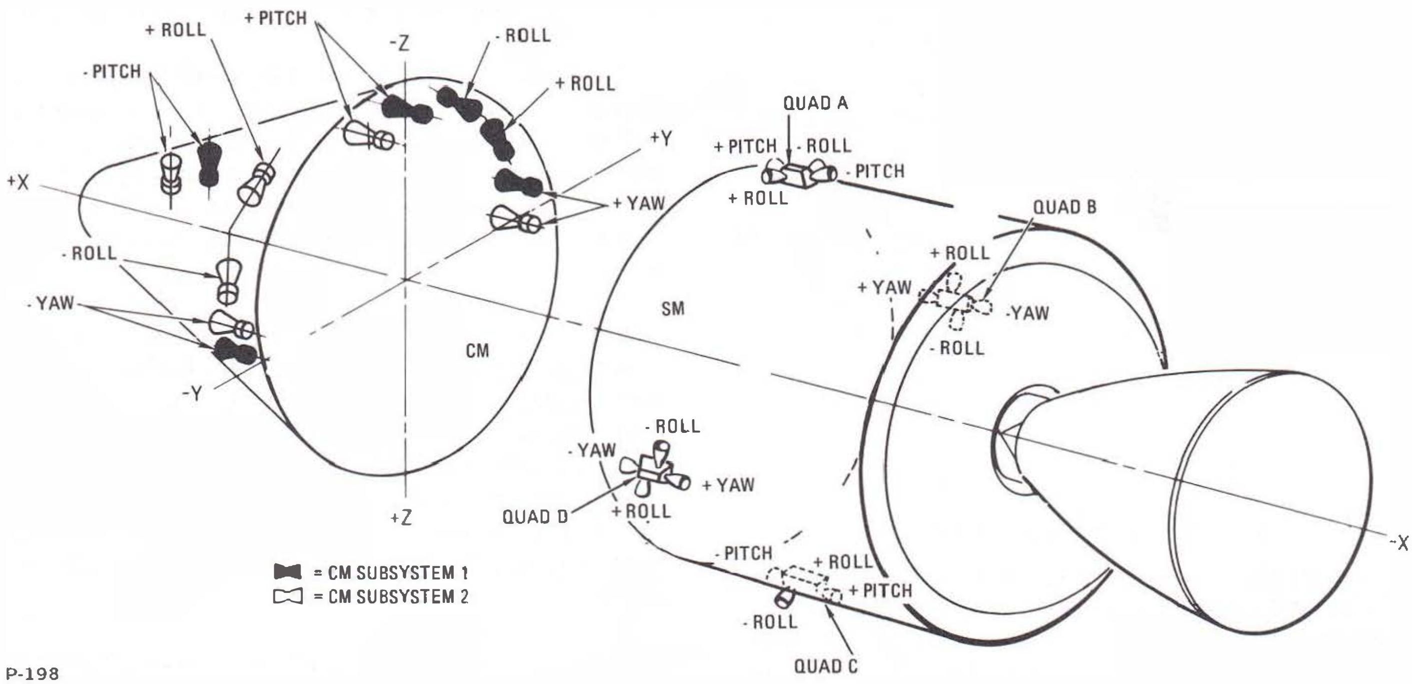


Location of reaction control subsystem engines

The reaction control subsystem provides the thrust for normal and emergency attitude maneuvers of the Apollo spacecraft. Operation of the subsystem is in response to automatic control signals from the stabilization and control subsystem in conjunction with the guidance and navigation subsystem. It can be controlled manually by the crew. The reaction control subsystem consists of CM and SM reaction control systems.

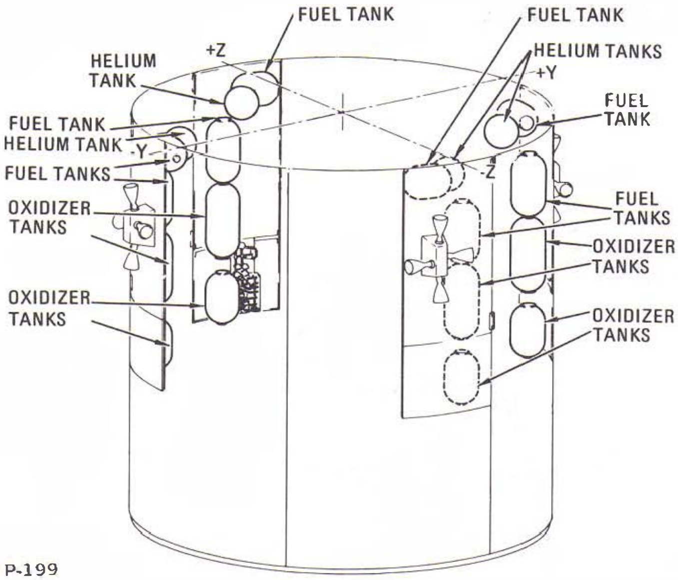
SM REACTION CONTROL SYSTEM

The SM reaction control system consists of four similar, independent systems (quads) located 90 degrees apart around the service module. It provides thrust required for three-axis stabilization and control of the spacecraft during earth orbit, translunar trajectory abort, transposition and docking, and translunar, lunar orbital, and transearth flight. It also may be used for minor course corrections both on the translunar and transearth flights.

The system provides the small velocity changes required for service propulsion subsystem propellant-settling maneuvers (ullage). Only roll axis control is provided during service propulsion engine thrusting. In addition, it provides velocity changes for spacecraft separation from the third stage during high-altitude or translunar injection abort, for separation from the boost vehicle after injection of the spacecraft into translunar trajectory, LM rendezvous in lunar orbit, and for CM-SM separation.

The four quads can be operated simultaneously or in pairs during spacecraft maneuvers. Each quad is mounted on a honeycomb structural panel about 8 feet long and 3 feet wide. It becomes part of the integrated service module structure when hinged and bolted in place. Center lines of engine mounts are offset about 7 degrees from the Y and Z axes. The cluster of four engines for each quad is rigidly mounted in a housing on the outside of the honeycomb panel. Laterally mounted (roll) engines are used for rotating the vehicle about the X axis. Longitudinally mounted engines are used for rotating the vehicle about the Y and Z axes and translational maneuvers along the X axis. Roll engines are offset to minimize engine housing frontal area to reduce boost heating effects. All engines in each cluster are canted 10 degrees outward to reduce the effects of exhaust plume impingement on the service module structure.

Each engine provides approximately 100 pounds of thrust and uses hypergolic propellant. The fuel is monomethyl hydrazine (MMH) and the oxidizer is nitrogen tetroxide (N_2O_4). The engines are produced by The Marquardt Corp., Van Nuys, Calif.



SM reaction control subsystem quads

The reaction control engines may be pulse-fired (in bursts) to produce short-thrust impulses or fired continuously to produce a steady thrust. The short-pulse firing is used for attitude-hold and navigation alignment maneuvers. Attitude control can be maintained with two adjacent quads operating.

Each quad contains a pressure-fed, positive-expulsion propellant feed system. The propellant tanks (two fuel and two oxidizer) are located on the inside of the structural panel; feed lines are routed through the panel to the engines. The propellant tanks are produced by Bell Aerosystems Co., Buffalo, N.Y., a division of Textron, Inc.

Helium is used to pressurize the propellant tanks; a single helium tank is located on the inside of the panel. Helium entering the propellant tanks around the positive-expulsion bladders forces the propellant in the tanks into the feed lines. Oxidizer and fuel are thus delivered to the engines. The fuel valve on each engine opens approximately 1/500th of a second before the oxidizer valve to provide proper ignition characteristics. Each valve contains orifices which meter the propellant flow to obtain the proper (2 to 1) mixture ratio. The propellants are hypergolic; that is, they ignite when they come in contact in the engine combustion chamber without an ignition system.

CM REACTION CONTROL SYSTEM

The CM reaction control system is used after CM-SM separation and for certain abort modes. It provides three-axis rotational and attitude control to orient and maintain the CM in the proper entry attitude before encountering aerodynamic forces. During entry, it provides the torque (turning or twisting force) required to control roll attitude.

The system consists of two independent, redundant systems, each containing six engines, helium and propellant tanks, and a dump and purge system. The two systems can operate in tandem; however, one can provide all the impulse needed for the entry maneuvers and normally only one is used.

The 12 engines of the system (produced by North American Rockwell's Rocketdyne Division, Canoga Park, Calif.) are located outside the crew compartment of the command module, 10 in the aft compartment and 2 in the forward compartment. The nozzle of each engine is ported through the heat shield of the CM and matches the mold line. Each engine produces approximately 93 pounds of thrust.

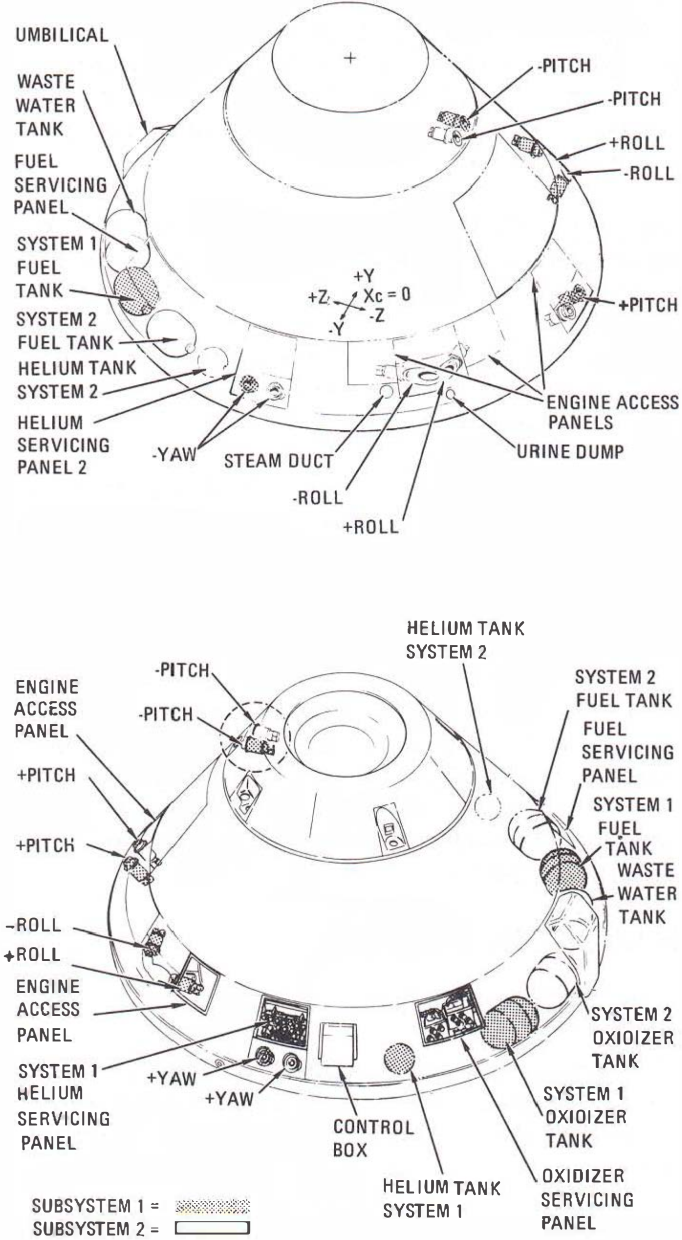
Operation of the CM reaction control engines is similar to the SM. Propellant is the same (monomethyl hydrazine and nitrogen tetroxide) and helium is used for pressurization. Each of the redundant CM systems contains one fuel and one oxidizer tank similar to the fuel and oxidizer tanks of the SM system. Each CM system has one helium tank.

The helium is isolated from the system by squib valves before entry; these are valves which contain small explosive charges (squibs). These valves are activated before CM-SM separation.

High-pressure helium flows through regulators (to reduce the pressure) and check valves to the propellant tanks, where it maintains pressure around the positive-expulsion bladders in each tank. The propellants are forced into the feed lines, through a burst diaphragm, and to the engines. The diaphragm must rupture for propellant to reach the engines; it is additional assurance that the engines cannot be fired inadvertently.

Oxidizer and fuel is fed to the 12 engines by a parallel feed system. The injector valve on each engine contains orifices which meter the fuel and oxidizer so that a flow ratio of 2 oxidizer to 1 fuel is obtained.

The engines may need heating before use so that the oxidizer doesn't freeze when it comes in contact with the injector valve. Astronauts monitor



Location of CM reaction control subsystem components

P-200

the temperature of the engines on a cabin display and turn on the engine injector valve direct coils which act as heaters if necessary.

Because the presence of hypergolic propellant can be hazardous at CM splashdown, the propellant remaining in the fuel and oxidizer tanks is disposed of by burning during the final descent on the main parachute. After all propellant is disposed of the feed lines are purged with helium. The burn and purge operations are controlled manually by the crew except during an abort in the early part of boost (up to 42 seconds after liftoff), when dumping and purging is automatic.

EQUIPMENT

SERVICE MODULE

Helium Tanks (Airite Div., Sargent Industries, El Segundo, Calif.) – The four spherical tanks are made of titanium and weigh 11.5 pounds each. Each has an internal volume of 910 cubic inches. The helium is pressurized to 4150 psig. The outside diameter is 12.37 inches, a wall thickness of 0.135 inch, and a capacity of 1.35 pounds. The tanks store helium used to pressurize the propellant tanks.

Primary Fuel Tanks (Bell Aerosystems Co., Buffalo, N.Y.) – There are four cylindrical titanium tanks with domed ends, one tank for each quad of engines. The tanks have Teflon bladders. Each tank is 23.717 inches long with an outside diameter of 12.62 inches. Wall thickness is 0.017 to 0.022 inch. Combined propellant ullage volume is 69.1 pounds, resulting in tank pressure no greater than 215 psia at 85 degrees. The tanks store fuel (monomethyl hydrazine) and supply it on demand to the engines.

Primary Oxidizer Tanks (Bell) – There are four cylindrical titanium tanks with domed ends, one tank for each quad of engines. The tanks have Teflon bladders. Each tank is 28.558 inches long with an outside diameter of 12.62 inches. Wall thickness is 0.017 to 0.022 inch. Combined propellant and ullage volume is 137 pounds resulting in tank pressure no greater than 215 psia at 85 degrees. The tanks store oxidizer (nitrogen tetroxide) and supply it on demand to the engines.

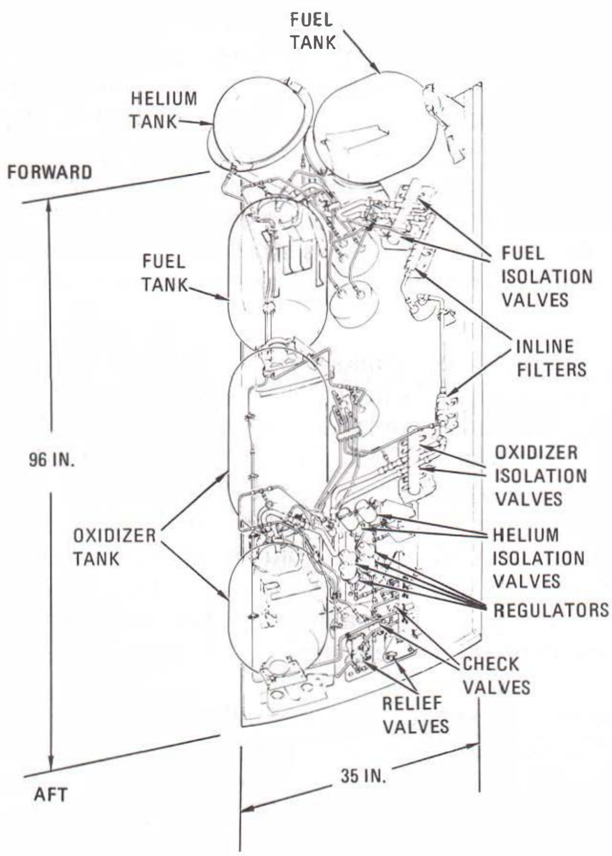
Secondary Fuel Tanks (Bell) – There are four cylindrical titanium tanks with domed ends, one tank for each quad of engines. The tanks have Teflon bladders. Each tank is 17.329 inches long with an outside diameter of 12.65 inches. Wall thickness is 0.022 to 0.027 inch. Combined propellant and ullage volume is 45.2 pounds, resulting in tank pressure no greater than 205 psia at 105 degrees. The tanks store fuel and supply it upon demand to the engines.

Secondary Oxidizer Tanks (Bell) – There are four cylindrical titanium tanks with domed ends, one for each quad of engines. The tanks have Teflon bladders. Each tank is 19.907 inches long and has an outside diameter of 12.65 inches. Wall thickness is 0.022 to 0.027 inch. Combined propellant and ullage volume is 89.2 pounds, resulting in tank pressure no greater than 205 psia at 105 degrees. The tanks store oxidizer and supply it on demand to the engines.

Engines (Marquardt) – There are 16 radiation-cooled engines grouped in clusters of four 90 degrees apart on the outside of the service module. They are the only nonablative engines on the command and service module. The thrust chambers are pure molybdenum, and nozzle extensions are a cobalt-base alloy. Each engine is 13.400 inches long and weighs 5 pounds. Nozzle exit diameter is 5.6 inches. Each engine has a nominal thrust of 100 pounds. Service life of each engine is 1000 seconds: any combination of pulsed (intermittent) and continuous operation up to a maximum of 500 seconds of steady-state firing. Minimum firing time is 12 milliseconds. Each engine is capable of 10,000 operation cycles. The engines are used for translation and rotational maneuvers and for obtaining star sightings.

COMMAND MODULE

Helium Tanks (Menasco Manufacturing Co., Burbank, Calif.) – The four spherical tanks are made of titanium. Each has a volume of 365 cubic inches. The helium is pressurized to 4150 psig. Outside diameter of each is 9.2 inches, and wall thickness is 0.102 inch. Capacity of each is 0.57 pound. The tanks store helium to pressurize the propellant tanks.



P-201 *Typical SM quad*

Fuel Tanks (Bell) – There are two titanium tanks identical to the secondary fuel tanks on the service module system.

Oxidizer Tanks (Bell) – There are two titanium tanks identical to the secondary oxidizer tanks on the service module system.

Engines (Rocketdyne) – There are 12 engines – 10 in the aft equipment compartment and two in the apex cover area. They are ablative engines and are installed with scarfed (smoothed into the surface) ablative nozzle extensions. Each engine is 12.65 inches long and weighs 8.3 pounds. Nozzle exit diameter is 2.13 inches. Thrust is 93 pounds. Service life for each engine is 200 seconds. Its minimum firing time is approximately 12 milliseconds. Each engine is capable of 3000 operational cycles. The primary use of the engines is for rotation maneuvers, rate damping, and attitude control during entry.

DETAILED DESCRIPTION

SM REACTION CONTROL SYSTEM

The SM system is composed of four separate, individual quads, each containing pressurization, propellant, rocket engine, and temperature control systems.

The pressurization system regulates and distributes helium to the propellant tanks. It consists of a helium storage tank, isolation valves, pressure regulators, check valves, relief valves, and lines necessary for filling, draining, and distribution of the helium.

The helium supply is contained in a spherical storage tank, which holds 1.35 pounds of helium at a pressure of about 4150 psia. Isolation valves between the helium tank and pressure regulators contain two solenoids: one is energized momentarily to latch the valve open magnetically; the other is energized momentarily to unlatch the valve, and spring pressure and helium pressure forces the valve closed. The isolation valves in each quad are individually controlled by switches on the main display console. The valves are normally open to pressurize the system. They are held open by a magnetic latch rather than by the application of power which conserves power and prevents overheating of the valve coil. Indicators above each valve switch show gray when the valve is open (the normal position) and diagonal lines when the valve is closed. The valve is closed in the event of a pressure regulator unit problem and during ground servicing.

Helium pressure is regulated by two assemblies connected in parallel, with one assembly downstream of each isolation valve. Each assembly incorporates two (primary and secondary) regulators connected in series. The secondary regulator remains open if the primary regulator functions properly. If the primary regulator fails open, the secondary regulator will maintain slightly higher but acceptable pressures.

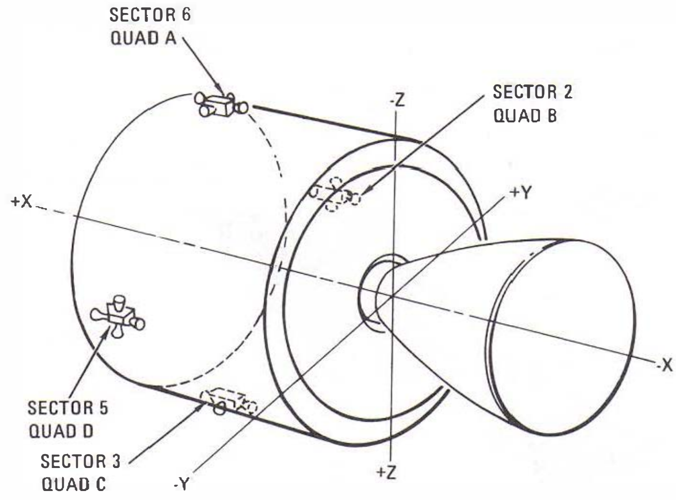
Two check valve assemblies, one for oxidizer and one for fuel, permit helium flow to the tanks and prevent propellant or propellant vapor flow into the pressurization system if seepage or failure occurs in the propellant tank bladders. Filters are incorporated in the inlet to each check valve assembly and each test port.

The helium relief valve contains a diaphragm, filter, a bleed device, and the relief valve. The diaphragm is installed to provide a more positive seal against helium than that of the actual relief valve. The diaphragm ruptures at 228 psia. The filter retains any fragments from the diaphragm and prevents particles from flowing onto the relief valve seat. The relief valve will open at 236 psia and dump excessive pressure overboard. The relief valve will reseat at 220 psia.

A pressure bleed device vents the cavity between the diaphragm and relief valve in the event of any leakage across the diaphragm, or upon completion of checkout of the relief valve. The bleed device is normally open and will be fully closed when the pressure increases to 150 psia; it will be fully opened when the pressure decreases to 20 psia.

The propellant system consists of two oxidizer tanks, two fuel tanks, two oxidizer and two fuel isolation valves, a fuel and oxidizer inline filter, and associated distribution plumbing.

The oxidizer supply is contained in two titanium alloy, hemispherically domed cylindrical tanks. The tanks are mounted to the SM structural panel. The



Location of SM quads

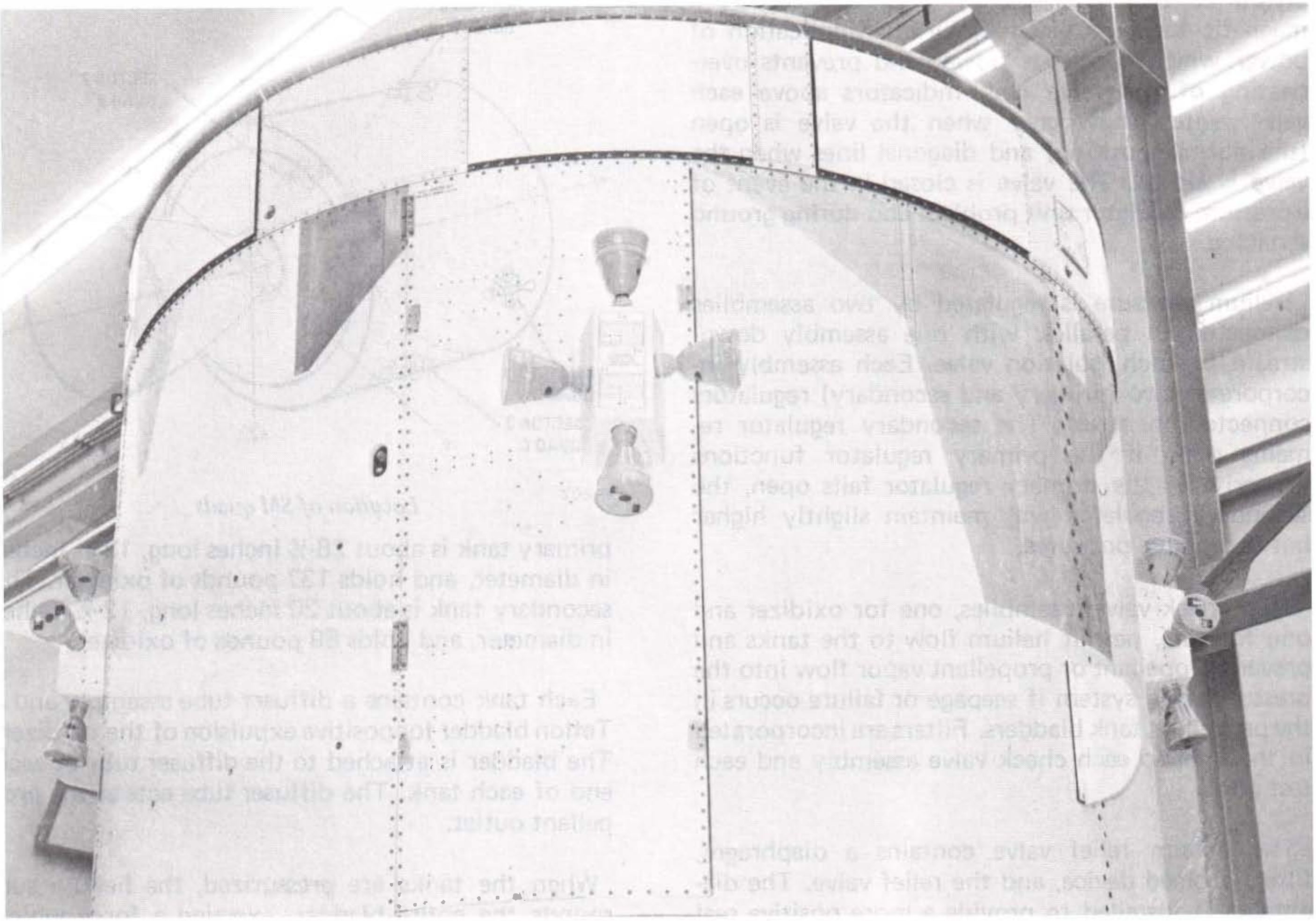
primary tank is about 28-½ inches long, 12-½ inches in diameter, and holds 137 pounds of oxidizer. The secondary tank is about 20 inches long, 12-½ inches in diameter, and holds 89 pounds of oxidizer.

Each tank contains a diffuser tube assembly and a Teflon bladder for positive expulsion of the oxidizer. The bladder is attached to the diffuser tube at each end of each tank. The diffuser tube acts as the propellant outlet.

When the tanks are pressurized, the helium surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant, forcing the oxidizer into the diffuser tube assembly and out of the tank outlet into the manifold, providing expulsion during zero gravity.

The fuel supply is contained in two tanks that are similar in material, construction, operation, and diameter to oxidizer tanks. The primary tank is about 23-½ inches long and holds 69 pounds of fuel; the secondary tank is about 17 inches long and holds 45 pounds of fuel.

Isolation valves in the fuel and oxidizer tank lines in each quad are controlled by switches on the main display console. Each isolation valve contains solenoids and indicators that operate in the same manner as the helium isolation valves. The primary tank valves are normally open and the secondary valves closed. When a propellant quantity indicator displays 43 percent propellant remaining, the secondary valves are opened and the primary valves are closed. The valves may be closed to prevent fluid flow in the event of a failure such as line rupture or a runaway thruster.



P-203

Quad panels installed on service module in Downey clean room

Propellant distribution plumbing is identical in each quad. Each quad contains separate similar oxidizer and fuel plumbing networks. Propellant in each network is directed from the supply tanks through manifolds for distribution to the four engines in the cluster.

Filters are installed in the fuel and oxidizer lines between the propellant isolation valves and the engine manifold to prevent any particles from flowing into the engine injector valves and engine injector.

The SM reaction control engines are radiation cooled, pressure fed, bipropellant thrust generators which can be operated in either the pulse or steady-state mode.

Each engine consists of a fuel and oxidizer injector control valve which controls the flow of propellant by responding to automatic or manual electrical commands and an injector head assembly which directs the flow of the propellant from each control valve to the combustion chamber. A filter is at the inlet of each fuel and oxidizer solenoid injector valve. An orifice in the inlet of each fuel and oxidizer solenoid injector valve meters the propellant flow to obtain a nominal 2:1 oxidizer-fuel ratio.

The propellant solenoid injector valves use two coaxially wound coils, one for automatic and one for direct manual operation. The automatic coil is used when the thrust command originates from the controller reaction jet assembly, which is the electronic circuitry that selects the required automatic coils to be energized for a given maneuver. The direct manual coils are used when the thrust command originates at the rotation control, direct ullage pushbutton, service propulsion subsystem abort, or the SM jettison controller.

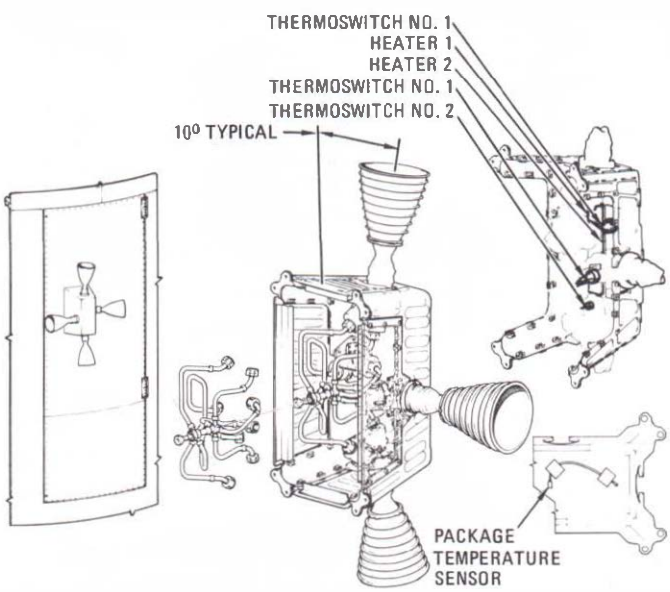
The main chamber portion of the injector will allow 8 fuel streams to impinge upon 8 oxidizer streams for main chamber ignition. There are 8 fuel holes around the outer periphery of the injector which provide film cooling to the combustion chamber walls.

The injector contains a precombustion chamber in which a single fuel and a single oxidizer stream impinge upon each other. The precombustion chamber provides a smoother start transient. There are 8 fuel holes around the outside of the precombustion chamber providing cooling to its walls.

The combustion chamber is constructed of unalloyed molybdenum which is coated with molybdenum disilicide to prevent oxidation of the base metal. Cooling of the chamber is by radiation and fuel film cooling.

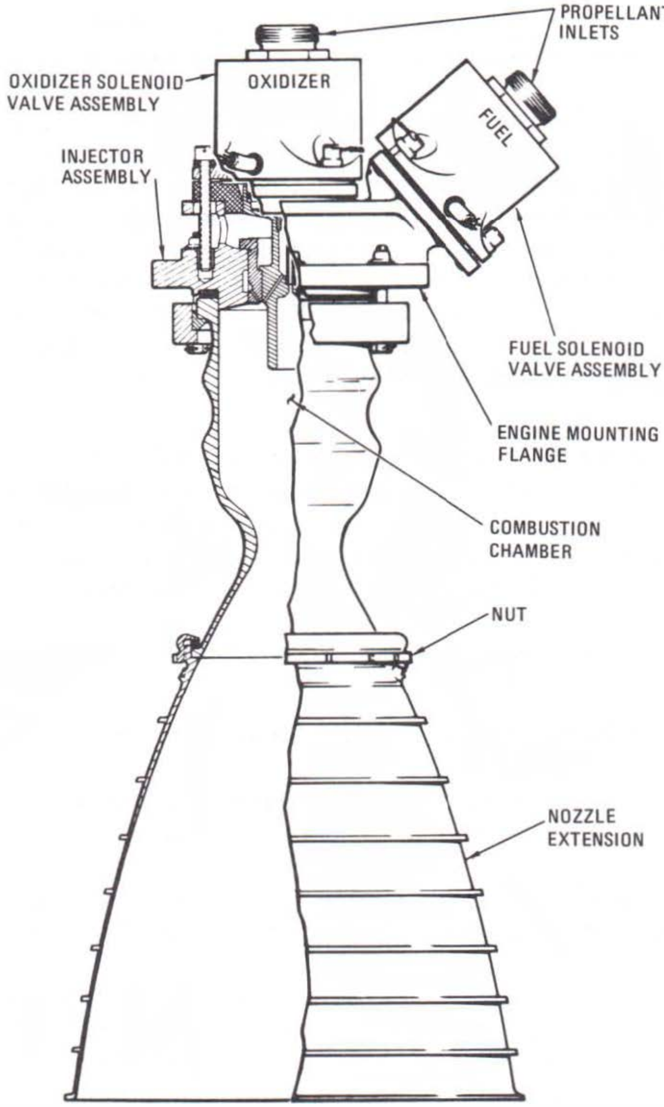
The nozzle extension with integral stiffener rings is machined from a cobalt base alloy.

Each of the engine mounts contain two electrical strip heaters. Each heater contains two electrical elements. One element in each heater is controlled by a secondary temperature therm-o-switch that is set to open at 118°F and close at 70°F. When a switch on the main display console for that quad is set for the secondary system, dc power is supplied to the therm-o-switch in each heater of that quad and will automatically open and close according to the temperature.



P-204

SM reaction control engine housing



P-205

SM reaction control engine

When the switch is set for the primary heater, power is supplied to the redundant element in each heater for that quad. This therm-o-switch is a higher temperature switch and will automatically open at 134°F and close at 115°F. The heaters provide propellant temperature control by conductance to the engine housing and engine injector valves.

A gauge on the main display console is used to monitor the package temperature of any one of the four SM quads.

The helium tank supply pressure and temperature for each quad is monitored by a pressure/temperature ratio transducer. This provides a signal to a switch on the main display console. When the switch is positioned to a given SM quad, the pressure/temperature ratio signal is transmitted to a propellant quantity gauge, and the propellant quantity remaining for that quad is indicated in percent.

The helium tank temperature for each quad is monitored by a helium tank temperature transducer. A switch allows the crew to monitor either the helium tank temperature/pressure ratio as a percentage of quantity remaining, or helium tank temperature which can be compared against the helium supply pressure readout. Helium tank temperature is not displayed in the first Block II spacecraft, although it is telemetered to the ground.

In the SM reaction control system, the main buses cannot supply electrical power to one leg of the channel enable switches and controller reaction jet assembly until the contacts of the subsystem latching relay are closed. These are closed after separation of the spacecraft from the third stage, or to prepare for a service propulsion subsystem abort.

CM REACTION CONTROL SYSTEM

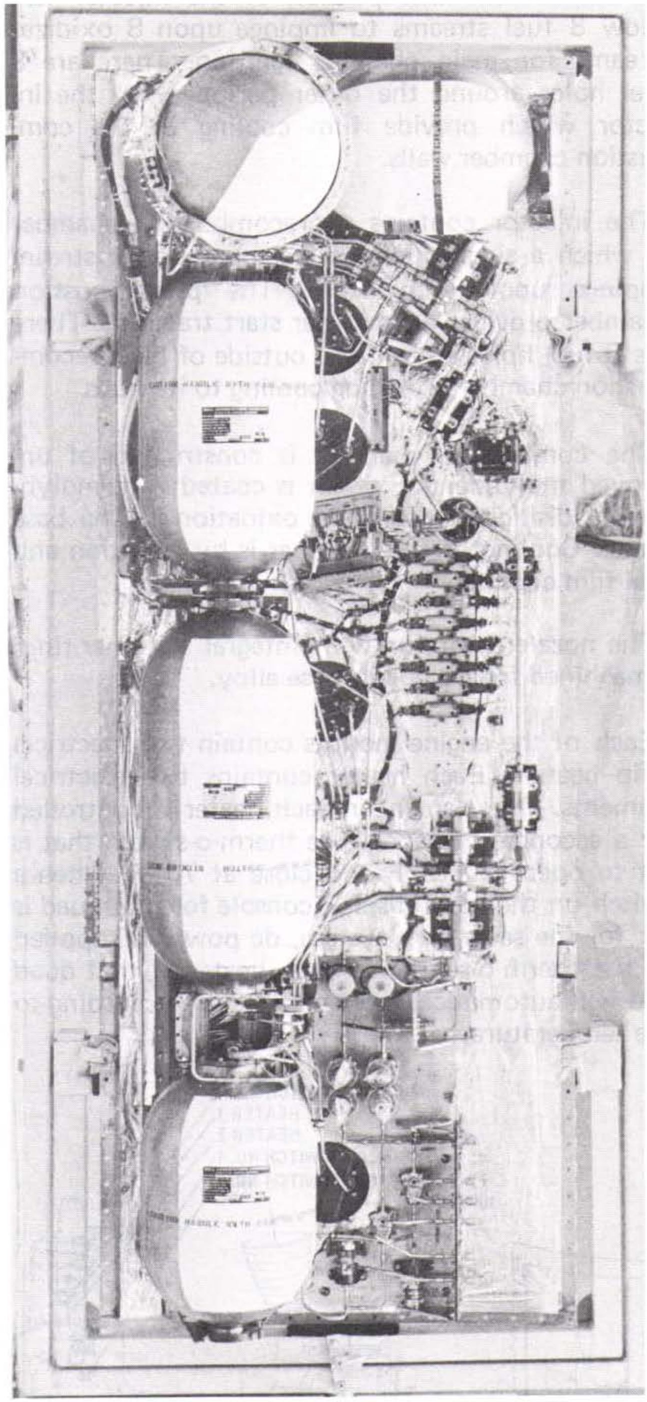
The CM reaction control system is composed of two separate, normally independent systems, called System 1 and System 2. They are identical in operation, each containing pressurization, propellant, rocket engine and temperature control systems.

The pressurization system consists of a helium supply tank, two dual pressure regulator assemblies, two check valve assemblies, two pressure relief valve assemblies, and associated distribution plumbing.

The total high-pressure helium for each system is contained in a spherical storage tank about 9 inches in diameter and containing 0.57 pound of helium at a pressure of 4150 psia.

Two squib-operated helium isolation valves are installed in the plumbing from each helium tank to confine the helium into as small an area as possible to reduce helium leakage until the system is used. Two squib valves are employed in each system to assure pressurization.

The pressure regulators used in the CM systems are similar in type, operation, and function to those used in the SM system. The difference is that the regulators in the CM system are set at a higher pressure than those of the SM system: 291 psia against 181 psia for the primary regulators and 291 against 187 for the secondary regulators.



P-206

SM quad prepared for installation

The check valve assemblies used in CM system are identical in type, operation, and function to those used in the SM system. The helium relief valves also are similar to those in the SM system except that the rupture pressure of the diaphragm in the CM system is higher (340 psia instead of 228) and the relief valve relieves at a higher pressure (346 psia instead of 236 psia).

Each propellant system consists of one oxidizer tank, one fuel tank, oxidizer and fuel isolation valves, oxidizer and fuel diaphragm isolation valves, and associated distribution plumbing.

The oxidizer supply is contained in a single titanium alloy, hemispherical-domed cylindrical tank in each subsystem. These tanks are identical to the secondary oxidizer tanks in the SM system.

Each tank contains a diffuser tube assembly and a Teflon bladder for positive expulsion of the oxidizer similar to that of the SM secondary tank assemblies. The bladder is attached to the diffuser tube at each end of the tank. The diffuser tube acts as the propellant outlet.

When the tank is pressurized, the helium gas surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant, forcing the oxidizer into the diffuser tube assembly and out of the tank outlet into the manifold.

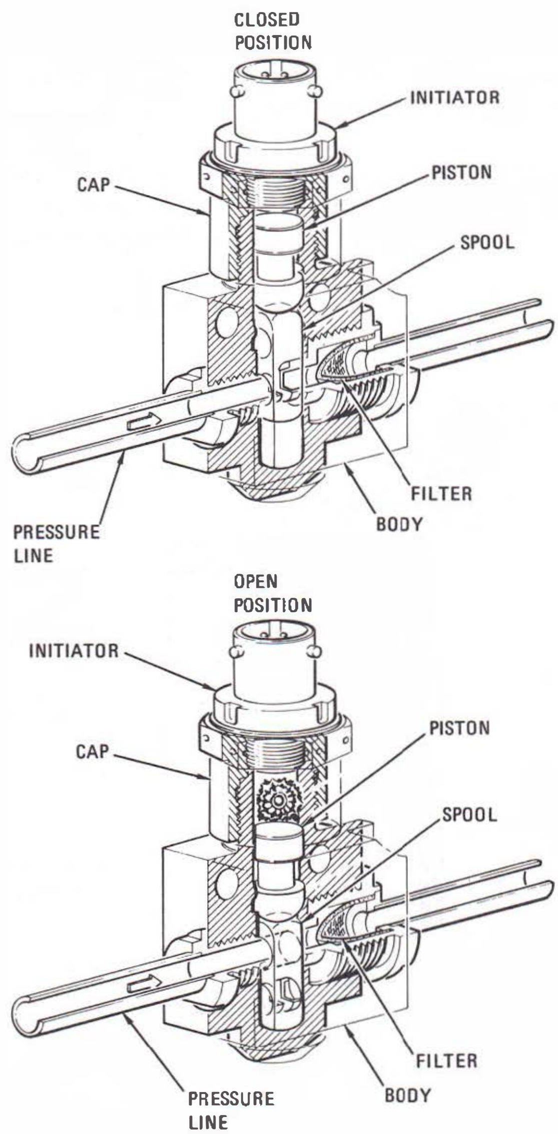
The fuel supply is contained in a single titanium alloy, hemispherical-domed cylindrical tank in each subsystem that is identical to the SM secondary fuel tanks.

The diaphragms are installed in the lines from each tank to confine the propellants to as small an area as possible throughout the mission.

When the helium isolation squib valves are opened, regulated helium pressure pressurizes the propellant tanks creating the positive expulsion of propellants into the respective manifolds to the diaphragms, which rupture and allow the propellants to flow on through the propellant isolation valves to the injector valves on each engine. A filter will prevent any diaphragm fragments from entering the engine injector valves.

When the diaphragms are ruptured, the propellant flows to the propellant isolation valves. These are controlled by a single switch on the main display console. Each propellant isolation valve contains two solenoids, one that is energized momentarily to latch the valve open magnetically, and one that is energized momentarily to unlatch the magnetic latch. Spring force and propellant pressure close the valve. An indicator on the main display console shows gray indicating that the valves are open (the normal position) and diagonal lines when either valve is closed. The valves are closed in the event of a line rupture or runaway thruster.

The distribution lines contain 16 explosive-operated (squib) valves which permit the helium and propellant distribution configuration to be changed for various functions. Each squib valve is actuated by an explosive charge and detonated by an ignitor. After ignition of the explosive device, the valve remains open permanently. Two squib valves are used in each subsystem to isolate the high-pressure helium supply. Two squib valves are used to interconnect System 1 and 2 regulated helium supply which assess pressurization of both systems during dump-burn and helium purge operation. Two squib valves in each subsystem permit helium gas to bypass the propellant tanks and allow helium purging of the propellant subsystem. One squib valve in the oxidizer system permits both oxidizer systems to become common. One squib valve in the fuel system permits both fuel systems



P-207

Typical CM squib valve

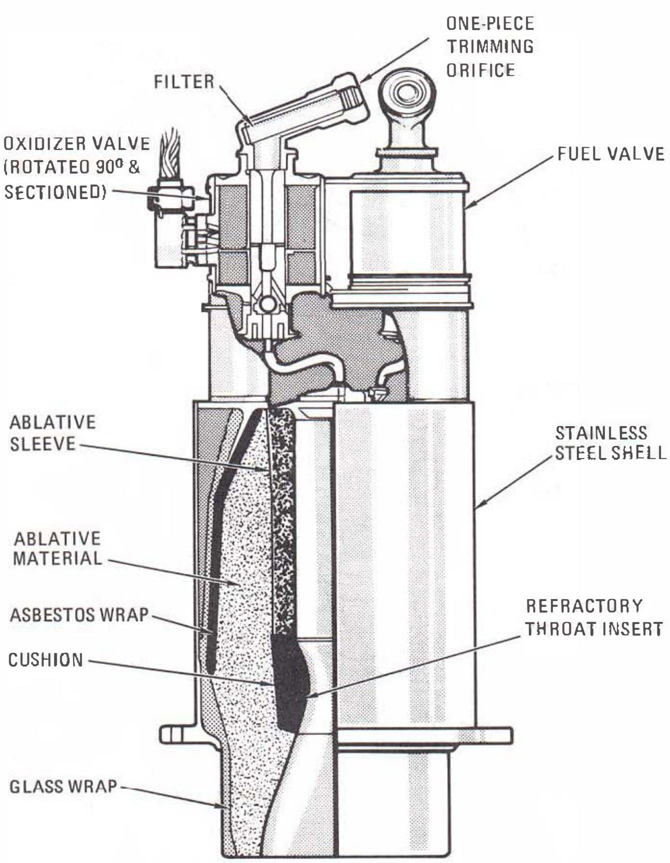
to become common. Two squib valves in the oxidizer system and two in the fuel system are used to dump the respective propellant in the event of an abort from the pad up to 42 seconds after liftoff.

The CM reaction control subsystem engines are ablative-cooled, bipropellant thrust generators that can be operated in either pulse or steady-state mode.

Each engine consists of fuel and oxidizer injector valves which control the flow of propellants, an injector and a combustion chamber in which the propellants are burned to produce thrust.

The injector valves use two coaxially wound coils, one for automatic and one for direct manual control. The automatic coil is used when the thrust command originates in guidance and control electronics. The direct manual coil is used when the thrust command originates at the astronaut hand rotation control. The engine injector valves are spring-loaded closed and energized open.

The automatic coils in the fuel and oxidizer injector valves are connected in parallel from guidance and control electronics. The direct manual coils in the fuel and oxidizer injector valves provide a direct backup to the automatic system. They are connected in parallel.



P-208 *CM reaction control engine*

The injector contains 16 fuel and 16 oxidizer passages that impinge on a splash plate within the combustion chamber. This pattern is referred to as an unlike impingement splash-plate injector.

The thrust chamber assembly consists of the combustion chamber ablative sleeve, throat insert, ablative body, asbestos, and a fiberglass wrap. The engine is ablative-cooled.

The CM reaction control engines are mounted within the structure of the CM. The nozzle extensions extend through the CM heat shield and are made of ablative material. They match the mold line of the CM.

Temperature of the CM engines before activation is controlled by energizing injector valve direct coils on each engine. Temperature sensors are mounted on 6 of the 12 engine injectors. The temperature transducers have a range from -50° to +50°F. The temperature transducers from the System 1 and 2 engine injectors provide inputs to two rotary switches located in the lower equipment bay of the CM. The specific engine injector temperature is monitored as dc voltage on the voltmeter in the bay. If any one of the engines registers less than 48°F, the direct manual heating coils of all 12 engines are switched on. If 48°F (approximately 5 volts on the dc voltmeter) is reached from the coldest instrumented engine before 20 minutes, the valves are turned off. If 20 minutes pass before +48°F is reached, the valves are turned off then. The heaters prevent the oxidizer from freezing at the engine injector valves and the 20-minute time limit assures that the warmest engines will not be overheated.

All automatic thrust commands for CM attitude are generated from the controller reaction jet assembly. These commands may originate at the rotation controls, the stabilization and control subsystem, or the CM computer. If the controller reaction jet assembly is unable to provide commands to the automatic coil of the CM engines, switches on the main display console will provide power to the rotation controls for direct coil control. The CM-SM separation switches automatically energize relays in the reaction control system control box that transfer the controller reaction jet assembly and direct manual inputs from the SM engines to the CM engines. These functions also occur automatically on any launch escape subsystem abort.

The transfer motors in the control box are redundant to assure that the direct manual inputs are transferred from the SM engines to the CM engines, in addition to providing a positive deadface.

The RCS transfer motors may also be activated by a transfer switch placed to "CM" position; this is a manual backup to the automatic transfer.

CM Systems 1 and 2 also may be checked out before CM-SM separation by use of the transfer switch.

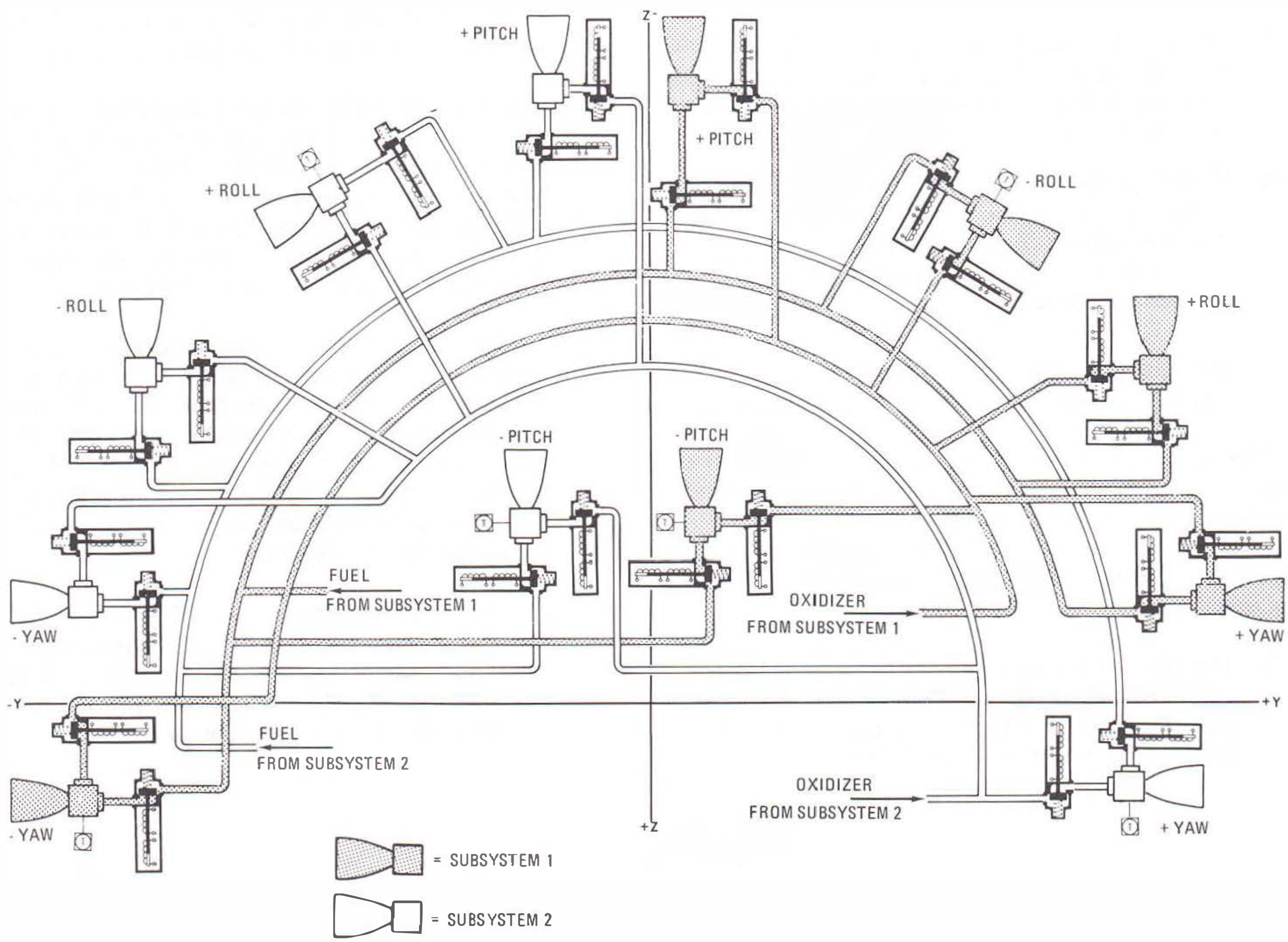
There are two sequences of propellant jettison. One sequence is used in the event of an abort while the vehicle is on the launch pad and through the first 42 seconds of flight. The second is used for all other conditions.

The sequence of events before and during a normal entry is as follows:

1. The CM system is pressurized by manual switching which fires the helium isolation squib valves in both System 1 and 2.

2. The CM reaction control engines provide attitude control during entry; and at approximately 24,000 feet, a barometric switch is activated unlatching the subsystem latching relay, inhibiting any further commands from the controller reaction jet assembly.

3. When the main parachute is fully deployed, a crewman will turn on the CM reaction control propellant dump switch, simultaneously initiating the two helium interconnect squib valves, the fuel interconnect squib valve, and the oxidizer interconnect squib valve, and energizing the fuel and oxidizer injector valve



P-209

Schematic of reaction control engines

direct manual coils on 10 of the 12 CM engines. (The two forward or pitch engines are not energized because their plume might impinge on the parachutes.) The remaining propellant is burned through the 10 engines. The length of burn time will vary depending on the amount of propellant remaining. If an entire propellant load remained, a nominal burn time would be 88 seconds through 10 engines. In the worst case (only 5 of the 12 engines burning), a nominal burn time would be 155 seconds.

4. Upon completion of propellant burn, the CM propellant purge switch is turned on initiating the four helium bypass squib valves to allow the regulated helium pressure to bypass around each fuel and oxidizer tank bladder and purge the lines and manifolds out through the 10 engines. Purging requires approximately 15 seconds (until helium is depleted).

5. In case of a switch failure, the remaining propellants may be burned by manipulating the two rotation controllers so that 10 of the 12 CM engines will fire.

6. If the purge switch fails, the CM "helium dump" pushbutton would be pressed to initiate the four helium bypass squib valves, purge the lines and manifolds out through 10 of the 12 engines, and deplete the helium source pressure.

7. After purging, the direct coils of the CM engine injector valves are switched off manually.

The sequence of events during an abort from the pad up to 42 seconds after liftoff is controlled automatically by the master event sequence controller by manually rotating the translation control counterclockwise. The following events occur simultaneously:

1. The CM-SM transfer motor-driven switches are automatically driven upon receipt of the abort signal, transferring the logic circuitry from SM reaction control engines to CM engines.

2. When the abort signal is received, the two squib-operated helium isolation valves in each system are initiated, pressurizing Systems 1 and 2.

3. The squib-operated helium interconnect valve for the oxidizer and fuel tanks are opened even if only one of the two squib helium isolation valves opens. Both subsystems are pressurized as a result of the helium interconnect squib valve.

4. The solenoid-operated fuel and oxidizer isolation shutoff valves are closed to prevent fuel and oxidizer from flowing to the thrust chamber assemblies.

5. The squib-operated fuel and oxidizer interconnect valves are opened. Even if only one of the two oxidizer or fuel overboard dump squib valves opens, the oxidizer and fuel manifolds of each system are common as a result of the oxidizer and fuel interconnect squib valves.

6. The squib-operated oxidizer overboard dump valves are opened and route the oxidizer to blowout plug in the aft heat shield of the CM. The oxidizer shears a pin due to the pressure buildup and blows the plug out, dumping the oxidizer overboard. The entire oxidizer supply is dumped in approximately 13 seconds.

7. Five seconds after abort initiation, the squib-operated fuel overboard dump valves are initiated open and route the fuel to a fuel blow out plug in the aft heat shield of the CM. The fuel shears a pin due to the pressure buildup and blows the plug out, dumping the fuel overboard. The entire fuel supply is dumped in approximately 13 seconds.

8. Thirteen seconds after the fuel dump sequence was started, the fuel and oxidizer bypass squib valves in Systems 1 and 2 are opened to purge the fuel and oxidizer systems through the fuel and oxidizer overboard dumps.