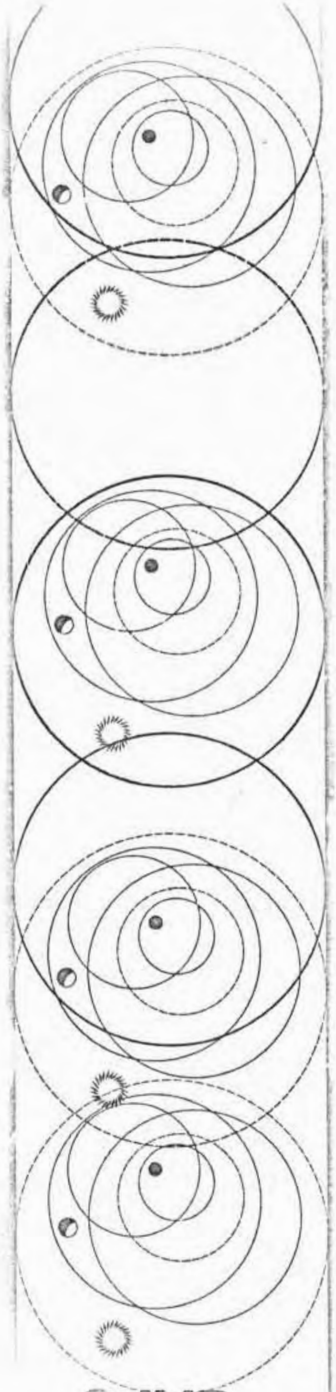

SATURN QUARTERLY TECHNICAL PROGRESS REPORT

S-IVB

DAC-56533
MARCH 1967

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XIV 4

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
HUNTINGTON BEACH/CALIFORNIA

SATURN S-IVB QUARTERLY TECHNICAL PROGRESS REPORT

DOUGLAS REPORT DAC-56533
MARCH 1967

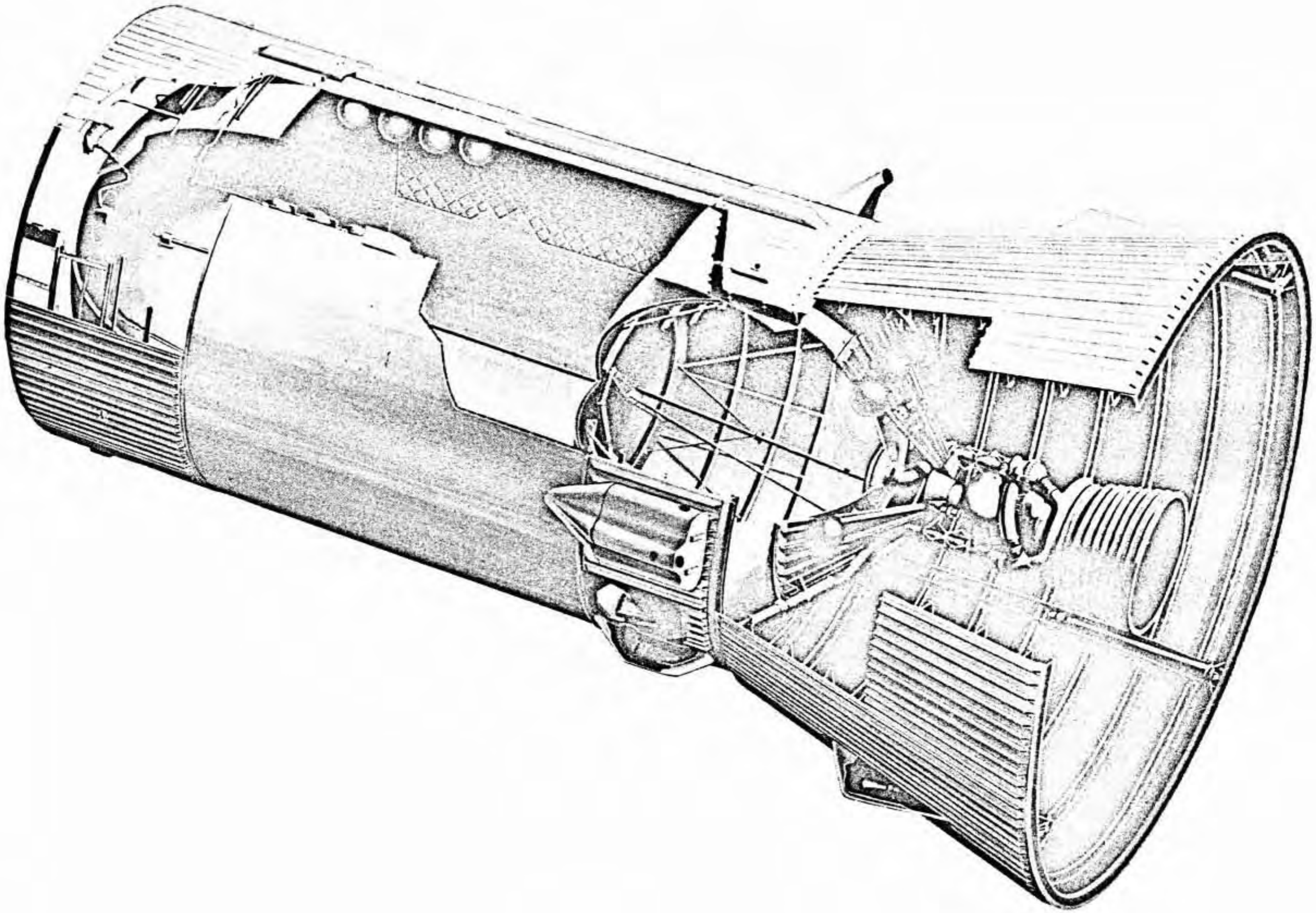
PREPARED BY: B. J. RAINWATER
SATURN PROJECT OFFICE

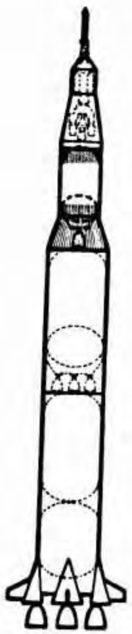
PREPARED FOR:
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
UNDER NASA CONTRACT NAS7-101

APPROVED BY: A. P. O'NEAL
DIRECTOR, SATURN DEVELOPMENT ENGINEERING

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION
SPACE SYSTEMS CENTER — HUNTINGTON BEACH, CALIFORNIA

SATURN V/S-IVB





A B S T R A C T

Douglas Aircraft Company Report DAC-56533, Saturn S-IVB Quarterly Technical Progress Report, covers design and development progress on the Saturn IB and Saturn V configurations of the S-IVB stage during January, February, and March 1967. This report is prepared for the National Aeronautics and Space Administration under Contract NAS7-101.

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PROGRAM STATUS

S-IVB PERT PROGRAM FORECAST

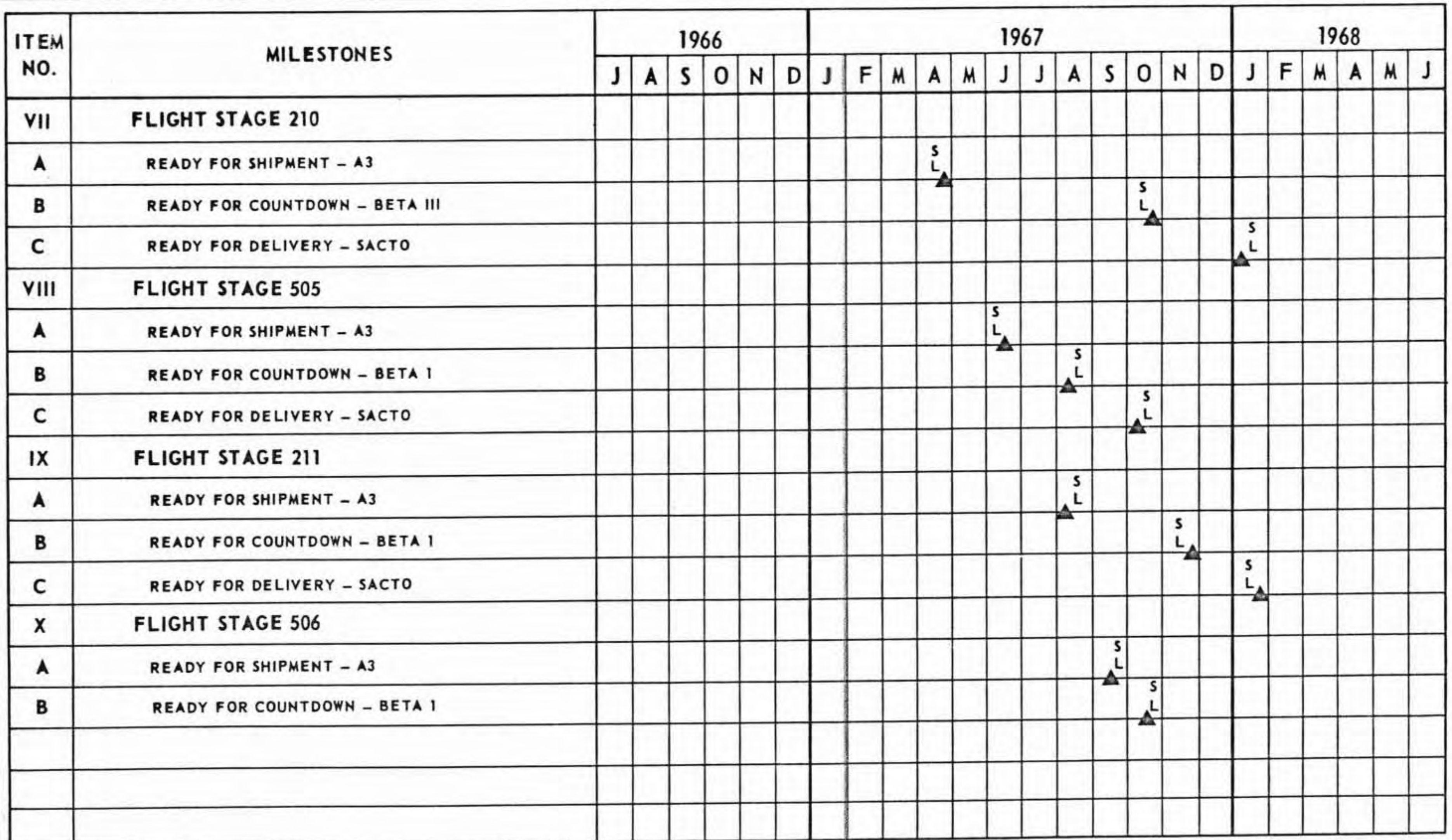
ITEM NO.	MILESTONES	1966						1967												1968					
		J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
I	**QUALIFICATION TESTING**																								
A	COMPL RELIABILITY VERIF TESTING																S L ▲								
II	**NASA SUPPORT EQUIPMENT**										VARIOUS														
III	**FLORIDA TEST CENTER**																								
A	204 COMPL APS LOAD (LC34)													S L ▲											
B	206 COMPL APS LOAD (LC37)										TBD														
C	501 COMPL APS LOAD (LC39)													S L ▲											
D	502 COMPL APS LOAD (LC39)															S L ▲									
IV	**FLIGHT STAGE 208**																								
A	READY FOR DELIVERY – SACTO									S L ▲															
V	**FLIGHT STAGE 504**																								
A	READY FOR COUNTDOWN – BETA 1										S L ▲														
B	READY FOR DELIVERY – SACTO													S L ▲											
VI	**FLIGHT STAGE 209**																								
A	READY FOR SHIPMENT – A3									S L ▲															
B	READY FOR COUNTDOWN – BETA 1												S L ▲												
C	READY FOR DELIVERY – SACTO														S L ▲										

LEGEND

HF = HELD FOR
T/N = TIME NOW
S = SCHEDULE DATE
L = LATEST ALLOWABLE OR NEED DATE

▲ = PERT PREDICTED COMPLETION DATE THIS T/N
△ = PERT PREDICTED COMPLETION DATE LAST T/N
▼ = PERT PREDICTED COMPLETION DATE FOR ALTERNATE PATH THIS T/N

S-IVB PERT PROGRAM FORECAST



PROGRAM SUMMARY

Design and development progress on the Saturn IB and Saturn V configurations of the S-IVB stage continued during the first quarter of 1967. The majority of layout drawings reflecting late changes have been completed and forwarded to NASA. The majority of late changes to production drawings have been completed. Individual system and module design and hardware and component design development, qualification, formal qualification, and reliability verification testing are now being emphasized.

Battleship testing was completed early in the program establishing the validity of Saturn S-IVB design concepts and functional operation of flight-type hardware. S-IVB/Saturn IB and Saturn V auxiliary propulsion system module testing has been completed.

Static firings have been accomplished on eight S-IVB/Saturn IB flight stages (S-IVB-201 through S-IVB-208) and two S-IVB/Saturn V flight stages (S-IVB-501 and S-IVB-502). The S-IVB-503 stage was destroyed during static firing countdown. Ten S-IVB stages have been delivered to NASA (Dynamics, S-IVB-500F Facility Checkout Stage, S-IVB-500-ST MSFC stage simulator, S-IVB-201 through S-IVB-204, S-IVB-206, S-IVB-501, and S-IVB-502). S-IVB stage flight performance has been successfully demonstrated during the first three Saturn IB missions, AS-201, AS-202, and AS-203.

Testing

Flight Testing (Kennedy Space Center)

Preparations for launch of the AS-204 vehicle were discontinued after a fire occurred in the spacecraft during testing in January. The S-IVB stage was not damaged. The AS-206 mission will be transferred to the AS-204 launch vehicle.

S-IVB-206, S-IVB-501, and S-IVB-502 stage prelaunch checkout and modifications continued during the quarter.

Acceptance Testing (Sacramento Test Center)

S-IVB-205 stage post-turnover modifications continued during the quarter. Shipment to Kennedy Space Center is scheduled for 29 June.

S-IVB-207 stage Category II and III modification work and checkout were completed and the stage was placed in storage. Shipment to Kennedy Space Center is scheduled for 11 July.

S-IVB-208 stage acceptance firing was successfully accomplished on 12 January. Mainstage duration was 424.3 seconds, with automatic cutoff initiated because of imminent liquid oxygen depletion. All test objectives were achieved.

The S-IVB-209 stage arrived at the Sacramento Test Center on 10 March and was installed in the Vertical Checkout Laboratory on 27 March. Stage modifications and static firing preparations were in process at the end of the quarter.

S-IVB-502 post-turnover modifications and preparation for shipment were completed and the stage was shipped to Kennedy Space Center on 21 February.

The S-IVB-503 stage was destroyed on 20 January during acceptance firing countdown on the Beta 3 Test Stand. Post-accident investigation revealed that an ambient helium sphere weld was commercially pure Ti-55A titanium, not the specified Ti-6Al-4V titanium.

The S-IVB-504 stage arrived at the Sacramento Test Center on 25 January and was installed on the Beta 1 Test Stand. The Beta 1 Test Stand is being modified to accept S-IVB-504, which will precede S-IVB-209 through acceptance firing. Stage acceptance firing is planned for late April.

Component Testing

Design development testing is nearing completion, with 323 tests completed of 342 tests scheduled. Qualification testing is also nearing completion, with 688 tests completed of 741 tests scheduled. Formal qualification testing is progressing, with 23 tests completed of 42 tests scheduled. Reliability verification testing is continuing, with 4 tests completed of 19 tests scheduled.

Manufacturing

S-IVB-209 factory checkout, initiated on 28 November 1966, was completed on 26 January. The stage was airlifted to the Sacramento Test Center on 9 March.

S-IVB-210 forward and aft skirts and thrust structure installations were completed in mid-January. J-2 engine installation was completed in late January. Final installations and hookup were completed in early February. Factory checkout, initiated on 10 February, was completed on 21 March. Shipment to the Sacramento Test Center is planned for April.

S-IVB-211 tank insulation and clip bonding was completed in early February. Installation of the liquid hydrogen tank fire retardant liner was completed on 12 March. Joining of the thrust structure and forward and aft skirts was initiated on 23 March.

S-IVB-212 internal insulation installation and clip bonding were in process at the end of the quarter.

The S-IVB-504 stage was shipped to the Sacramento Test Center on 25 January.

S-IVB-505 tank installations were completed in mid-January. Dual repressurization sheet metal installations and joining of the skirts and thrust structure were then completed. J-2 engine installation was completed in February. Final installations were completed and stage checkout was initiated on 20 February.

S-IVB-506 liquid hydrogen tank internal insulation was completed in late March. Tank installations were in process at the end of the quarter.

Fabrication assembly at the Space Systems Center and at Santa Monica continued during the quarter on stages S-IVB-507, S-IVB-508, and S-IVB-509.

SECTION II

ENGINEERING

2. ENGINEERING

2.1 Propulsion

2.1.1 Liquid Oxygen Tank System

Weight Reduction Study

A feasibility investigation is being conducted on joining 6061 aluminum alloy ducting to stainless steel bellows as a weight reduction measure for the new nonpropulsive vent system installation.

Liquid Oxygen Tank Nonpropulsive Venting System

The currently proposed liquid oxygen nonpropulsive venting system has been designed to utilize the existing liquid oxygen tank vent and relief valve for ground venting. A new blowdown valve with a 3-inch nonpropulsive duct system will be installed downstream of the valve in a manner similar to the design utilized for the S-IVB-503 stage. Nonpropulsive venting is achieved by discharging vent gases through two diametrically opposed nozzles located 180 degrees apart on the aft skirt.

Orbital Workshop Passivation

Orbital workshop passivation studies are continuing. Dumping liquid oxygen through the J-2 engine is one method currently being investigated.

Liquid Oxygen Tank Rupture

A study was conducted to establish the minimum tank rupture area required to produce the initial liquid oxygen tank pressure decay rate of 1,000 psi per second which occurred during the S-IVB-503 incident. Calculations indicate that a rupture below the liquid oxygen level would require a liquid oxygen flow area of 46 square feet to generate the observed pressure decay rate. A rupture area of 4 square feet would provide an adequate gas flow area to produce the same decay rate.

Liquid Oxygen Tank Relief Valve Blowdown Times

Liquid oxygen tank relief valve blowdown times have been calculated for ground and orbital venting of the IB and V configurations. It was recommended that the valve be tested to a collapse rate of 10 psi per second to insure reseating under worst possible conditions. Orbital chatter time (maximum) for the liquid oxygen tank relief valve was also plotted as a function of valve flowrate for a 4 1/2-hour orbital coast period.

S-IVB-204 Total Liquid Oxygen Tank Impulse

Total impulse values obtainable from 10-minute vents at various orbital coast periods have been plotted for S-IVB-204.

2.1.2 Fuel Tank System

Orbital Workshop

Feasibility studies were conducted to support design requirements for the Orbital Workshop. Design layouts were generated on the following items:

a. Passivation plug for liquid hydrogen feed duct and a removable anti-vortex screen, which enables the astronaut to remove the screen prior to passivation plug installation.
b. Modified pressurization duct to incorporate passivation plug.
c. Modified fill and drain diffuser to incorporate passivation plug.
d. Modified liquid hydrogen vent duct to incorporate passivation plug.
e. Chilldown pump cover for passivation.
f. Liquid hydrogen nonpropulsive vent system (secondary system for passivation).
g. Modified chilldown return line to incorporate passivation plug.

Stage Fuel Residual Proposal

A feasibility study has been concluded on employing a collector manifold or an internal bladder within the fuel tank to reduce stage fuel residual. As a result, a fiberglass collector manifold is proposed and would be internally mounted within the trough of the fuel tank extending from the liquid hydrogen feed elbow around the circumference of the tank (approximatel 150 degrees in each direction).

AS-211 Fuel Tank Secondary Nonpropulsive Vent Sizing

Using a minimum heating rate of 25,000 BTU per hour, a vent orifice effective area was sized to maintain a 4-psia tank pressure. Tank pressure during a maximum heating rate of 80,000 BTU per hour was estimated for this orifice and time required for isothermal blowdown (at various temperatures) was determined.

Continuous Vent Regulator Poppet Pressure Profile and High Frequency Chatter Investigation

The continuous vent regulator poppet pressure profile was determined for various poppet positions.

Maximum Permissible Blowdown Pressure Drop While Avoiding Liquid Hydrogen Loss for S-IVB/Saturn V Liquid Hydrogen Tank Orbital Venting

The effect of blowdown pressure drop on the liquid hydrogen surface has been calculated. The maximum acceptable pressure drop versus initial pressure for saturated liquid hydrogen at various ullage volumes was calculated.

Effect of Partial Failure of the S-IVB/Saturn V Continuous Vent System on Mission Completion

The effect of orifice flow control solenoid or regulator failure in either the open or the closed position during burn, coast, and repressurization has been examined. It was concluded that probably mission completion will follow either regulator or orifice failure close at restart, or orifice failure to open during coast. Regulator failure to open during coast would probably cause a mission failure.

AS-501 Safety Monitoring Study

The AS-501 fuel system safety monitoring study was completed. Analysis indicated that fuel system prevalve operation failure could be considered catastrophic, although further study is required. There were potential failure modes which could jeopardize mission accomplishment. Instructions were provided for detecting and circumventing the malfunctions.

2.1.3 Pneumatic Control and Pressurization Systems

2.1.3.1 Design

The pneumatic system installation drawing (1A39323) has been revised. Effort involved (1) adding the 4.5-cubic-foot helium supply bottle for S-IVB-205, (2) replacing the 1B66692-1 actuation control module with the 1A49982-517 module for S-IVB-506 (which features added thermal insulation), and (3) adding a check valve (1B67481-1) in the vent port of the actuation control module that controls the prevalves and shutoff valves to prevent cryopumping. This change is effective on S-IVB-204 through S-IVB-216.

The forward skirt pneumatic system installation drawing (1B52500) has been revised to add a control orifice to the inlet port on the actuation control module that operates the liquid hydrogen continuous vent module (effective S-IVB-501 through S-IVB-515).

The S-IVB/Saturn IB aft section pneumatic power installation drawing (1B58002) is being revised to include (1) adding low emissivity paint to the pneumatic power control module to maintain module temperature above -125°F (effective S-IVB-211), (2) adding the 4.5-cubic-foot helium bottle for S-IVB-207 to meet mission helium requirements, and (3) relocating the common bulkhead vacuum monitoring transducer to increase monitoring system reliability (effective S-IVB-208 through S-IVB-216 and S-IVB-504 through S-IVB-515).

The S-IVB/Saturn V aft section pneumatic power installation drawing (1B58003) is being revised to include (1) replacing the 1B66692-1 actuation control module with the A149982-517 module for S-IVB-501 (which adds thermal insulation to the module) and (2) adding a check valve (1B67481-1) in the vent port of the actuation control module that controls the prevalves and chilldown shutoff valves to prevent cryopumping (S-IVB-501 through S-IVB-515).

The main oxidizer tank pneumatic system installation drawing (1B58006) has been revised to (1) relocate pressure transducer D016 due to temperature failures encountered during qualification testing, and (2) install -503 helium dump module (1B57781) in place of the -501 configuration as a result of qualification test failures.

2.1.3.2 Analysis

Oxidizer Pressurization System Changes for Increased Oxidizer Loading

Effects on the oxidizer pressurization system resulting from an increased oxidizer load (to 195,522 pounds) have been investigated. Analysis indicates the slosh baffle will be effective for the larger load and a change in the present baffle system is not required. The pressurization system would require an orifice change and/or sequence change.

Liquid Oxygen Tank Repressurization

Maximum and minimum liquid oxygen tank repressurization rates were established for the oxygen-hydrogen burner based on burner performance dispersions and limiting liquid oxygen tank ullage conditions. Heat losses between the burner outlet and liquid oxygen tank diffuser were based on data obtained from the S-IVB-502 stage acceptance burner simulation test. Calculations indicate a maximum repressurization rate of 1.56 psi per minute and a minimum rate of 0.74 psi per minute.

Liquid Oxygen Pressurization Control Module Bang-Bang Operation

Peak pressure in the plenum chamber downstream of the liquid oxygen pressurization control module, while the module is operating in the bang-bang (backup) mode, has been determined. Results indicate that plenum pressure will be within system operating limits during bang-bang operation.

S-IVB Stage Module Bang-Bang Operation

Two stage modules (pneumatic power control and cryogenic repressurization control) have been investigated to determine peak downstream system pressure during bang-bang (backup) operation. Preliminary results indicate that peak pressure will be within system limits for both modules.

Cryopumping Nitrogen into Liquid Oxygen Tank Pressurization Module Regulator

Analysis was conducted to determine the possibility of nitrogen cryopumping into the regulator. Results indicated that the regulator would be operable in both the acceptance and flight cases.

Mylar and Vespel for use as Valve Seat Material

Mylar and Vespel were investigated for valve seat material in the two parallel shutoff valves in the liquid oxygen pressurization control module. Results indicated that although the Vespel material is subject to higher leakage rates, it is more suitable than Mylar due to its longer life capability.

Ambient Helium Bottle Trajectory

The hypothetical trajectory of the upper half of the ambient sphere which burst during the S-IVB-503 incident has been established. It is estimated that no more than 10 per cent of the total available energy is imparted to the upper sphere half in an unconfined expansion (as occurred in the actual sphere explosion). This corresponds to an initial velocity of 440.0 feet per second and an impact point no farther than 2,000 feet away from the stage.

S-IVB Fuel Tank Pressurization Data Required for Propellant Utilization System Specification Modifications

S-IVB fuel tank pressurization performance curves have been predicted for use in updating J-2 engine thrust variation specifications. These updated thrust specifications are required for redefining propellant utilization system performance specifications.

Liquid Hydrogen Repressurization Relief Valve

The current flow requirement for the liquid hydrogen repressurization system relief valve has been investigated. In the event of a GSE failure, the current relief valve flow requirement (2 pounds per minute) will provide a pressure differential of 60 psi between the GSE regulator discharge and the liquid hydrogen repressurization sphere (a single relief valve). The relief flowrate would limit bottle pressure to 3,500 psia for a GSE console pressure of 3,560 psia. It should be noted that in the actual case, two relief valves would be available for relief venting and that GSE console overpressures would require a failure of the GSE relief valve as well as a high regulator setting.

Mission Safety

A mission safety monitoring study was conducted for S-IVB-204 and S-IVB-501 defining all parameters that should be monitored to assure satisfactory mission safety status.

2.1.4 Oxygen-Hydrogen Burner System

Oxygen-Hydrogen Burner Combustor-Dome Burnthrough

Documentation of two combustor-dome burnthroughs (occurring on 20 and 22 October 1966) was completed during January. It was thought that the first burnthrough was a random failure caused by defective material and/or weld. It was concluded that the second burnthrough resulted from a faulty repair job on the first burnthrough. No design changes are planned; however, leak checks will be made on all production burners prior to and after each countdown and prior to launch.

Oxygen-Hydrogen Low Chamber Pressure Burner Failure Detection System

Orbital Chilldown

The time required to chill down the cold helium system through the oxygen-hydrogen burner liquid hydrogen tank repressurization system to a temperature between 125°R and 150°R at the voting circuit was predicted. Predicted chilldown time was a minimum of 16.5 seconds and a maximum of 34 seconds.

Oxygen-Hydrogen Burner Propellant Valve Inlet Duct Bond Numbers

Analysis was made to determine the bond number upstream of the oxygen-hydrogen burner propellant valves as an aid to determine if the propellant ducts would contain liquid prior to J-2 ignition. Analysis concluded that a bubble will not pass through the screen during either an acceptance test or a flight for an acceleration field less than 32 g's.

Feasibility of Using Aft Skirt to Heat Helium

The feasibility of using aft skirt stringers to heat cold helium to repressurize the liquid oxygen and liquid hydrogen tanks is being studied.

Oxygen-Hydrogen Burner Preignition Chamber Pressure

Analysis is in progress to determine oxygen-hydrogen burner chamber pressure at ignition and to describe the procedure used to determine the time of ignition.

Oxygen-Hydrogen Burner Injector Temperature Gradient Across the Core Wall

Temperature gradients across the injector core wall are being determined. This information will be used to determine injector thermal stresses and the diluent slot effective area change.

Oxygen-Hydrogen Burner Cross-Ignition Investigation

The mixture ratio and gas velocity in the spool at the time of cross-ignition are being determined. This information is required to understand the cross-ignition phenomena.

2.1.5 Auxiliary Propulsion System

2.1.5.1 Design

Propellant Positive Expulsion Tank System Gas Formation (S-IVB/Saturn V)

ECP 2054E1, concerning the controlled bleedoff of gases from the tank bladder prior to launch, has been approved and redesign of the auxiliary propulsion propellant tank recirculation system has been accomplished.

Glass Bead Peening of Tank Shells

NASA has directed a configuration change for all S-IVB/Saturn V auxiliary propulsion system propellant tanks, effective with S-IVB-503. This change requires glass bead peening of tank shell interiors per 1B39468-503, -504. Douglas will perform the peening process.

Production Tank Assembly Processing and Checkout

Flight worthiness of tanks subjected to methanol during cleaning is being reviewed. S-IVB-504 auxiliary propulsion system propellant tanks were found to have excessive moisture content. Several days of purging were necessary to meet system dryness requirements of MSFC-SPEC-164. Bell was informed of the problem and Douglas will require proof of conformance before accepting future tanks.

2.1.5.2 Analysis

S-IVB/Saturn V Gas Bubble Formation Study

An analytical model of the mass transport phenomena associated with the gas bubble formation in the S-IVB/Saturn V auxiliary propulsion system propellant bladders has been established. This model was used to describe bubble formation methods and controls to minimize the phenomena in a flight module.

AS-208 Liquid Oxygen Vent Compatibility

NASA was informed during the quarter that the present liquid oxygen vent alignment was not compatible with the AS-208 mission as now defined. Realignment of the vent to an angle of 18 degrees, 33 minutes was recommended.

Feasibility of Extending Auxiliary Propulsion System Lifetime

A study was made in conjunction with the Orbital Workshop study of extending auxiliary propulsion system lifetime. Difficulties that might be encountered in extending the lifetime of the modules to at least 6 months were discussed. The study concluded that the lifetime could be increased with little difficulty, although requalification would be required.

Auxiliary Propulsion System Malfunction Study

An auxiliary propulsion system malfunction study was conducted to investigate possible malfunctions which could be detected by parameter monitoring, and possible corrective action.

AS-501 Auxiliary Propulsion System Propellant Requirement Prediction

Auxiliary propulsion system propellant requirements from the predicted impulse requirements necessary to maintain AS-501 attitude control, ullaging, and perform the required maneuvers have been determined. These predictions will be used as a method of comparison during AS-501 flight data evaluation.

Auxiliary Propulsion System Propellant Requirement for Liquid Oxygen Tee Venting

Auxiliary propulsion system propellant requirements as a function of liquid oxygen vent unbalance through a tee have been determined. Analysis showed that the present AS-204 liquid oxygen vent alignment requires less propellant than the tee vent.

AS-504 Propellant Allocation Report

Auxiliary propulsion system propellant requirements from impulse requirements necessary to maintain AS-504 attitude control and perform the required maneuvers have been determined. Results indicate that the quantity of on-board propellants exceeds requirements.

2.1.6 Solid Propellant System

S-IVB/Saturn IB and V Ullage Rockets

Ten ullage rocket motors (Serial Numbers K-801-4 and -6 through -14) were delivered on 30 January and stored at Thiokol, Huntsville, Alabama.

Thiokol has responded to a Douglas request for a quote on reduction of batch size to prevent exceeding ullage rocket shelf life. Information on shelf life extension of other motors of the same family was also included. Thiokol also quoted on conducting an aging program for the purpose of extending shelf life of the TX-280-10 motor.

Saturn IB/S-IB Retrorockets

Two static test firings of internally insulated retrorockets (Douglas Part Number 1A59670-505) at 60°F have been completed successfully. The motor cases were instrumented with thermocouples. No temperature rise occurred during motor operation. No hot spots were formed although one motor had a 1/2-inch-diameter void in the web of the propellant.

Douglas was directed by NASA to utilize all retrorocket motors (without internal insulation) that have been delivered, after completing reinspection. Six of these motors have been reinspected at Thiokol, Elkton, Maryland, and returned to Kennedy Space Center. The remaining motors have been returned to Thiokol for reinspection. Retrorocket motors for use on S-IB delivered during the quarter are noted below.

Part No.	Quantity	Vehicle	Date
1A59679-505	4	AS-209	13 January
1A59670-501-005	4	AS-207	15 February
1A59670-505	4	AS-210	28 February

Thermal analysis has been initiated to further evaluate adequacy of the internal insulation. This action was taken as a precaution after a Recruit motor malfunction on the ARC Athena Program.

NASA direction and authority have been received to subject two 1A59670-505 rocket motors (with internal insulation) to tests involving the most severe environments to which the 1A59670-1 rocket motors were subjected in the original (T-8) Qualification Test Program (with modifications as applicable to S-IB). Two 1A59670-505 rocket motors have been borrowed from those delivered on 28 February. These motors have been subjected to radiographic inspection, temperature cycling, a repetition of the radiographic inspection, and have been shipped from Elkton, Maryland, to Thiokol's Wasatch Division, Brigham City, Utah. Vibration testing at -10°F and static test firings (one at -10°F and one at +155°F) are scheduled during April.

Saturn V/S-II Retrorockets

Retrorocket motors for use on Saturn V/S-II delivered during the quarter are noted below.

Part No.	Quantity	Stage	Date
1A59679-503	4	AS-504	13 January
1A59670-503	4	AS-505	28 February
1A59670-1-005	4	AS-503	9 March

The Saturn V/S-II retrorocket motor external insulation has been reevaluated as follows:

a. It has been determined that a design modification can reduce cost, weight, and installation time. An ECP has been initiated requesting authority to proceed with this change.

b. A thermodynamic analysis has been made to determine adequacy of the Saturn V/S-II retrorocket insulation for a 12-hour hold on a Florida cold day (+29°F). Analysis indicates the need to cover the inboard side of the "torque box" in which the retrorocket motor is installed with a lightweight Mylar panel. An ECP has been submitted requesting authority to proceed with this change.

Retrorocket Case Temperature Prediction

A prediction of retrorocket case temperature versus time is being prepared. Analysis results will indicate how hot the retrorocket case becomes before burnout. In addition, this analysis will assist in evaluation of the AS-202 retrorocket case failure.

Ullage Motor Specific Impulse Change (AS-501 and AS-504)

An analysis was made in response to a NASA inquiry regarding the effect on excess propellant quantity, if the ullage motor specific impulse was changed from 270 to 255. It was determined that the net reduction in excess propellants is in the order of 7 pounds, assuming propellant loadings according to current schedules.

2.2 Structural/Mechanical

2.2.1 Structures

2.2.1.1 Analysis

A study was completed of the Synchronous Orbit Mission to identify long lead time items that will be required.

Structural/Mechanical supported the investigation of the destruction of the S-IVB-503 stage during acceptance firing countdown at the Sacramento Test Center on 20 January. Investigation results are reported in Section 4.

2.2.1.2 Design

Tankage

Changes calling out direct current TIG (Tungsten Inert Gas) welding were made to drawings of the (1) liquid hydrogen fill line, feed line, and chilldown return line elbows, and (2) liquid oxygen chilldown return line elbow. This welding process will replace the alternating current TIG method previously used. These changes, made to increase the weld quality of the assemblies, are effective on S-IVB-510 through S-IVB-515 and S-IVB-213 through S-IVB-216.

Forward dome instrumentation probe attach fitting requirement was deleted, effective on S-IVB-213 through S-IVB-216 and S-IVB-507 through S-IVB-515. This fitting is no longer required because the instrumentation probe no longer extends to the forward dome. Deletion of the fitting eliminates a welding operation.

The forward dome liquid hydrogen vent line bracket drawing was revised because it will be installed by lockbolt attachments in lieu of being welded. This revision was made effective on S-IVB-213 through S-IVB-216 and S-IVB-510 through S-IVB-515.

Insulation

Additional drawing revisions are being made to delete balsa wood parts from S-IVB-213 through S-IVB-216. These parts, which constituted an interim modification of the liquid hydrogen tanks of S-IVB-209 through S-IVB-212, were installed around the 112-stud fittings for Orbital Workshop experimentation. This effort to reduce weight and manufacturing costs will be completed within the next quarter.

Orbital Workshop

In preparation for an Orbital Workshop preliminary design review scheduled for April, analyses and layouts are being prepared, including Workshop floor, crew quarters, meteoroid shield, and vacuum outlets.

Additional analyses and investigations are being performed on the workshop crew entrance hatch design. The mockup hatch design that was completed early this quarter, per ECP 2031, is being reviewed; refinements will be incorporated into the layout for a flight-rated quick-opening hatch.

Engineering assistance and direction is being provided in the construction of a full-scale mockup of the Orbital Workshop.

Tank wall attach provisions for the environmental curtain and other workshop requirements are being coordinated with other groups and sections.

Drawings were revised to delete the requirement for the NASA 10M14504 equipment hanger fittings from S-IVB-211 through S-IVB-216, per ECP 0683 R2.

An installation drawing was released, per ECP 2107, to install a 0.002-mil aluminum foil coating in the S-IVB-211 liquid hydrogen tank. The coating retards flames due to meteoroid penetration.

Thrust Structure

Drawings were revised to replace the 0.5-cubic-foot bottle with the 4.5-cubic-foot bottle. This was accomplished per ECP 0616, to increase control gas capability on S-IVB-205 through S-IVB-207.

Drawings are being revised to provide tube feedthrough provisions in the thrust structure for the liquid oxygen chilldown pump purge module orifice, per ECP Log 7737. These revisions will be effective on S-IVB-204 and S-IVB-501 through S-IVB-515.

Impingement Curtains

The S-IVB/Saturn V impingement curtain installation drawing was revised to replace blind nut requirements with NAS679 type nuts and nutplates. This change was made to reduce material and manufacturing costs, per an employee suggestion.

Curtain drawings were revised to add additional stitching to the Velcro tape to eliminate tape separation from the curtains.

Pressure Vessels

Cold helium bottle strap assemblies were revised to replace the monel rivet attachments with A286 cres hi-lok attachments through the straps and center trunion fitting. This change, which eliminates a gap between the straps and the fitting, was made per FARR (Failure and Rejection Reports) Numbers A228200, A233573, and A235551. The change was made effective on S-IVB-506 through S-IVB-515 and S-IVB-212 through S-IVB-216.

Specification control drawings for subcontractor-supplied ambient helium bottles and for the plenum chamber bottle have been revised to add a requirement for an Eddy current test. This test assures compatibility of the weld material with the bottle parent material. The revisions, accomplished per ECP 2130, were made effective on all bottles installed, in stock, or allocated as spares.

Stage Tunnels

The aft auxiliary tunnel cover was revised to increase the vent area from 3.14 square inches to 9.42 square inches, effective on S-IVB-206 and S-IVB-208 through S-IVB-210, per ECP 1013. Additional venting was required because the previous venting path through the forward skirt was decreased.

S-IVB Stage

Drawings were reviewed and revised, as required, to update requirements for age control items. This effort was effective on S-IVB-209 through S-IVB-216 and S-IVB-505 through S-IVB-515.

Painting and Markings

The S-IVB/Saturn V painting and markings drawing was revised to agree with the aft umbilical panel markings required by NASA. The drawing was made effective on S-IVB-501 through S-IVB-515.

NASA documents for painting and markings on S-IVB-501, S-IVB-502, S-IVB-205, and S-IVB-206 are being reviewed to determine their compatibility with Douglas drawings.

The Saturn IB painting and markings drawing was revised to correct the aerodynamic fairing location markings. This change was brought about by ECP 0258, which removed the propellant dispersion detection system and resulted in a reconfiguration of the fairings.

Other effort included:

a. ECP 1197, which modifies the aft interstage S-IVB interstage test. The shortened aft interstage will be used as a loading structure for S-II testing to be conducted by North American Aviation.
b. ECP 3363, which authorizes the release of drawings to add flutter-prevention stiffeners to the outside of the forward skirt skin for vehicle staged. For skirts that are in the assembly stage, stiffeners will be added to the inside of the skin.
c. ECP 2057E, which entails preparation of a layout incorporating design egress for the nonpropulsive liquid oxygen vents and structural changes required to strengthen cutout. Layout preparation is progressing.

2.2.2 Environmental Control

Actuation Control Module

The following drawings were revised to incorporate the requirement for preconditioning the actuation control module to maintain a limit of -30°F:

a. 1B66382, Base Assembly, Actuation Control Module
b. 1B66383, Cover Assembly, Actuation Control Module
c. 1A67878, Duct, Flanged, Environmental Control, Aft Interstage
d. 1A67979, Purging, System Installation, Aft Interstage

Updating of Development Fixture Requirements

The environmental control system development fixture drawing (1A81879) was revised to update development fixture requirements for each stage.

Prevention of Overpressurization of Freon Bottle

Documentation has been released to require that (1) the gaseous nitrogen facility valve be closed during R-12 Freon leak checking, and (2) the R-12 Freon bottle be disconnected when not in use. This requirement eliminates the possibility of the Freon bottle becoming overpressurized.

S-IVB-209 Purge and Preparation for Shipment to the Sacramento Test Center

On 3 March, preparations were begun for installing hardware from the Model DSV-4B-1862, Purge Kit, into S-IVB-209. The purge, commenced on 6 March, was completed on 7 March. Following the purge, the desiccant system covers were installed.

S-IVB-209 was shipped from Huntington Beach to the Sacramento Test Center on 9 March.

2.2.3 Ordnance

Investigation of Ullage Rocket Jettison Fuse Rupture

An investigation of an incident of confined detonating fuse ruptures reported in qualification test report SM-53172 (TPI AE-5) was completed in January. The report concluded that the system was qualified and that the ruptures did not constitute a failure. Complete confinement was not established as a requirement for this application.

Engineering investigation indicated a likelihood that parts exhibiting rupture were manufactured from an inferoir lot of raw material.

New confinement requirements were defined by Change Order 982 and CL 6-1568. Additional production acceptance tests were conducted by firing 30 feet of fuse material from a particular lot and two particular fuse assemblies returned from Kennedy Space Center. Test results demonstrated that the three specimens met the newly defined confinement requirements, and provided assurance that parts in the field made from the same lots will not rupture.

2.2.4 Installations

2.2.4.1 Analysis

Liquid Hydrogen Collector Manifold

A study of a collector manifold to provide improved fuel utilization and better liquid hydrogen tank passivation was initiated in cooperation with the Douglas Propulsion Department. Several installation approaches were investigated and layout drawings illustrating the respective advantages were prepared.

Synchronous Orbit Mission

Accommodations for various flight hardware were reviewed in response to revised proposed mission study ground rules.

Liquid Oxygen Nonpropulsive Vent

Several approaches to the design and installation of this system are currently being reviewed. One system proposed consisted of using a duct installation, similar to that successfully employed in the AS-203 liquid hydrogen experiment, plus venting out through the interstage. Other systems under consideration were (1) an external wrap-around vent duct mounted on the aft skirt, and (2) an internal wrap-around duct mounted on the thrust structure and venting out through the aft skirt. The latter approach was tentatively selected by the Systems Development Office for further study. This study is currently under way.

Liquid Hydrogen Nonpropulsive Vent

A general arrangement of this system was selected from several proposed. The system selected uses a modified oxygen-hydrogen burner hydrogen feed valve mounted in the forward skirt. Layout drawings exploring the installation requirements are being prepared.

Dual Launch Mission

Accommodations were established for revisions in hardware installation for the dual-launch mission proposal in its present form. No production drawing changes were initiated pending authorization to proceed.

2.2.4.2 Design

Dual Repressurization System

Modification drawings were completed for S-IVB-503 through S-IVB-506. Production drawings were completed for S-IVB-507 through S-IVB-515. The oxygen-hydrogen burner vacuum-jacketed liquid oxygen feed duct failed during vibration testing (TPI AH-6). Additional supports were provided as a result of this failure.

Ambient Helium Bottle

ECP 0616 authorized the installation of one 4.5-cubic-foot ambient helium bottle for S-IVB-205 through S-IVB-207. Rework SEO 1A95637-002 was released for S-IVB-205 and S-IVB-207, to be followed by production changes. S-IVB-206 was handled by DCRSEO to be followed with production changes.

Additional Flight Measurements, S-IVB-504

Douglas has been directed to provide additional flight measurements on S-IVB-504 in order to approximate AS-503 mission objectives. Included in the work currently in process are major revisions to the support installations in the forward and aft skirts, new wire panels, and the addition of another signal-conditioning rack in forward skirt panel position No. 9. Releases are approximately 30 per cent complete.

Revisions to Thermoconditioning Supply Line Support Installation

The upper support was completely redesigned to accommodate variations in fabrication and assembly of the supply line, and the location of the support fitting in the Instrument Unit. The effort required to prepare a PIRN (Preliminary Interface Revision Notice) was completed. The design changes will require MSFC ECP approval.

Revisions to Thermoconditioning Return Line Support Installation

Structural/Mechanical was advised by Douglas representatives at Kennedy Space Center that IBM had redesigned the return line by adding a hex fitting at the clamping point. Since this change was not previously coordinated with Douglas, ECP Log No. 7751 was prepared requesting authorization to revise support details and ICD's (Interface Control Drawings). Although NASA has acknowledged the problem and the need for a solution, the change has not been authorized pending submittal of a formal ECP with a PIRN. Effort required for the PIRN was completed.

2.3 Electronics

2.3.1 Analysis

2.3.1.1 Networks

Electronics supported the investigation of the destruction of the S-IVB-503 stage during acceptance firing countdown at the Sacramento Test Center on 20 January. Investigation results are reported in Section 4.

An investigation was conducted to determine usage of the 10-ampere general purpose relay. Relay failures during Qualification Testing indicated a moisture problem. Functions and criticality were listed and forwarded to the Project Office.

Power studies were updated for S-IVB-206, S-IVB-209, and S-IVB-504 based on new information pertaining to sequence of events. A computer program which tabulates instantaneous current, voltage, instantaneous power, and expended energy is now functional. The program will also plot the load profile (current versus time).

An investigation was made to determine usage of the 2-ampere general purpose relay. A list of usage and recommendations for replacement was defined.

A preliminary feasibility investigation was performed on installing cables and lights in the liquid hydrogen tank to support the orbital workshop. Preliminary results indicate many problems associated with connectors and lights. More detailed information will be available by the next report period.

2.3.1.2 Subsystem

A silicon backup chilldown inverter is being studied at NASA request. A report has been submitted to NASA detailing Failure Reports written against the chilldown inverter.

Methods for restarting the propellant utilization system at a Reference Mixture Ratio of 4.5:1 have been submitted at NASA request. Methods to initialize the propellant utilization system were also submitted. All modifications to implement these changes will be external to the propellant utilization box.

Crew safety and mission accomplishment details were prepared for Kennedy Space Center personnel involved with the propellant utilization system, chilldown inverter, stage batteries, and exploding bridgewire firing units.

The large Delta R temperature bridge (1A98088) is being redesigned at NASA request to increase the temperature range.

2.3.2 Design

2.3.2.1 Networks

Design is under way on a high performance oxygen-hydrogen burner. New thermal probe locations and new temperature ranges for burner flameout are required. Completed system requirements will be available by the next report period. The S-IVB-504 stage has been modified to add research and development measurements as a result of the destruction of S-IVB-503. All system design is complete with no FM/FM kit or tape recorder installed.

Design is in progress on a passivation kit to insure S-IVB hydrogen tank safety for manned occupancy. The system incorporates provisions for venting all high pressure vessels and dumping residual propellants.

During S-IVB-204 testing at Kennedy Space Center, an excessive number of cycles accumulated on the auxiliary propulsion system relay packages. The problem was traced to incompatibility between the Overall Test and stable table operating time in the Instrument Unit. The test history and recommended action is being documented.

During S-IVB-208 and S-IVB-209 Space Systems Center Vertical Checkout Laboratory tests a residual voltage was present on the engine control bus with engine cutoff "On." Analysis revealed that this condition would be expected due to transistor leakage current.

Exploding bridgewire pulse sensors have been acting erratically during subsystem testing. Pulse sensors were being reset for no apparent reason. After testing on a unit, there is a design deficiency that allows the pulse sensors to be reset with a negative going spike on the power bus. Investigation results are being documented.

2.3.2.2 Subsystem

An Engineering Change Proposal has been initiated for relay control package (1B57731-1) seal redesign. The welded assembly will be replaced with a gasket-sealed assembly. The vendor cannot economically produce welded assemblies at a rate commensurate with Douglas schedule requirements.

The helium heater exciter-ignition system failed after "hard mount" vibration testing at Wiley Laboratories. Failure analysis revealed that the ignitor was damaged causing an open circuit. Further analysis revealed that "hard mount" vibration levels exceeded system requirements. The unit will be repaired and subjected to vibration on the next assembly (AH-25).

Douglas and Deutsch have field reworked center coaxial contacts of all cryogenic feedthrough connector assemblies for S-IVB-205, S-IVB-211, S-IVB-212, S-IVB-501, S-IVB-506, and S-IVB-507.

In conjunction with the above rework, misassembled coaxial contacts in the internal cryogenic feedthrough were discovered. Misassembly consisted of (1) the use of external type contacts, which presents a liquid oxygen incompatibility problem, and (2) improper assembly of details, resulting in recessed contacts. The Douglas Process System has been clarified to prevent recurrence and all internal coaxial contacts are being replaced.

High Reliability parts are being received for modules to be built for testing under the High Reliability Program. Systems involved include propellant utilization, 5-volt module, and chilldown inverter. The propellant utilization system valve amplifier module and oscillator driver module have been built and successfully tested. The units are now being encapsulated.

2.3.2.3 Electro/Mechanical

Two harness installation books (forward skirt and internal tanks installation) have been released for additional S-IVB-504 flight measurements. All drawings were released by the end of March and development fixture engineering development is complete. Electronic equipment and transducer installations are complete.

The automatic passivation system modification installation drawing is 30 per cent complete.

During the stress corrosion susceptible parts investigation, EWB26 bolts used for battery installation were revealed to be susceptible to stress corrosion. Batteries are installed 72 hours prior to launch and the time element precludes a corrosion problem. Also the EWB26 bolt is designed to take torque values of 150 to 180 inch/pounds and the installation drawings call for 140 to 150 inch/pounds; therefore, bolts are not stressed to their limits. The EWB26 bolt is the only bolt available meeting requirements of the blind nut used by Structures consisting of a BN-330-428-2 sleeve and BB-341-12 expander without designing a new bolt. As a solution to this problem, an expedited Engineering Change Proposal and an Engineering Work Order were submitted on 10 March to design a 12-point external wrenching 200,000-psi bolt.

2.4 Weight Status

Current weight status on all contracted S-IVB flight stages is indicated below.

S-IVB STAGE NO.	CURRENT DRY SPECIFICATION WEIGHT	CURRENT DRY WEIGHT PER WEIGHT RECORD	CURRENT MEASURED STAGE DRY WEIGHT	SPECIFICATION WEIGHT MINUS BEST AVAILABLE WEIGHT
201	24,555	23,456	23,286 (3)	1,269
202	24,576	23,505	23,306 (3)	1,270
203	26,143	25,145	25,198 (3)	945
204	23,823	23,936	23,646 (1)	177
205	22,262	22,143	21,948 (2)	314
206	22,140	22,065	21,741 (1)	399
207	22,129	22,012	21,912 (2)	217
208	22,141	22,032	21,783 (2)	358
209	22,239	22,078	N/A	161
210	22,234	22,082	N/A	152
211	22,234	22,116	N/A	118
212	22,234	22,116	N/A	118
501	26,763	26,701	26,443 (1)	320
502	26,797	26,578	26,364 (1)	433
503	27,020	26,483	26,285 (3)	735
504	25,142	24,879	24,612 (2)	530
505	25,140	24,884	N/A	256
506	25,210	24,949	N/A	261

(1) Based upon final actual weighing

(2) Based upon Space Systems Center actual weighing

(3) Final dry weight

NOTE: Current dry weight per weight record is used as best available weight where measured weight entries are nonexistent.

More detailed weight information is presented in Douglas report DAC-56536: Saturn S-IVB Weight and Balance Status Report Model DSV-4B, dated 15 March 1967.

2.5 Aero/Thermodynamics

AS-204 Maximum Heating Trajectory Evaluation

A thermal analysis was made to determine stage compatibility with the AS-204 maximum heating trajectory. Results were used to establish stage external insulation requirements for S-IVB-204 and subsequent S-IVB/IB stages per MSFC direction.

S-IVB/Saturn V General Protuberance Heat Transfer Test

Evaluation of protuberance heat transfer test data has been completed and results have been published.

S-IVB/Saturn V Propellant Heating Analyses

Analysis was made of S-IVB-501 liquid hydrogen heating utilizing AS-203 flight data. Maximum and minimum heating values were determined.

S-IVB/Saturn V Fuel Tank Ullage Heating Evaluation

Thermal analyses to determine the predicted range of hydrogen tank ullage heating rates for S-IVB-501 have been completed.

S-IVB/Saturn IB and V Cold Plate Analyses

Analysis to determine the heat loss from S-IVB stage cold plates and associated components has been completed. Maximum heat losses were determined for the operational configurations of S-IVB/Saturn IB and V stages.

S-IVB/Saturn IB Dual Launch Component Thermal Evaluation

Component heating analyses were completed for the Dual Launch Mission. Passive thermal protection requirements for propulsion and electronic components have been defined.

S-IVB/Saturn IB and V Propulsion Component Temperatures

Analyses were made to determine maximum and/or minimum temperatures of the actuation control module, continuous vent regulator, gaseous hydrogen vent disconnect, and pneumatic angle valve.

S-IVB/Saturn V Low-Density Plume Impingement Test

Model fabrication and test setup have been completed and calibration and facility verification runs are in progress.

2.6 Flight Dynamics and Control

Control System Analysis

The S-IVB-207 stage control system design assurance analysis was completed and results were transmitted to MSFC during February. Analysis results showed that S-IVB-207 control system stability margins are acceptable under all expected parameter variations.

The S-IVB-504 stage control system shaping network recommendation transmitted to MSFC during March recommended that S-IVB-503 shaping networks be used in the S-IVB-504 control system.

S-IVB/Saturn V Coast Attitude Control System/Sloshing Interaction

An analog simulation to evaluate the interaction between propellant sloshing and the attitude control system during orbital coast has been completed. Preliminary simulation results show that propellant sloshing motion (primarily liquid oxygen) causes a significant increase in auxiliary propulsion system propellant consumption required to perform attitude maneuvers. Incorporation of liquid oxygen slosh baffles near the liquid oxygen fluid surface level during the coast period resulted in a slight savings of auxiliary propulsion system propellant. However, auxiliary propulsion system propellant reserves are adequate for the AS-501 through AS-503 missions without additional slosh baffles. Therefore, additional liquid oxygen baffles are not required for these missions. Investigations are continuing to determine auxiliary propulsion system propellant requirements on subsequent Saturn V missions.

S-IVB Stage Thrust Variation Predictions

Analysis was conducted to determine the effect of propellant utilization system modifications on S-IVB stage thrust variations. These modifications consist of a propellant utilization slosh filter and propellant mass sensor reshaping.

Propellant utilization system modifications reduced thrust variations effected by propellant utilization system nonlinearities; however, thrust variation limits established by MSFC (some of which are not effected by propellant utilization modifications) will not be met in all cases.

Contract End Item Specification Thrust Variation Limits

A study has been completed to determine S-IVB stage thrust variation limits to be incorporated in the Contract End Item specifications for stages S-IVB-204 through S-IVB-212 and S-IVB-501 through S-IVB-515. Contract End Item specification thrust variation limits were transmitted to MSFC during March.

Sequence of Events

Several sequence of events Interface Control Drawings and Interface Revision Notices were reviewed for compatibility with S-IVB stage design and operation. Results of these reviews have been transmitted to MSFC. The sequence of events for the following vehicles were reviewed.

Vehicle	ICD
AS-206	40M33606A
AS-207	40M33607
AS-208	40M33608
AS-501	40M33621B

Orbital Workshop

The investigation of thrust vector control system requirements during orbital workshop passivation propellant dumps has been completed. Results will be transmitted to MSFC in April.

AS-204 and AS-501 Alternate Mission Analysis

In response to Change Order 1053, a review of the NASA Apollo Flight Mission Assignments Document M-D MA 500-11, SE 010-000-1, dated July 1966, was performed to determine alternate mission compatibility with the S-IVB stage. It was determined that in all instances, except for the case of AS-501/S-IC flight with one engine inoperative in a wind/gust environment, that the S-IVB stage is capable of performing the specified alternate missions. The analysis results show that on AS-501 for an S-1C engine out in the wind/gust environment that S-IVB stage design loads are exceeded and that control of the launch vehicle may be lost. Analysis results will be transmitted to MSFC in April.

2.7 Strength

2.7.1 S-IVB/Saturn IB

Stress analysis has been started on Orbital Workshop structural components. This effort includes unique hardware such as the Orbital Workshop floor, walls, passivation system, and meteoroid bumper, as well as the effect these items will have on the basic S-IVB stage structure. Sufficient preliminary analysis is being performed to assure structural capability for the April Preliminary Design Review. Final stress analysis will be documented similar to other stress analysis packages and transmitted to NASA/MSFC.

A study was performed on S-IVB-204/AS-204 Backup Mission loads, including the effect of first stage engine out. Study results indicate the S-IVB stage is not critical for the side wind load condition normally imposed at maximum αq (the type of load criterion used in the past). However, trajectories and wind loads transmitted to Douglas by NASA also included a new criterion of head wind loads. Investigation of this new criterion indicates inadequate S-IVB structural capability. This information has been transmitted to NASA/MSFC.

2.7.2 S-IVB/Saturn V

Stress analysis has been performed in various functions to support investigation of the S-IVB-503 stage malfunction. These include studies of ambient helium sphere pressure and stress levels, wind and blast load effects on the S-IVB-503 stage, as well as the S-IVB-208 stage, and existing stress levels in the propellant tankage at the time period just prior to the explosion.

Preliminary investigation of the maximum αq loads with one engine out for the Saturn V vehicle indicates inadequate structural capability. This problem is being studied further with a possibility of panel tests to determine if redesign is necessary.

Detail stress analysis has been completed for the S-IVB-501 forward skirt, aft skirt, aft interstage, auxiliary propulsion system module, thrust structure, and tunnels. This material has been compiled and transmitted to NASA/MSFC. The propellant tankage detail stress analysis is nearing completion.

This effort is dependent upon final comparison to test results from the Hydrostatic No. 2 test. The areas for comparison are the forward dome/skirt to cylinder joint, the aft dome/skirt to cylinder joint, and the common bulkhead to aft dome joint.

Investigation of insulation removal from the oxygen-hydrogen burner for temperatures and loads on the ambient helium spheres mounted on the thrust structure has been completed. Results indicate the ambient helium sphere installation is less critical for the oxygen-hydrogen burner firing or heating effect than for normal ambient loads.

2.7.3 S-IVB/Saturn IB and V

To support the effort involved in the S-IVB-503 stage malfunction, analysis is being performed to assist in the rebuilding of the Sacramento Test Center Beta 3 Test Stand. Additional effort is being supplied for the proposed blast protection modification.

Detail stress analysis of the liquid hydrogen fill and drain line assembly has been completed and documented with copies transmitted to NASA/MSFC.

An investigation was performed on the liquid oxygen and liquid hydrogen feed line bellows after cracks, with a consequent loss of vacuum, were discovered during qualification testing. Analysis, later confirmed by inspection, indicated a random assembly interference on a later configuration produced a stress riser and consequent failure in the bellows weldment. Nondestructive inspection techniques (X-ray) were used to select components that could meet flight worthiness criteria. A minimum assembly gap was calculated based on the installation and operational loads for the bellows assembly.

2.8 Reliability

2.8.1 Reliability Analysis

2.8.1.1 Reliability Engineering Models and Supplements

The S-IVB-209 Reliability Engineering Model was submitted to MSFC on 27 February. Models for S-IVB-210, S-IVB-505, and S-IVB-506 are being prepared.

Flight Critical Items Second Tier Analysis

Second Tier Analysis effort for various stage items continued during the quarter. All analyses were completed by the end of March.

Time/Cycle Significant Items

Establishment of a new criterion for the auxiliary propulsion system bellows assembly (1A67911-503 and -505) was documented. The new criterion is 3,000 inches of linear travel.

Agreement was reached during the period on meeting bladder cycle collection requirements by Bell Aerospace.

Cycle criterion on the control relay package is being clarified. The present criterion is 25,000 cycles, by NASA direction, but the applicable relay specification indicates that a greater cycle criterion would be more realistic.

Multifailure Analyses

The Depletion Sensor System Multifailure Probability Analysis was released. A report on the Multifailure Analysis of the S-IVB Stage Severance Subsystem is nearing completion.

A report on the Multifailure Analysis of Quad Redundant Auxiliary Propulsion System Propellant Valve was completed during the quarter.

Reliability Prediction and Criticality Determinations

The S-IVB-209 stage prediction was computed during the period.

A revised probability was calculated for failure of the thrust OK pressure switches to transmit a dropout indication at the end of J-2 engine burn.

Computer loading and key punching for S-IVB-210 stage predictions were initiated.

Failure Effect Analysis of Ground Support Equipment

Douglas Report DAC-56520: Failure Effect Analysis and Criticality Determination for Selected S-IVB Ground Support Equipment, was submitted to MSFC in February.

2.8.1.2 Test Report and Test Drawing Review

Reliability Analysis reviewed the following reports, drawings, and procedures:

	Total Reviewed	Total Approved	Returned to Design Sections for Corrections
Qualification Test Reports	76	73	18
Formal Qualification and Reliability Verification Test Procedures	11	10	1
Formal Qualification Test Reports	2	2	0
Qualification Test Test Control Drawings (New)	6	6	0
Qualification, Formal Qualification, and Reliability Verification Test Test Control Drawing Engineering Orders	90	86	4

2.8.1.3 Reliability Assessment

Douglas Report DAC-56532: Reliability Assessment, Saturn S-IVB Stage, 503 Mission, was submitted to MSFC in March.

2.8.1.4 Formal Design Reviews

Formal Design Reviews held on Flight Critical Items and Special Attention Items during the quarter are noted below.

Part Number	Item
1B58005	Oxygen-Hydrogen Burner Pneumatic System Installation
1B62676	Oxygen-Hydrogen Burner Installation
1B62933	Oxygen-Hydrogen Burner Schematic
1B62600	Welded Oxygen-Hydrogen Burner Assembly
1B63385	Oxygen-Hydrogen Burner Control System Schematic

2.8.1.5 Engineering Drawing Reviews

Documentation reviewed and approved during the quarter included 1 Vendor Information Request, 7 Waiver Requests, 57 Engineering Orders, 29 Production Acceptance Test Engineering Orders, 10 Drawings, and 1 Memorandum Engineering Order.

2.8.1.6 Malfunction Detection System Design Analysis Status

The S-IVB-503 revised analysis and the S-IVB-504 preliminary analysis were delivered to MSFC during February. Effort is in process on the S-IVB-505 preliminary analysis and the S-IVB-504 revised analysis.

2.8.1.7 Orbital Workshop Support Activities

Reliability Engineering provided support for various Orbital Workshop stage modification and preliminary design review activities during the quarter.

2.8.2 Human Engineering

Human Engineering evaluated and approved drawings for two access platforms for use in the Vertical Checkout Laboratory for installation and removal of auxiliary propulsion system units from S-IVB stages.

Layout of the thermoconditioner/oxygen analyzer control panel for the Sacramento Test Center Beta Complex Test Control Center to be used during stage static firings was evaluated and Human Engineering recommendations were submitted.

A Human Engineering evaluation was performed on handling of cold helium spheres at the Sacramento Test Center Kappa Complex. A recommendation is being prepared.

Human Engineering participated in the Systems Safety Operations Review of the Auxiliary Propulsion System Checkout Laboratory.

2.8.3 Reliability Data Acquisition

2.8.3.1 Subcontractor and Supplier Control

The Calmec Company was visited during the quarter to coordinate and expedite reliability data on the cold helium fill module (1B57781), which is a Flight Critical Item.

Reliability Engineering reviewed 69 Vendor Information Requests and 3 Design Drawing Reviews covering vendor submittals during the quarter.

2.8.3.2 Failure Reporting and Corrective Action

Reliability Engineering participated in a failure analysis on a pressure switch (7851847-535, Serial Number 100) at the Frebank Company, Glendale, California during January.

2.8.3.3 Reliability Case Analysis Presentation

The monthly RECAP report for the period ending 13 January, containing 1,439 items, was submitted to NASA on 16 January. The report for the period ending 13 February, containing 1,276 items, was submitted on 14 February. The report for the period ending 13 March, containing 1,425 items, was submitted on 14 March.

2.8.3.4 Traceability

Approximately 4,000 drawings and drawing changes were reviewed for identification/traceability requirements; 55 drawings were processed for additional requirements, effectivities, and incorporation in the Identification/Traceability Parts List.

2.9 Component Standards

Component Standards activities during the quarter are noted below.

Maintaining and coordinating the Approved Parts Lists included processing 50 requests for the approval of parts and adding 58 approved parts, mechanical and electrical, to the GSE and Vehicle Approved Parts Lists.

Monitoring parts testing included:

a. Testing parts from the Riedon Company as a second source to Resistor Specification 1A77189.

b. Testing on Raytheon transistor, 2N2102, Drawing 1A88722, to determine power handling capabilities.

c. Documenting the qualification test results of Texas Instruments semiconductor, P/N 1A96573-1 (IN-R-QUAL-66-17).

d. Evaluating and qualifying Bendix semiconductor, P/N 1B54541-501, by similarity to 1B54541-1.

e. Issuing an S-IVB Test Plan Change Requests on relays, P/N's 1B50992-505, 1B66899-1, and 1B66900-501, to authorize qualification testing.

f. Evaluating test data for high reliability chopper, P/N 1B53353-1.

Participating in parts failure analysis included:

a. Performing failure analyses on relays, P/N 1B58584-501; and on relays P/N's 1B50992-501 and -503.

b. Evaluating failure analyses performed on diodes, JAN 1N649; JAN 1N3001B; UT 265; P/N 1B66308-1; JAN 1N1206.

c. Evaluating failure analyses on transistors, P/N's 1B52282-1; 1A89618-501 and -1; 1B52283-1; 1A88722-1.

d. Performing failure analysis on Bourns 1B16298 high reliability potentiometers.

e. Performing failure analyses on bus connector, 1B57771.

f. Performing failure analyses on Kemet solid tantalum capacitors, P/N S0845.

g. Investigating failures involving microswitch, P/N 1HM1, in valves.

h. Performing failure examination on electrical plug, 1B37872.

i. Performing failure analysis on 1B29981 filter inductor.

j. Performing failure analysis on 1B32111 transformer.

Participating in surveys of supplier facilities included:

a. Conducting a vendor survey for a second source to Douglas Specifications (resistors) 1A27871, 1B16298, and (capacitors) 1B64048, and 1A59565.

b. Surveying the Hoffman Semiconductor Company, located in El Monte, California, relevant to diode, P/N 1B52277-547.

c. Surveying the Bourns Inc. facility, located in Riverside, California, as related to failures associated with potentiometer, P/N 1B16298.

d. Surveying the Electro Plating Service located in Gardena, California.

e. Surveying the new Aerovox Resistor facility located in Burbank, California.

Providing coordination among Douglas MR&PM, Design Sections, and Manufacturing for parts requiring special tooling, procedures and assembly included:

a. Coordinating with MR&PM to determine the disposition of diodes, P/N 1B32499-1 and -501, having an excess and nonuniform nickel strike on leads.

b. Coordinating with MR&PM for further research into vacuum encapsulation.

c. Coordinating with MR&PM and stage design on Dickson diode, P/N 1B32499-1 and -501. The parts had lead material which was not within specification.

d. Coordinating with MR&PM on problem of terminating 7869679B22-1SJ wire into a Bendix connector.

e. Coordinating with MR&PM on transistor leads, P/N 1B52283-1.

SECTION III

MANUFACTURING

3. MANUFACTURING

Manufacturing and fabrication of S-IVB stage components and subassemblies continued during the quarter at the Santa Monica, California, facility with stage assembly and checkout at the Huntington Beach, California, Space Systems Center. Fabrication progress on individual stages is described below. Stage activity following checkout is reported in Section 4.

3.1 S-IVB/Saturn IB Stages

S-IVB-209

S-IVB-209 stage factory checkout, initiated on 28 November 1966 in the Space Systems Center Tower 5, was completed on 26 January. Installation and requalification of replacement bus modules were accomplished after checkout. Thirty-five tests were completed. The only parts not installed at the time of All-Systems Testing were the liquid hydrogen feed duct (1A49320-507) and engine transducers for measurements C1, C2, and C215. The only test discrepancies existing at the conclusion of testing were (1) one data channel showed excessive noise when the chilldown inverters were on, and (2) one data channel had an excessive level change during open loop transmission. Following checkout, leak checks were completed in Tower 8 on 10 February. Installations and final checkout were completed on 24 February and the stage was prepared for shipment. The stage was airlifted to the Sacramento Test Center on 9 March.

S-IVB-210

S-IVB-210 forward and aft skirts and thrust structure installations were completed in the Space Systems Center Vertical Checkout Laboratory Tower 2 on 17 January and the stage was moved to Tower 6. J-2 engine installation was completed in late January. Electrical and mechanical installations and hookup were then completed. Systems checkout, initiated on 10 February, was completed on 21 March. Stage shipment to the Sacramento Test Center is scheduled for April.

S-IVB-211

Insulation and clip bonding of the S-IVB-211 stage tankage was completed on 7 February in the Space Systems Center Insulation Chamber. The stage was moved to Tower 4 for cleaning and then returned to the Insulation Chamber for installation of the hydrogen tank fire retardant liner, which was completed on 12 March. The stage was then moved to Building 42 for cleaning. Joining of the thrust structure and forward and aft skirts was initiated on 23 March.

S-IVB-212

Internal insulation installation and clip bonding of S-IVB-212 stage tankage was in process in the Space Systems Center Insulation Chamber at the end of the quarter. Aft skirt and forward skirt assembly was in progress at the end of March.

3.2 S-IVB/Saturn V Stages

S-IVB-504

The S-IVB-504 stage completed the "Ready for Shipment" milestone at the Space Systems Center on 18 January and was moved to Los Alamitos Naval Air Station on 19 January for air shipment to Mather Air Force Base. Engine difficulties delayed arrival of the aircraft and the stage was returned to the Space Systems Center. Following aircraft repairs, the was airlifted to the Sacramento Test Center on 25 January.

S-IVB-505

S-IVB-505 tank installations were completed and the tanks were sealed on 13 January and the stage was moved to Tower 4 of the Space Systems Center for dual repressurization sheet metal installations. Joining of the skirts and thrust structure was completed in late January. J-2 engine installation was completed in February. Systems checkout was initiated on 20 February and is expected to be concluded on 12 April.

S-IVB-506

Proof, leak, and dye checks were completed on the S-IVB-506 tankage on 31 January. The stage was then moved to the Space Systems Center Insulation Chamber for insulation and tank installations. Internal insulation was completed on 23 March. Liquid hydrogen tank installations were in progress in Building 45 at the end of the quarter.

S-IVB-507

Tank cylinder panels were received at the Space Systems Center and assembly of the S-IVB-507 liquid hydrogen tank was initiated in the Building 45 trim and weld fixture in February. The liquid oxygen tank was completed and shipped to the Space Systems Center on 21 March. Fabrication of the forward dome was in process at Santa Monica at the end of the quarter. The liquid hydrogen tank cylinder assembly was completed on 23 March and was moved to Tower 1 for joining with the liquid oxygen tank and forward dome.

S-IVB-508

Fabrication of the S-IVB-508 liquid oxygen tank was in process at Santa Monica at the end of the quarter. The forward dome was nearing completion at the end of March and will be shipped to the Space Systems Center in early April. Work on tank cylinder panels was progressing in the trim and weld fixture at the Space Systems Center at the end of March.

S-IVB-509

S-IVB-509 tank cylinder segments were being formed at Santa Monica at the end of the quarter.

SECTION IV

TESTING

4. TESTING

4.1 Systems Testing

Testing of S-IVB stage systems continued during the quarter at the Huntington Beach Space Systems Center, Sacramento Test Center, Kennedy Space Center, and at other Douglas and vendor facilities.

4.1.1 Flight Testing (Kennedy Space Center)

S-IVB-204

Preparations for launch of the AS-204 vehicle were discontinued after a fire occurred in the spacecraft during testing on 27 January. Post-accident inspection and investigation during February indicated that the S-IVB stage performed as designed during testing in progress, was not damaged during the fire, and did not contribute to the cause of the incident.

Following de-erection of the spacecraft on 17 February, a requalification period was accomplished on the launch vehicle which consisted of the LV Emergency Detection System test and LV Systems Plugs-In test. Both tests were completed successfully with no problems.

A decision was made to transfer the AS-206 mission to the AS-204 launch vehicle. The AS-204 vehicle will be transferred from Launch Complex 34 to Launch Complex 37, which is configurated for the AS-206 mission. The mission will be identified as AS-204 L.

S-IVB-206

The S-IVB-206 stage was transported to Launch Complex 37 and erected on 23 January. Stage subsystem checkout progressed smoothly, completing all objectives in preparation for the first integrated tests. Integrated testing which followed consisted of Launch Vehicle Electrical Mate, Power Transfer, and Propellant Dispersion tests.

Because of program realignment, testing of the AS-206 vehicle was suspended in early March. Following the decision to move AS-204 to Launch Complex 37, AS-206 was de-erected and the S-IVB stage moved to Hangar AF where it was prepared for shipment to the Sacramento Test Center for storage.

S-IVB-500F

Facilities auxiliary propulsion system module inert oxidizer and fuel loadings were conducted at Launch Complex 39A on the Mobile Service Structure. These two inert loadings were followed by a hot fuel loading, which was accomplished with no significant problems.

Douglas was directed to ship the stage to MSFC for use as a mockup during the AS-204 Apollo launch. A dummy J-2 engine was installed and the stage de-erected from Low Bay Cell No. 2 and prepared for shipment. Prior to the scheduled ship date, the AS-204 mission was scrubbed and shipment of the 500F stage was cancelled. The stage was returned to the checkout cell and placed in storage.

S-IVB-501

Following a long power-down period, the LV Systems Overall Test No. 1 with the S-II Spacer was rerun to requalify the AS-501 vehicle prior to de-erection. The stage was de-erected on 14 February and placed on the transporter for orbital coast instrumentation installation in the liquid hydrogen tank. Following erection of the flight S-II stage, the S-IVB stage was re-erected on 24 February.

Integrated testing was initiated following the power-up activity. Integrated testing has progressed smoothly from the LV Electrical Mate test through the LV Flight Sequence and exploding bridgewire test.

S-IVB-502

The S-IVB-502 stage arrived at Kennedy Space Center on 22 February, was unloaded, and temporarily moved to Hangar AF. On 25 February the stage was transported to the Vehicle Assembly Building Low Bay and erected into Low Bay Cell No. 1 where subsystem checkout activity was initiated. The stage was erected on AS-502 in the High Bay Cell No. 2 on 29 March.

4.1.2 Acceptance Testing (Sacramento Test Center)

S-IVB-205

Post-turnover modifications were nearing completion on the S-IVB-205 stage at the Vertical Checkout Laboratory at the end of the quarter. Stage shipment to Kennedy Space Center is scheduled for 29 June.

S-IVB-207

S-IVB-207 stage Category II and III modification work was completed at the Vertical Checkout Laboratory during January. Tasks included replacing the ambient helium bottle required for dual launch capability. Final purges and thermoconditioning checkout were accomplished and the stage was placed in storage on the transporter on 19 January. Shipment to the Kennedy Space Center is scheduled for 11 July.

S-IVB-208

The S-IVB-208 stage acceptance firing was successfully accomplished on 12 January at the Beta 1 Test Stand. Mainstage duration was 424.3 seconds, with automatic cutoff initiated because of imminent liquid oxygen depletion. The acceptance firing satisfied all major test objectives. The stage was transferred to the Vertical Checkout Laboratory on 27 January for post-firing checkout and All-Systems Testing. GSE checkout, stage power turnon, and engineering checkout of stage subsystems procedures were accomplished during February. Work during late February included propulsion leak checks, Mylar installation on the forward dome, retrorocket plume impingement curtain installation, and engine start bottle system modifications. All-Systems Testing was completed on 16 March and the stage was placed in storage. Shipment to Kennedy Space Center is scheduled for 5 July.

S-IVB-209

The S-IVB-209 stage arrived at the Sacramento Test Center on 10 March. Following inspection and limited modification activities, the stage was installed in the Vertical Checkout Laboratory Tower No. 1 on 27 March. Stage modification and preparation were active at the end of March.

S-IVB-502

Post-turnover modifications and preparation for shipment were completed on the S-IVB-502 stage at the Vertical Checkout Laboratory during February. Activities included liquid oxygen tank sump screen inspection, low pressure duct reinstallation, and installation of special orbital coast internal temperature transducers in the liquid hydrogen tank. The stage was then shipped to the Kennedy Space Center on 21 February.

S-IVB-503

The S-IVB-503 stage was destroyed on 20 January during acceptance firing countdown on the Beta 3 Test Stand.

The stage was installed in the test stand on 14 October 1966. Structural inspection commenced immediately, followed by modifications that were completed approximately 6 January. Installation and checkout of the oxygen-hydrogen burner installation proceeded in parallel with subsystem/ system tests.

The simulated static firing countdown (1B70264) was conducted on 14 and 16 January. The test area was secured over the weekend and the data were reviewed.

The stage was certified as "Ready for Static Firing" on 18 January. The static firing countdown was initiated 19 January; the actual firing was scheduled for 20 January.

The first firing attempt was aborted at T_0 +180 seconds (T_0 = simulated liftoff) due to a computer check sum error indication. Resolution of the problem permitted resumption of the countdown, which was recycled to T_0 -23 minutes.

During the second terminal countdown, the S-IVB-503 stage exploded and was destroyed at T_0 -11 seconds. T_0 -11 is 522 seconds prior to actual engine start command.

Immediately following the incident, the following committees were formed to support the NASA Board of Inquiry, headed by Dr. K. Debus:

a. Data Protection and Inventory
b. Documentation Review
c. Crew Procedure, Operation, and Safety
d. Personnel Interviews
e. Damage Assessment and Mapping
f. Cause Isolation Investigation
g. Photographs

Investigation results revealed that the test was planned and executed in a professional manner and that all stage and GSE systems performed as designed up to the point of the incident. It was determined that it would not have been possible for operating personnel to have predicted or to have prevented the incident.

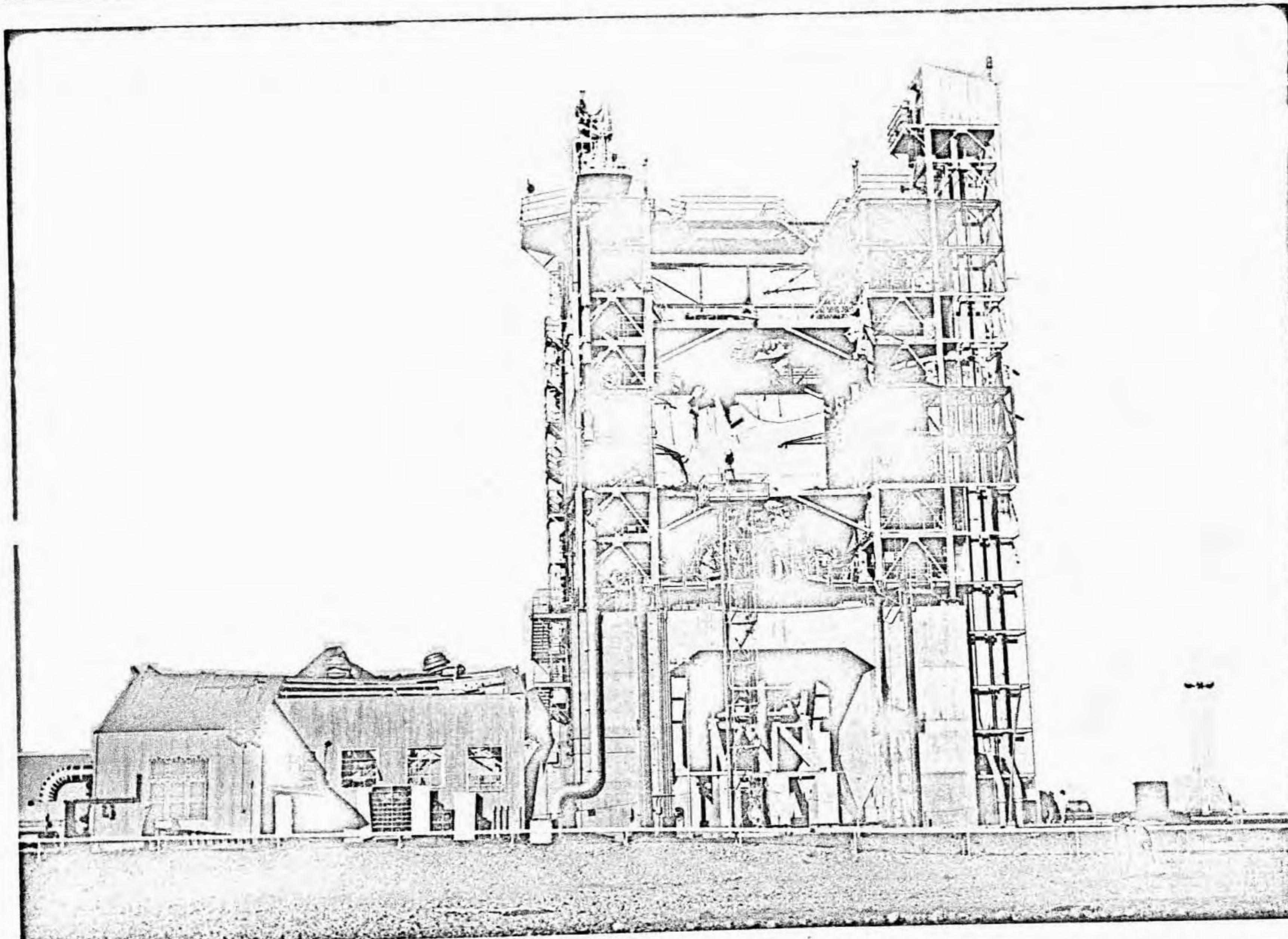
Post-accident investigation revealed that an ambient helium sphere weld was commercially pure Ti-55A titanium, not the specified Ti-6Al-4V titanium.

Complete investigation results will be published in a Douglas report now being prepared.

Figures 1 and 2 show the damaged test stand and one of the recovered ambient helium hemispheres.

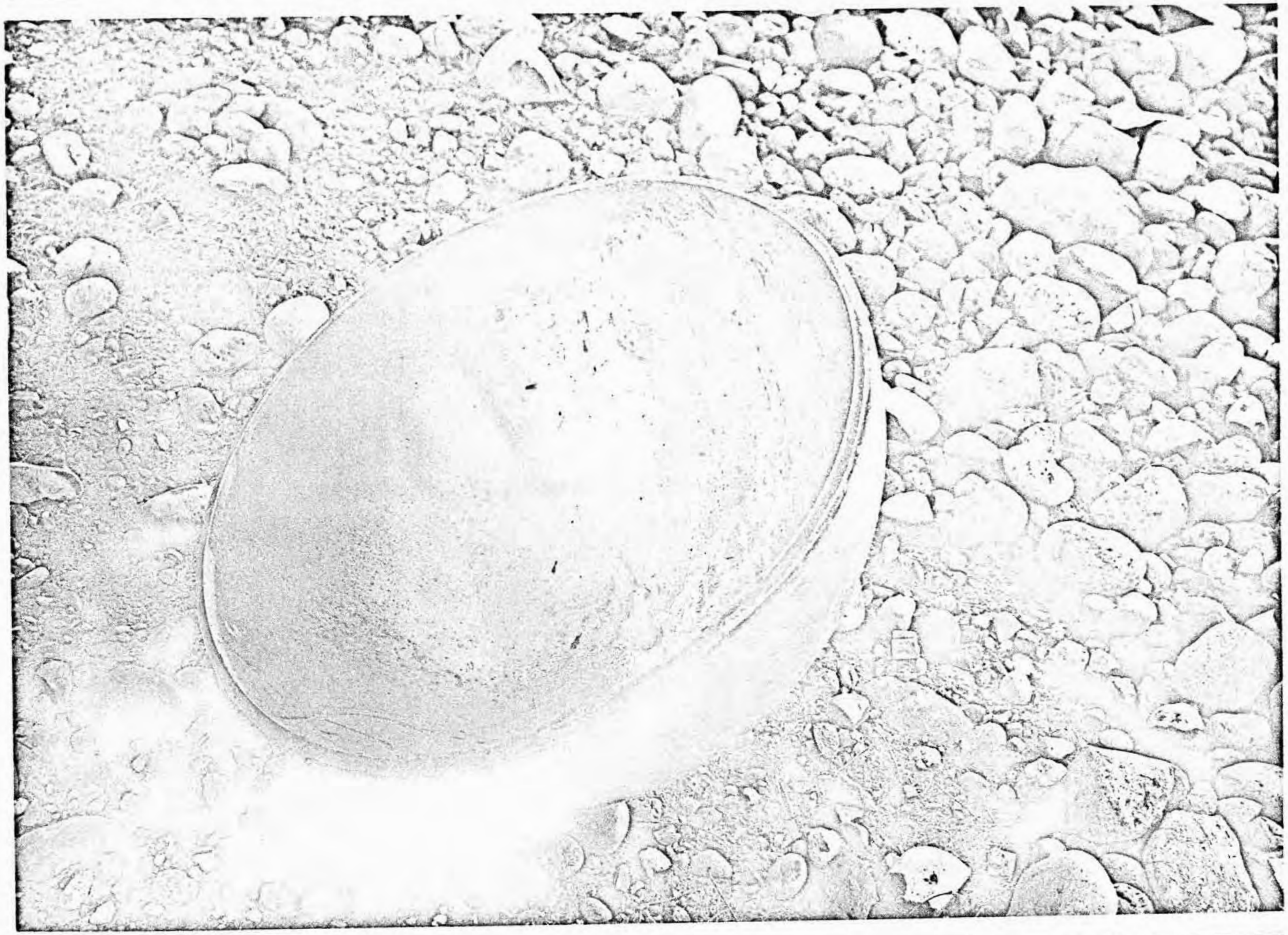
S-IVB-504

The S-IVB-504 stage arrived at the Sacramento Test Center on 25 January and was installed on the Beta 1 Test Stand on 27 January. The Beta 1 Test Stand is being modified to accept S-IVB-504, which will precede S-IVB-209 through acceptance firing operations. Prefiring activities during February included oxygen-hydrogen burner subsystem and associated supporting equipment buildup, automatic GSE checkout, stage test preparations, and stage power turnon procedures. Stage power turnon was accomplished on 24 February. The 96-hour common bulkhead purge with Argon and the oxygen-hydrogen burner gaseous nitrogen altitude simulation system checkout were conducted on 23 March. Subsystems checkout was essentially completed by the end of March. Stage acceptance firing is scheduled for 26 April. Per NASA direction, the S-IVB-504 stage will be employed with Launch Vehicle AS-503, maintaining the original S-IVB-504 identity.



SM–483311

Figure 1. Overall View of Beta 3 Test Stand



SM–483327

Figure 2. Ambient Helium Hemisphere Located Near Test Stand

4.2 Subsystems Testing

4.2.1 Design Development Testing

Design development testing is continuing to provide information which can be applied to the Saturn S-IVB effort. Design development testing is nearing completion with 323 tests completed of 342 tests scheduled. Significant design development testing accomplished during the quarter is described below.

4.2.1.1 Airframe/Structures

Mechanical Properties of Welded Tank Joints (A-16D)

Twenty additional coupon specimens representing critical welded joints in the S-IVB tankage were tested. This makes a total of 97 specimens that have been tested to date under A-16D. Of the 20 additional specimens, eight represented the common bulkhead Y-extrusion to aft dome aft fillet weld, one represented the common bulkhead Y-extrusion to aft dome forward fillet weld, five represented the forward dome to cylindrical tank weld, and six represented the aft dome to cylindrical tank welds. A final test, consisting of six coupon specimens, will be performed. It is expected that a final total of 103 specimens will have been tested under A-16D.

Liquid Oxygen Tank Redesigned Aft Dome Jamb Development Test (A-63)

The following tests were performed on one specimen of the redesigned liquid oxygen tank aft dome jamb (1T09008-511):

a. Room temperature proof pressure test
b. Room temperature pressure cycle test
c. Liquid nitrogen temperature pressure cycle test
d. Liquid nitrogen temperature limit pressure test
e. Liquid nitrogen temperature ultimate and burst pressure test

The specimen failed at a pressure of 126 psig. The testing of A-63 is complete. A second specimen previously scheduled for testing was cancelled.

Fire Resistant Coating Test - S-IVB Liquid Hydrogen Tank Insulation (A-65A)

Development tests were conducted on aluminum foil and Dyna-Therm D-65 fire retardant liners for the S-IVB liquid hydrogen tank insulation. The test specimen was the 8-foot-scale tank (5863864-501), equipped with S-IVB flight-type insulation, and lined with aluminum foil on the upper half of the inner tank wall and with Dyna-Therm D-65 on the lower half. The specimen was purged with air (at 70 to 90°F and a maximum relative humidity of 65 per cent) for 72 hours, then subjected to seven cycles of liquid hydrogen fill and drain. During the first cycle, the tank was vented to the atmosphere; during cycles 2 through 7, the tank was pressurized with helium gas to 27.5 ±1 psig for 10 minutes. The specimen was then subjected to a post-test evaluation program. A-65A testing is complete.

4.2.1.2 Propulsion System Components/Fuel Tank Pressurization System

Continuous Regulator Valve (H-43A)

Development tests to eliminate main poppet chatter of the continuous regulator valve have been completed. Life cycle tests of three main poppet bellows assemblies will be completed during the next quarter.

4.2.1.3 Auxiliary Propulsion System

Low-Pressure Helium Module (L-68)

A program to check diodes in the low-pressure helium modules in all stages was initiated after diode failures occurred during formal qualification tests. A large number of defective units were replaced. Vendor Acceptance Test Procedures and all Douglas checkout procedures were revised to require diode checks as termination checks after solenoids are operated.

The solenoid on formal qualification specimen No. 1 failed voltage dropout tests during post-propellant-exposure tests. Disassembly of the unit revealed that the inside surface of the solenoid and solenoid plunger had corroded. Corrosion caused high friction and drag in the solenoid plunger area and subsequent low dropout characteristics. Vendor usage of materials (B1113 carbon steel plated with nickel) incompatible with propellant vapors was the cause of the failure.

Redesign was initiated and a development program is being established. One development consists of new solenoids constructed from compatible materials. A second development makes use of existing solenoids which have been plated with compatible materials. Upon completion of L-68 testing, the best approach will be selected and ECP 7715 will be revised for production.

Auxiliary Propulsion System Shipping Shock Recorder (L-69)

A new line item (L-69) has been created to determine the required shock amplitude range. Upon determination of this range, a unit will be selected for subsequent development testing.

4.2.1.4 Propellant Dispersion System Components

Safety and Arming Fragility Test (AC-30)

A series of development tests was conducted by subjecting the safety and arming device to vibration levels higher than those previously established as fragility levels for the device. Four specimens were tested, in three orthogonal axes, in random and sine vibration. Two of the four units were inoperative after testing. However, in both cases, difficulties experienced with the shaker equipment allowed the specimens to be exposed to levels that were higher than those specified in the test requirements. The tests established that these test levels will not cause autorotation of the safety and arming rotor.

4.2.1.5 Cryogenic Repressurization System

1-Inch Shutoff Valve (AH-14)

Development testing on the 1-inch shutoff valve (1B59010) is progressing satisfactorily. Actuator leakage tests have been completed and tests are in process to determine the effects of temperature extremes on operation of the position indicator. An ECP to redesign the -501 valve and reconfigurate to -503 for use on S-IVB-501 through S-IVB-515 has been approved.

Oxygen-Hydrogen Burner Liquid Oxygen Line Shutoff Valve (AH-24)

An ECP to redesign the pneumatic actuator and change the part number from 1B66485-1 to 1B66639-503 has been approved. The new design incorporating a heavier spring and other hardware improvements, has been completed. Development testing to identify and eliminate any additional problem areas is continuing.

4.2.2 Qualification Testing

Qualification testing of parts, components, subassemblies, and higher levels of assembly to ensure that the design is capable of meeting established requirements is continuing. Qualification testing is nearing completion, with 688 tests completed of 741 tests scheduled. Significant qualification testing accomplished during the quarter is described below.

4.2.2.1 Propulsion System Components/Ambient Helium System

Actuation Control Module (J-3B)

All qualification testing required for the actuation control module (1B65292) has been completed. The module was subjected to tests during Sterer development testing (J-3D) and the solenoid bolts failed under the increased vibration levels. No usage or further testing of this module is planned.

Actuation Control Module (J-3C)

During the vibration portion of qualification testing, the -1 actuation control module (1B66692) exhibited excessive leakage and structural failure of the solenoid case occurred. A redesigned prototype module was tested successfully (J-3D). The module was reconfigurated to -501. Reinforced solenoids and smaller poppet balls were incorporated. The -501 configuration is in production and the first three modules to be completed are scheduled for formal qualification testing. Due to revised thermal analysis, thermal isolation spacers will be required for stage installation of the modules. An ECP to install the spacers has been initiated.

Pneumatic Power Control Module Assembly (J-6)

An ECP has been initiated to replace the 1A58345 modules with new modules, which will incorporate hermetic sealing of the vent solenoid and provide for a vent port check valve. Additional qualification testing will be required upon approval, since all four 1B43657 modules failed at low temperature in the regulator failure mode during Reliability Verification testing. Response time of the shutoff valve varied from 6 to 30 seconds. The maximum specification limit is 500 milliseconds. The four specimens were returned to the vendor and Item J-6C has been established for development testing to determine the cause of failure and corrective action required.

Liquid Hydrogen Repressurization Module Assembly (J-18)

The cold helium control solenoid valve (1B43660) has been reconfigurated from -507 to -509 to incorporate a Vespel poppet seal identical to the new seat in the -503 configuration of the cold helium dump module (1B57781). Qualification tests were completed during the quarter and no further testing of the solenoid valve is required except in conjunction with formal qualification tests of the next assembly.

4.2.2.2 Auxiliary Propulsion System

Auxiliary Propulsion System High-Pressure Helium Tank (L-63)

Two specimens of the tank manufactured by the vendor have successfully completed qualification tests. An additional line item will be created to qualify two specimens of the tank manufactured by Douglas.

4.2.2.3 Ullage Rocket System

Detonator Block and End Fitting (AE-8)

A series of 30 tests was successfully completed to qualify the end fittings for the explosive fuse assembly (1B56400-501) and the detonator block (1A84223-503). These components are used in the ullage rocket jettison system on Saturn V.

Ullage Rocket Confined Detonating Fuse Ignition System (AE-16)

An auxiliary vibration survey test of one confined detonating fuse assembly was completed satisfactorily. This test supplemented the AE-16 tests reported complete in the last quarter. The purpose of the test was to measure vibration levels near the fuse that failed to propagate its entire length. A fuse assembly (1B53581-541) was installed to duplicate a dual installation like the segment that failed to propagate. During vibration testing, the specimen was observed visually and monitored with a slip-sync camera. No large displacements of the fuse were observed. After vibration, the specimen was fired successfully.

4.2.2.4 Cryogenic Repressurization System

Ignition System Excitor (AH-12)

The ignition system excitor (1B59986) (Serial Number 010) failed to operate after vibration during qualification testing. The unit will be repaired and shipped to Douglas to be vibrated as a part of test AH-25.

The unit had been subjected to low temperature, high temperature, mechanical shock, and vibration. Serial Number 013 has successfully completed low temperature, high temperature, mechanical shock, vibration, and electromagnetic interference testing. Both units will be subjected to acoustical noise testing. Life test will be performed by the vendor.

4.2.3 Formal Qualification Testing

Formal qualification testing, to demonstrate, through controlled component tests, that Saturn S-IVB stage hardware meets established requirements under various applicable combinations of service environments, is continuing. Twenty-three tests have been completed of 42 tests scheduled in the formal qualification test program. Significant formal qualification testing accomplished during the quarter is described below.

4.2.3.1 Propulsion System Components/Oxidizer Tank Fill System

Liquid Oxygen Auxiliary Motor-Driven Chilldown Pump (G-7)

Formal qualification tests of the three specimens of the liquid oxygen auxiliary motor-driven chilldown pump (1A49423) were completed during the quarter. The ECP to reconfigurate the -505 pump to -507 by incorporating a different seal spring and controlling assembly torque has been approved.

4.2.3.2 Propulsion System Components/Fuel Tank Pressurization System

Fuel Tank Vent and Relief Valve (H-5)

Formal qualification testing of the fuel tank vent and relief valve (1A48257) is progressing satisfactorily. A new configuration of the valve (-511) has been installed on S-IVB-501 and S-IVB-504.

4.2.3.3 Propulsion System Components/Oxidizer Tank Pressurization System

Cold Helium Dump Module (I-2)

Formal qualification test of one -503 specimen is in process. An ECP has been initiated to replace the present relief valve vent check valve with a 1B67481-1 check valve to reduce the possibility of stress corrosion affecting the Belleville springs in the relief valve.

Liquid Oxygen Tank Pressurization Control Module (I-3)

Two -503 modules have completed all formal qualification testing. The third specimen has been reconfigurated to a -505 module, which contains Vespel poppet seats and a check valve in the regulator vent port. The check valve has been added to reduce the possibility of stress corrosion affecting the Belleville springs in the regulator.

Oxidizer Tank Vent and Relief Valve (I-7)

Formal qualification tests of the oxidizer tank vent and relief valve (1A48312) are progressing satisfactorily. A new configuration of the valve (-505) has been installed on S-IVB-501 and S-IVB-504.

Oxidizer Tank Relief Valve (I-9A)

Formal qualification testing of the first specimen of the new 1A49490-515 valve has been initiated. An ECP to install the valve on existing and future production stages has been initiated.

4.2.3.4 Propulsion System Components/Ambient Helium System

Liquid Hydrogen Repressurization Module Assembly (J-18)

Formal qualification testing of the -505 specimen is progressing satisfactorily. The two -511 specimens are being held for rework of the valve seats in the cold helium control solenoid valve (1B43660) incorporated in each assembly. An ECP has been initiated to delete the relief valve from all configurations of the assembly. Formal qualification testing is proceeding without the relief valves installed.

4.2.3.5 Flight Control System Components

Engine-Driven Hydraulic Pump (M-3)

Formal Qualification testing of the engine-driven hydraulic pump was completed satisfactorily during the quarter.

Auxiliary Motor-Driven Hydraulic Pump (M-29)

Formal qualification testing of the auxiliary motor-driven hydraulic pump was successfully completed during the period.

4.2.4 Reliability Verification Testing

Reliability Verification testing, designed to increase the engineering confidence in the probability of flight, continued during the quarter. Four tests have been completed of 19 tests scheduled. Significant testing during the quarter is described below.

4.2.4.1 Propulsion System Components/Ambient Helium System

Helium Fill Module (J-11)

Two specimens of the helium fill module (1A57350) failed during reliability verification testing. The first failure was due to excessive leakage during vibration and the second was due to excessive leakage at low temperature during post-vibration tests. Both specimens have been returned to the vendor for inspection. Although inspection has not been completed, cause of both failures is believed to be due to poor quality control and assembly practices by the vendor.

4.2.4.2 Flight Control System Components

Hydraulic Accumulator-Reservoir Assembly (M-8)

During this test, a seal failure occurred in test specimen No. 3 of the accumulator-reservoir (1B29319-519). The failure occurred when the turcon backup ring on the high-pressure side of the reservoir piston extruded from the groove during the room-temperature, repeat-cycle phase of testing. This failure, which occurred after 816 cycles of operation, resulted in the destruction of the O-ring packing and leakage of hydraulic oil from the reservoir vent relief valve.

To determine the cause of the backup ring extrusion, a development test was conducted at various high oil temperatures and cycling pressures. It is believed that the failure was due partly to excessive piston clearance and partly to rough surface finish.

4.2.4.3 Auxiliary Power Supply System/Electronic Components

Hydraulic Power Unit Motor-Driven Starter Switch (P-47)

Reliability Verification testing was successfully completed on the hydraulic power unit motor-driven starter switch (1B32647-505) during the quarter.

4.2.4.4 Electrical System Components

Hydraulic System Temperature Control Thermal Switch (U-37A)

Reliability Verification testing was successfully completed on the hydraulic system temperature control thermal switch (1A74765-507) during the quarter.

4.2.5 Special Testing

Helium Storage Sphere Strength Verification Tests

Fourteen ambient helium storage spheres (1A49990-501) made of Ti-6AL-4v titanium alloy and welded with either commercially-pure titanium weld rods or the specified Ti-6AL-4v titanium alloy weld rods, were subjected to a strength verification test program. One sphere having the pure titanium weld burst at 5,660 psig. Six spheres having the proper Ti-6AL-4v titanium alloy welds burst between 8,920 and 9,940 psig.

Various pressure cycle and hold tests were completed on seven spheres having pure titanium welds. These spheres are being prepared for an assortment of additional tests.

Bonded Segmented Bulkhead (DA-103) Test

The DA-103 bonded segment bulkhead specimen was shipped to the Sacramento Test Center during the quarter. Insulation of the specimen was completed and the specimen is being set up for testing at the Alpha I test site. Testing is scheduled to commence in mid-April.

Insulation

A liquid hydrogen tank flame-retardant coating test was completed at the Sacramento Test Center. An 8-foot-diameter test tank was utilized for the test. Two materials, reinforced Dyna-Therm D-65 and 0.002-mil aluminum foil, were tested simultaneously. One half of the tank was coated with the foil, and the other half with Dyna-Therm.

The results of the test, which simulated stage utilization, indicated that the reinforced Dyna-Therm D-65 had a 0.7 per cent area debonding, wheras the 0.002 aluminum foil coating had a 0.2 per cent area debonding. In addition, loose pieces of the Dyna-Therm D-65 coating were found in the tank following completion of the test.

Pressure Vessels

A test program has been initiated to verify the integrity of all 1A49990-1 and -501 ambient helium spheres which have been delivered to Douglas.

An eddy current inspection of all sphere weldments was conducted to isolate all helium spheres fabricated with commercially pure titanium weld wire, and remove the spheres from production systems. Tests consisted of comparative eddy current readings between the parent metal of the Ti-6AL-4V sphere and the weld material. All spheres that the eddy current tests revealed to have been welded with commercially pure filler wire were removed from stock and from stages. These spheres will be replaced.

Burst pressure tests of Ti-6AL-4V welded spheres were conducted to verify structural integrity. All burst-tested specimens were metallurgically examined and compared to the failed spheres involved in the S-IVB-503 incident. Design burst requirements were 8,000 psig at 210°F. All spheres met that requirement satisfactorily. Metallurgical examination of the failed spheres did not reveal any anomalies. Testing of the six spheres verified that the integrity of the 6AL-4V filler wire welded ambient helium storage spheres (1A49990) is adequate.

Testing is also being conducted to determine weld integrity by conducting burst and cycle pressure tests of spheres welded with commercially pure titanium filler wire.

A weld test program was conducted to determine the individual effect of aging, cleaning, proof pressure, cyclic, and sustained loading on 6AL-4V titanium alloy welded with 6AL-4V filler wire and commercially pure filler wire, as related to the formation of titanium hydrides. Other objectives were to determine the effect of titanium hydrides, and the magnitude and effect of residual stresses in titanium pressures spheres welded with both 6AL-4V filler wire and commercially pure filler wire.

Oxygen-Hydrogen Burner Performance Improvement Program

The oxygen-hydrogen burner performance improvement program produced satisfactory test results during the quarter. Improvements included decreasing the fuel injector effective area coupled with enlarged subsonic orifices, producing a higher nominal chamber pressure and eliminating icing. Several 4 1/2-hour tests were successfully completed. The increased chamber pressure also decreased the effects of cross-ignition (one igniter out) and eliminated the requirement for the back-pressure purge. Igniter tip material was studied for reduction of slag in the injector core area. Of those materials tested, the stainless steel (304L) tip was found to be the cleanest burning and least expensive of the two types. Preliminary evaluation of recent tests performed with a liquid hydrogen pressurization ramp rate of 4.5 psi per minute (instead of the nominal 3.3 psi per minute) indicates that the burner will operate satisfactorily if that rate is required during stage tank repressurization. The new series of tests, designed to determine the effect of initiating helium repressurization flow prior to, during, and after burner start, has been completed and has shown that the initiation of helium flow after the burner start transient produced the most satisfactory chamber pressure increase of the three flow sequences.