E41000
RSS-8559-1-1-1

SPACE SHUTTLE TECHNICAL MANUAL

SSME DESCRIPTION AND OPERATION

(INPUT DATA)

IN 37
047 775

SPACE SHUTTLE MAIN ENGINE

PART NUMBER RS007001

ROCKETDYNE DIVISION
ROCKWELL INTERNATIONAL CORPORATION

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15. LOW-PRESSURE OXIDIZER TURBOPUMP

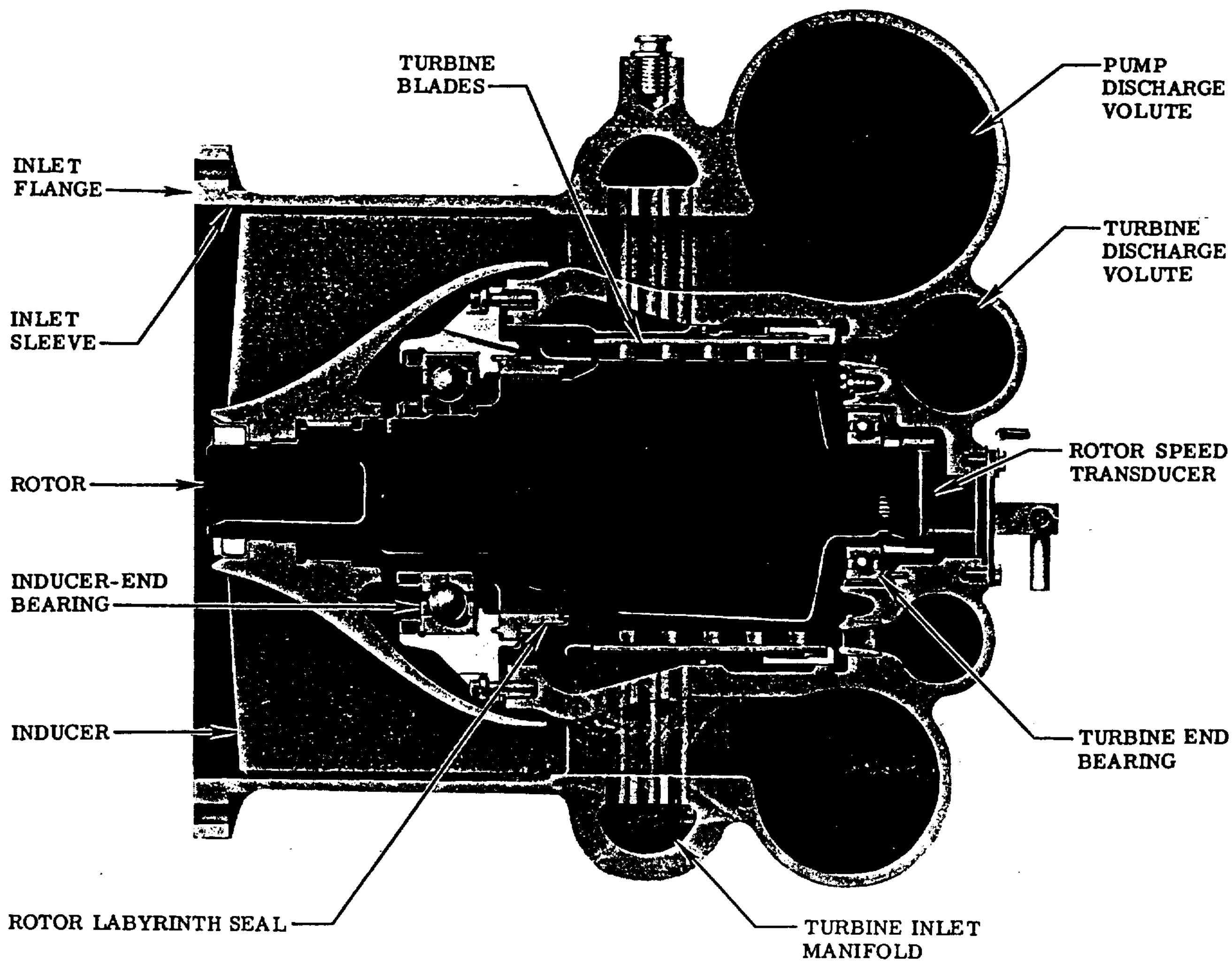
The low-pressure oxidizer turbopump (LPOTP) is an axial-flow pump driven by a six-stage turbine that is powered by liquid oxygen. During engine start and mainstage, the LPOTP maintains sufficient pressure to the high-pressure oxidizer turbopump (HPOTP) to permit the HPOTP to operate at high speeds without an inducer and without cavitation even in the worst case of engine inlet conditions. Turbine-drive fluid is tapped from the HPOTP discharge and, after powering the turbine, is injected into the pumped fluid through a port between the turbine discharge and pump discharge volutes. The combined flows are then routed to the HPOTP inlet. Since the pumped fluid and turbine drive fluid are both liquid oxygen and the LPOTP is located upstream of the oxidizer valves, the requirement for dynamic seals, purges, and drains has been eliminated.

The rotor is supported by two liquid oxygen-cooled ball bearings. The turbine-end bearing coolant flow path is from the last stage of the turbine, through the bearing, hollow rotor, radial holes in the rotor, and to the inducer discharge. Coolant for the inducer-end bearing is from the turbine inlet, through the rotor labyrinth seal, through the bearing, and to the inducer discharge.

A redundant-element, magnetic-type speed transducer is installed on the turbine end of the turbopump housing.

Access ports in the vehicle duct allow periodic inspection of the inducer blades for damage. Inspection is performed with a fiber optic borescope.

The LPOTP is a line replaceable unit and has an approximate overall dimensional envelope of 18 by 18 inches.



16. LOW-PRESSURE FUEL TURBOPUMP

The low-pressure fuel turbopump (LPFTP) is an axial-flow pump driven by a two-stage turbine that uses gaseous hydrogen (GH_2) as the power medium. During engine start and mainstage operation, the LPFTP maintains sufficient pressure to the high-pressure fuel turbopump (HPFTP) to permit the HPFTP to operate at high speeds without an inducer and without cavitation, even in the worst case of engine inlet conditions. The turbine is driven by GH_2 from the main combustion chamber (MCC) coolant outlet manifold.

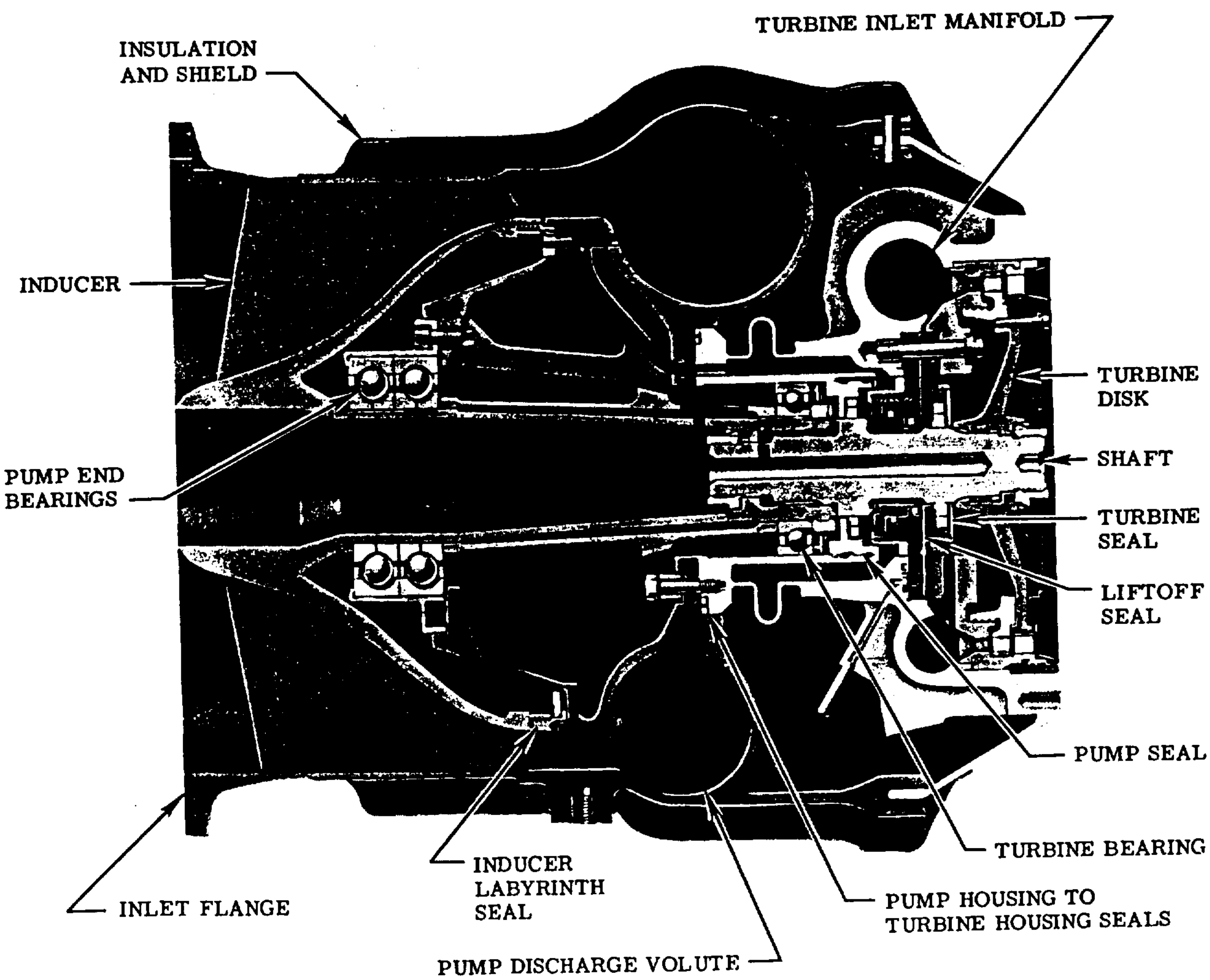
The inducer and shaft are supported by three liquid hydrogen-cooled (LH_2) ball bearings. The bearing coolant is the leakage across the inducer discharge labyrinth seal. The coolant flows through the pump end bearings and turbine bearing and is returned to the pump inlet through passages in the shaft, bearing bearing spacer, and inducer.

Three shaft seals are used to control leakage between the pump and turbine before engine start and during operation. Before engine start, leakage from the pump into the turbine is prevented by a spring-loaded-closed, propellant pressure-actuated-open, lift-off seal. During engine start the seal nose is separated from its mate ring when increasing fuel pressure overcomes the spring force. A positive separation between the seal nose and mate ring is maintained until engine shutdown when fuel pressure decreases below spring force. During operation, leakage from the turbine into the pump is minimized by the pump and turbine seals.

A redundant-element, magnetic-type speed transducer is installed in the pump volute to monitor shaft speed.

Access ports in the vehicle duct allow periodic inspection of the inducer blades for damage. Inspection is performed with a fiber optic borescope.

The LPFTP is a line replaceable unit and has an overall dimensional envelope of approximately 18 by 24 inches.



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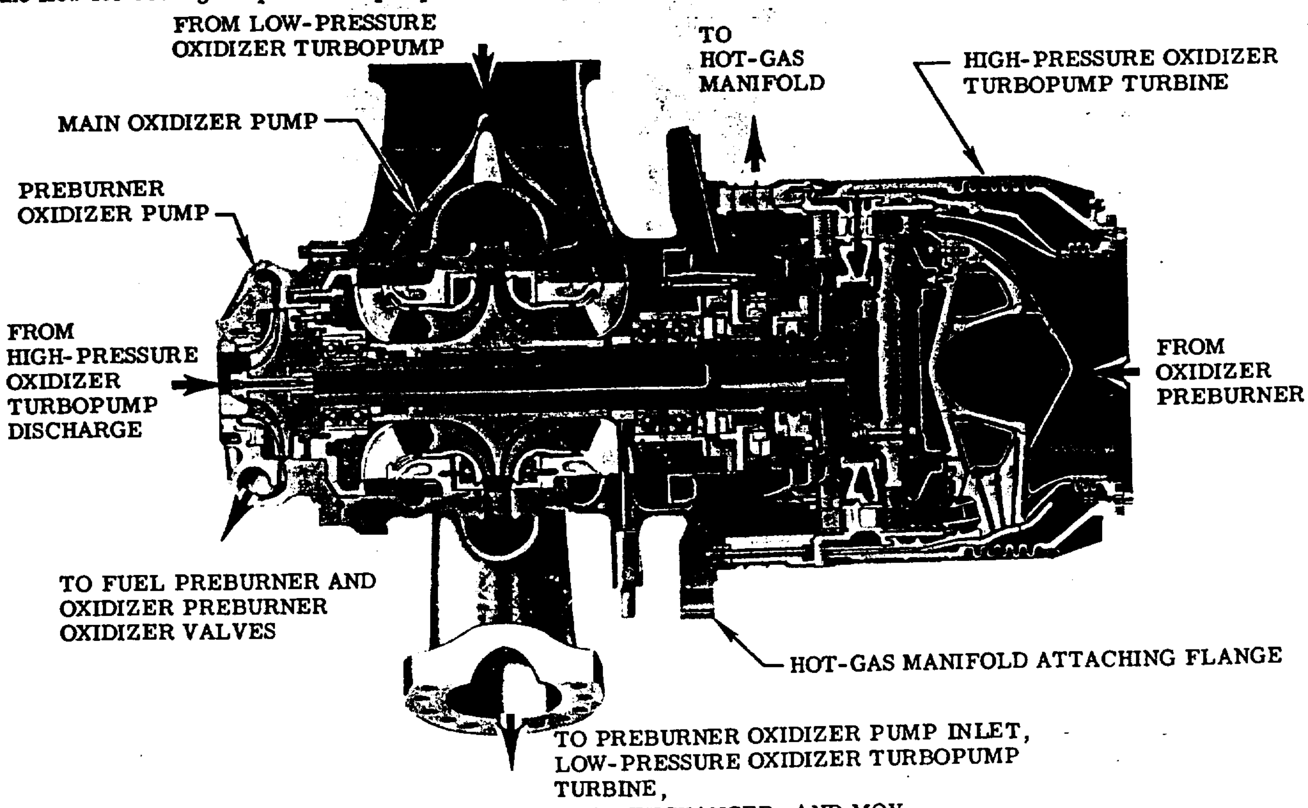
17. HIGH-PRESSURE OXIDIZER TURBOPUMP

The high-pressure oxidizer turbopump (HPOTP) consists of two single-stage centrifugal pumps on a common shaft that are directly driven by a two-stage hot-gas turbine. The main pump receives oxidizer from the low-pressure oxidizer turbopump (LPOTP) and supplies oxygen at an increased pressure to the LPOTP turbine, the heat exchanger, the preburner pump, and the thrust chamber injector. The preburner pump further increases the pressure to the level required by the oxidizer preburner (OPB) and fuel preburner (FPB). The turbine is powered by hot gas (hydrogen-rich steam) supplied by the OPB. Mixing of oxidizer and hot gas is prevented by seals, a purge, and drains. Two duplex sets of liquid oxygen-cooled ball bearings support the rotating parts. The HPOTP is flange attached to the hot-gas manifold (HGM) and is canted at a 10-degree angle out from the engine centerline. The HPOTP is a line replaceable unit (LRU) with an overall dimensional envelope of approximately 24 by 36 inches.

The HPOTP main pump has a single inlet with a 50-50 flow split into a double-entry, common outlet impeller. Liquid oxygen enters the main pump through the main pump housing where the flow split is made. Inlet vanes direct the flow to the impeller inlet guide vanes, which in turn direct the flow to the impeller inlets. The impeller has four full and four partial blades in each half. After passing through the impeller, the flow is redirected into the discharge volute by diffuser vanes.

Turbopump shaft bearings are cooled by liquid oxygen from the preburner pump. Coolant for the preburner-end bearings is through the preburner pump impeller hub labyrinth seal, through the bearings, and to the main pump impeller inlet. The turbine-end bearings coolant is through the preburner impeller bolt, through the hollow shaft, through the bearings, and to the main pump impeller inlet. Pump shaft axial thrust is balanced in that the double-entry main impeller is inherently balanced and the thrusts of the preburner pump and turbine are equal but opposite. Residual shaft thrust is controlled by a self-compensating, nonrubbing, balance piston function by using the main impeller seal leakage flows and controlling the pressure on the impeller shrouds by orifices at the impeller discharge tips. Mixing of oxidizer and turbine gas is prevented by a dynamic shaft seal package that is between the main pump and the turbine. The seal package consists of an oxidizer labyrinth seal, a hydrodynamic primary oxidizer seal, a pressure-actuated controlled-gap intermediate seal, and two controlled-gap turbine hot-gas seals. Drain cavities with overboard drain lines are located between the primary oxidizer seal and the intermediate seal, between the intermediate seal and secondary turbine seal, and between the secondary and primary turbine seals. To further ensure against the mixing of oxidizer and turbine gas, a helium purge is applied between the elements of the intermediate seal during engine operation.

The preburner pump has a single-entry impeller that discharges oxidizer through diffuser vanes into the discharge volute. The preburner pump housing is flange-mounted to the main pump housing. Impeller seals interface with labyrinths cut in the outside diameter of the impeller shroud and hub to minimize leakage back to the pump inlet and control the flow for cooling the preburner pump-end bearings.

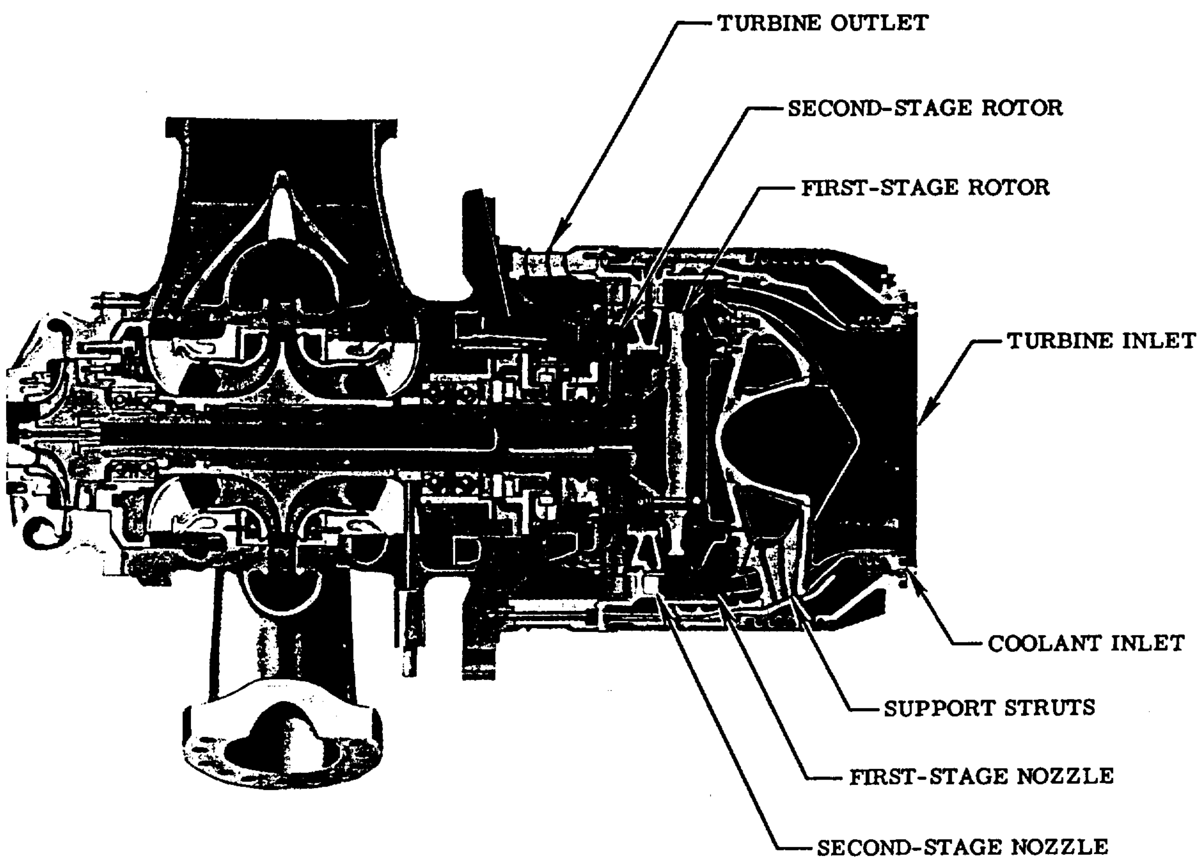


18. HIGH-PRESSURE OXIDIZER TURBOPUMP TURBINE

The high-pressure oxidizer turbopump turbine is powered by hot gas generated by the oxidizer preburner (OPB). Hot gas enters the turbine and flows across the shielded support struts, through the first- and second-stage nozzles and blades, and is discharged into the hot-gas manifold (HGM). The turbine rotors are mated through a curvic coupling and are held together with a circle of bolts. The second-stage rotor is integral with the pump shaft. Turbine blade-to-housing leakage is minimized by lands on the outer perimeter of the blade shrouds that run against seals in the turbine housing.

All components of the turbine are cooled by gaseous hydrogen flowing over or through them. Coolant is supplied from the OPB coolant jacket. After cooling the turbine components, the coolant is exhausted into the hot-gas flow stream.

Turbine-to-OPB sealing is accomplished by a pair of concentric bellows that load dual seals in the turbine inlet flange to the OPB. Turbine component materials are primarily of nickel- and cobalt-base alloys. The diameter of the turbine rotors with blades is approximately 11 inches.



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19. HIGH-PRESSURE FUEL TURBOPUMP

The high-pressure fuel turbopump (HPFTP) is a three-stage centrifugal pump that is directly driven by a two-stage hot-gas turbine. The pump receives fuel from the low-pressure fuel turbopump (LPFTP) and supplies it at increased pressure, through the main fuel valve (MFV), to the thrust chamber assembly coolant circuits. The turbine is powered by hot gas (hydrogen-rich steam) generated by the FPB.

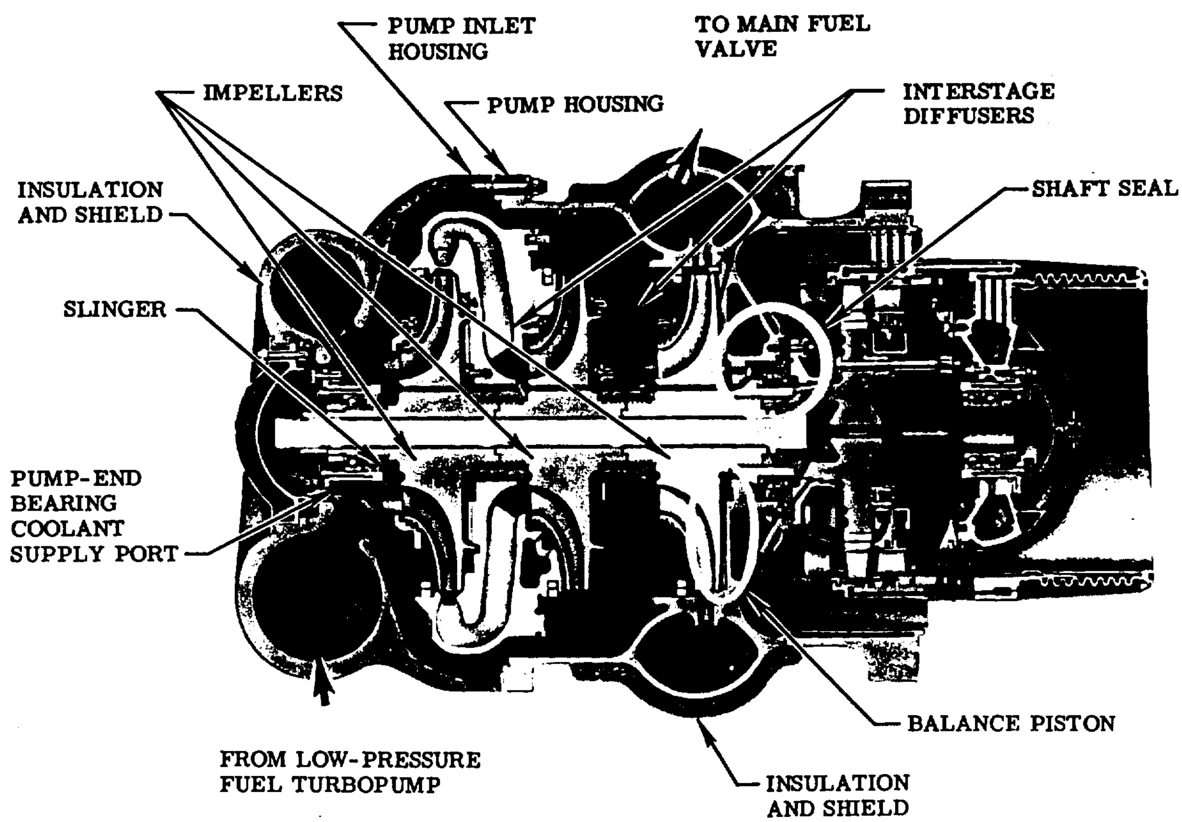
Fuel flows in series through the three impellers from pump inlet to outlet, with flow being redirected between the impellers by interstage diffusers.

Coolant flow across the pump-end bearings is provided by the pumping action of a slinger located between the bearings and first-stage impeller. The coolant is tapped off downstream of the pump inlet turning vanes and returned to the inlet of the first-stage impeller. Coolant flow to the turbine-end bearings is supplied from the pump balance piston cavity through the shaft static lift-off seal.

Axial rotor thrust is controlled by a self-compensating, double-acting balance piston that operates between high- and low-pressure orifices to maintain thrust at zero during normal operation. A thrust bearing (not shown), located at the pump inlet end of the rotating assembly, controls rotor thrust during start and cutoff transient operations.

Before engine start, leakage from the pump into the turbine is prevented by a spring-loaded-closed/propellant pressure-actuated-open, lift-off seal. During engine start the seal nose is separated from its mate ring when increasing fuel and turbine-gas pressure overcomes the spring force. A positive separation between the seal nose and mate ring is maintained until engine shutdown when actuating pressure decreases below spring force. Propellant flow through the seal and mate ring is used to cool the turbine-end bearings and the turbine components.

The HPFTP is flange attached to the hot-gas manifold (HGM) and is canted out from the engine centerline at a 10-degree angle. The HPFTP is a line replaceable unit with an overall dimensional envelope of approximately 22 by 44 inches.



3. SSME PROPELLANT FLOW SCHEMATIC

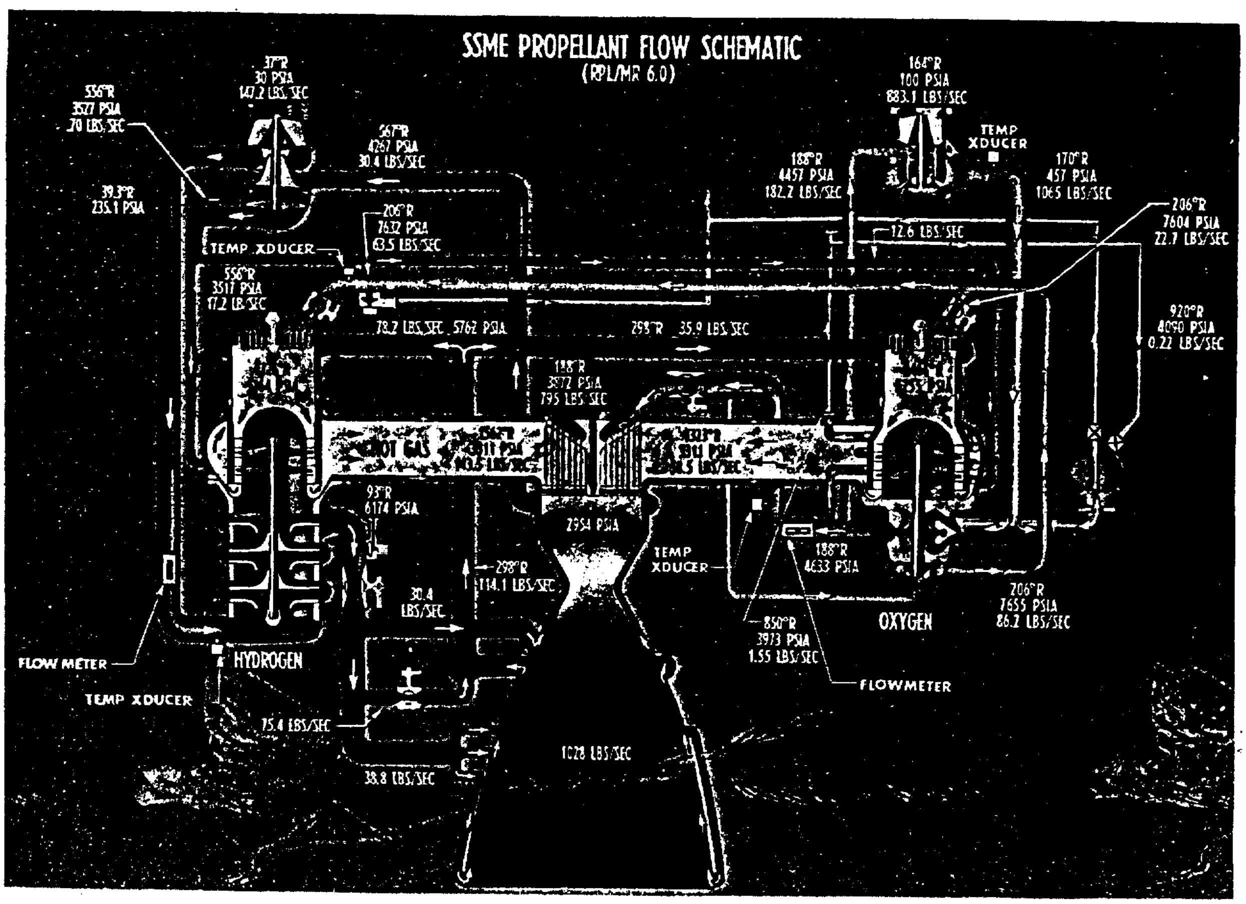
The SSME uses a staged combustion cycle in which propellants are partially burned at high pressures and relatively low temperature in the preburners and then completely burned at high pressure and temperature in the main combustion chamber.

The propellant system uses four turbopumps. The two low-pressure turbopumps operate at low speed to permit low pressures in the vehicle tanks. The function of these pumps is to provide enough pressure to eliminate cavitation at the inlets of the high-speed, high-pressure pumps. The discharge from the low-pressure pumps is fed to the inlets of the high-pressure turbopumps.

Approximately 75 percent of the flow from the HPOTP goes to the main combustion chamber, and approximately 10 percent is directed to the preburner pump that raises the pressure to the preburners operating level. Small quantities are bled through the heat exchanger for oxidizer tank pressurization and pogo suppression and the balance of the oxidizer drives the hydraulic turbine powering the LPOTP and is then recirculated to the inlet of the high-pressure pump.

Approximately 20 percent of the high-pressure fuel pump discharge flow is used to cool the main combustion chamber, drive the low-pressure fuel-pump turbine, cool the hot-gas manifold and injector, and provide fuel tank pressurant. The remaining fuel is first used to cool the nozzle, then supply the preburners.

The hot-gas hydrogen-rich steam from the fuel and oxidizer preburners drives the high-pressure pump turbines, then flows to the main injector where it is mixed with additional oxidizer and fuel and injected into the main combustion chamber.



	no. Of stages	fluid density	efficiency	disch. Press. (psi)	inlet Press. (psi)	flow (GPM)	turbopump wt. (lb)	RPM	HP	NS
F1 RP1	1+inducer	50.5	72.6	1960		15640	3080	5490	22700	1110
F1 LOX	1+inducer	71.4	74.6	1550		25080		5490	30000	2095
SSME HPFTP	3			7040	214	16360	775	37355	76560	1123
SSME HPOTP	1+inducer			8435	392	7240	622	31100	27770	1902
SSME LPFTP				289	30	16320	177	15800	2950	
SSME LPOTP				432	100	6080	276	5450	1740	

	NSS	inlet dia. (in.)	inducer tip dia.	impeller tip dia.	impeller eye dia.	disch. Dia.	head coeff.	flow coeff.	overall Length	Overall Dia (in.)
F1 RP1	34200		15.7	22.95		6	0.55	.0572-ind		
F1 LOX	35400		15.75	19.5		8	0.456	.0927-ind		
SSME HPFTP		7.2	none	12	7.2	3.4	0.575	0.131	37	21
SSME HPOTP		7	4.7	6.25	4.7	4.61	0.436	0.076	32	19
SSME LPFTP		12.06	12.014			5.2	0.166	0.27	18	19
SSME LPOTP			11.725			6.3	0.233	0.0772	18	19