SID 63-1028-2

SATURN S-II

ANNUAL PROGRESS REPORT

1 July 1963 through 30 June 1964

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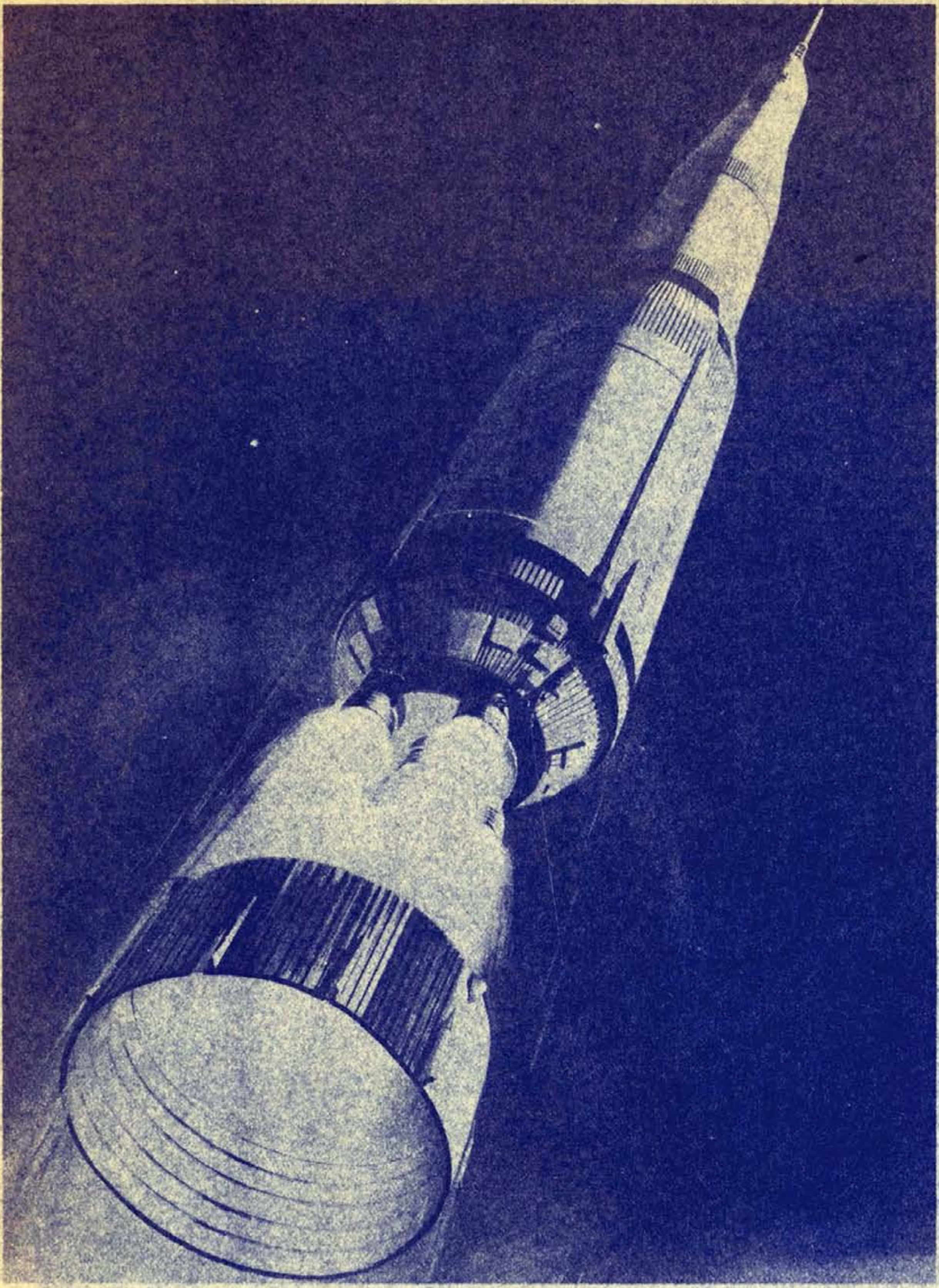

FOREWORD

This document is the second annual progress report of the Saturn S-II Program. The report provides a summary and technical analysis of results of contract work by the Space and Information Systems Division of North American Aviation, Inc., for the period 1 July 1963 through 30 June 1964. This document was prepared in compliance with NASA contract NAS7-200.

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I. PROJECT SUMMARY

ELECTROMECHANICAL MOCKUP

DESIGN

Fiscal year 1964 saw the beginning of the transition from paper design to actual hardware for the EMM. Most of the basic design was released during fall and early winter. and by yearend cables and GSE were being delivered.

It became apparent by early winter that nomenclature would have to be identified for the various EMM configuration phases that support succeeding stages. In addition, the EMM configuration would have to lead the early stages (S-II-T, S-II-1, etc.) to support them adequately. Accordingly, the title "Configuration X" was assigned to the first functional or activation phase of the EMM, which must lead the S-II-T to support GSE integration and the development of tape programs to be used at Seal Beach for S-II-T checkout. The EMM configuration either had to be frozen before that of the S-II-T, or the S-II-T configuration would have had to be frozen earlier than was desirable.

The former choice was exercised. Some functional differences, however, will arise out of changes to be incorporated subsequently into the S-II-T but which would not be reflected in the activation phase of the EMM. As a result, it was planned that a basic set of tape programs would be developed and verified through the EMM and updated through the computer program development facility (CPDF) to incorporate the functional differences between the EMM and S-II-T. On 5 and 6 February, S-II program representatives presented the Configuration X concept to MSFC and obtained verbal concurrence.

In December 1963, a preliminary freeze was established on the EMM. An in-house mockup inspection was held on 11 and 12 March 1964, and 104 requests for alteration (RFA) were submitted by S&ID personnel. NASA personnel who participated in the inspection submitted 14 additional comments. All were turned over to the Engineering department for action. After the inspection, mockup harnesses were removed for measuring, and jig boards were fabricated for manufacture of actual flight-weight harnesses.

Action also was initiated in early February to examine all existing MCR's for the purpose of establishing a configuration freeze of the activated EMM that would support GSE integration and development of the tape program checkout. On 3 April, Configuration X was formally defined. This action cut off further changes except those needed to assure proper operation of the equipment and those which, after review, were deemed to be of particular importance and which could be included as scheduled without affecting the program.

Although definition of Configuration X accomplished its purpose, a very heavy flow of mandatory design changes has followed. These changes have affected the schedule deliveries of GSE and airborne systems to be installed in the EMM. The result is that the integrated systems checkout tape program for S-II-T has slipped from 26 March to 31 May 1965.

END ITEMS

By fiscal year end, harness installations in the upper skirt had commenced, and the following GSE and SDD end items had been delivered:

C7-101	Automatic checkout computer
C7-59	Engine checkout electrical-power cable set
C7-601	Hydraulic power console (reidentified as SDD-193)
C7-104	Data printout rack
C7-105	Auxiliary memory rack
C7-511	Digitizing system rack
C7-516	Tape recorder racks (2)
S7-10	Hydraulic system jumper unit
SDD-151	Intercom headsets
SDD-152	Protective datacom headsets
SDD-154	Electrical terminal distributor
SDD-214	Engine actuation simulators (8)
SDD-310	Systems recording oscillograph (3)

Documentation to support the actual integration of GSE was well under way by the end of June. All test plans for the various stages and particular GSE items had been published, except those for the C7-44 GETS and the automatic checkout integration. Of the 12 appendices that give step-by-step procedures for GSE checkout, five have been completed by T&O and the rest are scheduled for completion by 31 August.

BATTLESHIP

CONSTRUCTION

An initial design freeze was imposed early in this reporting period to facilitate completion of the construction effort.

Phase I construction of the S-II portion of the Santa Susana Field Laboratory has been completed. The various construction tasks covered during this phase of effort were:

Test stand foundations of Coca 1 (Battleship stand) and Coca 4 (All-Systems stand)
Enlargement and modification of the fire control center
Test stand structures, Coca I and IV
On-stand systems installation
LH_2 storage dewar
LOX storage tank
GH_2 storage vessel
High pressure gas storage vessels
Design and fabrication of Battleship stage
Water storage vessels
Road modifications
Water reclamation
Off-stand (interconnect) systems
Installation of control center electrical network and instrumentation
Flame deflectors, Coca 1 and 4

Activation of the basic facility was begun by Rocketdyne of 4 May and S&ID on 18 May. Rocketdyne effort consists primarily of checking out and testing the facility systems to the GSE interface point at the two test stands. Those Rocketdyne tasks which have reached 50-percent completion or more include:

Minor facility modifications
Recording-center instrumentation systems
GH_2 system
Helium system
GN_2 system.

Items less than 50-percent complete include:

Area instrumentation
LH_2 system
LO_2 system
LO_2 storage
LH_2 storage
GH_2 recovery system
Coca 1 functional and leak checks.

Activation by S&ID consists primarily of installation and checkout of fluid distribution systems and cables on the stand and in the Control Center. Tasks 50-percent complete or better include:

Preparation of Battleship LOX and LH_2 tanks for hardware installation
Installation of System interconnect cables in the control center
Checkout and adjustment of the Battleship fluid distribution systems
Installation of recorders in the control center (EA and Brush recorders).

The following SDD/GSE items have been delivered:

A7-14	Engine compartment light set
A7-35	Service mechanism, LH_2 tank
C7-41	Rack, power distribution
C7-59	Cable set, engine checkout
S7-37	Portable vacuum pump
SDD-132	Electrical power-control rack
SDD-151	Headset, intercom (without muffs)
SDD-152	Headset, intercom (with muffs)
SDD-155	Umbilical arm disconnect
SDD-156	Umbilical arm disconnect
SDD-168	Purge and thermal control, GN_2
SDD-171	Tank air conditioning unit
SDD-185	Test conductor's console.

A special heavy-duty thrust structure for the Battleship stage was fabricated in stainless steel. Stage attach points are the same as for flight structures and can be changed later if necessary.

DESIGN CHANGES

The prime problem encountered in the facility and stand construction were numerous design changes. The majority of these resulted from air vehicle and system changes that established a new or modified test stand requirement. This made the construction task significantly greater than originally planned and resulted in additional time and money to complete the initial construction phase.

The side loads induced by J-2 engine firing at sea level required the design and construction of additional GSE and structures to restrain the engine and to reduce strain. Problems associated with J-2 engine movement during the engine start phase made it necessary to redesign and rebuild the LOX feed lines. Engine movement during the start phase would have caused original lines to fail.

During July NASA/MSFC personnel inspected the facility, where they had an opportunity to review progress to date. Recommendations made at that time are under study to determine what remedial action is necessary and feasible.

ALL-SYSTEMS

Engineering design for the S-II-T vehicle systems and GSE was frozen May 21. A completed baseline configuration report defined both the S-II-T and S-II-1 in terms of MCRs applicable to All-Systems and GSE end items. This report also defined change points for all deferred MCRs.

Manufacturing effort was concentrated on the fabrication of structural and systems components.

Table I-1 lists the items that were completed by the end of June.

Table I-1. Manufactured Items Completed

Section	Components Completed
Thrust structure	Four quarter panels
Aft skirt	Three quarter panels
LH_2 cylinder panels	Two number one's; two number two's; three number three's; three number four's; three number five's; and two number six's
LH_2 cylinder forward bulkhead	Twelve gores
Common bulkhead fwd facing sheet	Nine thin and 12 thick sections
Common bulkhead aft facing sheet	Fully completed
Aft LOX bulkhead	One thick segment and 12 thin segments
Pressurization system	Fabrication of detail parts
Propulsion system	Fabrication of detail parts

Fabrication continued on the remaining bulkhead and cylinder components, as well as, on the forward skirt, center engine beam, final aft skirt quarter panel, and LOX tank baffles.

The first phase of construction on the All-Systems test complex, Coca 4 was completed. See Figure I-1. Design of the final phase, approximately 60-percent complete, includes: control and instrumentation cabling, fluid distribution system, emergency LOX drain, structural steel guide rails, access platforms, and stage cover mounts, as well as, side load arresting-mechanism attachments and the secondary power system.

Purchase orders for bulk cable have been placed, and components for the fluid distribution system have been received.

Test planning has progressed. The first issue of the all-Systems test plan was completed and coordination copies were circulated. The All-Systems measurement list has been published, and development is progressing on the GSE installation and checkout plan, the manufacturing verification test plan, and the preparation and installation plan.

COMMON BULKHEAD TEST TANK

ENGINEERING

Detail drawings and load-data requirements have been released from Engineering, and instrumentation data requirements are being implemented. Test priority is being established because of potential conflict with other test programs at the SSFL.

MANUFACTURING FACILITIES AND TOOLING

The meridian welders and buildup tools for bulkhead assembly were certified during the S-II-S cycle. The cylinder welder and trim tools were similarly certified. Cylinder bonding parameters for insulation were established.

MANUFACTURING

The aft common facing sheet and the special forward skirt have been completed. Cylinder Panels 1 and 6 are available but await completion of the ultrasonic inspection tool before assembly. Insulation for these panels is available and has been partially bonded to various panels. Insulation for the forward skirt, of the bolt-on type, has been ordered for delivery in September. Leak detection and purge systems have been released to the vendor, and detail provisions are incorporated in the common bulkhead and the external insulation.

TOOLING

The tool certification program for CBTT has been completed for the bulkhead/cylinder assembly building. Circumferential welds remain to be certified during assembly of the static stage.

INSTRUMENTATION

Instrumentation requirements have been released and priorities are being set. Test jigs and fixtures are being fabricated.

TEST COMPLEX

Test complex designs, finalized by Rocketdyne and S&ID, have been let out for bid.

TEST PLANNING

Load cylinders are available. Test planning and scheduling are under way to define Rocketdyne effort at SSFL and the efforts of the contractor for completion by 15 August.

STATIC TEST STAGE

ENGINEERING

Detailed fabrication and assembly drawings have been released. Structural test load and instrumentation requirements have been finalized and are being implemented.

MANUFACTURING FACILITIES AND TOOLING

The bulkhead/cylinder assembly building has been completed and the assembly tools placed in operation. The meridian welder, the hydrostatic test fixture, the dollar welder, and the autoclave for bulkhead buildup have been certified for production. The cylinder welders and trim tools have also been certified. Weld capabilities of the Slauson facility have been transferred to the Los Angeles Division (LAD), and subassemblies have been certified for production. The Vertical assembly building is occupied, and the circumferential welders for 0.296-inch-thick material have been certified. Three material thicknesses are still to be certified. The bulkhead assembly hydrostat, Station V, has been certified, and the Station VI vehicle hydrostat is expected to be available in October for scheduled usage in static test.

MANUFACTURING

The following assemblies for the Static stage are complete:

> The forward skirt, the engine mount beam, the thrust structure, the aft interstage, the LOX baffles, and the static firing skirt with associated vehicle handling equipment.

Completed and in final assembly position are:

> The bolting rings; Cylinders 1, 2, 3, 4, and 6; the forward LH_2 bulkhead; the aft common facing sheet; the forward common facing sheet; and the honeycomb core assembly.

Completed and awaiting further support structure are:

The thrust structure and the forward skirt fitup.

The LH_2 bulkhead and Cylinder 6 have been joined by a circumferential weld and successfully hydrostated. The aft common facing sheet and the phenolic core have been bonded; machine operations to match the inner mold line of the forward facing sheet is under way. During the bond cycle of the aft common facing sheet, a distortion that developed at a thick/thin weld necessitated structural repair. The repair was made successfully, and the bond cycle parameters were reestablished to prevent reoccurrence. Aft LOX bulkhead cores are available to start bulkhead buildup pending welder certification.

INSTRUMENTATION

Instrumentation requirement lists have been released and strain gages are being installed on a noninterference basis during the S-II-S manufacturing cycle.

STATIC TEST TOWER

Tower design was completed and released for bid, although full design loads and details of load application points were not known at the time. Subsequently the extra effort to provide loading structure and other essential provisions was submitted to NASA. The test tower has been erected, and S&ID has occupied the control room. Recorder setup and test control provisioning are under way.

The schedule for the static test tower schedule has been released, and priority measurements are under study. Test jigs and loading devices are being readied for installation in the test tower.

II. ENGINEERING

DESIGN AND STRUCTURES

Nomenclature for major structural components of the S-II stage is shown in Figure II-1.

LH_2 TANK

Manufacturing Progress

Fabrication of the LH_2 tank for the Static Test stage (S-II-S) is progressing satisfactorily. Already completed are all individual cylinder assemblies, the LH_2 forward bulkhead, the welded joint between the LH_2 forward bulkhead and the upper cylinder, and certification of cylinder-to-cylinder welding.

Structural Change

S&ID was directed by MSFC to increase the LH_2 tank pressure from 37 to 39 psia to meet net-positive-suction-head (NPSH) requirements for the J-2 engine. The tank skin thickness was increased from 0.146 to 0.153 inch minimum to account for this 2-psia increase for S-II-1, S-II-2, and S-II-3. In addition, the weld land thickness was increased from 0.290 to 0.310 inch minimum.

Structural Analysis

An extensive analysis was conducted to evaluate the effect on the structural behavior of the LH_2 tank of the severe temperature gradients which occur during the initial stages of propellant loading. Significant hoop compression stresses are developed in the lower region of the LH_2 tank cylindrical wall for LOX and LH_2 loading operations. Analysis indicated that preconditioning of the LH_2 tank to -50 F prior to LOX loading and to -160 F prior to LH_2 loading is required to reduce the magnitude of the induced hoop compression stresses to a level where local buckling of the skin will not occur. Skin buckling could jeopardize the structural integrity of the tank under prelaunch conditions or cause damage to the external insulation. Preconditioning requirements have been coordinated with MSFC, and efforts to implement preconditioning provisions are under way. Detail stress analysis of all tank primary structure was completed; and analysis of secondary structure, such as systems tunnel and aerodynamic fairings, is nearing completion.

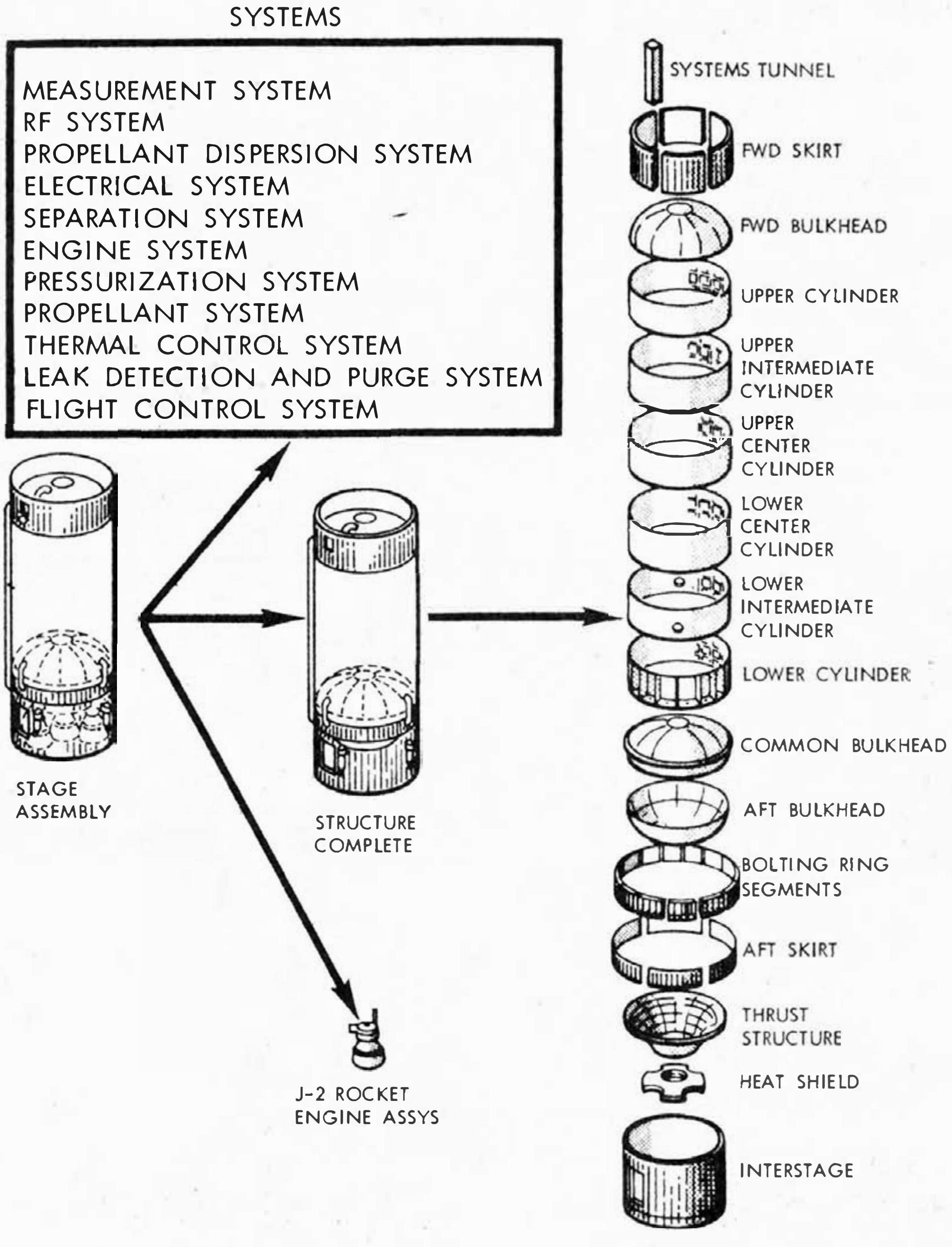

Figure II-1. S-II Stage Nomenclature

Hydrostatic Test

Hydrostatic testing of the LH_2 forward bulkhead was successfully completed; stress distributions determined from strain gage acquired during the hydrostatic test agreed with predicted stresses.

LOX TANK

Slosh Baffles

Model test data established that the LOX tank center baffle and lower baffle can be eliminated. The lower baffle and its supporting structure therefore are being removed from all stages. To prevent a manufacturing schedule slip, the center baffle at the equator will be used through the second flight stage. Beginning with the third flight stage, this baffle will be replaced by a structural frame approximately 8 inches deep.

Common Bulkhead

The forward and aft facing sheet welded assemblies (Figure II-2) were completed for the S-II-S. Bonding of the core to the aft facing sheet was ac-

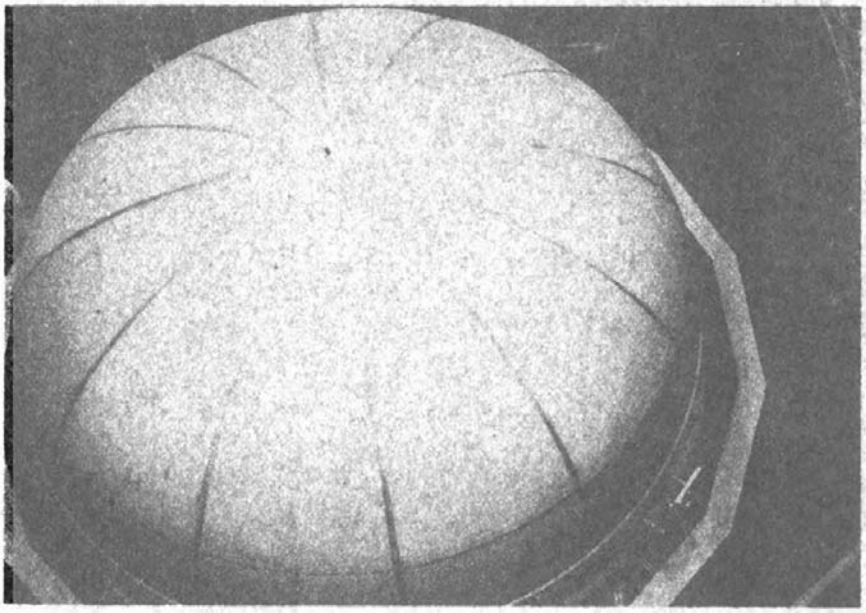

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Figure II-2. Common Bulkhead Aft Facing Sheet Assembly complished, and the forward surface of the core is now machined. On the S-II-S only, 0.06-inch-wide by 0.18-inch-deep slots were machined in the forward face of the core to provide better venting of gases formed during bonding of the forward facing sheet to the core. These slots replace slashing of the core. Subsequent bulkheads will use the perforated-type vented core. Impression fit checks for the S-II-S indicate a good fit between the forward facing sheet and the core. The final operation of bonding the forward facing sheet to the core is scheduled for 22 July 1964.

The common bulkhead core assembly was revised to include a higher-density 12-pound strip of core approximately 17 inches wide at the lower edge of the forward facing sheet. The high density core in this area offers advantages in both manufacturing and strength.

J-section welding for the S-II-S was accomplished manually in light of Manufacturing scheduling problems. However, certification of J-section machine welding has now been completed, and subsequent J-sections will be machine welded.

Buckling of the aft facing sheet was encountered during first stage bonding. The buckle was located just above the waffle grid panel, and it extended the full width of one gore section (approximately 100 inches). A repair was made in this area. Analysis indicated that the buckling resulted primarily from compression stresses and temperature gradients associated with bonding pressure and temperature. To eliminate buckling on subsequent bulkheads, bonding procedures for the first bond operation have been revised to use substantially lower pressures and to reduce temperature gradients.

Structural Analysis

Detail stress analysis has been completed on all production drawings for the LOX tank, including the alternate design concept for the forward facing assembly of the common bulkhead. Structural equations were formulated to evaluate internal stress distributions and deflections of the sandwich core of the common bulkhead under varying pressure and temperature distributions and to include secondary effects such as bulkhead bending deflections and shear deflection of the core. A digital computer program, written to expedite a solution, is in final checkout. This analytical tool will provide a significant improvement in scope and accuracy over membrane theory solutions and will permit rapid evaluation of new design conditions or revised structural geometry.

Preliminary acceptance standards for quality of the adhesive bond between the facing assemblies and the core of the common bulkhead were established on the basis of theoretical analysis. Requirements are based on the maximum size of a no-bond or void area that will not involve local buckling of the facing assemblies. The permissible size of individual voids varies from about one-half to two inches, depending upon the local facing thickness and the design stress level. These preliminary standards will be improved and updated as data become available from the evaluation test program.

The structural design of the common bulkhead is based on specific temperature and pressure conditions occurring during prelaunch and flight. Special tanking and pressurization tests are planned for one tank loaded with propellant; this imposes a temperature environment quite different from basic design conditions. A study was therefore conducted to determine the envelope of permissible differential temperature and pressure combinations for the common bulkhead; a summary of this study was transmitted to MSFC.

Hydrostatic testing of the forward and aft facing assemblies of the common bulkhead for the S-II-S has been successfully completed. Stress distribution values derived from strain measurements during the hydrostatic tests reasonably agreed with predicted values.

Structural investigation of a local buckling failure that occurred during bonding of the core to the aft facing assembly of the common bulkhead for the S-II-S was made, and corrective action was determined. It is believed that buckling was due to biaxial compression stresses induced in the facing assembly by the bonding pressure and to initial local deflections resulting from temperature difference between waffle-stiffened and thin gore regions of the facing assembly. Corrective action includes reduction of bonding pressure, relocation of control thermocouples, and reduction in permissible temperature gradient.

SKIRTS

Forward Skirt

The forward skirt structure was redesigned to withstand a pressure differential of 7.7 psi. The skirt will be sealed to maintain a maximum of 30 square inches of leakage area, including an allowance for drain holes. Forward skirt drainage will be accomplished by means of approximately twelve 0.5-inch diameter holes equally spaced around the stage. Complete agreement has been reached between MSFC, Douglas, and S&ID on the S-II/S-IVB interface attachment. Three fittings have been installed on the interface frame of the S-II to assist in alignment during staging operations of the S-IVB.

Aft Skirt

Effort in this area has been concentrated on the incorporation of design requirements for the installation of systems and umbilical disconnect for the All Systems stage S-II-T. This was necessary because these requirements were not incorporated in initial drawing releases for S-II-S. Fairings for external protuberances and LOX vent valves are being designed.

Structural Analysis

Detail stress analysis has been completed on all primary structural details, including redesign of the forward skirt assembly, to accommodate increased bursting pressures experienced during S-IC boost. (Design pressures were increased from 5.0 psi to a maximum of 7.7 psi.) Stress analysis of secondary structures, such as aerodynamic fairings, is in progress.

Structural deflections due to loading and temperature environments have been evaluated for the complete range of operating conditions to provide basic design information relative to clearance studies, fluid line, and various system motion requirements.

SYSTEMS TUNNEL

Systems tunnel drawings are 100-percent released, and manufacturing is proceeding at S&ID's Tulsa facility. The principal effort on the systems tunnel has been associated with the addition of lightning protection.

Requirements were received from MSFC to add shielding for protection of wiring and instruments within the systems tunnel. Three methods of protection were studied: an all-metal tunnel; shielding for wiring and instruments within the tunnel; and a metallic lined Fiberglass tunnel incorporating a metallic foil or mesh, spray metallic paint, plating, metallic resin, or carbon cloth. The results of the study indicated that the Fiberglass tunnel cover (door) with an inside layer of 0.001 aluminum foil (1145-0, ASTM-8373-63T) was the optimum design from weight, strength, and thermal considerations. The systems tunnel substructure is constructed of alclad aluminum for ease of manufacturing.

THRUST STRUCTURE

The initial release of all thrust structure drawings for the S-II-S was completed. A redesign of the center engine beam was completed to accommodate the loads imposed by the side load arresting mechanism (SLAM). A major portion of the thrust structure design effort has been in local redesign of structure for incorporation of common support bracketry for engine service, pressurization, and recirculation lines, and the provision for access holes and backup structure for the installation of systems components.

Elastic equations were developed to predict the manner in which the engine thrust loads diffuse from the thrust longerons at each engine support point to the adjacent shell structure; these equations have been programmed for digital computer solution. An analytical tool, they provide improved accuracy over the semi-empirical analysis techniques employed in the initial design of the thrust structure. A recent study was completed to determine the allowable temperature distribution over the thrust structure, on the basis of internal load distributions evaluated by current methods. Allowable temperatures varying from approximately 150 F adjacent to the thrust longerons to values in excess of 300 F midway between engine locations were determined. Comparison of these results to temperatures predicted on the basis of S&ID evaluation of model tests to define base heating environment indicates that no insulation of the thrust cone structure will be required.

Deflection influence coefficients were determined for the center engine installation. Deflection coefficients were determined in three coordinate directions at the engine gimbal and stiff-arm attach points. These data will be used to determine the possible thrust vector excursion for the center engine and effects due to engine side loads occurring during thrust build-up and decay transients.

Detail stress analysis of all basic primary structure has been completed; analysis is in progress of installation of supporting bracketry for various system components and lines.

INTERSTAGE

The initial drawing release for the S-II-S interstage was completed in August 1963. A special test interstage section extending from Station -23 to Station 0 was ordered by MSFC, and drawings for this section were released. Design of the full-scale separation test structure was completed, and drawings were released.

INSULATION

Concept

The insulation concept for the liquid hydrogen tank of the S-II stage has been a major development problem since the beginning of the S-II program. Operational requirements demand the combination of low weight, low thermal conductivity, environmental compatibility, and structural integrity under cryogenic and boost conditions. The insulation systems selected for the various S-II stages are described below.

Insulation For the Test Common Bulkhead, S-II-T, S-II-F, and S-II-D

For the test common bulkhead, S-II-T, S-II-F, and S-II-D, the insulation selected will consist of 0.8-inch thick, 3/4-inch honeycomb core filled with low density polyurethane foam and covered with an outer facing sheet of nylon phenolic laminate and a Tedlar membrane seal. The insulation will be purged with helium gas.

Test programs using sixteenth-scale tanks (Figure II-3) and 30- by 30-inch panel tanks (Figure II-4) were conducted for thermal and structural verification of the 0.8-inch insulation. Additional thermal tests were conducted with the S&ID banjo and comparator apparatus (Figures II-5 and II-6).

The structural tests were successful and indicated no degradation of the insulation components. An average thermal conductivity of 0.75 Btu-in./hr-ft^2 °F at an insulation mean temperature of -200 F was obtained from the thermal tests.

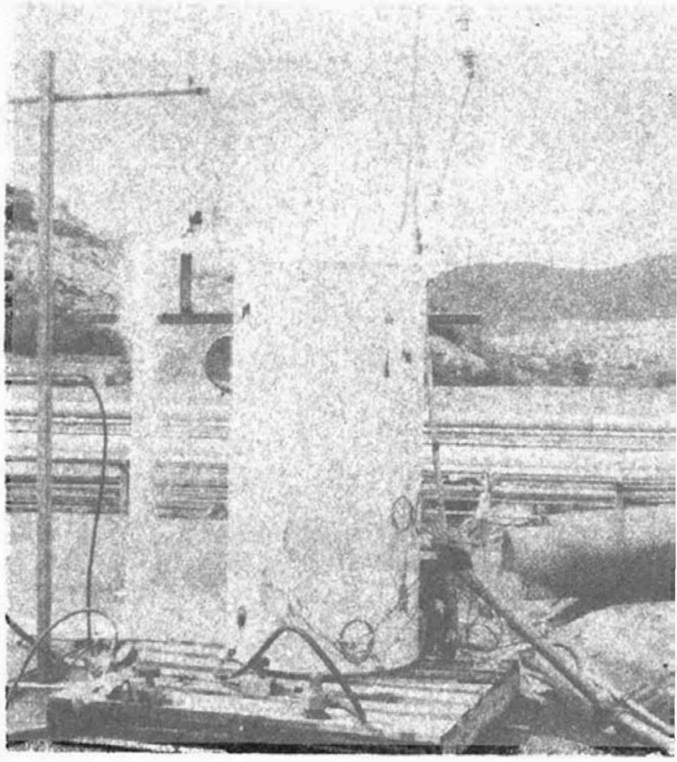

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Figure II-3. Sixteenth-Scale Tank Test of 0.8-Inch Insulation During LH$_2$ Testing

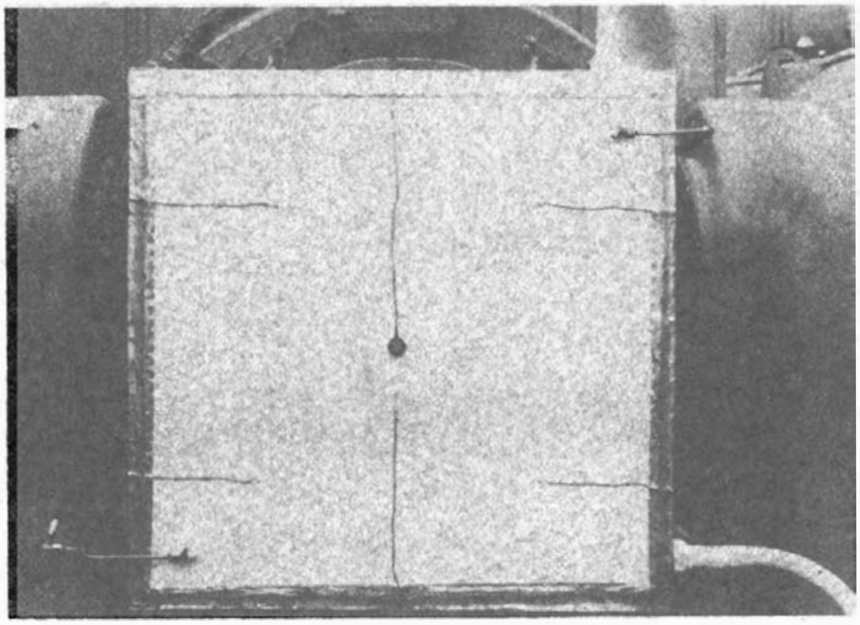


Figure II-4. Panel Test of 0. 8-Inch Insulation During LH_2 Testing

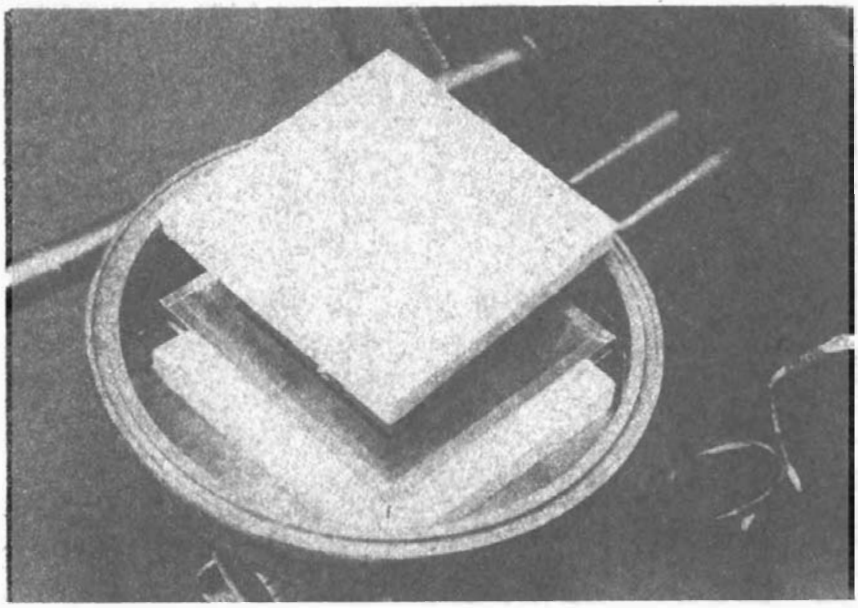
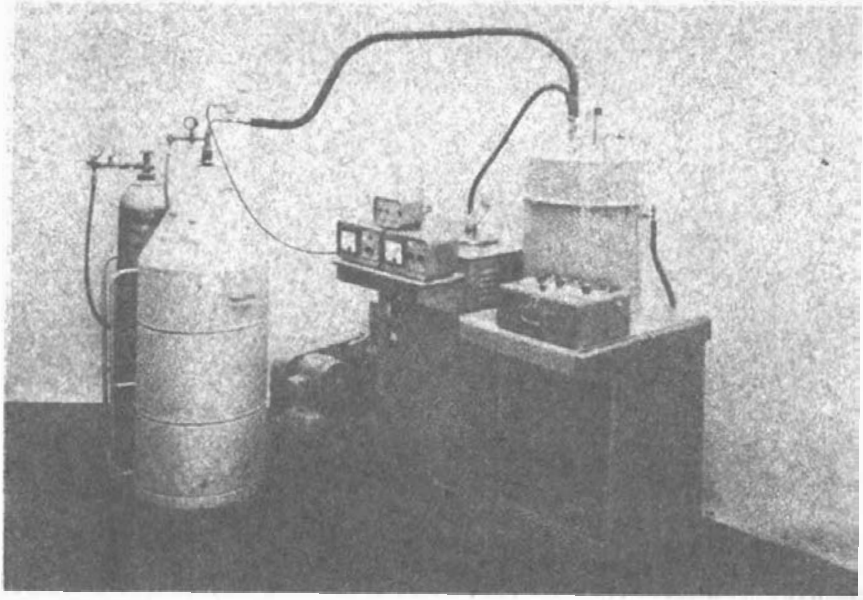


Figure II-5. LH_2 Banjo With Samples and Heater



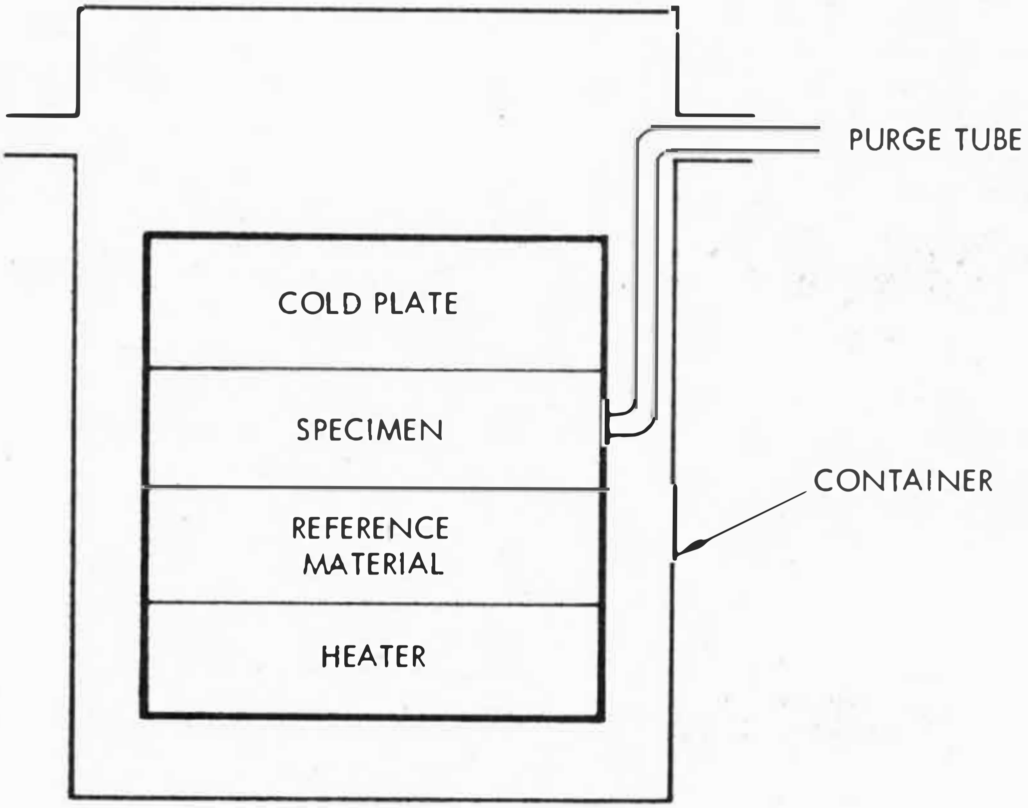


Figure II-6. Comparator Apparatus

Insulation of one-quarter scale tank No. 2 (Figure II-7) with the 0.8-inch insulation was completed, and the tank was set aside for future testing. Considerable experience, applicable to the 1.6-inch insulation, was gained in the fabrication of the insulation and in insulation repair techniques.

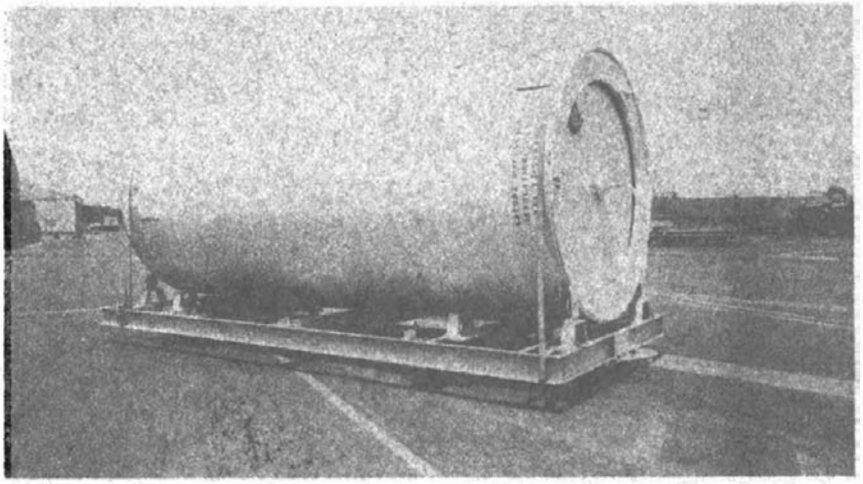

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Figure II-7. Quarter-Scale Tank 2 With 0.8-Inch Insulation

Insulation for S-II-1, S-II-2 and S-II-3

Flight stages S-II-1, S-II-2 and S-II-3 will incorporate a design essentially the same as the one for the nonflight stages except that the insulation thickness will be increased to 1.6 inches. This increase was necessary to meet the mission payload requirement in light of the additional phenomenon of thermal stratification in the liquid hydrogen and the final thermal conductivity tests of the insulation.

Verification testing of the 1.6-inch insulation was started on six 30- by 30-inch panels with successful results in each case. These tests were run at liquid nitrogen cold side temperatures.

The first four insulation panels were 3/4-inch and 3/8-inch core, used Aerobond 430, Type I and Type II adhesives, and were heated to 350 F and subjected to increases of pressure at increments of 3 psig until failure. Failure of the outer laminate at 17 psig occurred on the 3/4-inch cell Type I adhesive panel (Figure II-8). Failure of the edge seals at pressure above 17 psig occurred on the other three panels. There were no laminate skin failures on these three panels.

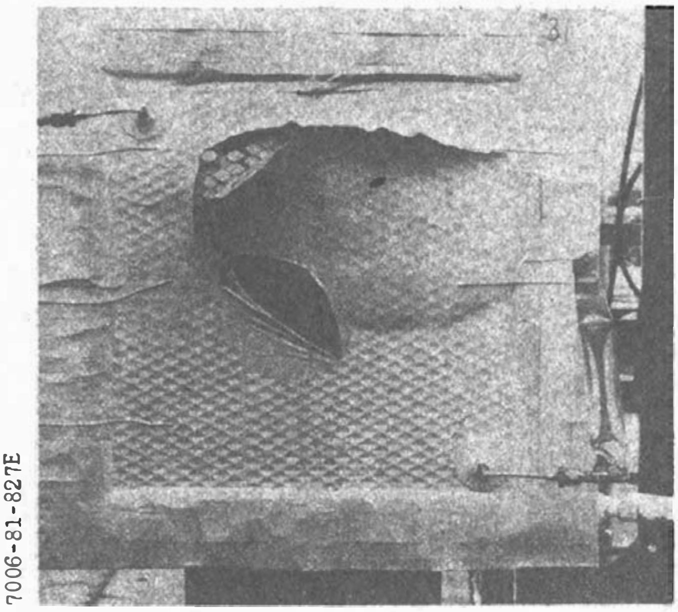

Figure II-8. LH_2 Test Panel Failure of 1.6-Inch Insulation at 17 Psig and 350 F Surface Temperature

On the basis of the first four tests, the insulation using 3/4-inch core and Type I adhesive was considered adequate and was further tested on panels 5 and 6. For these verification tests, the insulation was subjected to simulated aeroheating and pressure profiles (Figure II-9). No failures of any kind occurred.

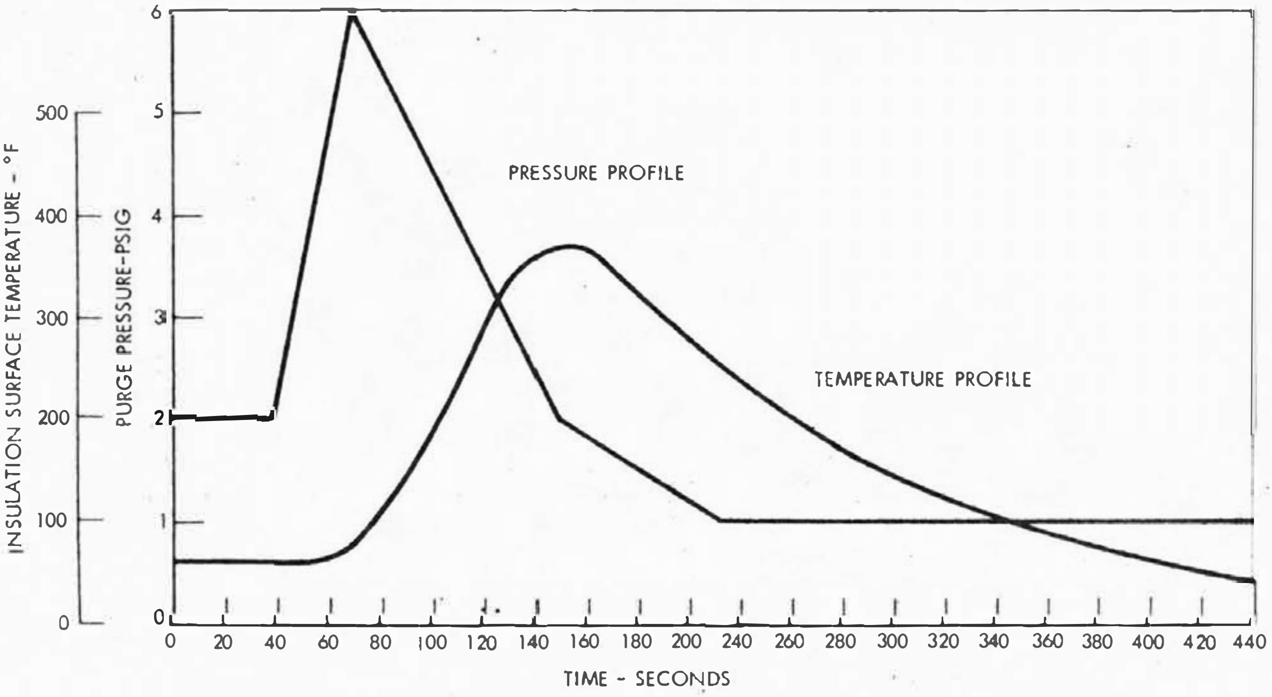

Figure II-9. Predicted Insulation Surface Temperature and Purge Pressure During Boost

Three additional 30- by 30-inch panels of the 1.6-inch insulation (3/4-inch core and Type I adhesive) were tested, with liquid hydrogen used as the cryogenic test fluid (Figure II-10). These tests, witnessed by NASA, were successful, with all three panels meeting every design requirement. This success was the direct result of knowledge and experience gained from previous tests. A major contributing factor was the close control of materials and fabrication techniques.

Because the supplier has no method of proof testing to demonstrate the quality of materials used and the proper fabrication of panels prior to bonding the insulation composite to the corresponding S-II tank section, the qual-

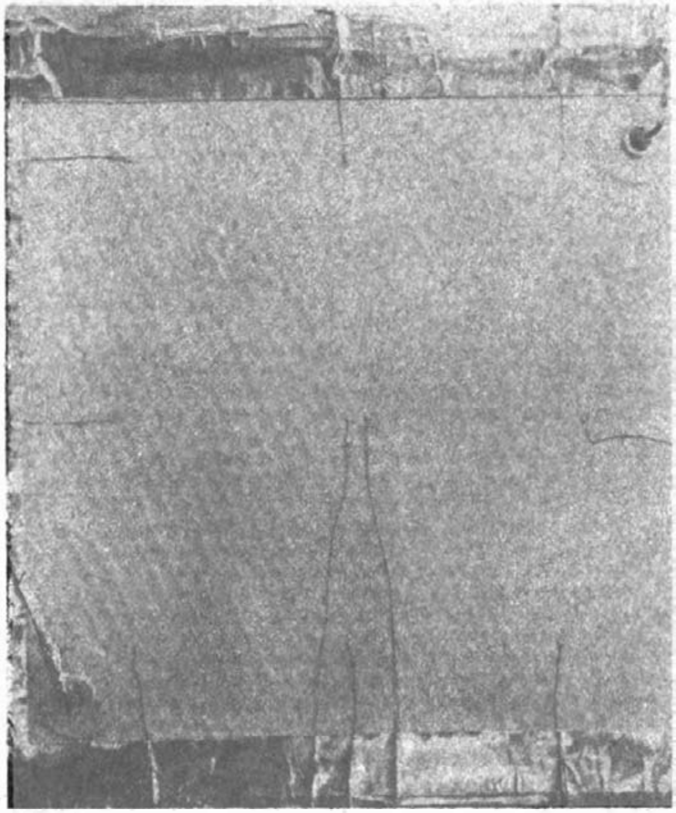

Figure II-10. LH_2 Test Panel After Temperature and Pressure Profile ity of materials and workmanship is entirely dependent upon the quality control and surveillance at the supplier's plant.

Insulation for S-II-4 and Subsequent

Alternate insulation concepts, variations of the 1.6-inch insulation, and the NASA double seal insulation are being studied for selection of an insulation system for S-II-4 and subsequent stages.

Design

The design effort described below shows the support given to the test programs and the goals achieved in conjunction with the stage insulation that would comply with the established LH_2 boiloff rates. The type of insulation that would most efficiently satisfy such requirements must undergo development.

Quarter-Scale Tank Test Program

Quarter-Scale Test Tank No. 1 - Insulation of this test article (Figure II-11) was completely installed. Because this insulation configuration was not to be used on the S-II stage, no insulation verification tests were scheduled. However, heat rate calibration tests at 100 F, 200 F, and 300 F surface temperatures were conducted as part of the stratification test program. The insulation laminate fractured under the heat rate tests, but no peeling of the insulation occurred (Figure II-12).

Quarter-Scale Test Tank No. 2 - Insulation on this test article is identical to the insulation applied on the test common bulkhead, as well as the S-II-T, S-II-D, and S-II-F stages. All of the required insulation detail, installation, and instrumentation drawings were released on 5 September 1963. A new tank structural drawing was submitted to suppliers for bids. The Southwest Welding and Manufacturing Company of Alhambra, California, was awarded the contract to build the tank structure. The tank was delivered to S&ID on 31 December 1963. The contract to fabricate insulation panels went to the Space Equipment Corporation of Torrance, California. S&ID installed the insulation on the tank on 10 July 1964.

Base Heat Shield

Description

The base heat shield is designed to protect the thrust structure and components from the hot gases exhausted from the J-2 engines during firing.

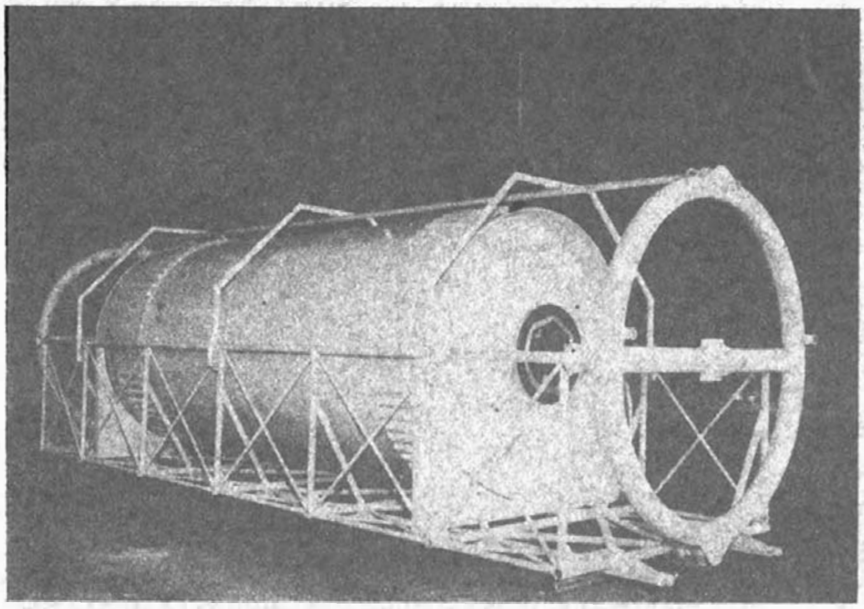
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Figure II-11. Quarter-Scale Insulation Test Tank 1

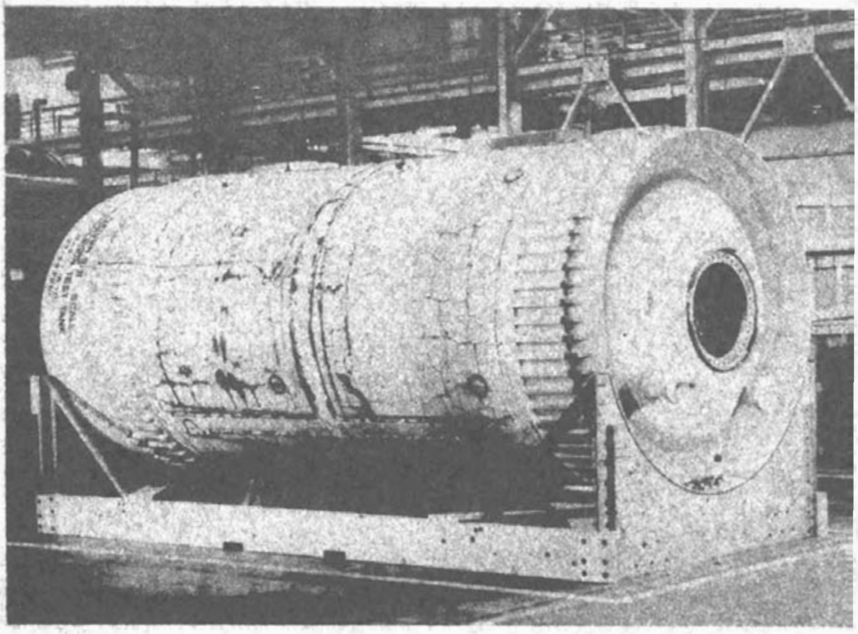
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Figure II-12. Insulation Laminate Fractured Under Heat Rate Tests

It is composed of a rigid panel mounted to the thrust cone structure and flexible curtains mounted to the rigid panel and attached to the J-2 engines. The rigid panel, made in four quadrants, is joined together by splice plates. The center engine flexible curtain comprises three panels, which will be joined together to close off the area surrounding the center engine. Each outboard engine has a separate flexible curtain. Approximately 180 degrees of the area surrounding each outboard engine is closed off. When the rigid panels and flexible curtains are installed (Figure II-13), the area above the heat shield will be protected from the J-2 engine hot gases to a diameter of 256 inches.

Design

The nominal diameter of the rigid shield was changed from 210 to 256 inches. This extension will give additional thermal protection to the thrust cone area (Figure II-14).

The rigid panel is being designed to incorporate instrumentation requirements for the base heat shield. Each quadrant of the panel will be designed differently because of the difference in size and location of instrumentation. Each panel will be designed with removable plugs. The instrumentation units can be added or removed as required to meet different requirements in flight instrumentation. With this concept, one heat shield design can be used for all flight stages (Figure II-15).

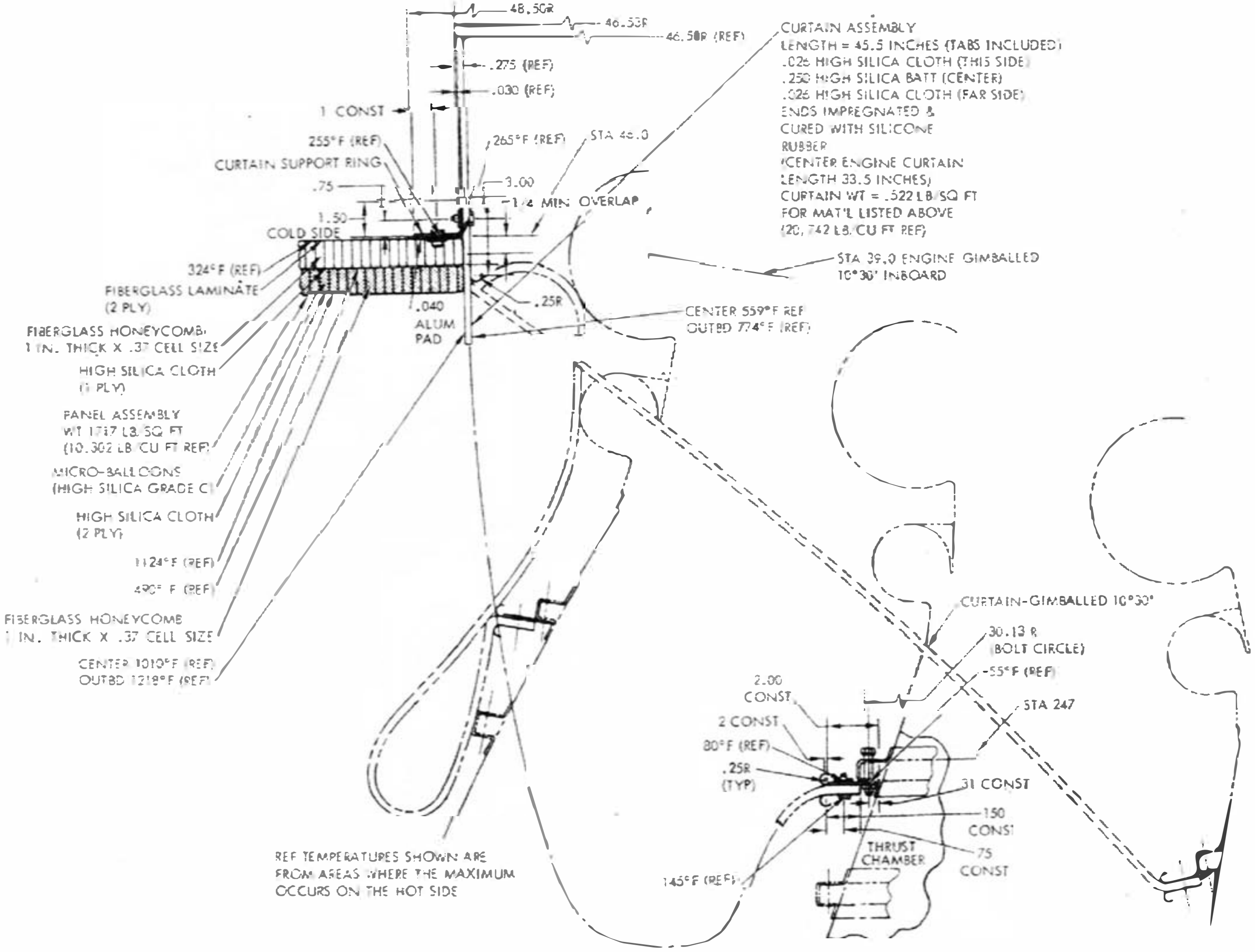
WEIGHT CONTROL

Weight and Balance Reporting

Regular weight and balance reporting for the S-II stage has been carried out by formal submittal of monthly status reports. The reports include forecasted specification weights for the first flight stage (S-II-1) and the first operational stage (S-II-4). The forecasted weights summarize the effect of pending change orders and contract specification amendments. The first issue of Mass Characteristics and Distribution for Saturn S-II Stage (SID 63-1130) was prepared and transmitted to NASA.

Weight Trends

During the reporting period, the specification weight forecast for S-II-1 increased from 81,227 pounds to 84,377 pounds. This net weight increase is due primarily to the following changes and additional system requirements:



REF TEMPERATURES SHOWN ARE FROM AREAS WHERE THE MAXIMUM OCCURS ON THE HOT SIDE

Figure II-13. Base Heat Shield Curtain Attachment

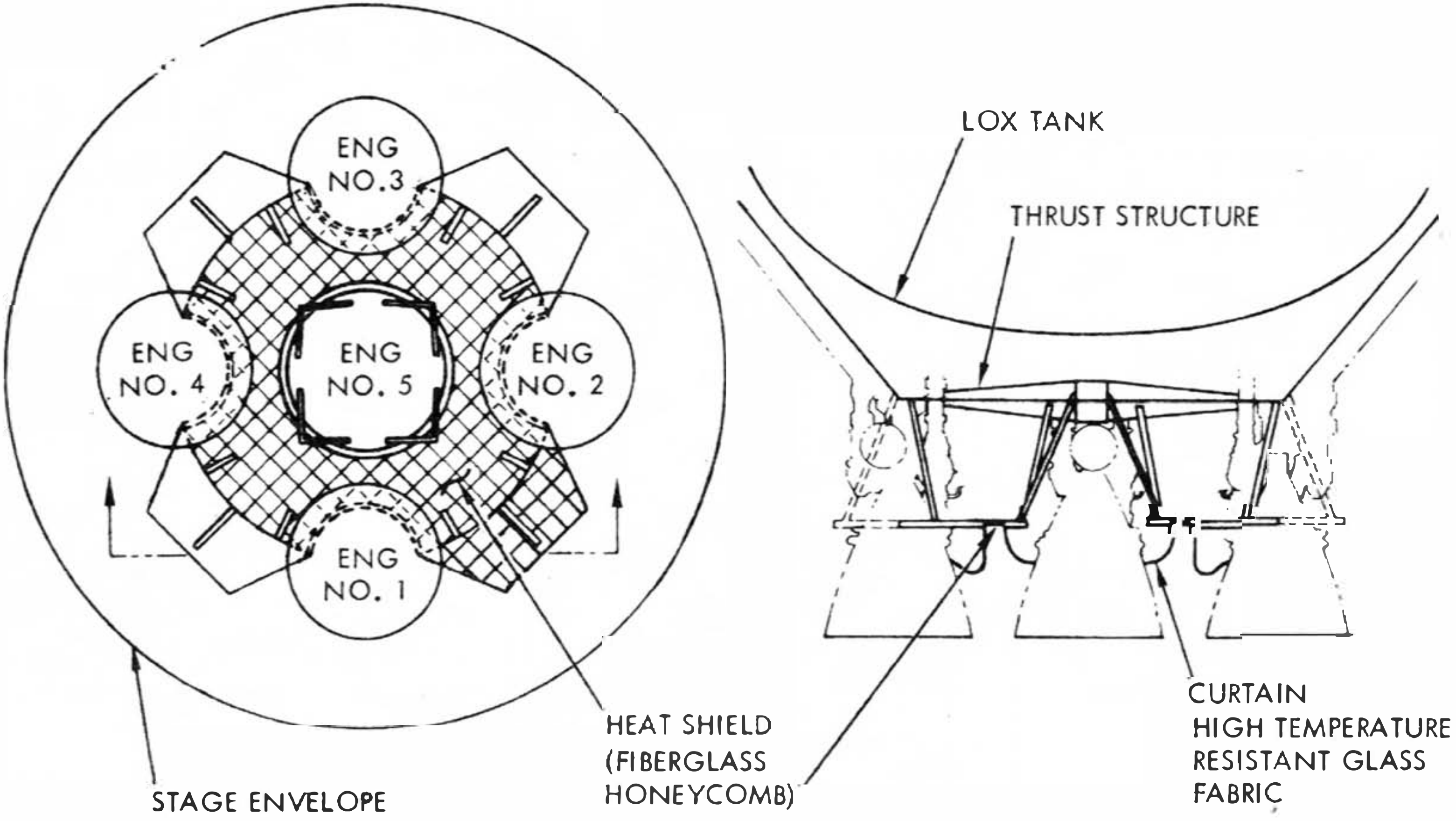


Figure II-14. Flight Base Heat Shield

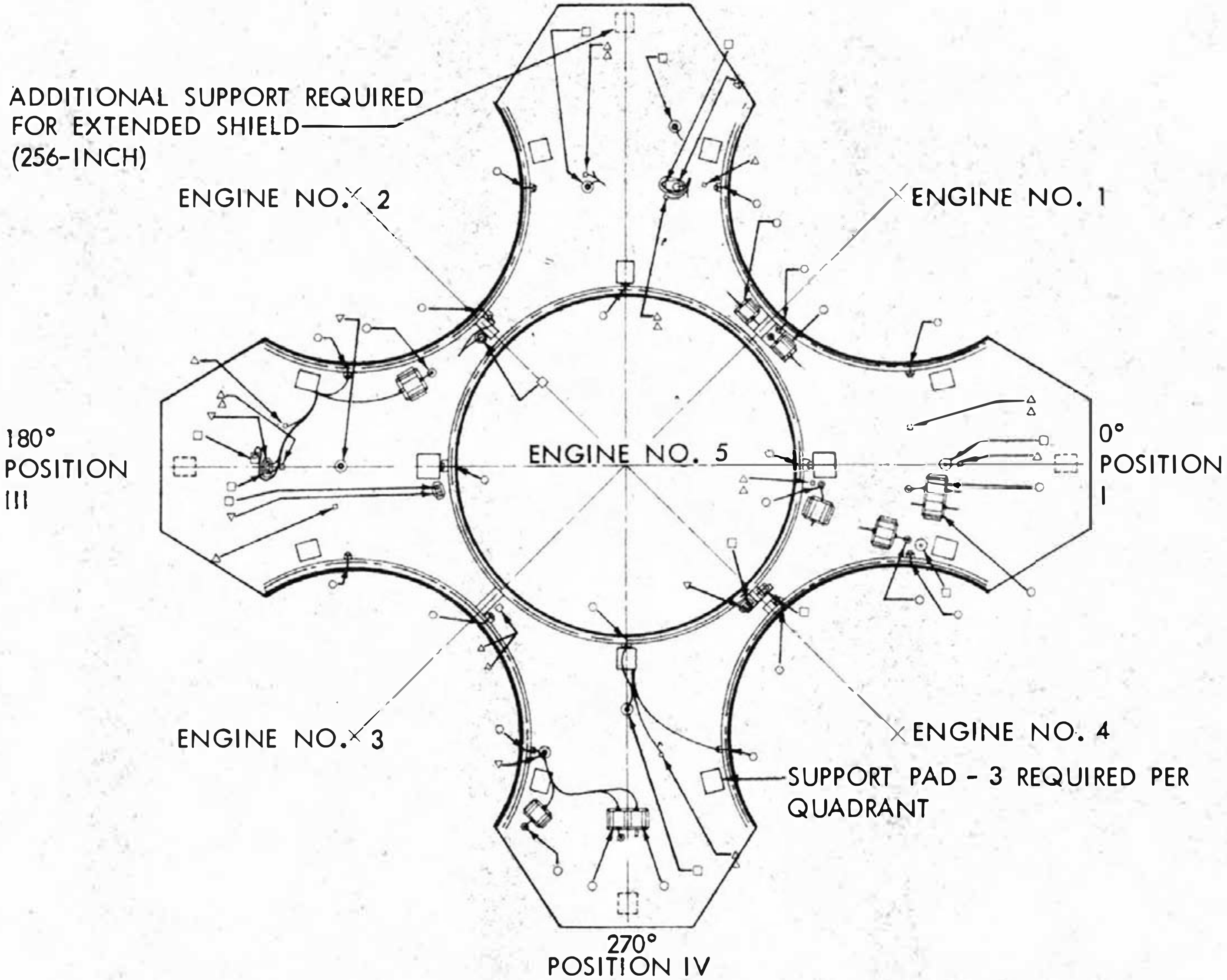


Figure II-15. Instrumentation and Extended Shield Outline - View Looking Aft

Item (S-II-1)	Weight Change (lb)
1. J-2 engine specification weight revisions	298
2. LH_2 tank insulation thickness change (Resulting from CO. No. 41 increases effected during this reporting period. Total CO No. 41 increases amount to 2439 pounds.)	1589
3. Addition of measurement requirements for S-II stage per TD 22, Revision 1 (1558MA), dated 4 December 1963, in conjunction with the flight measurement working agreement	825
4. Redesign of forward skirt for increase pressure differential (CO No. 40)	128
5. Tape recorders for flight stages (CO No. 117)	100
6. Redesign LOX slosh baffle structure (CO No. 107)	-330
7. Procurement of airborne digital data acquisition equipment (CCN No. 15)	129
8. Revised weight estimate for replacement of present thermal control system with a continuous flow GN_2 system (CO No. 21)	126
9. Implementation of control rate gyros and accelerometers (CO No. 34)	95
10. Redirection of S-V timing system design (switch selector) (CCN 11)	92
11. Miscellaneous change order numbers 22, 25, 30, 42, 44, 48, 58, 73, 84, 97, 99, 101, 103, 109, and TD 162-1.	98

An investigation was made of potential weight reductions that could be achieved by changes to design criteria, design concepts, and system requirements. A list of 18 potential items for weight reduction was identified, and rough-order-of-magnitude (ROM) proposals were submitted to NASA to present the approximate costs, magnitude of weight reduction, and earliest possible stage effectivity for each of the selected items. The following specific changes were approved by NASA for incorporation on the S-II-4.

Item (S-II-4)	Weight Change (lb)
1. Substitution of steel fasteners with titanium (CO No. 106, CRN No. 380)	-200
2. Combining of weight reduction proposals (CO No. 124, CRN No. 477)	-4100
a Reduction in maximum LH_2 tank pressure	
b Permission of a negative margin of safety up to seven percent and a positive margin not to exceed five percent	
c Material substitution for skirts, thrust structure, and interstage stringers and frames	
d Pressurization of the LH_2 tank during prelaunch to withstand 99.9 percent wind criteria on launch pad	
e Increase in propellant loading to 970,000 pounds, tanked to a mixture ratio of 5.275	
3. Elimination of propellant tank pressurization stored helium, (CO No. 110, CRN No. 399)	-465
4. Redesign of stage wiring gauge (CO No. 108, CRN No. 382	-360
5. Definition of operational stage instrumentation (CO No. 129, CRN No. 383)	-1092

6. Redesign of LOX tank center baffle (CO No. 107, CRN No. 381)	-140
7. Deletion of measurement requirements previously added to S-II-1, S-II-2, and S-II-3 stages	-825

These changes will reduce the forecasted specification weight for S-II-4 from 84,377 to 77,195 pounds.

Miscellaneous Studies

An investigation of weight saving possibilities associated with the use of Y section stringers on the skirts and interstage in place of the present hat section was conducted. Results indicated that a theoretical weight saving was possible for the basic stringer cross-section. But this advantage was more than overcome by additional weight of the more complex stringer end fittings and additional aerodynamic drag of the deeper cross-section, so that a net performance improvement was not achieved.

Current weight distribution characteristics were summarized for the entire Saturn V vehicle for use in body vibration modal analyses.

TESTING

Structural Static Test

Test loading conditions, order of loading applications, and test instrumentation required for each test loading condition have been finalized.

The test tower is complete, but must undergo modification of the frontal opening to allow for two directional shear load application.

Under the provisions of the Master J 1 Test Schedule, the test program will commence 1 January 1965 and terminate 31 December 1965. It appears that these dates will be met. Fabrication of the static test stage (S-II-S) is scheduled for completion 1 November 1964.

Test Common Bulkhead

Testing of the test common bulkhead will be performed at the Rocketdyne Propulsion Field Laboratory at Santa Susana. All sections of the test article and test jig are in fabrication and will be completed by 1 December 1964. Final instrumentation drawings have been approved.

A formal contract will be released to Rocketdyne in September 1964 for construction of the test facility. S&ID occupancy is scheduled for 2 January 1965; the start testing date is 1 March 1965.

Development Tests for the Alternate Common Bulkhead Design

During the reporting period, an alternate design approach was developed for the S-II common bulkhead. It permits bonding of the forward facing sheet to the honeycomb core in individual gore segments. Test programs to support design development and to verify structural and sealing integrity have been completed, and final summary reports are being prepared.

Two sandwich panel test specimens incorporating the riveted structural splice and welded strip seal design details were fabricated. These panels were subjected to 1000 cycles of loading from limit tension to limit compression stress level. Periodic inspection of the strip seal welds was performed with dye penetrant used to check for weld cracks; no evidence of cracking was indicated throughout the program. After completion of the repeated load cycles, the panels were loaded in edgewise compression to failure; both panels exhibited ultimate failure stresses in excess of design requirements.

Another design concept to seal the upper facing sheet of the common bulkhead is to employ an all-welded membrane shell that would rest over the structural assembly. However, it is impossible to provide a perfect fit for this membrane shell to the upper facing contour. Therefore, the buckling behavior of a thin membrane shell under collapsing pressure and with some clearance to the supporting substructure becomes a matter of concern. A model test program was conducted to evaluate structural behavior.

A 55-inch diameter sandwich model bulkhead of ellipsoidal contour with electrodeposited nickel facing shells as the supporting substructure was used for testing. Thin membrane shells were fabricated of electrodeposited nickel material and fitted over the model bulkhead in a special test fixture that permitted controlled variation of gap between the membrane shell and supporting bulkhead. The test fixture with model bulkhead installed is shown in Figure II-16.

Twenty-five cycles of collapsing pressure were applied at an initial gap of 0.050 inch between the membrane shell and model bulkhead. The gap was then systematically increased in 0.040-inch increments, and the pressure cycles were repeated until the model was permanentely damaged. The typical golf-ball buckle patterns developed in the membrane shell is shown in Figure II-17.

In tests of the first few specimens, cracks occurred at the equatorial edge of the seal so that the desired collapsing pressure could not be

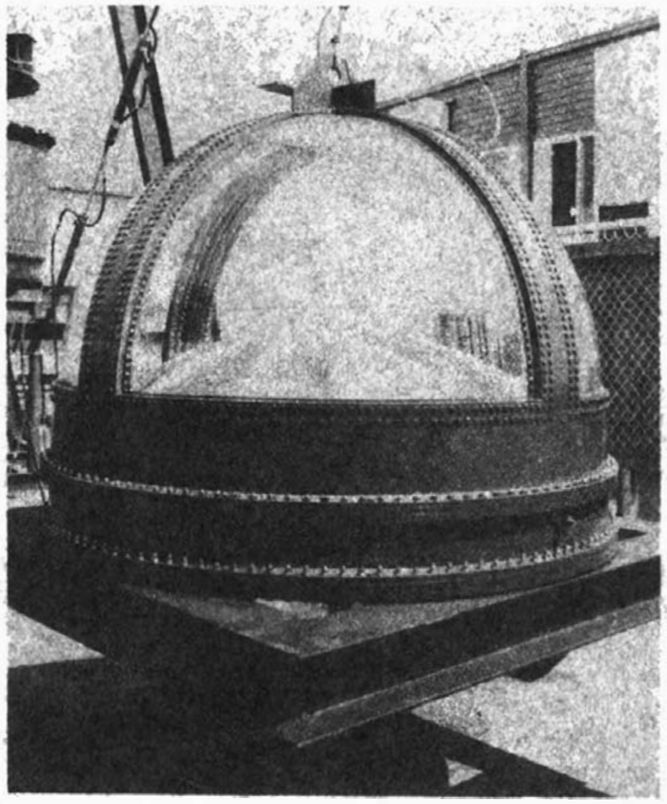


Figure II-16. Membrane Seal Test Setup

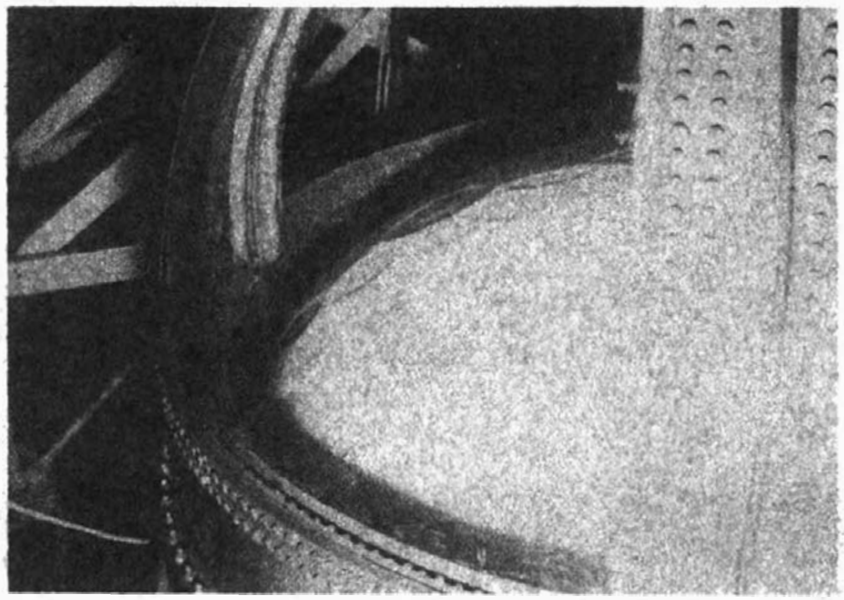


Figure II-17. Buckle Patterns After Membrane Seal Test maintained. These cracks were considered to be due to the geometry of the test specimen and to the brittle nature of the electrodeposited material, and were not representative of a failure mode that would occur on the full-scale article. The test fixture was therefore reworked to modify the edge support and sealing provisions, and further testing proceeded satisfactorily.

The J-ring and trough seal equatorial joint configurations proved satisfactory in tests, with the complete range of pressure cycles up to a maximum gap of 0.33 inch being sustained before permanent damage occurred. This value corresponds to a full-scale gap of approximately 2.25 inches. It is therefore concluded that the membrane seal design concept will exhibit satisfactory structural behavior.

LH_2 Tank Panel Tests

A test program involving large full-scale curved compression panels representing a portion of the LH_2 tank wall was implemented. Three identical panels approximately 15 feet high and 18 feet wide were fabricated, instrumented, and shipped to the test contractor. The test panels incorporate a circumferential weld and stringer splices at the midsection; typical frame segments are also installed to divide the panel into five equal bags of 36-inch length. The panels will be loaded in axial compression until primary buckling failure occurs. If the structural capability of the test panels is verified to equal or to exceed design requirements in the critical prelaunch loading condition, it will be possible to save approximately 50 pounds in the structural design of the LH_2 tank. A contract was negotiated with Lockheed Missiles and Space Company, Sunnyvale, California, to perform the panel testing in the large test machine at the University of California at Berkeley. Lockheed has conducted a number of similar tests as part of its RIFT development program, and the test loading and support fixtures designed and fabricated for that purpose are directly applicable to the present program. Testing of the first panel is scheduled for 17 July 1964, with completion of the last panel scheduled for the first week in August.

Cryogenic Shock Tests

Operational experience with the S-IV stage has indicated problems of weld cracks and local buckling of the forward facing sheet of the common bulkhead, problems believed to be primarily caused by thermal stresses resulting from severe temperature gradients during propellant loading. A limited test program was therefore initiated to evaluate whether similar problems could occur on the S-II common bulkhead. Three 24 by 24-inch sandwich panels were fabricated in a manner to simulate common bulkhead construction.

Typical weld and weld land intersections were incorporated in the center of each panel. A flow of liquid helium (-450 F) was suddenly imposed over a local area centered on the weld intersection, so that maximum thermal shock and temperature stresses would be concentrated in this critical region. Ten thermal shock cycles were applied to each panel; ultrasonic inspection of the bond between facings and core and dye penetrant inspection of the welds to detect cracks were conducted at regular intervals. No evidence of damage to welds or adhesive bond was detected in any specimen throughout testing. The panels were loaded in edgewise compression after the thermal shock cycles; no influence of the thermal history on ultimate allowable compression stress was indicated.

Burst Tests

Burst tests of cylindrical tank specimens constructed of 2014-T6 aluminum alloy and incorporating typical weld joint details were initiated. Their purpose was to verify that the design allowable strengths for weld joints determined from conventional uniaxial tension tests are applicable to the design of S-II propellant containers, in which biaxial stress conditions exist. The test program covers 42 burst cylinders, including smooth specimens and specimens in which typical weld land details are incorporated. Seventeen specimens will be tested at room temperature with water used as a pressurizing medium; 25 specimens will be burst tested with LH_2. To date, five specimens have been tested at room temperature and seven at LH_2 temperature. All tests to date have been on smooth specimens. Test results indicate failure stresses that are somewhat below the average of corresponding uniaxial control specimens; however, data obtained to date are not considered adequate for drawing firm conclusions or for revising the weld design allowables with confidence.

Material Properties Tests

The basic test program to determine material properties for parent metal, welds, adhesives, and sandwich assemblies was completed in the previous reporting period. Various detail design and fabrication problems have required additional specific test investigations during this reporting period.

Initial test results of weld specimens indicated a strong dependence of weld strength on joint offset; however, data over the complete range of interest were not available. Additional testing was performed for the ranges of offset in which data were lacking, and results confirm the original indication and establish a linear reduction in weld strength with increasing joint offset.

The properties of manual weld repairs of blow-holes are being evaluated. This type of defect was encountered in the fabrication of the S-II-S; corrective action applied to the welding processes should nearly eliminate the occurrence of this type of defect. However, it would be prudent to develop and qualify a repair procedure for application to subsequent stages in which cryogenic service is a requirement. The current program includes uniaxial tension and biaxial bulge tests at room and cryogenic temperatures.

The shear strength for a range of thickness of 12 lb/cu ft Fiberglass HRP core was determined for application to the closeout area between forward and aft facing sheets of the common bulkhead. A solid Fiberglass-phenolic filler strip was originally planned for this area. However, a considerable variation of thickness would result from contour deviations of forward and aft facing assemblies, with consequent difficulty in machining the filler strip to obtain proper fit. The use of high density honeycomb core in this area greatly simplifies the machining problem of matching the contour of the facing assemblies; it will also provide superior shear strength to facilitate the transfer of load from the forward to aft facing assembly.

CRYOGENIC SEALS AND JOINTS

The engine, propellant, and pressurization systems require approximately 290 cryogenic and hot gas seals per stage. The leakage requirements established for the seals and joints were based on maximum safety conditions.

Requirements

The cryogenic seals are exposed to LH_2 temperatures ranging from -423 F to +190 F. The hot gas seals must operate over a range from -320 F to +860 F.

Analysis and Design

Flanges and seals were designed especially to meet the aforementioned temperature ranges while being exposed to vibration, temperature cycles, and proof pressures to 6,500 psig. The extremely low leakage rate sought, 10^{-4} cubic centimeters per second per linear inch of seal, necessitated a very rigid, low-deflection flange design.

Summary

The seal and joint design verification test program is nearing completion. Various combinations of seal coatings were applied over a metal base. The following coatings were tested for cryogenic and hot gas seals:

1. Cryogenic

    Teflon
    Lead-coated K-6 alloy

2. Hot gas

Copper
Gold
Silver with nickel plated flanges
Gold alloy (2 percent Indium)
K12 alloy

Teflon coated seals were tested at cryogenic temperatures, and silver coated seals were tested at elevated temperatures. On the basis of the testing, a seal coated with a teflon-silver combination should offer considerable reduction in a leakage rates. Briefly, teflon over silver provides one coating for the low temperatures and another for the high temperatures. The soft teflon coating will provide sealing for the low temperatures. As the temperature approaches the 860 F, teflon will break down. The silver will then become soft and provide sealing. As the temperature returns to the cryogenic range, the metallic coating will have molded itself to the flange faces to form a seal. Any future testing will be concentrated on the teflon-silver seal coatings, since these coatings have had the best test results so far. However, the leakage rate of 10^{-4} cc per second per linear inch of seal circumference has not been attained in dynamic tests with temperature cycling. The effects of slightly relaxing the leakage rate requirements are now being studied.

Special cryogenic test facilities have been constructed for the seal testing program. Figure II-18 shows a portion of the remote-controlled

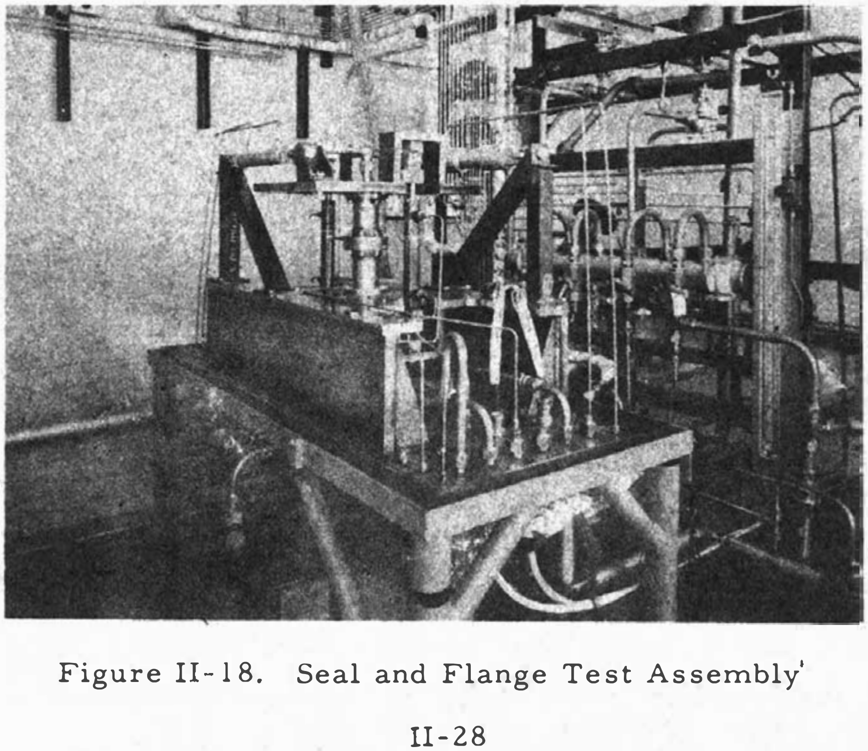

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Figure II-18. Seal and Flange Test Assembly test area for checking leakage rate, flange deflections, and dynamic loading at LH_2 temperatures (-423 F). A seal and flange assembly being tested may be seen in the left center of the picture. The test stand is covered with a partially evacuated hood during testing. The remote monitoring controls and recorders are located in an adjacent room of the cell where the test may be observed through ports.

TUBULAR WELD JOINTS

Reliability and weight restrictions for the S-II stage necessitated development of lightweight zero leakage plumbing connections. Preliminary investigation indicated that metallurgical processes — e.g., fusion welding would be the most effective production method for making them. The cryogenic environment imposed on the Saturn S-II stage propulsion system by the advent of liquid hydrogen technology creates severe design and operational requirements for tubular weld joints. Therefore, the requirement was created for the design, manufacture, and testing of tubular weld joints. Requirements of tubular weld joints are as follows:

1. Selection of materials capable of withstanding the environmental and operating conditions on the S-II stage
2. Selection of a practical preweld joint design for fabricating tungsten-inert-gas (TIG) weld joints in 304L stainless steel tubing
3. Development and selection of miniature TIG welding equipment for making in-place tube joints in S-II systems
4. Development and selection of in-place flaring tools
5. Selection of an acceptable method of inspection
6. Subjection of welds to temperature ranges of -423 F to +860 F while being exposed to vibrational temperature cycles and proof pressure up to 6,500 psig

Test Program

Type 304L stainless steel tubing was used for making all of the welded test specimens. The nominal dimensions of the tube specimens were 1.0-inch OD by 0.049-inch wall; 2.0-inch OD by 0.040-inch wall; 1.5-inch OD by 0.120-inch wall; 3.0-inch OD by 0.080-inch wall; and 8.0-inch OD by 0.040-inch wall.

The tube ends were flanged with high energy-type tooling used for tube sizes up to 3.0-inch diameter. For the larger diameters, the tube ends were red on a lathe. A manually operated flaring tool was designed and fabricated for experimental in-place flaring of 0.500-inch OD tubing. Miniature TIG welding equipment (Figures II-19, II-20, II-21, II-22) was developed and used throughout the test program. Approximately 200 304L tube joint specimens have been fusion welded with the in-place weld equipment.

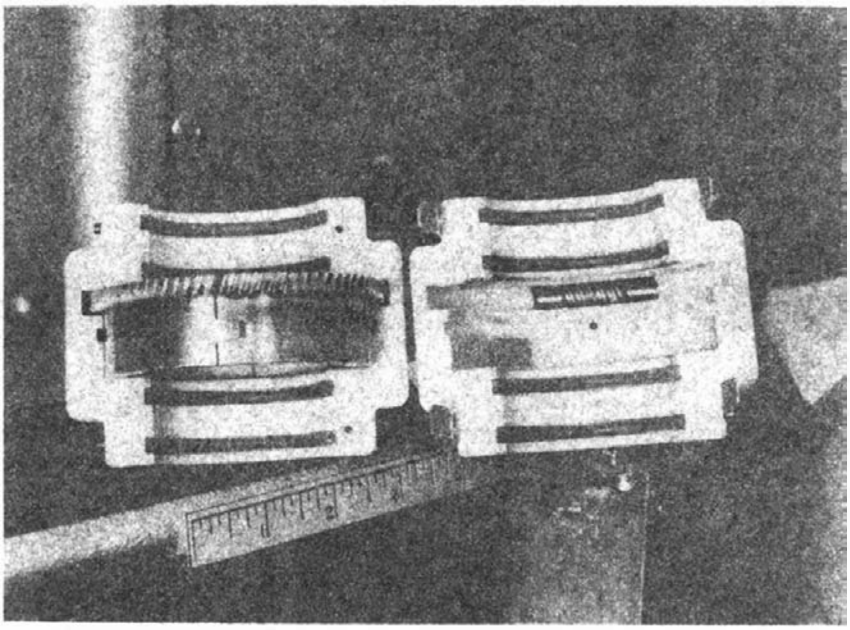

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Figure II-19. Internal Mechanism of Miniature Tube Weider

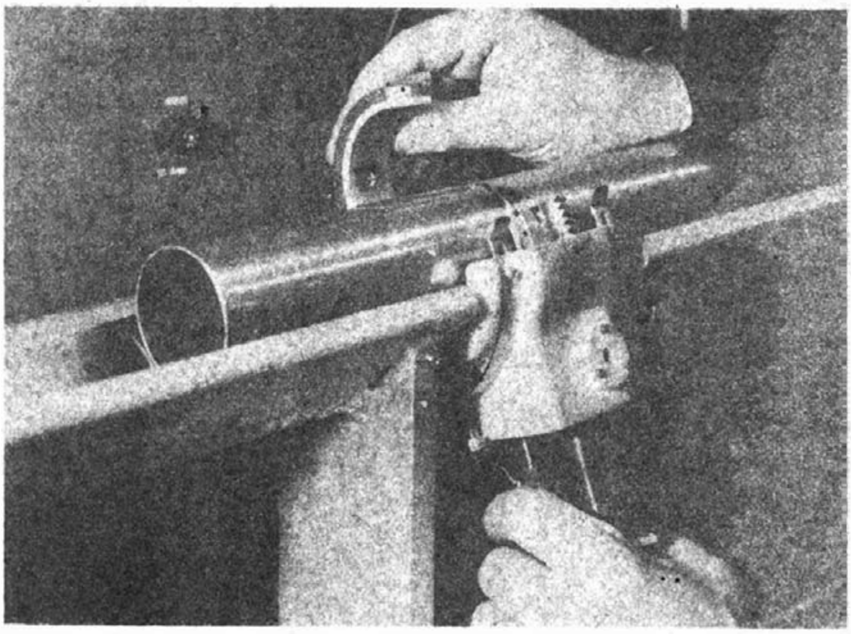

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Figure II-20. Placing Ring Gear Segments Around Flanged and Tacked Tube Joint

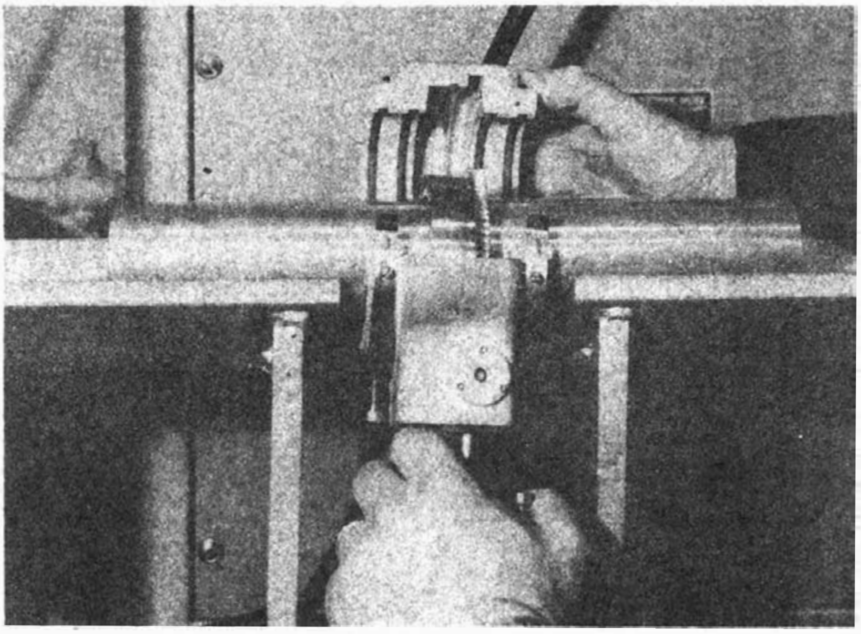


Figure II-21. Placing the Cover Around Ring Gear

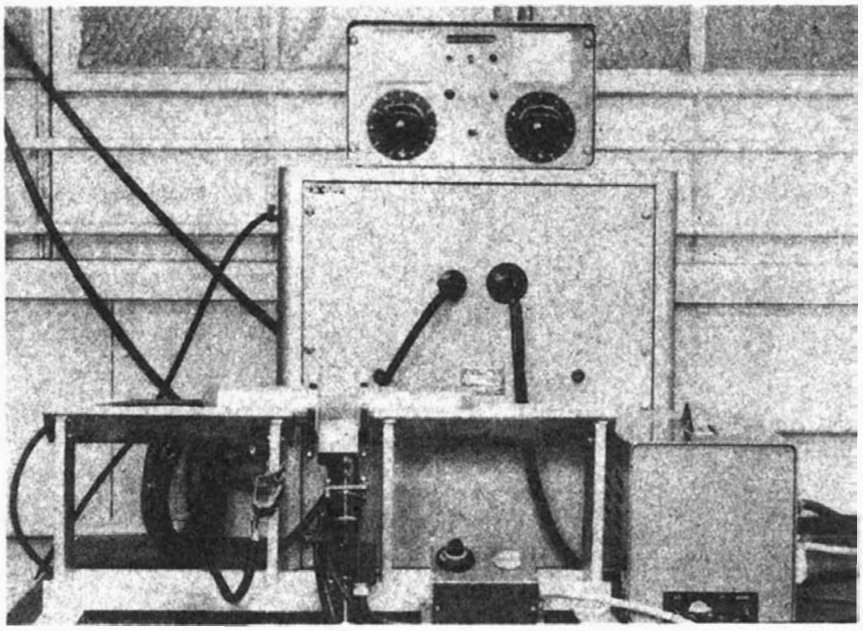
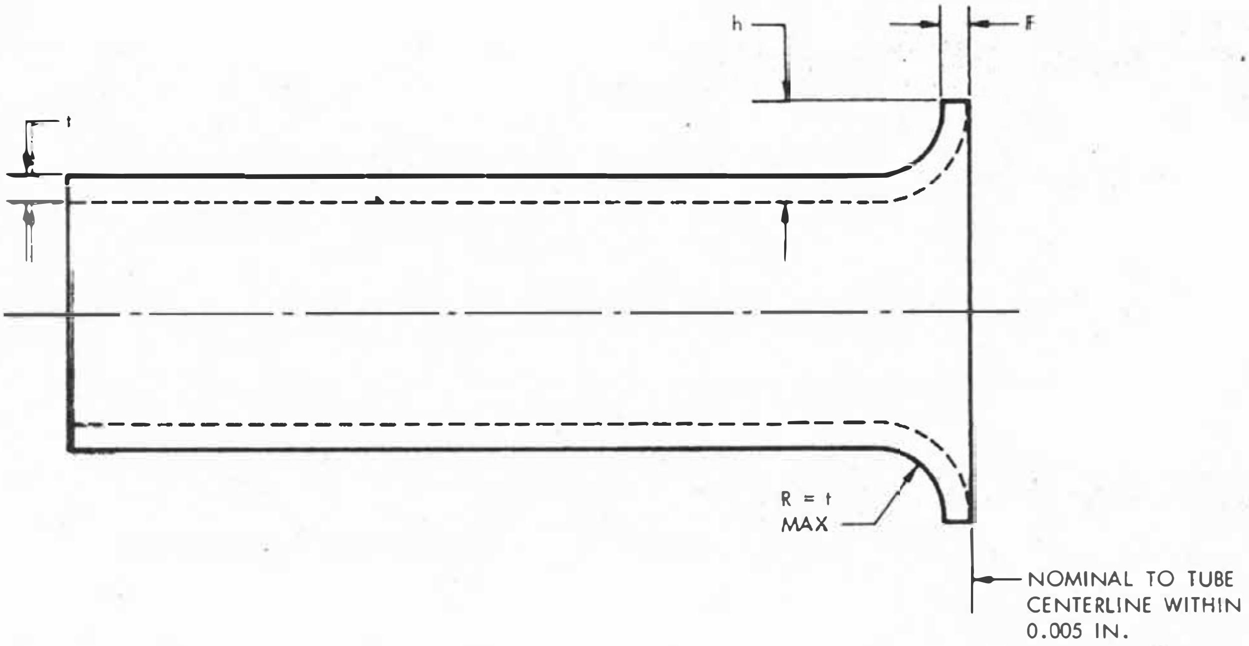


Figure II-22. Miniature Tube Welder Clamped Around Joint During Welding



NOMINAL TUBE WALL THICKNESS	FLANGE
IN INCHES: 0.020 0.028 THROUGH 0.125	F IN INCHES: 0.016 + 0.003 - 0.000 0.025 + 0.005 - 0.000
t IN INCHES: 0.020 0.028 0.035 0.049 0.060 0.083 0.125	h IN MINIMUM INCHES: 0.027 0.030 0.030 0.030 0.030 0.040 0.060

Figure II-23. Flange Butt Joint Dimensions

Techniques were established for welding type 304L stainless steel tubes. The tube ends to be butt-welded were flared as shown in Figure II-23. Automatic in-place TIG welds were made with the flared ends of the tubes providing the filler metal for the weld.

Uniaxial mechanical property tests of the welds were completed at -423 F, room temperature, and +280 F.

Internal pressure tests were completed at temperatures of -350 F to -423 F, room temperature, and +280 F.

Test Results

All welded specimens were radiographically inspected and were tested with a Veeco leak detector. None of the leak tested specimens exceeded the specified maximum rate of 1×10^{-6} std cc He/sec. All dynamic test specimens that were tested at room temperature, -423 F, and +280 F, exhibited internal pressure strengths and leakproof joint integrity that will meet engineering design requirements.

The test program on tubular weld joints was completed 28 February 1964. The final report, which gives test results in more detail, was released in May 1964.

SYSTEMS

MEASUREMENT SYSTEM

The S-II measurement system includes the signal conditioners, instruments, telemetry, and auxiliary equipment necessary for collection of stage data during flight. Major components are shown in Figure II-24.

Signal Conditioners

Development and packaging design on signal conditioners and associated equipment required for test programs and flight vehicles is approximately 80-percent complete. Design documentation is approximately 70-percent complete, and engineering evaluations approximately 10-percent complete. Total converter development now includes two power supplies, two attenuators, one differentiator circuit, nine converter and/or transducer simulator designs for test mockup, four tachometer-flowmeter converter designs with associated calibration sources, one acoustic converter and calibration source, one mixer circuit for discrete voltage measurements, and a complete temperature bridge system. Twenty-three acceptance checkout specifications and numerous electrical-component specification control drawings have been released in support of the development effort.

Instruments

Approximately 95-percent of the total flight-instruments procurement specification was completed by the end of June, with the completion and release of 29 additional specifications and specification control drawings.

Proposals were solicited on 14 specifications; 13 evaluations were completed, and suppliers were selected. Major design reviews were held on four specifications. In anticipation of the hardware phase of the S-II program, 29 process specifications for calibration and bench checkout were completed and issued. Laboratory test procedures for engineering evaluations were established for 14 items, and 11 engineering evaluation tests were completed.

Instrumentation program and components lists were released for the EMM, S-II-T, S-II-F, S-II-1, -2, and -3. Measurement systems test and checkout specifications were completed and released for EMM, S-II-T, S-II-F, and Battleship.

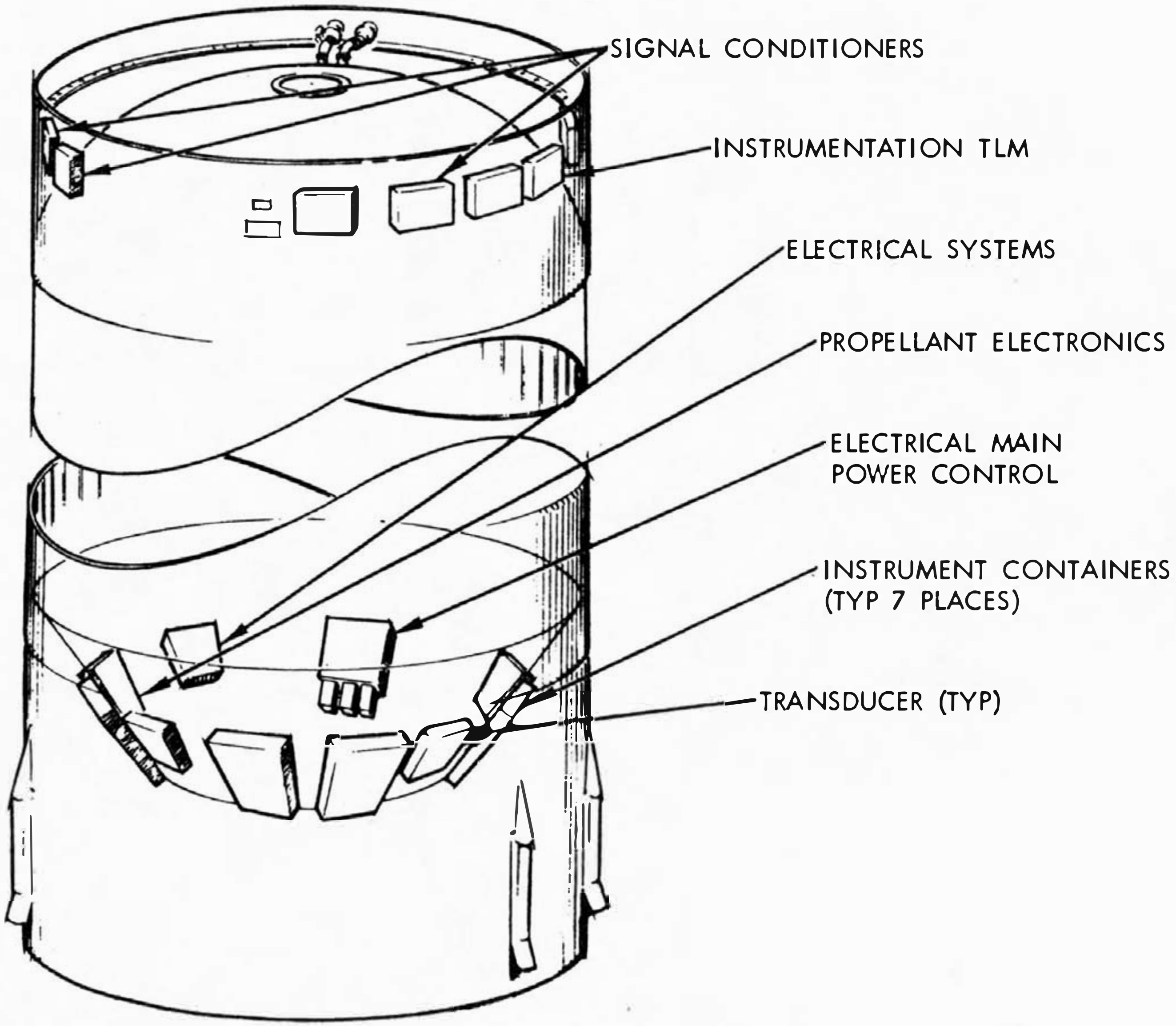


Figure II-24. Measurement System

Telemetry

System Design

The telemetry subsystem designs were updated several times to include new requirements. MSFC directives and other system design improvements were incorporated. Single-point grounding of the PAM-FM and PCM/FM subsystems was accomplished.

Systems compatibility tests were performed on components procured from suppliers as well as on breadboard models of components not yet received. Engineering laboratory test consoles were designed and fabricated to support continuing systems testing.

Hardware Procurement

Twelve subcontracts were placed for telemeter subsystem component packages for use on the EMM and the All-Systems stage, and in the engineering laboratory. Four types of components received are being tested in the engineering laboratory.

Specification control drawings (SCDs) were released for 11 telemeter subsystem component packages for use on flight stages.

An off-the-shelf low-level amplifier and wide-band amplifier were procured for evaluation for use in the MSFC directed FM/FM telemeter oscillator assembly and low-level time-division submultiplexer respectively.

Evaluation Tests

Performance and operating tests were performed on four major components received from suppliers - the single side band multiplexer, the PCM/DDAS assembly Model 301, the Model 270 time-division multiplexer, and the vibration multiplexer. Evaluation tests were performed on three mixer amplifiers, two low-level amplifiers, and one RF tramsmitter, all of which are off-the-shelf items. Breadboard evaluation tests were performed on the most critical parts of the SS/FM, the PAM/FM/FM, and the PCM/FM telemeter subsystems. The results of laboratory tests were coordinated with MSFC as the tests were completed. The resulting telemetry equipment design changes were incorporated into the MSFC documentation through the use of MSFC advance engineering orders.

Laboratory Equipment

Test panels to support component tests were designed and fabricated. Telemeter discriminators, a PAM and PCM decommutator and a single sideband demultiplexer were received. The laboratory was completely equipped with such auxiliary equipment as oscilloscopes, power supplies, voltmeters, counters, RF generators, etc.

Installation Design

System installation and wiring documentation, drawings, and lists were completed for the EMM (Configuration X) and for the initial configuration of the All-Systems test stage.

System wiring documentation for the facility checkout stage, S-II-F, was completed. System installation drawings for S-II-F and system installation and wiring documentation for the first powered flight stage were started and are on schedule.

Recoverable Camera System

A recoverable camera system was added to the S-II stage.

System design concepts have been established and effort necessary to implementation of them is under way. Designs under way include component installation, wiring diagrams, capsule ejection subsystem, control circuits, system checkout equipment, and measurement instrumentation. Studies of camera-capsule ejection and re-entry and in-flight photography are in progress. Requirements for 20 specification control drawings have been established. A test which evaluated tracking light requirements by photographic means was completed, as well as tests of control-circuit latching relays and timer input trigger levels. The results of these tests have been used in the system design.

Hardwire Instrumentation System

The hardwire instrumentation system includes the basic static firing measurement program and hardwire special data measurements for Battleship, the All-Systems stage, and the flight vehicles at the Mississippi Test Facility. In addition, it includes the off-stage measurements for Battleship and All-Systems test programs.

System Design

Phase I documentation of the system design has been completed for the implementation of the hardwire instrumentation system, including transducer installation and procurement, signal conditioning design, and recording capabilities.

The point-to-point design requirements for the implementation of the hardwire system for Battleship and All-Systems stages have been 100-percent released.

Hardware Procurement

Specification control drawings and procurement specifications were released for Battleship and All-Systems required static-firing transducers, signal conditioning equipment, and the drag-in type of cables. Approval is pending on the pressure and accelerometer specifications.

RF SYSTEMS

RF systems installation is shown in Figure II-25.

MISTRAM Tracking Aid

Two production-model transponders (GFP) and the latest configuration test set (GFP) have been received and used in formulating post-installation checkout specifications. The electronic test equipment required for checkout of the portable MISTRAM test set has been received. A two-week MISTRAM system analysis course was conducted by General Electric Corporation at S&ID, Downey.

RF Transmission Lines

Three specification control drawings have been released, and contracts awarded for coaxial cable assemblies, coaxial connectors, and RF umbilical connectors.

The S&ID method for closed-loop checkout of the telemetry and range safety command systems during umbilical drop tests was approved by MSFC, and design changes were incorporated into the S-II stage.

Range Safety Command

Range safety command receivers (GFP) refurbished for the new 450-megacycle carrier-frequency assignment have been received at S&ID. The range safety command post-installation checkout specification has been released for the EMM and S-II-T. Engineering evaluation laboratory tests necessary for integration of the range safety command receivers and associated antenna system components are in progress.

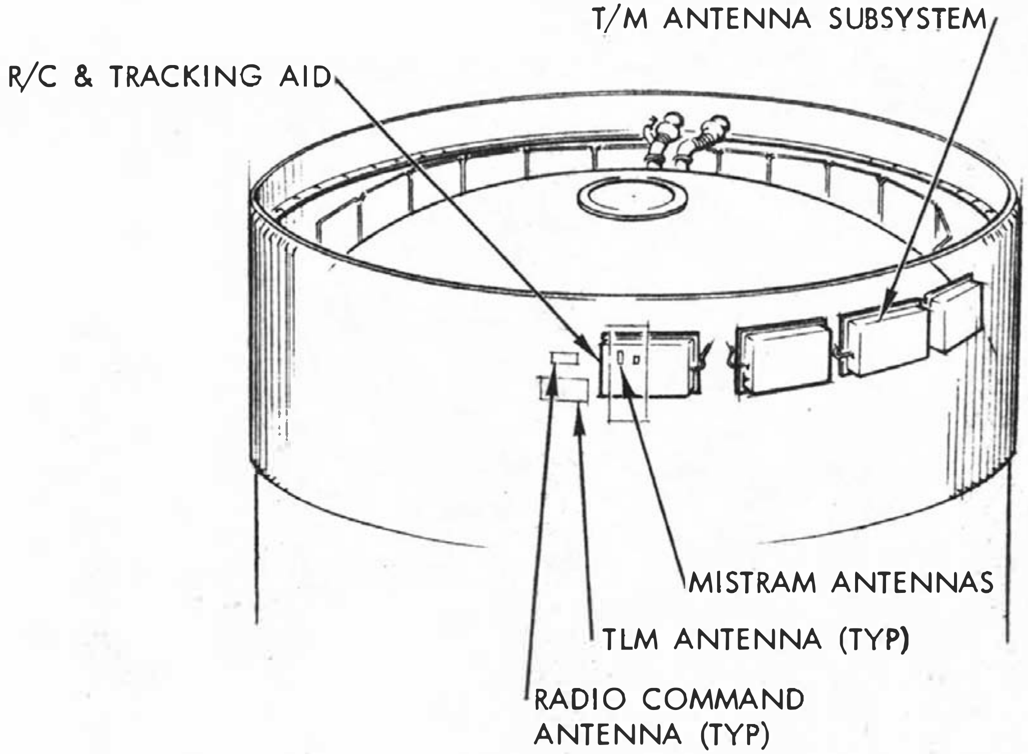


Figure II-25. RF Systems Installation

S-II Antenna Subsystems

Procurement specifications were released, and purchase orders were placed for all components required for range safety command, telemetry, and MISTRAM antenna subsystems. Engineering laboratory component evaluation tests were conducted, and bench checkout process specifications were prepared for each component. Work on integrated antenna subsystem tests was initiated, and the effort is 50-percent complete. Some of the components are presently undergoing qualification testing. Feed networks, especially developed to simulate S-II range safety and telemetry antenna systems,- were used for scale-model tests (Figure II-26). Radiation patterns for both systems were taken and reduced for contour plot presentation. The test results satisfy the contractual requirements for omnidirectional radiation coverage.

The production MISTRAM antenna assembly was received (Figures II-27 and II-28), and radiation patterns tests were initiated (Figure II-29).

PROPELLANT DISPERSION SYSTEM

Description

The propellant dispersion system (Figure II-30) is defined as that portion of the flight termination system which is downstream of the UHF range safety command receivers (RSCR). This system is required to terminate the flight if the vehicle flight path deviates beyond the assigned corridor. The system is designed to effect a zero-thrust condition during S-II boost and to provide propellant dispersion. The ordnance part of the system is required to transmit the propellant-dispersion action to the adjacent stages. The overall system must be designed to the requirements of AFMTC Regulation 80-7, Airborne Flight Termination Systems (Range Safety) and must be approved by the Range Safety Office prior to the first flight. The objectives are to provide a system capable of imposing a condition of maximum safety to ground personnel without adversely affecting the chances of achieving flight objectives.

The inclusion of a manned payload on the Saturn V vehicle requires a means of assuring adequate time for safe ejection of the capsule concurrently with engine shutdown and prior to propellant dispersion. This is accomplished by time delay provisions incorporated in the range safety officer's console. The time delay presently anticipated for the S-II stage is three seconds.

In the flight configuration, the destruct controllers, exploding bridgewire (EBW) firing units, no-safing plugs, EBW detonators, and safety

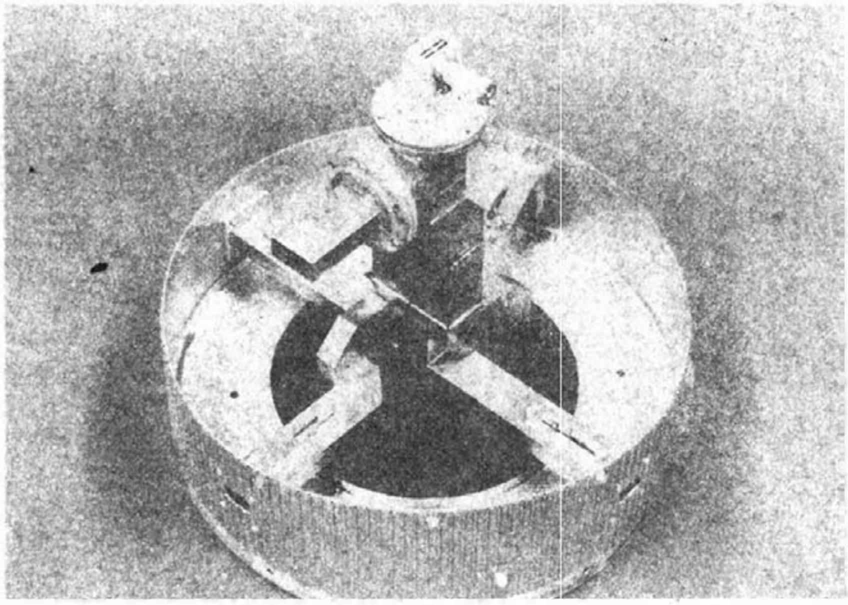


Figure II-26. Scale Model Feed Network—Telemetry Antenna System

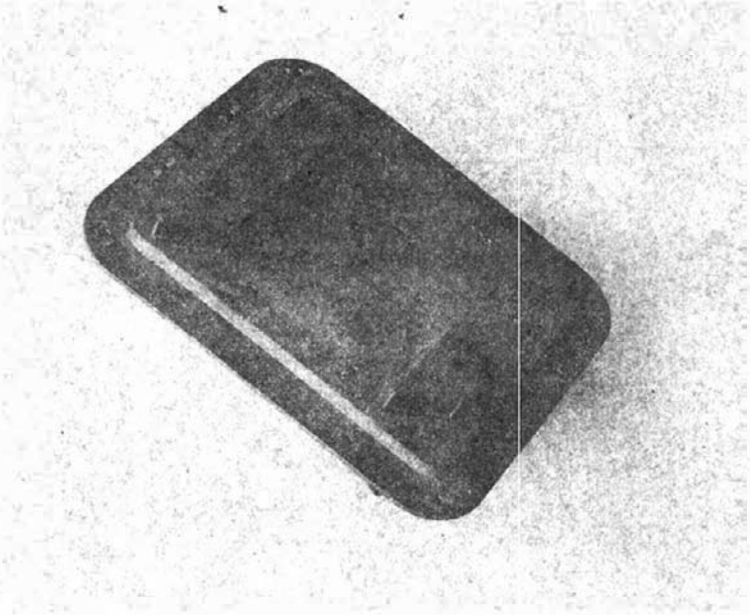


Figure II-27. MISTRAM Antenna Assembly (Outboard View)

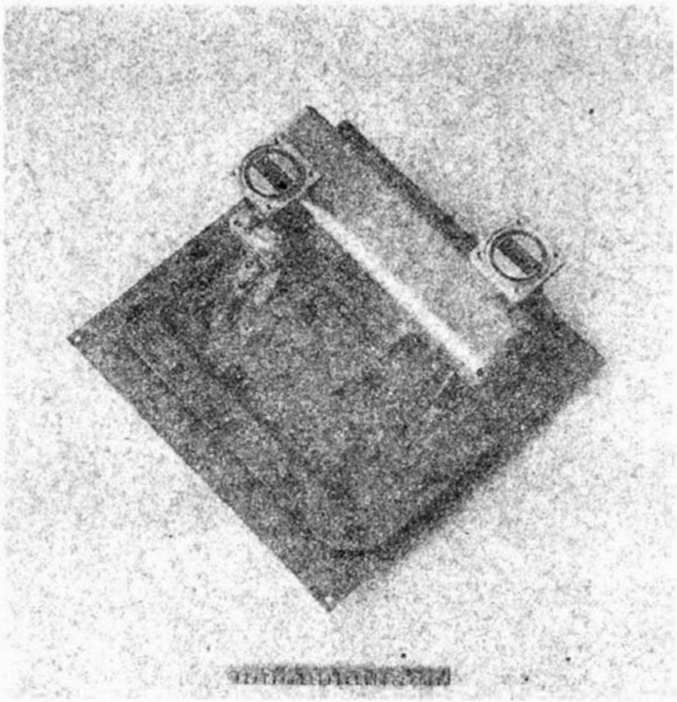


Figure II-28. MISTRAM Antenna Assembly (Inboard View)

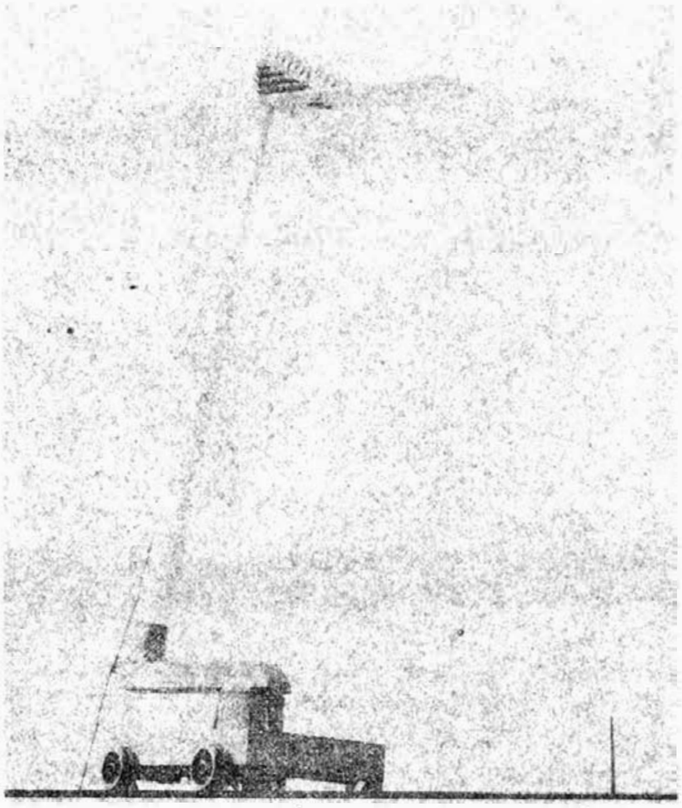


Figure II-29. Radiation Pattern Test—MISTRAM Antenna System

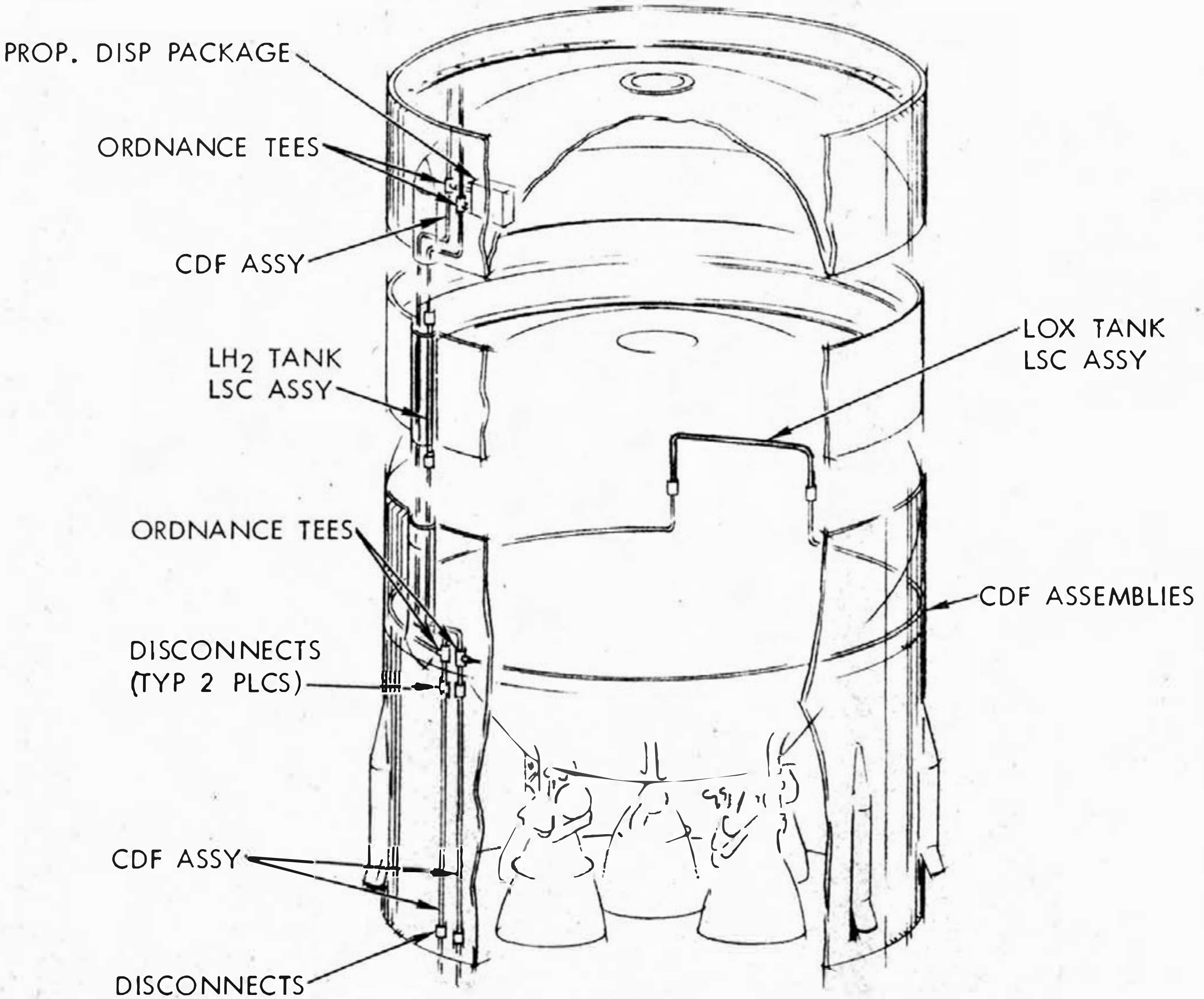


Figure II-30. Propellant Dispersion System and arming device are packaged in a single container mounted in the forward skirt area with two confined detonating fuse (CDF) assemblies entering from the ordnance train.

The electrical part of the propellant dispersion system incorporates two independent systems referred to as Systems 1 and 2. The electrical part of each of these systems consists of a range safety system controller, EBW firing unit, and a no-safing plug.

The range safety system controller controls all signals to an EBW firing unit and the power signal to an RSCR. The controller has the capability of switching the EBW firing unit and RSCR power from external to internal and vice-versa. When the RSCR liftoff signal is applied to the controller, it is rendered incapable of responding to the RSCR propellant dispersion command and the RSCR propellant dispersion arm and cutoff command. After liftoff (removal of RSCR liftoff signal), the controller is rendered operational. A time delay is incorporated in the range safety officer's console. On transmission of the RSCR propellant dispersion arm and cutoff command signal by the range safety officer, this incorporated time delay effects a predetermined interval before the RSCR propellant dispersion command signal is transmitted. This enables the controller to effect a zero-thrust condition with sufficient elapsed time for payload ejection before initiating propellant dispersion.

The EBW firing unit contains the circuitry necessary to generate and store the high-voltage energy pulse required to initiate the EBW. This energy is held off by a gap switch until release is commanded.

The ordnance part of the system consists of two EBW detonators, one safety and arming device, 13 CDF assemblies, four ordnance disconnects, four ordnance tees, one LOX tank destruct assembly, and one LH_2 tank destruct assembly.

The EBW detonator is initiated by the high-voltage energy pulse released from the EBW firing unit. The bridgewire in the detonator explodes with a rapid release of energy which, in turn, initiates the explosive train. The CDF assembly consists of a low-energy detonating core used to transmit a detonation wave between ordnance components, with a multilayer protective sheath to confine the explosive effects. It has a propagation rate of more than 20,000 feet per second. The destruct charge assemblies are initiated by CDF assemblies and are capable of rupturing the applicable tank structure The ordnance disconnects provide ordnance train separation capability at the separation planes. The ordnance tees transfer the detonation from one CDF assembly to two other CDF assemblies.

The safety and arming device has the capability of providing continuity and discontinuity in the ordnance train by means of an electrically controlled rotor. When the safety and arming device is in the armed position, the detonation wave can propagate through the explosive loads in the rotor. When the safety and arming device is in the safe position, the rotor blocks the detonation propagation.

Components

The propellant dispersion system for the Saturn V vehicle has been standardized wherever possible to assure a high degree of reliability and to simplify certification of components and system design. Propellant dispersion is to be effected by ordnance items initiated by EBW techniques. The EBW firing unit and detonator and the safety and arming devices are being developed by Douglas Aircraft Company under a separate NASA contract. The confined detonating fuze (CDF), destruct charge assemblies, and ordnance disconnect and tees are being developed by S&ID. The range safety system controller and no-safing plug are being supplied by NASA as GFE.

Summary of Progress

This system design has proceeded through Phase I into the Phase II approval stage with no problems anticipated. System Report SID 62-134 was reissued to incorporate the latest changes and information in order to be compatible with MSFC and ETR safety requirements. On each ordnance component feasibility testing was completed, procurement specifications were released, and subcontractors were chosen. Except for the ordnance disconnect, purchase orders have been placed, and development programs are progressing on each ordnance component, all of which, except the dispersion charges, are being developed for use on all stages of the Saturn V vehicle.

Procurement

Confined Detonating Fuze (CDF) Assembly

The CDF assembly meeting the requirements of Specification MC901-0052 is required to transmit detonation between ordnance components on all stages of the Saturn V. It is also required for the development and qualification testing of Saturn V ordnance components (except stage separation charges). In-house feasibility tests and tests to determine design requirements of CDF assembly were completed in October 1962. The purchase order for the assembly was placed with the Ensign Bickford Company, Simsbury, Connecticut in May 1963. All development problems were resolved by June 1964, when major design review approval was granted. Production is progressing on 570 assemblies (168 for CDF assembly qualification and 402 for early development of the LOX destruct charge, tee, disconnect, initiator, manifold, and LH_2 destruct charge). Qualification testing of the CDF assembly is scheduled to begin on 19 August. Completion of qualification is expected by 14 October. After qualification 926 assemblies will be fabricated (245 for final development, and 681 for qualification of other Saturn V ordnance components).

Ordnance Tee and Ordnance Disconnect

Procurement specifications covering the ordnance tee and ordnance disconnect were released in December 1962. A supplier has been selected for each component. The purchase order for the tee has been released, and the purchase order for the disconnect is expected to be released in August. Both components will be used on other stages of the Saturn V vehicle.

LOX Tank Destruct Assembly

The procurement specification covering this linear explosive charge was released April, 1963. The purchase order was placed in January, 1964. Development is approximately 90-percent complete.

LH_2 Tank Destruct Assembly

The procurement specification was released on September 3, 1963. The purchase order has been placed, and the development program has started.

Confined Detonating Fuze (CDF) Development

During the supplier's development program, several problems arose - (1) the end fittings could not confine the explosive forces of the booster charge; (2) "random" propagation failures occurred in the fuze and booster charges at -300 F; and (3) the explosive core in the fuze was unable to withstand vibration. End-fitting confinement problems have been corrected by incorporation of a high-strength threaded connector in place of the original bayonet connector. Ease of installation was retained by adapting an M-F thread locking device on the connector, thus eliminating the need for torquing or lock-wiring the threaded connector. Low-temperature (-300 F) explosive propagation failures were corrected by better control of the CDF and better sealing of the booster charge. No propagation failures have occurred in the last 1200 feet of CDF fired at -300 F or the last 100 booster charges tested at -300 F. To eliminate the vibration damage to the explosive core, the confining structure was redesigned to reduce flexing from vibration and to provide better support of the explosive core. Since the redesign, CDF assemblies have successfully passed tests for

(1) High- and low-temperature (+160, -300 F) sine-wave vibration with six inches of slack between supporting clamps, and (2) ambient random vibration with 60 pounds tension on the fuze. Development testing of the CDF assembly is considered complete, and qualification testing is scheduled to begin on 19 August.

ELECTRICAL SYSTEM

The S-II electrical system is shown in Figure II-31.

Electrical Control System

Description

The electrical control system is a stage-installed system that is closely integrated with GSE. It provides electrical control for all of the electromechanical components of various mechanical systems. It also includes the electrical equipment that controls the mechanical system. This close connection between mechanical and electrical systems permits uniformity of electrical requirements, and provides a central point for electrical interfaces.

The components are packaged in three controller units. The first unit is the propellant electronics package (forward skirt), containing the electrical components for the LH_2 propellant level-monitoring system (PLMS). The second unit is the propellant electronics package (aft skirt), containing the components for the LOX PLMS, the propellant-depletion engine cutoff circuitry, and the capacitance propellant-utilization system circuitry. The third unit is the electrical sequence controller, which contains the relays, diodes, resistors, and timers that provide the electrical control for the pressurization system, hydraulic accumulators, J-2 engine start and cutoff, prevalve operation, LH_2 recirculation system, and the emergency detection system.

Status

The electrical control system definition has been updated by revised preliminary and advanced schematics and a revised system report. Phase II approval was received for the system details, with minor exceptions. Design changes have been initiated for these exceptions. Primary areas of design analysis included the revision of propellant recirculation, engine control, pressurization, and engine actuation, and the design of the propellant-level monitoring and engine-cutoff electronics. Manufacturing checkout specifications have been released for components of the system manufactured in-house. Procurement activity has culminated in the

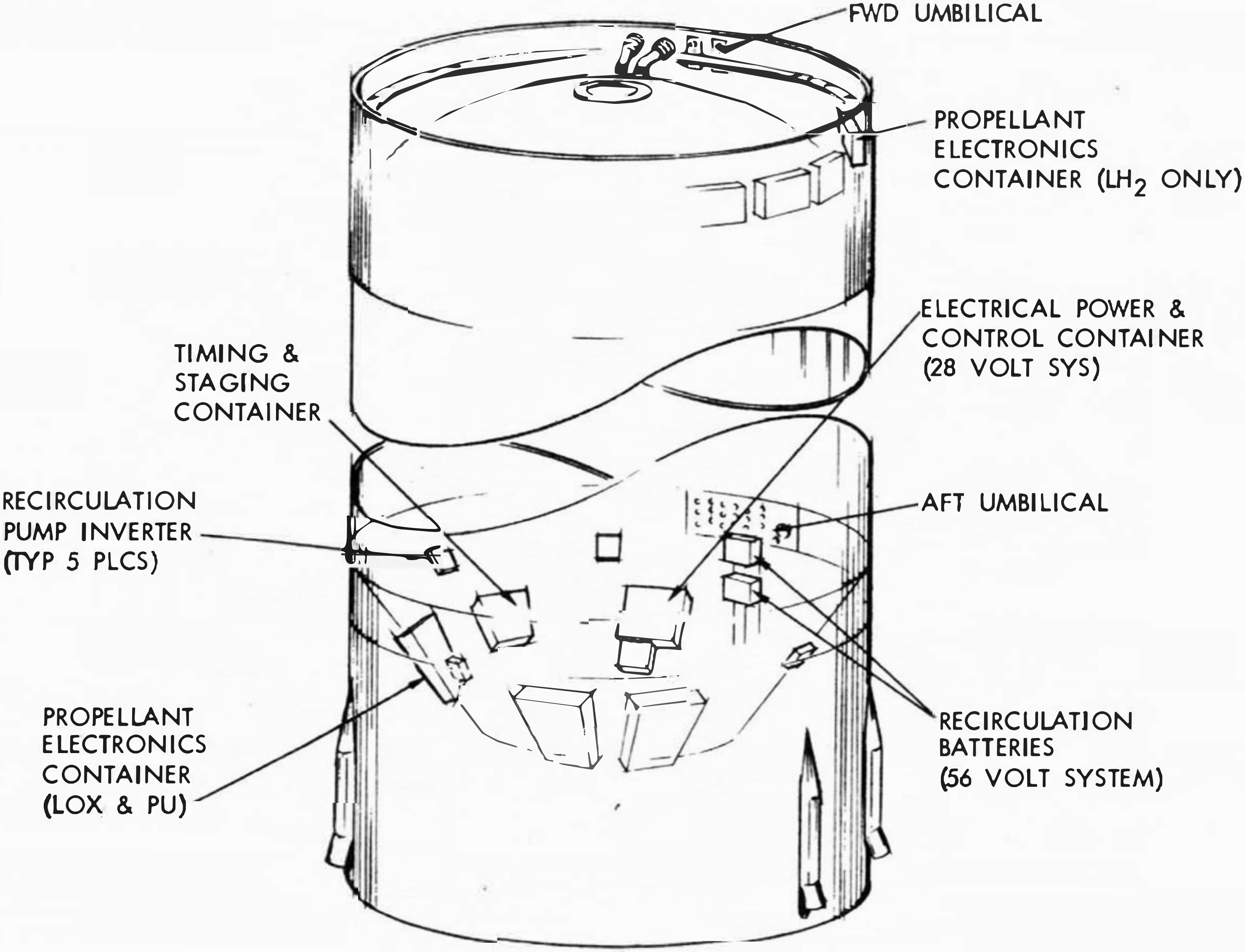


Figure II-31. Electrical System

selection of all suppliers and the placing of all procurement requests. Testing activity has verified details of stage electrical design.

The electrical control system has undergone preliminary and advanced design reviews in conjunction with the various mechanical systems. Phase II approval has been received from NASA for all of the advanced schematics, with minor exceptions. The exceptions include the addition of manual troubleshooting contacts on each module and the rerouting to the umbilical connector of several stimuli and measurements which were originally routed to the special test connector. These exceptions are the result of final definition of MSFC policy on the level of checkout required on the launch pad.

By direction of MSFC, the engine valve position switches were deleted from hardwire and added to the telemeter. A change by Rocketdyne in the timing of the J-2 engine shutdown sequence required a change in the delay of prevalve operation. Redundant, calibrationable, mainstage OK pressure switches were added by MSFC direction.

The propellant recirculation system was revised to provide control of normally open recirculation valves rather than normally closed valves, resulting in considerable circuit simplification and consequent increased reliability. The only critical phase of the recirculation system is the opening of the LH_2 prevalves to allow engine start. A redundant method of opening the valves is provided to increase the probability of engine start.

Direction to proceed with the addition of the emergency detection system (EDS) was received from MSFC. It has been determined that when any two of the five J-2 engines shut down during any phase of the S-II flight, the remaining J-2 engines should shut down automatically. Incorporation of this requirement will cause a major design change in the electrical propellant prevalve system and the engine electrical control system. The EDS also adds redundant pressure transducers to sense LH_2 tank ullage pressure, and adds redundancy to engine cutoff, engine start, and prevalve operation circuits.

The design of the propellant level monitoring, overfill, and fast-fill cutoff and the engine cutoff systems has proceeded from conception through the initial release of all advanced schematics, production drawings, and process specifications. The nucleus of these systems will be an encapsulated welded module containing checkout and logic circuitry for a pair of hot-wire point-sensor control units to be mounted upon it.

During the last year, a process for sealing wires and cables within the cryogenic tanks was developed and tested successfully (Figure II-32). This process utilizes heat-shrinkable TFE-FEP Teflon tubing. Samples were tested and found to be sealed when, after being soaked in liquid nitrogen, they were treated with Freon at room temperature and 75 psi. It is expected that this process will greatly facilitate wiring inside the cryogenic tanks.

Testing

Testing of diode-resistor networks for suppression of solenoid voltage surges was performed and confirmed engineering analysis of stage design. Testing of connectors intended for use within and through the cryogenic tanks was completed, and the formal S&ID test report of this phase was released. These connectors were tested at -452 F, utilizing liquid helium. One of the tests consisted of vibration at -452 F; this represented a unique accomplishment, verifying the S&ID design approach (Figure II-33).

Procurement and Component Development

Procurement of the solid-state timer is now in the final stages of completion. The supplier has started manufacturing the timers, and initial delivery of nonqualified prototypes is scheduled for late September.

During the year, the timer passed a major design review, development tests were satisfactorily passed, qualification test plans were submitted and found acceptable, as were acceptance test procedures. Failure mode analysis and traceability procedures were submitted and accepted.

Procurement of relays is in the final stages of completion, with unqualified parts scheduled for delivery in September. Major design reviews were successfully completed in May and June. Qualification and acceptance test plans have been submitted; development testing was not required.

Electrical Power System

Description

The electrical power system generates and distributes both direct and alternating current to the stage systems during the launch countdown, S-IC boost, and S-II boost. A power system is being designed which utilizes batteries for in-flight power and converts a portion of the power to three-phase a-c power during checkout and countdown.

The electrical power system includes three battery systems to provide power during flight. A 28-volt main battery powers the various stage control systems, except for the recirculation pump motors and

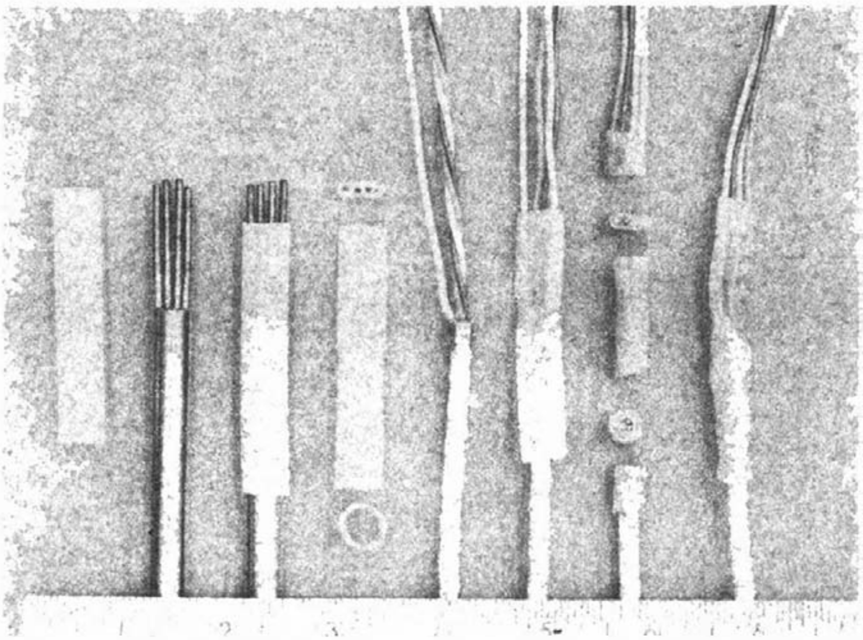


Figure II-32. Wire and Cable Sealing for Cryogenics Use

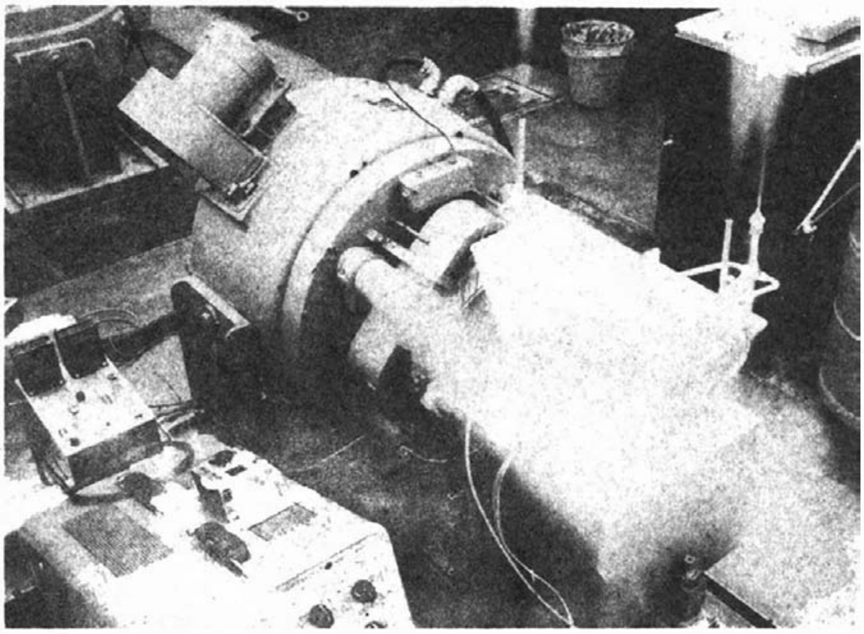


Figure II-33. Test Setup for Electrical Connectors Vibrated at Cryogenic Temperature

J-2 engine ignition system. A 28-volt instrumentation battery powers the measurement, telemetry, and tracking systems. A 56-volt battery system powers the inverters of the recirculation pump motor. A 28-volt tap on this battery system is used to supply the J-2 engine ignition system. Primary silver-oxide/zinc batteries of two different ampere-hour capacities supply the in-flight requirements. Five solid-state inverters convert the 56-volt recirculation battery power to 56-volt (peak) three-phase 400-cps quasi-square-wave power for the recirculation pump motors. Motor-operated power transfer switches are used to transfer the bus power source from the ground-regulated supplies to the batteries just before launch. Other bus systems are used to supply those loads requiring operation during countdown or checkout.

Status

During this reporting period, the Phase II review of system design was held. MSFC requested revisions in a few circuits to achieve compatibility with the launch-pad GSE design. These included deletion of the stage power feedback to GSE, limiting of 16-gauge umbilical pin currents to 5 amperes to control voltage drop when using standardized cables, and the addition of the last-break connection to the forward skirt umbilical. Implementation of these changes is being coordinated.

Development tests have been completed on the power transfer switches and are nearing completion on the batteries. Nonqualified power transfer switches were delivered. The supplier for the recirculation inverter was selected.

Although Engineering evaluation of prototype hardware is in the early stages of test, early results indicate that the wet-stand life of the batteries is satisfactory.

Redirection by MSFC to utilize a common LH_2 recirculation pump resulted in a 25-percent increase in the rating of the inverter. This change necessitated minor revisions in stage wiring but did not affect the stage/GSE interface.

Analysis of the battery terminal voltage under various test conditions indicated that excessive voltage may be applied to the J-2 engine ignition circuits and to the propellant dispersion system. One test condition will occur when the ignition d-c bus is switched to the recirculation battery tap with no load on the recirculation bus (the recirculation pumps are not operating). The second test condition will occur when the propellant dispersion system is switched to the battery without switching the other bus loads. Both test conditions are expected to occur. To solve this problem, load banks will be added to the GSE to load the batteries sufficiently during these conditions so that the bus voltage does not exceed 32 volts.

Testing

Individual battery cells were delivered by Electric Storage Battery Co. for use in parallel tests by S&ID to verify wet-stand life, performance characteristics at various temperatures, and the ability of the cells to support the calculated stage load profiles. Preliminary data reduction indicates that the batteries will still exceed their rated capacity requirements after exposure to 120 F for five days.

Procurement and Component Development

Development of the power transfer switches by the Planautics Corporation has been completed, and initial nonqualified units have been received for installation on Battleship and the EMM. The fabricated hardware is shown in Figure II-34. Development tests on the batteries by Electric Storage Battery Company are in process and are expected to be completed in September 1964. Individual cell tests have indicated compatibility of the cells with vibration, shock, and temperature environments. The Engineered Magnetics Division of Gulton Industries has been selected as the supplier for the recirculation system inverters.

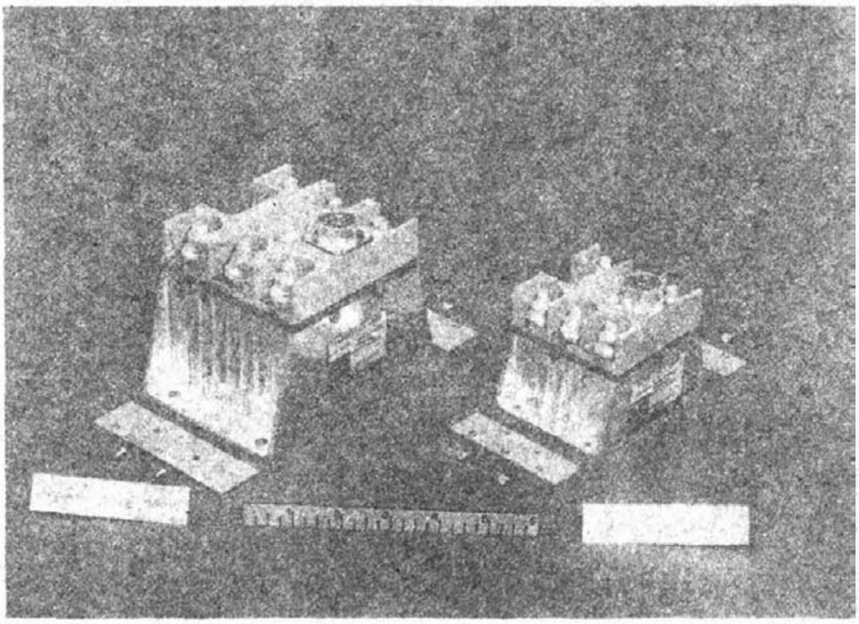

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Figure II-34. Power Transfer Switches

SEPARATION SYSTEM

The S-II Stage separation system is shown in Figure II-35.

Description

The function of the S-II stage separation system is to (1) provide the physical detachment of the S-IC from the remainder of the Saturn V vehicle after completion of the first stage boost, (2) provide ignition for the eight S-II ullage motors. Separation occurs at two separate planes in order to sequentially detach, first, the depleted S-IC and, second, the S-II aft interstage structure. Separation at two planes permits the removal of maximum interstage weight without increasing the risk of damage to the S-II propulsion units during the separation process.

The electrical control of the system consists of a switch selector and separation controller. The former sequences the system functions when stimulated by a coded signal from the Saturn V airborne computer; the latter, which receives electrical inputs from the switch selector, contains components and circuitry necessary for operating EBW firing units.

The EBW firing units are devices which generate, store, and deliver the initiating power to the EBW detonators used for system ordnance. The high-energy input of the firing units permits the use of the relatively insensitive (and therefore safe) EBW detonators.

Two detonators each are used to initiate first-plane separation, second-plane separation, and ullage-motor ignition. For both first- and second-plane separation, linear-shaped charge LSC assemblies are used to sever the separation-joint tension members. Special nonelectric pyrogen initiators are used to ignite the eight ullage motors. Ordnance manifolds and CDF assemblies are used to multiply and transfer the output of two detonators to the 16 pyrogen initiators.

The output of 16 CDF assemblies is required to initiate the 16 pyrogen initiators (two in each ullage motor). The CDF manifolds, which initiate the CDF assemblies, consist of an explosive charge contained in a metal block of sufficient strength to confine all explosive effects. The explosive charge is initiated by an EBW detonator. The output of the charge is sufficient to initiate simultaneously all output CDF assemblies.

The initiator of a solid-propellant motor must be capable of performing two discrete functions: (1) provide proper and consistent ignition of the pyrogen igniter and (2) provide a seal to prevent escape of motor gases through the initiator port. Study and feasibility testing indicated these goals could most readily be met by use of a through-bulkhead type of initiator.

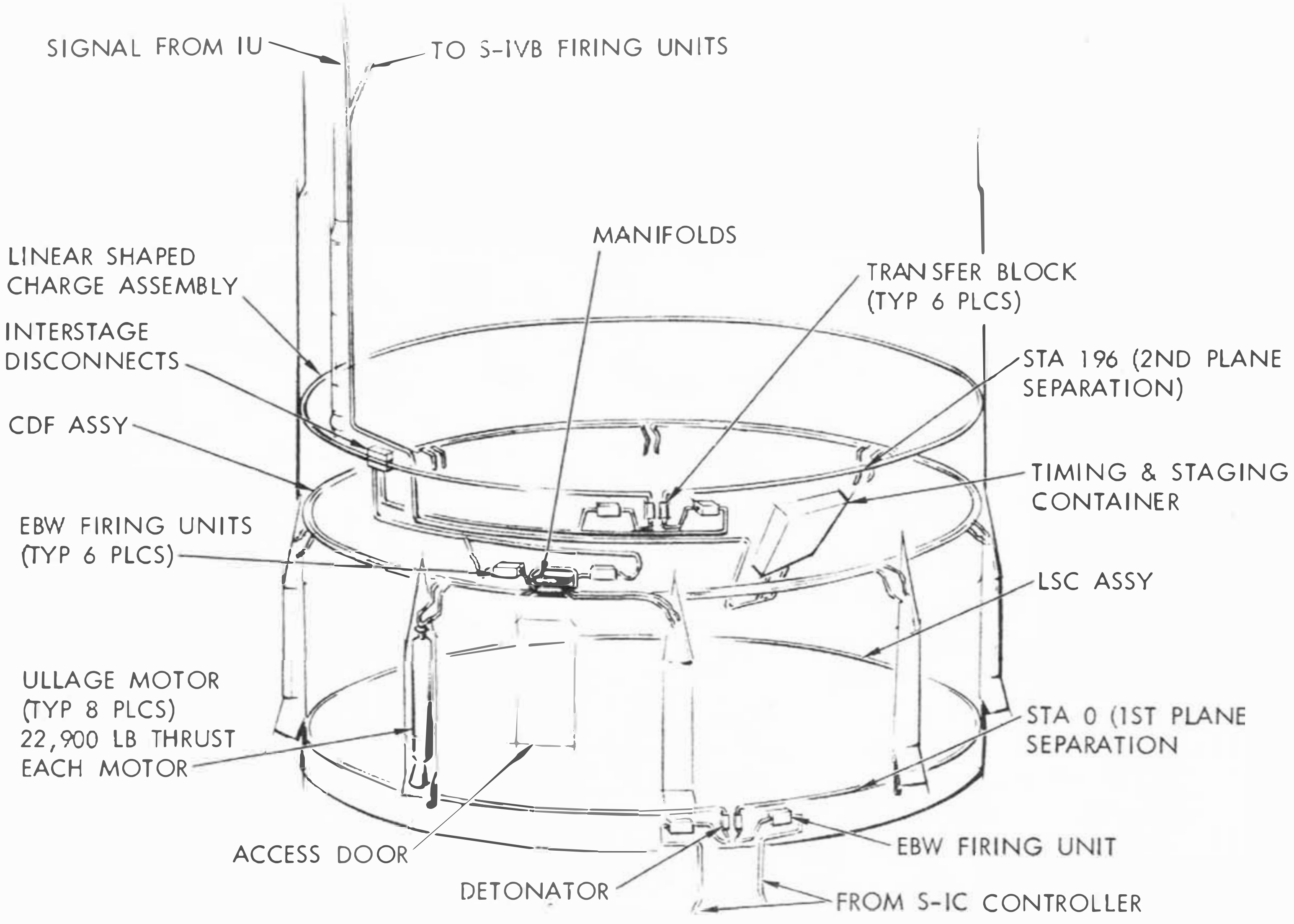


Figure II-35. Stage Separation System

This initiator receives its input energy from a CDF assembly, which is used to detonate a pentaerythritol tetranitrate (PETN) donor charge. The resulting shock wave passes through a steel barrier and initiates a second PETN charge on the opposite side of the barrier. The detonation of this charge ignites a metal oxidant powder which, in turn, ignites the motor pyrogen. The steel barrier remains intact after the initiator has functioned and provides a positive seal to prevent escape of motor gases back through the spent initiator.

Status

The EBW components used on the separation system are being developed by Douglas Aircraft Company under a separate MSFC contract.

The LSC assembly, the ordnance device used for stage separation, is being developed by an outside ordnance supplier. Installation hardware for the LSC is being designed at S&ID. The LSC assembly and associated installation hardware are being evaluated by means of five full-scale tests conducted at S&ID. The components used for ullage motor ignition are being developed by outside ordnance suppliers; these components include the CDF manifold, CDF assembly, and the pyrogen initiator.

The switch selector is being supplied as GFE by MSFC. The separation controller, which is being designed by S&ID, consists of the following modules: junction box assembly, electrical controller, and power distributor.

The splice-plate design used for S-II separation allows the use of a much smaller LSC than would be required if it were necessary to sever a combined compression and tension structure. The external location of the splice plate obviates the heavy shielding which would be required for an LSC installation within the vehicle. The design of the external splice plate utilizes the vehicle skin to shield internal components from the LSC blast effects. The relative freedom of access for external LSC installation permits the use of a one-piece assembly, and this is desirable from the standpoint of reliability.

An external cover is required for the LSC assembly in order to position the LSC on the splice plates and to shield it from aerodynamic effects.

Testing

Three full-scale separation tests have been conducted. Two additional tests will complete the series. The purpose of the full-scale separation test series is to determine and correct any problems encountered in the use of an LSC for S-II separation. The basic test structure is a full-scale simulation of a 54-inch section of the S-II which includes a structure typical of both separation planes.

Experience gained during the first three tests will be used in the development of a preliminary installation procedure, which will be used and evaluated during the last two tests.

One of the objectives of the full-scale test series is to aid in the development of a convenient LSC installation. The installation times for the first three tests were 8, 7, and 5-1/2 hours, respectively. It is expected that this time will be substantially reduced for the final two tests.

The detonation rate corresponded to that which was expected for RDX. The longest duration for complete propagation around the vehicle (from one end only) is approximately 5 milliseconds. No difference in LSC performance was detected as a result of single or dual initiation. All three tests were successful from the standpoint of complete severance of the splice plate. In two cases, however, the severance was caused by blast effect without the cutting section of the LSC jet. The first of these was caused by improper positioning of the LSC assembly on the splice plates near the detonator area.

The lateral bend of the LSC in this area requires additional support. Improvements in the installation design will eliminate this problem. The second case of improper LSC functioning occurred as a result of water accumulation between the LSC and the splice plate. This problem is being eliminated by incorporating a foam filler in the assembly to exclude contaminate from the LSC jet formation region.

Procurement and Component Development

LSC Assembly

The LSC assembly supplier has completed the first phase of the development program. Prototype LSC assemblies were delivered for use in the first three full-scale tests. The second phase of the development program will contribute needed improvements to the LSC assembly. The continued development effort will improve elasticity, heat resistance, and length stability of the assembly. Provisions will also be added to exclude water from the LSC jet formation region.

CDF Manifold

The CDF manifold vendor proposals were evaluated, and the purchase order released. Preliminary development testing indicates that die-cast manifold bodies are less satisfactory than bodies machined from bar stock.

Pyrogen Initiator

The pyrogen initiator development program is now nearly complete. The only remaining work involves testing of initiators under environmental conditions similar to those to be encountered in qualification. The Bruceton statistical tests have been completed on the bulkhead with highly encouraging results. The 50-percent point for bulkhead rupture was approximately 0.040 inch, and the 50-percent propagation was 0.120 inch.

The associated sigma limits indicate that a bulkhead can be selected which will ensure, with great confidence, that the detonation will propagate and the bulkhead remain intact.

A special powder composed of magnesium, copper oxide, and ferric hematite was developed to meet the high calorific output required. Thermal stability tests on this powder indicate that it will withstand 500 F for 260 hours with no detectable degradation in performance.

At NASA direction, a second supplier was contracted for the design, development and qualification of the pyrogen initiator. Negotiations with the supplier have been completed, and the purchase order will be released soon.

ENGINE SYSTEM

The S-II engine system is shown in Figure II-36.

Description

The main propulsion for the Saturn S-II vehicle is provided by five J-2 engines, each with a rating of 200,000-pound vacuum thrust. The four outboard engines are gimbaled to provide lateral control during the S-II portion of the programmed trajectory. Shutdown of one engine during S-II boost does not preclude continuance of the S-II operation, since the stage is designed for single-engine-out capability. The engines are completely self-contained and require minimum inputs for start, stable mainstage, and shutdown. Maximum performance is obtained with optimum configuration, considering size and weight.

The J-2 engine uses liquid hydrogen and liquid oxygen as propellants. The engine features a single tubular-wall bell-shaped thrust chamber and independently driven, direct-drive turbopumps for delivering the propellants under high pressure to the thrust chamber. The pumps are driven by a gas generator which utilizes the same propellants as the thrust chamber. The engine incorporates a propellant utilization (PU) valve which provides control of the mixture ratio and the capability of simultaneous depletion of both propellants by bypassing liquid oxygen from the discharge side of the pump to the inlet side through the PU valve, which is controlled by a small servometer.

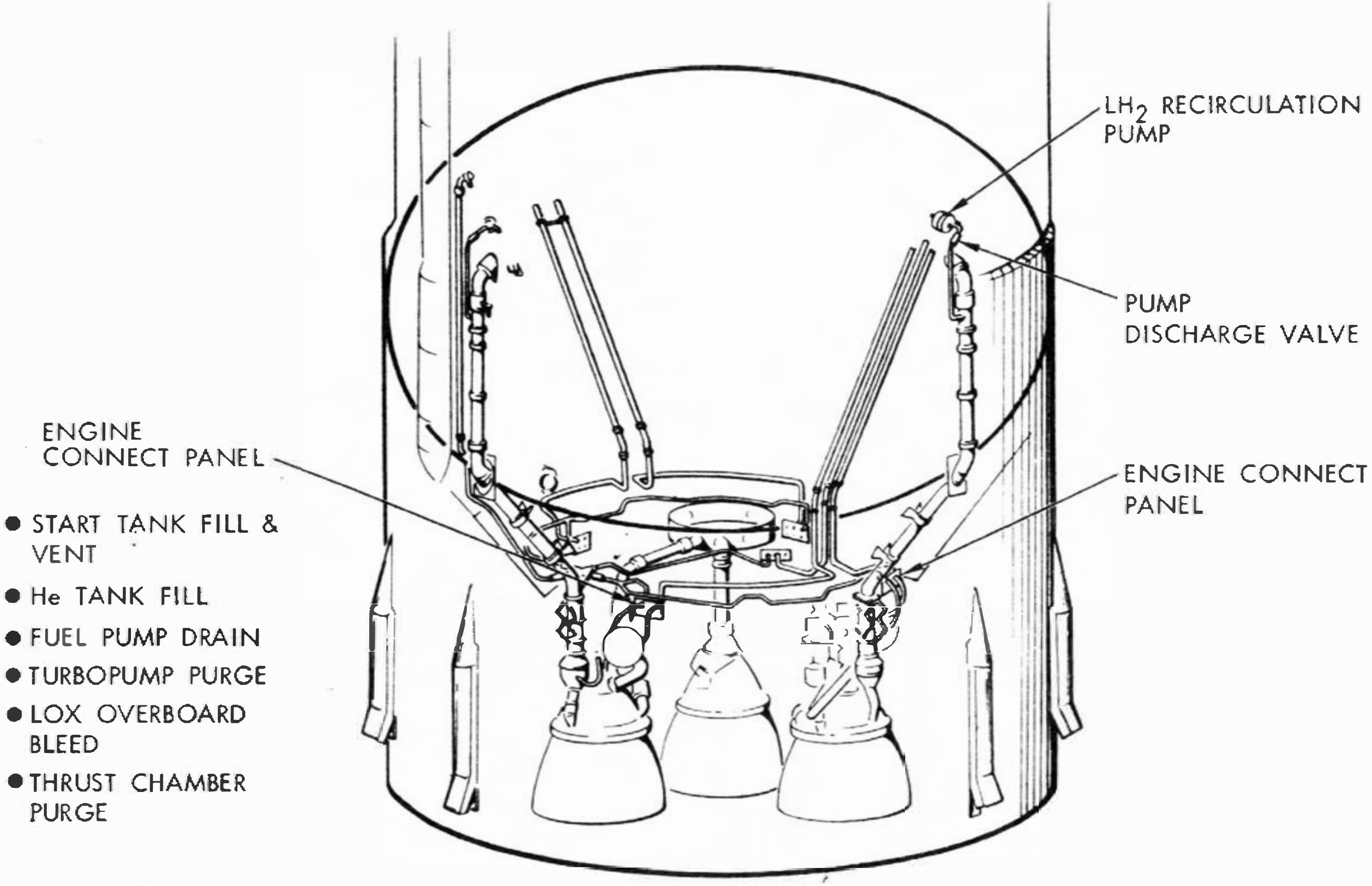


Figure II-36. Engine Systems

Status

The first production J-2 engine, J2006, was received by S&ID late in this reporting period. After receiving-inspection checkout of the engine, it will be installed in the S-II Battleship test stand for single-engine static tests later this year.

A performance prediction program for the S-II propulsion system has been prepared and is now ready for use.

The problem associated with the occurrence of side loads in the J-2 engine thrust chamber due to jet separation during sea-level testing has been redefined. Design of the side-load arresting mechanism (SLAM) has been modified accordingly.

Procedures for checkout and operation (hot firing) of the engine system on the Battleship test stand have been completed for the single-engine configuration. Procedures are also complete for automatic checkout of the engine system. These will be used to write the computer tapes for automatic checkout.

Systems utilized to cut off the engines in the event of combustion instability, gas generator over- or under-temperature or turbopump overspeed are in design. During this period, the vibration safety cutoff design responsibilities were revised. Instead of being designed and installed at all test sites by S&ID, the MSFC technical systems design contractor will furnish this system at the Mississippi Test Facility; S&ID will continue with this responsibility for the Battleship and All-Systems test stands.

A study was conducted for the purpose of selecting a method for disposal of the gaseous hydrogen expelled from each J-2 engine thrust chamber at engine start. The method selected utilizes five hydrogen burners positioned one at each thrust-chamber exit and ignited just prior to engine start.

Results of new thermodynamic studies of heat fluxes around the thrust chamber indicate a requirement for thermal protection of the thrust chamber hatbands for the outboard gimbaling engines. Design effort to implement this change is awaiting clarification of responsibility and NASA direction.

In conjunction with the new heat fluxes and addition of the static-firing diffuser flange on the thrust-chamber exit, the center-engine plume shield was redesigned. The new configuration, as shown in Figure II-37, consists of four radial segments and utilizes the existing bolting pattern of the diffuser flange. Columbium has been selected as the material for the shield because of its mechanical properties at elevated temperatures and heat-resisting characteristics. A shield temperature of 2200 and 2400 F could occur as a result of a dual-engine actuator failure at initiation of the S-II boost phase.

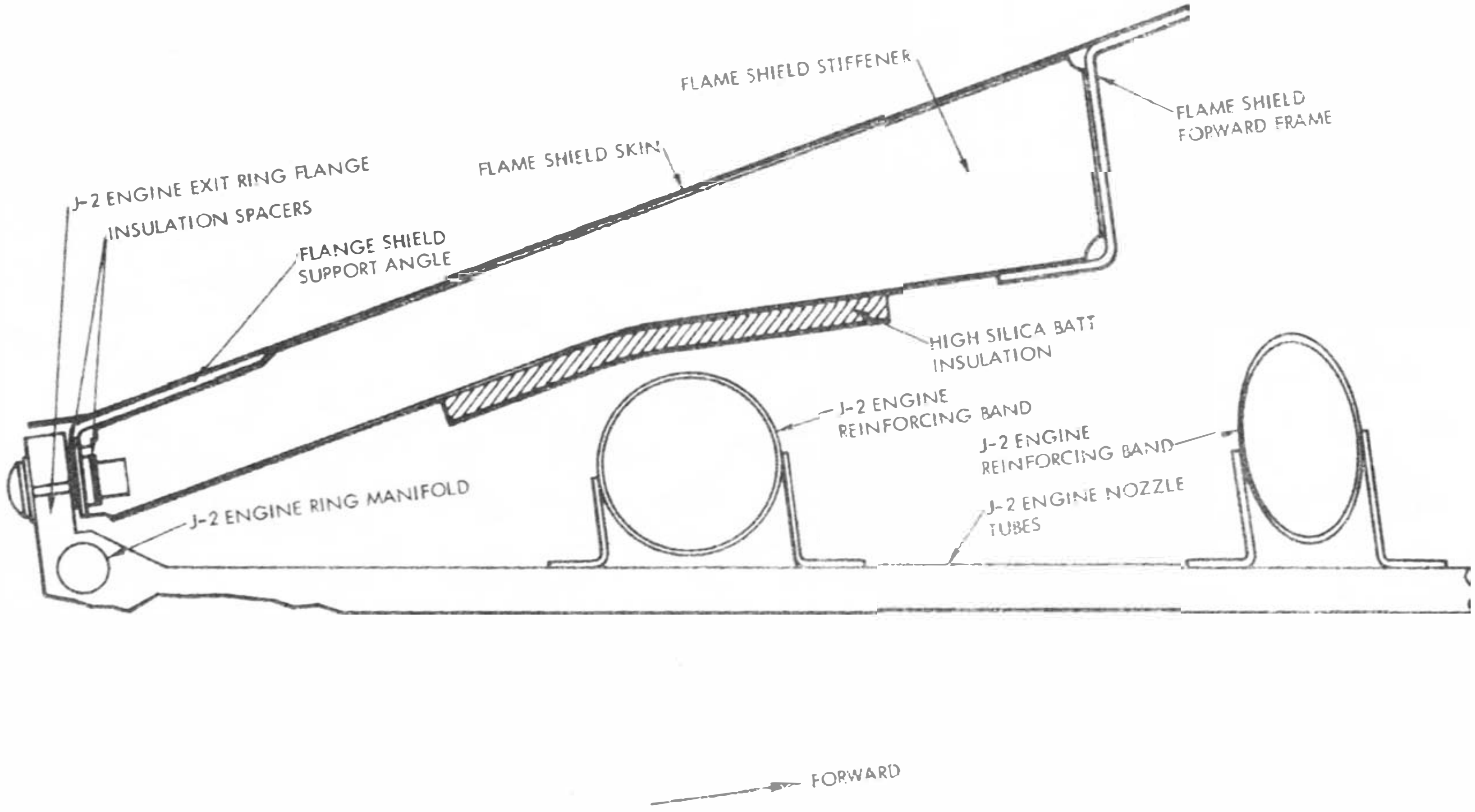


Figure II-37. Flame Shield and J-2 Engine Thermal Model

Suppliers experienced in the production and fabrication of columbium components have been surveyed as potential producers for the plume shield. Production drawings are 100-percent complete and are being reviewed by Rocketdyne for structural compatibility with the J-2 engine.

In May 1963 S&ID prepared an estimate of the base thermal environment during static firing of the S-II to be used as preliminary design criteria in the design of thermal protective shields. Rocketdyne reviewed this report, together with drawings of the static-firing radiant heat shield proposed by S&ID, and announced in August 1963 that additional protection would be required for engine components. S&ID, accepting full responsibility for providing this additional protection, conducted a study to determine the optimum method. It was discovered that any mechanical shield located at the thrust chamber exit level would interfere not only with engine gimbaling but also with GSE presently located in that area. It was concluded that this type of shield has several design and installation problems associated with it which will require extensive study to resolve. Because of these difficulties, it was decided to use a water-spray heat shield for the Battleship test stand and, at the same time, to begin a detailed study program of analysis and tests to define more clearly the environmental and design criteria.

Performance Prediction

On completion of the S-II propulsion prediction program, a report was prepared and is now in the process of being published. The object of this program is to predict propulsion-system performance prior to a stage test and to determine what effect a change in a parameter or a set of parameters will have on the performance of the stage propulsion system.

SIDE-LOAD ARRESTING MECHANISM (SLAM)

Results of tests conducted by Rocketdyne indicate that the side-load arresting mechanism (SLAM) must be attached to the four outboard engines during start only. The SLAM is disconnected from the outboard engines after start and is no longer required to relatch to the engines at cutoff. During steady state and engine shutdown, the side loads are of short enough duration so that the problem is resolved by incorporating, for static firing, a convergent water-cooled cone at the thrust-chamber exit.

Rocketdyne J-2 engine test data show that the engine side loads generated in the start phase during static firing are in excess of the 130,000-pound design capability of the engine-to-stage rigid struts for the center engine. These loads are also capable of causing damage to the engine actuator attach points. To prevent failures of this type, a four-point center engine restraint has been incorporated. The mechanism will consist of four horizontal tension rods anchored to the outboard-engine SLAM supports at one end of each rod and attached to a square framework which circles the center engine at the other end. The framework is in turn attached to the engine. Design of this equipment is complete for the Battleship and All-Systems test stands. Fabrication is under way for the Battleship equipment.

Gaseous Hydrogen Burn-Off

The method proposed by S&ID to dispose of the hydrogen expelled by the J-2 engines at start consists of five burners, one per engine, located at the thrust chamber exit plane. These burners, which utilize facility gaseous hydrogen ignited by a spark plug, are supported from the static firing fragmentation shield and are arranged in two clusters: one cluster igniting the free hydrogen from the center engine and two outboard engines, the other igniting the remaining two engines. Associated with each burner is a flame detection system which verifies proper operation of the burners.

The burners are ignited just prior to engine start. When the flame detectors indicate flame at all five burners, the engines are permitted to start. Shortly thereafter, having accomplished their task, the burners are shut down.

Engine Servicing System

The engine servicing system provides a means for preparing the J-2 engine for operation by transferring the necessary fluids at the proper temperature and pressure from the GSE facilities to the appropriate engine system. It also provides a means of venting overboard various seals and drains on the J-2 engine. Prior to static firing or launch, the engine is serviced with the required fluids in order that an engine operation may be attained. The system is composed of the following subsystems:

(1) Turbopump Purge - distributes gaseous helium purge to remove air and moisture from the system to each engine oxidizer, turbine seal cavity, fuel pump seal cavity, fuel turbine seal cavity, and the gas generator hydrogen injector cavities.

(2) Hydrogen Pump Seal Drain - provides a common manifold for venting each of the engine hydrogen pump seal cavities overboard.

(3) Oxygen Pump Seal Drain - provides a common manifold for venting each of the oxygen pump seal cavities overboard.

(4) Helium Tank Fill - distributes to each engine helium bottle gaseous helium supplied at a pressure of 3000 psi and at the temperature of 70 F necessary for J-2 engine start.

(5) Hydrogen Start Tank Fill - distributes to each engine hydrogen-start tank gaseous hydrogen supplied at a pressure of 1250 psia and at the temperature of -250 F necessary for engine start.

(6) Hydrogen Start Tank Vent Control - distributes to each engine vent-control valve gaseous helium required to actuate the valve.

(7) Hydrogen Start Tank Vent and Relief - provides a common overboard vent for the engine hydrogen-start tank.

(8) Thrust Chamber Fuel Jacket Purge - distributes to each engine thrust chamber gaseous helium for purge and chill of the chamber.

Each subsystem consists of disconnects, manifolds, and flex lines. In addition, Item (6) subsystem five solenoid valves. All purging is accomplished before propellant tanking.

J-2 Engine Development Testing

Development testing has been completed on all procured components, with qualification testing scheduled to start in August. Prequalified components will be delivered in August. Engineering evaluation testing on the J-2 engine at the S&ID Engineering Development Laboratory was completed in July. System test requirements have been completed.

Analysis and Design

The LOX-pump seal drain and hydrogen-start tank systems were revised as per TD 203-64 and 171-63 respectively. Redesign of the pump-seal drain consisted of relocating the J-2 engine/S-II interface from the pump housing to the engine connect panel and adding a vent manifold from the new interface point to the vehicle skin. Redesign of the start-tank system consisted of increasing the operating pressure from 800 to 1250 psia. A mainstage OK pressure switch and pressure-actuated sequence-valve remote-checkout system was added at MSFC direction. The system consists of a manifold and disconnect and associated GSE.

The configuration of the fluid-lines connect panel and the location of the center engine installation have been established. Three panels are separately mounted, as shown in Figures II-38, II-39, and II-40, to accommodate the engine-supplied lines so that the single-engine configuration is maintained. Because of an interference with the thrust beam, the gaseous-hydrogen supply-line interface was relocated at the engine stub port instead of the connect panel. The engine-supplied GH_2 flex line which was removed will be considered a spare part.

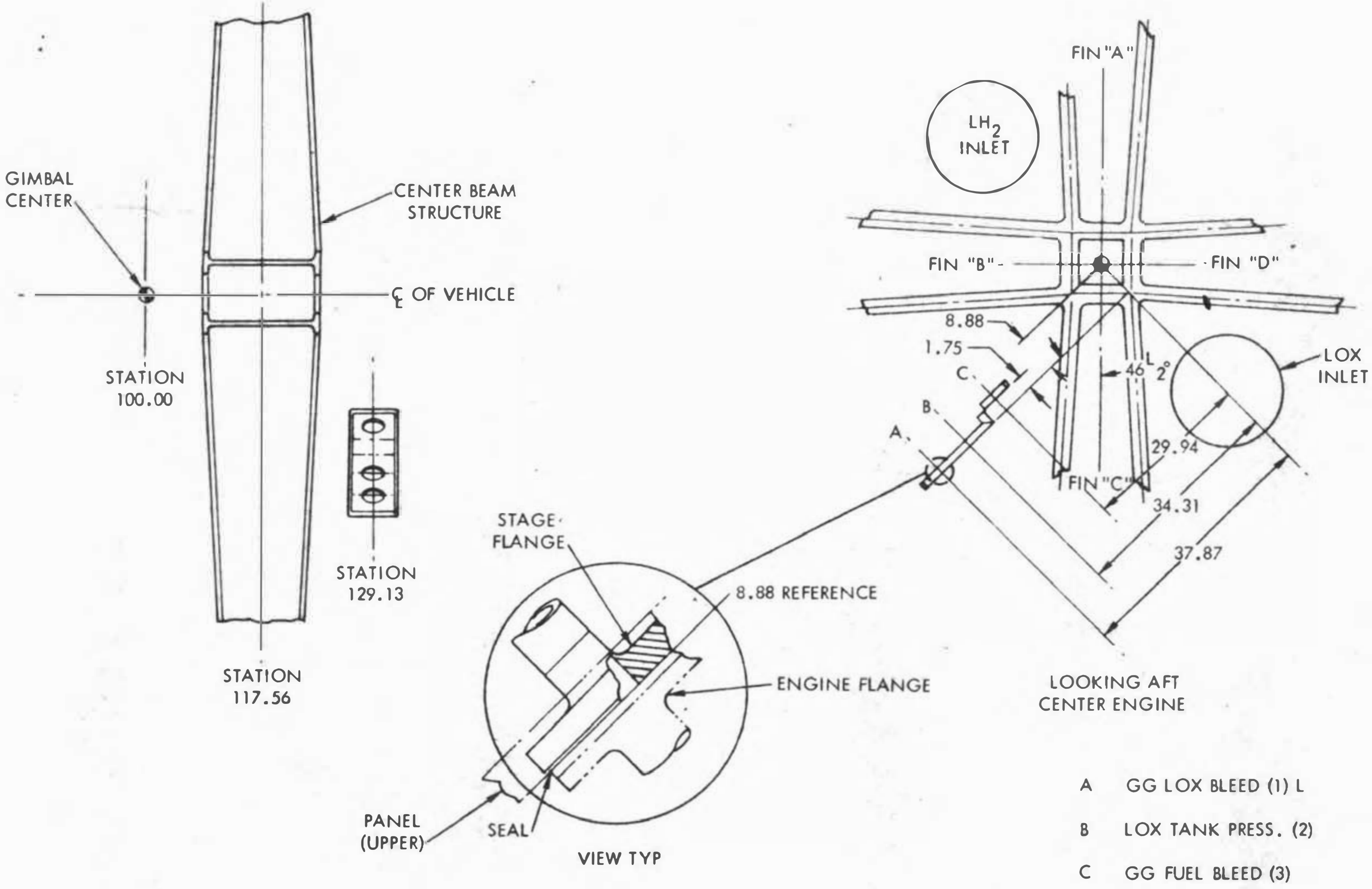


Figure II-38. Upper Panel—J-2/S-II Center Engine Fluid Lines Interface

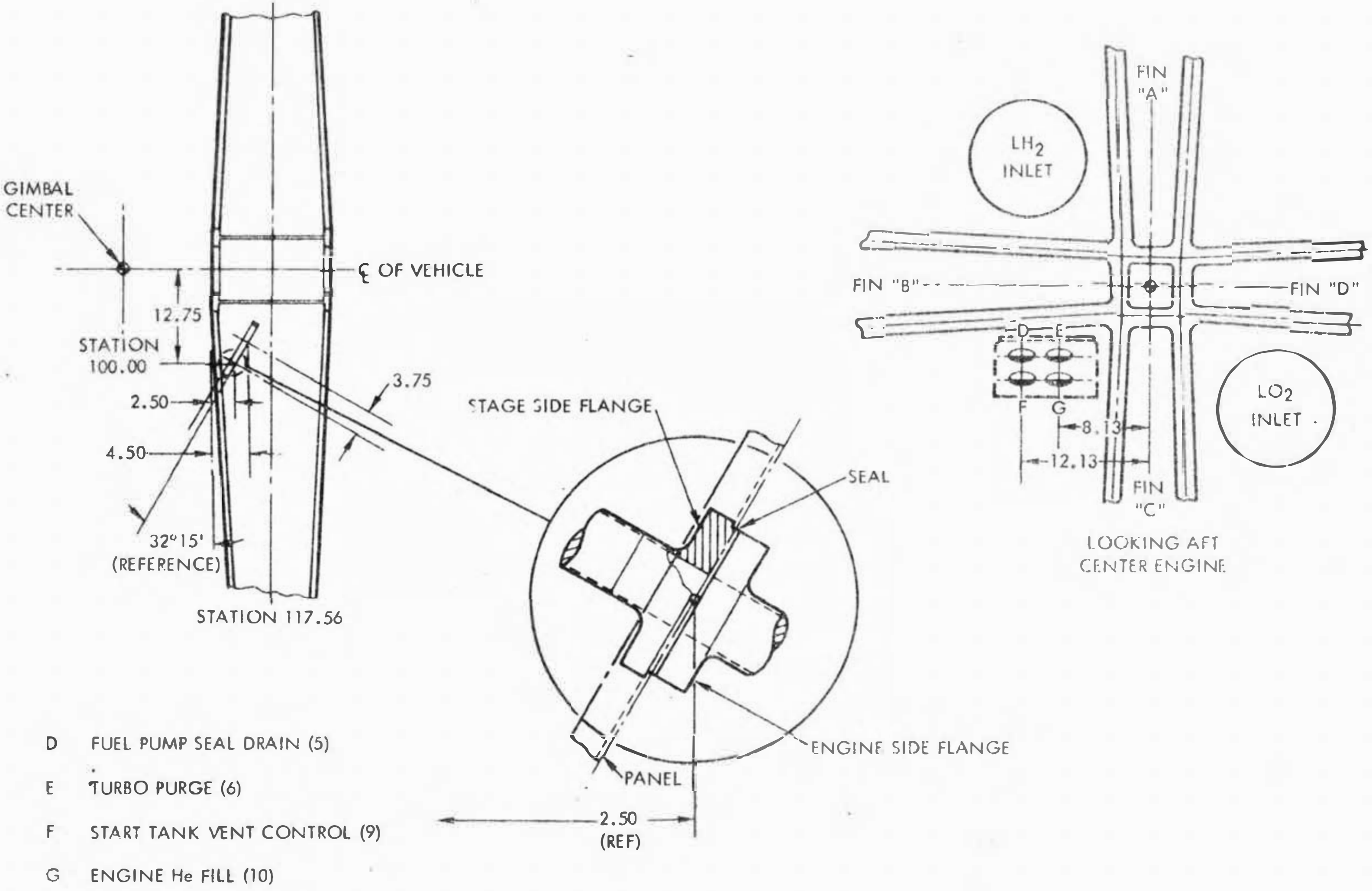


Figure II-39. Outboard Lower Panel—J-2/S-II Center Engine Fluid Lines Interface

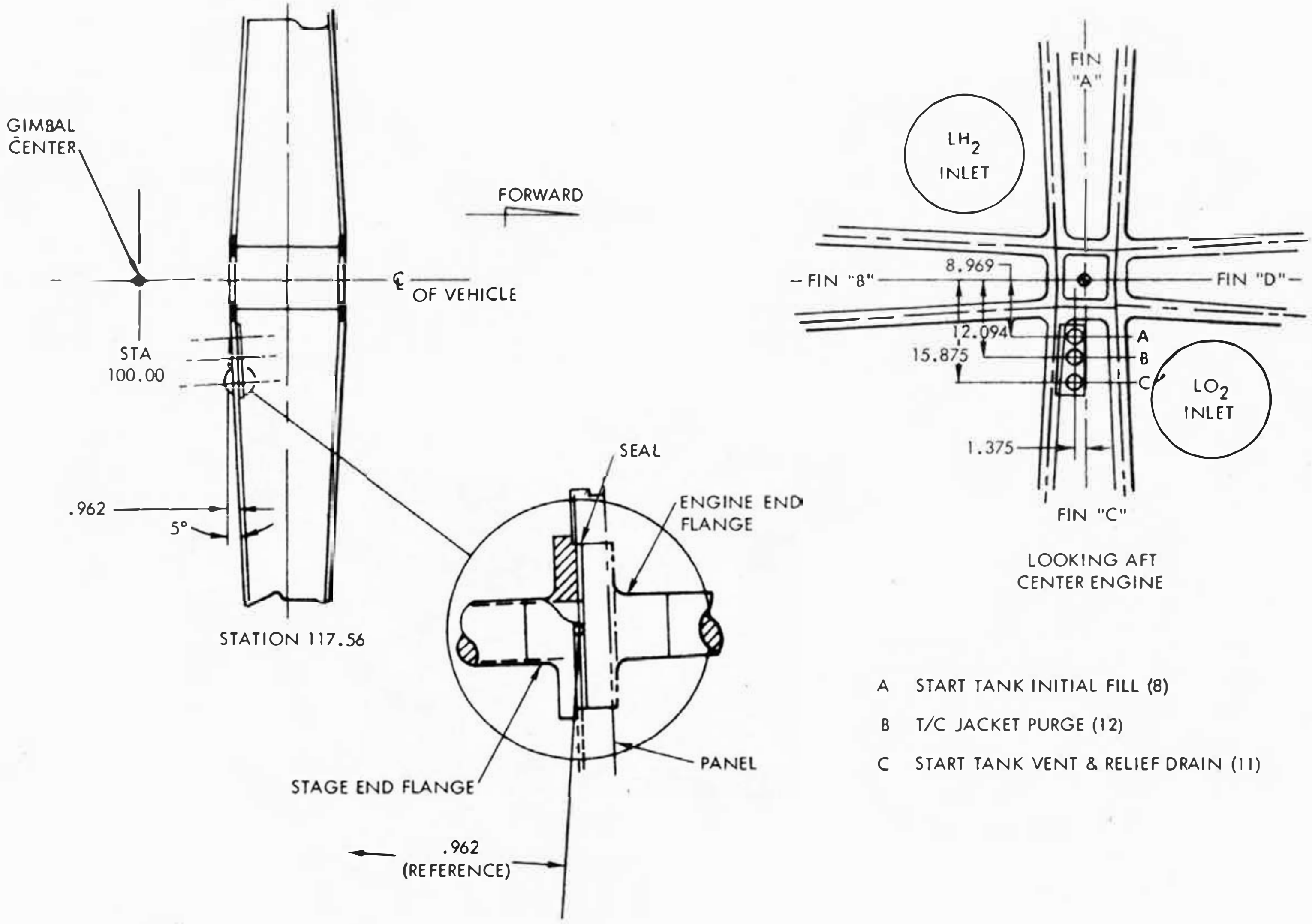


Figure II-40. Inboard Lower Panel—J-2/SII Center Engine Fluid Lines Interface

Procurement and Component Development

Disconnect Valve, Hydrogen and Oxygen (Specification MC144-0011) (Figure II-41, connected; Figure II-42, disconnected)

Development testing by the supplier, B.H. Hadley, was completed on 5 June 1964, with subsequent release of production drawings. A major design review was held on 27 December 1963 and resulted in design approval. Production parts are being fabricated and acceptance-tested for use on the initial test vehicles and the qualification test program.

Disconnect Coupling, Oxygen (Specification MC144-0014) (Figure II-43, connected; Figure II-44, disconnected)

Development testing by the supplier, B.H. Hadley, was completed 29 May, with subsequent release of production drawings. A major design review was held on 27 November 1963, and resulted in design approval. Production parts are being fabricated for use on the initial test vehicles and the qualification test program.

Disconnect Valve, Helium (Specification MC144-0010)

Production parts are being fabricated and acceptance-tested for use on the initial test vehicles and the qualification test program, which is scheduled to start on 7 August.

Solenoid Valve (Specification MC144-0012)

Development testing by the supplier, Futurecraft Corporation, was scheduled for completion on 30 July. Prequalification valves are being fabricated for use on the initial test vehicles. Qualifcation testing is scheduled to start on 14 August.

Testing

The J-2 engine thrust-chamber purge and chill tests conducted at the Engineering Development Laboratory were completed on 8 July. The test objectives were successfully achieved. Thrust-chamber chill was performed, using helium at -190 F instead of -250 F because of rapid depletion of LN_2 in the heat exchanger. Consequently the required chamber temperature of -100 F maximum was never achieved. However, the data obtained will be of value when correlated with the Battleship and All-Systems tests at PFL.

Engine Prestart Conditioning System

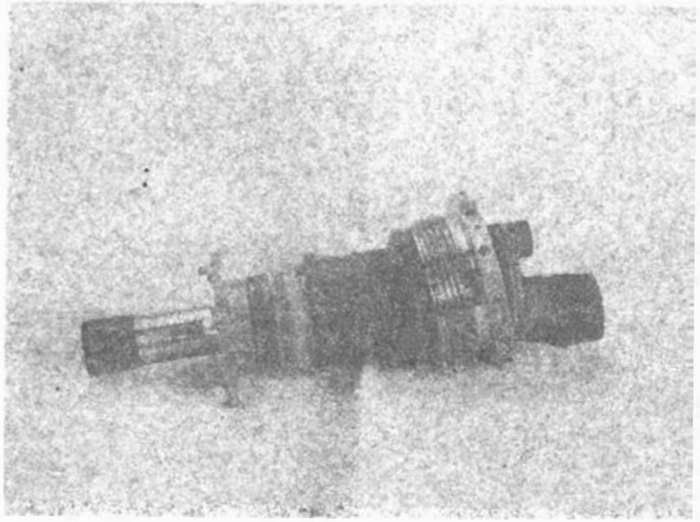


Figure II-41. Hydrogen and Oxygen Disconnect Valve—Connected

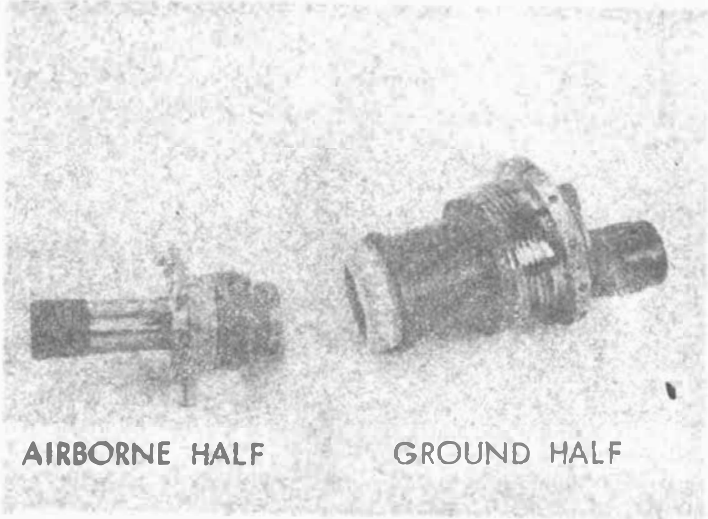


Figure II-42. Hydrogen and Oxygen Disconnect Valve—Disconnected

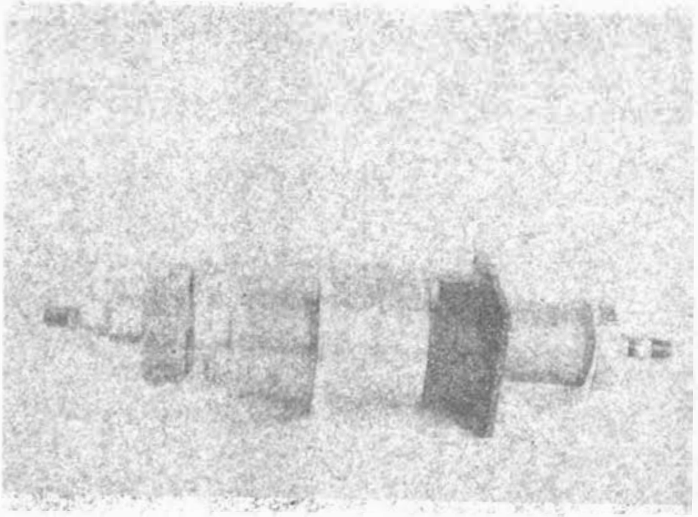


Figure II-43. Oxygen Disconnect Coupling—Connected

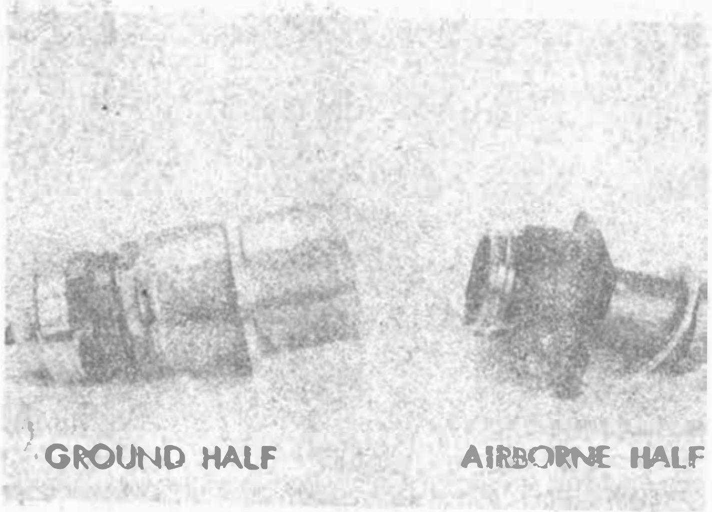


Figure II-44. Oxygen Disconnect Coupling—Disconnected

Description

The prestart conditioning system is designed to provide the J-2 engines with minimum NPSH requirements at engine start. This is accomplished by chilling the fluid and engine components in the engine feed and gas-generator circuits before launch and maintaining this condition during first-stage boost.

The fuel system is conditioned by means of a pumped recirculation flow, while the LOX system uses a natural convection recirculation flow. A description of these two subsystems follow.

Fuel System. J-2 engine minimum NPSH requirements have made it necessary to provide a subcooled liquid at the main fuel-pump inlets by chilling the engine and gas-generator components with a recirculation flow through the circuits prior to launch and maintaining the condition throughout first-stage boost.

The fuel preconditioning flow is initiated by five liquid-hydrogen pumps submerged in the fuel tank. The recirculation flow enters the main fuel ducts through pump discharge lines, passes through the main fuel valves and gas-generator bleed valves, and returns to the tank via a manifolded return. During operation, valves in the pump discharge and return lines are open with the prevalves in the main fuel ducts closed.

With MSFC direction, a forward-flow recirculation system utilizing a common pump with S-IVB has been incorporated. The system has five individual pumps which pump hydrogen through the pump discharge lines into the main fuel ducts. After flowing through the main fuel pumps, bootstrap lines, and gas-generator bleed valves, the fuel is returned to the fuel tank by means of a manifolded return. The system, as designed, results in a recirculation flow of 1.15 lb/sec per engine.

Oxygen System. The oxygen prestart conditioning system is designed to meet J-2 engine minimum NPSH requirements at the main oxidizer-pump inlets by means of a natural recirculation flow through the engine feed and gas-generator circuits.

The system consists of individual return lines from the gas-generator bleed valves to the LOX tank. Currently, standpipes are mounted inside the LOX tank from the bottom of the tank to just below the liquid interface, but these are being removed. Flow is initiated by the head resulting from the density difference due to unequal heating in the main ducts and return lines.

With the natural recirculation system, a flow of 0.40 lb/sec per engine results, which is marginal for satisfactory conditioning. This makes it necessary to provide the capability of injecting gaseous helium into the return lines to provide an additional differential head. During recirculation, the prevalves and LOX return line valves are open and the fluid flows in a forward direction.

Analysis and Design Considerations

Fuel System. The fuel prestart conditioning system must meet the minimum NPSH requirement of 130 feet at the fuel-pump inlet. Analysis shows that it is necessary to insulate the main fuel ducts and return manifold and line to ensure proper conditioning. Vacuum jackets have been placed on these lines.

J-2 engine testing has shown that it was necessary to enlarge the engine bootstrap line and gas-generator bleed valve to 1-1/2 inches to decrease the pressure drop. The system is sized as follows:

Component	Size (in.)
Pump discharge line and valve	2
Return - 1 engine	1-1/2
Return - 2 engine	2
Return - 3 engine	2-1/2
Return - 5 engine	3
Return line valve	2

With this configuration an initial flow rate of 0.18 lb/sec per engine (gaseous H_2) results, which gives a conditioning time of 96 seconds. After liquid flow is established, the flow rate is 1.15 lb/sec per engine.

Oxygen System. The oxygen prestart conditioning system must meet the minimum NPSH requirement of 25 feet at the LOX pump inlet at engine start. S&ID has been directed by MSFC to use a natural convection system with a helium-injection backup.

The natural convection system works because of the heating of the LOX in the return lines, which creates a pressure head because of the difference in density in the two lines. It was necessary to enlarge the gas-generator bleed valve and bootstrap line to 1-1/2 inches to minimize the pressure drop.

The return lines were optimized at 4 inches, but 3-inch lines are being used because of structural difficulties. Individual return lines are made necessary by uneven flow. The LOX return lines inside the LOX tank have been rerouted to attach to the upper LOX slosh baffle. This eliminated the guywire support system, two gimbal joints per line, and load concentration at the LOX-tank sump structural ring, reduced the congestion of components on the centerline of the vehicle, and simplified the design.

Another change was the common bracket mounting of lines on the inside of the thrust cone; this organized the plumbing into a uniform routing and reduced the variety of brackets in the area by standardization. A design change is now being issued which will remove the section of the LOX return lines inside the LOX tank from flight vehicles.

The helium injection system injects 0.4 lb/sec per engine of helium into the LOX return lines just downstream of the engine connect panels. A 3/4-inch check valve and a flow-control orifice are mounted in each helium injection line upstream of the injection point.

With the natural convection system, a flow of 0.40 lb/sec per engine and a chilldown time of 180 seconds result. Analysis shows that satisfactory operation of the system is marginal because of the low head available, making the helium backup necessary.

Procurement and Component Development

The result of MSFC's direction that a common S-II/S-IVB pump be used in the liquid-hydrogen recirculation system is that S&ID and Douglas Aircraft Company have negotiated a common procurement specification. Agreement has been reached on the control documents, which, although they are Douglas documents, have also been released by S&ID. A purchase order is now being prepared to purchase the pumps from the Pesco Products Division of Borg-Warner Corporation.

The inverters, which will provide the a-c power for the pumps, are not a common item; a purchase order for them has been placed.

The purchase order for the helium injection check valves was placed with the Stratos Division of Fairchild Stratos on 12 June. A major part of the plumbing for this system is being procured. Precision Metal Products, a Division of Fairchild Camera and Instruments Corporation, was awarded the contract on 10 July to produce this plumbing. This consists of the LOX return lines from the engine connect panels to the outlets inside the LOX tank approximately at the LOX full-level line, the LH_2 bypass lines at the tank outlets for the propellant feed lines, and the LH_2 manifold and return line from the engine connect panels to the LH_2 tank.

The S&ID portion of the installation design of the system is approximately 80-percent complete.

The Phase I control drawing of the system installation was submitted to NASA on 3 December 1963, and NASA conditional approval was given on 24 January of this year.

The preliminary design review of the system was held on 26 July 1963, and all resulting action items have been incorporated or resolved.

Decision on the use of a common LH_2 pump required that a six- to eight-bolt flange adapter be placed in the pump discharge lines to accommodate this revision.

The LOX return lines inside the LOX tank will not be used on flight vehicles, but the subcontract will not be cancelled until after qualification, so qualified hardware will be readily available if installation becomes necessary.

Engine Compartment Conditioning System

Description

The engine-compartment conditioning system provides a means of purging the engine and the interstage areas of explosive mixtures during propellant loading. The engine-compartment purging, which is done with nitrogen, is completed before liftoff. The purge system consists of a perforated 10-inch circular manifold (Figure II-45), four thrust-cone ducts, four distribution ducts, a 13-inch purge feed line, a quick disconnect, a thrust-structure closeout shroud, and a series of 92 overboard vent holes surrounding the aft skirt, interstage, and S-IC forward skirt. The circular manifold, which is mounted above the engines near the bottom of the thrust chamber, remains with the stage during flight.

Purging the engine compartment is accomplished by injecting warm gaseous nitrogen (of from 300 to 500 lb/min flow, at 80 to 250 F under a pressure not to exceed 1.5 psig) through the large manifold. The airborne engine-compartment purge manifold will be made up of a 13-inch feed line and a 10-inch annular manifold. The annular manifold will be located below the thrust structure. This manifold will encircle the center engine inside the four outboard engines. Purge orifices will be placed in the annular section of the manifold to direct purge gases in the following manner (referenced to Figure II-45): (1) Inward toward the center engine, (2) horizontally outward, (3) vertically downward between the engines, and (4) vertically upward.

In addition to the purge manifold, a thrust-structure closeout shroud will be provided to separate the volume above the thrust cone and the volume below the thrust cone into two separate compartments. The object of this is to maintain structural temperatures as low as possible and at the same time maintain ambient temperatures below the closeout above -50 F.

To meet the objectives of the closeout shroud, allowable leak area through or around the shroud must be limited to 1,250 sq in. The shroud must be capable of withstanding a pressure differential of 0.006 psig acting

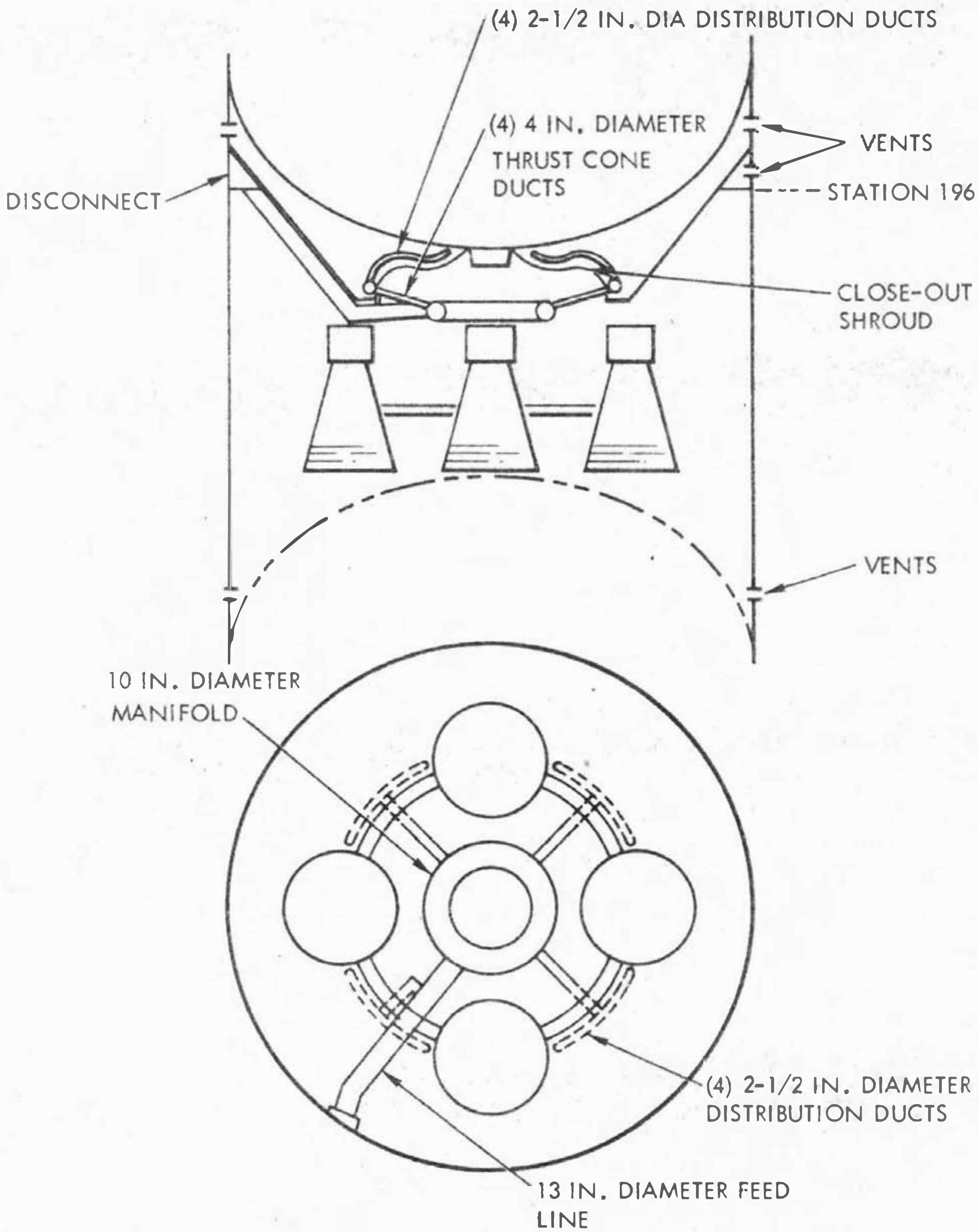


Figure II-45. Flight Purge System

in a downward direction during ground hold operations. During this time, the closeout shroud will be subjected to ambient temperatures ranging from +90 to -150 F. After liftoff the closeout has no functional value. At the time of J-2 engine start the closeout will be subjected to an upward pressure differential of 0.01 psig and a heat rate of 0.40 Btu/sq ft/sec. At this time the closeout may either maintain its integrity or disintegrate with no fallout harmful to the operation of the Saturn V vehicle. The weight of the closeout, including bracketry and supports, will not exceed 25 pounds.

To purge above the closeout, four 4-inch thrust-cone ducts will be extended, as shown in Figure II-45. The distribution ducts shown above the closeout will contain a total orifice area of 15 sq in. This will direct one-sixth of the engine-compartment purge gas above the closeout.

The S-II vent holes have been placed under approximately 92 supporting hat sections located on the exterior surface of the S-II aft skirt. This configuration will cover the vent holes and inhibit gusts of wind, rain, and dust from entering the interstage. Distribution of vent area is as follows:

(1) 70 square inches above the thrust cone

(2) 70 square inches just below the thrust cone

(3) 293 square inches on the S-IC forward skirt.

Status

In the last year several components have been added to the system, and some testing has been conducted. The components added are the thrust structure closeout shroud, the static-firing purge manifold, and the auxiliary manifold.

NASA is currently conducting fifth-scale model S-II boattail environment tests at Huntsville, Alabama. Results of these tests were expected to be available in July. Tests have been conducted by S&ID on full-scale models of the enclosed (flight) and open (static firing) engine compartments. The results of these tests are being revised and will be incorporated into the purge system design.

In the last year several items have been added to the engine compartment conditioning system. One is the thrust-structure closeout shroud. The reason for this addition has been discussed above. Purge gas trapped above the closeout (Figure II-45) and made old by contact with the LOX tank will keep structural temperatures low by convection along the inside surface of the thrust cone.

Two manifolds were developed for engine-compartment purging during static firing. These are the static-firing purge manifold, which is used to flow 250 lb/min of gaseous nitrogen (GN_2) above the thrust cone, and the auxiliary purge manifold, which is used to flow 250 lb/min GN_2 between the thrust cone and static-firing skirt.

Testing

Three tests have been planned for the development and qualification of the engine-compartment conditioning system. The objectives of these tests are described below.

A fifth-scale model of the S-II/S-IC interstage is being used by NASA to conduct model boattail environment tests at Huntsville, Alabama. The objective of these tests, as formulated by S&ID, is to provide insight into the flow distributions, extent of GN_2 mixing, resultant temperatures, extent of inerting, and the effect of the various purge parameters. The purge parameters are:

1. Manifold configuration
2. Vent distribution
3. Flow rate
4. Purge temperature.

Tests based on S&ID's configuration are currently being conducted, and test results are expected by 1 September.

Tests have been conducted on a full-size simulation of the S-II/S-IC interstage and on the open-engine-compartment configuration at Rocketdyne's hazards-suppression test stand. The flight-weight purge manifold satisfactorily inerted the boattail to 2-percent oxygen in 15 minutes. The original manifold tested during static-firing open-engine-compartment purging operations did not satisfactorily inert the compartment. Additional testing is being conducted on modified manifolds in an effort to optimize the static-firing purge system.

The third test will be conducted on a full-size simulation of the S-II/S-IC interstage and the S-IC LOX dome at the All-Systems test stand. The objective of this test is to determine specific values of:

1. Purge flow rate (range 300 to 500 lb/min)
2. Purge gas temperature (range 80 to 250 F)

and to verify predicted:

1. Boattail ambient temperatures
2. Structural temperatures
3. Degree of inerting
4. Performance of LOX recirculation system
5. J-2 engine heat-up rates.

Component Development

Development of the plastic film concept for application to the purge manifold was resolved to the point where the procurement specification was released, a supplier was established, and a material was selected.

To solve the problem of residue fallout of the duct material after exposure to the compartment heat fluxes, S&ID conducted environmental tests on Armalon and H film, both DuPont Teflons. The H film exhibited brittleness and fallout at elevated temperatures and was therefore rejected. The Armalon specimen (Figure II-46) consisted of Armalon-impregnated glass-fiber scrim. The material was subjected to a temperature of 1400 F for 30 seconds, reduced to 420 F for 450 seconds at a pressure equivalent to that at 200, 000 feet. The darkened area of the specimen in the photo is the portion where the Teflon sublimated, leaving the glass fiber scrim intact. The light area of the specimen in the photo is the clamping area and indicates the condition of the specimen exposure to high temperatures.

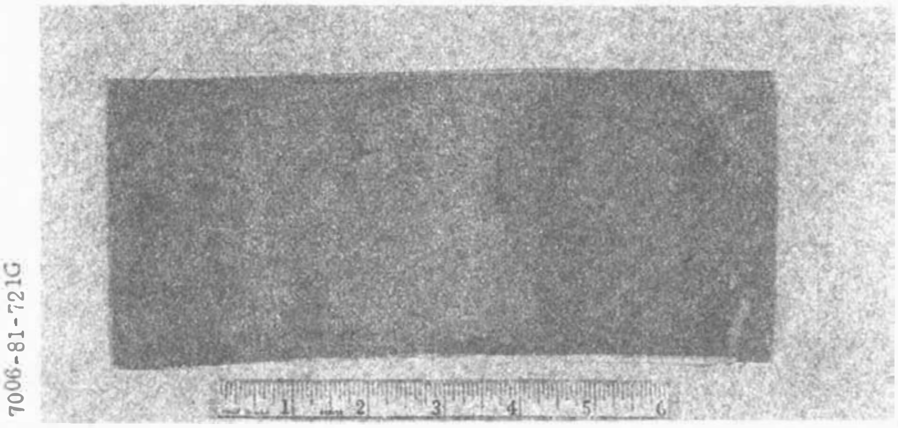


Figure II-46. Test Setup 2—Series 2 Armalon

During a full-size S-II interstage hazards test at the Rocketdyne field laboratory, a full-scale simulated engine-compartment conditioning plastic duct was tested. Using GN_2 at 500 lb/min flow, the simulated duct experienced no failures, demonstrating that use of a thin plastic-film duct is feasible.

FIRE DETECTION SYSTEM

Description

During the last year, a closer examination of the fire detection systems at Santa Susana and Mississippi Test Facility has shown the need for a stage-oriented fire detection system for Battleship, All-Systems, and MTF static firings. A system has been developed which provides coverage in the vicinity of hydrogen feed lines, engine compartment, systems tunnel, and forward skirt.

The fire detection system selected is a temperature-sensitive device that indicates a fire when the temperature of the area covered exceeds a preset limit. This detector is available as an off-the-shelf item. It is a continuous thermistor cable which will be located in the areas of potential fires. This system will provide coverage and discrete fire indications for each of the following areas;

(1) Each J-2 engine

(2) External and internal portion of LH_2 feed lines

(3) Systems tunnel

(4) Hydrogen-tank vent lines

(5) Hydrogen-tank vent disconnects

(6) Hydrogen fill and drain disconnect

(7) Umbilical panel 3A

(8) Engine connect panels

(9) Servicing manifolds inside thrust cone.

Thirty-two discrete fire indications will be displayed in the control center. Development tests on a small section of the system will be conducted on Rocketdyne's hazards-suppression test stand.

Analysis and Design

A stage-oriented fire detection system must be capable of detecting a hydrogen fire in the following areas: engine compartment area, vicinity of LH_2 feed lines, systems tunnel, and forward skirt area. It is believed that fires resulting from leaks through the hydrogen tank insulation may be detected visually because of discoloration of the insulation in the vicinity of the fire.

Leakage in LOX for GOX lines will also result in potential fire hazards. A fire cannot occur, however, until the oxygen comes into contact with some other compatible material. Unlike hydrogen leaks, where the hydrogen will most likely be in contact with air in the immediate vicinity of the leaking line (purging will tend to alleviate this problem in the engine compartment), it is difficult to predict where a fire due to an oxygen leak will occur. For this reason, oxygen lines do not seem to warrant specific fire detection coverage. It is felt that the proposed detector locations will provide sufficient stage coverage to detect such fires even though they might not be localized around a hydrogen line.

For S-II static firings there are two types of fire detectors required. One, of a semipermanent nature, would be for Battleship and the All-Systems stages. The other type would include those where detection is furnished when a vehicle is moved into a stand for a series of tests and then removed. Installation on flight stages at MTF would have to be of this type.

Because of time limitations, the selection of a fire detection system has been based primarily on the experience of groups who have previously dealt with liquid-hydrogen propulsion systems. The most complete information obtainable was provided by the Missile and Space Systems Division of Douglas Aircraft Company. Contact was also made with personnel having experience with hydrogen-fire detection at General Dynamics/Astronautics and at Rocketdyne. Although personal opinions vary widely, the consensus of actual test experience tends to validate the findings presented in the Douglas reports. A continuous cable fire and overheat detection system based on these reasons and on a study of available types of fire detectors has been recommended for use on the S-II stage during static firing.

Testing

Prior to installation of the fire detection system on Battleship, development testing of the continuous-cable type of fire detection will be conducted on Rocketdyne's hazards-suppression test stand. This test will involve mounting one detector cable in a fire area of the liquid-phase test stand. Procurement of a control unit is also necessary to form an operational fire-detection system. Information obtained will be useful in determining detector locations relative to flanges and fittings on S-II static-firing stages.

The data will also help in determining threshold settings for the control units. Distances from the hydrogen source and hydrogen flame, rises in detector temperature, response times, and threshold settings will all be included in the data obtained. Allowance will be made for configuration changes after preliminary test data have been evaluated.

Procurement

A supplier has not been selected for procurement of fire-detection system components, nor has any hardware been purchased.

ULLAGE MOTOR SYSTEM

Description

The ullage motor system functions as a device to maintain the position of the liquid propellants in the S-II vehicle during the critical period of starting the S-II engines. As the first stage engines are shut down and the acceleration of the vehicle rapidly approaches zero, eight solid rocket motors are fired simultaneously. The combined thrust of these motors produces 0.1 g acceleration to the vehicle for approximately four seconds or until the J-2 engines of the S-II stage have ignited, and reached one-third of their maximum thrust. Without this acceleration force during staging, the liquid fuel would leave the lower bulkheads and unport the engine supply lines, thereby preventing the firing of the second stage (S-II) engines.

The ullage motor system consists of eight solid-rocket motors mounted equidistant around the periphery of the S-IC/S-II interstage. Each motor has a rated thrust of 22,900 pounds (vacuum) and a burning time of 3.74 seconds for a stabilized grain temperature of 70 F. The motors will have aerodynamic fairings designed to cope with the drag and temperature environment during the vehicle launch phase. Motor ignition is accomplished by means of a pyrogen ignition system which is connected to a CDF. Each ullage-motor igniter has two initiators for redundacy. The ignition system is triggered by an accelerometer set to react at 3.6 g. The motor exhaust nozzle has been designed in such a way that the exhaust gas plume will not impinge on the J-2 engines. The motors are supported at three points and no ejection system is necessary, since the entire interstage is separated from the S-II vehicle.

Status

Seven heavyweight motors were cast, six of which have been statically fired. The seventh was found to have a cracked grain after a 60-day exposure at 170 F. Twenty igniters were fired, the last six of which were of the lightweight design. The 3D test stand was checked out and used for the last five of the six heavyweight motor tests at the Rocketdyne facility at McGregor, Texas. Rocketdyne has redesigned the motor case, utilizing a more conservative design in keeping with the prevailing S-II policy on structure and components. The resulting schedule readjustment was absorbed by the program with no negative effect on MILA delivery schedules. During redesign, the aerodynamic fairing was changed from a partial fairing to a one-piece overall design that completely enshrouds the motor except for the nozzle exhaust area. An installation major design review was held on 26 November 1963. The design was not approved until a working mockup could be made and tested. The full-scale mockup was completed, and installation and removal were demonstrated on the EMM on 2 January of this year, with approval of the design following. The qualification test program was revised to include random vibration and aging tests and to exclude temperature gradient tests.

An informal status review meeting was held at Downey on 5 May, attended by MSFC, Rocketdyne, and S&ID personnel, for the purpose of facilitating communications and promoting ideas. As a result of this meeting, Rocketdyne was asked to investigate the use of a stronger steel, such as ladish DGAC, in the motor case. The results of the study indicated an unfavorable tradeoff of weight saved to the increase in cost; therefore no change was made.

Analysis and Design

The motor case of the ullage rocket has gone through a major redesign in an effort to produce an efficient, lightweight design that is still conservative enough to satisfy the requirements of S-II stress criteria. This effort was dictated by a change in stress criteria and in the yield factor of safety. The aerodynamic fairing was originally an assembly consisting of five pieces which created a complex environment for the motors. A new one-piece fairing has been designed which eliminates the temperature gradient in the propellant grain, aerodynamic heating of the motor case, and the complications in the motor case itself. This change in the motor environment also permitted the elimination from the test program of a number of expensive tests.

The motors will be shipped to MILA in reuseable wooden containers with the igniter installed. A humidity indicator will be installed inside the weather seal.

Testing

The motor development program to date has been very successful in all of its phases. The heavyweight motor firings have established the propellant grain design and the igniter design. Design changes in liner materials and processes for curing were the result of the cracked grain investigation performed on the seventh motor. A replacement motor was cast and will be placed in hot storage (170 F) for 60 days, after which the motor will be radiographed and fired on the test stand.

The igniter program has been progressing satisfactorily. Six lightweight igniters were fired, and the results show excellent reproducibility.

A weather-seal development test program which involved 16 specimens was completed. The test results showed the seal design to be more than adequate for its function.

All motor and igniter firings to date have used single initiators. From now on, it is planned to use dual initiators.

A hazard classification test involving five lightweight motor specimens has been negotiated with MSFC. This test will take place at the Redstone Arsenal at Huntsville, Alabama. The results will provide data for the Interstate Commerce Commission to use in determining appropriate classification for shipping and storage of the ullage motors. The qualification test program has been adjusted to include random vibration tests. MSFC issued a technical directive providing the criteria as levels of input to motor support brackets. A transmissibility survey test will be conducted to determine the correct test criteria to be used on the motor.

PRESSURIZATION SYSTEM

The S-II pressurization system is shown in Figures II-47 and II-48.

Description

The pressurization system is divided into several independent subsystems, the functions of which are (1) hydrogen tank pressurization, (2) hydrogen tank venting, (3) oxygen tank pressurization, (4) oxygen tank venting, (5) pneumatic actuation of valves for the engine prestart conditioning system, and (6) preflight purging of the hydrogen pressurant lines. The responsibility for the analysis and overall coordination of the propellant thermal stratification problem is also a concern of this system.

The pressurization subsystems provide the required tank pressures for structural integrity and engine inlet requirements for all phases of flight, from prelaunch to the end of S-II boost. The factors affecting the magnitudes of required and maximum ullage pressures shown in Figure II-49. The venting systems vent the tanks during tank chilldown and filling and limit the tank pressure during all phases from prelaunch to the end of S-II boost. The pneumatic actuation system provides the regulated pressure source and some of the control solenoid valves for actuation of the valves in the engine

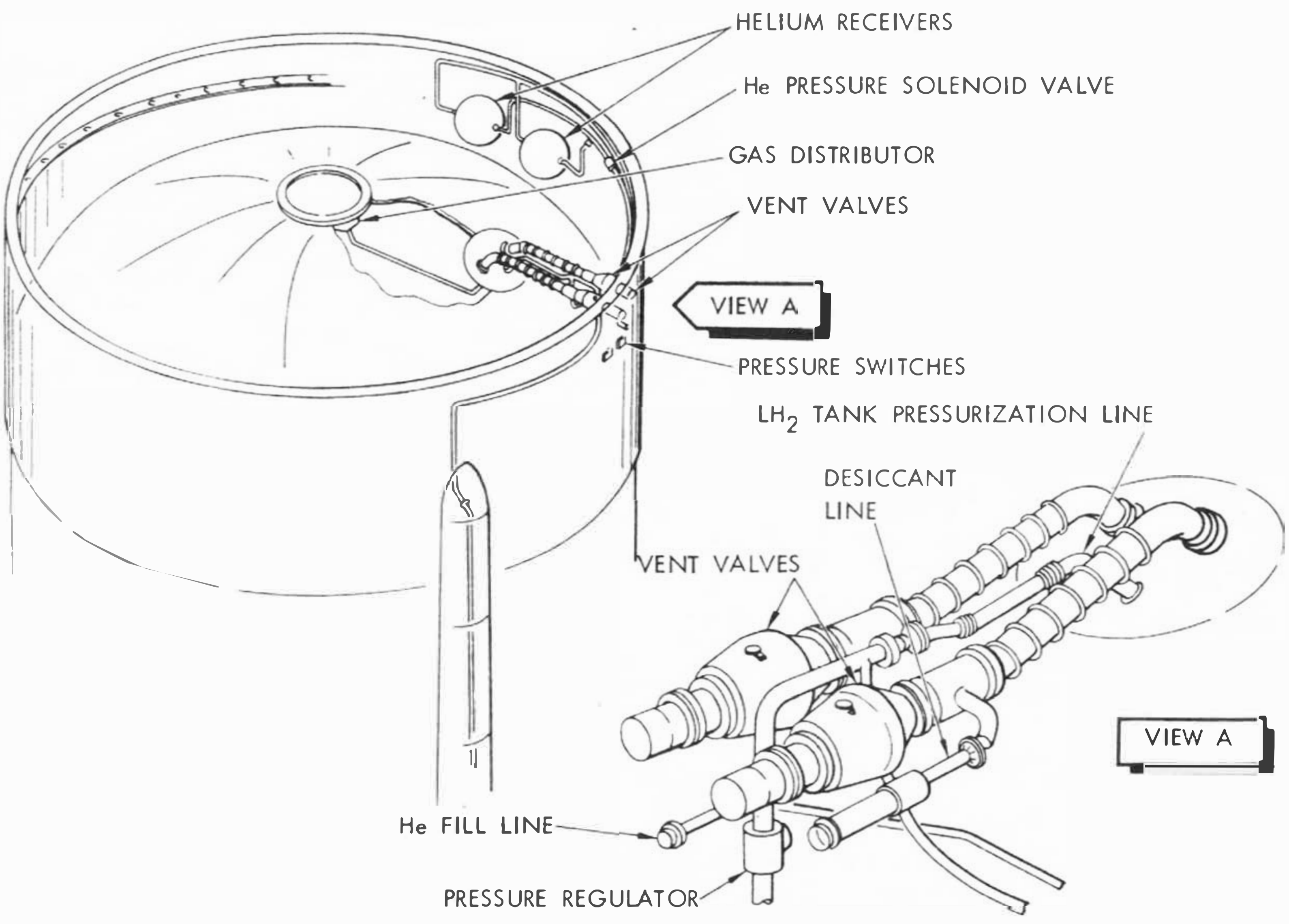


Figure II-47. LH_2 Pressurization System—Forward

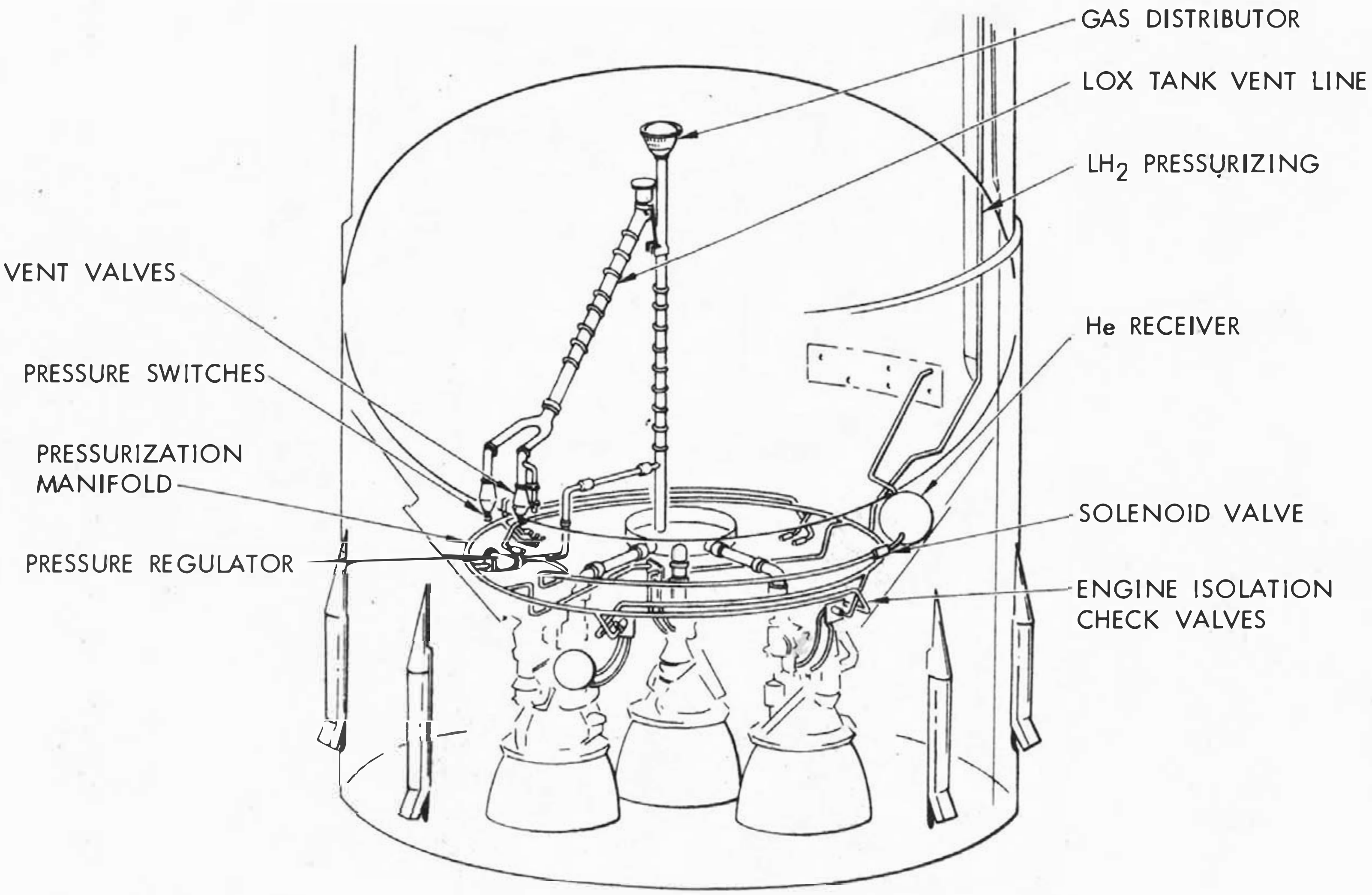


Figure II-48. LH_2 and LOX Pressurization System—Aft

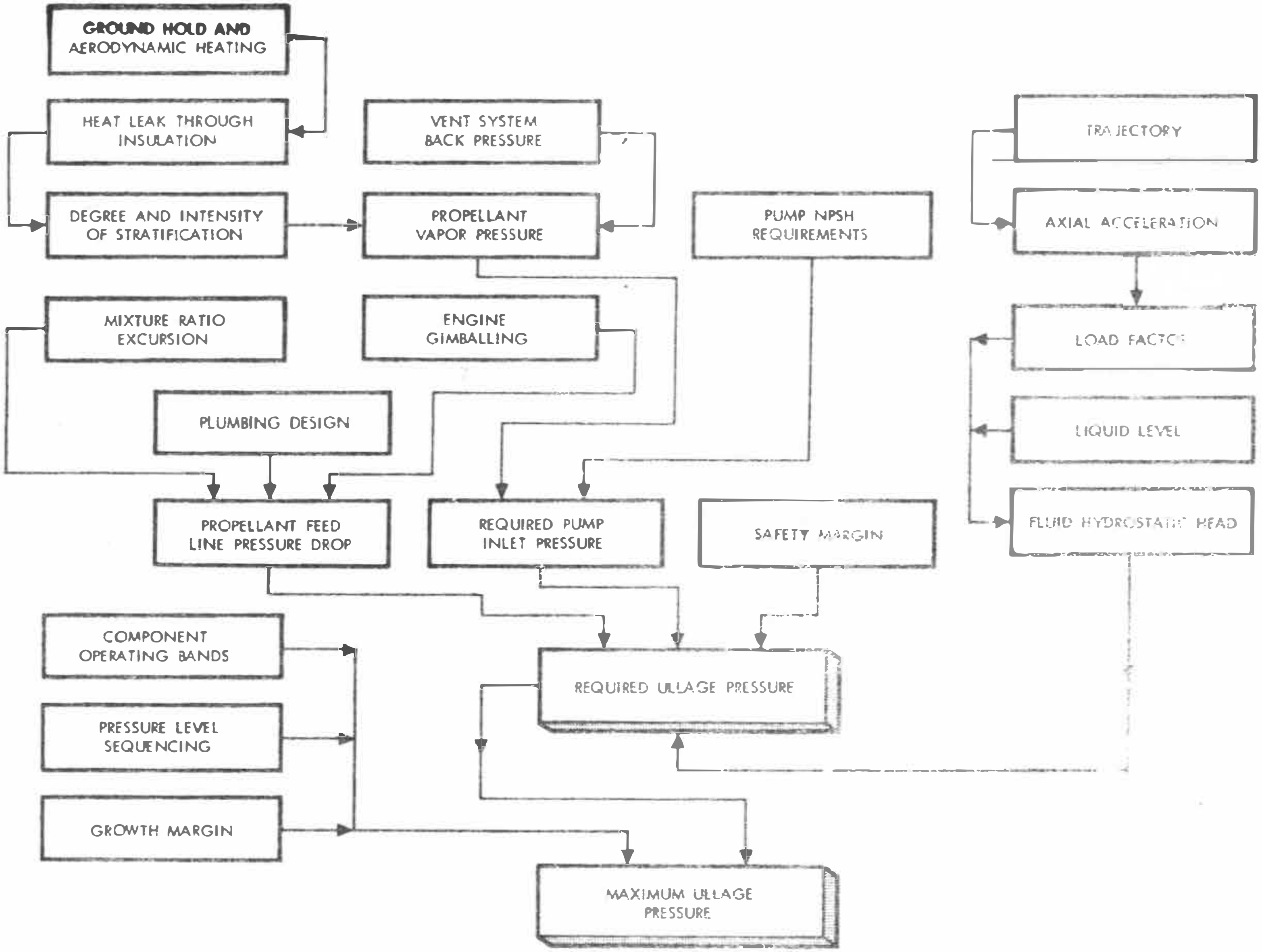


Figure II-49. Factors Influencing Required and Maximum Ullage Pressures prestart conditioning system during all phases from prelaunch to the end of S-II boost. This actuation system also provides the actuation pressure for prevalve operation during all of the flight phases. The hydrogen pressurant-line purging system is used only on the ground to remove condensible gases from the hydrogen-tank pressurizing line and to prevent the backflow of hydrogen gas through the engine injectors and into the engine compartment.

The successful operation of the engines is, to a large degree, dependent on the operation of the pressurization system. The overall weight of the vehicle is greatly influenced by pressurization system design and performance, since the structural weight is very sensitive to internal pressure and the pressurant weight is measured in thousands of pounds. In addition, a great deal is at stake in the assessment of thermal stratification and in the measures adopted to overcome its effects. The effects of thermal stratification are reflected in tank pressure level, pressurant weight, structural weight, insulation weight, and system complexity.

Tank Pressurization Subsystems

The tank pressurization subsystems for the hydrogen and the oxygen tanks are essentially identical in design, and identical components are used in both systems, except for the pressure level settings. The pressurization system actually consists of two separate subsystems, one for controlling helium and one for controlling evaporated propellant. The helium system is used for prepressurizing the tanks on the ground, maintaining tank pressure during first-stage boost, and maintaining tank pressure during the startup period of the S-II engines. The helium systems consist of pressure switches, solenoid valves, high-pressure receivers, and high-pressure fill disconnects. Prepressurization on the ground is accomplished by ground-supplied helium admitted through the high-pressure fill disconnect and controlled by the pressure-switch/solenoid-valve combinations. After tank prepressurization the high-pressure receivers are charged to 3000 psig, and this stored helium, controlled by the same pressure switches and solenoid valves, is used for tank pressurization during first-stage boost and engine startup.

After engine startup, pressurant gases are extracted from the engines. Hydrogen gas is extracted at a point just upstream of the engine injector. The pressurant flows from all five engines are manifolded together, and the total flow to the hydrogen tank is controlled by a flow control valve that senses tank pressure. The pressurant is admitted into the tank through a pressurant distributor designed to minimize turbulence, thereby reducing the heat loss in structure and propellant and consequently reducing the total pressurant requirement.

To compensate for thermal stratification, the tank pressure is increased toward the end of boost. At 250 seconds after S-II ignition, an electrical signal emanating from the master timer will operate a solenoid valve built into the flow control valve, causing the valve to go to a full open position (step pressurization). The tank pressure will rise until it is limited by the vent system.

The oxygen pressurization system operation is identical to the hydrogen system, except that oxygen gas is not available from the basic engine. Liquid oxygen is extracted from a point downstream of the turbopump and is vaporized in a heat exchanger located in the turbine hot gas discharge line. The vaporized-oxygen flows from the five engines are manifolded together and controlled by a single flow control valve.

Tank Venting Subsystems

The tank venting systems for the hydrogen and the oxygen tanks are essentially identical in concept and design. Two vent valves, in parallel, are used for each tank. The vent valves for the hydrogen and the oxygen tanks are identical, except for the pressure settings. The vent valves are pilot-operated and are actuated by tank pressure, no external electrical or pneumatic power being required for operation in flight. Pneumatic pistons incorporated into the design of the valves permit the valves to be opened or closed at will, during ground operations. The oxygen vent valves discharge directly to the atmosphere at all times. During ground operation, the hydrogen vent valves discharge into a line which ducts the gas away to a safe disposal area. This requirement for the hydrogen has resulted in the need for hydrogen vent disconnects.

Pneumatic Actuation System

The pneumatic actuation system consists essentially of a high-pressure fill disconnect, a high-pressure receiver, a pressure regulator, check valves, actuation solenoid valves, and surge tanks. The surge tanks are installed near the points of usage to minimize the transient flow requirements of the regulator and to increase the probability of successful prevalve operation under potential failure modes. The system is very straightforward in design and presents no special problems.

Hydrogen Pressurant-Line Purging System

This purging system, used only on the ground, consists of a single pressure disconnect plus check valves and orifices to inject helium at the engine isolation check valves in the hydrogen-pressurant supply lines. The incorporation of this system permitted the deletion of burst diaphragms in the pressurant supply line of each engine.

Status

Although no major changes were made in the pressurization system design of the first three flight articles, in subsequent vehicles the high-pressure helium receivers, used for propellant-tank pressure maintenance, will be removed.

Component and system design analysis has been completed. Other studies included tank collapse, venting thrust at separation, stratification, self-pressurization and Battleship operating requirements.

Six procurement specifications were issued. The elimination of the high-pressure helium system will involve the removal of three receivers.

The most important testing was done on the quarter-scale tank, where filling, pressurizing, stratification, and bubbling tests were conducted.

Analysis and Design

The analyses required for the basic design of the pressurization system and its components were completed during the year. In addition, other important studies were made, including the following:

(1) Elimination of high-pressure helium system - The elimination of this system resulted from a study showing that prepressurization of the propellant tanks would be sufficient to meet ullage pressure requirements through S-IC boost and engine start. This change will result in a considerable saving in weight.

(2) Tank collapse study - The first phase of a study was completed in which the discrete conditions which could cause tank collapse were tabulated. This covered the periods of fabrication, storage, transportation, chilling, and filling. Other related analyses showed the need for positive tank pressure during tanking and showed that no need existed for prepressurant and high-pressure helium to be at temperatures below 210 R.

(3) Weight reduction - Separate analyses showed that savings in overall weight of more than 2000 pounds could be effected by bubbling helium through the tanked hydrogen to induce bulk heating by mixing or by using an insulating sleeve to prevent the formation of a stratified layer at the surface.

(4) IBM computer programs - Computer programs were constructed covering: (a) the thermal stratification of liquid hydrogen, (b) nonoscillating flow through a vaporizing heat exchanger,

(c) steady flow of fluids in pipes with heat transfer, and (d) the relationship of pressure and boiloff during tank filling.

(5) Venting thrust analysis - This study was concerned with the force which would result from venting the propellant tanks at the moment of separation of S-II and S-IVB and with the possibility that this force might cause a collision between the two stages. The analysis showed that there is no danger.

(6) Pressure requirements for Battleship - The required pressures for successful operation of the Battleship engines was determined.

The greatest change in the pressurization system design is the elimination of the helium high-pressure subsystem, which is to be effective on S-II-4 and subsequent versions. This change will eliminate the helium receivers from both the hydrogen and oxygen tanks, with a considerable reduction in weight. The only other change of consequence has been the addition of a pneumatic system for the ejection of a movie camera. This is a relatively simple system involving a small number of components for which analysis and design had just been started at the end of this report period.

Testing

A series of tests were conducted in the quarter-scale tank at the Boulder, Colorado, facilities of Beech Aircraft. They included observations on the filling, pressurization, heating, and thermal stratification of liquid hydrogen. Figure II-50 is a sketch of the quarter-scale tank as installed in the Beech Facility. Figure II-51 is a photograph of the tank interior from the top access port, including the instrumented float, some of the fixed instrumentation, and the bubbling augmentation tubes.

Significant results obtained from these tests included the following:

(1) Self-pressurization occurred to a degree which indicated the possibility of dispensing with the high-pressure helium system for the maintenance of ullage pressure during S-IC boost and engine start.

(2) Stratification occurred in a manner close to that predicted by the S&ID analysis previously reported.

(3) Stratification could be destroyed by bubbling helium through the liquid hydrogen during a simulated flight. It was also found that by prepressurizing the hydrogen tank with submerged helium inlets stratification is greatly reduced during the subsequent

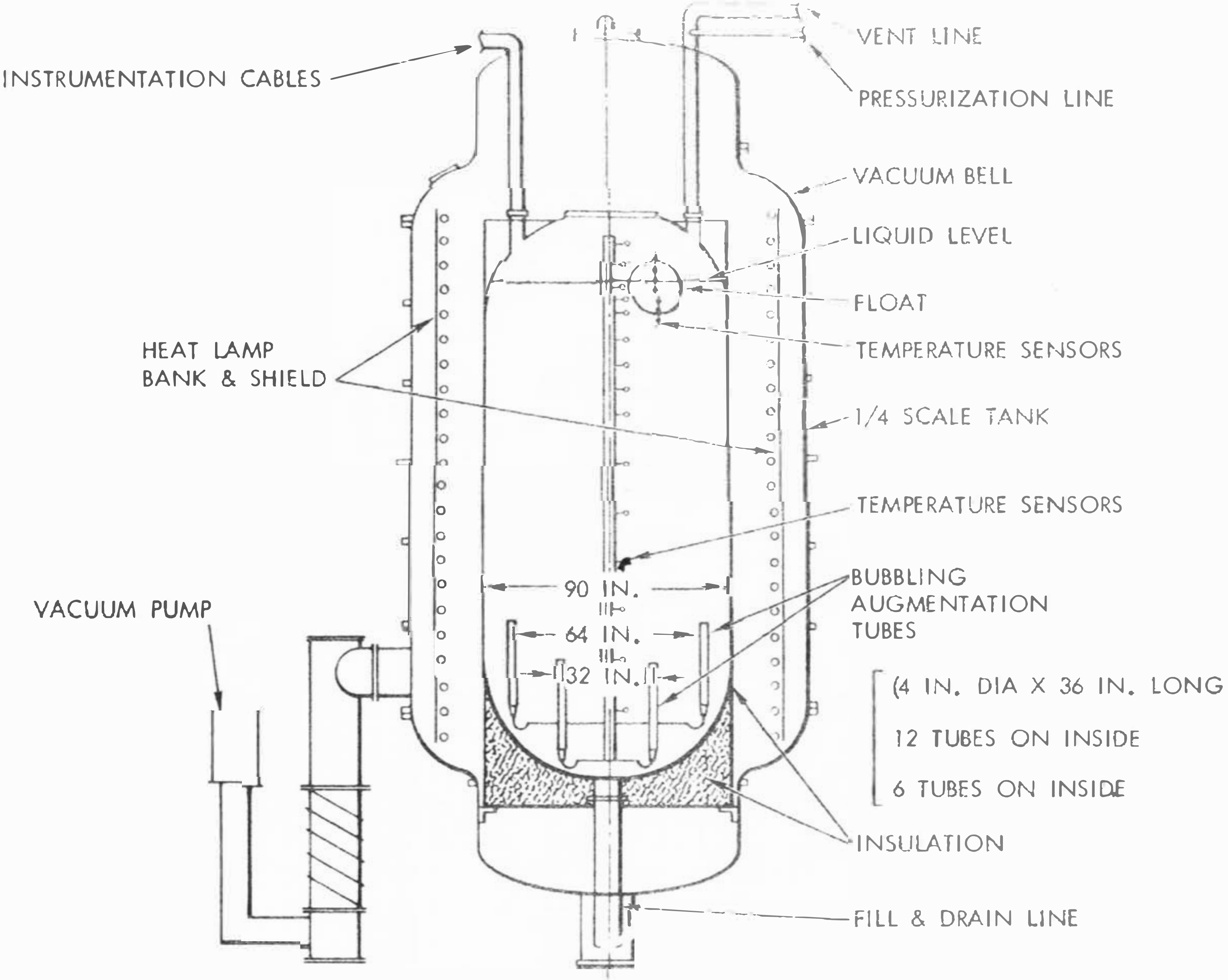


Figure II-50. Quarter-Scale Tank

flight period. No geysering effects were noted as a result of admitting helium at the bottom of the hydrogen tank.

(4) The presence of internal ribbing had little effect on the formation of thermal stratification.

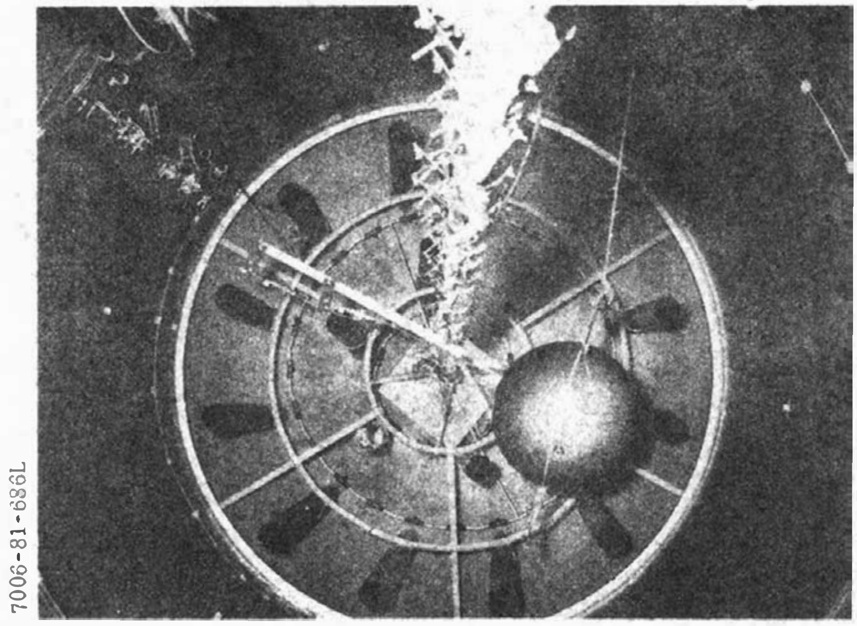


Figure II-51. Interior of Quarter-Scale Test Tank

Insulating sleeve tests - A test of the insulating sleeve was also conducted during the last year. This test was made with water heated in the annular space between sleeve and tank wall. The result indicated that if the sleeve extended from above the liquid surface down to the tank inlets, a good degree of mixing could be expected to occur and that the undesirable effects of stratification would be obviated.

Procurement and Component Development

Six procurement specifications were prepared and issued for components required for the engine prestart conditioning system and for the changes to the basic pressurization system that became effective during the previous year. The elimination of the high-pressure helium system will cause the deletion of three helium receivers from the pressurization system. Purchase orders have been placed covering a total of 14 specifications.

A prototype of the vent valve was received from the vendor. This valve was returned for modification and rework. The hydrogen vent disconnect has been redesigned to eliminate the actuation and latching features.

PROPELLANT SYSTEM

The S-II propellant system is shown in Figure II-52.

Propellant Feed System

Description

This system includes valves, lines, and disconnects to control all phases of propellant transfer. The propellant feed system for the S-II supports the operation of the five J-2 engines during powered flight and the prelaunch loading of the S-II propellant tanks.

The propellant loading subsystem is a nominal 8-inch-dia system with fill line, filling shutoff valve, and a disconnect coupling for each of the propellant tanks. The design of these components meet the requirements of both the LH_2 and LOX propellants.

The engine supply subsystem consists of individual 8-inch-dia LOX and LH_2 feed lines to each engine. Each line contains a normally open prevalve which can be pneumatically actuated closed to isolate an engine which has been shut down from the tanked propellants.

Status

The design of the propellant feed system configuration is complete, and production of detail parts is proceeding. Analytical results and necessary changes have been incorporated into the design.

Purchase orders for all detail components have been placed. Testing of development parts is proceeding and is approximately 80-percent complete.

Analysis and Design

Analysis and design of the established propellant feed system is complete. Analysis and performance data have been kept current with changes in the design of the engine feed lines. The design concept of the propellant fill disconnect coupling was changed, and this change has been incorporated by B.H. Hadley, Inc., the supplier.

Design of propellant system valves by Rocketdyne was completed and approved after a major design review. B.H. Hadley, Inc., is proceeding on schedule with production.

The duct design for the main propellant engine feed has been completed by the Solar Aircraft Company, including redesign of the center engine ducts.

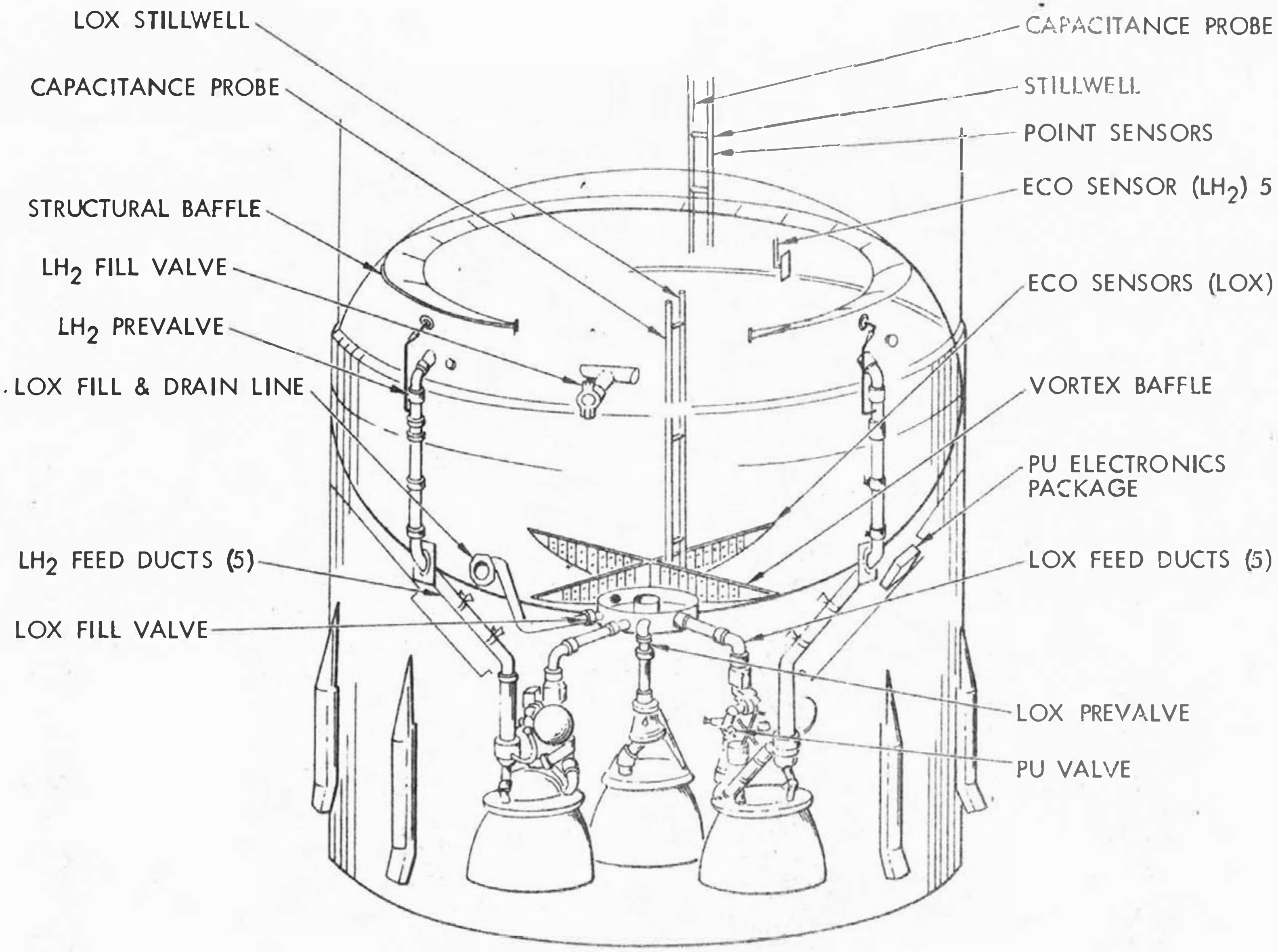


Figure II-52. Propellant Systems

The major design review on the Solar design of the engine feed ducts has been accomplished, except for the center engine lines.

S&ID system installation design is complete, and production drawings have been approximately 90-percent released to Manufacturing.

Testing

Development testing of the propellant feed system lines and components was approximately 90-percent complete as of 30 June.

Development testing on the prototype models of the fill valve, prevalve, and two-inch shutoff valve has been completed except for minor testing of product improvement. The main seal lock and lock actuator seals of the propellent-fill disconnect coupling have been tested.

Cycle- and pressure-testing of the gimbal bellows, testing of the vacuum jacket for all engine feed lines, and vibration-testing of the lower free bellows for the center engine line have been successfully completed.

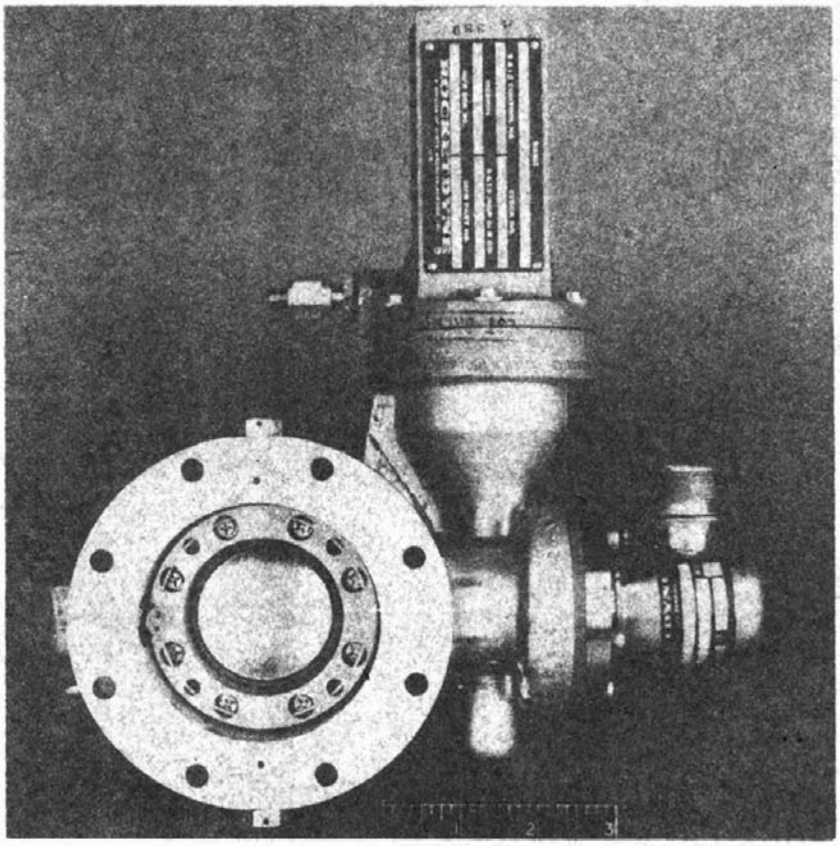


Figure II-53. Two-Inch Recirculation Shutoff Valve

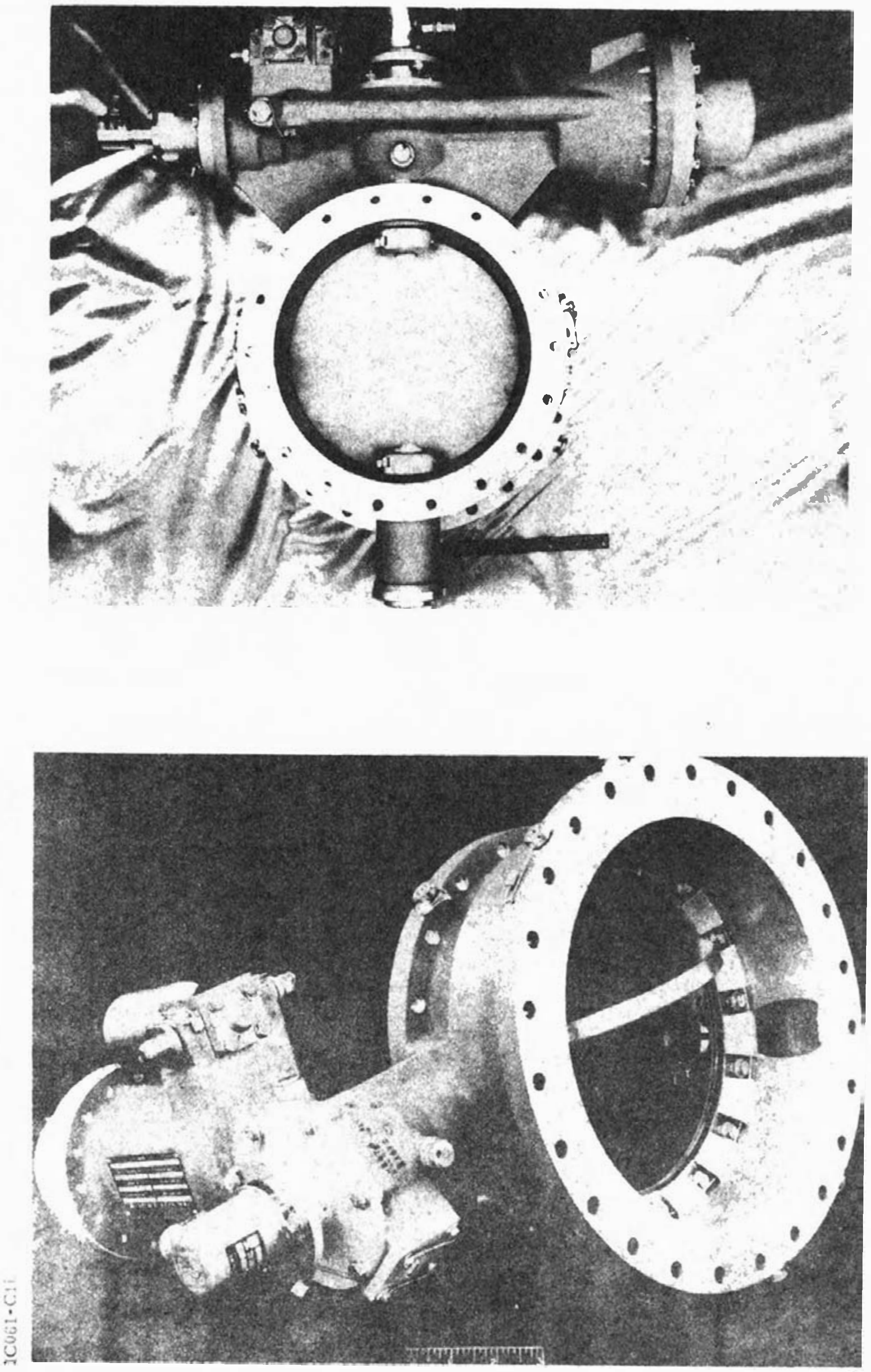


Figure II - 55. Eight - Inch Prevalve

Procurement and Development

Purchase contracts for all components of the propellant feed system have been placed, and development is approximately 80-percent complete.

Prototype development units of the propellant fill valve, two-inch shutoff valve, and prevalve are shown in Figures II-53, II-54, and II-55.

The development model of the propellant fill disconnect coupling was completed in February 1964, and a prototype development coupling is nearing completion. The Solar Aircraft Company has developed a compact gimbal bellows for the propellant feed ducts which reduced the gimbal weight approximately 60 percent over previous designs.

Propellant Management System

Description

The S-II propellant management system provides the following:

1. Accurate loading of LOX and LH_2 propellants to produce optimum payload boost capability, including the functions fo fast-fill cutoff and overfill cutoff
2. Propellant utilization during flight to achieve nearly simultaneous depletion of LOX and LH_2 to minimize end-boost residuals
3. Engine cutoff at propellant depletion.

The system is composed of propellant tank gauging elements and associated electronic equipment, as shown in Figure II-56, to perform the functions of propellant loading, propellant utilization (PU), and engine cutoff.

The tank gauging system includes a full-length capacitance probe in each tank which is the primary system for propellant loading and PU control. In addition to the capacitance probes, each tank contains point-level sensors to provide the engine cutoff signal at propellant depletion and serve as backup fast-fill cutoff and overfill cutoff sensors. A series of point-level sensors is also provided for monitoring of propellant level and calibration-checking of the capacitance probe.

The associated electronics to support the gauging equipment and provide the output signals and controls are contained in environmentally controlled boxes in the forward and aft interstages.

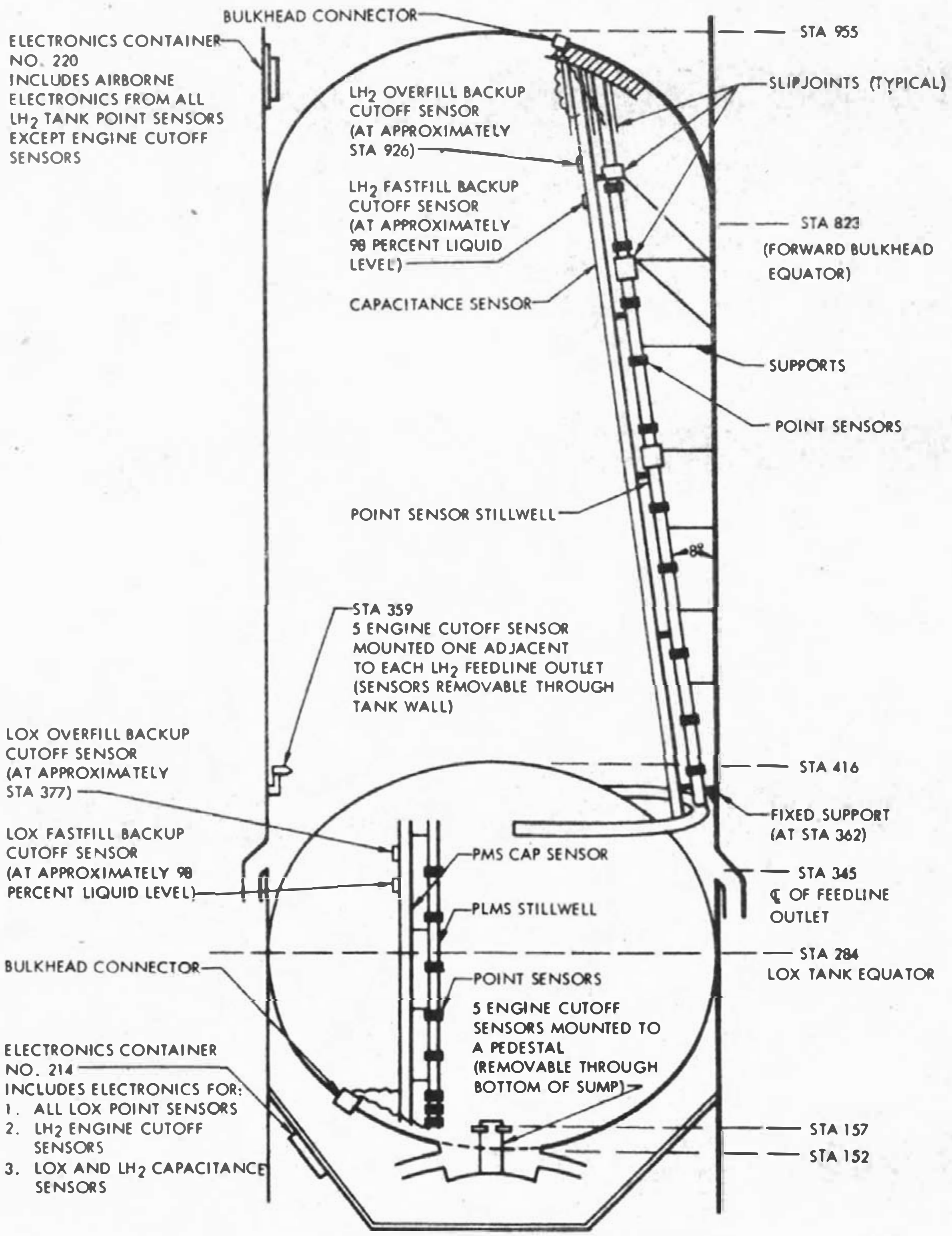


Figure II-56. Propellant Management Subsystem Installation

Status

Drawings of the Phase I propellant management system submitted to NASA were approved with qualifications, all of which were heeded in the final design. All installation drawings have been released to Manufacturing, and production of hardware has begun. Phase II drawings were submitted to NASA. Engine-cutoff logic drawings and point-sensor controller-packaging drawings were approved by NASA and released to Manufacturing.

The Douglas Aircraft Company has essentially completed preliminary design and analysis of a modified S-IVB PU system for use on the S-II vehicle. Breadboard testing of the airborne electronics package is under way, and procurement of long-lead-time items was initiated. The capability for programming engine mixture ratio has been included in the S-II PU system design.

Agreement with NASA has been reached on manual loading capability for the Propulsion Field Laboratory and the Mississippi Test Facility. Automatic capability will be provided for MILA and MTF. Recommended changes and procedures for LH_2-tank preconditioning have been submitted to NASA.

The thermal-wire type of liquid-level point sensor has been selected for the S-II. Hardware has been received to support the EMM and Battleship schedules.

Analysis and Design

The design of the S-II PU system as made by Douglas Aircraft Company will be as close to the S-IVB design as possible. Both systems, for instance, will use passive filtering.

Differences between the S-II and S-IVB requirements include the following: (1) Tank geometry, (2) five engines versus one engine, (3) higher environmental criteria, and (4) lower sloshing frequencies.

Programmed mixture ratio (PMR) for the S-II will be accomplished by adjusting the control setting of the PU system to approximately 4.6 tank mixture ratio and loading the tanks to approximately 5.275 mixture ratio. The resulting system error will position the PU valves "hardover" at 5.5 engine mixture ratio for the first 70 percent of flight until the excess LOX is burned off, after which the system will position the PU valves near the control setting of 4.6 mixture ratio for the remainder of flight.

The resulting PMR effects on engine thrust and specific impulse will provide a gain of approximately 3560 pounds of Apollo payload. Increased heat flux in the S-II base area will probably result from the increased mixture ratio; however, studies to date have verified the feasibility of PMR for the S-II stage. A final report will be issued after base heating tests are completed at MSFC.

Authority has been received from NASA to proceed with implementation of PMR on S-II-4 and subsequent stages. This will probably necessitate redesign of the heat shield and require additional thermal protection for components in the base area. The control setting adjustability required for PMR has already been provided in the PU system design.

Proposed design changes and procedures for LH_2 tank temperature conditioning prior to loading have been submitted to NASA. Close coordination is being maintained with NASA to define S&ID/NASA loading interfaces.

Testing

Douglas has fabricated a breadboard PU electronics package and completed initial testing of system characteristics.

As a result of an explosion which occurred at General Dynamics/Astronautics involving a hot-wire point sensor, a contract was awarded by S&ID to the Arthur D. Little Co. to investigate the catalytic effects of platinum wire in air-hydrogen mixtures. As a result of these tests, the platinum-wire element of the S-II point sensors was gold-plated to increase the safety margin between the maximum design wire temperature and the ignition point of air-hydrogen mixtures to 1200 F.

Procurement and Component Development

Approval of production go-ahead for the Douglas-developed PU system was received from NASA, and joint agreement was reached between S&ID and Douglas on revisions of the PU procurement specification to serve as a basis for contract negotiations. With retrofit in certain cases, it appears feasible to provide PU on all desired stages (Battleship, All-Systems, S-II-F, EMM, S-II-1 through 10). Douglas is proceeding with procurement of such long-lead-time items as the probes and servo-rebalance potentiometers.

Acoustica Associates of Los Angeles were awarded a fixed-price contract to supply the thermal-wire type of liquid-level point sensor for the S-II. Delivery of prequalified sensors and controllers was received to support the EMM and Battleship schedules.

Slosh and Vortex System

Description

During S-II operation it is necessary to suppress any adverse liquid motion in the propellant tanks which might cause early breakthrough of gas into the engine feed lines. An additional requirement is to suppress liquid sloshing during S-IC operation. Antislosh and antivortex baffles in the LOX tanks limit these effects and assure satisfactory stage operation.

Such baffles are not required in the LH_2 tank as currently determined. No antislosh baffles are required in the LOX tank during S-II operation. The LOX tank contains one ring-type slosh baffle in the upper dome sections. Premature uncovering of the LOX tank sump due to sloshing near the end of boost is prevented by a cruciform baffle located in the bottom of the tank (Figure II-57). A vane type of antivortex baffle is mounted in the sump to prevent vortices from entering the engine supply ducts.

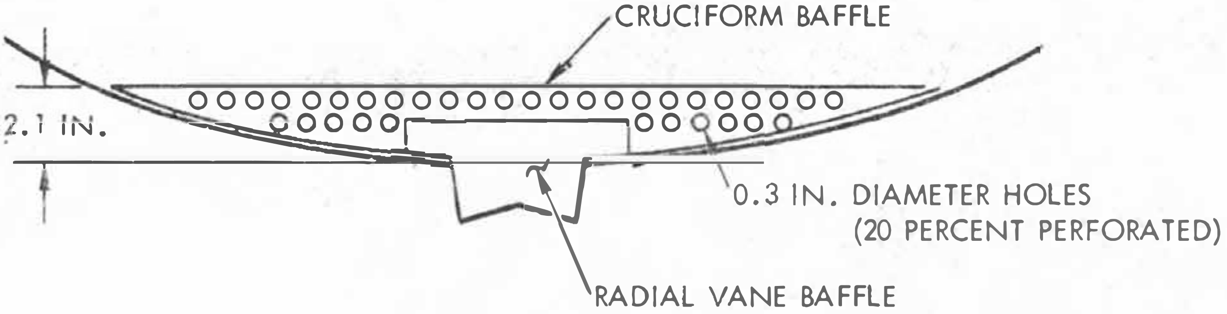
Status

The slosh and vortex tenth-scale plastic model test program was completed and the final report published. The slosh test program verified that no antislosh baffles are required for S-II slosh stability. The upper baffle, required for S-IC operation, provides a damping ratio of less than one percent. The cruciform and radial-vane antivortex baffles required in the LOX tank sump virtually eliminate vortexing.

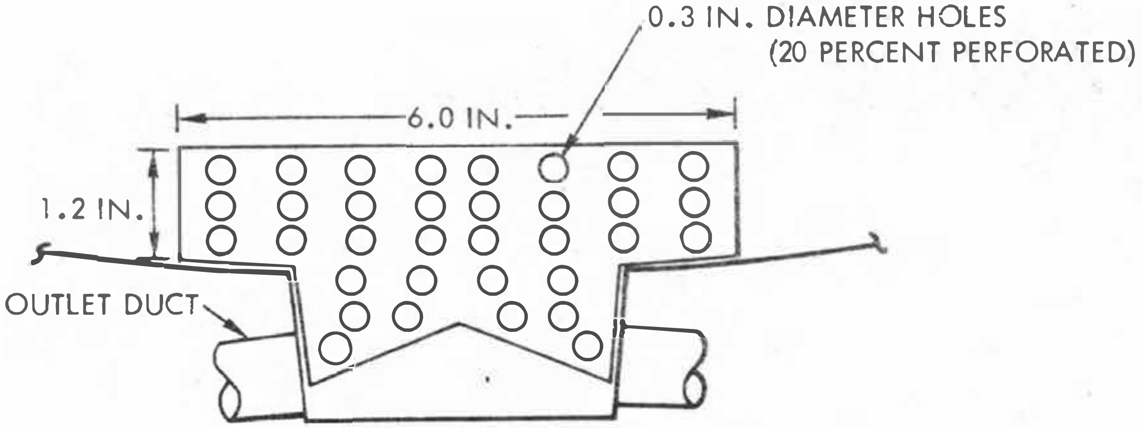
Testing

Verification of analytical methods for determining LOX tank slosh characteristics were made by comparison with experimental test data from the tenth-scale tank. On the basis of correlation of theoretical and experimental data, the inputs for slosh dynamics to S-II trajectory studies were verified. The results of the S-II trajectory studies show that baffles at the LOX tank equator and in the lower section of the LOX tank are not required for liquid damping. The requirement for the upper LOX-tank baffle still exists to provide for S-II slosh stability during S-IC boost. A damping ratio of less than one percent is exhibited by the upper LOX-tank baffle. The low damping appears to prevail because the liquid mass above the boundaries of the upper baffle sloshes independently of the tank liquid mass and therefore the upper baffle offers little resistance to the slosh wave. Higher damping might be obtained by reorienting the upper baffle parallel to the undisturbed surface of the free liquid.

The cruciform and radial-vane baffle, shown in Figures II-57 and II-58, is an effective device for preventing vortices from interfering with the continuity of liquid flow from the LOX tank sump. Model test have shown that antivortex baffles are not required at the LH_2 outlets, since the outlets are not susceptible to liquid vortexing.



CRUCIFORM BAFFLE SIDE VIEW



RADIAL VANE BAFFLE SIDE VIEW

Figure II-57. LOX Tank Anti-Vortex Baffles

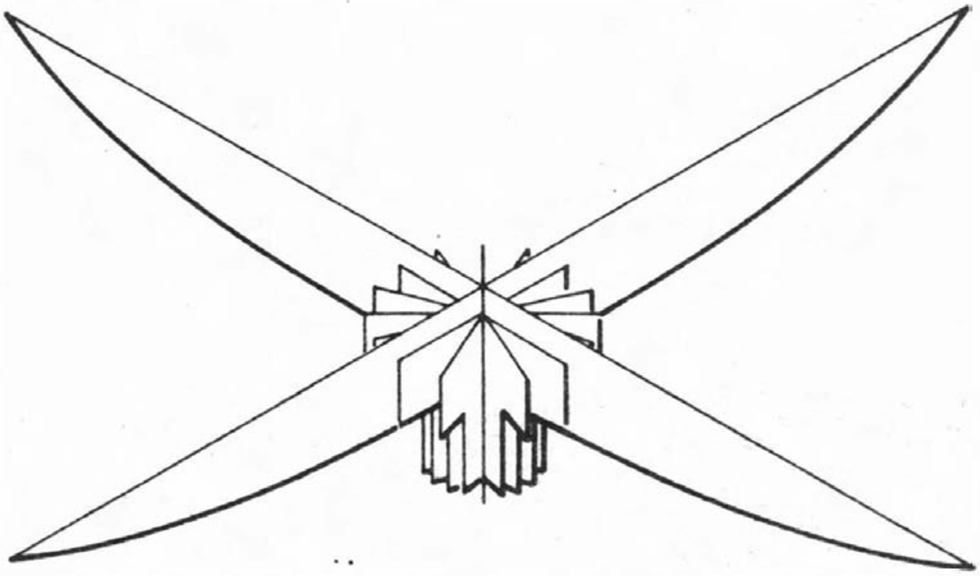


Figure II-58. Cruciform and Radial Vane

Attempts were made to estimate residual LOX by various methods of extrapolating model test data; however, the large residual variations after extrapolation indicate that full-scale residuals cannot be accurately predicted from tenth-scale model tests. The variations in prototype residual estimates are apparently the result of scale-factor magnification of the errors associated with the measurements of parameters for determining tenth-scale residuals.

THERMAL CONTROL SYSTEM

The S-II thermal control system is shown in Figure II-59.

Description

The S-II thermal control system is designed to provide a temperature range in the electrical and instrumentation systems containers which will permit the use of off-the-shelf components. Since most components are designed to military specifications and have displayed reliable operation over wide temperature bands, precise temperature control is not required. A range of 0 to 140 F is more than adequate for most containers. Protection for both upper and lower temperature limits is required in the Saturn S-II application. A warm environment exists during stage checkout operations; propellant loading creates a cryogenic environment, which is followed by heating during S-II boost. With the type of propellants used, the system must also provide an inert atmosphere throughout ground operations when the stage is tanked.

The thermal control system is basically a ground-operated system with thermal inertia and container insulation providing the required control during boost. The system provides a cool environment during checkout by delivering ambient, ground-supplied air to the electronic containers. An inert atmosphere and warm environment are maintained when propellants are loaded, by using heated gaseous nitrogen (GN_2). A supplementary manifold which delivers heated GN_2 to the forward skirt area provides some heating for the containers in addition to heating the components in this area.

System operation begins at the start of equipment checkout with the delivery of filtered air to the stage disconnects. The air flows through the manifold and into each container supply line where the flow is metered by an orifice. It then flows into the container, removes the excess heat from the operating equipment, and exits through the container bleed holes into the interstage area.

Prior to propellant loading, the cooling medium is changed from air to GN_2. The GN_2 flow path is identical to that of the air, but it is delivered at a higher temperature to warm the equipment which is exposed to the

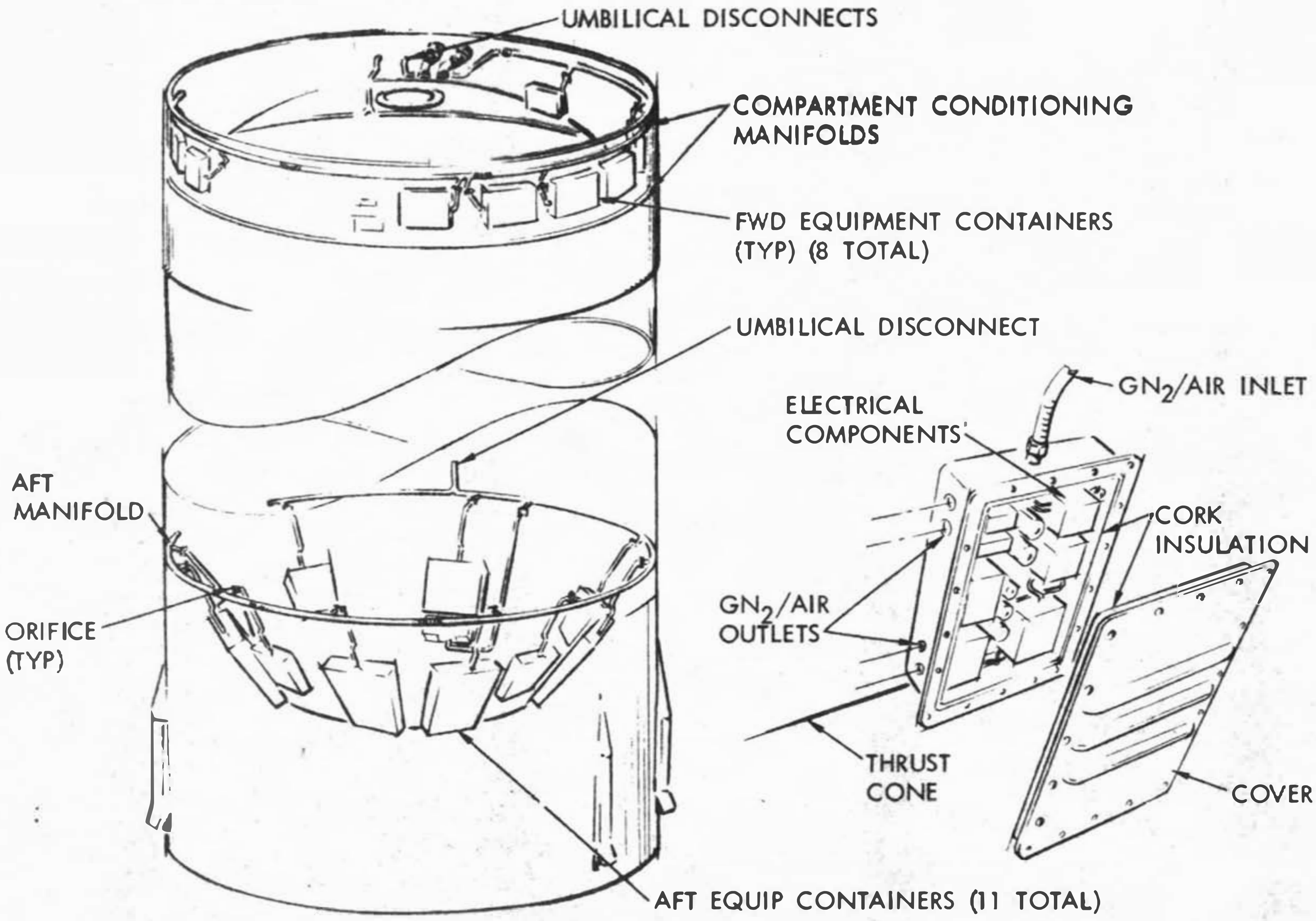


Figure II-59. Thermal Control System

colder environment caused by the propellants. A temperature sensor in each container gives ground indication of the above operations.

At liftoff the nitrogen flow is terminated by disconnect separation. Throughout boost the container pressure drops by expelling nitrogen through the bleed holes. Component temperature changes are minimized by container insulation and thermal inertia. The container insulation precludes excessive temperatures for those containers exposed to base heating.

Status

Thermal control system development has progressed according to previous plans except for the testing of flow balance. Changes which have increased the number of equipment containers from 15 to 20 and changes in the components in the containers have necessitated rescheduling this test. The only effect of this rescheduling is that the system orifices for S-II-T will not be installed in the planned production sequence. Installation will be made prior to operation.

Analysis and Design

System analysis has been completed, except for the analysis associated with detailed components and changes. Each container has been analyzed, and curves of supply temperature versus flow rate, similar to the example in Figure II-60, have been established. These curves reflect the flow required to cool the equipment for the design limit condition. A second curve gives the flow required for heating. The curves were constructed from the 7094 computer solution to an electrical analogy of the thermal network. Earlier curves were revised when panel tests of container walls gave better thermal property data. Since the flow is orifice-controlled, each container will receive its predetermined flow rate for both cooling and heating. Since the cooling flow and heating flow are not identical, the design margin for one of the two will be greater. For most containers the cooling margin is greater (i.e., heating is dictating the flow).

The system plumbing analysis is also complete for the design conditions. A computer program was written to solve the network and give both pressure and temperature results. This program gives results which consider the interrelation of pressure and temperature. The program is now being used to refine the system performance predictions and will be used later for off-design data and system changes.

Conclusion of the container analysis provided the requirements for plumbing analysis, and this in turn yielded the total system design requirements. Though the detail design could not be completed without all the requirements, it was started with preliminary data and has progressed on

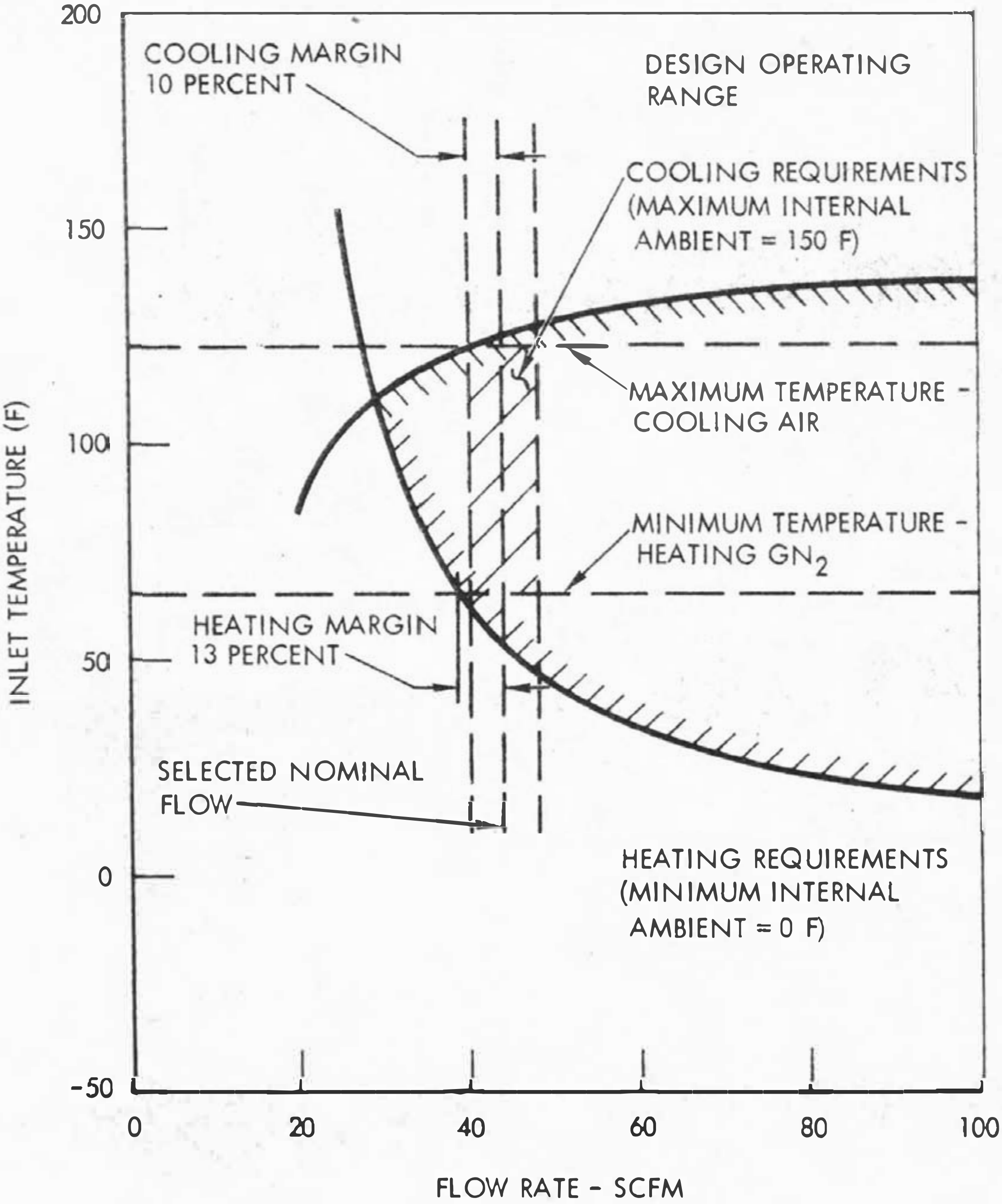


Figure II-60. Heating and Cooling Requirements for Typical Equipment Container schedule, so that all detail design and EOPRs for the thermal control system are complete and customer approval of all Phase I drawings has been received. In accordance with the previous plans, the installation drawings have already been started.

There are no significant design or analysis problems. Both are on schedule and basically complete. Detail component analysis and installation requirements remain.

Testing

The tests conducted on the thermal control system have included preliminary noise tests in the laboratory and on the EMM. These noise tests were conducted to ensure that the resultant noise level did not present a hazard or hindrance to maintenance personnel. Though the tests were preliminary, the results showed some correlation. As indicated in Figure II-61, there is a noticeable reduction in noise level when the orifice is located upstream of the container. Since the predicted system flows yield velocities in the lines and orifices of 100 ft/sec and 300 ft/sec, respectively, no acoustical protection is required.

The candidate insulations for the electronic-equipment containers shown in Figure II-62 were subjected to simulated base heating effects to determine which would survive the launch environment. On the basis of test results, a lightweight cork insulation of low thermal conductivity was selected. With the completion of a second series of tests to determine thermal properties of the cork insulation, we are now assured that this insulation will remain structurally sound during launch and provide the needed thermal protection for the equipment.

A representative equipment container with simulated flight equipment (Figure II-63) was exposed to environments covering the complete design range for ground operation. The flow rates and gas supply temperatures were varied to determine the role of these parameters in providing the required environment inside the containers. The results of the container flow tests are being evaluated.

The termal control system flow test has been rescheduled to the first lay-up period of the EMM. This test, which is required to establish the orifice coefficients and final sizes, was scheduled to provide results before S-II-T drawing release. However, changes which added containers and revised their contents have produced corresponding design changes such that the required hardware for the test cannot be designed, manufactured, and installed on the EMM before initial activation to support this test. As a result, the test will be run and the orifice sizes determined after system installation, during the first lay-up period. Establishment of orifice sizes

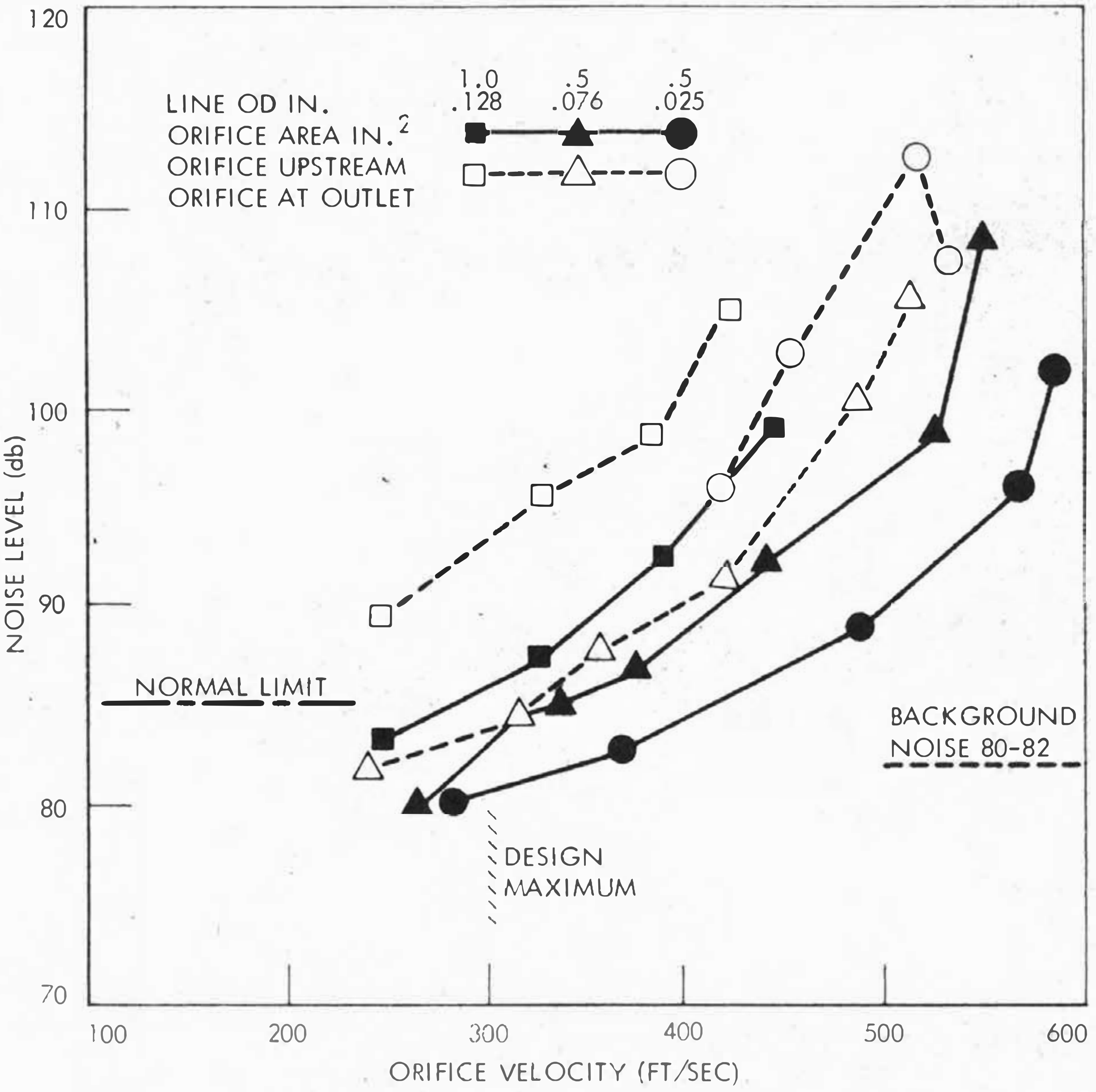


Figure II-61. Noise Test

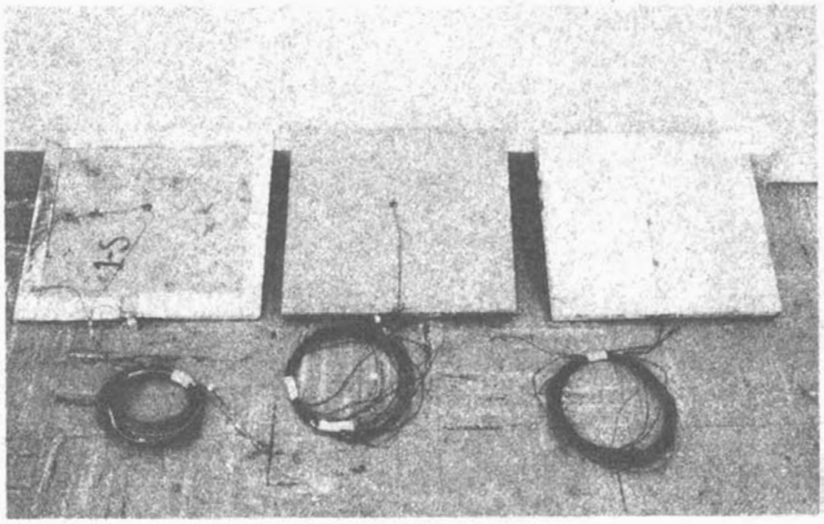


Figure II-62. Insulation Test Specimens for Electronic Equipment Container

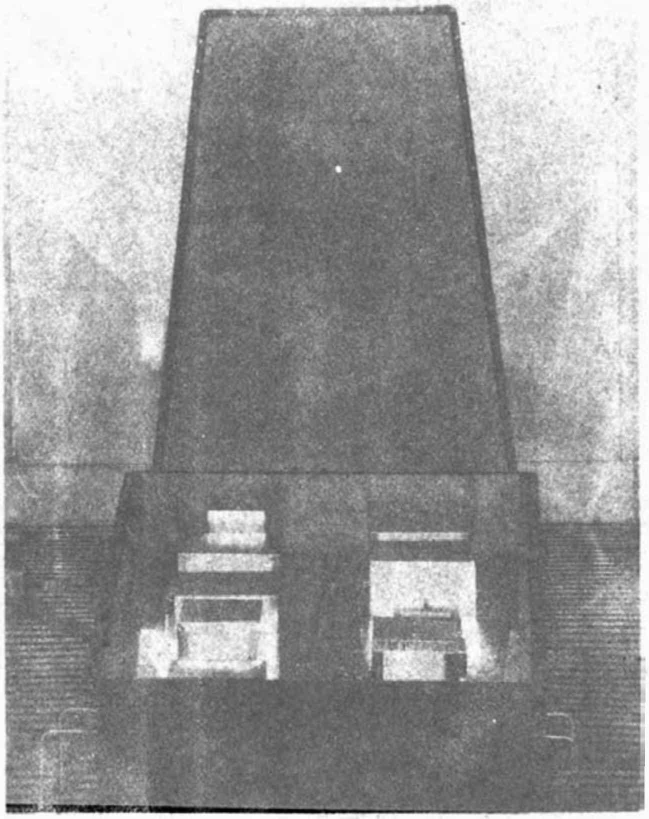


Figure II-63. Typical Equipment Container at this time will permit manufacture and installation on S-II-T before the first tanking test. The system orifices are flat sheet, with a hole for gas flow and four small screw holes for installation between two flanges in the lines. Hence, both manufacture and installation are simple operations which can be quickly performed.

Procurement and Component Development

Thermal control system procurement is limited to the forward system and compartment conditioning disconnects. This part was previously used by the propellant tank dessicant system. Since this system is no longer required, the part will be used only on the thermal control system.

Although the earlier schedule for delivery of these disconnects showed some schedule problems, these have been avoided. The earliest requirement was for the termal control system flow test, but by rescheduling this test to a later date the delivery of the disconnect is expected to be well in advance of need. Since the Battleship requirement has been deleted by using an "in-house" design, no schedule problems are expected.

All development of the part has been completed and major design approval received; qualification test plans are being reviewed.

LEAK DETECTION AND PURGE SYSTEM

The S-II leak detection and purge sytem is shown in Figure II-64.

Description

The leak detection and purge system has three main functions;

1. It provides the leak check at both ambient and cryogenic temperatures for the LH_2 tank, LH_2 tank insulation, and the common bulkhead on the completed S-II stage.
2. An inert atmosphere in the insulation and common bulkhead is maintained by purging with helium gas during cryogenic operation.
3. The pressure in the insulation and common bulkhead is controlled by evacuation during deloading to prevent a pressure buildup when a liquid or solid gas that might have leaked into the insulation returns to gaseous form.

The design consists of routing tubing of various sizes from the umbilical disconnect panels to the inlet and outlet headers of each area to be leak-detected or purged.

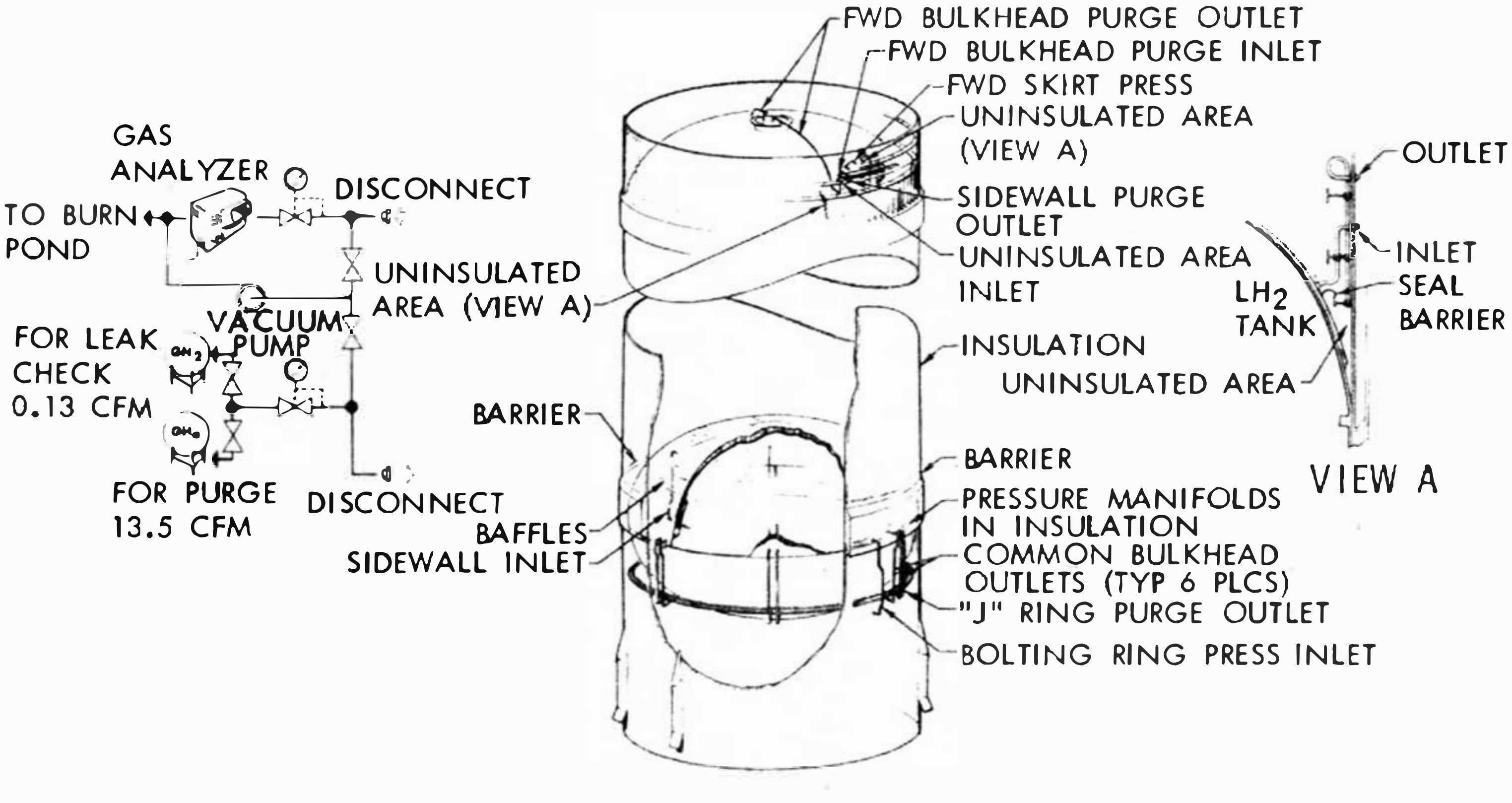


Figure II-64. Insulation Leak Detection and Purge System

The basis design has been established on the S-II-T. This design will be utilized for all vehicles, except where the insulation requirements dictate a change in line size. The system is designed to verify the sealing characteristics of the LH_2 tank insulation and the common bulkhead. It is also designed to verify the structural integrity of the weld joints on the LH_2 and LOX tanks under cryogenic conditions.

Prior to liftoff on the S-II stage, the LH_2 tank insulation, uninsulated areas, and the common bulkhead are purged with helium. Purging is recommended to provide an inert atmosphere around the LH_2 tank to reduce or eliminate the explosive hazards associated with LH_2 and LOX. The same system is used to evacuate the LH_2 tank insulation, the forward bulkhead insulation, and the common bulkhead. Evacuation reduces the possibility of an internal pressure buildup during the defueling phase.

The upper and lower umbilical arms are utilized for connecting the S-II stage leak-detection and purge system with the GSE monitoring system. Disconnects are mounted on the umbilical panels and separate from the S-II stage connectors during liftoff, when the helium flow is terminated by disconnect separation. The disconnect couplings are left open to allow venting of the helium gas to avoid an excessive pressure differential.

The areas that are leak-checked and purged are subdivided into seven circuits: LH_2 tank wall insulation, forward bulkhead insulation, common bulkhead, forward skirt insulation, lower bolting-ring insulation, forward bulkhead uninsulated area, and J-ring uninsulated area.

GSE supplies the required gases at a controlled pressure and flow and the gas analyzer unit and vacuum pump with all connecting plumbing up to the disconnect panels on the stage.

Operation

The operation of the leak-detection and purge system is divided into two categories – certification test operations and stage monitoring operations.

The certification test operations are performed at ambient temperature before and after cryogenic loading to assure a leak-free LH_2 tank and tank insulation.

The structural certification test checks out the LH_2 tank structure and the aft sheet of the common bulkhead. It consists of a helium tank test. The LH_2 and LOX tanks are pressurized with helium. Nitrogen gas is purged through the insulation and common bulkhead core. Samples of the returned purge gas are taken and analyzed for helium content in a GSE gas analyzer. With the helium concentration and flow rate of the purge gas known, the total leakage rate can be determined.

The insulation certification test checks out the seals of the LH_2 tank insulation and common bulkhead. It consists of a vacuum decay test for the LH_2 tank wall and forward bulkhead insulation. A flow test is conducted to check out the forward skirt and bolting-ring insulation.

The monitoring operations are performed during propellant loading, standby ground hold, and static firing or deloading. The tests consist of (1) purging the insulation, common bulkhead core, and other sensitive areas with helium gas, (2) leak detection of the LH_2 tank structure by sampling the returned helium gas for hydrogen content, and (3) evacuation of the insulation and common bulkhead core during and after static firing or detanking to prevent a pressure buildup.

Status

During the past year, the design requirements were established; they are:

1. To prevent air from entering the LH_2 tank insulation
2. To prevent hydrogen and oxygen from entering the common bulkhead core
3. To detect leakage and to measure leakage rates in the LH_2 tank structure, LH_2 tank insulation, and common bulkhead
4. To prevent a pressure buildup in the insulation and common bulkhead during deloading.

Analyses have been conducted to predict system performance and to define the requirements for the various components and provisions. The response time and sensitivity of the system have been determined, line sizes of the supply tubing have been established, and the GSE requirements have been defined.

All the procurement specifications have been released. All drawings for the S-II-T, S-II-F, and test common bulkhead were released. The test objectives for the leak detection and purge system on the test common bulkhead, and S-II-T were defined and released.

Testing

An extensive test program was conducted to evaluate the hazards of air liquefaction in the insulation. The test proved that the insulation is sensitive to both flame and impact during the warmup period after deloading.

The quarter-scale tank No. 1 (0.33-inch insulation) was used for flow tests and measurements of sensitivity and time response. The test data verified the analytical results. Future testing will be conducted on the test common bulkhead and All-Systems test stage (S-II-T).

FLIGHT CONTROL SYSTEM

Description

The flight control sytem must control the vehicle along a continuously computed optimum trajectory in response to vehicle guidance-error commands. Three guidance-position error signals from the guidance package located in the upper stage instrument compartment provide inputs to the flight control computer. Rate stabilization signals representing pitch and yaw body rates are supplied to the flight control computer from rate gyro packages located in the instrument compartment or from the gyros mounted on the S-II stage. The error commands and rate stabilization signals pass through shaping, sealing, and signal summing networks, and thence into eight servo amplifiers. The outputs from the servo amplifiers are applied to the engine servoactuator units which gimbal the engines. Hydraulic power to drive the servoactuators is supplied by the engine actuation system.

The major components of the flight control system, which are located on the S-II stage, are the four independent engine actuation systems (EAS), each consisting of: (1) engine-driven main hydraulic pump, (2) auxiliary motor pump, (3) accumulator reservoir manifold assembly (ARMA), (4) pitch and yaw servo actuator, (5) mounting and wiring provisions for two rate gyro packages and four accelerometers, and (6) flight control switch canister in the aft skirt EAS accumulator lockup control unit.

Status of Engine Actuation System Components

The S-II engine actuation system (EAS) is shown in Figure II-65.

Servoactuator

The last servoactuator on the production contract was completed and shipped to S&ID on 26 September 1963. The purchase order for the production servoactuator was approved and was transmitted to Moog Servo Controls on 1 November (Figures II-66 and II-67).

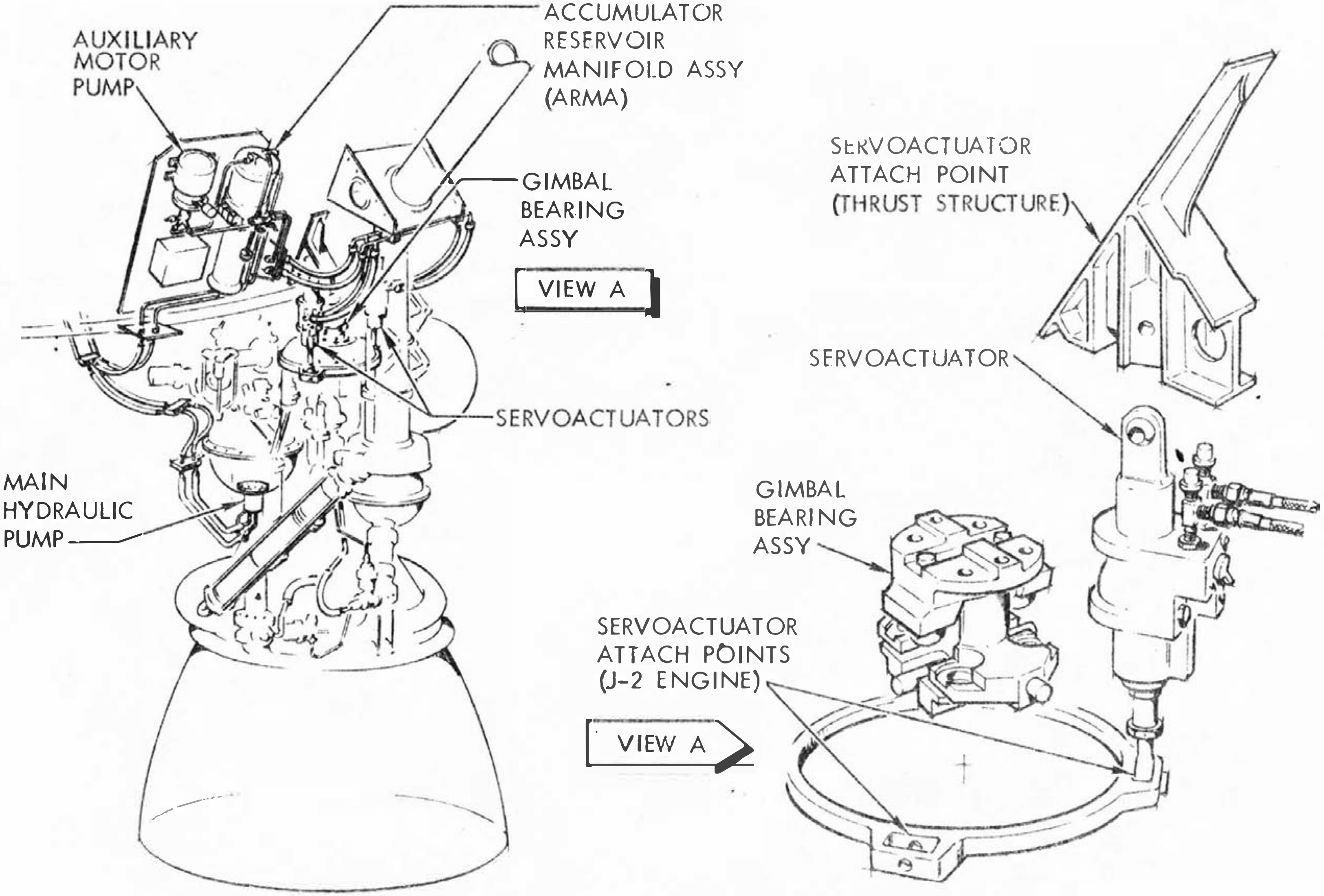


Figure II-65. S-II Engine Actuation System

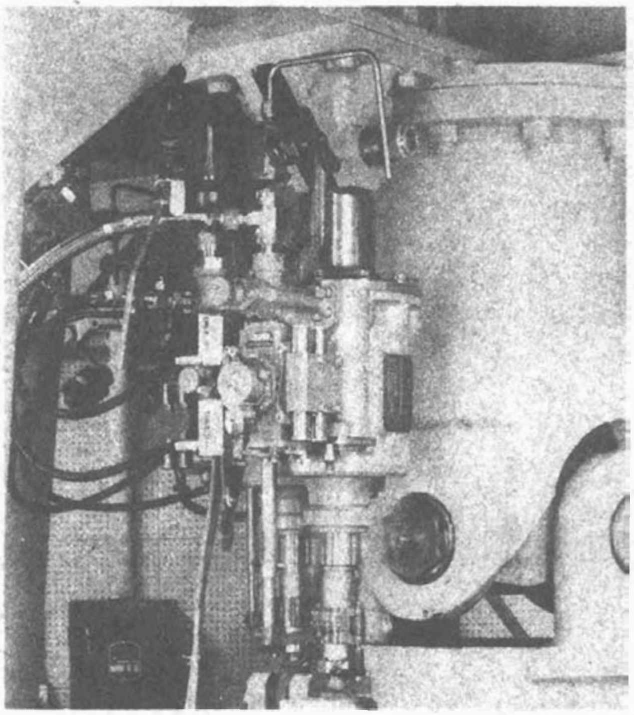


Figure II-66. Test Setup for Production Servoactuators

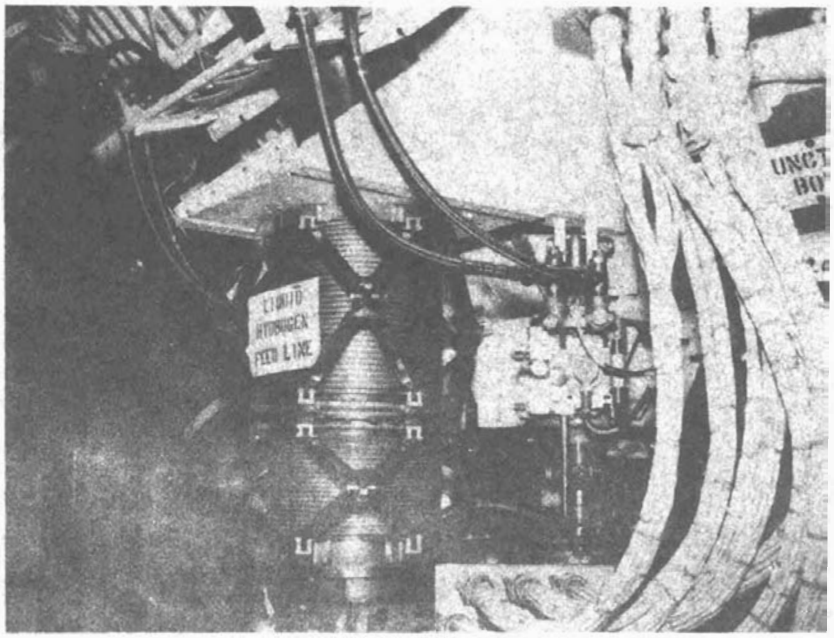


Figure II-67. Servoactuator Installation on EMM (on Right of Liquid Hydrogen Feed Line)

The major design review for the production servoactuator was conducted on 16 April. The supplier requested an increase in allowable weight from the present 44 pounds to 54.5 pounds. The supplier presented the results of an investigation on reasonable methods of reducing weight and was directed to submit a new design change proposal reflecting a weight consistent with this investigation. Subsequent to design review, the supplier submitted a design change proposal, which was approved, requesting an allowable weight of 50.4 pounds. The design has been approved pending resolution of minor action items, which will be resolved by routine engineering coordination between the supplier and S&ID. The supplier was requested to submit an additional design change proposal reflecting an all-out effort at weight reduction which could be incorporated in the future.

Accumulator Reservoir Manifold Assembly (ARMA)

The preproduction ARMA forged manifolds were machined, and the first ones were completed during the week of 16 September 1963. Burst pressure tests were successfully completed during the week of 11 October.

The production ARMA purchase order was approved by NASA, and the production go-ahead was given the supplier, Parker Aircraft, on 2 October. The supplier held an in-house preliminary design review on 14 October. An informal proposed production schedule was received, calling for:

1. Delivery of four prototype units from 7 February through 6 March 1964.
2. Qualification tests to be conducted from 24 April through 10 July 1964.
3. Delivery of eight prequalification units from 1 May through 22 May 1964; delivery of post-qualification units from 24 July through 21 August 1964.

During flight-control simulator tests, an external hydraulic fluid leak was detected at the reservoir of the ARMA, caused by a spiral failure of the O-ring in the reservoir boot-strap piston. The failure resulted from the backup rings having been installed on the wrong side of the O-ring, allowing extrusion and ultimate failure of the O-ring.

The failed ARMA was reassembled with new seals, installed on the flight control simulator structure, serviced, and satisfactorily checked out. During reassembly the reservoir piston was rotated to engage the follower in a normal manner. This ARMA was carried through to the completion of the simulator tests involving the preproduction EAS with no further delays (Figures II-68 and II-69).

Main Pump

Eight preproduction units were delivered to S&ID by the supplier, American Brake Shoe Co. (ABS). The material and manufacturing phases of the program were completed, leaving only the design evaluation tests to be finished.

On 6 November 1963 S&ID was informed by MSFC that the preproduction unit delivered to them had been subjected to an endurance test and that the cylinder barrel failed at 50 hours while operating at 3650 psi. This failure is in addition to two similar normal load failures occurring at the supplier's facility during development tests. A third overload test failure also occurred at the supplier's. Subsequent to the latter failures, an agreement was reached between S&ID and ABS to rework the two pumps, incorporating the necessary design corrections.

Contract negotiations with ABS for the production main pump were completed, and a purchase order issued during the week of 7 December 1963. The supplier started work on the drawings and procurement specifications for the component parts of the pump on receipt of an earlier letter contract from S&ID.

Acceptance of the major design review of the main pump, held on 12 March is dependent on the resolution of 13 action items, but the supplier was authorized to procure certain long-lead-time items. A specification amendment was released which incorporates requirements for a thermal barrier. The supplier submitted a proposed design and two alternate schemes which will reduce weight and minimize schedule impact; with minor changes, the design was considered acceptable.

Testing of an S-II preproduction main hydraulic pump during J-2 engine firing at Santa Susana was completed. For these tests a completely filled and bled test system was installed on the Rocketdyne test stand. Eight engine firings were performed from 16 to 26 May, resulting in a total of 900 seconds of pump running time. A tear-down inspection of the hydraulic pump revealed no defects or degradation. All wear patterns (i.e., shaft seal mating ring, valve plate, etc.) were normal, and no signs of overheating were found. The aluminum pump flange showed no cuts or scratches (Figure II-70).

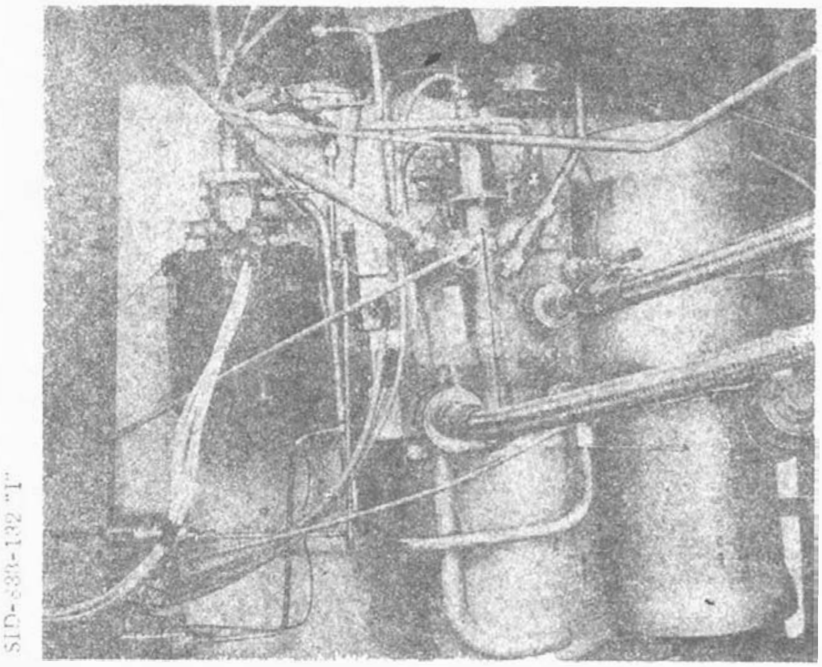


Figure II-68. Test Setup for ARMA and Auxiliary Pump

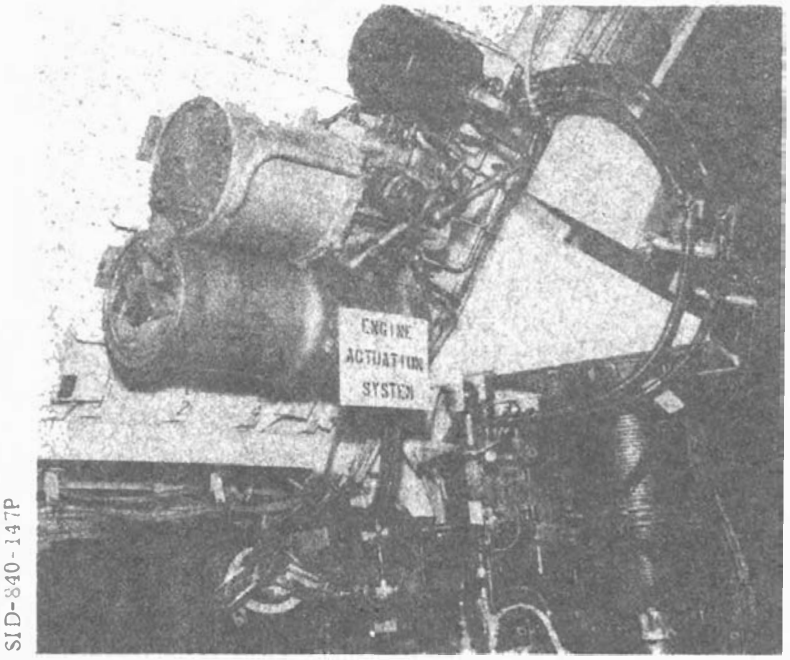


Figure II-69. ARMA and Auxiliary Pump Installation on EMM

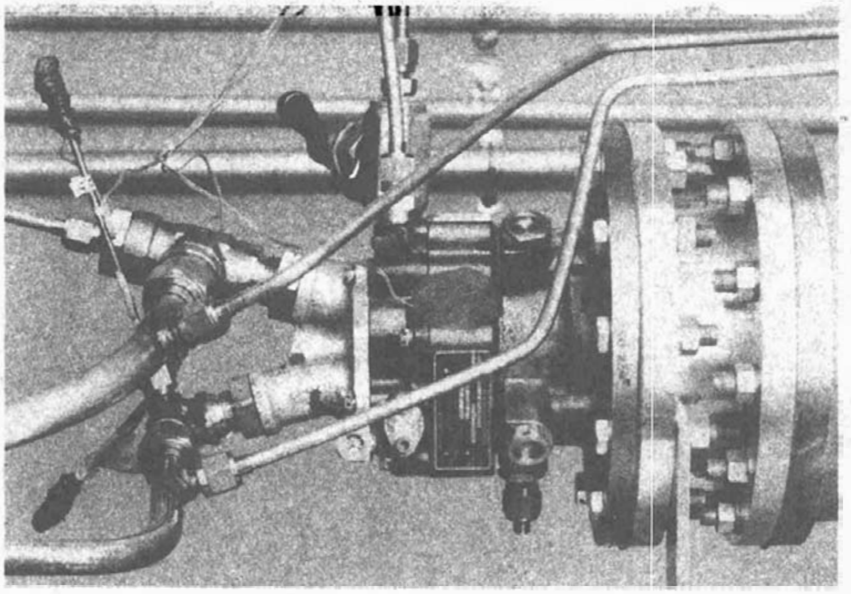


Figure II-70. Test Setup for Main Pump

Auxiliary Motor Pump

All phases of the preproduction auxiliary motor pump program have been completed. The evaluation of the technical proposal for the production auxiliary motoer pump (AMP) was also completed, and negotiations with the Aerospace Division of ABS, the supplier, were conducted during the week ending 24 August 1963.

The endurance test phase of the design evaluation program was concluded by the successful completion of a 150-hour overload condition test. This test was recommended by the supplier to provide information for evaluating the future capability of the AMP in meeting the overload requirements for the production units and was used instead of the normal load endurance tests.

The auxiliary motor pump completed a total of 125 hours of operating time in November 1963. The first 50 hours were at a nominal pressure of 3000 psi, the rest were at 3500 psi. This test was to determine the amount of contaminants generated when operating the auxiliary motoer pump as well as to determine the pump performance. The results show that the number of contaminants generated was less than expected and that pump performance was within specification.

A purchase order was issued in December 1963, although work had begun on design on the pump and motor on receipt of an earlier letter contract on 22 October 1963.

The electric motor is the pacing time for the AMP. Its design is considered acceptable, but negotiations by ABS with General Electric (GE) failed to obtain delivery of the motor before GE plant shutdown on 13 July for a vacation. Delivery will not be made until 7 August; however, qualification testing will proceed as scheduled on the pump.

Hydraulic Quick Disconnect Couplings

Major design review was conducted on 12 May with Aeroquip Corporation, supplier of the hydraulic quick disconnect coupling. The design was approved pending satisfactory action on several minor items.

EAS Bleed Valve

The purchase order for the bleed valve was transmitted to the supplier, United Aircraft Products, on 6 March. As previously requested by S&ID, the supplier will make the bleed valve completely of stainless steel; although this will increase the weight slightly, it will increase the design integrity considerably.

Thermal Insulation of the Engine Actuation System (EAS)

Thermal insulation is currently required for the production engine actuation system because the original concept of temperature control in tanking propellants required intermittent auxiliary pump operation. Since at the time little was known of the wear and contaminant-generating properties of the pump, a policy of minimum pump operation was adopted. Today, however, as a result of pump tests, more is known about these properties, and they are considered as not being detrimental to EAS operation. Thus, a restriction on pump operation is no longer necessary except as may be required for temperature control.

A study is being conducted to provide information on the EAS temperature control range and an approximate auxiliary-pump duty cycle. The study, which will be supported by three to six months of testing by the Engineering Development Laboratory, will also determine whether insulation is needed. A decision on the need for insulation will be made during August. Schedules should not be affected by this six-month delay, because the Battleship and All-Systems stages do not require insulation.

Flight Control Simulator

The American Machine and Foundry (AMF) flight-control simulator is shown in Figure II-71.

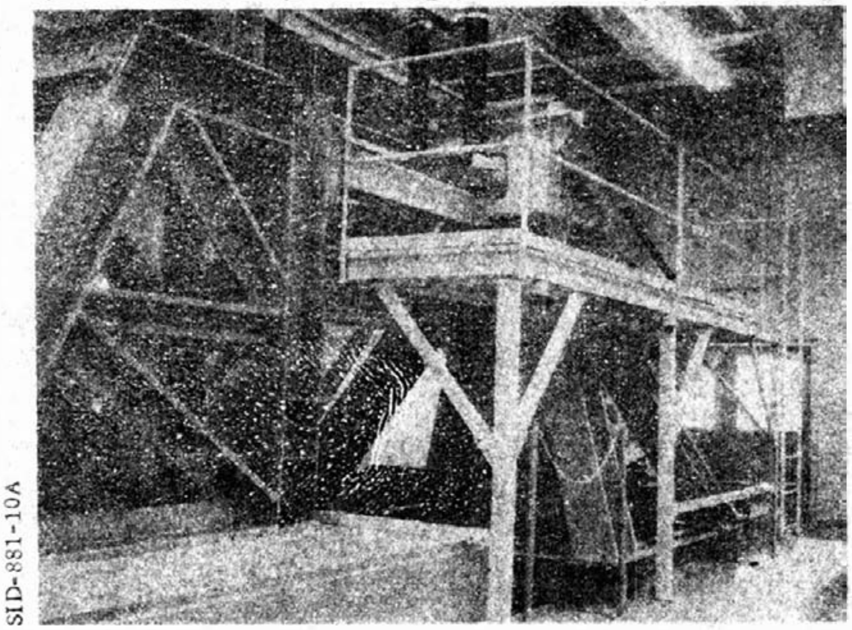


Figure II-71. Flight Control Simulator

Flight Control Simulator Test Plans

The objective of a test plan and operating procedures formulated for the flight-control simulator preproduction engine-actuation system is to determine performance characteristics of the system and components when subjected to simulated design conditions. Test data will be used to verify system and component design analysis. Significant tests to be run are (1) auxiliary motor pump capability, (2) accumulator charge and discharge capability, (3) simulated S-IC/S-II separation and flight duty cycle, (4) open-loop frequency response, and (5) servoactuator velocity versus force (Figure II-72).

A test plan was written for the engine actuation system as installed in the simulator. The plan which is part of the overall development plan for the system, will enhance and substantiate knowledge of the system operating characteristics gained from supplier and breadboard tests.

A listing of system parameters to be monitored visually at the simulator instrument console was compiled. These measurements were used as part of the safety precautions associated with simulator operation (Figure II-73).

Flight Control Simulator Operation

The operational start of the S-II flight-control simulator test program began on 27 January 1964, with the commencement of the EAS and total

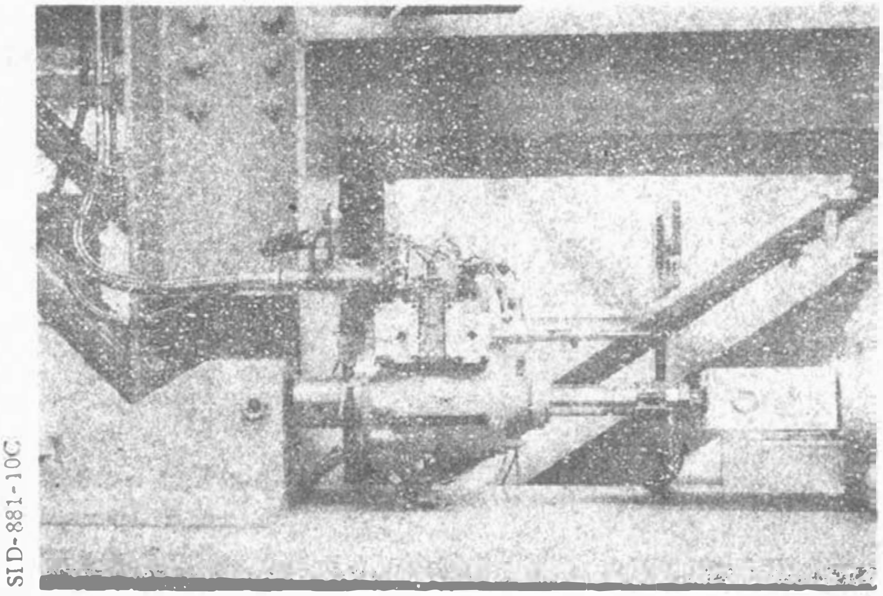


Figure II-72. Servoactuator Installation on Flight Control Simulator

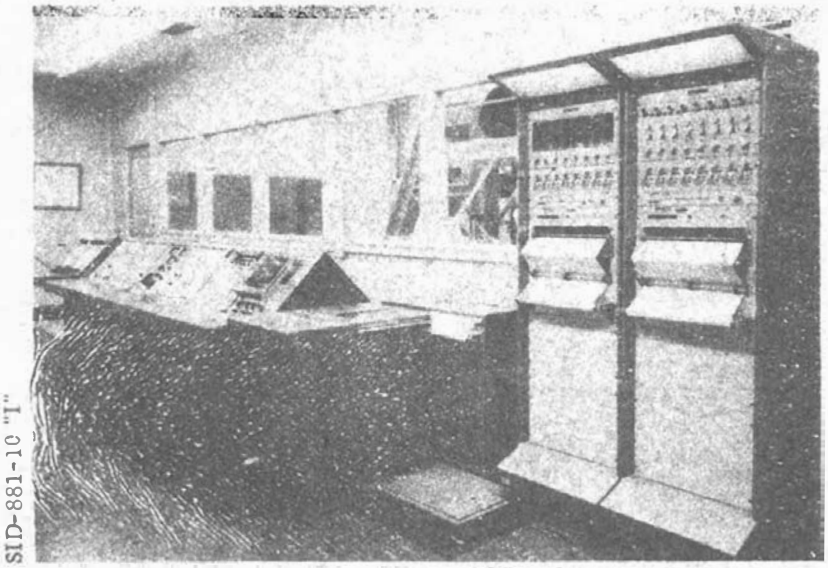


Figure II-73. Flight Control Simulator Control Room system evaluation tests. Basic system performance characteristics were determined, using a model system configuration consisting of nominal values for pendulum inertia, constant load, variable load, static friction load, and engine/structure spring. The month of February was to be used for simulator/analog-computer tie-in activation; the first simulation study runs began on 17 February and were completed on 28 February.

Activation of the flight-control-simulator/analog-computer tie-in included execution of step and sine-wave responses under computer command to verify simulator/computer operations in addition to line continuity and proper signal termination. In addition to obtaining data on the analog model of the engine gimbaling system for comparison with the physical system, "mid-burn" and "separation" condition studies were investigated.

The first flight-control simulator analog runs were completed on 28 Feburary. Applicable parts of the J-2 engine gimbaling tests were performed, using the simulator without analog tie-in. Data reduced from the simulator tests were used to verify adequacy of the test plan and for later comparison with actual J-2 test data.

The second run of the flight-control-simulator/computer study started on 1 June. This second series is being used to study step and frequency response under firing and nonfiring loading conditions, with and without diffuser inertia changes. No further tests were to be scheduled for the simulator using the preproduction EAS after 30 June.

Test results from the preproduction EAS and total system simulator tests completed 1 May are being analyzed; a report will be published on 21 August. Preliminary results from frequency response data indicate a total loaded system natural frequency of approximately 3.5 to 4.5 cps. Pendulum resolution of the loaded system is a function of position, constant load, and friction load and is on the order of a 0.05° average. Additional test results are being formulated from hysteresis, linearity, and null-position test data.

EAS and total system response tests were completed on 1 May. The concluding part of the series of tests included parameter variation studies and system operation utilizing the main and auxiliary motor pumps. In the former the effects of various load device changes on step and frequency response characteristics were obtained. The latter tests were for the purpose of verifying system operation with the pumps and the associated control and varidrive circuitry. Approximately 30 parameters were recorded throughout this series of tests and data reduction and evaluation effort for the test report was performed.

FLIGHT TECHNOLOGY

AERODYNAMICS

Separation

Clearance Distance Studies

Preliminary second-plane clearance distance results based on experimental impingement data (Langley cold flow model test) were presented at the Vehicle Dynamics and Control Working Group meeting held at MSFC, Huntsville, Alabama, on 9 October 1963. For the engine-out case, the experimental impingement data were obtained for a nozzle gimbal pattern in which the three operating control J-2 engines were gimballed 8 degrees (across corners) away from the "dead" engine. Results of an analysis (of the separation dynamics) indicated that, based on experimental data, the interstage would collide with the "dead" engine nozzle. As a result, S&ID recommended the use of auxiliary interstage retrorockets to implement engine-out second-plane separation capability. However, MSFC requested S&ID to investigate a concept that would not require interstage retrorockets.

This concept would limit the engine gimbal angle during second-plane separation to a value sufficient to guarantee interstage clearance with one J-2 engine out. As a result of this request, the Langley cold flow model tests were continued for engine angular gimbal patterns of 2, 5 and 8 degrees for the engine-out case.

Analytical impingement data (4- and 8-degree gimbal patterns) estimated by Aero-Astrodynamics were obtained. Using the 4-degree data (for 0.028 psi base pressure), the second-plane separation analysis indicates a clearance distance of 14 inches with the "dead" engine nozzle in the neutral position. This clearance distance includes the effect of the disconnect panel force and moment in the most adverse direction. If the disconnect panel effect is neglected, the clearance distance increases to 16 inches. The comparable clearance distance computed by MSFC for the latter case is 18 inches, indicating that the methodologies used by MSFC and S&ID give essentially the same separation relative motion trajectories.

Langley Cold Flow Model Tests Comparisons

Three basic second-plane separation cases were studied: nominal (2 degrees control); dual actuator failure; and J-2 engine-out. Prior to the

Langley test, separation studies were based on analytical impingement data computed by S-II Thermodynamics. A comparison of clearance distances obtained using analytical and experimental impingement data are summarized in Table II-1.

Table II-1. A Comparison of Clearance Distances Obtained by Analytical and Experimental Means

Case	Clearance Distance (in.)	
	Analytical Data	Experimental Data
Nominal (2° control)	Not available	37
Dual actuator failure	27	12
J-2 engine-out	23*	collision*

*Engine-out nozzle in full inboard position

Based on the experimental data, the interstage will collide with the engine-out nozzle even if the nozzle is moved to the full inboard position. Therefore, an auxiliary system is required to achieve successful second-plane separation for this case. Since previous studies showed that neither interstage guide rails nor expulsion devices are a practical means of obtaining clearance distance for this case, the use of small interstage retro-rockets was selected.

The results of the analysis indicate that adequate separation clearance can be obtained with retro thrust levels in the 500 to 7500 lbs/motor range, depending on the separation criteria used. Since the increase in retro thrust from 500 to 7500 pounds results in a LOR mission payload loss of only 31 pounds, it was recommended that the 7500-pound thrust per motor, 12-motor retrorocket system be incorporated in the second-plane separation system. By using this system, the "dead" engine toe-in requirement can be eliminated, and adequate clearance distance is obtained for all probable second-plane separation conditions.

J-2 Engine Gimbal Angle Limit

Clearance distance analyses were made to supply information which will be used to determine the J-2 engine gimbal-angle limit required to achieve successful engine-out second-plane separation. The results are based on the preliminary experimental J-2 plume impingement force test data (nominal mixture ratio, Langley test data) for control engine gimbal patterns of 2, 5, and 8 degrees (across corners) away from the "dead" engine. For the engine-out case, the critical collision dimension exists between the interstage and the "dead" engine nozzle. The results of this study, which were presented at the Dynamics and Control Working Group meeting last February, are summarized in Table II-2.

Table II-2. Results of Clearance Distance Analysis

Operating Engines Gimbal Angle in Degrees (across corners)	Clearance Distance (in.), "Dead" Engine Position	
	Neutral	2.8 in. inboard of neutral
2	21	26
3.5 (interpolated)	5.5	11
5	collision (-6)	collision (-0.5)
8	collision (-16)	collision (-10)

Table 2 shows clearance distances for two "dead" engine positions. Preliminary studies indicate that the "dead" engine nozzle will be a minimum of 2.8 degrees (across corners) inboard of the neutral position when second-plane separation occurs. Second-plane clearance distance shown in Table II-3 for the engine-out case is based on the assumption that a 3.5-degree (across corners) gimbal limit is used on the operating control engines during separation and that the critical "dead" engine nozzle is 2.8 degrees (across corners) inboard of the neutral position.

Table II-3. Summary of Second-Plane Clearance

Case	Clearance Distance (in.)
Nominal (2° control)	32.4
Dual actuator failure	14.1
Engine-out	11

S-II Flight Sequence

The current S-II stage nominal sequence chart, which shows all pertinent events except confidential J-2 sequences, was published and will be continually updated (Figure II-74).

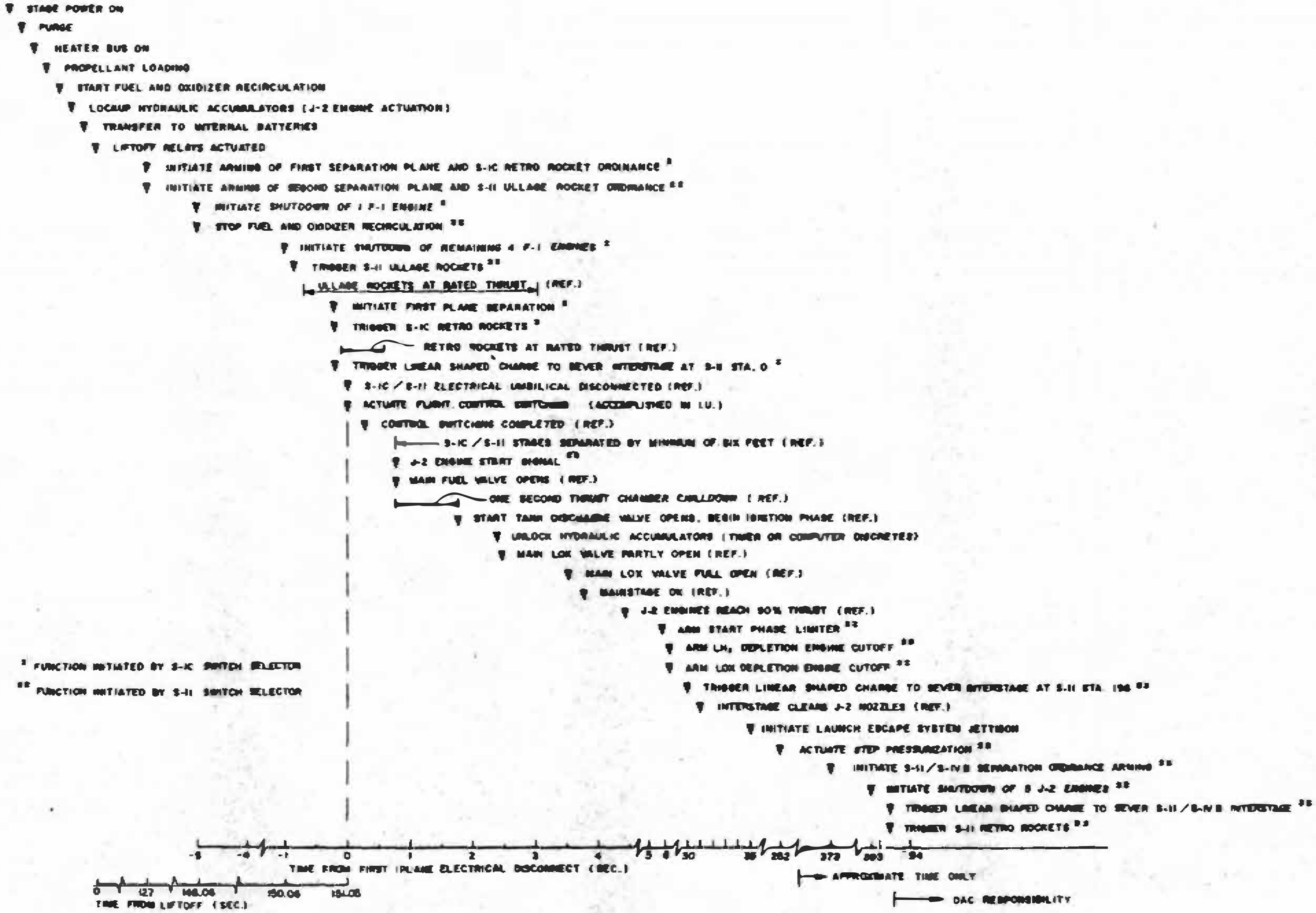


Figure II-74. Nominal S-II Stage Sequence Chart

Fallout Area

S&ID made a preliminary estimate of the fallout area for the S-II stage with a dispersion system which could shut down the S-II engines at any time during the S-II boost phase. The estimate is based on the following assumptions: (1) the S-IC boost phase trajectory is nominal, (2) the S-II stage retains all remaining propellant on board during descent, and (3) the launch azimuth varies from 70 to 105 F. The estimated fallout area for the S-II stage is shown in Figure II-75. The results indicate that no land mass is located within the fallout area, but, it should be noted that the fallout area misses Bermuda by a marginal amount.

J-2 Engine Chilldown

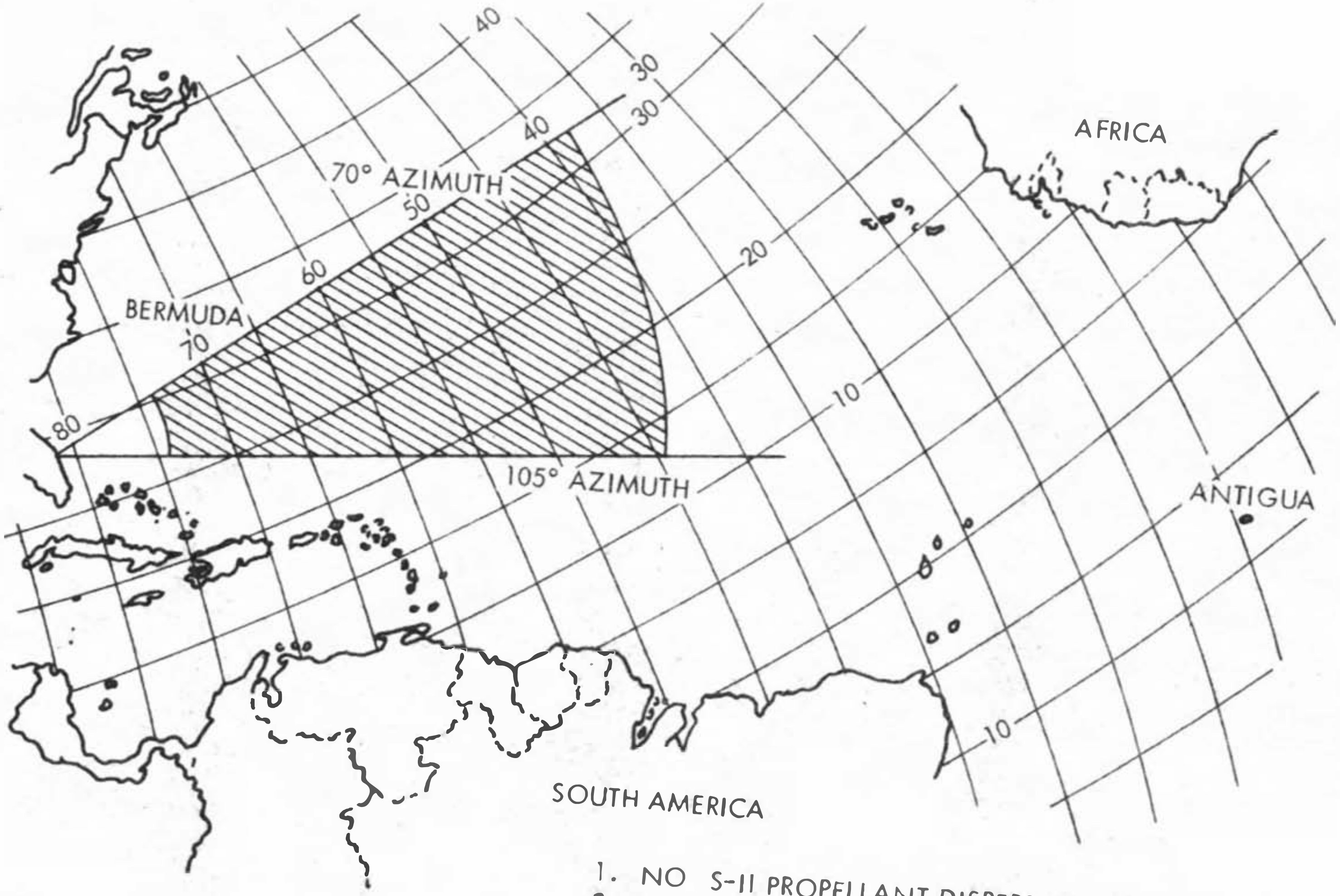
Rocketdyne currently recommends that provision be made in the S-IC/S-II separation system for a one-second J-2 engine thrust chamber chilldown allowance until a final chilldown requirement has been determined through additional development testing. As a result of this recommendation, a study was made to determine the effects of this change (from the current 0. 5-second chilldown time being used for design) in the areas of flight control, dynamics of separation, and ullage rocket requirements.

Results of the study indicate that the increase in chilldown time does not create any flight control problem areas, does not affect the dynamics of first-or second-plane separation, and does not affect the ullage motor thrust requirement. However, increasing the chilldown time may affect the ullage motor burning time requirement. The ullage rockets are triggered when the Saturn V vehicle has decelerated to approximately 3. 6 g during the F-1 engine thrust decay. Using the latest MSFC estimated F-1 engine thrust decay, the time from the ullage motor trigger signal to the J-2 start signal was determined to be 1. 55 seconds. This time will be used with the J-2 thrust buildup (containing a one-second chilldown) to determine the ullage rocket burning time required for propellant settling. The current ullage motor minimum burning time can be maintained by decreasing the accelerometer g level used to trigger the ullage rockets.

Performance

Mission Payload Studies

A preliminary analysis was made to determine the payload gains associated with a six-engine S-II configuration. In this analysis, both the constant and step systems of engine mixture ratio (EMR) were investigated. Optimum Saturn V trajectories were computed for each programmed EMR. For every trajectory computed, the weight of each stage and amount of propellant consumed in each stage remained fixed. Therefore, as the payload



1. NO S-II PROPELLANT DISPERSION SYSTEM
2. THE RESULTS ARE REPRESENTATIVE FOR THE S-II STAGE OR THE S-II + S-IVB STAGE (LESS MANNED PAYLOAD)

Figure II-75. S-II Fallout Area

weight was varied, the launch gross weight of the Saturn V also varied. However, the launch thrust-to-weight ratio was not appreciably affected, varying only from 1.25 to 1.2475. A summary of the results is presented in Table II-4.

Table II-4. Results of Mission Payload Studies

Mixture Ratio	LOR Payload (lb)	
	Five Engines	Six Engines
5.0 (constant)	0 (ease point)	3500
5.5 (constant)	1900	3800
Optimum programmed mixed ratio	2700	5120

An investigation was made to determine payload gains associated with weight reduction, J-2 engine improvements, and programmed mixture ratio (PMR). Engine improvements included nozzle extensions, precision calibration, and uprated (recalibrated) J-2. Weight reductions included three categories: (1) technically certain, (2) technically probable, and (3) technically possible but requiring additional study or testing.

The base point payload weight was based on the current S-II predicted specification cutoff weight of 94,842 lb. A loss in payload weight due to drag (330 lb) on the S-II stage external protuberances was also taken into account in the base point payload weight.

The effect of each design change on S-II weight, on J-2 engine performance parameters, and on mission payload weight are summarized in Tables II-5, II-6, and II-7.

Table II-5. Weight Reduction

Category	Δ Cutoff Weight (lb)	Δ Payload (lb)
I	-6295	+1875
II, III	-7475	2230
I, II, III	-10613	3164

Table II-6. J-2 Engine Performance

Method	ΔI$_{sp}$ (sec)	ΔT/eng. (lb)	ΔWt/eng. (lb)	ΔPayload (lb)
Nozzle extension (5 inch all engines)	1.4	800	120	431
Precision calibration	—	4000 ± tolerance (classified)	—	800
Uprated J-2	-1.0	19, 600	—	2810

Table II-7. Programmed Mixture Ratio

Engine Configuration	Δ Payload (lb)
Current engine	2765
Precision calibration	2530

On the basis of this study, the following recommendations were made: (1) delete PU system, (2) add precision J-2 calibration, (3) add PMR, (4) add 5-inch J-2 nozzle extensions, and (5) incorporate weight reductions corresponding to 2918 lb of payload gain. The total payload gain for the recommended design changes is 6313 lb.

A comparison study was conducted to determine the effect on net LOR payload due to a change in the number of J-2 engines on the S-II stage from five to eight. The results of this study show an increase of 8652 lb in net payload.

S&ID conducted a programmed mixture ratio (PMR) performance study to determine the effect on LOR mission payload of changing from the currently used J-2 engine 100 percent frozen combustion equilibrium data. Optimum Saturn V trajectories were computed for tanking mixture ratios varying from 5.1 to 5.4 with a first engine mixture ratio (EMR$_1$) of 5.5 and a second (reference) engine mixture ratio (EMR$_2$) of 4.5. The S-II propellant loading for all cases was 913, 389 lb.

Results of the study indicate that by using the 50-percent shifting-frozen equilibrium data a payload gain of 3,560 lb can be realized over the no-PMR case. The payload gain for the 100-percent frozen equilibrium case using the latest J-2 engine influence coefficients is 2,880 lb. Changing to J-2 engine 50-percent shifting-frozen equilibrium data, therefore, results in an additional 680 lb of LOR mission payload.

A brief study was made to determine how programmed mixture ratio LOR payload gains are influenced by using the S-IV propellant utilization (PU) electronics for the S-II PU system. Computer runs were made on a PU computer program and on an optimum trajectory program bracketing the gain values of both PU systems. Since an increasing PU system gain, K_w produces an increasing PU valve slue rate, it has an important bearing on thrust and flow-rate profile associated with programmed mixture ratio. The effect of a different PU system gain with the S-IVB electronics can therefore be translated into a performance effect in terms of payload.

Results of the study indicate that the critical performance gain, K_{wcp}, of the S-II PU system is 0.007 degrees per pound. The use of a PU system with a higher gain, while slightly changing the thrust and flow-rate profiles, does not alter the performance of the S-II stage. However, the use of a lower gain markedly influences the thrust and flow-rate profiles and rapidly decreases payload. The best current estimate indicates that the use of the S-IVB electronics will yield a S-II PU system K_w gain between 0.01 and 0.02 degrees per pound and, therefore, will have no effect on the payload.

MSFC requested a preliminary study to determine optimum S-II propellant loading with programmed mixture ratio (PMR). S-II propellant weights were investigated from a nominal 912,894 lb to a maximum of 982,152 lb. For each propellant valve selected, several tanking mixture ratios were assumed from the LH_2 full-tank condition to the LOX full-tank condition; Saturn V trajectories were computed for each case. Results of the study indicate that, at an optimum S-II propellant loading of 970,000 lb tanked to a mixture ratio of 5.275 (LH_2 tank full), a payload gain of 3,130 lb can be realized when compared to the no-PMR case. This value includes the effect of an increase in the aft bulkhead weight because of higher loads (LOX loading has been increased over the current design value). Previous results indicated that nominal propellant loading of 912,894 lb tanked to a mixture ratio of 5.24 produced a PMR payload gain of 2,700 lb. The optimum S-II loading, therefore, results in an additional 430 lb of payload.

At the request of MSFC, a PMR performance study was conducted to determine the effect on payload of increasing the S-II stage propellant utilization capability. Optimization was based on extending the range of first engine mixture ratio (EMR) from 5.5 to 6.0 and second (reference) engine mixture ratio (EMR_2) from 4.5 to 4.0. The S-II propellant loading for all cases was 912,894 lb. The results of the study indicate that a maximum gain in LOR mission payload of 3,950 lb over the no-PMR case occurs at an EMR_1/EMR_2 of 6.0/4.2. Previous results indicated that the present limiting PMR of 5.5/4.5 at an initial tanked mixture ratio (TMR) of 5.24 produced a payload gain of 2,700 lb. The optimum PMR (6.0/4.2), therefore, results in an additional 1,250 lbs of LOR mission payload

rodynamic Heating

MISTRAM Antenna

Aerodynamic heat transfer rates on the MISTRAM antenna were determined. The results show that no adverse heating will be experienced for antenna "x" lengths of less than 0.5 in. The antenna "x" length is defined as the axial distance the antenna extends beyond the end of the aerodynamic fairing.

Protuberance Wind Tunnel Tests

The aerodynamic-heating general-protuberance wind-tunnel tests being conducted by Douglas Aircraft Company at Cornell Aeronautical Laboratories started in March 1964. The 48-inch hypersonic shock tunnel is being used to investigate aerodynamic heat-transfer rates through Mach numbers 5.0 to 8.0. Additional testing was done at the Langley Research Center's unitary wind tunnel to obtain aerodynamic heat-transfer rates at lower Mach numbers (2.5 to 4.5). The S-II separation splice was also tested at Langley.

Boundary Layer Characteristics

An analysis was made to determine the S-II stage boundary layer characteristics for the latest Saturn V design configuration (10M04106, Revision H). The new configuration, when compared to the old 0299 configuration, causes new local flow properties and boundary layer characteristics to exist on the S-II stage. The results of this analysis indicate a difference in boundary layer characteristics of approximately 10 percent between the two configurations. Because of this small change, the aerodynamic heat-transfer rates predicted for configuration 0299 are still valid for the design of the S-II stage (assuming no change in design trajectory).

Aerodynamic Loads

Systems Tunnel

A study was conducted to determine the design aerodynamic loading (internal pressure and external pressure) on the systems tunnel, and design data were published. Since the systems tunnel may experience angles of attack up to 12 degrees during maximum aerodynamic loading, the effect of angle of attack on the external pressure distribution was included.

Longerons

A study was made to determine the increased aerodynamic heating due to misalignment of the longerons on the hinge side of the systems tunnel. It indicated that, because of longeron mismatch (maximum mismatch = 0.4 in.), the aerodynamic heat transfer rates at t = 150 sec will be approximately 7.5 times those in the case where the longerons are matched perfectly. As a result, longeron temperatures based on earlier data must be calculated by the S-II Engineering Thermal Control Group to determine whether any change in the current design criteria will be required.

Ullage Motor Fairing

An aerodynamic heat-transfer and drag tradeoff study was made on complete enshrouding of the ullage motor fairings. The new fairing is geometrically larger than those previously analyzed. Of the two modifications analyzed, one considered a 15-degree nozzle ramp angle flare and the other a 10-degree nozzle ramp angle flare.

The results of this study, are summarized as follows:

1. With the 15-degree nozzle flare, the aerodynamic heat transfer rates are basically unchanged from those previously determined for the unshrouded fairing. With the 10-degree nozzle flare, there is approximately a 10-percent reduction in the heat transfer rates on the flare portion of the fairing; the remaining heat transfer rates are unaffected.
2. This new fairing does not appear to present any local hot spot areas (caused by local stagnation flow, etc.). It represents a design improvement, from a heating standpoint, over the unshrouded design.
3. The proposed, completely enshrouded fairing with a 15-degree nozzle fairing (considering both aerodynamic drag and fairing structural weight) shows a payload degradation of approximately 16 lb over the current design. If the nozzle fairing angle is changed from 15 degrees to 10 degrees, the payload difference will be approximately 12 lb.

LH_2 Tank Sidewall Insulation

A study was made to determine the time history of the pressure differential acting on the LH_2 tank sidewall insulation. This insulation consists of a 1.6-inch thick honeycomb structure having a foam filler. Grooves have been cut in the honeycomb to allow the insulation to be helium purged. The results of this study show that the maximum bursting pressure that may be experienced on the LH_2 sidewall is approximately 5.8 psi. It should be noted that this loading is a limit load and is not to be used as an ultimate load. The pressure differential time histories at two discrete S-II body stations (324.5 and 816.61) that envelope the LH_2 tank side wall were calculated. The pressure time history for zero length venting lines was also calculated to determine the effect of frictional line losses. The results showed that a 30-percent reduction in maximum bursting pressure would be realized if the line length were zero (hypothetical case). Therefore, it was determined that every effort should be made to minimize the length of the leak-detection and purge-system lines.

Several aerodynamic fairing design layouts of protuberances were reviewed, and changes are being made. Studies indicated that the usually high compressive loading experienced on nose fairings can be reduced significantly by utilizing controlled venting in the nose fairings, which, in turn, reduces skin gauge thickness. Results from the Saturn I flights increased the confidence level with the in-flight venting programs used by MSFC and S&ID. The actual and predicted in-flight pressure time histories are in very good agreement.

FLIGHT DYNAMICS

S-II Control Capability With Actuator or Engine Failure

A study was conducted of the engine gimbaling control capability with actuator or engine failures. The study comprised a reevaluation of previous work, but utilized more recent data and reflected the effects of engine-out capability. Results show that a minimum ±2-degree deflection capability remains for stage control when one engine is out or if two actuators fail under certain conditions. If two actuators should fail in hardover positions, they would cause moments resulting from the thrust vector components to be additive in either pitch, yaw, or roll; and control would be lost.

Engine Actuation System Loads

Rocketdyne has presented results of analyses showing increased EAS loads caused by suction ducts and an additional large increase caused by loads calculated for customer connect lines. These loads result in an increase of approximately 10,000 lbs of actuator loading; and as a result, the loads on the S-IVB and S-II engine actuation systems are considerably in excess of design considerations (4000 to 6000 lb). Operation of the EAS and vehicle control could be seriously affected. To find a possible solution to this problem, it was decided to (1) re-evaluate all loads on the EAS, examining all possible load reduction areas, including all criteria used in evaluating loads; (2) organize complete and composite tables for all considerations; and (3) consider redesign.

An analog computer study was performed to analyze the magnitude and transient characteristics of loads applied to the J-2 engine gimbal structure by the engine actuation system. The primary objective of the study was to determine whether maximum actuator forces are transmitted to the gimbal structure and to examine the magnitude and time characteristics of these forces. Initial effort was directed toward designing a workable simulation model for loads such as the actuation system with compliance, engine dynamics, and the vehicle control system. The study was limited to the pitch plans and utilized typical actuator loads data, including loads caused by connect lines, friction, vehicle dynamics, recirculation pressures, engine acceleration, and thrust offset. The preliminary findings of the study indicate that the largest force exerted on the gimbal for a 10-degree step command to the servoactuator is 35,000 lb.

Another actuator-loads analog computer study was completed, in which the maximum and the average gimbaling rate were the criteria used to determine the effect of various load parameters on the engine actuation system. The study was conducted to meet the following objectives: (1) to define the sensitivity of gimbaling rate to variation of each load parameter; (2) to tabulate gimbaling rates for a spectrum of loads, making it possible to obtain a gimbaling rate for any given set of load conditions; (3) to investigate the response to periodic inputs and the effect of accumulator depletion and actuator lockup on gimbaling rates; and (4) to define engine response to inputs and loads which may be encountered in static gimbaling tests.

It was observed that under some conditions the engine gimbaling rate exceeded the maximum of 30 degrees per second specified in the J-2 engine manual. The acceleration maximum of 80 rad/sec^2, however, was well above any accelerations observed in this study.

Slosh Analysis

As a result of a completed slosh analysis program, the final antislosh baffle requirements for S-II stability were published. A baffle near the S-IVB LOX free surface is the only requirement. Baffling in the S-II LOX and LH_2 tanks is not required for the S-II stage. However, NASA has established a requirement for a baffle in the S-II LOX tank for S-IC stage stability.

Transient Side Loads Study

MSFC requested S&ID to: (1) analyze the presently considered holding devices for static firing to ensure that the engine actuator design load limits are not exceeded and (2) determine the dynamic damping and frequency response of the engine actuation system utilizing the actual test-data tapes supplied by Rocketdyne

Two analog computer studies were conducted to determine the effect of J-2 sea-level firing "side loads" on the S-II engine actuation systems (EAS). Simple single-plane models were used. Valve compensation (DLD) and load limiter bypass flow schemes were varied to test the feasibility of reducing attach point loads, actuator chamber pressures, thrust chamber excursions, etc. Both the amplitude and frequency of the side loads were varied for rectangular-pulse, half-sinusoid, and four-cycle sinusoid load wareforms. Only for shock loads of high frequency (greater than 7 to 9 cps) or low amplitude (75 to 100 K with minor system changes) can the EAS operate unassisted by secondary load paths, e.g., clutch or the shock-absorber type of restraining devices.

The inherent three-dimensional character of J-2 side loads and their effect on the S-II EAS strongly suggest that the scope of the side-loads analysis be expanded to cover the complete S-II EAS: two actuators, operating from a common ARMA and driving the three-degrees-of-freedom J-2 engine mounted on the three-degrees-of-freedom S-II thrust structure. Such a study is being formulated.

Recent J-2 test data from Rocketdyne indicates that the side load frequencies (1/2 to 2 cps) are much lower than originally expected. Unfortunately, the data from the first two analog studies do not adequately cover this low-frequency range. Primary emphasis on the current study, therefore, will be directed towards obtaining data in this area.

However, since these low frequencies are an order of magnitude below the EAS system resonance, it is not expected that the EAS can perform adequately by itself, even with load-limiter bypass devices. Secondary load paths will be required unless significant reduction of side-load amplitude or increase of side-load frequency can be effected by some means more closely related to the source of the problem.

J-2 Engine Gimbaling With Water-Cooled Diffuser

A study determined that sea-level performance of the engine actuation system (EAS) is essentially unaffected when a water-cooled thrust diffuser is attached to the J-2 engine (the water-cooled thrust diffuser is used during static test firing of J-2 engines). In the study it was necessary to estimate the loads (water flow and pressure, inertial, etc.) imposed on the EAS by the diffuser, actual load data lacking.

S-II Guidance Study

An analog simulation of an elementary path-adaptive guidance system was performed to ascertain what requirements, if any, are imposed on the positioning accuracy of the engine-actuation system by the path adaptive guidance mode. It was presumed that any inaccuracy in the position of the thrust vector would cause some increase in the consumption of propellants during S-II flight. The results of the study provided an estimate of the magnitude of increase that could reasonably be expected.

The results showed that the increase in propellant consumption resulting from a thrust-vector inaccuracy of 0.5 degrees was so small that it could not be detected by analog techniques (i.e., it was less than 0.1 percent). When the inaccuracy was increased to 2.0 degrees, at least twice the expected inaccuracy, and when the path-adaptive mode was reduced to only one correction instead of continuous corrections at one-second intervals, the increase in propellant consumption amounted to less than 0.2 percent of the total mass of propellants expended. The conclusion is that engine-positioning inaccuracy of 2.0 degrees or less will have negligible effect on propellant consumption.

Flight Control Simulator (FCS)

FCS Study 1 was concluded in May 1964. Results include the following:

1. The maximum obtainable static and coulomb friction moments have been determined as 66,400 inch-pounds and 50,000 inch-pounds respectively.

2. The lowest natural frequency attainable for the unloaded FCS with the present adjustable spring is 45 radians per second.

3. A comparison of actuator rates and flows of the FCS and an analog computer EAS model shows good correlation.

4. The control capabilities of the EAS during S-II vehicle separation and midburn were verified using the FCS.

THERMODYNAMICS

Base Heating Model Test Program (Cornell Aeronautical Laboratories)

The design evaluation base heating model test program began in September 1963 at the Cornell Aeronautical Laboratories (CAL). The first group of tests consisted of 18 runs, nine of which were made to test the effect of increased heat-shield diameter on the magnitude of the heat flux in the S-II base area. It was found that increasing the diameter lowered the heating rates on the thrust cone. The other nine runs were made with a 30-degree wedge on the outer edge of the heat shield. It was thought that these wedges might help turn the flow away from the base area. The tests indicated that they have a slightly beneficial effect only when employed on the nominal size of heat shield. They actually become a liability at the larger diameters. With all diameters, the wedges increased the heat flux on the heat shield in the vicinity of the wedges.

Preliminary data from the Series C tests indicate that the magnitude and distribution of heating rates on the base heat shield are not significantly different from those obtained in the Series A tests. The Series A preliminary test program indicated that the heating rates in the base area at altitudes above about 200,000 feet (60.9 km) show no increase. To check these results the altitude was varied during the Series C tests, and it was noted that, as the altitude was increased, an apparent increase in thrust-cone heating rates occurred; further studies are planned to investigate this effect.

During the month of October 1963 analysis of the Cornell recovery temperature data was completed. The conclusion, based on Series A Cornell test data, is that the recovery temperature on the S-II heat shield will be approximately 2700 R ± 433 ($1\ \sigma$) R.

Rocketdyne has established allowable rates of heat transfer to the J-2 engine reinforcing bands. To determine whether the environment is expected to exceed these values, estimates have been made of the heating rates to the reinforcing bands during flight, based on Cornell (Series A) test data. The heating rates were found to vary from 0.1 Btu/ft^2/sec to 1.3 Btu/ft^2/sec. These estimates indicate that some insulation will be required on Bands 93, 95, 97, and 99.

It was previously believed that none of the J-2 engine components forward of the heat shield would be exposed to exhaust gases expanding off the heat shield or the flexible curtain. An investigation of possible curtain deflection patterns was made by referring to a one-tenth scale model of the J-2 engine, curtain, and heat shield. When an outboard J-2 engine is gimballed 9 degrees inboard, it allows the flexible heat-shield curtain to distort and assume its most severe shape with respect to spilling gases into the region forward of the heat shield. The investigation revealed that the aftmost 20 inches of the fuel high-pressure duct and the main fuel valve and housing could be hit by exhaust gases expanding off the edge of a distorted flexible curtain. The predicted thermal environment of these two parts is 1.0 Btu/ft^2/sec and 0.7 Btu/ft^2/sec respectively.

Rates of heat-transfer on the S-II thrust cone increases with increasing altitude and decrease with increasing heat-shield diameter. Pending a detailed design study of an enlarged heat shield, a proposal was presented to MSFC in December 1963 describing a method of achieving reduced heat transfer rates and therefore, significant weight reduction. Although the design change will increase the weight of the heat shield perhaps as much 200 pounds, it will result in reducing the requirement for thrust-cone insulation, giving a net weight saving of from 200 to 300 pounds.

A review of the data available in December 1963 revealed the following:

1. Heat-transfer rates to the thrust-cone increase with increasing altitude to the extent that certain areas may reach critical temperatures.

2. Heat-transfer rates to the thrust cone decrease with increasing heat-shield diameter as determined by comparing environments using the nominal 210-inch heat shield and those using the 228-inch and 246-inch model heat shields in the tests. Further tests will be conducted using a heat shield of new shape, which is predicted to reduce heat transfer to the thrust cone.

3. Engine gimbaling, as in the extreme case which could be encountered as a result of an engine actuator failure, can produce a localized hotspot on the heat shield, the temperature of which exceeds the design limit of the shield. Testing of heat shield material will be conducted to determine the criticality of this effect.

4. With the interstage in place, a localized hotspot is produced on the thrust cone. At this time, it appears that the critical temperature will not be exceeded during the comparatively short time the interstage is in place during J-2 engine burn nor during the remainder of flight, provided the new heat shield is employed.

5. Injection of secondary flow into the rocket engine exhaust nozzles has been found to reduce heat-transfer rates to the thrust cone; however, only a limited amount of data on the effect of secondary flow is available.

The Series C base heating tests performed at Cornell Aeronautical Laboratories were completed on 14 February. Using the 256-inch diameter heat shield. 79 runs were performed in investigating the following conditions:

1. Nominal engine cluster deflection pattern
2. Single actuator failure pattern
3. Dual actuator failure pattern
4. Engine flexible curtains removed
5. Recovery temperature investigation

In general, preliminary results indicated that the thrust-cone heating rates are relatively unaffected by the engine cluster deflection pattern. (See Figures II-76 through II-79).

256 Inch Heat Shield

A comparison was made of the CAL S-II model base environment when using a 256-inch heat shield and when using a 210-inch heat shield. Results of the CAL base heating tests with the 210-inch sheild showed that the peak thrust-structure heating rate was greater than 0.15 Btu/sec/ft^2. Thus, thrust structure insulation would be required if the S-II stage were fitted with this shield. To reduce the heating rate of the thrust structure, it was recommended that a 256-inch shield be adopted. Subsequent testing at CAL, in which the S-II base heating-test was fitted with a shield of the shape recommended, showed that the heating was rather more than that predicted. However, the new 256-inch heat shield was found to reduce the peak heating rate on the thrust structure to less than 0.15 Btu/sec/ft^2. The heating rates obtained were about the same as those obtained in earlier tests with a 246-inch circular shield, although the new 256-inch shield is lighter than the 246-inch shield. Peak heat rates and pressure measured in the model base region when using the 256-inch heat shield are shown in Table II-8.

Table II-8. Peak Heat Rates and Pressure—256-inch heat shield

Parameters	Without Interstage		With Interstage	
Parameter	Thrust Structure	Heat Shield	Thrust Structure	Heat Shield
Heating rate, Btu/sec/ft^2	0.11	4.8	2.4	5.3
Static pressure (psia)	0.00207	0.030	0.022	0.03

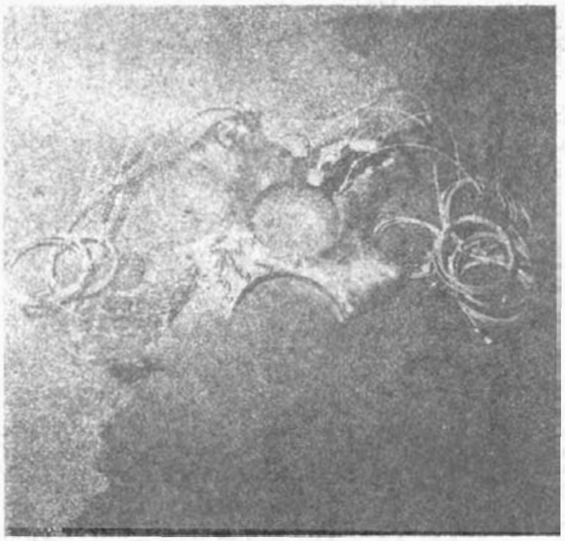


Figure II-76. Backside of 1/25-Scale Model Heat Shield Showing Instrumentation

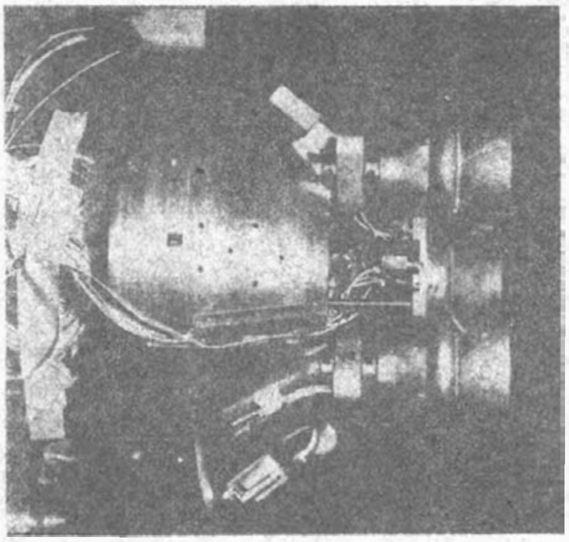


Figure II-77. Side View of 1/25-Scale Base Heat Model Without Heat Shield

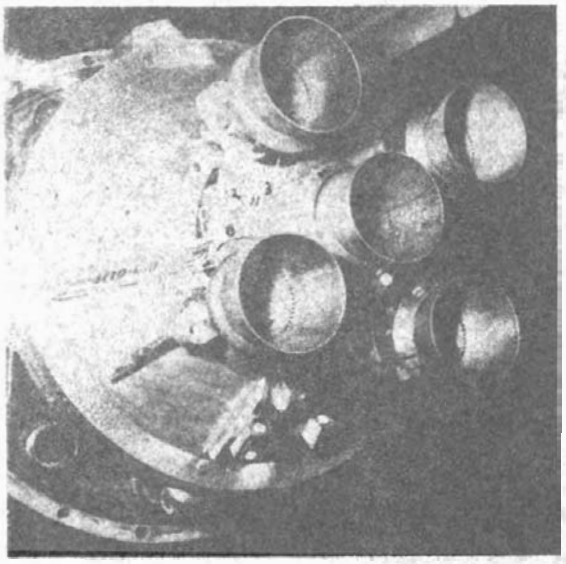


Figure II-78. S-II 1/25-Scale Base Heating Model

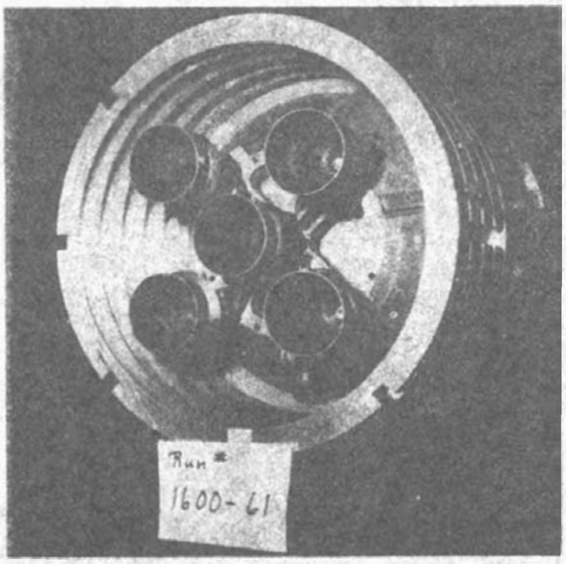


Figure II-79. 1/25-Scale S-II Base Heating Model Without Heat Shield With Interstage In Phase

BASE HEATING MODEL TEST PROGRAM—MSFC

The first S-II base heating test runs conducted at MSFC were made on 27 April. These runs showed that the vacuum tank at MSFC, which is 18 feet in diameter compared with 13 feet for the CAL tank, allows an increased run time of about five or six milliseconds as compared with the three or four milliseconds for the Cornell tank. The first 14 test runs duplicated the conditions in the Cornell facility in every way except that a larger tank was used. Preliminary results from these runs indicate that under nominal conditions (256-inch heat shield, 240,000-feet altitude, no nozzle deflection, no interstage) the maximum thrust-cone heating rate was less than 0.1 Btu/sec/ft^2. These results agree with those of the CAL Series C base heating tests; however, it appears that the CAL thrust-cone heat-flux traces were not really stabilized because of the shorter run-time available at CAL. Some of the MSFC thrust-cone heat-rate traces appeared to stabilize five to six milliseconds after the start of the run. The heat-shield pressure and heat-flux traces showed considerable random noise, but the data showed surprising consistency from run to run.

An S&ID letter entitled "Preliminary S-II Flight Stage Base Region Design Environment" was transmitted to MSFC for comment. The environments presented in this letter are based on the Cornell Series C test results.

A request for some additional test runs was formally transmitted to MSFC. These will provide information about the S-II model thrust-cone heating rates which will make S-IV base-region flight data easier to interpret and apply to the S-II base-region design criteria. In addition, another set of runs has been scheduled which will test a less severe (reduced gimbal-angle requirement) set of actuator failure cases for their effect on base heating.

As a part of the Series C Test program at CAL, two gimbal patterns simulating a single actuator failure at 7.5 degrees were tested. One of these caused heating rates to reach 13 Btu/sec/ft^2 on the flexible curtain and 10 Btu/sec/ft^2 on a section of the rigid heat shield. These heating rates, thermal control has concluded, will cause a failure of the affected parts. Since flexible material can withstand the heating rates caused by this gimbal pattern, the problem cannot be solved by using a more highly heat-resistant material. Thus, a single actuator failure at a gimbal angle of 7.5 degrees must be considered a failure mode. But the probability of an actuator failing in this position is about 0.00009, and consequently accepting this failure mode will not greatly decrease the probability of a successful mission. However, if sufficient control of the vehicle can be achieved with less gimbaling capability and if less gimbaling gives heating rates that can be tolerated by the curtain and heat shield, this failure mode can be avoided.

Study of Removal of Flight Base Heat Shield

A feasibility study entitled Removal of Flight Base Heat Shield was completed in June.

The object of Phase I of the study was to conduct a feasibility study to determine the advantages, if any, of removing the flight base heat shield and supplying local insulation as required. The results of this phase will be reviewed with MSFC, and direction will be given to S&ID either to terminate the study or to proceed with Phase II, a detailed preliminary design.

The base region flight environmental data were estimated for the case of the 256-inch heat shield and for the case where the heat shield is removed. A preliminary study was made to estimate local insulation requirements of the S-II base area if the heat shield is removed. Two configurations were considered — Configuration A, without a heat-shield closeout at Station 112 and Configuration B, such closeout at Station 112. The closeout, covering an area of 242 square feet, eliminates the requirement of insulating the LOX-tank aft bulkhead (1377 square feet) and the interior surface of the thrust cone (675 square feet).

The estimated local insulation weight for Configuration A is 2523 lb and for Configuration B 1448 lb. The weight of the present 256-inch heat shield, including rigid shield, flexible curtains, attachments, and support tubes, is approximately 740 lb. Thus it is estimated that removal of the heat shield would result in a weight increase of 1783 lb for Configuration A and 708 lb for Configuration B. Because of these figures and the fact that removal of the heat shield would result in a major base area redesign, it was recommended that the present heat-shield configuration be retained.

Dual Plane Separation

Reduction of the dual-plane separation test data from the Langley Research Center was completed in January. A report was issued covering the forces and moments on the S-IC/S-II interstage and the effects of EMR on interstage forces and moments during separation. This data is being used for the calculation of interstage clearances for various EMRs and for given engine nozzle arrangements. A summary of the results of the Langley tests was distributed to the MSFC meeting at S&ID on 25 February.

Cornell Separation Tests

A test plan was written for a short series of dual-plane separation tests to be conducted at CAL. These will utilize the 0.04-scale model that CAL used for base heating studies. The purpose of these tests is to check the gas simulation of the cold flow tests conducted at Langley Research Center last year. These tests will be conducted sometime in 1964.

SYSTEMS INTEGRATION

TECHNICAL REQUIREMENTS

S-II Systems Integration has maintained technical integration of the Stage Model Specifications: S&ID 61-361, S&ID 62-622, S&ID 62-623 and S&ID 62-624. These specifications have been amended continuously to reflect changing technical requirements.

On the basis of these documents, S-II stage design, configuration, and design changes have been monitored and evaluated. Concepts, configuration definitions, and operational studies have been maintained to insure overall technical integration and compatibility with existing NASA requirements.

SYSTEMS COMPATIBILITY

Compatibility Analysis

A complete EMM compatibility analysis was performed to determine whether GSE and facilities provided the required functional capabilities to check out and service the stage. Step-by-step checkout and operating procedures were compared with documentation of the actual hardware design. Incompatibilities were brought to the attention of cognizant design groups and were eliminated. This analysis is continually updated as changes occur in the EMM stage or GSE systems.

Combined Systems Schematic

The preliminary combined systems schematics for the EMM have been released. The schematics present a combined electrical and mechanical view of the stage systems and their interface with ground support equipment and facilities. The schematics have proven a valuable tool in systems compatibility analysis and are used as a reference for trouble-shooting, training, and analyzing the effects to stage systems.

SYSTEMS INTEGRATION STUDIES

Seal Beach - MILA Study

A study was made tracing S-II stage checkout from initial manufacture at Seal Beach through static firing at MTF to the launch pad at MILA. The study reviewed checkout operations and determined the effects of recent facility and operational changes. Specifically, the study covered:

1. The addition of stations 8 and 9 at Seal Beach
2. The addition of a two-station vertical checkout building at MTF
3. The routing of the S-II interstage through MTF
4. The revised MILA low bay operations
5. The economic use of equipment when two sets of GSE service two checkout stations.

The completed study presented to MSFC showed the basis for a smooth working checkout schedule.

Alternate Manufacturing Checkout Study

A separate study for modification of the present Seal Beach facility was conducted to provide for an alternate manufacturing checkout station. Basic study ground rules required that program continuity be maintained. The study proposed the use of a parallel manufacturing checkout flow as opposed to the present series flow. Test requirements, checkout requirements, facility capability, and flow time were taken into consideration. This study culminated in Checkout Stations VIII and IX.

CONFIGURATION REQUIREMENTS

The systems integration group has compiled a number of condensed stage system summaries and charts, matrices, and technical data manual sheets. These have proved helpful, both in their intended use as a management review tool, and also as a condensed summary for personnel in associated programs who have needed a brief updating in specialized program areas.

FLIGHT SEQUENCE

A study of the Saturn S-II stage flight sequence was finalized. The study describes each functional event in relation to the S-IC booster from prelaunch through S-II/S-IVB separation. Emphasis was placed on the events of the functional S-II stage systems. The flight sequence was illustrated by a bar-type chart; a descriptive list of events in time sequence was compiled in table form.

This information was presented along with a brief description of the stage systems in SID 62-653, Flight Sequence Report (Confidential).

FACILITIES REQUIREMENTS

SSFL

Numerous revisions to the document, Engineering Requirements for Saturn S-II Stage Captive Firing Facility, Santa Susana, California, were processed and transmitted to Rocketdyne. This document contained new and revised facility requirements resulting from action which affected the facility design. Requirements having considerable effect on facility design were as follows:

Expansion of the C7-603 console and resulting relocation of the C7-601 console

Addition of antenna supports at the test control center

Deletion of the computer room RFI shielding and addition of computer equipment

An increase in J-2 engine start tank pressure from 800 psi to 1500 psi

Addition of the halogen system

Addition of bumper guards and guide rails

Addition of side load arresting mechanism (SLAM)

Standby generator set (400 cps)

Blast instrumentation

Emergency LOX drain

False floor modification, test control center, and ground service center.

Detail design changes have been monitored by reviewing the various phases of Rocketdyne design drawings and on-site coordination.

Component Test Facility

S&ID was requested to present requirements to NASA for a component test facility. This facility would be operated and controlled by NASA's base contractors on an "as required" basis. The facility would be developed and operated according to the following ground rules:

1. Hazardous testing will be isolated at this facility and limited to:
    a. Transducer calibration under cryogenic conditions
    b. Small components requiring test under cryogenic conditions
2. No flow tests will be made with hazardous cryogenic liquids.
3. Other test positions at this facility will provide the necessary nonhazardous testing and servicing capability.

S&ID requirements for the facility were transmitted to NASA.

Docking Facilities

The facility requirements documents, SID 61-410 and SID 61-411, for the docking facilities at Seal Beach and Port Hueneme were completed and published.

MTF

Cable Terminal Racks

A problem concerning cables and cable terminal racks at MTF was resolved. NASA will supply nine terminal racks for each test stand at each end of the cables between the test control center and the ground service center. NASA also will supply eight additional terminal racks in each ground service center for cables running to the test stand and stage.

Vertical Checkout Facility

A study was made of facility requirements for a vertical checkout facility at MTF. Study ground rules were as follows:

1. Initially, one checkout cell would be provided, with capability for a second one later.
2. A complete set of checkout GSE, including computer, would be provided for each checkout position.
3. The stage would be rotated from horizontal to vertical outside the building.
4. Building height would be based on stage growth of 10 feet.
5. Checkout cell area would be based on stage diameter of 33 feet and access requirements.

6. Provision would be made for 100-percent access to the exterior of LH_2 tank.
7. No cryogenic fluids would be utilized in this area.

The study was completed and the requirements were transmitted to NASA.

Mechanical Systems Integrated Leak Test Sequence

MSFC technical direction established a different leak and functional test philosophy than that proposed by S&ID for specific test site operations. Working within the ground rules of the new concept, equivalent process specifications were generated by the responsible systems groups. These system-oriented process specifications were inadequate when superimposed on an integrated leak test program as related from one test site to another.

A coordinated effort was made to prepare an integrated leak and functional test sequence that would be instead entirely stage-oriented. The primary objective — generating a document delineating the stage-oriented integrated leak and functional test sequence for stage mechanical systems— was accomplished as were the secondary objectives listed below:

1. Documentation that relates systems leak test process specifications with the detailed leak test operations
2. An appraisal of basic safety precautions for the protection of personnel and the stage during leak testing at the various test sites
3. The establishment of provisions for maximum efficiency in the utilization of test time and test personnel and for the precluding of unnecessary waste of test gases
4. The generation of a concept and ground rules essential in establishing design criteria for GSE implementation of leak test functions

Interlocks

The initial S&ID concept for safety interlocks during stage test and static firing operations was based on a computer-controlled tape program.

In the course of S-II program growth, this initial concept was greatly modified. MSFC technical directives, in general, slanted test operations in the direction of transmitting functions between stage and GSE by manual hardwire rather than by automated binary coded decimal (BCD). Technical

Directive 87 specifically directed S&ID to provide a relay interlock rack for control of hardwire stimuli and responses between the stage and GSE. It was further specified that the rack be located between the stage and all solid state BCD logic functions.

The systems integration group analysed all stage control functions generated by the various pieces of ACE/GSE in each operational mode (i.e., static firing and stage system checkout). The ground rules governing interlock requirements were concerned with prevent out-of-sequence control functions being sent to the stage wherever such stimuli would result in a catastrophic failure to the stage (or stage component) or in an injury to test personnel.

The analysis provided the basic ground rules for determining the functions to be interlocked by the relay logic rack (C7-213), which houses all relays associated with the interlock concept.

Integrated Systems Tests

Test documents were prepared for the EMM, All-Systems stage (S-II-T), and the single and multiple engine configuration of Battleship. These documents specify a checkout procedure for the various stages wherein all of the stage systems are active and provide raw data to the computer programming group for the implementation of the automatic checkout routine. The lists are designed to provide end-to-end checks rather than detailed component verification.

A primary design objective was to develop tests that provide minimal but complete stage checkout wherein all stage functions are exercised, but repetitive operation of a particular function is avoided as the complete test is performed. To accomplish this end, the Test procedure was subdivided for independent stage systems which are tested as units, simulated launch countdown and flight sequence tests, and a general networks test of all functions not included in the preceeding. An integrated systems test procedure will continue to be prepared for each stage configuration and, where possible, conformity will be maintained on formal and level of testing.

C7-800 Design Criteria

As a result of an S&ID S-II automation plan, manual static firing control equipment is required for testing purposes. The basis static firing concept was established in June 1963 by S-II systems integration. This concept was basically adaptable, utilizing existing ACE in its present configurations. The approach was to provide a manual add-on capability for hardwire position control of the propulsion system, pressurization system, propellant loading, propellant feed, and engine control. No redundant active control between the automatic checkout and manual static firing equipment was to be permitted. Phasing of growth to any degree of static firing automation was to be provided.

The design requirements for the manual static firing control equipment were prepared by S-II systems integration and transmitted to the design groups on 30 August 1963. The requirements called out the stimuli and responses between the stage, GSE, and facility and included requirements for interlocking, hazardous monitoring and safing control, and panel indicator for engine cutoff annunciator.

To formulate design requirements for the manual static firing control equipment, it was necessary to analyze the S-II stage to determine those functions requiring control from the start of propellant loading and through the actual "hot firing" of the engines to stage securing.

In establishing these requirements it was readily apparent that many functions required performance during the last 10.5 minutes of the countdown. To accomplish these functions within a reasonable time span, a method had to be devised that would provide for the functions to occur at the proper time. An automatic sequencer controlled by relay logic was specified for this purpose. This sequencer also would have manual overrides where the logic could be bypassed if a relay failed or the function was required for stage safing. Each function performed by the sequencer is predicated on the successful accomplishment of all previous functions and, therefore, works in harmony with the static firing interlocks.

In July 1963, MSFC directed S&ID to provide pneumatic servicing and control equipment for use on the launch umbilical tower and in the blockhouse at MILA. NASA indicated this equipment also would replace the pneumatic servicing console set (C7-605) at SSFL (for the All-Systems stage) and at MTE. S-II systems integration reviewed this design effort for design requirements changes to the manual static firing control, including the automatic sequencer.

S-II systems integration presented design requirements for a "simulate mode" to be added to the static firing control equipment. The "simulate mode" of operation will operate the equipment utilized during the countdown without performing actual propellant loading or engine firing. This mode of operation will verify overall ground countdown systems prior to the active countdown, providing confidence that all stage/GSE is capable of performing the actual countdown and static firing.

Fusing Concept

A method for fusing the interface wiring between the S-II stage and GSE was developed to comply with Technical Directive 87. The method consists of dividing the interface wiring into various classes comprised of 28-volt or greater low-level signal lines, high-current power lines and low-level 0.5-volt analog lines. The concept proposes the use of a nominal size (2 ampere) fuse for all signal lines, selected sizes for power lines depending upon the individual circuit current and no fuses for the analog lines. This approach to fusing and the engineering data justifying the method were presented to MSFC on 15 May 1964.

Heliarc Welder Electromagnetic Interference (EMI) at Seal Beach

Because heliarc welders are, inherently, generators of EMI, tests were performed on the welders in the bulkhead fabrication building at Seal Beach to determine the extent of filtering and suppression required. From data obtained, filters were specified for and installed on the welders, which were later installed in the VAB. Subsequent testing indicated that the filters on the welder power lines attenuated the conducted interference sufficiently, but the welding arc and head radiated excessive levels. As a result of the high level of radiated interference, changes were recommended in the building design and the planned utilization of station 3 adjacent to the checkout station.

Marker Beacon EMI Problems

Because the proposed site of the dual checkout facility is adjacent to the Federal Aviation Agency marker beacon on the approach to the Long Beach airport, NASA and S&ID were concerned that the transmissions from this marker beacon could interfere with checkout of the stages in the new facility. Antennas were set up on the roof of the present pneumatic test, paint and packaging facility (station VII), which is also adjacent to the marker beacon. Field intensities of all transmissions were measured in the frequency range of 15 kc to 100 mc from this position. Data obtained from this test was used as a basis to recommend design consideration for the proposed dual checkout facility.

Site Survey of EMM Area

A site survey of the EMM area was performed during September 1963 to determine the level of ambient interference and to determine whether there were transmissions in the area which might interfere during checkout operations at the EMM. The survey was performed by Genistron, Inc., of Los Angeles. Genistron issued a test report which was subsequently relayed to MSFC. The site survey indicated intermittent high levels of RF from transmitters which were not under S&ID control. As a result, S&ID recommended that the CDC 924A computer be installed in a shielded room. The data will be helpful in pinpointing interference problem areas during systems and integrated systems tests.

Revision of Electro-Interference Control Plan

The Electro-Interference Control Plan, SID 62-543, for the S-II stage was revised to include MSFC review comments. The revision also reflected some configuration changes in grounding and other EMI suppression measures. The revised document was submitted to MSFC for approval.

EMI Control at SSFL

A visual site survey was made of the Battleship and All-Systems test stands and the control center at Santa Susana. Upon completion, recommendations were made to upgrade the EMI characteristics of the facilities. A plan of action is being prepared, including an electromagnetic site survey of these facilities.

Annunciator and Hazardous Monitoring Panel Requirements

A study was conducted to determine monitoring requirements for the annunciator and hazardous monitoring panels. The annunciator panel requirements include all parameters that result in an automatic or manual engine cutoff. This panel is an "after-the-fact" display that indicates to the test conductor why the test was prematurely terminated. The hazardous monitoring requirements include those parameters in which "out-of-tolerance" conditions may result in damage to the stage or injury to personnel if allowed to continue.

As a result of this study, limit detector requirements were established. These requirements were necessitated because human reaction time was not compatible with several of the fast-reacting parameters. All measurements now displayed on red-line or blue-line recorders have been evaluated to insure that limit detectors are being used on all high response time parameters.

Buffering of Critical Measurements

Various recording and monitoring equipment has been classed as Criticality Category I items when directly associated to critical stage functions. A method for isolating this equipment by means of diodes and fuses was documented for the purpose of reducing their criticality rating to category III or IV.

HUMAN ENGINEERING

Checkout Equipment for Soft Mockup

A full-scale soft mockup was fabricated to assist in the design planning and development of S-II checkout equipment. The mockup (Figure II-80) is a design evaluation tool that was used during design reviews for the electrical checkout station (C7-200), digital data checkout station (C7-400), telemeter checkout station (C7-500), SDD Battleship checkout equipment, and during a presentation to MSFC demonstrating operation of the pneumatic checkout console set (C7-603). During use, each rack is depicted by incorporating full-scale panel layout drawings on a wooden rack frame. Because alternative designs can be shown readily, evaluation is facilitated for relationships of panel-to-panel, and rack-to-rack.

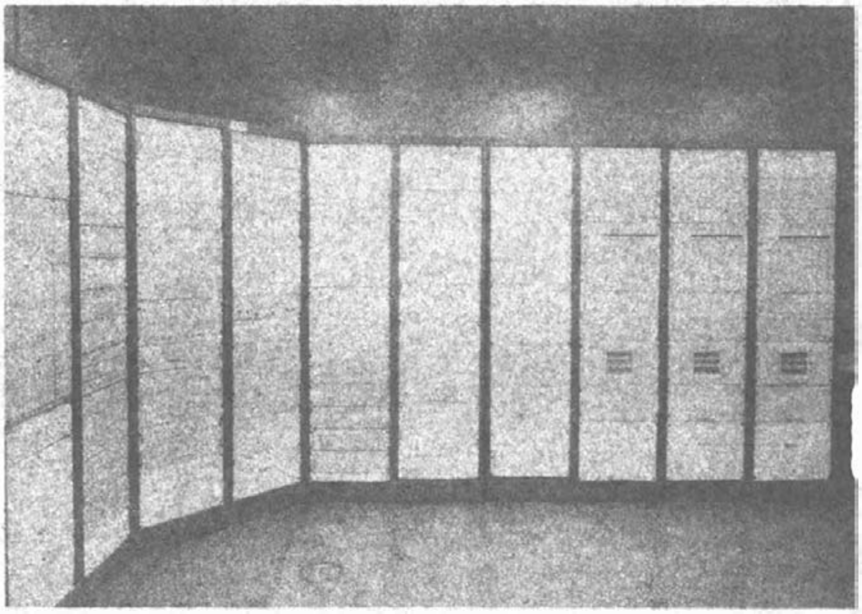


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Figure II-80. Checkout Equipment Soft Mockup

Human Engineering Splinter Meetings

S-II human engineering representatives participated in three Saturn V human engineering splinter group meetings at MSFC in July and November 1963, and February 1964. Presentations made to the group, a splinter group of the vehicle mechanical design integration working group, included:

1. Requirements for protective clothing and special devices

2. Implementation and use of human engineering manuals

3. Test and evaluation plans

4 Implementation of human engineering requirements in NCP-200-2

5. Human engineering factors involved in internal vehicle access platform design

In September 1963, representatives participated with MSFC and other Saturn V contractor representatives in a special meeting which resulted in the specification of design criteria for the Saturn V internal vehicle platform.

Stage Access Requirements

A study was conducted to define S-II access requirements and the access provisions available to meet these requirements. The results were documented in the report, (SID 63-1430) S-II Stage Access and Servicing Requirements and Provisions, dated February 14, 1964. All components located in the S-II forward skirt, aft interstage, LH_2 tank, LOX tank, and exterior stage are defined in terms of size, weight, and location. Access provisions to these components are defined for the All-Systems vehicle at Santa Susana, and for flight vehicles at MTF, at the MILA VAB (low and high bay areas), and at the launch area.

Control drawing V7-000111, Stage Provisions, Access and Servicing, was prepared and transmitted to MSFC. This drawing shows the location of access and servicing requirements for the S-II forward skirt, aft interstage, and exterior stage areas.

LOX Tank Component Removal Study

A study was conducted utilizing the EMM to establish whether it is physically possible to remove and replace major LOX tank components through the 20-inch access hatch. Additional study objectives were to establish component removal paths and envelopes, and to estimate manpower and GSE requirements. The study was documented to the LOX Tank Component Removal Study (SID 64-991), dated 15 May 1964. Figure II-81 illustrates the removal envelope for the LOX vent line, showing the vent line in eight positions during removal. Figures II-82 and II-83 illustrate the actual removal operation identified as step 4 in Figure II-81. The study concluded:

1. It is physically possible to remove the LOX recirculation lines, capacitance probe, and the stillwell from the LOX tank 20-inch access hatch at all field locations and after Saturn V mating, providing sufficient access provisions are available

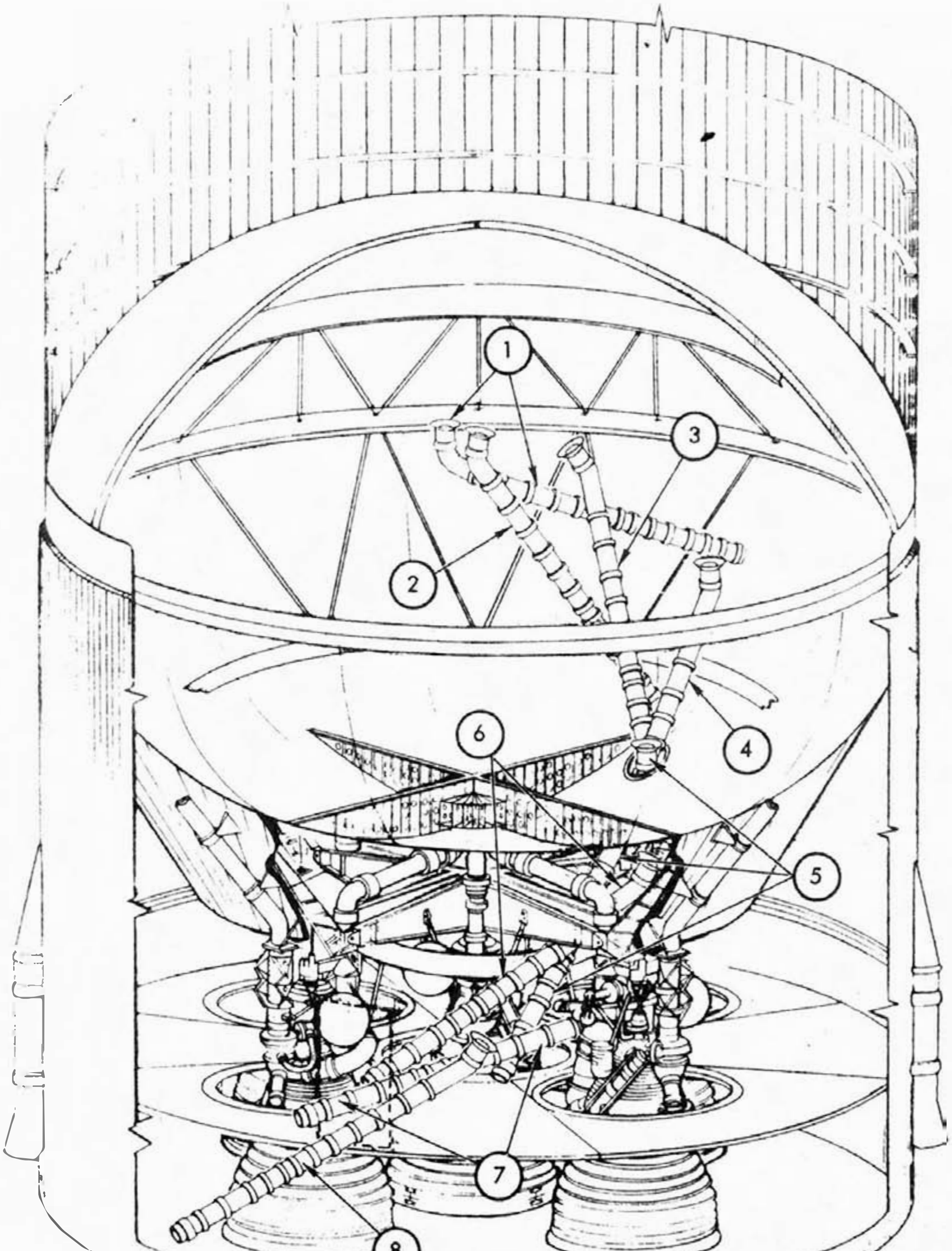

Figure II-81. Removal Envelope for LOX Vent Line

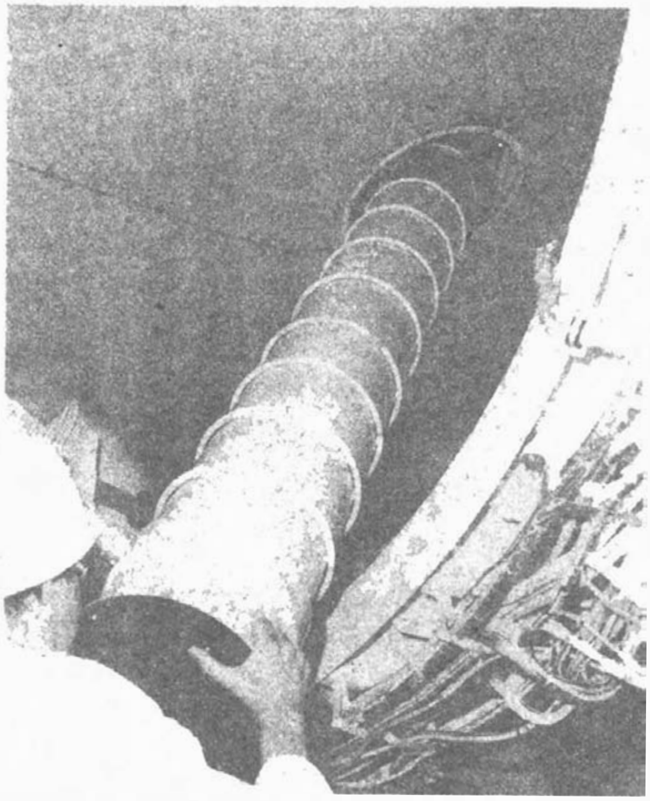

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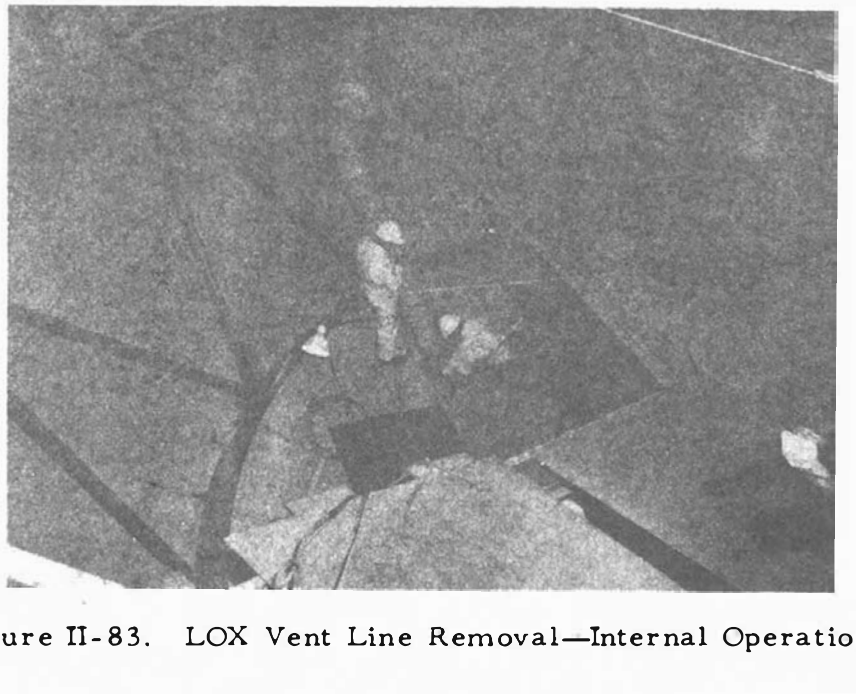
Figure II-82. LOX Vent Line Removal—External Operations



SID-810-157L

Figure II-83. LOX Vent Line Removal—Internal Operations

2. The LOX vent line and the pressurization mast cannot be removed unless heat shield sections between engines 1 and 2 and between 2 and 3 are removed or the components are designed to be comprised of two sections

3. Sections of the engine compartment platform must be removed to permit removal of the pressurization mast

Harness Evaluation

Four types of harnesses were evaluated for use during LH_2 tank entry operations. The harness is intended to provide the capability of removing LH_2 tank entrants quickly and safely under contingency conditions, i.e., (physical injury, sudden illness, or malfunction of the LH_2 tank servicing mechanism, A7-35). The harness types were the plain harness, harness coverall, net harness, and torso harness. It was concluded that the torso harness rates is the most suitable of the four. Effort is continuing to select the best torso-type harness for the S-II program.

LH_2 Tank Entry

A full-scale soft mockup was constructed to simulate the LH_2 tank manhole area with the carriage assembly for the LH_2 tank servicing mechanism (A7-35) in proper position for tank ingress and egress (See Figure II-84). Tests utilizing the mockup were conducted to establish ladder

Figure II-84. KH_2 Tank Entry Access Evaluation configuration and to evaluate overall accessibility (i.e., for the limited crawl-through area at the tank manhole, and possible obstructions by cables, chains, and platform railings). The mockup is being used in tests concerned with removal of an incapacitated tank entrant.

Test and Evaluation Plan

A human engineering test and evaluation plan was formulated and transmitted to MSFC for review in February 1964. This plan described general objectives and delineated specific evaluations proposed for conduct utilizing mock-up configurations and the S-II EMM facility. In addition, a plan was defined for fulfilling the human engineering requirements outlined in NCP-200-2. To date, mock-up evaluations have been completed for items of checkout and auxiliary equipment, and participation has been initiated in the S&ID non-conformance reporting system.

Tank Entry Safety Requirements

Safety requirements for S-II vehicle tank entry were defined in Safety Requirements for S-II Vehicle Tank Reentry (SID 63-1259), dated 30 September 1963. This document includes general safety precautions, special clothing and equipment requirements, manpower requirements, general entry procedures, and personnel selection and training requirements.

Special Protective Clothing and Equipment

A study was conducted to establish special protective clothing and equipment requirements for the S-II program. Personnel hazards considered included the possibility of falling from high places and those hazards associated with cryogenics and gases in terms of fire, explosion, cold temperatures, and asphyxiation. Stage equipment hazards considered included possible damage caused by falling objects and contamination of propellant tanks. Protective clothing and equipment were selected by visual inspection, testing, past experience, and manufacturers' specification. The results of the study were documented in Saturn S-II Special Protective Clothing and Equipment (SID 63-1218), dated 1 October 1963.

GROUND SUPPORT EQUIPMENT

SERVICING EQUIPMENT

LH_2 and LOX Tank Desiccation Systems (S7-3 and S7-4)

The desiccation systems (breather-type) were designed to be attached to the respective tanks to maintain a clean, dry atmosphere within during transportation and storage. The systems were designed almost identical in order to use the same parts and were completed and released in February. Fabrication had started but was stopped after a decision was made to replace the desiccant systems with a pressurization system capable of maintaining a positive pressure within the propellant tanks.

Portable Vacuum Pump (S7-37)

Engineering design was completed, and all drawings were released in August 1963. The pump and components were procured and assembled by S&ID, and Unit I (Figure II-85) was delivered to Santa Susana for use on the Battleship test stand.

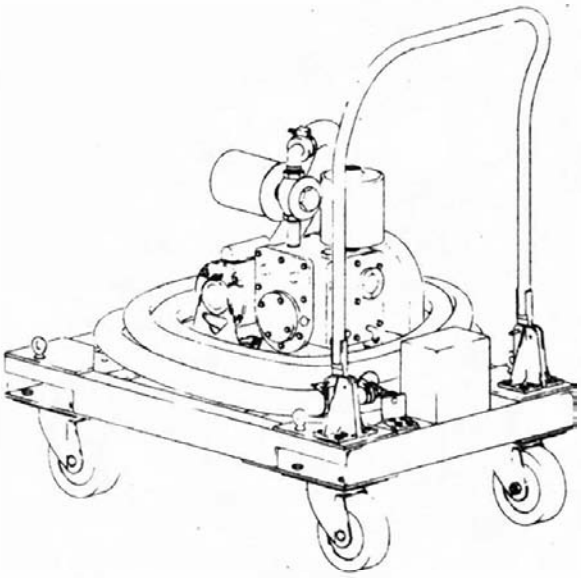


Figure II-85. Portable Vacuum Pump Unit

Pneumatic Servicing and Checkout Console Set (S7-41) and Pneumatic Servicing Electrical Console (S7-42)

These models were approved for design and fabrication 7 February 1964. Design proceeded steadily and was 10-percent completed. A design review was conducted by S&ID and MSFC beginning with preliminary approval 18 June 1964.

Two systems in the console set have been assigned to Criticality Category II. A design change was approved which reclassifies the system to Criticality Category IV.

AUXILIARY EQUIPMENT

Vertical Engine Compartment Platform (A7-12)

Design of the A7-12 was suspended in view of platform requirements established by MSDC. Subsequently, S&ID submitted a proposal that would establish a 3-level platform (A7-84) at S-II stations 34, 55 and 114 (Figure II-86). The platform concept utilizes the flight heat shield for support. Honeycomb sandwich material is presently planned for platform decking and structural members. All materials will be LOX-compatible.

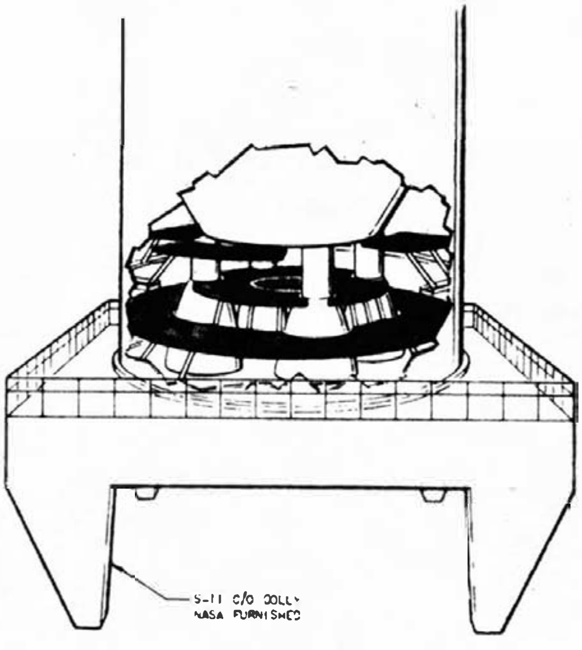


Figure II-86. Engine Compartment Platform Set (A7-84)

Thrust Alignment Set (A7-15)

The design and fabrication of the J-2 engine thrust alignment set was suspended upon directions from MSFC, pending the results of a Rocketdyne study to determine whether equipment or procedures can be developed which are compatible with both the S-IVB and S-II requirements.

LH_2 Tank Servicing Mechanism (A7-35)

The design and fabrication of the first unit of the LH_2 tank servicing mechanism (Figure II-87) was completed at S&ID Tulsa. The equipment has met design verification and manufacturing acceptance tests in compliance with procedures approved by MSFC. The equipment is undergoing particle generation tests to determine whether corrective action is required.

Static Firing Fragmentation Shield (A7-37)

Design of the static firing fragmentation shield (Figure II-88) was begun. A similar design for the static firing heat shield (SDD-227) was completed and will be tested on the Battleship facility.

A test to determine fragmentation stopping characteristics of the shield also was completed. Results showed the design to be effective in stopping a wide range of fragments, weighing up to 1.5 pounds, varying in shape from spherical to rectangular and impacting at velocities up to 1000 feet per second.

The S7-37 structure will act as the basic support for other equipment required for S-II static firing—i.e., static firing heat shield (A7-47), engine firex system (A7-74), hydrogen ignition systems (A7-80), and the GN_2 Firex System (A7-85). The structure also will support portions of the fire detection system and static firing instrumentation.

Forward Skirt Maintenance Walkway (A7-38)

The A7-38 design was completed. The design for Unit 2 and subsequent units was changed to a LOX-compatible configuration at the direction of MSFC. It was indicated that additional requirements for personnel "by-pass" capability and LH_2 tank bulkhead inspection will be specified for the platform. These requirements will have a significant effect on the present platform design.

Umbilical Systems

Umbilical systems design has progressed satisfactorily. Approximately 75 percent of the design was released for the umbilical carrier plates, Arms 3A and 4, Models A7-41 and A7-42 respectively. Fabrication was begun for the castings and machine details. The A7-41 and A7-42 are shown in Figures II-89 and II-90, respectively.

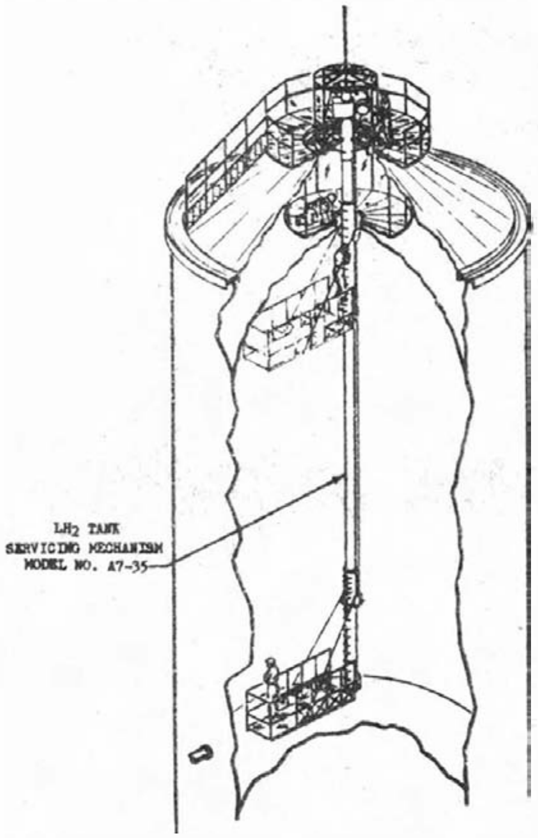


Figure II-87. LH_2 Tank Servicing

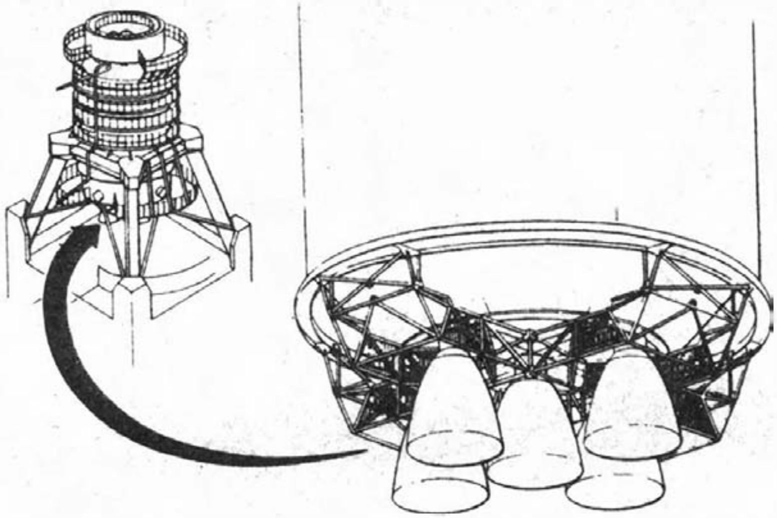


Figure II-88. Static Firing Fragmentation Shield (A7-37)

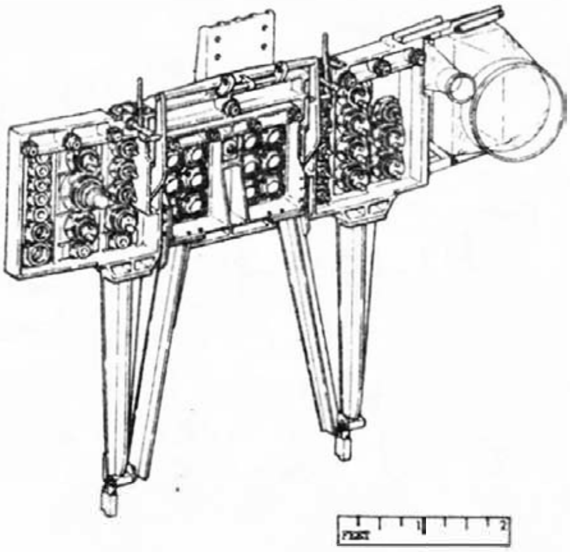


Figure II-89. Umbilical Disconnect Arm 3A Carrier Plate Assembly (A7-41)

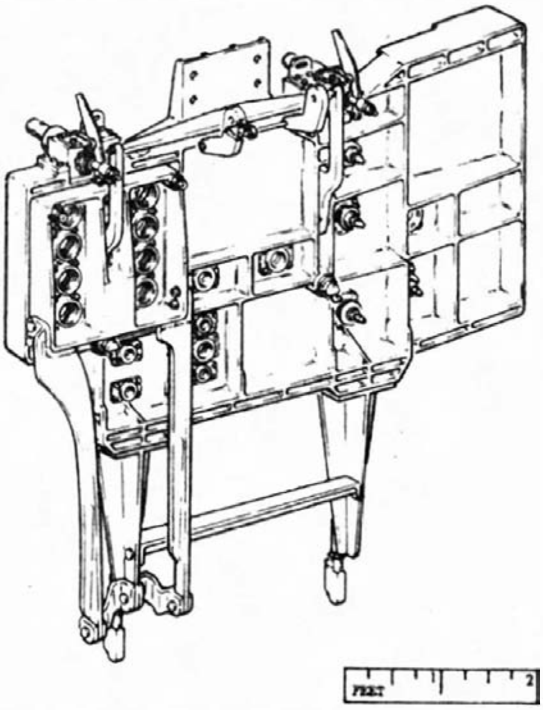


Figure II-90. Umbilical Disconnect Arm 4 Carrier Plate Assembly (A7-42)

Because of the critical schedule, it was determined to be prudent to embark on a "prototype" design. The prototype will be similar to the production GSE configuration, except that material substitution and commercial parts will be utilized when delivery schedules cannot be met. Use of the prototype will provide a reasonable period for design verification and for qualification test fixture set-up and checkout of test procedures. Use of the prototype also will permit timely development of hardware with a minimum of procedural and documentation control.

The preliminary design verification test program was submitted to MSFC and tentatively approved. Design, fabrication, and procurement of the test fixture proceeded on schedule.

Several technical directives listed below were received from MSFC and are being incorporated into the design.

1. TD 64-222 changes the secondary mode of the carrier plate separation to a lanyard actuation. Before the change a mechanical-ratchet system was utilized for the initial secondary mode, backed by a lanyard.

2. TD 64-224 directs that all disconnects be grounded to a common ground on the carrier plate assembly.

MSFC also requested that the latching type hydrogen vent disconnect on the A7-42 be changed to a pressure seal non-latching type. Action has been taken to incorporate the change.

The major casting pattern was completed for the A7-41 and A7-42. The first electrical ejection plate castings were machined.

Component testing to verify the design of the push-off pistons was accomplished. Initial testing showed a defect in the push-off piston seals for the electrical ejection plate. The part has been redesigned and is now undergoing design verification testing.

Umbilical plate design, as expected, was continually changed. The scope of these changes has in nearly every case increased the complexity of the carrier plate by incorporating additional disconnects. A growth potential included in the initial design has now been fully utilized. Further changes, requiring additional disconnects, will have a significant impact on the current configuration. MSFC, apprised of this situation, is investigating methods for simplifying checkout requirements which may result in a reduction in the number of disconnects.

The LH_2 fill disconnect (A7-64) and LOX fill disconnect (A7-65) are being procured from B. H. Hadley Company. The supplier's initial design utilized a ball-lock latching technique, which proved impractical, and a collet-type latching device is now being designed.

Fixed carrier plates are required for S-II static testing. These plates include Model A7-61 for the lower umbilical arm and Model A7-62 for the upper. Model design is approximately 80-percent complete. Many plate components are similar to those developed for the A7-41 and A7-42. No serious difficulties have been experienced.

Static Firing Heat Shield (A7-47)

The Battleship configuration of this item, designated SDD-227, will be used to determine actual heat flux levels and design suitability.

Thermal analysis, preliminary test program, and preliminary instrumentation plans have been submitted. The heat shield, located at S-II Station 100, is designed to protect stage equipment forward of station 100. The heat shield consists of a fiber-glass-type pillow filled with high silica glass fibers. The pillow, encased in a lightweight metal belting similar to the material used for the fragmentation shield (A7-37), will provide a barrier to fragments launched on vertical trajectories.

Heat shield fabrication is well under way; major components are completed. Subsequent to design release of SDD-227, thermal analysis indicated that protection was required for the J-2 engine and components located below S-II station 100. A study and design proposal was submitted to MSFC for a spray system to eject water below the engine nozzles to provide this protection.

Side Load Arresting Mechanism (A7-51)

No detail design has been made for this model. However, the equivalent Battleship item (SDD-217) has been designed and is now being fabricated.

The design provides for two structural links per outboard engine. The links affect the connection between the test stand and engine bridle. The connection to the bridle contains a "breakable joint"; separation from the J-2 is effected by an explosive bolt. Upon separation, the linkage swings and is locked clear of the J-2 gimbal envelope. The linkage also supports the electrical and fluid lines required for instrumentation and for servicing the J-2 diffuser with GN_2 and water. Subsequent to the initial design, it was determined that the center J-2 engine also required restraint. Due to the orientation of attach points, the engine bridle (GFP) could not be utilized, requiring a special design for the center engine. The design was submitted to Rocketdyne and MSFC for approval.

Two design approaches for side load measurements are being investigated:

1. Utilization of strain gages integrated with the structural linkage

2. Incorporation of a Baldwin-Lima-Hamilton load cell as part of the linkage

CHECKOUT EQUIPMENT

Cable Installations for MTF (C7-35, C7-38, and C7-40)

A plan of action for engineering support of the bid package for cable installations is being prepared.

Power Distribution Rack Console Set (C7-41)

The C7-41 (No. 1) is being installed at the Battleship facility.

Pneumatic Checkout Console Set (C7-603)

In August 1963 a meeting was held at MSFC to clarify the Phase I redirection of the C7-603 and its peripheral equipment. It was established that the C7-603 would operate as an independent station rather than be dependent on the elctrical checkout station for control and monitoring of stage functions. It was also established that additional recording capability was required. A change order was issued for this.

HANDLING AND TRANSPORT EQUIPMENT

Stage Handling Equipment

The following major stage handling equipment was completed:

Forward and aft stage support rings (H7-2 and H7-3)
Stage forward hoisting sling (h7-23)
Stage forward hoisting frame (H7-24)
Static firing skirt (H7-21)
Aft hoisting frame (H7-25)

Only minor design and fabrication problems were encountered, except for the H7-21 and these were corrected by new fabricating and tooling techniques and by corrective engineering.

An unexpected warpage problem developed in the fabrication of longerons for the static firing skirt (H7-21), a cylindrical, skin-stringer consruction of corrosion-resistant steel. On subsequent mechanical straightening, the fillet welds cracked, and it was necessary to equip Units 1 and 2 with "dummy" longerons. However, corrective design and fabricating techniques were developed. and successful production of acceptable parts was demonstrated on Unit 3. These dummy longerons are production parts for the original design and are satisfactory for the initial use of unit 1, supporting the fit-up fixture (H7-17) during transporter testing, and unit 2, supporting the initial buildup of the S-II-S. Both units will be retrofitted before application of longeron critical loading.

The forward stage handling equipment (Models H7-2, H7-23, and H7-24) successfully completed proof-load acceptance testing conducted under procedures approved by MSFC. No indication of undue distortion or strain was noted.

Component Handling Equipment

The design of component-handling equipment progressed satifactorily and is essentially completed for the following:

Sling, interstage and static firing skirt segment (H7-27)
Sling, ring segment, support (H7-28)
Sling, interstage and static firing skirt (H7-30)
Adapter, vertical installation, center engine (H7-94)

Some difficulty resulted from the design of the outboard engine installer (H7-95) used in conjunction with a Rocketdyne hoist-transfer unit (made available to S&ID as GFP). The H7-95's hoist points were found to be incompatible with the engine's hoist points because of a plumbing change on the engine. In order to retain the basic utility of the H7-95, it was necessary to use a 7-inch pitch diameter pulley instead of the 8-inch diameter specified by Rocketdyne. The new pulley design was submitted to Rocketdyne and MSFC for approval. Some problems still exist in regard to responsibility for removing components from the J-2 engine after the engine is installed in the stage. Some handling equipment is required because of weight access factor.

Transportation Equipment

The contractor proposed, and MSFC approved, the design of Type I and Type II S-II stage transporters. Type I (Figure II-91) is designed to operate on California highways; Type II, except for the short haul between the Seal Beach manufacturing site and the dock, will operate on government-controlled roads. The wheel load-axle spacing for Type I requires 24 wheels on six axles; the Type II has 12 wheels mounted on three axles.

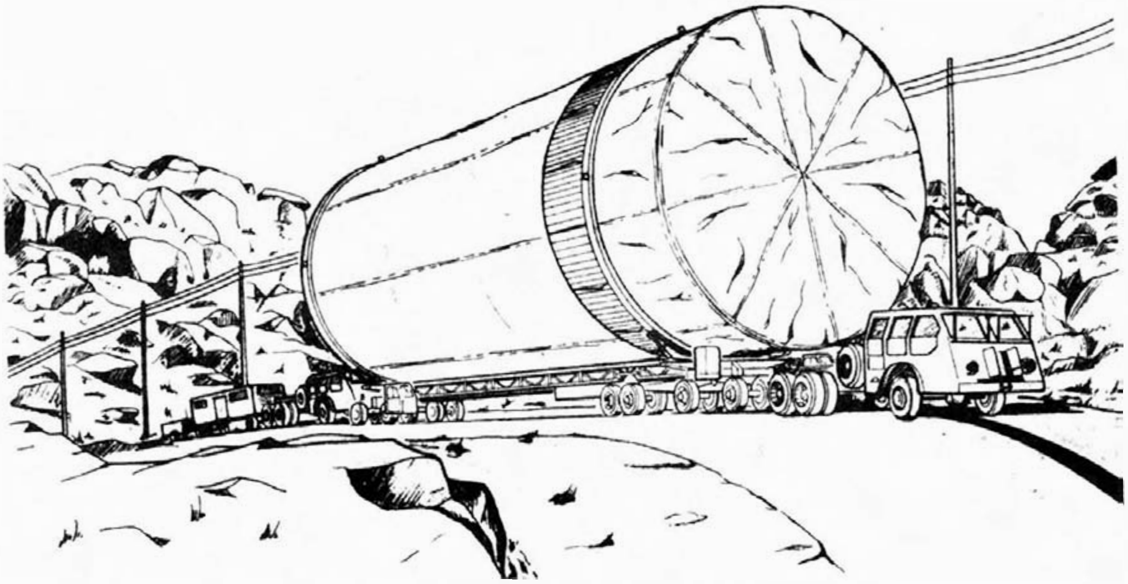


Figure II-91. Type I Transporter

The design, fabrication, and testing of the transporters were awarded in a fixed-price contract to American Machine and Foundry Company (AMF), York, Pennsylvania, in August 1963. The contract called for one Type I and four Type II transporters. After the award of the contract, the structural criteria for design was changed by direction of MSFC. The structural safety factors were changed from 1.5 on yield or 3 on ultimate to 3 on yield or 3 on ultimate, whichever governed. This change resulted in a substantial increase in the estimated weight of the transporters, particularly the Type I, which necessitated a change in axle-wheel loadings previously agreed on to comply with California laws. The change for increased loadings was conditionally granted.

The design of both types of transporters has been completed and fabrication of the first two units is well under way. Testing of Type I is scheduled for early August 1964, and Type II for early September. All S&ID and/or MSFC-furnished hardware in support of transporter tests has been delivered and assembled at AMF. This includes the fit-up fixture (H7-17), the attendant handling gear, and the government-furnished M-26A prime mover with auxiliary power-pack.

The H7-17 is designed to simulate the handling interfaces and weight of the S-II stage (Figure II-92). It can be ballasted with water to a 2-g configuration for testing, handling, and hoisting gear. The H7-17 was designed, fabricated, erected, and weight-balance tested at S&ID's Tulsa facility. Testing verified adequacy of design and demonstrated its functional compatibility.

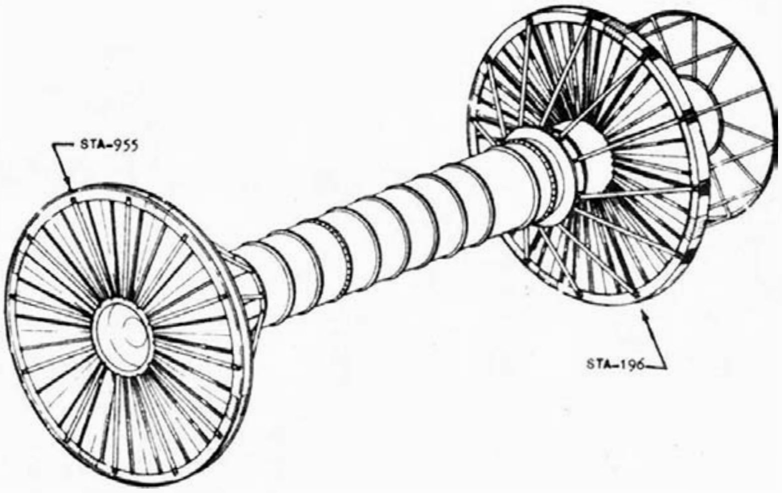


Figure II-92. Stage Fitup Fixture (H7-17)

The design of the aft interstage dolly (H7-8) was also completed at Tulsa. Fabrication is proceeding satisfactorily with no major problems expected.

SPECIAL DEVELOPMENT DEVICES

EMM Cable Installation (SDD-118)

The basic cable installation design has been completed, and cable assemblies and distributors have been manufactured. Wire harnesses have been fabricated and are being installed in the terminal distributor (SSD-154).

Changes increased the cable requirements between the control room and the mockup, resulting in a requirement for cable-tray expansion, increased distributor size, and increased catwalk size to support the larger distributor.

Approximately 1050 cable assemblies are contained in SDD-118.

All-Systems Cable Installation (SDD-104, -105, -107)

Approximately 25 percent of the cable assemblies for SDD-104 and SDD-105 were ordered. A total of approximately 1000 cable assemblies will be required for SDD-104 and SDD-105. Many of the cable designs are identical to those used for SDD-118.

All-Systems Test Stand Fluid Distribution System (SDD-109)

The initial design of the fluid distribution system was released in January. Transmittal of drawings to Rocketdyne resulted in a bid package for on-stand fabrication and installation by a trade contractor. All components that were the responsibility of S&ID have been procured and delivered.

Battleship Test Stand Fluid Distribution System (SDD-110)

All S&ID hardware items have been procured and delivered. Installation will be done by a trade contractor.

EMM Fluid Distribution System (SDD-119)

The design of the EMM fluid distribution system was initially released in August 1963. Installation is nearly complete.

Fluid Distribution System, Station 4, Seal Beach (SSD-164); Fluid Distribution System, Station 7, Seal Beach (SDD-165)

The design of these systems was completed and released in June, and bids have been let to trade contractors.

Pneumatic Servicing Unit (SDD-181 - Formerly C7-605)

All drawings of the electrical section (Figure II-93) released for End Item 1. All detail and subassembly drawings of the mechanical section were completed.

Nitrogen Purge and Thermal Control Unit (SDD-168)

This unit was delivered to the Battleship site on 19 June.

Hydraulic System Jumper Unit (SDD-224 - Formerly S7-10)

The first production S7-10 was accepted by NASA Inspection 20 March.

BATTLESHIP STAGE

The heavy-duty thrust structure for the Battleship stage was delivered on 1 November 1963; it was installed in mid-December.

A chill test was conducted in December 1963 to check performance of the LOX-tank using liquid nitrogen as a seal medium within the LOX tank.

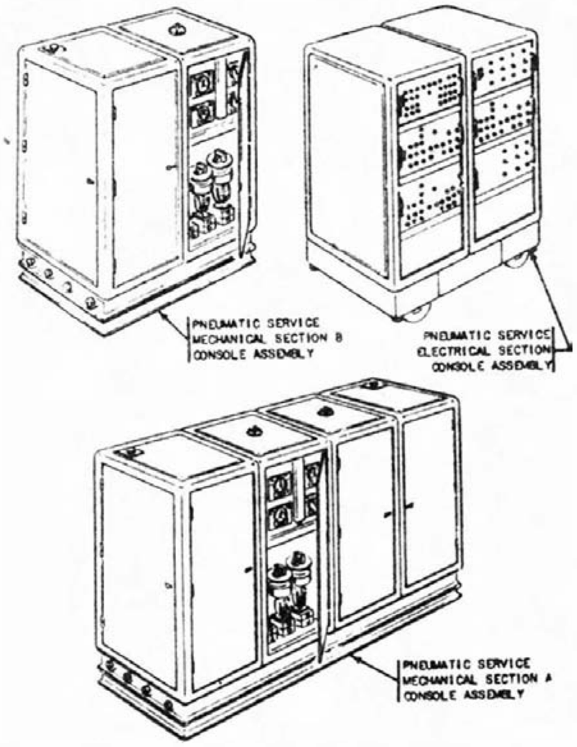


Figure II-93. Pneumatic Servicing Console Set (SDD-181)

The joints performed satisfactorily, and additional testing will be conducted late in the program to determine continuity of performance. It is planned to install permanent instrumentation on the LOX tank to assess performance of the tank throughout the program.

The heavy-duty sump was delivered on schedule in May and has been installed on the LOX tank. A pressure-proof test demonstrated the effectiveness of the main seal between the sump and the tank.

AUTOMATIC CHECKOUT EQUIPMENT (ACE)

Computer Program Development Facility Operating System

The computer program development facility (CPDF), employing the CDC 924A computer, peripheral equipment, and associated software, provides all the capabilities needed by systems programming engineers during initial checkout and verification of the automatic checkout program set (C7-2).

Following installation of the CDC 924A in September 1963, utility and service routines were programmed, and associated procedural information was written to provide input and output capabilities for subsequent programs. Other library routines necessary for C7-2-program-set debugging and generation were programmed and became operational in late 1963.

Because of the importance of these programs to C7-2 program development, an immediate goal of a fully operational library system received high priority. This goal was reached in March, and the system is being used in the development of the C7-2 program set.

The computer assembly program (CAP) used exclusively during the programming function to convert symbolic programming language to machine language was fully operational in November 1963. A second-generation CAP, which permits faster assembly and includes additional capabilities, is now being verified.

Design of command set generation computer programs has been completed. In addition, the development of these programs is about 90-percent coded and debugged, with completion scheduled for the first part of October 1964. Some design improvements have required additional editing functions which are being incorporated.

The command set generation computer programs are those programs required to process the coded test procedures for the S-II stage systems and to produce that part of the C7-2 program set which controls the automatic checkout sequences. Coding of these test procedures for the EMM is complete for the propellant dispersion, flight control, measurement, pressurization, electrical power, and propellant management systems. Coding of the separation and engine systems is about 80-percent complete, and coding of the integrated systems is about 35-percent complete.

With completion of the command set generation programs, these coded test procedures will be processed, and the generated command set tapes will be run with the simulator program to detect and correct program and test procedural errors before the tapes are run at the EMM. It is anticipated that this work will be completed on schedule.

The designs of the display/interrogate and executive/scheduler programs have also been completed, and the coding is being finalized. These two programs constitute the on-line operational programs controlling the stage checkout programs selected by the test conductor for execution. Development of the simulator program is on schedule. and the coding is about 95-percent complete. This program is used in debugging the on-line and stage checkout programs as an integrated system before actual contact with the checkout hardware. The simulator program verifies timing of the total checkout operation, validates certain portions of logical flow of the checkout, and provides NO-GO simulation to check display capabilities.

The primary function of the computer complex portion of the ACE is to permit automatic control of S-II stage checkout. The three subsections comprising the computer complex are briefly described below and consist of the following end items:

1. Computer group (Selected items are shown in Figures II-94 through II-99).
    a. Automatic checkout computer (C7-101) (Including the computer console and mainframe)
    b. Program input set (C7-103)
    c. Data printout rack (C7-104)
    d. Auxiliary memory rack (C7-105) (Comprised of four-digital magnetic tape recorders and one magnetic tape recorder control)
    e. Computer isolation and drive rack (C7-109)
2. Test conductor console
    a. Test conductor console (C7-102) See Figure II-100

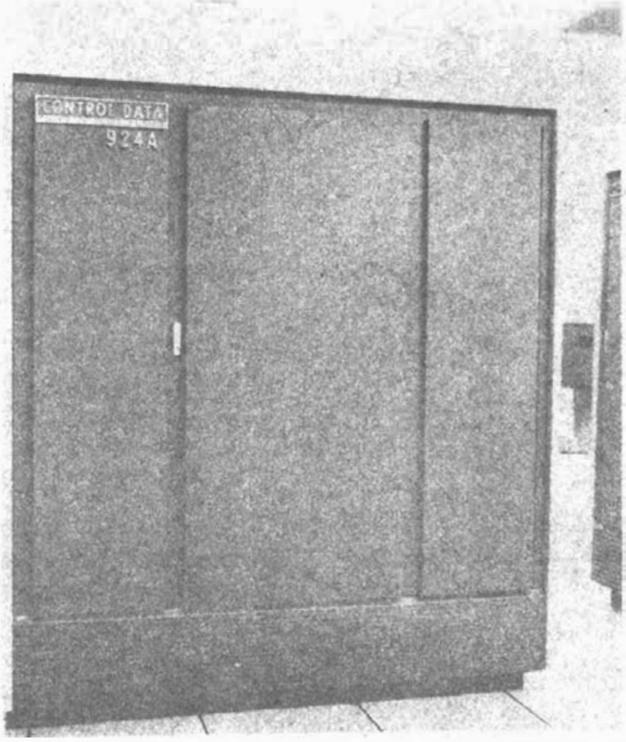


Figure II-94. Automatic Checkout Computer—C7-101 Mainframe

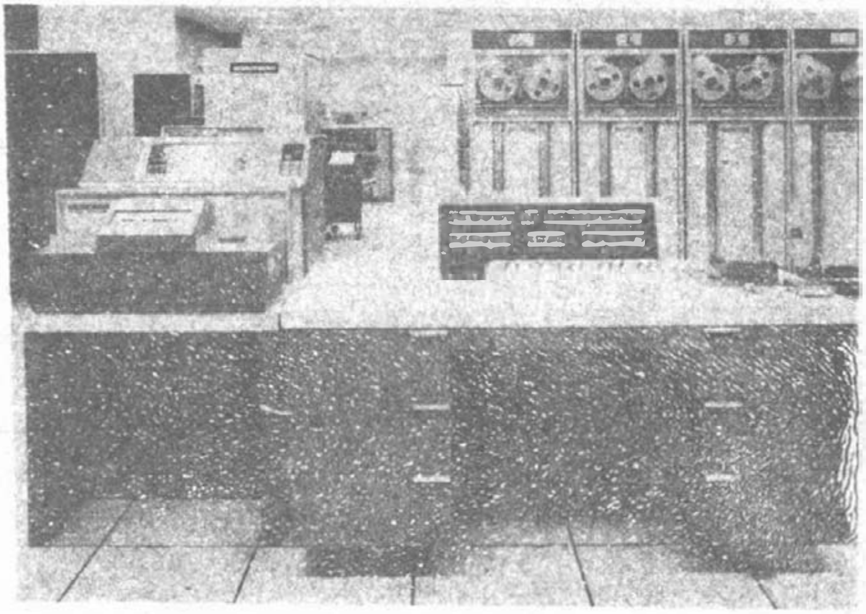


Figure II-95. Data Equipment—C7-103 Program Input Set (Left) and C7-101 Computer Console

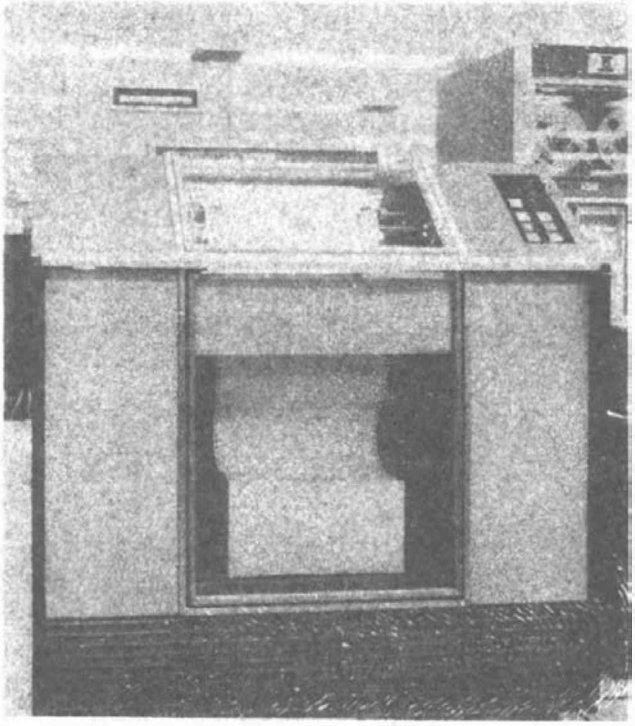


Figure II-96. C7-104 Data Printout Rack

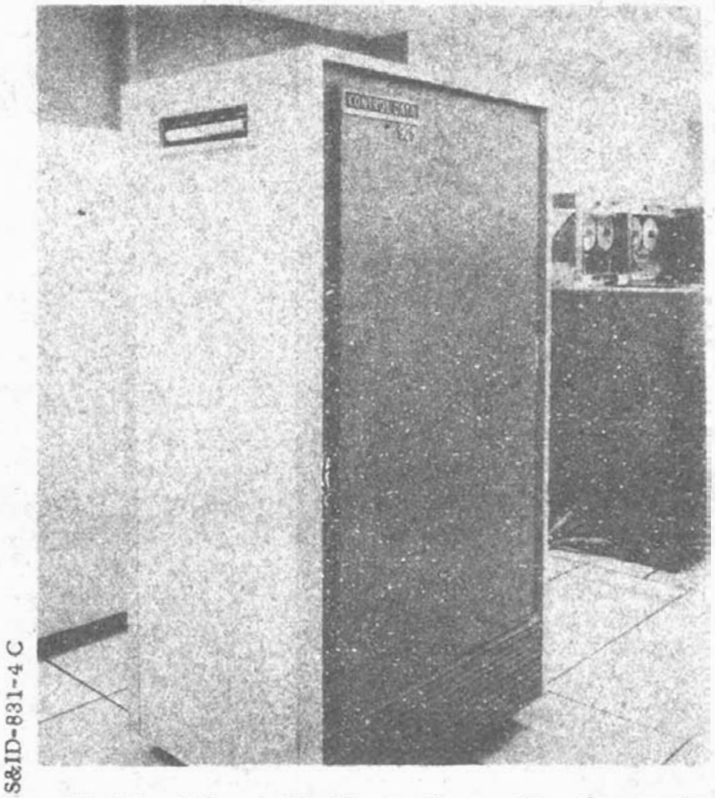


Figure II-97. Magnetic Tape Recorder Control for Auxiliary Memory Rack (C7-105)

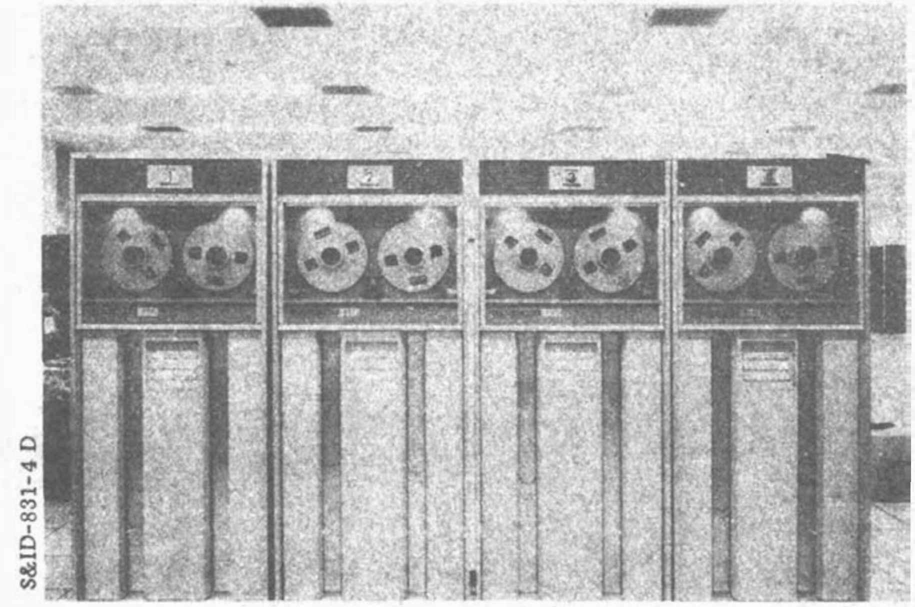


Figure II-98. Digital Magnetic Tape Recorder for C7-105

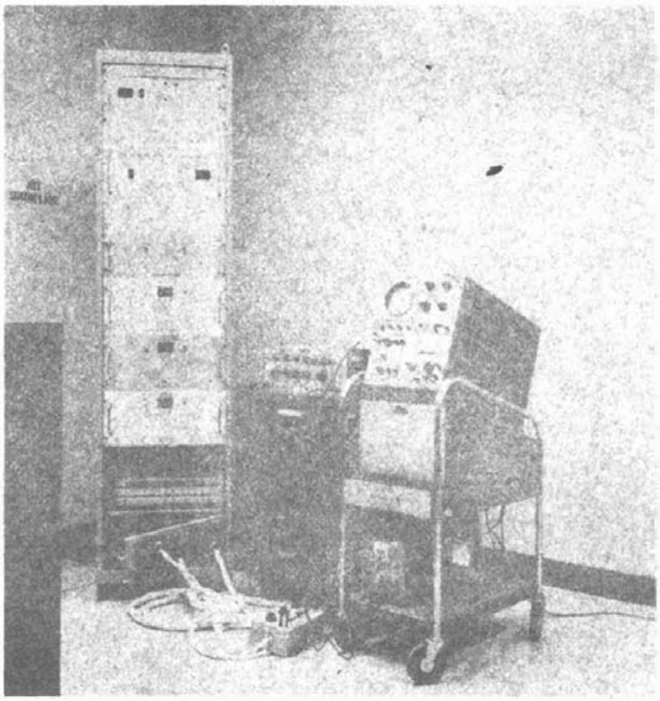


Figure II-99. Computer Isolation and Drive Rack (C7-109)

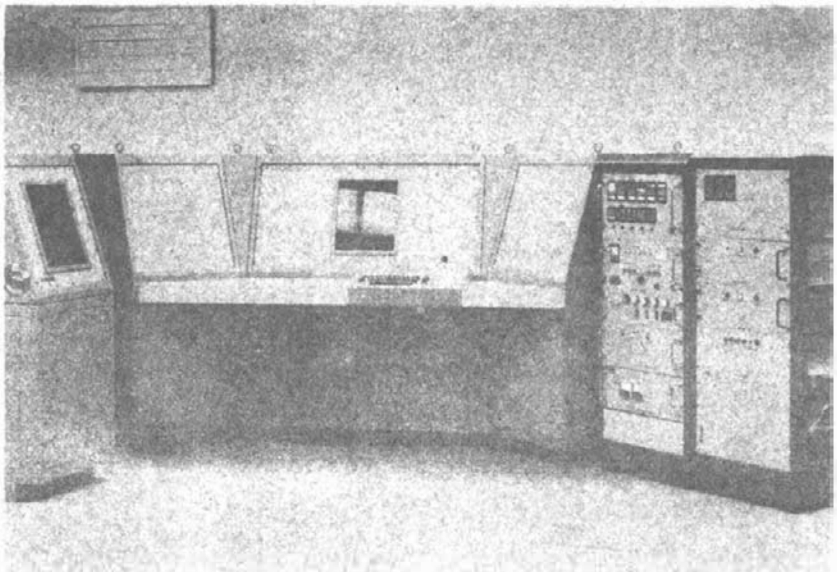


Figure II-100. Test Conductor Console (C7-102)

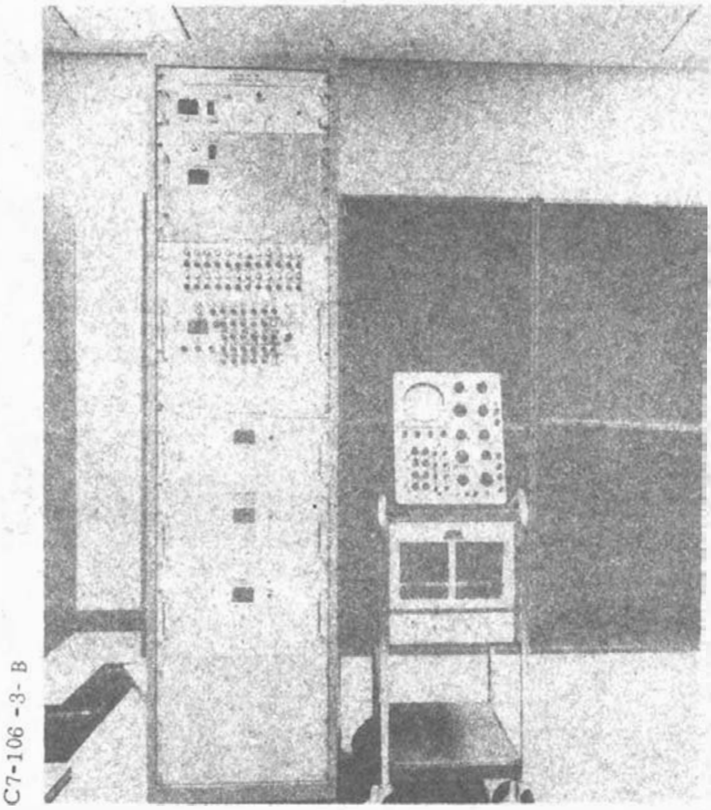


Figure II-101. Buffer Equipment Rack (C7-106)

3. Buffer equipment

   a. Buffer equipment rack (C7-106) See Figure II-101

   b. Local digital drive link rack (C7-107)

   c. Remote digital drive link rack (C7-108)

The computer group consists of items purchased from the Control Data Corporation of Minneapolis and one piece of equipment (C7-109) designed and fabricated by NAA. The mainframe is controlled by either the computer console or the test conductor console and is used to communicate test instructions to the ACE and to evaluate test results received from the S-II stage or ACE. The peripheral equipment (C7-103, C7-104 and C7-105) is used for both on-line and off-line communication. On-line communication refers to direct input/output to the computer. Off-line refers to input-output communications not involving the computer. An example of off-line communication is the input/output operation carried on between the program input set (C7-103) and the data printout rack (C7-104 line printer) — that is, punchcard information reproduced by the line printer as alpha-numeric hard copy. An example of on-line communication is the input/output operation carried on between the auxiliary memory rack (C7-105) and the computer memory — that is, information stored on magnetic tape feeds into the computer core-type working memory.

The C7-109 equipment serves the following three purposes:

1. It redrives (amplifies) computer outputs so that buffer equipment and ACE may be located at reasonable distances from the computer (more than 50 feet).

2. It isolates GSE single-point ground from the computer-signal ground through gating and isolation transformers.

3. It provides the computer complex with the capability of switching a portion of the computer control from the computer console (C7-101) to the test conductor console (C7-102).

The buffer equipment (C7-106, C7-107 and C7-108) interfaces with the ACE and the computer group. This equipment interprets and redirects computer controls, selects particular ACE for communication, and redrives computer signals in cases where the ACE is located far from the computer.

The test conductor console (C7-102) provides a degree of test conductor control of computer automatic and manual operation; e.g., the test conductor may start the computer or interrupt the computer input/output operations by causing the computer to jump to preprogrammed test routines.

In addition, the test conductor (1) exercises limited control and surveillance of test station status and mode (manual or automatic); (2) maintains maximum surveillance of test progress by calling for test-in-progress status display on his alpha-numeric cathode ray tube; (3) can request any information displayed to be printed out on a typewriter included in the console; and (4) may, through his typewriter keyboard, make changes in any item of information displayed on his cathode ray tube.

During the first half of this report period, initial design documentation was 100-percent released. In addition, the computer complex equipment successfully underwent Phase I design review, yielding a high confidence in the design approach to this equipment.

On 10 August 1963, the first delivery of units for the computer complex were installed at the CPDF where program analysis and development is continuing. The second delivery of units was installed in the EMM on 25 November 1963. This installation marked the initial activation of the EMM and, in conjunction with breadboard equipment, the units are being used for acceptance-testing of alpha-numeric units (major subunit of the test conductor console) and for the functional verification of equipment design, including solution of engineering problems.

The activation of the EMM breadboard equipment (BBE), shown in Figure II-102, was effected by interfacing of the C7-106 and C7-109 units with the CDC 924A computer on 15 January. This was the first time the computer had been interfaced with S&ID-designed equipment, and major milestone initiated an extensive test program which will continue until the expected delivery of manufactured end items on 1 August.

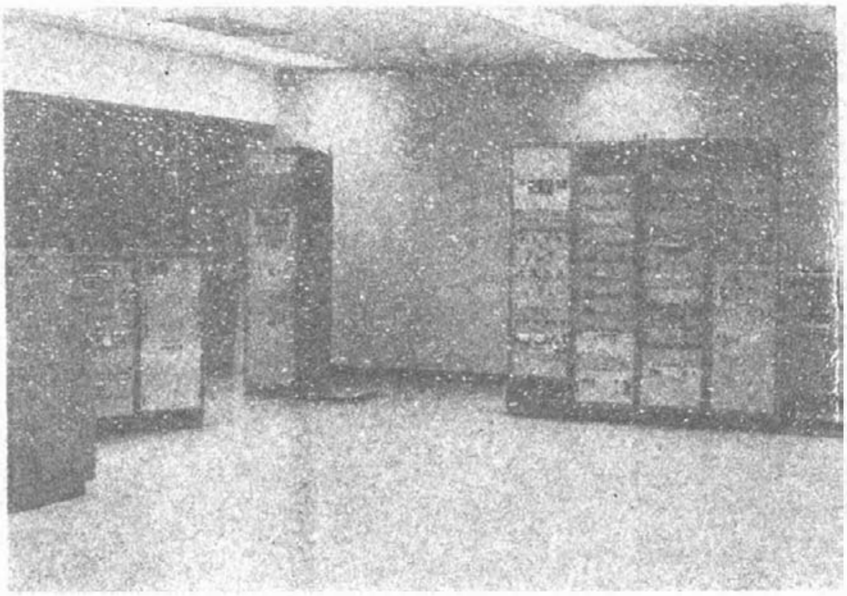


Figure II-102. Breadboard Equipment **Installed** in EMM Room

The objectives of this test program include:

1. Evaluation of equipment operation and assurance of system interface compatibility
2. Provision of documentation review at an early point
3. Establishment of correct equipment installation techniques
4. Development of operational and test procedures for efficient malfunction isolation
5. Analysis of malfunction effects on system operation and establishment of preventive design.

Returns on all these objectives have been realized during this report period, yielding considerable projected savings in time and money.

Time Code Rack (C7-48)

All the design documentation of the time code rack has been released on schedule. Phase I and Phase II documentation has been submitted to NASA, and the Phase I documentation has been approved. The time code rack is now being manufactured.

CDR Checkout Rack (C7-207)

The design documentation for this equipment has been released and Phase I and Phase II documentation has been submitted to NASA. Phase I documentation has been approved. The CDR checkout rack is now being manufactured.

Electrical Checkout Stations (C7-200 Series)

The electrical checkout station is capable of automatic and manual evaluation and control of stage and GSE functions. The major design of the station is complete, and all drawings for the EMM have been released. The following individual end items comprise the C7-200:

Automatic control unit (C7-201)
Manual control and display (C7-202)
Signal distribution rack (C7-204)
Special data rack (C7-205)
Station control and display rack (C7-208)
Local control and display rack (C7-209)
Stage substitutes rack (C7-210)
Scanner rack (C7-211)
Discrete display rack (C7-212)
Interlock relay rack (C7-213)

Static Firing (C7-800 Series)

The C7-800 equipment is used to provide the necessary monitoring and control for preparation of the stage static firing and for performing manual static firing. The unit is comprised of the following end items:

Static-firing A local rack (C7-801)
Static-firing A remote rack (C7-802)
Static-firing B local rack (C7-803 - being changed to SDD-333)

Engine-cutoff rack (C7-805)
Static-firing monitoring rack (C7-807)
Fire-detection rack (C7-806)

Status

Phase I control drawings on the C7-801 and C7-802 were partially submitted in April 1964. All drawings for the C7-803 were released by 23 August 1963, EOPRs by 16 August 1963, and process specifications by 28 October 1963. Documentation on the C7-805 is 95-percent released. No work has been done on the C7-806 and C7-807 during this reporting period.

Digital Data Acquisition System Station (DDAS Station)

The DDAS station, together with the electrical station and the computer complex, provides the major part of the automatic checkout capability for the S-II stage. The station receives DDAS data on a 600-kc carrier from the stage through a coaxial line and processes the data into usable form. The DDAS transfers this data on request to the computer complex for automatic checkout of the S-II stage or to other checkout stations for display purposes.

The DDAS includes the following racks:

Automatic control and display (C7-401)
Local control and display (C7-402)
PCM (C7-403)
Computer adapter (C7-406)

A major design review of the DDAS was conducted, and only minor design changes were needed. The design documentation is 100-percent released, and the equipment is now being manufactured.

Telemeter Checkout Station

The telemeter checkout station is a manual checkout station with limited automatic checkout capabilities. Its purpose is to check out the S-II stage PAM/FM/FM, SS/FM, and PCM/FM telemetry systems.

The telemetry checkout station consists of the following racks:

Automatic control and display (C7-510)
PCM format (C7-511) See Figure II-103.
Oscillograph (C7-512)

Decommutation (C7-513)
Discriminator (C7-514)
Receiver (C7-515)
Two tape recorders (C7-516) See Figure II-104.
Single sideband (C7-518)
PCM (C7-519).

The production design documentation for the telemetry checkout station is 95-percent complete.

Ground Equipment Test Set (C7-44)

The ground equipment test set simulates the S-II stage hardwire responses to verify the stage-GSE electrical interface and the functional readiness of the ACE; it also partially verifies program tapes. The C7-44 was redesigned to comply with NASA technical direction, and the redesign documentation is complete and the test set is now being manufactured. Phase I and II documentation was submitted to MSFC; approval have not been received.

Static Firing Signal Conditioning Rack (SDD-316)

The requirement for the SDD-316 rack was created during this reporting period to provide signal conditioning for the redundant instrumentation of the All-Systems stage at the Santa Susana Field Laboratory. The design of this rack is approximately only 20-percent released; consequently manufacturing has not begun. All specification control drawings for purchased equipment have been released.

Signal conditioning requirements for new off-stage instrumentation required the addition to this rack of one bay, which is being designed.

Remote Control Calibration Rack (SDD-325)

This rack was designed to provide remote calibration control of the static-firing signal conditioning racks (SDD-316 and SDD-328). All design documentation for these racks has been released, but the rack is not yet being manufactured.

Static Firing Signal Conditioning Rack (SDD-328)

The requirement for the SDD-328 was created during this reporting period to provide signal conditioning equipment for the redundant instrumentation in the Battleship stage at the Santa Susana Field Laboratory. All the design documentation for this rack has been released, and the rack is being manufactured.

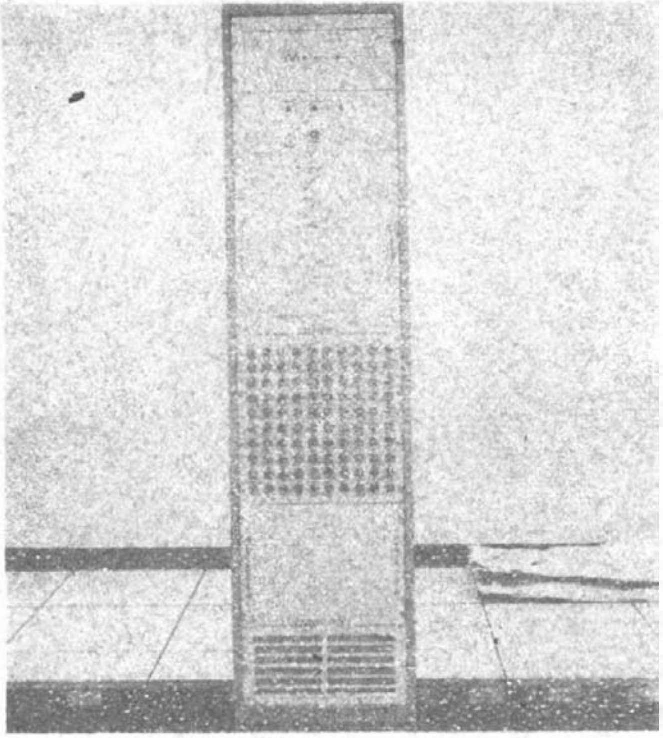


Figure II-103. PCM Format Rack (C7-511)

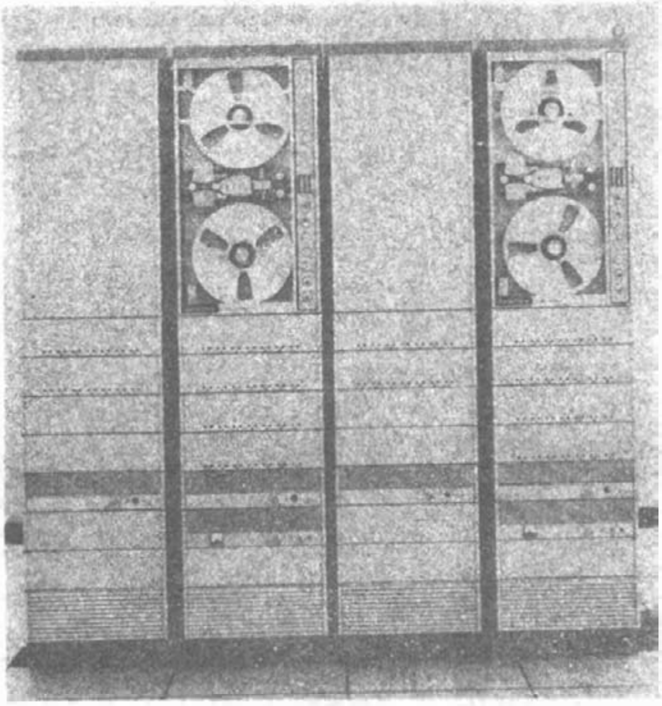


Figure II-104. Two Tape Recorder Racks (C7-516)

Signal conditioning requirements for new off-stage instrumentation required the addition of one bay to this rack. The design documentation for this change is complete and the bay is being manufactured.

Camera Time Code Distribution Units (SDD-322 and SDD-324)

The camera time code distribution units provide the signals to produce the timing marks for the cameras at the Santa Susana Field Laboratory. The time code generator rack (C7-48) provides the serial time code format AMR-D5 to the SDD-324 rack and also through the SDD-324 to four time code distribution units (SDD-322) containing neon distribution amplifiers. These amplifiers produce the signal levels required for the camera timing marks.

The design documentation has been released, and these units are being manufactured.

Breadboard Equipment (BBE)

The BBE is composed of drawers of equipment carefully selected to be representative of the ACE.

BBE of the checkout station consists of the following three bays of equipment: (1) an RF rack which simulates the CDR checkout rack (C7-307), (2) a telemetry rack which includes selected functions of the telemetry checkout station, and (3) an automatic rack which contains common logic drawers common to all checkout stations.

Numerous tests have been performed among drawers to establish internal functional compatibility. The BBE has also been integrated with the computer complex at the EMM to estimate the functional compatibility between the checkout stations and the computer complex. Functional operation between these systems has thus far been compatible, and many useful design benefits have been derived from the tests.

RELIABILITY

In the last year the S-II reliability program plan was further implemented, and significant achievements in design development were documented. Failure mode effect analyses and the determination of criticality categories continued to provide program control and implementation by defining design areas requiring modification, providing preferred considerations for modifications, and establishing minimum requirements for procurement documentation, product traceability requirements, designs requiring review, products requiring qualification and reliability tests, and product control levels relative to the confidence development plan.

The design reviews have identified specific problems, permitting assignment of action items to S&ID agencies responsible for their resolution. Supplier controls and coordination have proved to be technically and economically beneficial. Traceability requirements were further defined to assure achievement of technical program requirements and to provide a sound basis for economical considerations in negotiations with supplier and internally in S&ID. The confidence development plan has been implemented in relation to design development progress. The significance of the mechanical-excellence program has been realized in all areas and was further emphasized through recognition and adaption of the primary elements by MSFC in their "Manned-Flight Awareness Program."

RELIABILITY PROGRAM PLAN

The Saturn S-II Reliability Plan was revised to reflect close coordination with the reliability program and to reflect specific details of the program which had been activated. In addition, specific changes were made to conform to NASA requests and requirements.

Among the latter were the deletion of reliability degradation and adjustments within the plan and the deletion of contractor responsibility for GFE, GFP, and equipment designed or supplied by the Government. As a result of these specific deletions, two additional documents were required - Requirements and Implementation for Government Supplied or Directed Equipment (SID 63-1543) and Reliability Goal Status Report (SID 63-1544). Preparation of these documents has just started; they will be completed this year.

PROGRAM MANAGEMENT

S&ID policies and procedures, S-II implementing instructions, and test and quality assurance procedures were initiated and revised to provide the necessary requirements and controls for reliability in product design, procurement, manufacturing, testing, and use

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT)

The original PERT network was completely integrated into all pertinent Saturn S-II engineering, manufacturing, and test PERT networks. This provides closer control and monitoring for all phases of the reliability program. The initial reliability network, used as a basis for integration of reliability events into all networks, is being maintained for major milestones.

PROCESS SPECIFICATIONS

Two process specifications for traceability requirements were completely revised to include improved instructions and detailed inspection and recording requirements. The supplier-control specifications were revised to improve instructions, to keep pace with technical changes, and to provide better cost control.

MECHANICAL EXCELLENCE

All phases of the mechanical-excellence program have been fully implemented. More than 1200 S-II personnel have been trained in general mechanical-excellence skills. A total of 5158 S-II personnel were shown closed-circuit television programs as part of the training. The Tulsa division has instituted a similar program. A joint working group on mechanical excellence and safety was formed and has been effective.

Program personnel supported the Huntsville NASA office in establishing a similar program plan for NASA. Instruction materials and plans were supplied to the Huntsville office, together with S&ID comments on the NASA plan.

RELIABILITY EDUCATION

Nine closed-circuit television programs were completed and transmitted to Saturn S-II personnel. Three additional programs were written and approved for production. Virtually all Saturn S-II suppliers requested and were provided with copies of closed-circuit television kinescopes for use at their facilities. Five publications dealing with the statistical aspects of engineering and design analysis were published and transmitted to Saturn S-II and support engineering functions. Sixteen technical briefings on the S-II reliability program were presented to supplier organizations, and three supplier reliability synopses were conducted. One hundred and five classroom presentations on engineering statistical and design analysis were made, and one seminar on computer programs was held.

SUPPLIER AND LABORATORY SURVEYS

A total of 116 potential suppliers were surveyed during this period, some of them a second time for higher criticality categories of equipment. Currently, 190 potential suppliers are considered acceptable for procurement. Of these, 56 have received contract awards for critical equipment. Of those suppliers approved for procurement, 94 maintained adequate test laboratories and were approved for qualification and reliability testing. An additional 34 independent test laboratories were also approved for qualification and reliability testing.

SUPPLIER COORDINATION

Following contract awards to suppliers, S-II Reliability assured implementation of reliability programs through establishment of channels of communication, coordination, technical assistance and consultation, review, evaluation and approval of technical data submittals, design review and approval, and monitoring of qualification test programs.

Significant accomplishments resulted from this activity through design improvement, application of preferred processes, application of stringent quality controls assisted by technical measurement requirements employed to fulfill traceability requirements, improved qualification test set-ups, and supplier personnel motivation by presentation of S&ID educational and motivational materials.

FAILURE MODE ANALYSIS

The failure mode analyses of the S-II airborne and GSE systems have been expanded and revised to reflect design progress and configuration revisions. A total of 48 airborne failure mode analyses were revised for 17 systems and 79 GSE failure mode analyses were revised. An additional 126 failure mode analyses were completed for new GSE end items. Twenty-four GSE items of Criticality Category I were reduced to Category II or lower; 16 system major design improvements were recommended, and 1638 critical parts were reduced to noncritical status through recommended design changes.

A failure mode analysis computer program was developed and implemented to provide quantitative relationships between failure modes in terms of quantitative differentials, providing a tool for numerically evaluating failure mode effects. The program was extended to all S-II flight systems and specific GSE end items. The computer printout was redesigned to be readable without the use of coded information; it now includes descriptions and other information corresponding to the mathematically evaluated indices. The program was automated to the extent that all calculations, including preliminary numerical inputs, were computerized. This was accomplished through the additional development of a technique for calculating performance indices and another for calculating the performance index for each phase. The program has been written to accept additional components without a complete rerun, thus reducing feedback time.

SPECIAL ANALYSES

S-II Reliability analyzed certain processes and systems for improvement of reliability, reduction of personnel hazards, reduction of costs, and long-range benefits. Four of these analyses of particular significance are these related to bulkhead welding, hydrogen burnoff, fire detection systems, and switch-selector/electrical-sequence redundancy.

Bulkhead Welding

The bulkhead welding analysis was undertaken to improve welding durability, safety, strength and quality. The analysis included conventional heliweld, vacuum heliweld, and electron beam methods and techniques. Results of the analysis indicate some advance controls and detection methods which may produce welds of extremely high reliability.

Hydrogen Burnoff

The purpose of this analysis is to improve disposition of the free hydrogen expelled from the J-2 engines during a normal static firing. Pyrotechnic and combustible gas systems are being thoroughly evaluated from standpoints of functional operation, economic, and logistic parameters. Indications are that reliability could be improved, damage minimized, personnel hazards reduced, and a minimum criticality category assigned by the elimination of critical failure modes through redundancy and control processes.

Fire Detection System

This analysis proposes a maximum visibility for both internal and external fire detection. A multiple system has been devised for Battleship. The present internal design includes heat-sensing cables, the output from which actuates audio-visual alarms. An external flame detection system is proposed in which a dual closed-circuit television system is used on each quadrant of the stage. Standard visual equipment is used for the main picture, on which is superimposed an infrared-to-visual analog of any hydrogen flames.

Consideration may also be given to the use of newly developed techniques for the utilization of the far-ultraviolet content of flames. This technique can provide a flame-detection system that is not sensitive to hot bodies or high ambient temperatures.

Switch Selector/Electrical Sequence Redundancy

This analysis presented methods of increasing the inherent reliability of the S-II stage by the use of redundancy and sequence change. This is a built-in quality which permits tolerance of different types of failure conditions.

The analysis criteria included (1) elimination of first-order mission failure modes, (2) reduction of the probability of causing first-order mission failures, (3) utilization of sequence changes to reduce hazard time, (4) implementation of the requirement for complete checkout capability of each component in the redundant circuit, and (5) use of existing S-II electrical sequence configuration.

The proposed sequence changes are being incorporated as agreed between MSFC and S&ID on 29 April.

TRACEABILITY

In June 1963, the responsibility for determination of S-II traceability requirements was assigned to the S-II Reliability department. This effort was related to the failure mode effect (FMEA) and cause (FMCA) analyses. Failure mode effects which are critical, hazardous, or potentially damaging to assemblies, subassemblies, and components are reflected in the FMEA as Criticality Category I or II. Equipment in these categories must be traceable; the traceable parameters must be determined as a function of the causes of the critical failure modes. These ground rules have been applied to both S&ID-designed and supplied equipment.

Changes in supplier traceability requirements brought about significant cost reductions. Previously, all potential causes of failure were considered traceable. The supplier is now required to make a total list of characteristics from his FMCA. From this list, only causes which have significant variables (e. g., material cure dates and basic critical material histories) require recorded traceable parameters. The remaining characteristics are utilized by S-II Quality Control as one criterion for establishment of inspection requirements.

DESIGN REVIEW

Design review has accomplished all programmed evaluations for the period. Design review-board evaluations extended significantly into the supplier designs.

More than 240 reviews have been made, of which 50 were for items designed by suppliers.

Detailed evaluations of manufacturing, facility, and complete test programs have also been reviewed. Approximately 1500 action items were assigned for disposition.

S-II RELIABILITY ASSURANCE REPORTS

These reports are a reliability evaluation of each specific S-II stage or facility. As a continuous record of each stage, the reports provide single-source data relating the reliability of each stage to the particular configuration. The format of the report includes, among other items, the following:

(1) recommendations of measures to assure future reliability

(2) a discussion of the general configuration of the stage, systems, checkout equipment, etc., with related primary failure-mode criteria

(3) a failure mode analysis relative to safety considerations in checkout and future handling of the stage

(4) test assurance data relative to safety or additional checkout for reliability maintenance with no loss of confidence

(5) design review data on tests and operation of the stage, and

(6) a summary of applicable malfunction reports.

MATHEMATICAL MODEL SUPPORT

In support of Mathematical Model implementation, significant progress has been made through further development of additional computer programs, four of which were developed in support of the apportionment and prediction models. For assessment models, prime programs were developed for the analysis of variance, truncated normal tables with several entry methods, acceptance-test data evaluation, control level, configuration assessment verification, and the Kolmogorov-Smirnov "goodness-of-fit" program.

NONCONFORMANCE REPORTING AND FAILURE ANALYSIS

The initial production of S-II hardware was paralleled by the implementation of failure reporting and analysis. Personnel were assigned to nonconformance assessment areas at all S-II manufacturing and test sites. All failures occurring during fabrication, acceptance, and qualification testing are analyzed to establish causes of failure and to determine appropriate preventive action. Failures in qualification testing receive first priority and are processed by special handling methods to ensure preventive action as soon as possible.

CONFIDENCE DEVELOPMENT PLAN

Implementation of this plan has advanced by the placement of purchase orders and initiation of development of more than 80 of the approximately 140 procurred components. Nine qualification test programs were also initiated, two of which were successfully completed. Initiation of more than 40 qualification tests is projected for the next quarter. As a part of supplier selection and negotiation, attention was given to the cost of qualification testing to hold these to a minimum without sacrificing test validity. As a result, the suppliers' technical understanding of the test program was verified and costs were minimized before placement of the contract.

Performance and environmental tests of the approximately 46 GSE, ACE, and SDD end items which require qualification testing have been established. Test plans were initiated for all items, and several are complete. On-site qualification of unique end items was investigated and found to be feasible in several cases, thus ensuring the best possible schedules. In the systems test program, three of the ten preliminary test plans were expanded into detailed test plans and will be implemented in the near future. These include the approved supplemental programs which were generated as a result of cancellation of the operations simulator and substitution of the EMM. Hardware has been ordered for these tests, and test setups are under construction.

The systems and stage reliability assessment program is well under way with the publication of an assessment measurement list, itemizing those measurements necessary to properly assess system and stage performance during the stage level test programs, which will be conducted at various full-scale stage facilities, such as Battleship and All-Systems. Additional definition of the various facility data requirements to support confidence growth at the system and stage level is being formulated.

QUALIFICATION STATUS LIST

The Qualification Status List (SID 62-1224) was initiated on 1 October 1962 in partial satisfaction of the S&ID obligation to keep NASA informed of test progress under the confidence development plan. This report provides specific details concerning confidence attainment, test schedules, specific tests required and performed, testing agencies, and suppliers. During the current period, the qualification status list was upgraded by addition of a summary of major environmental parameters for each test required and by the institution of monthly revisions to supplement the annual printings. To maintain maximum management control, a daily schedule is maintained on all tests under the cognizance of S-II Reliability and the month-to-month status of those schedules is reported in the qualification status list. This year the qualification status list has more than doubled in size, reflecting continued development of firm component requirements for performance and test verification.

III. TEST AND OPERATIONS

SUMMARY

During this report period a large percentage of T&O effort was concentrated on activities that were preparatory to test site activation. However the transition from the planning to the operational phase has started for the earlier test program phases. The following significant activities reflect this transition:

1. EMM construction is essentially complete and ACE checkout and testing has started.
2. Soft mockups in the EMM are being replaced by flight-weight systems.
3. Construction on the Battleship progressed to the point that joint occupancy of the facility was effected with Rocketdyne, and site activation was initiated.
4. The primary data station was delivered to Downey and installed in Building 2. Checkout and acceptance testing is now in progress.
5. The test communications center was constructed and made operational.

Documentation necessary to define and support the test activities is being prepared. Documents include:

Test program plans
Development test plans
Detailed operating procedures
Facility support requirements
Measurement lists
Safety manuals
Site activation plans

Other documentation of specialized nature for individual sites has been prepared.

The J-1 master test schedule was formulated and published to assure the attainment of program objectives, even though a reduction of early test capabilities resulted from Amendment 5 and CCN 13. The test site program plans were revised in accordance with the schedule revision.

EMM

Most mockup systems were installed in the stage structure and their replacement with flight-weight hardware was started. Most facility construction for ACE was completed; system test plans were generated; and the GSE testing program was started.

Construction on the EMM facility was divided between the stage simulator area and the GSE checkout area.

The stage simulator area had been completed to existing requirements during the previous report period, except for the GN_2 and the GHe supply capabilities. Revised gas pressure requirements necessitated a redesign, now being accomplished. Facility changes in the stage simulator area were required because of additional cabling for the C7-44 ground equipment test set, modifications to the C7-41 remote power distribution rack, and a definition of the EMM umbilical disconnects. Except for gas requirements, the additional construction is scheduled for completion early in fiscal year 1965.

Facility construction of the GSE checkout area is essentially complete. Prior to construction, a radio frequency interference (RFI) test was conducted, from which it was determined that the ambient level of interference exceeded the specification limits of MIL-I-6181D. The tests confirmed the need to provide shielding for the 924-A automatic checkout computer. Construction of the facility room, including the 924-A computer room, was completed. Additional ACE requirements, added after construction was let for bid, necessitated expansion of the room. This expansion is complete except for minor details.

Planning for the EMM program, reanalyzed in the light of the current Saturn S-II program status, was subdivided into five phases instead of the original six. The basic scope of the program was not changed substantially. Specific phases are as follows:

Phase I	Development mockup operations
Phase II	EMM/ACE hardware compatibility test program
Phase III	EMM automatic checkout concept test program
Phase IV	EMM stage system compatibility test program
Phase V	S-II stage systems and test facility support

Test plans have been published for Phase II and are being written for Phases III through V.

Phase I mockup activities are progressing. Flight-weight cabling and bracketry are being installed, and a preprototype engine actuation system and five Block III J-2 engines were installed. The Block III engines are mechanically operable, but unsuitable for firing. The engines are being shipped by rotation to Rocketdyne for reworking to flight-weight configuration. The first reworked engine is scheduled for return to the EMM in October 1964. The entire rework program is scheduled for completion in April 1965.

Design engineering inspections of the stage simulator were completed by S&ID and NASA on 6 and 12 March. Discrepancies noted during the inspections were reviewed and rectified, and redesign was initiated where needed.

Phase II testing has begun. The major equipment in this program is the 924-A computer, which was received in the EMM in November 1963. The acceptance test was conducted by contractor personnel and the unit was accepted by S&ID design engineering in December 1963. The computer is connected to the C7-100 series breadboard equipment (BBE) and interstation BBE testing is being implemented.

Other ACE received and in various stages of testing is listed below:

SDD 151	Intercommunication headset
SDD 154	Electrical terminal distribution
SDD 193	Hydraulic power console (C7-601)
SDD 214	Engine actuator simulator
SDD 310	Recording oscillograph system
SDD 313	Real time readout
C7-59	Engine checkout electrical power cable set
C7-511	Digitizing system rack
C7-516 (2)	Tape recorder racks

Installation and integration testing of the total ACE should be completed in 1964. To meet this schedule, the design freeze points for the EMM stage systems and GSE were established at Engineering Design Change S00497, Redesign of the Engine Actuation System Hydraulic Lines. All changes up to this point, with the possible exception of six that are being reviewed, will be incorporated.

The Rocketdyne J-2 engine checkout GSE has been tested. Individual units tested are listed below:

G1035	Flight instrumentation checkout console
G3106	Pneumatic checkout console
G3121	Data recorder console

The J-2 engine checkout area is being redesigned, and an EMM support effort area is being planned for the tool crib and bench maintenance.

BATTLESHIP

The Battleship program progressed through several construction phases during the report period. The major milestone accomplished was the completion of the primary construction phase of the Santa Susana test area. The construction was completed 15 June 1964 and joint occupancy was effected with Rocketdyne Test Division personnel. S&ID activation has been initiated on 18 May, but the effort was limited since contractors were still working in the area. The activation effort has progressed smoothly; however, it does not support the J-1 schedule which was based on a joint occupancy date (JOD) of 1 May 1964. The slip in JOD affected the initial activation effort. However, an accelerated schedule, with appropriate implementing plans, has been generated by Battleship T&O to accomplish the major J-1 schedule milestone of a static firing test on 1 November 1964.

The following major Battleship T&O activities were completed in support of site activation:

Installation of the LOX tank service platforms (Model 904)
Installation of the control center cables (SDD-105)
Partial installation of the stand cables (SDD-103)
Preparation of the umbilical disconnect areas (SDD-155)
Partial checkout of the engine ground support equipment (GFP)

Facility construction was closely monitored by T&O to assure attainment of the required operational capability. Major deficiencies discovered were corrected during the initial construction period, and all minor discrepancies were documented so that corrective action could be determined and assigned.

Battleship T&O personnel also were actively engaged during first quarter 1964 in the LOX tank seal tests conducted on the Battleship stage. These tests have provided information valuable for Battleship tanking operations.

Battleship T&O manpower allotment, less than 25 percent fulfilled a year ago, is up to 98 percent at the present time. A total of 69 technicians are working on a two-shift basis. A large percentage of the personnel on the Battleship test program have received extensive on-the-job and formal classroom training in the following general areas:

J-2 rocket engine
Control center operation
Propellant handling
High pressure systems

Test stand operation
General testing philosophy and procedures
S-II stage and GSE systems

Technicians received on-the-job training, at various Rocketdyne test facilities, averaging three months per man with concurrent formal classroom training totaling 4872 hours. Emphasis also was placed on certification of skills required to support the various crafts (wire crimping, soldering, stud welding, etc.).

Engineering training consisted basically of formal classroom instruction and was directed primarily toward assigned areas of responsibility on various systems.

Considerable effort was expended in the preparation of supporting documentation for the Battleship test program. Documentation progress for the year is listed below.

Document	Percent Completed
Santa Susana safety manual	100
Santa Susana operations manual	100
Propellant and pressurant requirement manual	100
Procedures (installation, operating, and general)	50
Battleship test program plan	90
Santa Susana site activation plan	90
Installation and checkout plan	85
Cryogenics systems evaluation plan	40

The T&O organization at Santa Susana is now functioning as an integrated unit. The field office for Santa Susana operations has been established on a semipermanent basis in trailers near the test site. Various on-site support representatives have been assigned to respond to field requirements.

ALL-SYSTEMS

Construction of the basic facility at SSFL was completed, and the first phase of program test planning documentation was begun.

During the report period, engineering manpower was built up from 7 engineers to 23. The scheduled manpower requirement for this time is 26. Engineer training courses for orientation and familiarization and for specialized systems categories are 30-percent completed. The technician manpower program was limited to requirements for on-the-job training at the Battleship test stand. Personnel to be assigned to the All-Systems organization are assisting in the Battleship buildup and are acquiring experience useful for the activation and checkout of the All-Systems program.

Major construction completed to date at the All-Systems T&O site is as follows:

Test control center
All rigid structures on the test stand, including the flame deflector and spillway
The basic propellant storage and transfer systems up to the facility/GSE interfaces
Installation of storage tanks for GH_2, GHe, and GN_2

In addition, roadways and lighting in the Coca area are essentially complete.

Plans were formulated for a site survey to determine the ambient RFI in the Coca area. Bids were requested and received, and a contract will be awarded to start the survey on or about 1 August 1964. Survey results should indicate the RFI environment to which the stage and GSE will be subjected during test operations.

The hazard suppression program was initiated, and construction of the two test stands was completed. Testing during the early part of the program indicated the possibility of inadequate purge capability in the Battleship engine compartment. The engine compartment manifold was redesigned, and the GN_2 flow rates were changed. The redesign was verified, and the configuration was optimized by continued testing. At this point, a firing skirt simulation and an auxiliary manifold were added to simulate the All-Systems configuration. Testing on this configuration is scheduled to begin soon. It is anticipated that data from this program and from the NASA spill test program will provide support for a request to waive the 25-second static firing limitation for the All-Systems stage.

The All-Systems test program plan—the major All-Systems planning document after the Saturn S-II general test plan—has been written and will be submitted for review by the cognizant S&ID departments in the near future.

Individual system test plans have been written and submitted for review to engineering and quality assurance. This task accounts for the major effort expended by All-Systems during this report period. These documents provide the detailed planning to accomplish system development. They include such information as: system description, general and specific test objectives, test operations, data requirements, red line measurements, reporting requirements, schedule, and T&O procedure requirements.

The documentation status for the All-Systems Program at SSFL is listed below:

Document	Percent Completed
SSFL safety manual	100
SSFL operation manual	85
Propellants and pressurants manual	100
All-Systems T&O procedures	5
All-Systems data plan	85
All-Systems test program plan	85
Phase I test plans	15
Phase II test plans	40
Phase III test plans	5

The common bulkhead test program design phase was completed, and construction bids were sent out on 17 June.

MISSISSIPPI TEST FACILITY

Major effort during the report period was directed toward preparation of MTF test program plans and procedures. The general plans and 38 addendums are in work. Ground rules and format were resolved for the detailed operating procedures. These procedures, to be written during fiscal 1965, will be used in activation and operational testing at MTF. In addition, the Site Activation and Operating Plan has been released and reviewed by MSFC, and the Test Support Requirements document has been updated and negotiated with MSFC.

MTF T&O personnel participated in classroom and on-the-job training. Classroom training included courses in report writing, computers, and programming. On-the-job training included participation in tasks at Seal Beach, Rocketdyne, Douglas Aircraft Company, and MSFC. Additional training is planned for the next report period.

Resident T&O representatives at MSFC were increased from two to four to coordinate and resolve facility problems pertaining to the MTF test site. In addition, Downey personnel participated in design reviews and conferences at New Orleans, Huntsville, and St. Louis.

MTF personnel participated in a special study to evaluate stage checkout at Seal Beach, MTF, and MILA. The following conclusions were drawn from the study:

1. Only one vertical checkout station will be required for post-static-testing of stages under the J-1 schedule.

2. A second vertical checkout station would be desirable to provide program flexibility in case of a major modification program, possible loss of a test stand for an extended time, or other factors that could have a major impact on the schedule.

3. NASA directed that the S-II aft interstages be routed through MTF for compatibility checkouts. The checkouts are considered essential due to a change in MILA checkout philosophy whereby the interstages will not undergo checkout in the Low Bay. Under the revised routing procedure, modifications made to the stage after Seal Beach also could be tested at MTF.

4. ACE removal from test stands would be costly and result in serious impact on the schedule.

5. Sharing equipment between test stands would be more costly than using two sets.

Another study analyzed the effect on the program that would be caused by removing an S-II stage from the test stand each time a stage in the adjacent test stand is being tanked. Catastrophic failure during tanking could damage seriously a stage mounted in an adjacent stand. It was concluded that the risks and time involved in removing and replacing stages could offset the advantages gained. The scheduling of tests at MTF on a non-interference basis appears to be the most practical and economical solution.

In compliance with a NASA request, the component service facility requirements of T&O, Logistics, and Engineering were compiled and presented to the MTF working group. This compilation, combined with similar requirements from other contractors, was used to formulate the design criteria for the component service facility.

A study was made to determine the program impact that would result from a slippage of approximately eight months in the availability of the second MTF test stand. This slippage was indicated in a NASA-directed program change. A prime, study consideration was the fact that it would not be possible to return the S-II-F stage from MILA to MTF for facility checkout. It was concluded that the most practical solution would be to use the S-II-2 and S-II-3 flight stages for the facility checkout.

A major study completed during the report period covered manpower planning needs prior to and during MTF operations. An analysis was made of test personnel required to perform the MTF test program, and a plan delineating requirements was published. The availability of skilled labor to fulfill these requirements was investigated in the MTF area and it was found that there was a shortage at all levels. NAA representatives in Chicago and New York were contacted for assistance in the planned recruiting program.

FLORIDA OPERATIONS

During the past year MILA T&O personnel have been engaged primarily in operations planning, design review, and Saturn V support studies.

Continued support was given to the facility activation project group (FAPG). This committee provides an interface between S&ID and NASA for the interchange of facility requirements and other facility information. The design drawings for the VAB and the launcher/umbilical tower were reviewed, and comments were transmitted to NASA. The design concept of the arming tower was revised to incorporate adjustable platforms; the 60-percent drawings of the redesign were received and reviewed. No design information has been available on the ordnance storage facility. However, S&ID requirements and criteria have been transmitted to NASA, and facility design drawings are expected in the near future.

Continued support was given to the T&O automatic checkout evaluation committee. This committee evaluates the ACE, placing particular emphasis on safety, flexibility and maintenance.

The operational suitability evaluation committee (OSEC) was formed in August 1963 to review each stage system for compatibility with the established checkout and operational concepts and to optimize the operational suitability of the S-II stage. In addition to recommendations made to the design groups, two special evaluation tests were made. A simulated thermal control system was utilized in an EMM electronic equipment container to analyze the acoustical levels resulting from the flow through the system orifices. Test results indicated that flight stage acoustical levels would not be high enough to require protection for the ear canal. For the second evaluation a full-scale mockup of the ullage motor attachment fittings and sufficient portions of the stage structure and ullage motor was constructed to evaluate the installation task. The results indicated that the ullage motor attachment design is satisfactory and that no problems should be encountered during installation of the ullage motors.

The following major decisions were reached through activities of the launch preparation subgroup of the launch operations working group (LOWG):

1. The S-II stage/interstage will be mated in the VAB low bay prior to any checkout operations. This decision alters the previous plan of performing stage checkout on a spacer with interstage installation immediately prior to transfer to the high bay.

2. All ordnance will be loaded aboard the Saturn V in the VAB high bay rather than at the launch pad with the arming tower. The tower will not be utilized for any normal S-II stage operation.

   It was also resolved that the LH_2 tank propellant dispersion charge will be installed in the systems tunnel. Access to the tunnel beyond the facility platforms will be provided by scaffolding.

3. The facility stage (S-II-F) will contain only those systems required for propellant loading at MILA.

4. The overall flow sequence for the Saturn V, from S-IC delivery through launch, was established as 58 working days rather than 84 as had been previously planned.

Technical Directive 191-64 was issued to S&ID to conduct a study of GSE and manpower requirements for a reduced low bay checkout at MILA. Under ground rules originally established, the resulting study was based on the utilization of current design configuration GSE with the capability of expanding to the full low bay capability at a later date. The GSE requirements were reevaluated as S&ID obtained more information about the ultimate plan for stage checkout at MILA.

A special study group was formulated to evaluate the stage checkout from Seal Beach through MILA. The results and recommendations for GSE requirements and for stage flow sequence have been presented to NASA for consideration at the next LOWG meeting.

In February, a meeting of the instrumentation and tracking data acquisition subgroup of the LOWG was attended. The primary objective of this meeting was to establish ground environmental measurement requirements so that instrumentation could be incorporated into the design of Complex 39. A list of measurements was established and transmitted to the working group chairman. However, no extensive determination of requirements was made since the extent of S&ID responsibility beyond the low bay has never been defined.

Two S&ID engineers were transferred to the John F. Kennedy Spacecraft Center to fulfill a request for support in the electrical networks and flight control system areas.

Work was continued on the MILA documentation. The MILA Test Program Plan for Saturn S-II Stage, SID 63-114, was revised twice to reflect changes in the Saturn S-II program. The preparation of the S-II Activation and Operations Plan at MILA was started.

TEST PROGRAMS

During this report period, a major portion of the effort was directed toward support of the various test site T&O groups. In addition to support of the overall Saturn S-II test program, other T&O groups were supported by the participation of test programs personnel as T&O representative in design input meetings, pricing meetings, the change control board, and manufacturing status control board.

The test programs group supported the system checkout working group in the capacity of coordinator for S&ID input to the agendas and response's to action items generated at the meetings. Nine action items were generated at the 30 - 31 July 1963 meeting and have been responded to and closed; however, efforts continue on three of these items. At the 7 November 1963 meeting, eleven action items were generated. These have been closed, with continuing efforts on five of the items.

Changes in various stage measurement lists were necessary as a result of design changes, MSFC direction, deletion of the S-II-1FD stage and addition of a static firing measurement system. Because of the addition of the latter system, it was necessary to publish two measurement lists for the All-Systems stage and for each of the flight stages (Ground Checkout and Static Firing measurement list and Prelaunch Checkout and Telemetry measurement list). Technical coordination will continue with engineering design groups and MSFC. Revisions of the Master Measurement List (SID 62-1052) and measurement lists for the S-II-4 stage are being made.

To date, measurement lists for the EMM, Battleship, and S-II-F have been published. In addition, the two measurement lists required for S-II-T, S-II-1, S-II-2, and S-II-3 have been published and revised as required.

The test support requirements documents for the EMM, Santa Susana test site, and MTF have been reissued or revised. The MILA test site document is being revised. These documents delineate equipment and material requirements to support each S-II test site. The documents will be redefined and updated as required.

The Saturn S-II master test schedule was revised to reflect several program changes. Some of the more significant changes are listed below:

1. End points of the various programs were fixed and keyed to the important events they support in subsequent programs.

2. Stage delivery dates and testing sequence were realigned to conform to the J-1 schedule.

3. The nonpropulsive stage (S-II-1FD) was made into a powered flight stage; flight stages were renumbered S-II-1 through S-II-10 instead of S-II-1FD and S-II-2 through S-II-10.

4. The first static firings of the Battleship and All-Systems stages were scheduled for November 1964 and October 1965.

5. The tape verification to be done by the EMM was re-examined and scheduled as "Configuration X" and "Configuration X-1" tape debugging.

6. The 100-percent GSE delivery dates were rescheduled to support the J-1 schedule stage deliveries.

During November, the concept of configuration change points was coordinated between configuration control and T&O. For T&O, the important aspect of this concept is that the change points are event-oriented rather than time-oriented. Incorporation of changes and modifications thus can be firmly scheduled when a specific configuration is reached rather than being scheduled for a calendar date when the configuration at that time might be uncertain. Work was started in April on a graphic display of the configuration change points for the EMM, Battleship, and All-Systems programs. After subsequent coordination with configuration control and project engineering, an internal letter defining the change points was distributed. Effort continues to define further and to display graphically configuration change points.

The test programs group is working on a definition of the detailed test plan document. This document is a new T&O requirement that will be used by the test sites for test-to-test detailed planning.

A DOP development plan has been prepared. The purpose of this plan is to insure a maximum degree of uniformity in test documentation and a maximum utilization of available experience in preparing the documentation. Implementing instructions are being prepared to define use of the development plan.

An implementing instruction, covering test requests and technical directives for special tests to be performed at S-II test sites, has been completed and approved.

During October 1963, S&ID coordinated the layout and equipment for the S-II T&O communications center. Construction of the center began in March 1964 and was completed in April.

The revised T&O general training plan is being prepared. Requirements for this document are being coordinated with the training department and other T&O groups. Requirements for the LH_2 tank entry training program have been completed and submitted to the management development and training department.

The test programs group has maintained a working copy of the General Test Plan for Saturn S-II (SID 61-364), incorporating all amendments submitted to NASA. Forty amendments were submitted in the past year. Of these, nine have been approved and four cancelled. The remainder are in various phases of negotiation.

The T&O data handling working group was formed in January 1964, to resolve any problems connected with data reduction and coordination and to determine the most expeditious manner of handling raw or reduced data. As the problems are resolved and data handling plans formulated, this group will be phased out.

DATA ENGINEERING

Effort in this area has been concentrated primarily in the preparation of data station facilities and in the monitoring of subcontractor progress in the development and integration of data processing equipment.

The data station facilities area was completed and occupied in February 1964.

The digital processing system had been subcontracted in January 1963 to Radiation, Inc., Melbourne, Florida. Preliminary checkout at the Radiation, Inc., facility was completed in May 1964, and the system was shipped to Downey in June. System installation was completed, and preparations for the final acceptance tests are in progress. After acceptance, a personnel familiarization program will be initiated. The program will be oriented toward specialized training in the assigned areas of responsibility.

Figure III-1 shows a view to the north-east inside the data station. The Hogan plotter/printer is located in the foreground, the control console in the center, and various processing subsystems in the background.

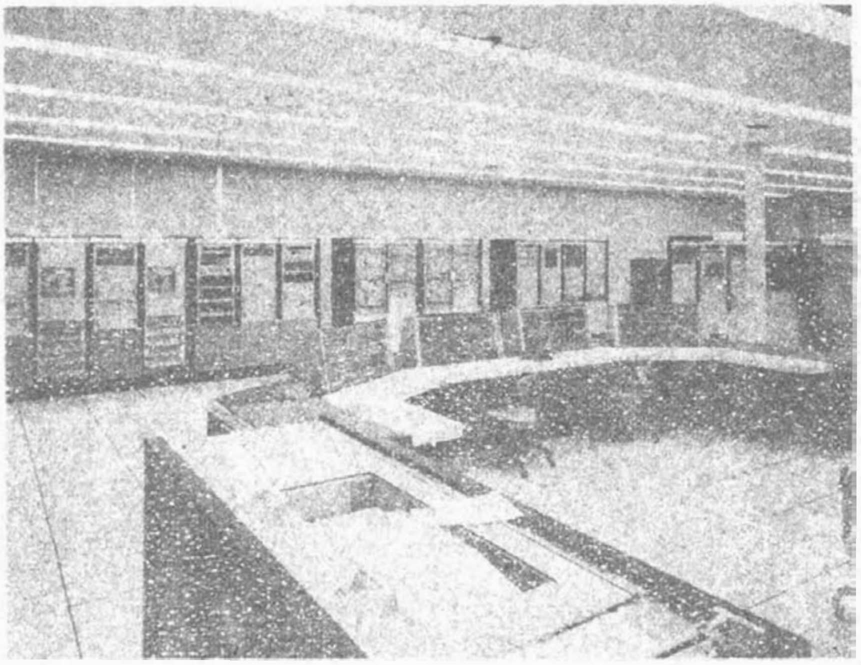


Figure III-1. Data Station

The vibration processing system will be part of the S-II data station. This system is being procured separately. NASA Technical Directive 111-63, dated 27 June 1963, defined the requirement for processing vibration and cycle-count data. Specifications for the processing equipment were prepared and released for bid to 13 companies in July 1963. Four companies responded with proposals in August. Contract negotiations with Gulton Industries were completed in October and NASA/MSFC approval was obtained in January. The system is scheduled to be completed and shipped to Downey in September 1964.

The data processing operations of the station are dependent on the computer programs that are integral to the operating concept of the system. The operating concept was established, and the detailed programming plan for implementation was completed. All actual programming effort during this report period was devoted to the IBM 7094 programs that are required to provide data reduction capability for the initial Battleship and EMM tests. Coding of the IBM 7094 data reduction programs was completed, and the programs are being checked out. Specifications for the data station computer (Scientific Data Systems 920) programs have been completed. However, only those programs basic to the primary data processing tasks are being developed during the initial programming phase.

S-II Logistics has been assigned the function and the necessary funding for procurement and inventory maintenance of the spare parts and consumable supplies necessary for data station operation. Routine maintenance of data station equipment will be done by S-II data engineering personnel. However, the possibility of extending service contracts for the four major equipment suppliers to maintain their equipment is being investigated.

Work has continued on the preparation of data engineering documentation. Two SID documents - S-II Data Engineering Installation and Activation Plan (SID 64-1000) and S-II Data Engineering Operating Plan (SID 64-1193) were published during the report period.

IV. FACILITIES

SITES

S-II Facilities is constructing and preparing facilities for S-II stage manufacturing and testing at three Southern California locations: Downey, Air Force Plant 16; Seal Beach, U.S. Naval Weapons Stations; and Santa Susana, Air Force Plant 57.

DOWNEY

Completed Downey facilities are the cryogenic test facility, EMM, antenna test range, slosh and vortex facility, flight control simulator, and data ground station. Of these, the flight control simulator and the data ground station were completed the past year. The pressurization systems development facility is under construction.

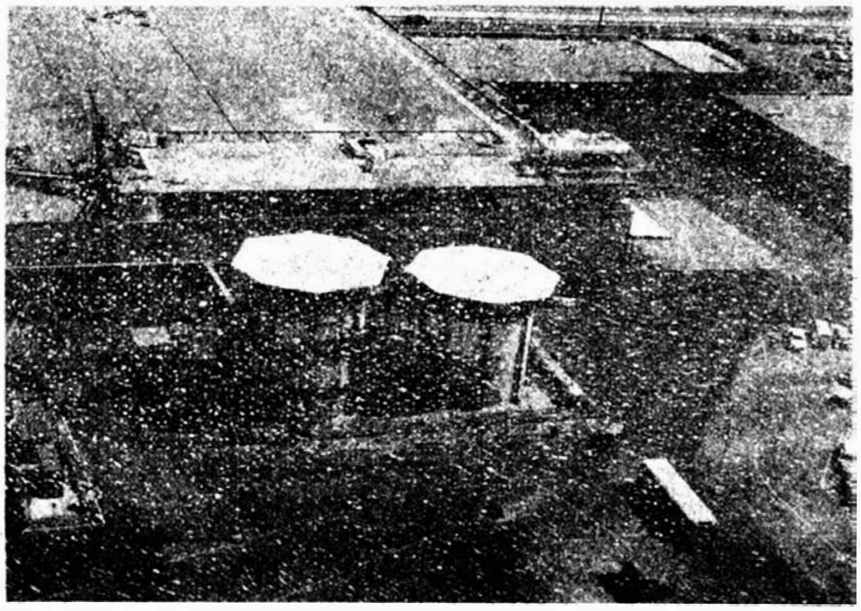
CRYOGENIC TEST FACILITY

The cryogenic test facility is used in the evaluation and study of S-II materials and components at controlled temperatures as low as -423 F. New functional requirements have been imposed on the facility, and an alteration program is currently in progress.

Additional equipment and modifications being added include: a CO_2 blanketing system to provide adequate protection for test operations involving liquid hydrogen; a warning light system to provide visual warning of tests in progress; a public address system to provide audible warning of the beginning of a hazardous test; schrapnel curtains to provide personnel protection in event of accidental explosion; filters for the GN_2 system to exclude scale and foreign matter; and supplemental equipment for the thermal control system to meet requirements of local, city, county, and state regulations pertaining to hazardous materials.

EMM

The EMM mockup test area (Figure IV-1) was completed on schedule and is operating satisfactorily. The automatic checkout area and the computer room were completed 15 November 1963. However, program changes required an expansion of the control room, which was completed 5 June 1964. ACE is being installed.



SID-820-44A

Figure IV-1. Electromechanical Mockup

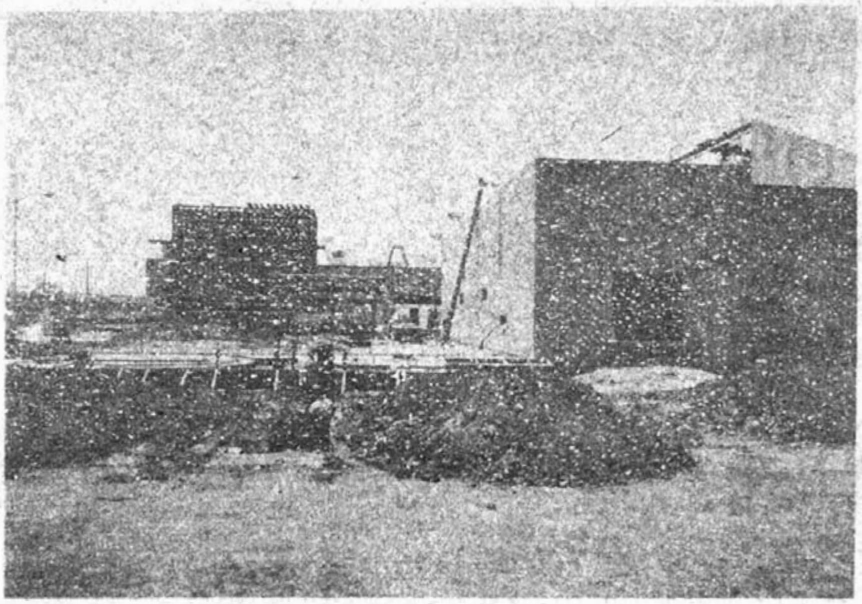
Stage checkout procedures and associated GSE have necessitated a revision of the high-pressure gas storage requirements. Design of this equipment is expected to begin in July, and construction is to commence in late August.

FLIGHT CONTROL SIMULATOR FACILITY

The flight control simulator was completed 23 September 1963 and is operating satisfactorily. A heavy steel framework mounted in a pit supports the simulated J-2 engine. Actuation equipment connected to the engine simulates various flight conditions.

PRESSURIZATION SYSTEM DEVELOPMENT FACILITY

This facility will develop capabilities for the S-II simulated pressurization system (Figure IV-2). Facility design was completed 6 September 1963. Construction began 17 February and is scheduled for completion in mid-August 1964.



S&ID-810-183B

Figure IV-2. Pressurization Systems Development Facility

DATA GROUND STATION

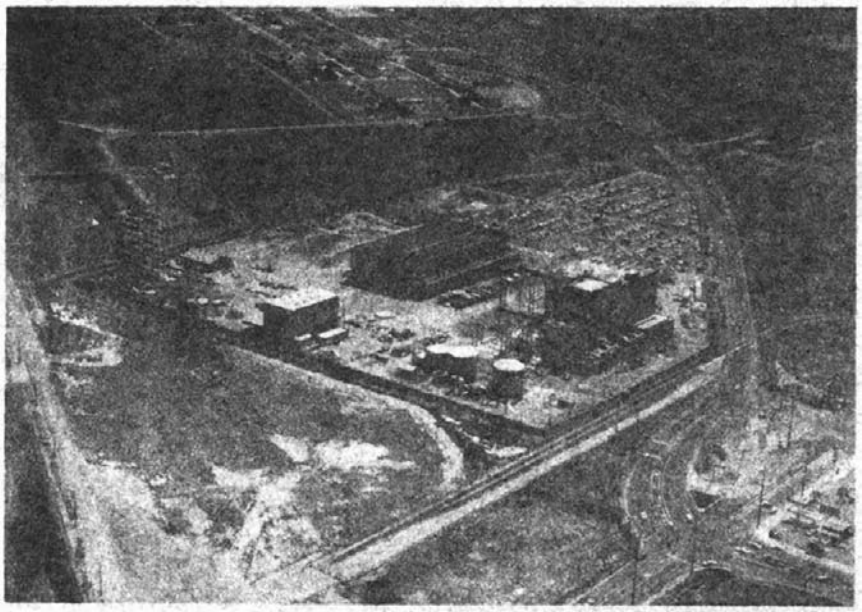
The data ground station will reduce taped telemeter data received from propulsion systems development areas and from the flight test area at the Eastern Test Range. Most data will be transmitted by computer tape.

Facility design was completed in mid-September 1963. The construction contract was awarded 4 November and construction was completed 8 February.

Equipment for the data reduction system—tape units, computers, printer-plotters, etc. —was delivered and installed in June.

SEAL BEACH

Major facilities (Figure IV-3, IV-4) under construction or completed are: the VAB and hydrostatic test facility; the bulkhead fabrication building; the water conditioning facility; the service building; the pneumatic test, paint, and packaging facility; structural static test tower; and the gear and maintenance building. In design are the two-station vertical checkout facility and a warehouse.



SEBE-820-33E

Figure IV-3. Seal Beach Facility

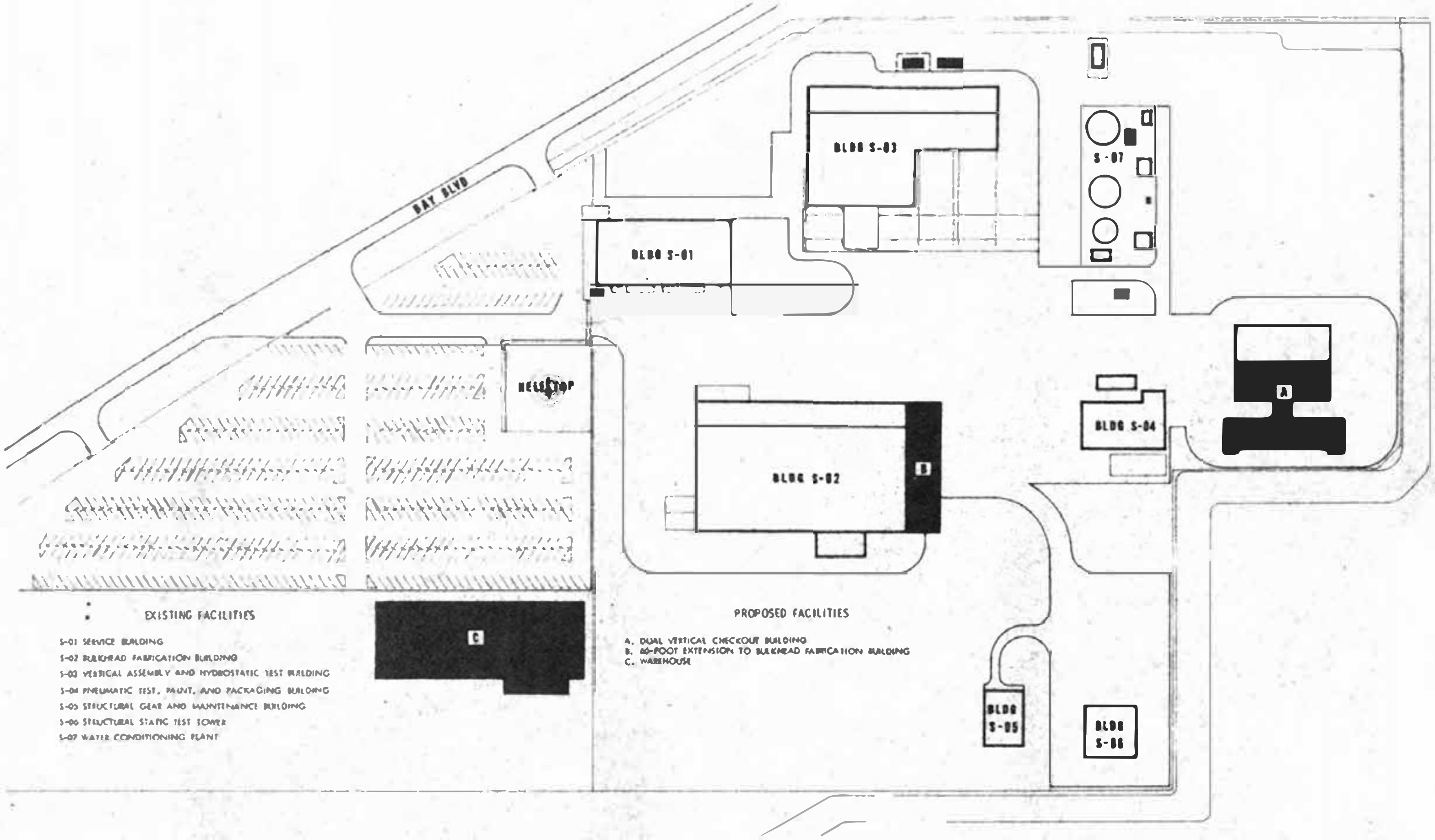


Figure IV-4. Seal Beach Facility Plot Plan

BULKHEAD FABRICATION BUILDING

Electrical and mechanical equipment and process piping have been installed and checked out. Manufacturing personnel took beneficial occupancy in all areas by 16 May.

The bulkhead fabrication building is to be extended 60 feet east. The criteria is being drawn up and design is scheduled to start in July (Figure IV-5).

VERTICAL ASSEMBLY-HYDROSTATIC TEST FACILITY

Phase I of construction, which is completed, covered the foundation, procurement, and installation of crane and hoist sub-stations, transfer table, and structural steel.

Phase II of construction began 1 August 1963 and covers the building enclosure and heating, lighting, air conditioning, and other operating requirements.

The first occupancy of the vertical assembly area occurred with installation of the stage handling dolly rails on 23 August 1963. In mid-January, beneficial occupancy was taken at Stations I and II in the vertical assembly area and Station VI of the hydrostatic test area.

Stations III and IV were turned over to S&ID on 8 April 1964. S&ID received beneficial occupancy of Station V (Figure IV-6), second to sixth floors, 7 July 1964.

STRUCTURAL STATIC TEST FACILITY

The structural static test tower (Figure IV-7) is to be used for simulation of flight stresses on the S-II stage. A gear and maintenance building was completed and occupied early in 1963. The design and specifications for the tower portion of this facility were completed 31 July 1963, and the construction contract was awarded 1 October 1963. The U. S. Navy administered construction. An addendum to the construction contract, covering air conditioning and fire protection, was effected in September.

The tower foundation was poured 25 November, and erection of the structural steel began 12 December. Beneficial occupancy of the tower and control room was taken 27 April 1964. The magnitude and location of the loads to be applied to Saturn S-II have been defined. The load definitions will permit the remainder of the tower to be completed.

The design of a GSE proofing area adjacent to the tower is complete, and construction is scheduled to begin in September.

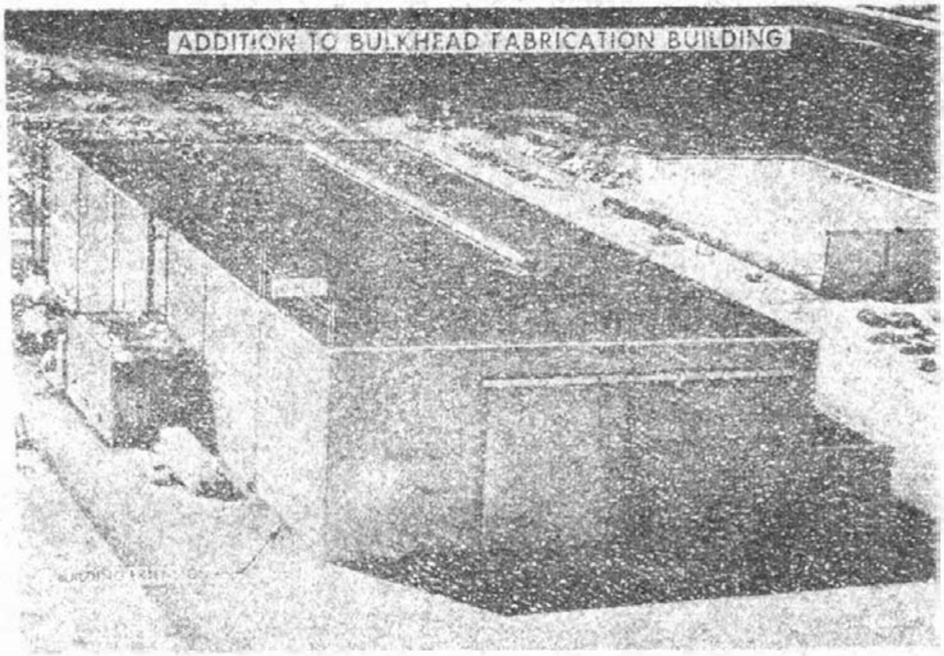


Figure IV-5. Addition to Bulkhead Fabrication Building

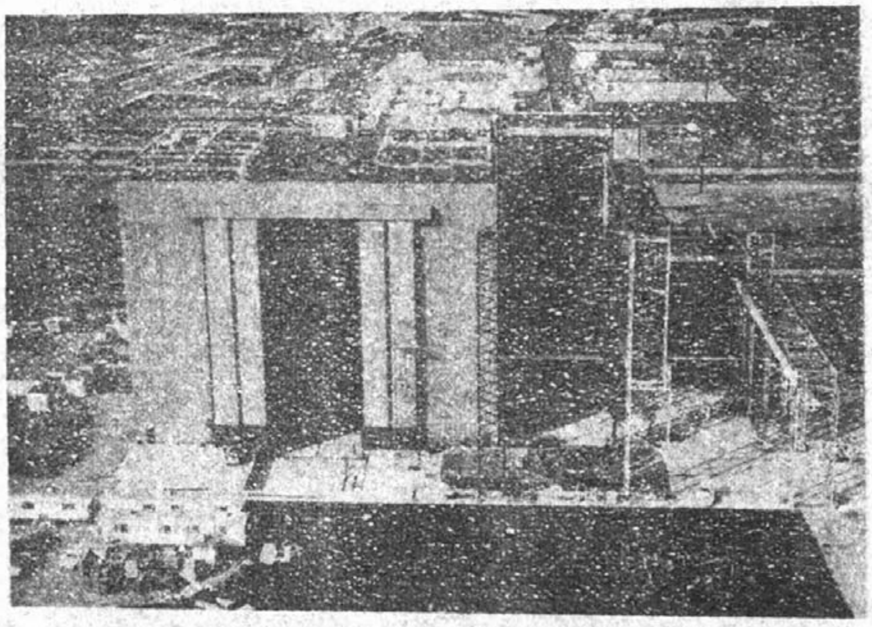


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Figure IV-6. Vertical Assembly and Hydrostatic Test Facility

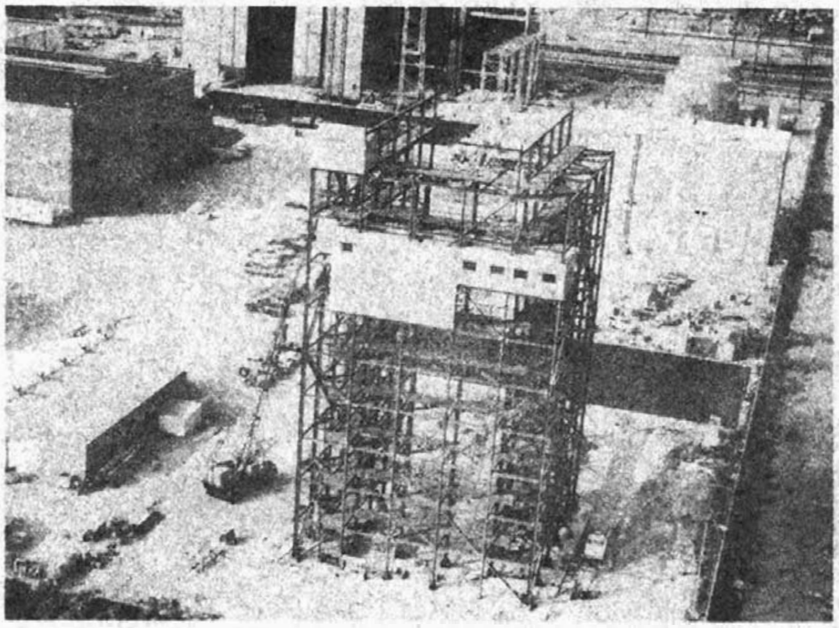
SEBE-820-27F

Figure IV-7. Structural Static Test Facility

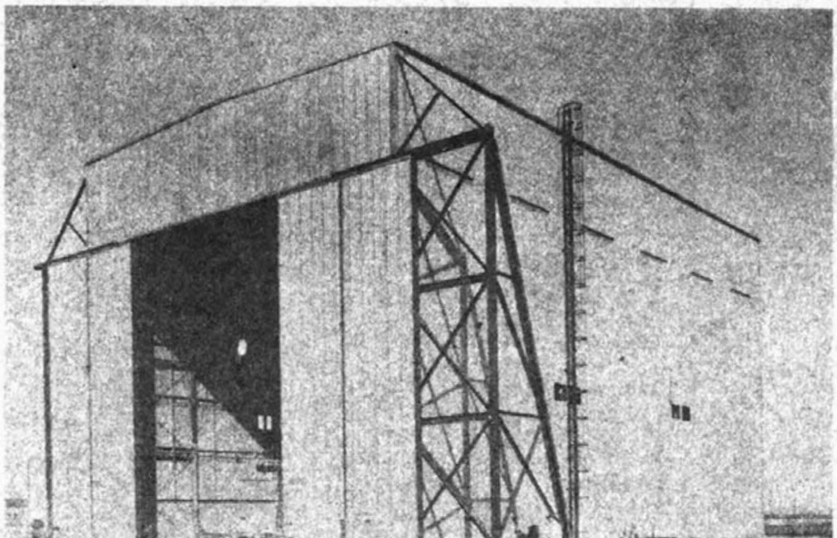
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Figure IV-8. Pneumatic Test, Paint, and Packaging Building

PNEUMATIC TEST, PAINT, AND PACKAGING FACILITY

This facility (Figure IV-8) will be used for checkout of the S-II stage pressurization systems and for leak and functional checks on the engine and propellant systems. Painting and packaging will be performed after systems checkout. The underground piping was laid and the foundation poured in early December. The erection of structural steel was completed in late December.

The exterior siding and blow-out panels were erected in January and February. In early April, joint occupancy was taken in several areas of this facility, and utilities serving the area were bought off.

SERVICE BUILDING

The service building (Figure IV-9) is an administrative and laboratory testing facility. Construction began 1 March 1963 and was administered by the U.S. Navy. Joint occupancy was taken by S&ID on 19 September 1963.

Installation of office partitions and telephone equipment and checkout of laboratory test facilities continued through September. Beneficial occupancy was taken on 7 October 1964.

WATER CONDITIONING FACILITY

The water conditioning facility (Figure IV-10) provides demineralized water, water for fire emergencies, cleaning solutions, and plant air. Construction started on 29 April 1963. Storage tank and pre-fab building erection were completed in June 1963. All underground work for this facility was completed in July.

On 9 December, field construction was complete, and occupancy and checkout had begun. In the months preceding buy-off, instrumentation and controls checkout progressed, the demineralized water storage and holding tanks were relined, the ion-exchange resins in the demineralizer were replaced, and checkout was conducted according to specifications. Final inspection and acceptance took place on 25 May.

NEW WAREHOUSE

A warehouse (Figure IV-11) presently in design will provide much needed storage area for Seal Beach. The building, enclosing approximately 30,000 square feet, will be used to store subassemblies, completed bulkheads, LH_2 cylinders, and small parts. Included in the area will be an equipment room, loading dock, and restroom facilities. Major equipment for this facility will consist of a mobile gantry crane and a 20-ton bridge crane.

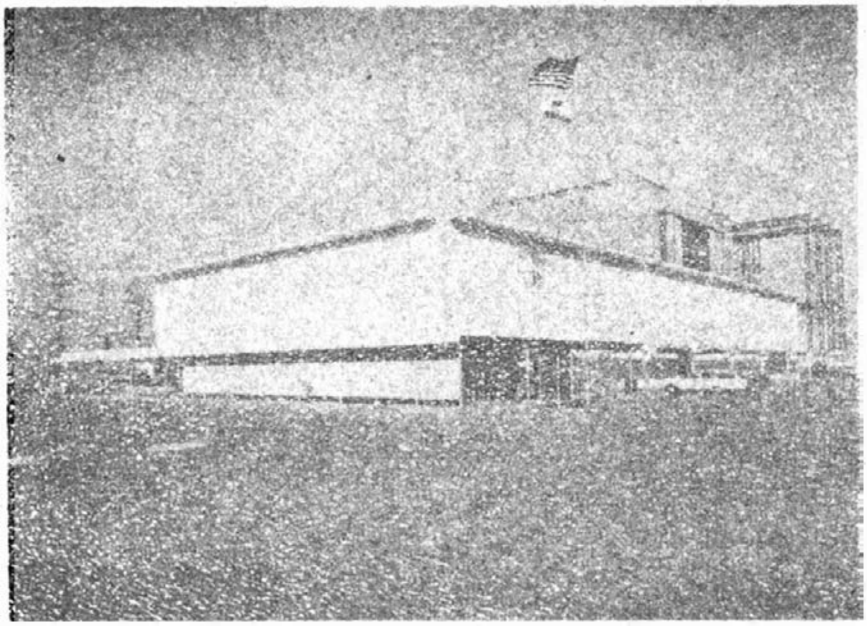

Figure IV-9. Service Building

Figure IV-10. Water Conditioning Facility

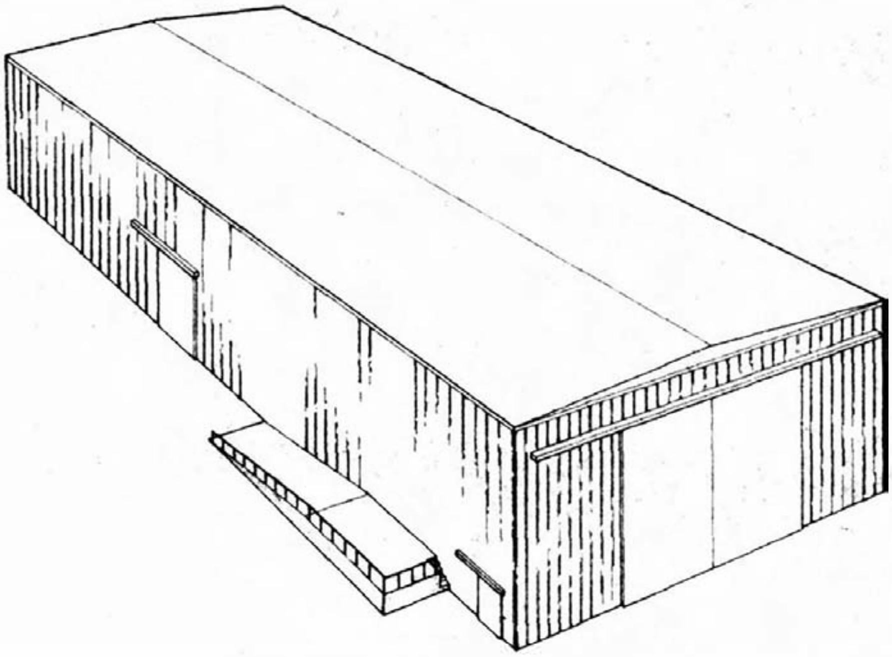

Figure IV-11. Warehouse

Design began in May 1964 and is scheduled to be completed 1 September. Construction is scheduled to be completed in April 1965. Design and construction is being administered by the U.S. Navy.

TWO-STATION VERTICAL CHECKOUT FACILITY

The two-station vertical checkout facility (Figure IV-12) will be capable of combined systems checkout (mechanical and electrical).

By mid-March, the architect-engineer retained by the Navy had started design. The present tentative milestone dates are as follows:

Date	Milestone
16 July 1964	60-percent design review complete
1 September 1964	Complete design
1 November 1964	Construction contract award
15 April 1965	Joint occupancy of the control room
1 October 1965	Construction complete

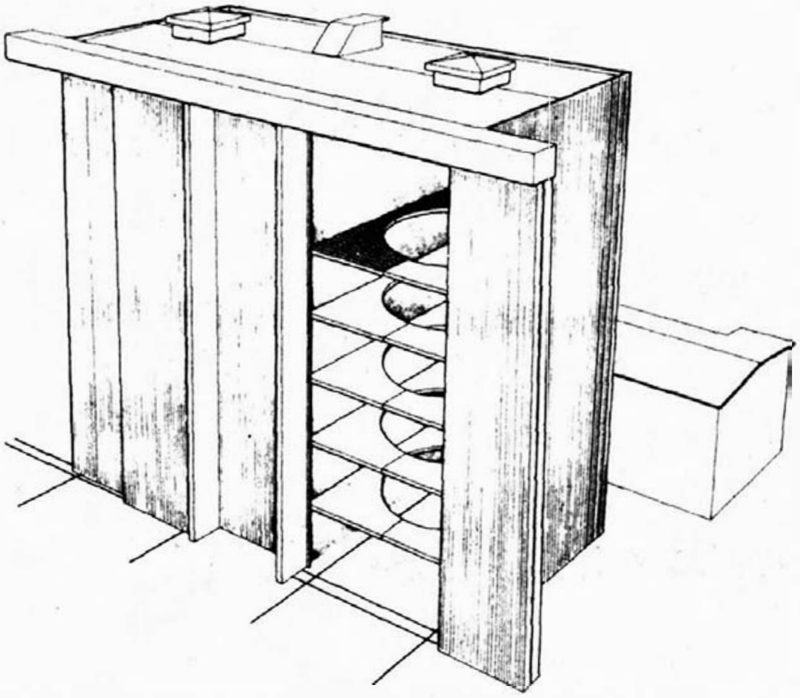

Figure IV-12. Proposed Dual Vertical Checkout Building

SANTA SUSANA

The S-II stage will be static-tested in the Coca area (Figure IV-13) of Air Force Plant 57. Since the last reporting, the basic facilities supporting the new static firing date have been completed.

The design and construction of the facilities was conducted by Rocketdyne under S&ID direction. Activation of the Coca test area is proceeding toward the Battleship firing, scheduled for 1 November in support of the current test program.

Construction of the facilities was accomplished by five major projects, as follows:

1. Battleship test stand
2. All-Systems test stand
3. Propellant and pressurants systems
4. Control center and electrical systems
5. Area services

BATTLESHIP TEST STAND - COCA 1

The Battleship (Figure IV-14) consists of LH_2 and LOX tanks of the same internal configuration as the S-II stage. The structural steel portion of the test stand was completed on 18 August 1963, and the work of covering

Figure IV-13. Santa Susana Facility

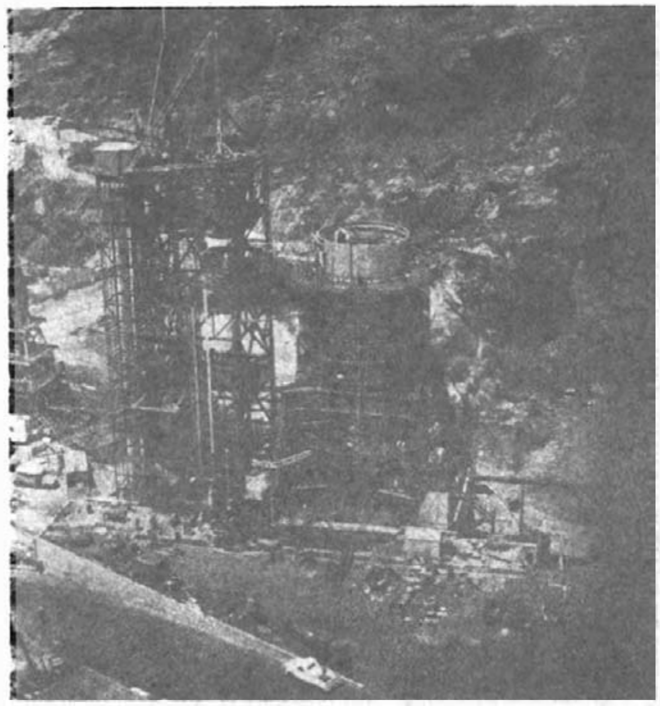

Figure IV-14. Coca 1

flame deflectors and dollies was completed on 13 December. The fabrication and installation of the Battleship vessel has been completed, and activation commenced on 18 May.

ALL-SYSTEMS TEST STAND

The All-Systems test stand (Figure IV-15) is approximately 80 percent complete. Construction of the superstructure is complete, and on-stand systems are presently being expanded.

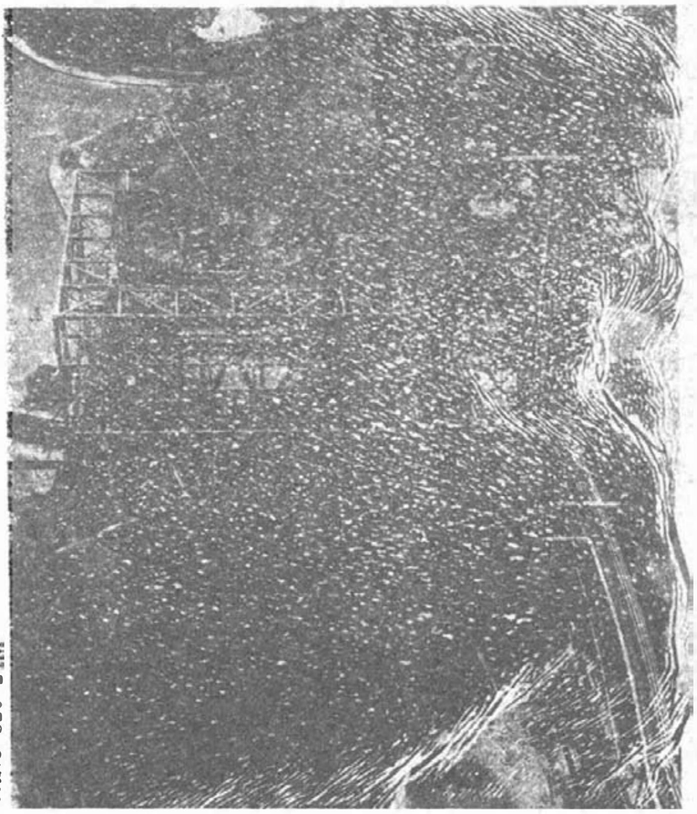

Figure IV-15. Coca 4

PROPELLANTS AND PRESSURANTS STORAGE AND TRANSFER SYSTEMS

Complete and centralized fluid distribution systems have been provided in the Coca area to transfer propellants and gases to either the Battleship test stand or to the All-Systems test stand. The propellants and pressurants storage and transfer systems were completed in May.

CONTROL CENTER AND ELECTRICAL SYSTEMS

Modification of the control center (Figures IV-16, IV-17), which houses the electrical and instrumentation systems, started 27 April 1963. The structural portion is complete.

The installation contract for the DRS-420 system was awarded to Astrodata, Inc., in February 1964. Scheduled completion date is 26 October 1964. The data recording system, which will record and analyze information obtained from the test firings, consists of: a patch panel, an analog data recording subsystem, a variable pulse rate recording subsystem, and a digital recording subsystem. The patch panel was delivered to the Santa Susana site on 1 July 1964.

Instrumentation cables were installed in a special-built tunnel from the control station to the Battleship test stand. Cabling and wiring are ready for GSE and all instrumentation equipment. Installation of the cabling system for the All-Systems test stand is in design and will be installed after 15 August.

The control center will be ready to support the test firing on the Battleship stand scheduled for November 1964 and the All-Systems firing for August of 1965.

AREA SERVICES

The north observation bunker is under construction. The south observation bunker has been completed and is ready for use.

Spillways to handle the huge water run-off from the flame deflectors have been excavated and constructed. Area lighting and fire extinguishing systems have been completed.

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Figure IV-16. SSFL Control Center

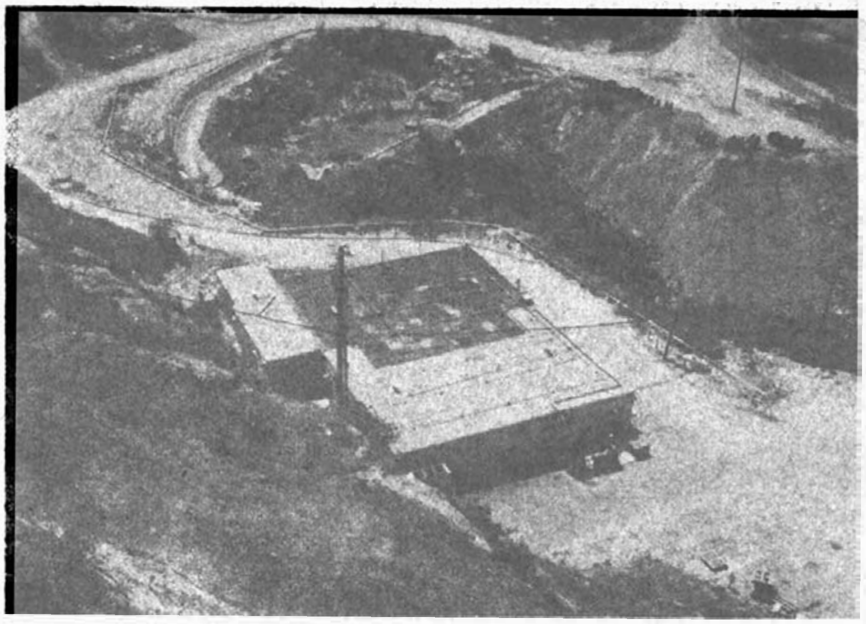

Figure IV-17. Closeup of Control Center

V. QUALITY CONTROL

PROCUREMENT

AUDIO-VISUAL PRESENTATION OF MQ0802-001A

An audio-visual presentation has been developed for quality control specification MQ0802-001A, General Requirements for NAA Suppliers' Quality Control System for NASA Contracts, has been developed. This aid presents a uniform interpretation and clarification of the different requirements of the specification. The showing and discussion period is approximately two hours. All current suppliers will have the opportunity to see t presentation, and new suppliers will see it during a post-award coordinatio visit.

QUALITY SPECIFICATION MQ0802-003

Quality specification MQ0802-003, Inspection System Provisions for Sellers of Material, Articles, and Services for Space Programs, has been released and is being implemented through instructions in S&ID quality assurance operating bulletin BQC-6.6. This document will provide a more complete range of specifications for assessing S&ID suppliers to ensure adequate quality requirements.

IMPLEMENTATION OF QUALITY CONFORMANCE AUDIT

In November 1963, Procurement Quality Control personnel began to perform conformance audits to verify the adequacy of suppliers' inspection controls and procedures. There are indications that beneficial preventive action may result. Deficiencies have been noted during the conformance review of nearly every supplier, and cooperation has been evidenced in the correction of these deficiencies.

STANDARDIZATION OF IDWA QUALITY REQUIREMENTS

A new standardized system of form and procedure for the establishment of quality requirements on interdivision work authorizations (IDWA) is being implemented. It measurably improves the understanding of quality requirements between divisions.

PROCUREMENT (RECEIVING) INSPECTION

In February 1964, the central warehouse was moved from Building 310 at the Los Angeles facility to Building 43 at Compton. Raw stock and some hardware were relocated to the El Segundo facility. Compton is a more central location, and the move there has relieved some communication problems.

MANUFACTURING

The following major items were accepted by S&ID and NASA Quality Control during this reporting period.

Item	Date
First meridian weld on upper LOX bulkhead (static)	7 January 1964
First meridian weld on aft common bulkhead (static).	9 January 1964
First veritcal climb weld on LH_2 cylinder	25 January 1964
First aft common bulkhead assembly (static)	5 February 1964
First dollar plate welded	6 February 1964
First upper LOX bulkhead (static)	12 February 1964
First successful bulkhead hydrostat test aft common bulkhead (static)	4 March 1964
First forward common bulkhead meridian weld (TCB)	9 March 1964
Aft common bulkhead (TCB) completed	6 April 1964
First circumferential weld No. 6 LH_2 cylinder to upper LOX bulkhead (static)	20 April 1964
Forward common bulkhead welding completed (static)	20 April 1964
First aft common bulkhead honeycomb core insulation and bond completed	5 May 1964

DETAILED TUBE FABRICATION

An Indi-Ron machine, which will be used for inspection of the concentricity of tube flares, was received from Cleveland Instrument Company in April of 1964. A representative of Cleveland Instrument Company set up the machine in Building 235 at Downey and instructed inspectors in the proper methods of operation. Use of the Indi-Ron machine will enable inspectors to assure that tube flares meet the stringent requirements of MC-146.

EMM

Ground Support Equipment (GSE)

Several items of GSE, including the 924A computer, were installed in the automatic checkout equipment control room during this reporting period. S-II Quality Control attached test and inspection record (TAIR) workbooks to all items of GSE as they were installed in the control room. The TAIR workbooks are used to document all work performed on the equipment.

Special Development Devices (SDD)

The SDD-154 electrical terminal distributor, the SDD-129 patch rack, and the SDD-118 cabling, which are all part of the interconnecting network between the stage systems and the automatic checkout equipment, are being installed. The installation is being inspected to assure compliance with the applicable drawing, and any discrepancies are being noted in the applicable FAIR workbook to ensure corrective action.

Installation of the SDD-119 fluid distribution system, which will be used to connect the hydraulic GSE with the stage hydraulic systems, is nearing completion. All installations are being inspected, and any deviations from the applicable drawings are being documented in the FAIR workbooks.

QUALITY IN DESIGN

During this reporting period, Quality Control participated in the following reviews.

Document	Number
Procurement specifications	426
Material specifications	293
Process specifications	324
Specification control drawings	692
Quality control specifications	27

SUMMARY OF REVIEWS

Procurement Specifications

Two hundred and seventeen of the procurement specifications reviewed were returned to the responsible engineering groups for corrective action—82 for improper document callout, 38 for incorrect technical data, and 97 for incorrect or insufficient quality assurance provisions. The remaining specifications were satisfactory.

Material Specifications

One hundred and thirty-three of the material specifications reviewed were returned to the responsible engineering groups with recommendations for changes. Sixty-nine contained technical problems; and 64 needed more adequate quality assurance provisions, such as additional qualification tests and more adequate documentation of results. The remaining specifications were satisfactory.

Process Specifications

One hundred and sixty-four process specifications were returned with recommendations for technical changes; and 32 were returned for inclusion of more adequate quality assurance provisions, such as expanded inspection parameters to ensure complete coverage of all phases of the process. The remaining specifications were satisfactory.

Specification Control Drawings

The specification control drawings (SCD's) reviewed consisted of QEL acceptance inputs for 244 and the review of 448 in vellum form to verify the incorporation of previous recommendations made by QEL.

Quality Control Specifications

Twenty-seven quality control specifications were completed for release during this reporting period. Three of the specifications reviewed are listed below:

MQ0203-003, Control of Subcontractor's Chemical Milling Processes, dated 10 June 1964. Released EO M252360. Issued to establish control requirements for subcontractors.

MQ0501-004D, Inspection, Penetrant Method, dated 1 May 1964. Release EO M252356. Specification was released to incorporate MSFC directed change which was missed in the "C" revision.

MQ0501-010, Inspection, Ultrasonic, dated 3 June 1964. Release EO M252353. Issued to define Quality Control requirements applicable to current contracts.

INSPECTION AND TEST PLANNING

FUNCTIONAL SYSTEMS INSPECTION PLANNING

Parts protection and cleaning requirements are being included in all new planning and are being added to existing planning whenever changes are made. This added protection will greatly improve the quality of parts.

High-reliability parts are being handled in a special way to ensure that extreme care is used during their transportation. It will be possible, by use of the FAIR system, to determine the inspector who checked the packaging and to determine which packaging specification was referenced on the FAIR ticket.

EMM

EMM items were not originally identified with the letters EMM to distinguish them from vehicle or GSE parts. An inspection bulletin was issued that defined the means of acquiring correct identification. Manufacturing planning has adopted a method of identifying the FAIR tickets with the letters EMM and also identifying the part so that it can be used only for EMM.

BULKHEAD FABRICATION AREA

The aft common bulkhead (V7-313103-901) FAIR book for the Static Test stage has been revised. The data have been documented on inspection test instruction (ITI) forms and incorporated into the FAIR system.

The production FAIR book for the forward bulkhead subassembly for Static Test stage has been revised and updated to include the sequence of the 12 meridian welds for gore panels. The inspection coverage included the recording of weld joints and the documentation of interface dimensional verification of ITI forms. The latter portion of FAIR has not been revised, because changes have been made in the installation of the access door ring (V7-312107) and the access door (V7-312106). The new changes are being evaluated in order to accumulate information for proper planning and adequate coverage in the production FAIR system.

LH_2 CYLINDER AREA

The production-released FAIR books have been revised in accordance with the latest manufacturing sequence of operations. Inspection coverage includes an increase in the number of inspection points and requirements to document the critical dimensions by using the ITI forms, which will be integrated with the FAIR system. The recordings will provide historical data and traceability.

AFT SKIRT AND THRUST CONE STRUCTURE

Quality Control personnel are reviewing data obtained during the first phase of assembly of the aft skirt sections (V7-315501, 601, 701, and 801) and the thrust cone structure (V7-315101-901) for the Static Test stage (Figure V-1). The first portion of each production FAIR book has been revised and updated. Initial dimensions, interface areas, and variable data are being documented in the ITI.

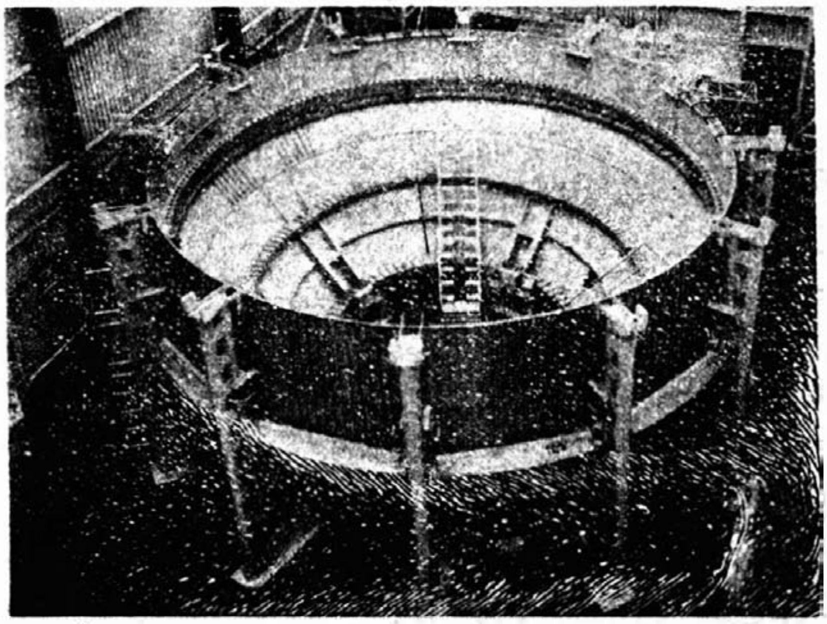
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Figure V-1. Aft Skirt and Thrust Cone Structure

AUTOCLAVE FIXTURE INSTALLATION

The installation of the autoclave fixture that will be used to bond the honeycomb subassemblies to the common bulkhead has been completed. A representative of the state safety department performed a pressure and temperature check and granted final approval. The next step—the functional acceptance test—will be accomplished by S&ID. Requirements set forth in the operating manual, the process specification, and the functional test procedure are being evaluated in order to define the quality control and inspection points for assurance of good bonding.

LH_2 CYLINDER FABRICATION

The insulation has been bonded on two DTT 7058-915, three V7-312702-905, and one V7-7312702-903 LH_2 cylinder panels for the test common bulkhead (TCB). The requirements for performance of ultrasonic inspection of these panels in accordance with Quality Control specification MQ0501-010 have been included in FAIR planning. The inspection of these panel has been satisfactorily performed.

PRODUCT EQUIPMENT INSPECTION RECORD (PEIR)

The final draft of the PEIR book for the installation of the computer-room consoles in the vertical assembly building at Seal Beach has been completed and released.

Quality Engineering personnel at Seal Beach have completed a rough draft concerning antenna checkout which will provide inspection verification of the proper functioning of the components of this unit. The console will be used at Station III of the vertical assembly building to test the components of Saturn S-II RF subsystems.

DOCUMENTATION

QUALITY CONTROL PLANS

A revision of the Saturn S-II Quality Control Plan (SID 62-285) was issued on 15 May 1964. In the program section, flow charts depict the major inspection control points and major quality control functions. These charts replace the information previously incorporated in Volume 2 of the plan. Section 1 pertains to Saturn S-II Quality Control, the Quality Control manager, and his organizational responsibilities. Sections 2 through 16 present the basic functions of the S&ID quality control system established to support S&ID contractual programs. Appendix A is a cross-reference index that relates NPC 200-2 requirements to appropriate paragraphs of the Saturn S-II Quality Control Plan and other S&ID documentation that spells out procedural methods of program accomplishment.

REPORTING

Twelve issues of the Monthly Quality Status Report (SID 62-446) and four issues of the Quarterly Summary of Quality Control Performance Audits (SID 62-555) have been submitted to NASA-MSFC. These reports provide current information on Saturn S-II quality progress and reflect the current status of product quality.

NONCONFORMANCE REPORTING

During this reporting period, 4422 nonconformance reports (NCR's) were processed on the Saturn S-II program.

The two most frequent causes of nonconformance (Figure V-2) during this reporting period were workmanship (61.1 percent) and insufficient or inadequate tooling (8.8 percent). Examples of problems and corrective action taken follow.

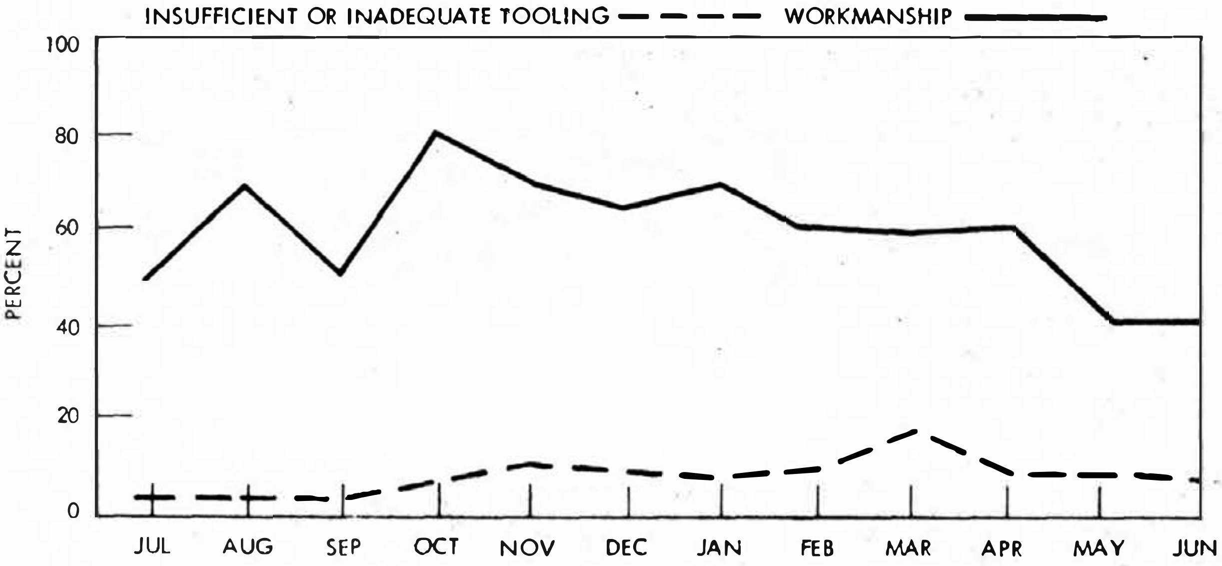

Figure V-2. Most Frequent Causes of Nonconformance

V7-313119 Panel - Forward Common Bulkhead (Seal Beach)

Problems

A gap check indicated that the bulkhead contour varied at the top of the meridian weld because of inadequate tooling.

X-ray revealed blow holes in the weld folds, deep undercut conditions, oxide inclusions, and porosity.

A blow hole was detected in the weld joint between panels when the operator failed to follow the manual override procedure.

Scratches and gouges on the V7-313105 panel were incurred by handling with the Vac-U-Lift sling.

Corrective Action

Tooling has been reworked to the proper contour, and alignment will be maintained by the use of the tooling holes.

The Quality Engineering Laboratory will monitor all controlled manual repair welding in accordance with schedule MR-5.

An observer will be assigned to ride with the welder to notify him when to switch to manual.

The ends of the sling have been covered with protective material, and personnel involved in bulkhead fabrication have been instructed to exercise extreme care while performing work on the bulkhead.

V7-312102 S/N CAA 1555 Forward Bulkhead (Seal Beach)

Problems

The meridian weld between panels had incomplete penetration because of an improper fit with the back-up bar.

Excessive post offset and insufficient penetration due to the loss of pressure on the hold-down fixture were noted.

The last 96 inches of the weld on the drop-through side showed no penetration, although the specification required 100-percent penetration. The malfunction was caused by a broken conductor and a shorted synchro-transmitter.

Corrective Action

The back-up bar has been cleared by means of modified tooling, and the incomplete penetration problem should not occur again.

Manufacturing Engineering and Tool Design Engineering have been requested to design a positive safety device. The pressure on the hold-down fixture has been increased to 40 psi during the welding process.

The connector and cable were replaced. Operational checkout will be performed prior to the weld operations. The carriage positioner will be observed continuously during the weld run by monitoring personnel.

V7-312202-901 S/N CAA 4153 LH_2 Upper Cylinder (Seal Beach)

Problems

On the drop-through side adjacent to the weld area, the parent metal had been ground below the metal surface at two places.

Heavy concentration of porosity on the RH fusion line and the drop-through side exceeded the allowable tolerance. The location of the tapered shim in this area increased the possibility of a contaminated weld area.

Rivet holes were drilled oversize.

Corrective Action

The use of a shield taped to the metal will prevent occurence of improper grinding during repair operations.

A more positive location for mating of the shim will decrease the possibility of weld contamination.

Employees have been made aware of the importance of rivet holes and correct procedures.

QUALITY CONTROL PERFORMANCE AUDITS

From 1 May 1962 through 30 June 1964, 1428 audits were conducted at the Downey facility. During the period, 1 January through 30 June 1964, a total of 196 audits were conducted at the Tulsa facility. The results of these audits are listed in Tables V-1 and V-2.

Table V-1. Downey Audits

Audit	Conducted	Satisfactory	Action Pending	Action Completed
Product	163	133	1	29
Conformance to procedures	727	546	46	135
Procedure review	216	92	47	77
Personnel performance	322	235	11	76
Totals	1428	1006	105	317

Table V-2. Tulsa Audits

Audit	Conducted	Satisfactory	Action Pending	Action Completed
Product	0	0	0	0
Conformance to procedures	193	107	25	61
Procedures review	0	0	0	0
Personnel performance	3	3	0	0
Totals	196	110	25	61

A more detailed account of these audits may be found in the Quarterly Summary Quality Control Performance Audits Saturn S-II reports, SID 62-555-7 through SID 62-555-10.

LABORATORY ACTIVITIES

RELEASE OF PENETRANT INSPECTION SPECIFICATION MQ0501-004C

The revised specification on penetrant inspection has been released. Major additions to the document include sections on the use of penetrants that have been approved for use on metal surfaces that will subsequently come in contact with liquid oxygen. All penetrant materials that will be used on LOX-wetted surfaces must meet the requirements of specification MA0115-005, which stipulates the testing compatibility requirements for materials for liquid oxygen systems.

LOX-SAFE MARKING

Various marking methods for use during radiographic inspection of aluminum welds used in liquid oxygen systems have been studied. Radiographic inspection requires a marking system to indicate the type, size, and location of each X-ray defect at the weld surface. It was recommended that sodium hydroxide solution be used with a Koh-I-Noor/Acetograph technical fountain pen to mark aluminum welds in LOX-wetted systems. This method of marking has now been implemented.

PENETRANT INSPECTION OF LOX-WETTED SURFACES

Problems encountered in the airless spraying of PGP-26BF penetrant have been resolved. The wash was satisfactory, but the developer used dried too fast to allow for a fine, even coating. The process was changed to call for a dry-powder developer instead of the wet developer. The first production gore for which this system was used was penetrant inspected and accepted. Appropriate changes have been incorporated into the specification.

FABRICATION OF CPR 18-6 POLYURETHANE FOAM PARTS

A problem was encountered in the fabrication of polyurethane foam seals (V7-954072 and V7-954073). Upon separation of the seal mold, the polyurethane foam (CPR 18-6) was adhering to the mold surfaces. A revised curing procedure—preheating of the mold and coating of the mold surface with a special parting agent—permitted proper mold separation, and satisfactory parts are now being produced.

METALLURGICAL PROPERTIES OF ALUMINUM ALLOY 2014 AFTER THERMAL BONDING AT SEAL BEACH

Most of the Saturn S-II tankage is being fabricated from aluminum alloy 2014. Because the alloy being used is heat treated by means of two different time-temperature cycles (those of NAA and the aluminum supplier), the effects of thermal bonding on mechanical properties as a function of the prior thermal treatments has been evaluated. The specimens treated by NAA and the aluminum supplier were affected similarly by the thermal bonding cycle, and both exhibited satisfactory mechanical properties after bonding. Coupons from trim areas of parts initially bonded at Seal Beach will be tested for compliance with blueprint mechanical-property requirements.

ANALYTICAL CHEMICAL EQUIPMENT

Newly acquired analytical chemical equipment has broadened the technical capabilities of the laboratory. Included in the new equipment are two Cosmodyne CS. 4. 4 cryogenic liquid samplers: one for sampling liquid nitrogen and oxygen and one for sampling liquid hydrogen. A LECO oxygen analyzer has been received and will soon be in operation. This instrument will allow rapid oxygen determinations to be made on metal alloys. To permit chemical analysis of the components of organic liquids and gases, a Perkin-Elmer gas chromatograph, Model 154, has been put into operation. This device is particularly useful in the analysis of paint thinners, organic cleaners, and other complex organic compounds. Basic molecular studies of mixtures may be performed with the new Beckman IR-5A infrared spectrophotometer. This device is principally applicable to studies of organic solids, liquids, and gases.

METALLOGRAPHIC EQUIPMENT

The capabilities of the metallographic unit of the laboratory have been expanded by the addition of two new sample mounting presses, a cutoff wheel, and manual and automatic polishing equipment. Complete photographic and darkroom facilities have also been added in support of basic material studies and failure analyses.

CONTAMINATION AND COMPATIBILITY

In support of Saturn hydraulic-component quality, a clean room has been activated in Building 1. Work is proceeding toward the completion of a contamination control laboratory at the Seal Beach facility. Routine contamination and compatibility efforts for the past year included 1193 dust counts and the inspection of 638 components, 36 filter elements, and 332 hydraulic fluids. Nonroutine activities included the construction of a LOX impact tester.

ULTRASONIC FIXTURE

Construction of the ultrasonic assembly has been completed. Six LH_2 panels have been successfully inspected and completed. After completion of certain minor modifications and the satisfactory inspection of the aft common bulkhead, final acceptance of the equipment can be accomplished.

TRAINING AND CERTIFICATION

The number of Quality Control personnel who hold valid inspection certificates is adequate for the current manufacturing rates. The number of personnel and the courses they have completed are given in Table V-3.

Table V-3. Certified Inspection Personnel

Course Title	Saturn S-II	Supporting Departments
Soldering	52	97
Crimping	48	75
Potting	3	16
Module Welding Inspection	6	26
Electronic Module Encapsulation	1	
Visible Dye Penetrant Type II, Class 3	12	8
Magnetic Particle Type I		3
Radiographic Film Interpreter	10	26
Fluorescent Penetrant		6
Ultrasonic Types I and II		7
Fusion Welding Inspector	31	128
Power Hoist	4	3

Additional training courses attended by Quality Control personnel during this reporting period included the following:

DITMCO - 610B Operation and Programming
S-II MISTRAM Tracking Aid
S-II Electrical System
S-II Instrumentation System
S-II Program Orientation
S-II Systems and Associated GSE Familiarization
S-II Telemetry Systems

J-2 Engine Indoctrination

Engine Actuation System
Reliability Indoctrination
Tektronics Test Equipment Operation

Bulkhead Hydrostatic Testing

Cryogenics and Safety
Leak Detector CEC-24-120A
Battleship Structures
Battleship Propellant Systems
Battleship Instrumentation

High Pressure Systems and Safety
Storable Propellant and Safety Equipment
X-ray Machine Maintenance
S-II Propellant System
Radiation Safety

Handling and Processing of Explosives
Computer Programming (CDC924-A)
S-II Structures
S-II Computer Complex
J-2 Engine GSE

Electrical Checkout Station (C7-200)

Automated Wire List

Hydrostatic Testing
FAIR
S-II SSB/FM/FM System
Engineering Technical Requirements
Engineering Order System
Electrical Blueprint Reading
Parts Protection for Planners

VI. MANUFACTURING

MILESTONES

Progress in the S-II Manufacturing program during this reporting period was marked by several milestones. Among these were the completion of the deliverable mockup, as required by contract, and its delivery to MSFC; the fabrication and completion of the second quarter-scale test LH_2 tank; the successful bonding of the first common bulkhead; and the first deliveries of GSE for Battleship and EMM. Fabrication of flight-weight systems for the EMM and Battleship was also begun during this report period.

DELIVERABLE MOCKUP

The S-II stage deliverable mockup (fore and aft sections) was completed and delivered on schedule to MSFC in October 1963 for use by S-IVB and S-IC contractors in establishing accurate stage interface.

SECOND QUARTER-SCALE TEST TANK

A second quarter-scale LH_2 test tank (Figure VI-1) was completed in June and delivered to the S-II engineering development laboratory in Downey. The tank was designed to prove the integrity of insulation and to be used for instrumentation tests. The structure and insulation were fabricated by suppliers, and the application of insulation was the responsibility of S-II Manufacturing. The tank is stored temporarily at S&ID, Downey.

EMM

The EMM program has been integrated to allow S-II Manufacturing to install mockup J-2 engines, dummy wiring, and systems mockups in the structures and subsequently to allow the removal of mockup components for replacement with flight-weight equipment as it becomes available. (See Figure VI-2.)

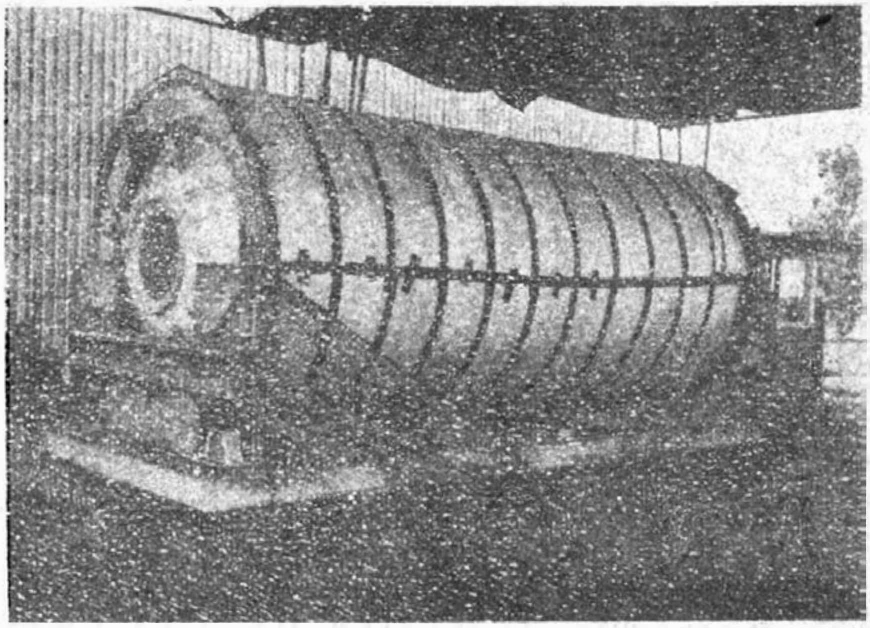

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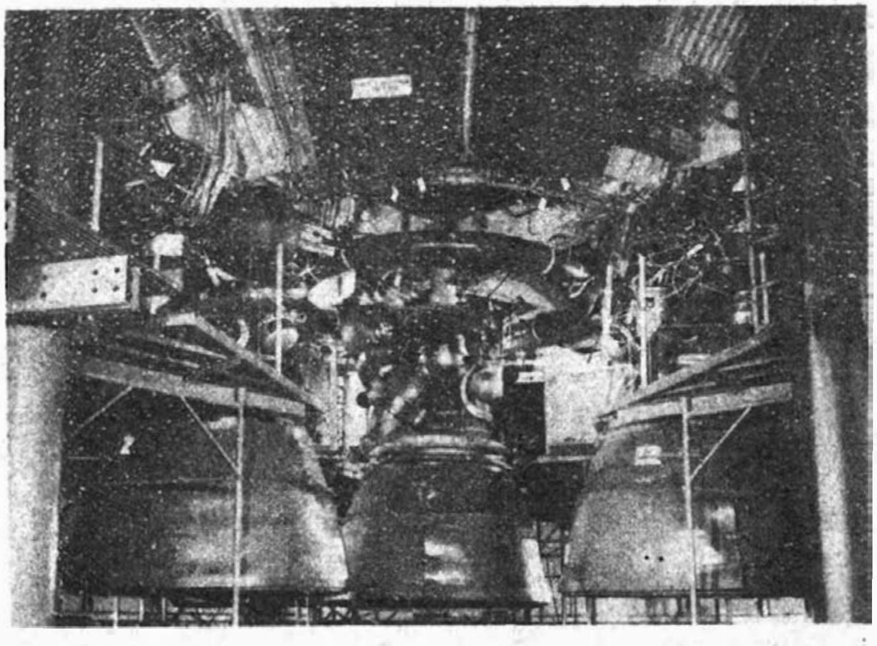
Figure VI-1. Second Quarter-Scale Test Tank Before Shipment



SID 810

Figure VI-2. Interior of EMM Aft Area (Showing Block III J-2 Engines and Mockup Harnesses)

By 15 March the developmental portion of the EMM was completed. The structures, including the forward, aft, and systems tunnel areas, as well as mockup trunk-wire harnesses, were reviewed during a design-evaluation inspection. Four Block III J-2 engines, fabricated at Rocketdyne, were installed and inspected at this time. Subsequently, mockup trunk-wire harnesses were removed, measured, and transferred to the S&ID Compton facility for flight-weight fabrication. Approximately 65 percent of flight-weight harness requirements for the EMM have been completed.

Fabrication of GSE for the EMM program increased notably during the latter part of this report period. Checkout consoles are being completed and delivered to the T & O area in Downey. Ten consoles were completed at the end of this reporting period, and approximately 15 more consoles are expected to be completed by late August.

All EMM mockup systems were completed during the last year. Almost all have been installed, inspected, and approved. Mockup systems are being removed and flight-weight components are being fabricated and installed.

BATTLESHIP

S-II Manufacturing completed fabrication of a mockup forward skirt and a work platform. A heavy-duty thrust structure was designed and fabricated at the Los Angeles Division (LAD), and an LH_2 and LOX tank was designed and fabricated at Rocketdyne. These items were delivered to SSFL basically on schedule. (See Figure VI-3)

S-II Manufacturing also has the responsibility of fabricating a complete set of prototype systems (including instrumentation, electrical, propulsion, and flight-control systems) and GSE for Battleship single-engine and engine-cluster firing.

Limited progress has been made in the fabrication of these systems because of various redirections in design. Although improving the integrity of the systems, these changes have affected the fabrication program. However, S-II Manufacturing is providing subassembly support of these systems. Total wire-harness assembly requirements are 90-percent complete; electrical and electronic work is 90-percent complete; and instrumentation, subcontracted to the Autonetics Division by interdivisional work authorization, is approximately 40-percent complete.

Two GSE checkout consoles and nine special development devices were fabricated by S-II Manufacturing, approved by NASA, and shipped to SSFL. Also completed as were various auxiliary, handling, and servicing models. (See Figure VI-4.)

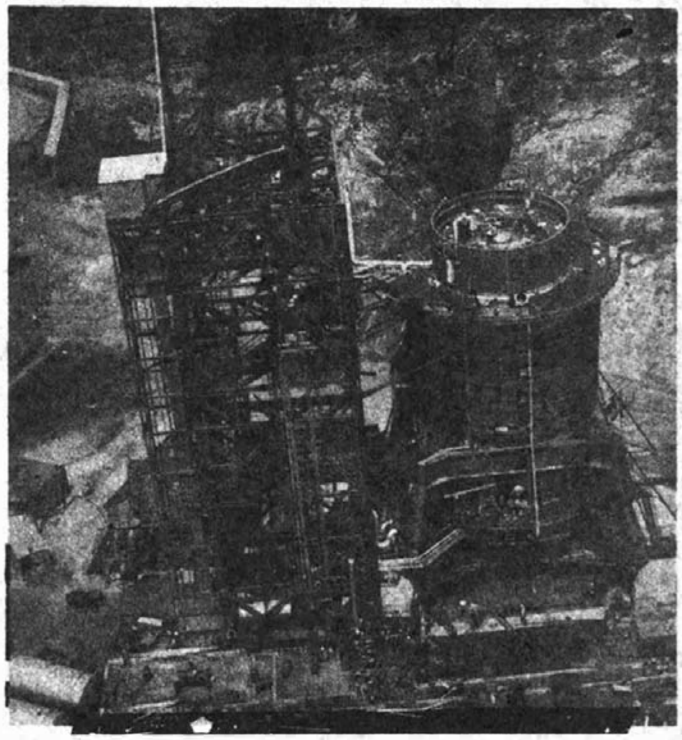


Figure VI-3. Battleship Test Site

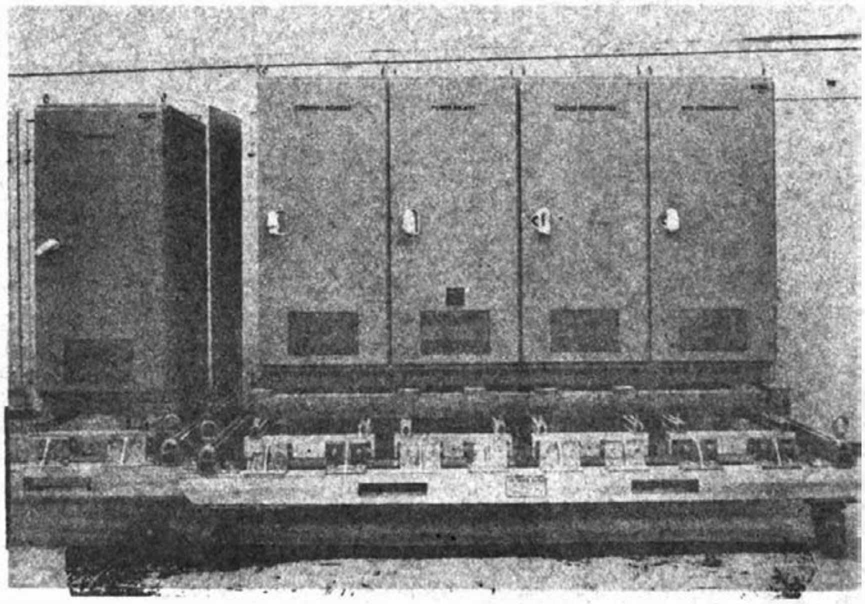


Figure VI-4. Remote Power Distribution Rack (C7-41) Completed and Ready for Shipment

STAGE ASSEMBLY

SUPPORT

Tooling and Facilities

S&ID's Seal Beach facility became operational during this report period. The aft facing sheet automatic weld jig (T-7200003) was certified and went into production in August 1963. In September, the bulkhead "dollar" welder (T-7200077) that installs the dome-center plates in S-II bulkheads was certified.

All bulkhead and LH_2 cylinder automatic weld fixtures have since been fabricated and certified. First article inspection of nearly all tools has been approved. The S-II program at Seal Beach also has been supported by various bulkhead and cylinder processing facilities, handling, pickup, and inspection fixtures. Additional tooling requirements as dictated by the J-1 schedule are being fabricated for stage vertical assembly operations.

Last February the vertical assembly building (VAB) at Seal Beach (Figure VI-5) was partially occupied by S&ID personnel. At that time S-II Manufacturing began installation of assembly tooling and fixtures in Stations I, II, and VI. Since then, all VAB assembly stations have been occupied, although minor station construction operations continue. The Static Test tower at Seal Beach is also complete and is being prepared for structural testing of the Static Test stage.

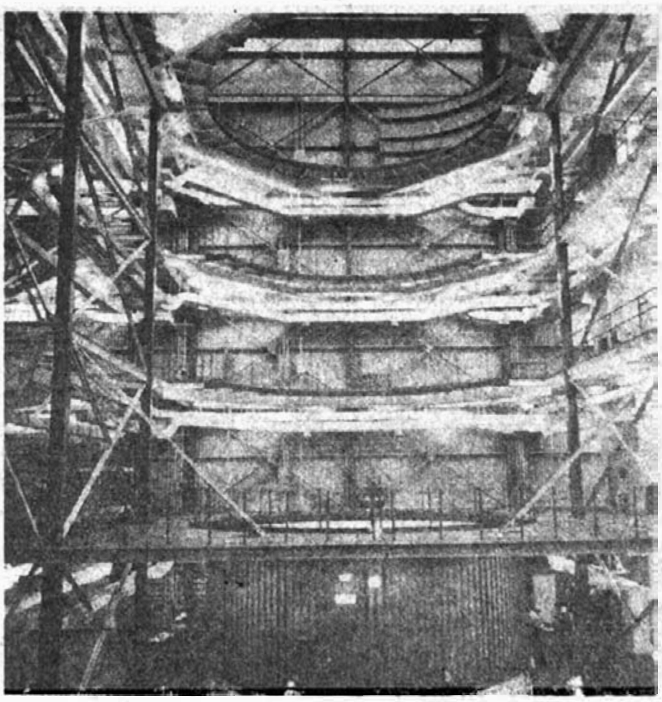


Figure VI-5. VAB Station IV, With S-II-S LH_2 Bulkhead/Cylinder Assembly and Forward Skirt

Detail and Major Component Support

LAD is responsible for supporting Seal Beach assembly operations with bulkhead and LH_2 cylinder components. Originally responsible only for fabrication of gore segments and three of the LH_2 cylinder quarter panels. LAD's responsibility now includes gore subassembly and the fabrication and detail subassembly of all LH_2 cylinder quarter panels and the bolt ring. LAD also assisted Douglas Aircraft Company in the development of bulkhead gore fabrication by the stretch-form process. Stretch-forming, which has replaced high-energy forming of thin gore material (0.125-inch), results in a higher quality of part and therefore facilitates assembly operations. An investigation is being made of the feasibility of stretch-forming thicker material.

The fabrication and subassembly of such major assembly components as thrust cones, skirts, and interstages is the responsibility of the S&ID Tulsa facility. Tulsa's support to S-II Manufacturing has been satisfactory and basically in accord with current schedules and Manufacturing's pacing items.

ASSEMBLY

Static Test Stage (S-II-S)

The S-II-S common bulkhead aft facing sheet was structurally completed, with the dollar plate installed, in early February. The assembly, first of its kind, took approximately 23 weeks. In a like period of time, the second and third facing sheets (for the CBTT and the S-II-T) and approximately half the fourth (for the S-II-F) also were completed. This acceleration is due to improved assembly methods and tooling gained from experience during assembly of the first end item.

Similar acceleration has been experienced in other assemblies and is expected to increase in subsequent assembly phases. Honeycomb core insulation was laid up and bonded to the aft facing sheet in May after extensive measurement and testing.

The forward facing sheet was completed in late May and approximately 8100 individual points were measured on the interior surface. Evaluation of these measurements provided the parameters to machine the honeycomb core of the aft facing sheet to achieve 100-percent contact with the forward facing sheet. Two impression checks (Figure VI-6) were made with the forward and aft facing sheets to verify contact. Results showed better than 97-percent contact in all cases.

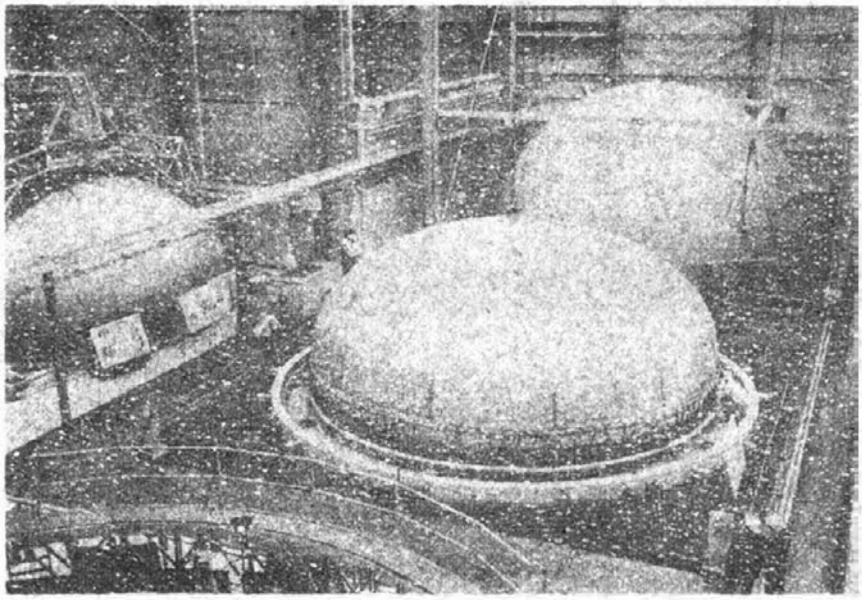


Figure VI-6. S-II-S Common Bulkhead During Impression Check

The S-II-S forward and aft facing sheets will be bonded to form the common bulkhead by mid-July. This will be followed by ultrasonic inspection and preparation for vertical buildup.

Assembly of the S-II-S LH_2 forward bulkhead was completed in mid-February. Meridian welding was facilitated because of experience gained during assembly of the S-II-S common bulkhead aft facing sheet and the relatively uniform thickness of the bulkhead gores.

In April, the LH_2 forward bulkhead and the upper LH_2 cylinder were welded in Station II, VAB. The first attempt resulted in thermal expansion during the circumferential weld. After problem evaluation and correction, the second circumferential weld was made and approved. The assembly (Figure VI-7) has been painted and is being mated to the S-II-S forward skirt.

Assembly of the LOX aft bulkhead is to begin in July 1964. Following completion of assembly, testing, and processing, the bulkhead will be transferred to the VAB to be fitted and welded to the S-II-S common bulkhead to form the S-II-S LOX tank assembly.

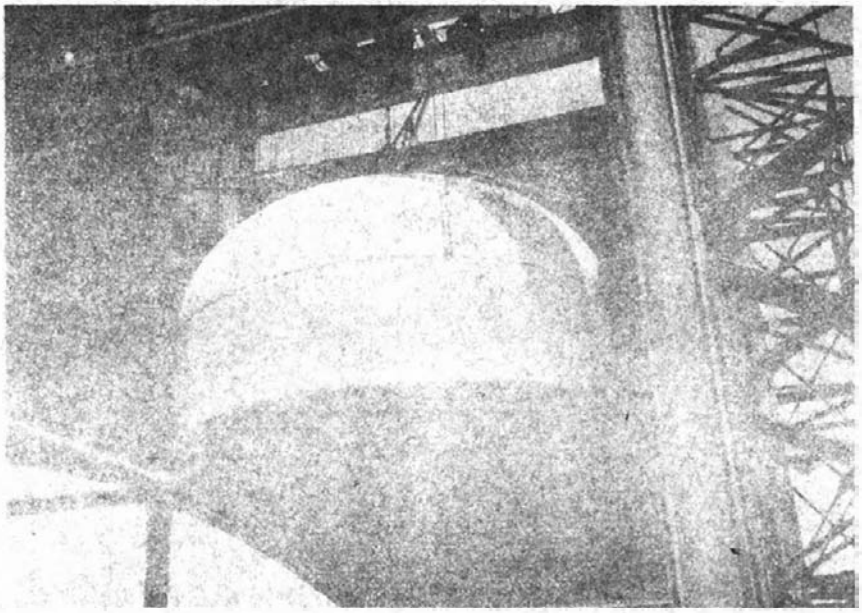


Figure VI-7. S-II-S LH_2 Bulkhead/Cylinder Assembly

All six LH_2 cylinders for the Static Test stage were assembled and transferred to the VAB, where they have been painted prior to vertical assembly. (See Figure VI-8.) Preparations are being made for circumferential welding of the lower and lower-intermediate LH_2 cylinders in VAB Station II.

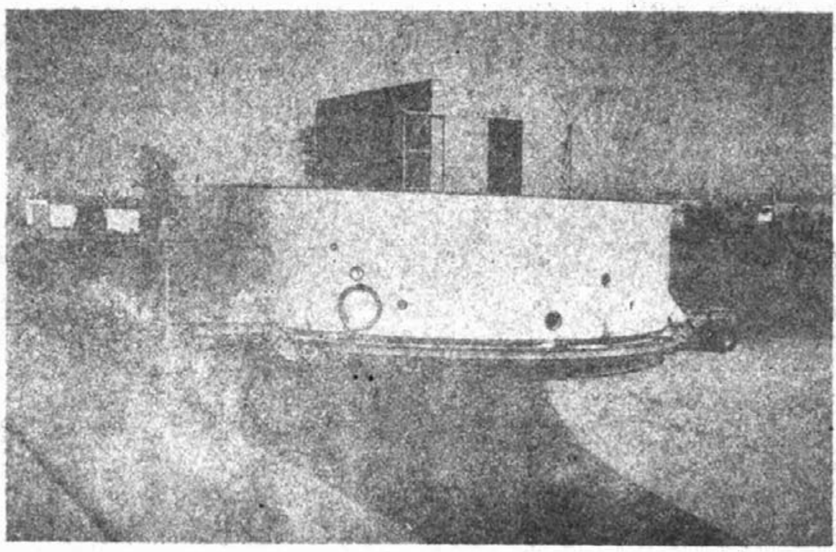


Figure VI-8. Completed Lower Intermediate LH_2 Cylinder

Assembly of the S-II-S thrust structure and aft skirt (Figure VI-9, VI-10) began last October after delivery of the final components from Tulsa. By June, the aft skirt and thrust structure were mated and the center engine beam was installed. The assembly was transferred to the VAB and prefit to the static firing skirt delivered from Tulsa. The thrust structure assemb has been painted preparatory to final mating to the static firing skirt.

Figure VI-9. S-II-S Thrust Structure/Aft Skirt Assembly

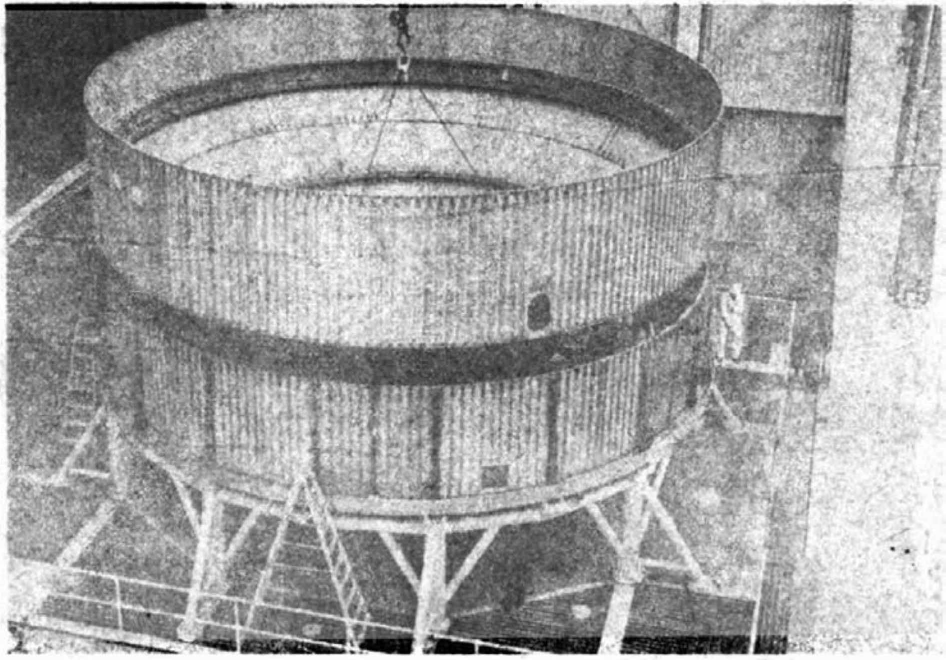


Figure VI-10. Fitting S-II-S Thrust Structure/Aft Skirt Assembly to Static Firing Skirt

The S-II-S aft interstage panels will be delivered from Tulsa in July. The aft interstage is being temporarily assembled to determine its acceptability with respect to form, fit, and function.

Common Bulkhead Test Tank (CBTT)

Both the CBTT LH_2 forward bulkhead and the common bulkhead aft facing sheet have been assembled. The LH_2 forward bulkhead will next be leak-tested prior to insulation, and the common bulkhead aft facing sheet is to be insulated with honeycomb core starting in July.

The lower and the modified upper LH_2 cylinder panels (Figure VI-11) have been fabricated and insulated. Assembly of the LH_2 cylinders is expected to begin in August. The bolt-ring panels are now being fabricated at LAD.

The CBTT forward skirt, fabricated in Tulsa, has been received at Seal Beach. Final assembly will begin after completion of the LH_2 forward bulkhead.

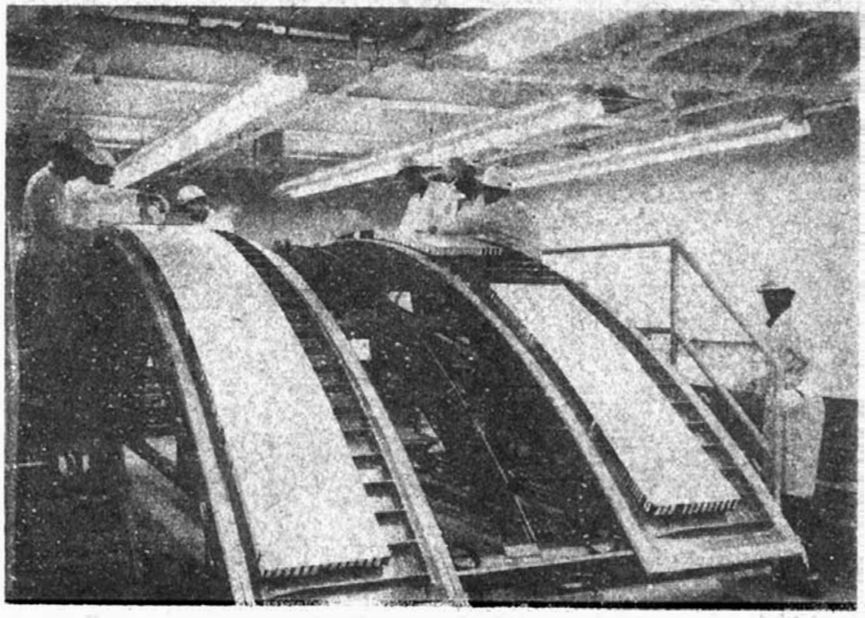


Figure VI-11. Insulation of Lower LH_2 Cylinder Quarter Panels for CBTT

All-Systems Test Stage (S-II-T)

The S-II-T common bulkhead aft facing sheet has been assembled. It is being inspected prior to the processing operations which prepare it for honeycomb core insulation. The thrust-cone is being assembled (Figure VI-12) and will be mated to the aft skirt in late September.

Quarter panels for five of the six LH_2 cylinders have been fabricated at LAD. Assembly of S-II-T LH_2 cylinders began at Seal Beach in June, when the first quarter panels for the upper LH_2 cylinder were insulated. Six quarter panels, including those for the upper and upper-center LH_2 cylinders, have been insulated and are being ultrasonically inspected to detect possible voids in the insulation bond.

S&ID Compton is responsible for the fabrication of systems for the S-II-T stage. Initial fabrication is proceeding satisfactorily.

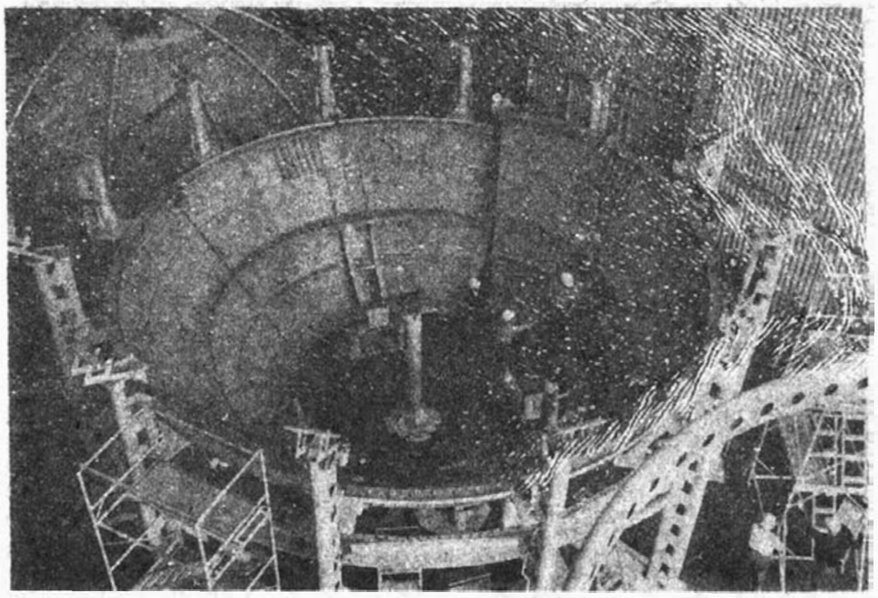


Figure VI-12. Assembly of S-II-T Thrust Cone Panels

VII. TRANSPORTATION

FULL SCALE MODEL

The Saturn full scale model was delivered to Huntsville in October 1963. The unit arrived on schedule in excellent condition.

ROUTE CLEARANCES

All job orders for utility companies to provide adequate clearances for the Saturn segments and stages to be delivered from Seal Beach to Santa Susana were completed in October 1963.

The purchase order with the California highway department for road modifications along the route—such as providing for adequate turning radius for ingress and egress to the freeway, and adequate bypass of overhead obstructions was finalized in February 1964. All modifications will be completed in time for a November test run utilizing the type I transporter.

BATTLESHIP THRUST STRUCTURE

The Battleship thrust structure was transported from LAD to the Santa Susana test site on 2 November 1963. The equipment departed LAD at midnight and arrived at the base of the Santa Susana access road at 6:00 a.m. The unit remained there until 8:30 a.m. to allow the morning traffic to clear the access road and then continued to the test site where it arrived at 11:20 a.m. The unit was 33 feet in diameter, 14 feet 6 inches high (loaded on truck), and weighed 30 tons. The transport was accomplished via commercial carrier under NAA direction and supervision.

FREEWAY HOURS OF MOVEMENT

A representative from the State highway division indicated that State personnel have reviewed the traffic flow pattern on the Ventura Freeway and decided to allow the Saturn vehicles to enter the freeway at 11:00 p.m. Authority will be obtained from other municipalities to allow Saturn shipments to depart the Port Hueneme dock at 10:00 p.m. This will allow time for the units to clear the public roadways and to enter NAA property by 6:00 a.m.

WEST COAST BARGE

A NASA Huntsville representative has indicated that the modifications to the YFNB-20 barge used for West Coast marine transportation will be finalized in time for the 1 November 1964 test run with the type I transporter. No completion date for barge modifications is available at this time.

FREEWAY BYPASS ROUTES

On 6 April 1964, a Facilities representative and a Transportation representative met with State highway officials to give final approval of bypass routes around freeway obstructions from Port Hueneme to Santa Susana. Approval resulted from recent simulated road tests run at S&ID, Downey.

TREE TRIM

Extensive time was spent tracing owners of property along the highway route between Port Hueneme and Santa Susana and acquiring signed authorization to trim or remove trees lining the roadway which impeded safe transport of the Saturn segments and stages. Approximately 90 percent of the required approvals have been obtained, and contacts and negotiations are being made for the remainder.

It is estimated that the trimming and removing of trees will commence about 1 September 1964 and that the work will meet the transportation requirements of the Saturn program.

STAGE SEPARATION SIMULATOR DELIVERY

On 2 June 1964, the Saturn stage separation simulator was transported from the Downey facility to the El Toro facility. This unit, 6 feet in height and 35 feet in diameter, was moved by commercial trucker under S&ID

supervision. The convoy departed Downey at midnight and arrived at El Toro at 5:00 a. m. A Saturn Transportation representative assisted the convoy movement.

TRANSPORTER

The type I transporter is fully assembled at the American Machine & Foundry plant at York, Pennsylvania and testing is scheduled to commence on 29 July 1964. The present delivery schedule will adequately support the Saturn program.

PRIME MOVERS

A NASA Huntsville representative has indicated that the two M-26 tank retrievers to be used as prime movers for the Saturn stages will be delivered to S&ID by 1 August 1964.

VIII. LOGISTICS

FIELD ENGINEERING AND TRAINING

S-II training has expanded greatly in scope in the last year. The transition from the familiarization phase—which involved only one formal S-II familiarization course of 44 hours—to that of detailed systems instruction was accomplished early. By the close of the period 22 different courses were available for scheduling to meet training requirements of various S-II and divisional departments. These courses are oriented specifically to flight articles and the Battleship test stage. The curriculum is being expanded to include SDD instruction and other special courses needed to satisfy progressive requirements.

Although classroom instruction is concentrated in the Downey area, it has been extended to include Santa Susana, Compton, and Seal Beach. Individual S-II briefings have been given to personnel of associate contractors and suppliers.

SUPPLY SUPPORT

Initial support parts to activate the EMM and Battleship test stages were delivered. A total of 2068 GSE and 556 stage support parts were involved for the EMM and 1830 GSE and 650 stage support parts for Battleship.

Santa Susana warehousing and supply support have also been activated.

Meetings are being held with Engineering, Manufacturing, Material, Test & Operations, and Quality Control to establish concurrence on support parts. The meetings also serve as a basis for communicating to engineering and test personnel the support concepts, selected support parts, and quantities needed. Logistics provides necessary data—such as drawings, EO's, test data, maintenance analysis, and formula results—for a comprehensive analysis in support of the systems. NASA representatives who attended the meetings have approved this mode of operation.

Concurrence meanings have been completed for 62 GSE and SDD end items and for four vehicle systems.

MAINTENANCE ENGINEERING

Preliminary Logistics Support Analysis reports have been completed. These cover peculiar equipment for SDD, EMM, and the Battleship and All-Systems test stages. Revisions have been made in checkout, servicing, handling and auxiliary GSE documentation and in MTF and MILA maintenance analysis reports.

SUPPORT DOCUMENTS

A total of 14 preliminary support manuals were prepared and delivered to MSFC. (See Table VIII-1)

The first revision of the Saturn S-II General Manual also was completed and delivered.

Table VIII-1. Completed Manuals

Number	Title	Date
SM-S-II-01	General (Revised)	1 Aug 1963
SM-S-II-02	Transportation	30 Oct 1963
SM-S-II-04	Stage Handling and Maintenance	15 Apr 1964
SM-S-II-06	Propulsion System Checkout	3 Jan 1964
SM-S-II-07	Flight Control System Checkout	12 Oct 1963
SM-S-II-08	Instrumentation System Checkout	23 Jan 1964
SM-S-II-11	Mechanical Checkout Station Maintenance	23 Jan 1964
SM-S-II-12	Command Destruct Receiver Checkout Rack Maintenance	15 Mar 1964
SM-S-II-13	Ground Equipment Test Set Maintenance	18 Dec 1963
SM-S-II-14	Electrical Checkout Station and Static Firing Station Maintenance	25 Mar 1964

Table VIII-1. Completed Manuals (Cont)

Number	Title	Date
SM-S-II-15	Telemeter Checkout Station and Time Code Rack Maintenance	10 Jun 1964
SM-S-II-16	Digital Data Acquisition System Checkout Station Maintenance	10 Mar 1964
SM-S-II-18	Handling Auxiliary and Miscellaneous Checkout Equipment Maintenance	10 Sep 1963
SM-S-II-20	Systems Inspection	13 Dec 1963
SM-S-II-21	GSE Inspection	6 Jan 1964

DOCUMENTATION AND PHOTO

All contractual documentation requirements for the year have been fulfilled. All formal documentation prepared under contract NAS7-200 is listed in SID 62-430, Documentation List for Saturn S-II Stage. The listing, published monthly, is alphabetically arranged by major subjects, with all published reports, specifications, and letters listed numerically in each section.

On-site photographers have been assigned to cover the Saturn S-II activities at Seal Beach, Santa Susana, and Downey/Compton. This arrangement has increased program visibility and curtailed travel to these areas. When required, services were furnished to remote areas and subcontractor locations.

The Saturn S-II Logistics Support Plan, SID 62-286, was revised as of 1 May 1964 to conform to the format requested by NASA and was delivered to MSFC on schedule.

MODIFICATION AND REPAIR

The Logistics Support Plan, SID 62-286, has been revised to include advances in modification and repair (M&R) planning. Included were the definition of M&R responsibility for major modifications and coordination of modification requirements. The format and methodology for a master repair list (MRL) is also included, and milestone charts have been brought up to date to reflect current schedules.

The modification and repair center has been established next to the manufacturing lines at Compton. This was done to obtain maximum use of production capabilities in handling reparable hardware from test sites. To date, 15 items have been processed. The initial MRL, identifying 1350 potential reparable items, has been released.

IX. MANAGEMENT CONTROL

MILESTONES

COMPLETED
- Fabrication of forward bulkhead, S-II-S
- Vertical Assembly Building
- Santa Susana Field Laboratory
- Receipt of all EMM engines
- Receipt of first fireable Battleship engine
- Battleship stage
- Mockup phase of EMM
- Program plan (based on Schedule J-1)

INITIATED
- Installation of flight weight systems, EMM
- Activation phase, Battleship test program

Schedule 3-D (NASA J-1) was negotiated and implemented as of 26 December 1963 to reflect a funding level of $129.5 million.

Sub-tier schedules were developed in support of the master schedule and were published in the semiannual program plan. Additional summary schedules are being developed for the following:

- Detailed operating procedure development
- Airborne systems
- GSE/SDD
- Detail project schedules for:
  - EMM
  - Battleship
  - S-II-S (static)
  - CBTT (common bulkhead test tank)
  - S-II-T (All-Systems)
  - S-II-F (facility)
  - S-II-D (dynamic)
  - S-II-1 (first flight stage)

Copies of the GSE/SDD schedules are forwarded to NASA and include the following: identification number, nomenclature, configuration, serial number, allocation, and status.

PERT

In the last year, S-II PERT developed and perfected many techniques which demonstrate that PERT, besides being a reporting medium between management and the customer, can be used effectively as an internal planning and monitoring tool at all management levels.

Among the more significant accomplishments was the conversion of all S-II PERT networks from event orientation to activity orientation, the establishment of departmental responsibility codes, and the development of a composite index of fragnet and responsibility information. Activity-oriented networks provide a twofold purpose:

1. Absolute compatibility between PERT networks and computer printouts
2. A sound basis for planning, unequivocal network logic and program interpretation, and valid interfaces among different tasks and functions

The establishment of departmental responsibility codes provides a basis for effective dissemination of PERT computer printouts for program analysis and for management evaluation of corrective action.

Several specific MSFC requests were received and satisfactorily carried out. One was the construction of an S-II PERT summary network containing some 500 significant milestones representing more than 11,000 activities of the integrated network.

With the establishment of specific flight and test-vehicle projects under separate project managers, S-II PERT assigned personnel to support this area of activity. Also in support of project management, stage computer shredouts are supplied regularly to PERT project coordinators for use in critical path analyses. In this way, project managers are provided with material for vehicle status evaluation. These evaluations, in conjunction with schedule status, form the foundation and backup information for vehicle project reports.

A number of major contract changes were initiated and negotiated by S&ID and MSFC, including the deletion of the nonpropulsive vehicle (S-II-IFD) and the changing of the master program schedule to Schedule 3 (NASA J-1). These changes had significant effect on S-II PERT networks, which evolved to reflect changes in program concept. To incorporate all authorized contract changes, all fragnets are continually modified through a direct tie-in with the change control board and master change records. Change implementation plans are examined in detail for compatibility with PERT critical path analyses for programs affected.

To make S-II PERT networks more meaningful and to provide backup information for program evaluation, these networks are being continually expanded to provide:

1. Full GSE coverage for all usage points
2. Detailed visibility in Test and Operations for EMM, Battleship, All-Systems stage (S-II-T), and facility checkout stage (S-II-F), as well as in activities of the engineering development laboratory for tests on the common bulkhead test tank (CBTT) and the static test stage (S-II-S)

To satisfy contractual requirements, S-II PERT redrew networks at specific times, as agreed with MSFC. A satisfactory PERT quarterly review was conducted, during which the management laid special emphasis on the role of PERT in the evaluation of problem areas and the development of corrective plans of action. Improved methods of operation are continually explored to reduce costs and increase efficiency.

One significant advance is the development of a new method of transmitting PERT computer input to MSFC. A customer report tape is generated during computer processing of PERT data and transmitted to Huntsville by a tape-to-tape method which uses Western Union teletype equipment coupled with the IBM 7707 complex. The generation and hand manipulation of computer card decks is thus obviated, and more accurate and expeditious transmittals result.

In further recognition of the S-II PERT program, the S-II flight control fragnet was selected as the pilot model network for PERT/Cost at S&ID. This program is well on its way, and should meet the target date of 1 October 1964. Feasibility under the present ground rules has been proven, and activation of this system for later programs should be possible without unduly upsetting present accounting methods.

COST

Problems associated with undetermined funding and scheduling were encountered in GFY 1964. Original funding levels had to be revised and curtailed.

During the first quarter, the first impact of changes for the year was realized and a revised funding forecast was submitted. This forecast showed \$102 million in basic funding, \$20 million for probable changes, and \$10 million for unidentified changes to support Schedule 2 during GFY 1964. Later in the same quarter at NASA direction, a series of plans, based on varying funding levels, was begun in support of Schedule 2. It soon became apparent that funding requirements would not be met, and a series of proposed revisions was undertaken.

Early in October 1963, S&ID advised NASA that immediate implementation of Schedule 3 (H revision) was required to minimize the impact of funding limitations.

In November, NASA directed S&ID to plan effort within a \$94 million basic funding limitation through Change Order 72. The Change Order was subsequently revised to \$105 million and an additional \$10 million was provided for unidentified changes.

In December 1963 an S-II master schedule was proposed for \$94 million in basic funding. Subsequently, NASA Schedule H was received, and an S-II master program schedule was prepared on the basis of a fiscal year funding requirement of \$120 million.

The problems of undetermined funding and schedule which beset the program from September through December were further aggravated by a hiring freeze initiated by NASA on 9 December and extended through the first week of January 1964.

Late in December NASA Schedule J-1 (Schedule 3) was received, indicating cumulative funding through GFY 1964 of \$228 million.

In March NASA announced that funding for FY 1964 would be limited to \$129.5 million, \$4.5 million less than originally indicated. In reply, S&ID stated that cumulative funding could be met only by deferring commitments and depleting reserves to support Schedule 3 (J-1).

By April, S&ID had received cumulative funding totaling $214.5 million and indicated that this amount would be depleted by 1 June 1964. S&ID reiterated the requirements for FY 1964 funds of $129.5 million, or a cumulative $223.5 million. Later in the quarter, NASA indicated that only $2 million additional funding would be forthcoming for the balance of FY 1964. This was a cumulative total funding level of $216.5 million—$11.5 million less than originally requested to support Schedule 3 (J-1).

This level was not adequate to cover expenditures and unliquidated commitments through the fiscal year, and corporate funds were required to sustain operations during June.

Consistent with our previously indicated funding requirements, S&ID will require $183.5 million for FY 1965, or a total cumulative funding of $400 million, to maintain Schedule 3 during the fiscal year.