DATA H-1 ROCKET ENGINE

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R-3620-1

TECHNICAL MANUAL

ENGINE DATA

H-1 ROCKET ENGINE

MODELS
H-1C AND H-1D

(ROCKETDYNE)

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H1-274	37	30	16 Nov 1965
H1-275	--	37	N/A
H1-277	38	38	16 Nov 1965
		39	
H1-278	42	43	N/A
H1-279	37	30	16 Nov 1965
H1-280	--	--	N/A
H1-281	--	--	N/A
H1-283	40	41	16 Nov 1965
H1-284	--	--	N/A
H1-285	41	42	N/A
H1-286	43	44	N/A
H1-287	52	54	N/A
H1-288	44	45	3 Mar 1966
	45	46	
H1-289	--	50	N/A
H1-290	46	47	N/A
	47	48	
H1-291	48	49	3 Mar 1966
H1-292	54	56	N/A
H1-293	49	51	6 May 1966
H1-293R1	--	--	N/A
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	51	53	
H1-297	53	55	6 May 1966
H1-297R1	--	--	N/A
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H1-309	59	61	N/A
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H1-311	57	59	3 Jan 1967
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H1-316R1	63	65	N/A
H1-317	57	59	N/A
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H1-322R1	65	67	N/A
H1-323R1	64	66	26 Sep 1967
H1-325	66	68	N/A
H1-326	67	69	N/A

Figure 2. H-1C and H-1D Engines Configuration Changes--Manual Effectivity (Sheet 3 of 3)

H-1C INBOARD ENGINES		H-1D OUTBOARD ENGINES	
Serial Number	Stock Number	Serial Number	Stock Number
H-4051	H-1161	H-7053	H-1164
H-4055	H-1169	H-7055	H-1170
H-4059	H-1180	H-7057	H-1174
H-4063	H-1188	H-7061	H-1178
H-4064	H-1189	H-7066	H-1193
H-4065	H-1190	H-7067	H-1194
H-4066	H-1191	H-7068	H-1195
H-4067	H-1192	H-7069	H-1196
		H-7070	H-1197

Figure 3. H-1C and H-1D Engines (200,000-Pound Thrust) Stock and Serial Number Cross-Reference

SECTION I

ENGINE DESCRIPTION AND OPERATION

1-1. SCOPE. Engine description and operation data is presented to provide a thorough knowledge of the H-1 rocket engine system and components. The theory of operation includes a complete operation sequence from ignition signal to shutdown. Characteristics of the H-1 engine and its components are fully described. The material in this section is applicable to H-1C and H-1D engines.

1-2. ENGINE CONFIGURATION AND ARRANGEMENT. (See figures 1-1 and 1-2.)

1-3. Two models of the H-1 rocket engine are used in the eight engine cluster of the Saturn vehicles. H-1C is the model designation of the four fixed, inboard engines. H-1D is the model designation of the four gimbaled, outboard engines. Basically, the physical characteristics of the two models are identical, with the exception of the exhaust system and vehicle attach hardware. The major exhaust system difference is the exhaust gas exit. H-1C engines contain a curved exhaust duct while H-1D engines utilize an aspirator (figure 1-20).

1-4. Each engine is attached to the vehicle structure by a gimbal assembly. The inboard engines are stabilized in their positions by struts attached to the thrust chamber stabilizing lugs. The outboard engines have gimbal actuators attached to thrust chamber outriggers, permitting the outboard engines to gimbal for vehicle directional control. Figures 1-3 through 1-6 illustrate the relationship of the H-1 engine to the Saturn 1B vehicles. They show the relationship of the engines to the tanks, arrangement of inboard and outboard engines, and engine canting.

1-5. ENGINE DESCRIPTION.

1-6. The H-1 rocket engine is a calibrated, fixed thrust, bipropellant rocket engine. H-1C inboard engines not incorporating MD37 change and H-1D outboard engines not incorporating MD30 change have a nominal sea-level rating of 200,000 pounds thrust. H-1C inboard engines incorporating MD37 change and H-1D outboard engines incorporating MD30 change have a nominal sea-level rating of 205,000 pounds thrust. The thrust chamber is gimbal-mounted, regeneratively-cooled with fuel, and has an exhaust-nozzle expansion ratio of 8:1. The propellants,

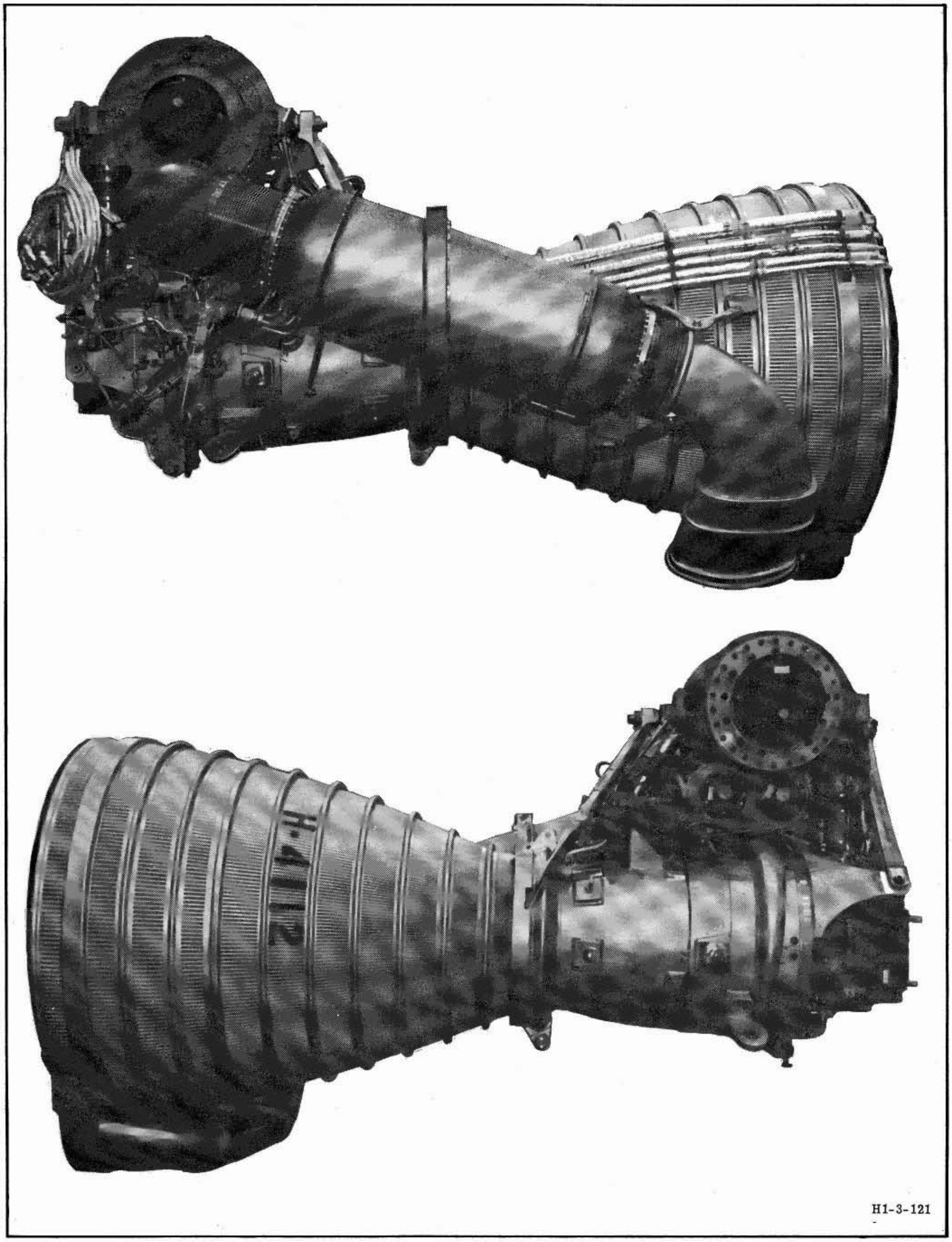

Figure 1-1. H-1C (Inboard) Engine

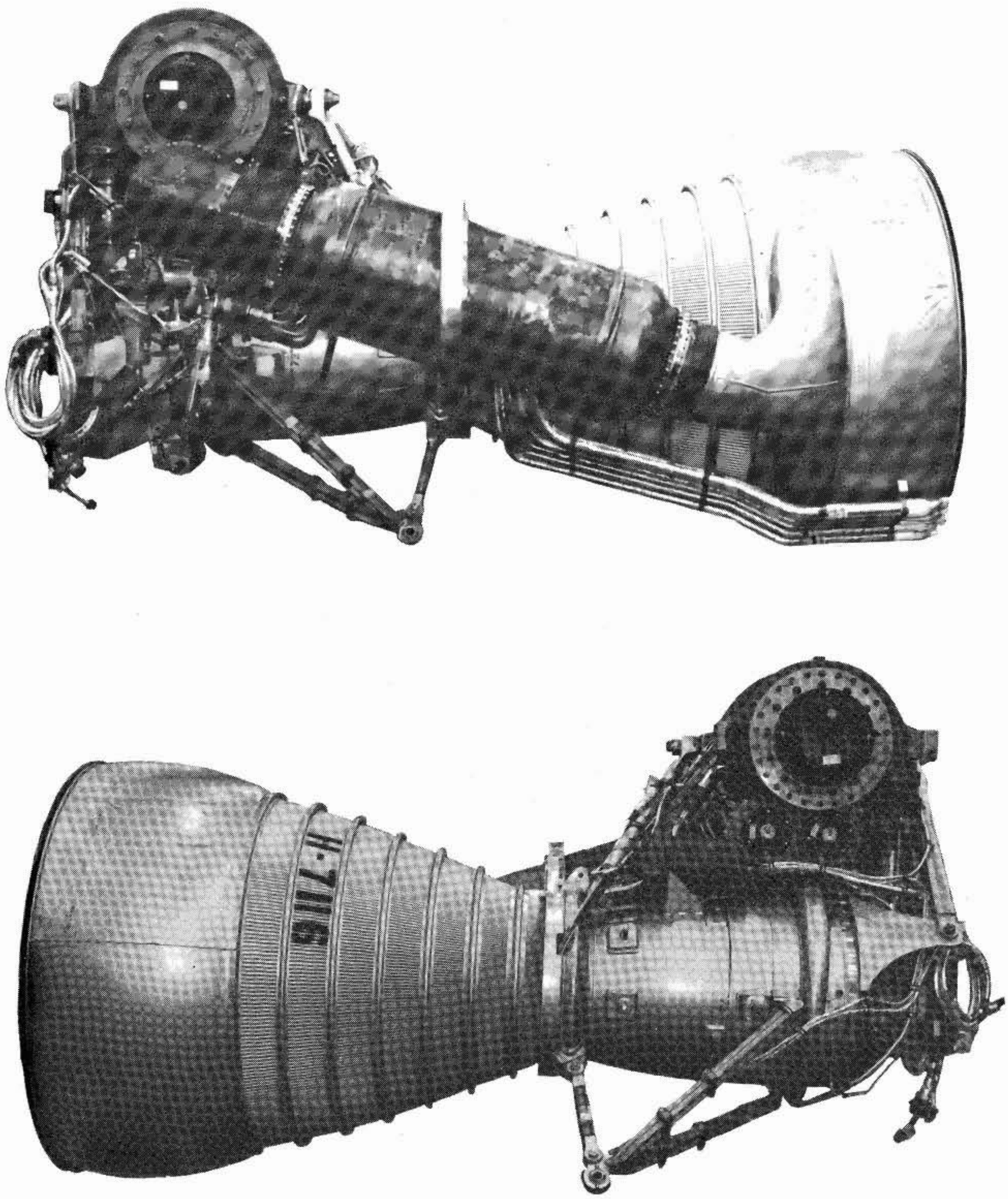

Figure 1-2. H-1D (Outboard) Engine

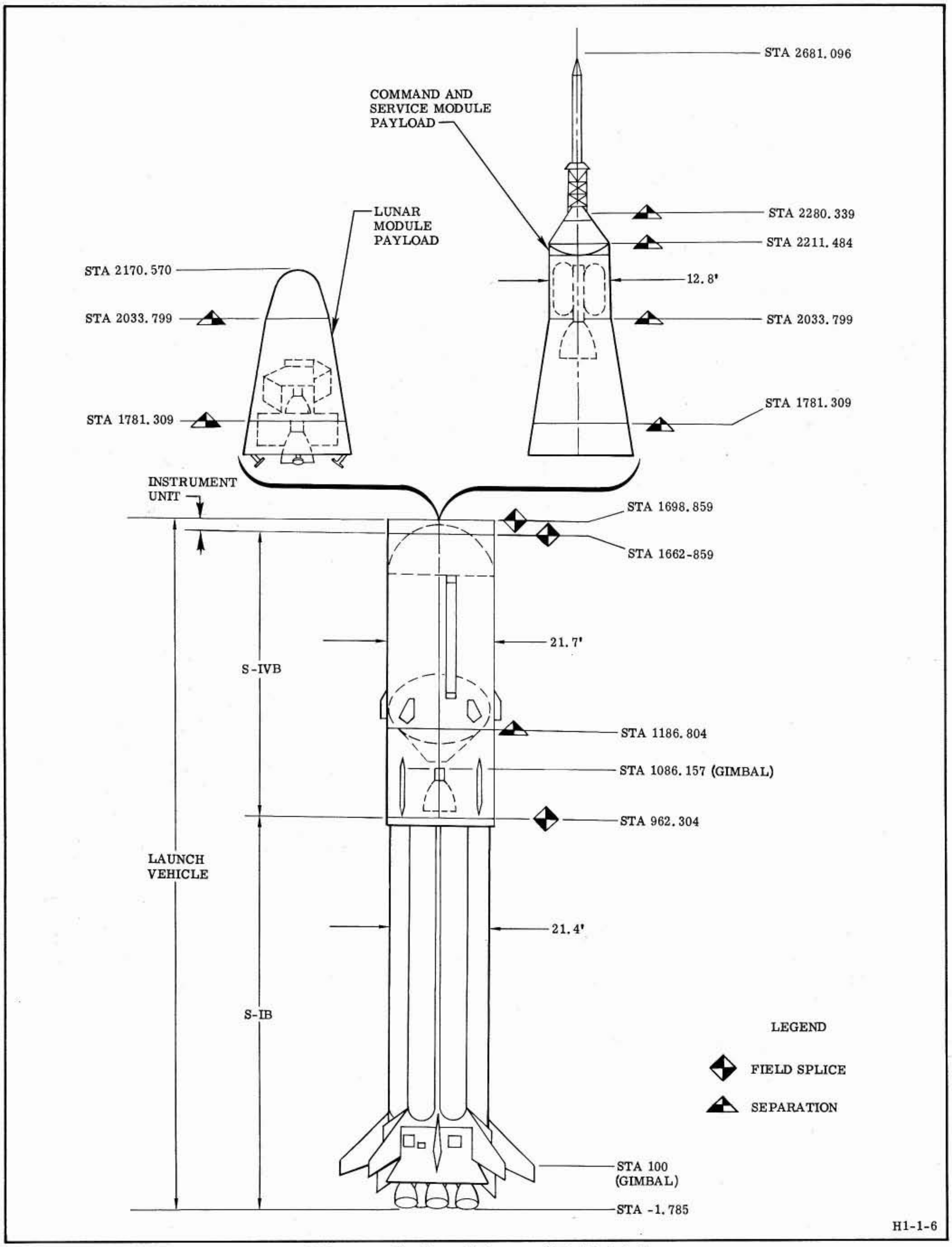

Figure 1-3. Saturn 1B Vehicle

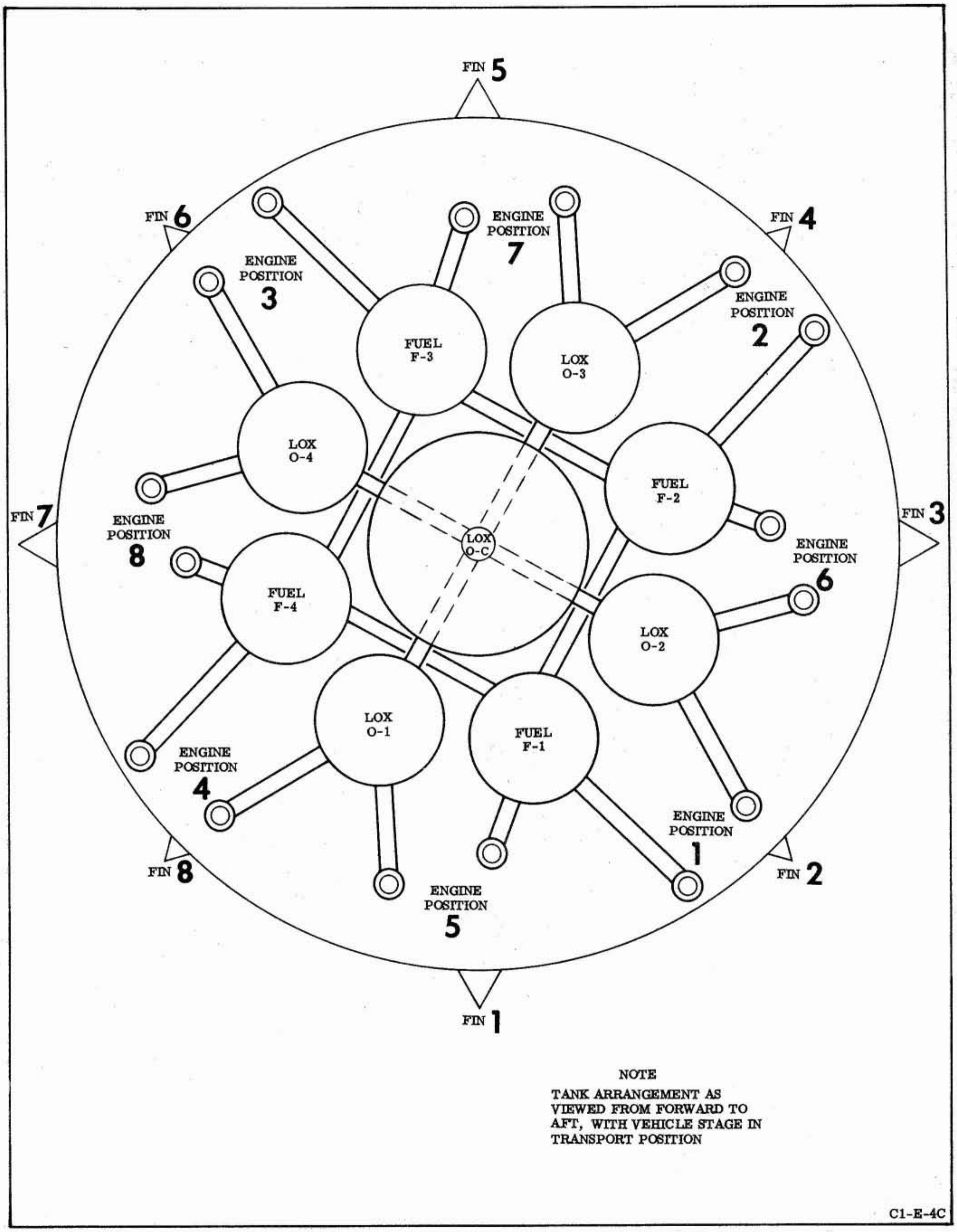

Figure 1-4. Saturn Propellant Tanks and Ducts

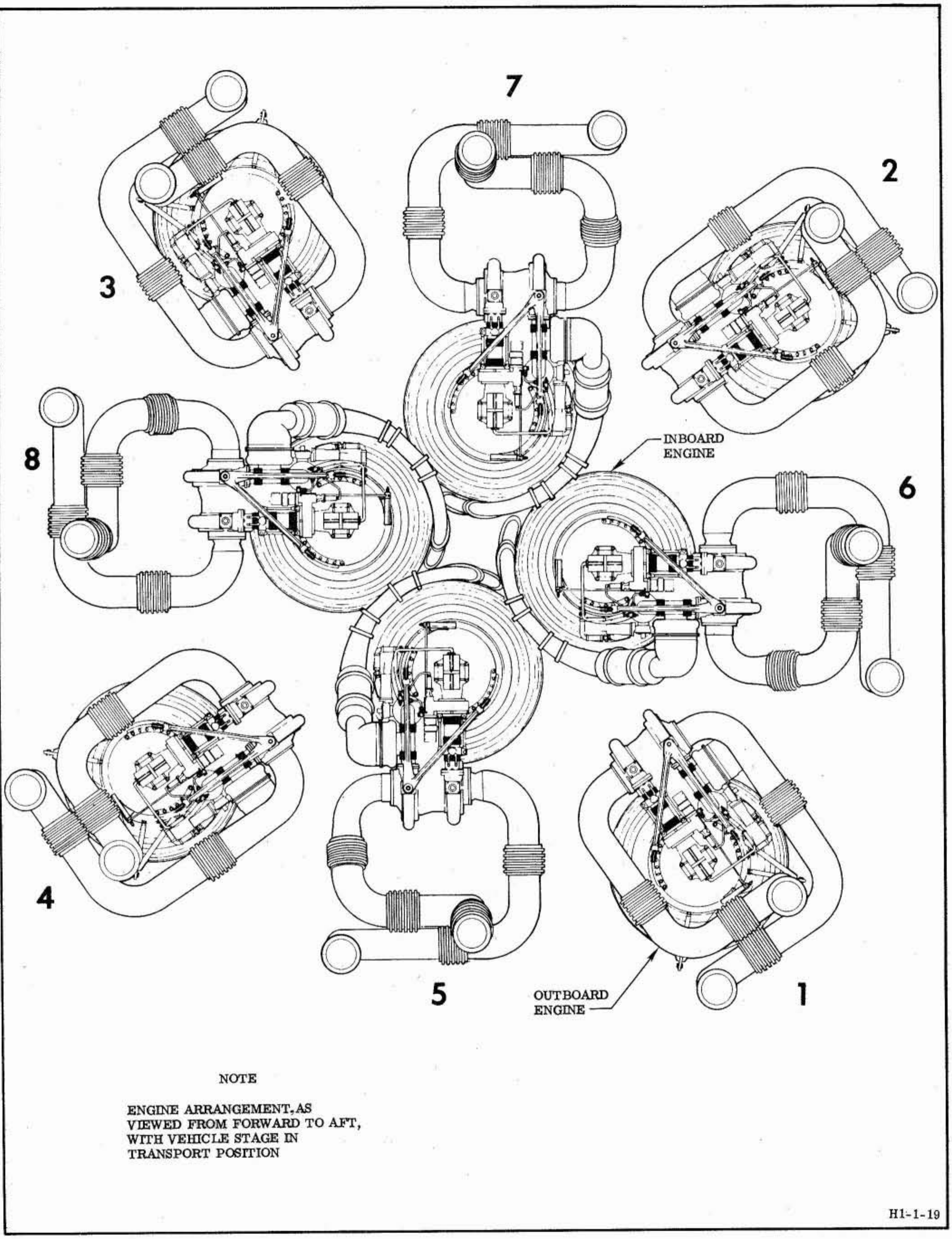

Figure 1-5. Saturn Engine Cluster

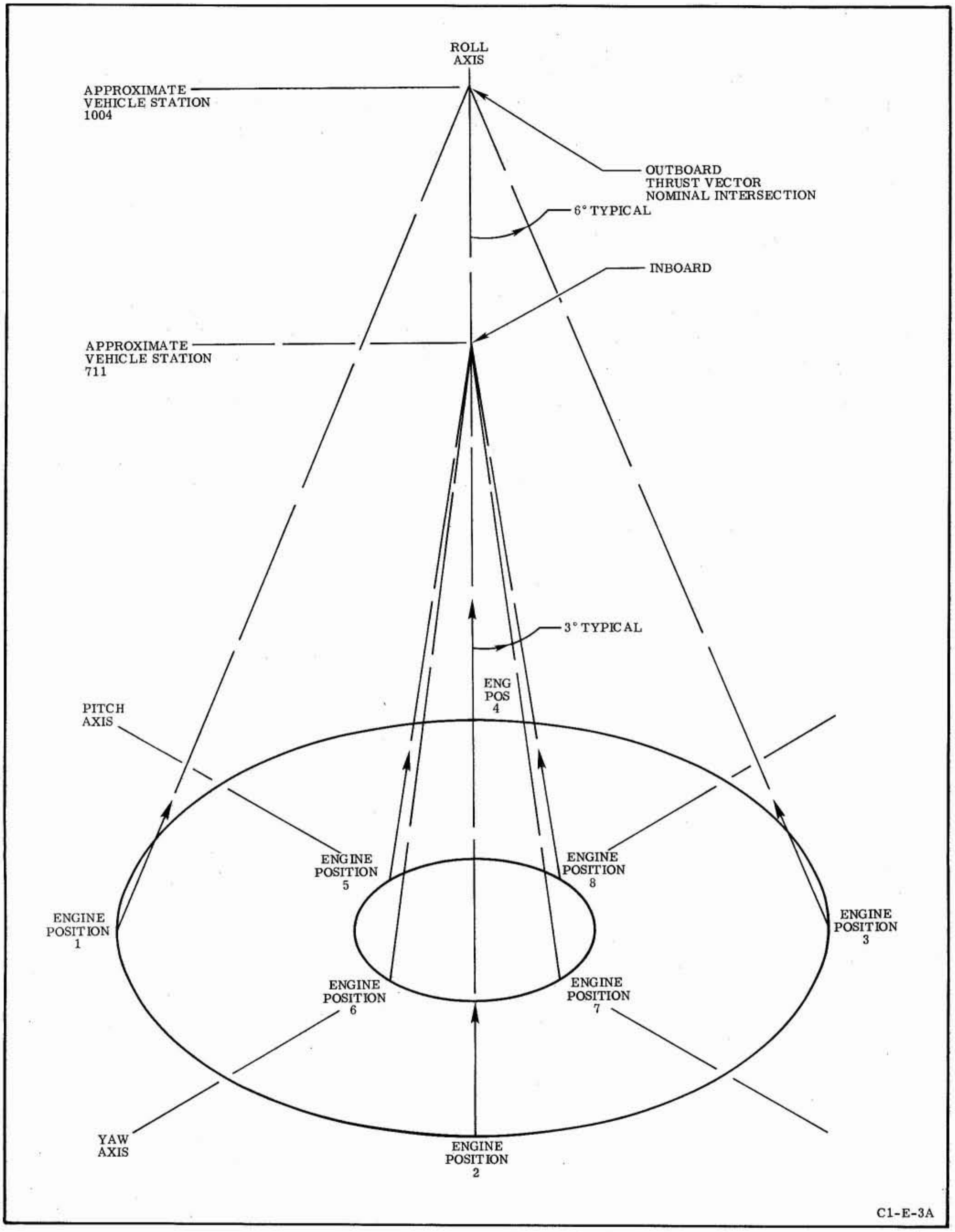

Figure 1-6. Thrust Vector Intersection

liquid oxygen and RP-1 fuel, are supplied to the thrust chamber by a turbopump. A gas generator, using the same propellants as the thrust chamber, powers the turbopump. Reservicing the propellants and fuel additive and replacing the solid propellant gas generator, initiators, igniters, hypergol cartridge, and main LOX valve closing control valve are required for restart.

1-7. ENGINE LEADING PARTICULARS.

1-8. The H-1 rocket engine requires a minimum number of customer connections, thereby simplifying engine installation. Refer to sections II and III for engine and component weight information.

Figure 1-7 (Sheets 1 through 6) deleted.

1-9. PROPELLANTS AND FLUIDS.

1-10. The propellants for the engine must conform to military specifications and requirements of the engine. Physical properties of the propellants and fluids are listed in figures 1-8 through 1-11.

1-11. OXIDIZER.

1-12. Liquid oxygen is a pale-blue, odorless, nontoxic liquid conforming to MIL-P-25508. The chemical formula of liquid oxygen is O_2. The physical properties of liquid oxygen are listed in figure 1-8. Liquid oxygen is chemically stable. When liquid oxygen is contaminated with grease, oils, or petroleum-derivative fuels and oils, it forms a highly impact-sensitive gel and may react with an explosive force approximately equivalent to that of nitroglycerin. Although liquid oxygen is not flammable, the gases produced through vaporization will violently support combustion.

Item	Value
Molecular weight	32.00
Boiling point at 14.7 psia	-297.33° F
Critical temperature	-181.1° F
Critical pressure	736.3 psia
Standard density (used for data reduction)	70.79 lb/cu ft
Weight per gallon	9.51 lb
Standard temperature (used for data reduction)	-297.4° F
Static head conversion	2.02 ft/psi
Purity	99.5 percent by volume

Figure 1-8. Physical Properties of Liquid Oxygen

1-13. FUEL.

1-14. RP-1 fuel (MIL-R-25576) is chemically stable and a nontoxic liquid hydrocarbon. The physical properties of RP-1 fuel are listed in figure 1-9.

All data on pages 1-11 through 1-12B deleted.

Item	Value
Molecular weight	175
Freezing point	-47° to -64° F
Boiling range at 14.7 psia	330° to 525° F
Flash point	119° to 145° F
Specific gravity	0.810 at 68° F
Explosive limits	1.6 to 6 percent to air
Standard density (used for data reduction)	50.45 lb/cu ft
Weight per gallon	6.74 lb
Standard temperature (used for data reduction)	60° F
Static head conversion	2.85 ft/psi
Viscosity at 60° F	2.40 to 2.65 centistokes

Figure 1-9. Physical Properties of RP-1 Fuel

1-15. LUBRICANT.

1-16. A blend of RP-1 rocket engine fuel (MIL-P-25576) and of Oronite 262 conforming to extreme-pressure additive RB0140-006 (Rocketdyne) is used to lubricate the turbopump gearcase. The properties of RB0140-006 are listed in figure 1-10.

Item	Value
Specific gravity	1.08 at 68° F
Flash point	340° F
Viscosity	82-127 centistokes at 100° F 6-10 centistokes at 210° F
Chemical composition	Phosphorus, zinc, and sulfur in a neutral-base oil diluent

Figure 1-10. Physical Properties of Extreme-Pressure Additive RB0140-006 (Rocketdyne)

1-17. HYPERGOLIC FLUID.

1-18. Triethylaluminum (TEA) is a clear, colorless liquid used in hypergolic igniters for spontaneous ignition in rocket engines. TEA is pyrophoric, igniting spontaneously in the presence of any source of oxygen, and reacts violently with water, alcohol, acetone, and chlorinated hydrocarbons. The physical properties of TEA are listed in figure 1-11.

Item	Value
Molecular weight	114.5
Freezing point	-53° F
Boiling point	381° F
Specific gravity	0.84
Density	52.3 lb/cu ft
Weight per gallon	7.02 lb
Energy release	18,300 BTU/lb
Flame temperature	1,200° F

Figure 1-11. Physical Properties of Triethylaluminum

1-19. ENGINE OPERATION. (Figure 1-12.)

1-19A. ENGINE PREFIRING PREPARATIONS. (Figure 1-12A.)

1-19B. To prepare the engine for firing, the fuel additive blender unit is serviced with additive, the thrust chamber jacket is prefilled with fuel, and the main LOX valve closing control valve, solid propellant gas generator, gas generator igniters, hypergol cartridge, and solid propellant gas generator initiators are installed. The LOX pump seal cavity and gearbox pressurization purge and LOX system by-pass purge are initiated, and propellants are dropped to load the LOX and fuel pump sections of the turbopump and fill the engine high-pressure ducts up to the closed main LOX valve and main fuel valve. Fuel is routed through the series control line to the main LOX valve closing control valve, fuel additive blender unit, igniter fuel valve, and opening control port on the main LOX valve. Activating purges for the LOX system, gas generator LOX injector, and thrust chamber fuel injector complete the engine prefiring preparations.

1-20. ENGINE IGNITION. (Figure 1-12B.)

1-21. When engine prefiring preparations are complete, the engine firing switch is actuated, sending an electrical signal to the solid propellant gas generator (SPGG) initiators which ignite the solid propellant charge. Burning of the solid propellant produces hot gases which accelerate the turbine, causing turbopump

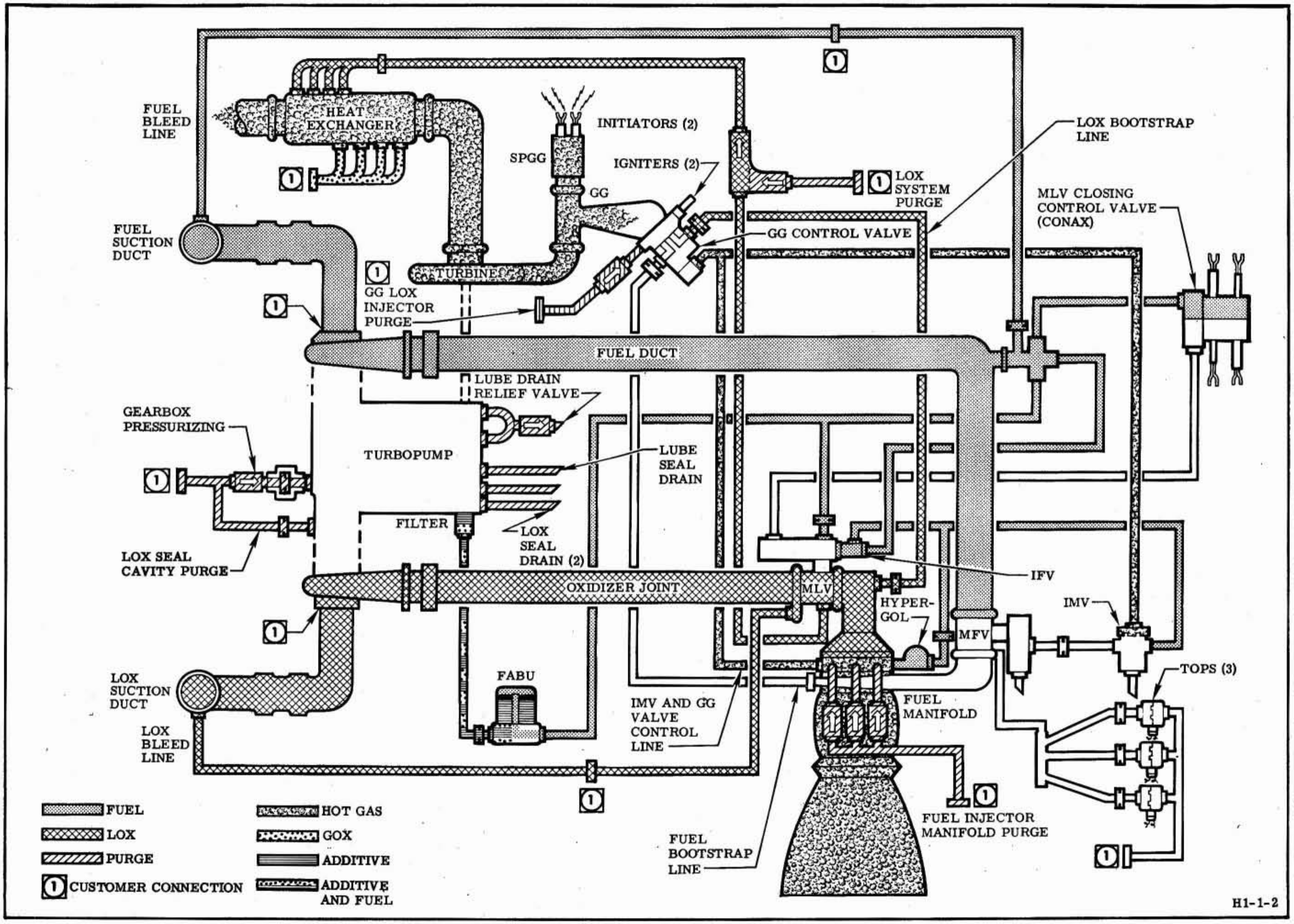

Figure 1-12B. Engine Ignition Schematic

monitor valve control port. Sufficient pressure at the control port opens the ignition monitor valve which allows fuel control pressure to open the main fuel valve. Fuel, under turbopump pressure, flows through the open main fuel valve, to the fuel bootstrap line, through the thrust chamber fuel jacket, through the injector, and into the thrust chamber combustion zone where main propellant ignition is accomplished. Increasing fuel pressure, resulting from main propellant ignition and sensed at the thrust chamber fuel injector manifold, opens the liquid propellant gas generator control valve. Bootstrap propellants enter the liquid propellant gas generator, with a slight LOX lead, and are ignited by hot gases from the solid propellant gas generator and the two gas generator igniters. The turbopump accelerates, the thrust builds up, and rated operation is attained.

1-24. ENGINE SHUTDOWN. (Figure 1-12D.)

1-25. Engine shutdown is achieved by an electrical cutoff signal which fires a pyrotechnic-actuated main LOX valve closing control valve. Opening of this valve allows fuel pump discharge pressure to enter the closing port of the main LOX valve actuator, equalizing the fuel pressure on both sides of the valve actuation piston. The main LOX valve then closes by the fuel pressure acting on the larger piston surface area on the closing side plus spring force, cutting off LOX flow to the thrust chamber and gas generator, resulting in turbopump speed and propellant pressure decay. Closing the main LOX valve allows the igniter fuel valve to close, shutting off fuel pressure to the hypergol container inlet, ignition monitor valve inlet, and main fuel valve opening port. When the main fuel valve actuation pressure decays to approximately 200 psig, the main fuel valve closes under spring force, completing engine shutdown approximately one second after cutoff signal. A fuel-rich shutdown is provided to prevent a temperature spike in the liquid propellant gas generator. A natural, fuel-rich shutdown occurs in the thrust chamber.

1-26. THRUST CHAMBER AND GIMBAL ASSEMBLY.

1-27. DESCRIPTION.

1-28. The thrust chamber and gimbal assembly includes an oxidizer dome, injector and hypergol container, thrust chamber body, and gimbal assembly. The purpose of the thrust chamber (figures 1-13 and 1-14) is to receive the propellants under turbopump pressure, mix and burn the propellants, and impart a high velocity to the expelled combustion gases to produce thrust or vehicle propulsion. The thrust chamber also serves as a mount or support for all engine, and certain vehicle, hardware.

1-29. OPERATION.

1-30. LOX, under turbopump pressure, enters the oxidizer dome and flows through the injector LOX ring orifices into the thrust chamber combustion area. Fuel, under turbopump pressure, enters the fuel inlet manifold and is distributed

Item	Description
Combustion chamber area A_c (at injector end)	332 sq in.
Combustion chamber diameter (at injector end)	20.56 in.
Throat area A_t	204.35 sq in.
Throat diameter	16.13 in.
Exit area A_e	1,634.8 sq in.
Exit diameter	45.62 in.
Contraction ratio A_c/A_t (combustion chamber)	1.62:1
Combustion chamber shape	Tapered, converging
Nozzle expansion area ratio A_e/A_t	8:1
Characteristic length $L^* = \frac{V_c}{A_t}$	39.10 in.
Overall length	86.15 in.
Combustion chamber volume V_c	4.62 cu ft.
Total fuel jacket volume (inlet elbow to top of tube ring)	3,694.5 cu in.
Fuel inlet manifold volume	472.6 cu in.
Tube wall thickness	0.012 in.
Number of tubes	292

Figure 1-17. Thrust Chamber Body Characteristics

Parameter	Unit of Measurement	Engine Rating	
		200K	205K
Sea level thrust	lb	199,300	204,300
Sea level specific impulse	sec	267.9	268.7
Total propellant flowrate	lb/sec	743.9	760.2
Mixture ratio	O/F	2.338	2.341
Oxidizer flowrate	lb/sec	521.0	532.8
Fuel flowrate	lb/sec	222.8	227.5
Injector end chamber pressure	psia	689.3	701.8
Nozzle stagnation pressure	psia	638.2	652.5
Characteristic velocity (C*)			
C* based on injector end pressure	ft/sec	6,093.0	6,099.0
C* based on nozzle stagnation pressure	ft/sec	5,641.0	5,647.0
C* efficiency (nozzle)	percent	97.60	97.60
Thrust coefficient (C_F)			
C_F based on injector end pressure		1.415	1.419
C_F based on nozzle stagnation pressure		1.528	1.532
C_F efficiency (nozzle)	percent	101.00	101.40
Ratio of injector end pressure to nozzle stagnation pressure		1.080	1.080
Jacket pressure drop:			
At 225 lb/sec (standard flowrate)	psig	135.0	135.0
At 222.8 lb/sec	psig	132.0	--
At 227.5 lb/sec	psig	--	138.0

Figure 1-18. Thrust Chamber Nominal Operating Characteristics

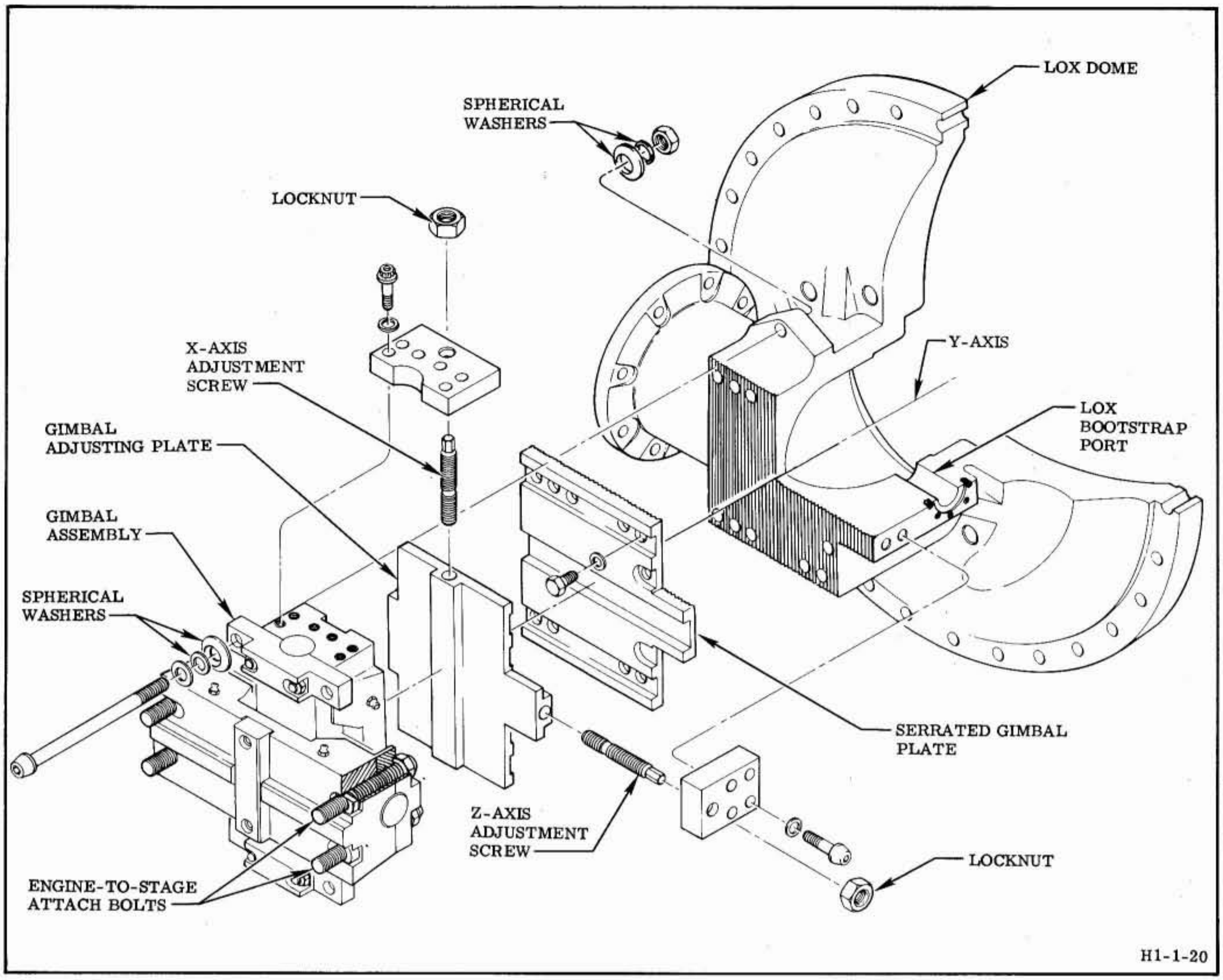

Figure 1-19. Gimbal Assembly and Oxidizer Dome

1-39. <u>EXHAUST SYSTEM.</u> (Figure 1-20.)

1-40. DESCRIPTION.

1-41. The turbine exhaust system on the outboard engines consists of a turbine exhaust hood, heat exchanger, heat shield, heat exchanger LOX supply line, and aspirator to distribute and direct the exit flow of gas generator exhaust gases. On inboard engines, the turbine exhaust system consists of a turbine exhaust hood, heat exchanger, turbine exhaust duct, heat shield, and heat exchanger LOX supply line.

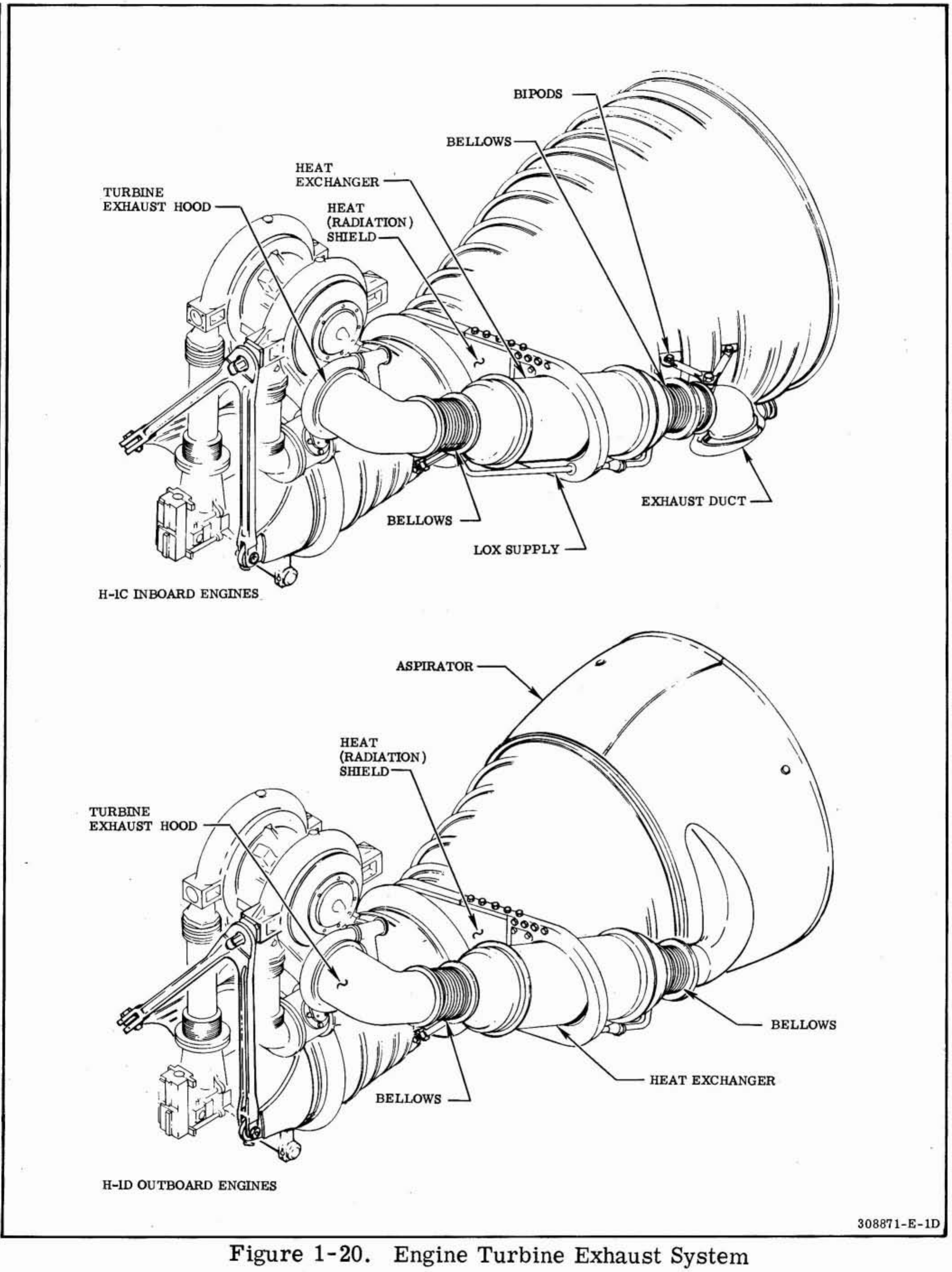

Figure 1-20. Engine Turbine Exhaust System

1-42. OPERATION.

1-43. The combustion gases, produced by the gas generator, drive the turbine and are vented through the turbine exhaust hood into the heat exchanger, where the heat of the gases is used to convert liquid oxygen (LOX) into gaseous oxygen (GOX) for vehicle systems use. The fuel-rich exhaust gases then enter the thrust chamber aspirator or the exhaust duct to be directed into the thrust chamber exit flow stream.

1-44. TURBINE EXHAUST HOOD.

1-45. The turbine exhaust hood is a stainless-steel, welded elbow assembly incorporating two mating flanges, two doubler rings, a bellows section, and an integral liner to protect the bellows section. The bellows permits the degree of movement required by the system.

1-46. HEAT EXCHANGER. (Figure 1-21.)

1-47. The heat exchanger is a welded, stainless-steel assembly consisting of an outer shell; inlet and outlet flanges; a helix-wound, four-coil system; and coil inlet and outlet manifolds. Turbine exhaust gases passing through the shell heat the coils. Liquid oxygen (LOX), under turbopump pressure, enters three coils of the four-coil system, to be converted to gaseous oxygen (GOX) for vehicle system use. The fourth coil is blanked off and not utilized. On H-1C engines incorporating MD64 change and H-1D engines incorporating MD66 change, a clamp is installed on the two top coils of both the inside and outside coils opposite the GOX outlet. (See figure 1-21.) The clamp prevents coil movement and possible damage by holding coils firmly against the coil displacement support assembly.

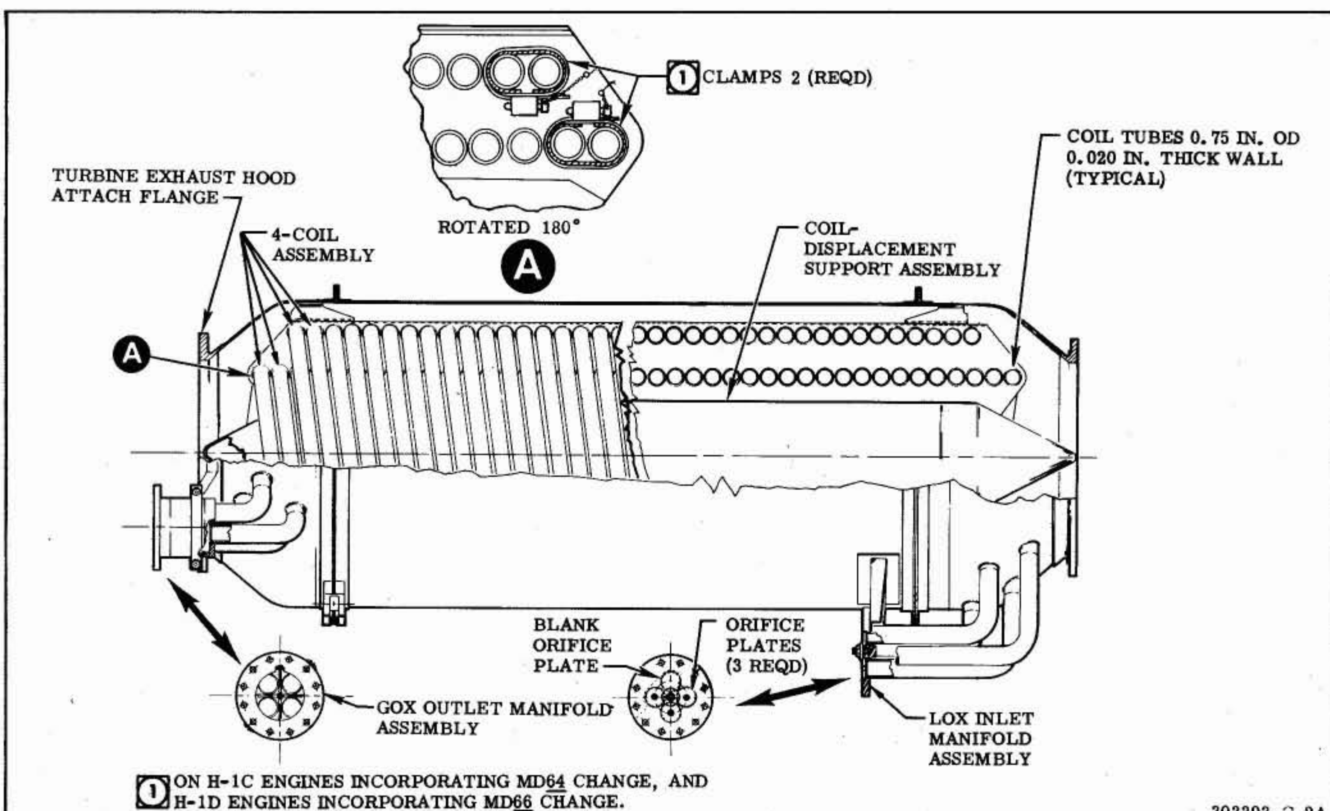

Figure 1-21. Heat Exchanger

1-48. TURBINE EXHAUST DUCT.

1-49. The turbine exhaust duct is a curved, stainless-steel assembly, mounted on inboard engine thrust chambers, which consists of a mating flange, forward support bracket, bellows section, curved duct, and aft support bracket.

1-50. ASPIRATOR.

1-51. The exhaust gas aspirator is a welded, Hastelloy C shell assembly installed over, and extending beyond, the thrust chamber exit on all outboard engines. The aspirator is welded to the thrust chamber forward channel band, located approximately 20 inches forward of the thrust chamber exit. The aft end of the aspirator is not secured to the thrust chamber. This provides a 0.440-inch clearance between the thrust chamber fuel return manifold and the aspirator, for the gas generator exhaust gases to escape.

1-52. <u>GAS GENERATOR AND CONTROL SYSTEM.</u>

1-53. DESCRIPTION.

1-54. The gas generator and control system consists of a liquid propellant gas generator, ignition monitor valve, purge check valve, orifices, bootstrap lines, thrust OK pressure switches and the hose and line assemblies which make up the series control line. The gas generator and control system controls engine start sequencing and supplies the power to drive the turbopump.

1-55. OPERATION.

1-56. Initial power required to spin the turbopump and increase the control pressures necessary for an engine start is provided by the firing of the solid propellant gas generator. The control pressure (fuel) is utilized to open or actuate the main LOX valve and the fuel additive blender unit, and to rupture the hypergol cartridge burst diaphragms. Rupture of the burst diaphragms allow pyrophoric fluid, followed by igniter fuel, to enter the thrust chamber for thrust chamber ignition. If a satisfactory ignition has been achieved, thrust chamber fuel injector manifold pressure actuates the ignition monitor valve which directs control pressure to actuate the main fuel valve. Main propellant ignition pressures open the gas generator control valve, initiating gas generator operation. The high-pressure gases produced by the gas generator power the turbopump during mainstage operation.

1-57. SOLID PROPELLANT GAS GENERATOR. (See figures 1-22 and 1-23.)

1-58. The solid propellant gas generator is a solid propellant cartridge, bolted to the liquid propellant gas generator flange, which supplies power to the turbine for engine starting. It is a disposable unit that cannot be reloaded or reused. The mounting end is closed by a burst diaphragm and an orificed retaining plate. Threaded bosses are provided for two initiators which ignite the solid propellant gas generator grain. The engine start signal energizes both solid propellant gas generator initiators. As the solid propellant grains start to burn, the burst diaphragm ruptures (pressure is approximately 650 psi), releasing a gas flowrate of approximately 4.68 pounds per second. This constant flowrate is maintained for approximately one second. These gases spin the turbine which, in turn, drives the LOX and fuel pumps until fuel control pressure opens the liquid propellant gas generator control valve. The liquid propellant gas generator begins to receive bootstrap propellants from the turbopump propellant discharge ducts as solid propellant grains are consumed. Ignition of liquid propellant gas generator propellant is accomplished by solid propellant grain, which burns approximately 100-200 milliseconds after LOX and fuel enter the combustor. Ignition of liquid propellants is ensured by the use of two autoignition igniters.

Item	Value
Density of propellant	0.055 lb/cu in.
Flame temperature	2,544° F
Ratio of specific heats	1.250 C_p/C_v
Molecular weight of exhaust gases	20.94 G/Mol
Characteristic velocity (C*)	4,035 ft/sec

Figure 1-23. Physical Properties of Solid Propellant Gas Generator

1-59. IGNITION MONITOR VALVE. (Figure 1-24.)

1-60. The ignition monitor valve is a three-way, pressure-actuated valve which physically senses satisfactory thrust chamber ignition before directing control (fuel) pressure to open the main fuel valve. The valve is mounted on the main fuel valve and is connected to the main fuel valve opening port by a close-coupled orifice fitting. During engine start, the main LOX valve opens the igniter fuel valve which directs igniter fuel to the hypergol container and fuel pressure to the ignition monitor valve inlet port, for subsequent main fuel valve actuation. When satisfactory thrust chamber ignition has been achieved, the pressure buildup sensed at the thrust chamber fuel injector manifold will open the ignition monitor valve. (See figure 1-25 for valve actuation.) If ignition is not established, ignition monitor valve actuation pressure will not be available; therefore, the main fuel valve will not open. During engine shutdown, decreasing thrust chamber pressures allow the main fuel valve actuator spring to close the valve, and the ignition monitor valve to close and vent.

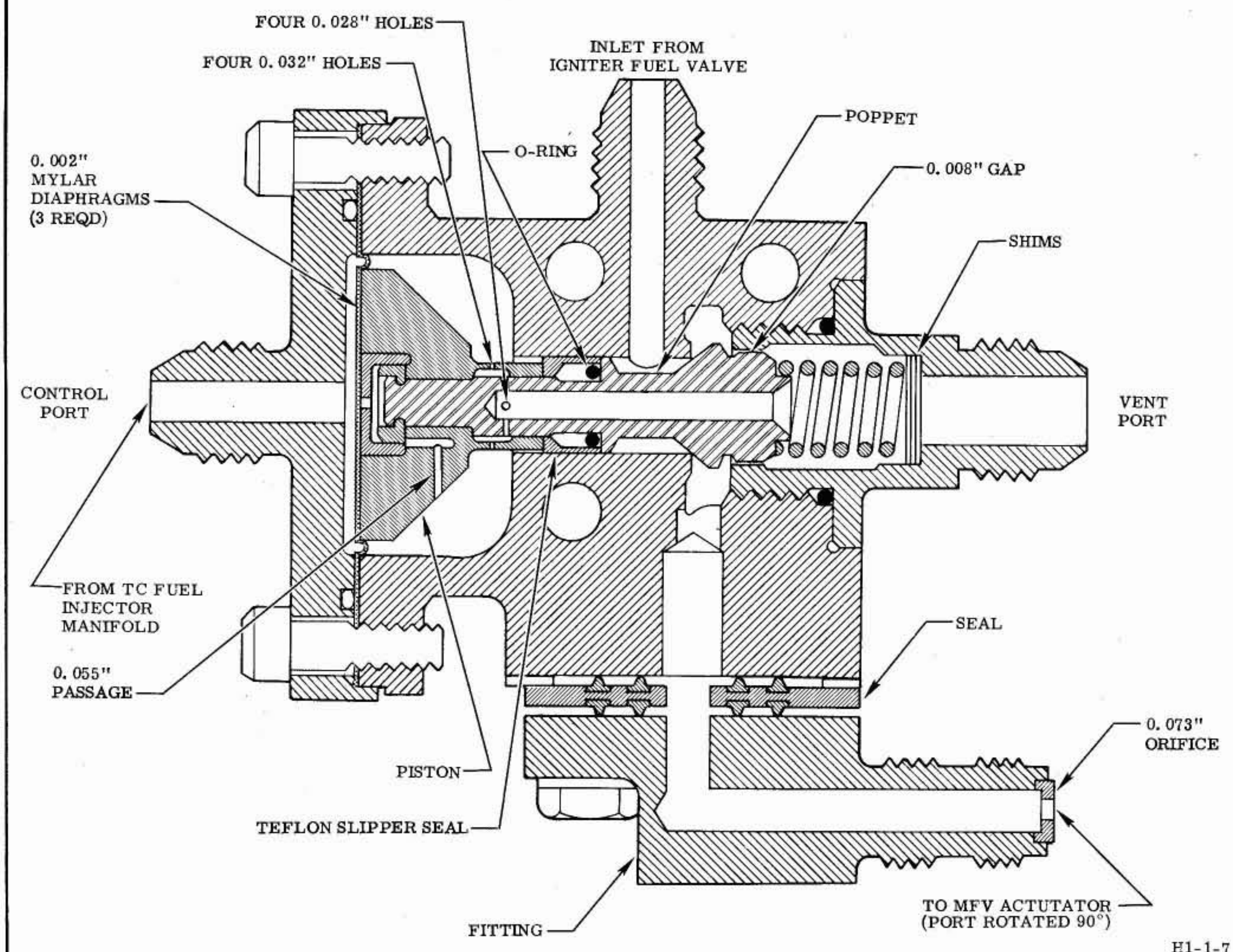

Figure 1-24. Ignition Monitor Valve (IMV)

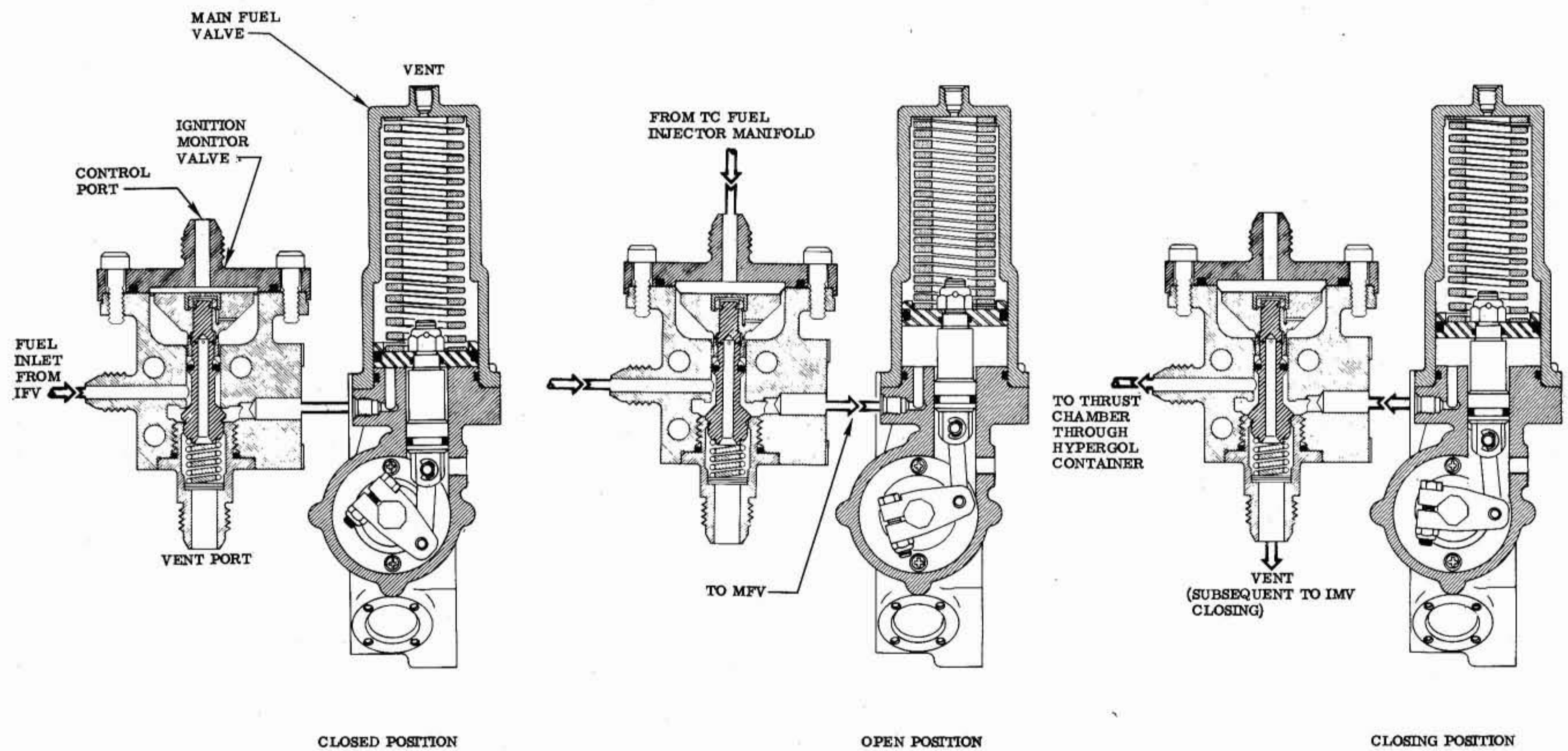

Figure 1-25. Ignition Monitor Valve and Main Fuel Valve Actuation

1-61. LIQUID PROPELLANT GAS GENERATOR. (Figure 1-26.)

1-62. The liquid propellant gas generator produces combustion gases during mainstage operation to drive the two-stage turbine which, in turn, supplies the power through a reduction gear train to drive the propellant pumps. The gas generator assembly consists of the gas generator control valve, injector assembly (figure 1-27), and combustor. The control valve oxidizer poppet and fuel poppet are opened by pressure sensed at the thrust chamber fuel injector manifold, when main propellant ignition is established. The propellants flow through the open poppets and the separate manifolds and orifices in the injector to the combustion chamber. The propellants are ignited by the solid propellant gas generator hot gases augmented by the two autoignition igniters. The gas generator injector is a uniform mixture-ratio type featuring two fuel streams impinging on a single oxidizer stream, producing a total of 44 impingement points. Injectors used on engines nominally rated at 205,000 pounds thrust (MD30 or MD37 change) have slightly larger orifice holes than those injectors used on engines nominally rated at 200,000 pounds thrust. Gas generator characteristics are listed in figure 1-28.

1-63. GAS GENERATOR CONTROL VALVE.

1-64. The control valve is a normally closed valve with poppets that control the flow of propellants to the gas generator injector and combustion chamber. The valve contains a fuel poppet, oxidizer poppet, piston, fuel poppet spring, and oxidizer poppet bellows assembly. These units are contained on a single housing bolted to the injector. The control valve is opened by fuel pressure at main propellant ignition. This pressure, sensed at the thrust chamber fuel injector manifold, forces the piston on the fuel side of the valve down to open the fuel poppet. A yoke integral with the piston opens the oxidizer poppet. During engine shutdown, the control pressure decays, and the fuel and oxidizer poppet are closed by spring pressure. The propellant injector cavity design permits an oxidizer lead, during start, to prevent detonation; the yoke design ensures a fuel-rich cutoff to eliminate the possibility of turbine burning.

1-65. MAIN LOX VALVE CLOSING CONTROL VALVE (CONAX). (Figure 1-29.)

1-66. Closing of the main LOX valve and subsequent shutdown of the engine is accomplished by firing a single-body, opposed, pyrotechnic-actuated control valve (Conax). This valve is designed so that actuation of either one or both trigger assemblies will allow fuel pump outlet pressure to flow through the valve body to the closing port of the main LOX valve. Each section of the valve is self-contained and pyrotechnic-actuated. Valve operation is two-way and normally closed. Upon receipt of an electrical signal for engine shutdown, the explosive charges within the valve ignite, producing the mechanical force required to shear the metal membrane in the valve body which allows high-pressure control fuel to flow through to the closing control port of the main LOX valve. Conax valves containing visual indicator plug assemblies are used during static test. During vehicle launch operations Conax valves containing electrical position indicators are used to remotely sense the position of the valve. The electrical circuitry of the position indicators consists of a bridge wire that is sheared when the trigger assembly is fired.

Parameter	Unit of Measurement	Rating at 200K	Rating at 205K
Total flowrate	lb/sec	17.22	17.95
Mixture ratio	O/F	0.346	0.343
GG chamber pressure (injector end)	psia	629.10	647.8
GG chamber temperature	°F	1,212.0	1,203.0
Flowrate:	lb/sec		
Oxidizer		4.43	4.58
Fuel		12.79	13.36
Orifice resistance and pressure drop across orifice:	psid		
Oxidizer (at 4.0 lb/sec and 70.79 lb/cu ft)		58.01	75.97
Fuel (at 12.0 lb/sec and 50.45 lb/cu ft)		71.08	71.08

Figure 1-28. Gas Generator Characteristics

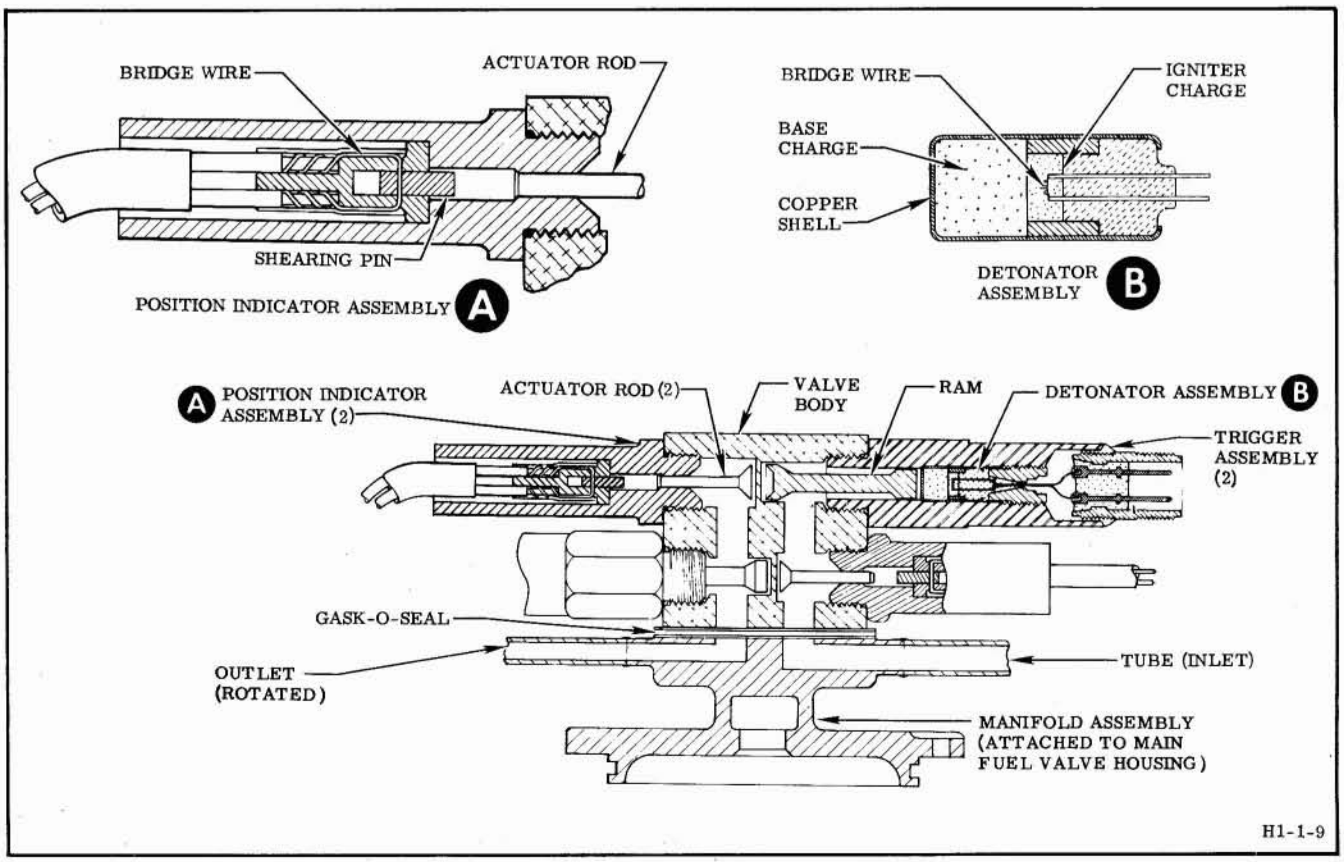

Figure 1-29. Main LOX Valve Closing Control Valve (Conax)

1-67. THRUST OK PRESSURE SWITCH. (Figure 1-30.)

1-68. The three thrust OK pressure switches are two-position, normally open, pressure-actuated electrical switches. These switches sense fuel pressure downstream of the main fuel valve. The fuel pressure signal is indicative of satisfactory engine operation and is used in the vehicle launch commit circuitry. In flight, the switches sense performance decay and provide a cutoff signal when performance decays below ninety percent. The three switches utilize a common calibration check port on the customer connect panel for checking actuating and deactuating pressure settings.

1-69. HYPERGOL CONTAINER.

1-70. The hypergol container is an integral part of the thrust chamber injector and includes a cylindrical housing to accommodate a six-cubic-inch hypergol cartridge and a hypergol-installed detector switch. A lockpin is provided to secure the cartridge or closure in the container. Figure 1-31 shows the hypergol container, the installation of the hypergol cartridge, the detector switch, and the associated fuel passages.

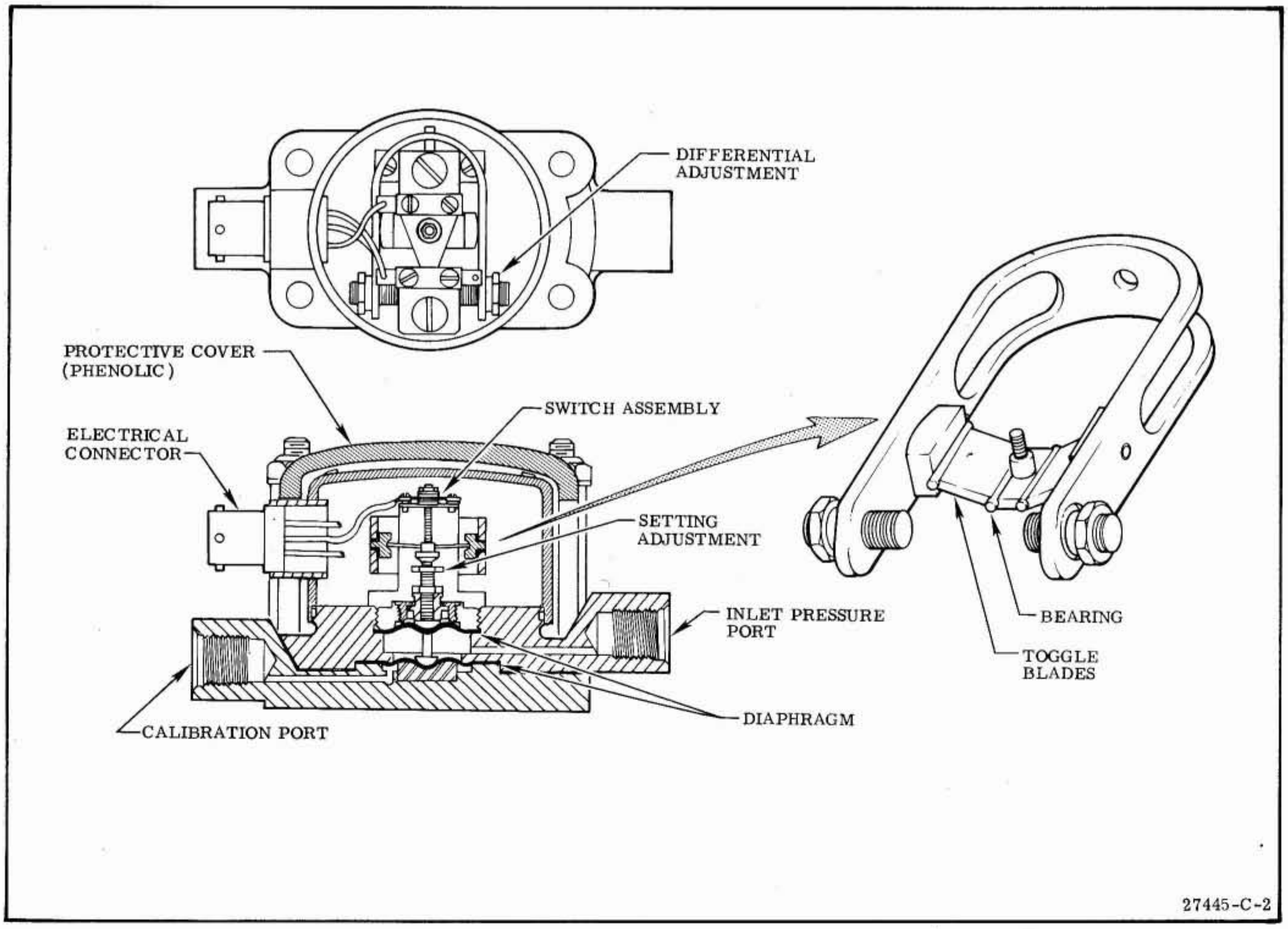

Figure 1-30. Thrust OK Pressure Switch (TOPS)

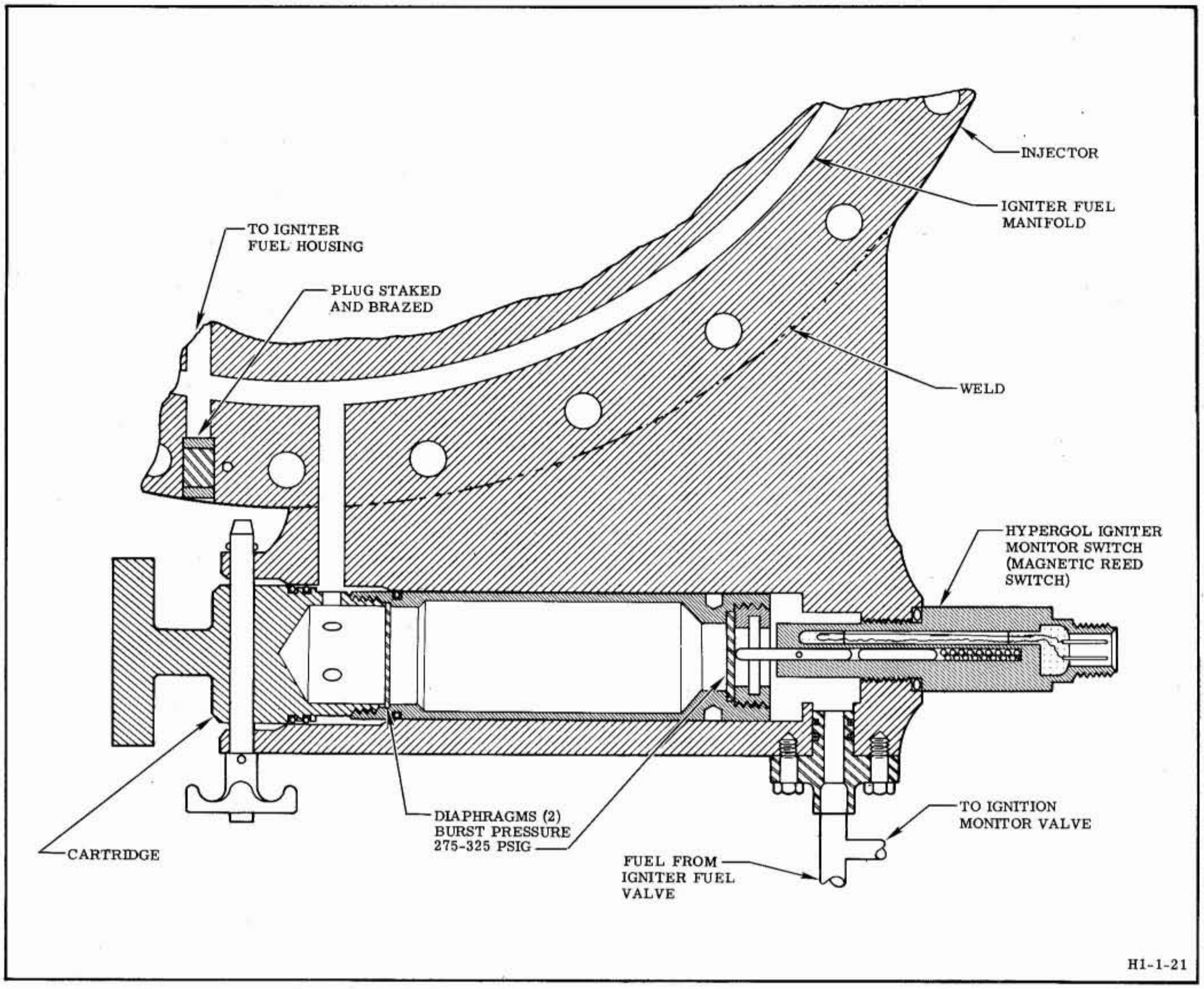

Figure 1-31. Hypergol Container With Cartridge Installed

1-71. GAS GENERATOR IGNITERS AND SOLID PROPELLANT GAS GENERATOR INITIATORS.

1-72. Igniters and initiators are pyrotechnic devices used to initiate burning of the propellants in the liquid propellant gas generator and the solid propellant gas generator (SPGG) for engine start.

1-73. GAS GENERATOR IGNITERS. (Figure 1-32.) The gas generator igniter (two on each engine) is an auto-igniting pyrotechnic device used to provide a positive heat source for the ignition of gas generator liquid propellants. A two-ampere link wire provides circuitry to sense premature ignition. (This link signal is used during vehicle launch only; a metal cap and copper seal are installed over the electrical connector for vehicle static tests.) The igniter first-fire pyrotechnic is ignited by heat from the SPGG. The main igniter pyrotechnic burns for approximately two seconds, thereby providing a heat source for the liquid propellants even if the SPGG should burn out prior to their entry into the combustor.

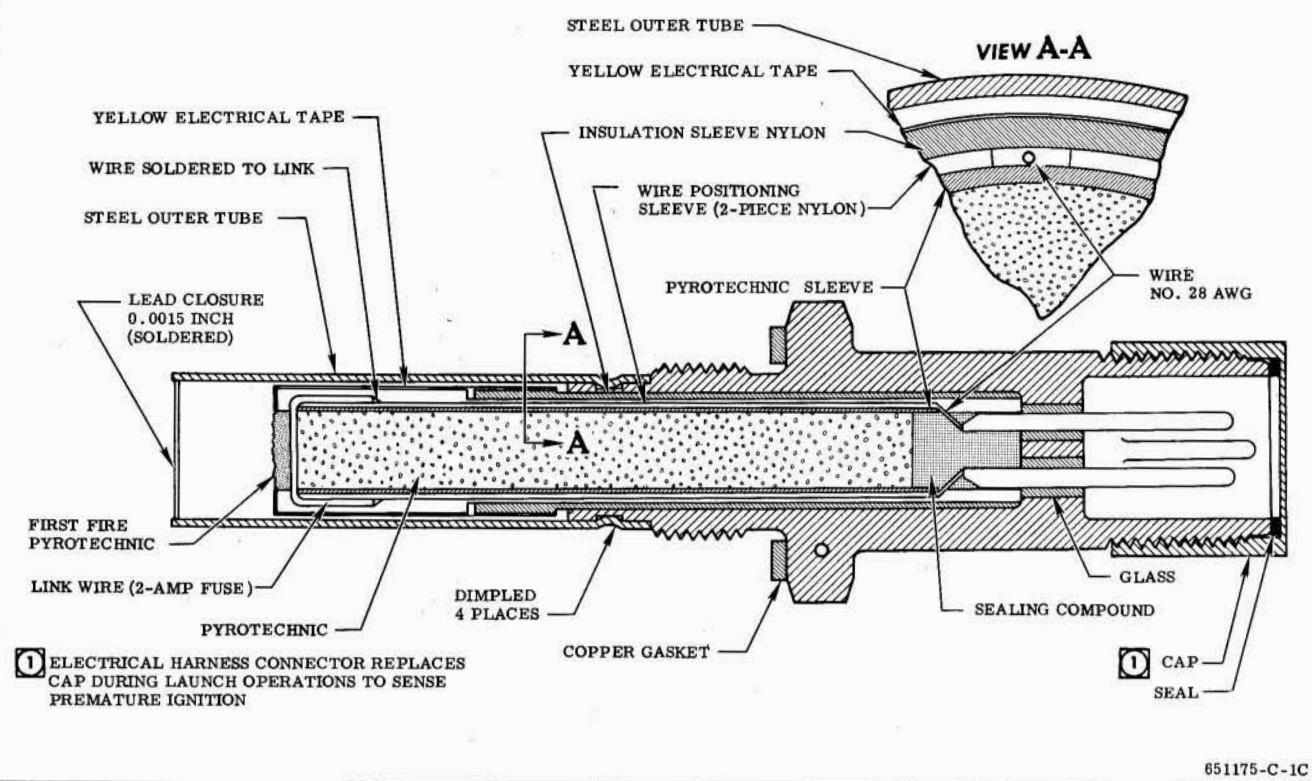

Figure 1-32. Gas Generator Igniter

1-74. SOLID PROPELLANT GAS GENERATOR INITIATORS. (Figure 1-33.) The SPGG initiator is a pyrotechnic device used to initiate burning of the solid propellants in the SPGG. Two initiators are used, each consisting of a two-pin electrical receptacle and a moisture-sealed cartridge assembly housing a pyrotechnic material. The initiators are capable of withstanding 250 vac without igniting. An electrical impulse of 500 vac, 1.5 amps minimum, is required to ignite the pyrotechnic material.

1-75. <u>SYSTEM CHECK VALVES AND COUPLINGS.</u>

1-76. CHECK VALVES.

1-77. POPPET CHECK VALVES. (Figure 1-34.) Poppet-type check valves are used in the turbopump gearcase pressurization, thrust chamber fuel injector purge, and gas generator injector LOX purge systems.

1-78. UNITIZED HEAT EXCHANGER LOX AND LOX SYSTEM PURGE CHECK VALVE ASSEMBLY. (Figure 1-35.) The check valve assembly unitizes the LOX system purge and heat exchanger LOX supply check valves into an integral part of the heat exchanger LOX supply line. The unitized valve assembly is flange-mounted and incorporates two poppet-type check valves.

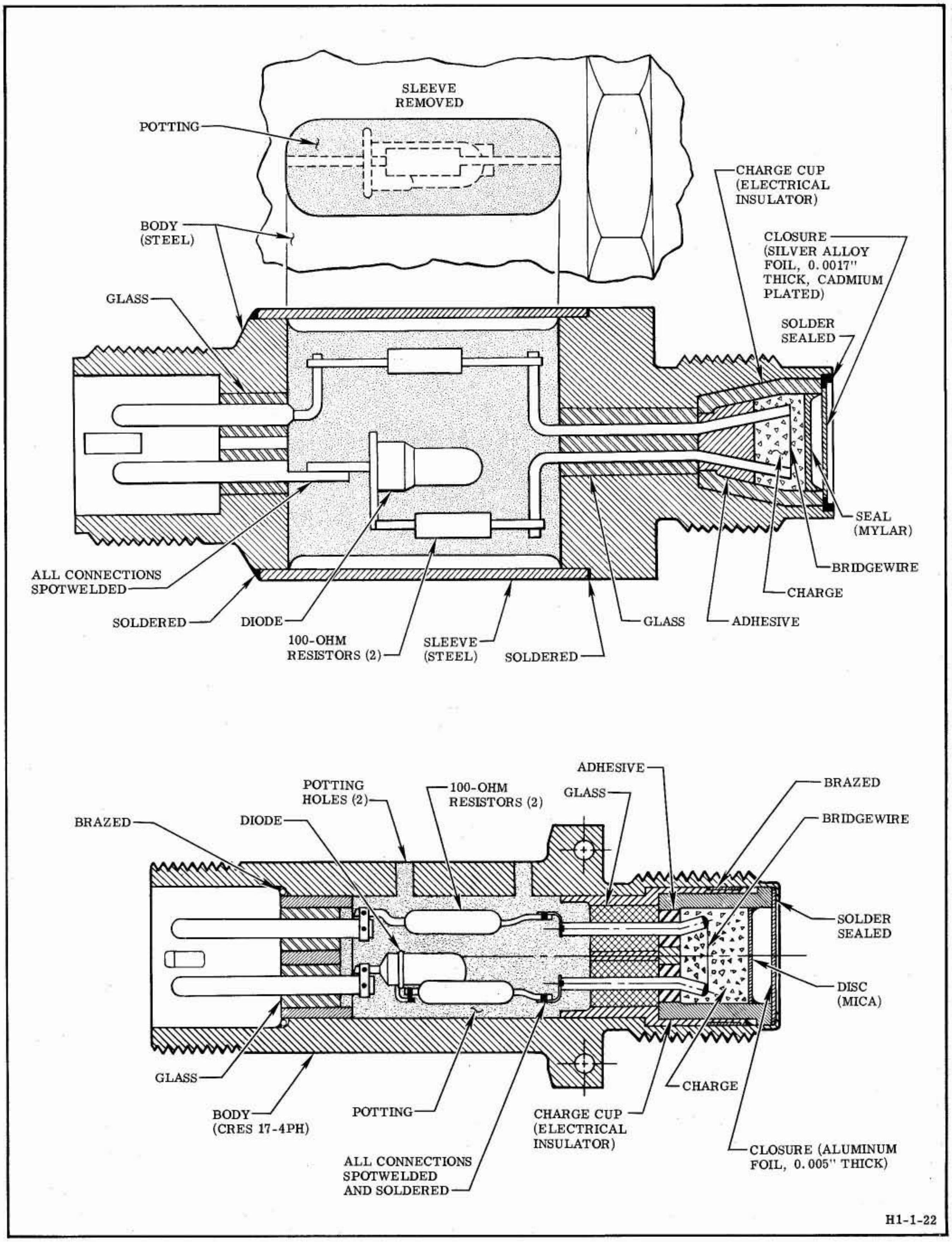

Figure 1-33. Solid Propellant Gas Generator Initiator

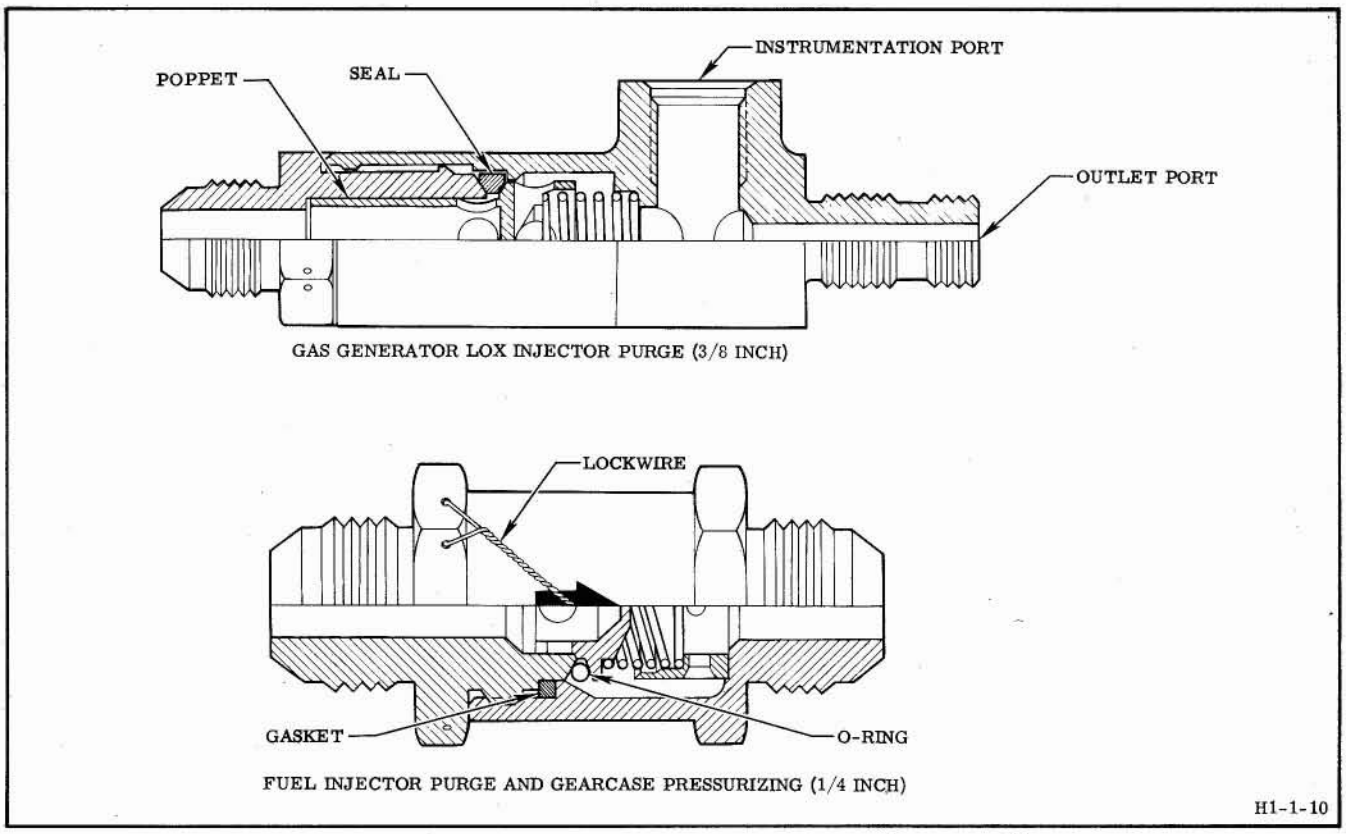

Figure 1-34. Poppet Check Valves (Typical)

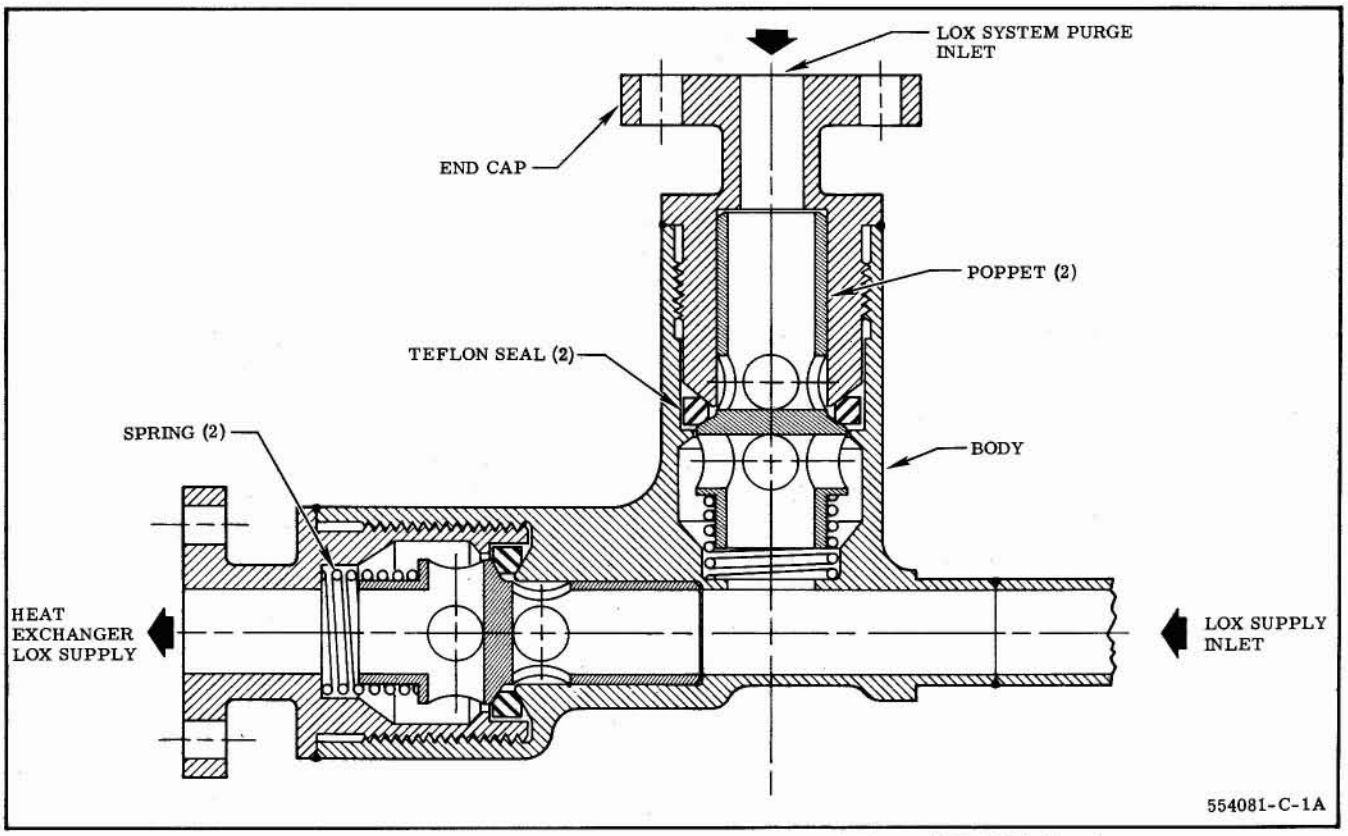

Figure 1-35. Unitized Heat Exchanger LOX and LOX System Purge Check Valve Assembly

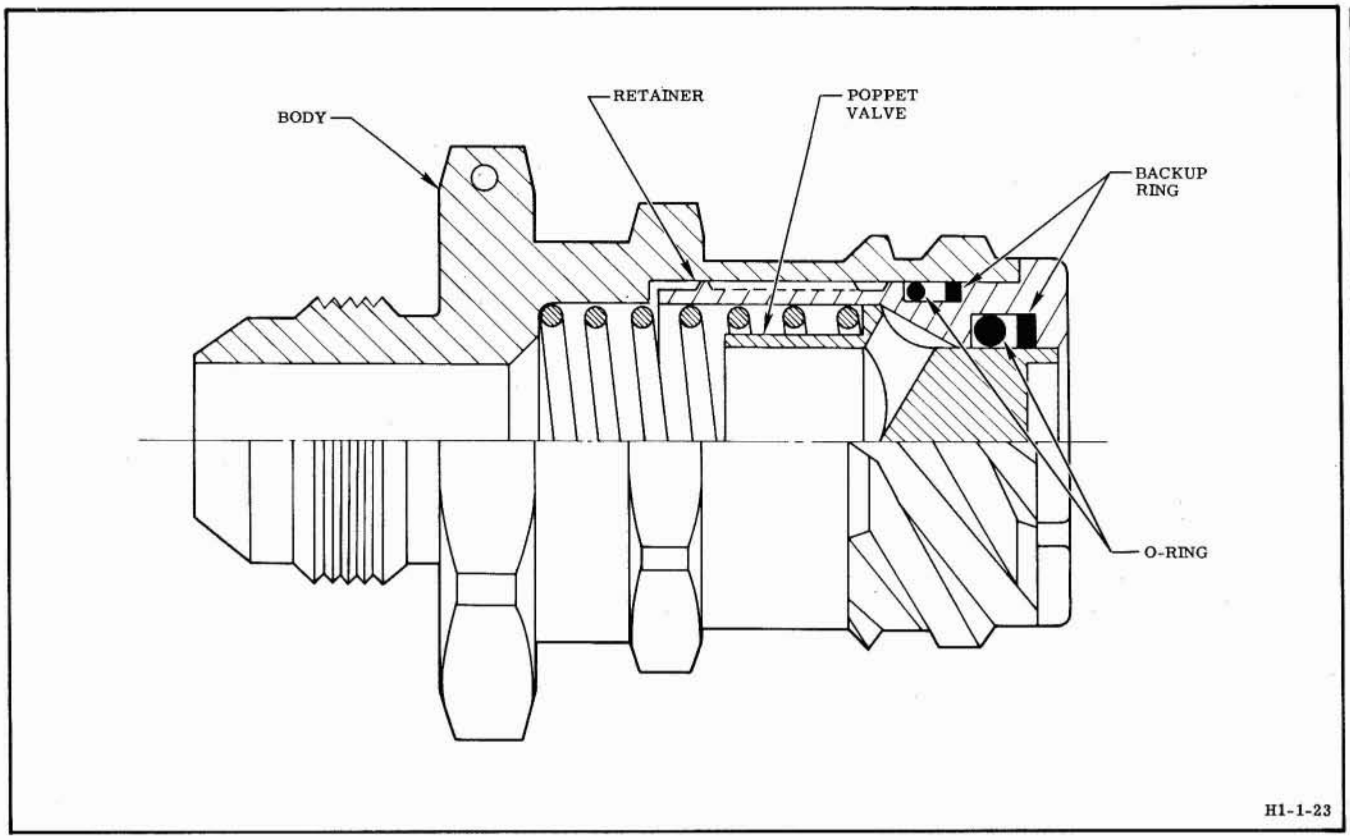

Figure 1-36. Quick-Disconnect Coupling

1-79. QUICK-DISCONNECT COUPLINGS. (Figure 1-36.)

1-80. Quick-disconnect, self-sealing couplings permit the transfer of fluids without loss of fluid from, or introduction of air into, the system. The three couplings used on the engine are for filling the fuel jacket, servicing the fuel additive blender unit, and draining the series control line.

1-81. PROPELLANT FEED SYSTEM.

1-82. DESCRIPTION.

1-83. The propellant feed system consists of the main fuel valve, main oxidizer ignition control valve (consisting of the main LOX valve and the igniter fuel valve), propellant high-pressure ducts, turbopump, unitized check valve, and orifices. The propellant feed system supplies the propellants to the thrust chamber and gas generator and LOX to the heat exchanger.

1-84. OPERATION.

1-85. Initial power to develop turbopump discharge pressures is supplied by the solid propellant gas generator. The turbopump pressures are utilized to operate the fuel additive blender unit, open the main LOX valve (which opens the igniter fuel valve), rupture the hypergol cartridge burst diaphragms, and open the main fuel valve. When fuel pump discharge pressure increases to 70-110 psig, the fuel additive blender unit opens permitting lubricant flow to the turbopump. When the pump discharge pressure increases to 300 ±50 psig, the main LOX valve opens permitting LOX flow to the dome and injector. The igniter fuel valve, when opened by the main LOX valve, directs fuel control pressure to the hypergol container and ignition monitor valve inlet ports. When fuel pressure at the hypergol inlet reaches approximately 300 psig, the hypergol cartridge burst diaphragms rupture and pyrophoric fluid, followed by igniter fuel, enters the thrust chamber to initiate ignition stage. When thrust chamber ignition is established, the ignition monitor valve directs control (fuel) pressure to the opening port of the main fuel valve. High-pressure fuel then enters the thrust chamber to establish main propellant ignition. Pressures resulting from main propellant ignition and sensed at the fuel injector manifold cause the gas generator control valve to open. Bootstrap propellants enter the gas generator where they are ignited and burned, and the resulting gases drive the turbine which powers the turbopump. The turbopump supplies propellants to the thrust chamber and the gas generator at the required pressures and flowrates during mainstage operation.

1-86. OXIDIZER IGNITION CONTROL VALVE. (Figure 1-37.)

1-87. The oxidizer ignition control valve assembly consists of the main LOX valve, actuator cylinder heater, and igniter fuel valve.

1-88. MAIN LOX VALVE. (Figure 1-38.)

1-89. The main LOX valve, used for controlling the flow of oxidizer to the thrust chamber, is a balanced butterfly-type valve installed between the thrust chamber inlet elbow and the high-pressure duct. The actuation cylinder on the main LOX valve is equipped with a blanket-type heater to prevent lubricant and packings from freezing, due to the low temperature of the oxidizer. The heater is controlled by a thermostat which closes at 90 ±5° F and opens at 110 ±5° F. The valve actuation pressure, supplied by the fuel pump discharge, enters the opening port and applies force on the actuation piston. This pressure overcomes the spring force and moves the piston toward the open position. As the piston moves to the valve open position, the piston rod linked to a crank rotates the valve shaft and gate 90 degrees to the open position. A position indicator (resistance potentiometer), mounted on the end of the gate shaft, indicates valve gate position. (See figure 1-39 for valve actuation.) The main LOX valve is closed by firing a pyrotechnic-actuated main LOX valve closing control valve, which permits fuel pressure to flow to the closing port of the main LOX valve. This equalizes fuel pressure on both sides of the actuation piston, allowing spring force and the difference in area ratios to actuate the valve to the closed position.

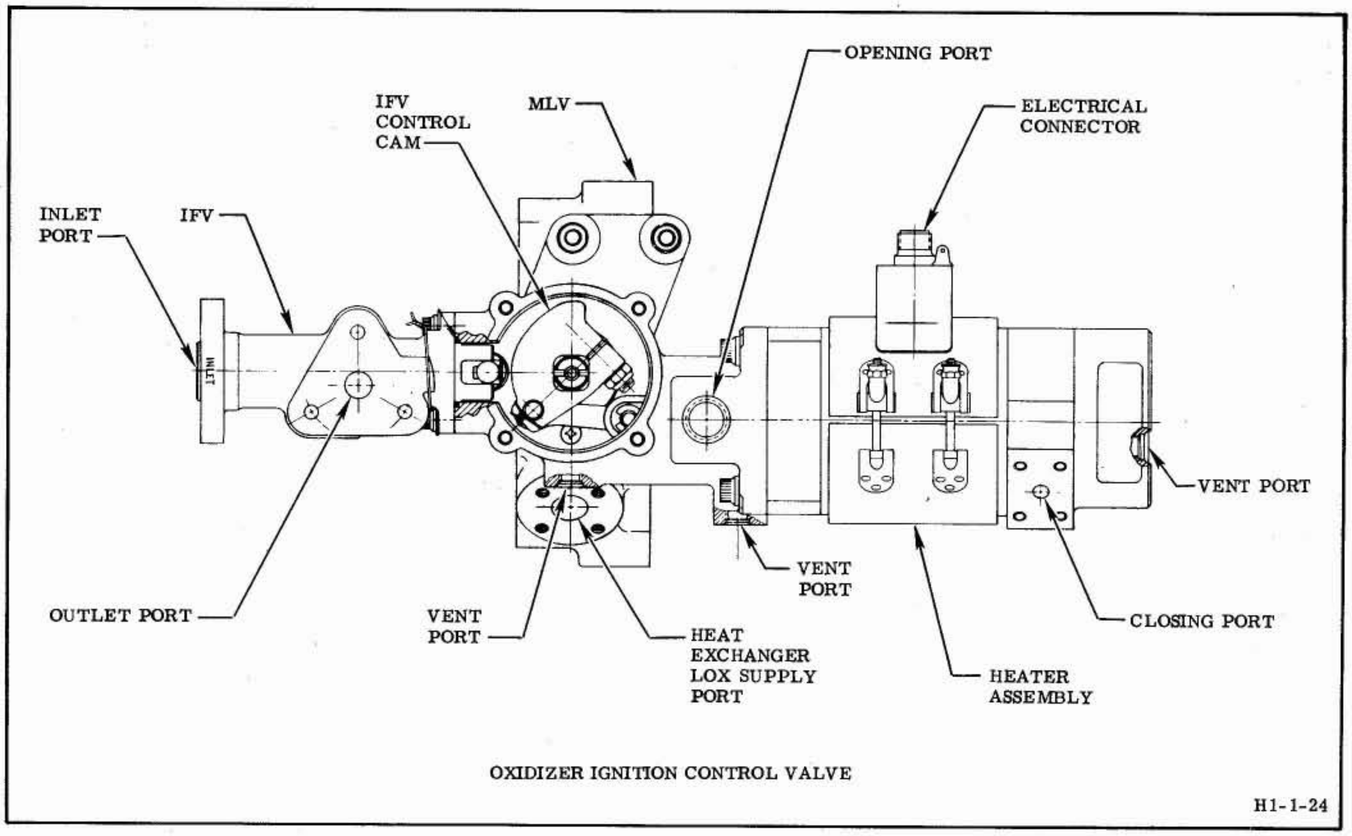

Figure 1-37. Oxidizer Ignition Control Valve

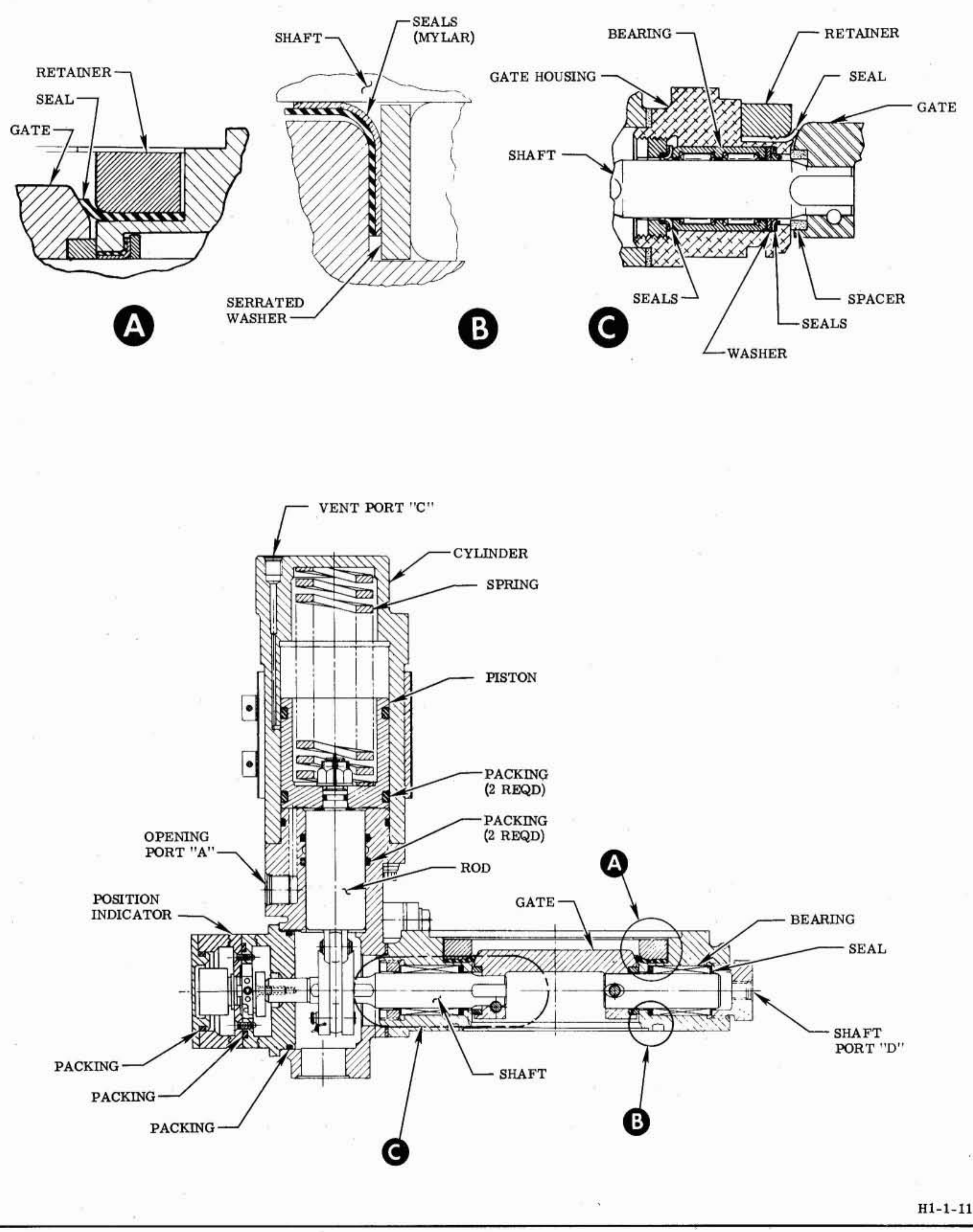

Figure 1-38. Main LOX Valve (MLV)

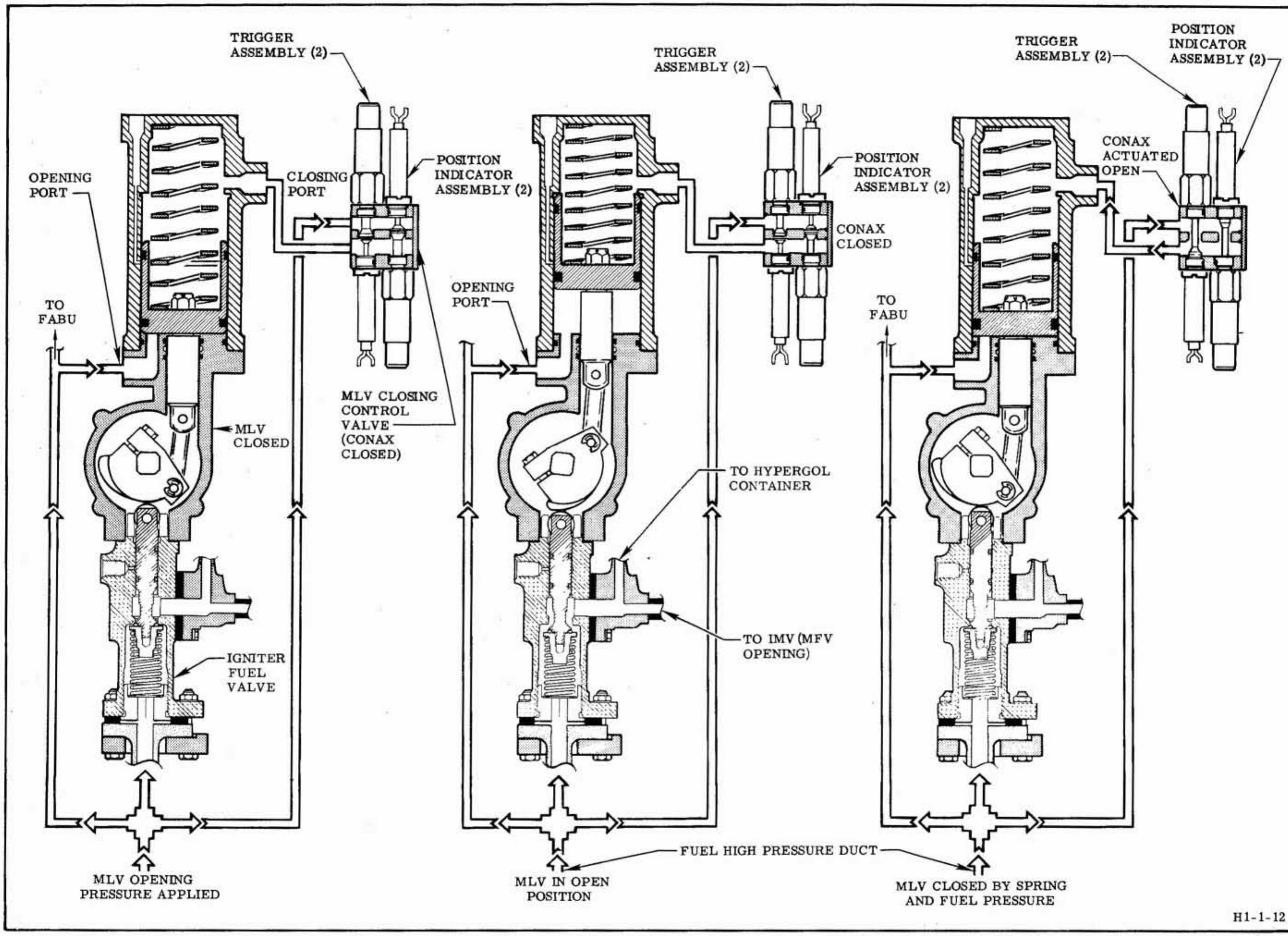

Figure 1-39. Main LOX Valve Actuation

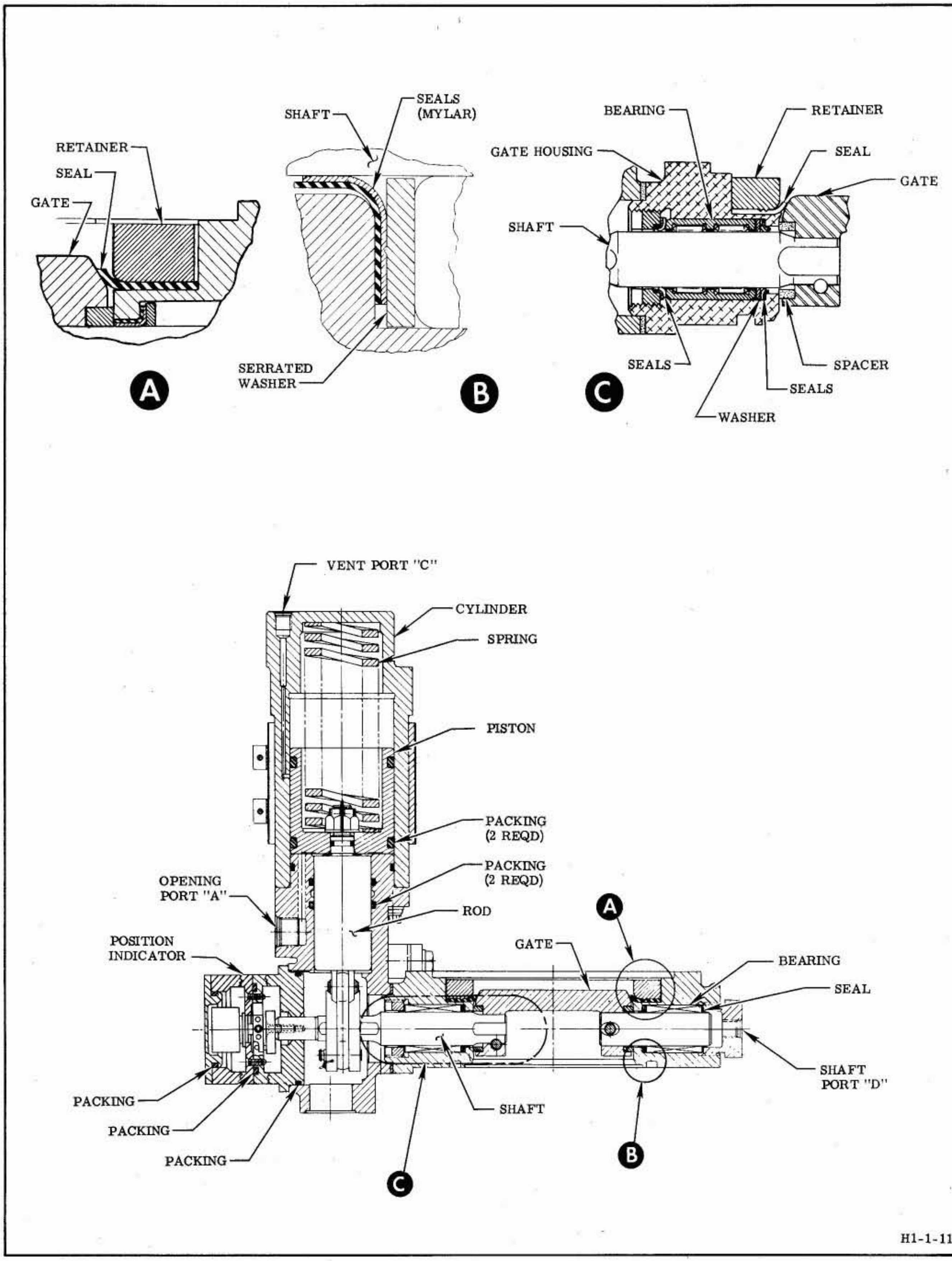

Figure 1-38. Main LOX Valve (MLV)

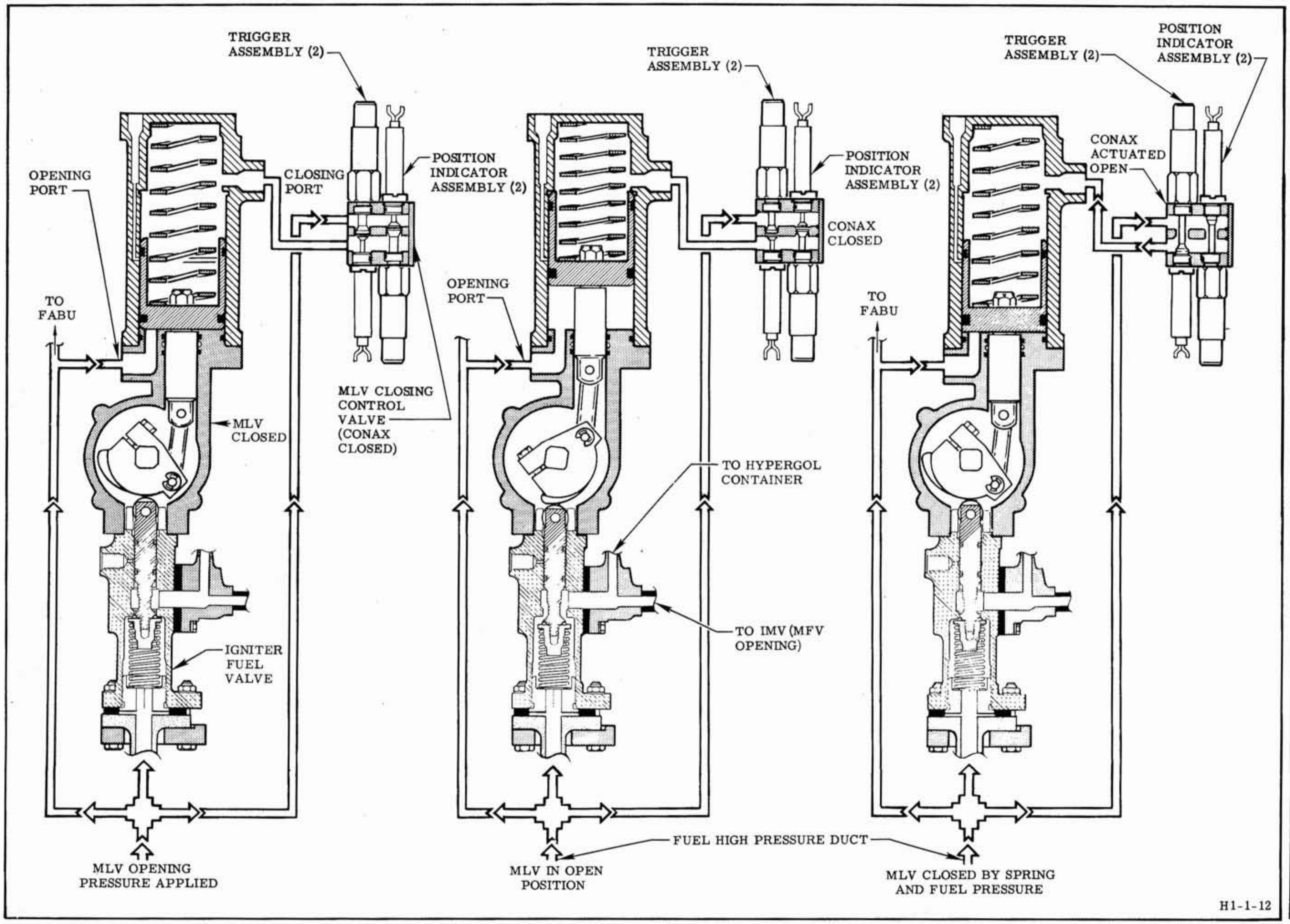

Figure 1-39. Main LOX Valve Actuation

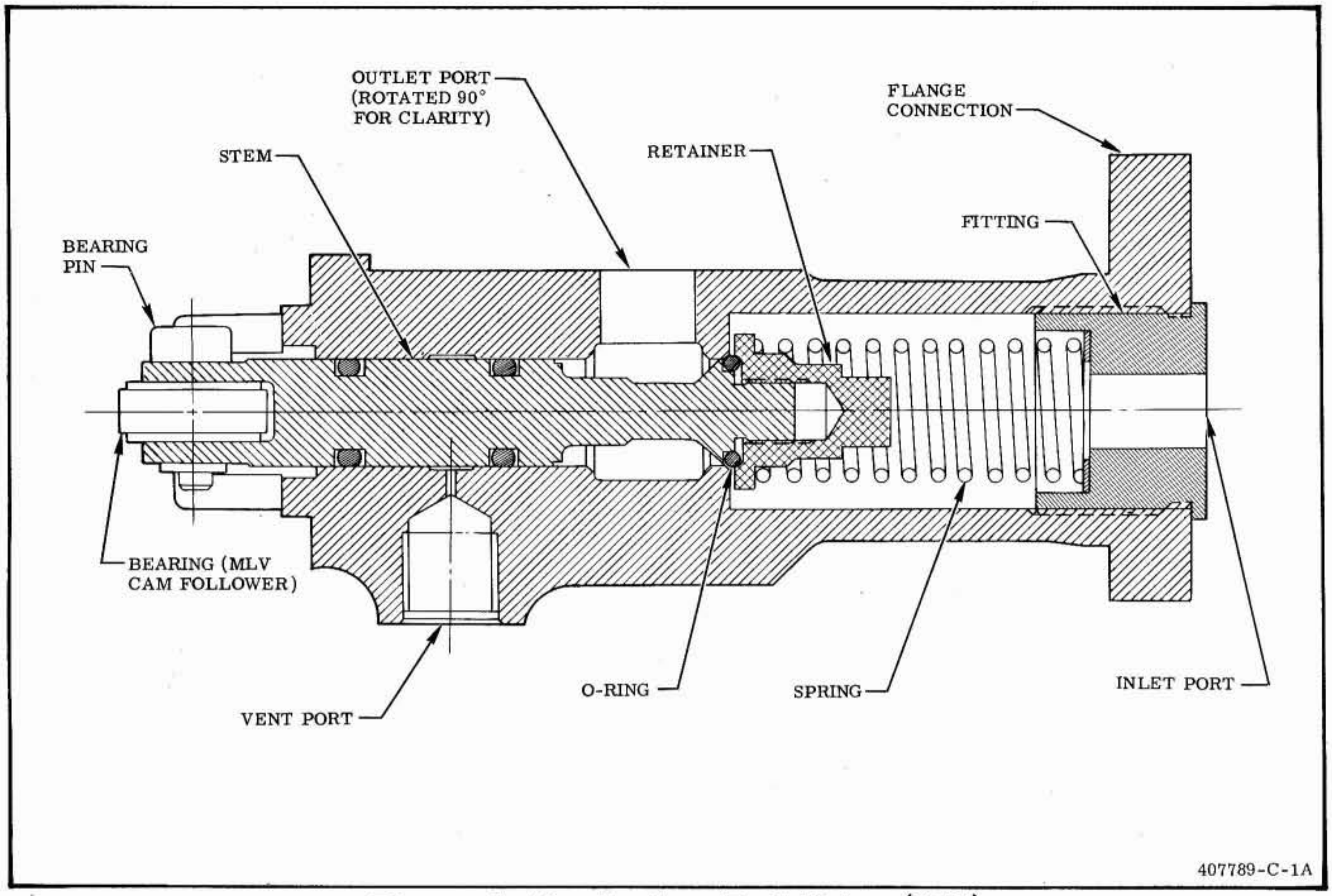

Figure 1-40. Igniter Fuel Valve (IFV)

1-90. IGNITER FUEL VALVE. (Figure 1-40.)

1-91. The igniter fuel valve is attached to, and operated by, the main LOX valve. During engine start, the igniter fuel valve is used to sequence the flow of ignition fuel. The igniter fuel valve is actuated by a cam on the main LOX valve gate shaft. During engine start, the igniter fuel valve leaves the closed position when the main LOX valve reaches 60 degrees of gate rotation, and reaches the fully-open position when the main LOX valve is 80 degrees open. The igniter fuel valve remains open, permitting fuel flow to the hypergol container and to the inlet port of the ignition monitor valve for main fuel valve actuation. During engine shutdown, the igniter fuel valve closes as the main LOX valve starts to close, shutting off fuel flow to the thrust chamber igniter fuel spray disks and to the ignition monitor valve.

1-92. MAIN FUEL VALVE. (Figure 1-41.)

1-93. The main fuel valve is used to control the flow of fuel to the thrust chamber and is located between the thrust chamber fuel inlet manifold and the high-pressure duct. The main fuel valve is similar to the main LOX valve with the exception of

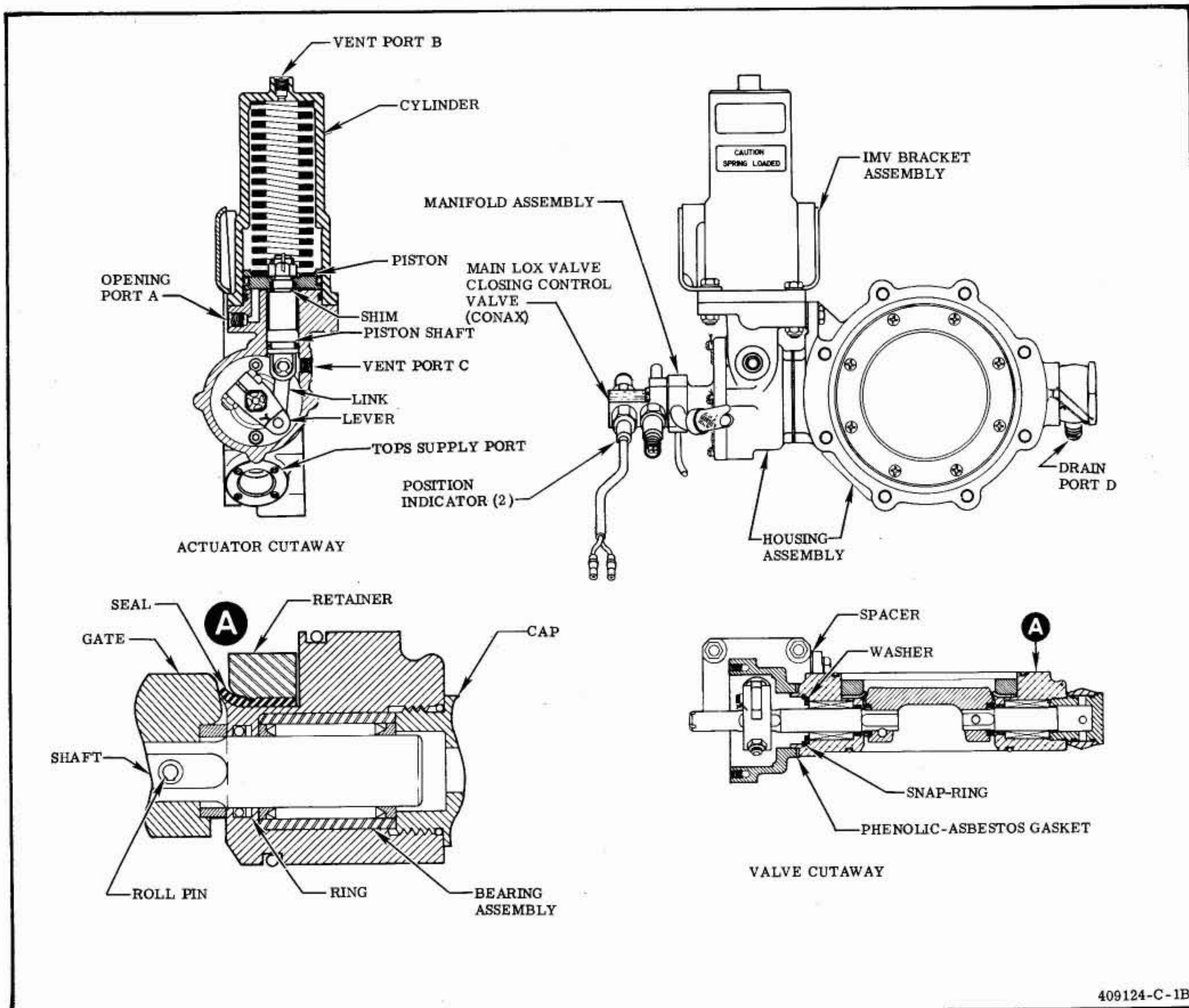

Figure 1-41. Main Fuel Valve (MFV)

the closing control and the absence of the heater assembly, the cam for igniter fuel valve actuation, and the position indicator. The main fuel valve is opened by fuel pressure from the ignition monitor valve and closed by spring force. The main LOX valve closing control valve is bolted to the main fuel valve actuator housing.

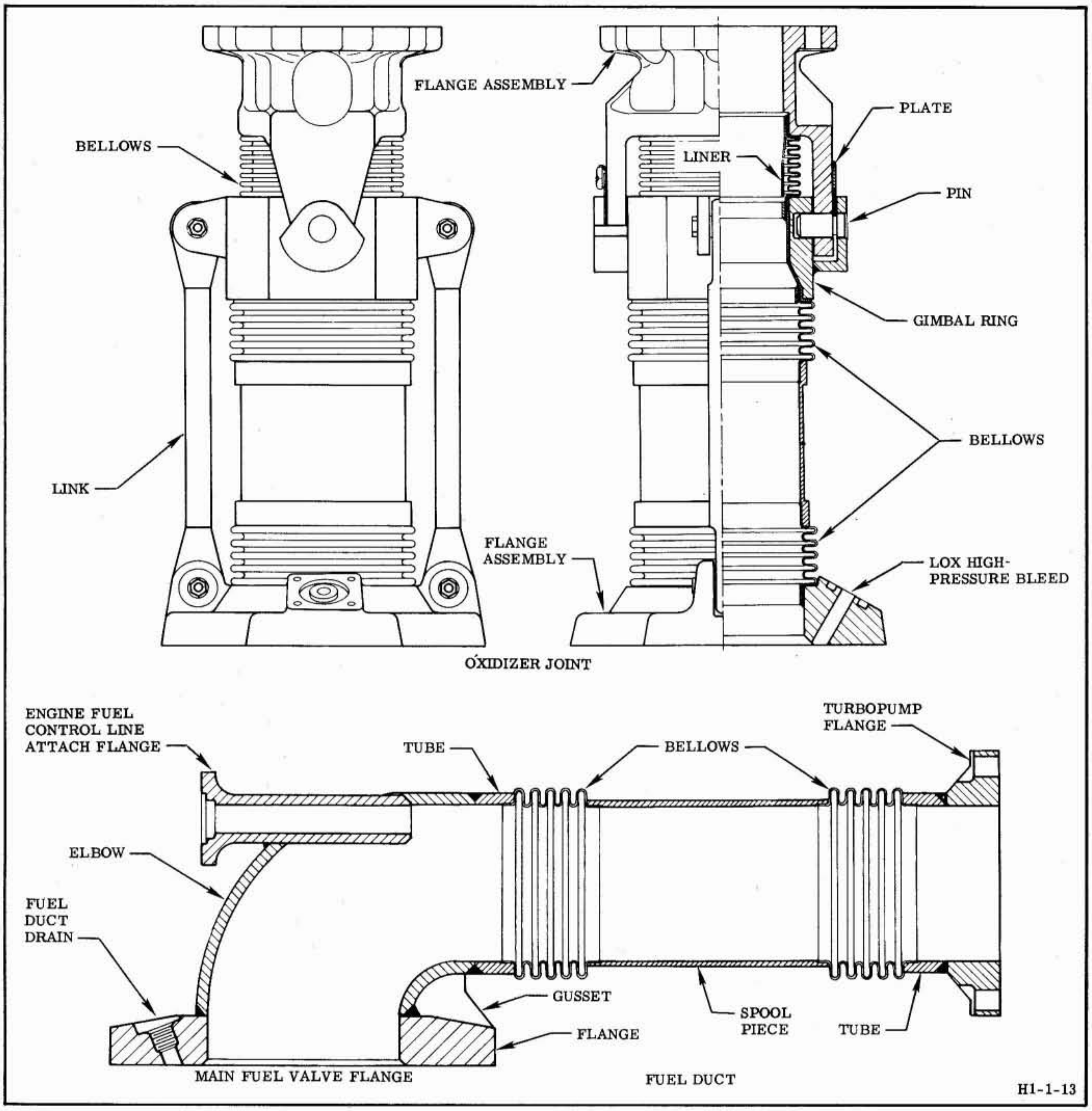

Figure 1-42. Propellant Ducting

1-94. PROPELLANT DUCTING. (Figure 1-42.)

1-95. The high-pressure propellant ducts connect the oxidizer and fuel pump outlets with the main LOX and the main fuel valves on the thrust chamber. The ducts contain bellows sections which permit the degree of movement required between the thrust chamber and the turbopump. The fuel high-pressure duct bellows are capable of accommodating a combined, simultaneous deflection of +0.5-inch offset and +0.25-inch axial displacement, plus one degree of flange angulation, while operating under a maximum internal pressure of 1,124 psig. The LOX joint bellows assemblies are capable of deflecting ±3 degrees in any plane, allowing for a 0.25-inch parallel offset, and withstanding ±0 degrees, 20 minutes of torsional rotation, while operating under a maximum internal pressure of 1,195 psig at -300° F. The structural loads imposed on the LOX joint are borne by the two plates, a gimbal ring, and the two links.

1-96. TURBOPUMP. (See figures 1-43 through 1-47.)

1-97. DESCRIPTION. The turbopump is a turbine-driven, dual-pumping unit consisting of an oxidizer pump, fuel pump, reduction gearbox, accessory drive adapter, and turbine. To simplify the engine system high-pressure plumbing, the turbopump is mounted on the side of the thrust chamber, with the main shaft positioned 90 degrees from the vertical centerline of the thrust chamber. This mounting provides a high-pressure duct routing with minimum pressure drop. The outlets of the oxidizer pump and the fuel pump are integral parts of the respective pump volutes. These outlets are attached to the main propellant ducting. During engine operation, the turbopump supplies oxidizer and fuel to the thrust chamber at required pressures and flowrates. The turbopump also supplies the liquid propellant gas generator with the required flow of oxidizer and fuel.

1-98. OPERATION. The power for operating the turbopump is provided by the high-speed turbine driven by hot gases from the liquid propellant gas generator. The turbine shaft drives a series of reduction gears which drive the pump shaft, inducers, and impellers. Rotation of the inducer and impeller pumps the propellant by centrifugal force. During operation, the turbopump gears and bearings are cooled and lubricated by the fuel additive subsystem. Turbopump characteristics are listed in figure 1-44.

1-99. OXIDIZER AND FUEL PUMPS. The turbopump incorporates two single-entry, centrifugal propellant pumps mounted back to back, one on each side of the gearbox. The fuel pump is bolted to the gearbox and the oxidizer pump is secured to the gearbox by radially-inserted steel pins. The steel pins allow the oxidizer pump housing to expand and contract during extreme temperature changes without distortion and misalinement. Both pumps are driven by a common shaft and each pump has an axial-flow inducer, a radial-flow impeller, and an integral diffuser. The oxidizer pump and the fuel pump pressurize the propellants for thrust chamber and gas generator combustion. The axial-flow inducers increase the pressure at the impeller inlet and allow a lower NPSH. Hollow-vaned, radial-flow pump impellers are used for pumping the propellants. The propellants pass

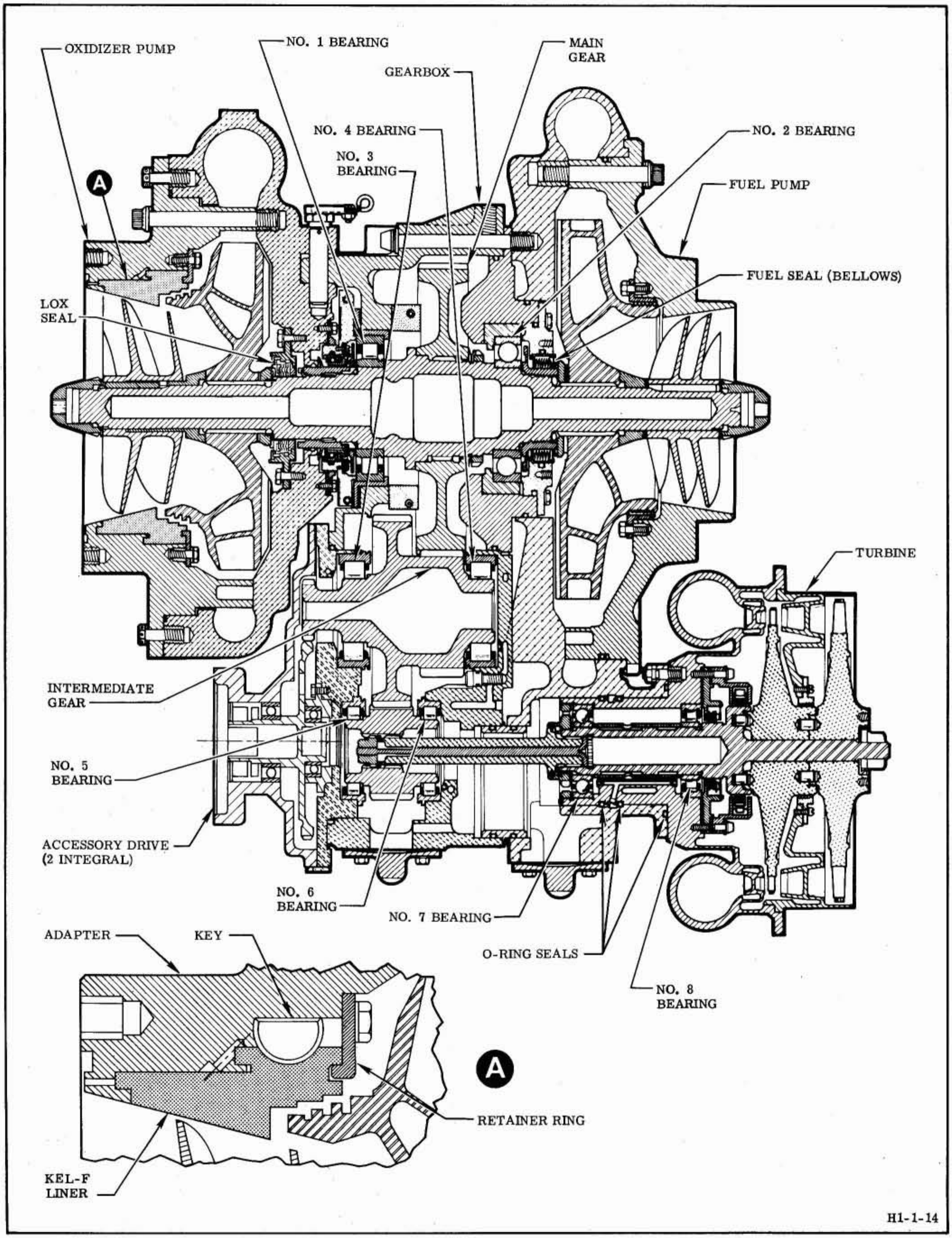

Figure 1-43. Turbopump

Item	Unit of Measure	200K Oxidizer	200K Fuel	205K Oxidizer	205K Fuel
Inlet density	lb/cu ft	70.79	50.45	70.79	50.45
Inlet pressure, total	psia	65.0[(a)]	57.0	65.0[(a)]	57.0
Discharge pressure, total	psia	950.2	1,011.8	970.0	1,012.0
Shaft speed	rpm	6,717.0	6,717.0	6,680.0	6,680.0
Developed pump head	ft	1,811.0	2,720.0	1,851.0	2,719.0
Pump internal cavity volume	cu in	213.0	161.0	213.0	161.0
Volume flow	gpm	3,382.0	2,102.0	3,458.0	2,149.0
Flowrate	lb/sec	533.5	236.3	545.4	241.6
Efficiency	percent	77.12	72.44	77.88	71.78
Shaft Power	bhp	2,277.0	1,613.0	2,357.0	1,664.0
NPSH required	ft	35.0[(b)]	35.0[(b)]	35.0[(b)]	35.0[(b)]

(a) Mainstage only. Engine starting requires 80 psia.
(b) Starting requirement.

Figure 1-44. Turbopump Characteristics

from the inducers into the impeller inlets, which incorporate guide vanes, through the impeller slinger vanes, to stationary diffuser vanes on the pump adapter, and into the pump volutes. The diffuser vanes give uniform distribution of pressure and reduction of fluid velocity around the impellers. Balance ribs are provided on the inboard side of the impellers, for hydraulic balancing of axial thrust on the pump shaft. See figure 1-44 for turbopump characteristics.

1-100. GEARCASE. The gearcase, with lube passages cast within its walls, contains the gear train which reduces the turbine speed applied to the main drive shaft. The gears are all of full depth configuration. The intermediate and pinion gears contain integral inner races for the roller bearings. Both roller bearings and ball bearings are used. The ball bearings restrict axial movement of the main drive shaft and the turbine shaft. Lubricant is applied to the bearings and to the disengaging side of the gear meshes (except accessory bearings and gears) through jets. The oxidizer pump main shaft bearing (No. 1) is provided with cal-rod heaters; one heater is attached to the inner surface of the gearcase and one is integral with the bearing retainer. Thermocouples are provided to sense bearing operating temperatures. Thermocouples for bearings No. 2 through No. 8 and their associated electrical harnesses have been deleted on H-1C engines incorporating MD56 change and H-1D engines incorporating MD58 change. The arrangement of gears and bearings is shown schematically in figure 1-45.

1-101. TURBINE. The turbopump turbine (figure 1-46) is an impulse, two-stage, pressure-compounded unit used to drive the turbopump. The turbine is bolted to the fuel pump housing and consists of an inlet manifold, first- and second-stage turbine wheels and nozzles, turbine shaft, and splined quill shaft connecting the turbine shaft to a high-speed pinion gear. The turbine inboard shaft bearing (No. 7) is a split-race ball bearing; the outboard shaft bearing (No. 8) is a roller

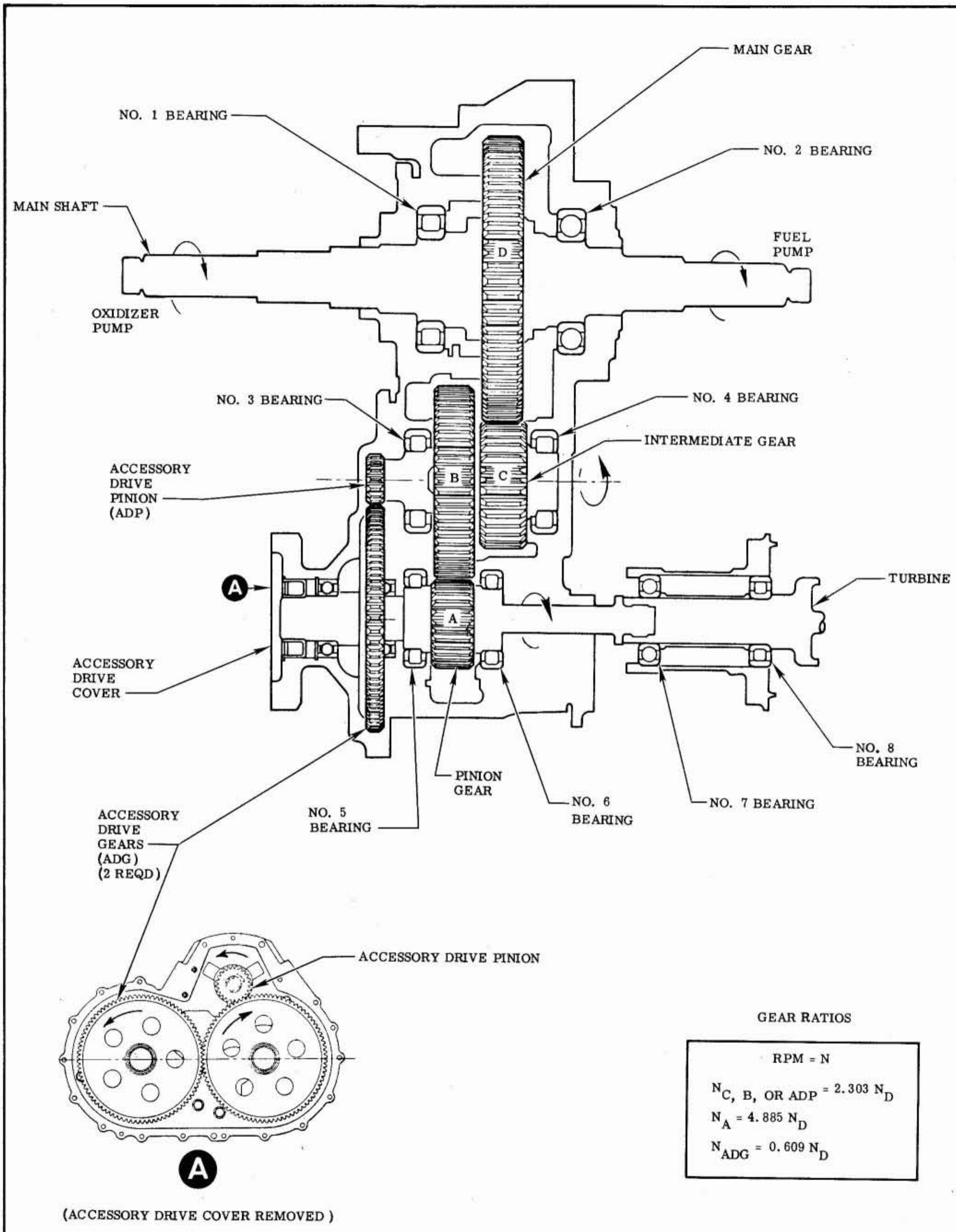

Figure 1-45. Turbopump Gears and Bearings

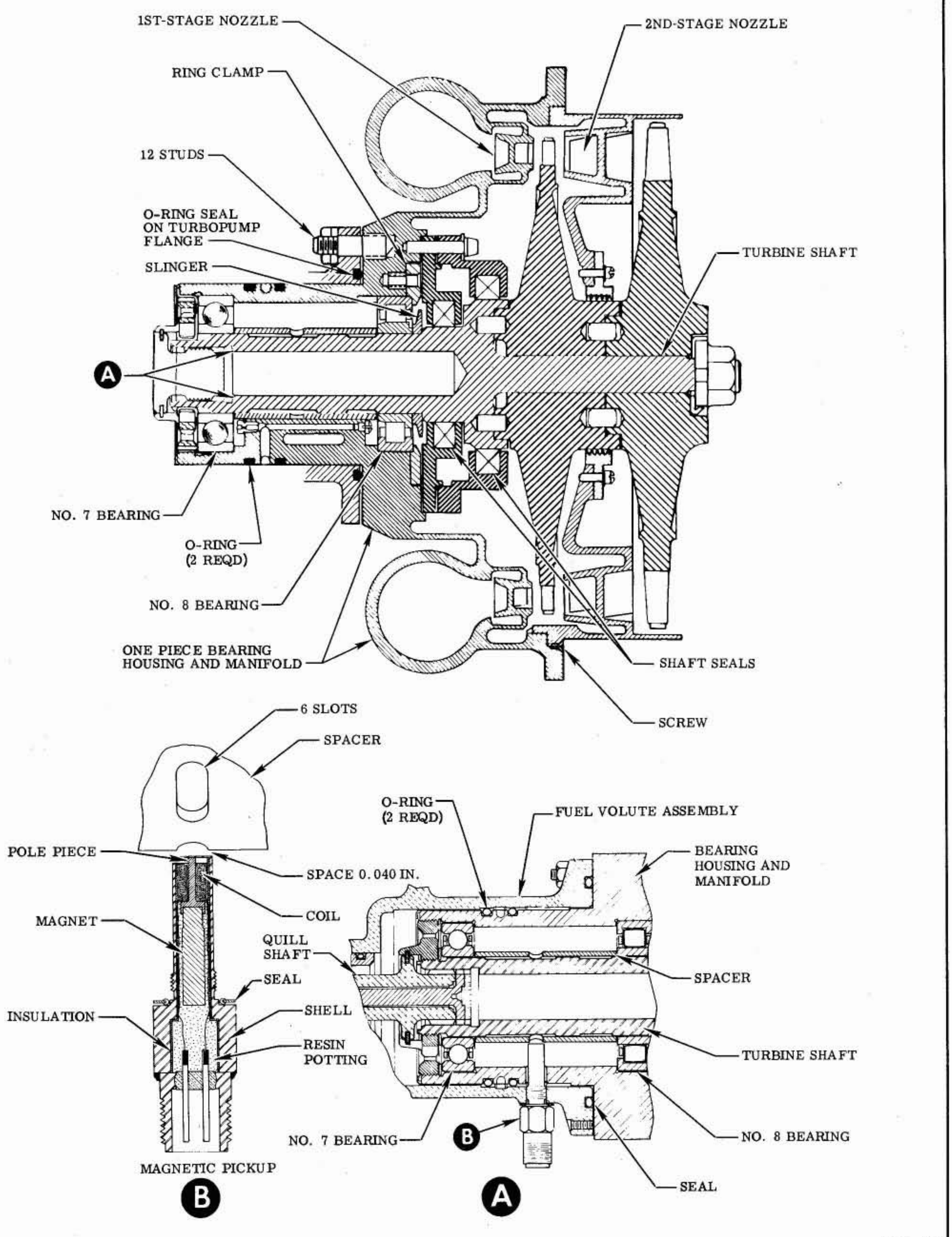

Figure 1-46. Turbopump Turbine

Item	Unit of Measure	Rating at 200K	Rating at 205K
Inlet pressure, total	psia	599.0	624.0
Exit pressure	psia	33.8	35.2
Pressure ratio, total inlet/static exhaust		17.75	17.74
Inlet pressure, static	psia	519.0	540.7
Brake horsepower	hp	4,007.0	4,141.0
Efficiency	percent	69.59	69.77

Figure 1-47. Turbine Characteristics

bearing. Two carbon ring shaft seals are used for preventing hot-gas leakage into the bearing area. An electronic tachometer that uses a single element magnetic pickup is used to sense turbine shaft speed. See figure 1-46 for a detailed illustration. A calibrated, liquid propellant gas generator system controls the flow of hot gases which drive the turbine. The turbine inlet manifold distributes the gases to the first-stage inlet nozzles which distribute the gases to the first-stage turbine wheel. After passing through the first-stage turbine wheel, the gases increase in velocity by passing through the second nozzle and the second-stage turbine wheel. The gases then leave the turbine through the exhaust ducting. A labyrinth seal, installed between the first- and second-stage wheels, prevents the hot gas from bypassing the second-stage nozzle. Turbine characteristics are listed in figure 1-47.

1-102. ACCESSORY DRIVES. Two counter-rotating accessory drives are provided in a housing attached to the gearbox. The attachment pads for the drives are identical.

1-103. PNEUMATIC AND LUBRICATION SYSTEM.

1-104. DESCRIPTION.

1-105. The pneumatic and lubrication system includes purge, pressurizing, vent, and drain lines, a turbopump relief valve, fuel manifold check valves, a gearcase pressurizing check valve, a turbopump lube filter, and a fuel additive blender unit (FABU). The FABU blends fuel and extreme-pressure additive RB0140-006 (Rocketdyne) for turbopump gearcase lubrication. The purge lines and check valves serve as connect points for the gaseous nitrogen purges required during test and maintenance procedures. Check valves are shown in figures 1-34 and 1-35 and are described in paragraphs 1-77 and 1-78.

and check valves serve as connect points for the gaseous nitrogen purges required during pre-test, test, post-test, and certain maintenance procedures. The check valves prevent flow reversal at connect points. Check valves are shown in figures 1-34 and 1-35 and are described in paragraphs 1-77 and 1-78. The fuel additive blender unit blends fuel and extreme-pressure additive RB0140-006 (Rocketdyne) for turbopump gearcase lubrication.

1-106. OPERATION.

1-107. The purges required for engine test, post-test, and maintenance are the LOX seal purge and turbopump gearcase pressurization, gas generator LOX injector, LOX system, thrust chamber fuel injector manifold, and LOX bypass. Source pressures, connect point pressures, and orifices, where used, determine the gaseous nitrogen flowrates in the system. Engine gaseous nitrogen purge pressures and flowrates are shown in figure 1-48.

Purge	Supply Source (psig)	Customer Connect Point Pressure (measured under flow conditions) (psig)	Flowrate (scfm)
TC fuel injector	450 max. [(a)]	350 ±50	238 ±35
LOX system	250 max.	95 ±10	200 ±20
LOX bypass	250 max.	2-8	1-13
GG LOX injector	450 max.	225 ±22.5	76 ±7
LOX pump seal	None	750 ±75	1.35 ±0.6
Gearcase pressurization	None	750 ±75	1.85 ±0.6

(a) Supply pressure can be increased to 550 psig maximum at facilities where connect point pressures of 350 ±50 psig cannot be obtained with a supply source of 450 psig maximum.

Figure 1-48. Gaseous Nitrogen Purge Pressures and Flowrates

1-108. FUEL ADDITIVE BLENDER UNIT. (Figure 1-49.)

1-109. DESCRIPTION. A fuel additive blender unit (FABU) is incorporated into the engine system to provide a means of introducing an additive to the turbopump gearbox lubrication system. Extreme-pressure additive RB0140-006 (Rocketdyne) is injected into and mixed with RP-1 fuel from the fuel pump discharge. This mixture is introduced into the turbopump gearbox where it lubricates and cools the gearbox components.

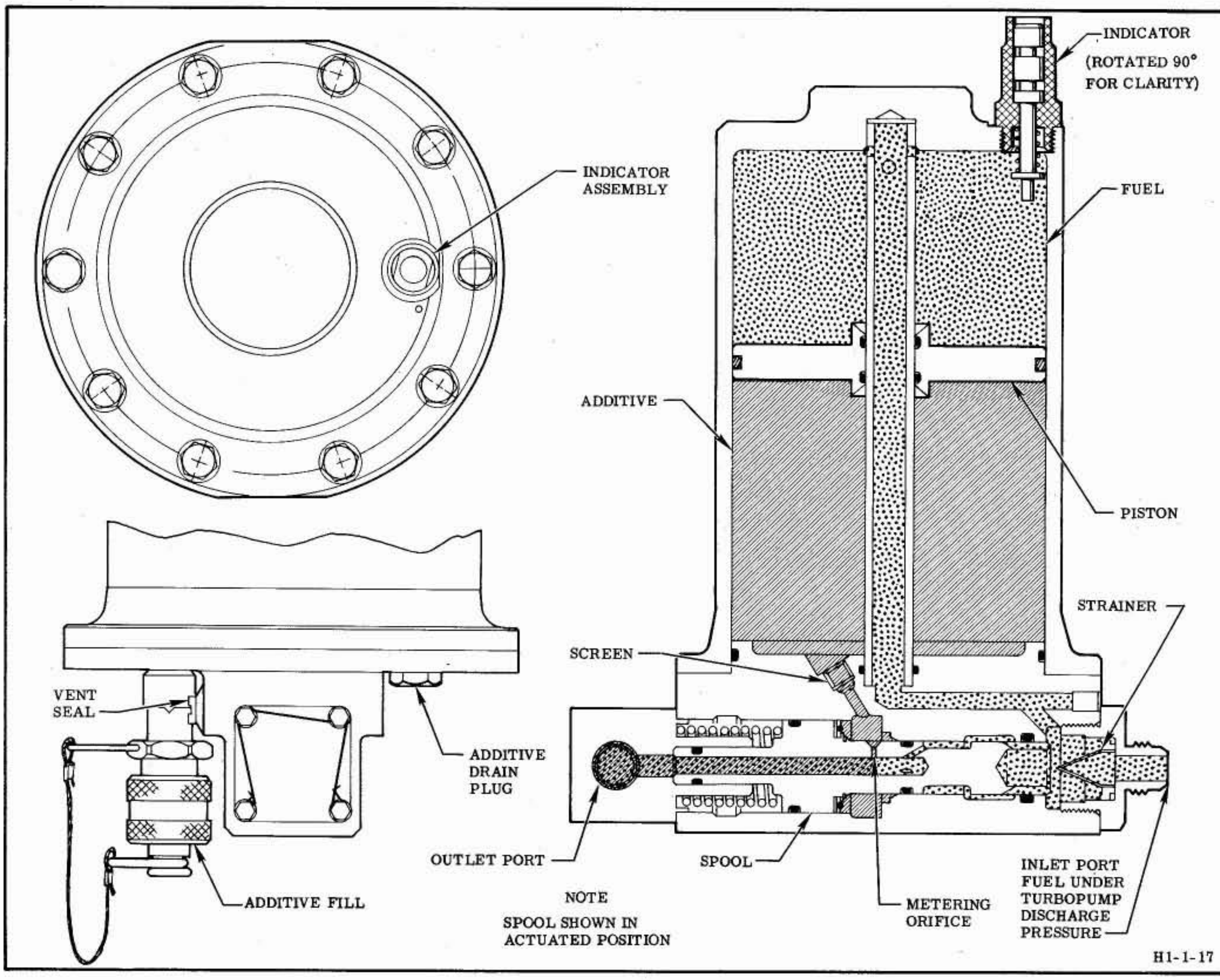

Figure 1-49. Fuel Additive Blender Unit (FABU)

1-110. OPERATION. Actuation of the FABU is accomplished by fuel pump discharge pressure, with the metering provided by an orifice. Fuel pressure directed to the FABU inlet initially moves the FABU shuttle check valve (FABU spool) from the closed position. A portion of fuel flows through the FABU into the turbopump gearcase; simultaneously, a portion of fuel is directed to the FABU piston which pressurizes the additive (Oronite). As the fuel pump discharge pressure increases, the FABU spool is opened farther until the metering orifice allows the additive (2.75 ±0.75 percent by volume) to blend with the fuel being routed to the turbopump gearcase. The fuel and additive mixture is then routed overboard. The lubricant consumption rate is 5-6 gpm. Metering of the additive is a self-sustained operation which ceases after the fuel pump discharge pressure has decayed sufficiently to allow the shuttle check valve to close. Prior to engine start, an electrical heater is used for maintaining the correct viscosity of the additive. The FABU is serviced with additive RB0140-006 (Rocketdyne) through a quick-disconnect additive fill port. Properties of additive RB0140-006 (Rocketdyne) are shown in figure 1-10.

1-111. ENGINE FILTERS AND SCREENS.

1-112. The materials and physical characteristics for the fuel additive blender unit fuel inlet strainer, additive outlet screen, thrust chamber fuel injector screen, and turbopump lube filter are given in figure 1-50.

Location	Material	Mesh	Diameter (Inches)
FABU fuel inlet strainer	Monel	35 (0.0118 dia)	0.625
FABU additive outlet screen	Monel	100 (0.0045 dia)	0.365
TC fuel injector screen	18-8 CRES (ceramic-coated)	10 (0.059 dia)	
TP lube filter	18-8 CRES	40 micron, nominal 75 micron, maximum	

Figure 1-50. Filter and Screen Characteristics

1-113. <u>ELECTRICAL SYSTEM.</u> (See figures 1-51 through 1-54.)

1-114. DESCRIPTION.

1-115. The engine electrical system (figure 1-51) consists of armored and unarmored electrical harnesses that provide circuitry for pyrotechnic initiators, switches, component heaters, and thrust OK pressure switches. The electrical system conditions the engine and controls engine start, flight, and cutoff. See figures 1-52 and 1-53 for wiring harnesses.

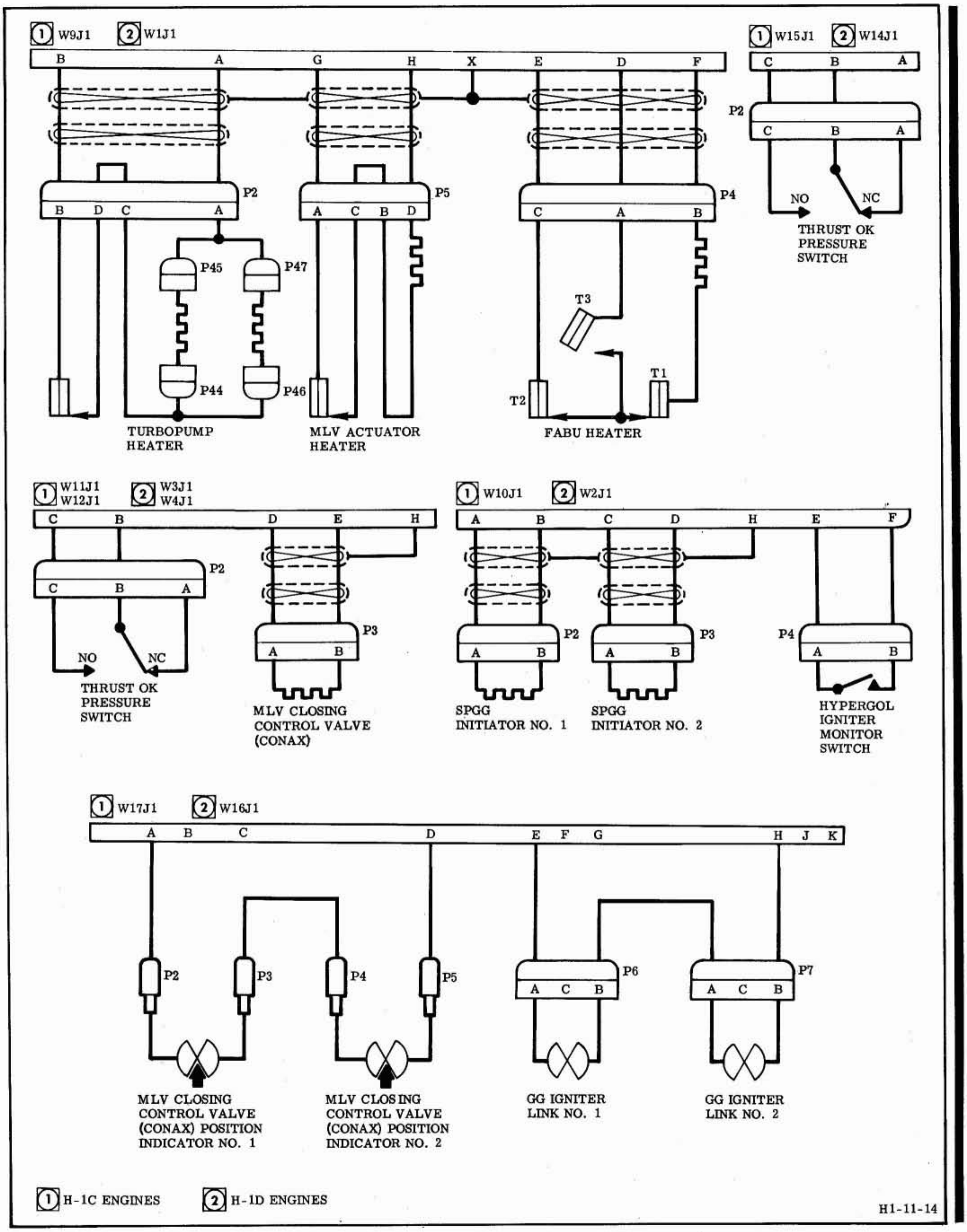

Figure 1-51. Electrical System Schematic

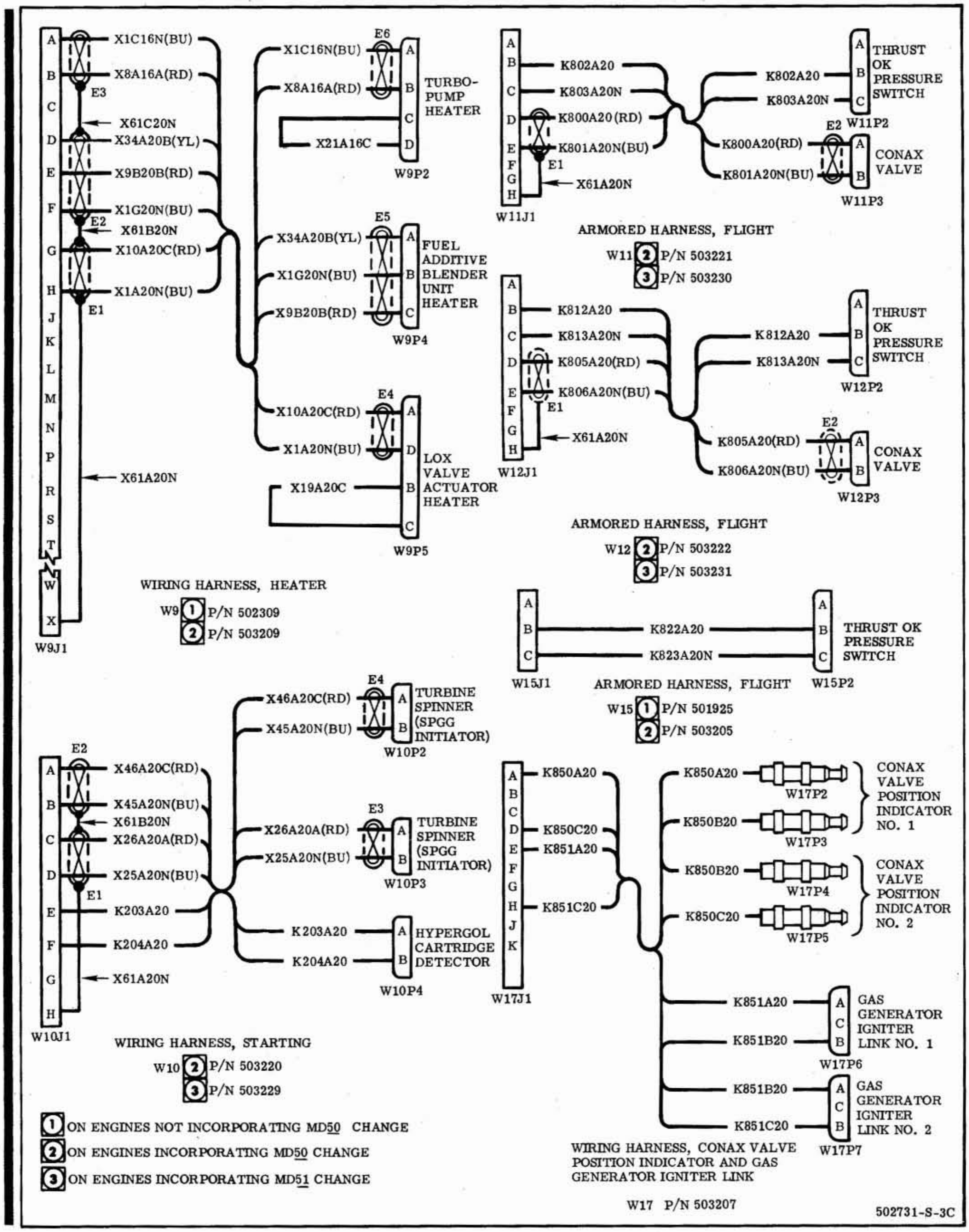

Figure 1-52. Wiring Harness Assemblies for H-1C Engines

1-116. OPERATION.

1-117. The electrical system conditions the engine by maintaining required component temperature levels with electrical heaters. Thermostat nominal ranges for engine heaters are given in figure 1-54. The electrical system functions in engine control by initiating and terminating engine firing during normal or abnormal conditions.

1-118. HEATERS.

1-119. Engine heaters maintain required temperature levels of components. The power requirements and range of thermostat settings are shown in figure 1-54.

Heater	Power (watts)	Thermostat Nominal Range (°F)	
		Dropout	Pickup
FABU	300 ±30		
Control (T1, normally closed)		130 ±4	121 ±4
Undertemperature (T3, normally open)		105 ±4	114 ±4
Overtemperature (T2, normally closed)		152 ±4	138 ±4
MLV Actuator	400 ±60	110 ±5	90 ±5
Turbopump	1,200 ±120	110 ±8	90 ±5

Figure 1-54. Engine Heater Power Ratings and Thermostat Settings

1-120. INSTRUMENTATION SYSTEM.

1-121. The standard instrumentation system consists of instrumentation taps located at various points throughout the engine. The taps are provided for installation of sensing devices which monitor the performance of engine components and subsystems during engine operation. The tap code system and the instrumentation tap chart are shown in figure 1-55.

Tap Designation	Description and Location
CF2b	TC fuel injector (Purge)
CF2c	TC fuel injector
CF2d	TC fuel injector (Purge)
CF2e	TC fuel injector (Purge)
CF2f	TC fuel injector (GG/IMV control)
CG1b	TC gas
CG1c	TC gas
CO2a	TC LOX injector
GG1a-1	GG combustion area (igniter)
GG1c-1	GG combustion area (igniter)
GG1d-1	GG combustion area
GG1e-1	GG combustion area
GF6a	GG control valve fuel injector
GO6a	GG control valve LOX injector
LB1	No. 1 bearing (lubrication jet)
LB2	No. 2 bearing (lubrication jet)
LB9	A & B gear
LB10	C & D gear
LF1	Gearcase pressure
LF2	Gearcase pressure
PF2a	Fuel instrumentation port
PO2b	LOX instrumentation port
TG1a	Turbine inlet
TG1b	Turbine inlet
TG2a	Exhaust hood outlet pressure[a]
TG4a	Exhaust duct inlet pressure[a]
TG4b	Exhaust duct inlet temperature[a]
	Primary LOX seal cavity drain line temperature port

TAP CODE DESIGNATION

Example:

G G 1 a - 1

- 1 — Identifies component in a multicomponent system.
- a — Signifies more than one tap of the same measurement.
- 1 — Identifies tap on the component or system.
- G (second) — Identifies medium being sensed or operating feature connected with tap; i. e.:
  - B - bearing
  - F - fuel
  - G - gas
  - O - oxidizer
- G (first) — Identifies major component or basic support system; i. e.:
  - C - thrust chamber
  - G - gas generator
  - L - gearcase
  - P - pump
  - T - turbine

(a) H-1C engines only.

Figure 1-55. Instrumentation Taps

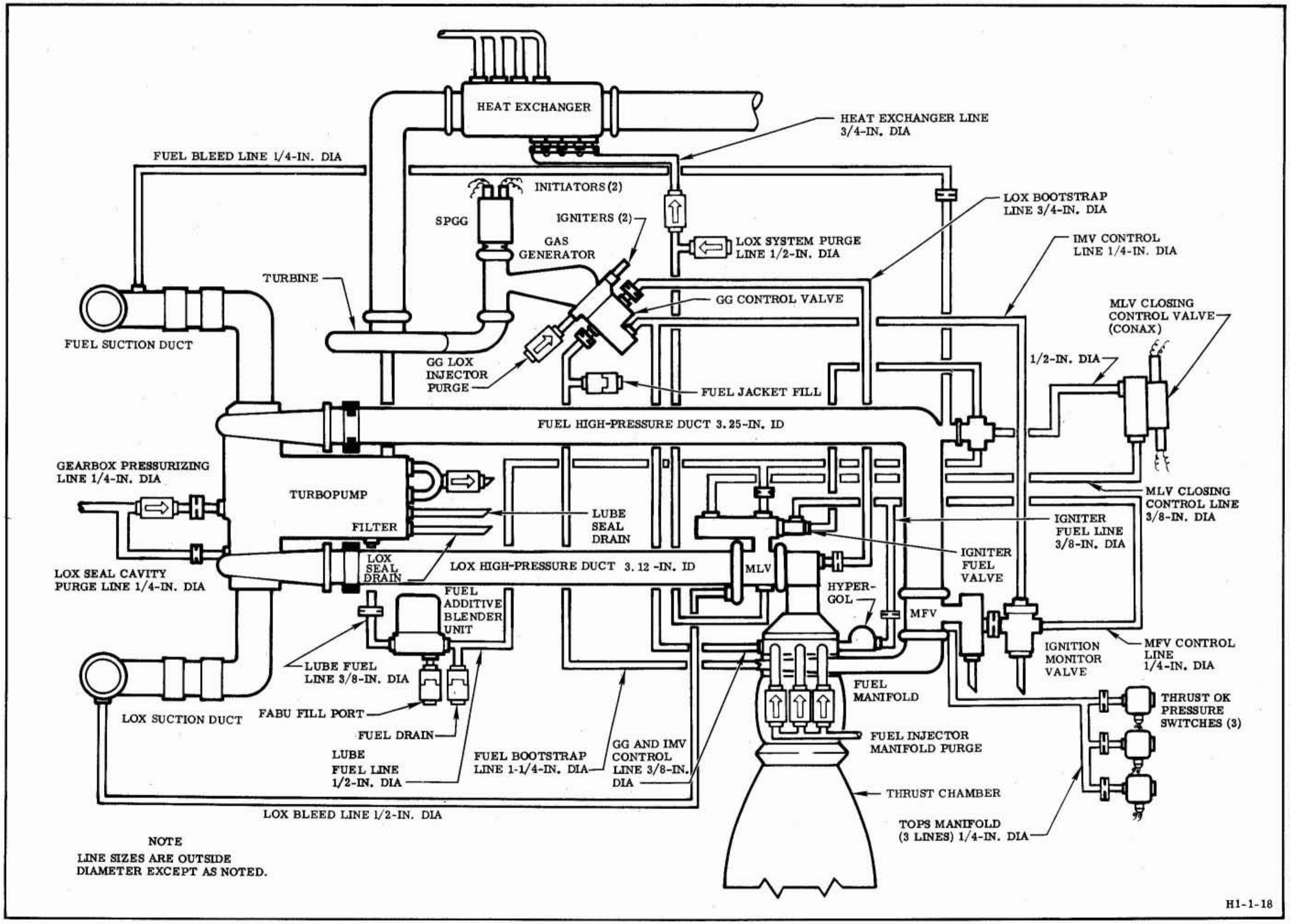

Figure 1-56. Line Size and Nominal Flowrates (Sheet 1 of 2)

Line Description	Nominal Flowrate (lb/sec)	
	200K Engines	205K Engines
Turbine Gas Flow	17.2	18.13
Heat Exchanger Line	3.0	3.0
LOX Bootstrap Line	4.43	4.61
Igniter Fuel Line	1.4	1.4
Thrust Chamber		
LOX	521.0	532.8
Fuel	222.8	227.5
Fuel Bootstrap Line	12.79	13.52
Lube Fuel	0.63	0.63
Main LOX Flow	525.5	545.4
Main Fuel Flow	235.6	243.0
LOX Bleed Line	5.0	5.0

Figure 1-56. Line Size and Nominal Flowrates (Sheet 2 of 2)

1-122. ENGINE FLUID AND PROPELLANT LINE CHARACTERISTICS.

1-123. LINE SIZES, FLOWRATES, AND DYNAMIC PRESSURES.

1-124. Engine line sizes and operating flowrates are shown in figure 1-56. Engine dynamic operating pressures are shown in figure 1-57. Purge flowrates are shown in figure 1-48.

1-125. ORIFICE LOCATION AND SIZE.

1-126. Engine orifices are of two types, variable and fixed. Variable orifices are engine calibrating orifices; their actual size is determined during engine test. They are identified by stamping or banding and their actual size is recorded in the Engine Log Book. Verification of orifice size or part number is necessary for proper engine performance. Engine orifice location and size are shown in figure 1-58.

3-10. LINE PRESSURE VERSUS ENGINE SYSTEM POSITION FOR 205K ENGINES.

3-11. Graphs indicating fuel and oxidizer lines pressures in relation to system position (pump inlets to turbine exhaust) are shown in figures 3-9 and 3-10.

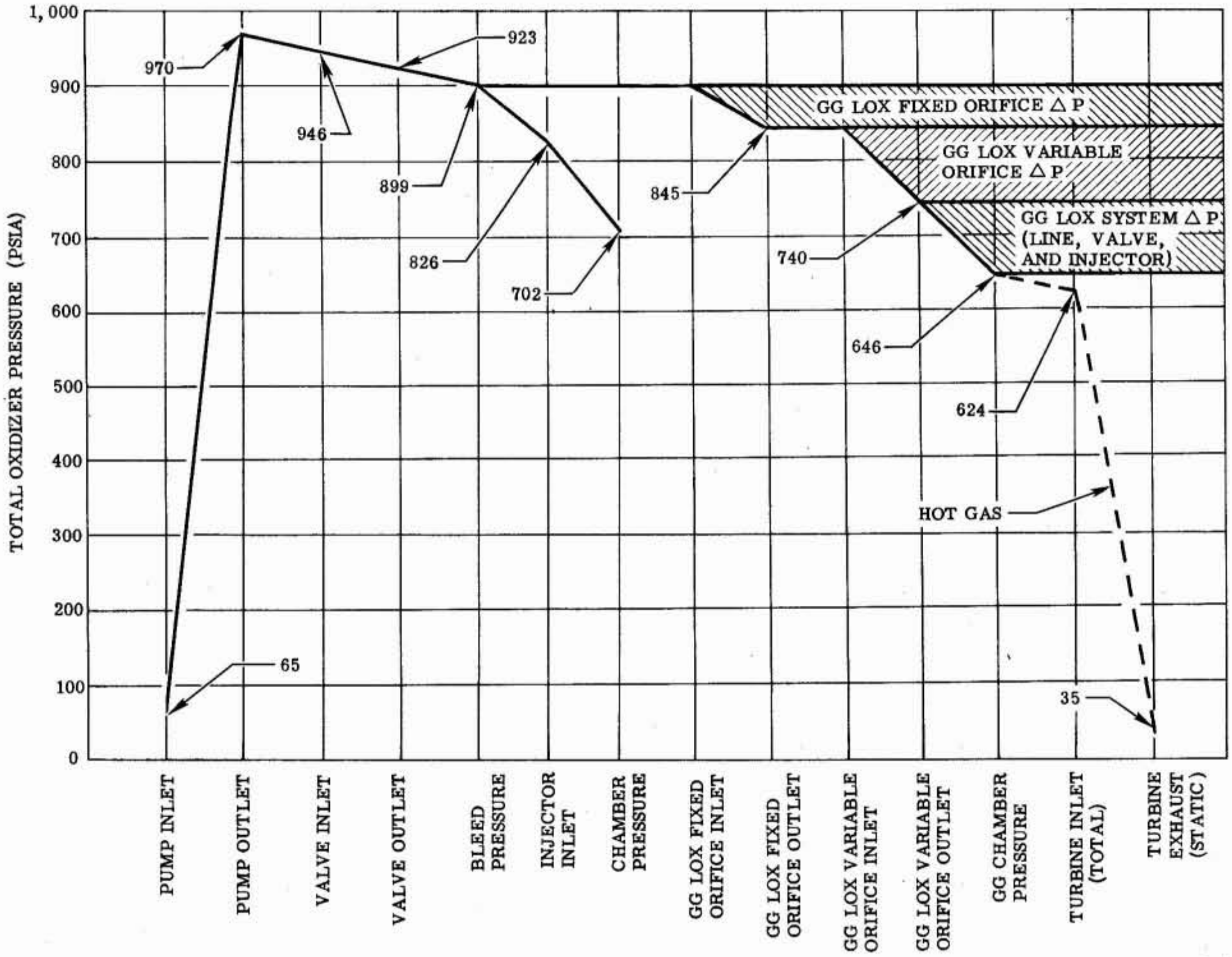

Figure 3-9. Oxidizer Pressure Versus System Position for 205K Engines

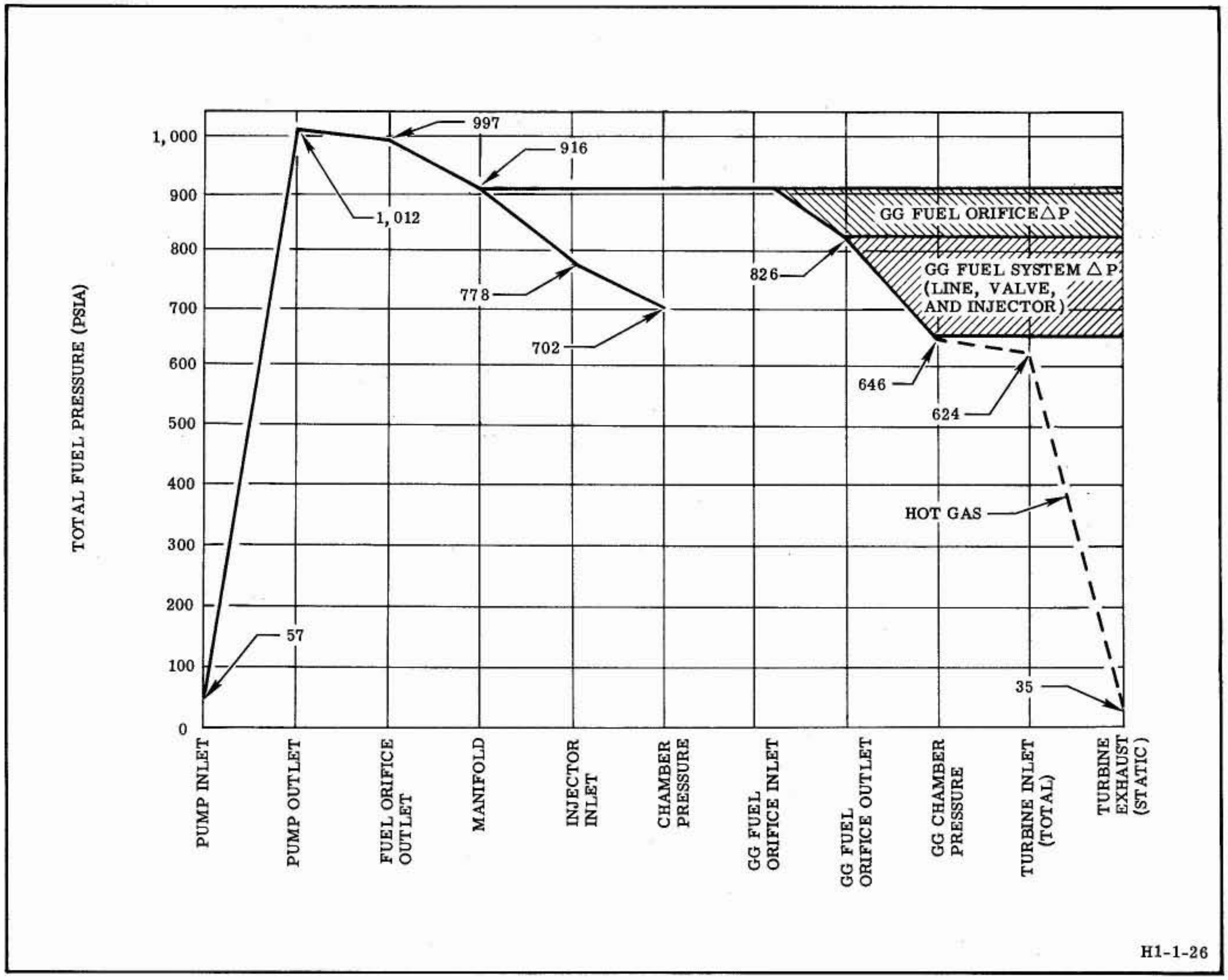

Figure 3-10. Fuel Pressure Versus System Position for 205K Engines

3-12. SEQUENCE TIMES AND RECORDED TRANSIENTS FOR 205K ENGINES.

3-13. The sequence times and recorded transients information shown in figure 3-11 are based on data from acceptance tests of the 64 engines, including spare engines, assigned to vehicles S-1B-6 through S-1B-12. Bearing temperature data was obtained from summarized data of engine tests having a duration of less than 100 seconds (tests averaged 43.1 seconds). The maximum acceleration and LOX seal drain line temperature data was obtained from acceptance test data from the 8 engines, plus 2 spare engines, assigned to vehicle S-1B-13.

Parameters	Mean Value	Standard Deviation
IGNITION SIGNAL	0.0	--
SPGG ignition delay time (ms)	32.1	6.78
SPGG duration (ms)	987.2	31.97
GG link break (ms)	133.6	34.05
MLV starts to open (ms)	209.3	20.28
MLV opening time (ms)	332.5	20.43
Thrust chamber ignition time (ms)	551.7	26.38
Chamber pressure prime time (ms)	846.1	32.45
Time to 90% thrust (ms)	1,040.8	125.70
Inboard TOPS pickup (ms)	1,058.0	151.49
Outboard TOPS pickup (ms)	1,055.2	147.07
Forward TOPS pickup (ms)	1,030.8	105.43
CUTOFF SIGNAL	0.0	--
MLV starts to close (ms)	73.6	4.13
MLV closing time to 100% (ms)	255.1	19.51
Inboard TOPS dropout (ms)	199.4	4.78
Outboard TOPS dropout (ms)	199.1	5.01
Forward TOPS dropout (ms)	200.1	7.48
Time to 10% thrust decay (ms)	265.8	18.20
Time to 100% thrust decay (ms)	1,645.4	73.20
CONDITIONS DURING TEST		
SPGG midpoint pressure (psig)	1,031.6	56.33
Fuel inlet start surge (psig)	129.9	30.15
Oxidizer inlet start surge (psig)	171.7	44.14
Thrust chamber ignition pressure (psig)	51.2	4.30
Thrust rise, from P_c trace (lb/10 ms)	82,453.2	11,938.73
Turbopump prime speed (rpm)	5,542.7	284.26
Gearcase pressure (psig)	4.2	0.26
High lube pressure, gears (psig)	677.4	17.36
Low lube pressure, bearings (psig)	117.8	12.07
Oronite mixture ratio (volume % Oronite/fuel)	3.1	0.23
No. 1 bearing temperature (°F)	147.4[a]	20.60

(a) Bearing temperature data obtained from START data summary of engine tests having a duration of less than 100 seconds (duration mean value, 43.1 sec).

Figure 3-11. Sequence Times and Recorded Transients for 205K Engines (Sheet 1 of 2)

Parameters	Mean Value	Standard Deviation
CONDITIONS DURING TEST (cont)		
No. 2 bearing temperature (°F)	130.2[a]	20.44
No. 3 bearing temperature (°F)	165.7[a]	20.71
No. 4 bearing temperature (°F)	158.6[a]	19.32
No. 5 bearing temperature (°F)	182.1[a]	18.88
No. 6 bearing temperature (°F)	179.0[a]	19.82
No. 7 bearing temperature (°F)	182.0[a]	23.14
No. 8 bearing temperature (°F)	183.8[a]	28.15
Cutoff impulse (lb/sec)	42,870.1	1,666.38
Oxidizer inlet cutoff surge (psig)	190.9	28.85
Oxidizer discharge cutoff surge (psig)	1,037.9	40.29
Maximum acceleration (grms)	50.7[b]	34.25
LOX seal drain line temperature (°F)	-92.6[b]	28.32
Test duration (sec)	77.5	54.14

(a) Bearing temperature data obtained from START data summary of engine tests having a duration of less than 100 seconds (duration mean value, 43.1 sec).

(b) Data obtained from START data summary of 8 engines, plus 2 spare engines, assigned to vehicle S-1B-13.

Figure 3-11. Sequence Times and Recorded Transients for 205K Engines (Sheet 2 of 2)

3-14. GIMBALING REQUIREMENTS AND LOADING LIMITATIONS FOR 205K ENGINES.

3-15. The engine must meet gimbaling requirements and withstand the loads specified in paragraphs 3-16 through 3-23.

3-16. GIMBALING REQUIREMENTS FOR H-1D 205K ENGINES.

3-17. The H-1D engine is capable of being gimbaled so that the angular displacement of the geometric thrust vector, from the normal to the plane of the gimbal bearing axes, is a maximum of 14.8 degrees, including snubbing, when both actuators are extended or retracted, either in-phase or out-of-phase. The angular displacement of the geometric thrust vector produced by the extension or retraction of a single actuator is a maximum of 10.5 degrees, including snubbing.

3-18. FLIGHT LOADING CONDITIONS FOR 205K ENGINES.

3-19. The engine and its structural mounts, while meeting the gimbaling requirements specified in paragraph 3-16, must operate satisfactorily without permanent deformation or failure under the following conditions:

a. Flight loading 8.0-g parallel to the direction of flight and 0.5-g perpendicular to the direction of flight.

b. Flight loading 4.0-g parallel to the direction of flight and 1.0-g perpendicular to the direction of flight.

3-20. FLIGHT AND GROUND LOADING CONDITIONS FOR 205K ENGINES.

3-21. The engine must withstand, without permanent deformation or failure, the maximum forces resulting from all combinations of loads specified in paragraph 3-18. For design purposes, the ultimate strength provides for a minimum of 1.5 times the forces resulting from the loading conditions. The engine is designed to withstand 4.0-g handling loads applied in any direction.

3-22. MAXIMUM EXTERNAL LOAD LIMITATIONS AT ENGINE CONNECT POINTS FOR 205K ENGINES.

3-23. The maximum external loads applied to the engine, from all effects such as misalinement, inertia loads, and gimbaling, must not exceed the combination of values shown in figure 3-12.

3-24. MASS PROPERTIES STATUS FOR 205K ENGINES.

3-25. A coordinate axes diagram for all H-1 engines is shown in figure 3-13. Engine system and major component weight status for 205K production engines is contained in figures 3-14 and 3-15. Weight, center of gravity, and inertia data for 205K engines is presented in figures 3-16 and 3-17 for general information only. For calculations based on weight, refer to the individual engine logbook for actual weights. Mass properties data contained in figures 3-14 through 3-17 is based on production engines H-4114 and H-7118 prior to retrofit.

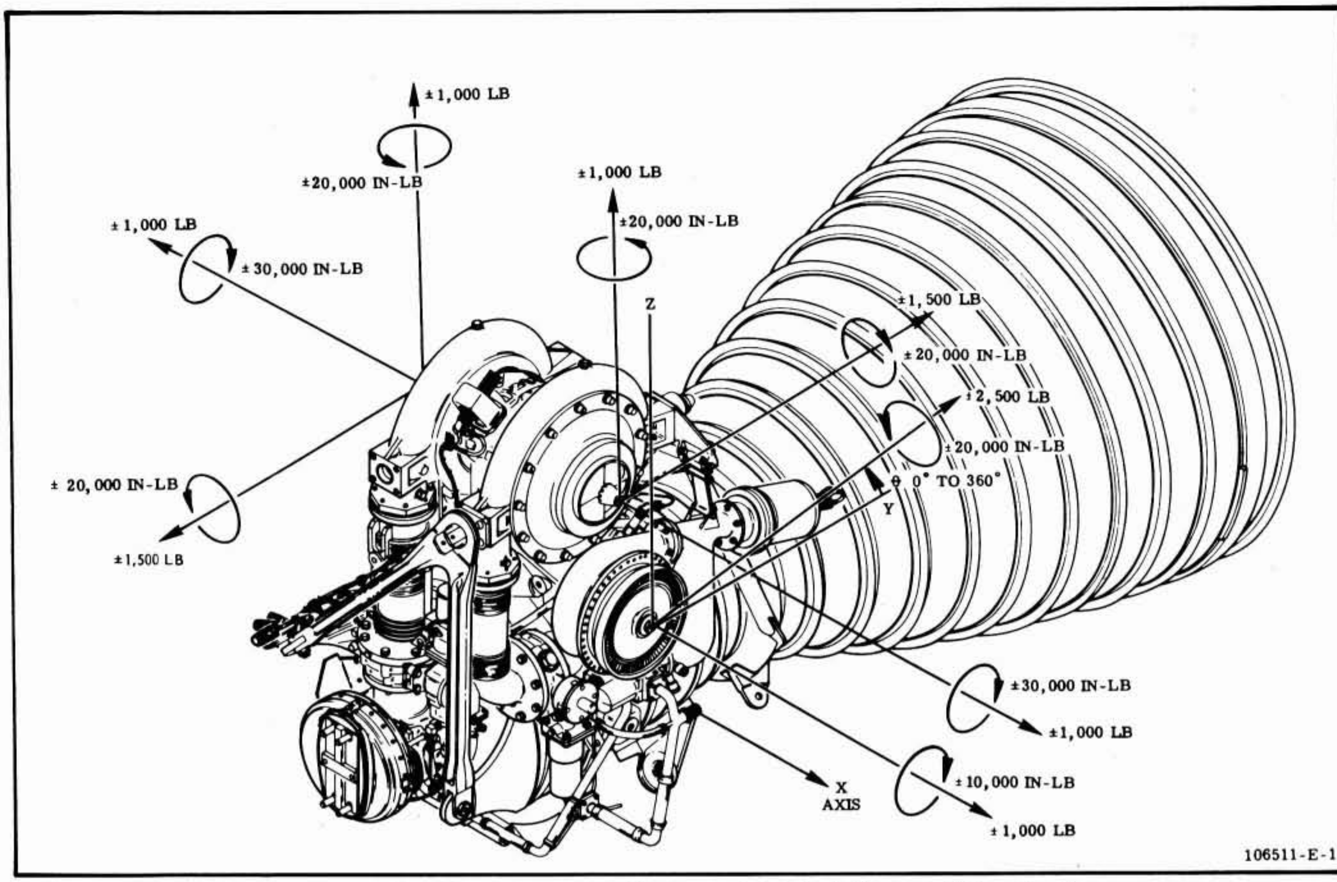

Figure 3-12. Engine Connect Point Load Limitations

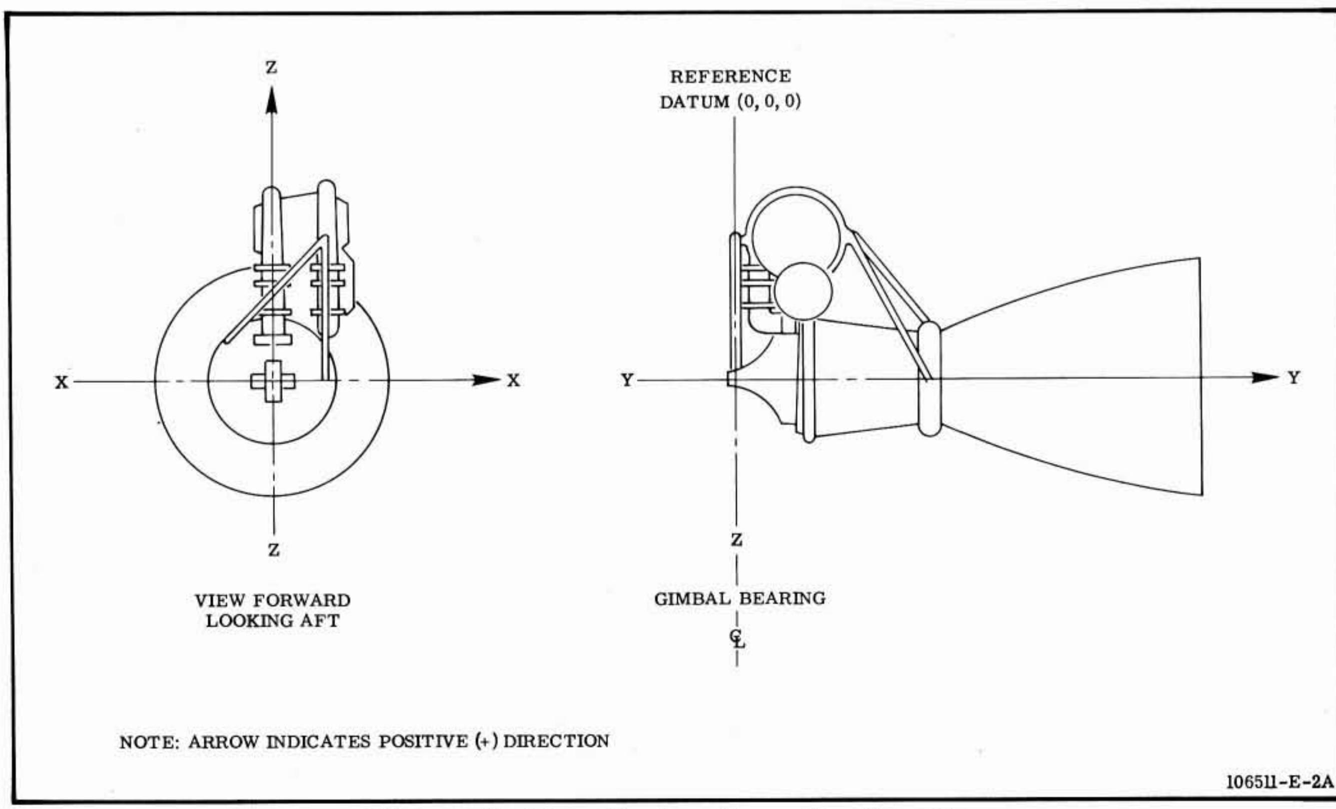

Figure 3-13. Engine Axes Designation

Item No.	Item	Weight (Pounds)
1	Engine and accessories at burnout (3+7)	2,176
2	Engine and accessories wet (3+8)	2,230
3	Engine and accessories dry (6+9)	2,010
4	Engine at burnout (6+7)	2,108
5	Engine wet (6+8)	2,162
6	Engine dry	1,942
	Thrust chamber	782
	Gimbal bearing	66
	Turbopump and mount	519
	Oxidizer system	74
	Fuel system	41
	Electrical system	17
	Lubrication system	20
	Gas generator system	45
	Start system	21
	Drain system	32
	Purge system	7
	Control system	11
	Insulation	78
	Exhaust system	229
7	Engine fluids at burnout	166
8	Engine fluids at start	220
9	Accessories dry	68
	Stabilizer struts (turnbuckles)	27
	Radiation shield	41

Figure 3-14. System and Major Component Weights for H-1C 205K Engines

Item No.	Item	Weight (Pounds)
1	Engine at burnout (3+4)	2,169
2	Engine wet (3+5)	2,223
3	Engine dry	2,003
	Thrust chamber	798
	Gimbal bearing	66
	Turbopump and mount	519
	Oxidizer system	74
	Fuel system	41
	Electrical system	30
	Lubrication system	20
	Gas generator system	45
	Exhaust system	204
	Start system	21
	Drain system	37
	Purge system	5
	Control system	11
	Insulation	91
	Radiation shield	41
4	Engine fluids at burnout	166
5	Engine fluids at start	220

Figure 3-15. System and Major Component Weights for H-1D 205K Engines

Item	Weight (Pounds)	Center of Gravity From Gimbal Point (Inches)			Moment of Inertia About Axes Parallel to Reference Axes Through Center of Gravity (Slug Ft^2)			Product of Inertia (Slug Ft^2)		
		Y	X	Z	I_Y	I_X	I_Z	I_{XZ}	I_{YZ}	I_{XY}
Engine (Dry)	1,942	30.5	6.3	7.9	142	396	353	12.13	-75.92	8.40
Engine (Wet)	2,162	30.9	5.8	7.8	157	448	401	13.32	-82.76	5.99
Engine (Burnout)	2,108	31.4	5.9	8.0	156	443	396	12.91	-84.32	4.74
Accessories[a]	68	29.3	9.5	-2.5	5	8	9	1.27	2.79	2.25

(a) Turnbuckles and radiation shield.

Figure 3-16. Weight, Center of Gravity, and Inertia Data for H-1C 205K Engines

Item	Weight (Pounds)	Center of Gravity From Gimbal Point (Inches)			Moment of Inertia About Axes Parallel to Reference Axes Through Center of Gravity (Slug Ft^2)			Moment of Inertia About Axes Parallel to Reference Axes Through Gimbal Point (Slug Ft^2)			Product of Inertia (Slug Ft^2)		
		Y	X	Z	I_Y	I_X	I_Z	I_{YY}	I_{XX}	I_{ZZ}	I_{XZ}	I_{YZ}	I_{XY}
Engine (Dry)	2,003	30.5	5.9	8.4	140	387	361	---	---	---	11.39	-53.90	4.16
Engine (Wet)	2,223	30.9	5.4	8.3	155	439	408	---	---	---	12.66	-60.83	1.83
Engine (Burnout)	2,169	31.4	5.6	8.5	154	434	403	---	---	---	12.23	-62.49	0.65
Gimbaled Mass (Dry)	1,975	31.1	5.9	8.5	139	378	351	185	820	778	11.27	-54.67	2.86
Gimbaled Mass (Wet)	2,195	31.4	5.5	8.3	155	430	398	202	931	881	12.55	-61.57	0.62
Gimbaled Mass (Burnout)	2,140	31.9	5.6	8.5	153	424	393	201	928	878	12.12	-63.29	-0.61

Figure 3-17. Weight, Center of Gravity, and Inertia Data for H-1D 205K Engines

ROCKETDYNE

A DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION

6633 CANOGA AVENUE, CANOGA PARK, CALIFORNIA 91304