Station Math Model. This model is used to analyze mission/system aspects, such as experiment scheduling, crew discipline mixes, and logistics. Variables include crew type, crew schedules, experiment priorities, and phased delivery of experiments.

The computer program is approximately two-thirds complete and LaRC is responding to several of our requests with the presently completed portions of the program. Several optional sub-routines currently being developed were described that will assist in our requested analyses. New supporting efforts were discussed and agreed upon that are commensurate with the development time of the Math Model.

C. Saturn V Workshop: Launch Vehicle

A reevaluation of the S-II/Saturn V Workshop separation analysis was made as a result of a configuration change to the ATM. Solar panels previously mounted to the ATM have been relocated on the Workshop, resulting in a decrease in the external diameter of the ATM by approximately four feet and an increase in minimum clearance of the ATM, with respect to the S-II/Saturn V Workshop interstage from 2 to 7 inches to 24 to 30 inches. These clearances are based on using the Service Module RCS to stabilize the configuration prior to initiating separation and then using either the RCS, springs, or the S-II retro motors to force the stages apart.

D. Saturn V Workshop: Resupply Logistics

A one-man-year effort on logistics and resupply for an orbital space station has been initiated. Primary study emphasis will be directed to near future (to 1975) applications with emphasis on low earth orbit space stations. More specifically, the effort will update and provide detailed information on the Saturn V Workshop, examine the various launch vehicles and spacecraft concepts, define mission profiles, and investigate various methods for orbit circularization. This effort will also include studies on various applications of developed and planned systems to other proposed and related missions. Logistics missions to high earth orbit stations (up to synchronous) and to lunar orbit and surface stations will be considered for both manned and unmanned systems.

The first phase of this effort is scheduled for completion on May 31, 1968. The primary tasks to be completed are comparison of fuel cells versus batteries for short-term Apollo CSM applications, evaluation of CSM weights as a function of orbit stay times, and compilation of potential logistics spacecraft characteristics. Potential spacecraft to be considered are the uprated Apollo, the Gemini derivatives, and the Big G spacecraft concepts, which utilize both Gemini and Apollo hardware in a single system.

III. Lunar

A. Small Manned Roving Vehicle (SMRV) Study

Roving vehicle performance data, power, and energy requirements were generated for two vehicle concepts. These two vehicles are the baseline SMRV with harmonic drive and a.c. power, and the SMRV I with a d.c. torque drive system. The baseline vehicle's performance was based on gear ratios of 80:1 and 100:1, operating over a 100-km course. A comparison of these two concepts operating over the same course shows the d.c. system is capable of higher speeds than the a.c. system for all slopes; however, the power demand for the d.c. drive system is approximately three times that of the a.c. drive system. This is still offset by the fact that the d.c. system requires less total energy or energy per kilometer than does the a.c. system. Data were also generated for the SMRV I operating at the above listed gear ratios over a 56-km course. Preliminary mass data were derived for the SMRV baseline and the total vehicle weight for the baseline concept was 528 pounds.

B. MTA Test Program

Test Laboratory personnel have indicated that testing cannot possibly begin before mid-May 1968, primarily because of higher priority program commitments. Therefore, the MTA Test Program will probably be delayed until late summer.

Messrs. Franz Kretzman and Ron Peterson of NASA Headquarters (Captain Scherer's Office), and Mr. Cliff Westbeld of MSC visited MSFC to discuss costs of lunar mobility systems. As a part of the two-day visit, personnel of this Office briefed the visitors on existing lunar surface vehicles here at MSFC. A tour of the facilities, including both of the MTAs and the BECO-built LSSM Mock-up, was arranged by this Office for the visitors.

IV. Planetary

A. Mars Fly-by Mission

1. Mars Soft-lander Probe Study --- The study to provide a conceptual design and analysis for a soft-lander probe, deployed during the encounter phase of a manned Mars fly-by mission, has been completed. The probe at deployment weighs approximately 4,200 pounds, including the sterile enclosure. Landed payload weight is approximately 1,500 pounds, which includes a large number of scientific instruments and television cameras.

The probe jettisons the aeroshell and deploys parachutes during descent through the atmosphere. At a low altitude the parachutes are jettisoned, and the final landing is made under rocket power.

The principal scientific objectives of the probe are collection and analysis of samples of Martian materials and televising scenes from the landing site. Sample analyses include chemical analyses of the air and of soil from various depths using gas chromatography and X-ray diffraction, and inoculation of culture chambers in an attempt to detect living organisms. Additional measurements include weather observations and detection of local seismic tremors and background radiation.

2. Mars Probe Module Study --- The study to define conceptually a probe module for the manned Mars fly-by mission, capable of containing and ejecting a defined probe complement to the vicinity of a target planet, was completed. The module defined was configured to structurally support, environmentally and biologically protect, and operationally deploy the proposed

experiment payload for a manned Mars planetary encounter mission. The probe module was designed to efficiently house a complement of nine probes: three atmospheric, two planetary, two soft-landers, one MSSR, and one orbiter. The module design, based on optimum packaging (minimum length but maximum freedom for deployment) developed into a cylinder 530 inches long and 260 inches in diameter and weighs approximately 60,000 pounds, including probes. A major conclusion was that inflight maintenance and repair of probes by the crew appears to be impractical because of the difficulty of providing for efficient crew access without causing biological contamination. Detailed results of the study are available.

The unmanned landing probe studies being performed by this Office for manned planetary missions are now terminated.

B. Evaluation of Unmanned Planetary Mission and Hardware Alternatives to the Voyager Saturn V Baseline

A first-cut outline of a one-man-year effort for the unmanned planetary program was established. Task categories in the outline are the following: (1) continued compilation of launch vehicle configuration and weight data; (2) adaptation of Centaur and Service Module to the Titan III-G; (3) sizing of orbiting spacecraft for the vehicles studied; and (4) conceptual design of spacecraft for use on large launch vehicles in the post-1977 time period. These categories are consistent with the work forecasted by R-AS for the unmanned planetary program.

Parametric data directed toward defining the configurational aspects of an unmanned landing probe vehicle in combination with an unmanned planetary spacecraft are now being determined. Scientific packages are being investigated based on planetary injected payloads between 8,000 and 25,000 pounds.

A cursory evaluation is being performed to determine what useful payload can be landed on the Mars surface via a Saturn IB/Service Module launch vehicle. Two landing modes are being considered: direct entry and an out-of-orbit entry. Drawings will be developed for the shrouded configuration during launch and the final landed configuration of the probe. Designs are to be based on a 1973 mission time and results should be available by May 3, 1968.

The first phase of the Unmanned Planetary Study was completed by the support contractor and is in the process of documentation. This work included the generation of weight statements and configurations on

various versions of the Saturn IB/Service Module, Saturn IB/Centaur, and Titan family launch vehicles which have potential application to the Unmanned Planetary Mission. An investigation, more detailed than the previous, will be made of the structural arrangement necessary to launch the Centaur stage, shrouded with the SLA, on the Saturn IB launch vehicle.

Sketches of the Saturn IB/Centaur, Saturn IB/Service Module, and payload enclosures on the Saturn and Titan vehicles were provided to R-AS for incorporation into a presentation by General O'Connor to Dr. T. Paine of NASA Headquarters.

V. General

A. ART/SRT Requirements

Personnel of R-ASTR-A, R-AERO-X, and R-P&VE-A are continuing with the development of SRT requirements related to advanced missions, at this time particularly those related to the Saturn V Workshop configuration. The EOSS computer requirements taken from the Douglas study were released to the Advanced Computer Project Group, headed by Mr. F.B. Moore (R-ASTR), on April 9, 1968. Computer requirements for planetary unmanned missions (Voyager type) were distributed on April 10. Power system requirements for the EOSS were also released to R-ASTR-E.

B. Project THERMO

Data were transmitted to Mr. R. Middleton, R-P&VE-P, on cryogenic requirements for orbital stations as part of the justification for Project THERMO. Information is documented in memorandum R-P&VE-AA-68-27. The assumed orbital program consisted of an early Saturn V Workshop, an advanced (or late) Saturn V Workshop, and a Common Mission Module. Cryogenic and gaseous storage data for life support systems such as quantities, tank size, number of tanks, mission times, etc., were listed. Other data included weights for N_2 and O_2 storage systems using all-gas, all-cryogenic, and hybrid systems. Other cryogenic requirements, such as those for cooling experiment sensors, were also mentioned.

C. Mechanical Power Conversion Systems

A study was completed which investigated some of the problems associated with the application of rotary equipment (turbine) for dynamic electrical power conversion. This study was directed primarily toward

understanding the design, operational and reliability problems of high-speed rotating machinery. In the event dynamic systems are used, power conversion will probably take place in a unit called the Combined Rotating Unit (CRU). These units contain the turbine, pumps, and alternator.

It was concluded that the application of the CRU offers large potential for future space missions. The primary reliability problem is caused by creep and/or failure of the turbine rotor. Based on current tests, a 20,000-hour life demonstration is feasible by 1975. Secondary problems concern the interface between the turbine and alternator; however, recent developments of high-speed alternators appear to have greatly reduced the magnitude of the problem.

Erich E. Goerner

GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-68-4

MONTHLY PROGRESS REPORT

APRIL 1, 1968 THROUGH APRIL 30, 1968

SATURN V

I. S-IC Stage

A. Evaluation of Commercial Adhesives

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

1. Polyurethane Adhesives

a. Investigation of the Useful Life of Z-6020 Primer Solution

In order to develop information requested by the Manufacturing Engineering Laboratory on the useful life of Z-6020 primer solution, a series of tests was run in which aluminum adherends were primed every hour over an 8-hour period using the same solution of Z-6020. This solution consisted of 0.2 g. Dow Corning Z-6020 dissolved in 9918 g. of anhydrous methanol. Acid etched aluminum panels were primed with this solution as soon as made, hourly over an 8-hour period, and a final set after 25 hours. After a one-hour drying time for the last set, all panels were bonded with 7343/7139 (100 g/11.5 g) including a control set. The specimens were cured for 24 hours at room temperature followed by 24 hours at 160°F (71°C). Test data on the samples indicate that Z-6020 primer can be used as an effective primer for aluminum for a period of up to 8 hours after preparation of the solution. The data also indicate that for maximum strengths, the primer solution should not be used any longer than 5 hours after preparation. Lapshear strength values for samples primed one hour before bonding and 5, 8, and 25 hours, were 2940 psi, 2820 psi, 2330 psi, and 1610 psi, respectively. The lapshear strength of the control sample was 1460 psi.

b. Study of the Effect of Water Addition to Z-6020 Primer

Since the reactive mode of Z-6020 primer with an aluminum surface is thought to proceed through partial hydrolysis of the coupling agent after application to the metal surface, tests were run to determine whether the addition of small amounts of water to the Z-6020 methanol

solution will enhance the performance of the primer. Lapshear specimens were primed with 0.2 percent Z-6020 methanol solution containing no water, 1.0 percent water and 5.0 percent water. Narmco 7343/7139 was used as the adhesive, and the specimens were cured for 24 hours at room temperature followed by 24 hours at 160°F (71°C). Results of the test were generally inclusive although there was some slight indication of improved strengths at both -300°F (-184°C) and +200°F (93°C) for the samples containing water in the primer solution. These tests will be repeated.

c. Investigation of the Effect of Cure Time on 7343/7139 Adhesive Bond Strength

Lapshear tensile specimens were bonded with Narmco 7343/7139 (100 g/11.5 g) and were tested after 1 day, 2 days, 3 days, 4 days, and 7 days room temperature cure. Adhesive mixes were made both with and without Z-6040 additive. Lapshear tests were made at -300°F (-184°C), room temperature, and +200°F (93°C). These data indicate that strengths at all three test temperatures increase throughout the cure period. The cryogenic strengths after 1 day cure are no further advanced relative to the ultimate 7-day values than are the strengths at room temperature or at +200°F (93°C). The beneficial effects of Z-6040 additive are apparent at +200°F (93°C) after 1 day, but are not obvious at cryogenic and room temperatures until the 7-day tests. From previous tests, it is probable that the sample containing the additive will increase in strength for the -300°F (-184°C), room temperature, and +200°F (93°C) test values with additional cure time, (8350 psi, 2100 psi, and 1270 psi). It is not expected that the sample without additive will increase appreciably over the 7-day cure strengths of 7980 psi, 1740 psi, and 640 psi, at -300°F (-184°C), room temperature, and +200°F (93°C), respectively.

d. Investigation of the Effect of Long-Term Aging on Polyurethane Adhesive Bonded Specimens

Tests were run on three series of samples that have been in ambient outdoor storage for 15 months. The samples were protected only from direct rain and sunlight. In this program aluminum adherends were primed with Z-6020 for one series and with hydrolyzed Z-6040 for another series. The primed adherends were bonded with the adhesive system: 100 g 7343; 12.5 g 7139; and 1.0 g Z-6040. A control series also was included in which the adherends were not primed and Z-6040 was excluded from the adhesive mix. After removal from storage the specimens were dried in a dessicator for 7 days before testing to eliminate any effects from moisture absorbed in the adhesive. Test results showed that the lapshear strengths exceeded those of the initial samples prior to aging in every case except the hydrolyzed Z-6040 primed samples at -300°F (-184°C). In this case the average lapshear strength only decreased from 8420 psi to 8280 psi. The results continue to show that the primed samples are stronger than the unprimed samples, particularly at room temperature and +200°F (93°C). On the basis of the results to date, there has been no deterioration of the bond strength during 15 months storage.

e. Evaluation of Narmco 7343/7139 With Z-6040 as an Adhesive for Bonding Aluminum Foil

To evaluate the effectiveness of Narmco 7343/7139 (100 g/11.5 g) containing 1.0 percent Z-6040 in the adhesive blend for bonding aluminum foil, a series of flatwise tensile and T-peel specimens were prepared. For the flatwise tensile specimens, 1.5 mil aluminum foil was bonded between aluminum test blocks; for T-peel, the aluminum foil was bonded between 20-mil aluminum sheets. Acid etch was used to prepare the surface of the aluminum foil for 1/2 of the samples, and solvent wiping for the other half. The adhesive was cured for 24 hours at room temperature followed by 24 hours at 160°F (71°C). The test results indicated no benefit for acid etched specimen except in the cryogenic peel test. The strength values for the acid etched specimens were, flatwise tensiles of 10,000, 1410, 750, and 630 psi at -300°F (-184°C), room temperature, +200°F (93°C), and +250°F (121°C), respectively, and T-peels of 43, 24, and 19 psi at -300°F (-184°C), room temperature, and +250°F (121°C), respectively. The surface of the aluminum test blocks were sanded in all cases, and the 20-mil aluminum sheets were acid etched.

2. Epoxy Adhesives

Evaluation of Z-6020 Silane Primer for Bonding Aluminum with Epoxy Adhesive

Lapshear tensile specimens primed with Z-6020 silane primer were bonded with Armstrong C-1 adhesive cured with Activator E. A control series was prepared using unprimed aluminum specimens. Results of tests performed at room temperature, +260°F (127°C), and -140°F (-96°C) show no clear strength advantage for the primed specimens. However, use of the primer would give longer processing time between surface preparation and bonding operations.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

The two objectives of this program are to develop (1) embedment materials with low dielectric losses and low thermal expansion coefficients for application to cordwood module-type circuitry and (2) conformal coatings having low dielectric loss and flexibility at low temperatures for application to printed circuit boards.

1. Embedment Compounds

Efforts have continued toward production of larger scale batches of intermediates which are used to prepare epoxy-siloxane embedment polymers. One of the basic intermediates, pallylphenyldimethylaminodimethylsilane, has been prepared successfully in larger scale quantities as an analytically pure material. This amino silane was utilized to prepare 30-40 grams of 1,4-bis((p-allylphenyldimethylsiloxy)dimethylsilyl)benzene. Purification and characterization of this compound are currently in progress. Approximately 30 grams of pure p-allylphenyldimethylsilanol have been

accumulated to date. It is anticipated that one more large batch of the corresponding chlorosilane will yield the remaining silanol needed.

2. Conformal Coatings

The General Tire and Rubber Company, who is to supply the saturated, hydroxyl-terminated, hydrocarbon prepolymer, has indicated that quality control problems will delay preparation of this material. Thus, discussion of this material will not be included in subsequent reports until the material is received.

Alternate attempts to reduce the unsaturated character of a commercially available hydroxyl-terminated butadiene prepolymer have been unsuccessful. This polymer was treated as a benzene solution with an excess of trimethylsilane in an attempt to add across the polymer double bonds. This reaction, if successful, would place trimethylsilyl groups at the site of the double bonds and render the polymer less susceptible to age hardening through oxidation. However, infrared analysis of the reaction product revealed no siliconmethyl absorption, indicating that the reaction did not occur to an appreciable extent.

Further studies of the silphenylene-siloxane polymer as a conformal coating will be carried out after receiving two of these polymer variants from Southern Research Institute.

3. Ceramic Materials

Efforts have continued in the investigation of commercially available ceramic materials for application as potting compounds for electrical components. Several commercial materials have been investigated with respect to workability. Two-inch diameter and 1/8-inch thick samples of these materials have been prepared and submitted for electrical property determinations. The results of the electrical property determinations will serve as a guide for directing the future course of the program.

C. Investigation of the Failure of S-IC Stage Hydraulic Actuators

Moog S-IC servoactuator S/N 30 was received from the Astrionics Laboratory for examination to determine if cracks developed during severe pressure testing. No cracks were found visually after the first series of tests nor after the second series; however, the actuator is being subjected to comprehensive NDT evaluation which might reveal discrete crack initiations. No cracks were found visually in actuators S/N 46 and 77. Due to the work load, these two actuators as well as S/N 64, which contains a known crack, have been set aside for future studies.

D. Investigation of the Failure of S-IC Stage Actuator Fasteners

Hardness measurements were made of the several fasteners removed from SA-502 S-IC Hydraulic Research actuators. The hardnesses ranged from R_C 38.5 to 42.7 with an average of R_C 40.5. These fasteners were not torqued to 75 percent of yield and held the prescribed 200 hours for hydrogen

embrittlement studies as were those reported last month since the latter had seen more severe loading in the S-IC-502 vehicle.

E. Investigation of Stress Corrosion of 17-7 PH Stainless Steel Actuator Springs

Stress corrosion studies have continued on various springs used in the engine servoactuators and S-IC LOX prevalve actuators. After six months of exposure only one 17-7 PH, CH900 spring has broken (five months of exposure at maximum load) and two Belleville springs (17-7 PH, RH950) also stressed to maximum load. The Belleville springs are being exposed in the humidity cabinet(98 percent relative humidity, 100°F (38°C)). One spring failed after 11 days of exposure and another failed during this report period, after 180 days.

II. Contract Research

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

A. Polymer Research, Development, and Testing

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

B. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

C. Nondestructive Testing Techniques

North American Rockwell, NAS8-20764

III. S-II Stage

A. Development of Fast Curing Adhesives for Use in Insulation Repairs

Efforts have continued in the development of fast curing adhesives in order to more effectively accommodate a possible requirement for insulation repairs between CDDT and launch.

The accelerated cure polyurethane formulation using adipic acid was developed for emergency repairs. Tests were run in which 1.0 g of Z-6040 was included in the adhesive mix (100 g 7343, 11.5 g 7139, and 0.1 g Adipic) along with check samples without Z-6040. Lapshear and T-peel test results after one-day cure at room temperature show essentially the same strength values at -300°F (149°C), room temperature, and +200°F (93°C) except for a marked improvement in T-peel strength at +200°F (93°C) for the samples containing the Z-6040.

B. Developmental Welding

Activities have continued in an attempt to establish a statistical correlation between heat-affected zone width and weld joint strength in welded joints of 2014-T6 aluminum.

All experimental panels of aluminum alloy 2014-T6 (1/4-inch plate) have been welded by the TIG and MIG processes (flat and horizontal positions) using both 2319 and 4043 filler metals with two selected joint configurations and evaluation of results is nearly complete. Ultimately, the results obtained from these panels will be compared to each other (results representing each weld condition) as well as to the results obtained from experimental weldments made by the pulsed arc MIG process

C. Evaluation of Corrosion Characteristics of 2014-T651 (063 Material) Aluminum Tank Materials

Metallographic studies have continued on selected failed specimens of 2014-T651 (063 material) from the stress corrosion test program. The studies indicate that failures are occurring in the large grain banded area of the "fine grain" plate No. 594395. All failures studied to date have been intergranular. The total failures as of April 26, 1968, include all large grain short transverse specimens (15) stressed to 10 ksi, 12 of 15 large grain short transverse (S.T.) specimens stressed at 5 ksi, 9 of 15 large grain S.T. specimens stressed to 3 ksi, 5 of 9 fine grain (nominally 35-50 grams/mm^2) (plate 594395) S.T. specimens at 10 ksi, 1 of 9 fine grain (plate 594395) S.T. specimens at 5 ksi and 2 of 9 fine grain (ca. 2 grain/mm^2 from plate 594392) stressed at 10 ksi. Three 1/4-inch diameter S.T. specimens stressed at 10 ksi, 5 ksi, and 3 ksi were removed from the alternate immersion tester for metallographic studies since no complete failures had occurred. The study indicated that several near-through cracks existed in the 10 ksi specimen, and severe pitting and cracking sufficient to relieve the strain was noted in the 5 and 3 ksi specimens.

D. Investigation of Failure of Hylok Fasteners in the S-II "C" Structure

Twelve additional 7075-T6 aluminum Hylok fasteners failed in the S-II "C" structure interstage, located at Building 4619. Approximately 25 fasteners have failed on the interstage since arriving last fall. Four of the twelve fasteners were received by this division for failure analysis. Both metallographic and fractographic studies indicate the failure resulted from stress corrosion cracking. The cracking occurred in recrystallized areas of either the head-to-shank area or the threaded areas of the fastener. These failures occurred since the first week of January when a post test inspection revealed no failed fasteners. The test to 1.10 safety factor made the last week of December is believed to have loaded the fasteners to a level beyond the stress corrosion threshold and retained this load to induce the stress corrosion failures.

Information received from North American Rockwell, Seal Beach, indicates that nine failed fasteners were found recently on the "B" ministage undergoing test at Santa Susana, California. These failures have been attributed also to stress corrosion cracking. It has been recommended that interstages S-II-4 through 11 be inspected for Hylok fastener failures and that a record be kept of the number, location, and frequency of failures.

E. Investigation of Failures of A-286 Stainless Steel Fasteners on the S-II Ministage

Two types of A-286 stainless steel fasteners Hylok 448 (Hi Shear and Voi Shan) failed during installation of components on the "A" ministage at the Manufacturing Engineering Laboratory. Most of the failures occurred in the Voi Shan fasteners. Failure of the fasteners was attributed to notched tensile overload during installation. Both types of fasteners met the established standard and appropriate specifications for the A-286 alloy fasteners. Manufacturing Engineering Laboratory personnel are checking out the lubrication used on the fasteners.

F. Investigation of Fracture Toughness

A comprehensive fracture toughness study is continuing related to fracture properties of 2014-T6 aluminum alloy weldments. A full in-house capability to make fracture toughness evaluations is being developed. Flaws have been induced in the surface of specimens to investigate the best methods of obtaining preselected flaw sizes after flaw induction. Characterization of the flaw growth rates through selection of initial starter flaw size and number of fatigue cycles could not be accomplished satisfactorily. Consequently, effort is being directed toward visual observation of cracking with a microscope and a strobe light during fatiguing of the specimens. Fatiguing of a given specimen will be terminated at the exact point when cracking has occurred along the entire periphery of the regional starter flaw. Samples of 2014-T6/5054 filler 1/16-inch and 1/2-inch thickness weldments are being machined into fracture toughness specimens along with the remaining panels fabricated by North American Rockwell (NR) last July 1967. Parent metal samples are being machined from 021 and 063 1-3/4 inch plate to determine large and fine grain effects on cracks located along the roll direction.

NR has reported that "Phase II, Task 1, Crack Growth," testing will be completed in about two weeks. The contractor also reports results which apparently reflect disagreement with The Boeing Company, Seattle, and Lewis Research Center on the preload effects upon crack geometry. North American Rockwell anticipates that the S-II Fracture Mechanics Program will be completed by the second week in July if there is no further change in the current budget.

G. Investigation of Nondestructive Techniques for Inspection of Composite Materials

The objective of this work is the development of methods and instrumentation required for the nondestructive evaluation of debonds and voids in spray foam-aluminum composite materials of the type and configuration used on the S-II stage. The particular spray foam insulation being investigated is the Nopco BX 250A polyurethane foam which has a nominal density of 2 pounds per cubic foot. Standard ultrasonic technology is inadequate for detecting lack of adhesion between this foam and aluminum because there is not enough difference between the magnitude of reflected energy from the aluminum-foam interface and that reflected from the aluminum-air interface when a debond exists to allow the use of pulse echo testing. Also, the high attenuation of the foam makes through transmission ultrasonics testing impractical. Therefore, several audio frequency methods have been investigated.

As previously reported, through transmission eddy current methods have been used successfully to detect lack of bond between spray foam insulation and aluminum plates. However, recent experiments have demonstrated that this method can be used also to detect voids in the foam. Simulated defects were made by drilling 1/4 inch diameter holes in the edge of a composite panel. Maximum sensitivity to these voids occurred when the longer dimension of the contact microphone was aligned parallel to the length of the hole. The microphone is about 3/4 inch wide by 2 inches long. Since the use of a smaller vibration detector will increase the sensitivity of the method, a smaller microphone has been ordered. This eddy current technique is not as sensitive as radiographic methods to small voids in cryogenic insulation of the S-II type. However, it will be very useful for evaluating voids in the foam of composites having thick metallic face plates, and it can also be helpful as a supplement to radiography in other applications.

Other related areas of activity include the successful application of eddy current techniques of debond detection of 1/4 inch aluminum - 2-inch foam composites and improvements in the technique of making frequency-amplitude scans of composite materials. Examination of typical scans of the transmission characteristics of 1/8 inch aluminum - 7/8 inch Nopco foam composites indicate that an inspection frequency near 5,000 Hz should be used for this particular materials system.

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

Investigations have continued into the use of liquid oxygen (LOX) sensitive dye penetrants for inspection of S-II stage hardware.

During this period, studies were continued on the optimization of dye penetrants. The aging test on PGP-26BF-6, MSFC Lot 1, Bottle 4, is continuing. The results of LOX impact tests indicate that this sample of PGP-26BF-6 shows no deleterious effects due to aging after 3-1/2 months. Studies have continued to determine the effect of anodic coating thickness (anodizing time) on the liquid oxygen sensitivity of various dye penetrants.

Specific dye penetrants were evaluated using discs anodized for various lengths of time. Four series of anodized discs were used; 30 minutes anodized, 15 minutes anodized, 7 minutes anodized, and 3-1/2 minutes anodized. An analysis of the data generated to date indicates that for any given dye penetrant the LOX sensitivity increases as the anodic coating thickness (time) is decreased. One explanation for these apparent anomalous results is the cushioning effect resulting from the thicker anodic coating (30 minutes anodized). As the anodic coating thickness decreases, the sample becomes more rigid; therefore, under impact less energy is absorbed by the system leaving more energy to the sample. Another interesting phenomenon uncovered during this study was that the amount of PGP-26BF-6 remaining on the anodized disc was constant and not dependent on anodic coating thickness. This tends to indicate that the porosity of sulfuric acid anodized discs is the same regardless of coating thickness.

Additional studies are in progress to study other dye penetrants to determine the optimum conditions for evaluating dye penetrants for LOX compatibility.

I. S-II Stage, Project Management, Materials

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

1. Investigation of 2014-T651 Aluminum Alloy (-063 specification) Material

A status review was held at North American Rockwell/Space Division (NR/SD) to explore, in depth, the NR/SD program for evaluation of the MB0170-063 material. It was disclosed that short transverse elongations were not consistently higher than the regular 2014 material (-021 specification). In fact, there were elongation values in the -063 material that were less than the typical values of the -021. The most significant finding, however, was that NR/SD did not know the procedure of this Center for determining failures in their stress corrosion test specimens. Until this time NR/SD had reported a limited number of failures at 25 ksi. Using the procedure of this Center for determining specimen failure, failures were detected in specimens as low as 5 ksi (in all three grain sizes 0.5, 1.0, and 2.0 grains/sq. mm); nearly all of the 10 ksi specimens were failed and all of the 25 ksi specimens. These results now compare favorably to those obtained at this Center.

As a result of the stress corrosion test program, NR/SD has recommended replacement of all MB0170-063 material including that in S-II-9 and S-II-10. The assessment of the schedule impact based on delivery to the launch site is no loss time for S-II-9, 3 weeks for S-II-10, and 7 weeks for S-II-11. No other stage schedules are affected.

2. Propulsion System Lines

A survey of the effect of materials processes used on the S-II propulsion system lines being built by Solar, San Diego, California, was conducted by this division. While the quality of the lines now being manufactured meets the minimum specification requirements, there is much to be desired in overall workmanship and inspection.

As a result of this survey the following recommendations have been made:

a. Solar MPS 7-520, Revision 4, which is a released specification, but not effective on all lines at this time, should be immediately implemented on all lines.

b. Solar should be directed to make preproduction weld tests to simulate a cylindrical weld typical of the line welds, on each working shift or after any weld machine repairs to insure a proper weld schedule prior to welding the hardware lines.

c. In conjunction with item b. above, Solar should be directed to optimize the welding schedules to produce a weld bead of uniform contour having a repetitive ripple smoothly blended into the adjacent base material.

d. North American Rockwell should be directed to investigate a sample segment line welded with the new weld joing alignment fixture to insure that the pressure applied by the alignment fixture during welding does not produce root side cracks that are not detectable by X-ray.

e. Solar should be directed to assess the material handling techniques and manufacturing operations to eliminate the excessive dents and scratches on the hardware components.

f. Solar has continued the use of only one radiographic exposure for a specific weld zone even after repeated demonstrations to Solar by NR that both the base metal and weld zone cannot be properly evaluated in the same exposure. Therefore, Solar must be directed to employ one exposure for evaluation of the base material adjacent to the weld and another exposure to evaluate the weld cast structure.

3. Weld Problems

a. Stress Relief Areas

Radiographs of the stress relief area for S-II-3, -5, and -6 were reviewed to insure that no defects were overlooked during routine inspections at NR. The S-II-6 vehicle had no indications which were considered critical; however, radiographs of both S-II-3 and S-II-5 showed defect indications beyond specification limits.

S-II-3 had two pores, one 0.050 inch and the other 0.015 inch in the most highly stressed area of the stress relief zone. In certain radiographic views these pores appeared connected but in other views they were determined to be 0.005 inch apart. Even so, they are considered one pore since they are not separated by more than the diameter of the smaller pore. Pending investigation to insure these pores are not connected to any surface defect, it has been determined that they would not degrade the structural integrity.

S-II-5 had one pore 0.075 inch x 0.025 inch and had penetrant indications at the surface. There was a high probability that the oxides from the large pore extended to the surface; therefore, it was necessary to remove the defect. The final grindout configuration was 0.058 inch deep, 0.375 inch wide at the top tapering to 0.187 inch at the bottom. Specimens simulating this groove tested at room temperature and -423°F (-253°C) indicated the structure was not significantly degraded to warrant further repair.

b. Weld Cross-Over Areas

Since removal of the stress relief area beginning with S-II-8, cracks have been more frequent in the cross-over welds. North American Rockwell has proposed to weld the vertical splice welds and bulkhead meridian welds using filler metal type 4043 which is somewhat less crack sensitive. Filler metal is certainly a contributing factor, but, as MSFC has recommended several times before, weld travel speed has a great influence on crack susceptibility. Since a change of filler metal will necessitate recertification of the welds we have proposed that North American Rockwell also slow down the welding speed.

IV. S-IVB Stage

A. Evaluation of S-IVB Cold Plate Isolator Materials

To obtain further verification of planned fixes for the isolator problems encountered recently, T-peel specimens were prepared using both Chemlok 607 and Dow Corning DC-S-2260 primer on aluminum surfaces. Attempts to bond silicone elastomer to these surfaces did not succeed on the first attempt, but the problem appears to be in the elastomer cure cycle. Further information has been requested on curing this elastomer.

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

Late in the AS-501 launch preparation it was noted that the Korotherm insulation on the S-IVB stage was flaking. Because of this problem the stage contractor stripped all Korotherm off the stages,

replaced the primer, and recoated the stages, starting with S-IVB-503. The wisdom of such repair at that time was questioned by this Center. Nevertheless, the stage contractor assured us that the corrective action would preclude a reoccurrence of the condition experienced on S-IVB-501.

Following the S-IVB-501 incident, another critical look was taken at all of the materials and specifications involved. The primer was changed to improve adherence of the Korotherm insulation to the stage, and some of the specification tolerances were tightened to administer closer control of fabrication processes. All of these changes were reflected in the appropriate specifications, and no other requirements were considered necessary to provide a flightworthy insulation system, except that the stage contractor should comply with the specified requirements.

Despite the stage contractor's assurance that the insulation problem had been identified and solved, we now know, after arrival of the stage at the John F. Kennedy Space Center (KSC), that the Korotherm insulation rework on S-IVB-503 was totally unsuccessful. The insulation is too thin, and the seal coat does not seal, because they were neither applied nor inspected in accordance with specified requirements. The inadequate seal coat allowed wetting of the insulation, hence, softening, swelling, and changing of its chemical composition. The stage contractor redried the insulation by exposing it to hot circulating air for two weeks. Having undergone a chemical change, the redried insulation now on S-IVB-503 is not the same as it was before. The extent of this change is not known. There is no information on the suitability of its physical and mechanical properties for the flight environment, there is no assurance that the stage contractor recognizes the problem.

Since the stage contractor has been unsuccessful in two attempts to provide acceptable Korotherm insulation for S-IVB flight stages, action is being taken to require the stage contractor to inform this Center of changes being implemented in process control and inspection functions to preclude a reoccurrence of the problem.

2. Vibration Isolators

Personnel of McDonnell Douglas Corporation made additional development, evaluation, qualification (DEQ) tests of vibration isolators and have compiled a matrix of all relevant data. Based on these data the contractor has proposed that a maximum 0.250 inch debond be allowed for flight application. This proposal is considered acceptable by this Center.

V. Instrument Unit

A. Investigation of Acceptability of Instrument Unit Environmental Control System Pump Housings

It was discovered recently that the aluminum castings for the Environmental Control System (ECS) pump housing do not comply with the specified Grade II-F casting in accordance with MSFC-STD-100, "Acceptance Standard for Radiographic Inspection of Aluminum and Magnesium Alloy

Castings." Some of these castings were assembled in pump units before the contractor became aware that the castings were not within specification. Now the contractor wants a waiver on the casting quality so that the assembled pumps can be used. Satisfactory radiographs of the assembled castings are not available, and to obtain new radiographs, the pumps would have to be disassembled. Thus, the contractor is asking for a waiver based on qualification tests of the casting, the results of proof-pressure tests made on the castings before assembly, and the quality of castings that have not been assembled. The following recommendations were made by this division:

1. The pumps should be disassembled and new radiographs made of the cast housing.

2. The radiographs for the castings evaluated in the qualification tests should be obtained for examination.

3. The casting that was pressurized to failure should be metallurgically examined and related to its radiograph.

When this information is available, the castings can be reevaluated.

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

Studies are continuing to determine the amount of hydrogen gas that can evolve from corrosion of LA141 and aluminum alloys in an alcohol-water mixture.

VI. F-1 Engine

Project Management, Materials

A trip was made to DK Aerospace Company, Batavia, Illinois, to examine fabrication procedures, plant tooling, etc., and to discuss actions of North American Rockwell (NR) to prevent reoccurrence of the bellows failures which have been experienced on the F-1 heat exchanger helium lines, P/N-260142. The material used in the failed bellows involved three separate heats of alloy 718; one of which was procured from a different supplier. A revision to DK Aerospace Company Process Specification DKS-5059-1, "Heat Treating of Inconel 718," was made to prevent alloy depletion at the surface. The damage was effected on the last 15 bellows of the contract which were shipped to NR in March 1968. Because the contract at DK was completed, the fabrication could not be observed and the tooling used was examined dismantled. The quality control records and metallurgical examination records for the sample analysis of bellows from lots No. 1 and 2, which were involved, did not uncover the reason for the failures. None of the bellows, nor parts of, from this contract were available at DK for examination. However, further investigation into quality control records is continuing, and a later report will be made by Quality and Reliability Assurance Laboratory.

VII. Orbital Workshop

A. Study of Flammability of Materials

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

During this report period, a number of materials were evaluated for flammability by the procedures outlined in MSC-A-D-66-3A. The samples included various elastomers and plastics. Samples of FEP Teflon were evaluated to determine if the basic material is nonflammable in 6.2 psia oxygen. The samples were 1 and 5 mil thick. All samples ignited and propagated from the bottom. A number of filled Teflon materials were evaluated for flammability using the procedures outlined in Test 1 of MSC-A-D-66-3A. None of these materials ignited under the conditions of this test. Three materials which had passed the MSC-A-D-66-3A test were evaluated as possible thermal curtain materials. These materials (Fluorogreen E-600; aluminum alloy 2014-T6, 0.016-inch thick; and McDonnell Douglas Corporation's (MDC's) aluminum foil-fiberglass-aluminum foil composite) were placed 1-1/2 inch away from a sample of 3-D insulation in a flowing system. The insulation was ignited and the effect of the burning insulation on the proposed thermal curtain material noted. Both the Fluorogreen E-600 and the MDC curtain material burned under these conditions. The 16-mil aluminum foil did not burn under the conditions of this test.

Numerous tests have been made, with support from Test Laboratory, to assess the flammability of the S-IVB internal thermal insulation coated with various thicknesses of aluminum foil. These tests were made in a large test chamber filled with gaseous oxygen flowing over the surface of the insulation at rates designed to simulate the gas flow anticipated in the Workshop. A new fan was installed in the 3-foot diameter chamber. This fan has the capability of output velocities up to 2000 ft/min at the center of the test samples. Flammability tests under flowing conditions were made on a number of samples. This necessitated intentional damage to the fire retardant liner. The oxygen flow velocity at the ignition point has been varied over a wide range from about 450 feet per minute to about 2250 feet per minute. Examination of test data and test specimens indicated that the specimen that was self-extinguishing, regardless of the extent of burning, did so at a point where the oxygen flow velocity was about 350 feet per minute. As the size of the initial defect increases, from 2-inch diameter, the limiting flow velocity for self-extinguishment decreases. Additional tests are in preparation utilizing larger test specimens (3 ft x 5 ft) and a more realistic flow system to determine more fully the effect of the higher velocities proposed for the Workshop.

Autoignition studies of an initial series of 30 polymer samples has been completed. However, further refinement of the data already collected will require several additional tests. This is due to recent improvements in equipment and technique that were incorporated into the test apparatus. It is planned to briefly recheck earlier samples for improved accuracy and data under the capabilities now available.

Additional materials are being obtained to study the ignition characteristics of various materials in controlled environments. Data to be collected will be flame point, flash point, autoignition point, differential thermal analysis, thermogravimetric analysis and thermo-mechanical analysis for each material.

B. Evaluation of Outgassing Characteristics of Fans for the Orbital Workshop

A second motor driven Vaneaxial Fan for the S-IVB Orbital Workshop was placed in a vacuum chamber to examine the outgassing characteristics of the fan at ambient operating temperature and also at 50°C. The system was pumped at ambient temperature to 1.4×10^{-7} torr.

Periodic mass scans were made with the residual gas analyzer (RGA) to determine the outgassing constituents. An initial mass scan at 25°C revealed mass peaks to 151 atomic mass units (AMU). After exposure to the vacuum environment for 18 hours, a mass scan showed only background atmospheric gases to be present.

The vaneaxial fan was heated to 50°C on a flat aluminum hot plate. Temperatures at three different locations were monitored to insure a temperature no greater than 50°C. Mass scans taken just after the fan reached 50°C showed mass peaks to 151 AMU. The fan was held at 50°C for 31 hours with a final pressure in the system of 1.5×10^{-7} torr. Mass scans made after 50 hours of testing revealed only background gases were present with no mass peaks above 44 AMU.

Test data indicate the fan assembly is acceptable for use on the OWS after a thermal/vacuum bake at 50°C at a pressure of less than 5×10^{-7} torr for 48 hours.

C. Investigation of Thermal Control Coatings for the Orbital Workshop

Work has continued to select thermal control surfaces for various components of the orbital workshop (OWS). Bright aluminum surfaces were considered for obtaining an effective emissivity (ε_{eff}) <0.052 between the meteoroid shield and the S-IVB tank exterior on the sun-lit side (between fins IV to I to II) of the OWS. Although the bright aluminum surfaces provide the requisite emissivity (ε), they are susceptible to corrosion resulting in objectionable changes in their ε values. One alternative is to bond goldized Kapton, which has an ε value of 0.04, to the surfaces. Narmco 7343 with 1 percent Z-6040 additive is being evaluated as the adhesive for bonding the goldized Kapton. Initial tests indicate that the adhesive has to be heat cured to meet the vacuum compatibility requirements.

On the dark side (between fins II to III to IV) of the OWS, an ε_{eff} of 0.25 is required between the meteoroid shield and the S-IVB tank wall. This can be obtained by coating one of the surfaces (either the interior of the shield or the exterior of the tank) with a paint having an ε of 0.9 and the other surface with a paint having an ε value of 0.25. Cat-A-Lac flat black paint No. 463-3-8 can be used for the surface requiring an ε of 0.9. Two commercial aluminum paints, Thermokote No. 625, manufactured by the Vita-Var Corporation, and Cat-A-Lac No. 643-1-1, manufactured by the Finch Paint and Chemical Company, are being investigated for the surface requiring an ε of 0.25. These paints are being evaluated with respect to optical properties and thermal vacuum compatibility.

During this report period, work was initiated on the preparation of inorganic coatings designed to match the proposed "Loewy" color scheme for the interior of the OWS. Good color matches have been formulated for the pastel blues and "off white." Work is now in progress to formulate the other pastel colors suggested. At this time there is no apparent difficulty recognized in preparing these coatings. In addition, other color formulations will be prepared to assure that we have a full color spectrum range. All of these coatings will meet the emissivity requirements of 0.8 or greater for the OWS. Thermal cycling between 285°F (141°C) and -320°F (-196°C) has shown that these coatings can take the thermal shock within this range without flaking. When the formulations on this color series have been completed, scale-up studies will be evaluated and tentative manufacturing costs will be based upon the scale-up studies.

D. Orbital Workshop, Project Management, Materials

1. Thermal Control Coating

The McDonnell Douglas Corporation (MDC) is in the process of qualifying Alodine 407-47 coating for thermal control of the aluminum foil liner. Studies completed to date include:

a. Cryogenic testing of the coating on the 3-foot dome at Sacramento, California.

b. Coating of the 8-foot tank, and

c. Coating of the 3-foot diameter discs for flammability testing at this Center.

2. LH_2 Tank Penetration Seals

McDonnell Douglas Corporation has finally agreed to test O-rings of CNR (carboxy nitroso rubber) in the penetration sealing devices for OWS applications. CNR is favored over silicone for the O-ring seals because it is not flammable.

3. The following documents were reviewed:

a. MDC STP0276, "Peening, Glass Bead, Aluminum Alloy"

b. MDC-56647, "Orbital Workshop Procedures and Requirements for Evaluation of Nonmetallic Spacecraft Materials".

VIII. Multiple Docking Adapter (MDA)

A. Investigation of Thermal Control Surfaces for the Multiple Docking Adapter

Efforts have continued in the evaluation and selection of thermal control surfaces for components on the multiple docking adapter (MDA). The external surface of the meteoroid shield requires a coating having an α/ε ratio of 1.12. Two black paints, Midland Sicon Black No. 7X933 and MIL-E-5556, have the requisite optical properties and are being evaluated for the external coating. Recent tests show that the Sicon Black has much better adhesion than the MIL-E-5556 at the low temperature (-150°F (-101°C)) at which the meteoroid shield will be exposed in space. Therefore, present efforts are concerned with qualifying the Sicon black rather than the MIL-E-5556 black. Qualification studies underway include optical property stability and thermal vacuum compatibility. The Sicon black paint must be cured at elevated temperatures to render it vacuum compatible. Three curing cycles have been tried without success. Other curing cycles will be investigated. This paint is being evaluated for optical property stability.

B. Investigation of Seal Materials for the MDA

Materials investigations are continuing in the search for materials suitable for seals in the MDA. Final selection will be made at such time as the thermal requirements are established.

IX. Apollo Telescope Mount

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. These investigations include (1) evaluation of weight loss of materials in vacuum, (2) evaluation of outgassing characteristics of components in vacuum, and (3) evaluation of the deposition rate and film thicknesses redeposited by outgassing materials.

1. Phase I Tests (Weight Loss)

a. Materials Tests

The outgassing characteristics of thirteen materials were evaluated in vacuum, 10^{-7} torr, to 100°C, by making continuous weight loss determinations and periodic mass scans on each material. Significant results of these tests are summarized as follows:

Acceptable weight loss characteristics were evidenced by the MDA fiberglass window shield and the LCA-4LV adhesive. The adhesive sample contained 100 parts LCA-4LV adhesive with 4.5 parts by weight of the activator BA-5. The sample was then cured per specification.

Narmco 7343 adhesive with 1 percent Dow Z-6040 was tested, one sample that was air dried only, and one sample that was heat cured. In spite of the curing cycle, both samples showed excessive weight loss and are unacceptable for use on the Apollo Telescope Mount (ATM).

Two greases, Dow Corning 33 and Celvacene "medium" vacuum grease were tested and found to be unacceptable since their maximum rate of weight loss exceed 0.2 percent/cm^2/hr.

Three rubber samples, PRC 1201Q polysulfide rubber, 3M sealer type EC 1763, and CNR were all found to be acceptable under thermal vacuum test conditions. The CNR outgassed excessively due to its nitrogen-oxygen bonding system.

Two samples each of Sicon black No. 7X933 and black paint per MIL-E-5556 were tested and found to be unacceptable. The curing of the black paint per MIL-E-5556 at 250°F (121°C) for 24 hours did not improve the thermal stability of the coating. Sicon black was improved with a high temperature cure but still exceeded the maximum allowable rate of weight loss for use of the coating on the ATM.

b. Component Tests

(1) Two rack strut spherical bearings coated with a dry film lubricant and inadvertently coated with Versilube F50 were exposed to thermal vacuum environment and evaluated for outgassing. The purpose of the test was to ascertain if the bearing could be given a treatment which would remove the Versilube 50 and make the bearing acceptable without returning it to the manufacturer. One of the bearings was chemically cleaned with carbon tetrachloride (CCl_4), placed in a vacuum chamber, evacuated to 1.8×10^{-7} torr, and heated to 110°C over a period of 22 hours. During the test periodic mass scans were made with an RGA (residual gas analyzer). At 50°C high molecular weight fragments were present to 122 atomic mass units (AMU). At 100°C fragment peaks were only present to 58 AMU and at 110°C only residual background gases were present.

The other bearing was placed in a vacuum chamber, evacuated to 6.1×10^{-7} torr, and heated to 87°C in 24 hours. Periodic mass scans were made during the test. At ambient temperature high mass fragments were present to 164 AMU. At 42°C the mass range decreased to 149 AMU and at 80°C after 19 hours in vacuum 56 AMU was the highest m/e ratio present. After 24 hours in vacuum and a maximum temperature of 87°C only residual background constituents were present.

The mass spectrographic data on these tests indicate that both bearings can be made acceptable for ATM use after receiving a thermal/vacuum bake at 87°C at a reduced pressure of $<5 \times 10^{-7}$ torr for 24 hours. The chemical treatment is recommended but has little effect on the final results.

(2) A 270 Time Division Multiplexer was exposed to a thermal/vacuum environment to determine the outgassing characteristics of the unit and to ascertain if a thermal/vacuum bake would make the assembly acceptable for use on the ATM. The multiplexer was tested with the black paint removed by chemical cleaning. The system was pumped at ambient temperature to a pressure of 1.1×10^{-6} torr for a 23-hour period. Periodic RGA scans revealed mass peaks to 150 AMU.

The multiplexer was then heated to 85°C and the system pressure rose to 2.1×10^{-5} torr. Extreme outgassing was evident since after a 50-hour period, the pressure remained at 5×10^{-6} torr. RGA scans showed high molecular weight fragments to 221 AMU.

The unit was examined after the thermal/vacuum test. It was determined that the main sources of contamination were the honeycomb laminated top and bottom plates of the multiplexer casing.

A subsequent test was made on the 270 multiplexer with the top and bottom casing plates removed. The system was pumped at ambient temperature to a pressure of 4.8×10^{-7} torr. Periodic mass scans showed peaks to 149 AMU. After a period of 25 hours, the unit was heated to a temperature of 50°C with a pressure rise to 2.2×10^{-6} torr. Again high molecular weight fragments were evident to 221 AMU.

After 31 hours of testing, the temperature of the multiplexer was increased to 85°C. The system pressure increased to 1.1×10^{-5} torr. The pressure dropped to 7×10^{-6} torr after the unit had been at 85°C for 24 hours. However, significant mass peaks were detected with the RGA to 221 AMU. Although the vacuum/thermal bake improved the unit, it still remains unacceptable for use on the ATM.

A recommendation has been made by this division that the multiplexer be baked at 85°C for 24 hours at $<10^{-6}$ torr. It should then be backfilled with gaseous dry nitrogen and the unit sealed. With this preparation, the 270 Time Division Multiplexer will be acceptable for use on the ATM.

(3) A gray painted magnetic core #51011-2A904 was exposed to a thermal/vacuum environment and evaluated for outgassing. The purpose of the test was to determine if the outgassing characteristics of the core were acceptable for use on the ATM or if a vacuum/thermal bake would make the unit acceptable.

The core was attached to an aluminum hot plate and placed in a vacuum system which was then pumped to 6.0×10^{-7} torr at 25°C. After 4 hours the magnetic core was heated to 85°C with a pressure rise to 1.2×10^{-6} torr. The pressure decreased to 1.9×10^{-7} torr after the core had been at 85°C for 21 hours.

Periodic mass scans were made to determine the outgassing constituents present in the system. An initial mass scan showed peaks to 151 AMU with the magnetic core at 25°C. When the core was heated to 85°C, the same primary peaks were present. Mass scans made after the magnetic core had been in vacuum for 20 hours revealed only background atmospheric gases were present.

These data indicate that the magnetic core #51011-2A904 will be acceptable for use on the ATM after it has been subjected to a thermal/vacuum bake of 85°C at less than 1×10^{-6} torr for 24 hours.

(4) A section of Flex-Weld cable was tested to determine its outgassing characteristics to ascertain its acceptability for use on the ATM prior to and after a thermal/vacuum bake. The cable was placed in a vacuum chamber and pumped to a pressure of 1×10^{-7} torr at 25°C. After 3-1/2 hours the flex-weld was heated to 100°C with a pressure rise to 9.4×10^{-7} torr.

During the tests, periodic mass scans were made with the RGA. At 50°C, only background gases were present. When the cable was heated to 100°C, mass peaks were evident to 280 AMU. After 32 hours in vacuum these mass peaks were still present in significant intensity. The flex-weld is silver plated copper laminated in Teflon and potted in epoxy. Under thermal/vacuum conditions, the epoxy was extremely unstable and unacceptable for use on the ATM. Test data indicate that a thermal/vacuum bake will not improve the flex-weld cable to make it acceptable.

2. Phase II Tests (Redeposition)

The purpose of this study is to determine the deposition rate and thickness of the films redeposited by outgassing components under prescribed conditions of temperature, pressure, and time. Rate of deposition and thickness of deposit are monitored.

A redeposition test was made on Lord BTR elastomer and braided nylon lacing tape, Style 18B at 100°C and 150°C at a pressure of 10^{-7} torr. The BTR elastomer yielded a frequency change of 600 Hz when heated from ambient to 100°C. When subsequently heated to 150°C an additional frequency change of 1.8 KHz was noted. Visual inspection of the glass slide revealed a very faint film had been deposited. Film thickness will be measured with an Angstrometer.

A total frequency change of 72 Hz was detected when the nylon lacing tape was heated from ambient to 150°C. No film was evident when the glass slide was visually inspected.

Two samples of Cat-A-Lac black paint were tested for redeposition characteristics. One sample, #67-7-14-2 was cured at 150°F for 48 hours prior to test. When heated from ambient to 150°C, no frequency change was measured and no film deposited on the glass slide. The second sample, #67-7-14-1, had been cured at 200°F for 24 hours. Again, no frequency change was detected and no film was visibly evident on the slide.

A total frequency change of 110 Hz occurred when a sample of Cat-A-Lac black paint on polyurethane foam was heated to 150°C. Any film deposited in this test is below the sensitivity of the angstrometer.

B. Assessment of Vacuum Chamber for ATM Thermal/Vacuum Testing

A decision has been made at the NASA Headquarters level to make the ATM thermal/vacuum tests in chamber A of the Space Environment Simulation Laboratory at the Manned Spacecraft Center (MSC), Houston, Texas.

Personnel at MSC have acknowledged that chamber A is badly contaminated. A procedure for cleaning the chamber with modifications to the chamber to make it acceptable for ATM use have been forwarded to MSC. Initial ATM testing in chamber A is scheduled for January 1969.

The contamination test apparatus is being modified in preparation for the scheduled test.

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.

Another sixty-day vacuum evaluation of the Bendix torque drive test system has started with a modified unit. The main modification by Bendix was a change in the gearing system and bearings. The system has been running for 14 days and appears to be running smoothly with very little wear on the brushes.

A universal bearing tester has been designed, fabricated, and assembled to test, primarily, journal bearings (furnished by Perkin-Elmer for use in ATM systems) ranging in bore size from 3/8 inch to 1-1/2 inch. This tester has been so designed as to enable various sizes of journal and ball bearings to be evaluated with only minor changes in the test fixture. To date six tests have been made. Five were made in vacuum (1×10^{-6} torr) and one at atmospheric pressure and ambient temperature with a 30-pound radial load.

Two of the Garlock DU bushing bearings were tested at 30 pounds radial load, two at 105 pounds radial load and the last one at 10 pounds radial load. The latter test ran for 22 hours while the other five were run for 7 hours. All the bearings were tested at 165°F (74°C) except for the one at ambient temperature. The results from these tests will be reported at the completion of all tests.

D. Investigation of Thermal Control Coatings for ATM

Selection of thermal control coatings for Apollo Telescope Mount (ATM) components has been completed for all surfaces which have been identified to this division as requiring thermal control surfaces. These surfaces include the solar panels, and the sun-end and side walls of the canister. It is anticipated that additional components and surfaces of the ATM will require thermal control coatings. Evaluation of coatings for these surfaces will begin as soon as the thermal control requirements are identified.

Comments have not been received from the IIT Research Institute on preliminary material and application specifications for S-13G thermal control paint. As soon as these comments are received, the specifications will be finalized.

E. Development and Evaluation of Vibration Dampening Materials for ATM

Several sheets of silicon sponge were prepared for evaluation as vibration dampening media in printed circuit card boxes of the ATM system. Since a rather large quantity of this sponge will be required in the ATM electronic system, efforts are underway to locate a commercial source.

F. Investigation of Materials for the ATM Environmental Control System

Experimental studies were initiated to provide data for selection of the most effective corrosion inhibitor for the coolant fluid (80 percent methanol - 20 percent water) used in the subject system. At the present time it appears that 0.1 percent sodium benzoate, which is presently used in the environmental control system of the Instrument Unit will be selected for this application.

X. Nuclear Vehicle Technology

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

A. Investigation of Propellant Heating

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

The modification to the contract providing for the experimental phase of the propellant heating program was negotiated with the contractor at the contractor's facility on April 3, 1968. The effective date of this modification is May 1. Presently, the contractor is preparing purchase orders for the long lead time items required for the experiment. One major problem which must be solved involves the procurement of the digital data acquisition system which will be used to record the temperature profiles in the liquid hydrogen test tank. Preliminary arrangements had been made to supply this item from the Test Laboratory as government furnished equipment (GFE); however, because of forthcoming ATM and OWS tests, it appears that the government will not be able to provide this critical instrumentation. Currently, efforts are being made to locate a suitable system at other government agencies. If one cannot be found, funds will have to be made available for the purchase of this item, probably through reduction of the scope of work of the contract to allow procurement by the contractor.

B. RIFT Tank Tests

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

The RIFT tank has been hydrostatically tested successfully by the Manufacturing Engineering Laboratory (ME). The next step is the application of the CPR 385-2 spray foam insulation. The latest ME schedule for this tank provides for a completion date such that the radiation tests at the contractor's facility should commence the first week in September.

C. Activation Analysis

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

Modification of the program to allow the output data to be generated in a form compatible with the digital plotter in the Computation Laboratory is proceeding satisfactorily. The majority of the plots of the Al-5456 alloy data were acceptable; however, adjustment of the scaling factors is required for some of the data.

D. Evaluation of Lubricants for Nuclear Vehicle Applications

To protect moving parts in a potential nuclear-powered spacecraft, lubricants will be required which will not be degraded by operation in hard radiation. In connection with this requirement a second series of tests are being made on various dry film lubricants irradiated with gamma radiation to a dose of 10^8 and 10^{10} ergs per gm carbon and tested in the Falex lubrication tester. Fifty specimens coated with each lubricant are to be tested, twenty specimens irradiated to 10^8 ergs per gm carbon (gammas), twenty specimens irradiated to 10^{10} ergs per gm carbon (gammas), and ten control specimens. The lubricants Electrofilm 5396 and Electrofilm 2006 (organic bonded MoS_2 films) and MLF-9 (MoS_2, graphite, Bi, $AlPO_4$) were tested during this period. Results of these tests indicate that the above radiation dosages seem to have no detrimental effects on the wear life of these three lubricants. Tests of the second series of lubricants are complete, and evaluation of the data is continuing.

ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

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

A. Polymer Development and Characterization

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

B. Adhesive Development

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

C. 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. McDonnell Douglas Corporation, NAS8-21083
3. 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, NAS8-20297
5. Kaiser Aluminum and Chemical Company, NAS8-20285
6. North American Aviation, Inc., NAS8-20285
7. Hercules, Inc., NAS8-21207

I. Explosion Hazards and Sensitivity of Fuels

Standard Research Institute, NAS8-21316

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

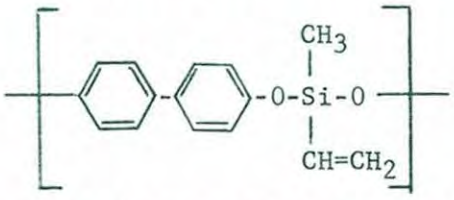
1. General Dynamics Corporation, NAS8-18024
2. Hughes Aircraft Company, NAS8-21087
3. IIT Research Institute, NAS8-21031

II. General - In-House

A. Development of High Temperature Resistant Polymers

Current efforts in the development of high temperature resistant polymers has centered around development of effective crosslinking systems for the aryloxysilanes, silphenylene-siloxanes, and polymers of related structure.

The polymer system illustrated as



has been studied in more detail during this reporting period. Variations in crosslinking agent concentration and cure time have been made in an attempt to optimize this formulation. Adhesive bond strengths of 2300-2400 psi at 25°C apparently can be obtained reproducibly within one polymer batch but not from one batch to another. Although the polymer batches are prepared under similar conditions, a difference in molecular weight or molecular weight distribution is occurring which alters their respective adhesive bonding capabilities. A more basic study of polymer character will be made when a large batch of this polymer, now under preparation, is available.

Both the above aryloxysilane and the silphenylene-siloxane polymers appear to be processible as sealant-type coatings for supersonic transport (SST) applications.

Preliminary coated specimens fabricated of titanium metal provide evidence that both polymers will cure to tack free coating on the titanium substrate. The aryloxysilane polymer provides adequate adhesion whereas the current silphenylene formulations are still marginal in this respect. Further experiments will be carried out to establish absolutely the bonding capability of these polymers to titanium.

B. Development of Fluorinated Adhesives

Reaction between chloropentafluorobenzene and potassium phthalimide and hydrazine did not yield the desired product, 1-chloro-2,4-diamino-3,5,6-trifluorobenzene, which is an intermediate in preparation of the corresponding diisocyanate. Extensive degradation of the fluorocarbon was evident. In an alternate approach, chloropentafluorobenzene was reacted with concentrated ammonium hydroxide under pressure. A crystalline product recovered by steam distillation melts near the recorded melting point for 1-chloro-2,4-diamino-3,5,6-trifluorobenzene.

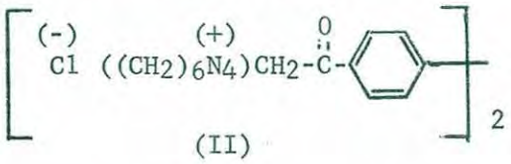
C. Development of Sealant Materials

Current investigations are directed toward the ultimate goal of developing polymers possessing good adhesion, thermal stability, and resistance to aviation fuels containing up to 17 percent aromatics.

Emphasis has been directed toward the preparation of the aromatic system, poly(diphenyloxazoles). As reported previously, the compound believed to be the first necessary intermediate, 4,4'-bis-ω-chloroacetyl-biphenyl, has been prepared in excellent yield through the Perrier modification of the Friedel-Crafts reaction of biphenyl with chloroacetyl-chloride. Although the infrared spectrum of the compound (I) and chlorine analysis support the proposed structure, final characterization is incomplete pending receipt of C and H analyses.

(I)

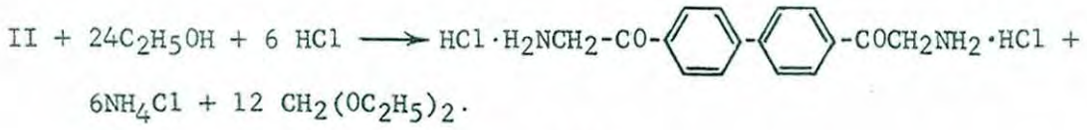
Treatment of (I) with 2 equivalents of hexamethylenetetramine, as previously described, yielded a product having physical properties consistent with those of an amine salt (II)



(II)

Elemental analyses are still pending on this derivative.

Conversion of (II) to the corresponding bis(amino ketone hydrochloride) (III) was accomplished through the Mannich reaction:

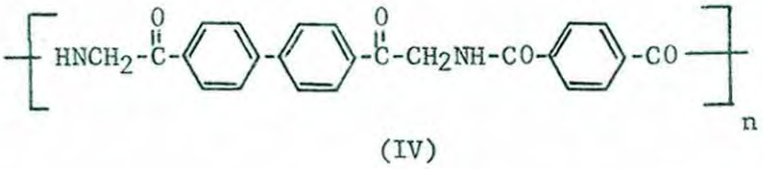


(III)

From a number of experiments it was determined that the maximum yield of (III) was obtained when a mixture of (II) in acidified ethanol was allowed to stand at room temperature for five days (heating the mixture actually decreased the yield). A near quantitative yield of product was obtained in several reactions. The crude product was recrystallized from water and had a melting point above 300°C. The presence of ethylal in the reaction mixture was confirmed through vapor phase chromatography.

The infrared spectrum of (III) was consistent with that of an amine·HCl salt. Elemental analyses are pending.

The polyamide precursor was prepared through the interfacial polymerization of (III) with terephthaloyl chloride in the presence of sodium carbonate. The product which was obtained (IV) was soluble in dimethylformamide and had an infrared spectrum which showed NH absorption at 3400 and 1640 cm^{-1} and carbonyl absorption at 1680 cm^{-1}.



(IV)

So far, attempts to effect thermal cyclodehydration of (IV) to the desired aromatic ring structure have been unsuccessful. Heating the polyamide both in vacuo and at atmospheric pressure at temperatures between 400 and 450°C has resulted in the recovery of the unchanged polyamide which failed to melt at these temperatures. The infrared spectra of the heated material remains unchanged as does its physical appearance. Attempts to effect cyclodehydration through dissolution of the polyamide in concentrated sulfuric acid have also been unsuccessful. Further work will be directed toward effecting the desired ring closure.

D. Development and Evaluation of Metallic Composites

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

1. Vacuum Infiltration Studies

During this report period, test samples of beryllium wire filament reinforced magnesium were solution treated and aged in order to inhance the as-cast properties of the matrix. All specimens showed tensile strengths greater than as-cast (24,000 psi); however, one specimen did not attain the mechanical properties of the solution treated and aged magnesium (AZ91C), i.e. 40,000 psi. This was possibly due to the excessive porosity

noted in the surface and fractured end of the specimen. Specimens using boron filaments are being prepared. Data using boron as the reinforcement agent are to be developed and later similar specimens will be made with silicon carbide coated boron, and a comparison will be made and results evaluated.

2. Explosive Bonded Composites

Approximately 30 explosive bonding tests were completed on aluminum laminates reinforced with AM355 stainless steel filament wire. All laminates consisted of three layers of steel wire sandwiched between four aluminum sheets. In earlier tests 0.032-inch thickness 1100 aluminum sheets were successfully reinforced with 0.009-inch diameter NS355 stainless steel filament wire. However, during this reporting period composites were fabricated of aluminum sheet of thinner gage (0.010 inch) and filament wire of smaller diameter (0.004 inch). The thinner sheets and smaller diameter wires were used to attain desirable filament to matrix volume ratios. Unfortunately, these wire reinforced laminates failed to withstand the required explosive loads used. Therefore, the laminates were then modified to incorporate a thicker outer sheet (0.032 inch) while retaining essentially the same thinner sheet (0.010 inch) and small diameter wire (0.004 inch). This eliminated longitudinal shearing of the laminates during explosive bonding; however, longitudinal splitting still occurred due to severe lateral deformation. This condition was corrected by enlarging the buffer plate and explosive charge so as to extend over the laminate stack on all sides. By this means the explosive forces the buffer plate against the anvil sides which acts as a lateral retainer. Current explosively bonded panels using the above technique appear to be bonded; however, X-ray analysis revealed extensive wire filament fracture, which was more prevalent in the 0.004-inch diameter wire-aluminum composite. Mechanical testing of these composite panels will be accomplished during the coming reporting period and effects of wire fracture will be evaluated.

E. Investigation of Stress Corrosion Characteristics of Various Alloys

Additional tests have been initiated using two different sections of a forging of 7001-T75 aluminum alloy in an effort to more closely establish the threshold stress level of this material and to determine the effect of the parting plane. Specimens taken in the short transverse grain direction were stressed to 15 ksi and 20 ksi, and specimens taken in the long transverse grain direction at two different locations were stressed at 50 and 60 ksi and 40 and 50 ksi. Tests have been in progress five days, and no failures have occurred.

Investigations have continued in the evaluation of the stress corrosion susceptibility of aluminum vehicle components under semi-controlled conditions. Bare and chromic acid anodized round tensile specimens of 2014-T6, 2024-T4, 7075-T6, and 7079-T651 were exposed to the outside atmosphere. Failures to date have been confined to outside atmosphere in all alloys stressed in the short transverse to 75 percent of the yield strength with the most recent being in the bare 7075-T6 after 371 days of exposure. This test has been in progress approximately 12 months.

Flat tensile specimens of 7075-T6 aluminum in the short transverse grain direction with both ground and polished surfaces were stressed to 75 percent of the yield strength and are being exposed in the alternate immersion tester. These specimens will be exposed until failure occurs. This test has a two-fold purpose (1) to obtain a more exact time to failure, and (2) to determine whether polishing has an effect on time to failure.

Because of the severe corrosion of the standard 3-1/2 percent salt solution on the 2000 series alloys, studies are being made to determine the feasibility of using a synthetic sea water environment for testing these particular alloys. In connection with the study of the S-II tank material, tests of this material are also being conducted in the synthetic sea water.

Initial tests to evaluate the stress corrosion susceptibility of Almar 362, PH15-7Mo, 17-4PH, 17-7PH, and PH14-8Mo (air melt and vacuum melt) have been terminated. Additional testing is being done with the 17-7PH and PH15-7Mo alloys at lower stress levels. Tests have also been initiated with PH13-8Mo alloys.

Tests on round tensile specimens made from 1/4-inch diameter music wire spring material stressed in the longitudinal direction to 70 percent of its yield strength and exposed in the alternate immersion tester have been terminated after 4-1/2 months of exposure. The other tests on specimens in the humidity cabinet, outside atmosphere, and semi-controlled atmosphere are continuing. There have been no failures in any environments after 164 days of exposure.

F. Investigation of Stress Corrosion Induced Property Changes in Metals

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

Sufficient exploratory work with several alloys has been accomplished to know that early stages of stress corrosion can be nondestructively detected in some alloys by measuring changes in electrical conductivity and ultrasonic attenuation. Therefore, current work is directed toward establishing a correlation between stress corrosion time-fo-failure and changes in electrical, acoustic, and mechanical properties.

Recent work involves limited metallurgical examinations, selection of stressing methods, and the design and fabrication of apparatus for acoustic emission and crack propagation studies.

G. Evaluation of Ultrasonic Stress Measurement Methods

The accuracy of applied stress measurements is being determined using the equipment produced under contract NAS8-20208. Although this is similar to work performed under the contract, the recheck is considered necessary prior to government recommendation of application. Work is being done with a four-point bending bar apparatus which produces equal stress along the curved surfaces of a rectangular bar, provided the bar is homogeneous. Tests are being made with a 6061 aluminum alloy bar, 1 x 1-1/2 inch in cross

section that is instrumented with photostress, strain gages, and is supported by load cells. Also, an optical strain measurement was devised using a thin steel strip. The photostress indicated the bar to be homogeneous throughout its cross section. The optical method was used on the tension side and the strain gage method on the compression side.

In addition to the stress measurement system, several transducers and a laboratory clamping device was delivered by the contractor. The transducers include "knife edge" surface stress transducers, suitable for curved surfaces, and interior stress measurement transducers. The knife edge transducers have been found to damage aluminum surfaces, especially the softer alloys. A coupling force of approximately 50 pounds is sufficient to cause knife edge depression. Experimentation with methods of reducing the coupling force without reducing the accuracy of the measurements is being initiated. Correlation of stress measurements made by conventional techniques and the surface wave system has been initiated.

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

Activities have continued in the development and evaluation of materials for electrical brushes for use in a vacuum environment.

Tests are continuing on the Boeing 046-45 brushes. The brushes are being evaluated against the 6-3/4-inch diameter commutators of the 7 ft-lb high temperature Inland Motors. Four brushes are used on each commutator, and the resulting average wear rates are recorded as a function of commutator RPM and current load. The tests are being made for 24 hours in a nitrogen atmosphere at various speeds and loads. From the results obtained so far it appears that the brush wear rate under these conditions decreases with an increase in motor speed, and may be a function of total current.

I. Development of Low Density Ceramic Foams

Efforts have continued to develop low density ceramic foams by expanding sodium silicates containing additions of Refrasil fibers to reinforce the foam structure. Present studies are concerned with improving the water resistance of the foams. Another method investigated for improving the water resistance was to dip the fabricated foam into a calcium acetate solution, dry, and heat cure the foam at 315°C (600°F) to decompose the acetate. Water immersion tests on this treated form indicate the water resistance is approximately equal to that of foams containing magnesium oxide or boric acid batch additions.

The microwave oven to be used in this project has been received and plans are underway to connect the oven to the power source. No further work to optimize the foam compositions or properties is contemplated until the microwave oven is in operation, as it is believed that the difference in the reaction of the foam materials to two heating methods will vary sufficiently to prevent correlation of results.

J. Developmental Welding

Activities have continued on the evaluation of the weldability of aluminum alloys X2021 and X7007. Tensile testing of unnotched and bead removed specimens was completed for 1/2-inch thick alloys X2021 and X7007 that were welded in the flat, horizontal, and vertical positions. The tensile results were plotted as a function of test temperature. Both alloy X2021 and alloy X7007 showed significant increases in strength and decreases in elongation with decreasing test temperature (ambient to -423°F (-253°C)). Weldments of 1/2-inch thick alloy X7007-T6E136 tested in the unnotched and bead removed tensile configurations at ambient, -100°F (-73°C), -200°F (-129°C), -320°F (-196°C), and -423°F (-253°C) displayed significantly higher mechanical properties than those of alloy X2021-T8E31. Generally, each alloy showed higher strength levels for flat and vertical weldments than for horizontal weldments. Tensile specimens of weldments tested with the weld bead removed displayed higher yield strengths than those specimens with intact weld beads; however, the ultimate tensile strengths between intact weld bead specimens and weld bead removed specimens were virtually the same at corresponding test temperatures through the test spectrum. Weldments for the remainder of the program are being fabricated into tensile specimens.

Experimental welding has continued on the study of the weldability of aluminum alloy 7039. Flat position weldments have been completed on 1/8, 1/4, and 1/2 inch thick 7039 for two alloy tempers, T61 and T64, by using two filler metals, types 5039 and 5183. The 1/4 inch thick unnotched T61 and T64 specimens were tensile tested at ambient, -100°F (-73°C), -200°F (-129°C), -320°F (-196°C), and -423°F (-253°C). Also, weldments in 1/8, 1/4, and 1/2 inch thick material are undergoing a 16-week material aging period. Six joint designs were selected to determine optimum weld procedures for the one-inch thick material. Two of the six joint designs were discarded on the basis of machine operator difficulty in welding. The remaining four joint designs are (1) double-V with a 1/8-inch land, (2) double-V with a 1/4-inch land, (3) double-U with a 1/8-inch land, and (4) double-U with a 1/4-inch land. These plates are being welded in the flat position by the TIG process with filler types 5039 and 5183. In addition, the mechanical properties of the base metal are currently being determined.

Investigations have continued in the determination of joint characteristics of aluminum alloys 2014-T6 and 2219-T87 welded in the flat position while passing a coolant (LN_2) through the backing bar. Additional panels of bead on plate welds were made by utilizing a cryogenic cooled back-up fixture. A macrostructure comparison between these welds and welds made without cryogenic cooling displayed a narrower weld width on the panels that were welded by using a cryogenic cooled back-up fixture. Additional panels will be welded and a comparison of mechanical properties made between weldments made by the use of backing cooling and backing cooling omitted.

A study was initiated to compare the mechanical properties and metallurgical characteristics of weldments in aluminum alloy 2014-T6 (1/8 inch thick) made by the TIG process with filler wires 2319, 4043, and M-934.

Filler wire M-934 is a high-alloy experimental material. Radiographic inspection of 42 panels showed welds of acceptable quality. These panels are being fabricated into tensile specimens.

K. Evaluation of Alloys

Multiphase alloy MP35N is a new fastener material developed by the Dupont Company, patented by the Standard Pressed Steel Company, and designated as SPS-M-573 material. This alloy offers high strength, toughness, corrosion resistance, and good cryogenic temperature properties. Multiphase is a quanternary alloy system with a nominal composition of 35 Ni-35 Co-20 Cr-10 Mo. Through a combination of cold work, transformation, and aging, multiphase can be strengthened to 260 ksi minimum ultimate tensile strength. The alloy has a density of 0.304 lbs/in^3 and a modulus of 33.6×10^6 psi. It offers excellent resistance to stress corrosion cracking and hydrogen embrittlement and is compatible with other alloys such as 6-4 titanium. Listed below is a comparison of fatigue and tensile properties of high strength bolts:

Alloy Designation	Ultimate Tensile Strength (Ksi)		Fatigue 135 ksi Max. R=1 (kilocycles)	
	Room Temp.	-320°F (-196°C)	Room Temp.	-320°F (-196°C)
Maraging 300	279.0	352.0	43	25
H-11 Steel	280.0	297.0	200	65
Multiphase	286.3	345.0	500	2, 302+

+Based on basic pitch diameter area.

Tensile tests made at the LH_2 temperature by this division resulted in typical values of 398 ksi Johnson's 2/3 yield strength and 408 ksi UTS.

L. Development of Porcelain Enamel Thermal Control Coatings

A program has been initiated to develop porcelain enamel coatings with special optical properties for application as thermal control coatings in the space environment. Porcelain enamel coatings will have the following advantages over paints presently used as thermal control coatings: (1) stability in space environment, (2) stability under prelaunch and launch conditions, (3) smooth, glossy surface that is easily cleaned, and (4) a range of optical properties can be attained by changing composition of the enamels. The enamel coatings will be developed for application to thin metal foils which can be mechanically fastened and/or adhesively bonded to spacecraft components.

Initial experimental efforts are directed toward coating aluminum foils with enamels prepared from commercially available frits. Two types of frits are being investigated: two high lead glasses (L-388 and N-390) manufactured by the Dupont Company, and a leadless glass (AL-8) manufactured by Ferro Corporation. Firing studies are being made with these frits to determine

their maturing temperatures as applied to aluminum foils. Initial studies are being made on the frits without mill additions to study the properties of the glasses as such, and to develop techniques for applying uniform thin coatings to the aluminum foils. An enamel coating prepared from the A1-8 frit and applied as a clear glass to 3-mil aluminum foil has a solar absorptivity and normal emittance of 0.32 and 0.82, respectively. Other compositions will be studied as the program progresses.

M. Investigation of Surface Treatment Processes

1. Evaluation of "TMC" Electropolishing Solution

Humidity tests have continued on electropolished and mechanically polished panels. After approximately 1600 hours of exposure in the high humidity environment, the electropolished panels are becoming more discolored and showing several spots of corrosion. The mechanically polished panels, however, have been severely tarnished for several weeks and are gradually becoming black.

2. Sulfuric Acid Anodizing

Salt spray tests of panels of aluminum alloy 2014-T3, anodized for about 7-1/2 minutes have been terminated. After approximately 600 hours of exposure, the panels showed no visible sign of corrosion. Samples of aluminum discs, anodized for 30, 15, and 7-1/2 minutes, and treated with a liquid oxygen sensitive dye penetrant, showed no significant difference in the amount of the dye that was absorbed by each group of specimens as determined by a weight gain method.

N. Study of Dielectric Materials

1. High Voltage Breakdown of Foams

Determinations of corona inception voltage, corona extinction voltage, apparent corona charge, and apparent corona current have been made as a function of specimen temperature on a Freon blown polyurethane closed cell foam. This work was carried out using the 150 KV d.c. corona test apparatus. Specimen temperature was varied from 20°C to 75°C. Test data indicate that within the temperature range of this test, increasing temperature caused no appreciable change in the corona characteristics of the foam. From 20°C to 30°C corona inception voltage did increase and then remained relatively constant to 75°C. The corona inception data indicate some improvement since a higher corona inception voltage implies greater material stability and less power loss by plasma formation.

The corona extinction voltage data show a relatively constant relationship between this characteristic and the corona inception point. At 20°C a difference of 11 KV occurs whereas at each higher temperature beginning at 45°C the average difference is from 5 KV to 6 KV. The difference

of 5 KV between corona inception voltage and corona extinction voltage taken typically at 75°C compared to its counterpart of 11 KV at 20°C indicates the effect of thermal excitation of electrons at the closed cell gas-solid interface producing more electrons in the low population level conduction band of polyurethane. Data from these tests will be used as baseline information for similar testing of polyurethane foams in vacuum.

2. Thermal-Vacuum Degradation

Specimens of 1/2-mil Mylar, 2-mil Mylar, RTV-60, and Stycast 2651 MM have been subjected to vacuum (10^{-6} torr) and temperatures up to 150°C to determine changes in capacitance, dissipation factor, and bulk conductivity. Examination of the test data indicates that an increase in specimen temperature of 133.2°C resulted in almost 2 decades increase in conductivity and a 32-percent increase in specimen capacitance. Dissipation factor values remained relatively stable as did system pressure. The specimen was characterized by a wrinkled and distorted appearance upon post-test examination although no shorting (electrical) across the electrodes occurred.

O. Literature Survey

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

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

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

APRIL 1, 1968 THROUGH APRIL 30, 1968

I. Radiography

Eighty-one miscellaneous parts, components, and test specimens were inspected radiographically during this report period.

II. Photography

	Negatives	Prints	Other
Engineering Photography	200	674	
Metallography and Fractography	236	784	
Miscellaneous Photography Processing, Copywork, etc.		17	26

III. Metallurgical and Metallographic Testing and Evaluation

A. The electron beam welding process was successfully used to fabricate a modified C-1 rocket engine. Several structural and seal-type welds were required to complete the assembly. Weld parameters of 90 KV, 7.5 ma, and 23 ipm were used for the structural welds, and weld parameters of 60 KV, 1.5 ma, and 23 ipm were used to seal various components.

B. At the request of R-P&VE-PM a review was made of drawing number SK20-3887, Cold Plate ATM with regard to joining procedures of aluminum alloy 6061. Resistance seam welding was recommended for joining the cold plates because of a lack of information concerning bonding. But it was recommended to start long duration testing on the existing radiator (bonded) as a back-up.

C. An aluminum cone (2014-0) was electron beam welded in support of R-P&VE-SSV. The material was 0.020 inch thick. Welding parameters of 60 KV, 8 ma, and a travel speed of 15 ipm were used to fabricate the cone in the two weld passes, one each side.

D. Support is being provided to R-ME-MW on the evaluation of weldments made by an experimental weld procedure which may be used to join S-II first skin to J-ring. The primary objective of this evaluation is to produce a weld having a superior quality (reduction of pores and pore size) than current production welds.

E. Support was given the Manufacturing Engineering Laboratory, R-ME-MW, in failure analysis of a fracture 7039 aluminum torus tank component. The initiation site was identified and forwarded to the Solid State Chemistry

Section, R-P&VE-MCS, for study on the electron microscope. Failure was attributed to stress corrosion cracking in the short transverse direction of the ring machined from a thick plate. Residual thermal stresses resulted from the adjacent weldment.

F. Metallurgical analysis was completed of three 1-1/2 inch diameter welded stainless steel fittings at the request of the Propulsion Division, R-P&VE-PE. No defects were found in the welded tube fittings which failed during fatigue testing. Cycles to failure in these tests were affected by the extension of weld metal between the sleeve fitting and tubing.

IV. Spectrographic Analyses

Two hundred and seventy-seven determinations were made on twenty-three samples and two hundred and eighty-two standard determinations were made.

V. Infrared Analyses

Forty-six determinations were made by infrared techniques on a variety of materials including experimental polymers and polymer precursors, rubber samples from cold plate isolators, oils, nylon and polyurethane specimens and several complex commercial chemicals.

VI. Chemical Analyses

	Determinations
Solder for tin content	1
Nitrogen tetroxide for	
purity	6
water equivalent	3
nitric oxide	3
Monomethyl Hydrazine for	
purity	3
Polymeric samples for	
carbon	6
hydrogen	6
nitrogen	4
silicon	2
chloride	4
Gas products from irradiated films for	
polycarbonate	40
phenolic	68
Teflon	8
chlorinated polyether	20
hydrogen	19
carbon dioxide	19
nitrogen	6
oxygen	6
"Monostrip EP" for	
carbon tetrachloride	3
ethylene chloride	3
Gas samples for	
hydrogen	20
nitrogen	15

	Determinations
oxygen	10
helium	4
Oxygen for purity	3
Nitrogen-oxygen mixtures for nitrogen	6
Nitrogen-oxygen mixtures for oxygen	6

VII. Physico Chemical Analyses

Density of RP-1 fuel	6
Viscosity of mineral oil	2
Specific resistance of coolant fluid	2
pH of coolant fluid	3
Chromatographic analysis of twenty polymer samples	84

VIII. Rubber and Plastics

	Items
molded and extruded	261
cemented	34
fabricated	83

IX. Electroplating and Surface Treatment

acid cleaned	3512
degreased	78
anodized	1206

X. Development Shop Production

A. A total of 4,723 man-hours, direct labor, was utilized during this period for machining, fabricating, and welding.

B. Two thousand one hundred and forty-seven man-hours, approximately 45 percent of the total man-hours, were expended on work orders listed below.

1. Flange Assembly

Fabrication work on the flange assembly is complete. The remaining effort is assembly of the components.

2. Vent Disconnect Assembly

Work on the vent disconnect assembly is approximately 95 percent complete.

3. S-II LOX Depletion Test Model

The S-II LOX depletion test model is complete and delivered.

4. Vacuum Electro Balance Mounting Assembly

The vacuum electro balance mounting assembly has been delivered.

5. MSFC Experiment #8 Test Components

Work on the test components of flight experiment #8 is approximately 50 percent complete.

6. Vacuum Chamber Assembly

Components for the vacuum chamber assembly are machined and ready for assembly.

XI. Miscellaneous

A. Six items of 4130 steel, one hundred and fifty-nine items of aluminum alloy and one item of 15-5 PH stainless steel were heat treated during this report period.

B. Twelve materials were evaluated for sensitivity when in contact with liquid oxygen in accordance with the requirements of MSFC-SPEC-106B.

C. Testing has been completed in the determination of the thermal conductivity of high performance insulation GAC-4. The requested thermal conductivity data have been reported to R-P&VE-P.

D. Several samples from a fractured Moog actuator were replicated and coated. Fractographs exhibited small intergranular mud crack patterns. These characteristics show that the failure was due to stress corrosion.

E. Several fractured sections from an S-IC "A" mini stage fuel tank slosh baffle was submitted to this branch for fractographic analysis. This work has been completed. The replica from the fractured surfaces showed a predominately mud crack pattern, some surface corrosion was present, as were many very sharp small cracks. Failure was determined to be due to stress corrosion.

F. Several samples of MB0170-063 (small grain) were submitted to this branch for fractographic analysis. The entire replicated area was well covered by a distinct mud crack pattern with very sharp cracks. A considerable amount of surface corrosion was also observed. Failure was determined to be due to stress corrosion.

G. Two samples from a failed Torus tank structure weldment of 7309 aluminum were submitted to this division for fractographic analysis. The fractographs showed an intergranular structure with a clear mud crack pattern. A considerable amount of surface corrosion was also observed. Failure was due to stress corrosion.

H. Thirty-three determinations of emissivity and twenty-five determinations of absorptivity were made during this report period on various commercial and experimental thermal control materials.

I. Seventy-six thermal property determinations were made including such tests as differential thermal analyses, differential scanning calorimetry, thermal gravimetric analyses, thermal conductivity, etc.

XII. Publications

Perry, C. L.; Krupnick, A. C.; and Harwell, R. J.: Design and Development of the Hazardous Gas Detection System for Launch Vehicle Propellant Loading and Checkout, NASA TM X-53720, April 3, 1968.

Materials Division: Developments Leading to Material Modifications in the Saturn I Workshop Crewbay, NASA TM X-53732, April 30, 1968.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-68-4

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(April 1, 1968, through April 30, 1968)

SATURN V

I. S-IC Stage

A. Propellant Dispersion System (PDS) Cowling

Concepts for the division's proposal to relocate the PDS cowling have been completed. The concept for the fuel and lox tank shows the Confined Detonating Fuse (CDF) routed along the edge of the electrical systems tunnel. This concept eliminates approximately 720 inches of the PDS cowl and CDF carrier. Also, the installation of the CDF carrier and the charge has been modified to provide easy installation and accessibility.

B. Cable Clamp Study

A preliminary definition of those S-IC critical system cables which utilize nylon clamps as the primary support has been completed. The clamp sizes will be evaluated against The Boeing Company (TBC) clamp test program to determine whether changes are required prior to manned flight.

C. Cable Clamp Developmental Testing

The fixture evaluation for the cable clamp testing was completed. The results indicate that a modification to the fixture design is necessary to control fixture resonances. A proposed fix has been submitted to Structures Division. The amplification factors during the initial runs were high due to fixture resonances. While utilizing the internal control accelerometers, the shaker was unable to reach the evaluation levels. The accelerometer on the end of the fixture was utilized as the control without any significant problems.

D. Lox Vent Valve Interlocks

1. Failure of position switch on the S-IC lox tank vent valve occurred during the SA-502 countdown demonstration test (CDDT). MSFC interlock requirements for this vent valve position switch had been deleted earlier, Engineering Change Request (ECR) (BBGE-300), to permit lox loading with a slight positive pressure in the lox tank. Kennedy Space Center (KSC), however, had interlocked this position switch (unknown to MSFC until this time) into lox tank purge prior to lox loading and into lox tank gravity drain. As a result, the failure of this switch and MSFC's deletion of its requirement for interlocking purposes has created a problem for KSC in their equipment. At the suggestion of this division, a proposal was made that KSC interlock "power on" for applicable operation (voltage applied through switch) in lieu of position switch. This proposed solution was readily accepted and its implementation is being pursued with KSC by Systems Engineering Office and Astrionics Laboratory.

2. The above problem has brought to light the fact that while adequate visibility of MSFC's interlocks is provided through the Functional Interlock documents prepared by this division, no such visibility exists for KSC's interlocks nor do MSFC personnel know how signals from the vehicle transmitted across the MSFC/KSC interface are being used beyond what MSFC requires. A formal request is being made to KSC, through appropriate channels, concerning this matter and to either eliminate or minimize future problems of this type.

II. S-II Stage

A. LH_2 Heat Exchanger (A7-71)

1. As a result of an increase in allowable helium contamination levels for stage usage, from a total of 50 parts per million (p.p.m.) to a total of 500 p.p.m., the effect on A7-71 heat exchanger operation has been questioned by North American Rockwell (NR). Consequently, NR is planning to run a series of cryogenic flow tests on the serial number (S/N) 7 heat exchanger at Santa Susana, California (battleship) prior to the SA-503 launch. Although the detrimental effect of the higher contamination level helium on heat exchanger operation is considered negligible by this division, concurrence with the NR test proposal was made in order to rule out the possibility of 500 p.p.m. contamination being the cause of equipment malfunction.

2. A division memorandum, Special leakage tests for the mobile launcher (ML)-1 S-II LH_2 heat exchanger, has been processed by Industrial Operations (IO). The enclosure to the memorandum outlines a series of ambient and cryogenic leak tests intended to determine if the heat exchanger possess inherent cracks. Configuration Control Board Directive (CCBD) 328-8-094 has been sent to MSFC Contracts Office for preparation of the appropriate change order.

B. S-II Pneumatic Console (S7-41)

The fluid distribution system (FDS) relief valve, installed between the A7-71 heat exchanger and the S7-41A regulation and distribution console, was isolated by KSC as a component contributing to a major depletion of facility helium during SA-502 CDDT. A CDDT hold, coupled with trapped cold helium in the FDS console interconnect line; failure to manually bleed down the S7-41A console engine thrust chamber circuit to clear the line of cold helium; and contamination failure of the FDS relief valve due to moisture and subsequent corrosion allowed the facility helium to escape to the atmosphere. As a result of these problems, the FDS relief valve was replaced. Prior to SA-502 launch, no further leakage problems were encountered. NR is preparing an Engineering Change Proposal (ECP) to add pressure transducers to facility supply inlet circuits, cold gas circuits, and the 750 p.s.i.g. static control pressure manifold.

III. General

A. Regulator Testing

1. The Saturn V mechanical ground support equipment (MGSE) uses APCO regulators in the S-IC and S-II stages. A problem was encountered due to the high pressure gases permeating the rubber backer plates of the Model 1357 regulators in the S-IC stage MGSE and causing bubbles when the pressure is relieved. Tests have been conducted on soaking the backer plates in GN_2 and GHe. On March 22, 1968, the nitrogen soak test on the regulator was concluded. This test consisted of applying 3500 p.s.i.g. GN_2 for 24 hours on the dome and inlet port. (Identical to the helium soak test except using GN_2). A new rubber backer was installed for this test with one-half punctured with a pin on one-quarter inch centers. After three days, no bubbles were noted on the backer plate. The rubber backer plate was then subjected to a helium soak test. After the soak test, the unperforated side had 1/4 inch diameter bumps. This concludes the investigation into permeation of the rubber backer plate with the following conclusions:

The rubber backed backer plate used in the APCO model 1357 is not an acceptable configuration for application in a helium atmosphere.

The perforation of the rubber backed backer plates indicates a reduction in the size of deformations but by the fact that there still is deformation precludes the acceptability of this application.

2. These regulators are being replaced by regulators or satisfactory design through ECP action.

B. Camera Recovery Study

A study has been completed on the recovery of the cameras from the S-IC and S-II stages for the AS-502 flight. Results of the study revealed that both the S-II cameras were ejected upon command but only one S-IC camera ejected properly. The failure of the S-IC camera to eject is believed to be due to inadequate pressure in the GN_2 storage system. This probably was the result of the bleed orifice installed by ECP0917 and low pressure at lift-off.

C. Documentation Reviews

Two S-IVB stage test reports were reviewed and found acceptable. They are: "Compressed Gas Control Helium Tank Repeat Qualification Test" and "Safety and Arming Compatibility Test Qualification."

ADVANCED TECHNOLOGY

I. Systems Design

Cluster Documentation

1. SK10-9694, "MDA Experiment Arrangement," was completed. This layout defines the basic location of the experiment packages inside the Multiple Docking Adapter (MDA).

2. SK10-9694 and SK10-9317 are being revised to incorporate the following changes:

Experiments M051, "Lower Body Negative Pressure"; M050, "Ergometer"; M058, "Body Mass Measuring Device"; M050, "Analyzer and Work Task Board" are to be launched in their deployed mode of operation in the MDA prior to launch.

The addition of an experiment support system and a Lunar Module (LM) docking control panel in the MDA.

The relocation of the electrical feed through plate and the vacuum vent outlet.

3. SK10-9540, "Penetration and Component Mounting Requirements-MDA, Dynamic Test Article," is being reviewed. It includes every penetration and/or mounting requirement that has been defined on the structural MDA.

4. The MDA platform and ladder assembly preliminary design is being developed. The present design will be similar at both levels.

5. The two designs for the MDA docking port protective covers are approximately 50 percent complete.

6. Two layouts are being prepared as follows:

"Electrical Equipment Mounting Panel," which defines the major electrical component mounting in the MDA.

"Miscellaneous Storage Envelope," which will define how the area over the vent vacuum chamber can be used to stow some of the smaller experiment packages that are unfeasible to mount to a grid or support structure.

7. With the exception of removable and hardmounted experiments, a test matrix logic diagram sheet has been completed on each MDA systems installation or assembly for which this division is responsible.

8. Requirements for the MDA engineering mockup have been coordinated with all responsible organizations and are being compiled into a mockup requirements document. A study will be made comparing the requirements with available hardware and documentation to define the engineering effort required to prepare the mockup documentation.

9. SK10-7266, "ATM Inboard Profile/Space Envelope Layout," is being revised. The following changes have been completed:

Envelope dimensions for baseline component locations.

Incorporation of interface date from SK10-7455, "ATM to SLA Clearance Envelope," and SK10-9921, "ATM to LM-Ascent Stage Clearance Envelope."

Inclusion of serpentuator envelope from SK10-9942, "Serpentuator Envelope Study."

Revision of lower support structure detail to latest drawing from the Structures Division.

Detail of cable transition from round cable to flat cable on rack to experiment package cable arch.

Electrical support equipment plug plate for the rack.

Star tracker envelope.

Thermal covers designed for +Y equipment bay and top ring mounted components.

10. SK10-7328, "Revision N, ATM Experiment Package Sub-Assembly" reflects changes in configuration and additional details as follows:

Addition of active cooling system.

Addition of cable envelopes.

Addition of N_2 purge system.

Update of apperture and film access doors.

Exchange positions of H Alpha #1 and HCO-C telescopes.

Detailed cable feed thrus into canister.

Added structure detail on LM end of canister.

Added insulation envelope detail.

Added C. G. location of most components.

11. ATM Alignment Drawing 10M03736 is being updated to include the latest alignment data from the ATM alignment matrix and the latest locations and outlines of all instruments.

12. "ATM Penetration and Component Mounting Drawing," SK10-1859, is being prepared to define all penetrations to the ATM structure.

13. ICD 13M20734, "ATM to Gimbal System ICD Physical Requirements," is complete and is being reviewed.

14. The preliminary design status for certain handling and access equipment is as follows:

ATM Platform and Ladder Assembly-100 percent complete.

ATM Ground Handling Fixture-80 percent complete.

ATM Clean Room Scaffolding-concept developed.

ATM Assembly Covers for Transportation-concept only.

ATM/LM-AS Hoisting Adapter-100 percent complete.

15. The Preliminary Design Review (PDR) for the ATM platform and ladder assembly was held April 11, 1968. The design approach and design were approved.

II. Systems Operations

Apollo Applications Program (AAP) Requirements and Analyses

1. The AAP-2 and AAP-4 fluids requirements documents 10M30742 and 10M30743 have been approved by the appropriate offices as baselines.

Work is continuing toward finalizing the requirements delineated in the baselines. When these requirements are finalized, the documents will be restructured for release as Interface Control Documents (ICD's).

2. Operations Analysis, MSFC document 10M30596, dated March 29, 1968, has been released. This document contains an operations analysis for the AAP-2 mission peculiar ground operations covering the period from arrival of the major assemblies and experiment equipment at KSC until the vehicle is launched. Major vehicle and experiment equipment arriving at the site include the S-IB stage, the instrument unit (IU) stage, the multiple docking adapter (MDA) airlock module (AM), the spacecraft LM adapter (SLA) panels, the nosecone, and the S-IVB stage Orbital Workshop (OWS). The purpose of the operations analysis is to present design reference sequence information on the AAP-2 sequence of operations as depicted on the "AAP-2 Prelaunch Sequence of Operations," drawing SK10-6161, revision B, which is included in Section 3 of subject document. This sequence and analysis will be used to formulate MSFC requirements for the AAP-2 ground sequence of operations to be performed at KSC. The document is to be used as detailed source data for the preparation of a ground support equipment (GSE) end item list against each operation shown on MSFC drawing SK10-6161. This activity would include the identification planning and scheduling of the following:

Ground handling equipment.

Mechanical servicing equipment.

Electrical support equipment.

Special test equipment (STE).

3. On April 18, 1968, the contracting officer's representative (COR) responsibility for the flight configuration serpentuator was assigned to this division. The proposed contract consisted of phase I design of a flight configuration and phase II design and manufacture of a neutral buoyancy unit. Meetings were held on April 19 and 22, 1968, with personnel of Manufacturing Engineering Laboratory and Propulsion and Vehicle Engineering Laboratory to discuss the pending contract finalization. This division concluded that the proposed scope of work and limited design parameters as defined were inadequate; therefore, the division will write a program plan and design specification for the flight serpentuator for program approval. The initial draft was completed on April 26, 1968, and the final release is scheduled for May 17, 1968.

III. Systems Engineering

A. Apollo Applications Program (AAP) Simulations

1. Comparison of the current neutral buoyancy simulation and McDonnell Douglas (MDC) engineering release schedules reveals that OWS

designs will be released for flight hardware manufacturing before corresponding verification simulation can be completed, except for one item. A recommendation has been made that engineering release schedules be amended for compatibility with realistic capabilities as reflected by the simulation program.

2. Design release dates for OWS hardware scheduled under MDC Plan G and the neutral buoyancy and zero-g simulation dates for the same hardware were incorporated into an integrated schedule. This schedule indicates that the simulations will be completed for only one line item (the OWS protection pad) before engineering release.

3. A lighting test of the Workshop Crew Quarters Experiment Area was performed April 18-19, 1968, in the workshop mockup in buidling 4755. The test was to evaluate illumination variations due to recommended color changes in the crew quarters and also alternate light locations. Upon starting the test, it was found that the lamp output was lower than when the original light level measurements were taken. The available light has apparently decreased by about 20 percent. This appears to be due to color changes in the Lexan sheath or the lamp. This problem is under investigation. Since lamp output has changed, little correlation can be made between previous measurements with the old colors and the present tests. Relocation of several lights was requested to provide increased illumination on the walls of the experiments area. Evaluation of the measurements taken is underway but indications are that the changes requested will affect the light balance of the experiment area. Therefore, if additional illumination is required in the area of the M-050 task board, an additional light assembly must be provided.

B. Cluster Requirements

1. The third meeting of the OMSF Ad Hoc Extra Vehicular Activity (EVA) Working Group, was held at the Ames Research Center (ARC) on April 30, and May 1, 1968. The laboratory participated on two agenda items, a presentation on Astronaut Translational Devices applicable to ATM film retrieval and preliminary requirement for a proposed AAP-2 experiment.

2. A meeting was held at ARC on April 10, 1968, to participate in a review and evaluation of an astronaut mobility aid Locomotion and Restraint Aid (LARA), for possible use on the S-IVB OWS. The device would give the OWS crew the capability to walk naturally in a zero-g environment. The LARA uses the principle of a negator constant force spring which rides in a track on the floor and is attached to the man at the crotch area by a shoulder harness. This concept was developed by the Bio-Science Laboratory of ARC. The system was tested in neutral buoyancy at ARC and was found to have practical applications for the OWS. Arrangements are being made to have the LARA test hardware shipped to MSFC for additional evaluation in the Neutral Buoyancy Simulator.

C. Multiple Docking Adapter (MDA) Experiment

1. A feasibility study of the integration of most AAP biomedical experiments, for early operational modes, within the MDA was conducted at the request of the laboratory Engineering Management Office. The twofold purpose of the study was to determine if the experiments could be integrated for detecting rapid biologic changes in the astronauts, which may occur early in the mission, and to obtain a broader spectrum of total biomedical data due to a longer acquisition time. Experiments selected for the study were the following:

M-018	Vectorcardiogram
M-050	Metabolic Costs of Inflight Tasks
M-051	Cardiovascular Function
M-052	Bone and Muscle Changes
M-056	Specimen Mass Measuring Device
M-058	Body Mass Measuring Device

The inclusion of experiments M-056 and M-058 was to accommodate the operation of experiment M-052, to which they are in direct support. The result of the study was the affirmative conclusion that the selected experiments and their ancillary supporting equipment could be mechanically and operationally integrated in the MDA for early actuation in the mission.

2. Zero gravity simulation aboard a KC-135 aircraft at Wright-Patterson Air Force Base (WPAFB) was scheduled to begin April 22, 1968, for a study of package transfer characteristics. The purpose of these tests was to determine values of mass moment of inertia for which packages of various masses become unmanageable. This data will be used in defining upper limits for mass and mass moment of inertia for objects to be handled by one man under weightless conditions.

D. Apollo Telescope Mount (ATM) Film Retrieval

1. A presentation of the conventional (manual) mode and serpentuator aided mode for ATM film retrieval EVA was given to the Center Director on April 17, 1968. It was noted that design status of the astronaut translational and film transfer schemes had not progressed beyond the concepts stage. Lack of design requirements criteria from MSC contributed to this situation. The life support umbilical appeared to be the biggest stumbling block to the incorporation of the serpentuator. The Portable Life Support System (PLSS) was recommended for the primary life support system with the serpentuator. This arrangement will simplify the serpentuator design interfaces and will also serve as the primary life support system for the Apollo lunar EVA. The procedures were outlined as follows:

Continue with development of the baseline, conventional mode EVA as the primary system.

Design, fabricate, and test a neutral buoyancy serpentuator demonstration article for feasibility verification.

Design and build an air bearing serpentuator for dynamic testing.

Perform the required human factors engineering for the man/system integration aspects.

IV. Systems Requirements

A. Orbital Workshop (OWS) Specifications

1. The Airlock Module/Saturn IB Workshop ICD, 13M02519, prepared by MDC for the Mechanical Panel, was approved by the panel and transmitted by ECR to the AAP level II Configuration Control Board (CCB) for approval and implementation.

2. Nine experiments to flight AAP-2 interface control documents (ICD's) were distributed for laboratory review. All experiments to flight AAP-2 ICD's are being prepared by the Martin-Marietta Corporation; comments received on those sent out for review can be applied to the remaining ICD's.

B. Multiple Docking Adapter (MDA) Schedule Analysis

A schedule analysis for the MDA, based on the revised AAP program plans, has been completed and submitted to the engineering manager for his review and coordination with other R&DO laboratories.

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-68-4

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

April 1, 1968 through April 30, 1968

SATURN IB

I. S-IB Stage

A. S-IB-11 Static Test Program Concluded

Static test program of S-IB-11 was concluded with the flight duration test on April 23, 1968. In addition to the standard tests for flight readiness, five additional tests were conducted for the following reasons:

1. Determine combustion stability characteristics of the H-1 engine in the S-IB stage.

2. Determine characteristics of the turbopump bellows-type LOX seal in S-IB stage.

Results of the tests were satisfactory. Bellows-type LOX seals will also be installed on stage S-IB-12 for additional testing.

B. Propulsion Flight Predictions

Propulsion flight predictions (both nominal and dispersion cases) for vehicle AS-207 and AS-206 were completed and released for use in mission planning.

C. Final Vehicle Propulsion Performance Reconstructions

Final reconstructions were completed for the AS-204 vehicle.

II. S-IVB Stage

ORBITAL WORKSHOP (OWS) AUXILIARY PROPULSION SYSTEM (APS)

Two Agena Target Vehicle fuel tanks were modified to the present APS mounting configuration. A complete acceptance test will be performed on these tanks, and one will be subjected to a series of tests to demonstrate its capability to meet the vibration, acceleration, leakage, pressures, and expulsion requirement of the OWS mission.

Studies show that incorporation of high-performance insulation (HPI) within the APS module will reduce to a minimum the heater power required for propellant tanks, valves, feed lines, and pressurant supply bottles. Anticipated average heater power should not exceed 50 watts per module. This represents a 250-watt saving over currently budgeted heater power. The current heater power budget of 300 watts will be retained until thermal systems tests can be performed. Questions have arisen as to the flexibility of the HPI within a compact system, such as the APS module. Problems within this realm deal with moisture contamination (aluminized mylar deterioration), outgassing ability, purge requirements, and effectivity of HPI with many insulation joints. Answers to these questions can only be obtained from the APS test program (planned for April 1969), but studies and literature surveys should provide clues to possible solutions and alternate system designs. However, at present, no other insulation seems adequate.

A failure effect analysis of the APS was completed and released. Engine "burn through" or explosion was the only first order failure.

SATURN V

I. S-IC Stage

A. F-1 ENGINE

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

Twenty tests were conducted, and a total duration of 2485.8 seconds was accumulated. Thirteen of these tests were full-duration runs (150 seconds or more). All of the tests ran for the intended duration.

2. Production Engine Testing at EFL

Three tests were conducted, and a total duration of 250.9 seconds was accumulated. One test was full-duration run, and all of the tests ran for the intended duration.

3. S-IC-2 Gimbal System Data Review

A review of flight data has shown that the S-IC-2 gimbal system parameters were normal, with the exception of filter manifold differential pressure. The negative readings obtained from this measurement indicated that the differential pressure transducer problem has not been corrected. The gimbal angles continue to be small, reaching a maximum of only 0.7 degrees during flight.

4. Failure Effects Analysis (FEA): F-1 and J-2 Engine-Stage Interface (All Stages)

First order FEA's were prepared on the F-1 and J-2 engine for SA-503 showing only the engine components which interface with the respective stages and whose failure or off-nominal performance could affect the stage.

B. Launch Countdown Readiness (All Stages)

The actual values obtained for the propulsion system redlines for AS-502 flight are being reviewed to determine if redline adjustments can be made.

C. S-IC-502 Thrust Oscillations

S-IC-502 thrust oscillations during flight are investigated. Comparisons are being made with S-IC-501 flight data and with static test data on both S-IC stages.

D. Position Switch Redesigned in Vent Valve

Redesign eliminates the spotwelded pin attachment by a mechanical connection and will be incorporated on the -503 and subs. stages.

E. Saturn Auxiliary Solid Systems Functional During SA-502

A preliminary review of the available telemetered oscillographic data from the flight test of launch vehicle SA-502 indicates that all of the solid propellant motor systems were operational and functioned in a normal manner during the launch. A more complete evaluation of the systems using on-board tape-recorded data is underway.

II. S-II Stage

A. J-2 ENGINE

1. R&D Testing at SSFL

Thirty tests were conducted, and a total of 3631 seconds was accumulated. None of the tests were full-duration runs. One test was terminated prematurely due to a facility malfunction.

2. Production Engine Tests at SSFL

Three tests were conducted, and a total duration of 315 seconds was accumulated. None of the tests were full-duration runs, and all ran for the intended duration.

3. J-2 Engine Tests at AEDC

Twenty-one S-IVB hot firings were conducted under simulated flight environmental conditions during this report period. These tests simulated first burns, one orbit, and two orbit restarts.

Engine operating conditions were set to simulate the most severe operating conditions. The data from these tests indicate that the engine will operate satisfactorily for all S-IVB specification limit and nominal conditions. The restart tests incorporated the narrow band vent and relief valve operating range limits. The data indicate that the valve is satisfactory.

4. J-2S Development

Assembly of J-111, the first full configuration J-2S development engine, was completed. The engine was shipped to the Santa Susanna Field Laboratory for test stand installation and testing; however, these tests are being delayed for basic J-2 engine testing to resolve SA-502 flight problems.

5. Investigation of SA-502 Engine Anomalies

A probable cause of both the S-II and S-IVB engine anomolies was identified as a failure of the fuel supply line to the augmented spark igniter. Efforts to reproduce the line failures by component tests have been unsuccessful. Both the LOX and fuel supply lines to the augmented spark igniter are being redesigned and will be subjected to both component and engine system qualification testing prior to production engine retrofit. Effort to reproduce the suspected line failures, and to confirm the engine system effects of such failures is continuing.

6. Engine Gimbal System Evaluation for SA-502 Flight

The hydraulic system of position 2 showed a number of anomalies. First, abnormal cooling was detected at the yaw, pitch and reservoir thermal probes. An apparent delta P ramp build-up exceeding 2200 psi was observed at the yaw actuator. This actuator stopped moving one minute before the termination of hydraulic pressure, indicating that frozen hydraulic fluid was causing blockage in this circuit. The reservoir was depleted of fluid at shut-down indicating a rupture of the low pressure line.

Testing at NRC and MSFC indicates that significant transducer shifts can be induced by the application of cryogenics. With low system flows, concentrated applications of cryogenics can lead to a non-operable actuator.

The EGS is adequate for all nominal missions but is not capable of sustained operations in a cryogenic atmosphere. The systems on positions 1, 3, and 4 operated in a normal manner.

Additional instrumentation is being requested for subsequent flights to be better able to determine the environmental conditions of the gimbal system.

B. S-II Fuel Recirculation

Evaluation of the S-II-2 and S-II-3 data from the fuel recirculation systems indicates inconsistent engine-to-engine variations in fuel recirculation system heating. Additional engine insulation was proposed, but it is unlikely that heating rates to engine components is the cause of the problem. During the S-II-2 acceptance testing, the engine 5 recirculation system indicated much higher heating rates than engines 1-4. Also, during the Countdown Demonstration Test (CDDT) and launch, the heating rates appeared to increase with cryogenic cycles, indicating insulation (foam) degradation, probably by moisture and liquid air. As a result of the abnormal system operation, the launch redline was modified during the prelaunch operations, and the recirculation system operation proved unpredictable and could have easily aborted the AS-502 launch. S-II-3 acceptance data shows similar problems on two engines, and inspection of stage insulation around the recirculation pump and engine is required before further engine insulation is considered.

C. S-II-3 and Subs Instrumentation

A plan for revising S-II engine area environment data was presented to the Instrumentation Committee. The proposed plan reduces the number of instruments but provides more intelligible aft interstage environment data, based on the experience of two flights. In addition, it was proposed that LOX recirculation temperature be measured at the customer connect panel, and ΔP transducers be added to the fuel recirculation pumps to provide launch support data for evaluation of propellant recirculation system during CDDT and launch.

D. Cryogenic Proof Pressure and Tanking Test of S-II-5

The cryogenic proof test of S-II-5 was conducted and a quick-look evaluation of the data indicates that all objectives of the test were accomplished. The proof pressure test level in the LH_2 tank was 36.205 psig.

III. S-IVB Stage

A. SA-502 APS Flight Evaluation

Evaluation of SA-502 APS flight performance is continuing. Flight data available to date substantiate the following observations:

1. The Ullage engine of Module 2 showed a longer than normal tail-off during cutoff of the second ullage burn. No comment can be made on the first ullage burn cutoff due to lack of data. This tail-off was shorter than that of SA-501.

2. During a number of pitch engine firings, the chamber pressure of the first pulse was low and after a few pulses the chamber pressure was up to normal. Chamber pressure as low as 55 psia during the first pulse was observed. This phenomena was not observed on the roll-yaw-engines.

3. Module 1 depleted fuel ahead of the oxidizer at approximately 22,000 seconds after lift-off and Module 2 depleted ahead of the oxidizer at approximately 22,600 seconds after lift-off. This type of depletion is considered the worst case from mixture ratio shift standpoint. The data showed that the APS operations under this condition were safe.

4. The APS propellant quantity remaining at the end of spacecraft separation was estimated to be approximately 25 percent of the lift-off quantity. This indicates that the actual propellant consumption was only approximately 7 percent more than the predicted nominal to complete the primary mission. The excess consumption was mainly due to the large attitude errors and body rates, high moment of inertia, and proximity of the vehicle C. G. to the APS.

B. SA-501 APS Anomaly Testing

Further testing was conducted by MSFC on the Saturn V/S-IVB APS to aid in the investigation of the SA-501 APS engine anomalies. The module was fired with the propellant feed system modified to determine the effects on engine chamber pressure caused by restrictions in the propellant flow path. The initial low chamber pressures during the flight were simulated by shutting off flow through the primary propellant lines and running the engines through the recirculation lines only. The cause of main feed line flow restriction in flight or location of the flow restriction was not determined. The tests were only conducted to determine the effect of propellant flow restriction.

C. Review of Gimbal System Data From SA-502 Flight

The hydraulic system performed adequately during first burn. Very high pitch gimbaling was encountered during the early part of the burn. A pitch angle of 6.6 degrees was observed that caused the accumulator to partially deplete and system pressure decrease by 400 psi. Later in the burn the yaw actuator began an abnormal temperature loss.

The hydraulic system did not operate during the coast mode or in preparation for second burn. This was due to a blocked inlet line caused by freezing of fluid medium. Free cryogenics were present on the hydraulic system during the terminal portion of the first burn. Testing has established that a hydraulic system line will freeze from 1 to 2 minutes when exposed to cryogenics with no hydraulic flow in the line. Freezing the inlet line to the auxiliary pump will produce a cavitating condition, and only 12 amps will be drawn by the motor. This was observed during flight on four separate occasions. (12 amps at auxiliuary pump motor).

The freezing was localized, and the thermal cycle was not initiated, because the temperature at the switch was above 10°F. Additional instrumentation is being requested to better determine the thermal profile and imminent faillures of the hydraulic system during flight.

D. Dual Restart Mission

The dual restart ("D") mission sequence was finalized. The restart sequence provides for a restartable O_2/H_2 burner for the 2nd burn repressurization and operation during the 3rd burn restart preparation to demonstrate the restart capability.

IV. Instrument Unit

A. BP-30 Check Valve Qualification Retest

A modified BP-30 check valve (size and material of spring changed) successfully completed qualification retests.

B. Gas Bearing Regulator

The Gas Bearing Regulator passed the acceptance test after completing the extended life test.

SPECIAL STUDIES

I. Investigation of Brazed and Welded Tube Connections

Ten 1 1/2-inch connections (five Aeroquip and five GE) satisfactorily completed vibration testing at LN_2 temperature while under a peak stress of 33,200 psi. Sixty-one 3/4 inch connections, five 1 1/4-inch connections, and fifteen 1 1/2-inch connections were leak-tested and all maintained zero leakage. The test setup for room temperature vibration of the 3/8-inch connections was completed and satisfactorily tested.

II. Sub-Scale Solid Motor Malfunctioned at Test Lab

Three malfunctions in a 1/58 scale of a 120-inch solid motor system have occurred in recent tests to study the effects of strap-on solids on a launch pad. Two of the malfunctions involved mis-fires or failure to ignite. The exact cause of these failures has not been established. The third failure involved the loss of an igniter pellet retainer plate in one motor. The anomaly was noted during the firing by a large perturbation on the motor's pressure versus time trace and was attributed to loss of the retainer plate during disassembly of the suspect motor.

III. Apollo Telescope Mount (ATM)

Quadrant IV Thermal Test

Thermal vacuum tests of the ATM quadrant IV were performed. Preliminary analysis of the data indicates pre-test predictions will correlate with the experimental results.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Engine Aerospike Experimental Investigation

The planned segment tests were completed with the demonstration of successful operation at a chamber pressure of 2000 psia and a mixture ratio of 6.0. The test hardware employed regenerative cooling with a copper, slotted panel chamber wall. Combustor geometry data evaluation indicate that chamber weight can be significantly reduced by decreasing both the chamber length and width without appreciably affecting performance. A chamber geometry of one-inch width by four inches length appears optimum (compared to the previously used 2x6 configuration), assuming the use of a concentric orifice injector using gas/gas propellants with a reasonably high performance level (97 percent C*). Test results also indicate significant reductions in upper chamber wall heating rates with the concentric orifice injector over an impinging jet type of injector. Ninety-eight segment tests totaling 417 seconds were conducted.

A test series of 8 tests totaling 47 seconds, which investigated chamber dynamic characteristics, was successfully conducted on the nickel tubewall thrust chamber. Test conditions reached 792 psia chamber pressure and 4.9 mixture ratio. Four of the tests successfully employed programmed facility valves to simulate propellant pump head/flow slopes during both ignition and throttling transients. The test hardware is in good condition. This series completes the planned thrust chamber tests which, including the stainless steel chamber series, totaled 17 tests for 63 seconds.

II. Small Engine Evaluation Program

Tests were conducted on Hamilton Standard Five and one pound thrust monopropellant engines. The five-pound engine was run to the standard test duty cycle for a total burn time of 644 seconds. The one-pound thrust engine was run for 22.5 seconds at sea level. Chamber pressure oscillations were less than ±5 psi throughout all the tests. Further testing of these engines is planned. Testing on the Aerojet bipropellant engines was delayed due to a shortage of N_2O_4 and facility priorities with other programs. The two twenty-five pound thrust Hamiliton Standard monopropellant engines were X-rayed to determine the post run condition of the catalyst bed. (Both of these engines incurred chamber pressure oscillations greater than ± 25 psi during testing). Engine S/N 001, which had a known void, was X-rayed and the void appeared to have moved to a different position inside the bed. X-rays on engine S/N 002 indicated the possible formation of a void inside the bed. It is presently planned to return the engines to the vendor for further examination and possible repacking.

PUBLICATIONS

1. "Tables and Graphs of Functions Necessary for Solving Nonlinear Heat Transfer Constant Area Fin Problems with Examples on Their Use," TM X - 53710, by A. R. Shouman and J. W. Price, dated February 23, 1968; published April 25, 1968.

2. "Laplace Transform Analysis of Longitudinal Accelerations of the Second Stage of the Uprated Saturn I Vehicle During Orbital Cutoff," IN-P&VE-P-68-1, by J. W. Price, J. Loose, and P. Rhodes, dated March 13, 1968; published April 17, 1968.

3. "Analytical and Experimental Study of Dynamic Characteristics of Turbopumps," TN D-4298, by H. Ohashi, dated April 1968.

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