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SATURN S-II

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1 July 1962 through 30 June 1963

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FOREWORD

This document, prepared in compliance with NASA contract NAS7-200, is the first annual progress report on the Saturn S-II Program at the Space and Information Systems Division of North American Aviation, Inc. It provides a summary and a technical analysis of results of contract work for the period 1 July 1962 through 30 June 1963.

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SUMMARY

ENGINEERING

DESIGN AND STRUCTURES

LH_2 Tank

The structural weight of the LH_2 tank was reduced by 650 pounds. This reduction resulted from improvements in the structural configuration and a reduction in design loads because of the change in the Saturn V primary mission from earth orbital rendezvous (EOR) to lunar orbital rendezvous (LOR).

LOX Tank

The trough seal between the common bulkhead and the LH_2 tank was replaced with a J section. The J section will improve the tank's structural integrity and facilitate fabrication and assembly. Tests were completed which verified J-section welding techniques and a design within maximum strength limits. A riveted gore-panel splice was selected for the forward facing sheet of the alternate common bulkhead because tests indicated that this splice had higher strength and considerably greater reliability than other splices.

The design of the LOX tank was simplified by replacing the structurally complex exclusion riser with a sump.

Forward and Aft Skirts

The weight of the forward skirt was reduced by 500 pounds because of the mission change from EOR to LOR.

Thrust Structure

The center-engine support beams were redesigned to eliminate interference between the J-2 engine and the thrust structure caused by an increase in the J-2 engine's suction-duct stability-link envelope. This redesign also involved the removal of the engine-furnished inlet ducts and the extension of the stage feed lines to the engine fuel-pump inlet flange.

Interstage

A Saturn V payload increase was achieved by moving the separation plane forward from stage station 156 to station 196. This latter station also doubles as a manufacturing joint. Structural design was simplified by the elimination of the second manufacturing joint at station 121.

Insulation

Tests of the low-modulus phenolic-nylon insulation verified its structural integrity throughout the expected operating environment. Two sixteenth-scale test tanks and five 30- by 30-inch panels were tested. No degradation of any of the insulation components (core, outer laminate, adhesive, and isocyanate filler material) occurred during these tests.

The first quarter-scale insulation test tank was completed and installed in the cryogenic test facility at Beech Aircraft Company, Boulder, Colorado. Tests to verify insulation structural integrity and thermal characteristics will be conducted during the latter part of 1963 and the first part of 1964. A second quarter-scale tank, incorporating design improvements and new requirements made subsequent to the completion of the first quarter-scale tank, is being fabricated. This tank will also be tested in the Beech facility.

SYSTEMS

Engine Systems

The problem of side loads in the J-2 Engine thrust chamber (caused by jet separation during sea-level testing) has been under extensive study. It is believed that the problem will be resolved by incorporating a converging cone at the thrust chamber exit in conjunction with an external restraining mechanism attached to the thrust chamber for use during engine start up. An analysis of the Engine Failure Sensing and Shutdown (EFSS) System was conducted during this period and a recommended system design was submitted to NASA.

Engine Servicing System design analyses were completed and component specifications were released. Based on system analyses, it was determined that disconnect standardization would be a practical concept and consequently, the same disconnect is used in more than one system.

The engine compartment conditioning system was changed during the report period from one which emphasized engine chilling and compartment displacement type inerting with cold GN_2 to one which emphasized the temperature control of temperature sensitive components with warm GN_2. This will require a more detailed experimental checkout than the cold GN_2 scheme, hence a small scale model test program has been proposed.

A pre-start conditioning system was designed to provide the J-2 engines with minimum NPSH requirements at engine start. This is done by chilling the fluid and engine components in the engine feed and gas generator circuit before launch and maintaining this conditioning during first stage boost. The fuel system is conditioned by means of a forward pumped recirculation flow, while the LOX system uses a natural convection forward recirculation flow with a helium injection subcooling overboard bleed backup. It is intended that a common pump development will be accomplished with the S-IVB stage contractor.

The Rocketdyne Division has been authorized to design, develop, and qualify the solid propellant ullage rocket motors. A procurement specification controlling the design and test requirements has been released. An optimization study of the motor configuration and installation was completed and the results were integrated into the motor design. Support fittings and aerodynamic fairing drawings have been designed and Phase I drawings are released.

Propellant Systems

The propellant feed system configuration, including valves, lines, and disconnects to control all phases of propellant transfer, was finalized following trade-off studies involving tank pressurization, trapped propellants, and fabrication problems of LOX tank exclusion risers vs a central sump.

The slosh and Vortex 1/10 scale plastic propellant tank model test facility was completed and the test program was initiated. Partial drain tests and slosh tests of the LOX tank have been accomplished.

The original selection by S&ID of a point sensor type of propellant management system was changed by MSFC preference for a capacitance S-IVB type of system modified to S-II requirements. Procurement of such a system is now proceeding, and will include propellant tank gauging elements and associated electronic equipment to perform the functions of propellant loading, propellant utilization control, and engine cutoff.

Pressurization System

Major changes made to the Pressurization System during the past year were (1) increase of the tank pressure levels, (2) addition of step pressurization, (3) addition of modulating pressurant flow control valves, (4) addition of a pneumatic actuation system to operate components in the engine pre-start conditioning system, and (5) addition of a hydrogen pressurant line purge system. System analyses have been completed as required to support the procurement of hardware and the installation design. The problem of liquid hydrogen stratification was intensively studied, and significant advances were made in the analysis and control of stratification. Testing consisted of exploratory tests to evaluate proposed solutions to the stratification problem and to evaluate an experimental gas distributor incorporating a Hilsch tube.

Thermal Control System

The flow rates, gas temperature, insulation thicknesses, and line, orifice, and relief-hole sizes for the equipment containers and gas plumbing have been determined. Preliminary tests have been completed to ensure that the system's noise level will not annoy maintenance personnel. Experimental thermal tests of a simulated plumbing network and a typical equipment container are planned.

Electrical Systems

The configuration of the electrical power system was finalized and received Phase I approval. Preliminary in-house design reviews were satisfactorily completed at the same time as Phase I data were submitted to MSFC. The design and development of components is in the early stages; some prototypes have been fabricated.

Phase I approval of the electrical control system was received. Preliminary design analyses were conducted on the use of an emitter follower for engine control, the control requirements of the propellant recirculation and management systems, and the effect of incorporating the Saturn V timing system switch selector. Procurement specifications were completed for relays, timers, and module connectors. Development programs to optimize the design of the component modules were implemented and design checks were successfully performed in simulated environments.

Destruct System

This system electrical design has proceeded through Phase I into the Phase II approval stage with no electrical problems anticipated. The system ordnance has progressed from basic concepts to feasibility testing and detail procurement specification completion. Development testing has begun and is proceeding on schedule. By direction, S&ID is developing the Confined Detonating Fuze components such that they could be employed on all stages of the Saturn V vehicle.

Separation System

This system electrical design has proceeded through Phase I into Phase II approval with no electrical problems anticipated. The system ordnance has progressed from basic concepts to detail procurement specification completion. The installation design for the separation linear shaped charge has been submitted for Phase I approval. Significant development progress has been achieved in the optimization of the linear-shaped explosive charges used to sever the interstage structure. For example, in-house feasibility tests conducted revealed that two linear shaped charges in "piggy-back" arrangement provide redundancy with optimum installation design and maximum reliability. Feasibility of manifold detonation of multiple Confined Detonating Fuze leads and through-bulkhead, Non-Electric Initiator for solid propellant motor ignition was established and confirmed by tests.

Flight Control System

Components for the eight preproduction engine actuation systems were delivered. The first preproduction system was delivered to Huntsville on 15 June 1963.

Procurement specifications incorporating necessary design changes were released for production engine actuation system components, and procurement action was initiated.

Requirements for automatic checkout of the flight control system were released 15 January 1963. The flight control test consoles for the laboratory tests of the engine actuation system were designed and fabricated.

Mechanical feedback was adopted for the engine actuation system. This eliminated the need for the multipole flight control switch, but the Douglas S-IV switch will be used to maintain capability for conversion to electrical feedback.

FLIGHT TECHNOLOGY

Dual-plane separation of the S-II from the S-IC was adopted at the direction of MSFC. S-II station O was selected as the first plane of separation, and preliminary studies indicated that the second plane should be at station 196.

Separation studies were conducted, and S-IC retro-motor requirements were established. Ullage motor requirements and an S-IC/S-II separation sequence were also established.

It was recommended that aerodynamic fairings be used on certain protuberances. Fairings are necessary because of the high aerodynamic heat-transfer rates on these protuberances and desirable because they could provide a gain in payload weight. Fairing and cap angles should be 15 degrees or less.

The effects of varying single J-2 engine failure times on the LOR mission payload weight were determined.

GSE

The GSE Branch of Engineering has documented the addition of 74 new end items of GSE while deleting 53 end items during the past year. A contributing factor was the NASA redirection which resulted in the replacement of automatic checkout equipment for Battleship stage testing with eight pieces of manual checkout equipment.

Auxiliary equipment to satisfy the requirements for access to the LH_2 and LOX tanks was under study and design work was initiated on those items required for the Battleship installation.

A review of propellant fill and topping requirements disclosed major differences between those for the Propulsion Field Laboratory and Mississippi Test Facility and led to the cancellation of units for the MTF.

Phase I review of mechanical checkout equipment produced major redefinition of requirements and caused redesign of some GSE. The pneumatic checkout console set was significantly affected.

The computer program development facility became operational and automatic checkout program de-bugging was initiated. Several programs were completed and others were accelerated.

A static firing control station was added to the checkout and control category of GSE, for use at static firing sites.

The telemeter checkout station was affected to the extent of an 85 percent redesign effort as a result of a NASA concept review.

The ground equipment test set (GETS) concept was introduced by NASA, and replaced the automatic GSE systems verification equipment. The capability for checkout using PCM, telemetry, and RF simulators, was eliminated.

TEST AND OPERATIONS

Cancellation of the Operations Simulator and reorientation of the Battleship test program reduced the test capability and program requirements for these early programs. In order to retain essential test capabilities and to minimize effects on the Confidence Development Plan, portions of the original test objectives were transferred to subsequent test programs. To accomplish these major changes, effort was concentrated in planning, evaluating, scheduling, budgeting, manpower loading, and establishing support requirements for all subsequent test programs. The General Test Plan, master test schedule, and other supporting documentation, also were revised.

Electromechanical Mock-Up

Construction of the EMM facility was planned as a two-phase operation. Phase I, construction of the S-II stage simulator area, was completed with no serious problems. Phase II, construction of the GSE checkout area, was started. Activation of major mock-up operations began at the completion of Phase I and is currently in progress. The mock-up is being used to resolve interface problems and to ensure proper fit of S-II stage components.

Battleship

The Battleship test plan, measurement lists, and support requirements were established. Additionally, requirements were published for manual checkout and manual control of static firings. Specifications were completed for additional instrumentation recording equipment, and bids for supplying this equipment are being evaluated. The detailed activation plan and electrical-checkout procedures for the GSE and SDD equipment are now being finalized. Work was started on preparation of functional block diagrams for the stage electrical-power and electrical-control system.

All-Systems

The All-Systems program schedule, measurement lists, and support requirements were established to support the static-firing measuring system concept and boat-tail cryogenic environment tests. The test plan and manpower loading requirements were updated to reflect the increased scope of the All-Systems program. A plan for a propellant hazards program was completed. Data from this program will be used as support for a request for waiver of the All-Systems 25-second static-firing limitations at Santa Susana.

Mississippi Test Facility

The MTF Activation Plan, MTF Operations Plan, MTF Flight Acceptance Test Program Plan, and Preliminary MTF Static Firing Countdown were prepared and published. The test site facility design criteria and design details were reviewed to ensure compatibility between the stage, the associated GSE, and the facility. Firm budgetary and manpower loading requirements were established to reflect the addition of the static firing instrumentation, the addition of a second control center computer complex, and the deletion of the vehicle-service building.

Atlantic Missile Range

The Atlantic Missile Range (AMR) test program schedules and support requirements were established. An S-II test sequence and other operational documents were prepared and submitted for NASA approval. Other activities included publication of the AMR Test Plan, formulation of planning groups, and a concentrated study effort into the automatic checkout concept.

The lack of facility checkout capability prior to receipt of the first flight stage and need of details of the operations at the high-bay and launch-pad areas are present AMR problems requiring NASA direction.

Data Processing Center

Requirements for equipment, personnel, and facilities were established for the S-II data processing center. A contract was awarded for design and fabrication of the primary data reduction equipment with delivery scheduled for April 1964. Technical approval of the design concept for vibration and cycle count systems was obtained, and contracts will be awarded in the near future for fabrication of this equipment.

Test Programming

Measurement lists were published for the Elec mechanical Mock-Up, Battleship, S-II-2, S-II-IFD, and S-II-F stages. A Saturn S-II master measurement list was also published, and a preliminary measurement list is being compiled for the S-II-3 stage. Test site support documents delineating equipment and material requirements were published for each test site. The master test schedule was updated to reflect present program plans. A total of 35 amendments to the original General Test Plan were submitted for approval. Of this number, 12 amendments have been approved; the remaining 23 are in various phases of negotiation.

RELIABILITY

During the report period, achievements in reliability primarily involved the detailed implementation of the Reliability plan. Also, major progress was made in the establishment of detailed criticality category criteria used to determine the extent of the optimum reliability effort required. Progress in design review included the creation of supplier design reviews held within S&ID. A statistically designed experiment was implemented to fulfill all of the integration requirements of the Confidence Development Plan. The mechanical excellence program was developed for the prevention of reliability degradation during manufacturing, testing, and handling. To allow Saturn S-II management to examine the progress of the reliability program and to expedite the resolution of problem areas, the Reliability Progress and Review Board was formed.

FACILITIES

S-II Facilities is constructing and preparing facilities for the Saturn S-II stage in three major locations in California: Downey, Seal Beach, and Santa Susana. The Downey site is located at Air Force Plant No. 16; the Seal Beach facility is located at the U.S. Naval Weapons Station, Seal Beach; and the Santa Susana site, Air Force Plant No. 57, is located at the Propulsion Field Laboratory (PFL) in the Santa Susana mountain range, near Chatsworth. Work at all sites is proceeding satisfactorily.

QUALITY CONTROL

Several organizational changes have occurred within S&ID's Quality Control department during the Saturn S-II program. Saturn S-II assembly operations subsequent to detail fabrication are now product-line oriented, and responsible personnel report directly to the Saturn S-II Quality Control manager. Direct-line reporting includes all effort at the Seal Beach facility, the Propulsion Field Laboratory, and the Mississippi Test Facility. This change will improve the control of inspection operations and the direct response and corrective action given to problems. First-shift inspection operation at Seal Beach began on 11 June 1963.

DOCUMENTATION

The preliminary Saturn S-II Quality Control Plan was issued 21 May 1962. Revisions have been issued for Volume I (30 October 1962) and Volume II (31 December 1962); both volumes are now being revised. In order to provide current information on the progress Saturn S-II quality control, a Monthly Quality Status Report (SID 62-446), and a Quarterly Summary of Quality Control Performance Audits (SID 62-555) are published periodically.

The Seal Beach Facilities Inspection Plan was released on 28 June 1963. The resubmitted quality control plan for the fabrication of bulkhead segments and the Battleship thrust structure have both been approved by S&ID.

Twenty-one quality control specifications were issued or revised during this reporting period and 345 Quality Control performance audits were conducted. The fabrication, assembly, and inspection record (FAIR) system was put into use on the Saturn S-II program. The project equipment installation records (PEIR) system has been established for the Seal Beach and Santa Susana facilities. In late October 1962, S&ID initiated a new system of handling Material Review Board (MRB) actions. This system is identified as nonconformance reporting and conforms to the requirements of NASA publication NPC 200-2.

QUALITY ENGINEERING LABORATORY

The Quality Engineering department and the Quality Control Laboratory have merged to become the Quality Engineering Laboratory (QEL). This laboratory has made considerable progress in developing nondestructive testing techniques for the S-II program, such as designed criteria for an ultrasonic inspection fixture. This fixture will be fully automatic, capable of performing either pulse-echo or through-transmission ultrasonic inspection of the honeycomb insulation and of accepting eddy-current equipment for surface inspection. A study of penetrant inspection problems connected with the S-II patent disclosures has been made for a LOX-safe penetrant. QEL is providing assistance to Manufacturing in such problem areas as cable assemblies, circuit boards, and tube flaring. Certification of S-II skate-welding equipment has started at the Seal Beach facility.

MANUFACTURING

Manufacturing's prime milestone was the production of 12 waffle and 12 thin gore segments for the first bulkhead. Explosive forming has proved to be the best means of producing these complex components to close tolerances. Manufacturing's efforts were stepped up to the point where "proof-of-method" and production schedule commitments could both be attained.

The following articles, all in support of Engineering test requirements, were shop completed by Manufacturing during this report period:

1. Three forty-eighth scale models
2. Two tenth-scale models
3. Twentieth-scale model
4. Structures for the development mock-up phase of the Electromechanical Mock-Up
5. Preproduction hydraulic engine actuation system
6. Quarter-scale test tank
7. Nine 55-inch test-model bulkheads
8. Separation plane test hardware

PLAN V

A program schedule change brought about by limited fiscal year funding and customer-requested engineering changes was accepted by S&ID management. The schedule change is in accord with NASA letter Plan V, dated 29 October 1962. Manufacturing completion dates for the Static Test stage were moved out five months; completion dates of subsequent stages were moved out as much as 12 months. Detailed manufacturing schedules, as well as requirements for tooling, factory checkout, GFAE, and facilities, were revised immediately to reflect full program support.

SEAL BEACH

During the last six months of this reporting period, Manufacturing personnel have been moving into the Seal Beach facility. Five major tools and welders have been installed at this facility. The aft common bulkhead segment welder is in production, and the other four welders are in various stages of certification or rework. The autoclave and supporting equipment and the hydrostat tool and test installation are progressing toward scheduled completion.

TRANSPORTATION

Routes to be traveled by the Type I and Type II transporters have been established, permit assurances have been secured from all affected municipalities, and plans for route modification and obstruction removal have been approved. A transportation training program has been developed to ensure proper handling of S-II materials, tooling, and fixtures. The effectiveness of this program is evidenced by the successful moving of the Electromechanical Mock-Up segments from Building 1 to Building 2 in Downey.

S&ID will probably [illegible] a converted B377 Stratocruiser for air transportation of S-II items, although the use of helicopters is also being considered. A test run with the AKD "Point Barrow" was conducted to study the ocean-going phases of S-II transportation.

LOGISTICS

During the report period, the S-II Logistics department accomplished detailed planning, scheduling, and coordination in the functional areas of modification and repair, customer training, supply support, support documents, and maintenance engineering in support of the master program schedule. Spares for the Electromechanical Mock-Up have been ordered and were delivered. Spares for the Battleship stage have been ordered.

The Logistics Support Plan (SID 62-286) was published on 10 November 1962 and revised on 1 April 1963 to ensure total Logistics support for the Saturn S-II program. A second revision will be published on 1 October 1963. All contractoral support documents required during the report period were delivered on schedule.

MANAGEMENT CONTROL

MILESTONES

Milestones completed in the past year include the delivery to NASA of the following:

1. Tenth-scale model
2. Forty-eighth scale model
3. Twentieth-scale model

4. Tenth-scale diorama model
5. Engine actuation systems
6. Aft master mating gauge

PERT

PERT is now being used extensively by all levels of S-II program management. Many management decisions have been made with the aid of PERT, as evidenced in a number of biweekly narrative reports. The biweekly Wednesday conference of the S&ID S-II program manager and the Saturn Systems Office is indicative of their mutual interest in and desire to use PERT as an executive tool.

I. ENGINEERING

DESIGN AND STRUCTURES

The nomenclature for the S-II stage is presented in Figure 1.

LH_2 TANK

In July 1962, studies to optimize the structural configuration of the LH_2 tank were begun. The preliminary configuration consisted of five 33-foot-diameter cylinders stacked and welded to form the tank skin. Integral stringers were machined in the skin to form a rectangular pattern. Longitudinal stringers were spaced at 8.6 inches, and circumferential stringers were spaced at approximately 33 inches. Ring frames approximately 6 inches deep were attached to the circumferential stringers. The studies indicated that structural efficiency could be increased if the stringer spacing was increased from 8.6 inches to 11.5 inches and the frame spacing from a constant 33 inches to a spacing that would be proportionally increased in the areas of decreasing loads.

New Saturn V design loads that reflected the change in mission from EOR to LOR were received from MSFC in October 1962. Studies based on the new loads were completed in January 1963. The resulting detail design set the skin thickness at 0.145 inch, stringer spacing at 11.519 inches, frame depth at 7 inches, and frame spacing at 34.25 inches at the aft end and 40.25 inches at the forward end. The changes in mission design loads and the structural configuration resulted in a net weight saving of 650 pounds.

Following completion of the detail design, the stringer column end-fixity coefficient was decreased, at MSFC direction, from 1.5 to 1 for stages S-II-IFD, S-II-2, and S-II-3. This change was made to ensure conservative design in order to provide compression-panel stability under prelaunch loading conditions for this block of vehicles, and resulted in a tank weight increase of approximately 350 pounds.

A proposal for compression tests on large curved panels that will simulate the LH_2 tank wall was submitted to MSFC. These tests, if successful, will verify the structural integrity of the original tank-wall design and permit a weight reduction of approximately 350 pounds in stages subsequent to S-II-3.

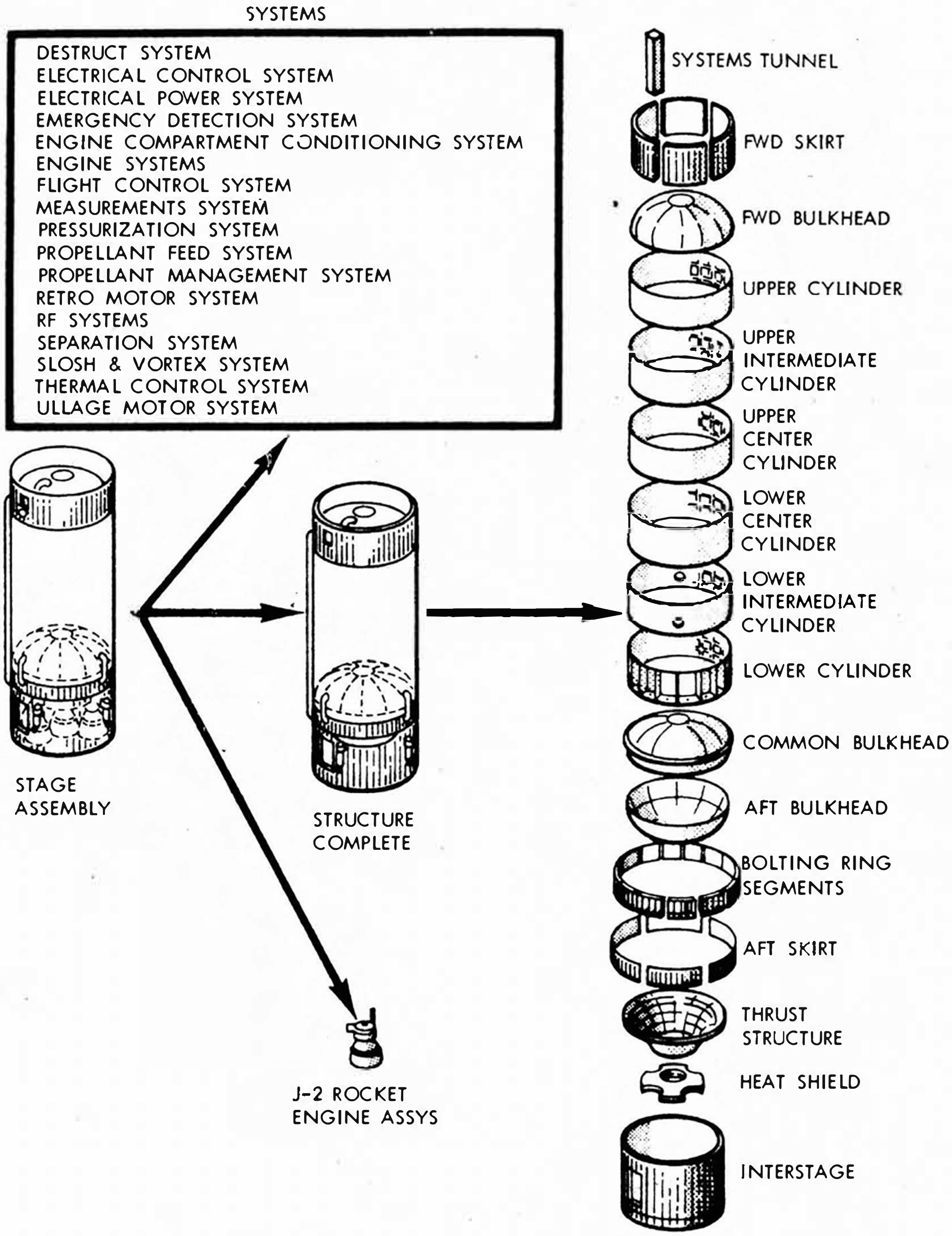

Figure 1. S-II Stage Nomenclature

LOX TANK

Common Bulkhead

J-Section Design

In October 1962, the J-section configuration was adopted in place of the original trough-seal arrangement. (See Figure 2.) The J section improves structural integrity and facilitates the fabrication and assembly of the common bulkhead.

Internal Insulation

The adoption of the J section necessitated a study of the insulation in the area just above the section. Arrangements with the insulation on the LH_2 tank side of the common bulkhead were studied, but tank cleaning problems were encountered. The final arrangement is shown in Figure 3. Stainless-steel honeycomb is fitted into the waffle grid panel pockets on the LOX tank side of the bulkhead, and an aluminum cover sheet is welded to the waffle grid panel. The test parts fabricated in order to verify the welding techniques for this installation are shown in Figure 4.

J-Section Weld Test Program

A J-section weld test program was conducted in order to verify welding techniques and design allowables. Sample parts and a report on the physical properties of welds were submitted to MSFC.

Perforated Core

A perforated core was incorporated into the common-bulkhead design. Small holes connecting the core cells permit increased gas flow through the core. This increased flow is needed for leak detection and also for the out-gassing which takes place during the bonding process.

Extensive trade-off studies were conducted in order to evaluate the effect of the inlet temperature of the pressurant on the structural weight of the common bulkhead and on the total weight of pressurizing gas in the tank at the end of S-II boost. The objective of the study was to select a pressurant inlet temperature and a corresponding bulkhead design that would minimize the total weight. Results of the study indicated that the lower facing temperature should be limited to a maximum of 100 F.

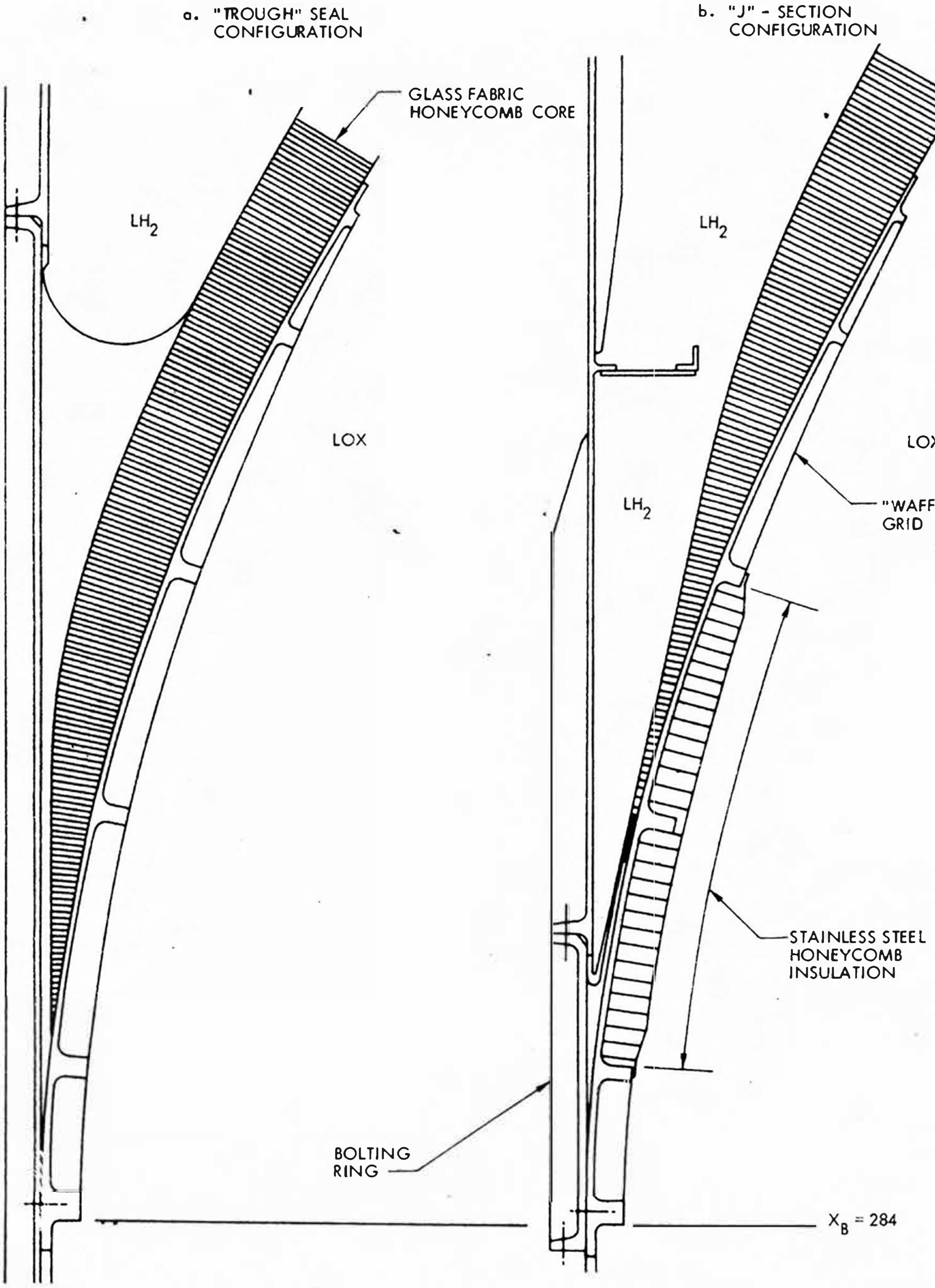

Figure 2. Early and Present Configuration of Common Bulkhead

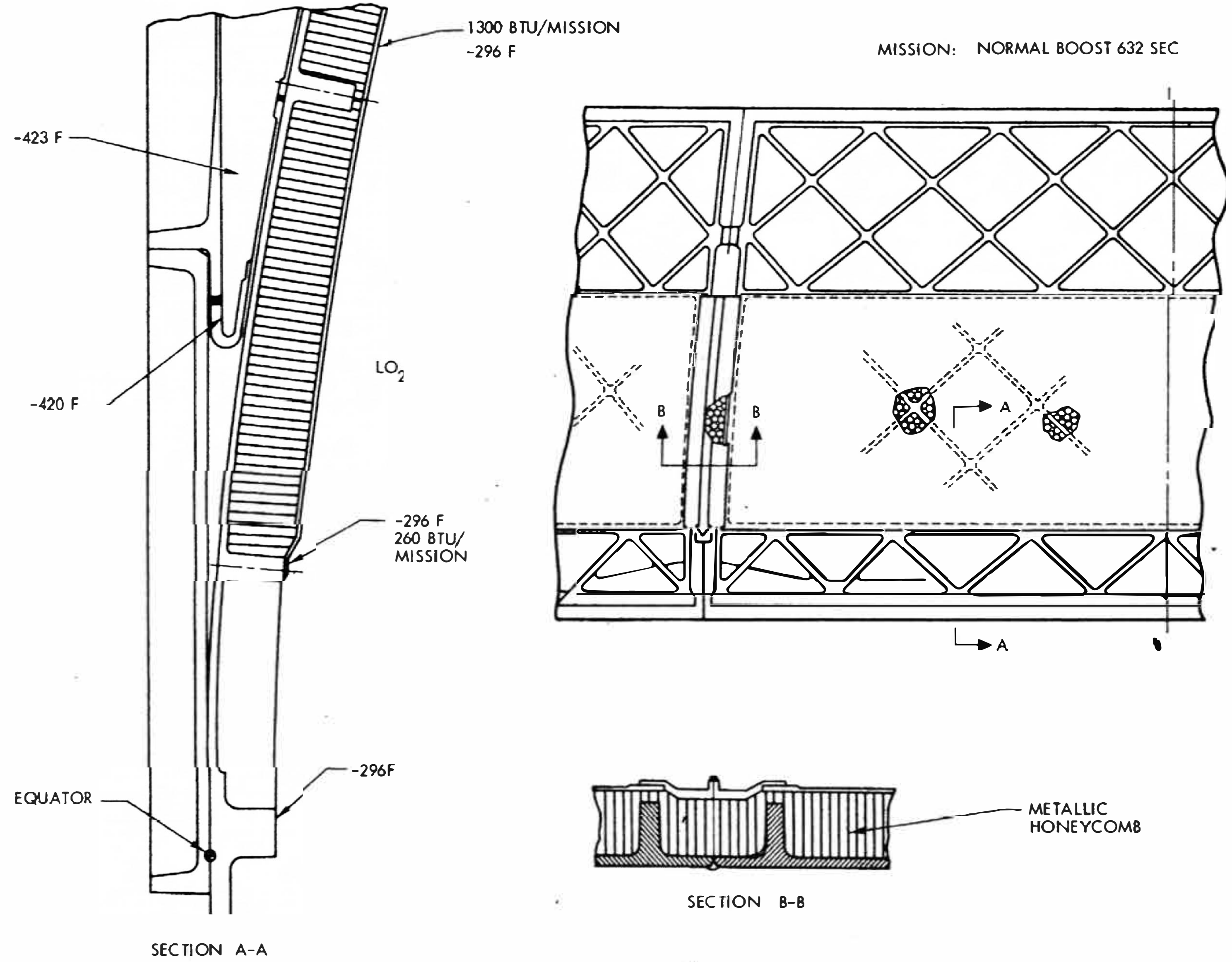

Figure 3. Common Bulkhead Insulation

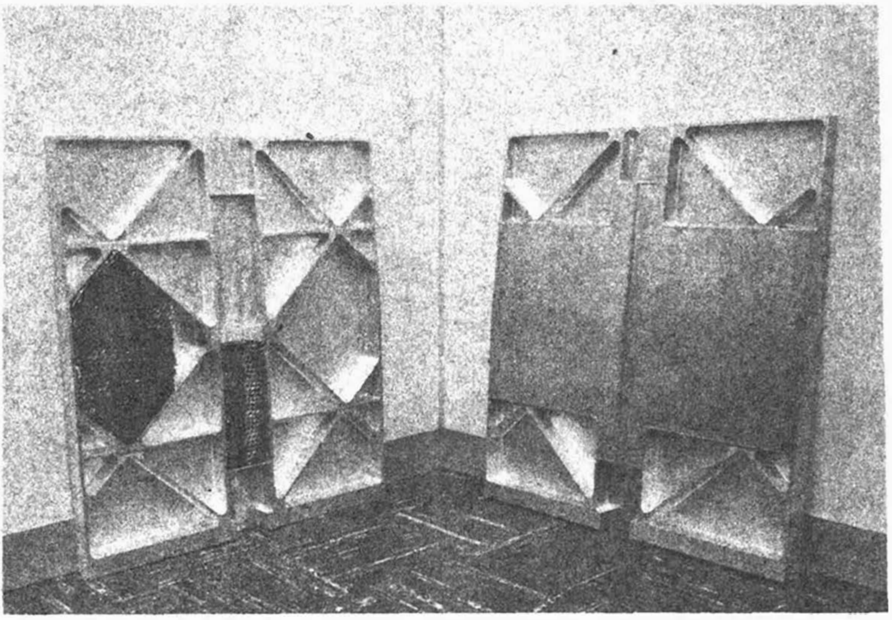

Figure 4. Welding Test Parts

A highly complex structural interaction exists at the junction of the LOX tank and the cylindrical skirt section. Therefore, in order to maintain compatible deflections, IBM 7090 computer programs were developed and refined. These consider the effects of tank pressures, body axial loads, and temperature distributions on the discontinuity loadings applied to the tank and skirt structure in the joint region.

The effect of using sheet metal that is heat-treated and stress-relieved at the mill (2014-T651) instead of sheet metal that is heat-treated by the user (2014-T6) was evaluated. The results showed that this change facilitates the forming of the thin gore sections in the annealed condition with subsequent aging to the T-62 temper. The difference in material temper results in a small change in mechanical properties. No change in material thickness is required for common-bulkhead facings, but a slight increase in thickness is necessary for the aft bulkhead.

Common Bulkhead Facing Fit-Up Tests

A test program was initiated in order to determine the most effective means of fitting the completely assembled forward facing shell of the common bulkhead into firm contact with the honeycomb core over all of the surface area. In this program, a controlled gap, or deviation from contour, was introduced into contoured aluminum panels, and vacuum pressure was applied between the test panel and a surface plate of the correct contour. The objective of the program was to determine how much initial gap could be successfully drawn to contour without buckling or wrinkling and approximately how much pressure would be required to accomplish this.

A total of 28 rectangular panels of 2014-T6 aluminum alloy were tested in this program. The basic contour of each panel was representative of the common bulkhead in the equatorial region; test panel gauges of 0.032, 0.050, and 0.071 inches were employed, and initial contour deviations ranging from 0.030 to 2.00 inches were covered. Test results demonstrated that the capability of drawing to contour without buckling increased with panel thickness. It was determined that maximum initial deviations of 0.050 inches for 0.030 inches of facing thickness and 0.15 inches for 0.070 inches of facing thickness could be drawn to contour by approximately 5 psi vacuum pressure.

A complete description of the test program and results is given in S&ID laboratory report SDL 388. The general test setup is shown in Figure 5. A typical 0.032-inch panel with an initial contour deviation of 0.070 inches prior to tests is shown, with check template, in Figure 6; the same specimen under the pressure differential that drew it smoothly to contour is shown in Figure 7.

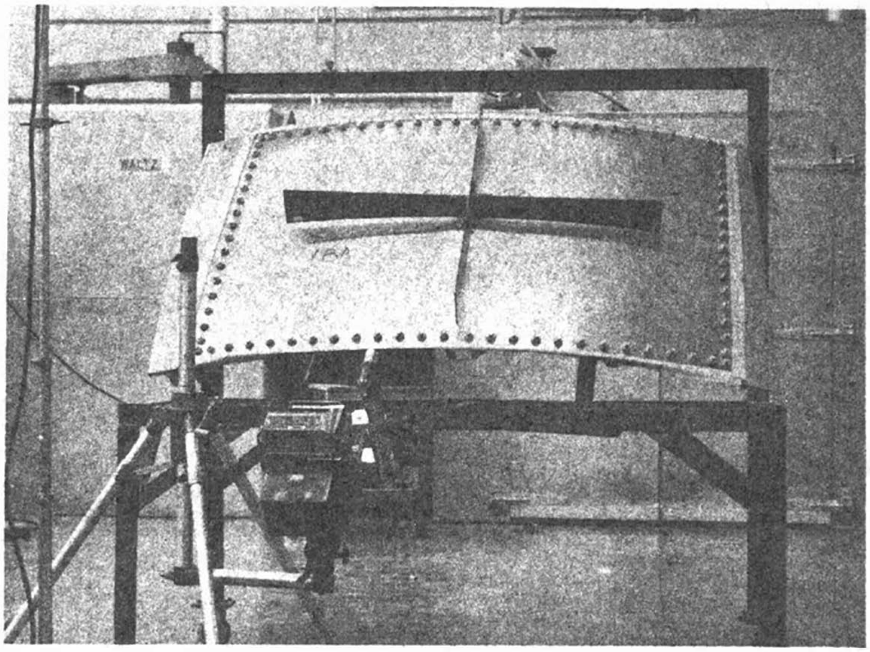

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Figure 5. Bulkhead Fitup Tests Depicting Material Distortion

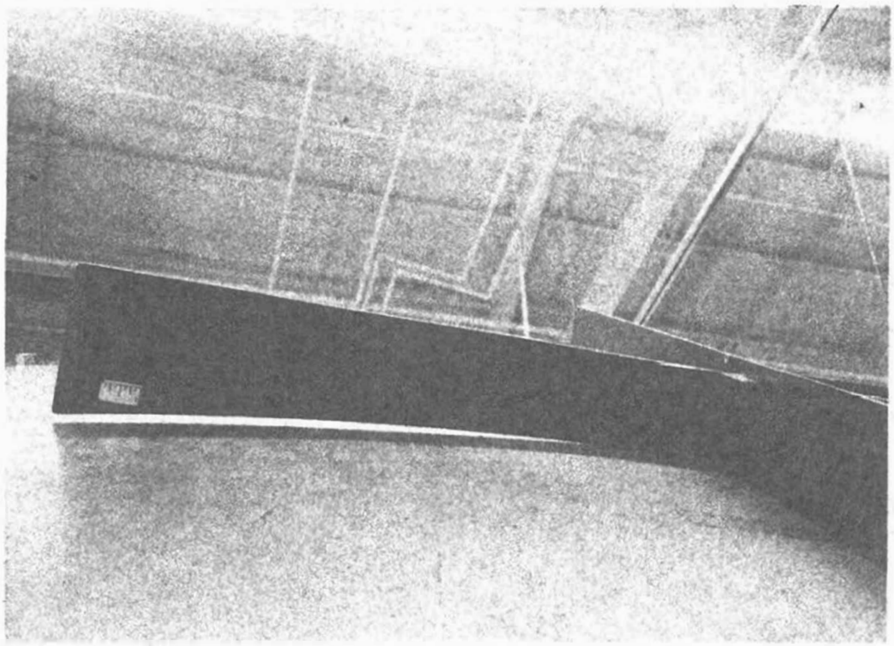

Figure 6. Bulkhead Fitup Weld Test Showing Distortion

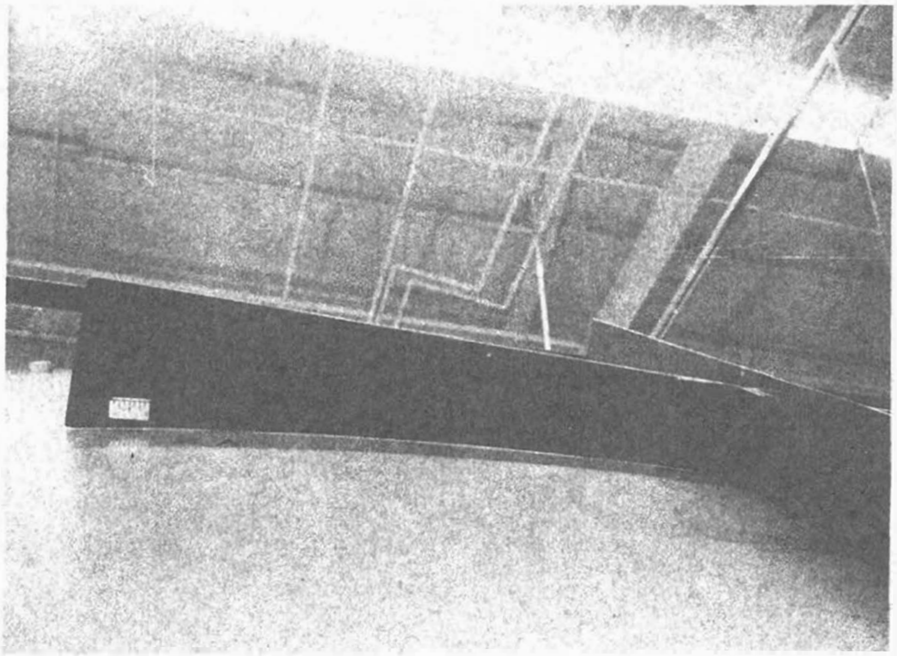

Figure 7. Test Specimen Drawn to Contour

Common Bulkhead Acceptance Standards Tests

A test program was initiated to evaluate the effect of bond void area on the strength of the common bulkhead. Voids of various controlled sizes will be introduced in the bond line of uniaxial and biaxial compression test specimens. Static and fatigue loadings will be applied and regular ultrasonic inspection of the specimens will be performed during the fatigue program to detect any tendency toward void propagation. Ultimate compression strength will be determined at the conclusion of the repeated-load program. The uniaxial specimens will be tested at room temperature and -320 F; biaxial specimens will be tested at room temperature only. Material procurement and test planning for this program is in progress.

Alternate Common Bulkhead

Two design studies were initiated during December 1962 parallel to the current design of the common bulkhead. A strip seal is used in one design, and a full membrane seal is used in the other. By the use of either seal method, the forward skin of the common bulkhead can be bonded to the core in 12 individual panels; the current design requires bonding of a single welded facing-sheet assembly to the core.

Two types of joints were considered for the strip seal: an adhesive-bonded joint and a riveted joint. The riveted joint (Figure 8) was selected because of its higher strength and considerably greater reliability. Analysis showed that the addition of splice-strip area significantly affected the distribution of pressure and thermal loading between the two facings of the common bulkhead.

Production drawings for the membrane and strip-seal designs are being prepared. Detail parts will be fabricated for use if sever fit-up problems are encountered in fabrication according to the current design.

Alternate Common Bulkhead Design Development Tests

An alternate design for the S-II common bulkhead is being investigated at the request of MSFC. The forward facing sheet would be bonded to the honeycomb core in individual gore segments, which would be subsequently spliced to obtain structural continuity. Two methods of sealing the upper facing are being considered: one method involves the use of strip seals applied over the structural splices and welded along the edges to the bulkhead gore segments; by the other method, a complete membrane shell would be built up as a welded assembly over the structural bulkhead.

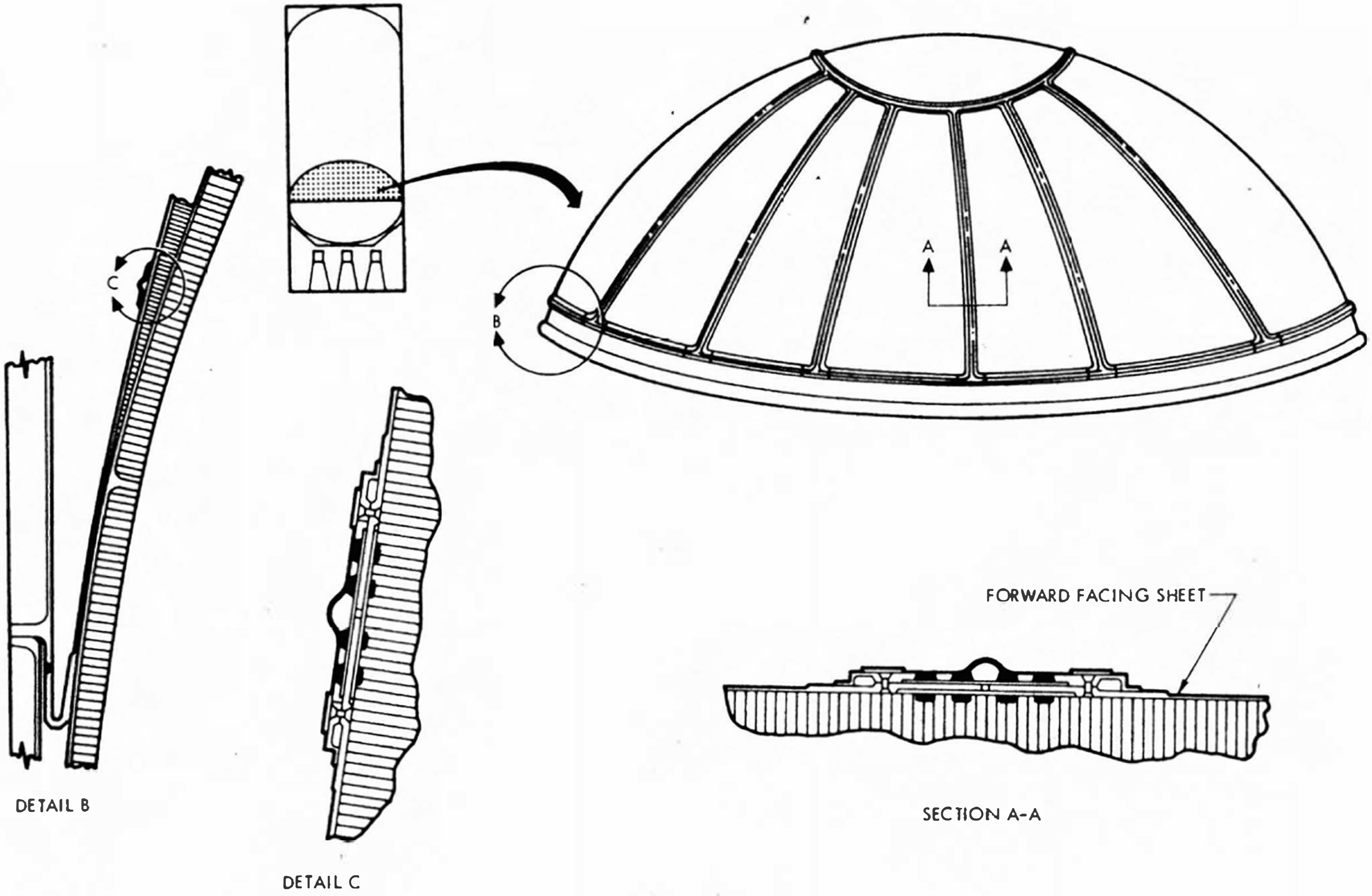

Figure 8. Common Bulkhead Strip Seal Arrangement

Slosh Baffles

The original LOX tank configuration included one slosh baffle at the equator. Good structural support for the baffle was provided by the common-bulkhead grid panel.

Flight dynamics studies indicated a need for two additional baffles to satisfy damping requirements for LOX sloshing during first-stage and S-II boost. The baffles are located approximately 68 inches above and 96 inches below the equator. Support of the baffles presented a problem. Attachment directly to the bulkhead facing sheets was not feasible; therefore, a supporting truss structure attached to the common-bulkhead grid panel at the equator was selected.

Trade-off studies were conducted on the relative merits of open-section versus closed-tube members for the truss support structure. The closed-tube members were found to have a slight weight advantage.

Sump

The LOX tank was redesigned to include a sump instead of an enclusion riser. There are two advantages to this change. First, it eliminates the major problems associated with the fabrication of complex brazed-honeycomb exclusion risers. Second, it eliminates a potentially serious safety hazard which could develop due to trapped LOX in the exclusion riser honeycomb structure. Cracks could develop in the close-out welds due to structural flexure during transportation, propellant loading, and static firing; this would permit LOX to permeate the honeycomb structure. The presence of trapped LOX would pose a potential explosive hazard during defueling. It would be difficult to take adequate safety precautions, since techniques for providing satisfactory monitoring of the leaks are not available.

FORWARD AND AFT SKIRTS

Studies conducted to account for the change in design loads from the EOR to the LOR mission resulted in a reduction in stringer cross-sectional area, an increase in stringer spacing, and a net weight reduction of 500 pounds.

SYSTEMS TUNNEL

Design studies and layouts were started in July 1962 in order to optimize the original configuration of the systems tunnel. Changes in tank and systems designs and the addition of rate gyro packages caused several adjustments in tunnel size and location.

The systems tunnel is to be located at 29 degrees 10 minutes from position I toward position II, running from station 930 to station 197. Its half-circle configuration is designed to take hoop compression from aerodynamic loads, reduce frontal area, and minimize requirements for stiffener frames. The Fiberglas tunnel is bolted to the LH_2 tank skin by means of tapped holes and to the forward and aft skirts by means of nut plates. Slotted holes in the tunnel at the attachment points allow for differential expansion and contraction between the tank and the tunnel.

THRUST STRUCTURE

Final design of the thrust structure began during this reporting period. The center-engine support beam was redesigned because of changes in the J-2 engine. Relocation of the main oxidizer-valve actuator and an increase in the size of the inlet-ducts/stability-link envelope and main oxidizer-valve acturator caused interference with the center-engine support beams. To eliminate this interference, three basic configurations were investigated:

1. Parallel support beams, engine not rotated, customized inlet ducts
2. Nonparallel support beams, engine rotated 45 degrees, standard J-2 inlet ducts
3. Converging support beams, engine not rotated, standard J-2 inlet ducts

The first configuration proved to be the lightest, and approval was received from MSFC to proceed with this design. The use of customized ducts involves the removal of the center engine-furnished inlet ducts and the extension of the stage feed lines to the engine fuel-pump inlet flange. This change eliminates thrust-structure interference by eliminating the stability links, which are not required for the fixed center engine.

A study was also performed to determine the effect of making the thrust structure strong enough to resist engine side loads during static-firing thrust-buildup or decay periods. A weight penalty of 470 pounds was indicated; therefore, a decision was made to provide external supports directly to the outboard engines in order to arrest side loads during static firing. This solution was not considered feasible for the center engine because of difficult access for the external supports; the center-engine support beam structure was therefore strengthened to accommodate the engine side loads.

An extensive analysis of deflection-influence coefficients at engine gimbal and actuator support points was undertaken in support of flight-control studies performed by the Flight Technology branch. Linear deflections in three coordinate directions were determined at all attachment points, as well as angular deflection in two coordinate directions at the engine gimbal point. Results are expressed in an 11-by-11 matrix of influence coefficients; 25 such matrices were developed, one for nominal values of stiffness of thrust-structure elements, the others reflecting the changes resulting from arbitrary variations in the stiffness of the primary structural elements.

INTERSTAGE

A Saturn V payload increase was achieved by moving the separation plane from station 156 to station 196. A result of this change was the elimination of a second manufacturing joint at station 121. This joint is now combined with the station 196 separation-plane joint. At the termination of dual-plane separation studies, a second separation plane was established at station 0. The designs of the two separation-plane joints are similar. To maintain an optimum-weight structure, the interstage frame spacing was modified to agree with the relocation of the separation plane, the elimination of the manufacturing joint, and the addition of the second plane at station 0.

Investigations were made of several types of joint details for flight separation joints and the interface joint to the S-IC forward skirt. A detail design for the interface joint, similar to the flight separation joint (compression fittings on the stringers), was proposed, but manufacturing schedules on the S-IC forward skirt did not permit incorporation of the change. The selected joint design consists of two bolting angles, back-to-back, with structural loads transferred at the skin line. This produces some load eccentricity on the skin-stringer panels, which results in radial loadings on the supporting frames. The magnitude of loading is dependent on structural characteristics on both sides of the interface joint, so close coordination was maintained with Boeing and MSFC to ensure compatible design of the interstage and the S-IC forward skirt.

Load diffusion around the access door in the interstage was analyzed to ensure adequate strength and stiffness properties and to achieve a reasonably uniform loading distribution at the flight separation joints.

Studies were made of various ullage-rocket mounting configurations, including external, internal, and semiflush arrangements. The external configuration was adopted, and structural mounting provisions were incorporated in the interstage design. Aerodynamic fairings were incorporated into the support for the separation-joint linear-shaped charge. Aerodynamic fairings were also designed for the LH_2 feed lines; these fairings are being added to the aft skirt and interstage.

INSULATION

Structural analysis of the LH_2 tank external insulation was performed in order to evaluate critical stresses in the facing and core of the insulation panels and to compare the stresses with strength allowables. Thermal stresses are of primary importance. Environmental conditions associated with propellant loading, prelaunch hold, and boost were considered in this evaluation. The analysis results indicated that the original design, which employed Fiberglas-phenolic laminate for the external facing, is very marginal; results of environmental tests on tank-wall insulation panels conclusively demonstrated that it is not satisfactory. Low-modulus laminates for the external facing were under consideration, and investigation of nylon-phenolic material for this application was expedited.

Tests were conducted by utilizing sixteenth-scale tanks and 30- by 30-inch panels. The 30- by 30-inch panel size was necessary for environmental testing of the insulation under combined conditions of applied vibration, aerodynamic heat simulation, and cryogenic fluids. Two sixteenth-scale tanks were constructed with low-modulus laminates. The first tank had a nylon-phenolic laminate, and the second tank had a nitrile-modified phenolic-nylon laminate. Figure 9 shows a sixteenth-scale test tank undergoing LN_2 boil-off tests.

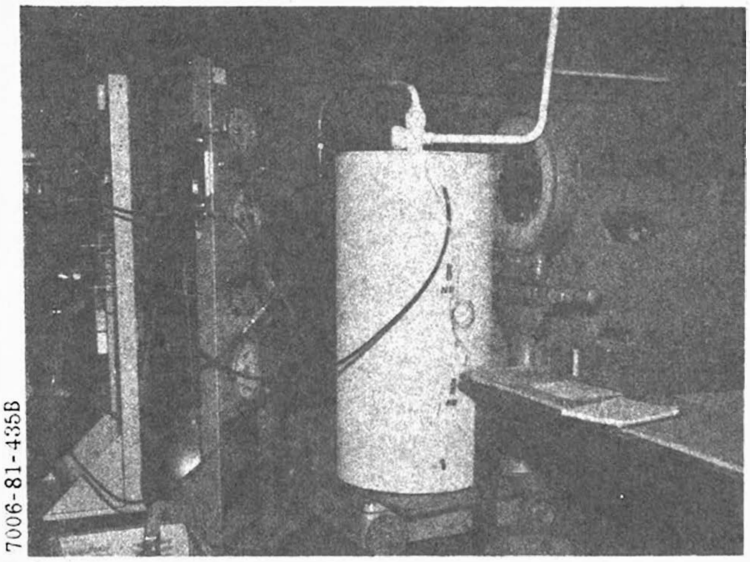

Figure 9. Sixteenth-Scale Tank During LN_2 Boil-Off Tests at S&ID

Nylon-phenolic laminates were used in the fabrication of five additional 30- by 30-inch panels. These panels were used for more complete environmental testing of the insulation on areas representing large panel sectors and close-out areas of the tank. The results of this program were satisfactory. No degradation of any of the insulation components was noted during any of the tests, and ultrasonic bond-line inspection before and after testing indicated that all bonding agents operated satisfactorily. Figure 10 is a photograph of a 30- by 30-inch panel fabricated with a 0.8 inch thick, 3/4-inch cell-size core and a low-modulus laminate. This figure shows the panel after vibration and cold-soak tests with LN_2.

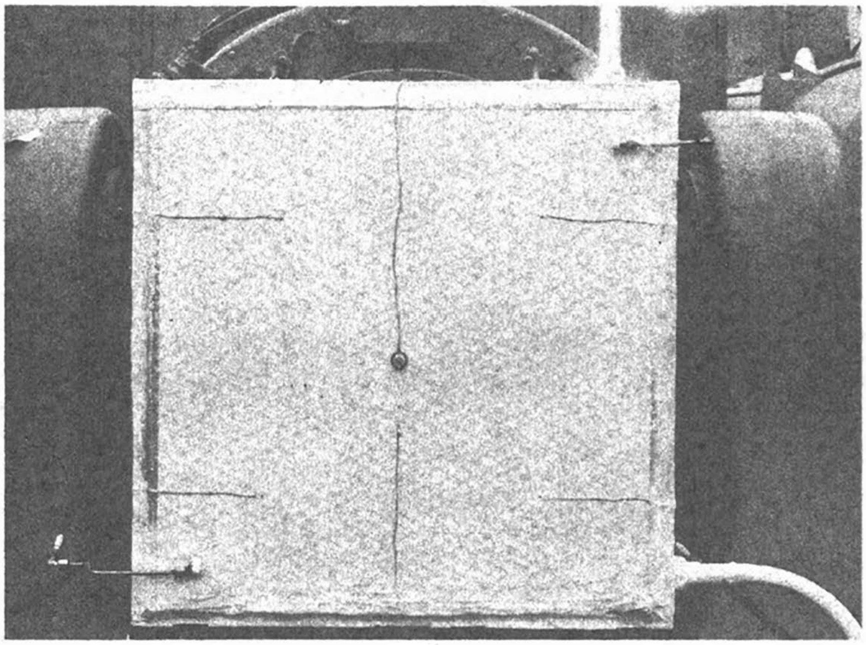

Figure 10. 30- by 30-Inch Panel After Vibration and Cold Soak With LN_2

During aerodynamic heating tests on one of the sixteenth-scale tanks, the 2-psi helium purge was inadvertently continued through the trajectory heat portion (peak temperature 425 F) of the test. Ordinarily, the insulation is vented to the atmosphere during this phase. As a result, the Tedlar film sealer bubbled away from the skin in many places. This was to be expected, because Tedlar will appreciably soften above 300 F. However, there was good distribution of the helium gas through the insulation; bubbling was more or less uniform over the surface.

Figure 11 shows the first quarter-scale test tank installed at the pretest tower at Beech Aircraft Corporation, Boulder, Colorado. The second quarter-scale tank incorporating the 3/4-inch cell size, 0.8 inch-thick honeycomb and the nylon phenolic laminate is representative of the current design.

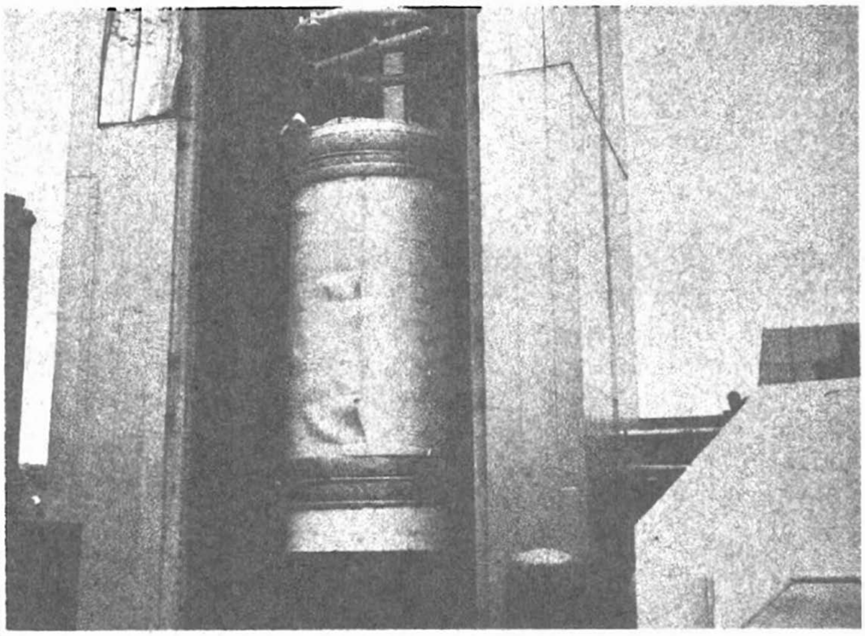

Figure 11. Quarter-Scale Test Tank Installed in Pretest Tower at Beech Aircraft Corp.

In recent months, a thorough investigation of the insulation leak-detection and purge system was conducted. The system can be used to determine the hydrogen leakage rate across the structural welds on the hydrogen tank. Testing has been done with the helium mass spectrometer in order to prove the feasibility of this technique; but final proof cannot be obtained until later phases of the test program, when complete evaluation of the insulation-purge and leak-detection system can be conducted.

HEAT SHIELD

The first portion of the heat-shield testing program was aimed at verifying the structural aspects of the shield. The first tests with heat alone, used to calibrate the test equipment, indicated a significant amount of delamination of the high-silica cloth facing sheet on the hot-side face at 1500 F. Close observation of subsequent tests indicated that in air the phenolic impregnant was breaking into flames. Early this year, additional specimens were constructed, the first of which was tested in an environment simulating 200,000 feet altitude with aerodynamic heating starting from a prechilled condition.

These samples did not delaminate, and showed surprising resistance to the heat. Additional samples were then tested at atmospheric pressure on a shaker purged with carbon dioxide to prevent an oxidation reaction. Results of these tests closely approximated the results of the tests conducted in the altitude chamber. Samples as large as 12 by 12 inches performed satisfactorily up to 1500 F, the predicted maximum operating temperature. The flexible curtain material was tested up to 1800 F. Further tests were conducted, and accurate properties were obtained; this permitted reduction of the design temperature to 1500 F. All specimens tested at this temperature met design requirements.

STUDIES

Extensive studies related to the S-II stage were completed in support of other technical activities. The body stiffness characteristics of the S-II stage, including axial, bending, and shear stiffness, were evaluated; and similar data were compiled or estimated for the other stages of the Saturn V vehicle. This information is required for determination of body natural frequencies and mode shapes for use in stability and control studies or dynamic loads analysis.

The allowable loadings that may be applied to the S-II stage during static firing operations were determined for several selected stations; the results are expressed in terms of maximum allowable bending moment, axial load and shear, or interaction equations defining permissible combinations of these loadings.

Evaluation of allowable bending moments versus time during S-IC boost at several selected stations has been completed.

STRUCTURAL TESTING

Basic Material Properties Tests

Extensive tests were completed at room and cryogenic temperatures (to -423 F) to establish design mechanical properties for 2014-T651 parent metal and welded joints; adhesive, core, and composite sandwich construction of the common bulkhead; and high-strength fasteners and mechanical joints. Tests were also conducted at room and elevated temperatures on the adhesive, core, facing material, and composite sandwich assembly of the LH_2 tank external insulation. Statistical reduction of the test data was accomplished to establish strength allowables for use in the design of S-II stage structure.

Testing of parent metal specimens included determination of tensile ultimate and yield strength, elongation at failure, compressive yield strength, shear ultimate strength, bearing ultimate and yield strength, and modulus of elasticity in tension and compression. Several plate and sheet thicknesses were investigated, and data were obtained at room temperature, -100 F, -300 F, and -423 F. Approximately 15 specimens were tested for each data point: a total of approximately 1600 specimens for the parent metal program. The cryostat used for testing at LH_2 temperature and the test fixturing with cryostat removed are shown in Figures 12 and 13.

Uniaxial testing of weld joints in 2014-T651 sheet and plate was conducted to determine ultimate tension strength and elongation at failure. A range of sheet and plate thicknesses was covered, and the effects of weld psoition, joint offset, and weld repair were investigated. Tests were performed at room temperature, -100 F, -300 F, and -423 F. Normally 10 speciments were tested for each data point: a total of approximately 1800 specimens for the weld program.

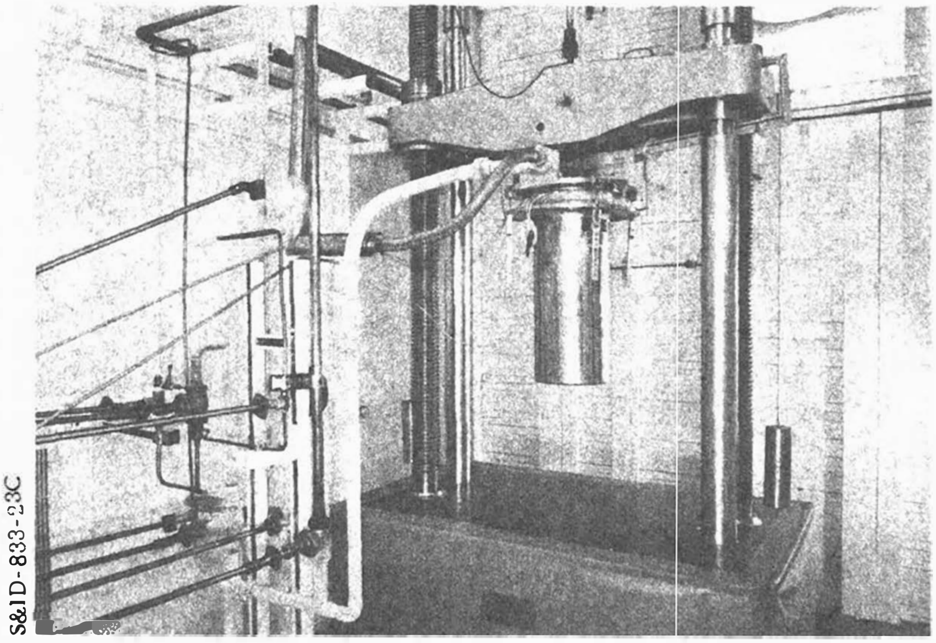

Figure 12. Cryostat

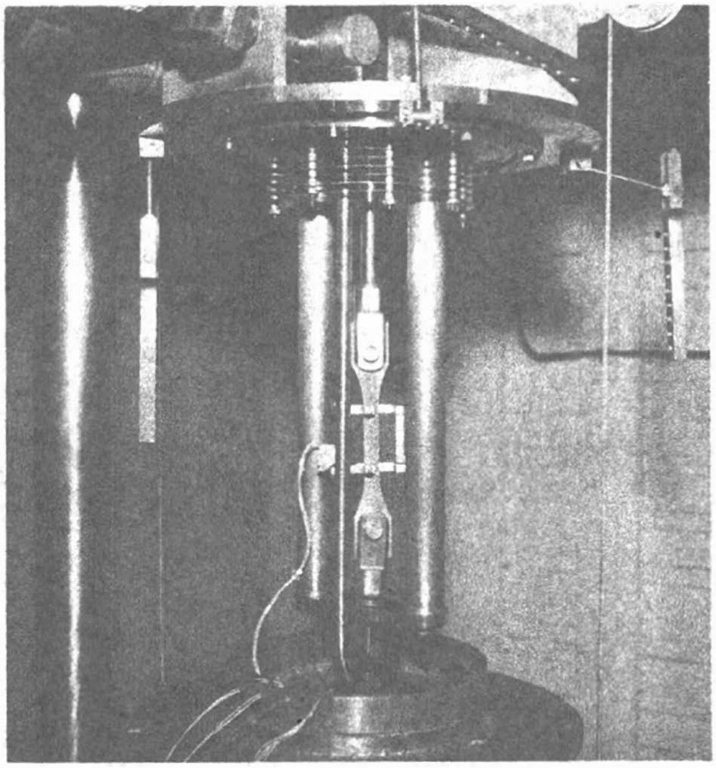

Figure 13. Cryostat Test Fixturing

Flatwise tension and compression and block-shear tests were performed on the Fiberglas honeycomb core of the common bulkhead to determine the ultimate strength and modulus. Tests were conducted on a range of core thicknesses from 5/8 to 6 inches at room temperature, -300 F, and -423 F. Edgewise compression tests were also conducted to evaluate the ultimate compressive strength of the 2014-T6 facings as supported by the core. Approximately 600 specimens were tested in this program.

Model Bulkhead Stability Tests

A two-phase test program was initiated to investigate the stability under uniform collapsing pressure of bulkheads having hemispherical and ellipsoidal contours. The objectives of the program were to verify the design buckling coefficient used for the full-scale common bulkhead, to support theoretical investigations of buckling behaviors, and to evaluate effects of unequal facing thickness, core stiffness characteristics, and temperature gradients on buckling behavior.

The initial phase of the test program involved collapsing-pressure tests on hemispherical and ellipsoidal monocoque shells of 8 inches base diameter. The test specimens were hydropress formed from 7075-T6 aluminum alloy and subjected to selective Chem-Milling to achieve a uniform thickness distribution. Various thicknesses were selected to cover a radius-to-thickness ratio of approximately 30 to 200. The equivalent radius-to-thickness ratio for the full-scale common-bulkhead sandwich structure is approximately 50. Twenty-four hemispherical shells and 20 ellipsoidal shells were tested in this program, and the test data were statistically reduced to obtain plots of buckling coefficient versus radius-to-thickness ratio for both 90 and 99 percent probability. The 99 percent probability buckling coefficient is 0.26 for the hemispherical shells and 0.44 for the ellipsoidal shells. These values can be compared to a design buckling coefficient of 0.156 used for the full-scale bulkhead. (Buckling coefficients for ellipsoidal shells are based on the maximum radius of curvature, which occurs at the pole.)

A typical hemispherical shell installed on the base plate of the test fixture that is used to apply hydraulic collapsing pressure to the specimens is shown in Figure 14. Typical ellipsoidal shells after buckling failure are shown in Figure 15.

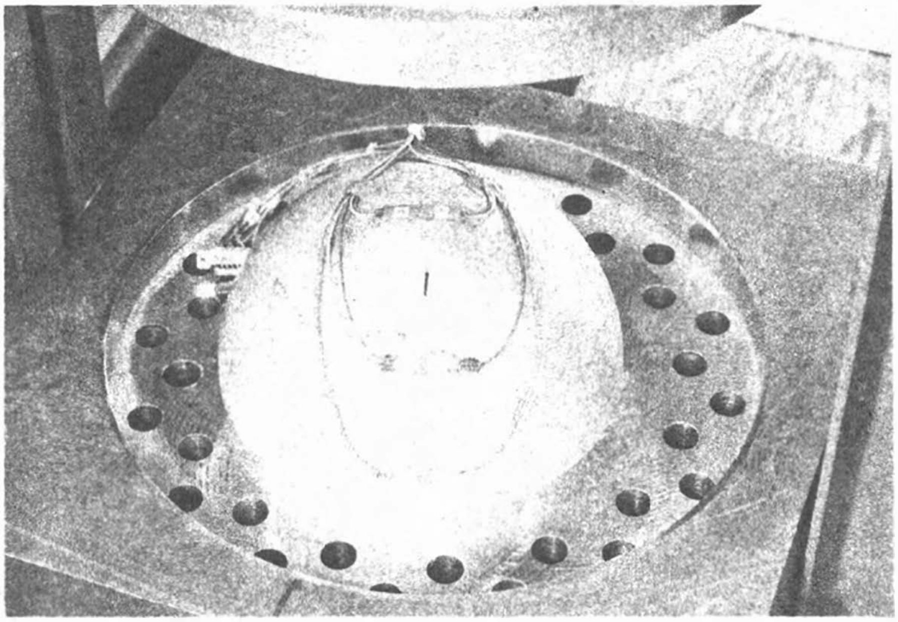
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Figure 14. Saturn Structural Test Setup

Results of the 8-inch model bulkhead tests assure that the design buckling coefficient employment for the full-scale common bulkhead has a margin of safety for prediction of the buckling of a monocoque ellipsoidal shell under collapsing pressure. At the end of this reporting period, one hemispherical and four ellipsoidal specimens had been tested. Test data have not been completely reduced, but preliminary results indicate that stability of the full-scale common bulkhead has been conservatively predicted. Views of a typical ellipsoidal model bulkhead are shown in Figures 16 and 17. The test fixture used to apply collapsing hydraulic pressure is shown in Figure 18. A view of a typical ellipsoidal specimen after buckling failure is shown in Figure 19.

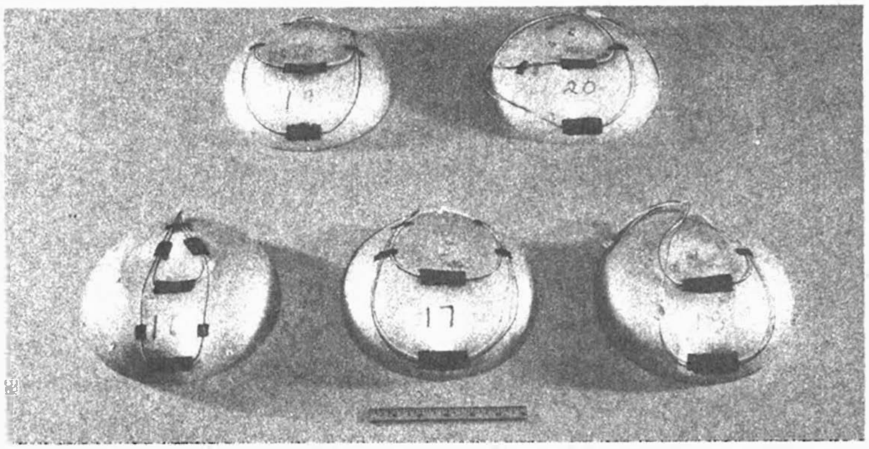

Figure 15. Bulkhead Stability Scale Size Specimens

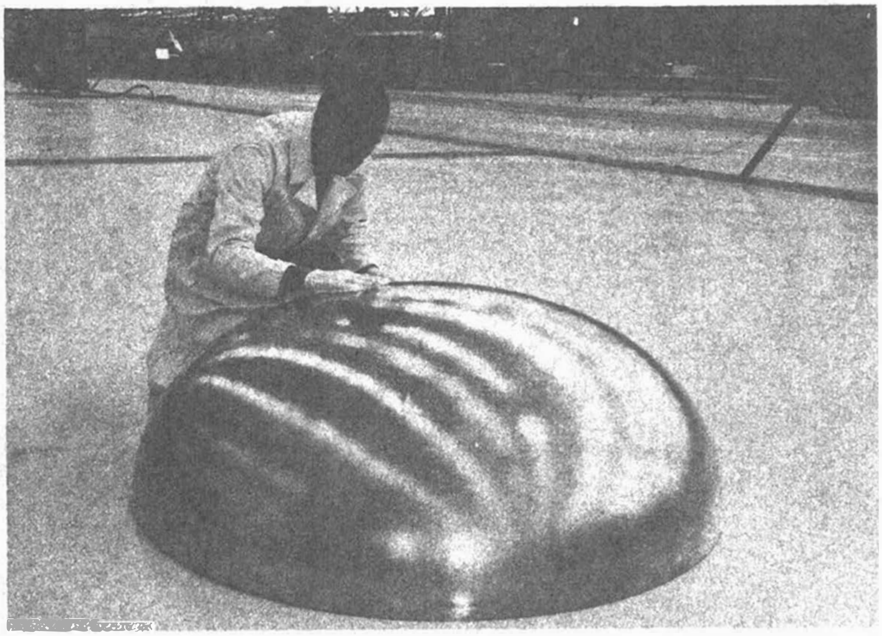

Figure 16. Ellipsoidal Model Bulkhead, Exterior View

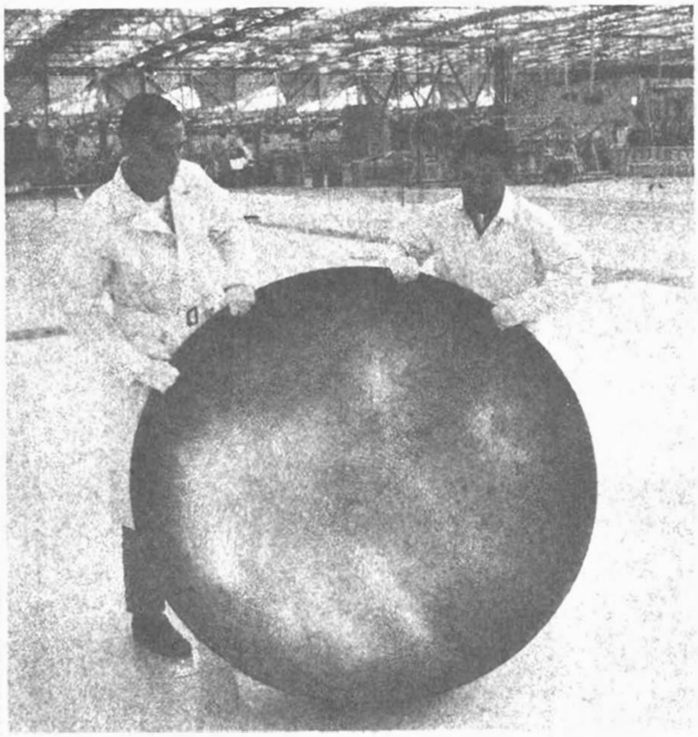

Figure 17. Elipsoidal Model Bulkhead, Interior View

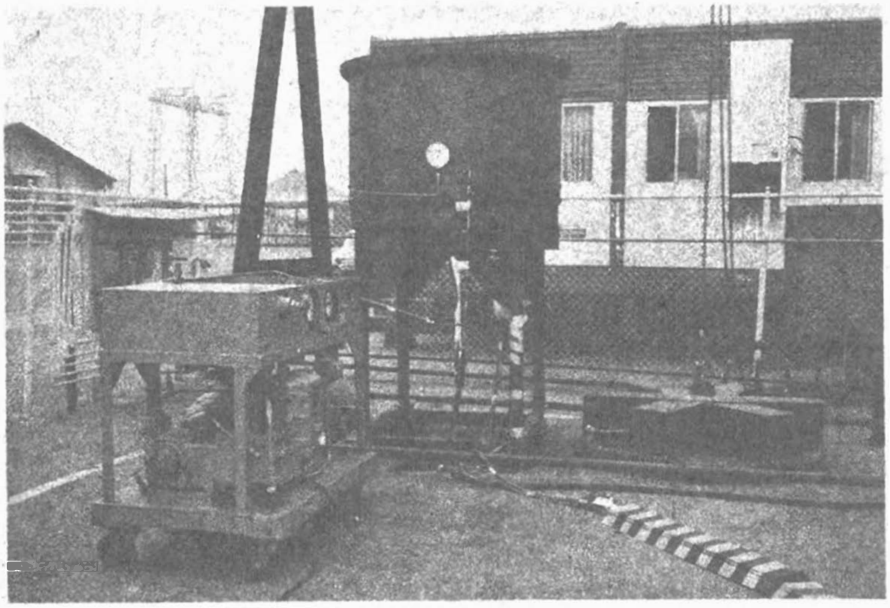

Figure 18. Hydraulic Pressure Test Fixture

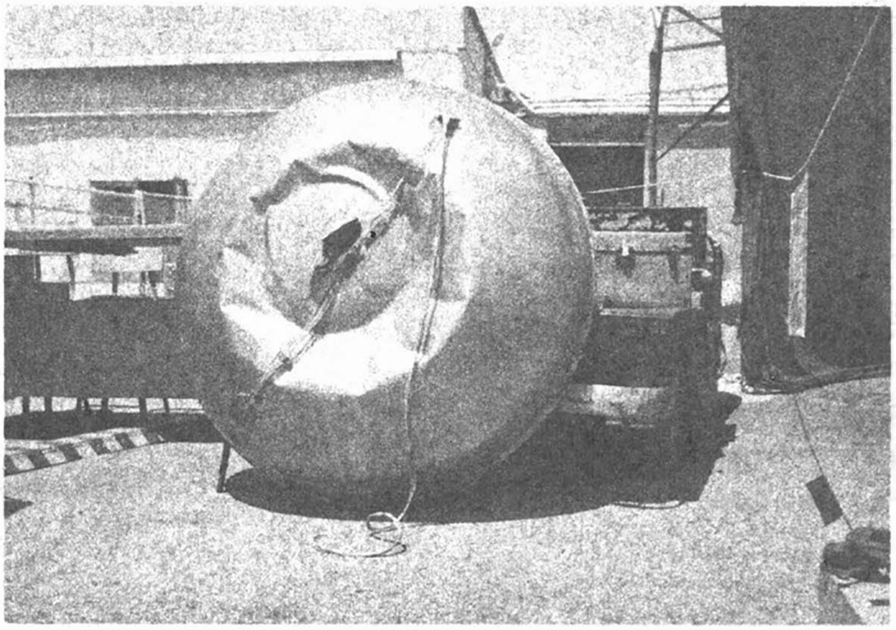

Figure 19. Ellipsoidal Specimen After Buckling Failure

An extensive test program was initiated to support this parallel design development. A large number of metal-to-metal lap-shear tests were conducted in order to evaluate the feasibility of using adhesive-bonded joints to splice the forward-facing gore segments. Single- and double-lap specimens were tested at room temperature, -300 F, and -423 F. Effects of splice thickness, lap width, and taper of the splice straps were investigated. A total of 214 specimens were tested during this phase.

Flatwise tensile and block-shear sandwich specimens with simulated riveted joints were tested to evaluate the effect of riveting on the strength of the bulkhead core.

Tests were performed on various welded strip-seal configurations to determine the strength and load-deflection characteristics of the seal and the effect of the sealing weld on the strength of the basic bulkhead gore. Three different aluminum alloys (5052-H34, 5083-H32, 3003-H14) were investigated as potential strip-seal materials. During this phase, 145 specimens were tested.

A model test program to evaluate the behavior of a complete membrane seal applied over the structural bulkhead was planned. A total of 20 model membrane seal shells will be tested in this program. The test fixture and model bulkhead have been completed, and the test is being set up (Figure 20). It is anticipated that testing will begin approximately 10 August 1963.

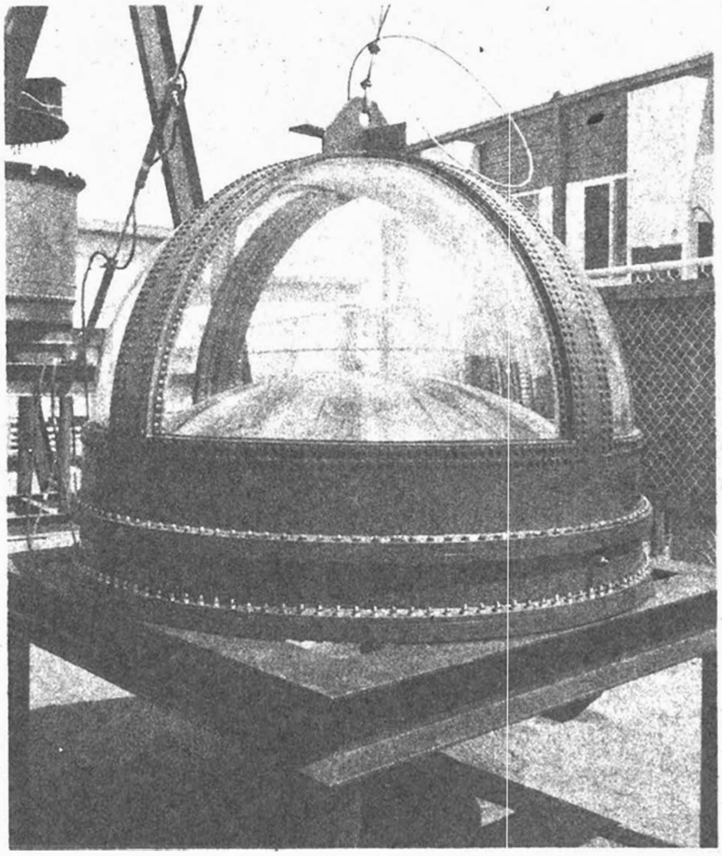

Figure 20. Membrane Seal Test Setup

Acoustic Panel Tests

Acoustic test specimens that simulate structural panels of the S-II forward skirt, LH_2 tank, aft skirt and interstage, and thrust structure have been defined. These panels will be exposed to design acoustics environment in order to verify the sonic fatigue resistance of the primary structure. Detail test planning is in progress. According to current plans, tests will be accomplished at the NAA Los Angeles Division acoustic test facility.

Full-Scale Common-Bulkhead Test

The general test plan for the full-scale common-bulkhead test program was defined and reviewed with MSFC, and general approval was obtained.

Basic facility requirements were negotiated with Rocketdyne, and design of test fixtures is in progress.

Hydrostatic Test

The hydrostatic proof-test program was completely defined and submitted to MSFC for review and approval; general concurrence was obtained. Structural analysis support has also been given to the Industrial Engineering department to stress check the bulkhead hydrostatic test fixtures and to evaluate discontinuity stresses in the bulkhead that are induced by the test fixture.

Structural Static Test Program

Preliminary definition of the structural static test program was completed and submitted to MSFC for review and approval. This definition includes setting of the major test conditions, determination of the approximate test loadings associated with each condition, and establishment of the basic concept for test-fixture design. Detail definition of strain gauge and deflection instrumentation and design of test fixtures are in progress.

WEIGHT CONTROL

Weight and Balance Reporting

Monthly weight and balance status reports were submitted - the first in July 1962. NASA initiated new reporting requirements during this period, which are defined in MSFC-PROC-252. Weight-reporting computer programs were revised to meet the requirements and format prescribed in this document, and the first monthly status report in compliance with these new requirements was submitted in February 1963.

Specification Weights

Several technical reviews were held with MSFC to establish agreement on a specification weight for the S-II dry stage that would be suitable for an operational stage. General concurrence was reached on a value of 75, 000 pounds, based on the S-II stage as defined in the February 1963 weight-status report with suitable modifications for an operational stage. Several recent system-design changes, in response to MSFC technical reviews or requirements, have increased the current S-II stage dry weight to 79, 297 pounds. A list of potential changes was submitted to MSFC for consideration in order to achieve the desired weight reduction to 75, 000 pounds.

S-II weight status is given in Table 1.

Table 1. Saturn S-II Weight Status

Item	Weight (lb)		
	Spec SID 61-361	Revised Spec	May Status SID 62-875-11 (S-II-2 and -3 only)
Usable propellant	930,000	916,000	916,000
Structure and equipment			
Skirts	10,565	7,691	7,389
Maintenance platform	420		
Propellant container	35,100	37,057	33,104
Thrust structure	6,225	6,191	6,907
Fairings and associated structure	265	265	265
Base heat protection	1,350	1,350	815
Paint and sealer	190	180	180
Equipment and instrumentation	5,350	5,261	5,358
Propulsion system and accessories			
J-2 engines (5)	15,400	16,491	16,491
Propellant systems	3,230	4,435	5,876
Thrust vector control	780	857	857
Ullage rocket provisions	150		
Purge system	80	80	80
Stage dry weight	79,105	79,858	77,322
Unusable propellants and gas residuals	8,355	11,255	13,487
Usable propellant residuals			
Engine performance other than normal	1,390	1,390	1,390
Thermally unusable			
Stage weight at burnout	88,850	92,503	92,199
Main stage propellant	930,000	916,000	916,000
Thrust decay propellant (cut-off to 10%)	50	50	450
Stage weight at lift-off (90% thrust)*	1,018,900	1,008,553	1,008,649
Stage mass fraction* $\frac{\text{LOR standard propellant consumption}}{\text{Current stage weight at lift-off}} = 0.908$			
*Does not include that portion of S-1C/S-II interstage documented to S-II stage			

Weight Studies

Considerable effort has been devoted to weight trade-off studies of various design arrangments and potential design changes in order to maintain minimum-weight design of the S-II stage. General support to the structural-arrangement optimization studies and detail evaluation of many design concepts, such as dual-plane separation, stations and expulsion techniques, ullage rocket mounting arrangement, and aerodynamic fairings over external protrusions, have been included in this effort.

STRUCTURAL DYNAMICS

J-2 Engine Acoustic Measurements

An acoustic measurement program was conducted at the Rocketdyne Propulsion Field Laboratory during initial firings of the J-2 engine. Acoustic levels were recorded during five engine firings of 10 seconds or longer duration. Near-field and far-field measurements were taken, and microphones were located at various positions on the engine test stand that corresponded to stations of interest on the S-II stage. Evaluation of the test results showed good agreement with predicted values. Copies of the recording tapes were transmitted to MSFC.

S-II Dynamic Environment

Acoustic and vibration design levels were predicted for all major areas of the S-II stage. The vibration environment was defined in terms of sinusoidal sweep and dwell vibration amplitude versus frequency; vibration levels were derived from the acoustic environment by empirical methods. Both static-firing and launch conditions were considered.

In general, the static-firing operation produces the critical dynamic environment except for the S-II/S-IC interstage and for those components not present on the stage during static firing. Close technical coordination was maintained with MSFC dynamics group personnel concerning prediction of the dynamic environment, and agreement on the results was reached.

Detailed compilation of vibration and acoustic measurements to be taken during ground and flight test programs was completed, and the requirements were coordinated with MSFC.

Body Modal Analysis

Natural body vibration modes were analyzed for the Saturn V vehicle during first- and second-stage boost phases. Longitudinal, lateral, and torsional modes were determined for several boost times during each boost phase. The first eight lateral and longitudinal modes were determined. The results of the modal analysis are completely summarized in SID 63-80, Body Vibration Modes for Saturn C-5 LOR Suborbital Configuration, dated 31 January 1963.

Body Loads Analysis

A comprehensive analysis was conducted to determine the body loads on the Saturn V vehicle during prelaunch, launch, and S-IC boost. Design atmospheric disturbances, changes in aerodynamic and inertial loads due to body bending, control-system characteristics, and tolerances on aerodynamic coefficients are considered during flight loads evaluation. A digital-computer program was developed with which to perform the flight-loads analysis by using basic body-modal data as input to allow evaluation of dynamic effects. A complete summary of the loads analysis and a comparison with design loads data established by MSFC are given in SID 62-1184, Saturn S-II Structural Design Loads Manual, revised May 1963.

Static-firing loads associated with S-II-T at Santa Susana and the production stages at Mississippi Test Facility are being analyzed. Wind load and dynamic transients associated with engine start or shut-down and engine gimbal programs are being considered in the analysis.

Dymanic-loads analyses of J-2 engine ingition at the beginning of S-II boost and of ullage-rocket ignition transient have also been performed. Preliminary dynamic-loads analyses for the Saturn V vehicle at launch, rebound, and during S-IC boost were performed on a passive analog computer in order to conduct parameter studies and identify problem areas.

Dynamic Response Studies

A detailed investigation was made of the behavior of propellants in the S-II tanks as a result of S-IC engine shut-down. The strain energy in the lower and common bulkheads and in the cylindrical shell of the stage due to acceleration loads is suddenly released at this time. Study results indicate that propellant will rebound away from the bulkheads and that approximately three or four seconds will be required to damp out the transient. This could make it difficult to have propellant available at the right time for proper J-2 engine starting. Studies of possible corrective measures are in progress.

The structural characteristics of the stage were accurately represented in the dynamic analysis; however, the propellant in each tank was visualized as a single, solid mass, connected to the body by a spring representing the stiffness of the supporting bulkhead. This is obviously a gross simplification of the actual hydrodynamic characteristics, and a research program involving theoretical and experimental investigations was proposed to MSFC as a means to acquire more fundamental knowledge in this general problem area.

SYSTEMS ENGINEERING

SYSTEMS INTEGRATION

The S-II Stage Maintenance Concept

Design guide lines for implementing the S-II stage maintenance concept have been developed and established in SID 62-1222, Maintenance Concept for Saturn Stage S-II, 26 October 1962. This document describes the accessibility requirements for the flight stages at each of the operational sites through launch-pad operations. A fault-isolation plan that minimizes stage system operating time in order to prevent the use of the stage as a test bed is also outlined.

Component Test Station

At the systems checkout working group meeting of 12 February 1963, Saturn V stage contractors were requested to submit a proposal describing the equipment, mode of operation, and degree of automation required for component test stations. S&ID recommended the semiautomatic mode of operation for electrical-electronic component checkout at Seal Beach, Electromechanical Mock-Up (EMM), Propulsion Field Laboratory (PFL), Mississippi Test Facility (MTF), and Atlantic Missile Range (AMR). The manual mode was selected for hydraulic cryogenic, and pneumatic test consoles for MTF and AMR. Technical descriptions of this equipment were prepared, and costing was initiated.

Interstage Handling and Checkout Plan

As a result of an action item from the 21 February 1963 systems checkout working group, the Aft Interstage Handling and Checkout Plan, SID 63-733, was prepared for submittal to MSFC.

Following assembly and installation of the interstage system, the following major operations will be accomplished at Seal Beach:

1. Interstage subsystem checkout
2. Mechanical fit check
3. Jumper cable checkout with the flight stage during integrated-systems tests
4. Packaging for shipment

The interstage will be shipped to AMR with all systems intact. At AMR, the interstage will be checked out with the stage by means of jumper cables during the low-bay, integrated-systems test. It will then be mated with the stage and transferred to the high-bay area for mating with the S-IC.

Redefinition of GSE Requirements at Seal Beach

The Phase I GSE review and the systems measuring devices (SMD) briefing held at S&ID on 14 May 1963 resulted in a redefinition of the operations and checkout equipment to be used at Seal Beach for Stations 3, 4, and 7.

Station 3

Station 3 operations will be confined to installation of all of the stage systems; no stage power will be applied in this station.

Station 4

At Station 4, all stage systems will be operated under local control, and trouble shooting of difficulties will be done as required. When the stage system are debugged to a reasonable degree, automatic-system level and integrated-system level testing will be initiated. The final checkout operations will be conducted with the checkout equipment under computer control.

Station 7

At Station 7, the stage power system will be activated and checked out. The hydraulic and pneumatic systems will be operated to full flight pressures. Thorough leak testing of the electromechanical systems as well as proportional control activation of each engine system will be conducted.

No SMD will be utilized in Stations 3, 4, and 7. All manufacturing checkout requirements will be satisfied by GSE and special development devices (SDD). The basic changes are as follows.

1. Event recorders and discrete displays will be provided to monitor stage and GSE responses.
2. Stage power buses will be continuously monitored, and voltages will be recorded.
3. Manual control and monitoring of all stage electro-mechanical components and system pressures will be included.
4. A proportional control will be provided for gimbaling each engine.

Static Firing Concept

The S-II stage static firing concept was established after a comprehensive study. The concept is basically an adaptive one. Equipment designed for local control of the automated checkout complex will be used for all noncritical control functions. Special direct-wire manual control equipment will be used to control critical firing functions. The only exception will be the automation of engine gimbaling during firing because of special frequency and amplitude requirements.

The basic stage checkout equipment and associated electrical and pneumatic interfaces will be used in their present configurations. During checkout operations, the manual static-firing control equipment will be disconnected; during static-firing operations, those portions of the electrical checkout station local control that are not required will be disconnected.

A ground equipment test set (GETS) will be used to verify both checkout and static-firing configurations prior to checkout or static-firing countdown. The approach will provide a manual capability in the manual static-firing control equipment for hard-wire, positive control of the propulsion systems: pressurization, propellant loading, propellant feed, and engine control. The remaining stage system control will be provided by means of local control of the electrical checkout station equipment. There will be no redundant active control between the manual static-firing control equipment and the electrical checkout station equipment during the static-firing mode of operation. They will be isolated by means of connection or disconnection with the output of the command distributor.

During static-firing operations, the local-control mode of operation for the electrical checkout station equipment will be used in order to maintain control of systems that are not directly associated with the hot-firing testing (such as separation, flight control, and power and control). A computer will be utilized as a passive monitor during static-firing operations. This concept provides for positive control of all functions necessary to restoration of the stage to a safe condition upon stage or GSE malfunctions and the capability for avoiding difficult situations without jeopardizing the stage or the operation.

Growth and flexibility are provided for by the method of positive enabling/disabling manual static-firing control equipment and by local control at the output of the command distributor. Positive means permit the retention of complete compatibility within checkout and static-firing configurations.

A phasing growth to any degree of static-firing automation without equipment modification is provided.

Electro-Interference (EI)

The Electro-Interference Control Plan, SID 62-543, was approved by MSFC after minor revisions.

The Electro-Interference Test Plan, SID 63-400, was published and submitted to MSFC for approval. This test plan describes methods of testing components, subsystems, and the integrated systems of the stage in accordance with the requirements of specifications MIL-I-6181D and MIL-E-6051C.

MSFC expressed concern for possible interference generated by the heliarc welders that are adjacent to Station 4 during checkout operations at Seal Beach. An S&ID ad hoc committee was organized to analyze the problem and make recommendations. A test program to determine the magnitude of the welder interference is under way.

Propellant Tank Entry

Tank entry equipment must be designed to prevent tank contamination, since tank cleaning facilities are not provided at any field locations. Also, cleanliness requirements limit the scope of activities permitted within the tanks.

The LH_2 tank servicing mechanism will consist of a rigid column supported by an external structure that can be inserted through the 36-inch opening in the LH_2 tank. A service platform will be attached to a sleeve and driven up and down the rigid column, as required. The platform will rotate about the column to afford access to any part of the LH_2 tank.

A portable clean room will be erected about the LH_2 tank access opening when the tank access cover is removed. The room, consisting of a simple framework with a polyethylene enclosure, will permit insertion of the tank-servicing mechanism.

An air-conditioning unit will supply dry, filtered air to purge the tank of nitrogen gas prior to entry of personnel and to maintain a safe working atmosphere for personnel during operations within the tank. The same air-conditioning unit will be used to service both propellant tanks, since simultaneous entry is not anticipated.

The recent change to a central sump for the S-II LOX engine feed and loading systems has eliminated the 36-inch personnel access opening in the LOX tank. Tank entry is now accomplished through a 20-inch diameter access opening located 104.75 inches from the apex of the aft bulkhead. Studies are being conducted to define the necessary equipment required for personnel entry and internal operations.

Integrated Systems Checkout Procedures

A preliminary integrated systems checkout procedure was prepared. This procedure will form the basis for the automatic tape program and for the detailed operating procedures that will be used at all S-II stage test sites. The integrated systems testing, which includes the latest Launch Operations Center (LOC) planning for Overall System Tests (OST), provides the following types of tests:

1. System readiness
2. Simulated launch
3. Simulated flight with umbilicals connected
4. Simulated flight with electrical umbilicals ejected
5. Injected system malfunctions

This testing will be included in the final manufacturing operations at Seal Beach, the prestatic firing and post-static firing tests at MTF, and the low bay checkout at AMR.

HUMAN ENGINEERING

Design Criteria

Human Engineering Criteria for Saturn Systems Design (SID 61-369) was revised and reissured to all S-II design groups on 11 January 1963. This document provides a basis for human engineering support to systems design. In addition, four general procurement specifications were developed to ensure incorporation of human engineering principles in supplier designs.

Stage and Systems Design Support

A full-scale, 60-degree soft mockup of the forward skirt areas was completed and used as a design tool in evaluating alternative packaging configurations, accessibility and maintainability requirements, work platform configuration, equipment marking, and other design support items. A component list which defines all S-II system components with respect to size, weight, and location was developed. This list, provided to MSFC and presented at the Fifth S-II Vehicle Mechanical Design Integration Working Group (VMDIWG), is being used as a basis for evaluating S-II accessibility requirements and provisions. Control drawing V7-000111, defining stage access and servicing provisions, was completed and transmitted to MSFC.

Human Engineering personnel participated in a splinter group meeting of the VMDIWG concerned with man-equipment interfaces in the Saturn V interstage areas. This splinter group has provided an excellent line of communication among Saturn V contractors for discussion of mutual interface problems.

Preliminary tank entry procedures, as well as special personnel protective clothing and equipment for use at all S-II facilities, have been defined.

GSE Design Support

A full-scale soft mock-up of S-II checkout equipment stations and the test conductor's console was completed and is being used as a design development and evaluation tool. Released drawings of checkout station panels are being incorporated into this mock-up so that the test conductor's console and each checkout station will be shown in its latest configuration.

Problem Report Analysis

A system for coding and classifying human error and error-likely situation data by means of automated data processing techniques was developed for integration in to the NAA master failure code. This system will be used for handling of human engineering data obtained from S-II malfunction data reports written during manufacturing and test operations. The coding system was developed in compliance with NCP-200-2 requirements.

CONFIGURATION CONTROL

Configuration Accounting

In order to permit fast and accurate accounting of the configuration changes resulting from authorized changes, an automatic data processing system, the configuration control master record (CCMR), was developed. This system assists in evaluating interchangeability, replaceability, conditions of incorporation, and other detailed facets of change implementation. The program is capable of providing the following current data for each end item (both GSE and stage) on the S-II program:

1. Correlation between model and drawing numbers
2. Reference system for identifying initial release and subsequent configuration change of any given part number
3. Complete description of part number application including next assemblies and end item effectivities

4. Mechanized sequencial configuration tabulation by end item

5. Mechanized indented drawing breakdown

Change Statistics

Since the formal implementation of Configuration Control on the S-II Program on 1 June 1962, approximately 270 changes have been identified and processed. Figure 21 is representative of this activity.

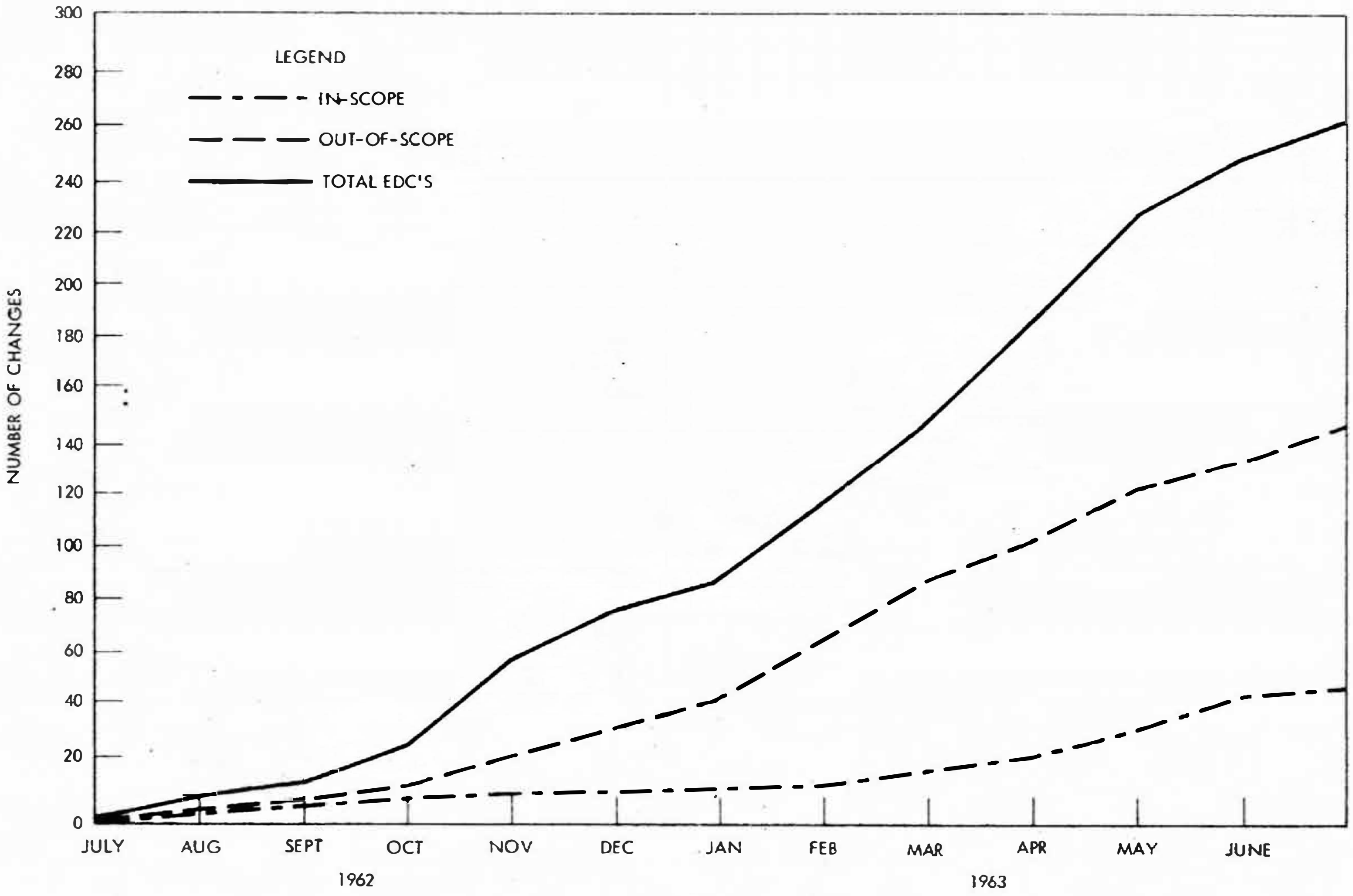

Figure 21. Representative Change Statistics

SYSTEMS

MEASUREMENT AND RF SYSTEMS

Measurement Systems

Measurement systems design concepts and hardware implementation were resolved for each type of measurement currently required. Instrumentation lists were completed for the S-II-2, the Electromechanical Mock-Up, the Battleship stage, and the All-Systems test stage. A preliminary instrumentation parts and equipment list for the S-II-2 was completed and submitted to MSFC for review and approval.

One single sideband telemeter system and one PAM/FM/FM telemeter system were deleted from use on the S-II stage. Changes are presently being incorporated to allow use of a PCM/FM telemeter system for inflight data acquisition. The number of RF links for the first S-II flight stage telemeter systems has been reduced to six.

Telemetry Systems

System Design. Phase I documentation of the system designs was completed and presented to the Astrionics Division, and was approved. Component package designs and installation layouts implementing these designs and several subsequent MSFC directives were completed.

Breadboard tests were conducted to confirm the compatibility of several specific subsystems (transducers and signal conditioners) with the FM/FM telemetry systems. Laboratory tests also were performed to determine the compatibility of airborne FM/FM telemetry equipment with several types of ground subcarrier discriminators.

Hardware Procurement. Specific control drawings and procurement specifications were released for 11 major telemetry-system component packages. Supplier proposals were obtained for six of these items, and bids are being obtained on the other five. Two additional specification control drawings are being prepared.

Evaluation Tests. Electrical and environmental tests (temperature and vibration) were conducted on voltage-controlled oscillators from six suppliers, telemetry transmitters from three suppliers, audio amplifiers from two suppliers, and RF power amplifiers from two suppliers.

A breadboard of the MSFC-designed telemeter calibrator was built and tested to determine its applicability to the S-II stage. A report on these tests is being prepared. Parts were ordered for similar tests on the 270-channel time-division multiplexer, the remote time-division submultiplexers, the single-sideband telemeter multiplexers, and the FM/FM telemetry system. Fabrication of these breadboards was begun.

Commercially available test equipment, including discriminators and demultiplexers, was ordered to support laboratory tests of the S-II telemetry systems; and several of these items were delivered. Test panels and test boxes required for these tests were designed and are being fabricated.

Converter Development

Initial laboratory test effort was completed to firmly establish the measurement systems design concepts. Following MSFC approval of the design concept, intensive development effort was conducted in the laboratory. Development effort, design, and breadboard evaluations were completed on seven signal conditioners, four specialized airborne calibration source modules, and two regulated power supplies.

Complete circuitry and parts lists were submitted to the instrumentation design group for packaging. Four checkout specifications were formally released.

Component Procurement

Measurement requirements necessitated the preparation and release of 31 procurement specifications. Prototype hydraulic measurement instruments were received to support the preproduction engine actuation systems. All currently active procurement specifications were transmitted to MSFC for review and comment. Several changes were recommended and incorporated into the procurement document; and some areas, particularly qualification and acceptance testing, are still under investigation.

Returned proposals on 23 specifications were evaluated, and acceptable suppliers to S-II Engineering were selected. Four bid packages are being evaluated; four proposal packages have not yet been received for evaluation.

Instrumentation Design

<u>Packaging Design.</u> The design concept for instrumentation packages was established. A total of 111 drawings of 24 packages was released, and prototype parts are being fabricated. For example, the chassis designs for flow and tachometer signal conditioners and for temperature bridges

use cases of aluminum or magnesium, mother boards of etched circuitry, and modular plug-in receptacles that are integral parts of the chassis. The signal conditioner modules will be of the welded-module type.

Instrumentation Wiring Design. Approximately 200 schematics were prepared for the Electromechanical Mock-Up. These schematics are being prepared on D-size vellums, using a format established by MSFC drawing number 10443376. This information is to be transferred to wire harnesses and given to Manufacturing in the form of automatic processed wire lists.

Installation Design. End-instrument installation layouts were completed for the Electromechanical Mock-Up, the Battleship, and the All-Systems test stages. These layouts are used to establish mounting bracket configuration and location requirements. The instrumentation container equipment layouts were completed, and instrumentation container sizes and locations were established.

RF Systems

Command Destruct Receiver

The command destruct receiver GFP equipment was received from MSFC in December 1962. Engineering evaluation tests are being conducted on the GFP receivers and voltage regulators. The command destruct receiver functional bench checkout specification was released, and the post-installation checkout specification is currently in work.

MISTRAM Tracking Aid

The MISTRAM tracking aid system was incorporated into the S-II stage, and is not longer for installation provisions only.

Engineering evaluation tests utilizing the MISTRAM test set are being conducted on the transponder. Both transponder and test set are preproduction models loaned to S&ID by the Air Force until production units become available. The test set checkout specification was released, and the transponder bench checkout and system post-installation checkout specifications are currently in work.

Antenna Tests

The antenna test range in Downey was completed in January 1963. Since January, antenna locations were established for all S-II antenna systems. In addition, model feed systems were developed to simulate actual S-II antenna systems during scale-model tests. Currently, final pattern sets are being recorded on the radio command antenna system.

ENGINE SYSTEMS

J-2 Engine

The main propulsion for the Saturn S-II stage is provided by five J-2 engines. The four outboard engines are gimbaled to provide lateral control. Shutdown of one engine during S-II boost will not preclude continuance of the S-II operation, since the stage is designed for single engine-out capability. The engines are completely self-contained, requiring minimum inputs for start, stable mainstage, and shutdown. Maximum performance is obtained with optimum configuration, considering size and weight.

Description

The J-2 engine is a 200,000-pound vacuum thrust, high-energy, upper-stage propulsion system utilizing liquid hydrogen and liquid oxygen as propellants. The engine contains 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 that utilizes the same propellants as the thrust chamber. The engine also contains a propellant utilization (PU) valve that provides mixture ratio control 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. An engine failure sensing and shutdown (EFSS) system continuously monitors critical engine parameters to detect malfunctions (or impending malfunctions) and to initiate engine shutdown before a catastrophic failure can occur.

Analysis and Design

Static Firing Side Load Study. Excessive side loading occurring in the J-2 engine because of unsymmetrical jet separation during static testing has necessitated the use of a device either to absorb the loading or to reduce the effects of the unsymmetrical jet separation.

The initial analysis was concerned with the design of a mechanism that would allow free gimbaling, absorb the side loads, and restrain the engine in any position during start and cutoff. Associated with this analysis was the study to determine the effects of uprating the engine to eliminate jet separation during steady-state operation.

Also, testing was begun on the use of a converging cone at the thrust chamber exit to reduce the effect of jet separation. This testing has produced promising results, and it is anticipated that the engine will require restraint only during the start sequence.

Effort to design a mechanism that restrains the engine only during start is presently in progress.

Performance Analysis. An investigation is being conducted of the effects of combustion equilibrium on engine mixture ratio. Two different equilibrium models (concepts) are under study: "frozen" equilibrium, in which burning is contained within the combustion chamber, and "shifting" equilibrium, wherein burning continues throughout the exhaust nozzle. The results of this study will influence engine mixture ratios as well as propellant tanking mixture ratios, thus producing an optimized programmed mixture ratio control.

A study is presently in progress to establish a performance analysis program for static testing. From this program, test data and data on the present MSFC performance-prediction model, a performance-prediction model for the S-II stage will be established.

Engine Failure Sensing Shutdown (EFSS) System. A failure mode analysis of the engine system was made to establish the requirements for the EFSS system, which will safely shut down a malfunctioning engine. Firm direction on this system has not been received; however, it is anticipated that the following parameters will be utilized for the EFSS system:

Item	Flight Testing	Static Testing
Gas generator over temp	X	X
LOX injection pressure	X	X
LOX pump speed		X
Fuel pump speed		X
Vibration safety cutoff		X

Procurement and Component Development

Checkout. A study is being conducted to determine the most feasible means of checkout of the engine system. As a result of this study, the following preliminary progress specifications have been written to establish GSE design:

Engine receiving inspection

Installed engine checkout

Battleship Engine system checkout (single engine)

Battleship engine system checkout (3 and 5 engine)

Unresolved problems with MSFC, Rocketdyne, and LOD must be resolved before the total checkout requirements for the engine system can be defined.

Development Test Plan. A development test plan has been written for the engine system during phase II battleship testing. This is intended to be used in establishing the over-all development test plan for battleship phase II testing.

Test objectives in the engine system plan are as follows:

1. Checkout procedures
2. Engine compartment purge
3. Thrust chamber chill
4. Engine helium tank fill
5. Start tank fill
6. Free hydrogen ignition
7. Countdown procedure
8. Propellant preconditioning
9. Fuel pump inlet conditions
10. Oxidizer pump inlet conditions
11. Engine start characteristics
12. Vibration characteristics
13. Propellant system pressure surges
14. Engine shutdown characteristics

Instrumentation Requirements. Engine-system instrumentation requirements for flight have been established, and the requirements for static firing are presently being studied. Conflicting direction has been received in this area, however, and until this problem is resolved, it will not be possible to firmly establish these requirements.

Engine Compartment Conditioning System

The engine compartment conditioning system provides a means of purging the engine and interstage areas of explosive mixtures during propellant loading operations and maintaining proper temperature control for critical stage components. Engine compartment purging, utilizing nitrogen, is accomplished entirely before lift-off. The purge system consists of an orifice-perforated, circular, 10-inch-diameter manifold; a 13-inch-diameter purge feed line; a quick disconnect; and a series of 182 overboard vent holes surrounding the aft skirt, interstage, and S-IC forward skirt. The circular manifold is mounted above the engines near the bottom of the thrust chamber and remains with the stage during flight.

Description

Purging the engine compartment is accomplished by injecting warm gaseous nitrogen (between 300 to 500 lb/min flow from 80 F to 250 F under a pressure not to exceed 1.5 psig) through the large manifold. The 10-inch circular manifold will contain 90 equally spaced, circular orifices. Thirty of these, 1.1 inches in diameter, are directed perpendicularly upward; 30, 1.2 inches in diameter, are directed perpendicularly downward; 20, 1.1 inches in diameter, are directed horizontally outward; and 10, 0.9 inch in diameter, are directed horizontally inward. The nitrogen is evenly distributed in the interstage area by these orifices to maintain a -50 F atmosphere in critical areas. It escapes through the series of vent holes surrounding the compartment.

The S-II vent holes have been placed under each of 182 supporting hot 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:

140 sq in. above the thrust cone

138 sq in. just below the thrust cone

155 sq in. on the S-IC forward skirt

Analysis and Design

The system as originally designed had the main objectives of engine chilling and a positive displacement-type compartment inerting. This was accomplished with the use of cold GN_2; temperature-sensitive electrical and hydraulic components were warmed with electric heaters. The system has now been changed at the request of MSFC to use warm GN_2, primarily to eliminate the need for electric heaters and to correspond more closely with test-stand conditions and facility planning at AMR. Chilling of the engine will be accomplished by separate means, and compartment inerting with the warm GN_2 will be accomplished by mixing and dilution. This system will require a more detailed experimental checkout than the cold GN_2 scheme; therefore, the only suitable facility is the All-Systems stage. The schedule for this facility will not permit early tests of the compartment conditioning system. To help relieve this problem, a small scale model test program has been proposed and system design changes will be made toward a more conservative configuration.

There are now two basic objectives of the engine compartment purge system:

1. To maintain ambient temperatures of critical areas within the S-II/S-IC interstage above -50F in order to eliminate as many electrical heaters as possible

2. To satisfactorily inert the engine compartment in order to reduce the hazard of fire and explosion

To meet these objectives, the purge manifold is required to perform as follows:

1. Direct purge gas so as to satisfactorily inert the engine compartment (maintain H_2 and O_2 concentration at 2. 0 percent or less).

2. Direct purge gas so as to maintain temperature-sensitive areas above -50F. The boundaries of the area to be temperature-controlled are: (a) the bottom of the thrust structure, including the lower surface of the thrust cone, (b) the aft skirt and interstage between stations 223 and 46, and (c) the top surface of the heat shield.

To meet these requirements, the purge system will require control of the purge temperature and flow rate between the limits previously called out.

The vents for the S-II engine compartment must be sized and located to:

1. Produce a compartment gas flow pattern conducive to good thermal control

2. Produce a compartment gas flow pattern most effective in expelling hazardous gases

3. Provide sufficient vent area to relieve an interstage pressure differential build-up during S-IC boost

4. Minimize vent area in order to exclude air from the engine compartment prior to launch

Procurement and Component Development

As a result of the changes previously described, the following components have been deleted:

Component	Number
Purge system disconnect	ME 144-0017
Gas analyzer manifold	
Gas analyzer disconnect	ME144-0010
Mass spectrometer	
Recorder	

The following is a list of the new components resulting from changes made within the last year:

Component	Number
Purge system disconnect	(Now to be made in house)
Purge manifold	MC 901-0208
Purge and thermal control nitrogen unit	ME 901-0249

To date, no contracts have been awarded for the manufacture of these items. Although development tests are planned for these components, no tests have been completed.

Testing

At the time of this writing, no tests have been conducted to develop the engine-compartment purge system. Two tests are being planned, however, for the development and qualification of this system. The objectives of these tests have been determined.

A tenth-scale model of the S-II/S-IC interstage will be used to conduct model tests, beginning in December 1963. The objective of the tenth-scale model tests is to provide knowledge of flow distributions, the extent of GN_2 mixing, resultant temperatures, the extent of inerting, and the effect of the following purge parameters:

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

The second test will be conducted with 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 verify predictions of the following for specific values of purge flow rate (300 to 500 lb/min) and purge gas temperature (80 F to 250 F):

1. Boattail ambient temperatures
2. Structural temperatures
3. Degree of inerting
4. Performance of LOX recirculation system
5. J-2 engine heat-up rates
6. Performance of thermal control system
7. Performance of hydraulic actuation system

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 so that an engine operation may be attained.

Description

The system is composed of the following subsystems:

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

2. Hydrogen pump seal drain—provides a common manifold for venting overboard each of the engine hydrogen pump seal cavities.

3. Oxygen pump seal drain—provides a common manifold for venting overboard each of the oxygen pump seal cavities.

4. Helium tank fill—distributes to each engine helium bottle, gaseous helium (at a pressure of 3000 psi and a temperature of -250 F) necessary for J-2 engine start.

5. Hydrogen start tank fill—distributes to each engine hydrogen start tank, gaseous hydrogen (at a pressure of 800 psi and a temperature of -250 F) necessary for engine start.

6. Hydrogen start tank vent control—distributes to each engine start tank 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 and chill—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, the hydrogen start-tank vent control subsystem contains five solenoid valves. All purging is accomplished prior to propellant tanking.

Analysis and Design

Engine servicing system design analyses were completed, and component specifications were released. From system analyses, it was determined that disconnect standardization would be a practical concept; consequently, the same disconnect is used in more than one system. Contracts have been let on all procurement specifications, and design and development testing is proceeding on a schedule commensurate with S-II delivery requirements. System development testing is scheduled for the EMM. and EDL.

The system requirements necessitated the following subsystem analyses:

1. Turbopump purge—The airborne half of the disconnect incorporates a self-sealing check valve to prevent contaminants from entering the system when the disconnects are separated.

2. Hydrogen pump seal drain—This seal requires continuous vent capability, but ground rules require that hydrogen must not be dumped overboard during boost. Therefore, a self-sealing check valve with integral relief valve was incorporated in the airborne half of the disconnect to restrict hydrogen dumping and prevent contaminants from entering the system when the disconnects are separated.

3. Oxygen pump seal drain—Due to the maximum allowable seal back pressure of 30 psig, it is necessary to route the servicing line horizontally over to umbilical panel 3, instead of up to umbilical panel 3A. The airborne disconnect will be an open disconnect to allow draining of the pump cavity without building up the back pressure on the seal.

4. Helium tank fill—The airborne half of the disconnect incorporates a self-sealing check valve to serve as a back-up to the helium tank fill valve and to prevent contaminants from entering the system when the disconnects are separated.

5. Hydrogen start tank fill—The airborne half of the disconnect incorporates a self-sealing check valve with an integral relief valve to prevent contaminants from entering the system and to relieve any pressure build-up in the system after launch.

6. Hydrogen start tank vent control—The airborne half of the disconnect incorporates a self-sealing check valve to prevent contaminants from entering the system when the disconnects are separated, and to standardize the disconnects.

7. Hydrogen start tank vent and relief—The tank requires continuous vent capability, but ground rules require that hydrogen must not be dumped overboard during boost. Therefore, a self-sealing check valve was incorporated in the airborne half of the disconnect to restrict hydrogen dumping and prevent contaminants from entering the system when the disconnects are separated.

8. Thrust-chamber fuel-jacket purge and chill—The airborne half of the disconnect incorporates a self-sealing check valve to prevent contaminants from entering the system when the disconnects are separated and to standardize the disconnects.

Procurement and Component Development

Contracts for Specifications MC144-0011 (Disconnect Valve, Hydrogen) and MC144-0014 (Disconnect Coupling, Oxygen) were awarded to the B. H. Hadley Company on 13 May 1963. Prototype and development hardware design was initiated immediately. To date, design layout and detail drawings are 90 percent complete. Development parts have been fabricated with testing approximately 50 percent complete. Qualification testing is scheduled to begin in October 1963 and finish in December 1963. Qualified components are scheduled to be delivered in December 1963.

The contract for Specification MC144-0010 (Disconnect Valve, Helium) was awarded to the Snap-Tite Company on 14 March 1963. Detail design drawings were completed and submitted for a design review on 10 July 1963, and the design was subsequently approved. Development testing was not requested by this supplier; consequently, qualification testing scheduled to begin during September to November 1963 will be the initial testing performed on this disconnect. Qualified components are scheduled for delivery in December 1963.

The purchase order for Specification MC144-0012 (Solenoid Valve) has been submitted for approval signatures. NASA approval was obtained on 30 August 1963. The selected supplier is the Futurecraft Company. Based on the contract go-ahead of 1 September 1963, development testing should start 1 November 1963, and qualification testing 1 January 1964. Qualified components are scheduled for delivery approximately in March 1964.

Testing

To date, no tests have been conducted that contribute to system definition. However, testing is being scheduled on EMM to determine the adequacy and effectiveness of the various engine-system purges, and to determine also if system manifolding results in workable systems. Tests are being scheduled in EDL using a J-2 engine to determine thrust-chamber heat-up rates after a chill-down cycle is performed, and to determine also heat-up rates for the helium and hydrogen start tanks while exposed to cryogenic environments.

PRESTART CONDITIONING SYSTEM

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

The fuel system is conditioned by means of a pumped recirculation flow, while a natural-convection recirculation flow with a helium-injection subcooling overboard-bleed back-up is used for the LOX system.

Fuel System

The fuel recirculation flow is initiated by five LH_2 pumps submerged in the fuel tank. The fluid 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, and the prevalve in the main fuel duct is closed.

Procurement of the valves and lines for the system and coordination of the procurement of the common pump and inverter with Douglas have begun.

Analysis indicates that the system will provide a recirculation flow of 1.15 pounds per second per engine, which is greater than the required S-II flow of 1 pound per second, by means of a pump designed to meet the common S-II/S-IVB requirements.

Oxygen System

The natural-convection LOX-recirculation system consists of five uninsulated return lines from the gas-generator bleed valve to the LOX tank and five insulated standpipes from the bottom of the LOX tank to just below the liquid interface.

The subcooling back-up consists of a helium-gas-injection system just above the main LOX pump and a manifolded overboard gas generator bleed.

During recirculation, the prevalves and return-line valves are open and the overboard-bleed valves are closed. During a bleed, the prevalves and overboard valves are open and the return-line valves are closed.

The natural-recirculation system provides a liquid flow of 0.5 pounds per second per engine, which is marginal for satisfactory conditioning. This makes it necessary to provide the back-up subcooling method

Analysis and Design

Fuel System

The fuel prestart conditioning system is designed to provide the minimum engine starting NPSH requirement at the fuel-pump inlet. The requirement of a common pump with S-IVB necessitates the use of an individual pump system rather than a simpler manifolded pump.

Analysis shows that it is necessary to insulate the main fuel duct and return manifold and lines to insure proper conditioning. Vacuum jackets have been placed on these lines.

With the pump supplied, it was necessary to enlarge the engine bootstrap lines and gas-generator bleed valve to 1-1/2 inches to decrease the engine pressure drop. The system components are sized as follows:

Component	Size (inches)
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, a flow of 1.15 pounds per second per engine results with liquid hydrogen, which gives a chill-down time of 96 seconds.

Oxygen System

The oxygen prestart conditioning system must provide the minimum NPSH required at the LOX pump inlet at engine start. S&ID has been directed to use a natural-convection system with a helium-injection backup by MSFC.

The natural-convection system works because of the heating of the LOX in the return line, which creates a pressure head because of the difference in density in the two lines.

To achieve as large a flow rate as is necessary for proper conditioning, a standpipe has been installed in the LOX tank just below the liquid interface to provide additional differential head. The return line has been sized at 3-inches. Individual return lines are necessary to provide adequate distribution at the very low head available.

The helium-injection system injects 5 pounds per minute per engine of helium into the main LOX duct just above the main LOX pump through an annulus placed around the duct. The helium line is 1 inch in diameter for serving 2, 3, or 5 engines and 3/4 inch in diameter for 1 engine. A 3/4-inch check valve and a sonic orifice to control flow are mounted in the line upstream of the annulus. To give proper helium-bubble size, 24 holes of 0.088-inch diameter are drilled in the annulus.

With the natural-convection system, a chill-down time of several minutes results. Analysis shows that satisfactory operation of the system is marginal due to the low head available, making the helium back-up necessary.

Procurement and Component Development

The major procurement and development activity on the prestart conditioning system will be associated with the LH_2 recirculation pump-motor assembly.

The direction by MSFC that the pump be usable for both S-IVB and S-II applications has necessitated coordination of S&ID and Douglas requirements, procurement, and reliability test programs. Agreement has been reached on the performance and design requirements for the assembly. Both Douglas and S&ID have prepared procurement specifications.

Douglas has reviewed supplier designs and has selected a supplier. The supplier and the selected design are acceptable to the S&ID, and therefore a request has been submitted by the Vehicle Systems branch to authorize mandatory-source procurement.

The supplier and the design of the inverter that will provide the 56 vac power for the pump assembly have also been agreed upon.

The development of the pump assembly and the inverter will be closely monitored at the supplier's facility and by means of review of periodic reporting. S&ID will also purchase pump assemblies as soon as they become available and perform pump-performance and simulated-systems tests.

ULLAGE MOTOR SYSTEM

The ullage motor system maintains the position of the liquid propellants in the S-II stage during the critical period of staging. As the first-stage engines are shutdown 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 for approximately 4 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 firing of the second-stage (S-II) engines.

Description

The eight solid-rocket motors are mounted equidistant around the outside 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 stablized 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-type igniter, fired by a pyrogen-type initiator connected to a confined detonating fuse. Each igniter has two initiators, providing the system with a redundance safety factor. The ignition system is triggered by an accelerometer, set to react at 3.6 g. The motor exhaust nozzle has been designed to prevent the exhaust-gas plume from impinging on the J-2 engines. The motors are supported at three points. No ejection system is necessary, because the entire interstage is separated from the S-II stage.

Analysis and Design

The Rocketdyne Division has been authorized to design, develop and qualify the solid-rocket motor. A procurement specification controlling the design and test requirements has been released. An optimization study of the motor configuration and installation was completed, and the results were integrated into the motor design. Support fittings and aerodynamic fairing drawings have been designed, and Phase I drawings have been released.

A preliminary design review of the ullage motor system was conducted, and the design was approved with minor criticisms. The motor handling and servicing concept has been defined and presented to the various NASA agencies. The motor manufacturer has reached the point of lightweight motor drawing release. Following a special suppliers' design review the design was approved with recommendations for improvements. The igniter, ballistics design, and heavyweight development motors are all proceeding on schedule.

The most practical installation of the motor was evolved from a system optimization study in which prime consideration was given to weight versus drag, plume impingement, and accessibility. The exhaust nozzle was controlled by specifying the area ratio and cant and divergence angles, the location of the motor support fittings, the maximum motor diameter, and the design of the aerodynamic fairings. The fairings will serve also to protect the motors from an excessive temperature environment during the vehicle launch phase.

The thrust level of the motor has been so established that the vehicle acceleration requirement will be met by seven motors. This creates the one-motor-out capability required by MSFC-directed criteria.

The ground support equipment required in the handling and servicing functions has been devised and submitted to NASA for approval. In the motor shipping configuration the igniter will be packed separate from the motor. A plug containing dessicant will fill the igniter port.

Testing

The development of a solid-rocket motor involves several concurrent activities, such as the igniter design, propellant design, ballistics design, heavyweight hardware design, tooling, test equipment, and lightweight motor design.

Progress has been made in all of these areas. Eleven heavyweight igniters have been fired, and the igniter design has been defined. Heavyweight motor hardware is being assembled for the first motor firing, scheduled for October 1963. The test stand and tooling design are near completion. A ten-inch test motor cast from a manufacturing propellant mixture has completed temperature cycling to test its stress characteristics.

PROPELLANT SYSTEMS

Propellant-Feed System

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

The propellant-feed system configuration was finalized following trade-off studies involving tank pressurization, trapped propellants, and fabrication problems of LOX-tank exclusion risers versus a central sump. The configuration consists of a LOX-tank central sump, five separate LH_2 tank contoured outlets, and 8-inch vacuum insulated LOX and LH_2 ducts (each containing a prevalve at the tank outlet). The LOX-tank discharge configuration originally consisted of five widely spaced individual outlets with tank-installed exclusion risers to minimize trapped propellant. Because the exclusion risers involve serious fabrication problems, a change was made to a 36-inch central sump containing five LOX outlets. The prevalves are now pneumatically actuated to meet the requirements of the forward-flow engine-prestart recirculation system. As originally designed, the prevalves functioned as squib-actuated emergency-shutoff valves. The 8-inch propellant-disconnect couplings were changed from the original MSFC-approved lock-unlock-retract design to a liftoff design. This change resulted from the establishment of an over-all C-5 vehicle umbilical concept.

The propellant-loading system consists of an 8-inch diameter line, a filling-shutoff valve, and an 8-inch disconnect for each of the propellant tanks. The design of these components fulfills requirements of both the LH_2 and LOX propellants. The engine supply system consists of individual 8-inch diameter LOX and LH_2 feed lines to each engine. Each line contains a pneumatically operated, normally closed prevalve to isolate the engine from the tanked propellants when not operating.

Analysis and Design

The propellant-feed system has been analyzed to determine optimum line and component sizes. As a result, the feed-system lines have been established at 8 inches for both LOX and LH_2. This common sizing will provide interchangeable components for either LOX or LH_2 and will minimize tooling, development, and spares cost.

Procurement and Development

The 8-inch propellant prevalves and filling shutoff valves are being designed and developed by Rocketdyne. Prototype components of the original design configurations have been made and tested. Rocketdyne is currently redesigning both valves to a "C" change specification necessitated by the recirculation system and the LOX tank sump. Prototype valves of the "C" configuration will be available early in 1964. Rocketdyne is currently designing a 2-inch shutoff valve to be used in the engine recirculation system. First units will be available early in 1964. The B. H. Hadley Co. is designing the 8-inch propellant disconnect coupling.

Testing

Rocketdyne has conducted tests on prototype 8-inch filling shutoff valves and prevalves (initial design). Flow testing in water, to determine pressure-drop characteristics, and operation in LN_2 have been the extent of testing. Results indicate specification compliance with requirements for operation in LH_2 and LOX. The redesigned "C" version of these valves, as well as the 2-inch recirculation valve, will be tested in LOX and LH_2 early in 1964.

Slosh and Vortex

During S-II operation, it is necessary to suppress adverse liquid motion (vortex) in the propellant tanks that might cause premature gas to break through into the engine feed lines. An additional requirement is to suppress liquid sloshing, which would have adverse effects on the flight-control system. Slosh and antivortex baffles are provided in the LOX tanks to limit these effects and ensure satisfactory stage operation.

Description

A tenth-scale plastic model for slosh and vortex testing was completed, and the test program was initiated. Partial drain tests and slosh tests of the LOX tank have been accomplished. See Figure 22.

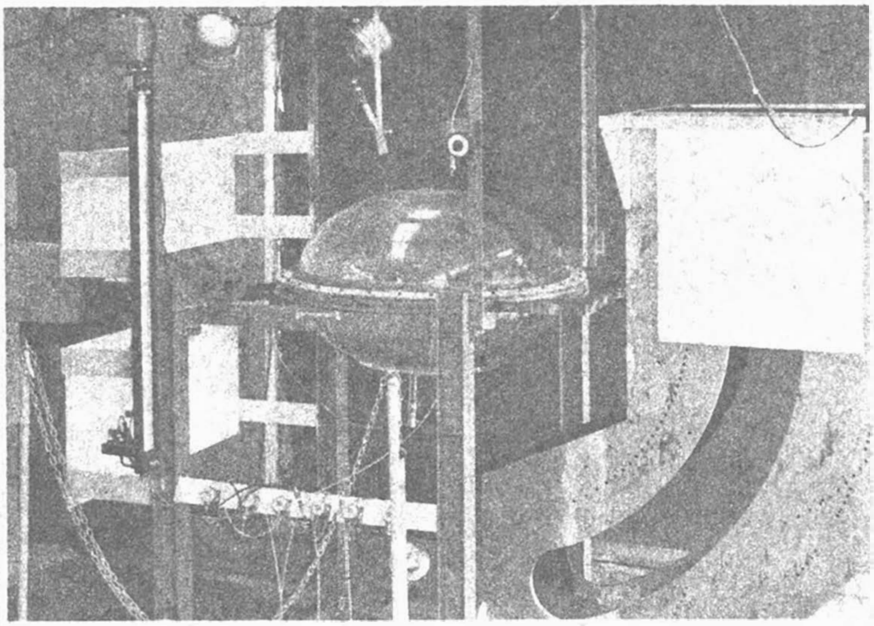
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Figure 22. Slosh and Vortex Test Setup

No slosh or antivortex baffles are required in the present LH_2 tank configuration. The LOX tank contains three-ring slosh baffles, one at the tank midpoint and one each in the upper and lower dome sections. A cruciform baffle on the bottom bulkhead is also provided to limit sloshing during end-boost draining. This will prevent premature uncovering of the LOX tank sump. A vane-type antivortex baffle is mounted in the sump to keep vortices out of the engine supply ducts.

Testing

Drain tests with the LOX-sump configuration were compared with the exclusion-riser model tests. A vane-type antivortex baffle eliminated vortexing in the sump. Slosh tests were begun with the unbaffled LOX tank to determine first-mode natural frequencies. Results were close to the predicted frequencies for the S-II LOX tank. Slosh tests of the LOX tank are continuing with several baffle configurations. At the conclusion of these tests, the LH_2 model tank will be installed, and drainage and slosh tests will be started.

Propellant Management System

The propellant management system for the S-II provides the following:

Accurate loading of LOX and LH_2 propellants to produce optimum-payload boost capability

Propellant utilization during flight to achieve nearly simultaneous depletion of LOX and LH_2 to minimize end-boost residuals

Engine cutoff at propellant depletion

The propellant management system consists of propellant-tank gauging elements and associated electronic equipment to perform the functions of propellant loading, PU control, and engine cutoff. The tank-gauging system, which includes a full-length capacitance probe in each tank, is the primary system for propellant loading and PU control. In addition to these probes, each tank contains point-level sensors to provide the engine cutoff signal at propellant depletion. A series of point-level sensors is also provided to accommodate tank-water calibration and subsequent calibration check against the capacitance probe in propellants. The associated electronics required to support the gauging equipment and provide output signals and controls are in environmentally controlled boxes in the forward and aft interstages.

S&ID's original selection of a point-sensor type of propellant management system was changed by MSFC's preference for a capacitance S-IVB type of system. Procurement of such a system is now proceeding.

The original procurement specification for the propellant-management system was submitted to prospective subcontractors for bid in July 1962. S&ID concluded that an Atlas-type point-sensor system should be chosen for the S-II because flight experience with this type of system promised to minimize S-II schedule and cost problems. However, MSFC did not concur with S&ID's conclusion, with the result that no contract was awarded, and all procurement activity was cancelled in December 1962. Since subsequent studies by S&ID indicated that only a small payload gain resulted from a closed-loop propellant-utilization system, recommendations for deletion of the system were made to MSFC. Instead of propellant-utilization control, S&ID proposed that a programmed mixture-ratio control (PMR) be used during S-II boost. This was to be open-loop controlled with a constant high engine mixture ratio during the initial portion of the trajectory and a shift to a low-mixture ratio midway through boost. The payload gain from PMR proved significantly greater than closed-loop PU control. MSFC reviewed the PU/PMR possibilities and advised S&ID to incorporate both a closed-loop PU system and the PMR control, which would achieve maximum payload advantages. Furthermore, MSFC required a capacitance system like the system Douglas Aircraft is developing for the S-IV and S-IVB, stating that a version of the S-IVB system on the S-II would be preferable. On this basis, S&ID is procuring an S-IVB system, modified to S-II requirements.

Analysis and Design

S&ID has been meeting with Douglas Aircraft to discuss the design of the S-II system. S&ID analysis indicates some improvement could be made in weight and accuracy if the S-IVB system were modified for use on the S-II. However, because of schedule requirements, Douglas will proceed with a strict S-IVB design for the S-II, to meet initial delivery requirements. Design improvements will be made at some change point in the program.

Procurement and Component Development

Under current arrangements, the S-II propellant-utilization system is to be supplied by Douglas Aircraft. Contractual coverage has not been completed for this effort. The initial arrangement is to have Douglas assist S&ID in the preparation of a procurement specification, complete a preliminary design and analysis of the S-II system, and begin the production design. The period for this initial effort was to be from 2 July 1963 through 30 September 1963. Negotiation for the production-contractual phase is planned on the basis of Douglas submitting a proposal to meet the requirements of the procurement specification.

Testing

A. D. Little conducted a liquid-level point-sensor test program for S&ID. Point sensors from eight suppliers were tested to determine performance and environmental suitability for application to the S-II. Results of this test program justified selection of the "hot wire" point sensor for the S-II. A. D. Little has submitted a three-volume report describing the tests and results.

PRESSURIZATION SYSTEM

The S-II pressurization system is divided into several independent subsystems. The functions of these subsystems are as follows:

Hydrogen tank pressurization

Hydrogen tank venting

Oxygen tank pressurization

Oxygen tank venting

Pneumatic actuation of valves for the engine prestart conditioning system

Preflight purging of the hydrogen pressurant lines

In addition to support of the active systems, the pressurization systems group is responsible for the analysis and over-all coordination of the propellant thermal-stratification problem. The pressurization subsystems provide required tank pressures for structural integrity and fulfill engine-inlet requirements for all phases of flight from prelaunch to end of S-II boost. The venting subsystems limit tank pressure and vent the tanks during chill-down and filling. The pneumatic-actuation subsystem regulates pressure and provides some of the control-solenoid valves to actuate the valves in the engine-pre-start conditioning system. This subsystem also provides actuation pressure for prevalve operation during all of the flight phases. The hydrogen pressurant-line purging subsystem is used on the ground only and prevents the backflow of hydrogen gas through the engine injectors and into the engine compartment. Successful operation of the engines is, to a large extent, dependent on operation of the pressurization system. The over-all weight of the stage is greatly influenced by pressurization-system design and performance, inasmuch as the structural weight is very sensitive to internal pressure and the pressurant weight is measured in thousands of pounds. Since the effects of thermal stratification are reflected in tank pressure level, pressurant weight, structural weight, insulation weight, and system complexity, assessment of thermal stratification and measures to overcome its effects is quite critical.

During the past year, a number of major changes were made to the pressurization system. These changes were (1) increase of the tank pressure levels, (2) addition of step pressurization, (3) addition of modulating-pressurant flow-control valves, (4) addition of a pneumatic-actuation subsystem to operate components in the engine prestart conditioning system, and (5) addition of a hydrogen pressurant-line purge system. System analyses have been completed as required to support the procurement of hardware and the installation design. Fourteen procurement specifications were prepared and issued, and the major part of the effort was accomplished on five additional procurement specifications for new components resulting from system changes. The problem of liquid-hydrogen stratification was intensively studied, and significant advances were made. Exploratory tests were conducted to evaluate proposed solutions to the stratification problem and to evaluate an experimental gas distributor incorporating a Hilsch tube.

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 tank pressurization subsystems actually consist of two separate subsystems, one for controlling helium and one for controlling evaporated propellant. The helium subsystem is used for prepressurizing the tanks on the ground, maintaining tank pressure during first-stage boost, and maintaining tank pressure during start-up of the S-II engines. The helium subsystem consists of pressure switches, solenoid valves, and high-pressure receivers and 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. The stored helium, controlled by the same pressure switches and solenoid valves, is used for tank pressurization during first-stage boost and engine start-up. After engine start-up, pressurant gases are extracted from the engines. Hydrogen gas is extracted just upstream of the engine injector. The hydrogen 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 distributor designed to minimize turbulence, thereby reducing the heat loss to the structure and the 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 downstream of the turbopump and is vaporized in a heat exchanger located in the turbine hot-gas discharge line. The flows of vaporized oxygen from the five engines are manifolded together and controlled by a single-flow control valve. A gas distributor is used in the oxygen tank to minimize turbulence of the incoming pressurant. Step pressurization is employed for the oxygen tank and is activated at the same time as step pressurization for the hydrogen tank.

Tank Venting Subsystems

The tank venting systems for the hydrogen and oxygen tanks are essentially identical in concept and design. Two parallel vent valves, are used for each tank. The vent valves for the hydrogen and the oxygen tanks are identical, except for pressure settings. The vent valves are pilot operated and are actuated by tank pressure. No external electrical or pneumatic power is required for operation in flight. Pneumatic pistons in the valves permit opening or closing, as desired, in response to stimuli from the ground. The oxygen vent valves discharge directly to 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 Subsystem

The pneumatic actuation subsystem 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 to minimize the transient flow requirements of the regulator and to increase the probability of successful pre-valve operation under potential failure modes. The subsystem is very straightforward in concept and design and presents no special problem areas.

Hydrogen Pressurant Line Purging Subsystem

This purging subsystem is used on the ground only and 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. Incorporation of this subsystem permitted deletion of burst diaphragms in the pressurant supply line of each engine.

Analysis and Design

A large number of detail analyses were conducted to predict system performance and to define the requirements of the various components. The use of computer programs was greatly expanded, and specific computer programs were prepared to solve the more difficult or lengthy analysis problems. Computer programs are prepared and used to analyze pressurant requirements, transient tank venting during fill, LOX heat exchanger performance, stratification, line pressure drop with heat transfer, thermodynamic functions, and subcooling of liquid hydrogen by helium injection.

A reevaluation of stratification effects, plus concurrent increases in engine inlet pressure requirements and maximum propellant flow rates, resulted in an increase in tank pressure levels. Maximum tank pressures are 39. 0 and 42. 0 psia for the liquid hydrogen and liquid oxygen tanks, respectively. The previous maximum pressure was 37. 0 psia for both tanks. Step pressurization toward the end of boost was incorporated as a means of preventing greater increases in tank pressures.

Reevaluation of the stratification effects was made after tests were conducted by Douglas Aircraft Company and Martin-Marietta Corporation. In meetings with MSFC personnel, it was decided to take a very conservative approach in order to assure the survival of the first flights. Subsequent analyses by S&ID indicate that S-II stratification may not be nearly as pronounced as in the Douglas and Martin tests, especially with the internal stiffening rings. It is also felt that vehicle acceleration in flight will tend to diminish the problem because acceleration greatly increases the internal boundary layer flow, thereby distributing an essentially constant quantity of heat throughout a much greater fluid mass. If these S&ID analyses are verified by test, significant weight savings may be achieved in the later vehicles.

The pressure-switch solenoid-valve flow control system for tank pressurization has been replaced by a modulating pressurant flow-control valve similar to valves on the S-I and S-IC. An independent pressure-switch solenoid-valve system was retained to control helium for tank pre-pressurization and pressurization during engine start.

A pneumatic actuation system was added for in-flight operation of the valves in the engine prestart conditioning system. This actuation system was required because of the adoption of the forward-flow conditioning system. Additional changes included the incorporation of a hydrogen pressurant line purge system to prevent backflow of hydrogen gas into the engine compartment during ground operations.

Checkout capabilities have been built into the system design, and checkout procedures have been prepared. In almost all cases, the checkout procedures are adaptable to either manual or automatic checkout.

Procurement and Component Development

Fourteen procurement specifications were prepared and issued, but five were deleted because of system changes. The major effort was accomplished on five additional procurement specifications for new components resulting from system additions and changes. Purchase orders have been placed for eleven components, and procurement action has been expedited on the remaining components. No prototype components have been received by S&ID.

Testing

Testing during the past year has been limited to exploratory and feasibility tests. Much effort has been directed toward evaluation of proposed methods for combatting stratification. In one test series, an insulating inner sleeve in the 1/10-scale plexiglas liquid hydrogen tank effectively isolated hot liquid (water) on the outside of the sleeve from the cold inner liquid. It then caused continuous mixing of the two liquids as the fluid was drawn into the discharge lines. Other tests have investigated the practicability of mixing the liquid hydrogen by helium bubbling. Although it is generally agreed that bubbling from a simple outlet requires too much helium, the chimney effect produced by bubbling through vertical tubes is expected to greatly augment the effectiveness of a given quantity of helium. Analyses and tests indicate that even more effective results may be obtained by admitting the helium into the vertical tubes in short bursts. A small-scale test is being set up at the Santa Susana test facility to evaluate these effects in liquid hydrogen. The 1/4-scale test program at Beech Aircraft has been extensively revised to incorporate specific tests relative to hydrogen stratification.

Experimental Hilsch tubes were built to S&ID requirements by AiResearch, and an experimental oxygen gas distributor incorporating the Hilsch tube was constructed and tested by S&ID. The intent was to permit higher pressurant inlet temperatures to be admitted into the oxygen tank without causing the limiting temperature of the intertank bulkhead to be exceeded. The use of higher-temperature gas will result in a significant reduction in pressurant weight. The function of the Hilsch tube is to separate the incoming gas into two streams, one colder than the inlet gas and the other hotter. The function of the distributor is to direct the two streams so that the intertank bulkhead senses only the colder stream. The tests at S&ID were quite successful. The temperature difference between the inlet and the cold outlet flows amounted to as much as 300 F at inlet temperature on the order of 600 F. The unit was adapted for installation in the MSFC oxygen test facility and is currently at MSFC awaiting test.

THERMAL CONTROL SYSTEM

The thermal control system for the Saturn S-II stage is designed to provide temperature control of the electronic and instrumentation components located within the equipment containers. Ground equipment provides either conditioned air or nitrogen gas to the stage disconnects. Air is used during ground checkout for cooling, and nitrogen is used for heating after propellant loading. The conditioned gas is directed to the equipment containers through insulated plumbing and then is exhausted into the interstage area. The flow is continuous and fixed by the system orifices. The gas-supply temperature is altered by ground electronic heaters, which are controlled by thermostats in the stage plumbing. During flight, container insulation and thermal inertia preclude out-of-tolerance equipment temperatures.

In the analysis of the Thermal Control System, the flow rates, line sizes, orifice sizes, electrical relief hole sizes, gas supply temperatures, and insulation thicknesses for the containers and plumbing have been determined. Preliminary noise tests have been completed to ensure that the resultant noise level will not present a annoyance to maintenance personnel. Experimental tests of a simulated plumbing network and a representative equipment container are planned.

Description

The thermal control system consists of provisions for delivering a continuous flow of air or nitrogen to the equipment containers. Two completely separate systems are provided: one for forward, S-II/S-IVB interstage compartment containers and one for the aft containers in the S-II engine compartment.

Thermal control system operation is initialed at the beginning of electrical equipment checkout. An electrical interlock provents energizing any components until clean air is delivered to the vehicle disconnects. The air flows through the manifold and into the container supply lines, where the flow is restricted by an orifice at each container as shown in Figure 23. With constant disconnect pressure, these orifices provide a fixed flow sufficient for both the cooling and heating requirements during ground checkout and propellant loading. The air then flows into the container, removes the excess heat from operating equipment, and exits through the container relief holes into the interstage area.

At least three minutes before propellant loading, the cooling medium is changed from air to gaseous nitrogen to inert the containers. The nitrogen flow is the same as the air flow.

After propellant loading, the plumbing and containers are subjected to much lower environmental temperatures; and thermal insulation is provided to maintain a minimum nitrogen temperature of 60 F at all container inlets. In addition, provisions are made for heating the nitrogen in ground heaters controlled by two stage-mounted thermostats, one located in the forward interstage plumbing and one in the aft interstage plumbing. For monitoring container temperatures, each container has a temperature transducer whose output is continuously telemetered to ground until lift-off.

At lift-off, the nitrogen flow is terminated by disconnect separation. Throughout boost, the container pressure drops by expelling nitrogen through the relief holes. Equipment temperature changes are minimized by container insulation and thermal inertia. The container insulation precludes excessive temperatures for containers exposed to base heating.

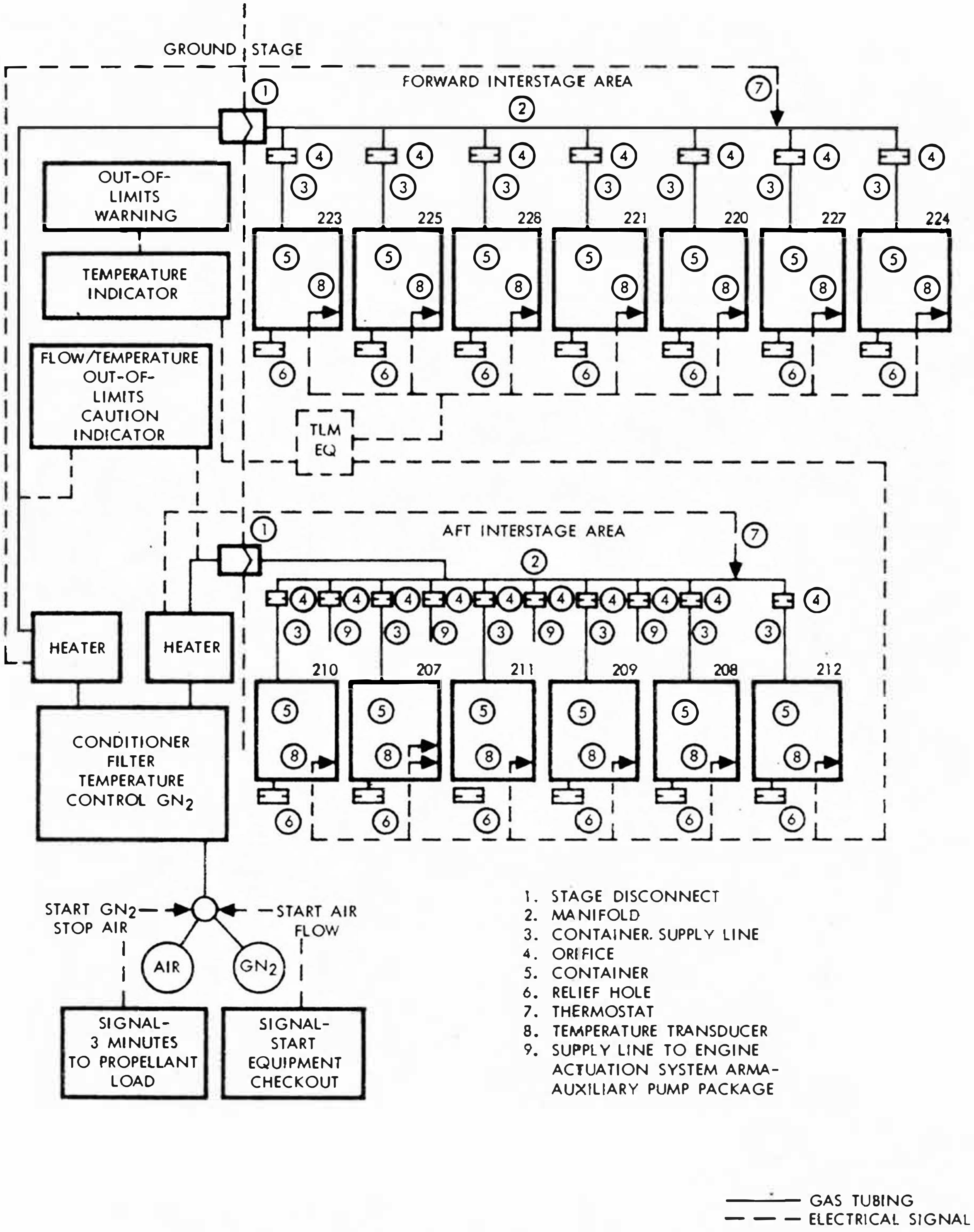

Figure 23. Thermal Control System Flow Diagram

Analysis and Design

Investigations of system concepts indicated that a variable conductance, cold-plate system was well-suited for the S-II application. A prototype that was tested proved satisfactory. However, the concept was abandoned because its ground support requirements were not consistent with those of the other Saturn stages.

The design objective for the present continuous-flow system is to select an optimum flow rate adequate for cooling during ground checkout and heating after propellant loading. During ground checkout, the air must be capable of removing excess heat dissipated by the equipment; also, the gaseous nitrogen delivered to the containers after propellant loading must offset the heat loss through the container walls to the cold external environment. For most of the containers, a flow rate of 40 scfm is required to meet both heating and cooling requirements. The total flow required at the forward-stage disconnect is 250 scfm, while 385 scfm is required at the aft stage disconnect.

The supply plumbing directs and controls the cooling or heating gases during ground operation, but serves no useful function during boost. In order to provide the flow required for temperature control of the containers at the design pressure (1. 5 psig), a 3-inch diameter manifold is required. Although the lines from the manifold to the container could be smaller than one inch in diameter and still provide the required flow, the one-inch diameter supply lines were selected to limit the resultant noise level. The noise level is also minimized by locating the orifices, which restrict the flow, as far upstream of the container inlet as possible.

While propellants are on board, the gaseous nitrogen flowing through the plumbing will lose heat to the cold external environment. In order to deliver the nitrogen to the container inlets at a temperature above 60 F, approximately 0. 5 inches of light-weight, low-thermal conductivity insulation is required on all plumbing lines.

The containers located in the S-II engine compartment will be subjected to base heating during S-II boost. The heating rates are sufficiently high so that the thermal protection afforded by the fiberglass structural walls of the containers will not limit the internal wall temperatures to that required for reliable equipment operation. Investigations have shown that the simplest and lightest method of providing a thermal barrier against base heating is to bond the required amount of lightweight, low-thermal conductivity fiberglass insulation to the internal wall of the container.

Testing

Extensive testing was conducted on the initial concept of the thermal control system. This concept made use of a variable-conductance mounting-plate system. Testing confirmed the adequacy of this system; however, the concept was abandoned because it imposed ground support requirements not consistent with those of the other Saturn stages.

Testing on the present continuous-flow system has been limited to preliminary noise tests to ensure that the resultant noise level did not present an annoyance or hindrance to maintenance personnel.

An experimental test of a simulated plumbing network is planned to obtain comprehensive performance data, including pressures, temperatures, and flow rates for nominal, limit, and transient conditions. Repeatability is also a requirement of this test, as the data will be correlated with limited data obtained by using the ground test stages. For the experimental test, a production-type thermostat will be used to obtain response rate and optimum location.

A representative equipment container with simulated flight equipment will be exposed to design environmental conditions. The flow-rate and gas-supply temperatures will be varied. Temperature measurements will be taken to ensure that all components receive the necessary gas flow, to determine heat transfer between the honeycomb mounting base and equipment, and to confirm predicted boost temperatures.

Confirmation of system design will be achieved by testing in the Electromechanical Mock-Up and All-Systems test vehicle. Instrumentation of these test vehicles will yield data on the cooling and heating performance of the thermal control system and confirm thermostat response.

ELECTRICAL POWER SYSTEM

The electrical power system contains provisions for generation and distribution of direct-current and alternating-current power 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, alternating current to supply the LH_2 recirculation-pump motors. Regulated ground power supplies will provide direct-current and alternating-current power during checkout and countdown operations.

The electrical power system includes three battery systems to provide power during flight. The 28-volt main battery powers the various stage control systems except for the recirculation-pump motors and J-2 engine ignition system. The 28-volt instrumentation battery powers the measurement, telemetry, and tracking systems. The 56-volt battery system powers the recirculation pump-motor inverters. 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 prior to launch. Other bus systems are used to supply those loads requiring operation only during the countdown or checkout.

During this reporting period, the system configuration has been finalized. Phase I approval was obtained prior to the addition of the 56-volt power system required for the LH_2 recirculation system. Resubmittal for Phase I approval after incorporation of this change has been completed. Preliminary in-house design reviews prior to or parallel with submittal of Phase I data to MSFC have been satisfactorily completed on both designs.

Components are in the early stages of design and development by the suppliers. Prototypes of the electrical power distributors have been fabricated and evaluated for application, producibility, and adequacy for their intended use.

The concept and engineering evaluation portions of the test programs have been completed. Battery sizing has been determined, a power diode assembly has been proved satisfactory during development testing, and cable electrointerference tests have been evaluated.

Analysis and Design

Analysis of the system requirements from a simplicity and reliability standpoint led to the following basic requirements for load division between the various buses.

1. All in-flight loads critical to mission success and one destruct system shall be supplied by the main d-c bus.
2. All instrumentation loads and the second destruct system shall be supplied by the instrumentation d-c bus.
3. All loads operational only on the ground shall be isolated from flight loads and supplied from ground power.

The addition of the LH_2 recirculation system necessitated a reanalysis of the bus system in order to achieve the most reliable system consistent with weight considerations. The system selected includes a 56-volt battery to supply voltage to a three-phase, 56-volt (peak), quasi-square wave output suitable to drive the a-c induction motors. The 56-volt battery supply is center tapped to supply the J-2 engine ignition load. This arrangement allows the high peak ignition current to be removed from the main battery requirements, thus permitting simplified battery cell design. The 56-volt battery supply is located on the aft interstage so that this excess weight can be jettisoned during second-plane separation.

Provisions have been made in the system design for installation of an alternate battery and associated equipment to supply critical loads after S-II mainstage operation is achieved. The critical loads would then be supplied through isolation diodes by two independent sources, while other main d-c bus loads would be supplied only by the main battery.

Since the major part of the instrumentation bus loads are now in the aft skirt area, the instrumentation d-c bus system has been moved from the forward skirt to the thrust structure. This permited a common negative with the main d-c bus.

Load analyses for the three battery systems led to the selection of a 25 ampere-hour battery and a 35 ampere-hour battery to supply the load requirements, including growth capability. The main battery supplies 35 ampere-hour, the instrumentation battery supplies 25 ampere-hour, and the recirculation battery supply uses two 25 ampere-hour batteries in series. The batteries were changed from secondary types to primary types as a result of requirements for maintenance and accessibility on the launch pad. This change permitted closer regulation control and more reliable activation procedures. Two motorized power-transfer switches, rated at 100 amperes and 300 amperes, are being developed to transfer the flight buses from ground power to battery power and for on-off control of heavy loads.

S&ID has designed an encapsulated power distribution device (Figure 24) which utilizes standard connectors and a distribution bus system which provides maximum reliability, ease of maintenance, and complete environmental protection. Since this represents a significant technological advance, S&ID is presently investigating the possibility of obtaining patents on this device. Similar devices requiring only an input and output connector are also used within the Electrical Systems.

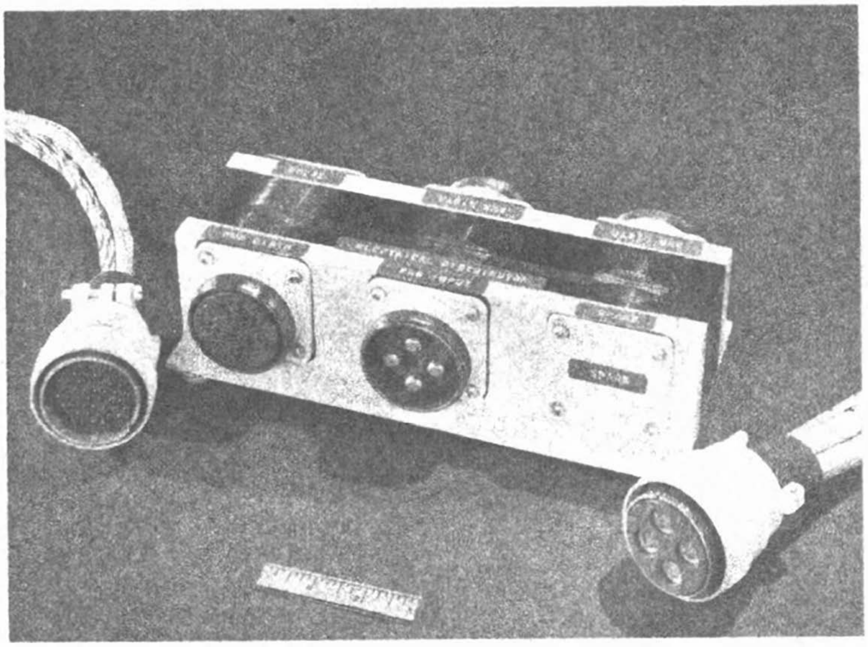

Figure 24. Encapsulated Power-Distribution Device

Procurement and Component Development

The suppliers for the batteries and power-transfer switches have been selected. The batteries will be developed by the Missile Battery Division, Electric Storage Battery Company and the power-transfer switches by the Planautics Corporation. The batteries and power-transfer switches are in the early stages of development. MSFC has directed S&ID to incorporate inverters for the recirculation-pump motors that are being developed by Douglas. A coordination-type procurement specification for the inverter is in the final stages of preparation.

Prior to the completion of procurement specifications, developmental power distributors were fabricated and evaluated for application, producibility, and adequacy for their intended use. The fabricated hardware is shown in Figure XX. Consideration was given to standardization of size and interchangeability. Procurement specifications have been completed for all of the hardware necessary to support the power distributors.

Testing

Sufficient battery tests were performed to permit sizing of the battery for procurement specification purposes. These tests indicated that a 35 ampere-hour primary cell is capable of supplying both the total energy requirements and the voltage regulation required for the main d-c bus, including the J-2 engine ignition load. Since these tests were completed, the ignition load was moved to the recirculation battery; however, the 35 ampere-hour requirement was retained to provide growth capability.

A development test program was undertaken and completed at MSFC direction on a power-diode assembly to meet the requirements of the alternate battery system. The specification requirements included a maximum voltage drop of one volt at the lowest operational temperature and the ability to dissipate the generated heat at the highest operational temperature. The ability to meet these requirements has been demonstrated.

Several laboratory tests were performed to finalize the power cabling requirements for minimizing coupling to sensitive circuits. These tests included study of the effects of twisting, shielding, coupling length, and cable separation on the voltage coupled into pickup cables. As a result of these tests, it was decided to twist and shield all a-c power cables. The shields will be grounded at a single point and will not be connected to the shields of sensitive circuits; shield loops will be avoided. The d-c power cables carrying pulsating currents will be twisted whenever practical. Cable separation techniques will be utilized whenever the above procedures are not sufficient.

ELECTRICAL CONTROL SYSTEM

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. The system also includes the electrical equipment that controls the mechanical systems. This close connection between mechanical and electrical systems provides for uniformity of electrical requirements, as well as a central control point for stage electrical interfaces.

The components for the electrical control system are packaged in three controller units. The first unit is the propellant electronics controller (forward skirt). It contains the components for the LH_2 fill system. The second unit is the propellant electronics controller (aft skirt). It contains the components used as a part of the LOX fill system, as well as the propellant-depletion engine cut-off circuitry. The third package 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 cut-off, prevalve operation, and LH_2 recirculation system.

The electrical control system has been defined in preliminary schematic diagrams and a system report during this reporting period. Phase I approval was received for the system concept. Primary areas of design analysis included emitter follower for engine control, propellant recirculation, propellant management, and the effect of incorporating the Saturn V timing-system switch selector. Procurement specifications were completed for relays, timers, and module connectors. Development programs were implemented in order to define the optimum design for the electrical control modules that contain these components. Tests were successfully performed to check the design in simulated environments.

Analysis and Design

Phase I approval has been received from NASA for all of the schematic drawings of the electrical control system. According to the concept approved, all control switching will utilize electromagnetic relays, and all circuits will have a minimum of complexity and a maximum reliability. NASA direction eliminated redundant circuit components and stressed individual component reliability.

An analysis was made of the various possible methods of packaging electrical components. The method chosen provides a uniform packaging concept which combines standard connectors, relays, resistors, and diodes in an environment-resistant module. All connections are achieved by the use of capacitance-discharge welding techniques. The modules are packaged on a system basis which provides maximum maintainability and fault isolation capability with a minimum of test effort. A representative module is shown in Figure 25.

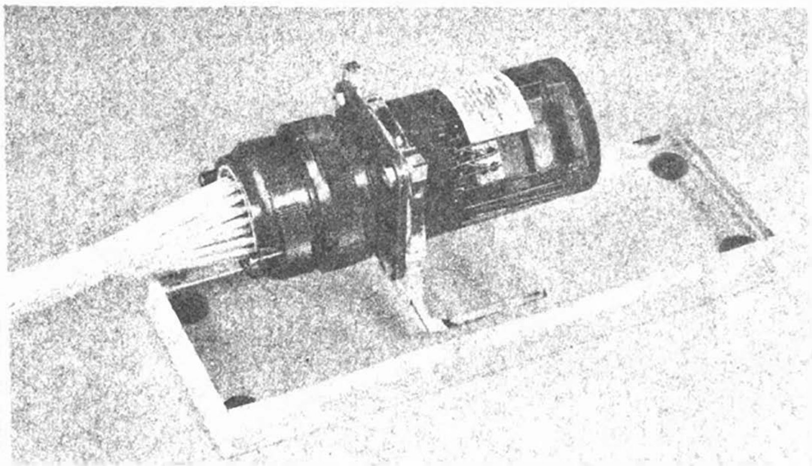

Figure 25. Typical Module

The initial J-2 engine design included current-limiting resistors in its electrical sequencer. Since these resistors were not compatible with the operation of the S-II stage control, it was necessary to design emitter followers to drive the relays. NASA directed Rocketdyne to eliminate the current limiters from the engine ready, mainstage OK, and internal engine cut-off circuits in the J-2 electrical sequence, and the emitter followers were subsequently removed.

The various methods proposed for a propellant-recirculation system were analyzed to keep the electrical control requirements current with the latest criteria. Even after the mechanical concept had been established, a major design change was caused by the MSFC decision to use a 56-vdc power system for the recirculation-motor pumps.

Analysis effort on the propellant loading system occured in two general areas: circuit analysis and system analysis. Circuit analysis of several types of liquid-level point sensors contributed to the decision to use the hot-wire type on the S-II. System analysis showed that the assumed advantages of a multiplexed point-sensor system (i.e., one control unit time-shared by several transducers) are negated by the large amount of control circuitry necessary for automatic operation. Further system analysis showed that both weight savings and more reliable operation could be achieved by splitting the propellant electronics into two packages: one installed forward, and one installed in the aft skirt.

Procurement and Component Development

Procurement specifications were completed and implemented to assure procurement of highly reliable relays and timers. The relays which have 2-ampere contact ratings will be procured from Filtors, Inc., and the 10-ampere-rated relays will be obtained from Babcock Relays. The supplier for timers is Tempo Instrument, Inc.

Procurement specifications were completed for the module connectors; considerable attention was given to standardization and interchangeability.

The procurement schedule for qualified parts did not support the manufacturing schedules for the EMM and Battleship test articles. Corrective action was taken by obtaining off-the-shelf parts for these two articles. These nonqualified parts will be replaced by flight-weight qualified parts as soon as is feasible.

An extensive development program for all control components included literature searches, supplier conferences, and evaluation testing. This program was followed in each of the following design areas: module packaging, solenoid surge suppression, and relay and timer specification preparation.

Testing

Development tests were performed on simulated solenoid control circuits to establish the optimum values and ratings for surge-suppression resistors and diodes. Tests were also performed to ensure that diodes would perform satisfactorily while mounted in encapsulated modules and subjected to environmental extremes of temperature and vibration. Evaluation tests were successfully conducted on electrical modules to demonstrate that the materials, processes, and techniques used are compatible with the anticipated S-II environments.

DESTRUCT SYSTEM

The destruct system for each stage of the Saturn V vehicle has been standardized where possible to permit the attainment of a high degree of reliability and also to simplify certification of component and system designs to the Atlantic Missile Range Safety Division. The system is to provide a zero thrust condition and propellant dispersion for flight termination. Propellant dispersion is to be effected by ordnance items initiated by means of exploding bridgewire (EBW) techniques. The EBW firing unit, EBW detonator, and the safety and arming device are being developed by Douglas Aircraft Company under a separate contract with NASA. The confined detonating fuze (CDF), destruct-charge assemblies, and ordnance disconnect and tees are being developed by S&ID. The EBW destruct system controller, destruct delay timer and no-time-delay plug are being furnished by NASA.

Description

The electrical portion of the destruct system incorporates two independent systems. The electrical portion of each system consists of an EBW destruct system controller, an EBW firing unit, and a destruct delay timer or a no-time-delay plug.

The EBW destruct system controller controls all signals from an EBW firing unit and the power signal to a command destruct receiver (CDR). The controller has the capability of switching the EBW firing unit and CDR power from external to internal and vice versa as commanded; provision is made for instrumentation. When the CDR liftoff signal is applied to the controller, the controller is rendered incapable of responding to the CDR destruct command and CDR destruct arm and cutoff command. After liftoff (removal of CDR liftoff signal) the controller is rendered operational.

The destruct delay timer is used on manned missions. Upon receipt of the CDR destruct arm and cutoff command signal by the controller, this unit will delay the response of the CDR destruct command signal for a predetermined interval of time (approximately 3 seconds). On unmanned missions, this unit is replaced with a no-time-delay plug.

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

The ordnance portion of the system consists of 2 EBW detonators, 1 safety and arming device, 13 CDF assemblies, 4 ordnance disconnects, 4 ordnance tees, 1 LOX tank destruct assembly, and 1 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. This energy in turn initiates the explosive train. The CDF assembly consists of a low-energy detonating core that is used to transmit a detonation wave between ordnance components, with a multilayer protective sheath to confine the explosive effects. It has a propagation rate in excess of 20,000 feet per second. The destruct charge assemblies are initiated by CDF assemblies and are capable of rupturing the 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 others.

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.

Analysis and Design

The destruct system is defined as that portion of the flight-termination system which is downstream of the UHF radio-command receivers. The system is required in order to terminate the flight if the vehicle's flight path deviates from the assigned corridor. The system is designed to effect a zero thrust condition during S-II boost and to provide propellant dispersion. The ordnance portion of the system is required to transmit the propellant dispersion action capability to the adjacent stages. The over-all system must be designed to the requirements of AFMTC regulation 80-7, Airborne Flight Termination Systems (Range Safety) and be approved by the range safety office prior to the first flight. The objectives are to design a system of maximum safety to ground personnel and which would not interfere with the achievement of flight objectives.

The inclusion of a manned payload on the Saturn V vehicle necessitates a means of assuring adequate time for safe ejection of the capsule concurrent with engine shutdown and prior to propellant dispersion. This is accomplished by provisions for replacing the no-time-delay plugs with delay timers. The time delay presently anticipated for the S-II stage is 3 seconds.

In the flight configuration, the destruct controllers, EBW firing units, no-time-delay plugs, EBW detonators, and safety and arming device are packaged in a single container. The container is mounted in the forward skirt area, and two CDF assemblies enter it from the ordnance train. Analysis of the container revealed that the minimum internal ambient temperature subsequent to lift-off will be -48 F on a cold (20 F) day. The maximum internal ambient temperature will be 112 F prior to propellant loading on a hot (120 F) day. These will be maintained with the thermal control system operating and supplying 10 scfm of $1N_2$ at 80 ± 20 F to the container for all operations prior to lift-off. The components environmental temperature range is maintained with the container design.

Procurement and Component Development

CDF Assemblies

The CDF assembly development program is progressing on schedule. Testing conducted at S&ID has established the following:

1. Reliable functioning of the CDF and booster charges could be expected at temperatures as low as -300 F.
2. The existing confining structure for the CDF is adequate at -300 F.
3. A quick-attach bayonent-end fitting could be developed which would confine the booster charges.

A development program was started by the supplier in May 1963, and qualification testing is scheduled to begin in September 1963. Qualified CDF assemblies will be required in December 1963 for development and qualification of other ordnance components.

As a result of the decision to use the CDF assembly on other Saturn V stages, some environment-requirement changes are expected. These changes are not expected to affect the design. However, they will require some repeat testing.

Ordnance Tee and Ordnance Disconnect

The procurement specification covering the ordnance tee and ordnance disconnect was released in December 1962. A supplier has been tentatively selected for each component. However, the contract will not be let until new requirements imposed by MSFC as a result of the decision to use the tee on the Saturn V stages are incorporated.

LOX Tank Destruct Assembly

The procurement specification covering the linear explosive charge has been released. The supplier has been selected, and development is scheduled to start in September 1963.

LH_2 Tank Destruct Assembly

The procurement specification covering the linear shaped charge assembly is being released after being delayed for the addition of new installation and performance requirements. These new requirements are a result of increased LH_2 tank insulation.

Testing

Confined Detonating Fuze Assembly

Tests were conducted using S&ID-designed and assembled CDF assemblies to verify the following:

1. Ability of the quick-attach PT connector to remain intact after firing
2. Ability of CDF assemblies to propagate from one to another over large gaps.

Ten tests were successfully conducted to prove the ability of one CDF assembly to detonate another over various gap spacings. This is a requirement which is specified in specification MC901-0052. At ambient temperatures, no failures were experienced in tests involving the propagation of X-349 of one CDF assembly to another through 0.005-inch steel barriers and gaps up to 0.700 inches. At a temperature of -300 F, the same test set-up propagated across a 0.300-inch gap, but failed at 0.350 inches. A 0.200-inch gap is required for a 0.999 reliability at a 90percent confidence level for successful propagation across a 0.100-inch gap. The 0.100-inch gap appears likely to occur through adverse tolerance build-up of mating parts in production.

Final development and qualification testing are being conducted by the supplier in accordance with the requirements of NAA specification MC901-0052.

LH_2 Tank Destruct Assembly

Twenty tests were conducted which indicated that 400-grain, aluminum-covered linear shaped charge (LSC) is adequate for the LH_2 tank destruct assembly. Two different 400-grain LSC's successfully severed the systems tunnel intercostals, LH_2 tank insulation, LH_2 tank skin, and the tank-skin weld lands with and without liquid backing on the skin. The 400-grain LSC will not sever the tank frames. However, it is not considered a requirement at this time.

LOX Tank Destruct Assembly

Feasibility tests have been conducted for the LOX tank destruct portion of the S-II destruct system. Two round aluminum tubes were mounted side by side and attached to the inside of the skin test panel with a stand-off of 1/4 inch and a 1-1/4 inch stand-off from the LOX tank test panel. These two panels were mounted in a test fixture that simulated the angle between these two surfaces in the S-II stage. A round explosive charge of 1100 grains per foot was inserted into each of the round aluminum tubes. The panels and tubes duplicated the actual material and configuration used in the present concept of the S-II stage. The results of these tests indicate that the explosive charge, configuration, and location will be adequate to sever the S-II stage structure as presently designed.

SEPARATION SYSTEM

The function of the stage separation system is to detach the S-IC from the remainder of the Saturn V vehicle after completion of first stage boost. This separation will occur at two separate planes: the detachment of the depleted S-IC tankage and the jettisoning of the S-II aft interstage. This sequential separation permits the removal of maximum interstage weight without increasing the risk of damage to the S-II propulsion units during the separation process. Physical stage separation is accomplished by means of an ordnance assembly that incorporates a linear-shaped charge (LSC), a detonating element capable of providing a continuous cut in a target. The system is electrically sequenced and controlled by an MSFC-designed switch selector. The LSC initiation is effected by exploding-bridgewire (EBW) techniques.

Description

The electrical portion of the system consists of an MSFC-designed switch selector, a controller, and six EBW firing units. The first plane separation (depleted S-IC tankage) is electrically controlled from the S-IC stage. The system electrically controls the second plane separation (aft interstage structure removal), ullage rocket ignition, S-II/S-IVB separation, and retro rocket ignition.

The switch selector is basically a series of low power switches, the input of which are individually selected and controlled by a coded signal from the Saturn V airborne computer. The switch selector decodes internally from the seven-bit word and furnishes an output from one of the three useful relay driver outputs at a time to sequence the system.

The separation controller contains the components and circuitry necessary for controlling the EBW firing units. It applies a return bus signal to all EBW firing-unit trigger circuits until the proper trigger signal is received. It prevents the occurrence of second separation in the event an outboard J-2 engine fails to attain mainstage.

The EBW firing units contain the circuitry necessary to generate and store the high voltage energy pulse required to initiate the EBW. This high voltage energy is held off by a gap switch until released by command from the controller.

The ordnance portion of the system consists of 6 EBW detonators, 17 CDF assemblies, 16 pyrogen initiators, 2 LSC assemblies, and 2 CDF manifold assemblies. The LSC assemblies are initiated at each end by EBW firing units and EBW detonators. The ullage rockets are redundantly initiated as follows:

1. One EBW firing unit is connected to an EBW detonator which is screwed into a CDF manifold assembly.
2. Eight CDF assemblies are attached to a CDF manifold assembly with one of the CDF aasemblies attached to a pyrogen initiator in each ullage rocket.

The LSC assembly receives detonation from EBW detonators attached to each end of the assembly. The sharply defined cutting action of the assembly severs the separation-joint tension members to effect physical separation. The EBW detonator employs the exploding bridgewire technique, which involves the exploding of a fine wire by passing a large pulse of high-voltage energy through it in a short period of time.

The CDF manifold is a device which, by means of the output of a single EBW detonator, is capable of simultaneously detonating 8 CDF assemblies. Detonation is transferred from the manifold to the pyrogen initiators. The pyrogen initiators transform this detonation into a deflagration to ignite the ullage rockets.

Analysis and Design

Linear-Shaped Charge (LSC)

Two basic LSC installations were considered: segmented and continuous loop. The segmented installation approach would necessarily be much more complicated because of the requirement for additional detonation transfer components. The continuous loop concept is attractive from the system reliability standpoint and does not complicate fabrication, handling, and installation problems.

The adoption of the continuous loop approach was made feasible by the following factors:

1. Capability of at least two suppliers to produce flexible LSC in 110 foot lengths
2. Availability of an extruded, flexible plastic backing for LSC
3. Capability of a supplier to provide the LSC, flexible backing, and detonation transfer blocks as a single prefabricated component. This component can be shipped on a 3-foot diameter reel.
4. Structural design of the separation plane that permits external installation of the LSC assembly and incorporates an outer tension splice plate

Continuous loop installations incorporating single, dual side-by-side, and dual piggy-back LSC runs were considered.

A continuous loop incorporating dual piggy-back LSC runs was selected for the following reasons:

1. It permits the use of only two EBW detonator and firing unit sets.
2. Multiple redundancy is provided by the cross propagating feature of the piggy-back.
3. It avoids the problem of the remaining ring left by two side-by-side LSC runs.

The LSC assembly will be an integral unit developed and qualified by an ordnance supplier to meet the requirements of NAA specification MC901-0019, which include qualification and acceptance testing to demonstrate the reliability of the LSC assembly for severing target plates that simulate the S-II separation plane tension plates.

Since the maximum tension which must be transmitted across the S-II separation planes is low compared to compressive loads, the full tensile strength can be provided by relatively thin splice plates which span the separation joint. The splice plates form attachments completely around the S-II at the two separation planes and at the appropriate time, are severed by the LSC assembly. The compression loads are carried by butted fittings which do not need to be mechanically or explosively uncoupled. In order to permit the use of the same type of LSC assembly for each application, the structural features of each separation plane are similar.

The splice plate design allows the use of a much smaller sized LSC than would be required if it were necessary to sever a combined compression and tension structure. The external location of the splice plate makes heavy shielding of internal components from the LSC blast effects unnecessary. The relative freedom of access that external installation allows permits the use of a reliable, one-piece assembly.

An external cover is required for the LSC assembly in order to position the LSC on the splice plates, to shield the LSC from aerodynamic effects, and to shield external vehicle components from fragment damage.

Ullage Motor Ignition System

The ullage motors are ignited by special nonelectric pyrogen initiators. Redundant ignition of the eight motors with EBW squib systems would require the weight and complexity of sixteen EBW firing units. In order to reduce the EBW component requirements, pyrogen initiators in conjunction with an ordnance distribution system are employed to provide eight ignition sources with the output of only one EBW detonator. A second detonator with associated pyrogen initiators and distribution system will provide redundant ignition for each of the eight ullage motors.

The confined detonating fuse (CDF) manifold used in the ullage rocket motor ignition system transmits a detonation from an EBW detonator to multiple CDF assembly outputs. A CDF is a very low energy detonating cord used to transmit a detonation pulse between the CDF manifold and pyrogen initiator; it consists of an MDF (mild detonating fuze) and a multilayer protective sheath designed to confine all explosive effects within the casing. The CDF assemblies consist of an appropriate length of CDF with quick-attach bayonet end fittings.

The pyrogen initiator is a non-electric ordnance device designed to ignite the pyrogen of a solid-propellant motor by means of the detonating output of a CDF lead assembly. The initiator utilizes a detonation pulse, which is transmitted through a leak-proof barrier, to produce an igniting flame within the motor pyrogen. The thru-bulkhead type is intended to use as its sole input energy the output of a confined detonating fuze assembly (MC901-0052). This energy will be used to detonate an explosive charge (donor) on the input side of the initiator bulkhead. This charge will transfer a shock through the bulkhead to an explosive receiver charge (receptor) on the output side. This receptor charge is then attenuated in order to ignite a deflagrating charge, the output energy of the initiator. This charge, in turn, initiates the pellets of the pyrogen igniter. In performing this energy transfer, the bulkhead of the initiator is not to be damaged in a manner which will allow motor combustion products to escape.

EBW System

Design and development of the EBW firing unit and detonator is being accomplished by the Douglas Aircraft Company under separate contract with NASA.

Switch Selector

The switch selector provides interface compatibility between the stage systems and the Saturn V airborne computer. In addition, it provides timing and staging sequencing. It is furnished as GFE by MSFC.

Procurement and Component Development

Linear-Shaped Charge

After several proposals and supplier facilities had been evaluated, the subcontract for the LSC assembly was awarded. The basic design approach was approved at the preliminary design review held in April.

Some delay in the program has been caused by the difficulty that a supplier is having in successfully extruding FEP teflon. The supplier will substitute TFE teflon, if FEP cannot be extruded satisfactorily. Problems encountered in incorporating elongation tests into the program have caused additional delays. These tests will qualify the LSC assembly for the surface expansion which will occur during first-stage boost.

Development tests, using prototype transfer blocks and other metal parts and short lengths of teflon machined to the approximate configuration of the teflon extrusion, are under way. Preliminary design of a test chamber to accomplish the low-temperature elongation tests is under way. Prototype units are expected to be available for full-scale tests in November 1963.

CDF Manifold

The manifold procurement program was delayed in order to incorporate MCR 197 (common Saturn V ordnance) requirements into the procurement specification. These changes have now been incorporated and the revised specification is scheduled for release in September 1963.

Pyrogen Initiator

The contract for the pyrogen initiator was awarded in July 1963. The development effort is proceeding on schedule.

Subject to statistical verification by more extensive testing, the primary design problems of preventing body rupture and establishing approximate bulkhead tolerances have been solved.

Testing

Manifold

The preliminary test work to prove the feasibility of the manifold has been completed. These preliminary tests involved the detonation of multiple outputs of breadboard-type CDF assemblies by a central core of explosive, consisting of commercially available material, such as MDF or LSC.

Fifty-three tests were completed during this preliminary investigation. The results show that a design approach with 15 to 25 gr/ft LSC as the core of the manifold will function satisfactorily through a range of adverse tolerances and environmental conditions. These results show that the LSC has a more concentrated output due to the Monroe (i. e., focusing) effect, whereas the MDF used has a uniform output about its axis. They also show that not only can LSC be used to cut material, but also to detonate explosive boosters by this explosive force concentration.

Most of the tests were conducted with a breadboard type test plate. Five and 10 gr/ft MDF and 10, 15, and 25 gr/ft LSC were tested as the initiating linear core. Final tests were conducted with a metal block (Figure 26) that more closely simulated the confinement conditions of the actual manifold.

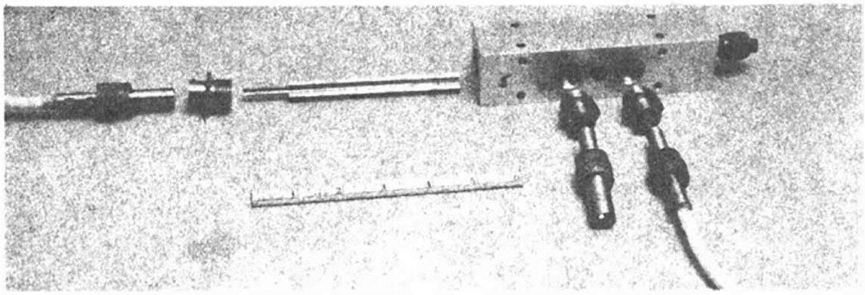

Figure 26. Metal Block Used in Final Manifold Tests

The CDF assembly receptor charges were simulated by test leads with sensitivity and charge size equivalent to the proposed CDF assemblies. The effect of air gaps and closures in excess of expected installation tolerances was evaluated, and the installation tolerances currently specified were found to be suitable. Metal barriers were interposed between the linear element and receptor charge of the CDF lead assembly to duplicate the end closure of the CDF assembly. Since explosives generally become less sensitive with decreasing temperature, all tests were conducted at -125 F, the lowest environmental extreme expected.

Pyrogen Initiator

A study was completed to determine the feasibility of transmitting a nonelectric stimulus generated by contained explosive energy through a bulkhead without jeopardizing the integrity of the bulkhead seal. Two design approaches were investigated:

1. A detonation shock-wave transfer system incorporating a solid steel bulkhead as an integral part of the igniter assembly

2. A self-sealing system incorporating a compressed or compressible resilient material to automatically seal the path of a detonating length of MDF automatically. The thru-bulkhead approach was selected as being most promising.

To aid in the evaluation of the thru-bulkhead design, the shock from the pickup charge was attenuated in order to ignite a boron-potassium nitrate ignition pellet. Twenty-three tests, investigating the transfer mechanism and the confined CDF quick-disconnect assemblies, were conducted as part of the feasibility study of the shock-wave transfer system.

Final evaluated design eliminated all but an absolute minimum explosive-to-metal and metal-to-metal interfaces; the test results indicated that the assembly was functionally feasible. Due to the limited scope of the program, only three assemblies with the final functional configuration were tested. The final test assembly was further designed to attenuate the detonation of the PETN receptor charge and to ignite a pressed pellet of boron-potassium nitrate ignition composition. For these specific tests, the quick-disconnect assembly was not evaluated; instead, a DuPont X-349 primer crimped to unconfined 2 gn/ft PETN core MDF was used to initiate the PETN donor charge. Each unit was fired into a 25-cc closed chamber. In all units the shock wave from the detonating donor charge propagated through the bulkhead and initiated the receptor charge; its detonation, in turn, initiated the deflagration of the boron-potassium nitrate pellet. Attenuation of the detonation is evidenced by the slow pressure rise characteristic of a deflagrating pellet of propellant. Without proper attenuation the wave, would have pulverized the ignition pellet and created a very sharp pressure rise. The fired units later were tested for bulkhead integrity by applying 3,000 psi to the output side of each unit. No evidence of leakage was detected.

Further development of the thru-bulkhead pyrogen initiator will be conducted by a qualified ordnance contractor. The final design must meet the environmental and performance requirements of NAA specification MC453-0004.

Linear-Shaped Charge

A test program was conducted to establish the sizing and arrangement of the linear charge and to develop a suitable installation and cover design. The first test series for charge sizing was conducted to determine the failure limits for the selected charge size, under various conditions of tension plate thickness, temperature, and stand-off. The second series demonstrated the adequacy of 25 grain/ft LSC for severing 0.125-inch 7075-T6 aluminum sheet. The third series demonstrated the adequacy of 15 gr/ft LSC to sever the revised S-II separation plane tension plate thickness of 0.080 inch 7075-T6 aluminum.

Tests were conducted to demonstrate the cross-propagating ability of the lower and upper elements of the piggy-back LSC arrangement. All tests to date indicate that the 10 to 25 and the 10 to 15 gr/ft combination will successfully cross-propagate in either direction, even with multiple breaks in each element.

Numerous tests were conducted to evaluate the strength and suitability of LSC cover designs. Two configurations were analyzed from the aerodynamic heat transfer standpoint and will be tested in a fixture that simulates the actual structural design. Additional tests are intended to verify the capability of the final cover design to protect the LSC assembly during first-stage boost.

In order to confirm the satisfactory performance of the complete structural and ordnance system, 10 full-scale tests, beginning in November 1963, will be conducted. These tests will utilize a structure representative of the S-II separation planes at stations 0 to 196. Only the ordnance devices, splice plates, and LSC covers will be expended for each test.

FLIGHT CONTROL SYSTEM

Preproduction Engine Actuation System

Summary

The year was marked by delivery of hydraulic system components for the eight preproduction systems. Delivery status is shown in the following listing.

Component	Delivery Status
Servoactuator	Seven have been received at S&ID. Last unit is scheduled for delivery by 9 August.
Accumulator reservoir manifold assembly (ARMA)	Four have been received at S&ID. Balance will not be delivered until a necessary fix has been made. Four delivered units will be retrofitted.
Main pump	All eight have been delivered to S&ID.
Auxiliary motor pump	All eight have been delivered to S&ID.

Figures 27, 28, 29, and 30 show the preproduction servoactuator, accumulator reservoir manifold assembly, main hydraulic pump, and auxiliary motor pump.

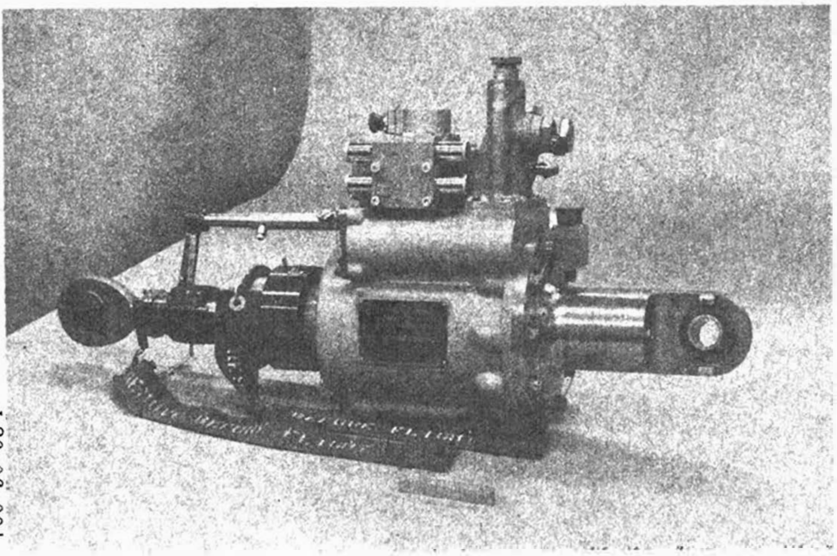

Figure 27. Servoactuator

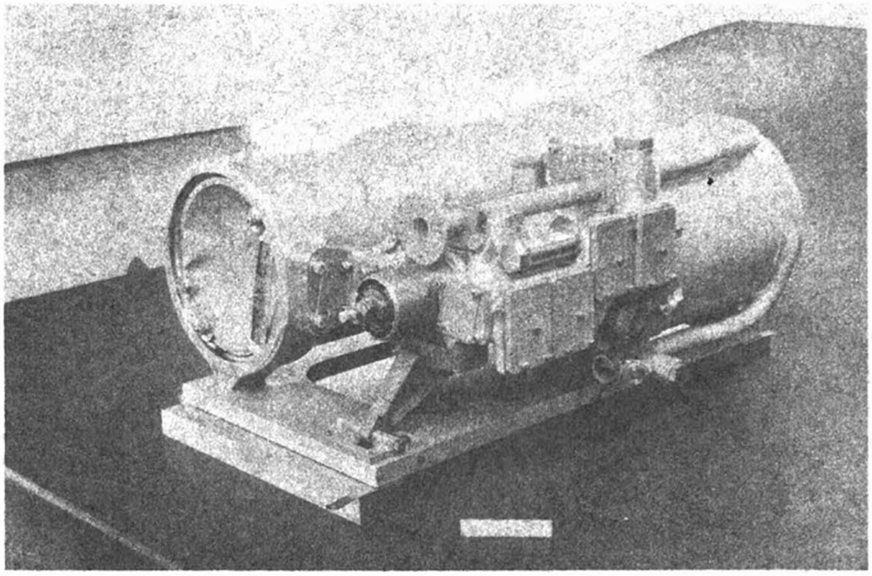

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Figure 28. ARMA

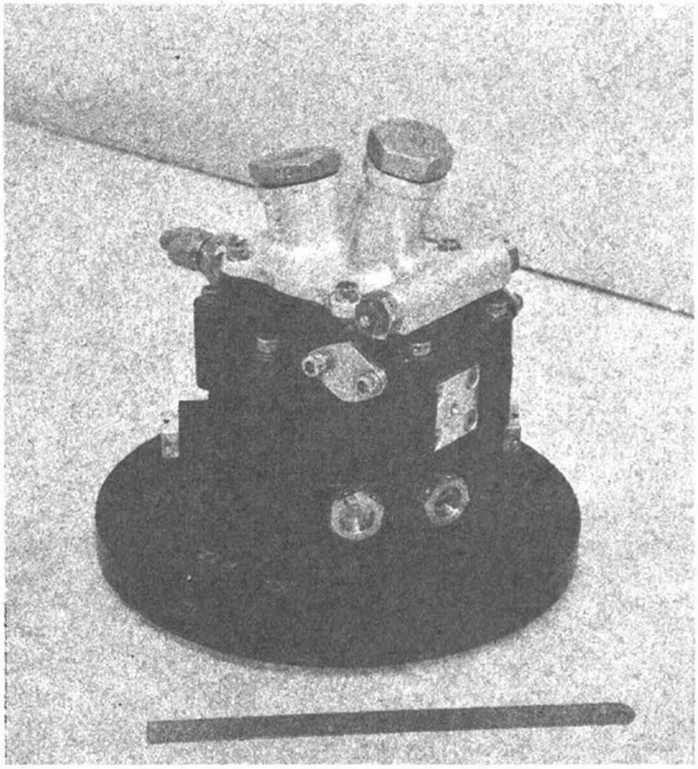

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Figure 29. Main Pump

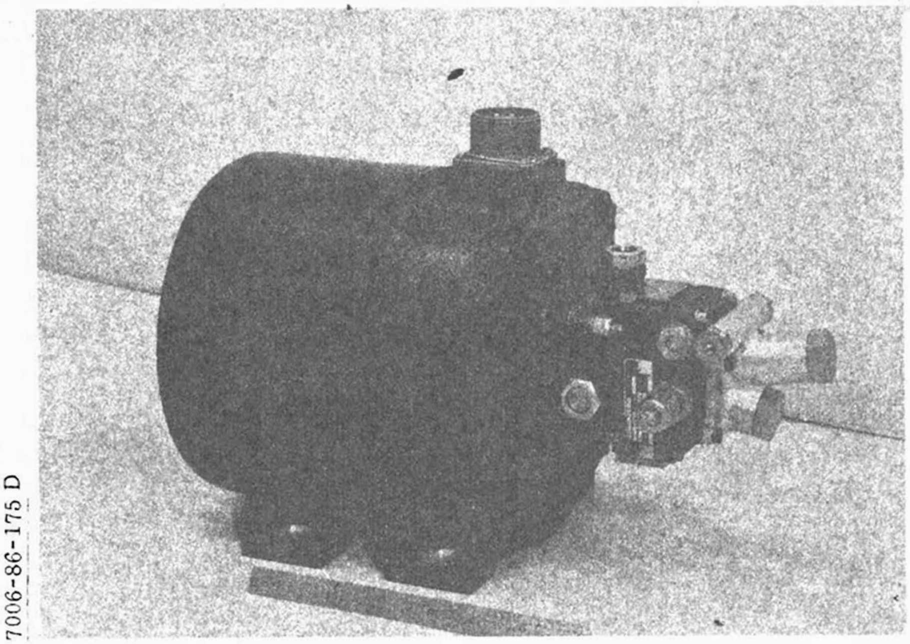

Figure 30. Auxiliary Pump

On 15 June, the first preproduction system was delivered at Huntsville. The system was shipped unassembled with all major components but short of some miscellaneous hardware.

By the end of the year, component testing at S&ID had begun on the main hydraulic pump. Servoactuator testing was scheduled to begin in early August. System tests were also scheduled to begin in August.

History

In the first quarter, the servoactuator piston area was increased from 11.5 in.^{2} to 14 in.^{2} and flow rate at design load was increased to 29 in.^{3}/sec. As part of this change, a decision was made to adopt a dynamic load damping (DLD) valve in the actuator. The increased actuator size also caused major design changes in all other actuation system components.

Another important directive was received in the second quarter. This directive effectively eliminated the original concept of a prototype system and a production system. Instead, the design configuration of the production hydraulic components was to be identical to that of the first units. These first units were subsequently designated as preproduction units. A reduction in the quantity of preproduction systems to be procured was also directed, and, as a result, five actuation systems were to be delivered to MSFC and three were to be delivered to S-II Engineering. Procurement specifications for all hydraulic components were amended to update requirements and, as intended, to provide a single specification for preproduction and production units.

Early in 1963, it became apparent that since the preproduction actuation systems were to be used only for ground engineering tests, it would be feasible and desirable to make certain amendments in the procurement specifications for the preproduction components. The amendments were deletion of requirements for qualification and reliability tests and revision of Quality Control requirements to reflect the requirements that were applicable in the 4 April 1962 version of the General Quality Control Specification, MQ 0802-001. The amendments were to be applicable to the procurement specifications for preproduction components only; it was intended to prepare new specifications for production components.

In March, information concerning the preproduction engine actuation system was transmitted to the NASA S-II resident manager in Letter 63MA3743. The letter included a list of drawings and specifications describing the preproduction system and components, a list of government documents with variances applicable to the preproduction components, and a history of events in preproduction system development. Subsequently, in April, the model specification for S-II Preproduction Engine Actuation Systems (SID 63-281) was submitted for NASA approval. S&ID also requested MSFC to change the quantity of deliverable preproduction systems. Specifically, it was proposed that one preproduction system be delivered to MSFC and that the other seven units be retained by S&ID for component testing, breadboard testing, flight control simulator, J-2 engine gimbaling tests, and installation in the Electromechanical Mockup. This change in deliverable quantities was subsequently approved by MSFC.

Possibility of a schedule slip arose when it became necessary to adopt a fix on the manifold for the ARMA. The manifolds were made from castings, and failures that occurred indicated that burst pressure requirements were not satisfied. As a result, a decision was made to make new manifolds from forgings and retrofit the existing ARMA's. However, a plan has been adopted by which engineering test schedules can be met despite the manifold fix. It is now planned that the second and third engine actuation systems will be delivered to the S&ID Engineering Development Laboratory with defective ARMA's on 9 August and 16 August. These systems will later be retrofitted with ARMA's with new manifolds, but early delivery with defective ARMA's will facilitate meeting test schedules. The remaining preproduction systems will be initially shipped short of the ARMA, and the ARMA's with fixed manifolds will be delivered later.

Production Engine Actuation System

Following MSFC's evaluation of the Study of Impact of Converting the S-II Hydraulic Servoactuator from Electrical Feedback to Mechanical Feedback (SID 63-146, February 11, 1963), S&ID was directed to change to a mechanical feedback servoactuator and resize the ARMA.

The system has been resized for production release with the requirements for a mechanical feedback actuator with a positive, minimum drift lock capable of driving a load of 30,000 pounds at a rate of 8 deg/sec and for an accumulator capability to effect full toe-in of an inoperative engine and engine-out to meet separation engine deflection history requirements.

Procurement specifications for production servoactuator, ARMA, main pump, and auxiliary motor pump incorporating necessary design changes were released in the period 14 to 18 June 1963; procurement action was initiated for these components at the end of the report period. Schedule analysis indicates that the production engine actuation system will meet test objectives and stage phases of procurement, development, manufacture, qualification, system assembly, and system checkout.

Flight Control Electronics

Requirements for automatic checkout of the flight control system were released 15 January 1963 in Process Specification MA021-1147, Saturn S-II Flight Control System Checkout Requirements. This specification outlines the test procedures, stimuli, and measurement requirements for checkout of the flight control switch and engine gimbaling tests under cold and static firing conditions.

The flight control test consoles for the laboratory tests of the engine actuation system were designed and fabricated. The hydraulic breadboard console was delivered to the laboratory to support the start of the engine actuation system servoactuator testing. The J-2 engine test console is in the final stages of modification to requirements for the static firing test at Rocketdyne.

Subsequent to completing design requirements for the multipole flight control switch, mechanical feedback was adopted for the engine actuation system and does not require the switch. In compliance with NASA technical directive TD 85-63 , S&ID will use the Douglas S-IV control switch to satisfy the requirement for maintaining capability for conversion to electrical feedback.

The preliminary release of the mounting provisions for the rate gyro package, including the basic environmental requirements for this design installation location, was forwarded to MSFC via Letter 62MA13877, dated 21 November 1962. The stage requirement and power provisions were discussed at the 13 December M-SAT-WDC meeting. The agreements reached in the meeting resolved the interface problems associated with the rate gyro package. Mechanical definition of the rate gyro package, consisting of a single external configuration drawing (50M35020), was received from MSFC on 17 June 1963. Location and mounting possibilities for the accelerometers and the forward gyro package are being investigated.

The S-II flight control subsystem report was revised and published in December 1962. This second issue contains a description of the Saturn V vehicle guidance and control concept, control component mechanization characteristics, and S-II flight control system development and test plans.

Gimbaled Engine Testing

One of the important test requirements from a flight control system standpoint is engine gimbaling under hot-firing conditions. The major tests in this area will be conducted at the Battleship and All-Systems test stands at Santa Susana. Preliminary coordination with the test area on test requirements and their effect on the Battleship and All-Systems stand design was conducted during the reporting period.

One of the principal test objectives in the Battleship and All-Systems gimbaling test program is to analyze thrust structure actuator and engine compliance characteristics. To evaluate the compliance during the hot gimbaling tests, a J-2 engine gimbal-bearing position indicator is required. Design of the gimbal bearing position indicator was by Rocketdyne using the concept previously developed on the F-1 engine.

The preproduction S-II engine actuation system will be tested at Rocketdyne on a single J-2 engine gimbaling test to obtain early gimbaling test data on a flight-type hydraulic system. S&ID will provide a laboratory flight control system console that will enable the entire electrical and hydraulic loop of the S-II flight control system to be tested. The modifications to the flight control console required by the interface requirement with the test stand instrumentation and wiring have been determined, and provisions for these changes have been implemented. The engine actuation system and the flight control console for this test are in the final phases of assembly and will be available for checkout at S&ID early in August, 1963, prior to shipment to Rocketdyne in the middle of September 1963. Figure 31 shows the test system and the control console in the laboratory during checkout. Installation and system checkout will be performed during the facility and test debugging period of approximately one month. Gimbaled testing should start in late October or early November 1963.

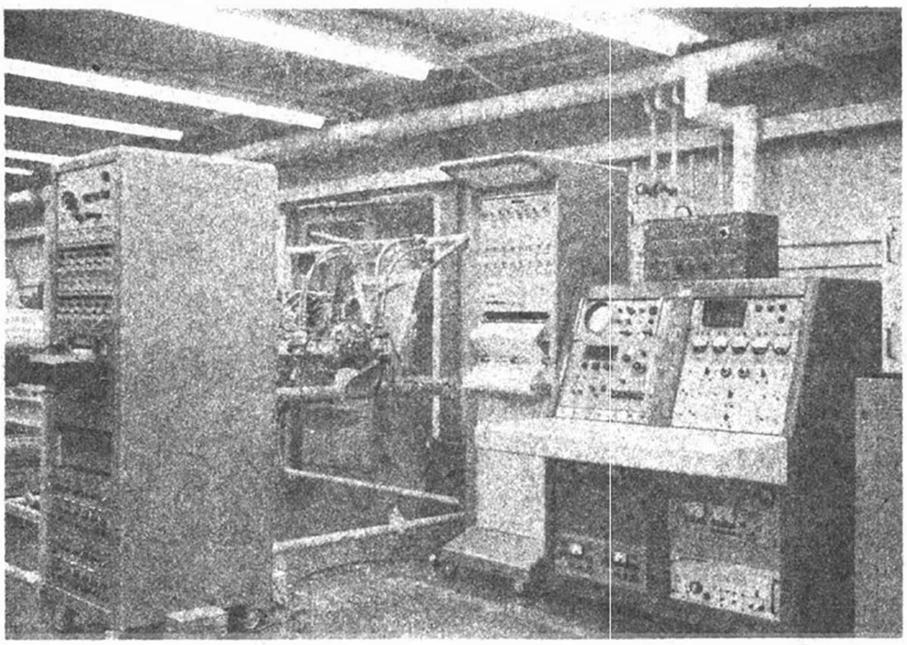

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Figure 31. Test System and Control Console

Flight Control Simulator

All the basic elements of the S-II flight control simulator will be completed early in NASA FY 1964. The American Machine and Foundry (AMF) simulator shown in Figure 32 is scheduled for delivery in August 1963, which is also the completion date for facility construction and for the control and instrumentation consoles. The S-II engine actuation system and console simulator installation is required before initial simulation testing begins in October 1963.

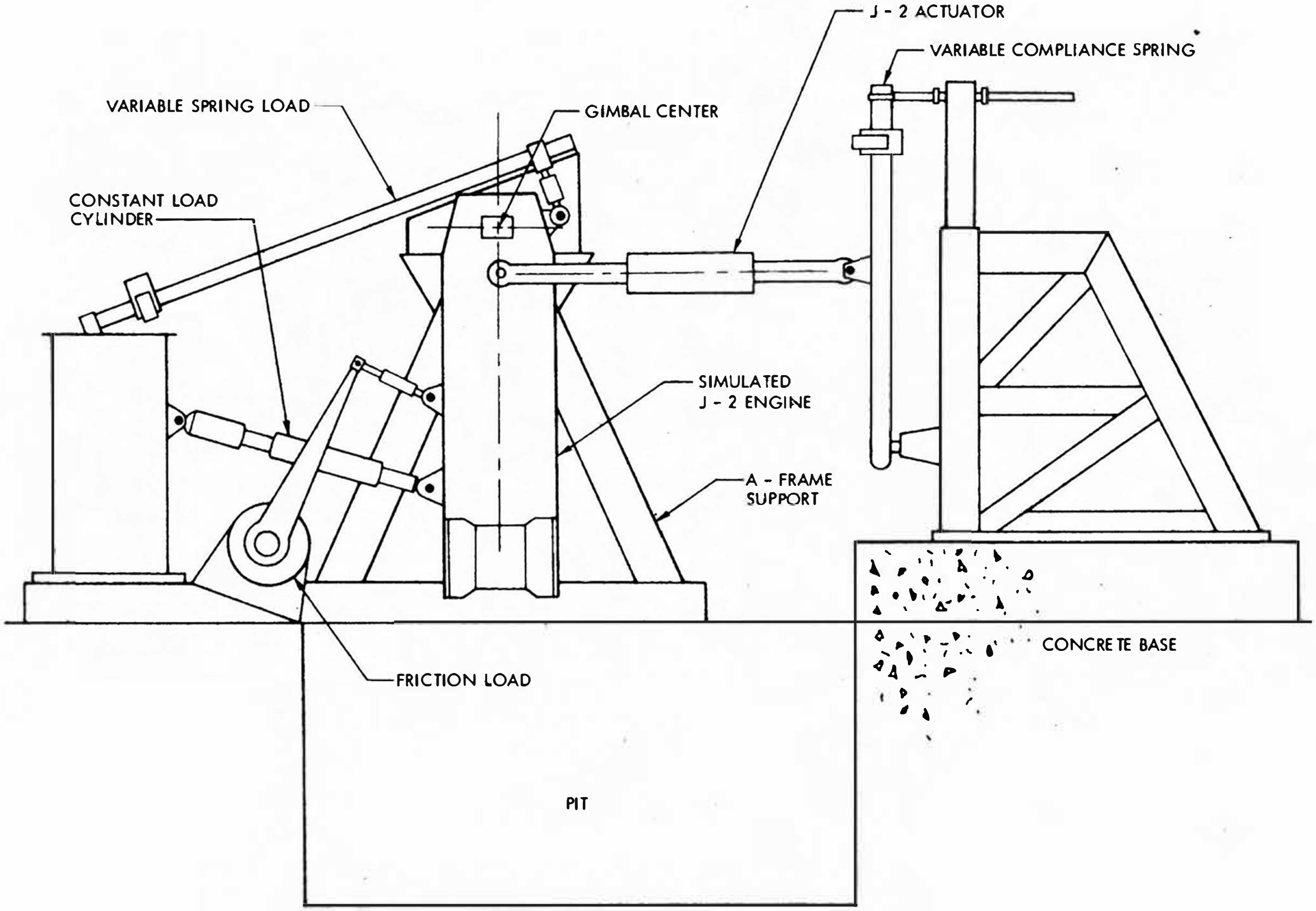


Figure 32. Flight Control Simulator

FLIGHT TECHNOLOGY

AERODYNAMICS

S-IC/S-II Separation Analysis

A directive to change to dual-plane separation was issued by NASA-MSFC before the S&ID briefing at MSFC on 19 September 1962 when the design approach was clarified. For the dual-plane mode, the S-IC/S-II interstage is severed at two distinct separation planes. Dual-plane scheme C as defined in S-II Dual-Plane Separation Study, Addendum I SID 62-895-1, dated 29 August 1962) will be implemented. The means to retain engine-out mission capability with scheme C and the critical need for impingement force wind tunnel tests will be investigated.

First-Plane Separation

For the selected dual-plane mode of coast separation, the S-IC/S-II interstage is severed at two distinct separation planes. Preliminary dual-plane studies (SID 62-845 and SID 62-845-1) established the second separation plane location at S-II station 196. Analyses were conducted to determine the most desirable first separation plane from the standpoint of first- and second-plane clearance distances, ullage rocket and J-2 engine exhaust impingement considerations, and mission payload weight.

Based on the results of the dynamics of separation analysis and the J-2 impingement data, a station 0 first separation plane was selected with a separation clearance distance of 20.5 inches (no actuator locks). A separation plane located forward (at station 10) would not significantly reduce the problems of second plane (station 196) separation dynamics in the case of no J-2 engines out nor significantly increase the mission payload weight. However, the collision potential at first-plane separation would be greater since the separation clearance distance at a forward station, such as station 10, is 12 inches.

Second-Plane Separation

A preliminary analysis of the dynamics of second-plane separation was made for the case of dual actuator failure (all five engines burning). Analytical J-2 rocket engine impingement data were used because experimental data were not available. For this case, the actuator-out engine, or free engine, was assumed to be in the hard-outboard position (7 degrees in pitch and yaw or 9.9 degrees across corners); the three other control engines were assumed to be gimbaled at 0.4 degrees in pitch and yaw (or about 0.6 degrees diagonally) toward the actuator-out engine. A critical collision dimension exists between the interstage and the controlled engine opposite the free engine.

For the nominal conditions assumed, the resulting interstage clearance distance between the J-2 nozzle and the forward point on the interstage at S-II station 196 is 33.7 inches, a decrease of 20.3 inches from the initial clearance distance (54 inches). The lateral translation of the interstage during this time is 21.1 inches, while the rotation of the interstage (0.5 degrees) adds 0.8 inches of clearance distance because of its rotation away from the J-2 engine. The clearance distance between the J-2 nozzle and the 10-inch interstage frame at station 159.5 is 27.3 inches. Therefore, the critical point on the interstage for second-plane separation is the 10-inch frame at S-II station 159.5.

Preliminary second-plane separation dynamics for separation at S-II station 196 with one controlling J-2 engine out were completed. The results, summarized in Table 2, are based on analytical J-2 engine impingement force and moment data.

Based on these preliminary results, the interstage will collide with the dead engine nozzle if the nozzle is in the outboard position. The results show that clearance distance can be achieved if provisions are made in the system to move and lock the J-2 nozzle inboard when engine failure occurs before second-plane separation. For example, when the dead engine nozzle is moved to the inboard position (both actuators full inboard) the resulting clearance distance is 23 inches.

Table 2. Results of Preliminary Second-Plane Separation Dynamics Analysis

J-2 Nozzle Position	Relative Nozzle Clearance Distance* To Outer Mold Line at Station 196	Relative Nozzle Clearance Distance* To 10-Inch Frame at Station 159.5
Outboard	Collision	Collision
Neutral	7	3.5
One actuator inboard One actuator neutral	16	12
Inboard	27	23

* Inches from dead J-2 Engine

Another method of obtaining second-plane clearance distance for the engine-out case is to use interstage-mounted retro rockets to avert the possible collision in the engine-out case when the J-2 nozzle is in the hard outboard position. Retro systems consisting of four, eight, and twelve motors (one motor assumed out in each case) were studied with individual thrust levels varying from 1000 to 6000 pounds.

The results of the study indicate that for the J-2 engine-out case the twelve-motor retro system is the only one capable of achieving satisfactory clearance, and each of the motors must be in the 4000- to 6000-pound range. The resulting clearance distance between the dead J-2 engine nozzle and the forward point on the first interstage frame (station 159.5) is about 9 inches. However, when the same retro motor system is used on the dual J-2 actuator failure separation case, the minimum interstage clearance distance is reduced from 27 inches to about 19 inches. There is also a payload penalty of about thirty pounds for the lunar orbital rendezvous (LOR) mission when the retro motor system is used. It is therefore recommended that no interstage retro rocket system be used for second-plane separation. Furthermore, it is recommended that the dead J-2 engine toe-in scheme be incorporated to achieve second-plane separation with one J-2 engine out.

Preliminary studies have been made to determine the effect of second-plane separation initiation time on mission payload weight and the dynamics of stage separation on second-plane clearance distance. Results of these studies were reported in SID 63-266-5, Saturn S-II Stage Monthly Progress Report (June 1963). In summary, it is recommended that jettison time remain at t = 30 seconds. Reducing the second-plane separation time will require an extensive wind tunnel program and will increase actuator loads. Further, the small gain in LOR mission payload weight does not justify the additional complications of the internal aerodynamics (J-2 impingement) caused by external aerodynamic forces that are difficult to determine.

Separation Criteria

The F-1 engine thrust decay used in early studies was superseded by the F-1 engine decay data obtained from MSFC in Memo M-P&VE-PP-96-63. A maximum estimated thrust-decay curve is shown in the revised MSFC data; it ranges from the cut-off signal to zero thrust. Nominal and minimum thrust decay curves from 10 to 0 percent are also shown forming a possible engine-to-engine deviation band. S&ID has extended the nominal and minimum curves from the 10-percent level to the cut-off signal by using an MSFC method. These data, which were used to reevaluate the S-IC stage retro rocket requirements, will be used for all future studies.

Retro Rocket Requirements

In response to a request from MSFC and Boeing, S&ID completed a study to determine the feasibility of reducing the thrust level of the retro motors based on the most current F-1 engine-thrust decay data.

For this study, retro-rocket thrust levels varying from a minimum value of 63, 000 pounds per motor to a maximum value of 100, 000 pounds per motor were investigated. A minimum acceptable thrust level was determined based on the condition that the retro rockets should not be at rated thrust prior to physical separation. On the basis of this, plus the current F-1 thrust decay data and the retro motor thrust buildup time of 150 ms, the required minimum total axial retro rocket thrust level is 440, 000 pounds, or approximately 63, 000 pounds per motor (seven out of eight firing). However, preliminary flight control analyses indicated that it is highly desirable to limit coast time to 1 second from the 10-percent F-1 thrust level (separation signal) to 6-foot clearance. Based on this, the required retro thrust level per motor is approximately 80, 000 pounds and the corresponding burning time is 1 second.

MSFC directed S&ID to base all future S-IC/S-II separation studies on statistical analysis. Time limitations did not allow a statistical combination of all the transients to determine retro motor requirements. However, preliminary studies showed that a statistical combination of separation transients will present essentially the same retro motor requirements.

As a result of separation studies, the following S-IC retro motor requirements were established:

1. Eight identical solid-propellant motors will be mounted in pairs within the F-1 engine fairings.
2. The retro motor thrust and nominal burning time will be sized with one retro motor out to satisfy the minimum net axial force profile requirements presented in Figure 5.1-4 of SID 63-476.
3. Based on the minimum net axial force profile and the current F-1 engine thrust decay data, the nominal vacuum retro rocket thrust (parallel to Saturn V centerline) per motor will be 80, 000 pounds. (Nominal thrust is defined as rated thrust at 70 F with a nominal burning time at this thrust level of 1 second.)
4. The maximum thrust rise time will be 0.15 seconds (from 0 to 90 percent thrust).

5. Retro motor (motor and/or nozzle) cant angle will not exceed 20 degrees.

6. The thrust vector misalignment tolerance will not exceed ±2 degrees. This tolerance includes the combined total misalignment caused by dynamic thrust vector deviation from the nozzle geometric centerline, the motor installation on the vehicle, and structural deformation resulting from dynamic loads.

7. The ignition altitude shall be a minimum of 53.3 kilometers (175,000 feet). Ambient pressure and temperature will be based upon the Patrick Air Force Base atmosphere.

Ullage Rocket Requirements

Previous separation studies have shown that the ullage rocket nozzle cant angle value has very little effect on first-plane separation clearance distance. However, the ullage motor nozzle must be designed so that the exhaust plume will not impinge on the linear-shaped charge (LSC) assembly (at S-II station 0) nor on the J-2 engines after first-plane separation. As a result, the optimum ullage motor cant angle and associated nozzle expansion ratio were determined from a standpoint of minimizing payload loss caused by aerodynamic drag, motor and mounting weight, and aerodynamic fairing weight. Aerodynamic fairings were assumed for the ullage motor drag analysis. The results indicate that a nozzle cant angle of 10 degrees results in the minimum incremental payload loss due to the ullage motors. Using the 10-degree cant angle and the 12-degree divergence angle, an expansion ratio of 8 is required to prevent ullage exhaust plume impingement on the S-II stage.

The ullage rocket nozzle centerline thrust requirement is determined by the 0.1 axial load factor criterion and the nozzle cant angle. Using the established 10-degree cant angle, the nozzle centerline thrust per motor is 22,000 pounds (assuming one inoperative motor, grain temperature of 20 F, and 7-percent deviation in thrust at a given ambient temperature). The ullage motor system is conservative in design, on the basis of this combination of adverse events taking place within each motor. Consequently, a statistical analysis was conducted to determine the probability of attaining 0.1 G if the system is designed to provide 0.09 G at 20 F, one motor out, and performance 7-percent low. The probability of encountering these design conditions is 3.8279×10^{-26}. With the ullage motors sized to provide 0.09 G under the most adverse conditions, the probability of attaining less than 0.1 G is 2.727×10^{-9}. Therefore, the ullage rocket minimum thrust per motor of 20,000 pounds has been determined on the basis of a 0.09-G minimum axial load factor.

The following ullage rocket requirements were established based on the preceding impingement and statistical considerations and the separation criteria:

1. Eight identical solid-propellant motors will be used in the system. The motors will be equally spaced on the interstage periphery with the inboard corner of the nozzle exit 3. 25 inches above the outer mold line at S-II station -0. 25.

2. The ullage motor nozzle centerline will be canted 10 degrees outboard from the motor case centerline. The nozzle half angle will be 12 degrees, and the expansion ratio will be 8. These three nozzle parameters are required to yield an optimum externally mounted motor configuration with no exhaust plume impingement on either the first plane LSC or the J-2 nozzles.

3. The minimum nozzle centerline thrust per motor will be 20, 000 pounds (at 20 F).

4. The minimum burning time will be 3. 25 seconds.

5. The maximum thrust rise time (from ignition to 75 percent chamber pressure) will be 0. 125 seconds.

6. The thrust vector misalignment tolerance will not exceed ±2 degrees. This tolerance includes the combined total misalignment due to dynamic thrust vector deviation from the nozzle geometric centerline, motor installation on the vehicle, and structural deformation resulting from dynamic loads.

7. The ignition altitude shall be a minimum of 53. 3 kilometers (175, 000 feet). Ambient pressure and temperature will be based upon the Patrick Air Force Base atmosphere.

Separation Sequence

The current S-IC/S-II stage separation system sequence is presented in Figure 33. These sequence times are based on the estimated F-1 engine thrust decay shown in M-P&VE-PP-96-63, 80, 000 pounds minimum axial thrust per retro motor, 20, 000 pounds minimum nozzle centerline thrust per ullage motor, and a 1-second J-2 thrust chamber chilldown allowance.

Separation Manual

During this reporting period, an interim issue of the Saturn S-II Separation Data Manual was published (SID 63-476, May 6, 1963).

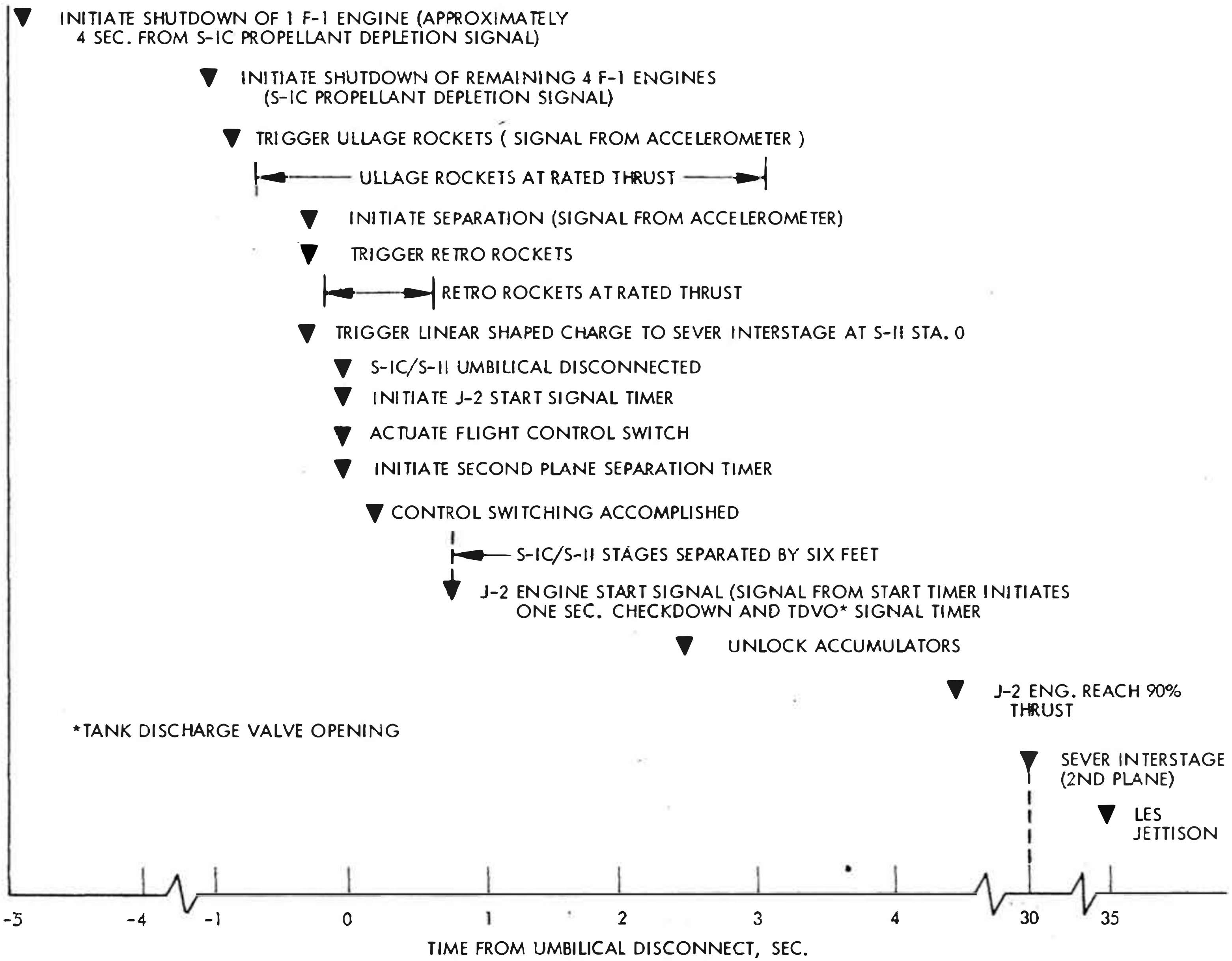


Figure 33. Separation System Sequence

Dual-Plane Separation Test Program

The dual-plane separation mode requires experimental verification of the J-2 jet impingement forces and moments imposed on the interstage after it is jettisoned. Analytical estimates of these impingement forces and moments indicate clearance of the interstage during separation. However, an experimental evaluation of impingement forces is required inasmuch as the complex nature of the plume impingement makes analytical predictions only approximate. Langley Research Center (LRC) was selected as the best facility for the investigation. Single nozzle impingement tests of limited scope were also carried out in the North American Aviation high-altitude rocket nozzle facility to provide test data for early analytical estimates of the forces. Design of the structure will proceed on the basis of analytical estimates. The status of the program is presented in the following paragraphs.

Cold Flow Tests. It was established that a twenty-fifth to fiftieth-scale model simulating the S-II base area, the J-2 cluster, and the interstage would be tested with cold gas as a propellant. The interstage was located on a force balance, and an operational altitude of 250,000 to 300,000 feet was required. Investigations of the 60-foot vacuum sphere at LRC revealed that LRC had adequate performance capabilities if a fiftieth-scale model was used, and the runs were limited to 100 milliseconds. Model requirements were established, and the Los Angeles Division of NAA designed and constructed the model (shown in Figure 34), which was shipped to LRC 10 June 1963. An investigation of various gas mixtures revealed that a mixture of argon and sulfur hexafluoride would provide excellent simulation of the J-2 engine exhaust properties and would be easy to handle. The mixture selected was 32-percent argon and 68-percent sulfur hexafluoride by weight. Model installation was begun on 24 June 1963.

Single Nozzle Tests. Tests of a single conical nozzle with a 2:1 area ratio were completed at the Los Angeles Division in February 1963. The objectives of the test were to determine the pressure distributions on a surface submerged within the exhaust plume at various locations, to correlate these results with the results of an analytical technique developed at S&ID, to determine the effect of pressure ratio on the pressure distributions, and to determine the effect of the working fluid properties on the pressure distributions. The results of the tests are as follows:

1. The experimental results can be predicted analytically by first computing the exhaust jet flow properties by an IBM 7090 method-of-characteristics program. The local flow properties incident on the submerged surface are noted or interpolated, and the Newtonian impact theory ($C_p = 2 \sin^2 \theta$) is used to derive local pressure coefficients and, finally, a pressure distribution.

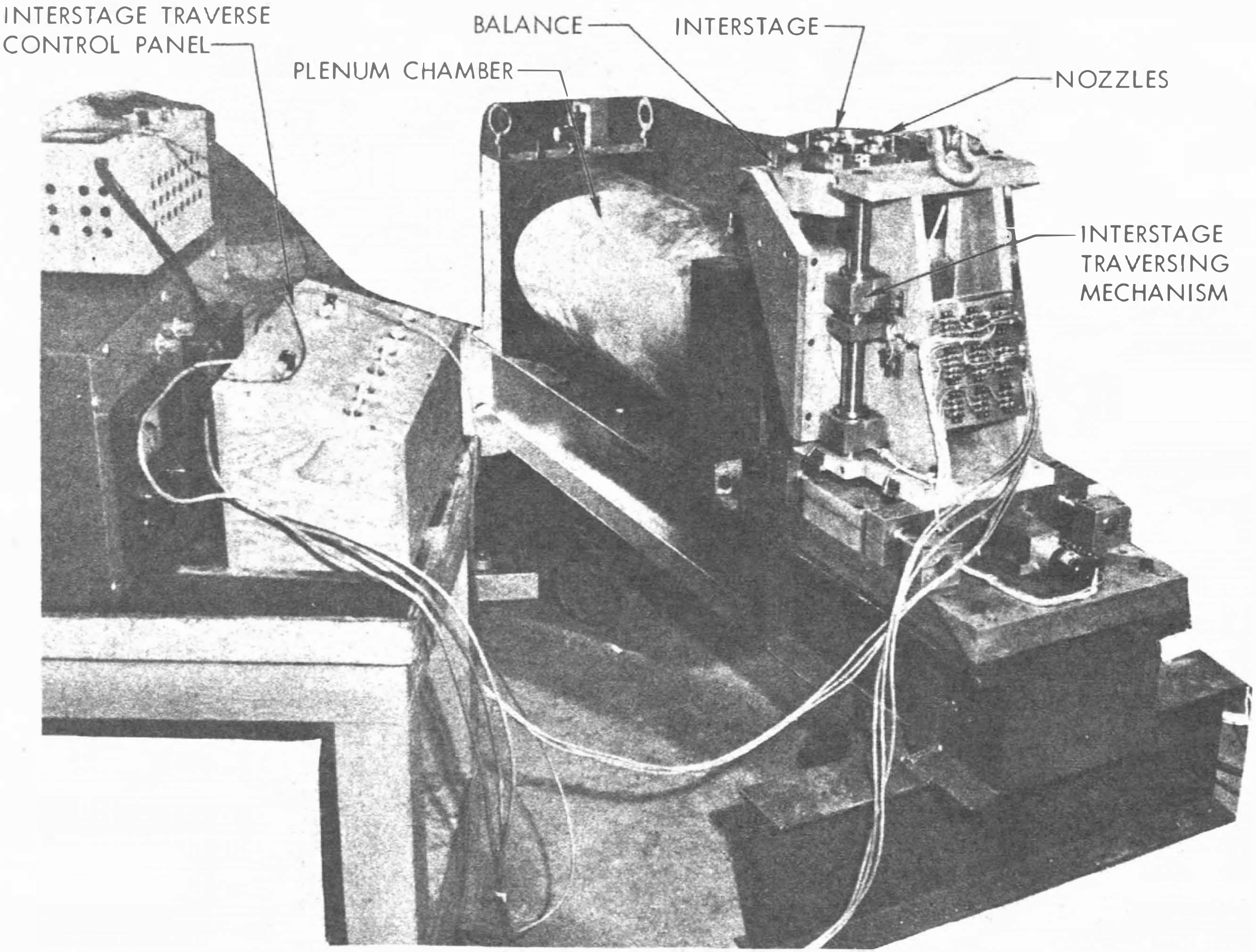


Figure 34. Dual Plane Separation Model

2. The effect of pressure ratio (or altitude) on impingement pressures of highly expanded jets is small and may also be predicted analytically.

3. The only important gas property in determining impingement pressures is the ratio of specific heats, assuming that geometry, pressure ratio, and supply pressure are simulated.

With these conclusions, it was analytically and experimentally demonstrated that a cold gas mixture can be used to simulate hot gas flows where force is the parameter of interest and that the design of the cold flow dual-plane separation tests was valid. It was also demonstrated that the method of characteristics and Newtonian impact theory can be used to predict impingement pressure distributions. This result was the basis upon which the forces on the interstage resulting from the impingement of the J-2 plumes were computed for use in current clearance analysis.

Control Requirements

Control requirements are defined primarily by conditions at separation because they are more severe than those at any other flight time. During the past year, S-II Flight Dynamics has made comprehensive studies of various separation schemes to determine the best method implementing engine-out separation capability. These studies, which included extensive analog computer simulations, are described in SID 63-239.

The requirements to implement the dual plane scheme of separation are as follows:

1. Engine initially in the null position

2. Minimum engine rate capability of ±8 deg/sec

3. Minimum engine acceleration capability of ±30 deg/sec^2

4. Minimum physical limits on engine deflection of ±7 deg in pitch and yaw planes.

5. Accumulator unlock at engine mainstage

6. Minimum simulator capacity of 325 cubic inches

Separation studies were continued, and a two-phase dual plane separation study on the analog computer was completed. The first portion of the study investigated flexible body dynamics, fuel sloshing, and nonlinear engine actuation. The second portion of the study incorporated a different mechanization of the engine actuation system to provide a means for investigating the engine-to-engine thrust buildup tolerances. A mechanical feedback actuator and revised actuator loads were also incorporated into the second phase of the study. The former addition is consistent with the MSFC redirection to employ a mechanical feedback type actuator. The data acquired in both phases of the study will be included in a future report. Control gains of 2.2 deg/deg for position gain and 0.7 sec^{-1} for the ratio a_o/a_{1_q} appear to be optimum for separation if the separation transients are to be controlled in a minimum time. When these gains are used, the separation transients are controlled so that the attitude rate is reduced to less than 0.3 deg/sec within approximately 15.0 seconds after separation.

Aerodynamic Loads

Aerodynamic Loads Design Data

Aerodynamic loads data have been received from MSFC for the Saturn V three-stage LOR mission via a 185.2-kilometer (100 nautical mile) parking orbit. The effect of the wind criteria at 95 percent probability level wind speed with a superimposed gust of 9 m/sec is included in the aerodynamic loads data. A comparison of MSFC data with those calculated by S&ID indicates that angles of attack compare within 0.1 degrees—a divergence probably attributable to the slight difference in input data.

S-II Aerodynamic Loads Data Manual

During this report period, two issues of the S-II Aerodynamic Loads Data Manual were published. The first revision (SID 62-589, revised 17 December 1962), includes aerodynamic loads design data which were established by MSFC. It should be pointed out that the aerodynamic data are not compatible with the shear and bending moment data that S-II Design and Structures has been directed by MSFC to use for design of the S-II stage. The final issue of the S-II Aerodynamic Loads Data Manual (SID 63-498) was also completed and published on 10 June 1963. This issue contains S-II design data in the areas of aerodynamic characteristics, static stability derivatives, pressure distributions, aerodynamic heat transfer rates, and acoustic environment. Data are presented for the basic S-II stage and for all known S-II protuberances including areas directly adjacent to protuberances.

Aerodynamic Heating

Smooth-Skin Heat Transfer Rates

Basic smooth-skin aerodynamic heat transfer rates for the Saturn V design mission and configuration were reanalyzed by S-II Aerodynamics. These data (published in SID 63-498) supersede those given in the S-II

Performance Data Manual (SID 62-591, revised 9 November 1962). The revised aerodynamic heat transfer rates, which are based on more refined analyses, include the effect of angle of attack. The results show that the peak aerodynamic heat transfer rates on the S-II sidewall are approximately ten percent less than those presented in the S-II Performance Data Manual.

Combination IBM Program

The aerodynamic heat transfer flow property program was modified to compute simultaneously the flow properties and turbulent flat plate convective heat transfer rates at any point (smooth skin) on the Saturn V vehicle. This change in the program will reduce IBM machine time by approximately one third. The program was checked out and is not operational. Local flow properties calculated with this program are in agreement with the data received from MSFC. Since the heat transfer rates are dependent on the local flow properties, the aerodynamic heat transfer rates may be assumed to be compatible with those being calculated by MSFC. However, since S-II Aerodynamics has not received any aerodynamic convective heat transfer rates from MSFC, a direct comparison between S&ID and MSFC data cannot be made at this time.

On 24 June 1963, MSFC indicated that S&ID's basic smooth skin aerodynamic heat transfer rates were approximately 50 to 60 percent greater (at a particular wall temperature and trajectory time) than those estimated by MSFC. However, there were some basic differences in the assumptions used by S&ID and MSFC as shown in the following tabulation.

Item	MSFC	S&ID
Trajectory	Nominal - LOR	Design includes trajectory perturbations
Angle of attack	0	Varied as function of time, included effect of 95% winds
Characteristic	From Apollo command module apex	Beginning of S-IVB/S-II frustum

S&ID subsequently conducted a study to determine whether the differences were due to basic methodologies or to the foregoing assumptions. The study indicated that a change of 26 percent was due to difference in trajectory, 25 percent was due to difference in angle of attack, and 4 percent was due to difference in characteristic length.

On 26 June 1963, MSFC was informed of the results of the study, and it was decided that S&ID should continue to use their own heating rates since angle of attack and trajectory perturbations should be taken into account.

Protuberances

S&ID analyzed each protrusion on the exterior of the vehicles from a standpoint of aerodynamic heating and loads, drag, weight, structural design, and accessibility. Where protrusions are required due to accessibility, structural design and other requirements, studies were made to determine whether aerodynamic fairings are necessary from an aerodynamic loads or heating standpoint. The results of a preliminary study made to determine heat transfer rates for all known S-II protuberances are summarized in Table 3. The following conclusions were reached.

1. The high aerodynamic heat transfer rates on some of the S-II protuberances indicate that aerodynamic fairings or insulation will be required.

2. Since payload trade-off studies indicate that a gain in payload weight can be realized if fairings are used, a recommendation has been made to include aerodynamic fairings on the following protuberances:

   Liquid hydrogen feed line
   Liquid oxygen vent valves
   Liquid hydrogen vent valves
   Liquid oxygen fill and drain valve
   Liquid hydrogen fill and drain valve
   Ullage rockets

3. Fairing and cap angles should be 15 degrees or less. Furthermore, in the cases indicated, the aft portion of the protuberance should also be faired to reduce base drag and sound pressure levels. Low fairing angles and aft fairings will result in higher fairing weights; however, since the trade-off between structural to LOR mission payload weight is 3 to 1 on the S-II stage (15 to 1 on items located below S-II station 196), the reduction in drag more than makes up for an increase in fairing weight.

Performance

Engine-Out Performance

A study was made to determine the effect of varying single J-2 engine failure times on the LOR mission payload weight. For this study, all three stages of the Saturn V vehicle were assumed to have a fixed propellant loading; therefore, as the payload weight was reduced, the launch thrust-

Table 3. Trade-Off Studies for External Protuberances on the S-II Stage

		Maximum Height (in.)		Projected Frontal Area (ft²)		ΔW_{pl} LOR Mission (lb)		Aerodynamic Heat Transfer Rates* (T_w = 600 R, M_∞ = 2.7)				Aerodynamic Heating Remarks	
								Preliminary		Design			
Protuberance	No.	Preliminary	Design	Preliminary	Design	Preliminary	Design	$\dot{q}_p$ (a)	$(\dot{q}_p/\dot{q}_b)$ (b)	$\dot{q}_p$ (a)	$(\dot{q}_p/\dot{q}_b)$ (b)	Preliminary	Design
Separation joints	2	2.58	2.58	33.14	33.14	-190	-90	1.512	1.19	1.116	1.09	30 degree forebody wedge angle	14 degree forebody wedge angle
LH_2 feed line	5	16.00	17.0	7.40	10.25	-185	-35	3.680 2.330	2.40	2.150 1.073	1.00	Elbow Vacuum jacket	15 degree conical cap cylinder afterbody
External stringer (aft)	216	2.00	2.00	17.28	17.28	-81	-75	1.179	1.12	1.061	1.09	20 degree forebody wedge angle	15 degree forebody wedge angle
External stringer and insulation forward)	144	1.83	1.83	15.81	15.81	-64	-41	1.825	N.A.	1.411 1.061	N.A.	30 degree cap	20 degree cap - 15 degree fairing-forebody
Ullage rocket	8	19.69	19.69	13.68	13.68	-56	-56	2.465	1.00	2.465	1.00	15 degree conical cap	15 degree conical cap
LOX vent valves	2	17.00	19.5	2.76	4.90	-33	-13	4.140	2.50	2.465	1.00	Shock impingement area	15 degree conical cap
LH_2 fill and drain valve	1	17.25	19.0	1.45	2.74	-12	-7	**4.590	3.20	**2.590	1.00	Stagnation value	15 degree conical cap
Lower umbilical arm disconnect	1	2.68	2.68	0.16	0.16	-1	-1	**4.150	3.20	**4.150	3.20	Highest protuberance stagnation	Highest protuberance stagnation
Systems tunnel	1	11.25	11.25	1.42	1.42	-5	-5	2.780	1.00	2.780	1.00	20 degree conical fairing	20 degree conical fairing
LOX fill and drain valve	1	11.30	12.5	0.67	1.14	-5	-3	**4.720	3.20	**2.610	1.00	Stagnation value	15 degree conical cap
LH_2 vent valves	2	4.50	6.5	0.50	0.809	-3	-3	**4.870	3.20	**2.965	1.00	Stagnation value	19 degree conical portion
Pressurization system disconnect	1	1.50	1.50	0.08	0.08	-1	-1	**2.835	3.20	2.835	3.20	Stagnation value for 5 inch diameter cylinder	Stagnation value for 5 inch diameter cylinder
Destruct system	1	1.32	1.32	0.019	0.019	-2	-1	1.709	N.A.	1.046	N.A.	Nonfaired steps	15 degree faired steps
MISTRAM antenna	2	0.50	0.50	0.007	0.007	0	0	1.639	1.70	1.639	1.70	Stagnation	Stagnation
LH_2 level sensing line	1	0.82	0.82	0.052	0.052	-1	-1	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Total				84.43	101.49	-639	-332						

*Aerodynamic Heat Transfer Rates and Ratios:
(a) Protuberance, $\dot{q}_p$ (Btu/sec-ft²)
(b) Vehicle skin surrounding protuberance, $\dot{q}_p/\dot{q}_b$
**Average values used

to-weight ratio varied from the nominal value of 1.25 to a maximum value of 1.255. The S-II stage was loaded to a no-engine-out LOR propellant loading of 916,000 pounds. For each case, the optimum boost trajectory was used so that the payload weight corresponding to a given J-2 engine-out time was maximized.

The results of this study show that one J-2 engine failure at S-II stage ignition results in a maximum LOR mission payload loss of 11,700 pounds. Payload losses of 6850 and 910 pounds resulted from engine failure after S-II ignition at 100 and 300 seconds. The S-II stage nominal burning time for the no-engine-out LOR propellant loading of 916,000 pounds is approximately 390 seconds. It should be noted that the payload loss corresponding to a J-2 engine failure at ignition is not comparable to the value presented in the <u>S-II Performance Data Manual</u>. The difference results because the vehicle configuration used in this study does not have the optimum propellant loading for engine-out operation.

S-IC/S-II Separation Coast Time Study

A preliminary study was made to determine the effect of S-IC/S-II separation (first plane) coast time on LOR mission payload weight. Investigations were made for two cases: ullage motors triggered when the Saturn V vehicle accelerates to 3.6 G after four F-1 engines shutdown and ullage motors triggered at J-2 start signal. These cases represent the earliest and latest times for ullage rocket ignition. For both cases the total ullage thrust and flow rate(w°)were held constant at 140,000 pounds (seven out of eight motors burning) and 605 lb/sec respectively. The ullage motor burning time after J-2 start signal was also held constant. To determine the weight of the ullage motors, a rocket mass fraction of 0.738 was assumed. The coast time was varied from 0.7 to 5 seconds.

Results of the study indicate that the first case has a greater mission payload loss than the second because the increase in payload weight realized from ullage thrust is not as great as the loss in payload weight due to the added weight of the ullage motors. For example, the mission payload change for the first case varied linearly from 0 at 0.7 seconds (taken as the base point) to -796 pounds at 5 seconds while the payload change for the second case varied linearly from 16 pounds at 0.7 seconds to -680 pounds at 5 seconds.

Trajectory Optimization

An optimal flight program (method of steepest ascent) was developed that makes it possible to determine the optimum path of a vehicle within the atmosphere. Previously, all optimum trajectory programs available at S&ID had to assume a ballistic path during the atmospheric portion of flight.

The results indicate that reduction in third-stage burning time (launch gross weight, first- and second-stage burning times and third-stage liftoff gross weight are the same for both cases) by using the optimum path within the atmosphere and starting from an altitude of 19, 576 feet is 3.77 seconds for a 100-nautical-mile orbit. The corresponding increase in LOR mission payload weight is approximately 830 pounds. Details of this program were published in SID 63-475.

Propellant Management/ Performance Study

The primary purpose of the propellant management/performance study was to evaluate the effect of different S-II propellant loading error levels, propellant utilization (PU) error levels, and fuel biasing levels on the mission payload capability of the Saturn V vehicle for the LOR mission. The effect of having no PU system on the S-II was also evaluated for the purposes of payload comparison. A secondary purpose of this study was to evaluate the S-II propellant residuals occurring with and without fuel biasing.

The proper definition of the Saturn V payload capability demanded a statistical investigation of the tolerances and deviations on all three stages. The study included the development and use of an IBM 7090 computer program to assist in the statistical performance evaluation of the propellant management (PM) system. This analysis pertains only to the performance capability of the PM system; hardware effects and system reliability were beyond the scope of the study.

The most important results of the propellant management/ performance study are presented in the following summary at the 99.9-percent probability level. These results were presented at the Dynamics and Control Working Group Meeting held at Huntsville, Alabama, December 1962.

1. The mission payload weight is relatively insensitive to the S-II tanking errors considered in this study. For example, reducing the tanking error (χ) from 0. 5 to 0. 25 percent results in an increase in payload of approximately twenty-two pounds.

2. The payload weight is relatively insensitive to a reduction in the PU system errors (ϵ) below 0. 25 percent. Reducing ϵ from this value to 0. 1 percent results in an increase in mission payload of only 15 pounds.

3. If no PU system is used on the S-II stage (and no fuel bias), the payload weights could be 1657 pounds less than the case of a 0. 25 percent PU system (0. 25 percent propellant loading system with optimum bias).

4. If no PU system with optimum fuel bias is used in the foregoing, the difference in payload weight could be reduced to 446 pounds.

The system weight of the PU system is not included in these performance comparisons.

On the basis of this performance study, an effort to reduce the PU system error below 0.25 percent does not seem necessary unless cost is no problem. Similarly, an effort to reduce the tanking error below 0.5 percent does not seem necessary. In the latter case, however, it is understood that a propellant loading inaccuracy goal of 0.25 percent is specified by MSFC from flight evaluation considerations. Finally, the fact that this analysis was only concerned with performance probabilities should be emphasized. The decrease in over-all vehicle reliability due to the PU system being incorporated in the Saturn V must be evaluated and considered before the system can be evaluated.

Programmed Mixture Ratio (PMR) Performance Study

A preliminary analysis was made to evaluate the LOR mission payload gain resulting from a programmed variable mixture ratio (MR) on the S-II stage. For this study, a two-step system was assumed where 496,165 pounds (54.2 percent) of propellant are consumed during the first step and 419,835 pounds (45.8 percent) are consumed during the second step. Only the performance aspects of this proposed MR change were considered in this study. No S-II weight changes were made to reflect any hardware modifications required for this particular MR history.

Other pertinent assumptions are summarized as follows:

Item	First Step	Second Step
Engine mixture ratio	5.5	4.5
Thrust change	+11 percent	-11.5 percent
Specific impulse change	-1.34 percent	1.20 percent
Fuel flow rate change	+4 percent	-4 percent
Oxygen flow rate change	+14 percent	-14 percent

The increased thrust in the first flight step coupled with the increased specific impulse (Isp) in the second step results in an approximate 2075 pound gain in LOR mission payload. The optimum flight path associated with this increased payload is a more level trajectory with correspondingly smaller gravity losses.

The results of this study were presented to MSFC on 7 February 1963. MSFC was very interested in the performance gains due to PMR and requested S&ID to continue studies in this area

At the request of MSFC, the performance capability of the following two PU/step MR systems were evaluated for the PU meeting held at S&ID on 7 and 8 May 1963:

System	Tanked MR	First MR	Second MR	ΔW_{pl}
Test (sea level)	5.35	5.4	5.3	1768
Flight (altitude)	5.05	5.4	4.7	1748

The higher test mixture ratio values are used to avoid the J-2 flow separation and side load problem during sea-level testing. It is interesting to note that case 1 payload capability is 20 pounds greater than for case 2. Also, LOR payload gains associated with both systems are larger than heretofore calculated and are due primarily to the change in J-2 influence coefficients. These new coefficients (dated 14 January, 1963) produce a larger thrust and a larger Isp than the previous coefficients for the same MR change.

A further investigation of the "flight" case in which only the tanked MR was varied (which varies the relative step burning times, Δt_1 and Δt_2) showed that additional gains could be made:

Tanked MR	First MR (for Δt_1 sec.)	Second MR (for Δt_2 sec.)	$\frac{\Delta t_1}{\Delta t_1 + \Delta t_2}$ %	W_{pl}
5.05	5.4	4.7	48	1748
5.10	5.4	4.7	55	2011
5.20	5.4	4.7	70	2197
5.30	5.4	4.7	85	2081
5.40	5.4	4.7	100	1681

Although the third case in the foregoing listing shows the greatest payload gain, it probably falls short of the optimum gain. This gain is largely dependent on how much in excess of 5.4 the first MR can be. As a result, MSFC requested that further studies be made to determine the optimum programmed mixture ratio step.

On 12 June 1963, , S&ID presented the results of the most current programmed mixture ratio performance analyses at the Fifth S-II Vehicle Mechanical Design Integration Working Group Meeting. Some of the more important results of the study are presented in the following tabulation.

Programmed EMR	Tanked MR	EMR_1/EMR_2	$\left(\frac{\Delta t_1}{\Delta t_1 + \Delta t_2}\right)^*$ (%)	LOR W_{pl} Gain
Constant	5.5	5.5	100	1920
Equal step	5.0	5.5/4.5	47	2040
Otpimum step	5.24	5.5/4.5	72	2700

* t_n – burning time at EMR_n

It can be seen that a significant gain (780 pounds) may be achieved with an optimum step EMR over a constant programmed EMR. If the choice of the step EMR is limited to one that can be tested at sea level (i.e., limiting the second EMR to 5.18 to alleviate J-2 flow separation), a loss of 420 pounds from the optimum step occurs.

Several basic conclusions have been reached as a result of this study.

1. The first EMR should be a maximum.
2. The second EMR should be a minimum.
3. The burning time ratio $\left(\frac{\Delta t_1}{\Delta t_1 + \Delta t_2}\right)$ should be approximately 65 to 75 percent.

However, the limiting performance criteria assumed in this study (rated engine conditions, no weight penalties associated with varying NPSH requirements) suggest that the optimum payload gain of 2700 pounds may not be attainable. Furthermore, the fluctuating values of the J-2 engine influence coefficients indicate that these optimum values may change considerably when engine test data become available. Therefore, the programmed mixture ratio design should be flexible enough to accept variations in magnitude and length of time of the EMR step.

THERMODYNAMICS

Base Heating Tests

The S-II stage base heating series A tests were completed at Cornell Aeronautical Laboratories (CAL) 2 October 1962. This test series consisted of parameter variation tests that were intended to furnish preliminary design base area environmental data to be used in the determination of the design configuration of the S-II base heat shield. Design criteria that were determined from the test data have been released and present estimates of the environment that is expected to exist in the S-II base area during flight. SID 62-1278, Saturn S-II Stage Base Heating Series A Test Data and Summary Report, was published June 24, 1963. Publication of this report was delayed because of many revisions of the basic data by CAL.

Following are some important conclusions resulting from the tests.

1. The heat rates on the heat shield decrease slowly with altitude. The maximum values, which occur at a location midway between outboard nozzles, are 0.035 psia and 4 Btu/ft^2-sec with no nozzle deflection and no skirt.

2. The presence of a skirt increases the environmental levels on the heat shield approximately 20 percent.

3. A star flame deflector offers substantial protection to the base area. Typical values are 0.002 psia and 0.2 Btu/ft^2-sec with a star shield compared to 0.0344 psia and 4 Btu/ft^2-sec without a star shield.

The heating environment on the thrust cone has been evaluated on the basis of test results. It was determined for skirt-off operation that 0.1 Btu/ft^2-sec is a reasonable value. However, an analysis of the data measurements for low heating rates revealed a 0.2 Btu/ft^2-sec spread, and a maximum value of 0.3 Btu/ft^2-sec could thereby be derived. Heat rates incident on the thrust cone during the skirt-on operation were also estimated, and a distribution of heat rates on the thrust cone varying from 1.97 Btu/ft^2-sec at station 112 to 0.75 Btu/ft^2-sec at station 223 was derived. The data and derivation of these values were discussed with representatives of MSFC on 14 February 1963. It was agreed that these values should be used as interim criteria for design study purposes until data from the design evaluation base heating tests are available, at which time final design criteria will be established.

Construction of the S-II final design base heating model has been completed. This model is intended to simulate the final S-II design configuration. The main objective of this test series, which is scheduled to begin on 1 August 1963, is to document the effects of base recirculation on the heating rates and pressure distributions on the boattail area of the prototype design. Effects of slight modifications to the heat shield edge design on the thrust cone heating rates will also be evaluated, and the heating rates to some critical discrete components located in the boattail area will be measured.

An optimum data interpretation technique for reduction of the CAL data from the final design S-II base heating tests has been derived. Definite procedures based on small-sample statistics and probability theory have been established for interpreting the oscilloscope traces of the data, for weighing the data obtained, and for determining the size of the standard deviation necessary to discard data.

The final design base heating tests were originally scheduled for December 1962. A directive resulting from a base heat shield splinter meeting held on 18 February 1963 instructed S&ID to drop the present guarded drape design and proceed with a flexible curtain design; consequently, test schedules were slipped to August 1963.

The latter design has advantages that can not be ignored irrespective of the influence of the change on the model test program. Briefly, deletion of the bellows provides a very significant weight reduction, reduces the actuator loads, deletes a costly materials and structural bellows problem, provides a shorter curtain, and significantly simplifies the heat shield design. Relocation of the rigid portion of the heat shield to Station 44 may also provide some reduction in thrust cone heat.

A test plan describing a proposed hot-flow jet impingement test was transmitted to MSFC and Cornell Aeronautical Laboratories on 7 January, 1963. In this test, pressures and heating rates are measured on a flat plate located within the exhaust plume of a single rocket engine. Both liquid and solid propellant model rocket engines will be employed during this test. The data from this test will be used in studies to predict the convective and radiant heat rates due to the exhaust plumes from such solid propellant rockets as ullage and retro rockets and the force exerted on a surface due to an impinging exhaust plume (required to support analytical estimates of the force exerted by the J-2 engine exhaust plumes on the S-II after interstage structure).

Gas Dynamics Analysis

Rocket Exhaust Analysis

A method-of-characteristics program for the calculation of flow properties within a supersonic nozzle is in the development stage and has been partially completed to the extent that a full-flow field for a conical nozzle can be obtained. The program is designed to calculate the characteristic network within a nozzle (contoured or conical) from the kernel line input to the right running characteristic in the nozzle lip. A variable input to control characteristic net geometry and size is incorporated as a subroutine that will decrease numerical error and the associated convergence failure in computation common to other nozzle flow programs. The equations and programming techniques to allow for the construction of internal shocks and downstream calculations have been investigated and are being incorporated into the basic program. The final program will be capable of handling internal shocks and will define streamlines and flow properties within a nozzle for frozen or shifting equilibrium flow.

An analytical investigation of the flow properties within rocket exhaust plumes has resulted in verification of the theory that the inner portion of a plume does not change significantly with altitude. The implication, which has been verified experimentally, is that forces resulting from plume impingement on nearby surfaces will remain constant after a sufficiently high altitude is reached.

Partial exhaust plumes for the J-2 engine have been derived and are available for altitudes from 75,000 to 234,000 feet.

Exhaust Radiation

To determine the thermal environment of the S-II base region during sea-level static firing, a study was made of the thermal radiation from the J-2 exhaust gases. The main volumes of radiating gas are the five undisturbed exhaust jets and the deflected gases flowing over the test stand flame bucket.

The temperature and pressure variations within these Volumes make a determination of the emitted radiation extremely complicated. Therefore, conservative simplifying assumptions regarding these distributions were made, and the emission of radiant energy from the gas surface was estimated after N. C. Hottel.

Geometrical configuration factors to elemental areas in the S-II base region were computed by machine program, and the incident radiation heat flux was determined. The final study is being completed, but preliminary estimates are given as the maximum incident radiation to any point in the base region within the cluster of nozzles will be 2.0 Btu/ft^2-sec while that incident on the thrust cone will be 0.7 Btu/ft^2-sec.

It should be noted that the results of the study are to be used as interim design values. When thermal radiation measurements from single J-2 or other similar engine firings are available, final values will be released.

Calculations of in-flight exhaust radiation heating are in progress. The methodology has been reviewed with specialists in the Space Sciences Laboratory and at Rocketdyne, and general concurrence has been obtained. It is worth noting that this area has been so little investigated that MSFC has funded a study of rocket exhaust radiation at Rocketdyne beginning 1 June 1963. S-II Flight Technology will follow the course of this study at the working level through contacts already established.

FLIGHT DYNAMICS

Digital Programming

Numerous programs for use on the IBM 7090/7094 have been written to support the Flight Technology analysis effort on stage S-II development. These programs provide analytical and response data used for analysis and determination of theoretical and operational modes in various flight regimes. The more commonly used program decks are presented in the following listing.

Title	Abstract
Pitch-Plane Perturbation Equations	Evaluates the perturbation equations, expands the resulting determinant, and extracts the roots of the expansion polynomial.
S-Plane Frequency Response Evaluation	Evaluates an S-Plane transfer function as the ratio of two polynomials and one or more frequency sets. Root locus option for this program is 60 percent complete.
Propellant Sloshing Mode Evaluation	Evaluates the slosh modes of a liquid-filled container that is axially symmetrical and moving in a longitudinal direction.
Dynamics of Separation	Simulates the separation dynamics of two bodies including interference forces, such as two booster stages.
Rocket Exhaust Plume Boundary Shape	Describes the geometry of expanding rocket exhaust plume boundaries into a quiescent atmosphere using method of E. K. Latvala.
Gas Radiation	Computes radiant heat flux from a nonuniform hemispherical volume of gas with only one radiating component to an elemental area at the base center by using derivatives of the hemispherical emissivity.
Method of Characteristics	Computes the flow properties between the exit plane, axis of symmetry, and right-running characteristic emanating from the lip of a nozzle.

Propellant Utilization	Determines mission payload probability distribution due to engine and vehicle variations on any one stage by means of a Monte Carlo random sampling technique.
Flight Path Optimization of a Multistage Vehicle	Optimizes two-dimensional vacuum trajectories using the "steepest descent" method of calculus of variations.
Flow Properties	Computes all pertinent local aerothermodynamic flow properties at any point on a general cone, cylinder, frustrum, cylinder-missile configuration.
Preseparation Statistical Study	Computes the normal distribution for the Saturn V vehicle inertial angular rates and attitudes at the initiation of S-IC/S-II first-plane separation.

J-2 Engine Transient Side Loads Studies

At the direction of the Vehicle Dynamics and Control Working Group, a high priority effort was initiated to determine the effect of short-duration, high-frequency, large-magnitude transient side loads that Rocketdyne had indicated existed in the J-2 engine during start-up and shut-down. Both analytical and analog computer studies were employed for the following objectives: (1) to determine the operational limits of the EAS in response to the anticipated transient loads, (2) to investigate parametrically the response of the engine actuation system (EAS) model to five representative simple transient load wave forms, and (3) to investigate load alleviation techniques, such as load limited by-pass.

Two analog computer studies were conducted to determine the effect of J-2 sea-level firing "side loads" on the S-II EAS. Simple single-plane models were used. Amplitude and frequency of rectangular pulse, half sinusoid, full sinusoid, and four-cycle sinusoid side-load waveforms were varied parametrically. Valve compensation (DLD) and load limiter bypass flow schemes were employed to test the feasibility of reducing attach point loads, actuator chamber pressures, thrust chamber excursions, etc. 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 shock absorber-type restraining devices.

The inherent three-dimensional character of J-2 "side loads" and their effect on the S-II EAS strongly suggested 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-degree-of-freedom J-2 engine mounted on the three-degree-of-freedom S-II thrust structure. Such a study has been completed and analysis of the data has begun.

Recent J-2 test data from Rocketdyne has indicated that side load frequencies (1/2 to 2 cps) are much lower than originally anticipated. Unfortunately, the data from the first two analog studies did not adequately cover this low frequency range. Primary emphasis in the recent study was directed towards obtaining data in this area.

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 increases of side load frequency can be effected by some means more closely related to the source of the problem.

GROUND SUPPORT EQUIPMENT

Saturn S-II GSE end items fall into four catagories, according to function. These catagories are defined as follows:

1. Auxiliary - Equipment of a miscellaneous or general nature. Twenty-four deliverable and seven SDD end items in this category have been identified.

2. Checkout - That equipment required for stage systems checkout. Included in the category are items of associated or supplemental equipment necessary to equip a complete checkout station, as well as manual and automatic control equipment. Fifty-seven deliverable models and twenty-five nondeliverable SDD's have been identified.

3. Handling - That equipment required for handling or transporting the stage, stage components, and support equipment. Fifty-one deliverable models and one SDD have been identified.

4. Servicing - That equipment required for providing pneumatic or hydraulic fluids to the stage internal systems during test operations and for fulfilling the requirements necessary for static operations. Thirteen deliverable models and nine special development devices (SDD) have been identified.

GSE requirements are continuously being reviewed by the GSE branch of Engineering and adjusted to those requirements absolutely essential to the program. During the past year, 74 new GSE end items were identified, and 53 end items were deleted. It must be noted that many of the items identified as new are presently in proposal status.

In addition to design and development of support equipment per se, the GSE branch also has responsibility for the design of the Battleship stage systems and some Battleship structure, as reported in more detail later in this report.

AUXILIARY EQUIPMENT

LH_2 Tank Servicing Requirements

Design work was initiated to provide the equipment necessary for internal servicing of the LH_2 tank. The equipment, which is presently being designed, is prototype and is scheduled for delivery to the Battleship test stand at Santa Susana. This equipment, as illustrated in Figure 35, consists of the following:

1. LH_2 tank entry mechanism, supported at the top of the tank and protruding inward to support a platform capable of moving to any location within the tank
2. A clean room located at the top of the tank
3. An air conditioning unit, which will provide air to the tank while servicing personnel are conducting maintenance operations

This mechanism, controlled by means of a dual set of controls, is designed in such a way that contaminates will be prevented from entering the tank. Phase I control drawings were submitted informally for review and comment.

LOX Tank Access Equipment

A study was initiated to determine the GSE required for internal servicing of the LOX tank. The initial phases of this study were centered around establishing realistic criteria for the location of servicing required, for the selection of installations to be serviced, and for the amount internal equipment that can be practically removed prior to entry.

CHECKOUT EQUIPMENT

Major progress was made in the area of automatic checkout equipment development. Figure 36 is a block diagram of the present concept. A complement of such equipment as it will be applied to the Electromechanical Mock-up is conceptually illustrated in Figure 37.

Programming

The executive control program, consisting of fourteen subroutines, is well defined. For the GSE simulator program, twelve subroutines were developed. Certain of these subroutines, specifically revised and updated for GSE simulation, accommodated the following functions: command decode, monitor, general table search, delay, initialization, and exit procedure.

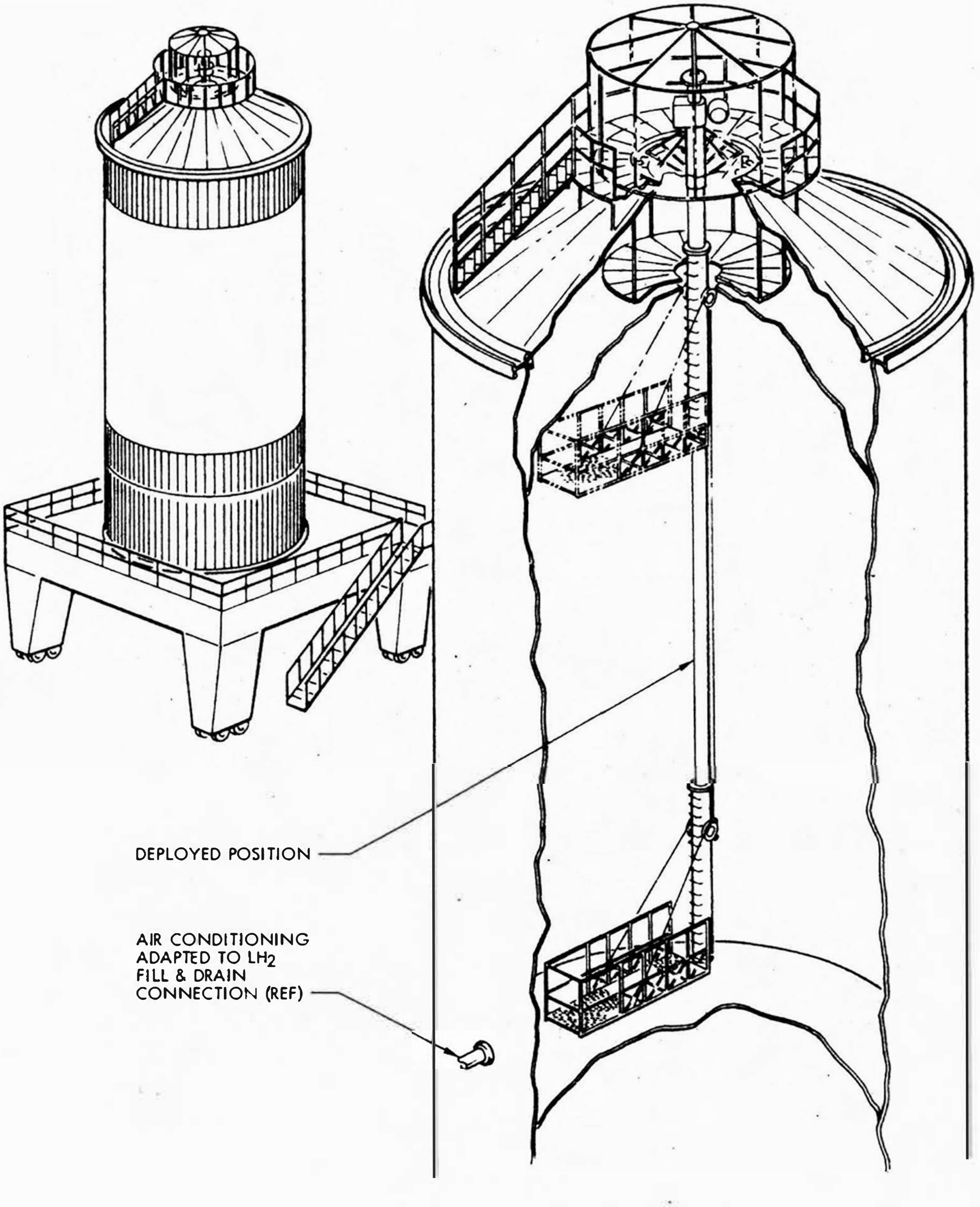


Figure 35. LH_2 Tank Servicing Mechanism (Model No. A7-35)

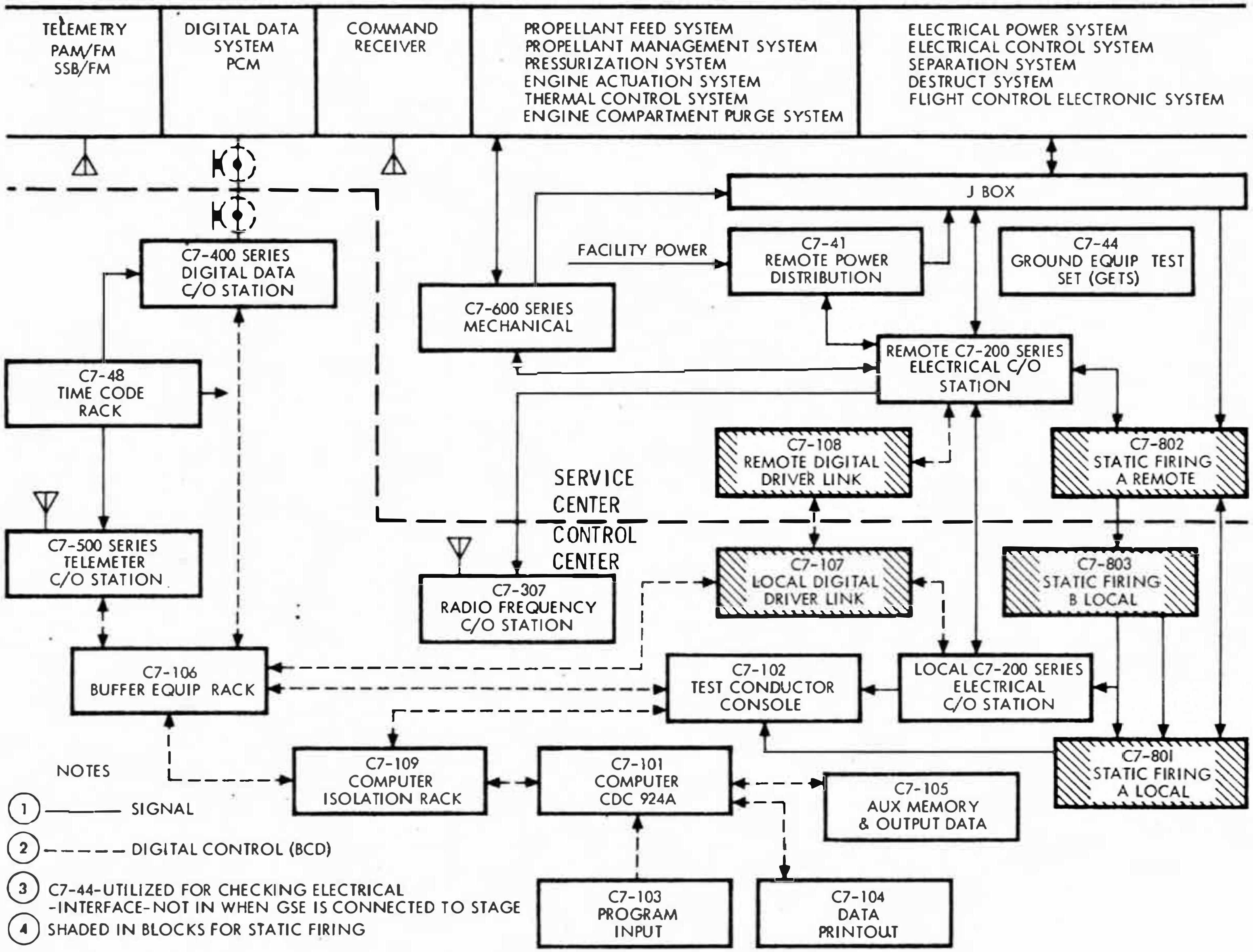
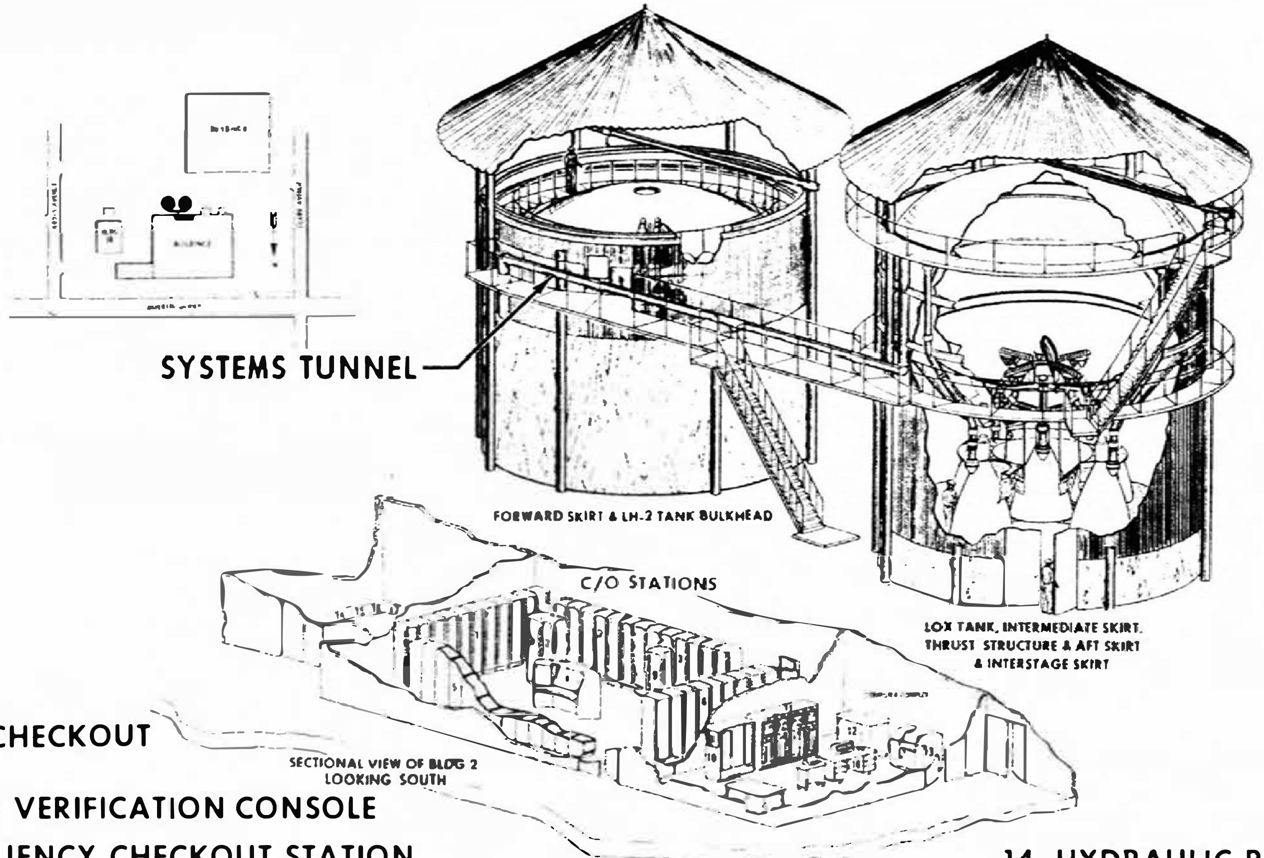


Figure 36. GSE Checkout



1. ELECTRICAL CHECKOUT STATION
2. GSE SYSTEMS VERIFICATION CONSOLE
3. RADIO FREQUENCY CHECKOUT STATION
4. DIGITAL DATA CHECKOUT STATION
5. TELEMETER CHECKOUT STATION
6. COMMUNICATION RACK
7. BUFFER EQUIPMENT RACK
8. TEST CONDUCTOR CONSOLE
9. INTERCOMMUNICATION SET
10. AUTOMATIC CHECKOUT COMPUTER
11. AUXILIARY MEMORY RACK
12. PROGRAM INPUT RACK
13. DATA PRINTOUT RACK
14. HYDRAULIC POWER CONSOLE
15. PNEUMATIC CHECKOUT CONSOLE
16. SERVICING UNIT, HYD FLUID
17. JUMPER UNIT, HYD SYS

Figure 37. Electromechanical Mock-Up

Rigorous debugging of programs will be accelerated since the computer program development facility (CPDF), located at S&ID, has become operational.

A command generation program for the CDC 924A computer is presently under development. Stage and GSE systems were analyzed to determine the organization of test information and its reduction to a format suitable for computer processing. The purpose of the command generation program is to build tables of subaddress/control instructions (commands to GSE) from test statement cards for use by the executive routine in controlling a test sequence. Utility programs are being prepared for use in general program development. Of these, card loader, printout, and trace monitor programs have been completed. The utility programs provide input and output information to the computer during test set-up and program development.

For a display/interrogate program, efforts were concentrated on the formulation of a basic mnemonic language for test conductor communication with the computer and for the development of flow charts for message interpretation.

For GSE self-check programs, tentative coding was completed for the greater portion of the computer self-check. Over 3,000 cards were key punched. Debugging of these programs is being accomplished.

Computer

The CDC 924A computer (Figure 38) did not meet the NASA requirement for isolation of signal ground from chassis ground, and drive capability was limited to 50 feet. To meet NASA requirements for isolation and to increase drive capability, as well as to provide switching capability between the computer main frame and the computer control console, the computer configuration was changed to include a new end item, the isolation and drive rack, shown in Figure 39.

Test Conductor Console

Design of the test conductor's console is approximately 85 percent complete. Purchase orders were released for the alpha-numeric units and console mechanical assemblies for the first three consoles. Breadboard testing of the logic modules is in process and is 75 percent complete. Design review, conducted by S&ID on the computer complex equipment, resulted only in minor changes to the test conductor's console (Figure 40).

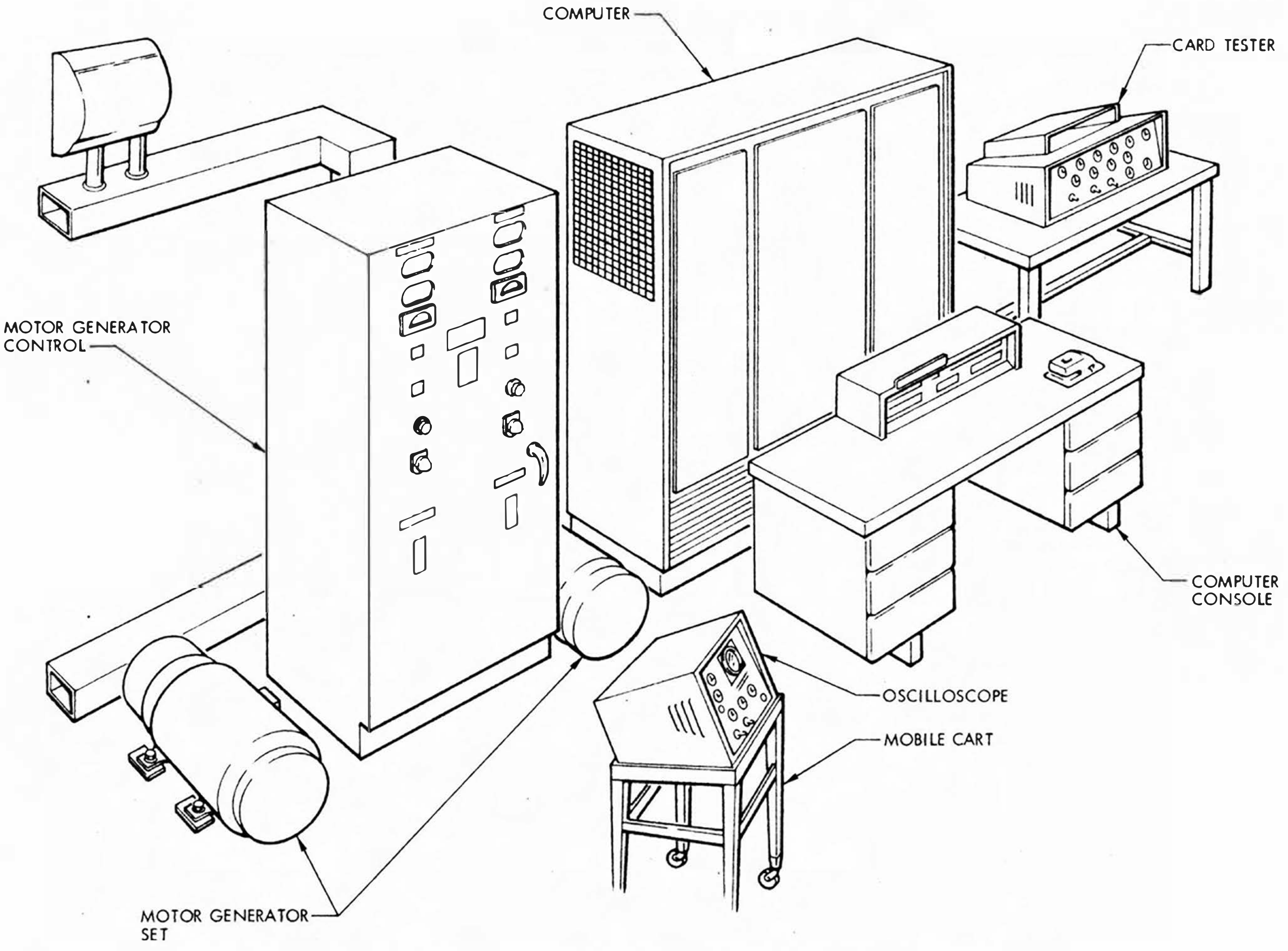


Figure 38. Automatic Checkout Computer (Model No. C7-101)

1. POWER CONTROL
2. FUNCTION INDICATOR
3. CONSOLE SWITCHING DRAWER
4. CHANNEL PAIR LINE DRIVER
5. INPUT ISOLATION DRAWER
6. OUTPUT ISOLATION DRAWER
7. BLANK
8. BLANK

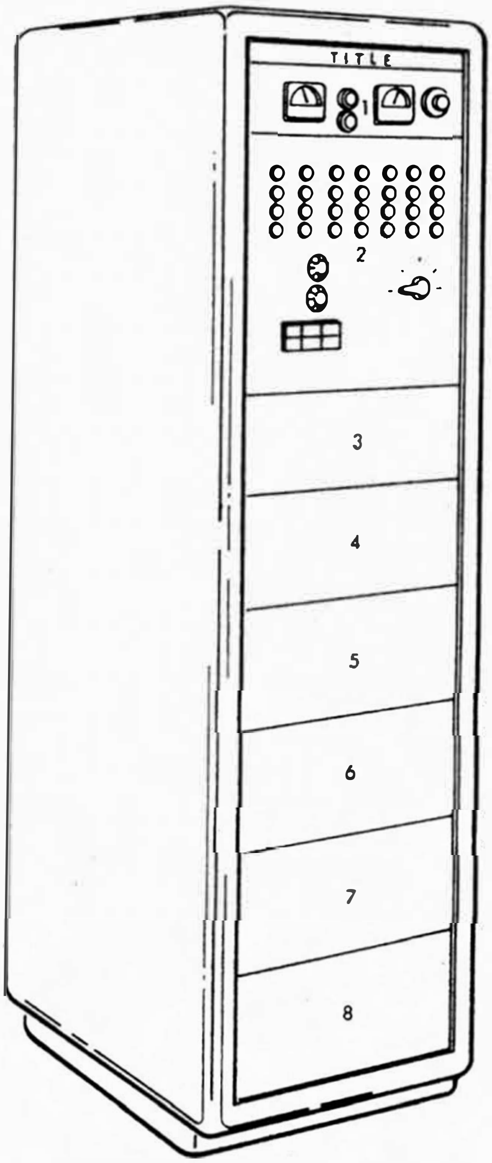


Figure 39. Computer Isolation Rack (Model No. C7-109)

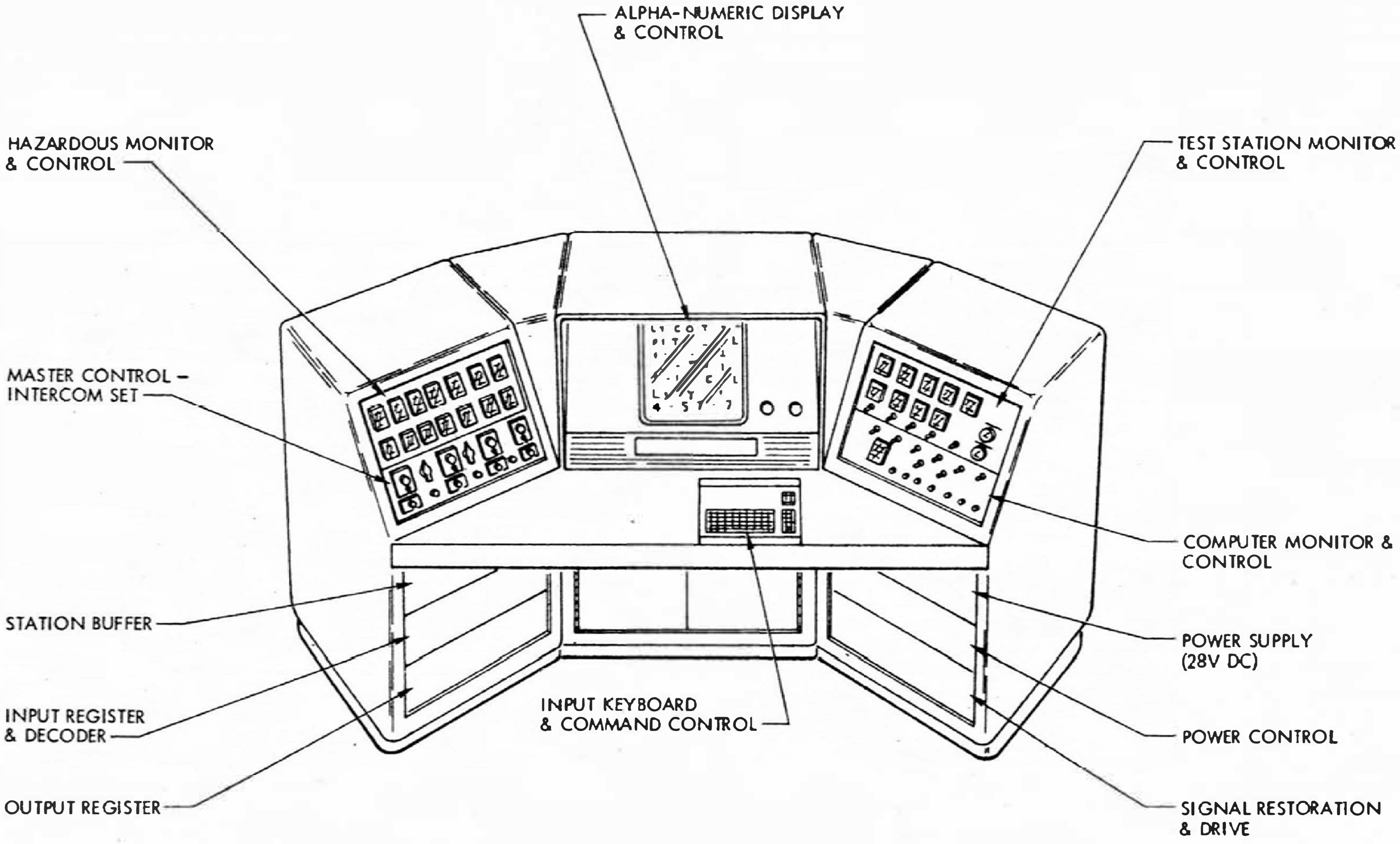


Figure 40. Test Conductor Console (Model No. C7-102)

Buffer Equipment

Breadboard testing is proceeding on schedule, with equipment functioning satisfactorily in total system simulation testing. The major effort of buffer equipment logic design was completed. The related documentation, while not completed, is progressing as scheduled. Mechanical design effort is nearing completion. Procurement action is in process.

Electrical Checkout Station

A program of standardization for the electrical checkout station was initiated. Efforts, directed largely to the manual control and display panels and the signal distribution racks, involved standardization of display panels, manual control panel, and most of the control logic.

In the manual control and display rack (Figure 41), display panels were standardized to accomodate 36 functions per panel, with manual control of functions standardized through four 9-position rotary switches, identical in construction. Function controls established all circuit conditions for application of stimuli to the S-II stage and, by indicator lamps, provided visual confirmation of stimuli transfer.

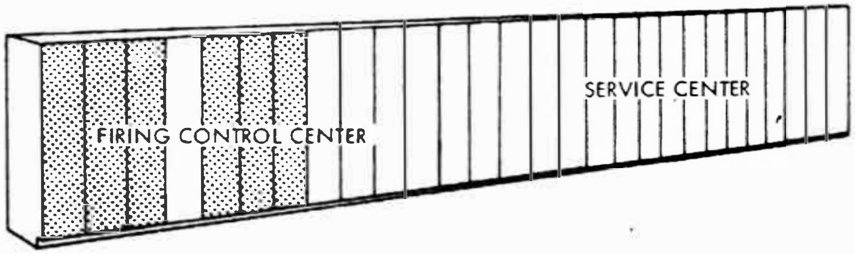
For the signal distribution rack (Figure 42) standardization of control logic extended to two drawer categories, a standardized flip-flop drawer and a standardized one-shot drawer. As a consequence of this drawer standardization, simplification of manufacturing and of procurement of spares is anticipated.

Static Firing Station

A new series of end items was created for use at static firing sites. This equipment will provide a long-distance data link between the two portions of the electrical checkout station (service center and control center). It will also provide manual controls and displays for use during the static firing countdown, after the stage has been completely checked out by the electrical checkout station.

Telemeter Checkout Station

Fairly late in the reporting period, NASA disapproved the S&ID design concept for the telemeter checkout station and redirected Phase I design effort. This effort, requiring approximately 85 percent redesign, is now underway. The approved station concept involved the replacement of six end items. Station functions were regrouped, and certain functions of the earlier system configuration were assimilated by this station.



1. DESTRUCT SYSTEM CONTROL DISPLAY
2. SEPARATION SYSTEM CONTROL DISPLAY
3. ELECTRICAL POWER CONTROL DISPLAY
4. DESTRUCT SYSTEM CONTROL
5. SEPARATION SYSTEM CONTROL
6. ELECTRICAL POWER CONTROL
7. BLANK
8. BLANK
9. BLANK
10. POWER CONTROL
11. FLIGHT CONTROL DISPLAY NO.
12. FLIGHT CONTROL DISPLAY NO. 2
13. BLANK
14. FLIGHT CONTROL DISPLAY NO. 2
15. FLIGHT CONTROL NO. 2
16. BLANK
17. BLANK
18. BLANK
19. BLANK
20. LOCAL CONTROL LOGIC NO. 2
21. SERVO ANALYZER CONT. DISPLAY NO. 1
22. SERVO ANALYZER CONT. DISPLAY NO. 2
23. ENGINE POSITION INDICATOR
24. SERVO. ANALYZER CONT. NO. 1
25. SERVO. ANALYZER CONT. NO. 2
26. STATION SELECT CONTROL
27. BLANK
28. BLANK
29. LOCAL CONT LOGIC NO. 1
30. PRESSURIZATION CONTROL DISPLAY
31. PROPELLANT FEED CONTROL DISPLAY
32. THERMAL CONTROL DISPLAY
33. PRESSURIZATION CONTROL
34. PROPELLANT FEED CONTROL
35. THERMAL CONTROL
36. BLANK
37. BLANK
38. BLANK
39. BLANK
40. PNEUMATIC CONSOLE CONTROL NO. 1 DISPLAY
41. PNEUMATIC CONSOLE CONTROL NO. 2 DISPLAY
42. HYDRAULIC CONSOLE CONTROL DISPLAY
43. PNEUMATIC CONSOLE CONTROL DISPLAY
44. PNEUMATIC CONSOLE CONTROL NO. 1
45. HYDRAULIC CONSOLE CONTROL
46. BLANK
47. BLANK
48. BLANK
49. BLANK

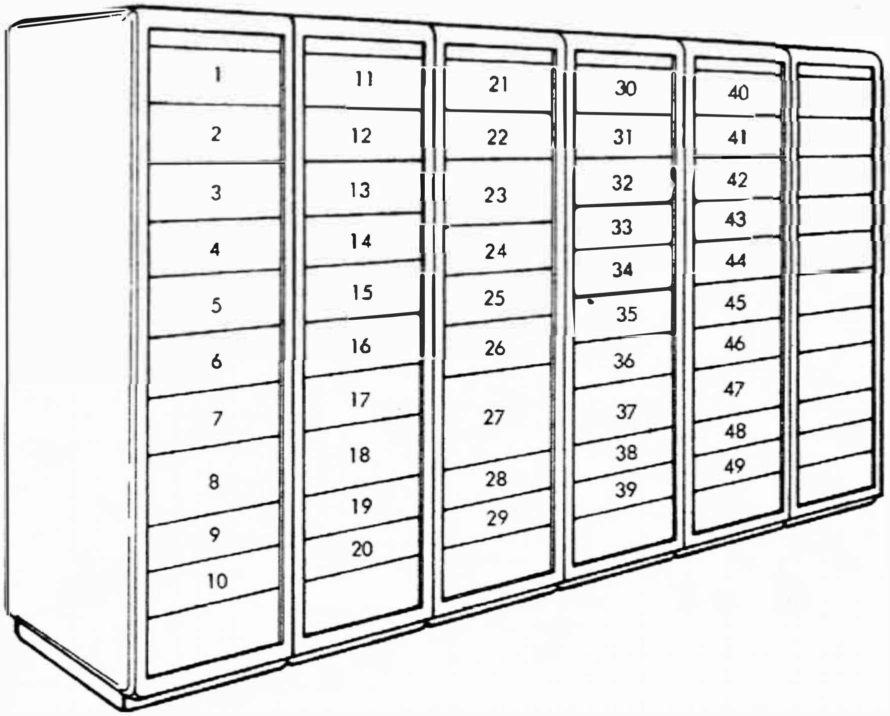
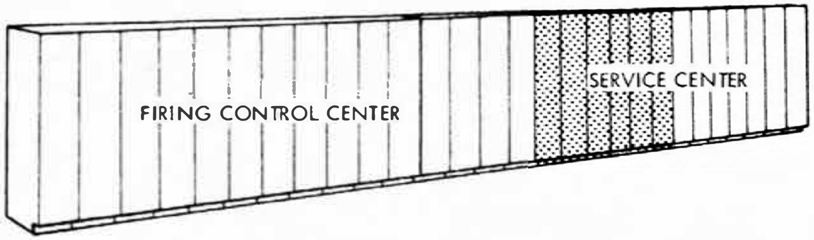


Figure 41. Manual Control and Display Rack (Model No. C7-202)



1. POWER CONTROL
2. TEST POINT SELECTOR CONTROL LOGIC NO. 1
3. -6 PWR SUPPLY
4. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
5. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
6. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
7. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
8. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
9. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
10. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
11. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
12. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
13. BLANK
14. TEST POINT SELECTOR
15. BLANK
16. COMMAND DISTRIBUTOR RELAY NO. 1
17. COMMAND DISTRIBUTOR RELAY NO. 1
18. COMMAND DISTRIBUTOR RELAY NO. 1
19. COMMAND DISTRIBUTOR RELAY NO. 1
20. COMMAND DISTRIBUTOR RELAY NO. 1
21. COMMAND DISTRIBUTOR RELAY NO. 1
22. COMMAND DISTRIBUTOR RELAY NO. 1
23. COMMAND DISTRIBUTOR RELAY NO. 1
24. COMMAND DISTRIBUTOR RELAY NO. 1
25. BLANK
26. OUTPUT PATCH PANEL
27. T/M CALIBRATOR CONTROL LOGIC
28. STATION DRIVER NO. 1
29. STATION DRIVER NO. 1
30. STATION DRIVER NO. 1
31. STATION DRIVER NO. 1
32. STATION DRIVER NO. 2
33. STATION DRIVER NO. 2
34. BLANK
35. FREQ CAL
36. COMMAND DISTRIBUTOR NO. 1
37. COMMAND DISTRIBUTOR RELAY NO. 1
38. COMMAND DISTRIBUTOR RELAY NO. 1
39. COMMAND DISTRIBUTOR RELAY NO. 1
40. COMMAND DISTRIBUTOR RELAY NO. 1
41. RELAY NO. 2
42. COMM DISPLAY RELAY
43. BLANK
44. BLANK
45. PROGRAMMABLE OSCILLATOR
46. BLANK
47. BLANK
48. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
49. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
50. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
51. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
52. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 1
53. COMMAND DISTRIBUTOR CONTROL LOGIC NO. 2
54. BLANK
55. BLANK
56. BLANK
57. +6 PWR SUPPLY
58. BLANK
59. TEST POINT SELECTOR CONTROL LOGIC NO. 1
60. TEST POINT SELECTOR
61. INPUT PATCH PANEL
62. PROGRAMMABLE PWR SUPPLY
63. PROGRAMMABLE PWR SUPPLY
64. PWR SUPPLY CONTROL LOGIC SUPPLY
65. BLANK

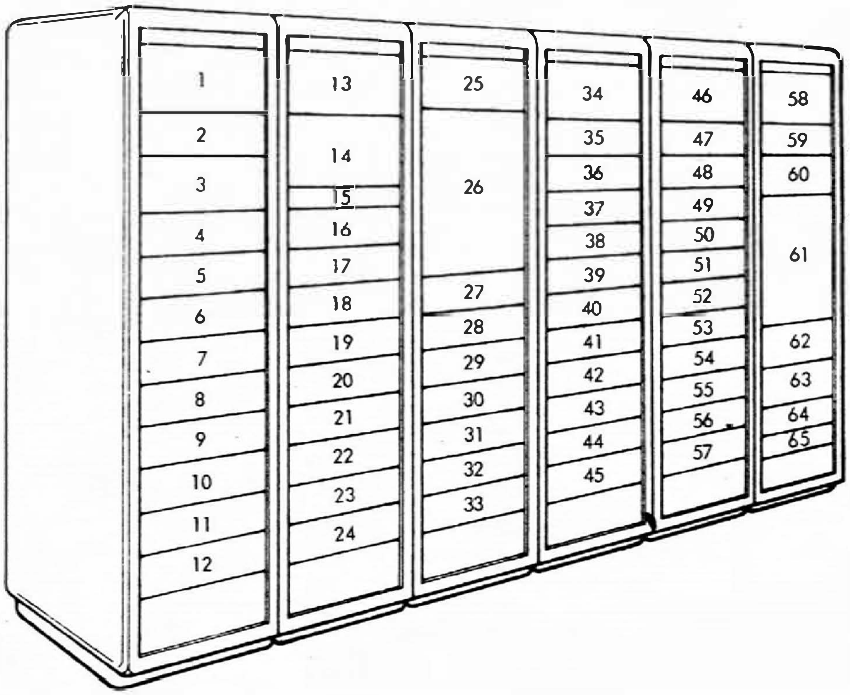


Figure 42. Signal Distribution Rack (Model No. C7-204)

Manual Command Destruct Receiver Checkout Rack

S&ID was directed by NASA to stop all effort on the RF checkout station and to proceed with procurement of standard equipment for manual checkout of the command destruct receivers. The RF checkout station, formerly a configuration of five racks, was supplanted by a single rack, the manual command destruct receiver rack (Figure 43).

Three specification control drawings (SCD) for major buy items, originally intended for the RF checkout station, are being utilized for the new rack. Purchase requests for standard equipment were prepared for all other major-buy rack items supporting the EMM schedule.

Ground Equipment Test Set (GETS)

In compliance with TD M-SAT-S-II No. 24-63, the systems verification console was redesigned and designated the ground equipment test set (GETS). The GETS provides minimal verification of automatic checkout GSE by providing proper electrical termination of hardware interfaces from the checkout stations. GETS operation is completely manual and independent of computer control. Differing in other respects from the previous console design, GETS has no provisions for PCM, telemetry, and RF simulators.

Although signals from stations are terminated in GETS and then routed back to the stations for measurement, GETS has a capability for monitoring voltages by means of test point selector and digital voltmeter. Manually controlled switches, potentiometers and adjustable-level dc power supplies provide GETS with a capability for simulating malfunction conditions in the system or systems checked.

During the report period, evaluation of the GETS concept was completed, and the preliminary rack layout was determined. By the end of the period, the schedule and list of basic drawings, process specifications, and specification control drawings were completed. Preliminary electrical design effort proceeded as scheduled.

Engineering Development Equipment

During the report period, development equipment in the form of breadboard elements and drawers were fabricated to provide research engineering information. The drawer assemblies are common to the several checkout stations and provide the electronic logic for controlling input/output requirements of the station equipment. Unit dimensions conformed to production print specifications, and commercial equivalents of SCD parts were released to manufacture. Noncommercial elements and circuitry conformed to released prints. Problems of design and manufacture experienced during fabrication were successfully resolved, and their solutions were incorporated in changes to released and nonreleased drawings.

1. POWER CONTROL
2. AUTOMATIC DISPLAY
3. COUNTER
4. TONE CODER
5. INTERCOM
6. -28V POWER SUPPLY
7. AUTO DISPLAY LOGIC
8. BLANK
9. BLANK
10. CDR. DISPLAY
11. F.M. SIGNAL GENERATOR
12. MANUAL CONTROL
13. AUDIO SIGNAL GENERATOR
14. -6V DC POWER SUPPLY
15. R.F. VOLTAGE STD
16. R.F. INPUT SELECTOR
17. BLANK
18. OSCILLOSCOPE
19. DC VTVM
20. AC VTVM
21. COMP TEST PANEL
22. +28V DC POWER SUPPLY
23. IMPEDENCE BRIDGE
24. STORAGE DRAWER

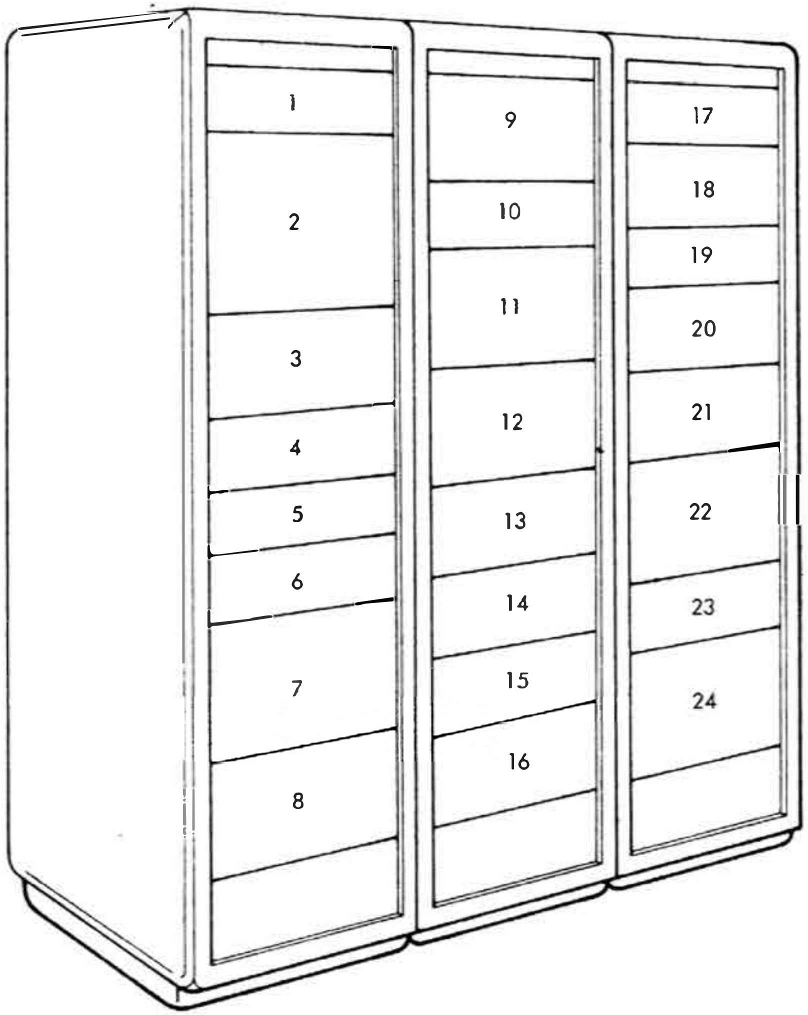


Figure 43. Command Destruct Receiver Checkout Rack (Model No. C7-307)

Already this equipment has demonstrated a significant reduction in engineering time for end-item equipment design. The benefits from this research will be reflected in the final deliverable equipment. Figures 44 through 47 depict of the fabrication process and testing of this equipment.

HANDLING EQUIPMENT

Stage Handling Equipment

During the report period, 100 percent design release of the major items of stage handling equipment was accomplished. These items of equipment received Phase I technical approval from responsible MSFC groups. Phase II approvals are now in process. The items of equipment encompass the following model numbers:

Model No.	Nomenclature
H7-2	Ring, stage support forward
H7-3	Ring, stage support aft
H7-21	Skirt, static firing
H7-23	Sling, stage erecting
H7-24	Frame, forward hoisting
H7-25	Frame, aft hoisting

SERVICING EQUIPMENT

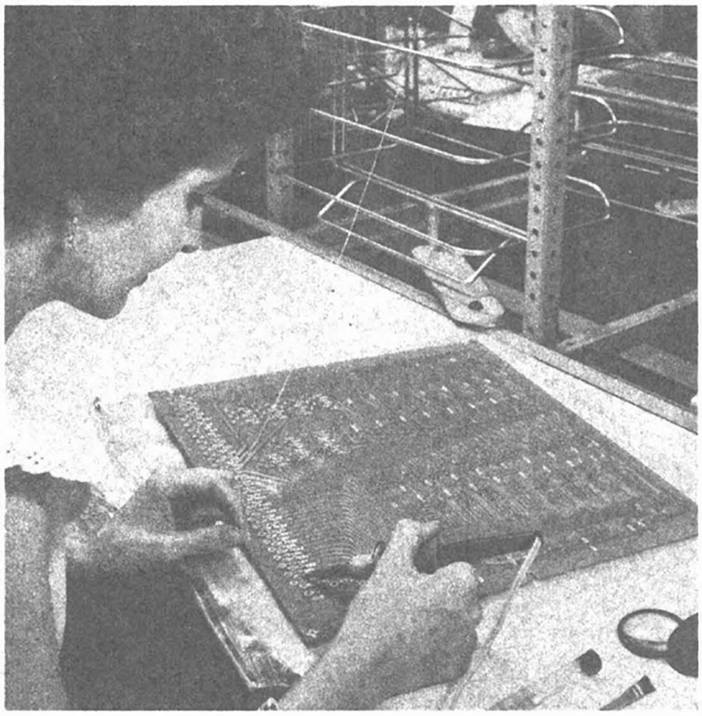
Propellant Loading Equipment

The requirements for the propellant fill and topping units (Models S7-1 and S7-2) for use at the Mississippi Test Facility (MTF) were cancelled. These units, shown in Figures 48 and 49, are now required only at the Propulsion Field Laboratory (PFL) in the Battleship and All-Systems test areas. The equipment has thus been given nondeliverable status. Accordingly, the model numbers were changed to SDD-157 and SDD-158, respectively.

The propellant loading at PFL is significantly different from what will be needed at MTF and the Atlantic Missile Range (AMR). Some of the main differences are the following:

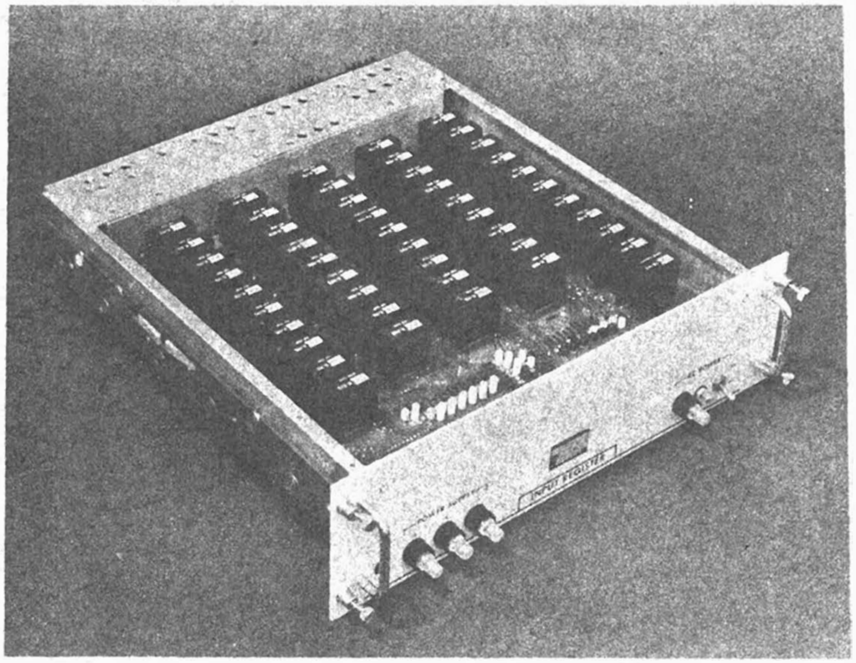
7006-83-7D

Figure 44. Assembly Operation of the Logic Drawers for the Automatic Rack of the Breadboard Test Set



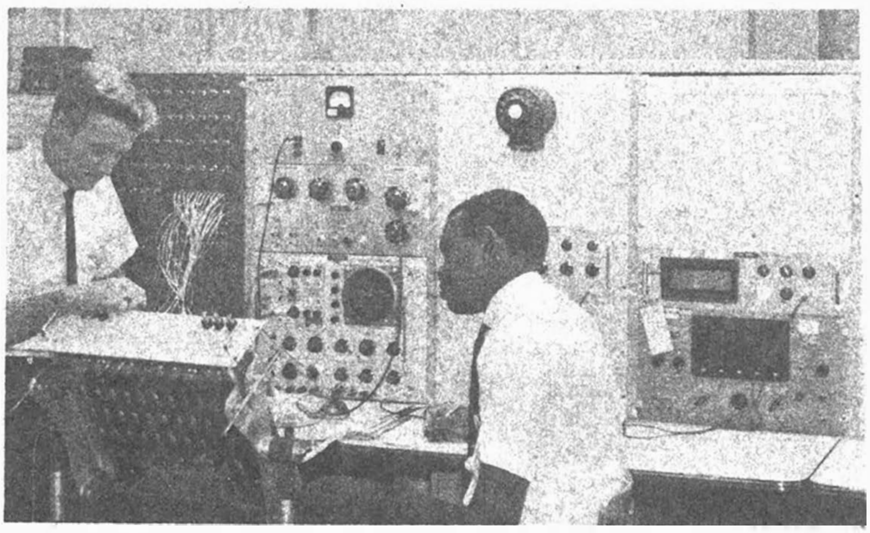
7006-83-7C

Figure 45. Assembly Operation on a Printed Circuit for a Breadboard Drawer of the Breadboard Test Set



C7-301(2)E

Figure 46. Completed Breadboard Drawer Assembly Used in the Breadboard Test Set



7006-83-7A

Figure 47. Evaluation Testing of a Completed Breadboard Assembly of the Breadboard Test Set

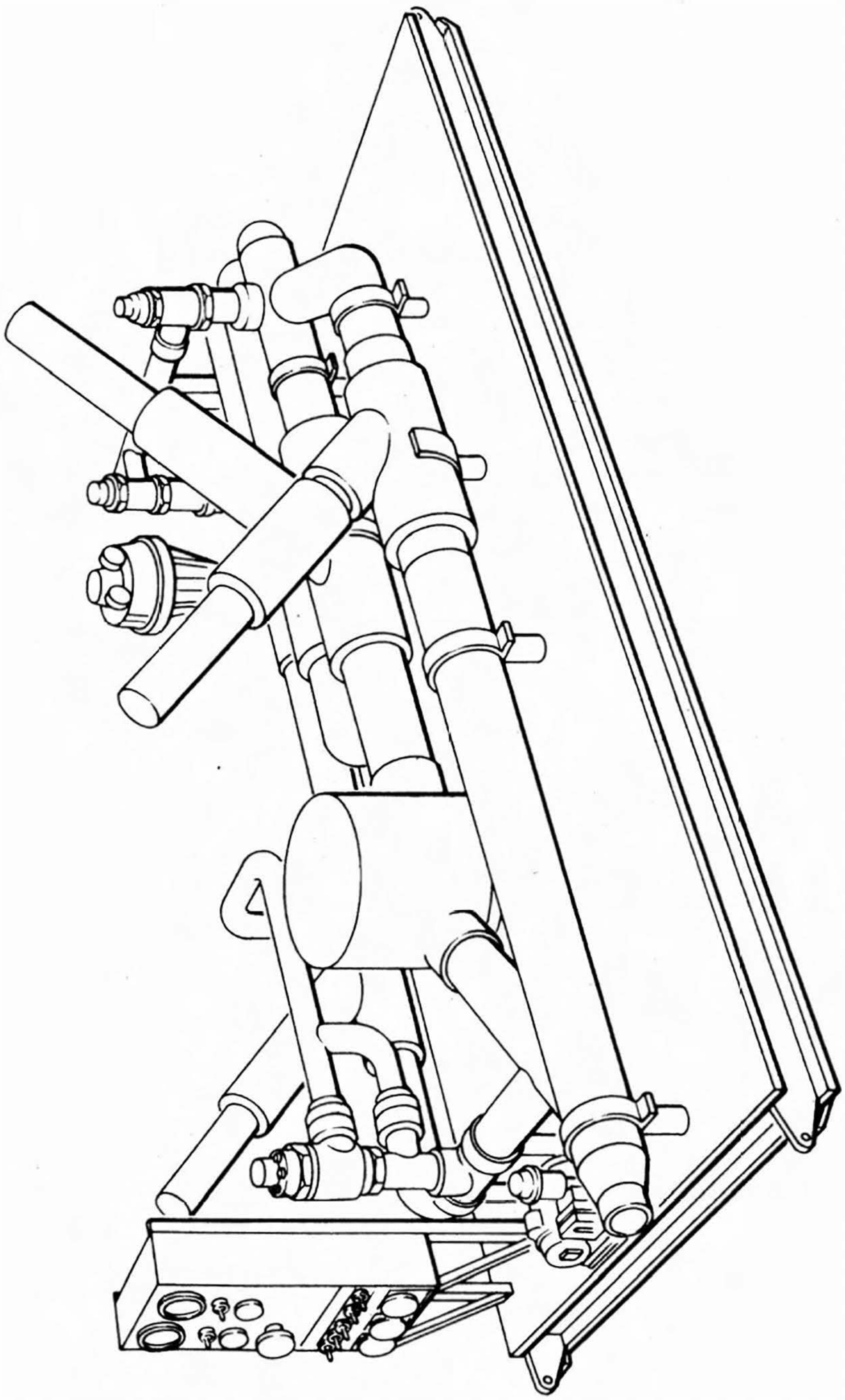


Figure 48. LH_2 Fill and Topping Control System (Model No. SDD-157)

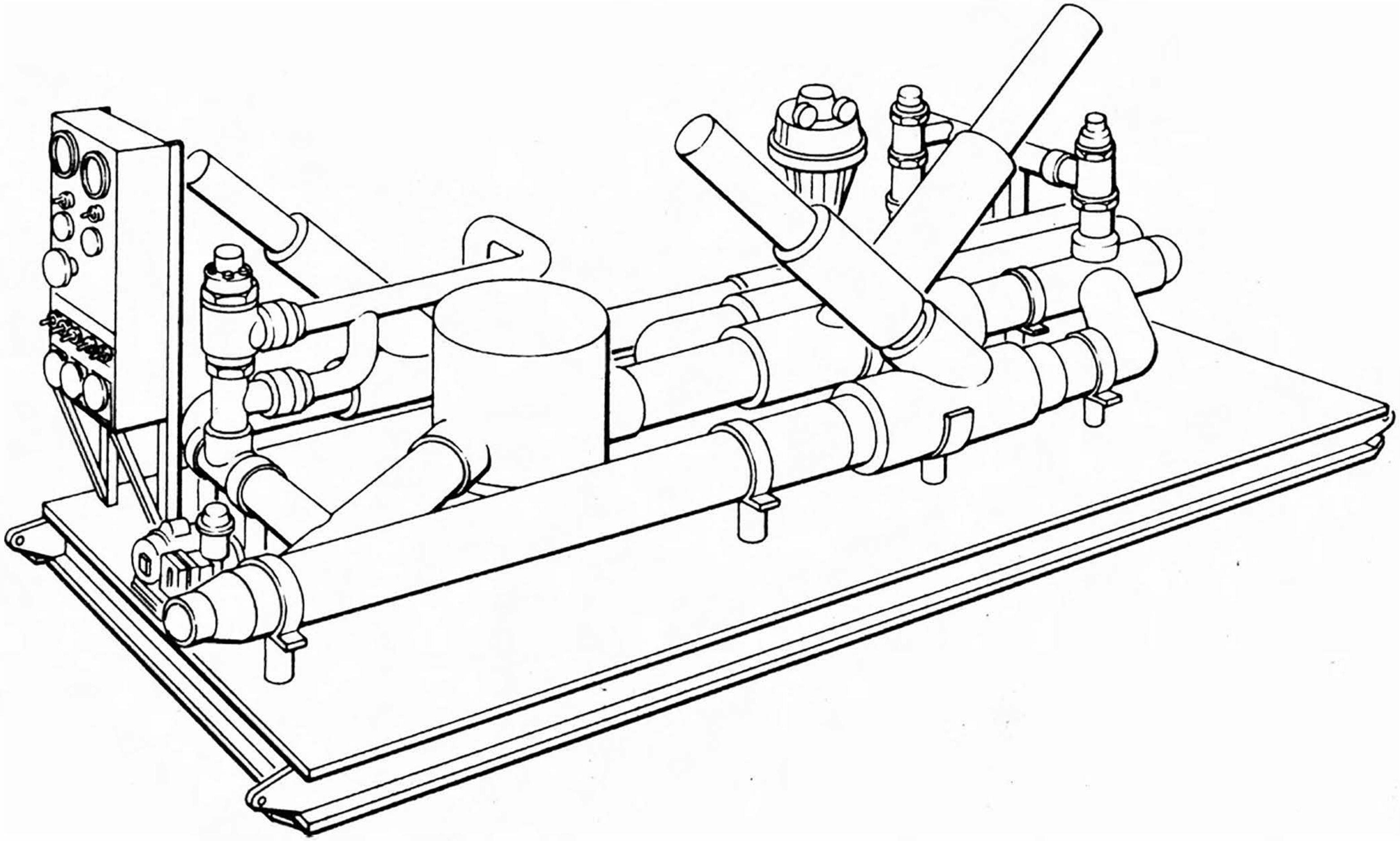


Figure 49. LOX Fill and Topping Control System (Model No. SDD-158)

1. There is no complete integrated testing of the ultimate propellant loading systems at PFL. MTF and AMR will have propellant fill and topping units, designed by the launch operation center (LOC) which are integrated into the launch pad systems.

2. There is no LOX topping control at PFL.

3. Point sensors are utilized at PFL. Douglas Aircraft Company capacitive system will be utilized at MTF and AMR.

It is considered that these differences are significant enough to prevent the accumulation of sufficient test data to verify system capability prior to MFR operations.

Umbilical Arms

On 6 November 1962, the umbilical arm study was completed and presented to the Launch Operations Directorate (LOD). A fourth scale model of umbilical arm No. 3A extension reflected an S&ID concept for access platforms, propellant loading disconnects, and multidisconnect carrier plate retraction. Since this presentation, a redefinition of interface by NASA definitized contractor participation to propellant disconnects and umbilical carrier plates only. Present plans call for development testing of this equipment at the Propulsion Field Laboratory. It is intended that NASA-furnished umbilical arm extensions will be utilized in support of these tests to ensure complete system compatibility. Design concepts are shown in Figures 50 and 51.

Servicing Requirements

In support of the propellant and gas panel (LOC workling group), detail propellant and gas requirements for the S-II stage at the ARM launch pad were furnished. These requirements are considered significant inputs to an over-all facility capability at AMR Launch Complex 39. In addition, a special study, requested by NASA, regarding design concept of cryogenic heat exchangers utilized for cooling gaseous helium in support of Saturn S-II servicing at the launch pad, was presented. This material will aid in standardization of AMR Launch Complex 39 servicing facilities.

The hydraulic fluid filter evaluation program was completed during this period. The purpose of this evaluation was to determine, through laboratory tests, the performance capabilities of filters proposed by prospective suppliers. As a result of this laboratory evaluation, three types of micronic filters were selected for utilization in S-II ground hydraulic servicing equipment. A typical test setup is shown in Figure 52.

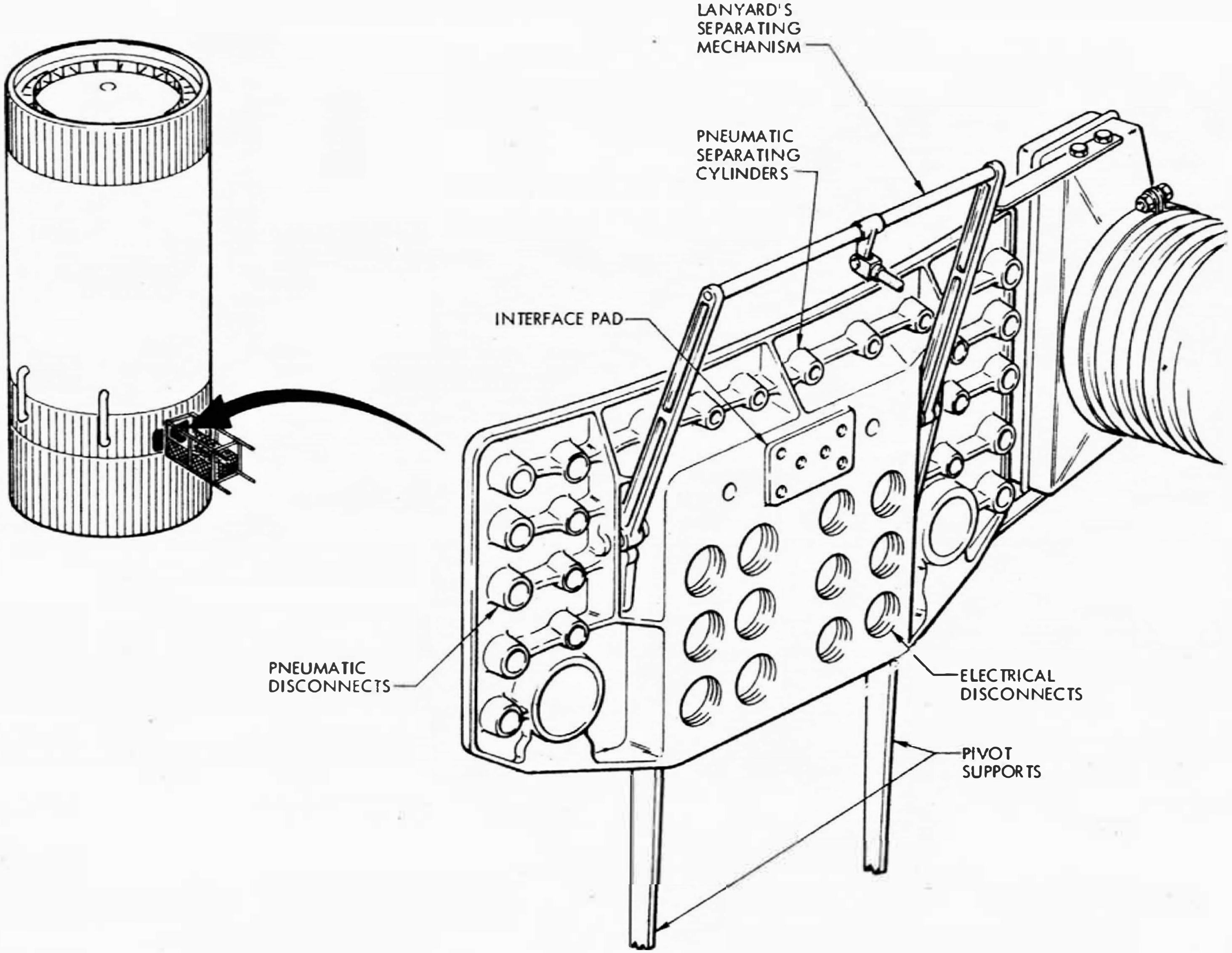


Figure 50. Umbilical Disconnect Arm No. 3A Carrier Plate Assembly (Model No. A7-41)

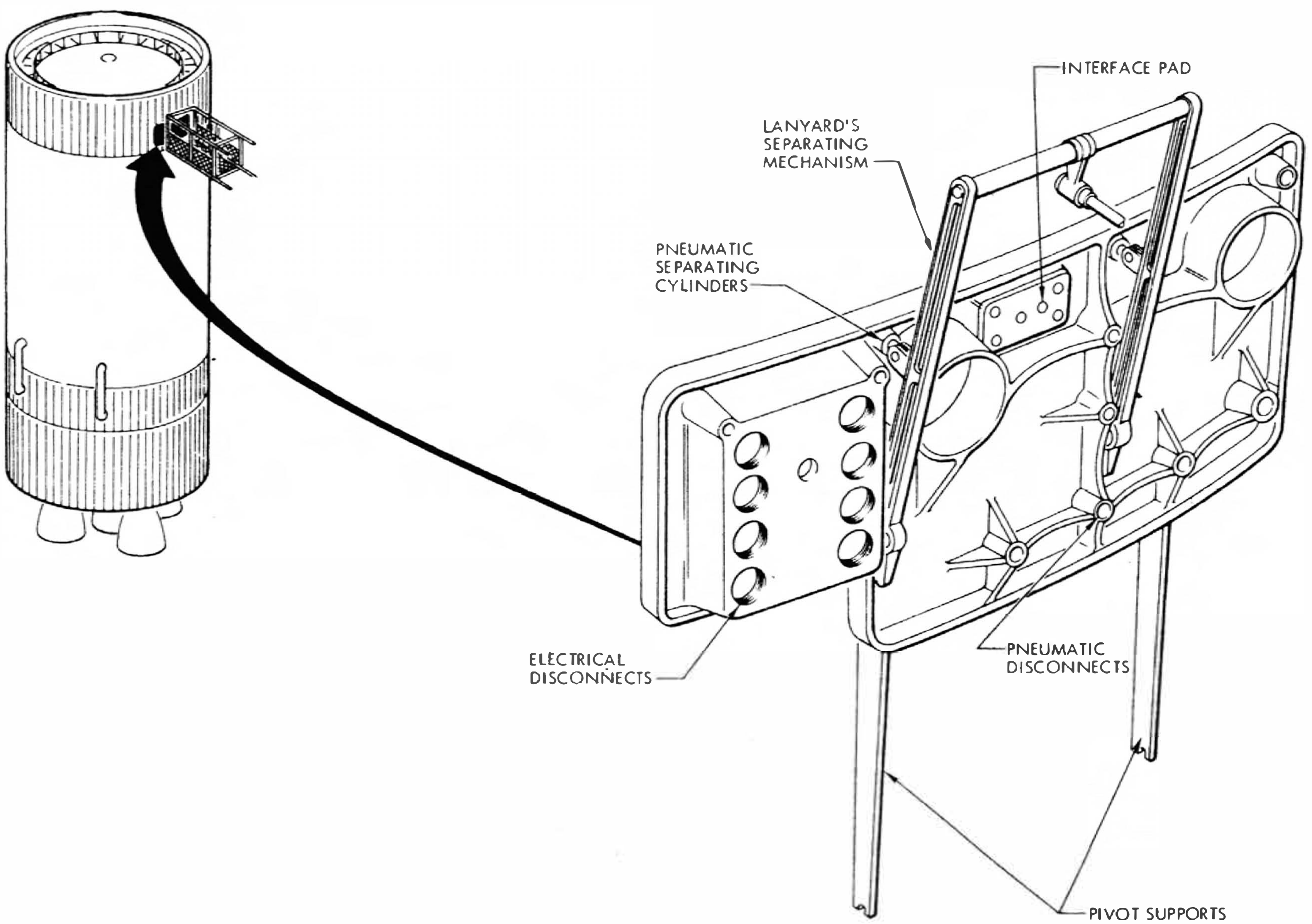
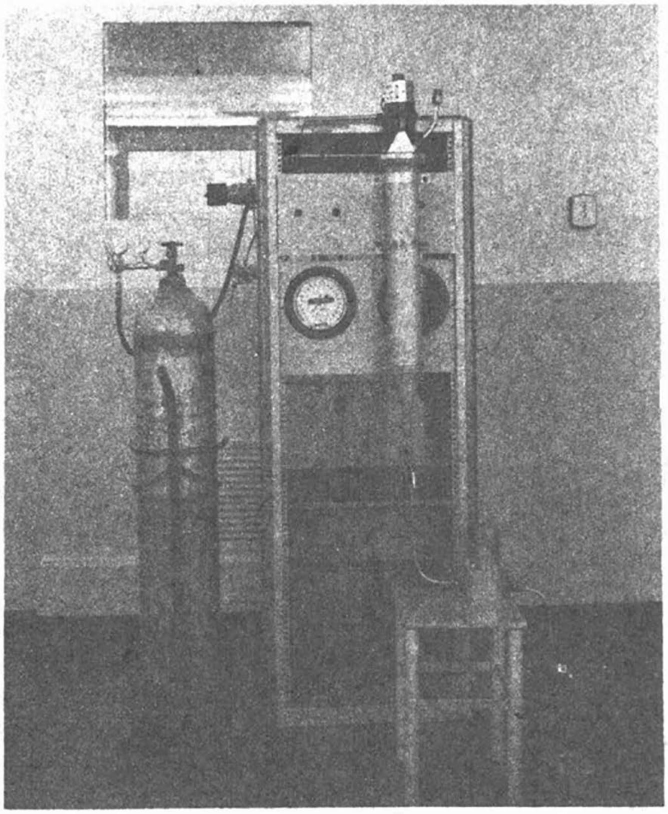


Figure 51. Umbilical Disconnect Arm No. 4 Carrier Plate Assembly (Model No. A7-42)



7006-81-134C

Figure 52. Filter Evaluation Tests

Cable Installations

Cable installations at the Propulsion Field Laboratory (PFL) have been considered critical hardware in support of the early activation dates. To expedite NASA approval for critical cable procurement, a PFL cable report was prepared. The purpose of this report is to document all new cable requirements for Santa Susana and show maximum utilization of existing facilitiy cables.

Pneumatic Servicing Requirements

A Phase I review of mechanical checkout equipment was held on 9 April 1963. As a result, extensive conceptual improvements were made in regard to mechanical-leak and functional testing required in preparation of combined systems testing. Redefinition of detail stage mechanical systems checkout requirements is in work; it is intended that Phase I conceptual approval of these procedures and the required GSE will be completed by September 1963. To satisfy early requirement in these areas, it will be necessary to utilize substitute equipment or to retrofit equipment as detail design and associated hardware become available. The pneumatic checkout console set, illustrated in Figure 53, is primarily affected.

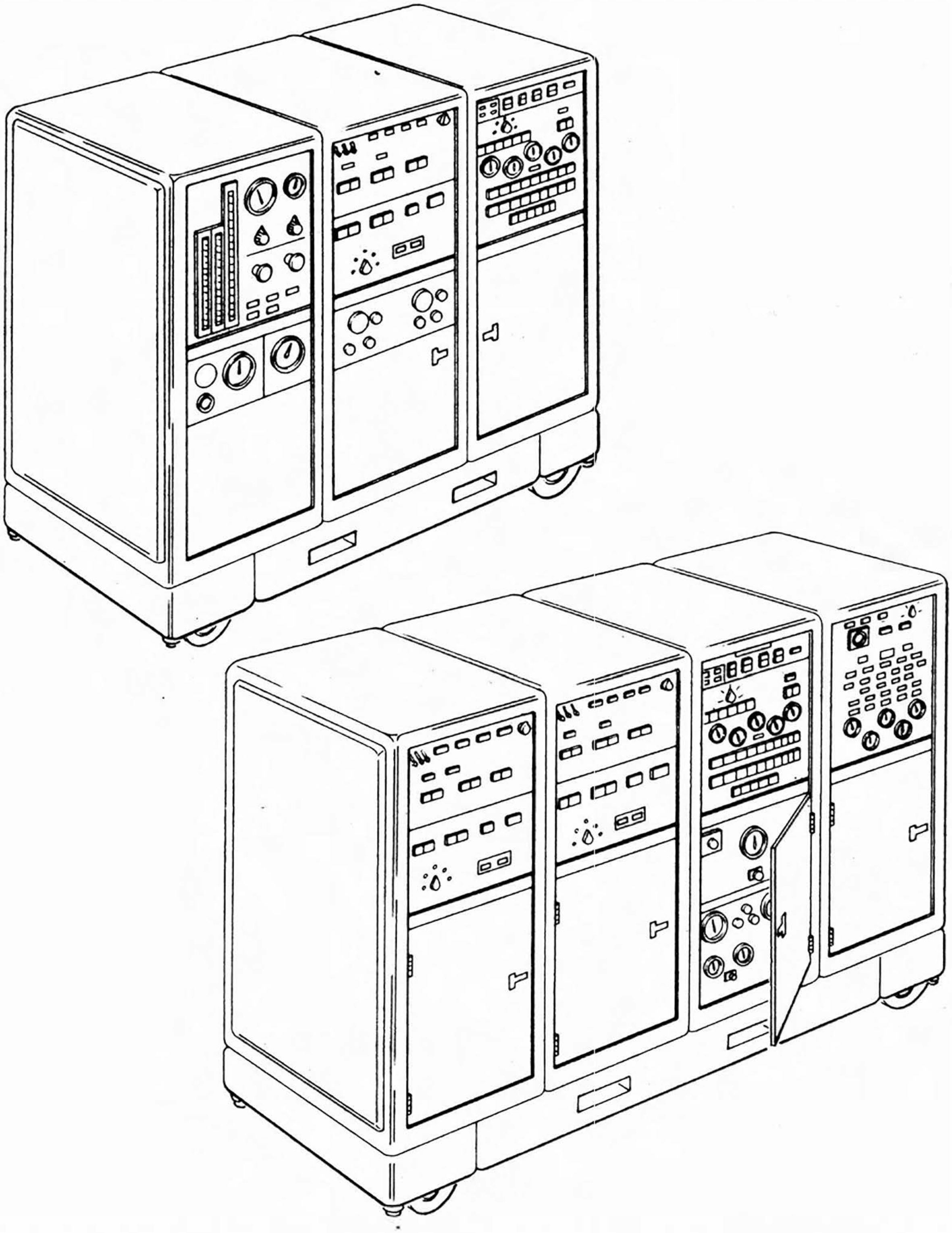


Figure 53. Pneumatic Checkout Console Set (Model No. C7-603)

Another associated item, the pneumatic servicing console set, is shown in concept in Figure 54.

An important equipment item, the hydraulic power console, which supplies high pressure hydraulic fluid to the engine actuators during gimbaling tests and static firings, has been completely designed and fabricated at the Tulsa facility and is currently undergoing acceptance testing. This unit is illustrated in Figure 55.

BATTLESHIP STAGE

Stage

Detail design of the Battleship stage is approximately 95 percent complete. Fabrication is in process and is 15 percent complete. Production drawings for the forward skirt, tunnel, and the forward skirt platform are 100 percent released; these items are in the process of being fabricated.

The status is presented below:

Model No.	Nomenclature
H7-27	Sling, interstage and static firing skirt segment
H7-28	Sling, support ring segment
H7-29	Adapter set, tag lines
H7-30	Sling, interstage and static firing skirt

Some of these items are illustrated in Figures 56 through 60.

Road Gauge

During the early part of the report period, a road gauge was fabricated to simulate the external dimensions of a transporter-mounted S-II stage. Mobile trial runs were conducted over the route that the All Systems stage and the test common bulkhead will take during delivery of these articles to PFL in Santa Susana, California. From the manufacturing plant at Seal Beach, the trial run included a roll-on loading operation on an AKD, ocean transport to Port Hueneme, and road transport to PFL. All desired information was achieved as a result of the trial run.

Figures 61 and 62 are photos of the road gauge in use.

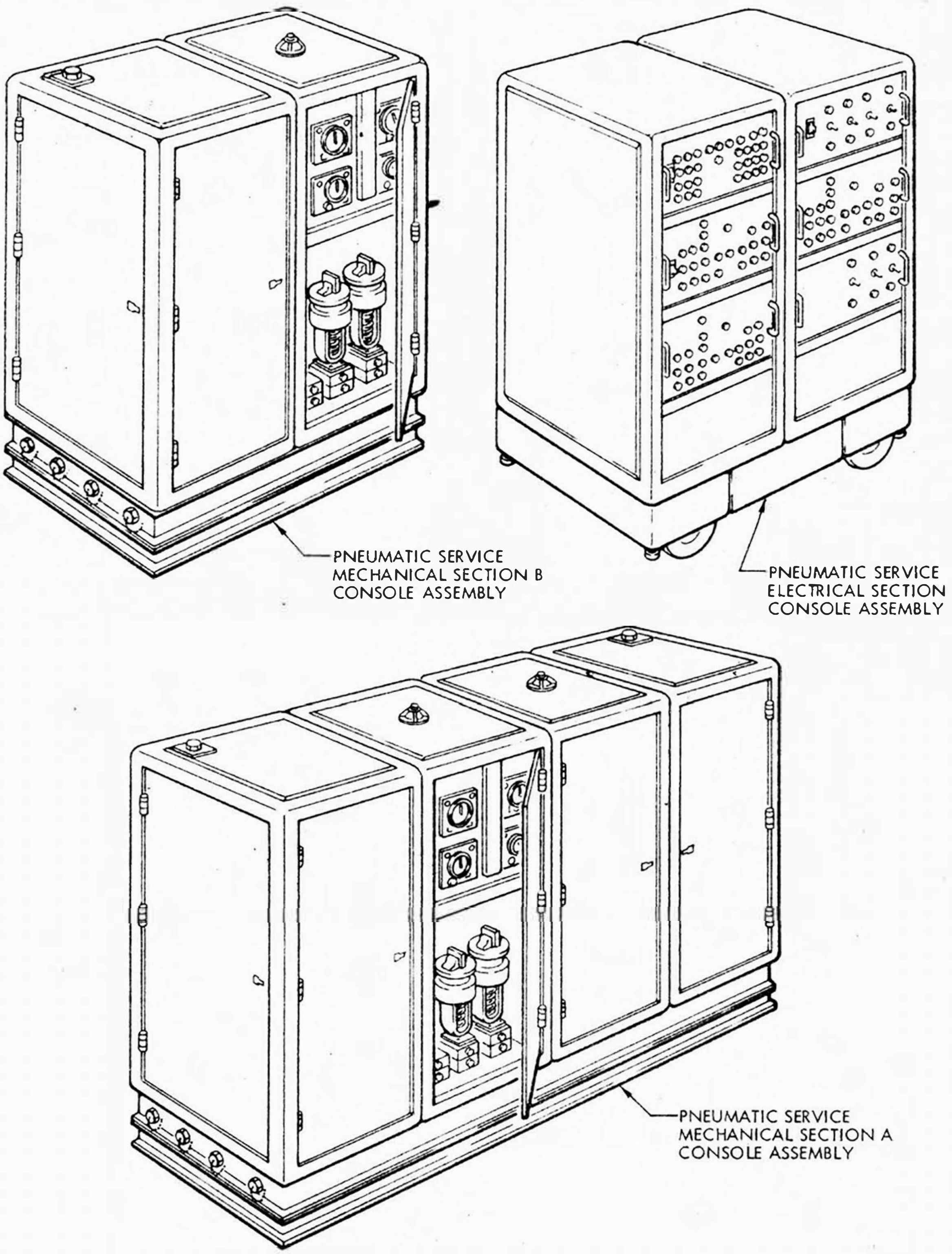


Figure 54. Pneumatic Servicing Console Set (Model No. C7-605)

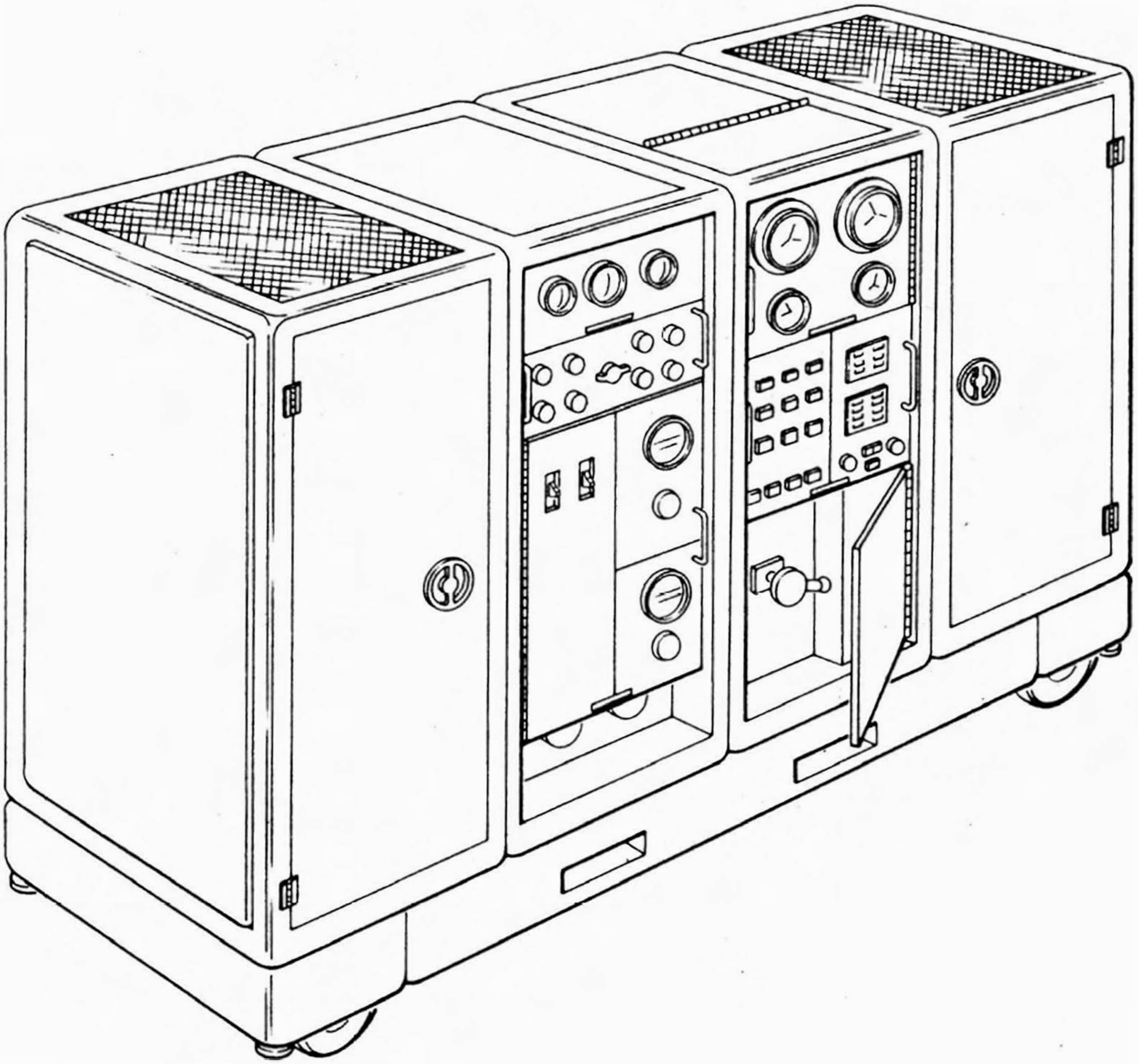


Figure 55. Hydraulic Power Console (Model No. C7-601)

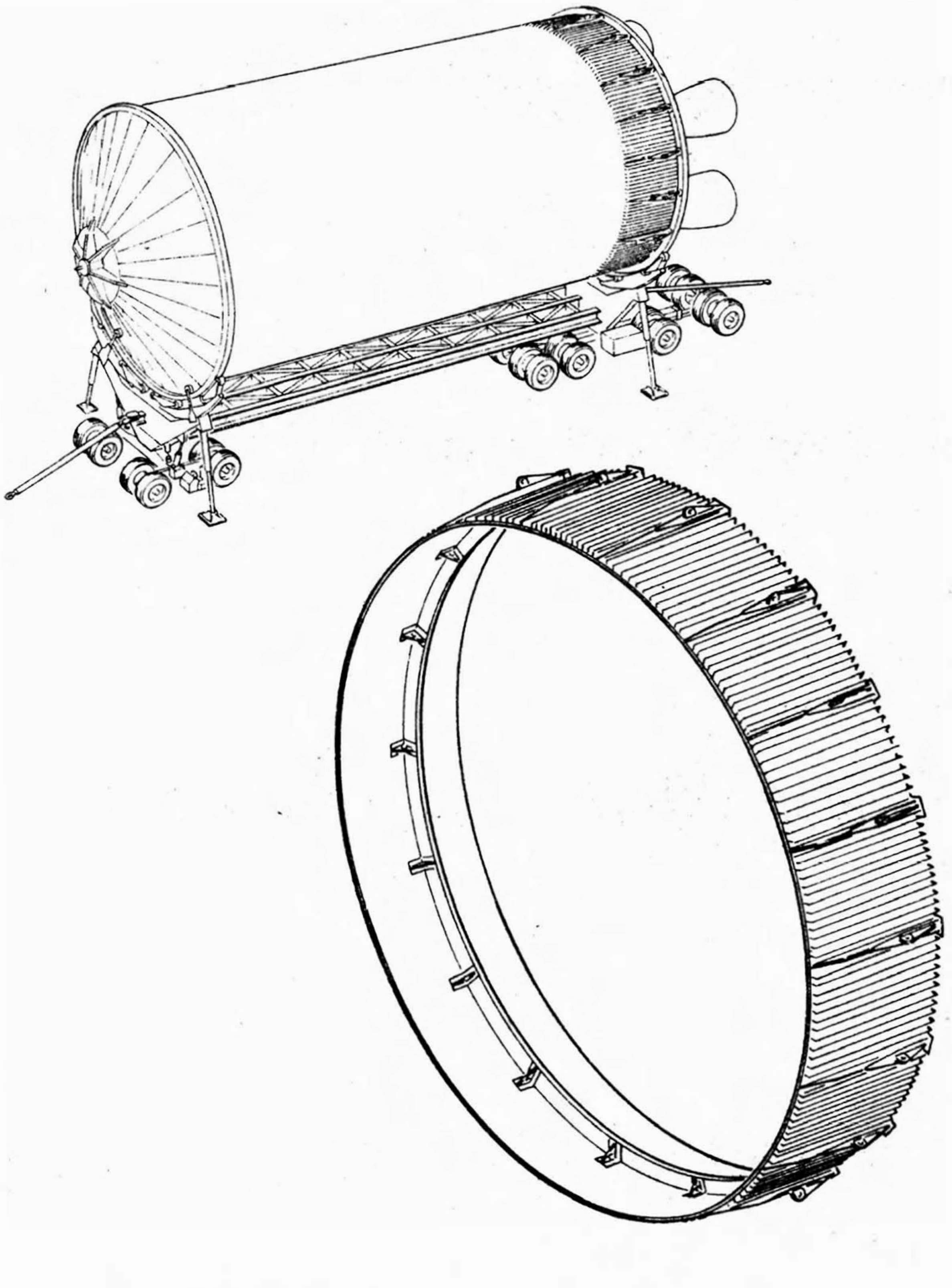


Figure 56. Static Firing Skirt (Model No. H7-21)

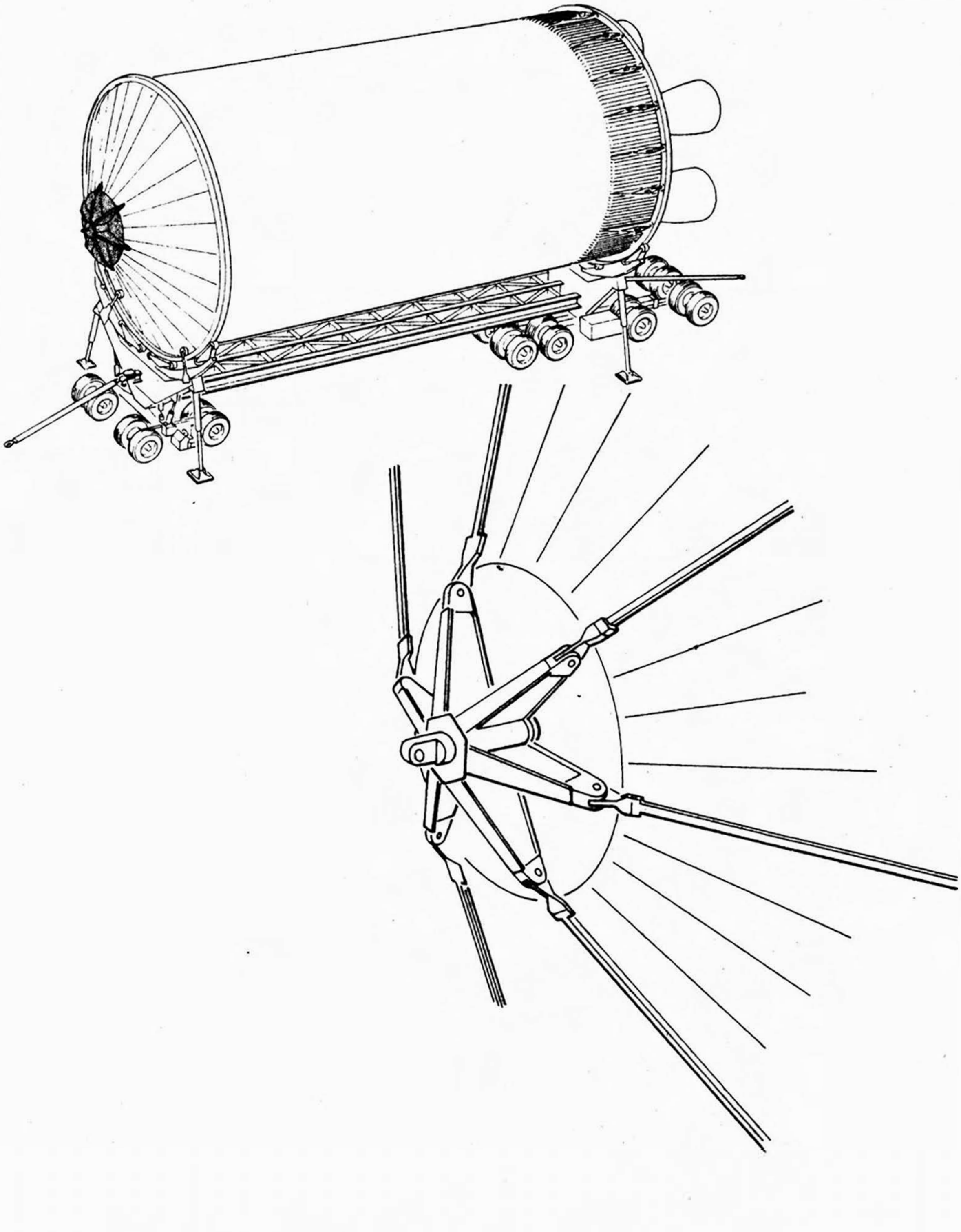


Figure 57. Stage Erecting Sling (Model No. H7-23)

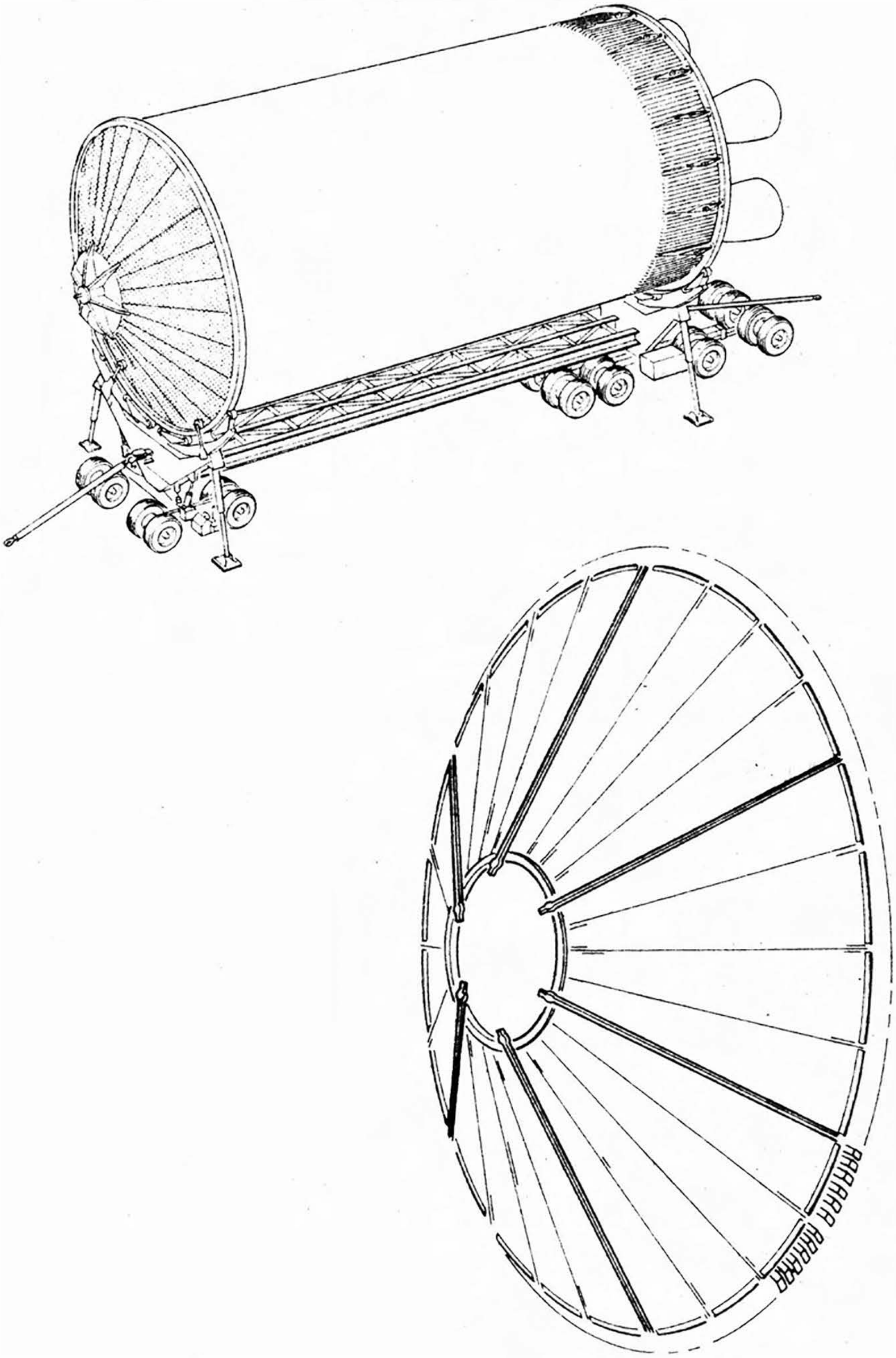


Figure 58. Forward Hoisting Frame (Model No. H7-24)

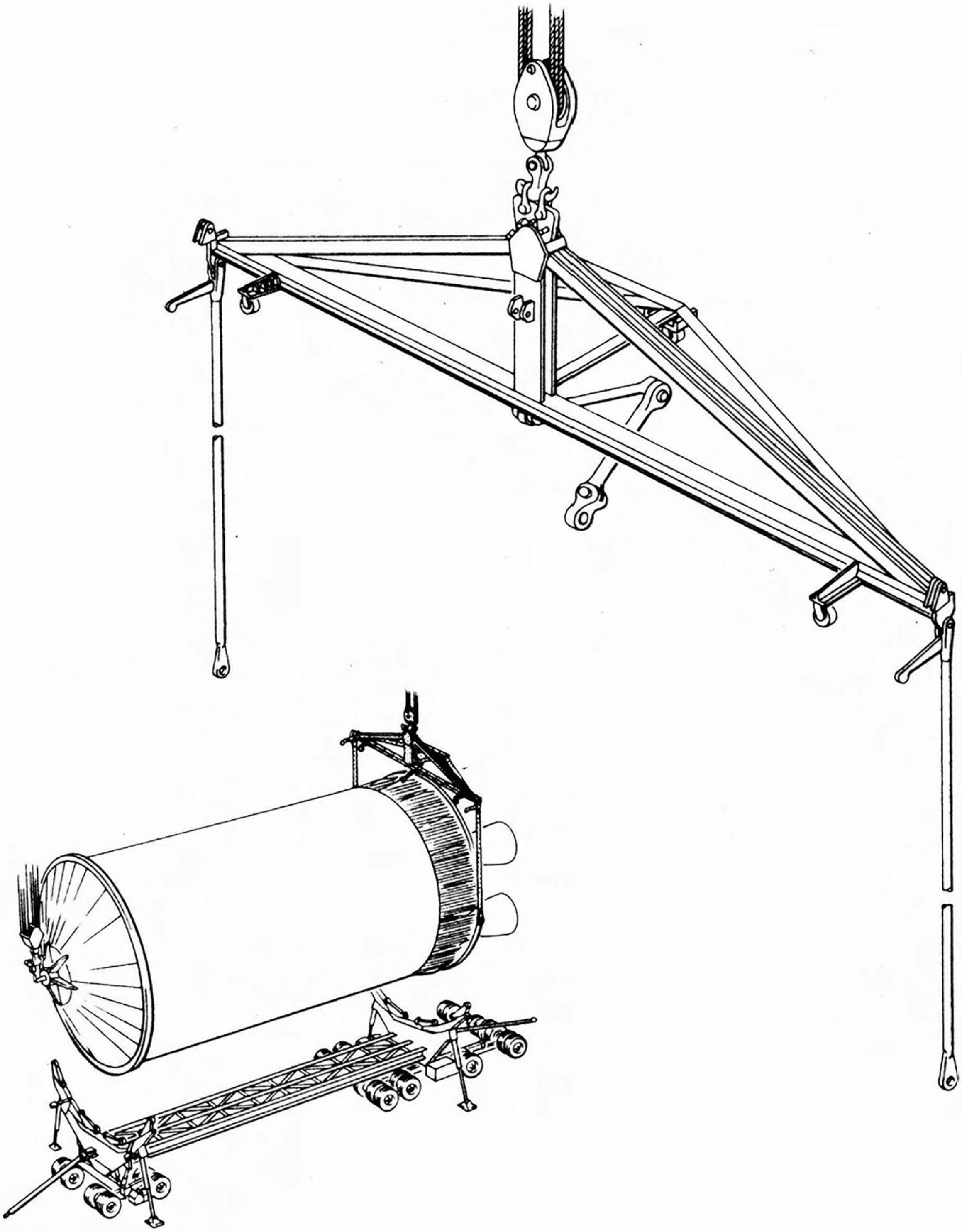


Figure 59. Aft Hoisting Frame (Model No. H7-25)

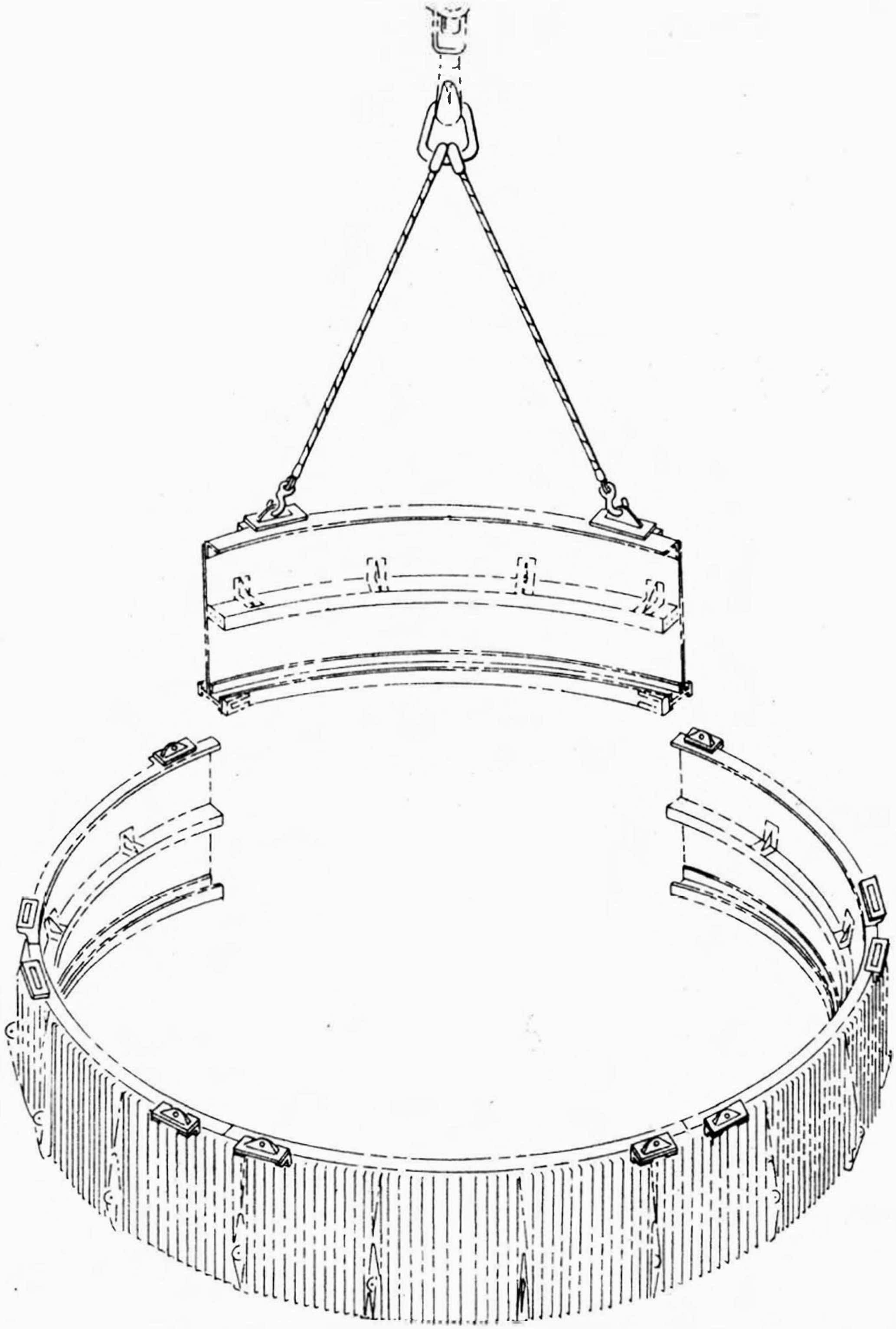


Figure 60. Interstage and Static Firing Skirt Sling (Model No. H7-27)

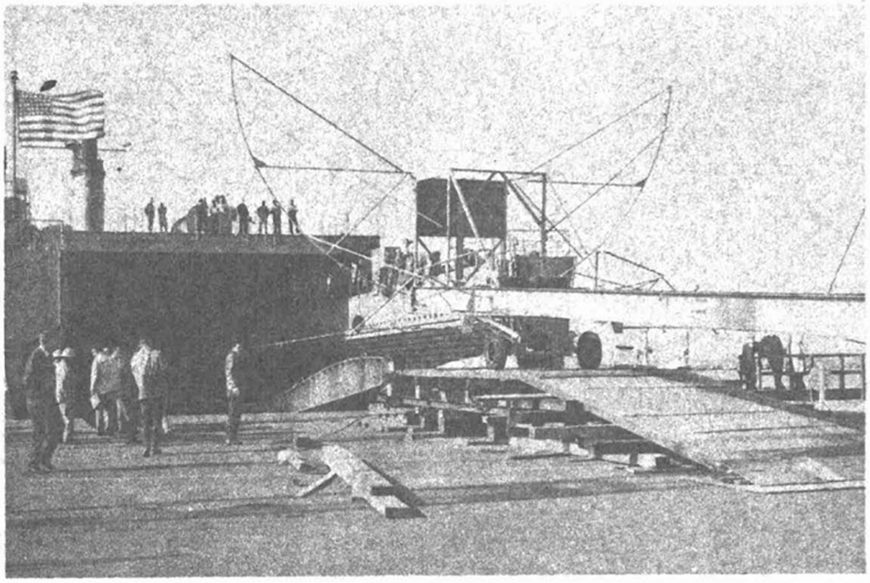


Figure 61. Unloading the Road Gauge

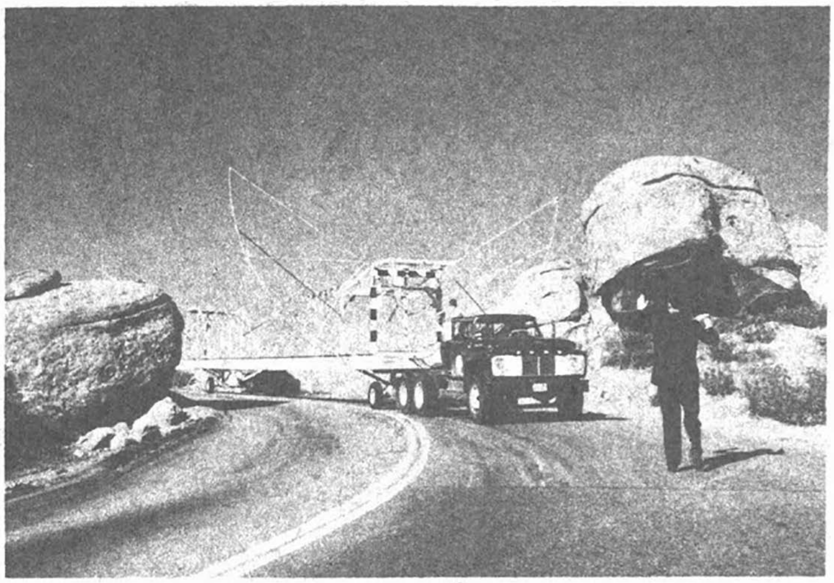


Figure 62. The Road Gauge Coming Around a Bend

Stage Transporters

Studies were completed to determine the most efficient type of transporter configuration to support the Saturn S-II program and the ramifications of utilizing the S-IC NASA modular wheel unit on the S-II transporter.

These studies indicated that two types of transporters are desirable: (1) an intrastate transporter (Figure 63), which meets all the California wheel-axle load-spacing requirements (6 axles-40 wheels), to be utilized to transport the bulkhead test specimen, the fit-up fixture (Figure 64), and the All Systems test stage from Port Hueneme to Santa Susana, and (2) an interstate transporter (Figure 65), a simplified configuration (3 axles-12 wheels), which will be utilized to transport the S-II stage from Seal Beach to MTF and AMR. The studies of the application of the NASA modular wheel to the interstate transporter configuration showed that the design was feasible but that it would result in unfavorable costs and schedule problems. S&ID therefore recommended that the NASA modular wheel not be utilized. This recommendation was concurred with by MSFC, and approval was granted to procure the two types of transporters. The procurement specification was released, and bids were received from five companies. Their proposals were evaluated, and American Machine and Foundry Company (AMF), Hartford, Connecticut, was selected to produce the transporters. A letter contract to proceed with design was subsequently accepted by AMF.

1. Heavy duty engine thrust structure — Drawing release is 100 percent, and fabrication of the unit is 50 percent.

2. LH_2 and LOX vacuum-jacketed propellant feet lines — Design is 100 percent completed on these assemblies. Procurement action has been initiated. Solar Aircraft was selected as supplier for these items.

3. LH_2 and LOX vent system — Design is 100 percent complete, and procurement action for the necessary hardware has been initiated.

4. Stage pressurization system — System design is approximately 90 percent complete.

GSE

As a result of NASA redirection, control equipment for the Battleship stage will not be automated. This redirection necessitated the development of approximately eight pieces of manual checkout equipment. Four of the required items are being designed by the Rocketdyne Division, and fabrication is being accomplished by S&ID. The total task definition was completed in early April; and to date, all schematic drawings for all of the systems

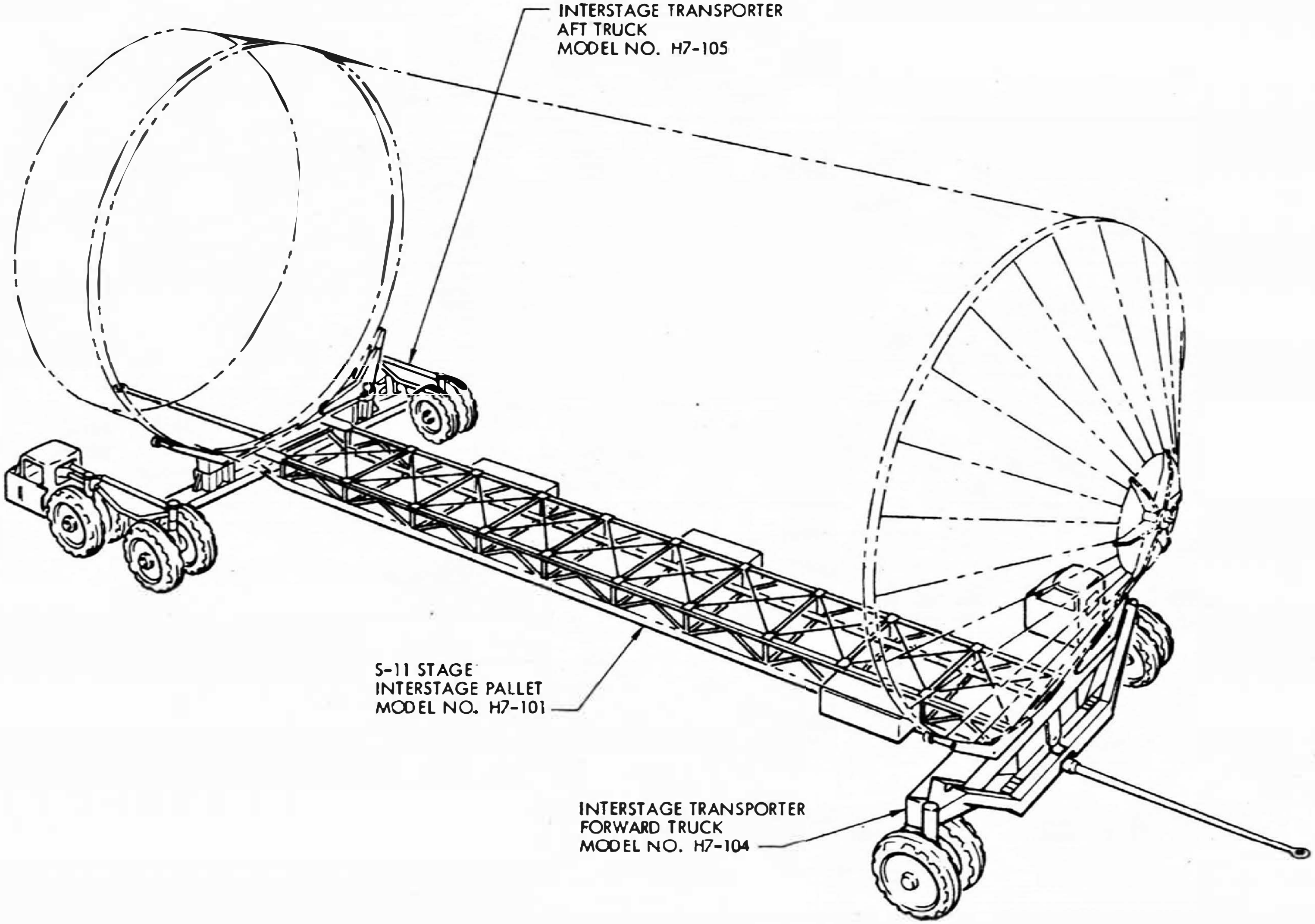


Figure 63. Intrastate Transporter

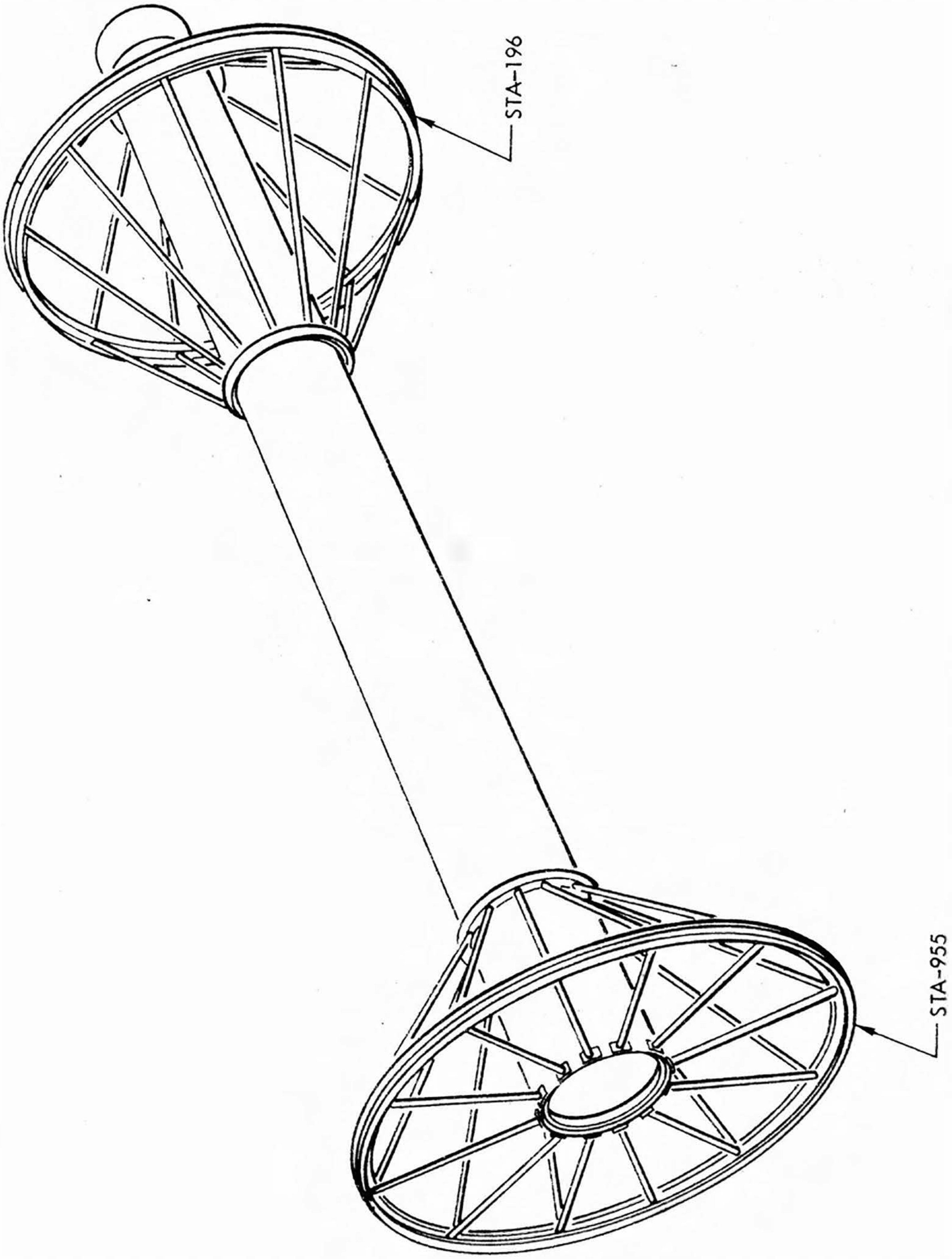


Figure 64. Stage Fitup Fixture (Model No. H7-17)

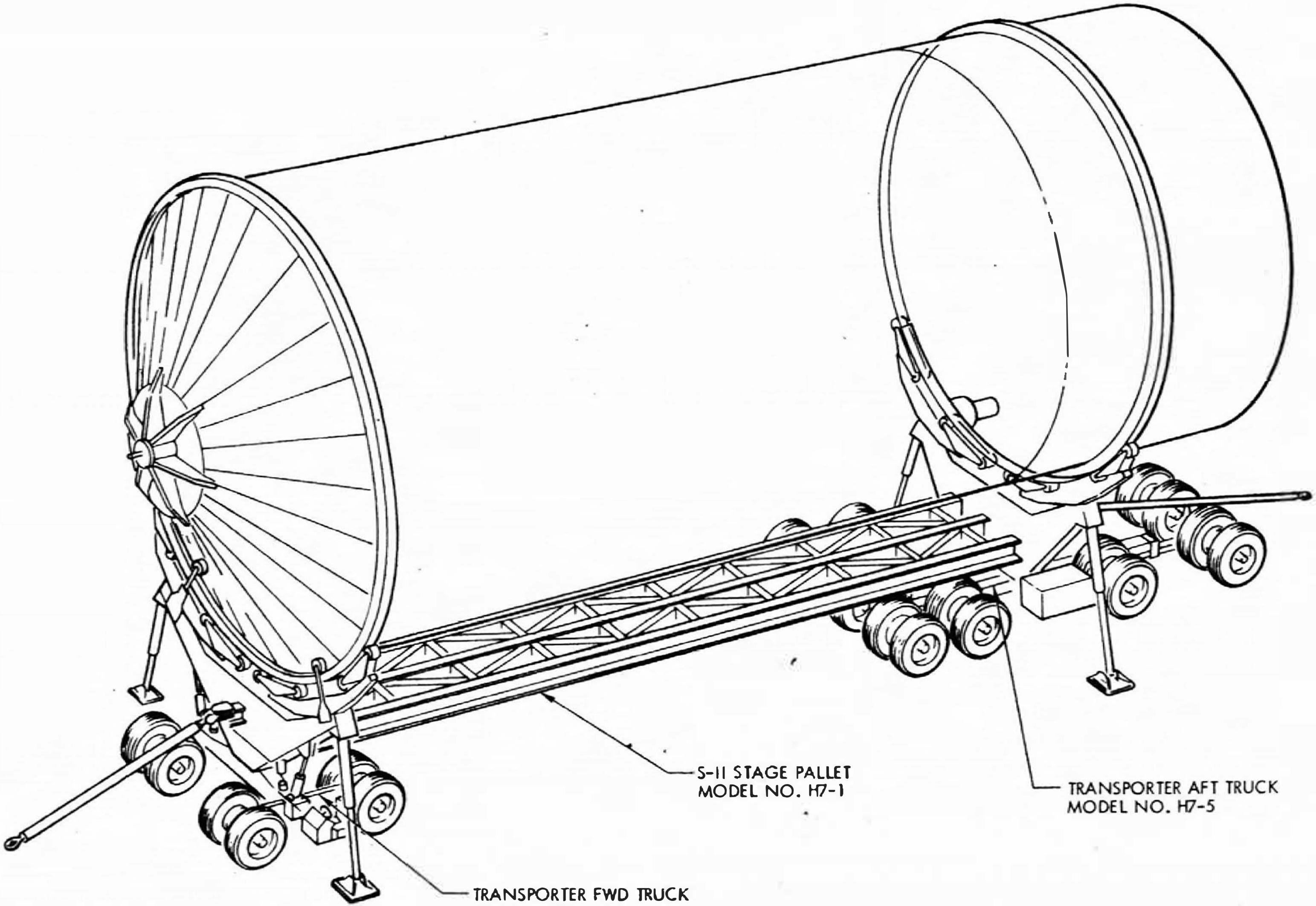


Figure 65. Interstate Transporter

required to support initial static firing of the No. 5 engine have been completed. Design for the equipment and system needed to support the 8 June 1964 firing is scheduled for completion in late October, 1963.

Figure 66 is a block diagram of the manual equipment, and Figure 67 is a representative example of its configuration.

More extensive pictorial representation of deliverable GSE and nondeliverable SDD equipment may be found in SID 61-421 and SID 63-115.

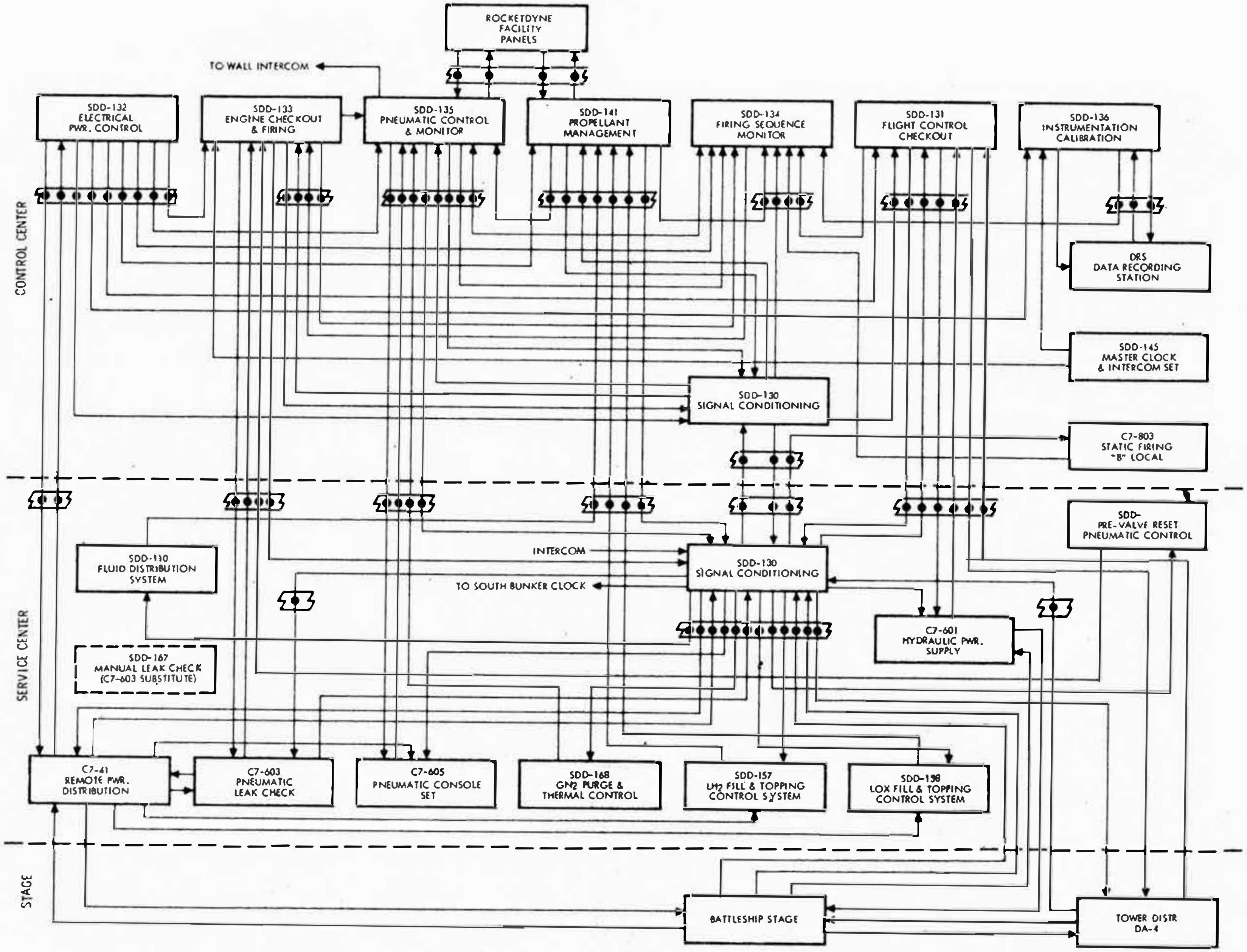
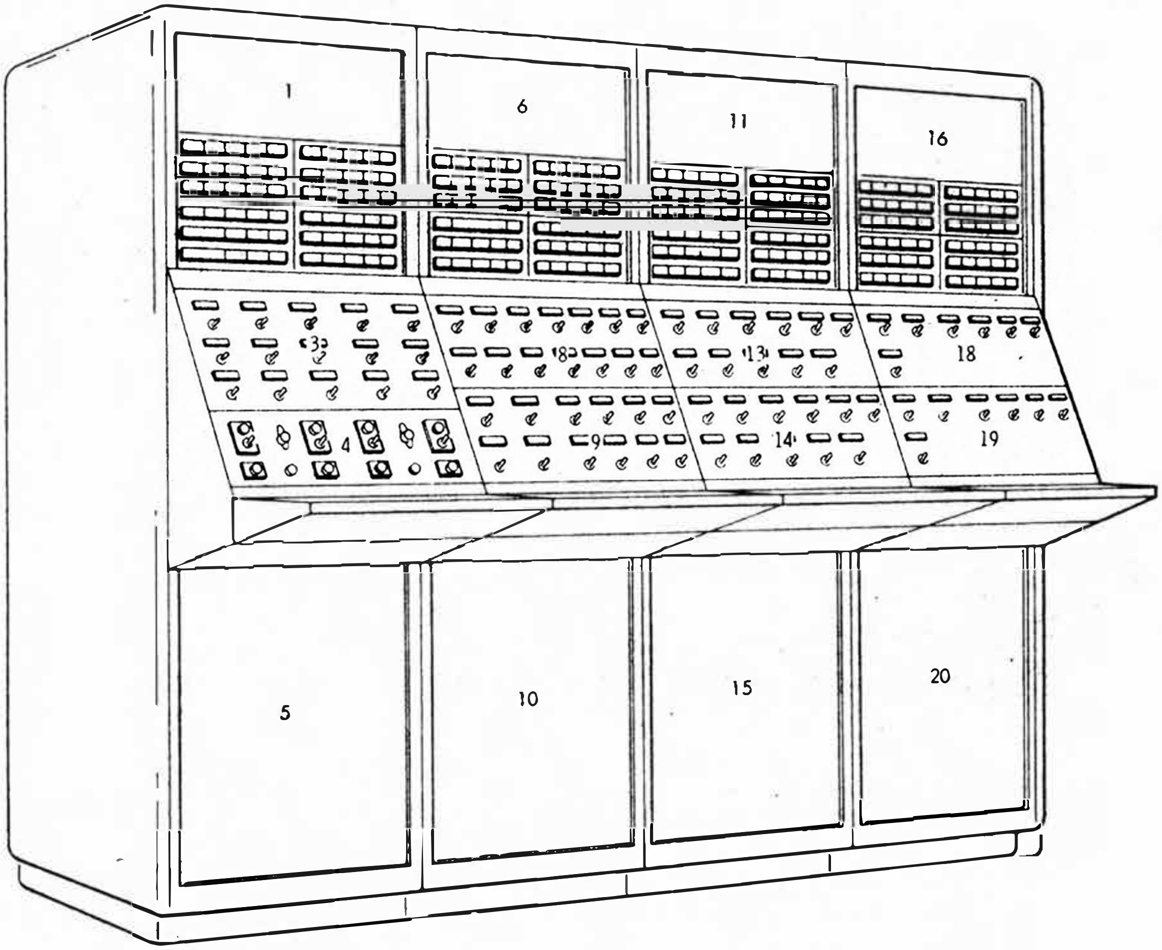


Figure 66. Block Diagram of Battleship Manual Checkout Equipment



1. BLANK
2. PURGE LH_2 SYSTEM MONITOR
3. PURGE LH_2 SYSTEM
4. INTERCOM
5. BLANK
6. BLANK
7. START COUNTDOWN, PROPELLANT LOADING (LO_2 & LH_2) MONITOR
8. START COUNTDOWN
9. PROPELLANT LOADING (LO_2 & LH_2)
10. BLANK
11. BLANK
12. PRESSURIZATION LO_2, MONITOR
    PRESSURIZATION LH_2, MONITOR
13. PRESSURIZATION LO_2, CONTROL
14. PRESSURIZATION LH_2, CONTROL
15. BLANK
16. BLANK
17. LO_2 FILL LINE START PURGE, MONITOR
    LH_2 FILL LINE START PURGE, MONITOR
18. LO_2 FILL LINE START PURGE
19. LH_2 FILL LINE START PURGE
20. BLANK

Figure 67. Pneumatic Control and Monitor Rack (Model No. SDD-135)

TEST AND OPERATIONS

During the report period, S-II Test and Operations effort was directed primarily toward test planning. Test plans and procedures, compatible with the program confidence-development plan, were formulated to ensure that program schedules and objectives will be met after the test sites have been activated. This required definition of support requirements, such as manpower, facilities, and instrumentation, for all test sites. Numerous supporting documents, prepared and published during this report period, include the following:

Preliminary test plans

Detailed activation schedules

Test development plans

Installation and checkout procedures

Detailed operating procedures

Measurement lists

Countdown time versus events charts

Documents related to over-all and specific phases of the program

Major changes to the program, particularly from Amendment 5 increased the work load required to accomplish the planning program. As a result of one of these changes, the Operations Simulator was cancelled, and the Electomechanical Mock-Up (EMM) test program was established.

ELECTROMECHANICAL MOCK-UP

The EMM, designed as an S&ID system test facility, is to be essentially a full scale mock-up of the S-II stage. Electrical and mechanical operations will be functionally identical to flight conditions, except for aspects associated with cryogenics and combustion. This will enable development and evaluation testing on vehicle systems under simulated flight conditions in a non-hazardous test environment. To further simulate flight conditions, development testing will be conducted with S-II GSE. The mock-up will then be integrated with production automatic-checkout equipment for functional evaluation and testing.

Construction of the EMM was divided into two phases: Phase I consisted of the S-II-stage simulator area and Phase II the GSE checkout area. Phase I was completed on 3 June 1963, without serious problems. Since completion of Phase I, the mock-up has been used by various departments of S&ID to resolve interface problems and to ensure that physical interference does not occur between stage components. Phase II began on 1 July 1963 and some delays have been encountered in this construction. A two-shift test operation will probably be used to minimize the resulting reduction in available test time.

The development test program planned for the EMM was documented and released on 15 June 1963, in SID 63-740, Saturn S-II Electromechanical Test Program Plan. In an effort to achieve optimum use of the EMM, the program was divided into six phases, as follows:

1. Development of mock-up operations
2. Automatic checkout equipment development testing
3. Stage-systems development testing
4. Stage systems and GSE integration
5. Checkout tape debugging and verification
6. S-II stage and test site support

The EMM program will include documentation and scheduling of test objectives for each phase. Development test plans containing detailed information to accomplish test objectives are being formulated for each phase.

Major development mock-up operations were started on 4 June 1963 and will continue until installation of flight-weight systems. Minor development mock-up operations will continue throughout the EMM program.

Phases 2 and 3 will essentially be parallel efforts. Phase 2 will include installation, checkout, and integration of the computer and automatic-checkout stations. Phase 3 will include installation of flight-weight systems, followed by a functional evaluation to resolve interface or compatibility problems. During Phase 4, the stage-systems and automatic-checkout equipment will be integrated. Individual systems will be integrated initially, using local control testing. Following this, the equipment will be integrated with the checkout computer, and automatic operations will begin with development and verification of checkout tapes. This will begin Phase 5, which will continue throughout verification of individual and integrated stage-systems checkout tape.

After the first set of checkout tapes have been verified, the EMM will be a fully integrated stage system and GSE test facility. It will be capable of stage-systems checkout operations, using both local-control and automatic modes of operation. It will evaluate design changes and resolve operational problems without interrupting static-firing or flight-test operations. This includes stage-system, checkout-equipment, and associated tape-program design changes, as required to support flight vehicles. In addition, the EMM will support other S-II test sites in the resolution of stage-system and checkout-equipment problems.

BATTLESHIP

During the report period, effort on the Battleship program was concentrated largely on reorientation to comply with customer redirection. These changes limited the Battleship test program to J-2 engine-cluster development testing, with S-II airborne systems limited to those required to support the development and use of manual equipment for checkout and control.

Considerable effort was expended on preparation of supporting documentation for the Battleship test program. This documentation consisted of the following:

Detailed activation schedules

Test development plans

Installation and checkout procedures

Detailed operating procedures

Cryogenic systems test development plans

Integrated systems checkout procedures

Santa Susana safety manual

Battleship operations manual

Countdown time versus events chart

Much of the work on this documentation was completed; however, major effort must still be devoted to such documents as the stage detailed-operating procedures for installation, checkout, and operation of stage systems, GSE, SDD, instrumentation, and integrated systems.

Battleship test and operations personnel were active in various special groups that were formed to resolve support and coordination problems for the test program at Santa Susana. Support requirements were established in the following basic areas:

Office and storage space requirements

J-2 rocket-engine refurbishment schedule

Santa Susana manpower distribution

Cafeteria, shipping, receiving, and vehicle maintenance

Laboratory and shop support

Industrial Security

Document control and reproduction facilities

In addition to these requirements, a working-relationship plan for S-II Test and Operations and Rocketdyne was formalized to ensure compatibility of job responsibilities with program requirements.

Plans for the instrumentation recording systems, definition of red-line limits, console layouts, and the Battleship measurement requirements were established. The recording system was designed to include the following equipment:

Digital recording system (DRS)—capable of accepting 750 analog inputs and 150 discretes. This system will also record the All-Systems static firing measurements.

Direct inking graphic recorders—present plans stipulate 120 Foxboro recorders (circular type) and 96 strip-chart recorders (8 channels per recorder).

Oscillographs and sequence recorders—Battleship fire control center will use 6 Heiland oscillographs (36 channels per oscillograph) and 18 Easterline-Angus sequence recorders (20 channels per recorder). Patch panels will be used for signal distribution to provide maximum system flexibility.

Bids received for the digital recording system are being evaluated. Battleship test and operations personnel completed specifications for an eight-channel strip-chart recorder. Ninety-six recorders will be required.

Additional effort was expended on tasks indirectly associated with the Battleship program. Budget and planning estimates were prepared for the S-II five and ten stage program, the S-II (120) operational vehicle test program, and the justification documents to support fiscal capital and facility fundings.

One-twentieth scale models of Battleship LOX and LH_2 tanks were fabricated and are being used by S-II test and engineering groups as a working aid.

Finalization of a detailed activation plan and electrical-checkout procedures for the Battleship GSE and SDD equipment is in progress. Functional block diagrams are being prepared for the stage electrical-power and electrical-control systems. Effort in this area is approximately 30-percent complete. End-to-end systems drawings pertinent to the Battleship electrical network are in preparation. Battleship personnel will continue close coordination and liaison with cognizant GSE and SDD design groups to ensure scheduled completion of the systems drawings.

ALL-SYSTEMS

The All-Systems facility was originally planned for initial flight-weight stage testing. This program was to begin after extensive preliminary testing had been conducted in the safer environments of the Operations-Simulator and the Battleship facilities. The substitution of the EMM for the Operations Simulator and the reduction in scope of the Battleship program resulted in the following major changes to the All-Systems program:

Qualification of the automatic-checkout equipment for the first time under static-firing conditions

Transfer of boat-tail environment temperature testing to All Systems

Additional testing imposed on All-Systems stage due to the change in rate of confidence development

The program was further affected by the Plan V extension and by the addition of a static firing measuring system. Support requirements for the All-Systems test program were reestablished, along with the budgetary and manpower loading requirements, propellant forecasts, and GFP/GFAE requirements.

The All-Systems preliminary test plan was updated to reflect Amendment 5. This test plan describes the program, test objectives, test configuration, organizational structure, operations plan, systems development plan, training plan, reporting, and equipment requirements.

Construction of the All-Systems test stand (Coca IV) has progressed to the concrete-pouring stage.

All-Systems personnel participated in GSE analysis and cost-cutting studies to determine cost savings resulting from the deletion of unnecessary or extraneous features which might have been added for the convenience of automatic checkout.

The determination of the effects of directed program changes on the All-Systems test program has been , and continues to be, a major effort. Numerous plans have been investigated to determine the effects on the over-all S-II program, as well as on the All-Systems program, in an effort to minimize the schedule impact. Coordinated effort between S-II Test and Operations, Engineering, and Manufacturing has established All-Systems GSE delivery dates. A briefing, based upon established delivery dates and various plans to minimize schedule impact, is being prepared. This briefing, which will outline the effects and proposed plan of action to minimize the effects will be presented to NASA in the near future.

Considerable effort has been expended in planning boat-tail environmental temperature tests, which were added to the All-System's test program because of the deletion of the Operations Simulator program. These tests will be the first and only prelaunch performance demonstrations of the flight-weight engine-conditioning and compartment-conditioning systems. Effects of the resulting environmental temperature on other stage systems will be determined. The plan of action and test objectives were used to establish the test hardware configuration and schedule. The basic concept is the addition of a series of special tests after the initial static-firing program. An aft enclosure and other special equipment will be used to simulate the S-II launch configuration and environment.

Static-firing at Santa Susana, on the All-Systems stage, is presently limited to tests of 25-second durations. Static-firing tests of longer duration require waiver approval from the Air Force. A plan for the Saturn S-II propellant hazards program has been approved. Data provided by this program and from the NASA spill test program, together with S&ID safety plans and procedures, will support the submittal of a waiver request for longer-duration static firings.

Preparation of system development plans has begun and will constitute a major part of future All-Systems effort. The development plans will detail step-development testing of each S-II system. The major areas to be included are as follows:

Specific test objectives

GSE, facility controls, and interfaces

System interlocks, sequencing, and controls

Measurement and instrumentation requirements

Stage-systems interfaces

Schedule

Detailed operating procedures

Preparation of documents that will describe these areas is planned, with the inclusion of the impacts of program redirection and of the effects of the limited-duration firings on the program. Technical problems associated with construction of the test stand will be resolved during the construction phase.

HAZARD SUPPRESSION

During this report period, NAA has been negotiating for Air Force site approval for Battleship and All-Systems test programs at the NAA Propulsion Field Laboratory. In compliance with Air Force request, a Saturn S-II Battleship tank design-verification program was started by Rocketdyne. With NASA and Air Force approval of the program plan, a series of 12 tests was conducted in November 1962 in support of this activity. The final report summarizing this activity was released by Rocketdyne on 5 December 1962.

In summary, the S-II Battleship tank design-verification test series concluded that ASME-coded vessels will withstand momentary pressure loads several orders of magnitudes in excess of calculated buckling pressures. Also, the S-II Battleship tank would not buckle or rupture because of engine systems detonation, based on the predicted detonation as presented in the program plan.

Review of the NAA-proposed Saturn S-II propellant hazards program continued through this report period. Task 1 defined a study program, Task 2 outlined a test program plan. Phase 1 of Task 2 primarily dealt with a spill-test series, and Phase II supported a hazards suppression test series.

Per NASA direction, Phase 1 of Task 2 was deleted from the program. Therefore, Phase II has been reidentified as a Saturn S-II propellant hazards suppression program plan. Construction-supporting Task 1 (gas-phase testing) is scheduled for completion in August 1964. Testing will begin the first week of September 1964.

MISSISSIPPI TEST FACILITY

During the report period, the major MTF Test and Operations effort was directed toward test program planning. Documents written during the past year delineated these plans. Preparation of these documents required extensive coordination with the S-II design groups and NASA-MSFC. Numerous problems, some of which were of major significance, involving basic concepts and test philosophies, were resolved during test-program planning.

The MTF facilities activation project group, formed on 12 October 1962, serves as the common S-II interface for the flow of information concerning design criteria planning, scheduling, funding, and GFP/GFAE between S&ID and the MSFC, as this information pertains to acceptance test facilities at the MTF. This group is headed by a representative from S-II Test and Operations, with staff members from Facilities, Facilities requirements, program management, and Systems Engineering.

The Mississippi test-site facility design criteria and detailed design were reviewed. This review was made to ensure compatibility between the S-II stage, its associated GSE, and the MTF.

Two Test and Operations resident representatives were established at the MSFC to coordinate and resolve facility-stage/GSE interface problems and to provide early on-site representation to the MTF test site.

Firm budgetary and manpower loading requirements were established in accordance with Amendment 5. Major program changes consisted of the following:

> Deletion of vertical stage-checkout capability in the vehicle-service building, which resulted in stage checkout at the two tests stands. (It is understood that the requirement for checkout in the vehicle-service building will be reinstated under the forthcoming fiscal year funding, and it is planned that the facilities will be operative with the arrival of the S-II-4 stage at MTF.)
>
> Addition of static-firing measuring system.
>
> Addition of second computer complex in the test control center.

The following major documents, applicable to the MTF, were published during the report period.

> Preliminary MTF-Flight Acceptance Test Program Plan; published or 10 September 1962. This report describes the entire acceptance test program that will be conducted to ensure delivery of a flight-ready stage to AMR.
>
> MTF Operations Plan; published on 15 March 1963. This report describes support and operational activities required to activate the facility and conduct the acceptance test program.
>
> Preliminary Saturn S-II Stage MTF Static Firing Countdown. This is a time-versus-events chart defining static-firing test operations beginning with T-8 hours through static-firing shutdown.
>
> MTF Activation Plan. This plan delineates, in sequence, installation and checkout of GSE, facility/GSE integrated checkout, and operations to be conducted with the Facility Checkout stage (S-II-F). Countdown control requirements and criteria were published. The static-firing concept was finalized by Test and Operations and Systems Engineering. Generally, this concept provides manual control of the S-II stage through hard-wire circuitry from the static-firing countdown equipment. This ensures positive control of the propulsion, pressurization-propellant loading, propellant feed, and engine-control systems. Other stage systems will be controlled using the local-control mode of the electrical-checkout station. The ground equipment test set (GETS) will be used to verify both manual static firing and automatic-checkout control systems.

At the first static-firing group meeting, held in January 1963, S&ID presented a proposal for operational data acquisition during MTF acceptance testing. This proposal would employ S&ID's digital data acquisition system to record test data during static firings. Hard-wire data would be acquired from the stage-flight transducers and routed to the test control center for recording. However, this proposal was not accepted by NASA. Consequently, S&ID was directed to incorporate static-firing instrumentation with a centralized data-acquisition facility for data recording. Within this concept, critical measurements required for safe conduct of tests are to be recorded in the test control center. Close coordination between S&ID and MSFC has been maintained to implement this method of data acquisition. The primary reason for adoption of this concept is its use of highly reliable heavy-duty transducers during static-firing tests. Activities planned for the next report period include continued coordination with NASA, both at the MSFC and at the test site for resolution of problems, and the publication of detailed test plans.

ATLANTIC MISSILE RANGE

As a result of contractual incorporation of the Plan V schedule during the past year, the applicable AMR schedules, PERT network, GSE on-site need dates, and the pre-AMR and AMR manpower loading were updated. The extent of S&ID support to the Launch Operations Center (LOC) for stage operations beyond the low-bay area has not been completely established; therefore, additional planning and scheduling revisions may be necessary.

The AMR test plan for the S-II stage was completely revised and published as SID 63-114. The test program and instrumentation systems sections were expanded to serve as an initial planning aid. Since it was necessary to make certain assumptions in preparing this plan, copies of the document were submitted to the LOC for review and comment.

The Test and Operations automatic-checkout equipment committee, formed during the past year, has monitored design of the automatic-checkout equipment. Also, by correspondence and personal contact with designers, the committee has transmitted S-II Test and Operations requirements to the GSE design unit. A number of trips have been made by committee members to observe other contractors' use of automation, e. g., automatic checkout of SA-5 at MSFC.

S&ID comments on the Complex-39 vehicle-assembly building, 30- and 60-percent design-review drawings, and the arming tower criteria were coordinated with LOC through the AMR facility activation project group. This group, headed by AMR Test and Operations, was formed during this report period. Direction was received to use a common S-II/S-IVB dolly, to be supplied as part of the facility for stage processing operations in the low-bay area. The dolly was necessary since the original S&ID concept of suspending the stage was incompatible with the 116-feet low-bay ceiling clearance. Changes to comply with this direction were coordinated through the AMR group.

NAA representatives attended Saturn V launch-operations working group meetings from 24 through 26 April 1963 at the AMR. A primary action item was a request that each stage contractor prepare an AMR test sequence for their respective stages, based upon a master Saturn V test sequence distributed at the meeting. The resulting AMR test sequence was prepared, coordinated at S&ID, and submitted to NASA for review.

A primary problem visualized by S-II Test and Operations is the lack of low-bay facility-checkout capability prior to receipt of the first flight stage. Briefings proposing additional systems and more checkout time for the S-II Facility Checkout stage at AMR have been sent to NASA. NASA's reaction to the proposal seemed to be favorable; however, the present

Facility Checkout stage is still only the basic shell of a flight stage, intended primarily to check out handling, access, and propellant loading capability at AMR.

To adequately plan and provide for stage operations at AMR, NASA must stipulate the manner of operation at the high bay and launch pad areas. LOC thinking on the anticipated mode of operation has been obtained; however, to date, no official direction has been received.

It is planned to revise and reissue the AMR test plan at six-month intervals to maintain this document's usefulness as a guide to planned stage operations at AMR. Review of the AMR test sequence by LOC should detect any differences in test philosophies if such differences exist. Effort will be directed during the forthcoming year to the resolution of these problems and to the subsequent effects of these problems on applicable test planning and documentation.

TEST PROGRAMMING

Measurement lists were published for the Electromechanical Mock-Up, Battleship, All-Systems stage, S-II-2, S-II-IFD, and S-II-F. In addition, a Saturn S-II master measurement list, which is a catalog of all known measurements for the S-II stage, was published. Numerous revisions to these lists were necessary as a result of such changes as (1) deletion of Operations Simulator and addition of the Electromechanical Mock-Up, (2) reorientation of the Battleship program, (3) incorporation of a static-firing measuring system, (4) change of S-II-IFD from boilerplate to flight-weight configuration, and (5) changes in design of stage systems. Technical coordination of measurements with engineering design groups and the MSFC will be a continuous effort. A preliminary measurement list for S-II-3 is being compiled, and future effort will be directed toward preparation of the measurement lists for S-II-4 and S-II-5. The following represents published measurements lists:

SID No.	Title	Date
SID 62-1052	Saturn S-II Master Measurement List	22 Apr 1963
SID 62-1053	Saturn S-II Stage S-II-2 Measurement List	5 Mar 1963
SID 62-1267	Saturn S-II Battleship Stage Measurement List	16 Feb 1963
SID 62-1268	Saturn S-II All-Systems Stage S-II-T Measurement List	11 Mar 1963

SID 62-1269	Saturn S-II Electro-Mechanical Mock-up Measurement List	15 Jan 1963
SID 62-1270	Saturn S-II Facility Checkout Stage S-II-F Measurement List	12 Oct 1962
SID 63-353	Saturn S-II Nonpropulsive Stage S-II-IFD Measurement List	15 Apr 1963

The test support requirements documents were published for each of the S-II test sites. These documents delineate equipment and material requirements such as electronic test equipment, raw stock, tools, shop equipment, protective clothing furniture, etc., to support the S-II test sites. The part or model number, quantity required, and required date for all items are specified in these documents, which will continue to be updated. The documents published to date are as follows:

SID No.	Title	Date
SID 62-1021	Electro-Mechanical Mock-up Test Support Requirements, S-II Test and Operations	27 Jul 1963
SID 62-1022	Santa Susana Test Support Requirements S-II Test and Operations	5 Apr 1963
SID 62-1023	Mississippi Test Support Requirements S-II Test and Operations	14 Sept 1962
SID 62-1025	AMR Test Support Requirements S-II Test and Operations	2 Nov 1962

The S-II master test schedule has been revised, as required, to incorporate program schedule changes. Some of the more significant test program changes that have resulted in test schedule changes are as follows:

Stage checkout area at MTF was deleted. All S-II stage checkout operations will be conducted on the test stands.

First Battleship static firing was rescheduled for June 1964.

Battleship program was reoriented to a J-2 engine cluster development program using manual-checkout equipment.

Operations Simulator program was deleted.

Electromechanical Mock-Up program was added to replace the Operations Simulator program.

Nonpropulsive stage S-II-IFD was changed from a boilerplate to a flight-weight configuration.

S-II stage delivery schedule to the AMR was revised by Amendment 5 to provide for later delivery to AMR.

The General Test Plan, SID 61-364, has been updated as required by specification amendments to incorporate program changes. These changes listed in the previous paragraph were documented by amendments to SID 61-364. A total of 35 amendments to SID 61-364 were submitted for approval, following the original publication date of 4 December 1961. Of this total, 12 amendments were approved, and the remaining number are in various phases of negotiation.

S-II DATA ENGINEERING

During the past year, the S-II data engineering group established requirements for equipment, personnel, and facilities required to process and handle S-II test data.

A contract was awarded to Radiation, Inc., Melbourne, Florida, to design and deliver a data reduction system that will meet S-II requirements. This equipment will be installed at the S&ID Downey facility. Pertinent milestones achieved during the past year on this subcontract include (1) the completion of contract negotiations in January 1963, (2) contract go-ahead in March 1963, and (3) detailed design review and approval in June 1963.

Equipment necessary for reduction and evaluation of stage-vibration and cycle-counting data is being developed separately, but will be compatible with the major data-reduction equipment. Specifications for the vibration and cycle-count system were presented to NASA/MSFC personnel. Technical approval of the design concept was obtained in MSFC Technical Directive 111, dated 27 June 1963. These specifications have been distributed for supplier price quotations, which are scheduled for review by S&ID on 9 August 1963.

Direct data support to the S-II project was minimal during this period, since the stage testing phase has not yet begun; therefore, effort was restricted to project-support planning. This planning was directed to the following general areas:

Development of computer applications to receive end-instrument calibration data in the format developed by the Instrumentation branch and translate into multiple-output format compatible with planned data-processing techniques.

Development of data reduction plans to effectively use all data processing equipment available to the S-II data engineering group.

Data engineering will steadily increase its S-II project-support functions. At present, this increased activity is largely devoted to defining and preparing computer programs for future use in processing S-II stage data. Near the end of 1963, limited data-reduction support will be given to the EMM tests. Full data station operation in support of the EMM will not be required until April 1964.

The contract with Radiation, Inc., will terminate upon final acceptance of the data-reduction system at S&ID, Downey, during April 1964. Effort directed toward this contract will remain at the present level until that date. Upon acceptance of the data-station equipment, a high level of activity will be shifted to the operation and maintenance of this equipment. Actual static-firing support is scheduled to begin with the initial stage firings at the Propulsion Field Laboratory, during June 1964.

RELIABILITY

S-II EQUIPMENT CRITICALITY CATEGORY APPLICATION

During the past year, specific application of the criticality categories was made in many functional assignments within the Reliability program. Criticality criteria are used to form a basis for design principles, to determine the depth of testing required during the Confidence Development Plan, and to determine reliable manufacturing and supplier requirements. Application of the catagories was made also in determining the requirements of the emergency detection system, in automatic checkout, and in the determination of traceability requirements.

Specific application of the relationship of criticality criteria to failure mode analysis, procurement, design review, testing and traceability in flight equipment is shown in Table 4. Other criticality relationships in the areas of instrumentation equipment, GSE components, GSE end items, and special GSE were also established and implemented.

FAILURE MODE ANALYSIS

A total of 99 failure mode analysis reports consisting of 3 parts — a failure mode effect analysis, a failure mode cause analysis, and a critical components summary — were released during the report period. These analyses deal with the manner in which components or systems fail, the reason for the failure, and the effect of the failure upon the system or mission. Initial evaluation of the designs of airborne systems resulted in the elimination or reduction to a lower order of failure of more than a third of the first order failure modes identified. As an example, a single design change to provide an emergency manual mode for a drain valve in the GSE was proposed as a result of failure mode analysis. This change permitted a reduction of over 50 first order failure modes to second order. Tables 5 and 6 show the breakdown of criticality for airborne components and ground equipment end items.

PROGRESS AND REVIEW BOARD

During the past year, the S-II Reliability Progress and Review Board was established for the purpose of providing a formal monthly review by S-II management of the progress being made in implementing the Reliability policies and for considering means of resolution of any existing problem areas. The board is composed of the S-II managers and is chaired by the

Table 4. Criticality Category Application of Flight Equipment (Minimum Requirements)

Equipment Criticality	I	II	III
Failure mode analysis	x	x	x
Effect analysis	x	x	x
Cause analysis	x	x	
Procurement			
NAA procurement specifications	x	x	
SCD, EOPR, or government specs.			x
Design review			
Preliminary	x		
Major	x	x	
Application approval	x	x	x
Testing			
Qualification	x	x	x
Reliability	x	x	x
Traceability	x	x	

Table 5. Airborne Critical Components

System	Component Criticality		
	I	II	III
Engine servicing	0	2	7
Propellant recirculation	2	2	0
Engine compartment conditioning	0	1	3
Thermal control	1	0	4
Propellant management	4	1	1
Pressurization	1	20	3
Propellant feed	6	2	0
Electrical power	11	12	0
Flight control	0	7	0
Destruct	8	1	2
Measurements	2	3	41
RF systems	0	1	32
Structure	10	1	0
Ullage motor	1	0	0
Separation	7	8	2

Table 6. Ground Equipment End-Item Criticality

Equipment Type	Criticality			
	I	II	III	IV
GSE	4	12	23	64
Special GSE	0	19	4	22

S-II program manager with the Reliability manager acting as assistant chairman. This organizational structure provides the proper impetus for board reaction. Since its inception, four meetings have been held. Typical action items resulting from board discussion are the following:

1. Direction of emphasis to the design review effort
2. Implementation and ground rules for the mechanical excellence program
3. Investigations of traceability requirements and their respective program implications

DESIGN REVIEW

The 100 design reviews performed thus far in the program include preliminary reviews of all stage systems with the exception of the emergency detection system. Major contributions were made in all areas of design; the most important were made in stage systems and structure, where many significant problem areas were identified and subsequently eliminated by the responsible design groups.

The areas covered by design review to date have included stage systems, structure, GSE, facilities, test programs, and airborne components. Of special interest during this period was the creation of the supplier design review, the first activity of this type within the industry, On the basis of initial experience, supplier design review work will be of great benefit to the program.

CONFIDENCE DEVELOPMENT PLAN

Over 140 component application approval test programs were prepared and released, as a part of procurement documents, in the Confidence Development Program. These test programs will be implemented through the latter part of 1964; three test programs have been initiated. Two of these three were terminated because of NASA design redirection. A third program resulted in failure of the item being tested. The failure was an erratic output signal occurring subsequent to exposure to dynamic test conditions. Investigation is under way to determine the actual cause of failure and the necessary corrective action.

In the systems testing program, ten preliminary test plans were generated for coordination; and preparation for implementation of these plans is under way.

Two major redirectives by NASA resulted in adjustments to the original Confidence Development Plan. The first was the substitution of an Electromechanical Mockup in lieu of the Operations Simulator. This change resulted in a supplemental test program to replace the reduction of simulated environmental conditions. This supplemental program is currently under review by NASA; and acceptance is necessary in order to meet the objectives of the Confidence Development Plan at the systems level. The second major redirective was contained in CCN 13; it reduced the Battleship program to an engine development facility. Additional redirectives deleted automatic checkout on the Battelship facility. An additional supplemental program was generated as a result to obtain the necessary data from the All-Systems program. This proposal is also under review by NASA. Again, acceptance is required to meet the objectives of the Confidence Development Plan.

LABORATORY EVALUATION STATUS

The test programs developed under the Confidence Development Plan must be conducted in laboratories that can meet standards of testing beyond those normally acceptable. It was necessary, therefore, to evaluate all test laboratory facilities to be utilized in performing tests of the Saturn S-II program. This evaluation is nearing completion. Of the independent laboratories surveyed, 28 were approved and 7 were disapproved for the lack of sufficient environmental test equipment to meet minimum program requirements.

In addition to the independent testing laboratories, the S-II Reliability department surveyed 50 environmental laboratories that are maintained by potential suppliers. Forty-six of these were found to be acceptable for use in the qualification testing of items of hardware manufactured by that supplier. Four supplier-maintained laboratories were disqualified because of inadequate test facilities.

QUALIFICATION STATUS LIST

As a part of the obligation of S&ID to keep NASA informed of test progress in the Confidence Development Plan, the Saturn S-II Qualification Status List (SID 62-1224) was issued on 1 October 1962 and revised on 1 April 1963. This document contains the specific details on confidence attainment, test schedules, specific tests to be performed, and the responsible testing agency at the part, component, subsystem, and system levels. For adequate management control, a daily schedule is maintained on all tests under the Control of S-II Reliability from which the Saturn S-II Qualification Status List is updated on a semiannual basis.

MECHANICAL EXCELLENCE PROGRAM

The mechanical excellence program became functional during this past year. The purpose of this program is to extend the emphasis of reliability beyond design and test to all personnel employed on the Saturn S-II project. The objectives of the program are four-fold:

1. To provide each person with the knowledge of what his job is
2. To acquaint each person with the knowledge of how his job relates and contributes to the project
3. To provide each person with the knowledge of how his job is to be done correctly
4. To motivate each person to make sure that when the work leaves his area of responsibility it will be free from errors.

The mechanical excellence program was implemented as follows:

1. Forty-six skill areas were identified as those requiring special training to assure technical competence commensurate with the reliability requirements of the program.
2. Milestones were established for the development of training courses to support these skill areas.
3. Training began and is in phase with the hardware development.
4. Special ME (mechanical excellence) symbols and training record cards were produced and are being awarded to graduates of the ME training courses.
5. Publicity articles appeared in the S&ID newspaper.
6. Twelve closed circuit television motivational telecasts were scheduled.
7. A poster publicity program was begun.
8. An ME motivational motion picture was purchased.
9. Plans were made for a continuous motivation campaign through the use of slogans, banners, posters, personal recognition, individual mailings, timecard stamps, news bulletins, etc. The presentation of astronauts, NASA and S&ID officials, and space program officials in live, closed circuit telecasts is planned, as circumstances permit.
10. Plans are under way to utilize kinescopes of S-II Reliability and mechanical excellence presentations for supplier indoctrination and motivation.

RELIABILITY EDUCATION

A reliability indoctrination and education program was started at the outset of the Saturn S-II program. This effort included education in recently developed reliability techniques, as well as indoctrination aimed at assuring a coordinated reliability effort through mutual understanding of the program objectives and methods of implementation.

During this reporting period, closed circuit television was introduced as a method of presenting educational and motivational material in the reliability field. The accomplishments of reliability education effort during the past year are summarized as follows:

1. One hundred eleven separate lecture classes were conducted.
2. Two television shows were made and taped to support the Reliability program
3. A closed circuit television schedule for reliability education was established.

The following courses were prepared and presented to reliability and design engineers and Test and Operations personnel as applicable:

Reliability plan

Design Review

Confidence development plan

Design analysis

Fundamentals of reliability mathematics

Reliability analysis techniques

Boolean algebra techniques

S-II math model.

Education effort during this reporting period included the writing and release of several reliability books. Among these were

Training manual for reliability test engineers

Definitions of reliability terms

Fundamentals of reliability mathematics

Reliability analysis techniques

SUPPLIER SURVEY STATUS

In order to assure a reliability awareness and capability on the part of S-II suppliers, the Reliability organization surveyed 148 potential suppliers. For this purpose, an S-II reliability supplier survey handbook, incorporating the elements of the S-II Reliability Plan (SID 62-128) was developed. Utilization of this document allows a numerical rating of the supplier to determine the degree of compatibility between the supplier's demonstrated reliability control system and the S-II requirements. Evaluations are made on the basis of the criticality rating of the item to be supplied. This evaluation survey and rating system reduces the need for supplier monitoring to a minimum. Of the 148 potential suppliers surveyed to date, the ratings are as follows: 22 were qualified for all criticality categories; 31 for category II and lower; 62 for criticality III and lower; 18 for criticality IV. Fifteen were disapproved. The prime reason for disapproval was the supplier's lack of a definite method for disseminating reliability design policies throughout their organization.

RELIABILITY PROCESS SPECIFICATIONS

Three process specifications dealing with traceability were issued during this report period. Specification MA 0201-1023, S-II Reliability Basic Equipment Traceability List, defines the traceability items of the S-II stage and GSE for which records are to be kept. This traceability list, contrasted with an exempt list, was given approval by NASA. Specification MA 0201-1051, Traceability Identification and Detail Requirements for the S-II Stage, defines the specific parameters and characteristics to be traced in the items listed in MA 0201-1023. Specification MA 0201-1050, Instructions to S-II Suppliers for Traceability Analysis, defines the methods by which the supplier shall evaluate traceability requirements for subunits as called for in the S&ID procurement specifications. The evaluation is made by an analysis of the failure modes of the design of the item. Release of these specifications provides S-II Reliability with the necessary controls over quality and traceability, both in house and at the supplier level.

Process specification MA 0201-1021, S-II Reliability Saturn Airborne Equipment Operating Time Record List (issued during this reporting period), establishes the definitions, requirements, methods, and a listing of operating time records for 122 airborne components and systems.

In addition, the five reliability process specifications on Reliability program requirements, design review, general test requirements, failure reporting, and failure mode analysis were revised to include the latest S-II Reliability program concepts. The application of these process specifications is based on the equipment criticality (so that, as an example, a criticality II item would have (1) major, application approval design reviews, (2) failure report, (3) failure analysis report, and (4) tests in accordance with general test requirements).

FAILURE MODE ANALYSIS COMPUTER PROGRAM

A computer technique for providing numerical relationships for failure mode analysis was developed to evaluate the quantitative effect of eliminating or reducing component failure modes. The input to this program consists of ranked component failure modes, their effect upon the system, other systems and missions, and apportioned component values. The output is made up of values for each failure mode for the component, subsystem, system, phase, and mission. Differentials are relative, quantitative values of particular configurations resulting from the elimination or alteration of component modes. The techniques are adaptable to a variety of system relationships. Presentations were made to NASA personnel, who are planning to utilize the method in conjunction with development of the emergency detection system for the Saturn V.

OTHER COMPUTER PROGRAMS

The computer programs listed below were developed specifically for the Saturn S-II program. They are mathematically derived programs and are designed to expedite the handling and retrieval of data by the use of automation. These S-II-oriented programs supplement the basic S&ID computer program file:

1. Equation writing
2. Apportionment evaluation
3. Prediction determination
4. Hazard function
5. Nonparametric statistics

MATHEMATICAL MODELS

The over-all formulation of the mathematical model program was advanced during this reporting period. The apportionment, prediction, and assessment reports were published and/or revised during this time. The newest publication, the assessment report (SID 63-464), describes further the four levels of assessment and how they combine to form an over-all assessment for the S-II program. These four models are the confidence level, control level, function evaluation, and operations evaluation.

Further advances in Reliability mathematical techniques were made in the following areas:

1. Airborne instrumentation equipment that is not flight-mission oriented, but actually measurement-information oriented. For this type of equipment, performance is the most important requirement. A math model for performability was developed to meet this need.

2. Ground support equipment (GSE). GSE is also divided into two specific areas. The area that does not deal directly with checkout of the stage has a requirement that is more maintenance oriented than reliability oriented. This orientation, termed "dependability", was mathematically expressed to meet the requirements for quantitatively measuring this phase of GSE operation.

PERT

During this reporting period, the PERT reliability network, G.O. 7193, was revised to show major milestones in the following three areas: documentation, design review, and confidence development. Of the total of 250 events in the reliability network, 44 were completed. During the same period of time, 896 detailed reliability events were incorporated into the engineering, manufacturing, and testing PERT networks.

IMPLEMENTATION LIST

The Saturn S-II Reliability Plan Implementation Documents List (SID 63-55) was released. This report is a compilation of 426 documents for implementation and support of the Saturn S-II Reliability Plan (SID 62-128). It is divided into five sections: program, procedures, specifications, studies, and miscellaneous.

RELIABILITY PLAN

The Saturn S-II Reliability Plan was revised and updated to reflect the adjustments and developments in the Reliability program during this reporting period. Detailed within this updated document are the advancements that have been made in the areas of criticality category criteria, statistical implementation of the Confidence Development Plan, the S-II Reliability Progress and Review board, and the expansion of the mechanical excellence program. Also included are the implementation plans for portions of the program which will phase at a later date with the development and testing of the S-II stage. This document was submitted to NASA for approval.

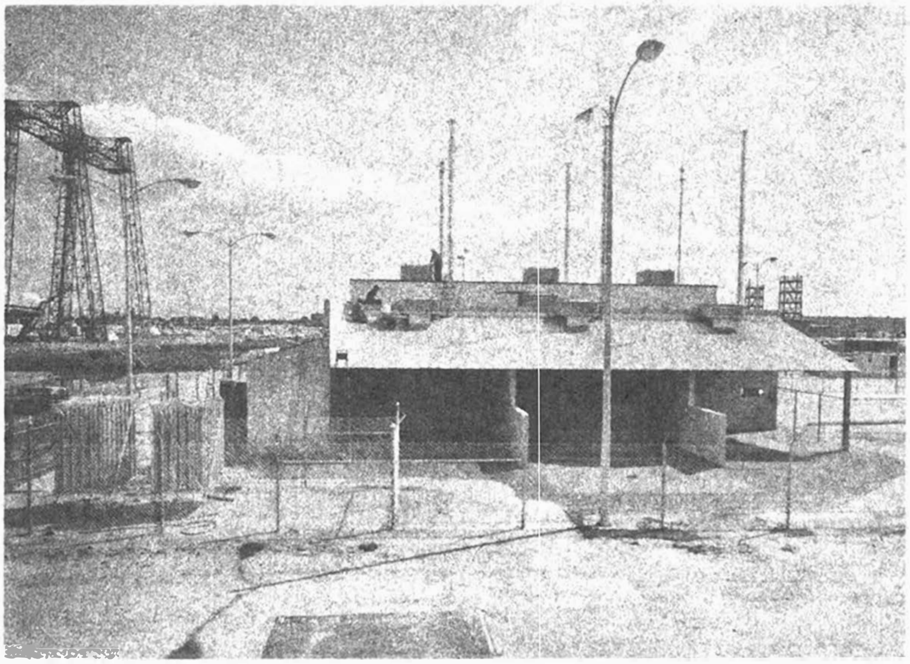
II. FACILITIES

DOWNEY

The major existing Saturn S-II facilities situated at the Downey site are the cryogenic test facility, the Electromechanical Mock-Up, the antenna test range, and the slosh and vortex facility. Major programmed facilities at Downey include a pressurization systems development facility, a flight control simulator, and a data ground station.

CRYOGENIC TEST FACILITY

The cryogenic test facility (Figure 68) is used in the evaluation and study of S-II materials and components in controlled temperatures as low as -423 F. Various liquefied gases are employed to create and maintain these temperatures.



S&ID-851-16B

Figure 68. Cryogenic Test Facility

The facility was completed on 19 April 1963; two days later, it was turned over to the engineering development laboratory (EDL). However, because of new functional requirements imposed upon the facility since completion by EDL, an alteration program is in progress. This program involves additional equipment and modification and is expected to be completed by mid September.

ELECTROMECHANICAL MOCK-UP

The Electromechanical Mock-Up (Figure 69) is a full-scale, developmental mock-up of the Saturn S-II stage for use by both S-II Engineering and S-II Manufacturing. It will be used to develop, evaluate, and functionally test the S-II stage systems.

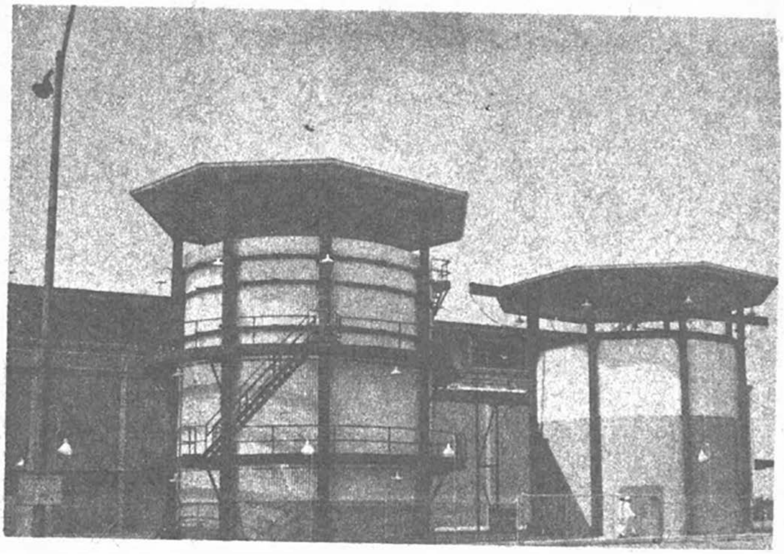

S&ID-881-4A

Figure 69. Electromechanical Mock-Up

The mock-up test area was completed on schedule and is in operation. Completion of the automatic check-out area and computer room is scheduled for 29 October 1963.

ANTENNA TEST RANGE

The purpose of the antenna test range (Figure 70) is to measure antenna radiation characteristics under environmental conditions using a scaled Saturn V vehicle. These characteristics will be obtained by transmitting appropriate frequencies to the Saturn V and recording the resulting signal strength.

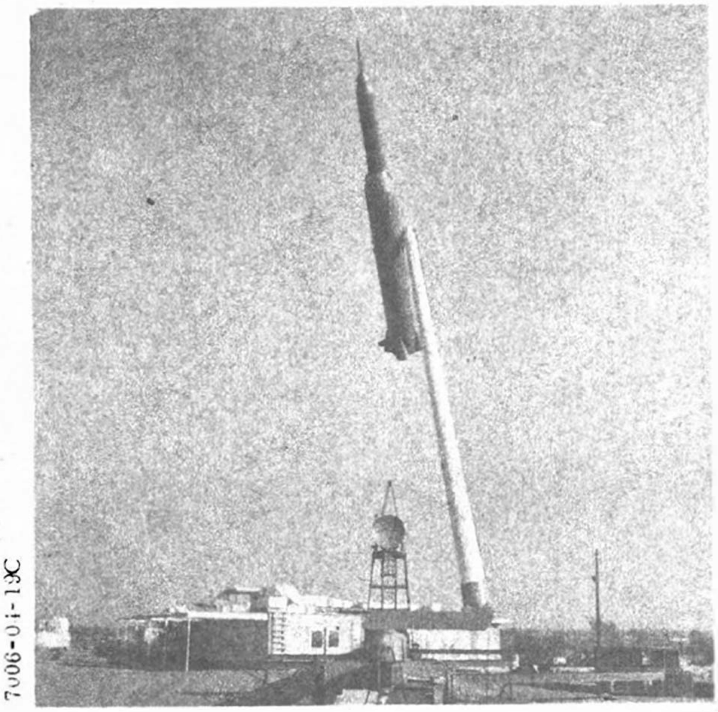


Figure 70. Antenna Test Range

The antenna test range, completed in January 1963, is operating in a satisfactory manner.

SLOSH AND VORTEX FACILITY

The slosh and vortex facility (Figure 71) is a unit designed for the study and measurement of the effects of liquid oxygen movement in the LOX tank of the S-II stage during flight.

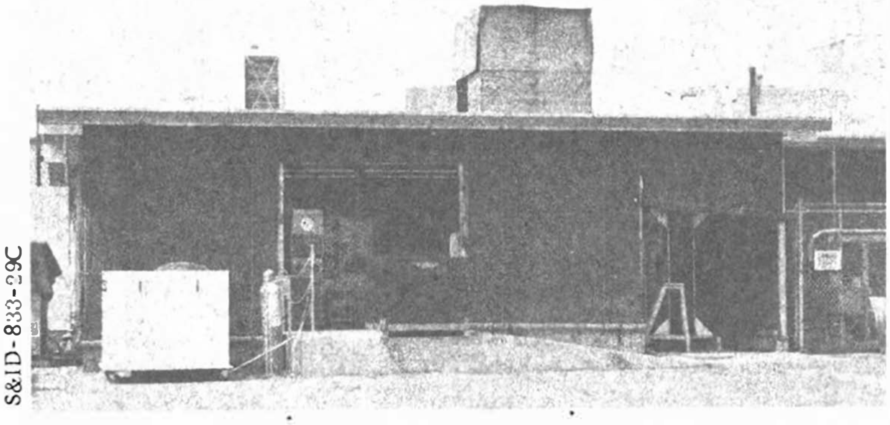


Figure 71. Slosh and Vortex Facility

The slosh and vortex facility was completed in February 1963 and activated at that time. It is operating in a satisfactory manner.

PRESSURIZATION SYSTEMS DEVELOPMENT FACILITY

The pressurization systems development facility will furnish a pneumatic system for the evaluation of the S-II propellant pressurization systems, subsystems, and components. It will consist of one new building and test equipment.

Design criteria for the pressurization systems development facility were issued on 18 January 1963; architectural and engineering (A&E) design was started on 23 April 1963. Originally, the facility was to be built adjacent to the cryogenic test facility, but because construction could not be programmed simultaneously with cryogenic testing, it was decided that the pressurization systems development facility would be relocated to a site approximately 100 feet north of the cryogenic test building.

A&E design, delayed because of this relocation, is to be completed by 30 August 1963. Construction of this facility is scheduled for completion in mid January 1964.

FLIGHT CONTROL SIMULATOR FACILITY

The flight control simulator will be used in the Saturn S-II program to develop engine actuation equipment and to check compliance of engine movement to programmed flights. The simulator will be used to establish operating and maintenance procedures and to improve reliability.

A heavy steel framework mounted in a pit will support the simulated J-2 engine and the actuation equipment. This equipment will be connected to the simulated engine to simulate different flight conditions.

Completion date for the flight control simulator facility is scheduled for 15 September 1963. Construction of the pit is expected to be completed on 23 August 1963, and assembly of the simulator will start on that date.

DATA GROUND STATION

The data ground station will be used to reduce taped telemeter data received from propulsion systems development areas and from the flight test area at the Atlantic Missile Range. Most of the data received will be transmitted by computer tape.

The equipment will include tape units, computers, printer-plotters, and associated equipment necessary for the data reduction system.

Design of the data ground station is under way, and construction completion is scheduled for 5 February 1964. Engineering and design criteria were established in early June 1963.

SEAL BEACH

Saturn S-II manufacturing facilities are being built at the Seal Beach site, a 35-acre area with 231,925 square feet (gross) of roofed facilities that include the following: bulkhead fabrication facility; vertical assembly-hydrostatic test facility; pneumatic test, paint, and packaging facility; service building; structural static test facility; and a control room and a gear and maintenance building that are integral parts of the structural static test facility. Aerial views of the Seal Beach site are shown in Figures 72 and 73.

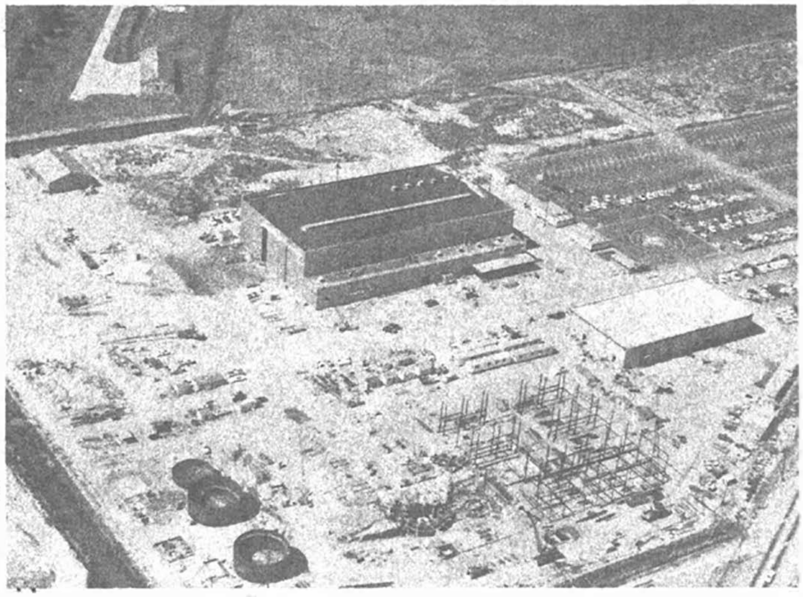


Figure 72. Seal Beach Site Construction as of 28 June 1963

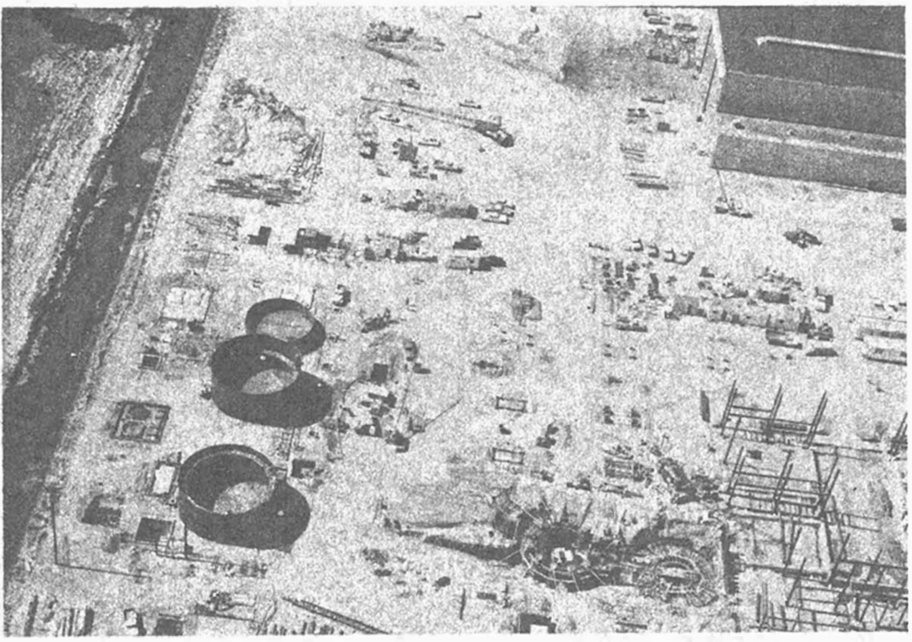


Figure 73. Seal Beach Site Construction as of 28 June 1963

Other features, which occupy 364,911 square feet (gross), include the following: water conditioning plant, electrical substations, helistop, employee parking area, outside runways and a dike area at the structural static test tower, and crane rails in the vertical assembly-hydrostatic test facility.

Paved concourses connecting the buildings consist of a 6-inch base course and 2-inch asphalt concrete cover that total 190,000 square feet.

A&E design is under the cognizance of S&ID, and construction is under the cognizance of the United States Navy.

SITE PREPARATION

Site preparation is 98 percent complete, the items remaining being base course and asphalt paving in areas where construction caused damage to the paving.

The 12-kv main switchgear was completed and energized on 17 April 1963. The south parking lot was completed on 16 March 1963. Underground water, gas, telephone, fire water, and air utilities were provided on 2 April 1963; and the sanitary sewer was completed on 24 April 1963. No major problems occurred during site preparation.

BULKHEAD FABRICATION FACILITY

The bulkhead fabrication facility (Figure 74) consists of a high bay area and a low-bay area. All bulkhead and cylinder welding, processing, testing, and bonding will be conducted in the high-bay area. The low-bay area supports the adhesive layup, honeycomb preparation, and metal testing.

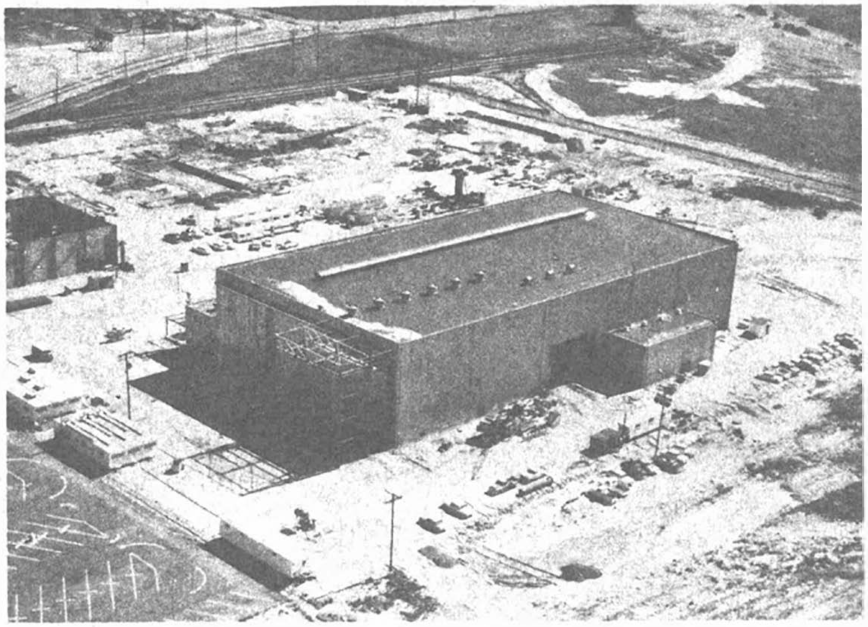


Figure 74. Bulkhead Fabrication Facility

Construction of the bulkhead fabrication facility is 95 percent complete. S&ID occupied 80 percent of the facility as of the end of this report period.

The United States Navy opened bids for the basic contract on 7 August 1962, and construction started on 20 August 1962. Design for major modifications and additions to this facility, including subassembly and expansion of the processing phases, began on 5 October 1962. The first increment of this design package was placed under construction contract in December 1962.

With the exception of a few minor field changes, prices have been negotiated with the builder for all current items under construction. Construction of this facility is scheduled for completion on 30 August 1963.

VERTICAL ASSEMBLY-HYDROSTATIC TEST FACILITY

The vertical assembly-hydrostatic test facility (Figures 75 and 76) consists of two connected areas—the vertical assembly area and the hydrostatic test area. The vertical assembly area comprises four stations where the S-II stage will be assembled. During assembly, components, and later, complete stages, will be transferred to the two-station hydrostatic test area.

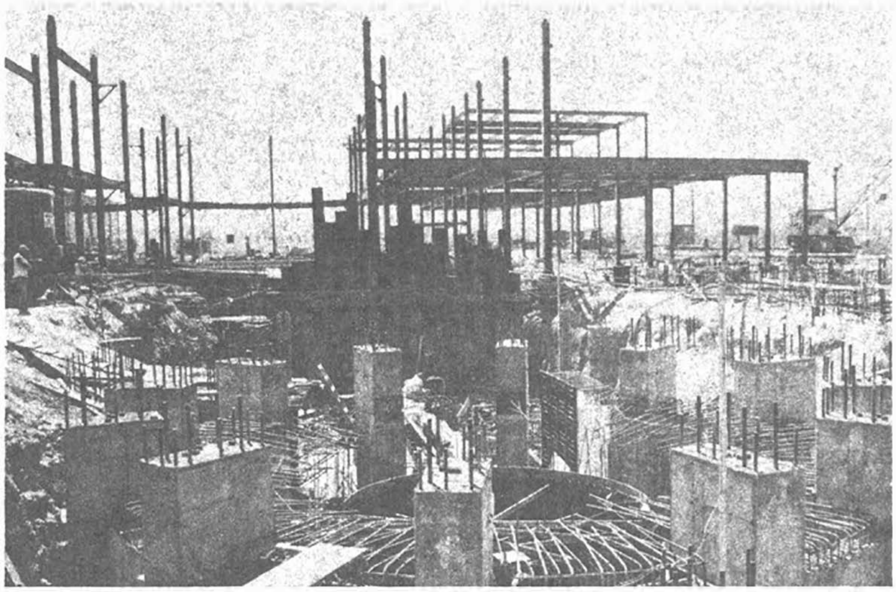

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Figure 75. Hydrostatic Test Portion of Vertical Assembly-Hydrostatic Test Facility as of 30 June 1963

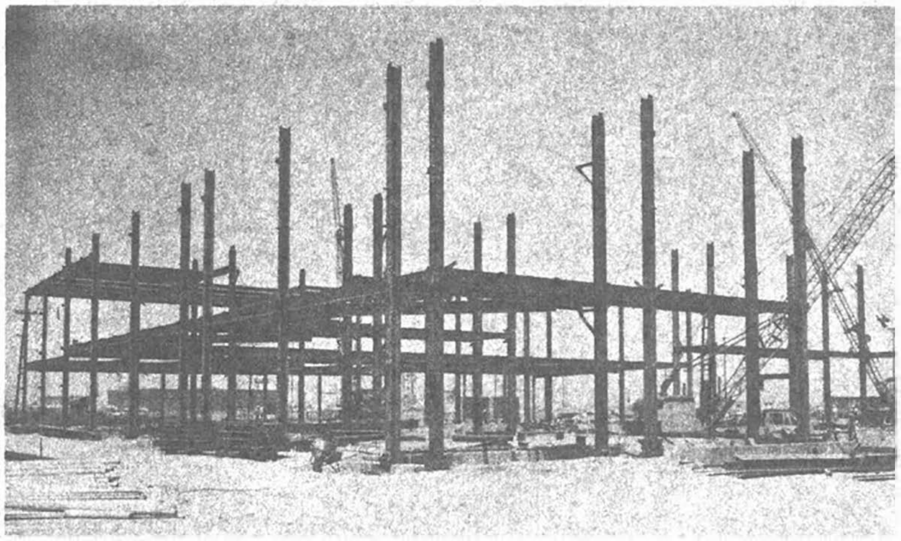
SEBE-810-35"I"

Figure 76. Vertical Assembly Portion of Vertical Assembly-Hydrostatic Test Facility as of 30 June 1963

Construction of the vertical assembly-hydrostatic test facility is 30 percent complete. The structural steel framework is being erected, supporting members and bracing are being installed, and the reinforced concrete for the hydrostatic test facility is being poured. Completion of the facility is scheduled for 5 June 1964.

The construction of this facility was divided into two phases due to funding constraints. Phase I consists of the construction of the foundation and procurement and installation of the cranes and hoists, substation, transfer table, and structural steel.

Phase II covers the remaining work, which involves enclosing the building, heating, lighting, air conditioning, and other operating requirements. Phase I was scheduled for completion by 30 August 1963; it was started on 9 September 1962.

The first scheduled occupancy date for the stage-handling dolly rails is 21 August 1963.

PNEUMATIC TEST, PAINT, AND PACKAGING FACILITY

The pneumatic test, paint, and packaging facility will be used for check-out of the S-II stage pressurization systems and for performance of leak and functional checks on the engine and propellant systems. Painting and packaging operations will be performed after systems checkout.

In anticipation of early appropriation of construction funds, this facility was scheduled as follows:

1. Design completion by 26 July 1963
2. Construction contract awarded by 1 October 1963
3. Construction completion by 1 April 1964

SERVICE BUILDING

The service building (Figure 77), an administrative and laboratory testing facility, is scheduled for completion on 2 September 1963. Construction was started on 1 March 1963 after a decision to provide facility funding for this building. The S&ID bids were returned unopened, and the project was rebid by the United States Navy. S&ID transmitted the drawings and specifications to the Navy on 2 January 1963.

Figure 77. Service Building Construction as of 30 June 1963

STRUCTURAL STATIC TEST FACILITY

The structural static test facility will be used for simulation of flight stresses on the S-II stage.

The gear and maintenance building portion (Figure 78) of this facility was completed on 9 April 1963; however, occupancy began on 19 February 1963.

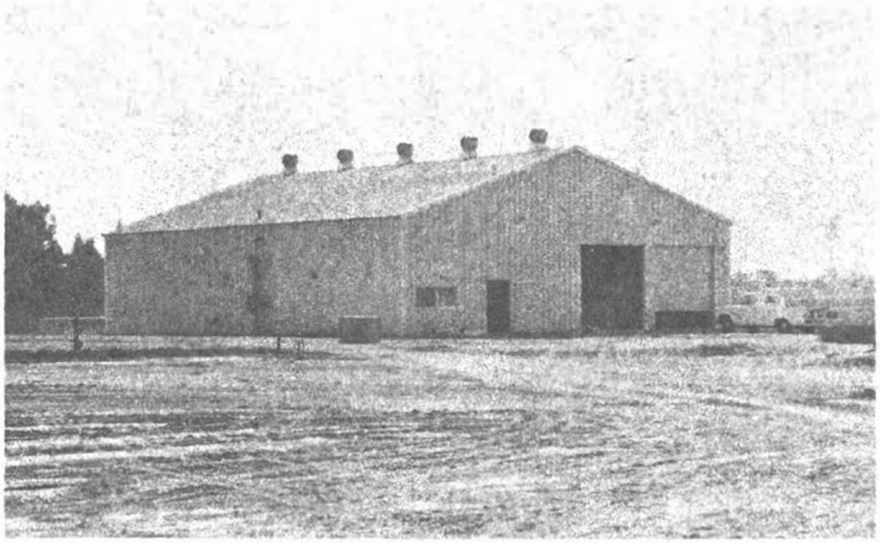

Figure 78. Gear and Maintenance Building

Plans and specifications for the tower portion of this facility are to be completed 31 July 1963, and construction is expected to begin on 1 October 1963; it is to be completed about 1 April 1964.

Plans and specifications for the foundation and dike portion of this facility are scheduled for completion on 2 August 1963; construction is expected to commence about 1 October 1963 and to be completed about 18 December 1963.

It is planned that the tower portion of this facility will be constructed under S&ID administration, but it is expected that construction administration will be transferred to the United States Navy by NASA.

WATER CONDITIONING PLANT

The final design of the water conditioning plant (Figure 79), which will provide demineralized water, water for fire emergencies, cleaning solution, and purified air, was transmitted to the Navy on 29 March 1963.

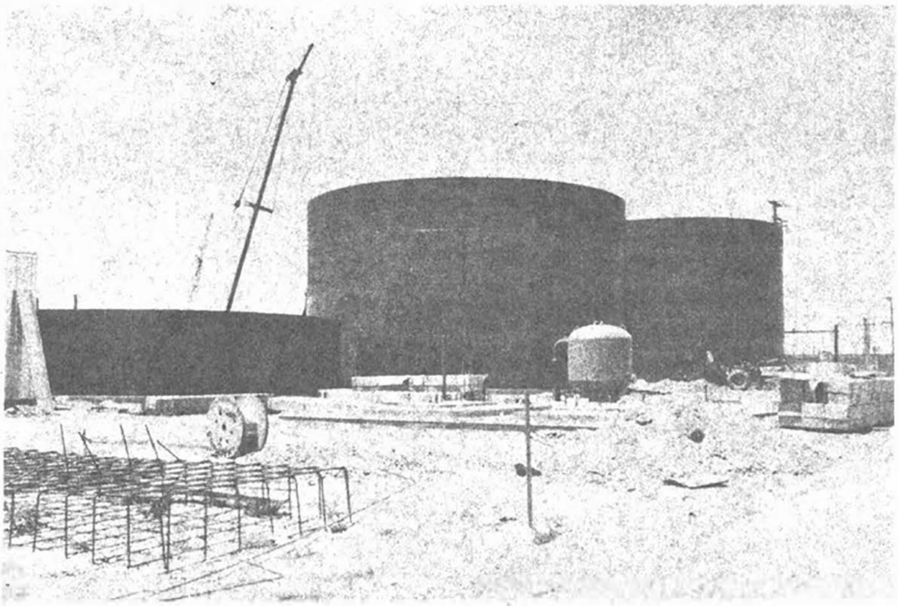

Figure 79. Water Conditioning Plant Status as of 30 June 1963

Construction was started on 29 April 1963 and is scheduled for completion on 28 September 1963. Plant air and demineralized water are expected to be available on 27 August 1963.

Construction of all underground work for the entire facility is virtually complete. Storage tanks and prefab building erection has been completed, and installation of above-grade piping and processing equipment is underway.

SANTA SUSANA

Static testing of the Saturn S-II stage will be conducted in the Coca area of Air Force Plant No. 57, Chatsworth, California, in the Santa Susana Mountain range. This facility is scheduled to be ready for activation by mid November 1963. Construction of the firing facility is being accomplished in five major projects because of the short over-all schedule for construction and activation of the facility. Aerial views of the Santa Susana site are shown in Figures 80 and 81.

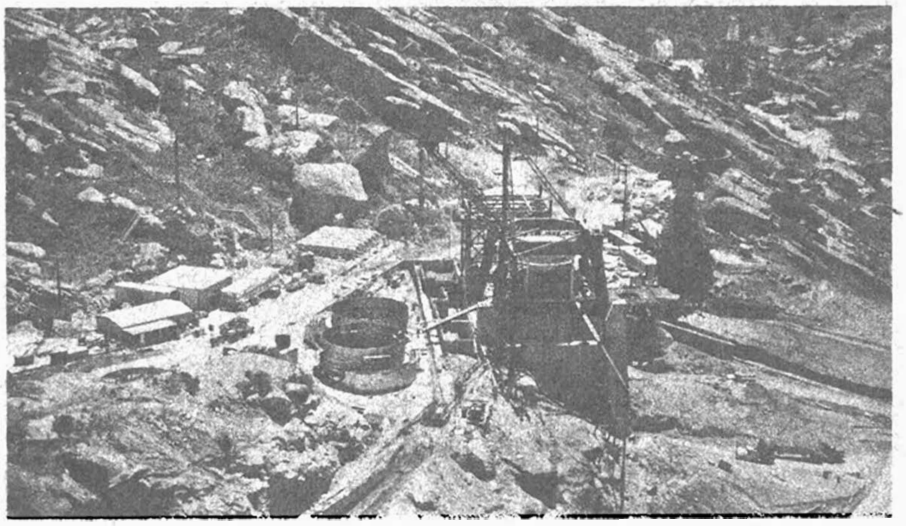

Figure 80. Aerial View of Coca 1 Construction as of 24 June 1963

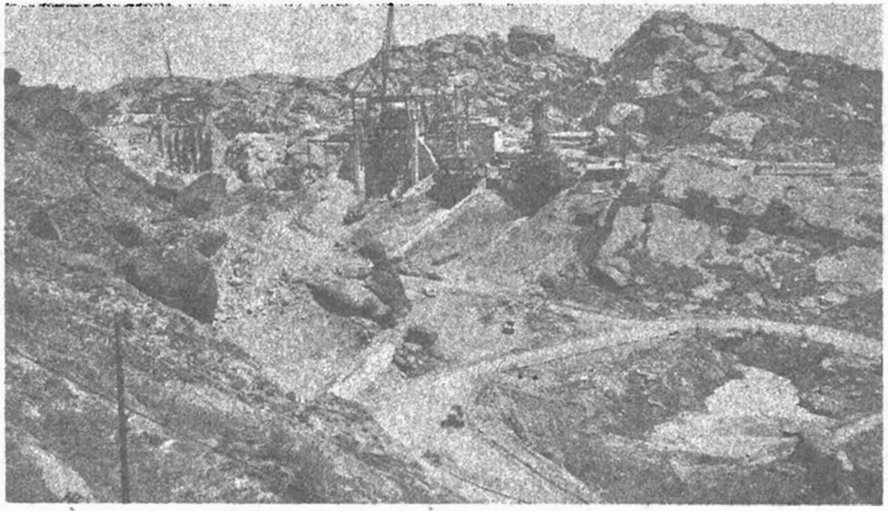

Figure 81. Aerial View of Coca 1 (foreground) and Coca 4 Construction as of 30 June 1963

The Rocketdyne Division of NAA has been assigned the responsibility for the coordination of design, construction, and activation of the facility because it is the contractor-operator of Air Force Plant No. 57. Rocketdyne performs its services under the direction and requirements of the S&ID Division S-II program office. The five major projects are as follows:

1. Battleship Test Stand
2. All-Systems Test Stand
3. Propellant and Pressurant Storage and Transfer Systems
4. Electrical and Instrumentation Systems
5. Area Services

Design has been completed on all of these items, and construction contracts have been awarded. Immediately upon completion of construction, NAA personnel will start activation effort and installation of GSE in support of the 8 June 1964 Battleship firing date.

BATTLESHIP TEST STAND COCA NO. 1

The Battleship test stand (Figure 82) and its associated facilities are being constructed to provide for the checkout and testing of complete systems and for the developmental test firing of the J-2 engine cluster. Full duration and intermediate firings of the five-engine cluster will be conducted on this stand.

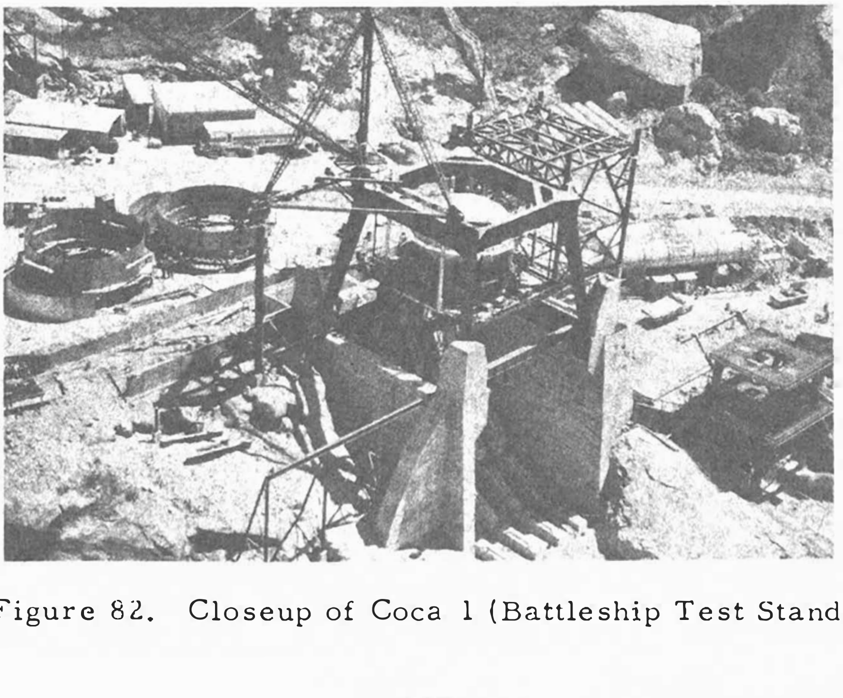
SANS-820-7C

Figure 82. Closeup of Coca 1 (Battleship Test Stand)

Construction of the concrete base of the Battleship test stand was completed 14 June 1963. The contract for the work was awarded to Oberg Construction Company, and construction began on 28 December 1962.

The contract for design, fabrication, and installation of the Battleship vessel was awarded to Pittsburgh-Des Moines Steel Company, and construction is approximately 50 percent complete. Construction was started on 14 August 1962 and is scheduled for completion on 24 September 1963.

Construction of the steel work for the test stand, awarded to the Kaiser Steel Company, is approximately 20 percent complete. Construction was started on 28 April 1963 and is scheduled for completion on 15 November 1963.

ALL-SYSTEMS TEST STAND COCA NO. 4

The All-Systems testing firing stand (Figure 83) is being constructed for the developmental and flight acceptance test firing of the complete Saturn S-II flight-weight stage. Automatic checkout and testing of all Saturn S-II systems will be performed on this stand. The test will verify the initial performance and the applicability of the Battleship test results to the flight-weight vehicle.

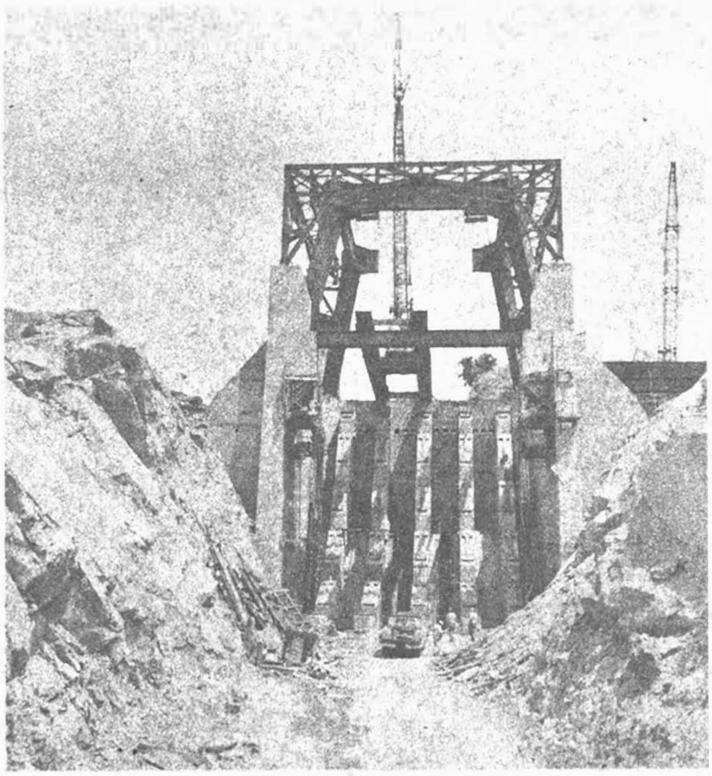
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Figure 83. Closeup of Coca 4 (All-Systems Test Stand)

Construction of the concrete base for the All-Systems test stand was scheduled for completion on 7 August 1963. The contract for this work was awarded to the Oberg Construction Company on 28 December 1962.

Construction of the superstructure of the test stand is approximately 25 percent complete and is scheduled for completion by 15 November 1963. The contract for this work was awarded to the Kaiser Steel Company on 28 April 1963.

PROPELLANT AND PRESSURANT STORAGE AND TRANSFER SYSTEMS

Complete fluid distribution systems have been provided in the Coca area to transfer propellants and gas, as required, to the test stands. Each is designed as a centralized system to provide fluids to either the Battleship test stand or to the All-Systems test stand.

Construction of the fluid transfer systems was awarded to the Alex Robertson Company, and construction began on 23 May 1963. Construction is approximately 20 percent complete and is scheduled for completion on 21 November 1963.

Figure 84 shows the status of the LH_2 storage vessel and Figure 85 the status of the GH_2 recovery sphere.

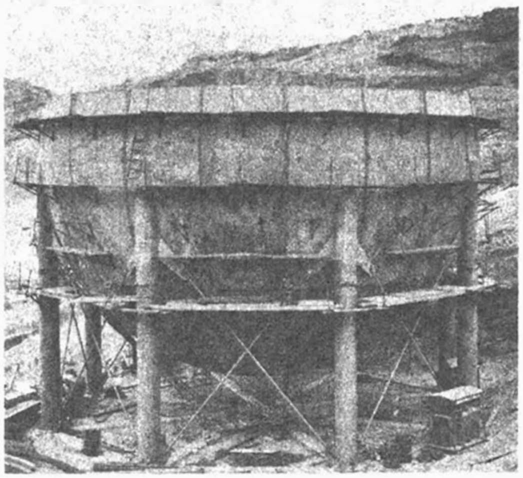

SANS-810-35GG

Figure 84. LH_2 Storage Vessel Construction as of 30 June 1963

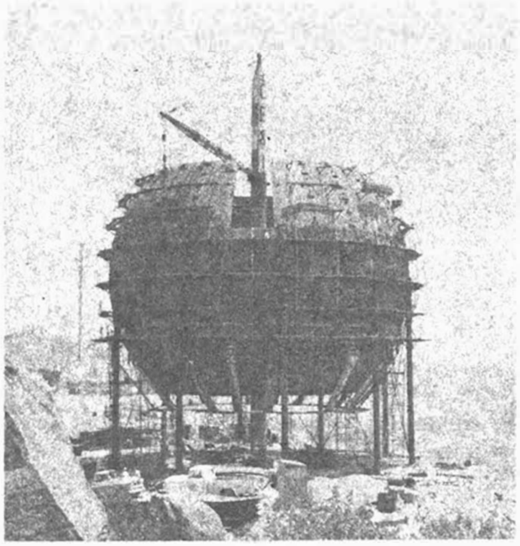

SANS-810-38P

Figure 85. GH_2 Recovery Sphere Construction as of 30 June 1963

ELECTRICAL AND INSTRUMENTATION SYSTEMS

The initial contract to modify the control center, which will house electrical and instrumentation systems, was awarded in April 1963; and work was started on 27 April 1963. Enlargement and modification of structural work on the control center is nearly complete. The cable tunnel, interconnecting the control center, the existing terminal house, and the test stands at Coca 1 and Coca 4, is complete.

Completion of the control center and the power and instrumentation cables for the Battleship tests is scheduled for June 1964 and for the All-Systems tests in April 1965.

AREA SERVICES

The first contract for Coca area services was awarded 14 September 1962, and work was started on 17 September 1962.

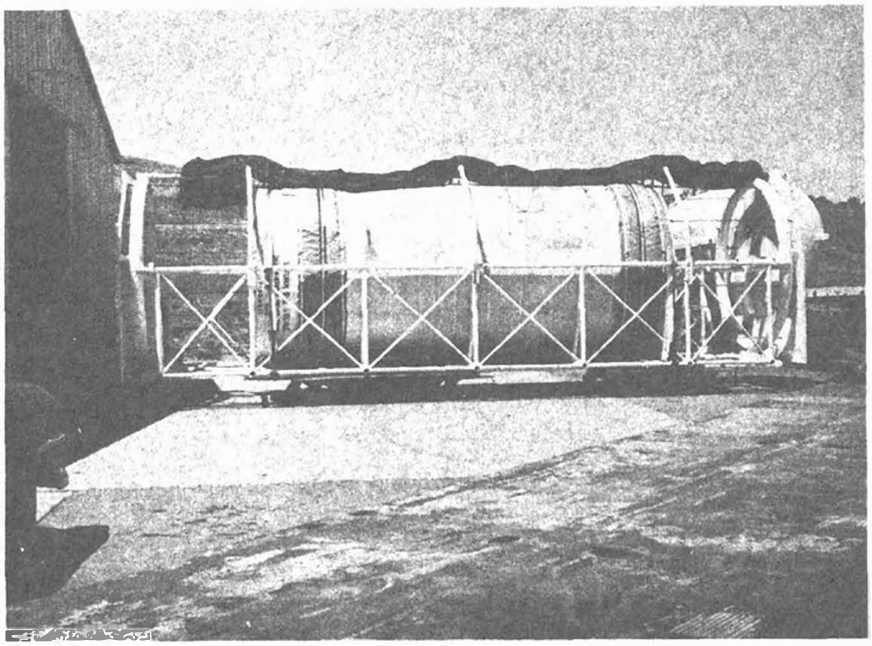
Water piping for fire control has been installed at the test stands, and the contract for an additional water storage vessel has been awarded.

Construction of the new pretest building and south observation bunker is well advanced, and work is underway on the spillway, the holding pond, and the overflow channel, all of which are required to accommodate the huge water run-off from the flame deflectors.

III. MANUFACTURING

QUARTER-SCALE TEST TANK

The Saturn S-II Manufacturing department has completed one quarter-scale test tank, a nondeliverable item, in support of Engineering testing requirements. This test tank was completed late in May 1963 and delivered to Beech Aircraft Corporation at their Boulder, Colorado facility, where it is being subjected to extensive testing. The purpose of this project is to determine the best method of insulating the LH_2 tank of the S-II stage. Another quarter-scale test tank, made from different materials by different techniques, will be completed late this year. Figure 86 shows the quarter-scale test tank at Beech Aircraft test facilities in Boulder, Colorado.

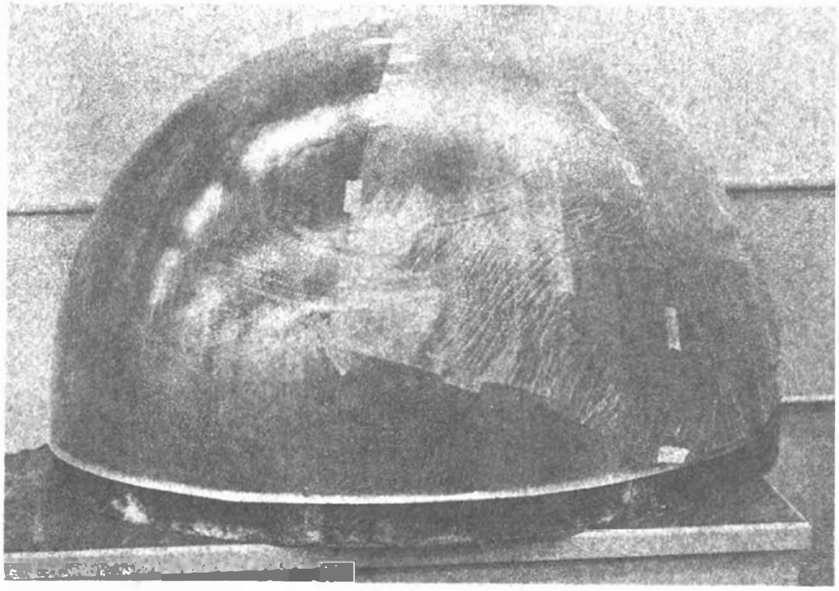


7006-81-430C

Figure 86. Quarter-Scale Test Tank at Beech Aircraft Test Facilities

TEST MODEL BULKHEADS

The 55-inch test model bulkhead program was also supported by S-II Manufacturing. This project is intended to verify the reliability of the existing design concepts for the common bulkhead. Manufacturing supported this undertaking by fabricating tooling that facilitates the bonding of the two facing sheets that compose each bulkhead. Manufacturing was also responsible for the actual bonding of these bulkheads. Four hemispherical and twelve ellipsoidal structures will be fabricated. As of 30 June, Manufacturing had completed nine of these bulkheads for evaluation by Engineering Development Laboratory personnel. Figures 16 and 87 show the ellipsoidal and hemispherical bulkheads respectively.



7006-01-28A

Figure 87. 55-Inch Hemispherical Test Bulkhead

SCALE MODELS

Six scale models of the S-II stage were completed by S-II Manufacturing and shipped to NASA at Huntsville, Alabama. These completions included three forty-eighth, two tenth-, and one twentieth-scale model. Figures 88, 89, and 90 show the twentieth-scale, tenth-scale, and forty-eighth scale models respectively.

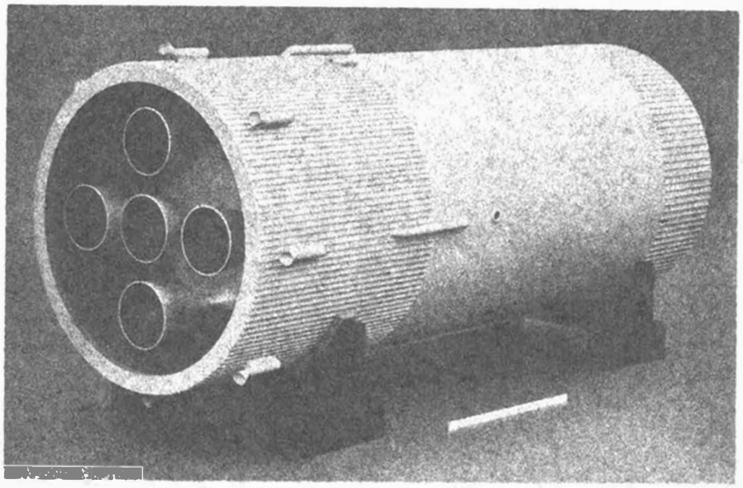


Figure 88. Twentieth-Scale Stage Model

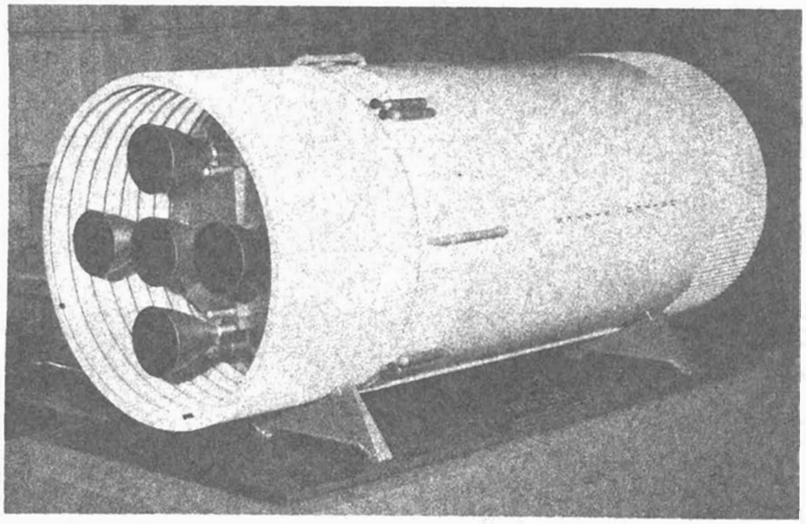


Figure 89. Tenth-Scale Stage Model

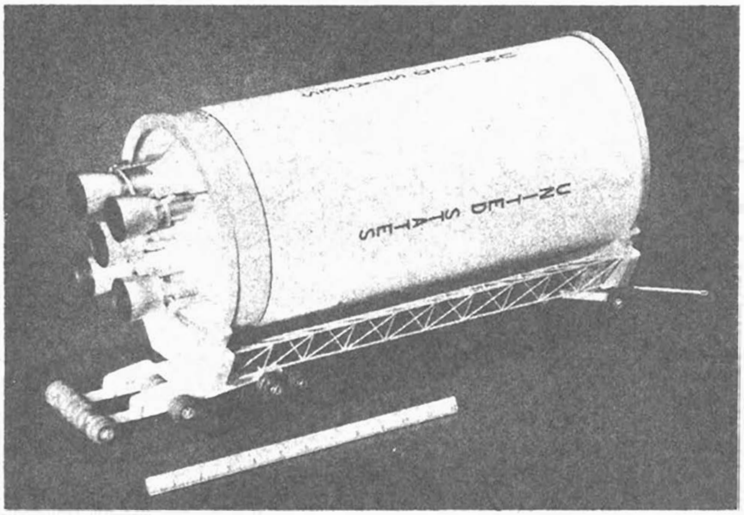


Figure 90. Forty-Eighth Scale Stage Model

ENGINE ACTUATION SYSTEM

The first preproduction hydraulic engine-actuation system was completed, approved by NASA, and delivered to Huntsville on 15 June as contractually committed. It was shipped unassembled at NASA's request. Certain MC fittings that were unavailable at the time were shipped several days later. Figure 91 shows the preproduction engine actuation system.

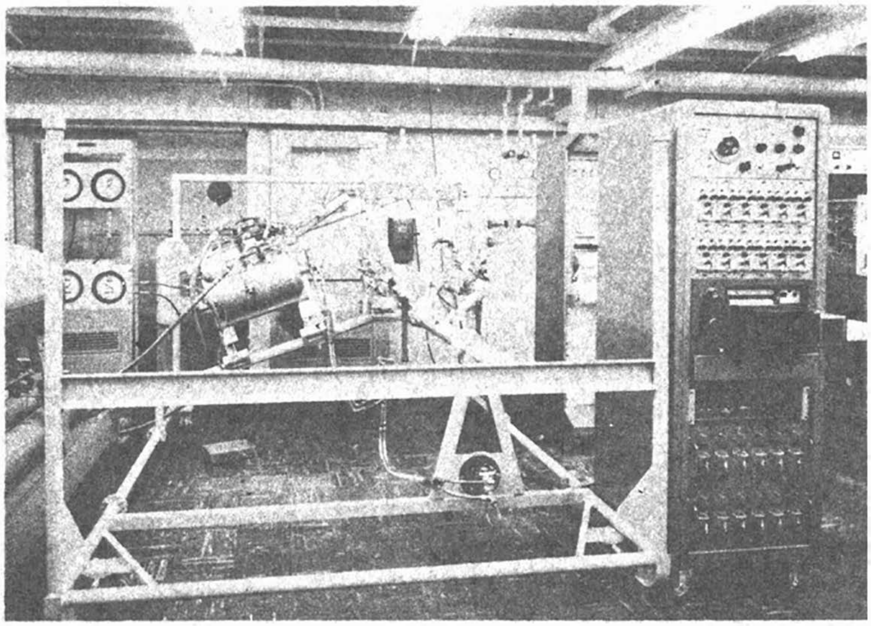


Figure 91. Preproduction Engine Actuation System

ELECTROMECHANICAL MOCK-UP

The facility for this mock-up was made available to S-II Manufacturing on 3 June 1963, and structures installation was begun immediately. By 30 June this installation was virtually complete, and two soft mock-up J-2 engines were installed. Manufacturing will now begin installation of dummy mock-up systems that will be replaced by flight-weight hardware as it is made available.

The Electromechanical Mock-Up will be used for conducting S-II stage systems integration, as well as for providing a controlled mock-up tool for S-II Manufacturing and Engineering. It will also provide a ground support equipment (GSE) automatic checkout actuation center.

DELIVERABLE MOCK-UP

This mock-up consists of two structures representing the forward area and the tail area of the S-II stage. These structures will be used by the S-IVB and the S-IC contractors to ensure accurate mating and clearance of the stages. The structure for the forward area of this mock-up will be full size and will consist of an aluminum-skin forward skirt, a fiberglass dome representing the forward bulkhead, wood or fiberglass instrumentation packages, and conventional materials for systems installation. The tail-area structure will consist of a short portion of the aft interstage, which will extend 74 inches above the mating plane. An engine support structure, 53 inches high and constructed of steel channel, will be attached to the aft interstage and will hold five broomstick-type engines. The center engine will be fixed in place, while the four outer engines will be capable of manual gimbaling. These engines will be made of steel pipe and plate.

The scheduled manufacturing completion date for both structures is 30 September 1963, in accordance with the contractual date of 30 October for delivery to MSFC. As of 30 June, the tail-area portion of this mock-up was approximately one month behind schedule as a result of a late tool completion and certain inspection procedures. The forward.area portion of this mock-up is on schedule and is progressing satisfactorily.

Since 30 June, a nearly complete catch-back effort has been accomplished on the tail-area structure. Both sections are now expected to be completed and delivered on schedule. Figure 92 shows the tail-area of the deliverable mock-up (right) and the upper-transitional section of it (left).

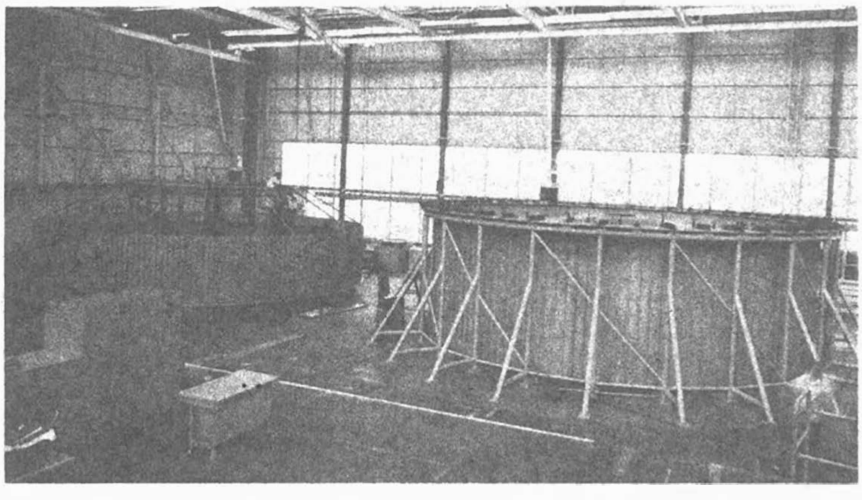

S&ID-810-19C

Figure 92. Deliverable Mock-Up, Tail Section Area (Right) and Upper-Transitional Section (Left)

SEPARATION PLANE TEST HARDWARE

S-II Manufacturing, in support of S-II Engineering testing requirements, has completed the separation plane structures and nine additional sets of splice plates for the S-II full-scale separation test. The structures represent two sections, each approximately 18 inches high. As of 30 June, this test article was slightly behind schedule as a result of material shortages. However, these shortages have been overcome, and the structures and splice plates have been delivered to the test site in accordance with internal Manufacturing schedules.

BATTLESHIP

The Battleship test stage is be constructed at the Propulsion Field Laboratory at Santa Susana by an outside contractor. S-II Manufacturing is primarily responsible for the fabrication of a mock-up forward skirt and work platform. A special thrust structure, being built by the Los Angeles Division (LAD), will be shipped directly to Santa Susana. S-II Manufacturing is also responsible for the fabrication of simulated systems, which will be installed in the test stage by the Test and Operations department. All four general systems categories, instrumentation, propulsion, electrical, and flight control, are represented by these simulated systems. While many of these systems were in work at a detail fabrication level as of 30 June 1963, most of the effort expended has been at an engineering level.

STATIC TEST STAGE

The Static test stage will consist of a structurally complete S-II stage, including tanks, bulkheads, thrust structure, and aft interstage. Engines will not be required, but engine support structure will be installed in the Seal Beach static-test facility with test support and loading fixtures to simulate the position of the S-IC and S-IVB stages.

The major manufacturing effort for the Saturn S-II program was accomplished at the Seal Beach and Tulsa Facilities of S&ID. Certain bulkhead tooling and production bulkhead details were accomplished by the Los Angeles Division. Tulsa is responsible for the fabrication of details and subassemblies for the thrust structure, and aft skirt, aft interstage, systems tunnel, and LOX-tank baffles. Subassembly of the tank structures, vehicle assembly, installations, checkout, and final shipment will be done at Seal Beach.

Tulsa effort for the year ending 30 June 1963 has been in the area of fabricating the necessary tooling, details, and subassemblies for the previously mentioned structures. The first structural item to be shipped from the Tulsa facility will be the thrust structure subassembly, which is scheduled to be delivered to Seal Beach on 25 October 1963 to support the assembly requirements for the Static Test stage.

As of 30 June, only initial effort had been completed at Seal Beach. The first gore segments for the aft common bulkhead of the Static test stage had been subassembled and minimum manufacturing schedules were being supported.

LAD is primarily responsible for the fabrication of bulkhead details and three of the six LH_2 cylinders. As of 30 June, seven bulkhead components had been fabricated at LAD, approved by NASA, and shipped to Seal Beach for subassembly.

Progress in the area of bulkhead components since 30 June has indicated that bulkhead assembly dates can be met by means of special parts handling and minimum flow time. The first stage (Static Test) is expected to be completed on schedule.

TOOLING

A sizeable portion of the S-II manufacturing effort has been in the area of tooling. Much effort and time have been expended on the high-energy forming dies and automatic weld jigs for the S-II bulkhead details and assemblies. The responsibility for the fabrication of these types of tooling involved S&ID, LAD, and Rocketdyne.

HIGH-ENERGY FORMING DIES

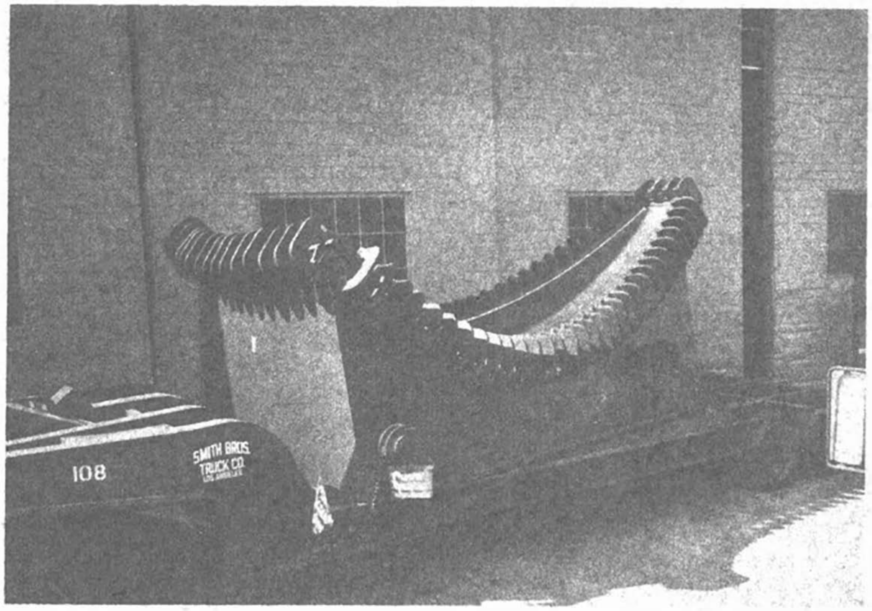
Originally, responsibility for the fabrication of the high-energy forming dies and the forming of parts by this method was delegated to Rocketdyne. The dies were being fabricated by the L. A. Division, and the forming was being done at El Toro. Scheduling and fabrication difficulties necessitated the activation of alternative forming procedures. The first alternative, hydropress forming, was dropped, primarily because a representative number of bidders with adequate equipment could not be found. The second alternate, bump forming, was dropped after initial efforts by the subcontractor. Parts formed by this method were so far out of tolerance that even if they had been further formed by means of creep sizing, they would not be usable as production parts.

In the meantime, extensive testing had been completed in the area of creep sizing by use of glass-rock dies. Encouraging results were obtained from these tests. Until bump forming was determined to be unsuitable for this program, creep sizing was being developed for use as a complement to bump forming for certain gore segments.

In order to alleviate the near-critical production schedule position that was developing as these alternate forming methods were being researched, Project King Size was initiated. This project consists basically of the fabrication of glass-rock dies upon which aluminum bulkhead components are formed from flat material by means of high-heat-age and quick-quench cycle.

This method is still being developed as a future alternative and is also being used to produce check fixtures for formed parts.

Responsibility for high-energy forming was transferred to LAD, where better facilities and more manpower were available. This division very successfully carried on the high-energy forming program. By using data gathered from Rocketdyne's experiences, LAD completed the fabrication of the dies, oversaw their installation, and accomplished the forming of the first acceptable production gore segments on 7 June 1963. Figure 93 shows a high-energy forming die.



7006-86-176"1"

Figure 93. High-Energy Forming Die

AUTOMATIC WELDERS

Another major tooling effort has been the fabrication of automatic weld jigs:

1.	T7200052	Segment welder for aft-common and aft bulkhead gore sections
2.	T7200003	Assembly welder for the gores composing the aft common and aft bulkheads
3.	T7200181	Segment welder for the forward common bulkhead thin gore sections and J sections
4.	T7200002	Assembly welder for the forward common bulkhead components
5.	T7200077	Dome center (dollar) welder for joining all assembled gores at bulkhead centers
6.	T7200120	Assembly welder for forward bulkhead gores
7.	T7200015 T7200040	Circumferential welder for joining the aft and common bulkheads; also welds forward common bulkhead to Number 6 cylinder and Number 6 cylinder to Number 5 cylinder
8.	T7200001	Vertical welder for joining LH_2 cylinder panels
	T7200515	Support
	T7200039	Skate
	T7200040	Welder
	T7200041	Trim skate
	T7200015	Support fixture
9.		Circumferential welder for joining LH_2 cylinders in vertical assembly sequence

As of 30 June 1963, the first five of these welders had been completed. The first welder had been certified and was in production. Two aft common bulkhead gores had been subassembled. The other four welders were in various stages of installation, certification, and rework. Figures 94, 95, and 96 show the aft common bulkhead welder, the dome center welder, and the thick-to-thin gore segment welder.

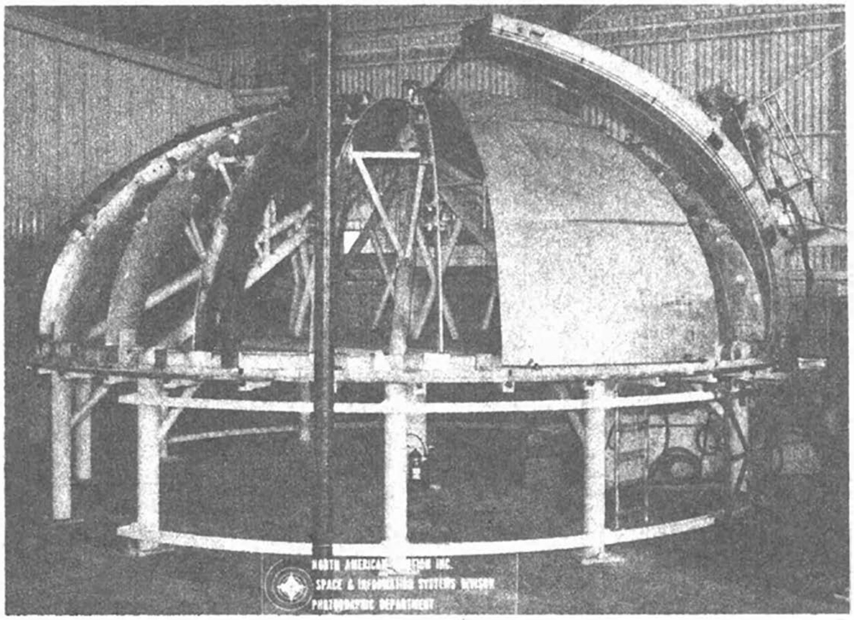


Figure 94. Aft Common Bulkhead Welder

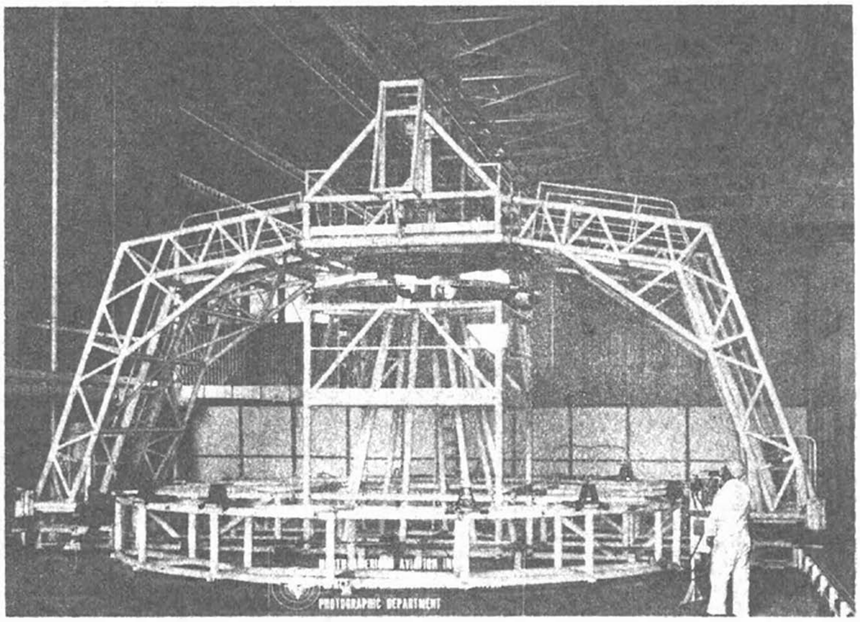


Figure 95. Dome Center Welder

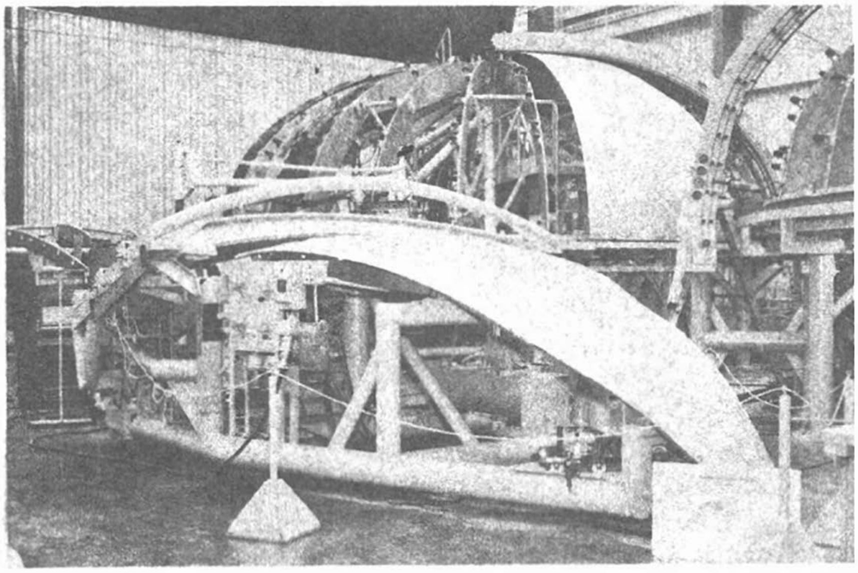


Figure 96. Thick-to-Thin Gore Segment Welder

GROUND SUPPORT EQUIPMENT

All Manufacturing effort on the GSE program has been at the detail fabrication level. This apparent lag has been caused by the many redirections (engineering design changes) from Phase I reviews. These have greatly affected the Engineering drawing release schedules, which in turn have caused continuous Manufacturing schedule revisions. During the month of June, schedule exercises were performed on all GSE checkout equipment in an attempt to determine a realistic Manufacturing schedule that would be supported by the Engineering design. The results of these scheduled exercises indicated that the 100 percent delivery of GSE to the EMM would shift from December 1963 to March 1964.

The first EMM checkout equipment to be delivered, model C7-106, is scheduled for completion 29 November 1963.

Auxiliary, handling, and servicing items are being fabricated principally at Rocketdyne and Tulsa. Much of this equipment has been deleted, at customer request, or reidentified as special development devices.

Two pieces of GSE—the H7-20, simulator, engine actuator, and the A7-14, illumination set—were completed at Tulsa and delivered to Downey on schedule.

IV. QUALITY CONTROL

PROCUREMENT

Quality Control specification MQ0802-001, General Requirements for Supplier's Quality Control System, was approved by NASA and implemented on the Saturn S-II program.

The supplier survey questionnaire form (902-V) was completely revised. The questionnaire now has 12 sections that contain questions relevant to the following major Quality Control functions:

Organization

Stamp control

Drawings, specifications, and standards

Tool and gauge control

Material review

Processing control

Receiving and shipping

Age control

Stockrooms

Shop control

Corrective action

Supplier controls

The supplier survey rating system was revised. Suppliers are now given one of the following ratings:

Approval

Conditional approval

Limited approval

Disapproval

Suppliers receiving a rating of conditional approval are required to correct deficiencies within a specified time period should they be awarded a contract.

The requirement for purchase order review prior to release was implemented by the release of policy J-417, Quality Assurance Purchase Order Review.

Inspection bulletin No. IB 6-15, defining quality requirements for the interdivision work authorization system, was developed, approved by Quality Control and NASA, and released.

On 15 June 1963, the Los Angeles Division (LAD) submitted their quality control plan covering the fabrication of bulkhead gore segments. This plan incorporated comments furnished previously by S&ID Quality Control and was approved as submitted. The LAD quality control plan relating to the design and fabrication of the Battleship thrust structure was also submitted and approved by S-II Quality Control.

MANUFACTURING

The following major items were accepted by S&ID and NASA Quality Control and were delivered during this reporting period.

Item	Date
Forty-eighth- and tenth-scale models	10 October 1962
Twentieth-scale soft model of the S-II stage	1 February 1963
Tenth-scale diorama model	14 May 1963
Two forty-eighth-scale models	11 June 1963
Quarter-scale test tank	11 June 1963

The Seal Beach Facilities Inspection Plan was released as bulletin 3-5 on 28 June 1963. First-shift operations at Seal Beach, consisting of common bulkhead fabrication with radiographic-inspection support from Quality Control, began 11 June 1963. The first production thick-to-thin gore section was welded, and radiographic inspection was performed. Very good results were obtained. One repair was necessary for oxide inclusions; otherwise the weld was radiographically acceptable.

Automatic weld jigs T7200052 and T7200181 for the thick-to-thin gore skin weld were certified at Seal Beach.

As of this reporting period, seven production gore assemblies have been welded, and approximately fifteen NCR's have been initiated. Satisfactory resolution of these discrepancies and initiation of appropriate corrective action are being accomplished.

ELECTROMECHANICAL MOCK-UP (EMM)

The very rigid reliability requirements and the small number of stages to be produced in the Saturn S-II program made it imperative that Quality Control take action to assure that the first article manufactured would comply with all requirements when installed in the initial end item. Quality Control personnel have therefore written procedures to be followed for EMM activities. These procedures are designed to control the EMM from the first lay-in of wiring and tubing through all steps of manufacturing.

REVIEW FUNCTIONS

SPECIFICATION REVIEW

Twenty-one general quality control specifications were issued or revised during this reporting period. These revisions were incorporated to clarify the specifications and to keep abreast of the requirements necessary to ensure quality and customer requirements. The specifications are constantly updated by means of intense coordination with all responsible personnel. Examples of this can be cited in MQ 0503-002 Identification and Traceability Requirements for Suppliers (revision), dated 22 April 1963, and MQ 0802-001A General Requirements for Suppliers Quality Control System (revision), scheduled for release in the immediate future.

A document entitled Guide and Instructions for Review of Procurement Specifications by Quality Engineers has been developed. It is to be used to obtain correlated results and provide systematic records of procurement specification reviews. Use of the guide helps the reviewer to ensure that each specification meets the high standards required by Quality Assurance and the customer.

A check list is used by Quality Engineering in reviewing procurement specifications and becomes a part of the documentation files.

During this reporting period, the following documents were reviewed:

24 supplier documents

191 procurement specifications (prior to release)

283 specification control drawings (prior to release)

Acceptance test requirements were developed for 349 procurement documents.

DESIGN REVIEW

Quality Control has participated in design review since the beginning of the S-II program by reviewing the design of the stage, ground support equipment, and facility equipment. Quality Control engineers also provide support to the Reliability design review program.

Typical Quality Control action items resulting from the S-II design review program are as follows.

Aft Skirt Structure - Major Review

Inspection Planning has been requested to provide stringent inspection of the entire aft skirt/aft interstage mating area at Station 196.

Thrust Structure - Major Review

Quality Control proposed that detail dimensions be added to structural parts drawings to permit adequate product inspection.

C7-200 Electrical Checkout Station - Preliminary Review

Quality Control and Logistics collaborated in preparing and documenting the procedure for utilizing the ac and dc standards provided in this equipment for calibration of measurement devices.

Linear Spaced Charge (LSC) Separation Assembly - Preliminary Review

Quality Control recommended that rejection criteria be added to the material specification for the LSC.

Propellant Fill Valve - Major Review

Quality Control investigated the acceptability, from an inspection as well as a functional standpoint, of the installed check valves on this assembly.

INSPECTION PLANNING

Since the award of the Saturn S-II contract, S&ID has completely revised its inspection-planning system to conform with the requirements of NASA quality publication NPC 200-2. Inspection activity on all items is now documented in the fabrication, assembly, and inspection record (FAIR). The FAIR record includes operations to be performed by Manufacturing and Quality Control, thus providing a closer relationship between these departments.

The inspection test effort required for flight articles is described in Volume II of the Saturn S-II Quality Control Plan, SID 62-285. The requirements in the Quality Control Plan are expanded on the FAIR ticket to show detailed operations. The FAIR ticket is the authorizing document for all manufactured items.

The working relationship between S&ID Inspection and NASA-0 Inspection has been defined through negotiations between the two organizations. In accordance with contract provisions, inspection is conducted by NASA continuously throughout the program. Certain inspection points are considered mandatory by NASA-0. When fabrication and assembly operations are completed up to such a point, NASA-0 inspection is performed.

Plans have been made to establish the criteria for inspection control and the recording of variable data in the project equipment installation records (PEIR) system. This system will be used to document the construction of facilities, the installation of plant equipment, and the fabrication and installation of project equipment for the Seal Beach and Santa Susana facilities.

DOCUMENTATION

QUALITY CONTROL PLANS

Preliminary editions of volumes I and II of the Saturn S-II Quality Control Plan were issued on 21 May 1962. Volume I describes the organization and functional responsibilities within the Test and Quality Assurance department. Selected Quality Control operating procedures (QCOP's) from the S&ID Test and Quality Assurance Manual (TQAM) and pertinent specifications were included in order to better describe Quality Control in the areas of procurement, product inspection, inspection planning, design review, test operations, process control, and audits. Volume II presents Quality Control requirements by relating inspection control points to flow charts of manufacturing operations.

A revision of Volume I of the Quality Control Plan was issued on 30 October 1962; a revision of Volume II was released on 31 December 1962. These revisions updated the documents to show the evolution of S&ID's Test and Quality Assurance department organization and functional responsibilities, including program changes and the quality control requirements for the Saturn S-II program.

The Saturn S-II Quality Control Plan is again being revised to include the latest changes in organization, methods, procedures, and functional responsibilities in the Quality Control program.

REPORTING

Sixteen issues of the Monthly Quality Status Report (SID 62-446) and five 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

Discrepant material dispositions were used for material review board (MRB) dispositions until late October 1962. At that time, a new system of handling MRB actions by utilizing the nonconformance reports (NCR's) in conjunction with S-II material review procedure M2-4.1.1, was initiated. This system conforms to the requirements of NASA quality publication NPC 200-2, section 8, "Nonconforming Material." The NCR activity since October 1, 1962 has been as follows:

Month	Quantity of NCR's
October	2
November	0
December	0
January	2
February	0
March	15
April	28

Month	Quantity of NCR's
May	38
June	66
	Total 151

The following significant corrective actions have result from NCR activity.

Changes were made in the drawings of Parker Aircraft Company's barrel assembly-accumulator, part No. S62A3092. A sharp radius on the unit, which was causing the plating to chip, was widened.

Corrective action requests were initiated in order to resolve a conflict of acceptance criteria for heat marks between process specification MA0113-002 and material specification MB0130-002. The conflict between these specifications, which are used for the manufacture and inspection of printed-circuit boards, made acceptance criteria ambiguous.

Gore section V7-313105 was cold formed after heat treatment. Cold forming is not required for proper contour on FAIR tickets. A corrective action request was directed to Engineering for an investigation of the condition. The Engineering Development Laboratory was requested to perform an analysis, in coordination with the Quality Engineering Laboratory, of the properties of this material on assembly and to determine whether the cold-forming operation must be performed. Action is expected to be completed by 1 September 1963.

A canning condition appeared in panel V7-313111-3 after it had been welded to panel 313108-5 to become gore-segment assembly V7-313105. This condition was submitted to Quality Engineering Laboratory for investigation. It was found that the vacuum chuck for holding the assembly in the weld jig did not function with vacuum pressure over its complete area (the tool is now being reworked). Tests were made on two panels by using this tool, sealed with tape, and a manometer adapted to a vacuum pump with a hand-operated valve to regulate vacuum on selection.

The fixture was installed on the first panel just forward of the horizontal weld, and vacuum was applied. The canning began to diminish at approximately 4-1/2 to 5 psi and was completely removed at 8 to 9 psi. Vacuum was applied and released several times, and conditions seemed to be constant. The second panel was then checked in the same manner; the canning began to diminish at 1. 5 to 2 psi and was completely removed at 4. 5 to 5 psi. This information has been transmitted to Engineering for comments and/or action.

QUALITY CONTROL PERFORMANCE AUDITS

During this reporting period, 345 audits were conducted. Following are the numbers of audits conducted in each category and the improvements effected as a direct result of the audit effort.

Audit		Improvement	
Procedure Review	106	14 percent	Improved coverage
Product	33	7 percent	Improvement in product inspection
Conformance to Procedures	135	20 percent	Improvement in conformance
Personnel Performance	71	13 percent	Improved job knowledge

QUALITY ENGINEERING LABORATORY ACTIVITY

ATMOSPHERIC CORROSION TESTS

Atmospheric-corrosion tests of aluminum-alloy panels were conducted at the Seal Beach facility. The test panels were exposed outdoors at an angle of 15 degrees from the horizontal, facing the prevailing sea breezes. The panels were examined after one week of exposure. Aluminum alloys 2014, 2024, 7075 bare, and 2024 clad, cleaned as directed in specification MA0110-011 but without protective coatings, showed evidence of corrosion. Aluminum alloy 6061 bare, prepared similarly, did not show corrosion. All of these alloys, without protective coatings, corroded when processed according to specification MA0110-024 (FPL etch), Table TT. There was no apparent corrosion of alloys protected with chemical films as described in specification MA0109-003 or of panels which were anodized per specification MA0109-009. There was one exception: the 7075 bare panel coated with the colorless chemical film was slightly corroded. The exposure testing is being continued in order to determine corrosion rates at Seal Beach.

METALLOGRAPHIC MICROSCOPE

A Leitz MM5 metallograph was set up in the laboratory area of Building 4 on 13 May 1963. This instrument will be used for extensive work in such areas as materials acceptance testing, process control of metals, electrical connections, circuit boards, and failure analysis, and in a variety of Quality Control investigations.

PREPRODUCTION HYDRAULIC ACTUATION UNIT

The Quality Engineering Laboratory provided extensive support for manufacturing build-up of the first preproduction Saturn hydraulic actuation unit. More than 400 parts were acceptance tested for cleanliness by performing hydraulic fluid counts. Many of the parts were cleaned four or five times before they met the necessary cleanliness levels. Over 50 percent of the parts submitted for inspection required final cleaning by laboratory personnel.

INFRARED THERMOGRAPHY

A demonstration of the Barnes heat-sensitive infrared camera was conducted in the nondestructive testing laboratory on 18 June 1963. Bonded honeycomb structures and a circuit board were used as test parts.

The thermal image is formed by this camera on a Polaroid Land picture material so that a finished print or transparency is available 10 seconds after a scanning cycle. Further evaluation studies of this equipment are being conducted.

OPTICAL PYROMETER CALIBRATION SYSTEM

An electrical circuit has been designed to control the brightness of the tungsten-strip lamps of the optical-pyrometer calibration system. Temperature standards laboratory personnel have designed and tested, and are now building, special liquid-cooled resistors. These resistors meet the high precision requirements of the optical-pyrometer calibration system.

ULTRASONIC TECHNIQUES

Laboratory personnel gave a demonstration of ultrasonic techniques and methods for members of S-II Engineering, the Engineering Development Laboratory, and resident NASA-QUAL representatives. The demonstrations included use of the Fokker bond tester; Kelvin-Hughes, Pulse-Echo, and through-transmission systems; and the Sonafax recording system. Panels representing the Saturn bonded structures were used to indicate how these instruments operate.

FLUORESCENT-PENETRANT INSPECTION

A full-size S-II bulkhead gore section has been fluorescent-penetrant inspected by members of the nondestructive testing group. The penetrant and emulsifier were applied by the use of airless spray equipment operated at a line pressure of 100 psi. A 0.062 spray-tip orifice was used to apply both materials (Shannon P-148 fluorescent penetrant and E-153 emulsifier).

Approximately one quart of penetrant and one-half gallon of emulsifier were used on each side of the gore. Final inspection under black light revealed no detrimental discontinuities.

EDDY-CURRENT DEFECTOMETER

After various eddy-current defectometer models were evaluated, Model 2154 was purchased from the Institute Dr. Forster, Reutlinger, West Germany. It is being used in the Quality Control Laboratory to establish standards for the inspection of Saturn S-II LOX-wetted surfaces from test blocks with known crack depths.

TUBE FLARES

The Leonard flaring machine in the Quality Engineering Laboratory has now been semiautomated and is in the process of proving repeatability. An improved method of cutting and deburring has been developed.

TRAINING AND CERTIFICATION

The number of Quality Control personnel holding valid certificates (for all programs) in the various areas of inspection is adequate for the current manufacturing rates. The number of personnel is as follows:

Course	Certified Personnel
Soldering	120
Visible dye penetrant, Type II, Class 3	37
Fluorescent penetrant, Type I, Class 2	9
Penestrip inspection, Class 4	2
Ultrasonic, Types I and II	5
Magnetic particle, Classes 1 and 2	9
Magnetic particle, Class 3	2
Fusion welding	100
Radiographic film interpreters	14

V. TRANSPORTATION

ROUTE CLEARANCES

The modification plans for overland routes to be traveled by the segments and the All-Systems stage have required continuous monitoring. All of the governing municipalities assured S&ID that permits will be issued for both the Type I and Type II transporters. In June 1963, the Type II transporter without the modular wheel concept was approved by NASA.

The first requirement for the Type I transporter will be to transport the bulkhead test specimen from Seal Beach to Santa Susana via Port Hueneme, in March 1964. The overland routes will be cleared for the move and will be left open throughout the Saturn program. The second and third requirements will be the movement of the fit-up fixture in October 1964 and the movement of the All-Systems stage in January 1965. After completion of these movements, the Type I transporter will be returned to Seal Beach, where it will be used as an in-house transporter and as a back-up unit for the flight stages destined for MTF and AMR. Figure 97 shows a model of the Type I transporter.

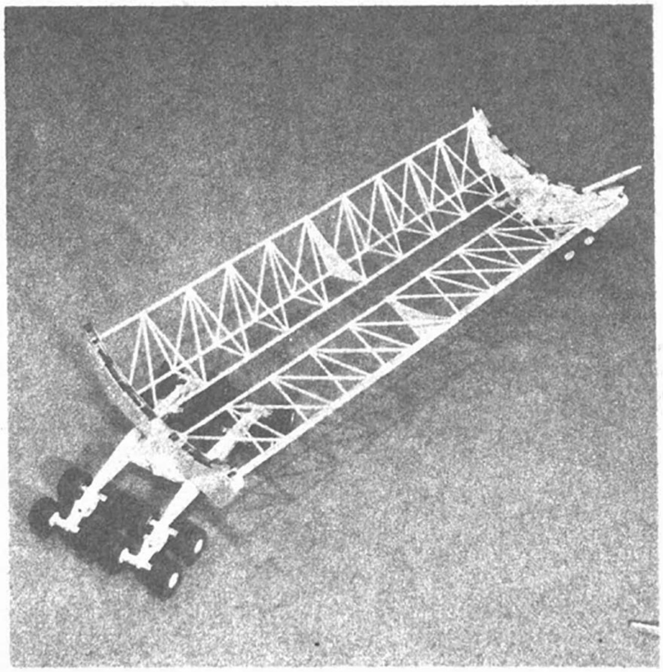


Figure 97. Type I Transporter

The route for the Type I transporter has been established. At dock facilities, units will be transferred by means of the roll-on and roll-off methods.

The Type II transporter is less complex than the Type I and has heavier wheel and axle loadings; it will be used only between the Seal Beach manufacturing site, MTF, and AMR.

All contracts for clearance of the overland route by the utility companies are being negotiated and will be written by September 1963.

The State of California Highway Department will have the primary responsibility for completing all road construction between Port Hueneme and Santa Susana, since most of the route is over State highways. The State of California Engineering Department began work in April 1963, using criteria furnished by North American Aviation for turning radius and wheel and axle loadings and spacing, to determine its requirements for modifications.

The Rocketdyne access-road clearance has been funded by North American Aviation, and modification will begin in September 1963. Criteria for the necessary tree trimming have been formulated and are being transposed onto maps in order to expedite negotiations for the necessary permits. The actual work of trimming trees will require only two weeks and will be done just before the move in order to avoid the necessity of trimming additional growth. All modifications will be completed by 31 December 1963.

MATERIAL AND PARTS HANDLING

The Traffic department, in conjunction with the Safety and Training departments, has conducted continuous training programs in material handling for NAA personnel. These training programs will be continued throughout the Saturn program to assure top-quality performance. The size, delicate nature, and unique characteristics of the raw materials, tooling, and fixtures for the Saturn program require the utmost attention in preparation, handling, and packaging. A weekly average of 15 oversized loads was handled between the S&ID facilities, North American support facilities, and suppliers. These units have been up to 18 feet high and 33 feet in diameter.

ELECTROMECHANICAL MOCK-UP

On 6 May 1963, the Electromechanical Mock-Up segments were moved from the manufacturing area, Building 1, Downey, to the south side of

Building 2, Downey. These segments were 16 feet high and 33 feet in diameter. The move was completed as planned without any problems. S&ID Security, as well as Downey City police, escorted the loads and controlled the traffic on Imperial Highway and Clark Street.

NEW METHODS OF TRANSPORTATION

Extensive effort has been made in search of new methods and modes of transportation. The use of helicopters for transport has been reviewed, and it was found that their lifting capacity was limited to 3000 pounds. The items to be lifted would also have to be small because of the sail that occurs when large units are attached to the outside of the helicopters. Clearance by the Federal Aeronautics Administration (FAA), a limited flight perimeter, and excessive operation costs also restrict the use of helicopters. S&ID is conducting a survey of the possible use of helicopters for transporting gore segments that must remain frozen during moves between manufacturing sites within the Los Angeles area.

AIR TRANSPORTATION

A converted B-377 Stratocruiser, owned and operated by Aerospace Industries of Van Nuys, has undergone the required test flights and been approved by FAA. NASA has contracted for it to transport engines, GSE, and spares in the Saturn program. Figure 98 shows the modified B-377 Stratocruiser, known as the "Pregnant Guppy."

AKD TEST RUN

On 12 March 1963, a test run with the AKD "Point Barrow" was conducted between Seal Beach and Port Hueneme. The purpose of this test was to check sea-keeping characteristics, tie-down equipment and facilities on board, vibrations on deck, position of the well deck relative to the dock when ballasted, winching ability, speed, and rework required for transporting Saturn units. A step-by-step schedule was drawn up for the operation, which began at 6 am and was completed by 6 pm. Visitors were present from NASA, Huntsville, NASA WOO, and Douglas Aircraft, and the operation was coordinated and conducted by S&ID personnel. The operation went exactly as planned and produced the information sought. Figure 99 shows the AKD "Point Barrow." Figure 100 shows the stage simulator on the well deck of "Point Barrow."

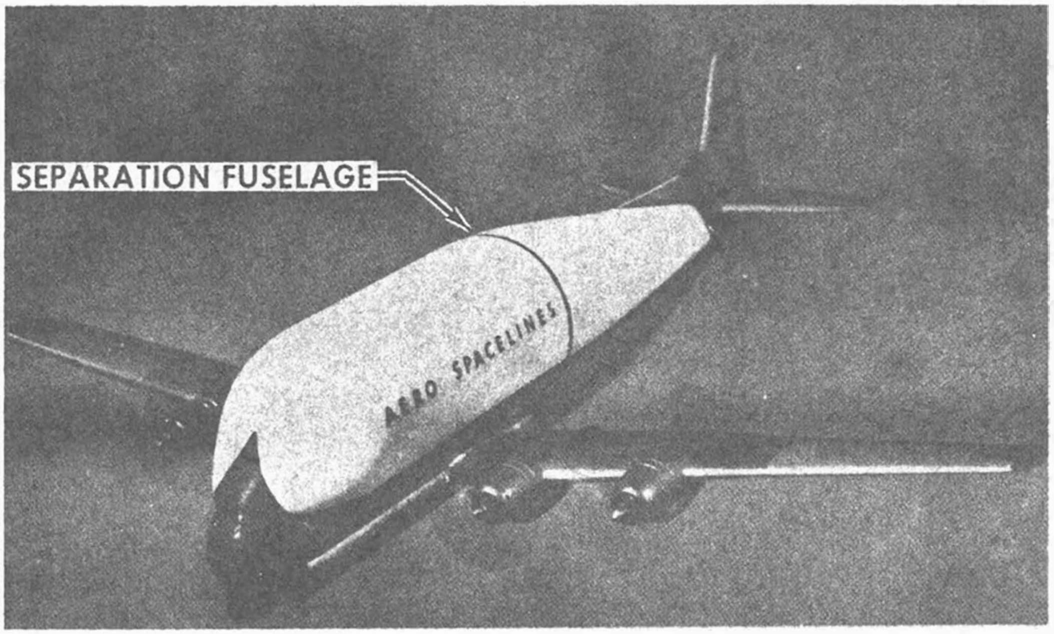


Figure 98. Modified B-377 Stratocruiser

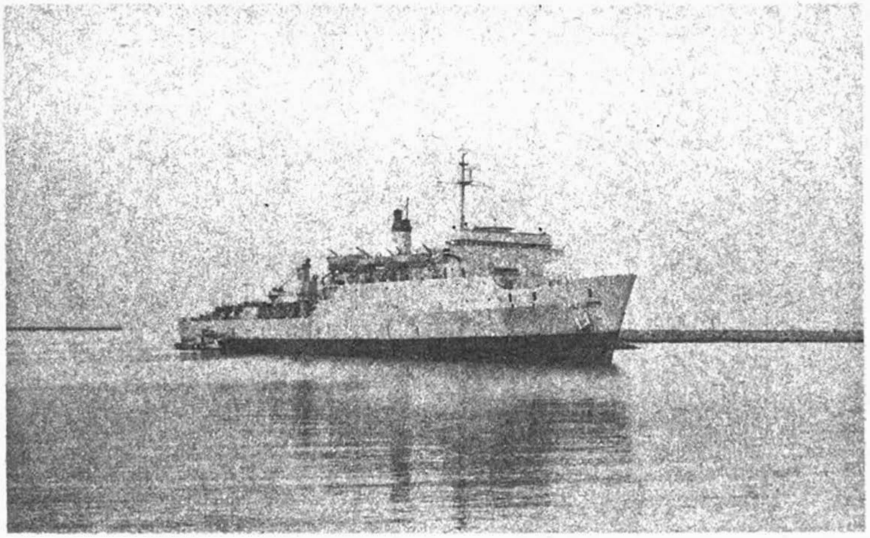


Figure 99. AKD "Point Barrow"

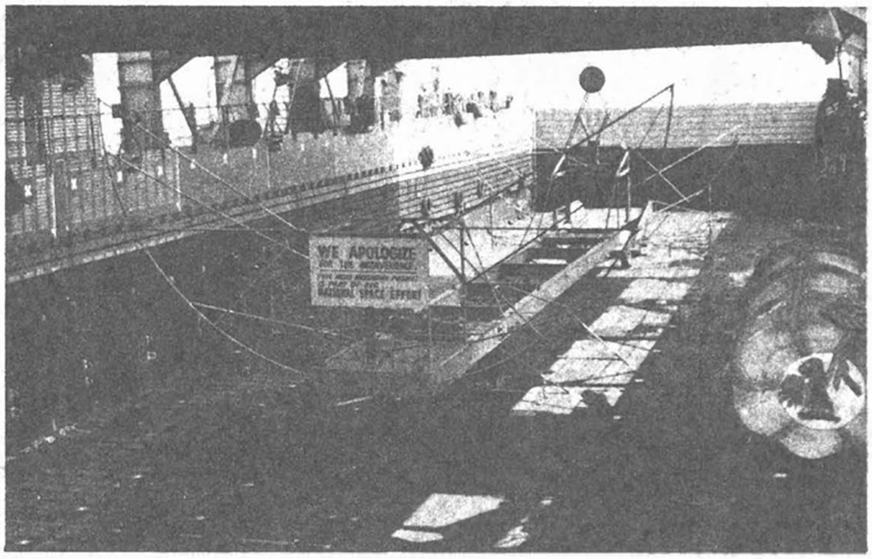


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Figure 100. Stage Simulator on Well Deck

VI. LOGISTICS

CUSTOMER TRAINING

Thirteen 44-hour S-II familiarization courses, involving all areas of S-II technical instruction, have been presented; and seven other classes have been offered in specialized categories, for a total of 20 separate courses. The following statistics summarize this effort.

Instructor Hours	Student Hours		Total	Number of Students		Total
	NASA	S&ID		NASA	S&ID	
560	2517	4275	6792	67	192	259

During this report period, three field trips were taken by instructor personnel, to Vandenberg AFB, Cape Canaveral, and Marshall Space Flight Center (MSFC). At Cape Canaveral and MSFC, S-II technical briefings were presented to 121 NASA personnel.

The training plan portion of the Logistics Support Plan (SID 62-286) has been revised on two occasions to reflect current support concepts.

Training course materials, such as documentation, graphics, and other aids, have been continually revised and expanded to remain current with S-II engineering and program development.

MODIFICATION AND REPAIR

Section VI of the Logistics Support Plan (SID 62-286) was revised to include the detailed procedures for controlling modification and repair (M&R) support to the test programs. The M&R shop was established at the Slauson facility of S&ID; it will be used as a central point of operations for the repair and/or processing of major repair items generated at the test sites.

Procurement actions were initiated to obtain the mobile repair vans that will be used at the test sites to accomplish the minor M&R requirements. M&R manloading and expenditure charts were developed to reflect future program requirements and for the control of M&R funds.

MAINTENANCE ENGINEERING

During this report period, the Logistics Support Plan (SID 62-286) underwent two revisions. This plan identifies the methods and procedures that will be used to assure that all areas of support are covered throughout the life of the contract.

The Logistics department analyzed the operating procedures and hardware that will be used at the Mississippi Test Facility (MTF) and at AMR. The MTF analysis underwent two revisions, and the AMR analysis was released on 1 August 1963. These analyses are designed to identify all of the support requirements for the stages and GSE at MTF and AMR.

An analysis of the transportation and handling operations and procedures was also made. This analysis is designed to identify all of the support equipment and maintenance parts requirements during transportation and handling operations.

SUPPORT DOCUMENTS

The following preliminary S-II manuals were delivered to MSFC during this report period:

Number	Title	Date
SM-S-II-01	General Manual	1 April 1963
SM-S-II-03	Engine Installation and Removal Manual	31 May 1963
SM-S-II-05	Electrical and Ordnance Systems Checkout Manual	31 May 1963
SM-S-II-06	Propulsion Systems Checkout Manual	1 June 1963
SM-S-II-17	Servicing Equipment Maintenance Manual	1 June 1963

The General Manual received NASA approval, and NASA comments on it are being incorporated in the next revision. The contractor is awaiting comments and approval on three of the preliminary manuals.

SUPPLY SUPPORT

On 3 August 1962, documents SID 62-530, -531, and -532 ordered ground support equipment for the California test programs.

On 29 August 1962, the Logistics department completed a study of a breakdown and historical record card suitable both for use within the S-II supply support group and for maintaining compatibility with other S&ID programs. On 1 and 4 October 1962, Saturn and Apollo supply support personnel met to coordinate a combined-use type shop release form and group assembly breakdown record card. Coordination with the maintenance engineering group has resulted in the production of a format, compatible with both groups, to transmit maintenance analysis information. This card will also be used to request maintenance analysis information on specific pieces of hardware.

On 14 November 1962, all spares support effort was combined into one area, California and off-site requirements, and program cost savings were thereby effected. Work under this plan began on 21 November 1962.

Initial spares to support the Electromechanical Mock-Up (EMM) were ordered on 17 January 1963.

The supply support group was given the additional responsibilities of coordinating and negotiating on-site need dates, manufacturing completion dates, purchase dates, and engineering drawing release dates for GSE end items and stage end systems for California and off-site locations.

The detailed milestone schedule report for GSE first line components, detail components of stage systems, and stage spares on the Electromechanical Mock-Up and Battleship stage was completed and submitted to Engineering on 29 January 1963, on schedule.

Coordination with the Apollo and Tulsa supply support groups to design forms for dealing with departmental interface areas has been completed. Compatibility in interface areas will result in extensive savings during the program.

Stage-fabricated and "buy" items, identified as logical spares to support the Engineering test program, have been selected from available material schedule authorizations (MSA's), engineering order purchase requests (EOPR's), and drawings and have been submitted to Logistics engineering for maintenance analysis inputs. Selection of GSE logical spares is in process. Fabricated auxiliary and checkout items were selected from available MSA's, EOPR's, and drawings and were submitted to Logistics engineering for maintenance analysis on 13 February 1963.

Logistics supply support requested a minimum warehouse area of 1000 square feet for spares to support the Electromechanical Mock-Up (EMM) program. This area will be close to the EMM test area.

Preparation of shop releases for the GSE end-item requirements at MTF and AMR is in process. Test and Operations need dates have been established for 64 GSE end items that were scheduled for shop release and distribution on 23 July 1963. The balance of the GSE end-item requirements, with established utilization and need dates, was scheduled for release on 25 July 1963.

DOCUMENTATION

During the report period, all contractual documentation requirements were fulfilled. All formal documentation prepared under Contract NAS7-200 is listed in Documentation List for Saturn S-II Stage (NAS7-200) (SID 62-430). This listing, published monthly, is alphabetically arranged into major subjects. Within each category, all the reports, specifications, and letters previously and currently published are listed in numerical sequence.

VII. MANAGEMENT CONTROL

SCHEDULES

Definitive contract NAS7-200, dated 15 October 1962, contains delivery schedules which are not significantly different from those in the previous letter contract NAS7-80. NASA Plan 5, however, changed the contract delivery requirements to such an extent that a complete rescheduling of the Saturn S-II effort was required. These changes were formally incorporated by NASA through Amendment V; and the proposed schedule to satisfy Amendment V, including fiscal year 1963 funding limitations, was submitted to NASA on 28 November 1962.

At NASA's request, a study covering the possibilities of accelerating Manufacturing's completion of the All-Systems stage (S-II-T) was conducted and presented to NASA representatives. The study's conclusion was to retain the S-II master program schedule of 24 January 1963.

The J-2 engine schedule received from NASA was reviewed for its support of the S-II master program schedule. A letter defining its support has been submitted to NASA.

Second-level schedule charts have been prepared to cover all aspects of the S-II program. They constitute a detailed presentation of the activities shown on the master program schedule and are organized to be generally parallel to the PERT networks. These schedule charts have been published in Program Plan (SID 61-363).

Schedule and cost proposals detailing S&ID effort necessary for the discharge of follow-on contracts in quantities of 5, 10, and 120 additional S-II stages have been completed and sent to NASA.

PERT

Eleven fragnets have been reconstructed in accordance with supplemental agreement (S/A) 17, which defines subdivisions of work to be accomplished. These networks, accepted by NASA-MSFC, form the basis of the Saturn S-II PERT biweekly report. The reconstruction involved a major rework of updating, designing, and constructing and incorporated all outstanding contract change notices (CNN) and master change records (MCR) issued on or before 15 April 1963 so as to comply with the NASA PERT and Companion Cost System Handbook, dated 30 October 1962. In addition, S&ID converted to a new mutual MSFC/S&ID single numbering system for PERT, with a complete interface change, which required the reintegration of the S-II PERT program.

During the reconstruction phase, the operational PERT program continued, together with its biweekly reports, so that no time was lost during changeover from the complex dual numbering system to the single numbering system. Furthermore, a standard interpretation of events and descriptions was accomplished by redefining nomenclature; and the renumbering of fragnets and subnets was oriented to minimize the time required by MSFC and S-II management to locate events.

The new integrated networks reflect an increase in the number of activities from 4611 to 8935. This increase results from hardware orientation of the networks and not from theoretical subdivisions of work, the inclusion of the effect of changes, and a requirement to portray greater depth. In addition, these fragnets contain all the milestones on which MSFC is required to report monthly to NASA headquarters; and they contain all major monitoring points, in accordance with the Saturn S-II master program schedule and second-level schedules.

Soft constraints that directly affected hardware delivery have been removed. The present fragnets also have received preliminary approval with respect to their satisfaction of both the PERT time and companion-cost requirements of the NAS7-200 contract.

The first quarterly review of the PERT operation was conducted in March 1963 with MSFC personnel. General agreement was reached on the contract changes involving both PERT and the financial reporting requirements of CCN 19.

To establish PERT report statusing for S-II management and NASA review, Program Control inserts schedule dates into PERT at the fragnet milestone level. Subsequent schedule impact is coordinated with the organizations affected. When an internal schedule change is necessary. Program Control determines whether organizations not involved in the negotiations are affected.

The PERT narrative coordination plan has been revised to allow time both for briefing the local NASA resident manager prior to narrative submittal and for the biweekly PERT telephone conference between the S-II program manager and the MSFC program manager, which normally follows biweekly submittal of the PERT narrative report.

The first computer run, dated 31 May 1963, utilizing reconstructed networks and corresponding data, produced a negative slack of 65.6 weeks against S-II-2 delivery to AMR. This negative slack was reduced to 20.1 weeks by 31 July 1963. S-II management has established a target of 8.0 weeks of negative slack by 27 August 1963.

Significant progress has been made toward integrating master schedules, PERT, and departmental statusing methods. Program Control now uses the S-II master program schedule and supporting schedules to provide a comparison between scheduled dates and their respective PERT expected dates. In addition, detailed schedules for biweekly PERT report coordination have been developed, and briefings have been presented to S-II managers responsible for the fragnets.

Transition from the 7090 computer to the 1410 computer has been completed. This transition has made possible a greatly improved computer program and has greatly increased the amount of activity data that can be successfully integrated.

During this report period, the introduction of the dataphone for PERT transmission to MSFC has done much to eliminate human error prevalent in other means of transmission or communication.

PROGRAM COSTS

During the first eight months of the S-II program, costs were planned and controlled in accordance with the firm cost proposal submitted to NASA. After the firm contract had been negotiated and ratified in October 1962, S-II Program Control established plans for expenditure of 99 million dollars during NASA fiscal year 1963.

In November 1962, plans for manpower application and other cost elements were revised to conform with the Plan 5 schedule revision that had resulted from limited NASA funding for fiscal year 1963. This funding reduction from 99 to 84 million dollars imposed a reduction in manufacturing and support departments activities. However, engineering activities were maintained at the prerevision levels.

Incremental funding by NASA necessitated close control. Consequently, interim budgets for cost element expenditures throughout fiscal year 1963 were established for each functional organization at the major contract task level.

Early in the second quarter of calendar year 1963, documentation was presented to NASA of requirements for 91.5 million dollars by the end of fiscal year 1963 to support additional changes in the program, and NASA provided funding to this level.

Expenditure and commitment trends continue to indicate that costs are being controlled within the funding limitation.

Funding requirements for fiscal year 1964 were presented to NASA in April 1963. They totaled 102 million dollars for the basic contract through Amendment V and an additional 20 million dollars for anticipated changes. To date, NASA has initiated and authorized changes that will consume approximately 14 million of the 20 million dollars.

MAJOR SUBCONTRACTING

Figure 101 shows the dollar distribution, by states, of subcontracting through 30 June 1963.

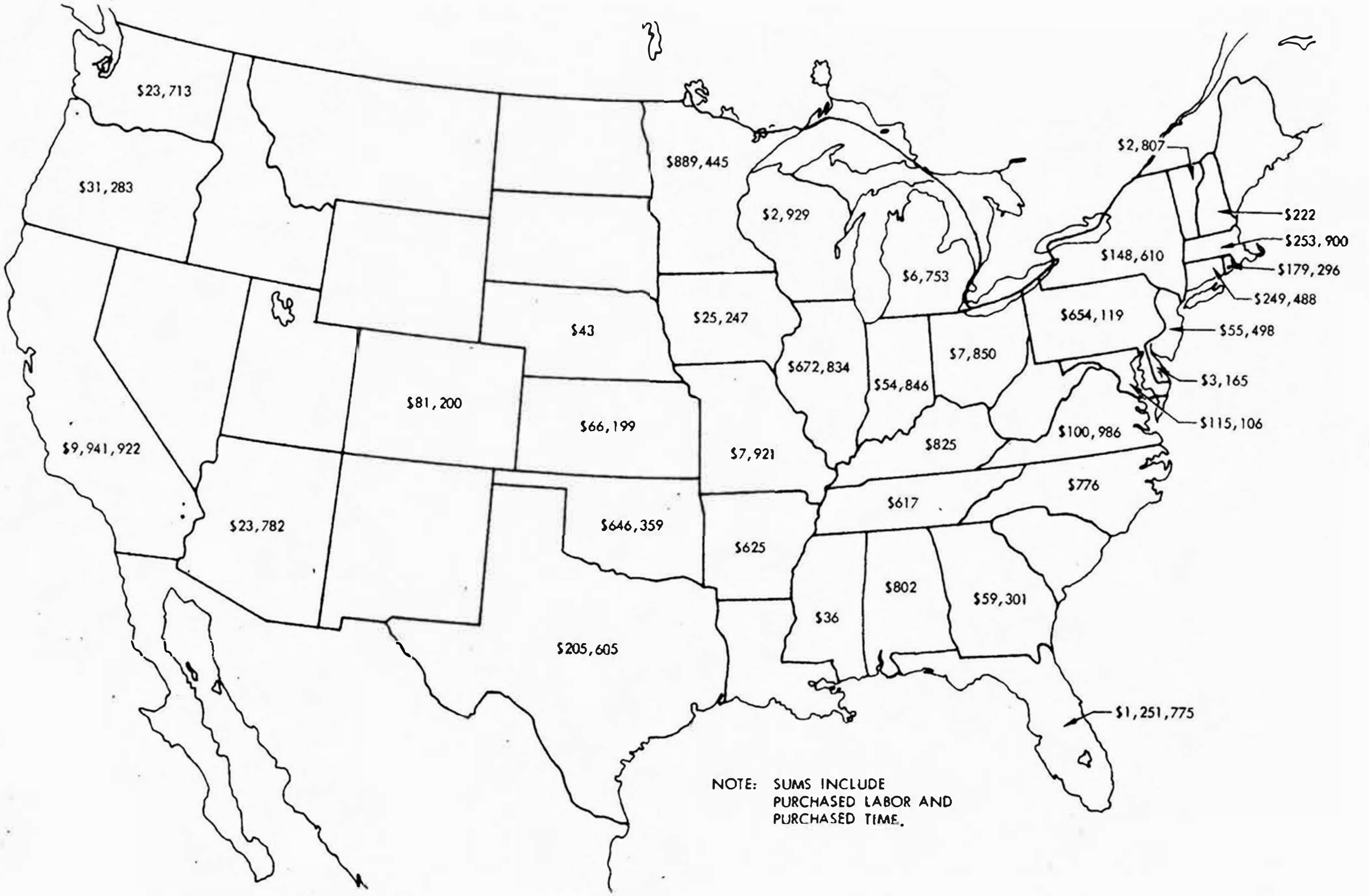
HYDRAULIC SYSTEM COMPONENTS

Purchase orders for the auxiliary motor pumps and the main hydraulic pumps were placed in August 1962 with American Brake Shoe Company, Oxnard, California. The incorporation of several design changes was necessary as a result of test failures, quality problems, and revisions to the procurement specification. By 30 June 1963, all of the main hydraulic pumps and four of the auxiliary motor pumps had been delivered.

A purchase order for sixteen servoactuators was placed with Hydraulic Research and Manufacturing Company, Burbank, California in June 1962. During the year, however, redirection from NASA and resulting procurement specification changes considerably altered the scope of the original effort. Furthermore, the supplier made several design changes in order to resolve test failures, quality control problems, and seal leakage. By 30 June 1963, seven servoactuators had been delivered.

A purchase order for eight accumulator reservoir manifold assemblies was placed in July 1962 with Parker Aircraft Company, Inglewood, California. As with the servoactuators and pumps, several design changes were necessary to incorporate revised requirements of the NAA procurement specification. Four units had been delivered by 30 June 1963; but it was then determined that the design of the manifold would not meet the requirements of the pressure tests. It is presently being re-designed to provide for manufacture from a forging rather than a casting.

A request for proposal was submitted in June 1963 for the production configuration of each of these components. Proposals are due in July 1963.



NOTE: SUMS INCLUDE PURCHASED LABOR AND PURCHASED TIME.

Figure 101. Subcontracting Business Distribution Through 30 June 1963

LH_2 TANK SKINS

In May and June 1963, purchase orders were placed with Missile Dynamics Corporation of Lynwood, California, for detail skin panels comprising the upper, lower, and lower intermediate ring segments of the tank structure. The first articles are scheduled for delivery on 15 September 1963, with subsequent deliveries scheduled to support the end-item delivery schedules.

Potential supplier surveys and evaluation efforts are continuing in an attempt to locate additional qualified suppliers for the skins yet to be procured.

S-II STAGE TRANSPORTER

Although the S-II stage transporter was originally to be designed "in-house," a decision to purchase it was made later. Facility surveys of prospective sources were conducted; and in March 1963, invitations to bid were extended to six sources. In June 1963, the American Machine and Foundry Company was selected as the source for the S-II stage transporter. Negotiations for a fixed-price contract are in progress.

CHECKOUT EQUIPMENT COMPUTER

In March 1963, a fixed-price purchase order was issued to the Control Data Corporation for the manufacture and delivery of six Model 924A computers, together with their varied peripheral equipment. Each of these units was procured for a specific program function and an individual destination. The first computer is scheduled for delivery at Downey, California, on 6 August 1963, for use in the Program Development facility.

EXPENDITURE VARIANCES

Figure 102 is an expenditure chart that shows the variances between the planned program expenditures and actual expenditures through 30 June 1963. At the time the planned expenditure curve was prepared, it was intended to place purchase orders in sufficient time to have hardware available for the Battleship test and the Electromechanical Mock-up. However, delays occurred during the preparation of specifications as a result of customer directed changes, NAA changes in design approach, and direct inputs for Quality Assurance requirements which would meet the requirements of the prime contract. Rather than place purchase orders using inadequate specifications, it was decided that substitute hardware would be procured for the Battleship test and the Electromechanical Mock-up. All of the latest requirements could then be incorporated in the procurement specification for deliverable flight hardware. It is believed that this delay in procurement accounts for the expenditure variances and that the variances do not indicate a behind-schedule position.

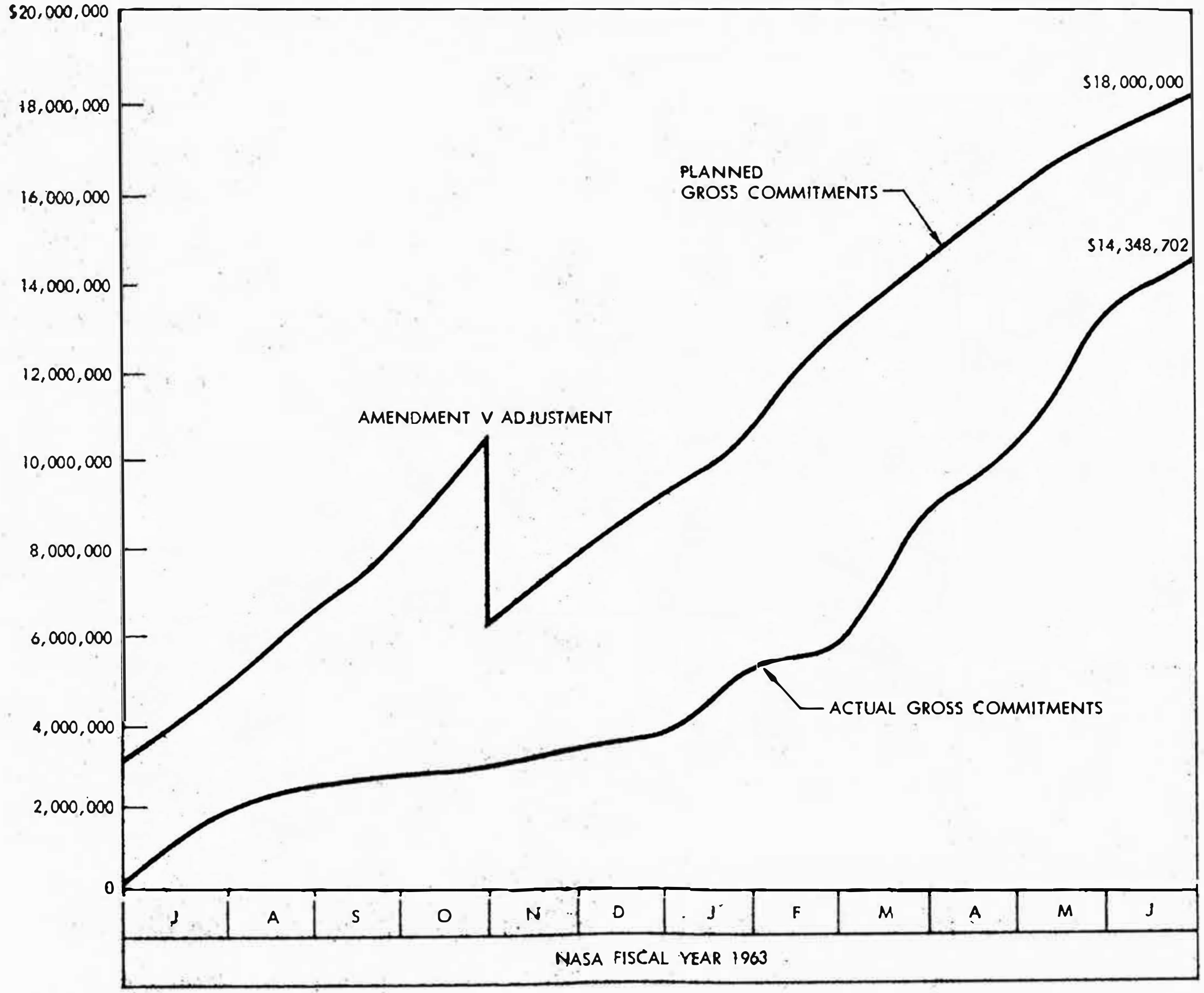


Figure 102. Subcontracting Expenditure Variances Chart