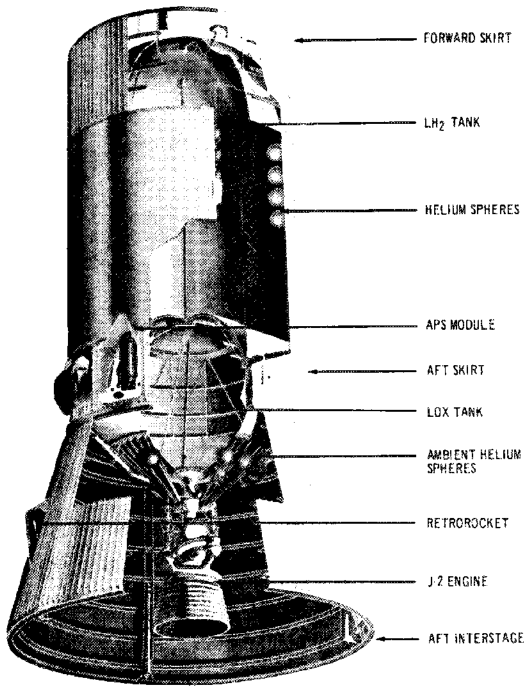
THIRD STAGE FACT SHEET



DAC-13067

WEIGHT: 34,000 lb. (dry) including 7,700-lb. aft interstage
262,000 lb. (loaded)
DIAMETER: 21 ft. 8 in.
HEIGHT: 58 ft. 7 in.

BURN TIME: 1st burn—2.75 min. (approx.)
2nd burn—5.2 min. (approx.)
VELOCITY: 1st burn—17,500 miles per hour at burnout (approx.)
2nd burn—24,500 miles per hour (approx. typical lunar mission escape velocity)

ALTITUDE AT BURNOUT: 115 miles after 1st burn and into a translunar injection on 2nd burn

MAJOR STRUCTURAL COMPONENTS

AFT INTERSTAGE
AFT SKIRT
THRUST STRUCTURE
PROPELLANT TANK
COMMON BULKHEAD
FORWARD SKIRT

MAJOR SYSTEMS

PROPULSION: One bipropellant J-2 engine
Total Thrust: 225,000 lb. (maximum)
Propellants: LH_2—63,000 gal. (37,000 lb.)
LOX—20,000 gal. (191,000 lb.)
HYDRAULIC: Power for gimbaling J-2 engine
ELECTRICAL: One 56 VDC and three 28 VDC batteries, providing basic power for all electrical functions
TELEMETRY AND INSTRUMENTATION: Five modulation subsystems, providing transmission of flight data to ground stations
ENVIRONMENTAL CONTROL: Provides temperature-controlled environment for components in aft skirt, aft interstage, and forward skirt
ORDNANCE: Provides explosive power for stage separation, retrorocket ignition, ullage rocket ignition and jettison, and range safety requirements
FLIGHT CONTROL: Provides stage attitude control and propellant ullage control

THIRD STAGE

STAGE DESCRIPTION

Basically, the Saturn V third stage, the S-IVB, is an aluminum air-frame structure powered by a single J-2 engine, which burns liquid oxygen and liquid hydrogen. The engine has a maximum thrust of 225,000 pounds. The structure has a bipropellant capacity of 228,000 pounds of fuel and oxidizer.

STAGE FABRICATION AND ASSEMBLY

The third stage structure consists of a forward skirt assembly, propellant tank assembly, thrust structure assembly, aft skirt assembly, and aft interstage assembly. The propellant tank assembly consists of a single tank separated by a common bulkhead into a fuel compartment and an oxidizer compartment.

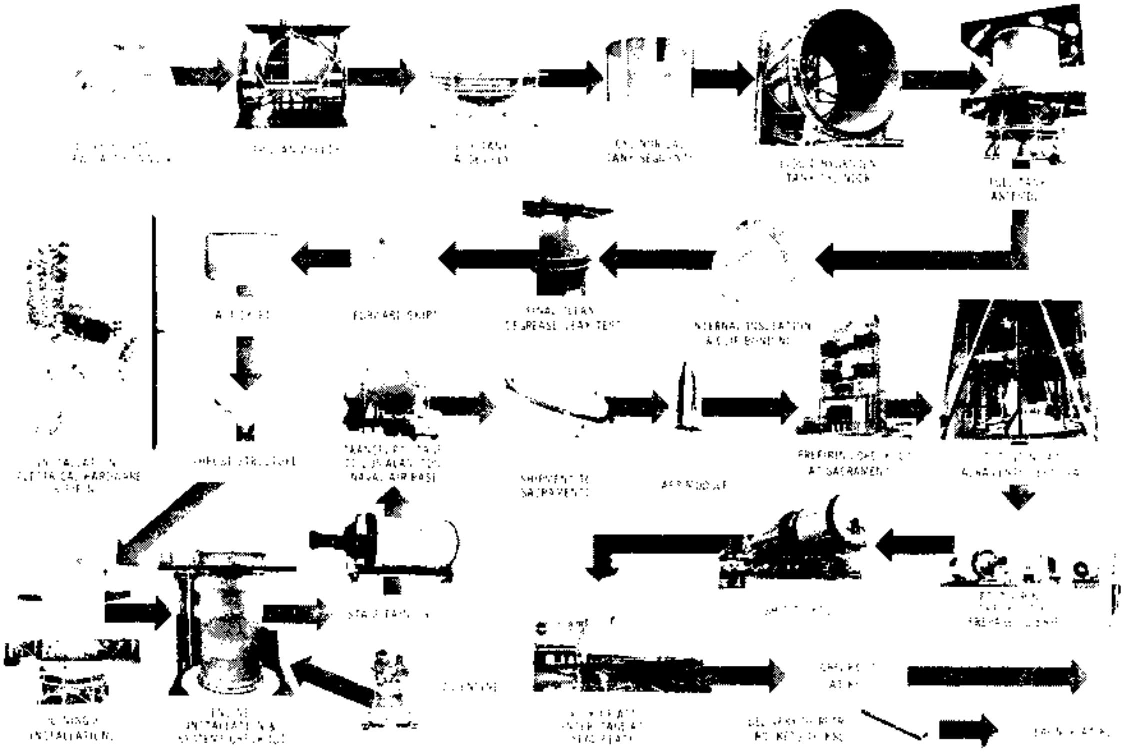
Forward Skirt Assembly

The forward skirt is a cylindrical aluminum skin and stringer structure that provides a hard attach point for the instrument unit. In addition, the forward skirt provides an interior mounting structure for electrical and electronic equipment that requires environmental conditioning, as well as range safety and telemetry antennas mounted around the exterior periphery. Environmental conditioning for electronic equipment is provided by cold plates which utilize a coolant supplied from the IU thermoconditioning system.

Propellant Tank Assembly

Structural elements of the propellant tank assembly are a cylindrical tank section, common bulkhead, aft dome, and forward dome. Seven segments are machined from aluminum alloy plate to form the tank section. A waffle pattern is then machine-milled into each segment to reduce weight and provide shell stiffness. The formed segments are joined into a complete cylinder by single-pass internal weld on a Pandjiris welding machine.

Aft and forward domes are made by forming "orange peel" segments on a stretch press. Orange peel segments are then joined in a dome welder. Each



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Third Stage Production Sequence

dome assembly rotates in the fixture under a stationary welding head which is automatically positioned by a servo-controlled sensing element. To complete the hemisphere, a 43-inch "dollar" segment is bolted in the top center of the dome. Subsequently, all fittings for various tank connections are installed by machine weld.

COMMON BULKHEAD

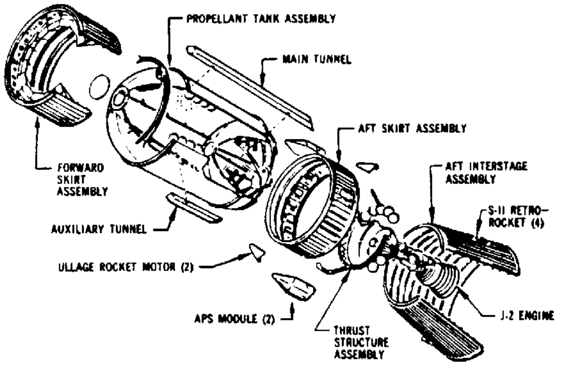
The common bulkhead, which forms the physical separation between the LOX and hydrogen tanks, is a 130-inch-radius hemisphere consisting of two aluminum domes separated and insulated by a fiberglass honeycomb core. The honeycomb core is bonded between the two domes under heat and pressure. Edges of two peripheral tees are welded together to provide a seal for the core. Joining of the common bulkhead and the aft dome completes the LOX tank subassembly. A slosh-baffle located within the LOX tank breaks up any wave action of the oxidizer during flight. The baffle is made up of four rings supported by "A" frames.

Thrust Structure Assembly

The thrust structure distributes J-2 engine thrust over the entire tank circumference. In addition, hydraulic system components, propellant feed lines, propellant tank ambient helium pressurization spheres, pneumatic components, and miscellaneous components which support engine operation are mounted on the thrust structure assembly.

Aft Skirt Assembly

The aft skirt is a cylindrical structure fabricated of aluminum, stringer-stiffened skin panels and provides structural interface between the aft interstage and propellant tank assembly. After second stage burnout, the second stage separates from the third stage at a separation plane located on the aft skirt assembly. Two auxiliary propulsion system (APS) engine modules, two ullage rocket modules, stage separation systems, an aft umbilical connector plate, and associated system support equipment are located on the aft skirt assembly.



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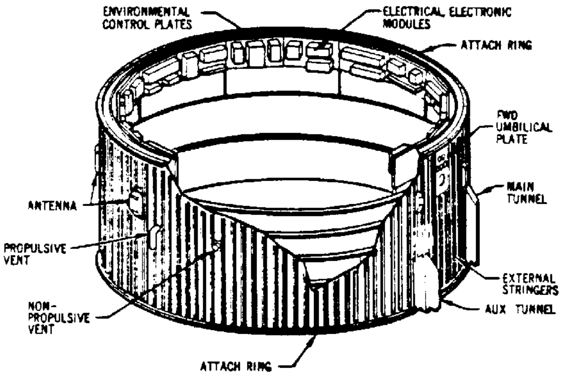
Third Stage Exploded View

Aft Interstage Assembly

The aft interstage is a truncated cone-shaped structure fabricated of aluminum skin and stringers. It attaches to the third stage aft skirt and provides the structural interface to the second stage. It also houses the second stage retrorockets.



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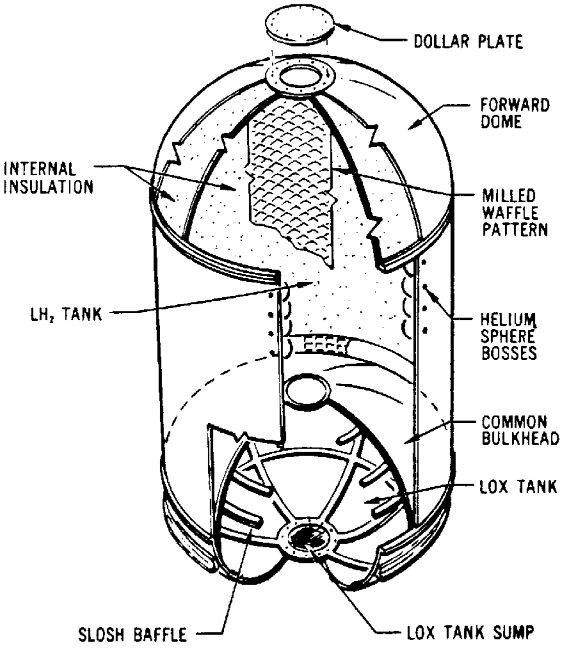
Forward Skirt Assembly



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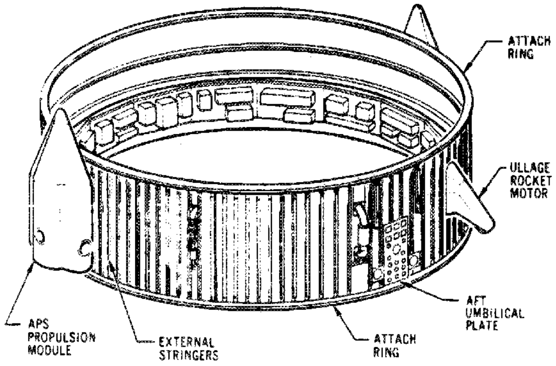
Propellant Tank Assembly



Aft Skirt Assembly

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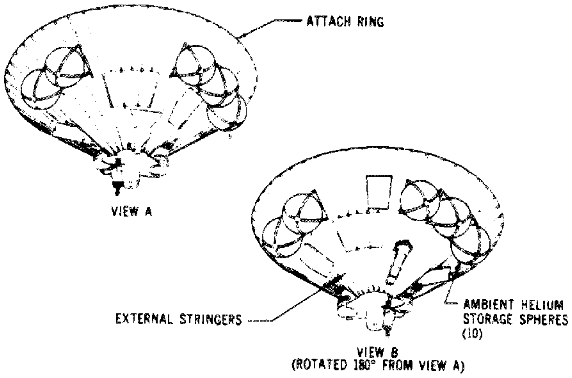

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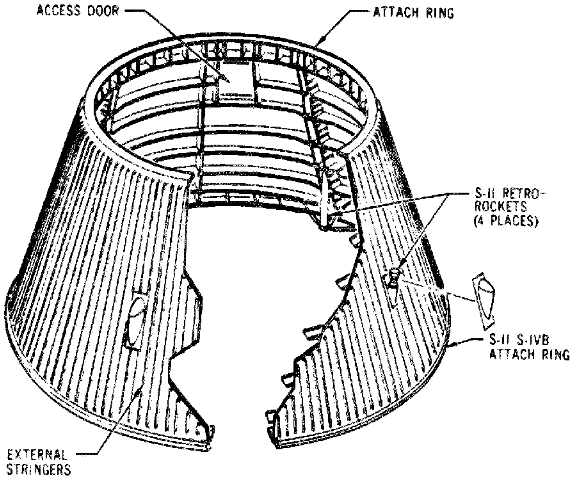
Thrust Structure Assembly



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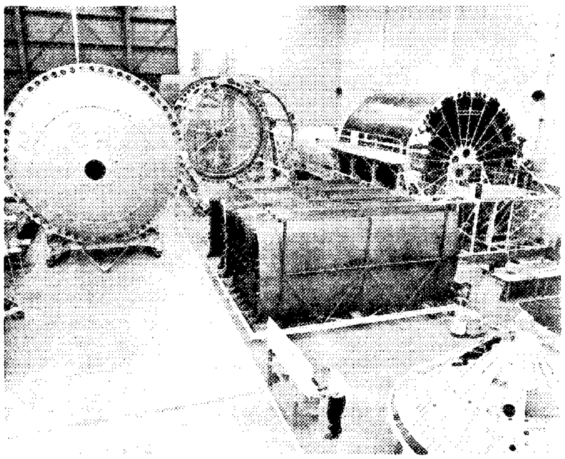
Aft Interstage Assembly

Final Assembly

Final assembly of the third stage propellant tank structural components is accomplished in the assembly and welding tower. The assembly is then removed from the tower and transported to the insulation chambers building where the LH_2 tank insulating tiles are fitted and installed, a glass cloth liner is placed on the insulation, and sealant is added. Propulsion system components, internally mounted in the LH_2 tank, are installed following the completion of tank insulation. The hydrogen tank contains a slosh baffle and wave deflector system, which contributes to fuel ullage control during flight, and eight cold helium storage spheres for LOX tank pressurization. The structure is then returned to the assembly tower where the forward and aft skirts and thrust structure are installed.



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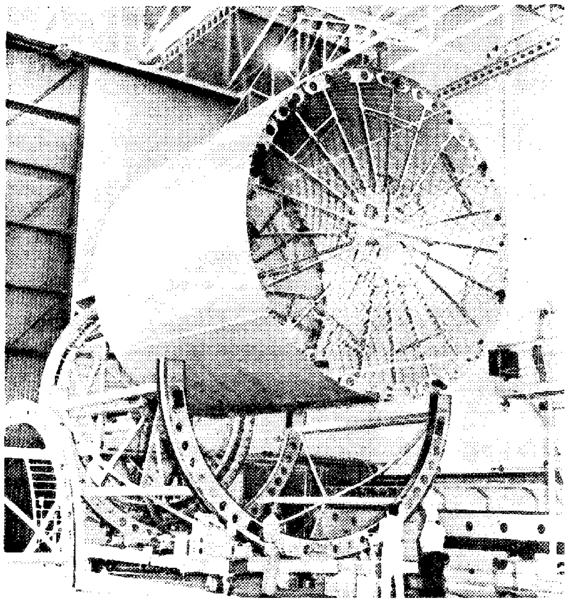
Propellant Tank Assembly Area at Huntington Beach



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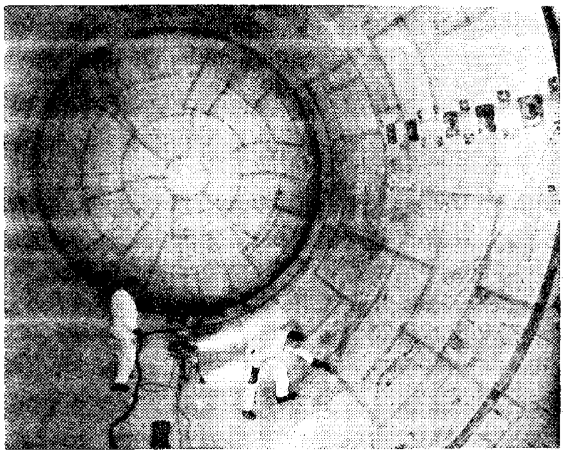
Tank Section in Trim and Welding Jig



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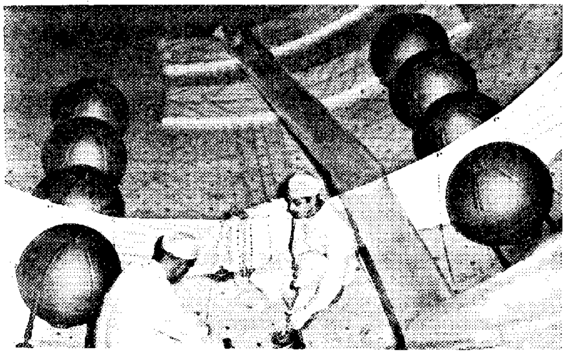
LH$_2$ Tank—Workmen apply resin to insulation tiles in LH$_2$ tank.



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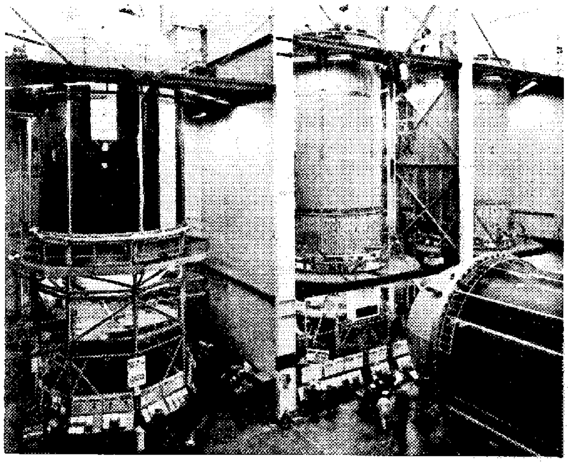
Slosh Baffle—Horizontal rings are installed inside LH$_2$ tank for propellant stabilization during flight.



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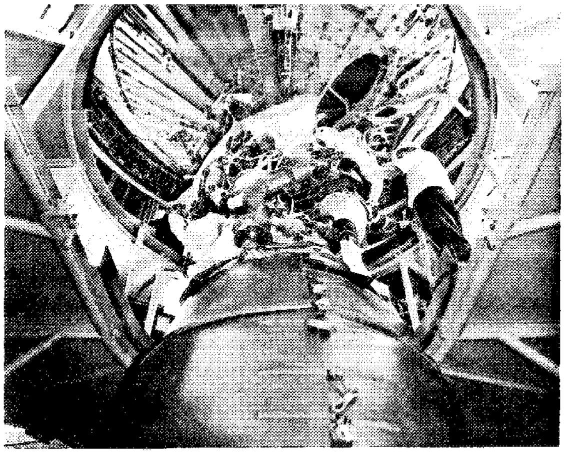
Third stage vehicles reach end of assembly sequence with final assembly and checkout in 115-foot vertical towers.



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Engine Installed—J-2 engine is attached to stage in final assembly tower at Huntington Beach.

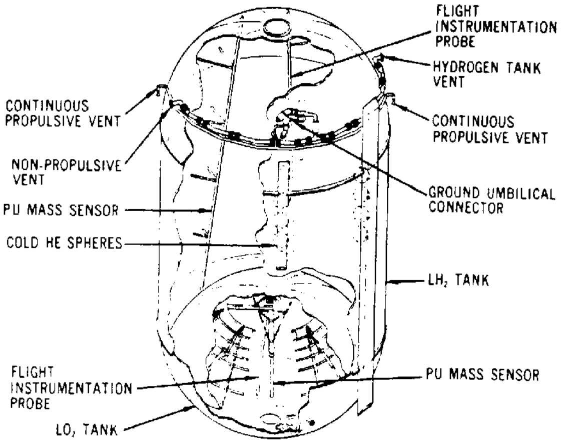
Final installation of various subsystem components is performed in a checkout tower, along with the installation and alignment of the J-2 engine. The stage is in a vertical position in the tower where a complete stage checkout of subsystems and systems is conducted except for actual ignition of engine. After satisfactory checkout, the stage is removed from the tower, placed on a dolly, and ground support rings are installed at each end of the stage. It is then painted, weighed, and prepared for shipment to the Douglas Sacramento Test Center for simulated and static firing of APS engines and J-2 engine.

THIRD STAGE SYSTEMS

Major systems required for third stage operation are the propulsion system, flight control system, electrical power and distribution system, instrumentation and telemetry system, environmental control system, and ordnance systems.

Propulsion System

The propulsion system consists of the J-2 engine, propellant system, pneumatic control system, and propellant utilization system. The J-2 engine burns LOX as an oxidizer and LH$_2$ as fuel at a nominal mixture ratio of 5:1. Both fuel and oxidizer systems utilize tank pressurization systems and have vent and relief capabilities to protect the propellant tanks from overpressurization. The pneumatic control system regulates and controls both the oxidizer and fuel systems. The propellant utilization (PU) system assures simultaneous and precise fuel and oxidizer depletion by controlling engine mixture ratio.



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Propulsion System Components

J-2 ENGINE

The engine system consists of the J-2 engine, propellant feed system, start system, gas generator system, control system, and a flight instrumentation system. The propellant feed system utilizes independently driven, direct-drive fuel and oxidizer turbopumps to supply propellants at the proper mixture ratio to the engine combustion chamber. Additional information on the J-2 engine system may be found in the J-2 Engine section.

PROPELLANT SYSTEM

The propellant system consists of related stage subsystems to support an initial J-2 engine propulsive burn phase and an engine restart capability to provide a second J-2 engine propulsive burn phase for the third stage. It includes the oxidizer system, fuel system, pressurization system, repressurization system, tank venting system, and chill-down recirculation system.

Oxidizer System

LOX is loaded into the LOX tank at a temperature of -297° Fahrenheit through a LOX fill and drain line assembly which disconnects automatically at the time of vehicle liftoff.

The LOX tank capacity is 2,828 cubic feet which provides tankage for approximately 191,000 pounds (20,000 gallons) of usable LOX. The tank is pressurized with gaseous helium at 38 to 41 psia, and is maintained at this pressure during liftoff, boost, and stage engine operation.

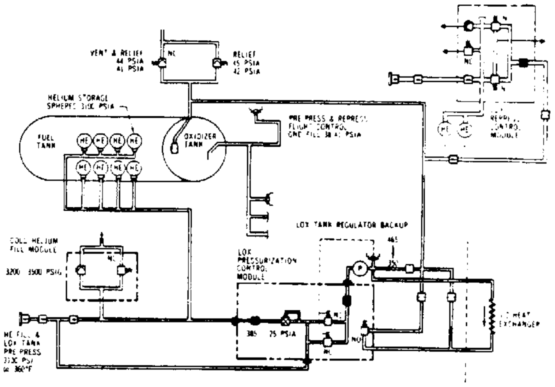
Fill and Drain—The LOX filling operation consists of purging and childown of the tank and filling in four stages: slow fill, fast fill, replenish (topping), and pressurization. The ground-controlled combination vent and relief valve is pneumatically opened at the start of the fill operation.

During slow fill, LOX is loaded at a rate of 500 gpm until five per cent of full level is attained; then fast fill at 1,000 gpm is initiated. When 98 per cent of the LOX has been loaded, the fill rate is reduced to a rate of 0 to 300 gpm. When the LOX tank is 100 per cent loaded, the full level is maintained until liftoff by a replenish flowrate of 0 to 30 gpm, as required to compensate for LOX boil-off.

If for any reason the LOX tank becomes overpressurized during fill, such as a vent malfunction, or by an excessive LOX fill flow, a pressure switch signals the LOX ground fill valve to close.

The LOX tank is capable of being unloaded by reversing the flow through the fill system under tank pressure and/or from gravity effect. Drain capacity is at 500 gpm at 33 psia.

LOX Tank Pressurization—The LOX tank is pressurized at 38 to 41 psia from a ground supply of cold helium regulated to -360° Fahrenheit. After liftoff and until engine ignition, the LOX tank pressure is maintained from eight helium storage spheres located in the LH$_2$ tank that have been charged to 3,100 ± 100 psi at -360° Fahrenheit. During J-2 engine burn, the engine heat exchanger heats and expands a portion of the helium flow before it is fed into the LOX tank. An ullage tank pressure switch controls inflight pressurization by opening or closing cold helium flow to the heat exchanger as required. In case of pressure switch failure in flight, a pressure switch and plenum chamber act as a backup pressure regulator.



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Oxidizer Tank Pressurization System

LOX Tank Repressurization—During the coast phase, prior to J-2 engine second ignition, the LOX tank pressurization system is inoperative, allowing LOX tank pressure to decay. However, before the second engine ignition the LOX tank is pressurized by the LOX tank repressurization system. The repressurization system utilizes helium from two ambient helium storage spheres located on the thrust structure. The repressurization helium supply is controlled by the LOX repressurization control module. Controlled repressurization is continued until second ignition is accomplished.

At second ignition and continuing through the second burn phase, the LOX tank is pressurized with cold helium gas heated by the engine heat exchanger and supplied by spheres contained within the LH_2 tank.

LOX Tank Vent-Relief System—The LOX tank vent-relief system consists of a tee assembly with a pneumatically operated vent valve and a backup relief valve. Pneumatic operation is provided by the LOX vent actuation module using helium gas from the pneumatic control system. The vent-relief valve is opened during the ground fill operation and closed prior to pressurization. During fill operations, the vent valve is capable of venting all LOX vapor.

The relief valve backup system automatically relieves at 45 psia and reseats at 42 psia. During liftoff and nonpowered stage flight, pressure relief or venting is not anticipated. However, the vent system becomes operational in the event of LOX tank overpressurization.

LOX Feed System—Prior to vehicle liftoff and prior to engine restart for the second burn phase, all LOX feed system components of the J-2 LOX turbopump assembly must be "chilled" to operating temperature for proper operation. Chilldown of the LOX system is accomplished by a closed-loop, forward-flow recirculation system. On command from the IU, a prevalve in the LOX feed duct closes and a bypass shutoff valve opens. An auxiliary, electrically driven centrifugal chilldown pump, mounted in the LOX tank, starts and LOX chilldown circulation begins. LOX is circulated from the LOX tank, through the low pressure feed duct, to the J-2 engine LOX pump and bleed valve, then back to the LOX tank through return lines. The pump is capable of delivering a minimum flowrate of 31 gpm at 25 psia. Recirculation chilldown continues through the boost phase and up to the time for J-2 engine ignition. In the event of an emergency, the chilldown system shutoff valve closes upon command from the IU.

A low pressure supply duct supplies LOX from the tank to the engine at a nominal flowrate of 391 pounds per second at -297° Fahrenheit at 25 psia and up.

The main LOX feed valve is a 4-inch butterfly-type valve and opens in two distinct steps: the first, a partially opened position; the second, a fully opened position. The LOX feed valve is solenoid-controlled.

A signal from the engine sequencer energizes the LOX feed valve, as required, to obtain steady-state operation. During steady-state operation, LOX feed is regulated by a propellant utilization valve which controls the oxidizer flow to the engine. A complete description of engine operation may be found in the J-2 Engine section.

Fuel System

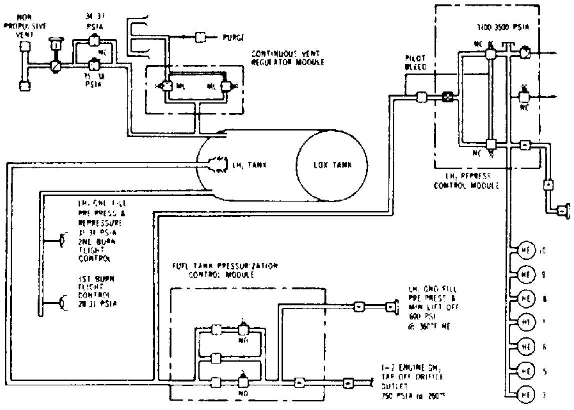
LH_2 is loaded into the insulated fuel tank at a temperature of -423° Fahrenheit through the LH_2 fill and drain valve assembly which is automatically disconnected at time of vehicle liftoff. The tank capacity is 10,446 cubic feet providing tankage for approximately 37,000 pounds (63,000 gallons) of usable fuel. The tank is pressurized from a ground source of helium at 31 to 34 psia. During liftoff, boost, and stage engine operation, pressure is maintained in the fuel tank at 28 to 31 psi.

Fill and Drain—The LH_2 loading operation consists of purging, chilldown of the tank, and filling in four stages: slow fill, fast fill, replenish (topping), and pressurization.

Immediately prior to LH_2 input into the tank, a combination vent and relief valve is pneumatically opened. Loading is then initiated at 500 gpm until five per cent of full level is reached; then fast fill begins. During fast fill, LH_2 is supplied to the tank at 3,000 gpm. When 98 per cent of the loading is completed, the loading rate is curtailed to between 0 to 500 gpm. When the LH_2 tank is 100 per cent loaded, the full level is maintained by a replenish flowrate of 0 to 300 gpm as required to compensate for LH_2 boil-off. During the final topping operation, the fuel tank venting system is closed and the tank is simultaneously pressurized from the ground source of helium. If overpressurization of the tank should occur during fill or during the boost phase, a relief valve, which is spring-loaded to open at 37 psia and close at 34 psia, is actuated to relieve excess pressure.

The LH_2 tank is capable of being unloaded through the fill system. LH_2 unloading is accomplished by reversing the flow through the fill system under tank pressure and/or from gravity effect.

Fuel Tank Pressurization—During initial tank pressurization, an external tank connection is made to a ground supply of helium. The helium is supplied to the fuel tank at -360° Fahrenheit at 600 psig. When the tank ullage pressure reaches a maximum of 31 to 34 psia, a pressure switch sends a signal to deactivate the ground pressurization valve indicating that a satisfactory liftoff pressure has been attained, and pressurization is discontinued.



Fuel Tank Pressurization System

During liftoff and prior to J-2 engine start, additional pressurization is not required, as tank ullage pressure will be maintained from fuel boil-off.

At the initiation of J-2 engine start, GH_2 is bled from the J-2 engine at 750 psia, -260° Fahrenheit to provide ullage pressure during fuel depletion. The pressure bled from the engine into the fuel tank is controlled by a fuel tank pressurization control module.

Fuel Tank Repressurization System—During the coast period prior to engine restart, there is no requirement for fuel tank pressurization. Tank pressure will build up within the tank due to LH_2 boil-off which is vented continuously through a propulsive vent system designed to provide a minimum thrust requirement to assure propellant settling. Additional pressure is vented through the fuel tank vent-relief system.

Prior to J-2 engine restart, the propulsive vent system and tank vent-relief system is closed in the pressurization control module. The tank is then repressurized between 31 to 34 psia from ambient helium gas stored in seven helium spheres mounted on the thrust structure.

Following engine restart, the LH_2 tank is again pressurized throughout the second burn phase with GH_2 bled from the engine.

Fuel Tank Vent-Relief System—Venting of the LH_2 tank is accomplished by a vent and relief system capable of relieving all excess pressure accumulated from overpressurization or fuel boil-off during fill and flight operation. During fill, vaporization is vented through a self-sealing disconnect located in the forward skirt. During liftoff and flight, the gases are vented overboard through a nonpropulsive exhaust.

The venting system consists of an actuation control module, vent valve, and nonpropulsive overboard exhaust. Actuation of the vent valve is commanded from an external ground signal during fill operations and from the flight sequencer during liftoff and flight. The vent valve is designed to open in a maximum of 0.1 second upon command.

The relief valve, which provides a backup capability in case of vent valve failure, opens at 38 psia and reseats at 35 psia, and has a flow/relief capability of 2 pounds per second at sea level.

A directional control valve directs excessive pressures through the ground disconnect during fill and directs excessive pressures through the nonpropulsive vent during liftoff and flight. The nonpropulsive vent system extends from the directional control valve into two 4-inch vent lines that terminate into two nonpropulsive exhaust ports. The ports are located 180° apart in the forward skirt area. The ports are arranged to direct the exhaust for total thrust cancellation.

LH_2 Continuous Propulsive Vent System

The continuous vent system is used to provide a thrust force required to position propellants at the aft end of each tank during coast. The system consists of a vent line originating at the vent-relief valve, terminating at two low thrust nozzles located 180° apart, and facing aft on the forward skirt. Continuous venting is controlled and regulated by a pneumatically operated continuous propulsive vent module.

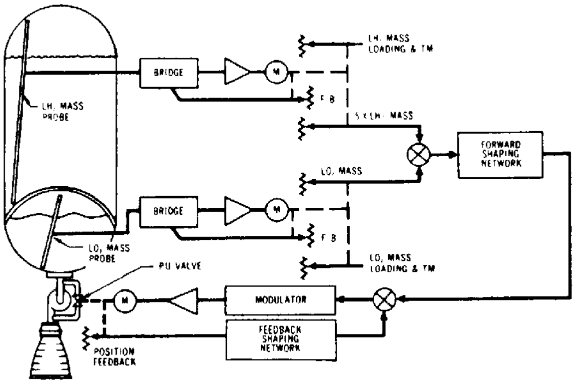
At the completion of the first burn engine cutoff, APS ullage engines are activated to settle the liquid propellants in the aft end of the tanks during the shutdown phase. LH_2 tank pressure is then vented through the continuous propulsive vent system, providing a continuous propulsive thrust to the stage. This maintains control of the propellants within the tanks. The APS engines are shut off after the transition is complete and the propulsive venting continues throughout the coast phase. The continuous propulsive vent module controls venting from a maximum of 45 pounds to a minimum of approximately 7 pounds.

LH_2 Feed System—Prior to vehicle liftoff and prior to engine restart, all LH_2 feed system components of the J-2 turbopump assembly must be chilled to assure proper operation. Chilldown of the LH_2 system is accomplished by a closed loop, forward-flow recirculation system. On command from the IU, the prevalve in the LH_2 feed duct closes and the chilldown shutoff valve opens. An auxiliary, electrically driven LH_2 chilldown pump, mounted in the LH_2 tank, circulates the LH_2 within the system and is capable of a minimum flowrate of 135 gpm at 6.1 psi.

LH_2 is circulated from the LH_2 tank through the low pressure feed duct, through the J-2 engine fuel pump, the fuel bleed valve, and back to the tank through a return line. Recirculation chilldown continues through the boost phase and up to J-2 engine ignition. In the event of an emergency shutdown requirement, the chilldown system shutoff valve is closed upon command from the IU. LH_2 is supplied to the J-2 engine through a vacuum-jacketed, low-pressure duct at a flowrate of 81 pounds per second at -423° Fahrenheit, 28 psia. The duct is located in the fuel tank side wall above the common bulkhead joint and is equipped with bellows to compensate for thermal motion. Signals from the engine sequencer energize the LH_2 feed valve, as required to obtain steady-state operation. A complete description of engine operation may be found in the J-2 Engine section.

PROPELLANT UTILIZATION SYSTEM

The primary function of the PU system is to assure simultaneous depletion of propellants by controlling the LOX flowrate to the J-2 engine. It also provides propellant mass information for controlling the fill and topping valves during propellant loading operations. The system consists of mass sensors, an electronics assembly, and an engine-mounted mixture ratio valve.



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Propellant Utilization System

During loading operations, the mass of propellants loaded is determined within one per cent by the mass sensors. Tank over-fill sensors act as a backup system in the event the loading system fails to terminate fill operations.

Continuous LH_2 and LOX residual readout signals are provided throughout third stage powered flight. Differences between the fuel and oxidizer mass indications, as sensed by the mass sensors, are continually analyzed and are then used to control the oxidizer pump bypass flowrate, which changes the engine mixture ratio correspondingly. The static inverter/converter supplies the analog voltages necessary to operate the PU system. It is commanded "on" and "off" by a switch selector and sequencer combination.

PNEUMATIC CONTROL SYSTEM

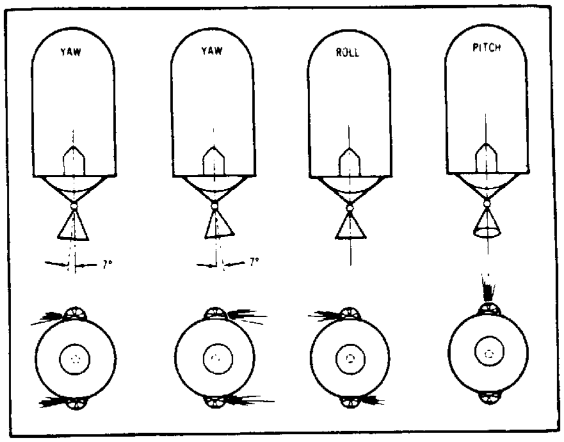
The pneumatic control system provides GHe (gaseous helium) pressure to operate all third stage pneumatically operated valves with the exception of those provided as components of the J-2 engine. GHe is supplied from an ambient helium sphere and pressurized from a ground source before propellant fill operations at 3,100 ± 100 psia at 70° Fahrenheit for valve operation. The sphere is located on the thrust structure and is pre-conditioned to above 70° Fahrenheit from the environmental control system before liftoff.

The pneumatic control system provides regulated pressure at 475 ± 25 psig for operation of the LH_2 and LOX vent-relief valves during propellant loading, LH_2 directional control valve, LOX and LH_2 fill and drain valves during loading, and the GH_2 engine start system vent-relief valve. It also provides operating pressures for the LH_2 and LOX turbopump turbine purge module, LOX chilldown pump purge module control, LOX and LH_2 prevalves, LOX and LH_2 chilldown shutoff valves, and the LH_2 continuous propulsive vent control module.

The pneumatic control subsystem is protected from overpressure by a normally open solenoid valve controlled by a downstream pressure-sensing switch. At pressures greater than 535 + 15, -10 psia, the pressure switch actuates and closes the valve. At pressures below 450 + 15, -10 psia, the pressure switch drops out and the solenoid opens, thus acting as a backup regulator.

Filght Control System

The flight control system provides stage thrust vector steering and attitude control. Steering is achieved by gimbaling the J-2 engine during powered flight. Hydraulic actuator assemblies provide J-2 engine deflection rates proportional to steering signal corrections supplied by the IU.



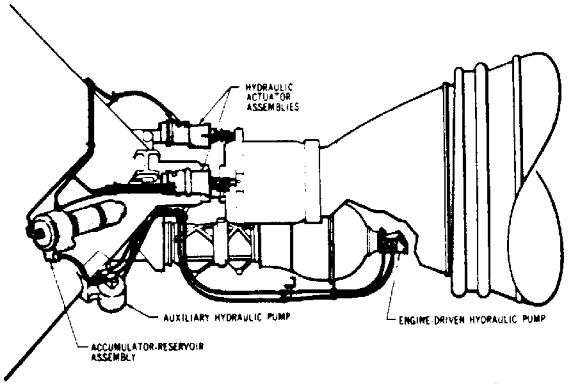
D-NRV-12

Flight Control System

Stage roll attitude during powered flight is controlled by firing the APS attitude control engines.

HYDRAULIC SYSTEM

The hydraulic system performs engine positioning upon command from the IU. Major components are a J-2 engine-driven hydraulic pump, two hydraulic actuator assemblies, and an accumulator-reservoir assembly.



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J-2 Engine Hydraulic System Components

The electrically driven auxiliary hydraulic pump is started before vehicle liftoff to pressurize the hydraulic system. Electric power for the pump is provided by a ground source. At liftoff, the pump is switched to stage battery power. Pressurization of the hydraulic system restrains the J-2 engine in a null position with relation to the third stage centerline, preventing pendulum-like shifting from forces encountered during liftoff and boost. During powered flight, the J-2 engine may be gimbaled up to 7° in a square pattern by the hydraulic system upon command from the IU.

Engine-Driven Hydraulic Pump

The engine-driven hydraulic pump is a variable displacement type pump capable of delivering hydraulic fluid under continuous system pressure and varying volume as required for operation of the hydraulic actuator assemblies. The pump is driven directly from the engine oxidizer turbopump. A thermal isolator in the system controls hydraulic fluid temperature to ensure proper operation.

Auxiliary Hydraulic Pump

The auxiliary hydraulic pump is an electrically driven variable displacement pump which supplies a constant minimum supply of hydraulic fluid to the hydraulic system at all times. The pump is also used to perform preflight engine gimbaling checkouts, hydraulically lock the engine in the null position during boost phase, maintain system hydraulic fluid at operating temperatures during other than the powered phase, and augment the engine-driven hydraulic pump during powered flight. It also provides an emergency backup supply of fluid to the system.

Hydraulic Actuator Assemblies

Two hydraulic actuator assemblies are attached directly to the J-2 engine and the thrust structure and receive IU command signals to gimbal the engine. The actuator assemblies are identical and interchangeable.

Accumulator-Reservoir Assembly

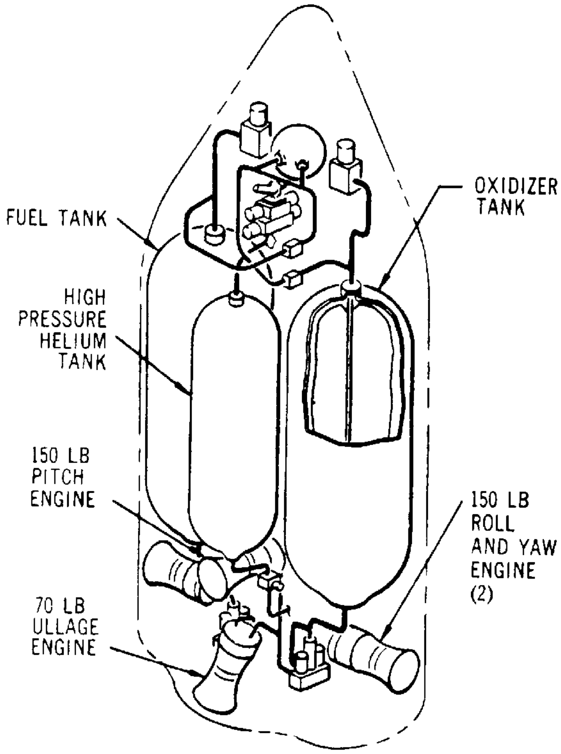
The accumulator-reservoir assembly is an integral unit mounted on the thrust structure. The reservoir section is the storage area for hydraulic fluid; the accumulator section supplies peak system fluid requirements and dampens high-pressure surges within the system.

AUXILIARY PROPULSION SYSTEM

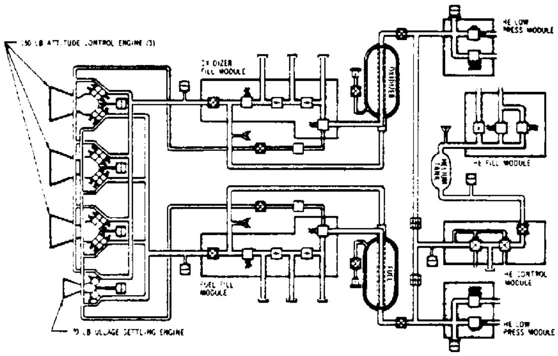
The APS provides auxiliary propulsive thrust to the stage for three-axis attitude control and for ullage control. Two APS modules are mounted 180° apart on the aft skirt assembly. Two solid propellant rocket motors are mounted 180° apart between the APS modules on the aft skirt assembly and provide additional thrust for ullage control.

APS Modules

Each APS module contains three 150-pound-thrust attitude control engines and one 70-pound-thrust ullage control engine.



Auxiliary Propulsion System Module



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APS Schematic

The attitude control engines are fired upon command from the IU in short duration bursts for attitude control of the stage during the orbital coast phase of flight. Minimum engine-firing pulse-duration is approximately 70 milliseconds. The attitude control engines are approximately 15 inches long with exit cones approximately 6.5 inches in diameter. Engine cooling is accomplished by an ablative process.

The ullage control engines are fired also upon command from the IU during the transition between J-2 engine first burn and the coast phase of flight to prevent undesirable propellant movement within the tanks. Firing continues for approximately 50 seconds until activation of the LH$_2$ continuous propulsive vent system. The ullage engines are again fired at the end of the third stage coast phase of flight and prior to J-2 engine restart to assure proper propellant positioning at inlets to the propellant feed lines during propellant tank repressurization.

The ullage control engines are similar to the attitude control engines and are approximately 15 inches long with an exit cone approximately 5.75 inches in diameter. Engine cooling is accomplished by an ablative process.

Each APS module contains an oxidizer system, fuel system, and pressurization system. The modules are self-contained and easily detached for separate checkout and environmental testing.

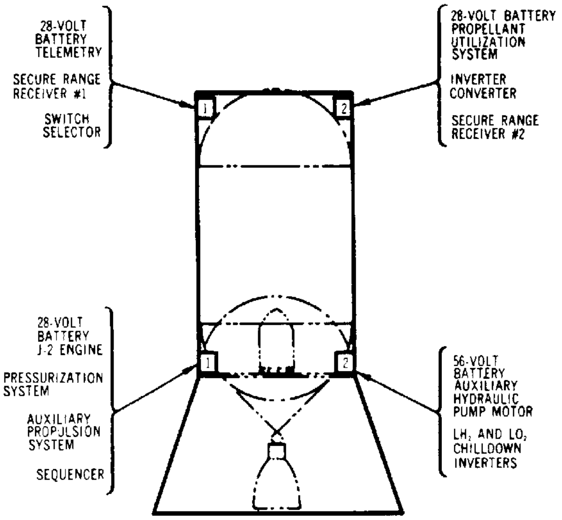
An ignition system is unnecessary because fuel and oxidizer are hypergolic (self-igniting). Nitrogen tetroxide (N_2O_4), the oxidizer, is stable at room temperature.

Separate fuel and oxidizer tanks of the expulsion bellows type are mounted within the APS module along with a high-pressure helium bottle, which provides pressurization for both the propellant tanks and the associated plumbing and control systems.

The fuel, monomethyl hydrazine ($CH_3N_2H_3$), is stable to shock and extreme heat or cold. The APS module carries approximately 115 pounds of usable fuel and about 150 pounds of usable oxidizer.

Ullage Control

Two solid propellant Thiokol TX-280 rocket motors, each rated at 3,390 pounds of thrust, are ignited during separation of the second and third stages for ullage control approximately 4 seconds before J-2 ignition. This thrust produces additional positive stage acceleration during separation and positions LOX and LH$_2$ propellants toward the aft end of the tanks. In addition, propellant boil-off vapors are forced to the forward end where they are safely vented overboard. Tank outlets are covered to ensure a net positive suction head (NPSH) to the propellant pumps, thus preventing possible pump cavitation during J-2 engine start. Ullage rockets ignite upon command from the stage sequencer and fire for approximately 4 seconds. At about 12 seconds from ignition, the complete rocket motor assemblies, including bracketry, are jettisoned from the stage, upon command from the stage sequencer.



D-NRV-15

Third Stage Basic Electrical Power and Distribution System

Electrical Power and Distribution System

Four battery-powered systems provide electrical requirements for third stage operation. Forward Power System No. 1 includes a 28 VDC battery and power distribution equipment for telemetry, secure range receiver No. 1, forward battery heaters, and a power switch selector located in the forward skirt area.

Forward Power System No. 2 includes a 28 VDC battery and power distribution equipment for the PU assembly, inverter-converter, and secure range receiver No. 2.

Aft Power System No. 1 includes a 28 VDC battery and power distribution equipment for the J-2 engine, pressurization systems, APS modules, TM signal power, aft battery heaters, hydraulic system valves, and stage sequencer.

Aft Power System No. 2 includes a 56 VDC battery and power distribution equipment for the auxiliary hydraulic pump, oxidizer chilldown inverter, and fuel chilldown inverter.

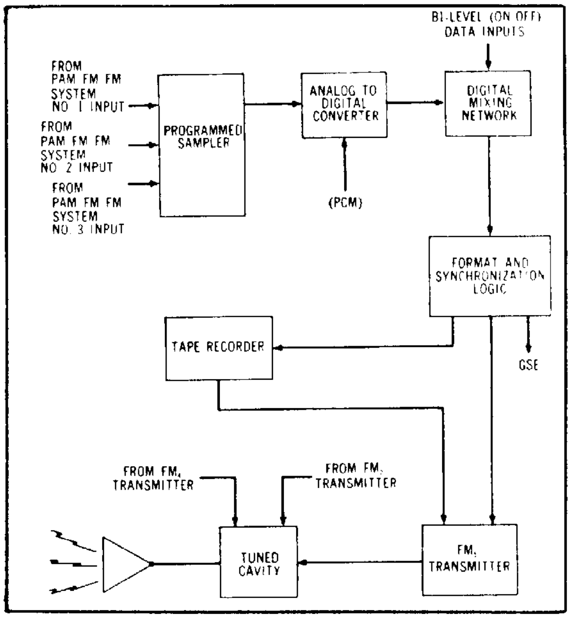
Silver-oxide, zinc batteries used for electrical power and distribution systems are manually activated. The batteries are "one-shot" units, and not interchangeable due to different load requirements.

Electrical power and distribution systems are switched from ground power to the batteries by command through the aft umbilical prior to liftoff.

Telemetry and Instrumentation System

Radio frequency telemetry systems are used for transmission of stage instrumentation information to ground receiving stations. Five transmitters, using two separate antenna systems, are capable of returning information on 45 continuous output data channels during third stage flight. The telemetry transmission links consist of five systems using three basic modulation schemes: Pulse Amplitude Modulated/FM/FM (PAM/FM/FM); Single Sideband/FM (SS/FM); and Pulse Code Modulated/FM (PCM/FM). There are three separate systems using PAM/FM/FM modulation.

A Digital Data Acquisition System (DDAS) airborne tape recorder stores sampled data normally lost during staging and over-the-horizon periods of orbital missions, and plays back information when in range of ground stations.



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Basic PCM Digital Data Acquisition System

PAM/FM/FM SYSTEMS

Transducer input signals constitute the PAM input. The PAM systems use an electronically switched network that samples up to 30 channels of transducer inputs at 120 times a second. Deviations in transducer input voltages are represented as output pulses of varying amplitude for subsequent evaluation.

SS/FM SYSTEM

The SS/FM system is reserved for pertinent research requirements. Vibration and acoustical data needed for manned flight development will be transmitted by this system.

PCM/FM SYSTEM

The PCM/FM system (DDAS) is used during automatic checkout to provide data for the ground checkout computer. The system is also used to provide precise information concerning stage environment and performance of systems during flight.

Environmental Control Systems

AFT SKIRT AND INTERSTAGE THERMOCONDITIONING AND PURGE

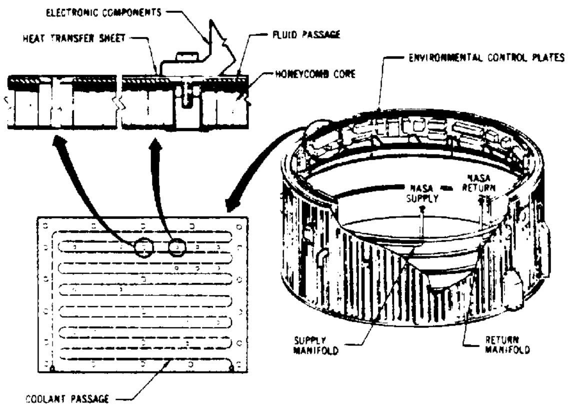
The thermoconditioning and purge system purges the aft skirt and aft interstage of combustible gases and distributes temperature controlled air or gaseous nitrogen around electrical equipment in the aft skirt during the vehicle countdown.

The purging gas, supplied from a ground source through the umbilical, passes over the electrical equipment and flows into the aft interstage area. Some of the gas is directed through each of the auxiliary propulsion modules and exhausts into the interstage. A duct from the skirt manifold directs air or GN_2 to a thrust structure manifold. From the thrust structure manifold supply duct, a portion of air or GN_2 is directed to a shroud covering the hydraulic accumulator reservoir.

Temperature control is accomplished by two dual-element thermistor assemblies located in the gaseous exhaust stream of each of the auxiliary propulsion modules. Elements are wired in series to sense average temperature. Two series circuits are formed, each circuit utilizing one element from each thermistor assembly. One series is used for temperature control, the other for temperature recording.

FORWARD SKIRT THERMOCONDITIONING

Electrical equipment in the third stage forward skirt area is thermally conditioned by a heat transfer system, using "cold plates" on which electronic components are mounted, and through which coolant fluid circulates. Coolant is pumped through the system from the IU and returned. Heat from electrical equipment attached to the cold plates is dissipated by conduction through the mounting feet and the cold plates to the fluid. Refer to the Instrument Unit section for a complete description of the IU environmental conditioning system.



Forward Skirt Environmental Control System

FORWARD SKIRT AREA PURGE

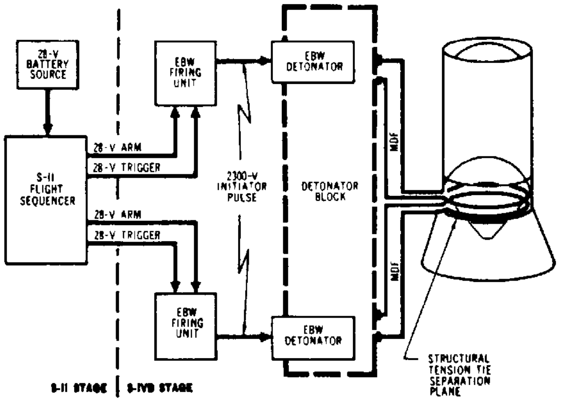
The forward skirt area is purged with gaseous nitrogen to minimize fire and explosion hazards while propellants are loaded or stored in the stage. Gaseous nitrogen is supplied and remotely controlled from a ground source.

Ordnance Systems

The ordnance systems perform stage separation, retrorocket ignition, ullage control rocket ignition and jettison, and range safety functions.

STAGE SEPARATION SYSTEM

The stage separation system consists of a severable tension strap, mild detonating fuse (MDF), exploding bridgewire, (EBW), detonators and EBW firing units.



Separation System

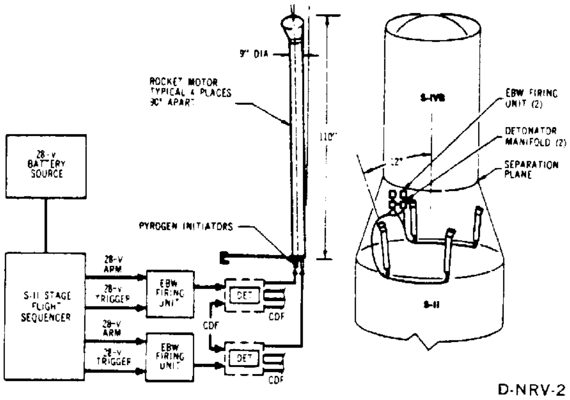
The severable tension strap houses two redundant MDF cords in a "V" groove circumventing the stage between the aft skirt and aft interstage at the separation plane. Ignition of the MDF cords is triggered by a signal from the second stage sequencer through the EBW and EBW firing units about 3 seconds after second stage engine cutoff.

The MDF consists of a flexible metal sheath surrounding a continuous core of high explosive material. Once detonated, the explosive force of the MDF occurs at a rate of 23,000 feet per second.

The EBW detonator is fired to initiate the MDF explosive train. A 2,300 VDC pulse is applied to a small resistance wire and a spark gap. The high voltage electrical arc across the spark gap ignites a charge of high explosive material which in turn detonates the MDF. The high voltage pulse requirement for ignition renders this system safe from random ground or vehicle electrical power. Upon command, each EBW firing unit supplies high voltage and current required to fire a specific EBW detonator.

RETROROCKET IGNITION SYSTEM

Four solid propellant retrorockets are mounted equidistant around the aft interstage assembly, and when ignited, assure clean separation of the third stage from the second stage by decelerating or braking the spent booster. Each retrorocket is rated for a nominal thrust of 35,000 pounds, weight of 384 pounds, and burn time of about 1.5 seconds.



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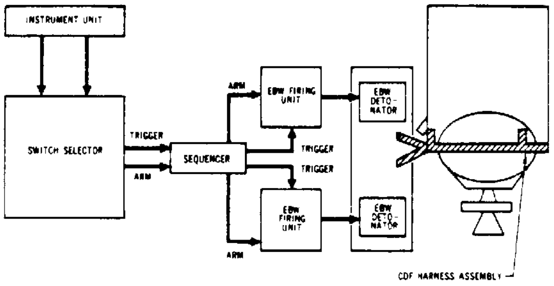
Retrorocket System

A signal from the second stage initiates two EBW firing units located on the aft interstage. The EBW firing units ignite two detonator manifolds, which in turn ignite the retrorockets through redundant pairs of confined detonating fuse (CDF) and pyrogen initiators.



D-NRV-22

Ullage Rocket System

ULLAGE CONTROL ROCKET IGNITION AND JETTISON SYSTEM

Two solid propellant ullage rockets, located on the third stage aft skirt just forward of the stage separation plane, are ignited on signal from the stage sequencer by EBW initiators.

After firing, the burned-out ullage rocket casings and fairings are jettisoned to reduce stage weight. Upon command from the stage sequencer, two forward and aft frangible nuts, which secure each rocket motor and its fairing to the stage, are detonated by confined detonating fuse (CDF), to free the entire assembly from the vehicle.

RANGE SAFETY SYSTEM

The range safety system terminates vehicle flight upon command of the range safety officer. Redundant systems are used throughout to provide maximum reliability.

Four antennas, mounted around the periphery of the third stage forward skirt assembly, feed two redundant secure range receivers located in the forward skirt assembly. Both receivers have separate power supplies and circuits. A unique combination of coded signals must be transmitted, received, and decoded to energize this destruct system.

A safety and arming device prevents inadvertent initiation of the explosive train by providing a positive isolation of the EBW detonator and explosive train until arming is commanded. Visual and remote indications of SAFE and ARMED conditions are displayed at all times at the firing center. Upon proper command, EBW firing units activate EBW detonators.

A CDF, detonated by the safety and arming device, explodes a flexible linear-shaped charge which cuts through the tank skin to disperse both fuel and oxidizer.