

481 WING
Field Training Flight

ENGINE OLM
HANDOUT 2

SECONDARY POWER SYSTEM

The Secondary Power System (SPS) provides a pneumatic power source for on-board start capability and Ground Maintenance Mode (GMM) operation of the aircraft systems.

The system provides for three modes of operation:

1. Ground Maintenance Mode (GMM).
2. Environmental Control System (ECS).
3. Main Engine Start (MES).

GROUND MAINTENANCE MODE

Ground Maintenance Mode of operation allows for the functional test of the aircraft electrical system, hydraulic systems and motive flow fuel system, without operating the F404 engines.

ENVIRONMENTAL CONTROL SYSTEM

Environmental Control System mode of operation allows the Auxiliary Power Unit (APU) to provide air to the ECS during augmentation and ground testing. The Environmental Control Systems are a group of 13 systems that control the cockpit environment and the environment of avionic equipment on the aircraft.

MAIN ENGINE START

Main Engine Start mode of operation provides on-board start capability without the aid of any GSE.

The Secondary Power System is made up of the Auxiliary Power Unit (APU), Airframe Mounted Accessory Drive (AMAD), Secondary Power Compressed Air System, Fire Detection System and Fire Extinguishing System:

AUXILIARY POWER UNIT (APU)

The APU is an airframe mounted gas turbine engine that has a hydraulic start motor which is powered by an accumulator, a self-contained lubrication and ignition system, and an airframe supplied fuel system. During operation, APU pneumatic air is used to start or motor a main engine or to drive an Airframe Mounted Accessory Drive (AMAD) for ground checkout of the aircraft hydraulic, electrical, and fuel systems. The APU pneumatic air may also be used for ground checkout of the Environmental Control System (ECS) or to supply the ECS during single-engine operation.

AIRFRAME MOUNTED ACCESSORY DRIVE (AMAD)

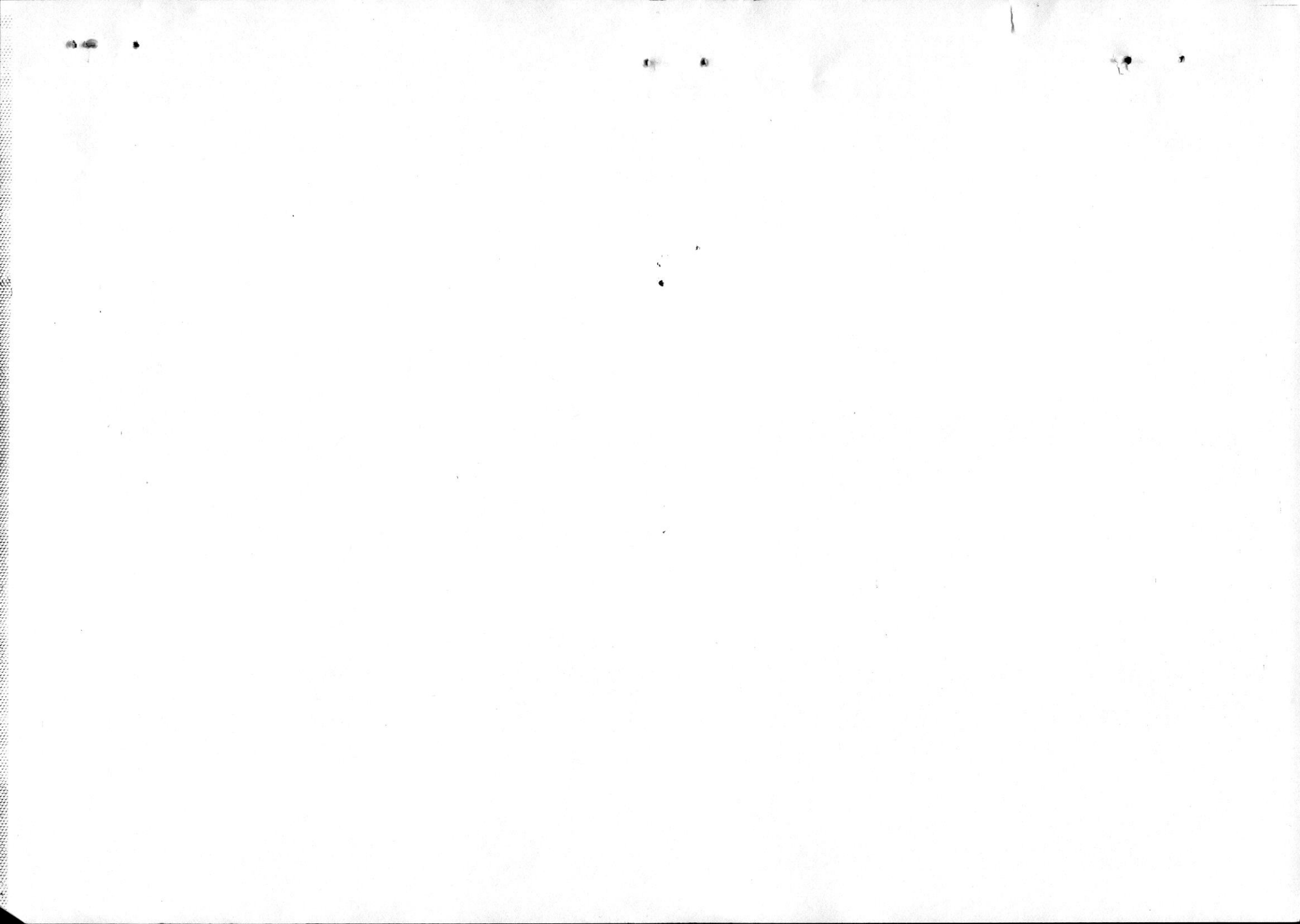
The left and right AMADs are gearboxes that are powered by an Air Turbine Starter (ATS) or an engine-driven Power Transmission Shaft (PTS). Each AMAD drives a hydraulic pump, generator and fuel pump. Each AMAD has a self-contained lubrication system that is also used to cool its corresponding generator. There are three modes of AMAD operation: engine start, engine driven, and ground maintenance. During the engine start mode, pneumatic air from the APU or external ground air source rotates the ATS. The ATS powers the AMAD which then rotates the PTS to either motor or start the engine. During the engine driven mode, the PTS powers the AMAD which in turn drives its corresponding accessories. During the ground maintenance mode, the PTS is decoupled from the AMAD and pneumatic air from the APU powers the ATS. The ATS powers the AMAD which drives the accessories without rotating the engine.

SECONDARY POWER COMPRESSED AIR SYSTEM

The secondary power compressed air system provides pneumatic power for operating the Air Turbine Starter (ATS) or the Environmental Control System (ECS). During APU operation, compressed air is routed to the ATS to drive either AMAD or to the ECS for cooling. An air connection in the right wheelwell allows use of an external air source for system operation. The secondary power compressed air system may also be used to crossbleed compressed air from one main engine to start or motor the second main engine.

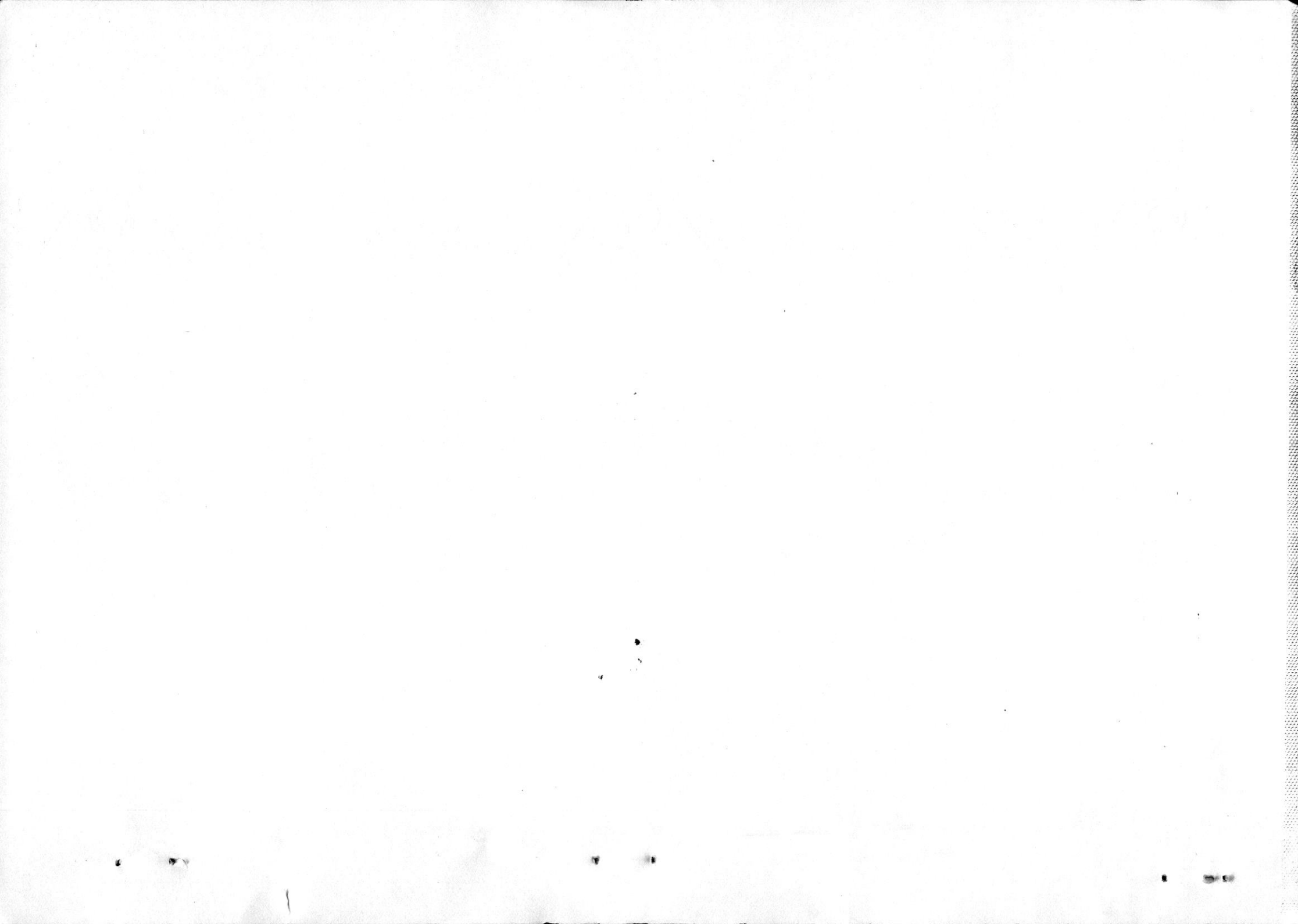
FIRE DETECTION SYSTEM

The fire detection system is a dual-loop system that provides fire warning for the APU bay, left and right AMAD bays and the left and right aft engine bays. The left and right forward engine bays only have a single-loop detection system. A fire condition in either engine or AMAD bay is indicated by a left or right FIRE warning light. When a fire condition is detected, a voice alert of ENGINE FIRE LEFT; ENGINE FIRE RIGHT or APU FIRE is transmitted to the headset.

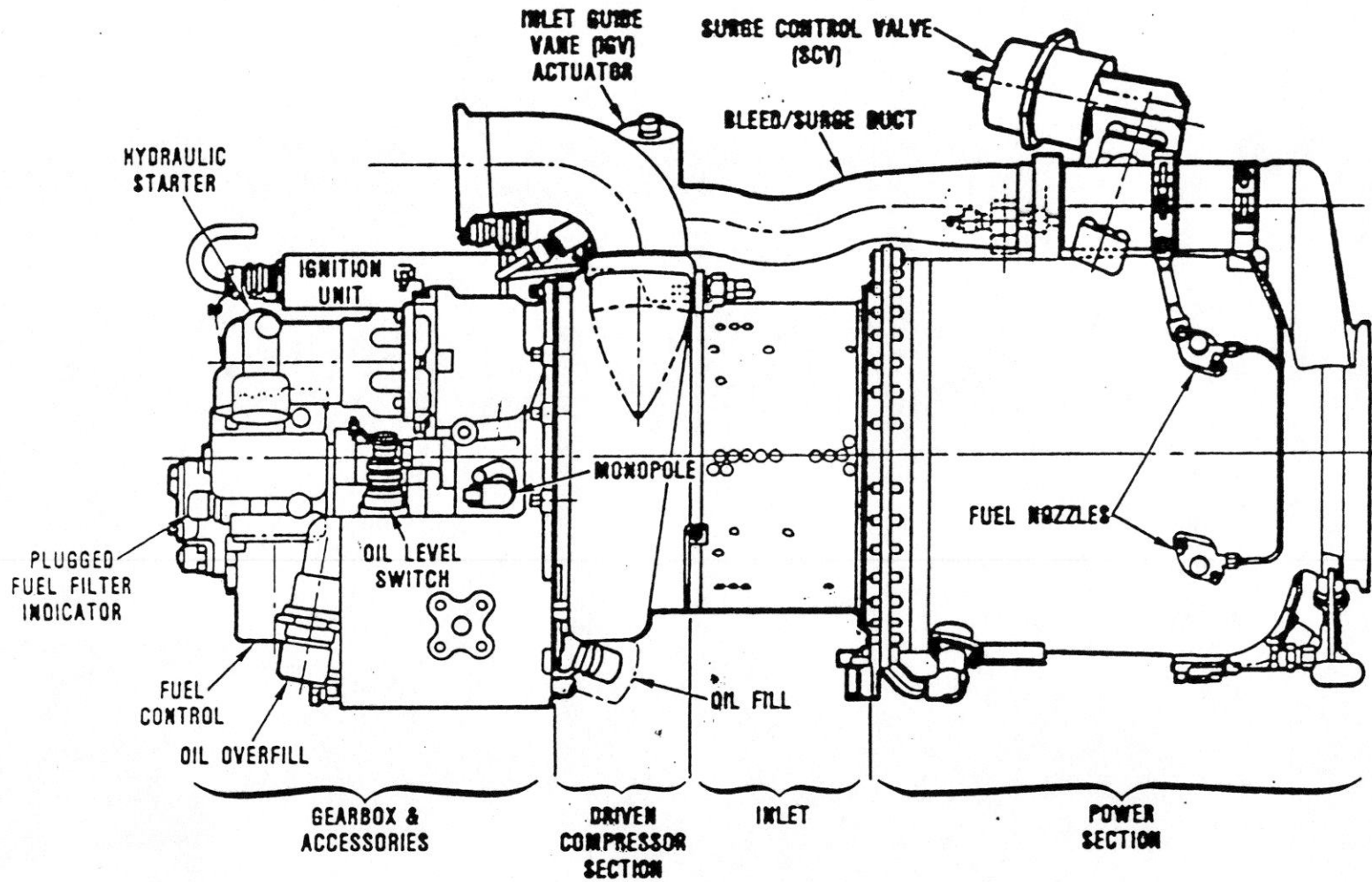


FIRE EXTINGUISHING SYSTEM

The fire extinguishing system uses a single fire extinguisher tank with three distribution lines, one for each APU or engine/AMAD bay. The system is a one-shot one-bay system. During ground operation of the APU, if the fire detection system detects a fire in the APU bay, the APU is automatically shut down and ten seconds later the fire extinguisher agent is discharged into the APU bay. The automatic system does not operate in flight. Manual operation of the APU fire extinguishing system is accomplished by pressing the APU FIRE warning light and then pressing the READY DISCHG light. Operation of the engine/AMAD fire extinguishing system is accomplished by lifting the guard over the left or right FIRE warning light and pressing the light. This shuts down the corresponding engine and arms the fire extinguisher. Pressing the READY DISCHG light causes the fire extinguishing agent to discharge into the selected engine/AMAD bay. On the TF/A-18A aircraft, the fire extinguishing system can only be activated from the cockpit.



GTC36-200 APU FEATURES



4

4

Table 1. Auxiliary Power Unit Leading Particulars

Model	GTC36-200
Type	Centrifugal flow turbojet
Compressor	1 stage centrifugal flow
Turbine	1 stage centrifugal
Driven (Load) Compressor	1 stage centrifugal
Variable Geometry	1 stage
Speeds	61,163 \pm 500 RPM = 98.7% RTL and GMM governed modes 62,400 \pm 500 RPM = 100.7% MES and ECS governed modes
Direction of rotation	Clockwise, aft looking forward
Dimensions:	
Height	20.4 inches
Length	35.4 inches
Width	12.8 inches
Weight Dry	128 lbs (approx)
Fuel	MIL-T-5624 JP-4, JP-5 or MIL-T-83133 JP-8
Lubricant	MIL-L-23699 or MIL-L-7808
Bleed Air Pressure	48 psia maximum
Compression ratio	Approximately 4 to 1
Air horsepower	Approximately 200 lbs. at 100% engine speed (61,974 rpm)
Oil sump capacity	2.73 qts. (2580cc)

Table 2. Operating Limits

Condition	Limit
Acceleration	15 seconds average 18 seconds maximum
Temperature: Inlet air Oil	130°F (54°C) maximum Dependent on ambient temperature to a maximum of 300°F (149°C)
Exhaust gas temperature	1236°F (669°C) maximum allowable steady state
Speed	68,171 rpm maximum
Pressure: Oil pressure Fluctuation Inlet fuel pressure	50 ±5 psig ±2.5 psi steady state operation 5 to 50 psig
Vibration	0.6 in./sec
Leakage: Fuel Oil	One drop per minute from accessory drain only 2 cc per hour from each rotating shaft seal

Table 2. Left/Rear Left Digital Display Indicator

Cautions	
MESSAGE	DESCRIPTION
L ATS	L ATS Speed
R ATS	R ATS Speed
L AMAD	L AMAD Oil Overtemp
R AMAD	R AMAD Oil Overtemp
APU ACCUM	APU Accumulator Low

Table 3. Nose Wheelwell Digital Display Indicator

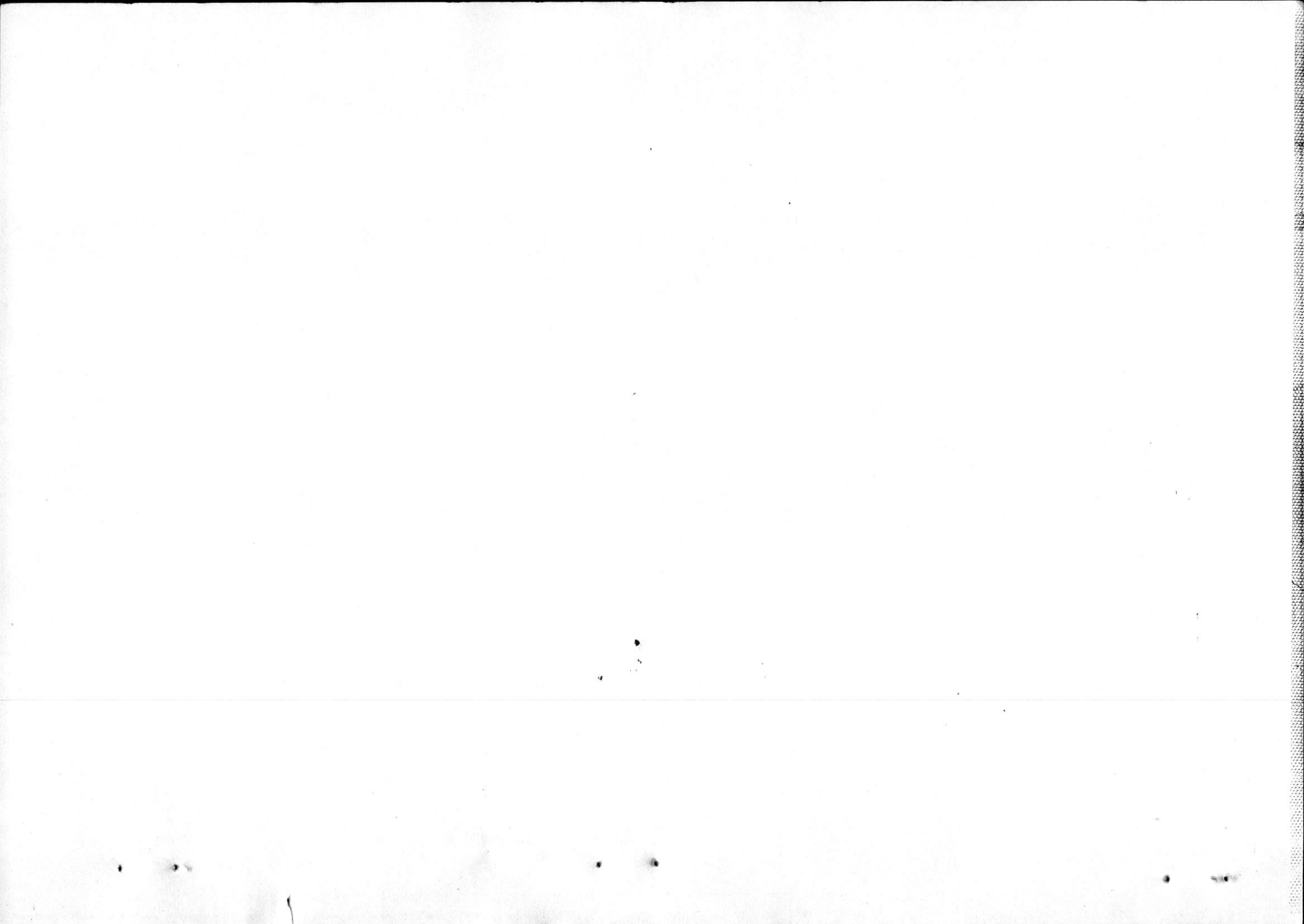
CODE	MALFUNCTION
800	APU Overspeed
801	APU Overheat
802	APU No Flame
804	APU Start Period Timer Timed Out
805	APU Fuel Shutoff Valve Failed to Open
816	Left Amad Oil Pressure Low
817	Right AMAD Oil Pressure Low
818	Left ATSCV Open
819	Right ATSCV Open
982	Left AMAD Oil Level Low
983	Right AMAD Oil Level Low
984	APU Oil Level Low

"APU"

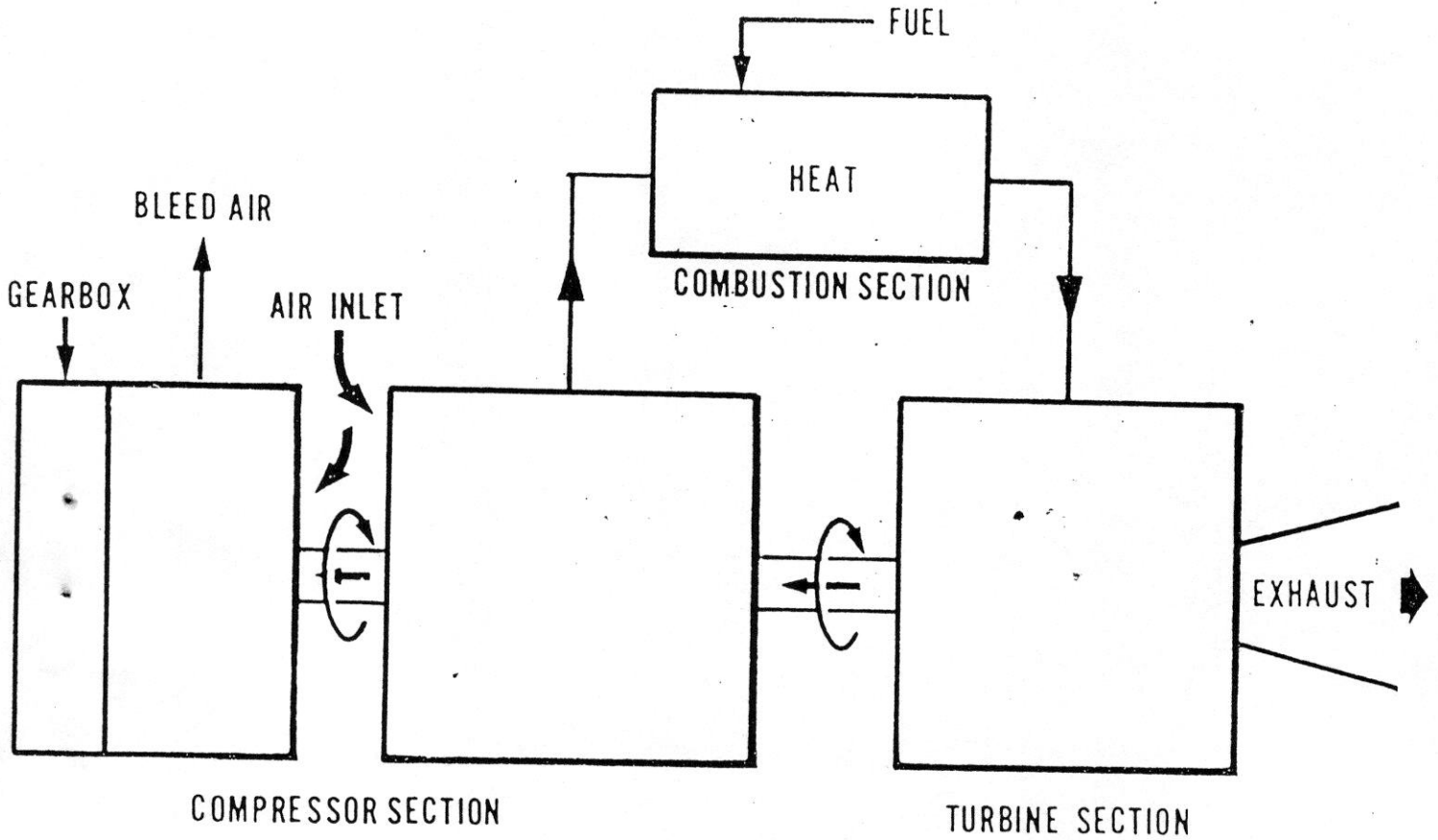
BASIC OPERATING CYCLE

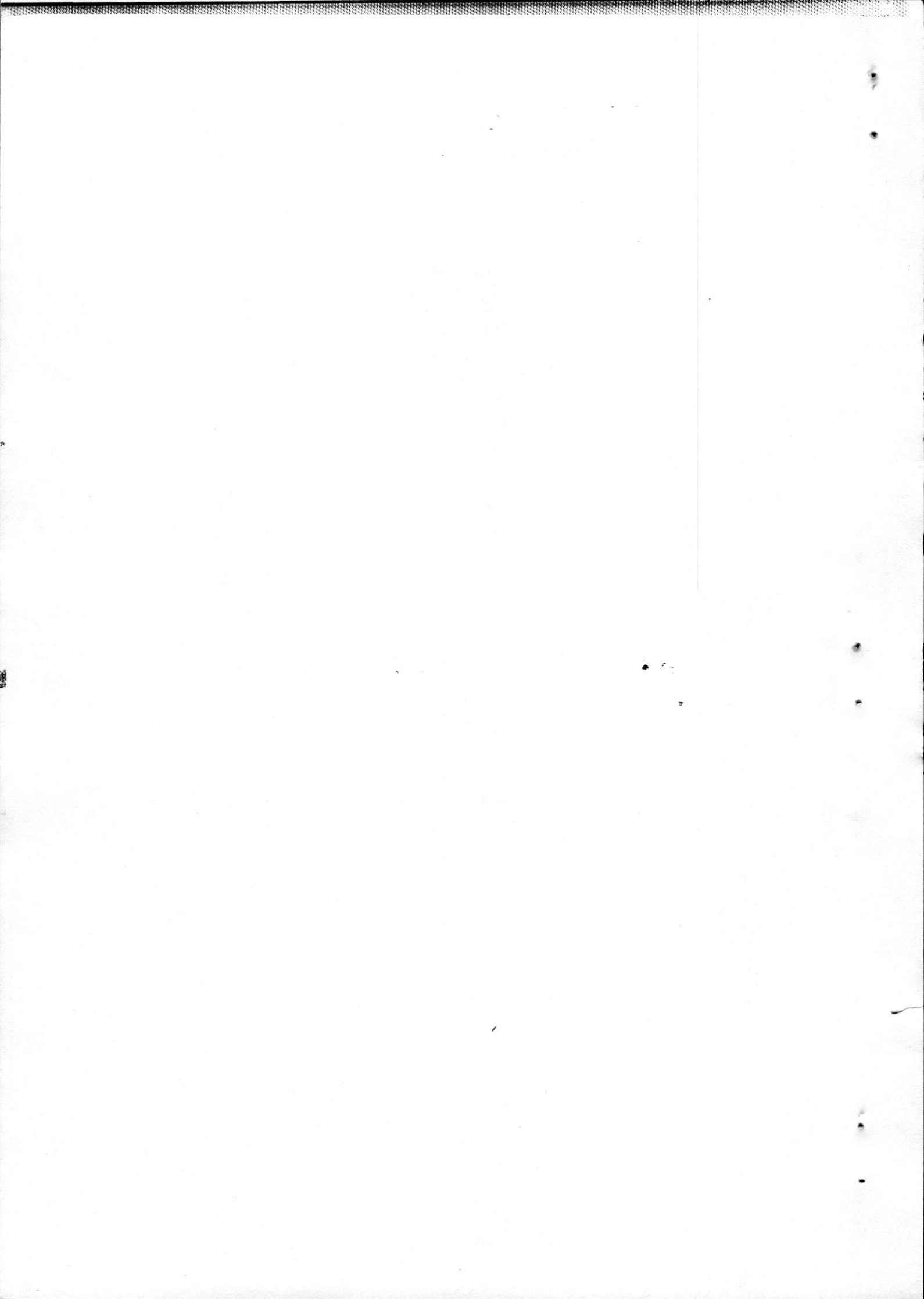
The major sections which make up a basic gas turbine are the compressor, combustor, turbine and the accessories. Such a gas turbine can be started by a starter motor, in this case hydraulic, which turns the gas turbine rotating group through the accessory gear train. The compressor draws in a large quantity of ambient air and forces it through the combustor, and turbine. Fuel is added to the air in the combustor, and the mixture is ignited. The heat energy generated by the burning of the fuel produces expansion of the air flowing through the turbine. The heated air flows at a high velocity through the turbine and returns to the atmosphere via the exhaust. The turbine converts the thermal and kinetic energy in the air into shaft power, which is used to turn the engine compressor, the load compressor and the reduction gears. The reduction gears drive the components necessary for the operation and control of the gas turbine.



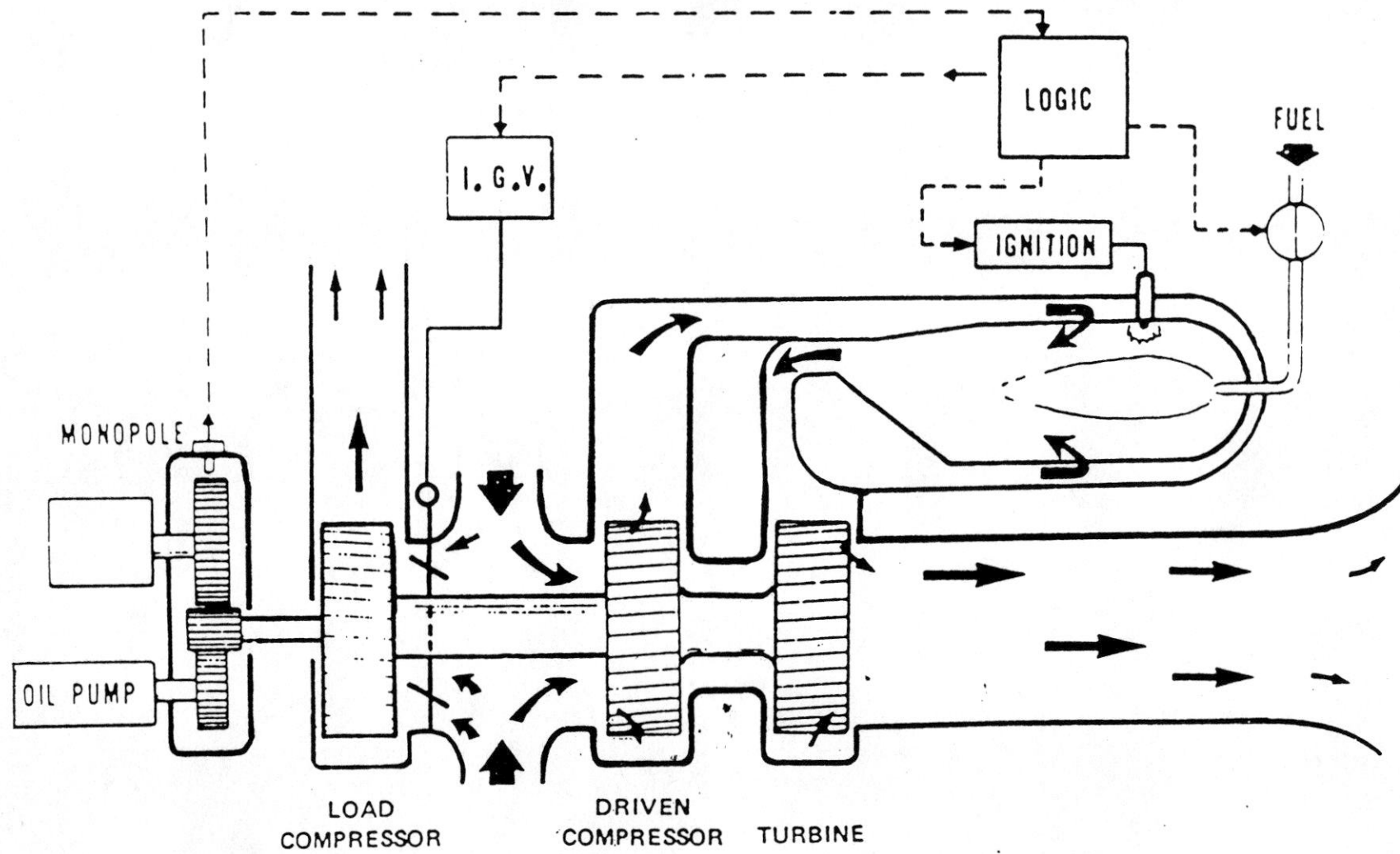


BASIC OPERATING CYCLE





LOAD AND FUEL CONTROL

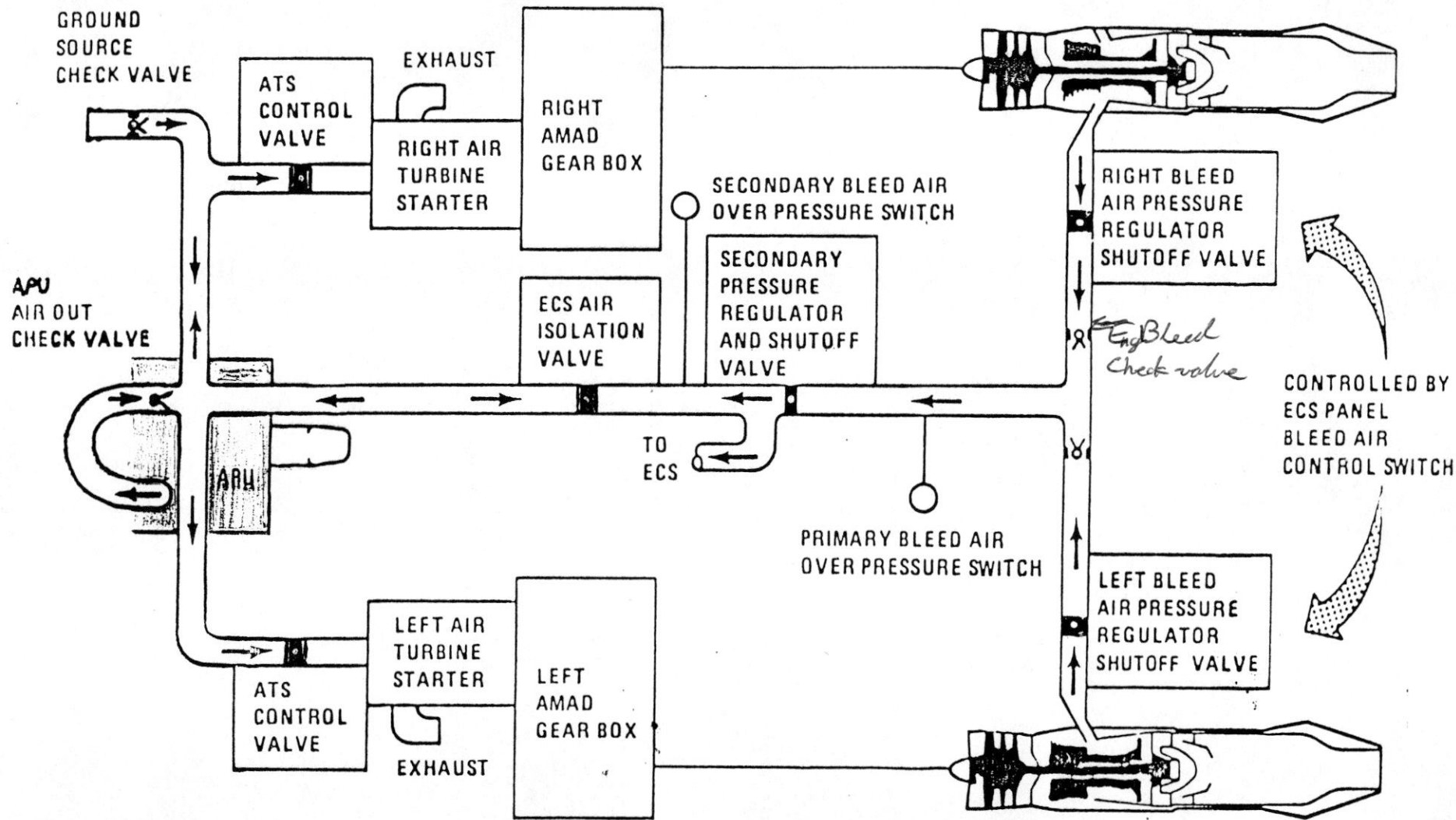


10.
PNEUMATIC CONTROL SYSTEM

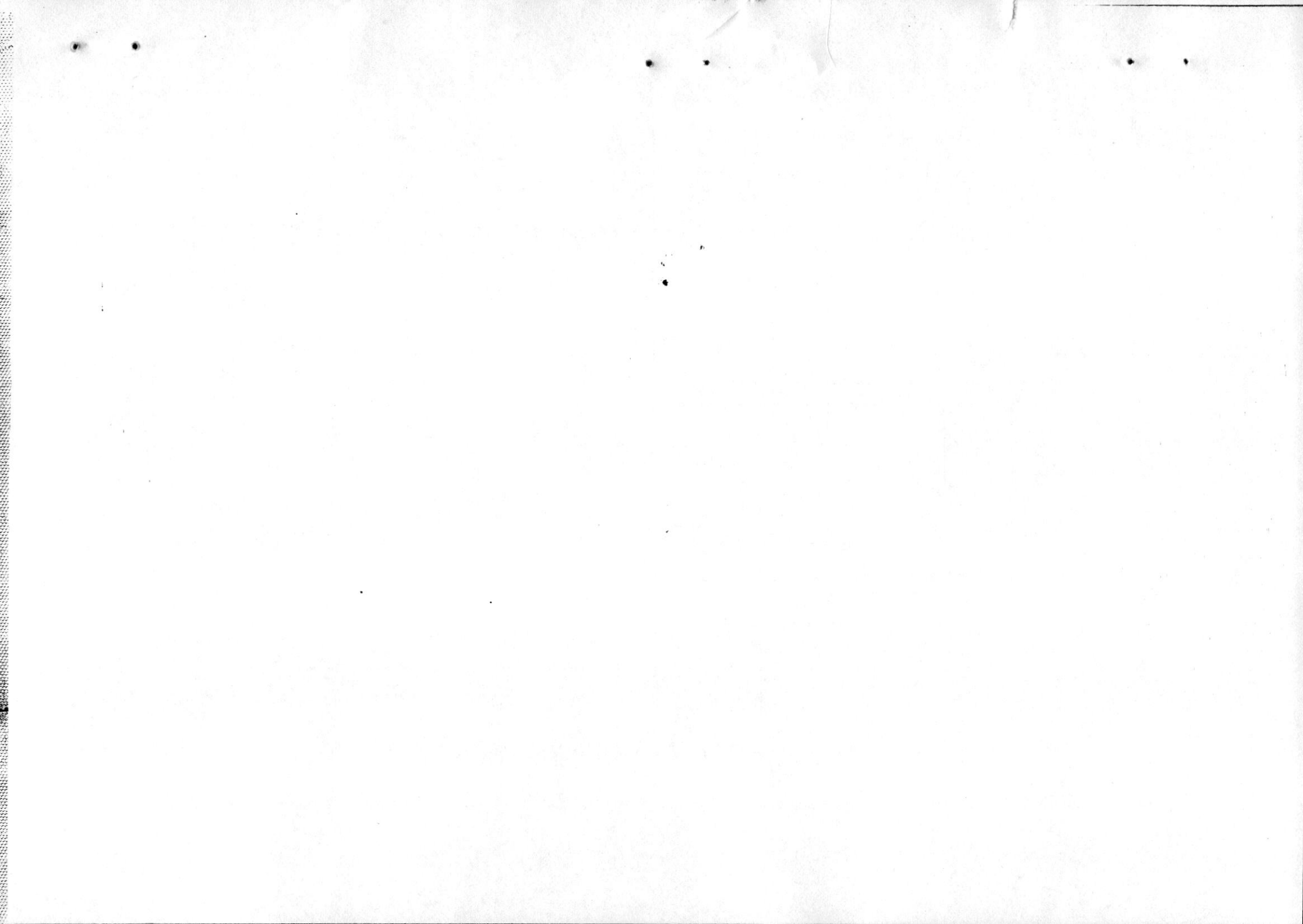
1. The pneumatic control system regulates APU pneumatic power output and provides surge free protection for the load compressor, regardless of system sequencing or demand of downstream pneumatic components.
2. On start the IGVs are closed and the surge control valve is open. At 40% rpm, the surge control valve begins to modulate. When 65% rpm is reach, the IGV actuator positions the IGVs open to 22 degrees. This effectively removes the pneumatic load and makes sure rapid and uniform APU starts are accomplished at all ambient temperatures. At 95% rpm the ECU arms IGV circuit and closes the RTL circuit. At 98.7% rpm the system is in the RTL mode.
3. System operation and modes are:
 - a. RTL. In the RTL mode the ECU signals the IGV actuator to hold the IGVs at the 22 degree position. The surge control valve is open, there is no air available for use, and rpm is maintained at 98.7%.
 - b. GMM. In the GMM mode the ECU signals the IGV actuator to position the IGVs to their full open, 73 degree position, the surge control valve is modulating, and rpm is maintained at 98.7%.
 - c. ECS. In the ECS mode, the ECU signals the IGV actuator to position the IGVs to their full open, 73 degree position, the surge control valve is modulating and rpm is maintained at 100.7%.
 - d. MES. In the MES mode, the ECU signals the IGV actuator to position the IGVs to their full open, 73 degree position, the surge control valve is closed, and rpm is increased to 100.7%.
4. During ECS and MES modes, if APU EGT reaches the ECU set point temperature of 1236°F (669°C), the ECU signals the IGV actuator to modulate the IGVs closed to limit EGT at that temperature.
5. Above 70°F (21°C) ambient temperature, the ECU modulates the IGVs. When ambient temperature decreases below 70°F (21°C), the EGT decreases and the ECU commands the IGV actuator to position the IGVs to their full open position and limits them there.
6. The IGVs are mechanically linked to a control ring, which is positioned by the IGV actuator.
7. Surge control valve operation is controlled by the differential pressures of Pt and Ps received from the flow sensor and load compressor inlet scroll.
8. The APU is installed in the airframe with four mounts. One hinged jaw type mount is on each side of the APU bay provides mounting points for the APU trunnions on each side of the gearbox. One crossbrace mount on the bottom of the combustion case flange mounts to a clevis on each side of the APU bay.

Table 1. Operational Modes Summary

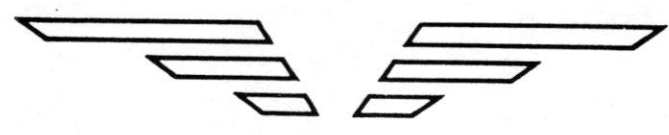
Control Mode	Cockpit Switch Position	Decoupler Position	Driven Compressor IGV Position (degree)	APU Speed (rpm)	Surge Valve
RTL	APU: ON ECS: OFF ENG CRANK: OFF	Coupled or decoupled	22° Open	98.7% (61,163)	Open
GMM	APU: ON ECS: OFF ENG CRANK: R or L	Both decoupled	73° Open	98.7% (61,163)	Modulating
ECS	APU: ON ECS: ON ENG CRANK: OFF	Coupled or decoupled	73° Open 1	100.7% (62,400)	Modulating
MES	APU: ON ECS: OFF ENG CRANK: R or L	Both coupled	73° Open 1	100.7% (62,400)	Closed
<p>1 The IGVs are against the full open stop (73 degrees) or modulating to maintain constant EGT (1236°F)</p>					



BLEED AIR SUBSYSTEM



SEI 477



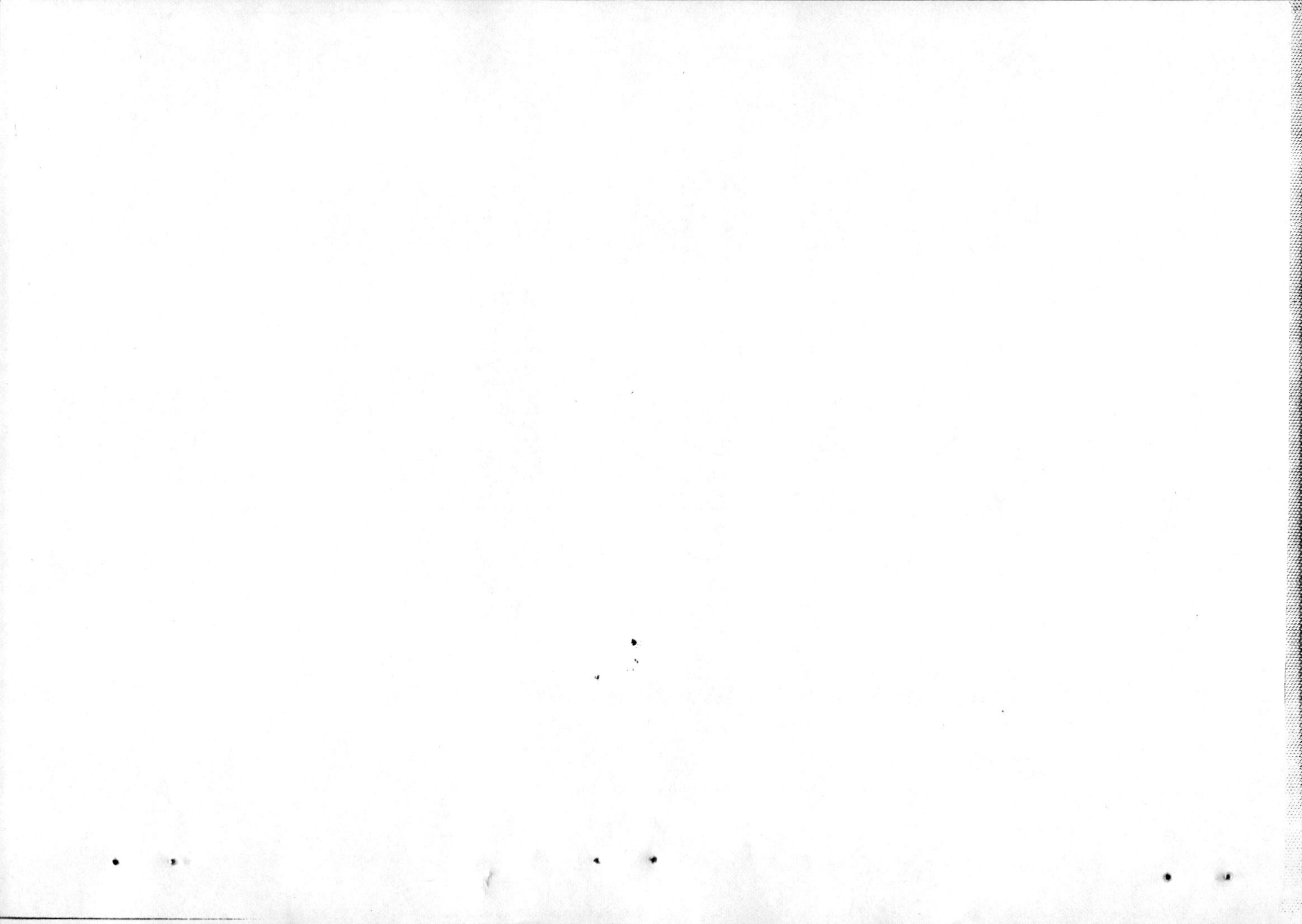
F404

TRAINING GUIDE



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INTRODUCTION

The purpose of this Training Guide is to provide background information on the General Electric F404-GE-400 Augmented Turbofan Engine. It is intended that it be used for training purposes only and not as an official document relative to installation or service.

Information on installation or service may be obtained from the appropriate official Technical Publication.



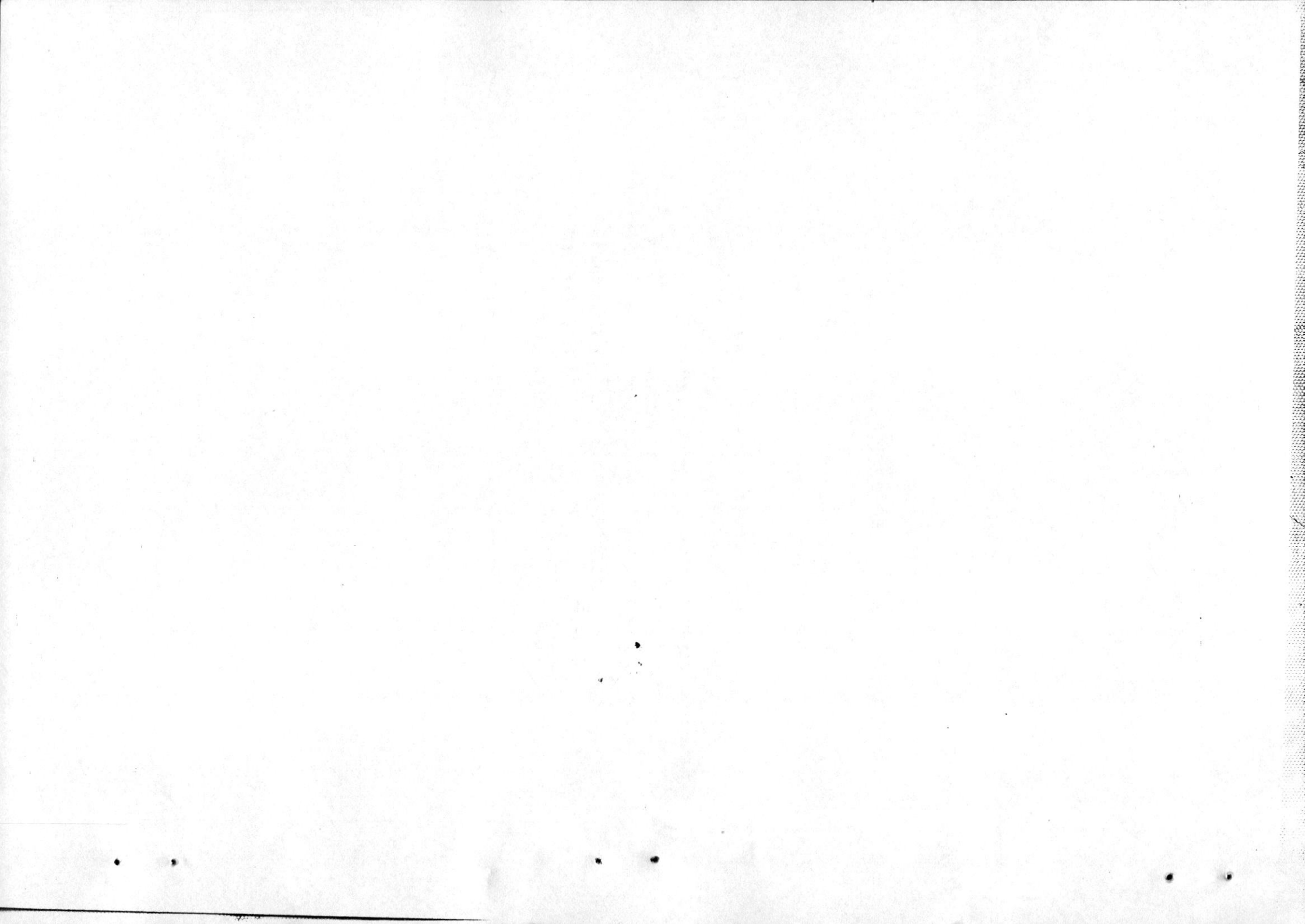
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COMMON ABBREVIATIONS

A_8	Variable Exhaust Nozzle (VEN) Throat Area
ABC	Afterburner Control
BH	Compressor Variable Geometry (CVG) Angle
BL	Fan Variable Geometry (FVG) Angle
C&D	Check-and-Drain (Valve)
CDP	Compressor Discharge Pressure
CVG	Compressor Variable Geometry
ECA	Electrical Control Assembly
EGT	Exhaust Gas Temperature
EOD	Engine Object Damage
F/B	Feedback
FOD	Foreign Object Damage
FVG	Fan Variable Geometry
HPC	High-Pressure Compressor
HPT	High-Pressure Turbine
IGV	Inlet Guide Vanes
IRP	Intermediate Rated Power Maximum Non-Augmented Thrust)
LPT	Low-Pressure Turbine
LVDT	Linear Variable Differential Transformer
MFC	Main Fuel Control
MFP	Main Fuel Pump
M_p	N2 Lockup
N_2	Compressor/High-Pressure Turbine Speed
N_1	Fan/Low-Pressure Turbine Speed
OAT	Outside Air Temperature
OBD	Overboard Drain
OGV	Outlet Guide Vanes
P_{BL}	Customer Bleed Throat Pressure
PLA	Power Lever Angle (Throttle Setting)
PLC	Power Lever Control
P_0	Ambient Air Pressure
P_{S3}	Compressor Discharge Static Pressure
PTO	Power Takeoff
$P_{15.6}$	Low-Pressure Turbine Discharge Total Pressure
PU	Power Unit

COMMON ABBREVIATIONS - (Continued)

RGI	Rocket Gas Ingestion
RTD	Resistance Temperature Device
RVDI	Rotary Variable Differential Transformer
SFC	Specific Fuel Consumption
TM	Torque Motor
T_1	Fan Inlet Temperature
$T_{2.5}$	Compressor Inlet Temperature
T_5	Low-Pressure Turbine Discharge Temperature
T_{5C}	Low-Pressure Turbine Discharge Temperature (Signal from ECA for Cockpit Indicator)
T_{5H}	Low-Pressure Turbine Discharge Temperature (Amplified Harness Signal)
VEN	Variable Exhaust Nozzle
VG	Variable Geometry
W_F	Combustor Fuel Flow
W_R	Afterburner Fuel Flow
W_{RM}	Afterburner Main Fuel Flow
W_{RP}	Afterburner Pilot Fuel Flow

SECTION 1

BASIC ENGINE

A. GENERAL (See Figures 1-1 through 1-5)

The F404-GE-400 turbofan engine is designed and manufactured by the Aircraft Engine Group of the General Electric Company in West Lynn, Massachusetts. It is a low-bypass fan engine with afterburner. The engine is of a modular construction, consisting of six major engine modules (see Figures 1-1 and 1-2). It consists of a three-stage fan driven by a single-stage low pressure turbine and a seven-stage axial flow compressor, which is driven by a single-stage high pressure turbine. Both the fan and the compressor incorporate a variable geometry system. The engine has a through flow, annular combustor. The engine-mounted accessory gearbox provides the necessary extracted power needed to drive the accessories. The lubrication and ignition systems are self-contained on the engine.

The two rotor systems are supported by a total of five main engine bearings. Bearings number one, two, four and five support the low-pressure system, ie. the three-stage fan and single-stage turbine. The high-pressure rotor system is supported by the number three and four bearings (see Figure 1-3). Bearings number one and three are ball bearings and are designed to absorb the axial thrust on the low and high pressure systems respectively. The number two and five bearings are roller bearings. The number four bearing, also a roller bearing, is a differential bearing and provides support for both the high and low pressure rotor systems. The engine bearings are housed by three sump areas (see Figure 1-3). The A-sump houses the number one bearing, the B-sump houses bearings two and three, and the C-sump bearings four and five. Oil in the sump areas is contained within the B and C sump by carbon seals at each end, and in the A-sump by a pressurized two step labyrinth seal at the aft end and the A-sump cover at the forward end.

The engine is divided into nine station locations which is shown in Figure 1-4. Station locations are used in describing engine temperature and pressure taps as well as borescope inspection locations.

The F404, being a low-bypass engine, takes the fan discharge air and splits this air at the midframe where approximately twenty-five percent is bypassed and the remaining seventy-five percent is used to supercharge the high pressure compressor.

There are three major structural frames on the engine consisting of outer and inner shells and support struts. The struts of the front frame, midframe, and exhaust frame are utilized for service lines to the sump areas. This strut usage is shown in Figure 1-5 and is discussed in more detail in the appropriate descriptive sections.

Some of the maintenance features on the F404 engine include the fact that the engine can be assembled and disassembled in six modules, thirteen borescope ports are provided throughout the engine; external components are mounted below the horizontal centerline for better access in the installed condition; electrical connectors are foolproofed; at organizational level there are no lockwire fasteners to cope with; engines are interchangeable in the left or right engine bays of the aircraft; maintenance on the engine can be performed either in the horizontal or vertical position; no trimming is required at the "0" level, and the engine does not require any quick engine change (QEC) components.

B. FAN MODULE (See Figures 1-6 through 1-14)

1. General. The F404 fan module consists of a front frame, fan rotor, fan stator assembly, variable geometry system, and number one thrust ball bearing, and the number two bearing inner race (see Figure 1-6).

2. Front Frame. (See Figure 1-7). The front frame assembly controls the flow of inlet air to the engine. It is a brazed construction consisting of an outer shell, anti-icing manifold, eighteen hollow struts, and the number one bearing support. Also included in the assembly are

- eighteen variable inlet guide vanes, a two-piece vane actuating ring, the inlet guide vane shroud, inlet centerbody, A-sump cover, and number one
- bearing ball cage and outer race. The eighteen hollow struts are equally spaced circumferentially between the outer shell and the bearing support. The bearing support locates the outer race of the fan rotor thrust bearing and also forms the engine A-sump. The A-sump seal and cover are fastened to the forward face of the bearing support.

Fourth-stage compressor bleed air is used to anti-ice the inlet centerbody and eighteen hollow struts by means of the anti-icing manifold which surrounds the front frame. The trailing edge of each strut has a series of holes through which anti-icing air flows to bath each inlet guide vane. The hollow struts also house the service lines to the A-sump (see Figure 1-5). The two o'clock strut is used for the oil-in line to the number one bearing, four-thirty o'clock strut is an overboard drain, and the seven-thirty o'clock strut is utilized for the A-sump scavenge line.

Located behind the fixed struts are the variable inlet guide vanes which are supported by spindles by the IGV shroud and inner shell. The outer spindles are attached by levers to a two-piece actuating ring (see Figure 1-8). Circumferential movement of the actuating ring causes synchronized opening and closing of the inlet guide vanes. The fixed struts and inlet guide vanes direct the inlet air to the fan rotor at the optimum angle for the particular condition of engine operation.

The A-sump houses the number one bearing which is the main thrust bearing for the low-pressure rotor system. The A-sump cover seals the forward end of the sump and the aft portion of the sump is sealed by a two step labyrinth seal which is pressurized by fan discharge air from the seal pressurization tube. The number one ball bearing has a split inner race. The forward half of the split inner race has a puller groove for assembly and dis-assembly purposes.

3. Fan Rotor. (See Figures 1-9, 1-10, 1-11). The fan rotor is a three-stage titanium rotor which is driven by the single-stage low-pressure turbine. The forward end of the fan rotor is supported by the number one ball bearing and the aft end by the number two roller bearing. Stage one has thirty-two blades with midspan dampeners, stage two has forty-two blades, and stage three has fifty-two blades. The rotor structure consists of three disks and an aft shaft bolted together (see Figure 1-9). The fan forward shaft is integral with the first-stage disk. Each disk has broached slots which radially retain the single-tang dovetailed blades. Assembled to the forward end of the rotor is the inner race of the number one bearing and the mating portion of the two step labyrinth A-sump aft seal. The tube, which passes through the center of the fan rotor, is called the seal pressurizing tube. Its purpose is to direct fan discharge air through holes in the forward shaft to pressurize the A-sump aft seals.

The stage one rotor blades are retained at their forward ends by a retaining ring and two balance rings. These balancing rings enable rotor imbalance corrections to be made within limits without removing the blades. The aft end of the first-stage blades are retained by the forward circumferential flange of the stage two disk, and the stage two blades are likewise retained by the stage three disk. At the aft flange of the stage one disk is a windage screen which is used to prevent recirculation of air through the stage one blade shank. The forward ends of the stage two blades, and the forward and aft ends of the stage three blades are retained axially by retaining rings (see Figure 1-10).

Interstage sealing is accomplished by three air seals on the stage two and stage three disk spacer flanges. An integral seal ring on the stage three disk forward flange prevents airflow through the stage two blade shanks. The fit of the stage three blade-to-disk dovetail at the forward end provides stage three interstage sealing. The stage three aft circumferential flange is attached to the fan aft shaft which couples to the low-pressure turbine drive shaft by means of a spline joint and are secured by the fan lock bolt. Assembled to the fan aft shaft is the number two bearing inner race, rotating air seal, and seal runner (see Figure 1-11).

4. Fan Stator. (see Figures 1-12 and 1-13). The fan stator consists of a two-piece case assembly, sixty-eight stage one fixed vanes, ninety stage two fixed vanes, one hundred and four stage three fixed vanes.

The two-piece titanium constructed fan stator case is split and flanged on the horizontal centerline. The forward end of the fan case is bolted to the front frame, and the aft end is bolted to the midframe forward flange.

The casing has sixty-eight equally spaced bosses with machined bores which support the outer spindles of the stage one vanes. The inner spindles of the vanes are supported by two, hundred and eighty degree segmented shrouds axially bolted together. A circumferential T-groove in the casing is used to retain the stage two and stage three fixed stator vanes. The inner ends of the stage two vanes are supported by a ten segment split aluminum shroud. The ten segments are attached to the vanes by means of a machined circumferential rail which slides onto the inner ends of the vanes. The inner ends of the stage three fixed vanes are supported by ten, thirty-six degree shrouds that engage the inner ends of the vanes through bushings and a ninety degree segmented retainer. After the stage two and three fixed vanes are loaded in each case half a vane key is inserted in the T-groove which serves to lock the vanes in place. These are located on the nine o'clock and three o'clock split lines.

The stage one vane outer spindles are secured to the stator case by means of a lockplate and washer assembly. The movement of the IGV actuating ring is caused by a fuel driven actuator through a bellcrank and turnbuckle arrangement located at the eight o'clock position on the fan casing. The bellcrank has two arms, one arm is connected directly to the actuator, and one is link-connected to the front frame inlet guide vane actuating ring.

At the five and eight o'clock positions on the fan stator case are located two fan speed (N_1) transmitters. The transmitters are located directly over the stage two blade tip path, and are used to transmit a fan rotor speed signal to the electrical control unit (ECA). Mounted also on the fan stator casing at the four o'clock position is the ignition exciter.

C. HIGH-PRESSURE COMPRESSOR MODULE (See Figure 1-15 through 1-29).

1. General. The F404 high-pressure compressor module consists of a midframe, a seven-stage axial flow compressor rotor, compressor stator, outer bypass duct, rear engine mount ring, combustion chamber case, the number two roller bearing outer ring, the number three high-pressure rotor main thrust ball bearing, fuel nozzles and fuel manifold, the compressor variable geometry actuation system, and power takeoff assembly.

2. Midframe. (See Figure 1-16). The compressor midframe is a one-piece casting with eight equally spaced hollow struts, and a splitter located at the aft end of the struts. The midframe forward flange is bolted to the fan casing aft flange. The fan exit fairing is supported by the forward inner hub of the midframe, and provides a path for fan discharge air to the compressor midframe, as well as providing additional support for the fan stage three vane shrouds. The midframe receives this air, and the splitter divides and directs the air to the compressor and bypass duct. Approximately twenty-five percent of fan discharge air enters the bypass duct and the remaining seventy-five percent supercharges the high-pressure compressor.

The number two bearing support is bolted to the inner forward end of the midframe and supports the number two bearing outer race and stationary seals, which in turn, support the fan rotor aft shaft. The number three bearing spring mount is attached to the inner aft side of the midframe and supports the number three thrust ball bearing outer race and stationary seals, which in turn, supports the compressor rotor forward shaft. The number three bearing is the exact same bearing as the number one ball

- bearing. The cavity formed between the number two carbon seal and number three carbon seal is the B-sump area. Also housed within the B-sump cavity just forward of the number three bearing, and assembled on the compressor forward shaft, is the PTO bevel gear which meshes with the PTO assembly bevel gear for extraction and transfer of engine power to the gearbox through the radial drive shaft.

The midframe hollow struts are utilized to provide access for service lines to the B-sump area (see Figure 1-5). In the aft looking forward direction the twelve o'clock strut is used to centervent the B and C-sumps. At the four-thirty o'clock position is the oil-in line and the number two seal drain. The seven o'clock strut is used for the B-sump scavenge and the number three seal drain.

The aft bolt flanges of the midframe provide the surfaces for attaching the outer bypass duct, and the compressor stator forward case. The midframe air duct, attached to the aft end of the midframe, supports the forward end of the compressor inlet guide vane support ring, provides the stationary air seal for the compressor rotor front spool, and ducts cooling air to the HPC rotor. At the six o'clock position on the midframe is provided a pad for mounting the accessory gearbox. Through the six o'clock strut passes the radial drive shaft which extracts the power from the engine, through the power takeoff (PTO) assembly to provide power to the accessory components via the gearbox (see Figure 1-21). The six o'clock strut also serves as a gravity drain for the oil from the B-sump to the gearbox. At the midframe, three and nine o'clock positions, pads are provided for attaching the engine thrust mounts. The lifting lug is bolted at the twelve o'clock position of the midframe.

3. Compressor Rotor. (See Figures 1-17 through 1-20). The compressor rotor is a seven-stage rotor driven by a single-stage high-pressure turbine. The rotor consists of a forward shaft, stage one and two forward

spool, stage three disk, and stage four through seven aft spool. These components are all bolted together at one major bolt circle on the stage three disk. The number of blades per stage are as follows: stage one and two (forty-seven), stage three (sixty-one), stage four (seventy-three), stages five, six, seven (eighty-two).

The forward shaft is supported by the high-pressure compressor number three thrust bearing. The forward shaft supports the number three bearing rotating oil seal, the inner race of the number three ball bearing and provides a spline at the forward end for assembly of the bevel gear that drives the accessory gearbox through the power takeoff radial drive shaft assembly.

The forward spool contains rotor stages one and two. The stage one and two spool incorporates axially broached dovetail slots which radially retain forty-seven blades in each stage. The blades on stages one and two are axially retained in each stage by retaining rings installed at both ends of the spool. Blade retention in the stage three disk and stages four through seven spool is accomplished by circumferential machined grooves. To prevent circumferential blade rotation, locking split nuts interspaced between specially adapted blades is employed (see Figure 1-20). Interstage sealing is provided by seal teeth integral with the forward and aft spools located between each stage.

Air directed to the compressor forward rotor shaft from the midframe struts is also used for compressor rotor cooling. This cooling air enters and fills the rotor through holes located in the forward rotor shaft. The cooling air exits the rotor cavity through the high-pressure turbine aft shaft and seals. Leakage of cooling air by the forward end of the rotor shaft air seals serves to pressurize the B-sump aft number three carbon seal. Airflow is covered in more detail in Section 2.

4. Compressor Stator. (See Figures 1-22 through 1-25). The compressor stator consists of an upper and lower forward and aft casing, variable inlet guide vanes, variable stage one and two vanes and variable geometry actuation system. There are fixed vanes on stages three, four, five

and six, and one outlet guide vane stage. The forward and aft cases are circumferentially bolted together at stage four and assembled between the compressor midframe aft bolt flange and the combustion chamber case forward bolt flange. For assembly and inspection purposes both the forward and aft casings are split and flanged at the horizontal centerline.

Machined in the forward casing halves are bosses which serve to support the outer spindles of the compressor variable inlet guide vanes and stage one and two variable vanes (see Figure 1-23). The inner spindles of all variable vanes are supported by shroud support segments which are assembled radially to each vane. There are fifty-six IGV's supported by fourteen inner shroud segments with four IGV's per segment. Variable stage one has eighty-four vanes and stage two has seventy-two. Both stage one and two have twelve inner shroud segments with seven per on stage one and six per on stage two. Each vane rotates within spindle bushings which are inserted between the spindles and shroud support segments. Axially installed at each end of the segments are two pins which captures a slot in each end bushing and radially retains each segment. Retention of the pins and spindle bushings for the inlet guide vanes is accomplished by four retainers assembled to T-rails on the inner diameter of the shroud support segments. The pins and spindle bushings for variable stage one and two vanes are retained by honeycomb air seals which are installed in the same manner as the inlet guide vane retainers.

The inlet guide vane and stage one and two variable vane outer spindles are individually attached by lever arms to a four-piece ninety degree segmented actuating ring. Two fuel-driven actuators, bellcrank, and linkage systems located on each side of the compressor case are used to drive the actuating rings. The actuating rings are linked together through connectors causing a synchronized movement of the inlet guide vanes and stage one and two variable vanes.

Stages three through six each contain twelve segmented sections of fixed vanes which are retained and assembled circumferentially in T-grooves in the stator casings, stage three in the forward case and stages four, five and six in the aft case. The inner end of each vane segment is shrouded by a honeycomb seal that is retained by l-rails. This honeycomb sealing together

with the labyrinth seals between each rotor stage is used to form the inter-stage sealing. The outlet guide vane stage is a fixed vane ring. The aft portion of the outlet guide vane ring assembles in a circumferential groove at the forward end of the combustion chamber case (see Figure 1-26). The vane ring is retained in place on the combustion chamber casing by twelve bolts.

Fourth-stage compressor bleed air is used for front frame anti-icing and for low-pressure turbine cooling. The compressor aft case provides a bleed air passage via a circumferential manifold externally welded and located over the fourth and fifth-stage vanes. Air enters the manifold directly through bleed air holes in the case shell. This air is directed to these from the aft side of the stage four fixed stator vanes. Connected to the manifold are three bleed air ducts. The bleed ducts at the one o'clock and seven o'clock positions are utilized for turbine cooling and the six o'clock duct is for front frame anti-icing (see Section 2).

5. Outer Bypass Duct. (See Figure 1-27). The outer bypass duct is a two-piece titanium case construction. It is split and flanged slightly below the horizontal centerline and is assembled between the midframe and the engine rear mount ring. The outer bypass duct provides an enclosure for the bypass air between the midframe and the afterburner module. Primary use for this fan discharge bypass air is for afterburner liner cooling. Also, air within the bypass duct enters the struts in the exhaust frame and is used to pressurize the number five and number four carbon seals of the C-sump.

Four borescope inspection ports are provided in the upper half of the bypass duct. Three are utilized for inspection of the combustor and one inspection port for the compressor. The lower half has two borescope inspection ports for the combustor and the high and low pressure turbine areas. Located at the five o'clock position, passing through the outer duct into the combustion chamber, is a single igniter plug. This igniter plug port also serves as one of the combustor borescope inspection ports. Located just forward of the igniter plug are two service pads. The forward service pad is used to support the anti-icing duct and the customer bleed air duct. The aft service pad supports two air pressure (Ps3) signal taps and the fuel inlet line.

6. Engine Rear Mount Ring. (See Figure 1-27). Assembled between the outer bypass duct and the afterburner module is the engine rear mount ring. The primary purpose of the rear mount ring is to provide vertical support to the aft end of the engine to the airframe. Four adjustable links at the two, four, eight, and ten o'clock locations, secure the rear mount ring to the turbine exhaust frame. In addition, it provides for absorption of radial and axial thermal expansion. The mount ring also supports the oil supply line and two scavenge lines which service the C-sump area. The C-sump oil-in line is located at the three-thirty o'clock position and the two scavenge lines are located at the five-thirty and seven o'clock positions (see Figure 1-5).

7. Combustion Chamber Case. (See Figure 1-26). The combustion chamber case is circumferentially bolted to the compressor stator aft casing bolt flange, and provides a path for compressor discharge air to the combustion module. The combustion chamber case consists of a diffuser, an outer case and inner case, all fabricated into one assembly. The diffuser contains six equally spaced airfoil-shaped struts which support an inner hub and outer case. The outer hub has an annular manifold that receives compressor discharge air through holes aft of the struts and directs the air to the customer bleed port at the six o'clock location. The outer hub also provides a flange on the forward side for attaching the outlet guide vanes.

Eighteen fuel nozzles are supported in the outer case of the combustion chamber by eighteen equally spaced pads. The outer case also has two pads for attaching the turbine cooling air tubes.

The eighteen fuel nozzles are supplied with fuel through a two-piece fuel manifold with pigtail attachments. The low-flow passages of the fuel nozzles remain permanently open and as soon as the fuel manifold fills, primary atomization of the fuel takes place. When a higher fuel pressure occurs across the nozzle, fuel is then supplied to a secondary chamber and dual atomization occurs.

D. COMBUSTOR MODULE (See Figures 1-30, 1-31 and 1-32).

1. General. The combustor module consists of a combustion liner, the high-pressure turbine nozzle, and the nozzle support and static seals.

2. Combustion Liner. The liner is a full annular through-flow assembly. The liner consists of Hastelloy-X inner and outer shells, inner and outer cowls, and a dome assembly with eighteen cast venturi swirlers. The dome assembly has eighteen equally spaced barrels which retain the venturi swirlers. The venturi swirlers are retained in such a manner that they are free to move to compensate for fuel nozzle alignment and thermal expansion.

Fuel is supplied from the fuel nozzles directly into the forward part of the liner assembly. The swirlers are designed to accept compressor discharge air, causing the air to rotate circumferentially while at the same time mixing with the fuel. The result being full and positive atomization of the air and fuel and a more complete burning of the mixture and thus less smoke emission.

A pattern of inner and outer louvers and dilution holes are located on both the inner and outer shells. These holes permit the passage of flowpath air into the liner where it will mix with the products of combustion and reduce the gas temperature to a level suitable for entrance into the high-pressure turbine nozzle.

At the five o'clock position of the outer liner there is a bushing and floating ferrule designed to accept the main igniter plug.

3. High-Pressure Turbine Nozzle. The high-pressure turbine nozzle is a segmented assembly consisting of twenty-two two-vane segments for a total of forty-four airfoils. Both ends of each segment are slotted and during assembly of the nozzle, small seal strips are installed between the segments to prevent air leakage out of the nozzle. The segments bolt to the nozzle

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support which provides the main support for the combustor module. Also contained on the nozzle support are the stationary air seals which control secondary air flow between the compressor and high-pressure turbine module creating the balance piston effect.

E. HIGH-PRESSURE TURBINE MODULE (See Figures 1-33 and 1-37).

1. General. The high-pressure turbine module consists of a single-stage rotor assembly, the number four differential roller bearing, the low-pressure fan drive shaft, and the C-sump air duct.

2. High-Pressure Turbine Rotor. (See Figures 1-34 through 1-39). The single-stage high-pressure turbine rotor drives the high-pressure compressor rotor. The high-pressure turbine rotor consists of the HPT disk, aft shaft, outer balance piston seal, forward shaft and inner balance piston seal, and sixty-four dovetailed blades. The disk construction is such that it has sixty-four broached dovetail slots which serve to radially retain the turbine blades. The sixty-four blades are retained axially by forward and aft cooling plates which are bolted to each side of the disk. These cooling plates also serve to prevent turbine rotor cooling air from leaking into the hot gas path. Assembled to the aft side of the HPT disk by a circumferential bolt circle is the HPT aft shaft. It is supported at its aft end by the number four differential roller bearing outer race. The number four bearing provides the main aft support for the high-pressure rotor system.

Bolted to the forward side of the HPT disk is the outer balance piston seal and forward shaft and the integral inner balance piston seal. The outer and inner balance piston seals incorporate labyrinth teeth which mate with the static seals of the high pressure turbine nozzle main support mentioned under the combustor chamber section. The balance piston effect is accomplished by secondary air entering the balance piston chamber through holes provided in the HPT nozzle support and accelerated through an inducer

into the balance chamber cavity. The inner and outer balance piston labyrinth type rotating seals also provide an air seal between the compressor and turbine rotors. By means of circumferential bolt circle the HPT forward shaft is bolted to the compressor rotor aft spool enabling the HPT rotor and HPC rotor to rotate as one unit. The compressor and high-pressure turbine rotor which makes up the high-pressure rotor system is now supported at the forward end by the number three ball thrust bearing, and as previously mentioned, at the aft end by the number four differential roller bearing.

Installed around the low-pressure drive shaft and between the compressor rotor forward shaft and high-pressure turbine rotor aft shaft is the C-sump air duct. This air duct forms the inner wall of the compressor and turbine rotor cavity. Fan discharge air is directed to this cavity through holes in the compressor forward shaft and is utilized for compressor and turbine cooling. This cooling air is permitted to exit this cavity through holes provided in the high-pressure turbine aft shaft. The cooling air is then allowed to flow under the low-pressure turbine disk and to exit through holes in the torque cone. Engine airflow is covered in more detail in Section 2.

The fan drive shaft which is part of the low-pressure drive system couples the low-pressure turbine with the fan rotor. The fan aft shaft engages the fan drive shaft at the forward end through a spline connection. The aft end of the fan drive shaft is also splined to the low-pressure turbine conical shaft. The drive shaft and fan rotor aft shaft are drawn together and secured by means of the rotor locking bolt. The number two bearing supports the forward end of the drive shaft through the fan rotor. Also a rotor locking bolt at the aft end draws the fan drive shaft and conical shaft together and secures the two. The inner race of the number four differential roller bearing is mounted by means of an interference fit to the aft end of the fan drive shaft and is used primarily to absorb the radial loading on the high-pressure turbine rotor and transmits this load to the turbine exhaust frame through the number five roller bearing.

At the one o'clock and seven o'clock positions mounted to the high pressure turbine shroud support are two heat shields. It is at these positions that the fourth-stage compressor turbine cooling air enters for use in cooling the low-pressure turbine nozzle and blades. These two heat shields prevent the high temperature of the hot gas from affecting the low-pressure turbine cooling air.

F. LOW-PRESSURE TURBINE MODULE (See Figures 1-40 through 1-47)

1. General. The low-pressure turbine module of the engine includes the low-pressure turbine rotor, the high-pressure turbine shroud and support assembly, low-pressure turbine nozzle, the turbine case, the number five roller bearing, the turbine exhaust frame and C-sump housing, and the low-pressure turbine shroud.

2. High-Pressure Turbine Shroud Support (See Figure 1-44). The high-pressure turbine shroud support is a one-piece nickel alloy shell assembled between the aft flange of the combustion chamber case and the low-pressure turbine casing. The high-pressure turbine shroud is made up of sixteen shroud segments which are supported by a flange on the HPT shroud support. Assembled between each shroud segment is a seal strip which prevents any leakage of air between segments. The shroud assembly is designed to restrict hot gas leakage at the high pressure turbine rotor blade tips. The aft end of each shroud segment is retained in place by sixteen retainer clips or C-clamps. Assembled next is a circumferential E-seal which provides more prevention against hot gas leakage between casings.

3. Low-Pressure Turbine Rotor Assembly. (See Figures 1-41 and 1-42). The low-pressure turbine rotor is a single-stage rotor which drive the fan rotor. The turbine rotor consists of a disk, eighty-two double tanged dovetail blades, a forward seal/retaining ring, and the conical shaft.

The blades are retained radially by axially broached dovetail slots in the circumference of the disk. The blades are retained axially on the forward side by the forward seal/retaining ring, and on the aft side by the conical shaft which is circumferentially bolted to the turbine rotor disk. In

addition to retaining the rotor blades on the forward side, the forward seal/retainer serves to provide a cavity which accepts turbine cooling air exiting the inducer and directs this air to the blade root through holes in the rotor disk.

Integral with the aft side of the torque cone is a labyrinth seal which provides an air seal between the exhaust frame and the rotor disk. On the forward and aft side of the rotor disk is a seal wire which serves to better seal off the turbine rotor area from the primary airflow.

On assembling the turbine blades into the dovetail slots on the rotor disk, a baffle is inserted between each blade which provides vibration dampening between blades.

The number five carbon seal runner, assembled to the aft side of the conical shaft, mates with the C-sump carbon seal and provides an oil seal for the C-sump cavity. Assembled to the conical shaft is the number five bearing inner race. Its primary purpose is to absorb the radial loading of the high and low-pressure turbine rotors and distribute this load to the turbine exhaust frame through the number five bearing. Assembled to the forward side of the conical shaft are the rotating air seal and number four carbon seal runner. The air seal engages the bore of the low-pressure turbine disk and restricts the flow of air to the forward side of the disk. The seal runner mates with the number four carbon seal on the high-pressure turbine rotor aft shaft and provides the second oil seal for the C-sump cavity.

4. Low-Pressure Turbine Nozzle. (See Figure 1-43). The low-pressure turbine nozzle is made up of twenty-five segments consisting of two vanes in each segment. The twenty-five segments are assembled on the forward side to a one-piece low-pressure turbine inducer. Assembled between each segment is an inner and outer seal strip which prevents any air leakage between segments. The assembled segments are bolted to the aft inner flange of the high-pressure turbine shroud support and form a path for the hot gases exiting the high-pressure turbine rotor to the low-pressure turbine rotor. Assembled to the aft side of the nozzle is an E-seal which provides even more sealing against air leakage between casings.

5. Low-Pressure Turbine Case. (See Figure 1-45). The low-pressure turbine case is a one-piece iron and nickel alloy circumferential shell bolted to the aft bolt flange of the combustion chamber case and to the forward end of the turbine exhaust frame. The turbine case supports the aft end of the low-pressure turbine nozzle and also provides grooves which retain the twelve low-pressure turbine shroud segments. The aft side of each shroud segment is retained in place by twelve retaining clips which capture the shroud segment and turbine case. The circumferential shroud restricts any hot gas leakage at the low-pressure turbine rotor blade tips. Positioned on the forward side of the low-pressure turbine case is a two-piece deflector. This deflector retains the bolts used for securing the turbine exhaust frame and also provides a smooth path for bypass air passing over the two case flanges. A clamp around the forward edge of the deflector prevents bending of the deflector during engine operation.

6. Turbine Exhaust Frame/C-Sump Housing. (See Figure 1-46). The turbine exhaust frame/C-sump housing, mounted on the aft end of the low-pressure turbine case, is connected to the engine rear mount ring by four adjustable links and provides the main structural support for the aft end of the engine. The turbine exhaust frame is a one-piece casting with eight equally spaced struts extending radially between the outer and inner rings. In addition to providing structural support for the exhaust frame, the struts are utilized for service lines to access the C-sump area. (See Figure 1-5). The oil-in line is located at approximately the three-thirty o'clock position. The five-thirty o'clock strut contains the C-sump scavenge line. The C-sump scavenge to the gearbox is located at the seven-thirty o'clock position. Flowpath fairings and strut fairings riveted together provide a path for the hot gases exiting from the turbine module and entering the afterburner module.

The outer ring of the turbine exhaust frame is bolted to the low-pressure turbine case and the inner ring provides a mounting surface on the forward side for the C-sump housing. Also secured to the forward side of

the inner ring is the low-pressure turbine rotor static air seal which mates with the labyrinth seal on the conical shaft. The aft side of the inner ring has a flange with anchor nuts used for attaching the exhaust centerbody.

A major structural part of the exhaust frame assembly is the C-sump housing. The housing is secured to the forward inner flange of the exhaust frame and provides support for the number five bearing, the number five carbon seal, and the oil nozzle. As mentioned previously, the number five bearing supports the aft end of the high and low-pressure turbine rotors and serves to transmit any radial loading to the exhaust frame through the C-sump housing. The number five carbon seal mates with the number five seal runner which is bolted to the torque cone providing one of the C-sump seals. The number five carbon seal includes a windback feature which serves to discourage oil from leaving the C-sump area. Forward of the number five seal runner is the C-sump drain which collects any oil which escapes the sump area and allows this oil to drain through the C-sump housing. The oil nozzle has four jet openings. Two of these jets direct oil onto the number five bearing and the other two direct oil to the number four bearing through passage and distribution holes in the low-pressure turbine rotor conical shaft. The number five bearing is secured by a locknut, keywasher, and retaining ring. The C-sump cover is bolted to the C-sump housing and encloses the sump at the aft end to form the C-sump cavity.

G. AFTERBURNER MODULE (See Figures 1-48 through 1-53).

1. General. The afterburner provides the area necessary for the complete combustion of the exhaust gas and fuel mixture before it is ejected through the exhaust nozzle. The afterburner module consists of an afterburner case, afterburner liner, mixer, flameholder, twenty-four main spraybars, six pilot spraybars, distribution valves, eight thermocouple probes, the afterburner flame sensor, variable exhaust nozzle (VEN), three VEN actuators, a VEN position transmitter, exhaust pressure probe, and the afterburner igniter.

2. Afterburner Case. (See Figure 1-49). The afterburner case is the main supporting structure of the afterburner and is bolted to the circumferential bolt flange of the engine rear mount ring. Bosses, provided in the forward end of the afterburner casing, are used to support eight thermocouple probes, twenty-four main spraybars, six pilot spraybars, an igniter, an afterburner flame sensor, and the PT_{5.6} probe. Provided at the aft end of the casing is an inner and outer flange used for mounting the variable exhaust nozzle. The afterburner casing also has two circumferential stiffening rings one of which has four supports for securing the forward end of the three variable exhaust nozzle actuators and the VEN position (A₈) transmitter.

3. Afterburner Liner. (See Figure 1-50). Located within the afterburner case is the afterburner liner. The liner is retained in place at the forward end by twelve radial pins, six of which are part of the flameholder support arms. The aft end of the liner is concentric with the case and is free to expand either axially or radially. The afterburner liner serves as a heat shield for the afterburner case and also provides a path for bypass air to the exhaust nozzle for cooling purposes.

Assembled to the forward end of the liner is the mixer. The mixer has twenty-four chutes located around its aft circumference which serves to mix bypass air with turbine exhaust gases entering the afterburner.

Located also within the afterburner liner is the flameholder which is supported by six support arms that attach to the afterburner case. The flameholder is annular in construction and has twelve airfoil-shaped partitions that impart a controlled swirl to the exhaust gases passing through the flameholder to create a turbulent zone in which these gases are mixed with pilot fuel and ignited. The flameholder provides the area in which the flame is held. The single igniter plug extends through the afterburner case and liner and penetrates the flameholder between partitions near the seven o'clock position. The igniter provides the electrical spark which ignites the pilot fuel and air mixture.

Installed at the forward end of the afterburner case are eight thermocouples. These thermocouples are made up of two identical harnesses with four thermocouples per harness. These eight thermocouples sense exhaust gas temperature (T_5) and send this temperature signal to the electrical control assembly (ECA).

Fuel is provided to the afterburner through six pilot spraybars and twenty-four main spraybars. Both pilot and main spraybars are part of a dual fuel manifold which are installed in the forward end of the afterburner case in the same axial plane. The six pilot spraybars are equally spaced and protrude through the afterburner case and liner and extend into the flameholder. The afterburner fuel control supplies metered fuel to each pilot spraybar through the pilot fuel manifold. Each pilot spraybar has its own pressure/flow valve. The twenty-four main spraybars are also equally spaced and extend radially through the afterburner case and liner and beyond the flameholder into the turbine exhaust gas path. Fuel is supplied to the twenty-four main spraybars from the afterburner fuel control through six distributor valves which are connected to the main afterburner fuel manifold.

When in a non-afterburning condition, fuel is circulated in the main fuel manifold by a separate fuel line. This circulating fuel serves to cool the distributor valves, and also reduces the manifold fill time when afterburner operation is first initiated. Located at the seven-thirty o'clock position on the afterburner case is the afterburner flame sensor. The afterburner flame sensor senses when positive ignition takes place and provides a signal back to the electrical control assembly (ECA), which in turn, releases a hold on the variable exhaust nozzle (VEN) area, and the afterburner fuel control then permits more than minimum afterburner fuel flow.

4. Variable Exhaust Nozzle (VEN). (See Figure 1-51 and 1-52). The variable exhaust nozzle is assembled to the aft flange of the afterburner case. The VEN provides the exit passage for hot gases exiting the turbine and

afterburner section and provides the correct contour for external airflow. During intermediate and full afterburner operation, the VEN is most important in providing maximum thrust efficiency while maintaining a controlled turbine exhaust gas temperature (T_5).

The VEN is constructed of twelve sectored hinge seals and twelve forward primary flap hinges. All are assembled to the aft inner flange of the afterburner case. The twelve primary flaps at the forward end are attached by hinge pins to the forward flap hinges, and the aft end are attached by hinge-pin bolts to the secondary flaps. The aft ends of the outer flaps are bolted to the elongated bolt holes at the aft end of the secondary flaps and are free to move axially during afterburner operation. The forward ends of the outer flaps are attached to the outer hinges at the outer flange of the afterburner case. Positioned between each flap are primary, secondary, and outer fairing seals which are held in place by retainers. A compression link is connected to each secondary inner flap and to hinge brackets attached to the afterburner case aft flange. These compression links function as pivot points for the secondary inner flaps while the VEN is in operation.

The forward end of the three actuators are secured through brackets on the afterburner case stiffening ring. Links connected to each side of the actuators and to the forward side of the afterburner case outer flange provide structural support for the actuators. The actuator rods are connected to the actuating ring which is positioned over the outer cam track of the primary flaps. The actuating ring has twelve main rollers which engage the cam on the twelve primary flaps and side rollers which engage the bottom and side of the track.

When the engine is in operation, exhaust gases create a force on the primary flaps and hold the cams against the actuating ring main rollers. When the electrical control assembly (ECA) provides a signal to the VEN Power Unit causing the actuator rods to extend, the track of the primary flaps, because of the exhaust gas load force, follows the rollers forcing the primary and secondary flap and compression link to pivot and increase the VEN throat and exit areas relative to the area scheduled by the control system. The elongated bolt hole at the aft end of the secondary inner flap allows axial

motion and prevents any possible binding with the outer flap fairing. The VEN position transmitter, assembled to the actuating ring, sends a feedback signal to the electrical control assembly indicating nozzle position. Likewise, when the actuator rods are retracted, the actuating ring rollers force the primary flaps inward, which in turn, closes the exhaust nozzle throat and exit areas.

H. ACCESSORY GEARBOX ASSEMBLY (See Figure 1-54)

The accessory gearbox is mounted to a pad provided on the compressor midframe at the six o'clock position. The gearbox extracts its power from the compressor rotor through the PTO and radial drive shaft. The radial drive shaft splines to the bevel pinion gear in the power takeoff drive assembly and at the other end with a shaft gear in the accessory gearbox. This shaft gear meshes with another shaft gear, which in turn, meshes with a train of spur gears. The spur gears provide the mechanical drives for engine and airframe accessories.

The gearbox has two drive pads on the forward side and two drive pads on the aft side for mounting of the accessories. Mounted on the forward left-hand gearbox pad is the lube and scavenge oil pump. The VEN power unit is mounted to the forward end of the lube and scavenge oil pump and is driven by the pump. The drive pad for the engine alternator is located on the forward right hand side of the gearbox. The customer power takeoff (PTO) is attached to the forward center pad. Aft looking forward, the three forward pads rotate in a clockwise direction.

The main fuel pump (MFP) is mounted on the aft left-hand gearbox drive pad and is secured by a coupling clamp. Attached to the aft side of the MFP is the main fuel control (MFC). The MFC is in turn driven by the MFP and secured by a vee band coupling arrangement. The afterburner pump (ABP) is mounted on the aft right-hand drive pad, and it is also secured by a vee band

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coupling. Bolted to the right-hand side of the ABP is the afterburner control (ABC). Again aft looking forward, the two gearbox drives rotate in the clockwise direction. Pad speed at 100% compressor rotor speed (N_2) are shown in Figure 1-54.

A supply line from the oil tank is connected to the forward side of the gearbox and supplies oil to the lube and scavenge pump through internal passages in the gearbox.

1. BORESCOPE INSPECTION (See Figure 1-55).

Engine inspection is accomplished by means of thirteen borescope ports located throughout the engine. The prime purpose of the borescope inspection is to monitor the fan and compressor for FOD, and for periodic inspection of engine hot section parts. This inspection is done without having to teardown or remove the engine from the aircraft.

There is one inspection port in the fan section located at approximately the five-thirty o'clock position between the second and third-stage rotor blades. This port allows the user to inspect the trailing edge of the second-stage rotor, and the leading edge of the third-stage rotor.

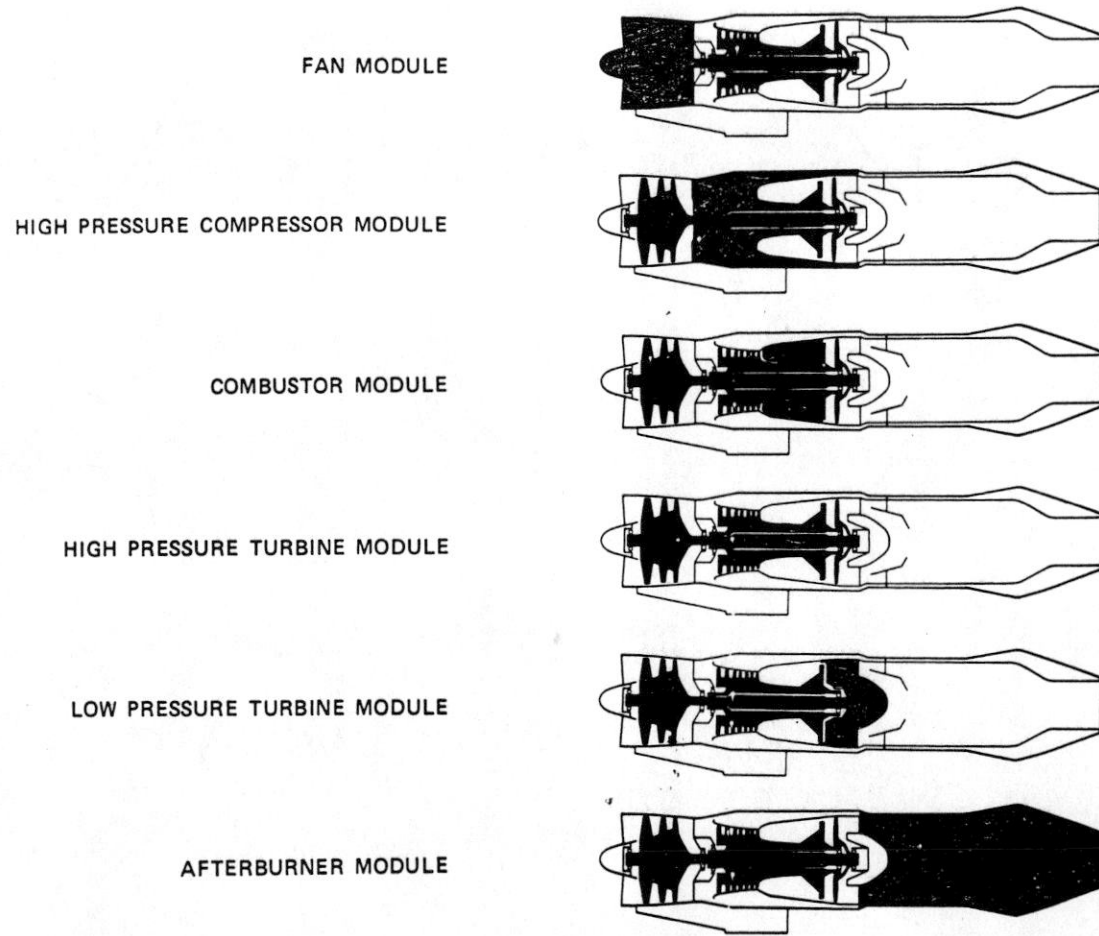
Compressor inlet inspection is done through four inspection ports located at the twelve-thirty and eleven-thirty o'clock position on the midframe. Two additional ports are located 15° below the centerline on the midframe. Depending on the engine position in the aircraft, two of these ports will be accessible. Inspection through these ports is done on the fan stage three blades, the midframe struts, stage three fixed vanes, and compressor inlet guide vanes and stage one blades.

A single port is provided at the eleven-thirty o'clock position for inspection of the compressor outlet guide vanes and the combustion liner dome area.

Borecope inspection of the combustion liner is accomplished through five ports located at the twelve, two-thirty, five, seven, and nine-thirty o'clock positions. The port at the five o'clock position is the same as that used for the igniter plug. Inspection through these ports is done on the combustion liner, inner and outer shells, dome assembly, fuel nozzles, and the high-pressure turbine nozzle.

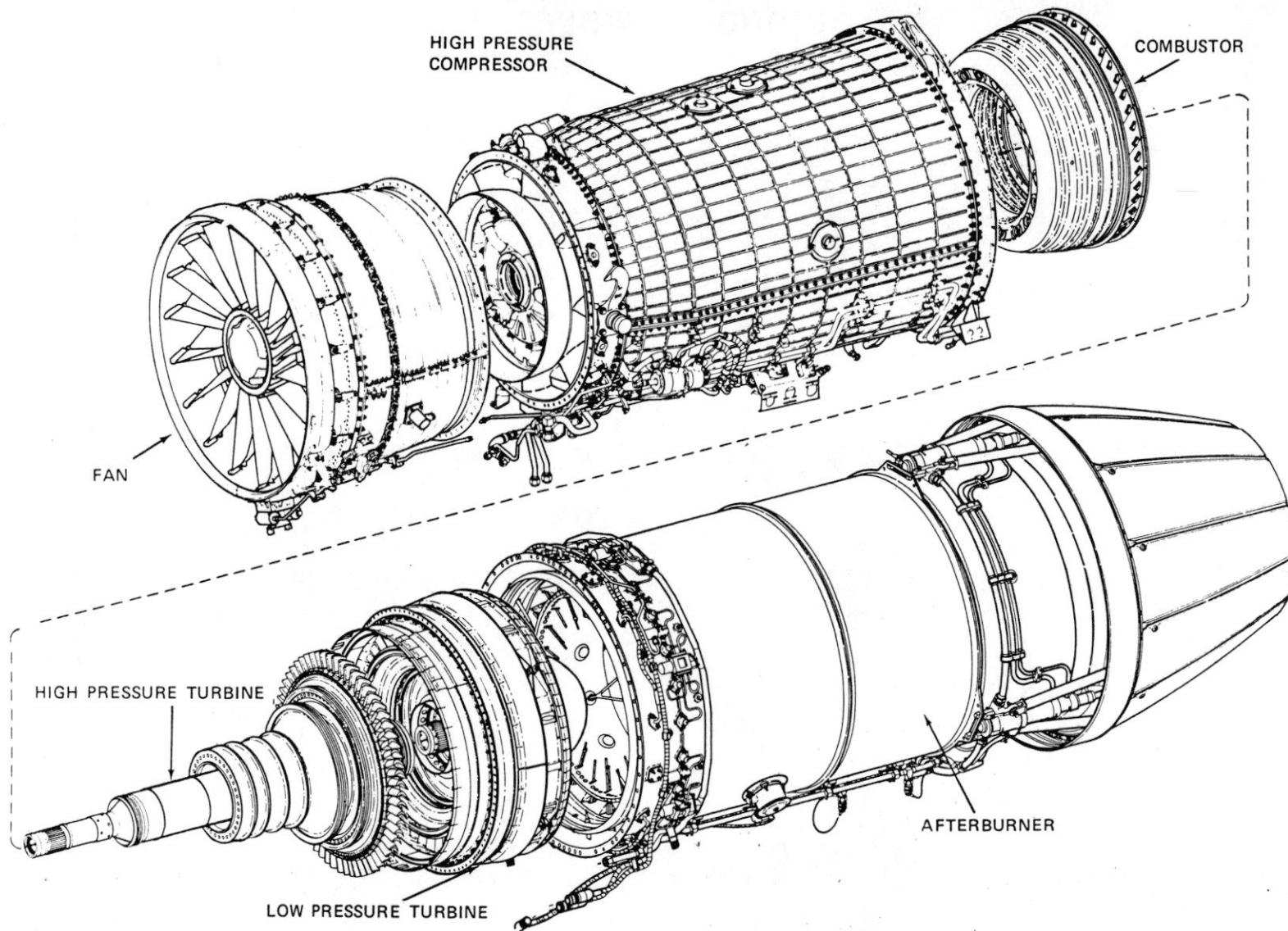
Located between the high-pressure turbine rotor and the low-pressure turbine nozzle is a single port at the six o'clock position used for inspection of the HPT rotor and the LPT nozzle.

Moving aft, at the six o'clock position located at the afterburner inlet, is a single inspection port. This port allows inspection of LPT blades trailing edge, the flameholder, exhaust frame, and the fuel spraybars.



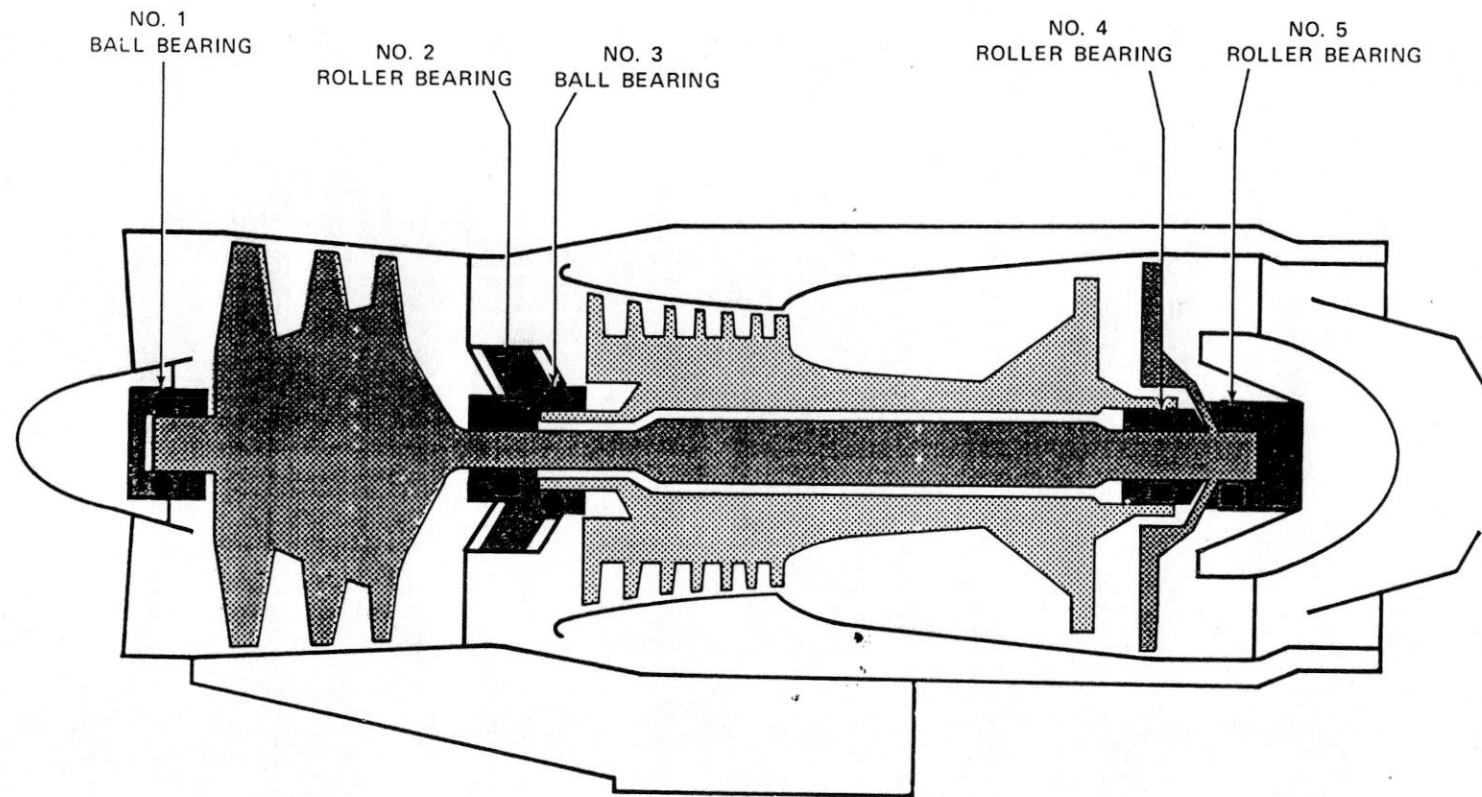
ENGINE MODULES

Figure 1-1



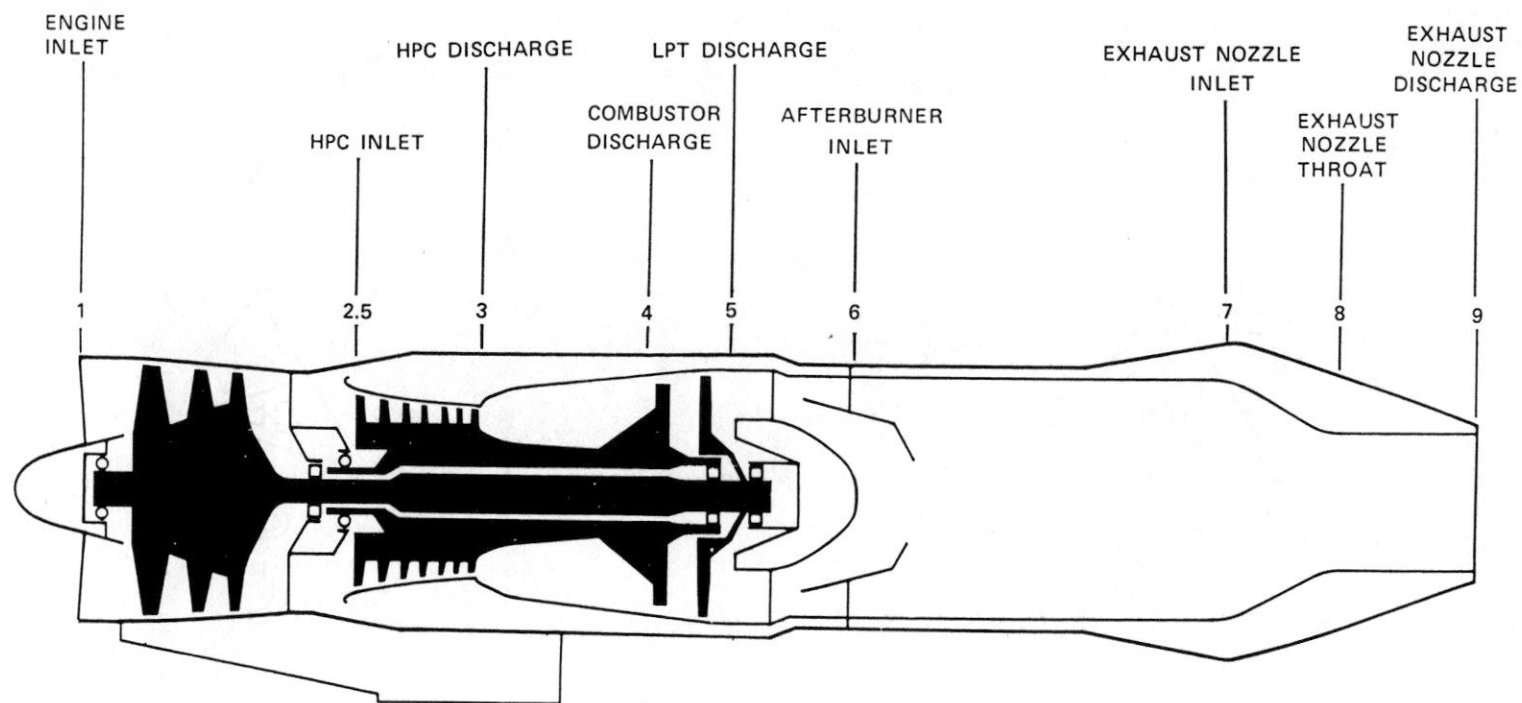
ENGINE MODULES

Figure 1-2



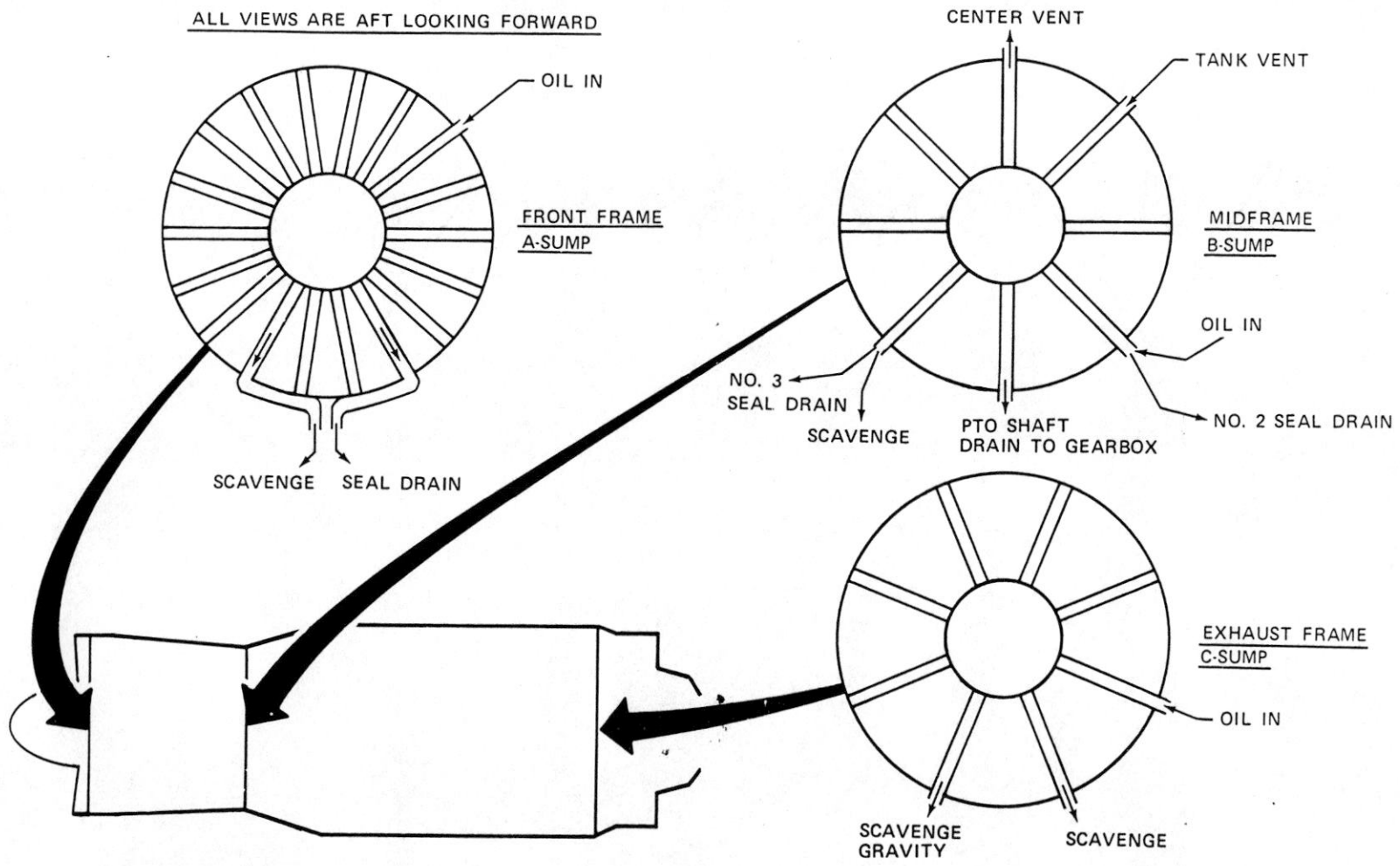
ENGINE BEARING STRUCTURE

Figure 1-3



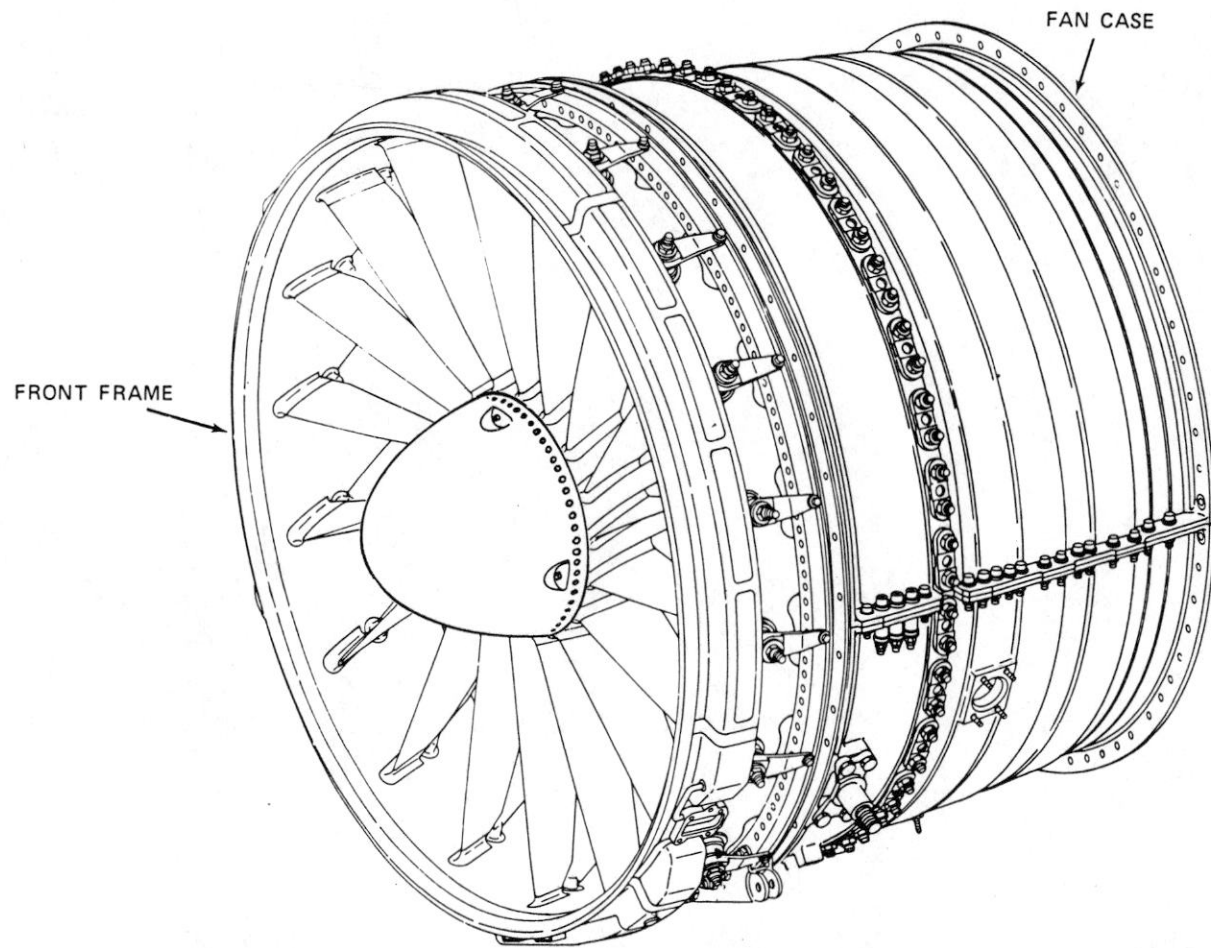
ENGINE STATION LOCATIONS

Figure 1-4



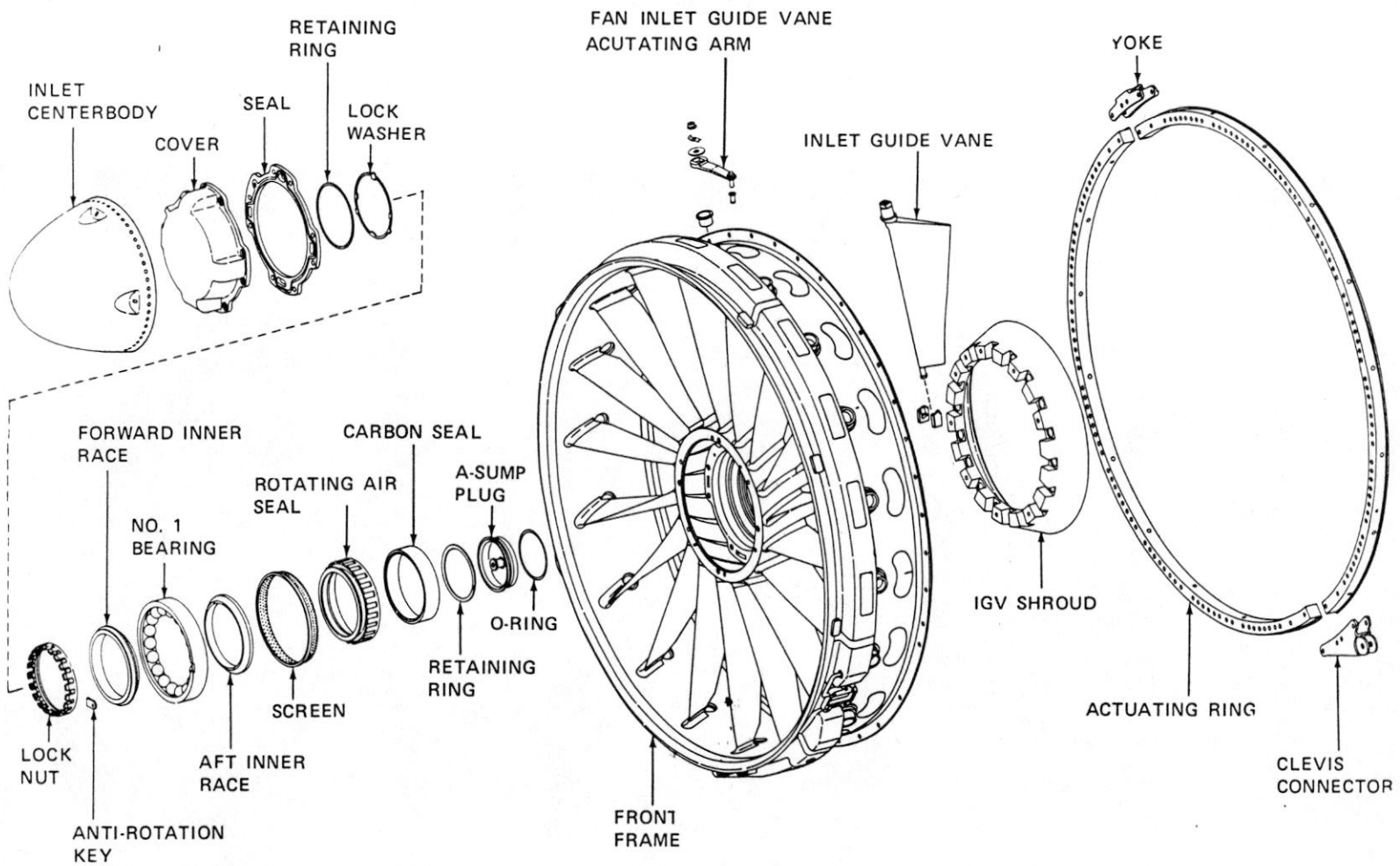
STRUT USAGE

Figure 1-5



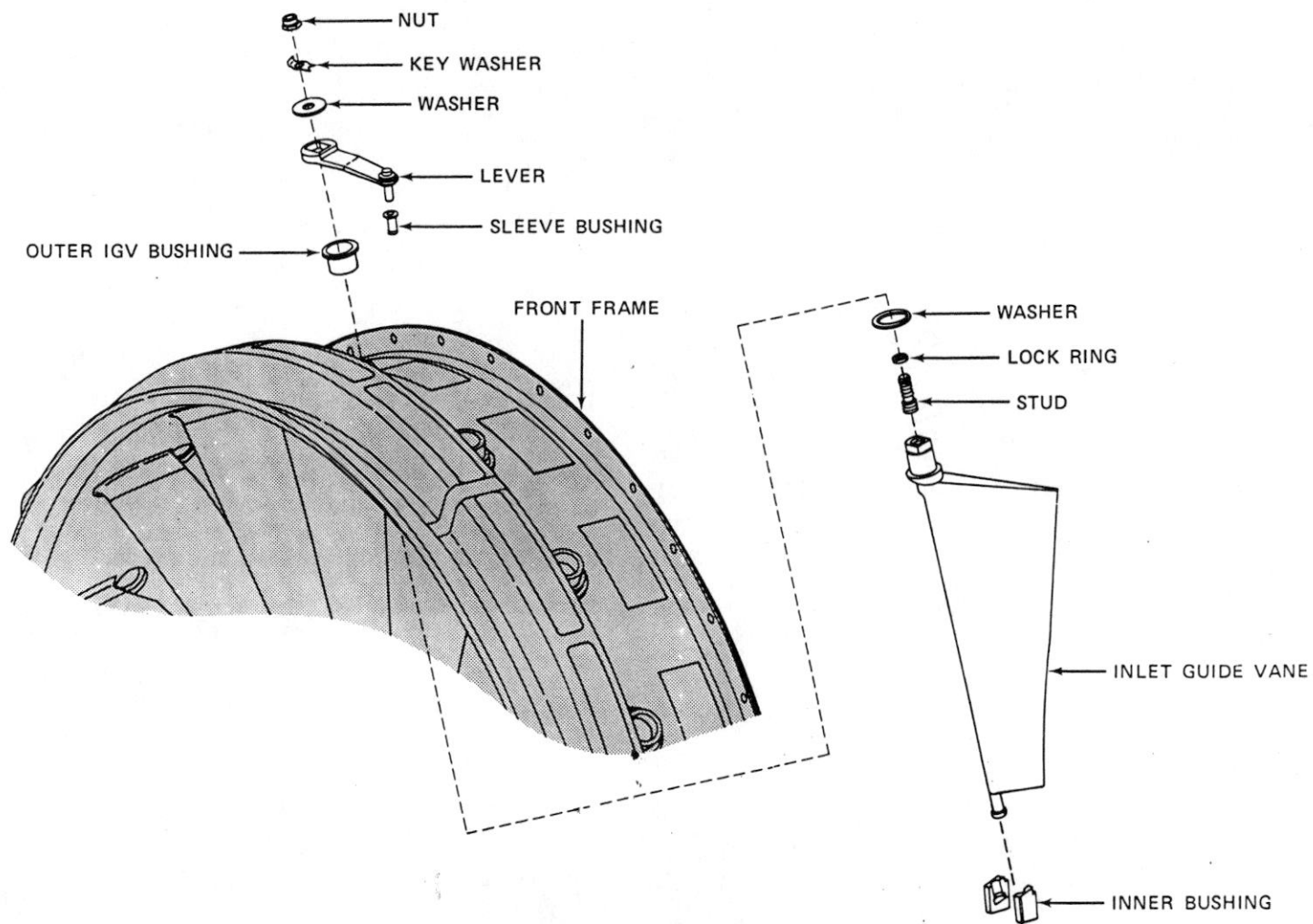
FAN MODULE

Figure 1-6



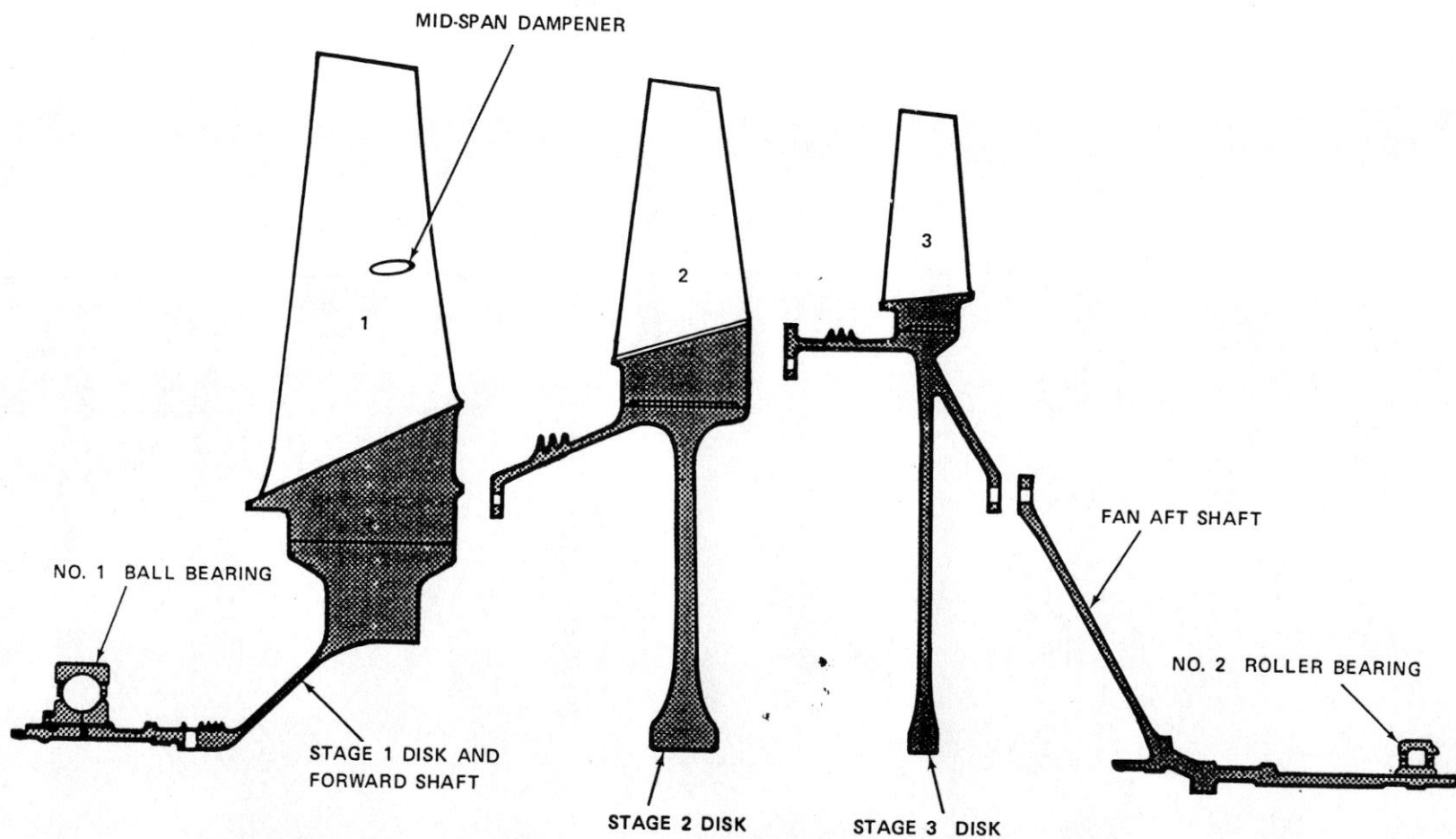
FRONT FRAME AND A-SUMP ASSEMBLY COMPONENTS

Figure 1-7



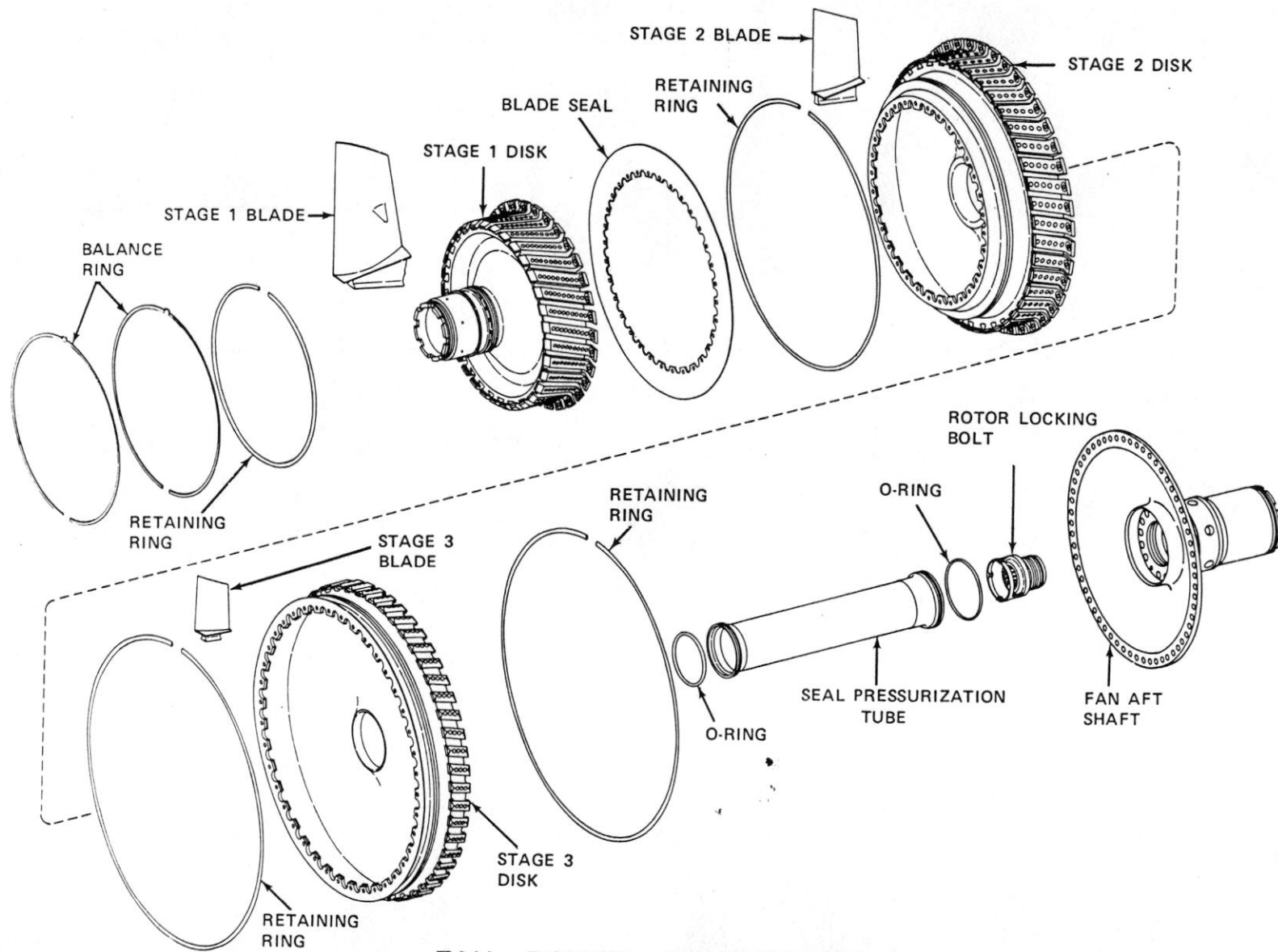
INLET GUIDE VANE ASSEMBLY

Figure 1-8



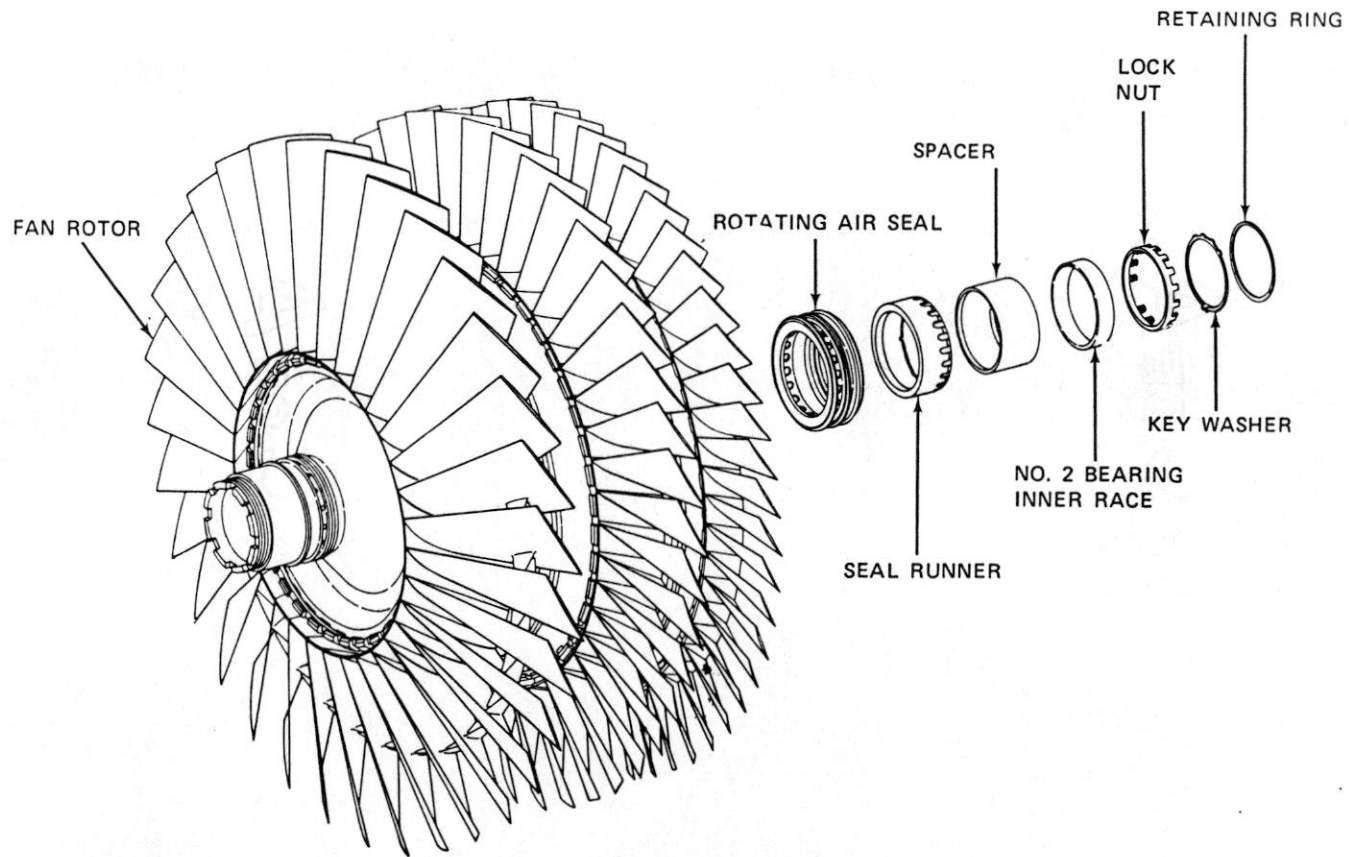
FAN ROTOR (CROSS SECTION VIEW)

Figure 1-9



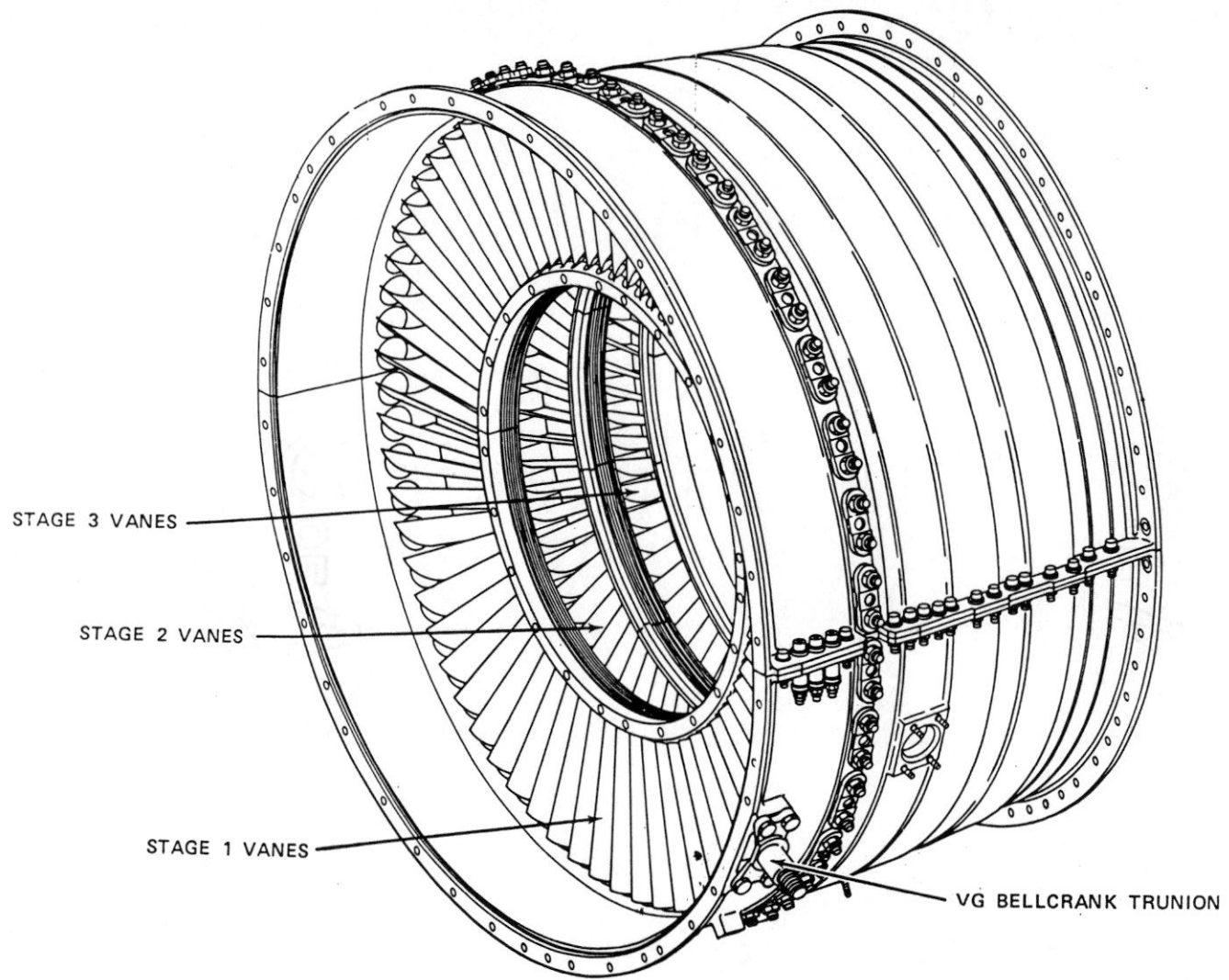
FAN ROTOR COMPONENTS

Figure 1-10



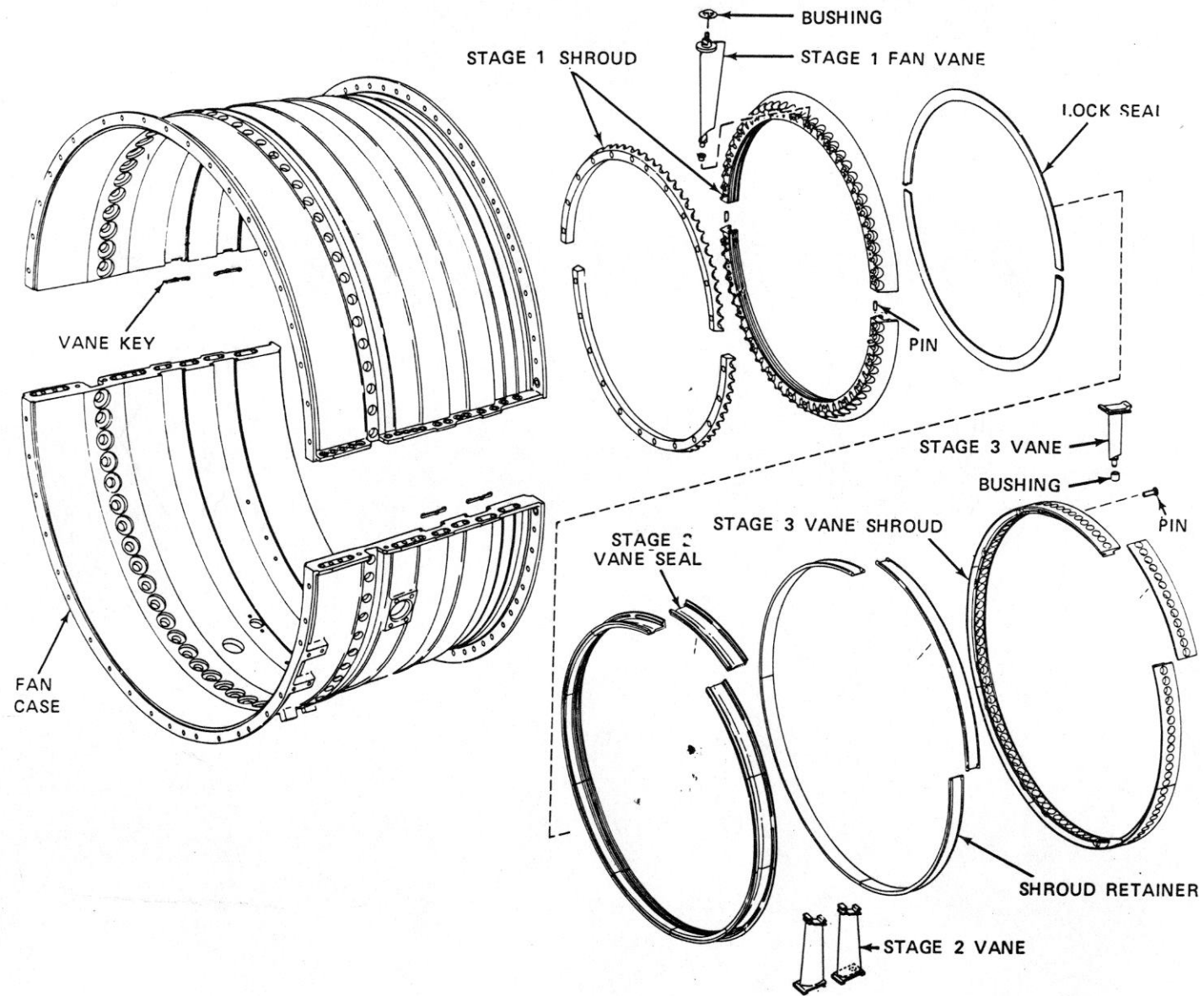
FAN ROTOR AFT SHAFT COMPONENTS

Figure 1-11



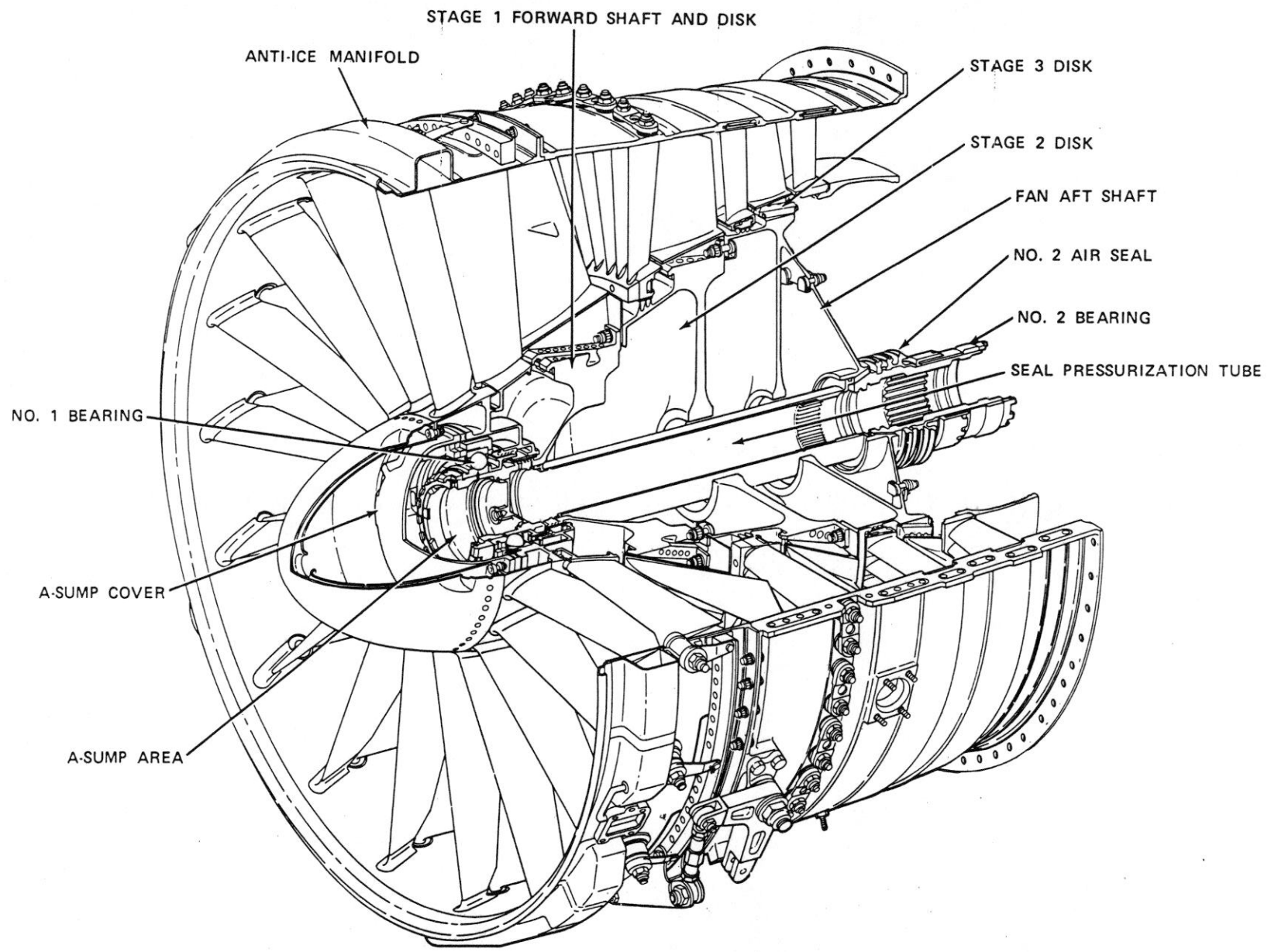
FAN STATOR ASSEMBLY

Figure 1-12



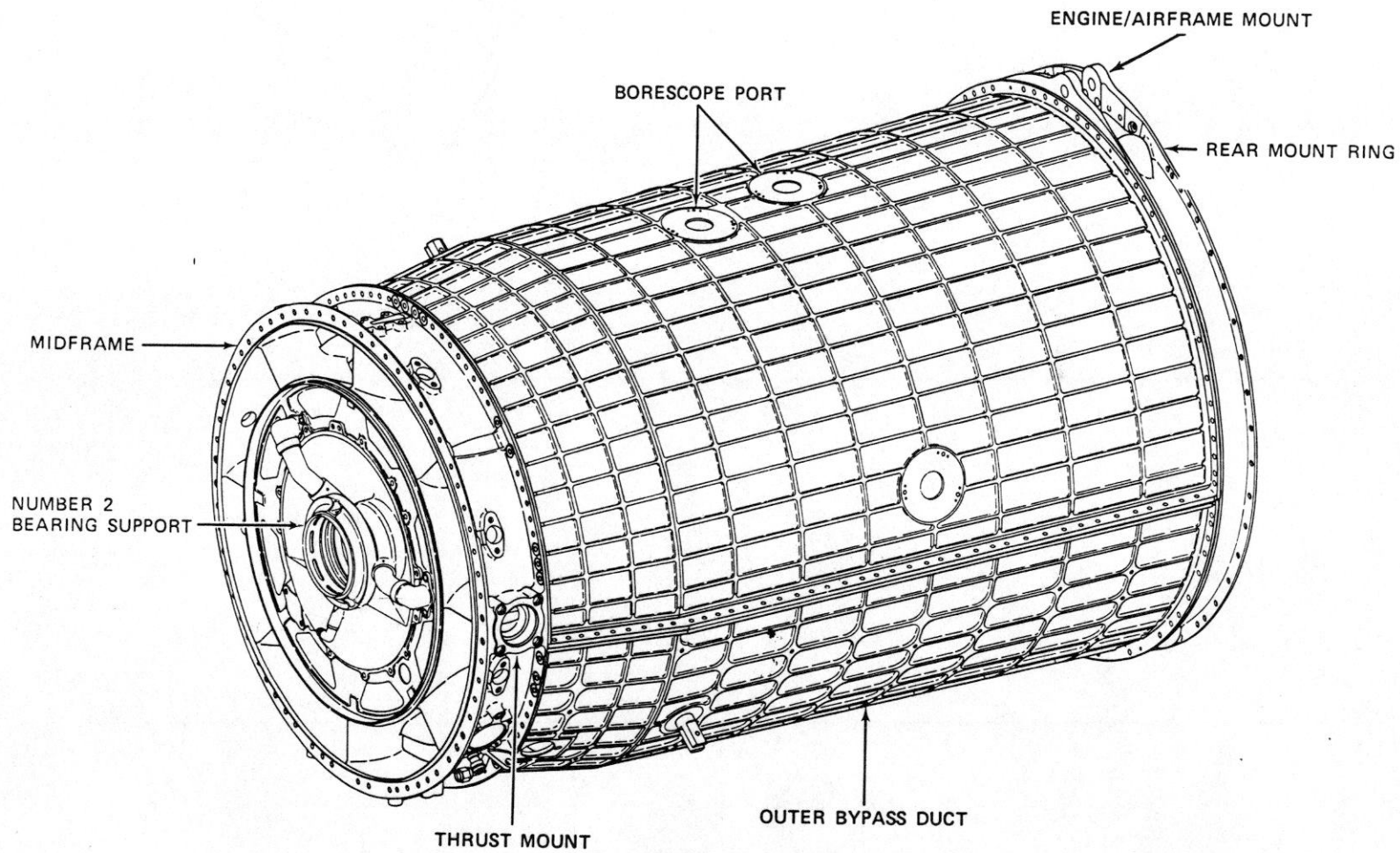
FAN STATOR COMPONENTS

Figure 1-13



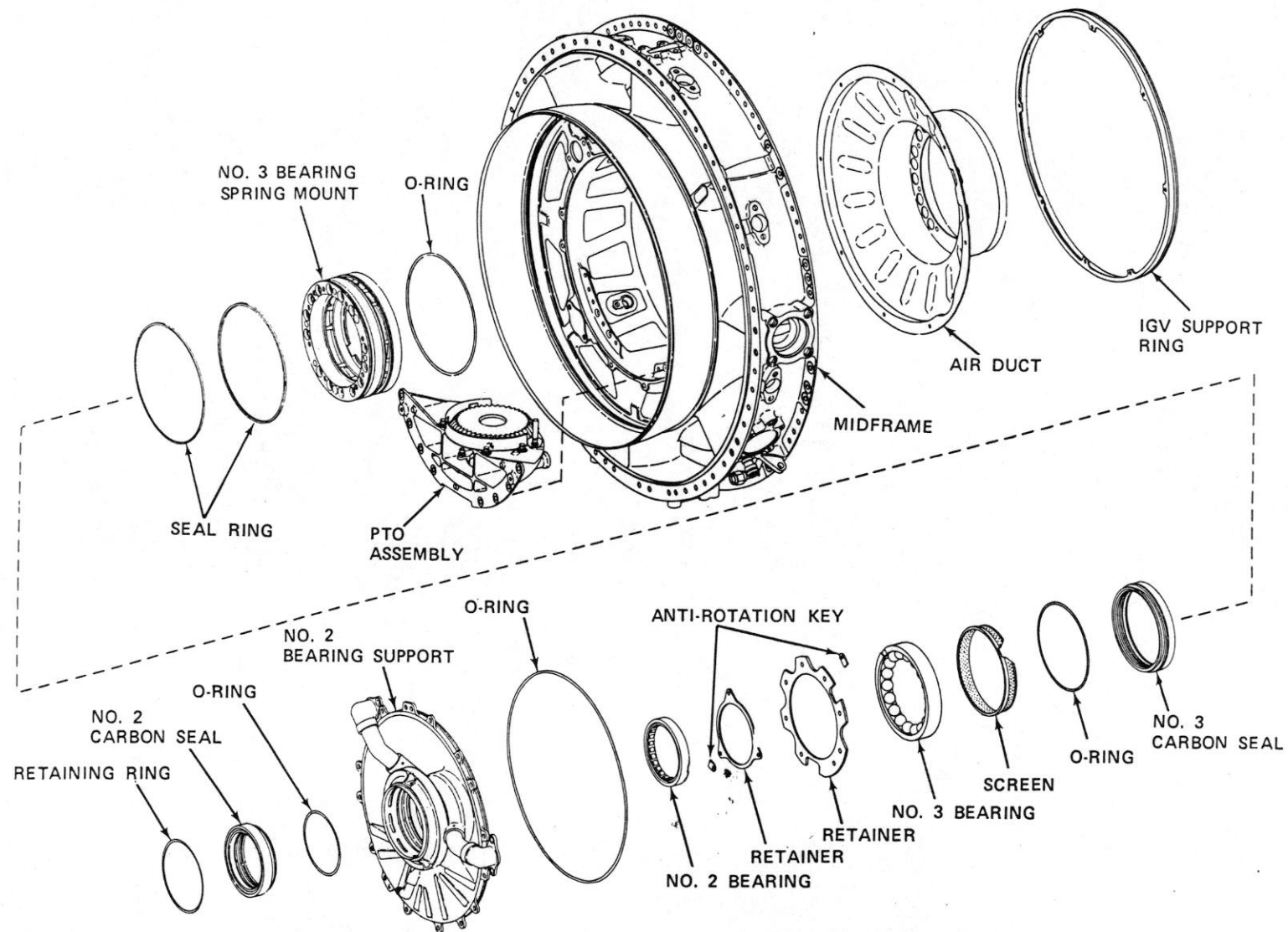
FAN MODULE (CUTAWAY)

Figure 1-14



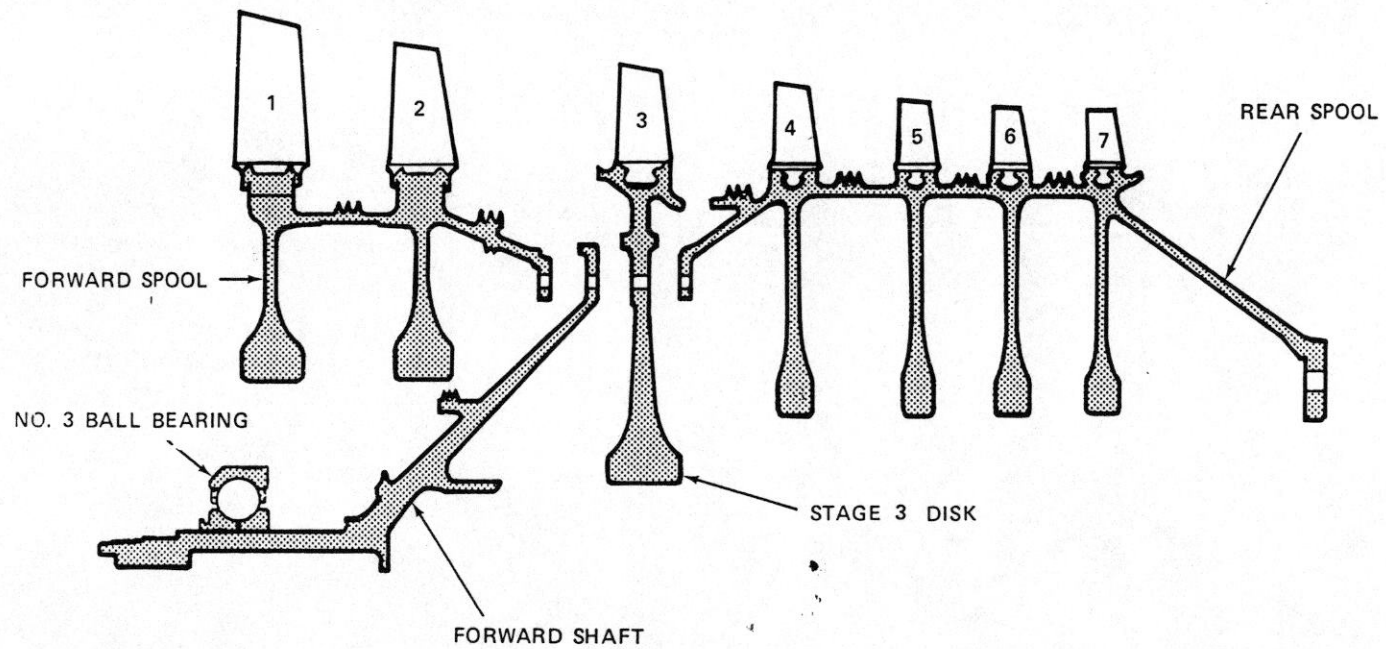
HIGH PRESSURE COMPRESSOR MODULE

Figure 1-15



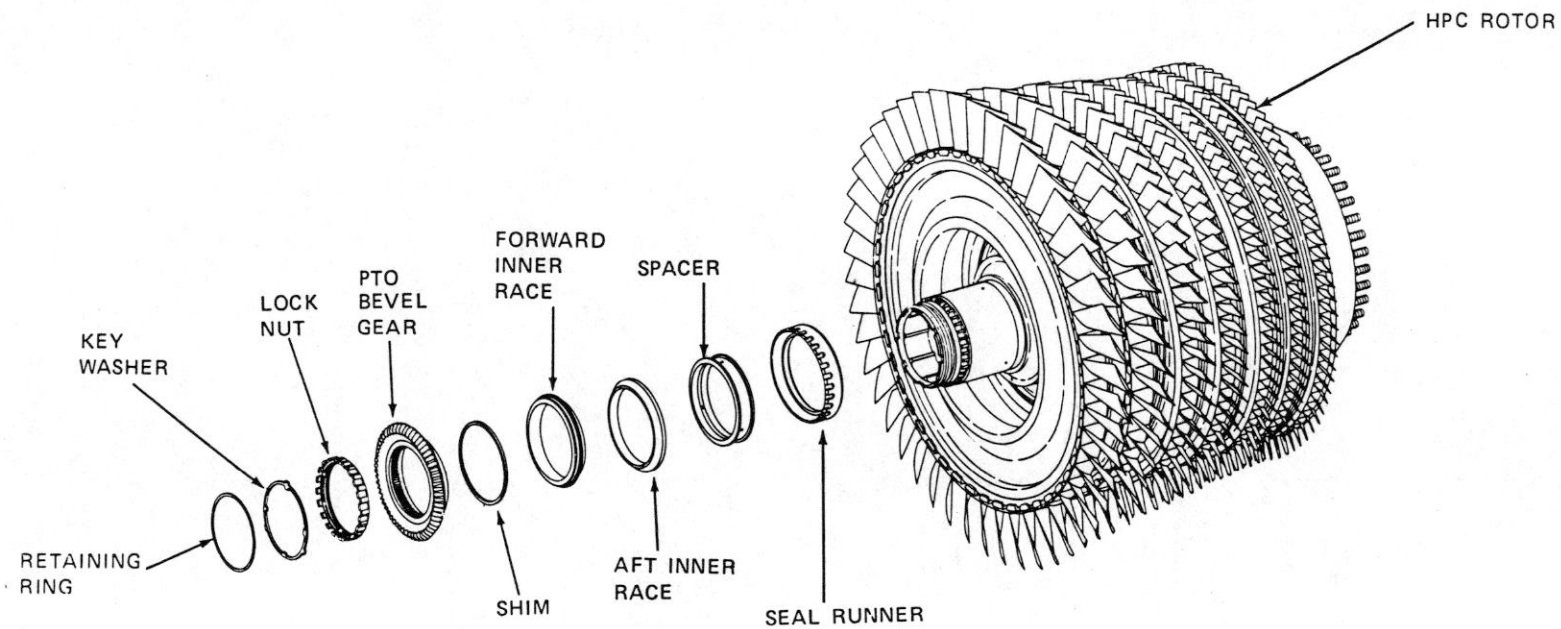
COMPRESSOR MIDFRAME AND B-SUMP COMPONENTS

Figure 1-16



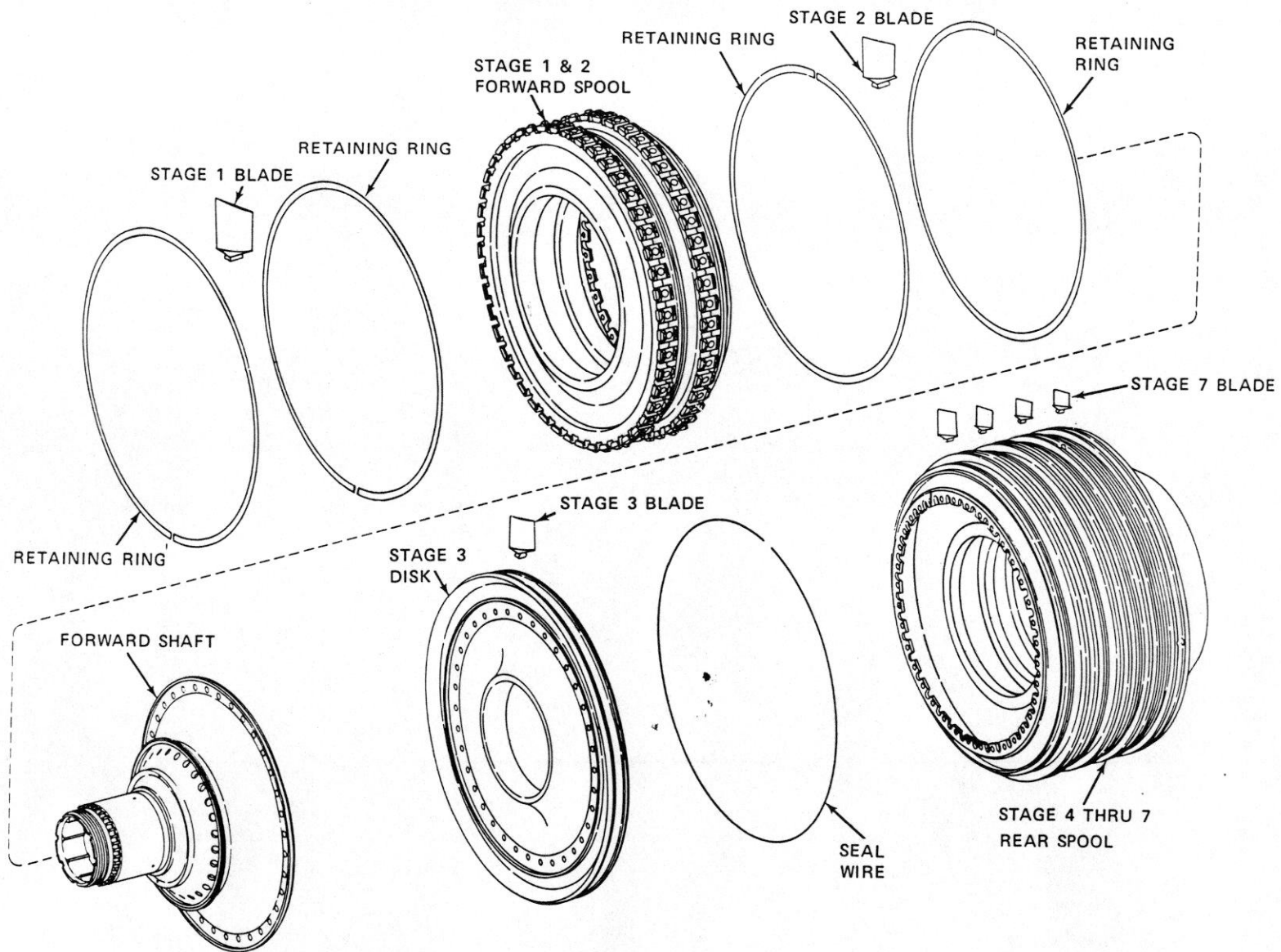
COMPRESSOR ROTOR (CROSS SECTION VIEW)

Figure 1-17



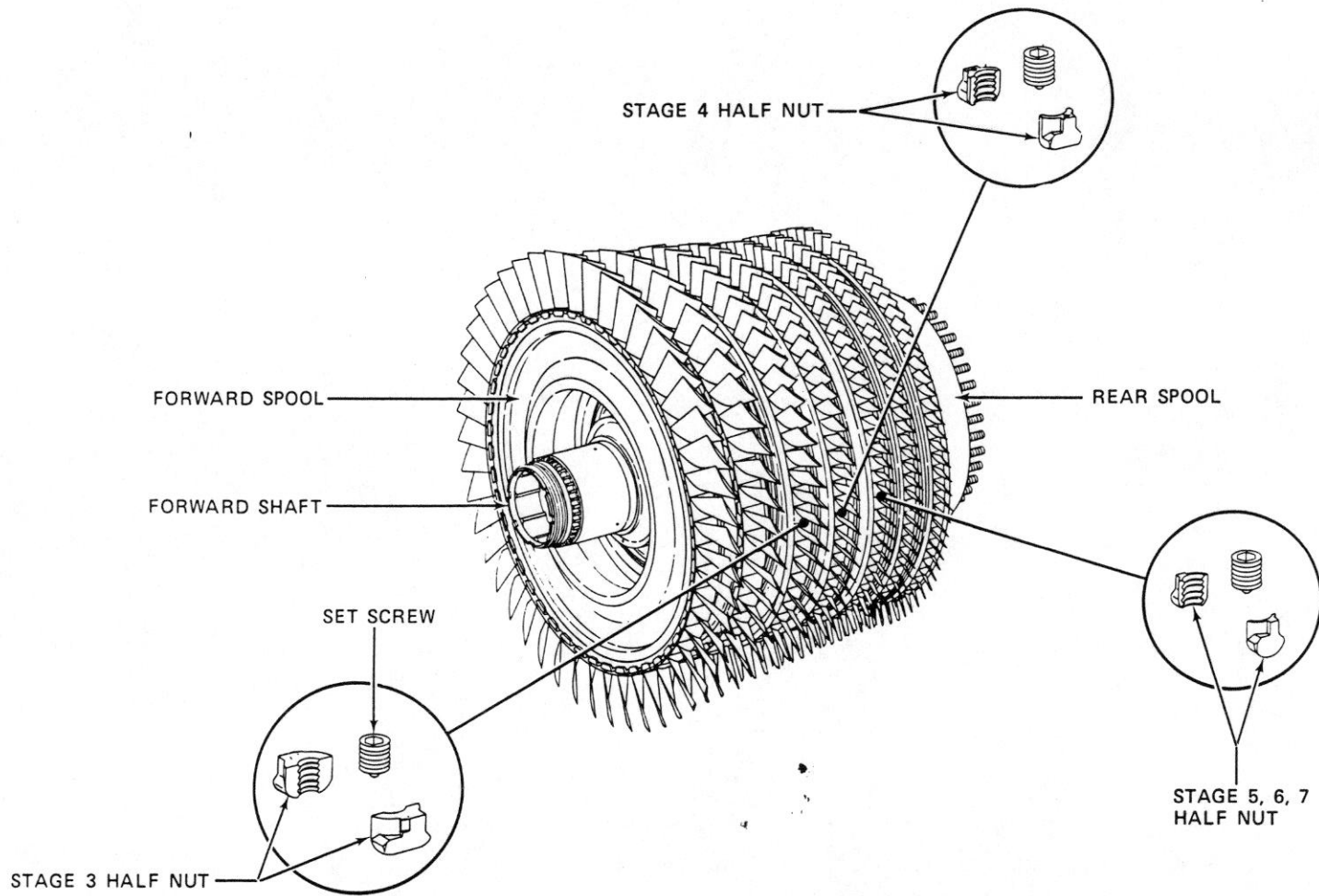
COMPRESSOR ROTOR FORWARD SHAFT COMPONENTS

Figure 1-18



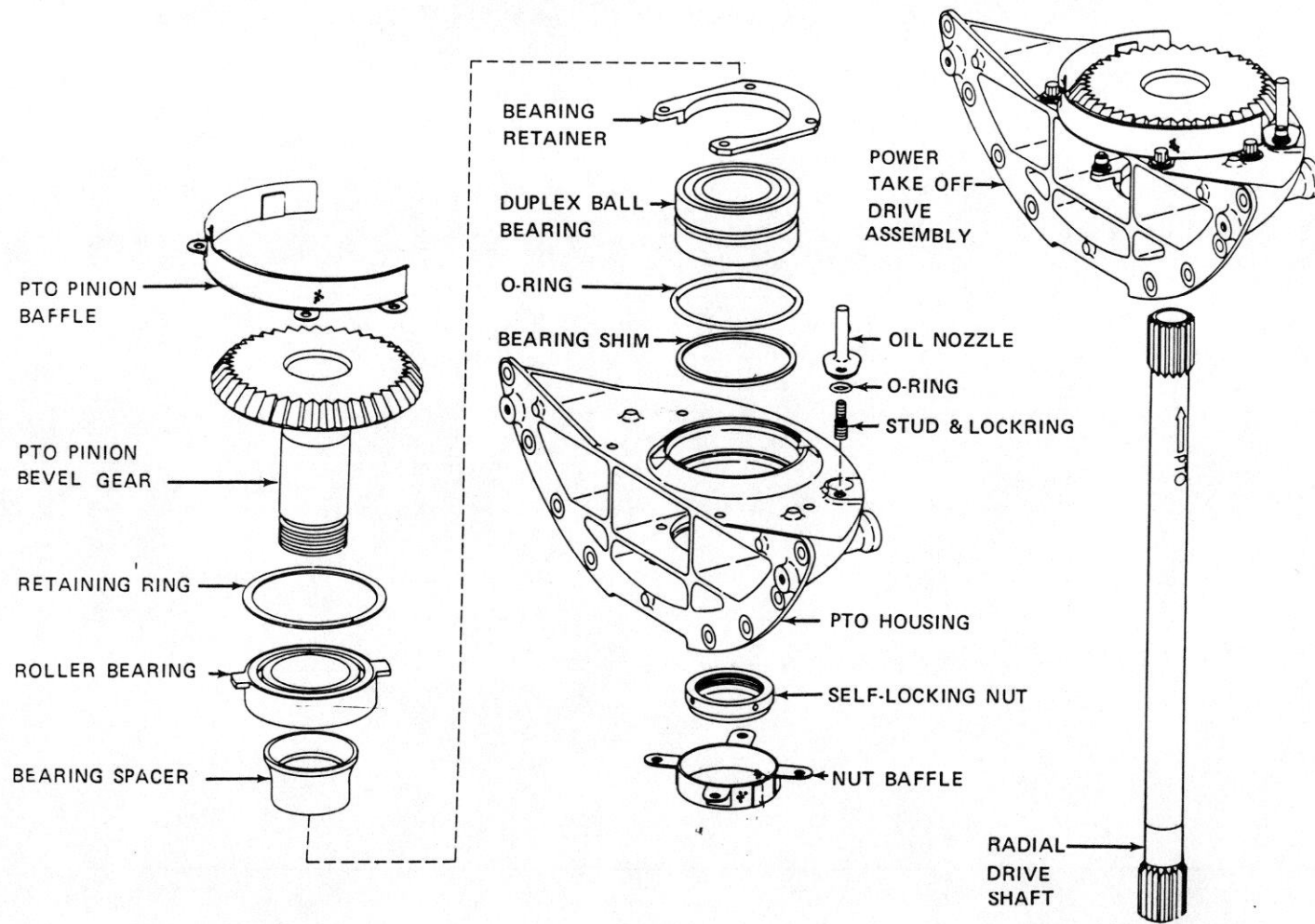
COMPRESSOR ROTOR COMPONENTS

Figure 1-19



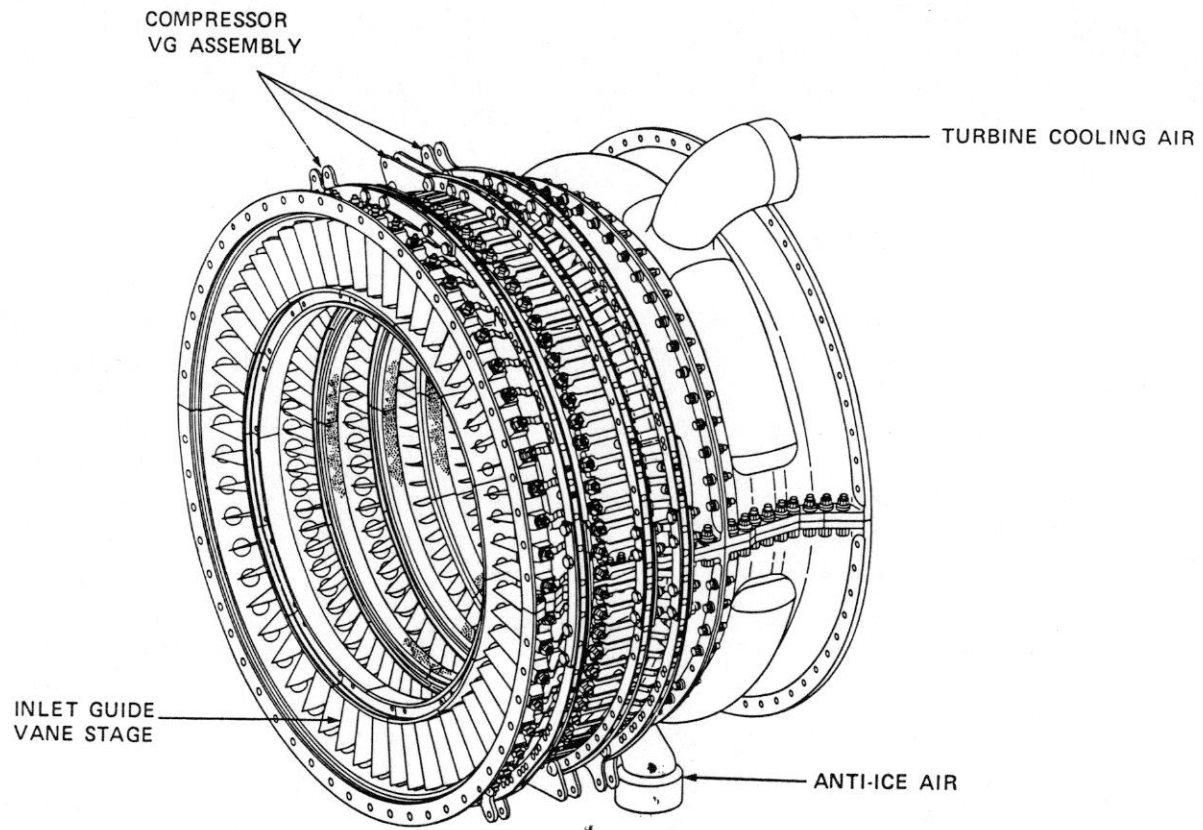
COMPRESSOR BLADE LOCKING

Figure 1-20



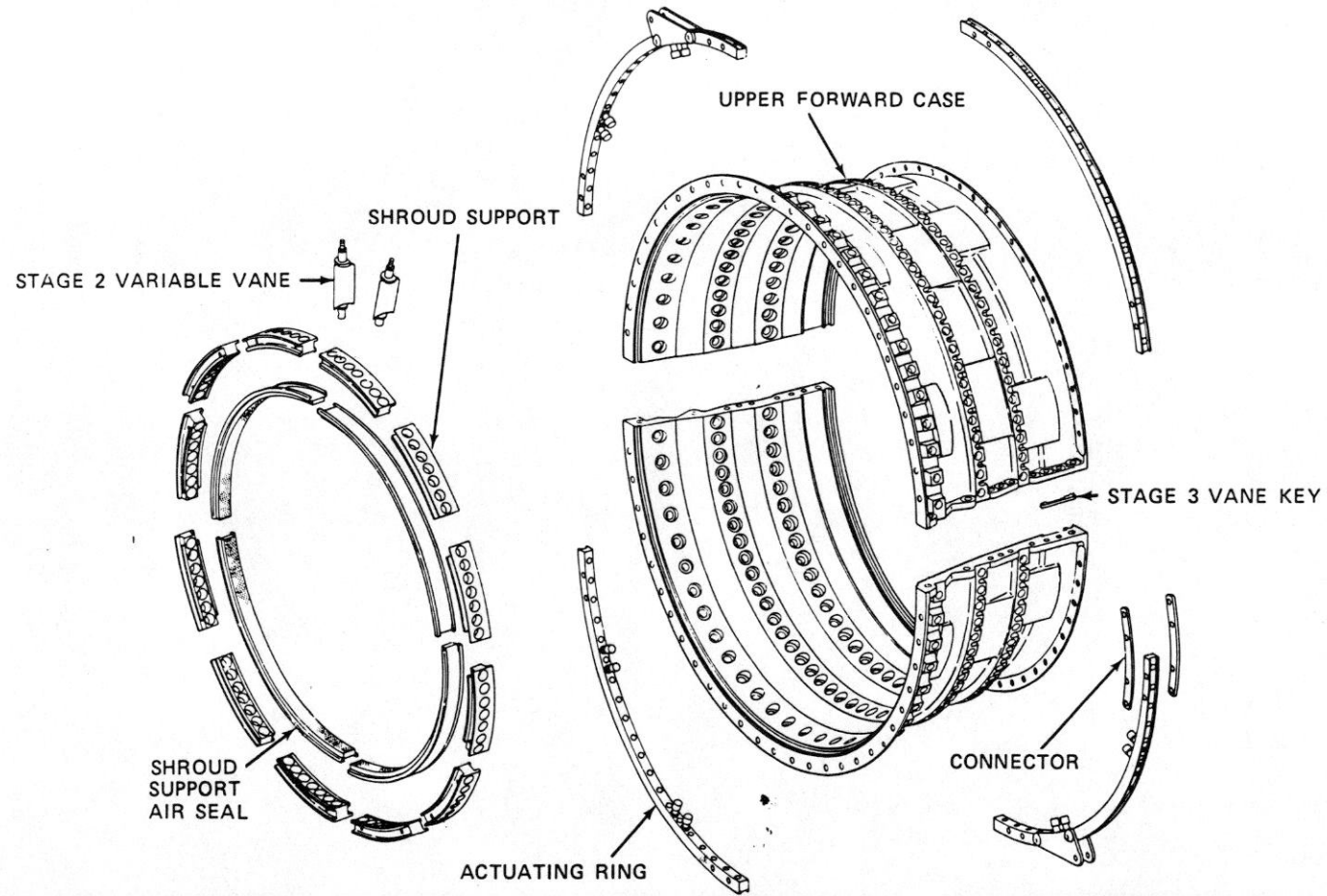
POWER TAKEOFF DRIVE ASSEMBLY

Figure 1-21



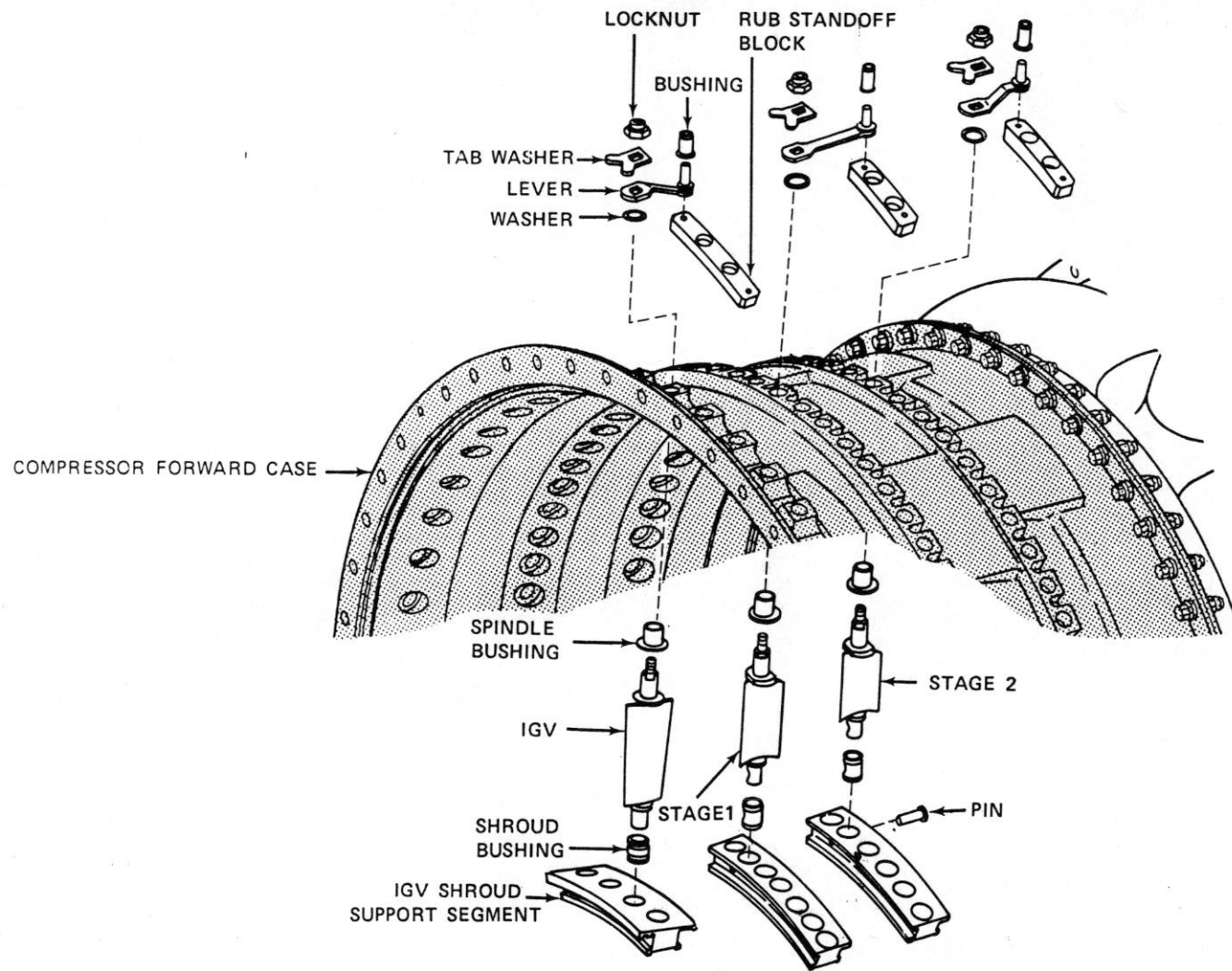
COMPRESSOR STATOR ASSEMBLY

Figure 1-22



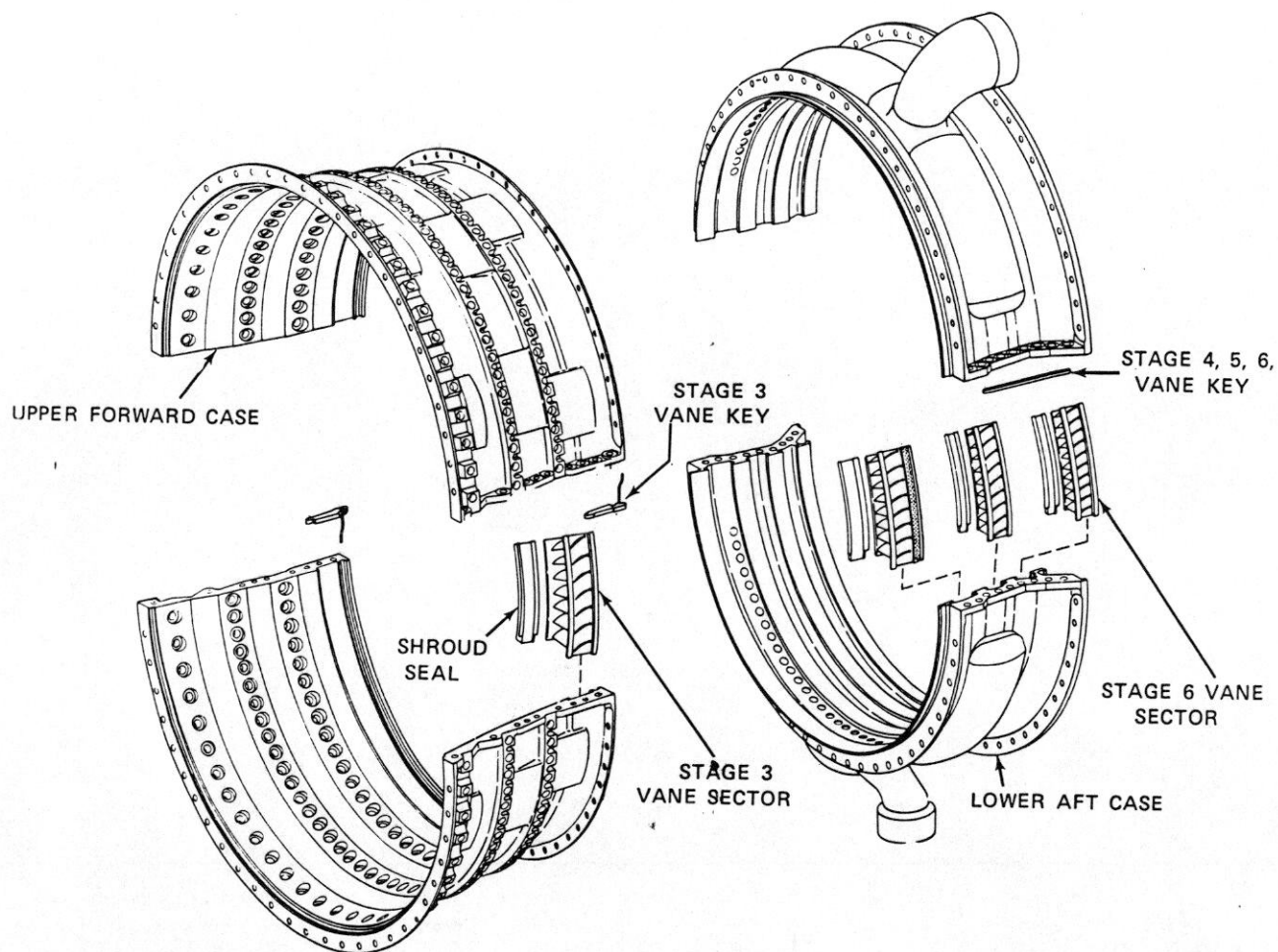
COMPRESSOR VARIABLE GEOMETRY COMPONENTS

Figure 1-23



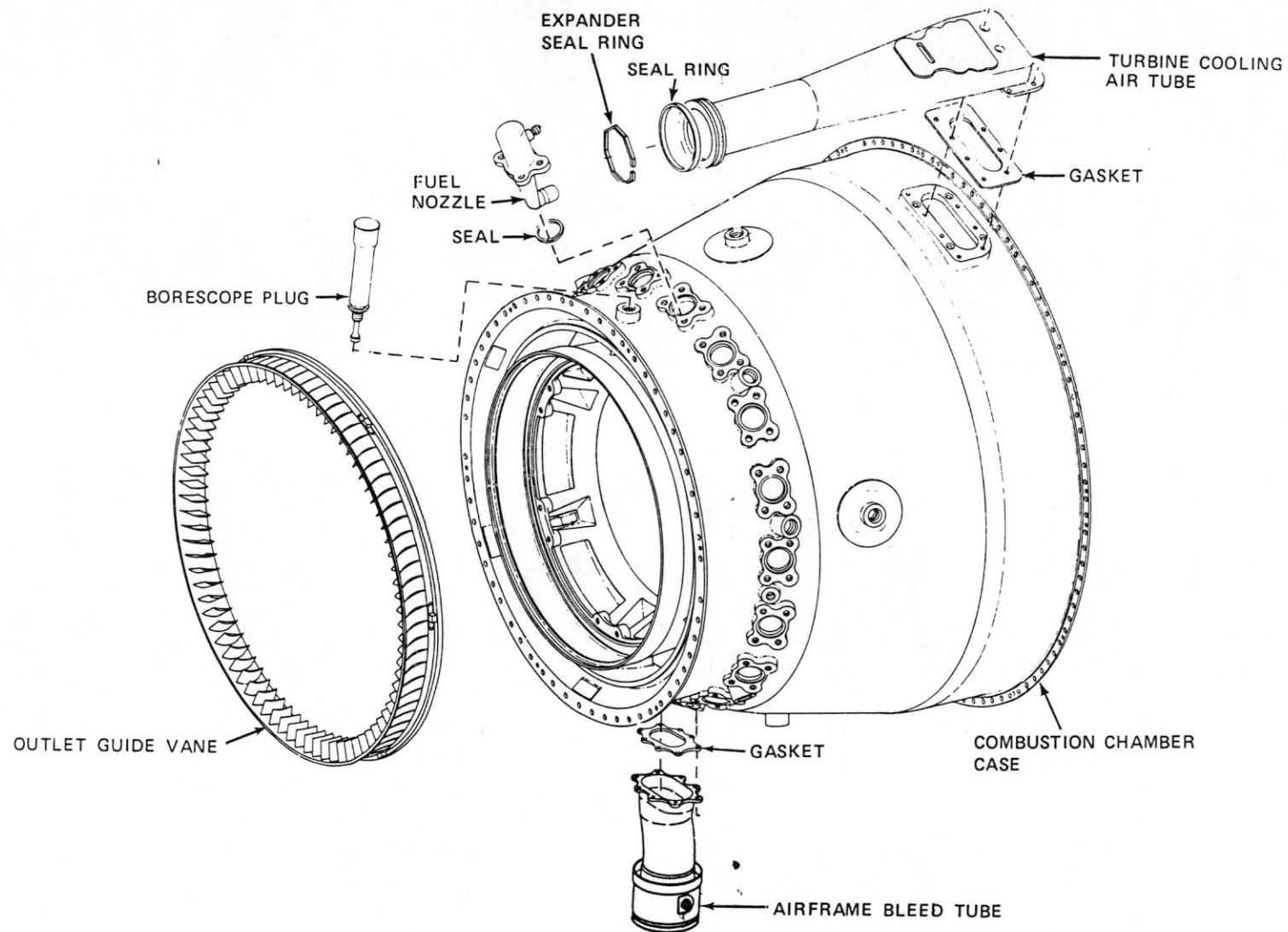
COMPRESSOR VARIABLE VANE COMPONENTS

Figure 1-24



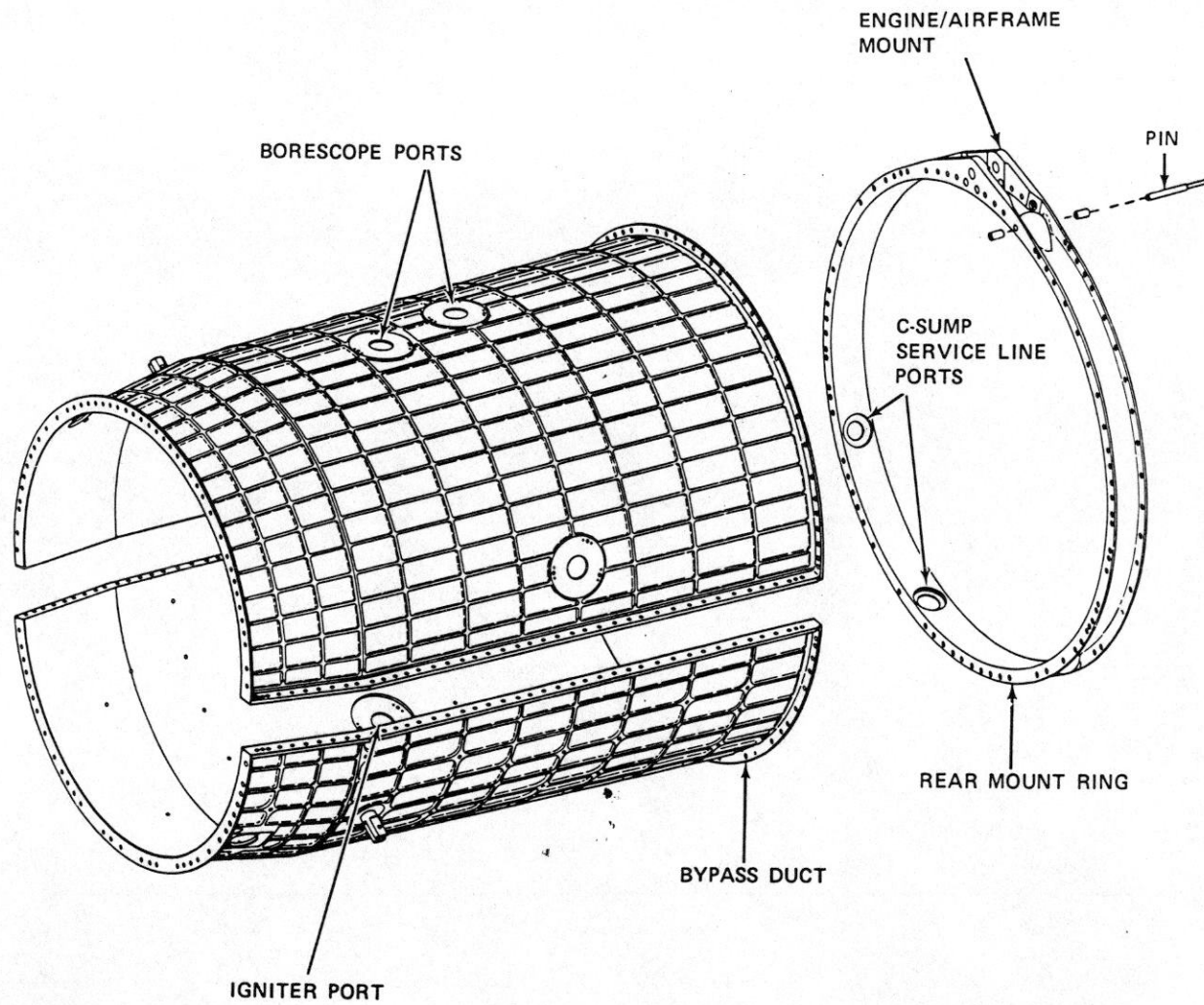
COMPRESSOR STATOR COMPONENTS (STAGE 3-6)

Figure 1-25



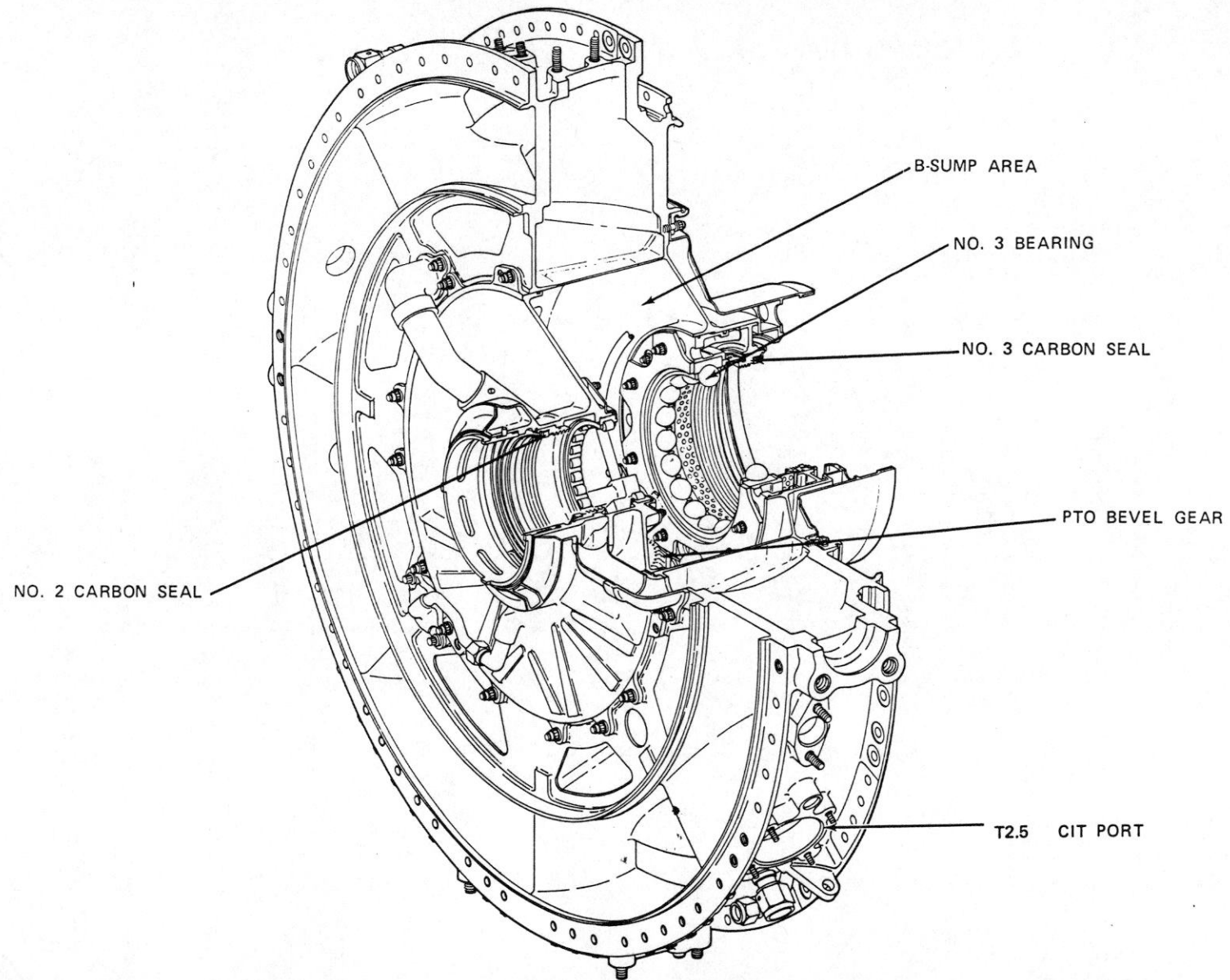
COMBUSTION CHAMBER CASE ASSEMBLY

Figure 1-26



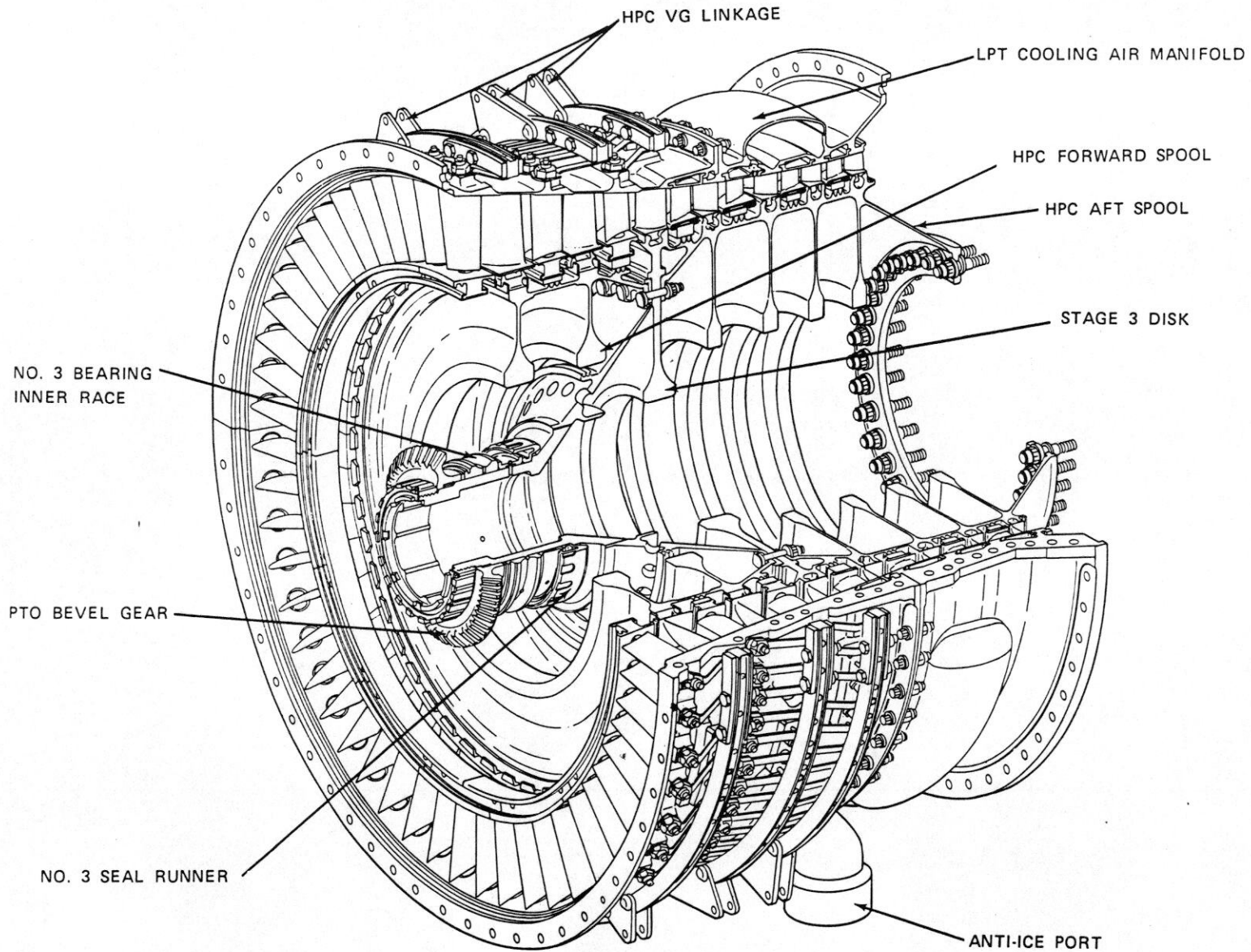
OUTER BYPASS DUCT AND MOUNT RING

Figure 1-27



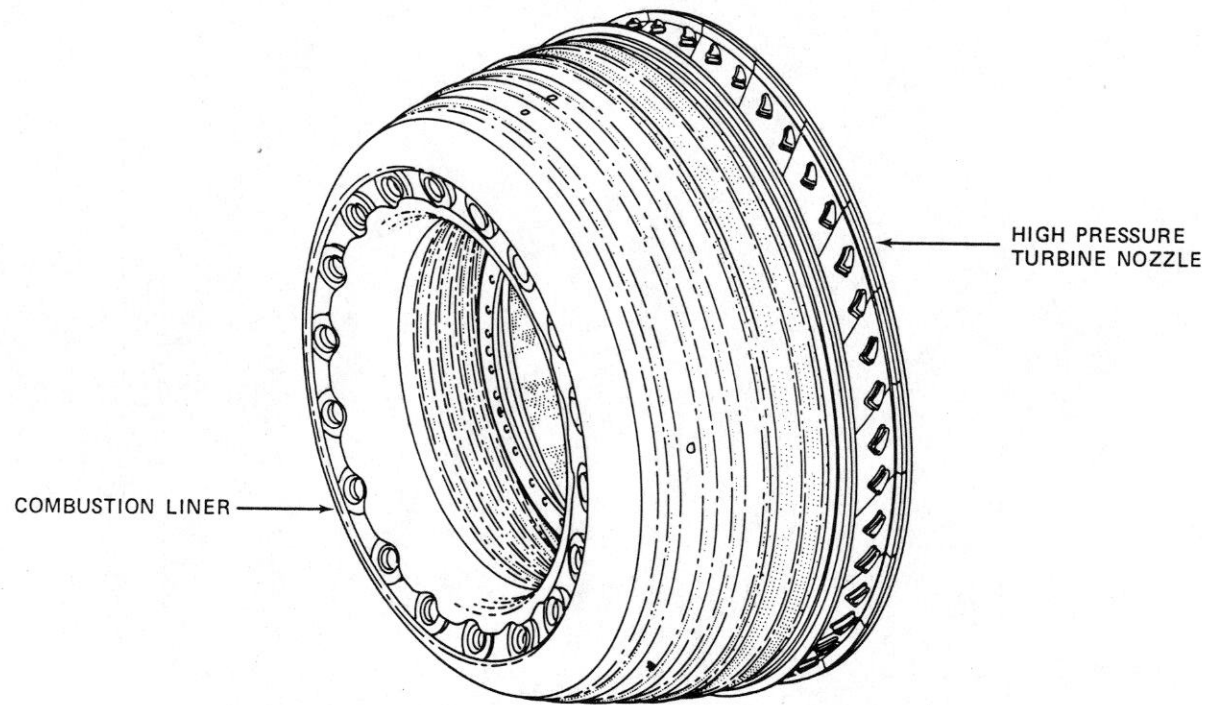
MIDFRAME (CUTAWAY)

Figure 1-28



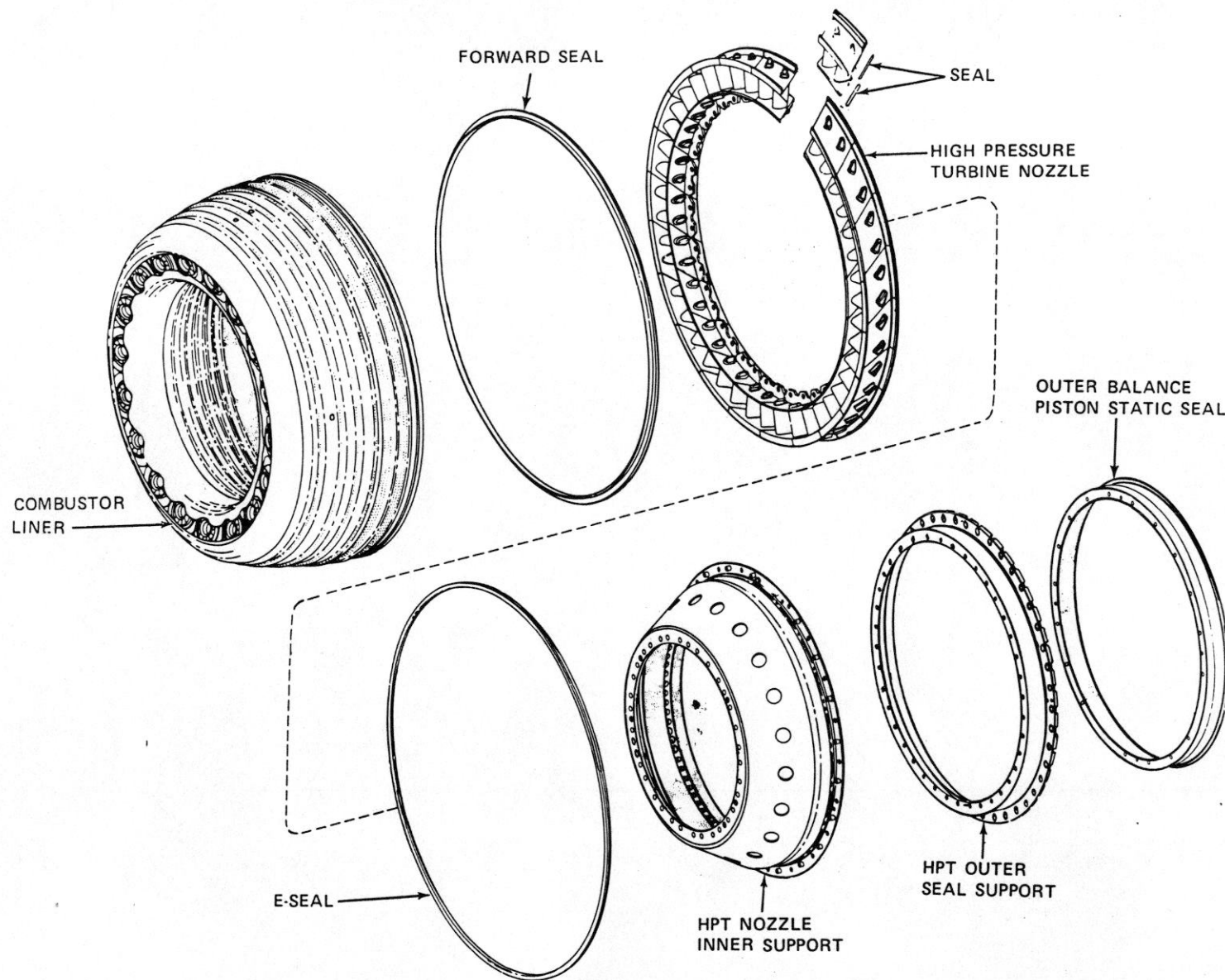
COMPRESSOR (CUTAWAY)

Figure 1-29



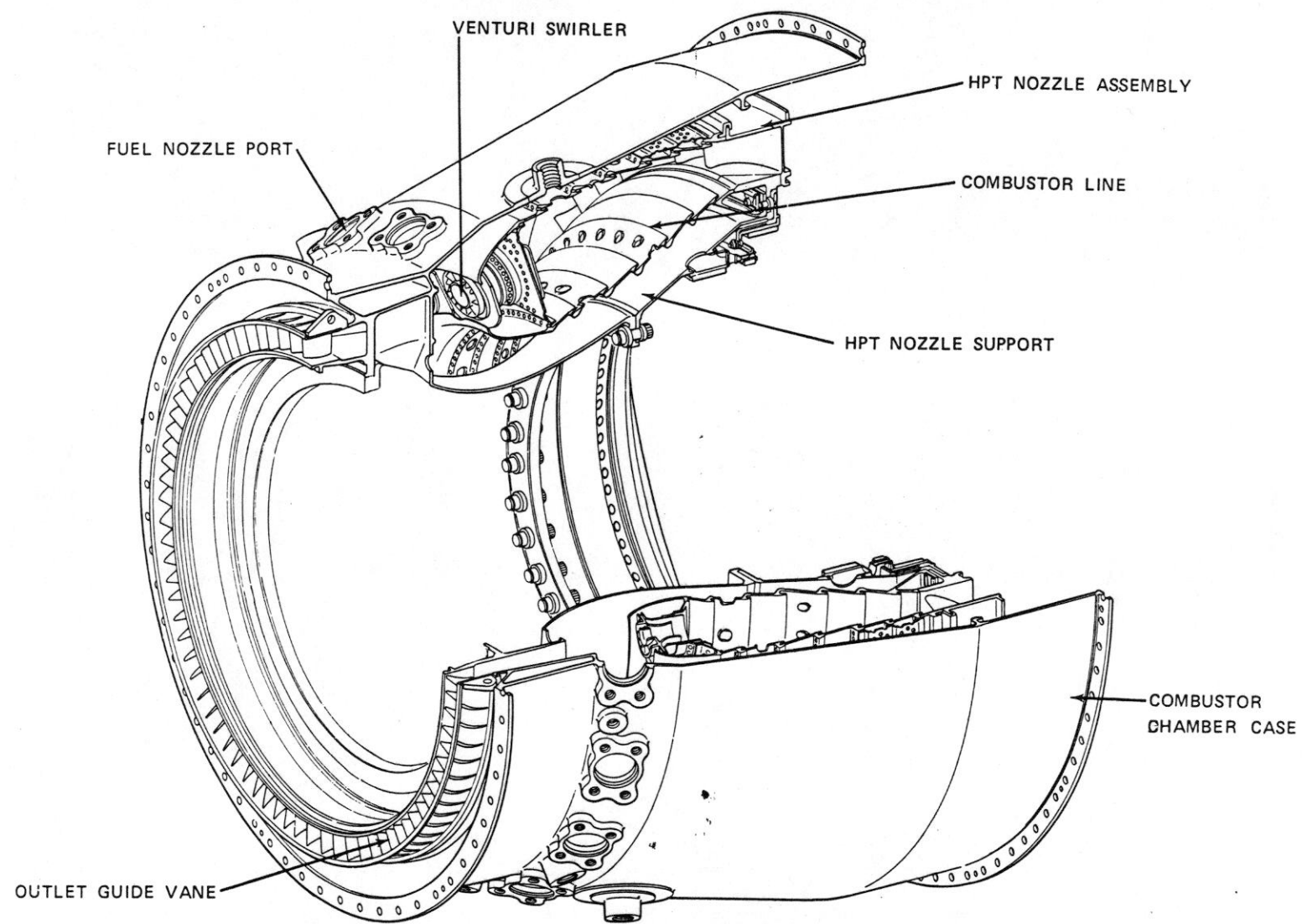
COMBUSTOR MODULE

Figure 1-30



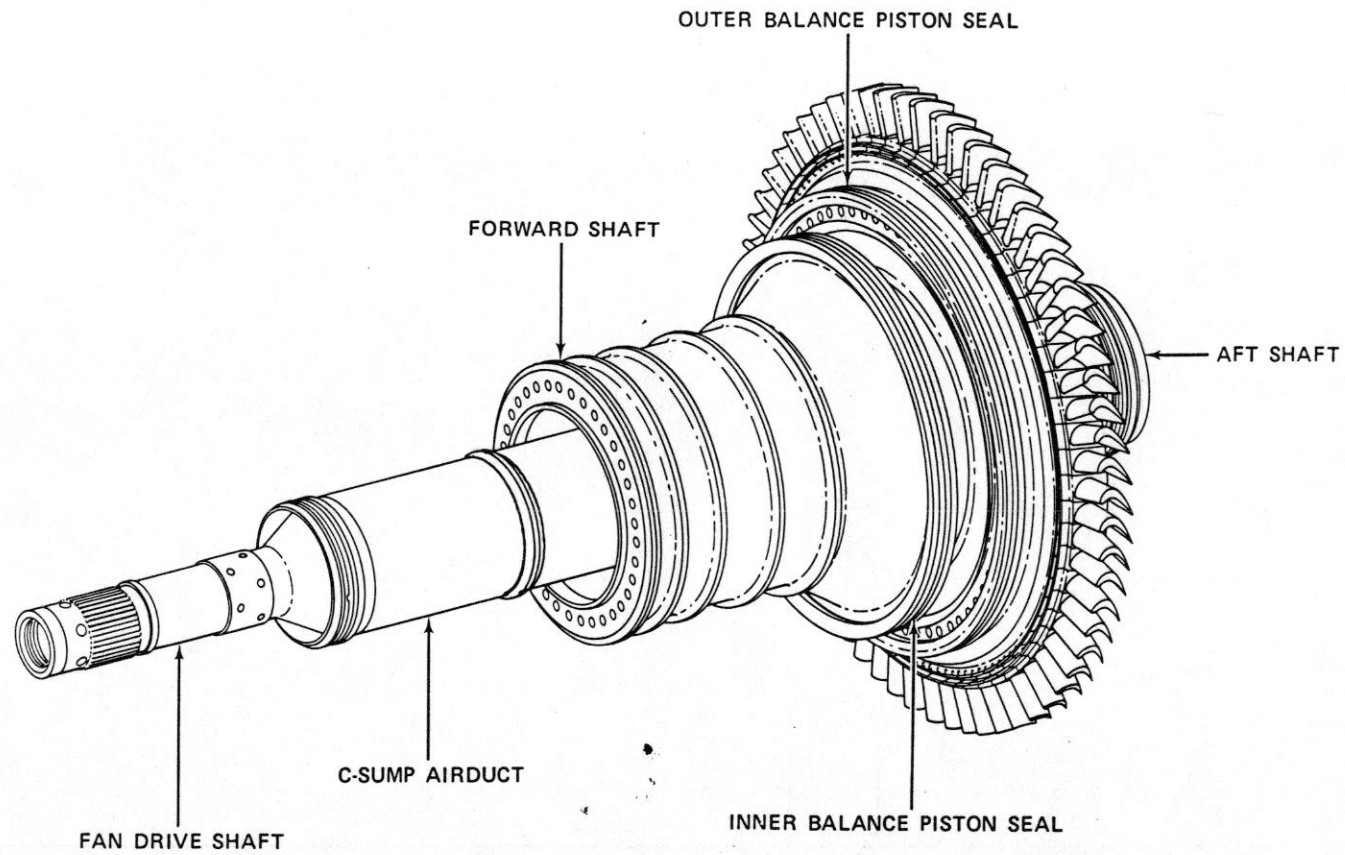
COMBUSTOR MODULE COMPONENTS

Figure 1-31



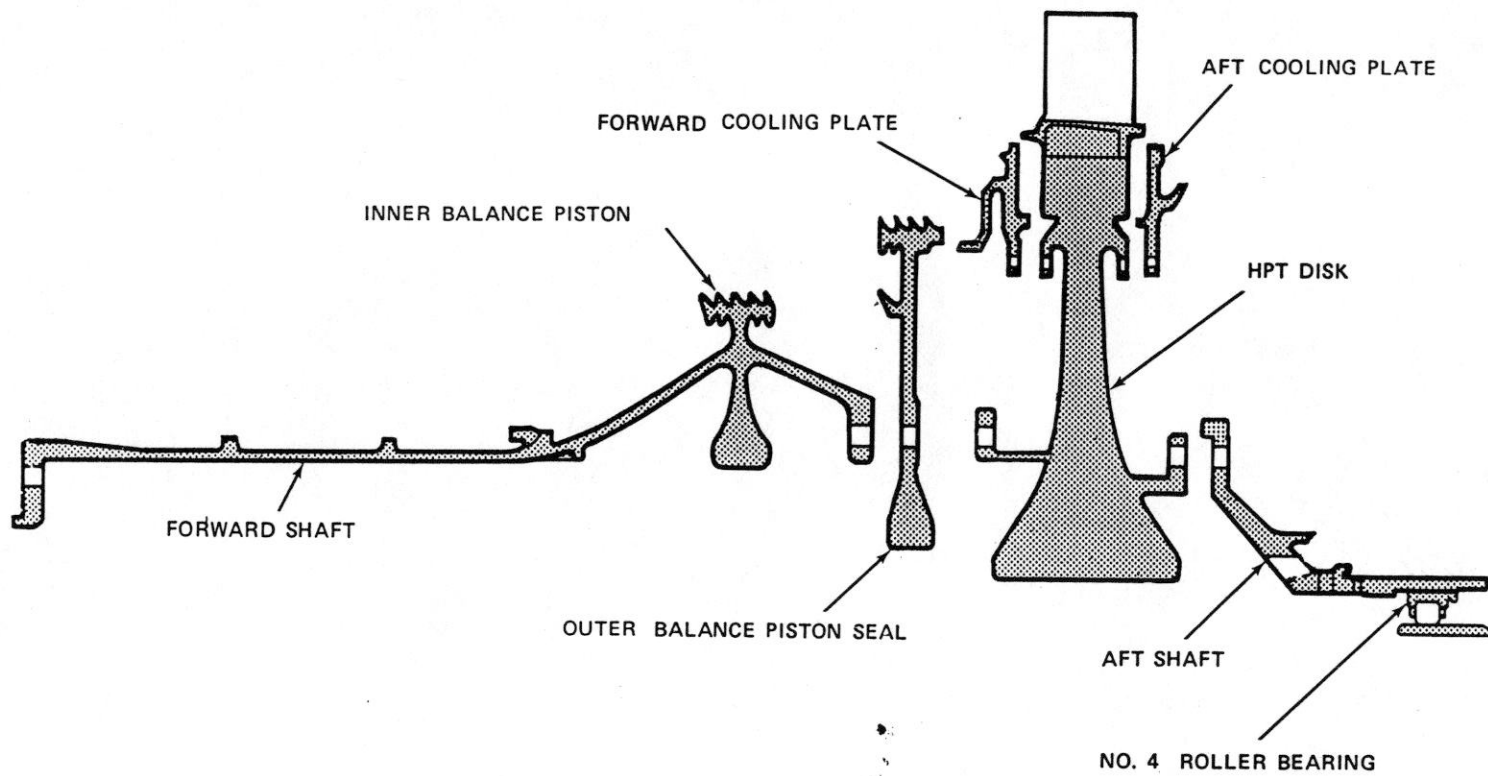
COMBUSTOR MODULE (CUTAWAY)

Figure 1-32



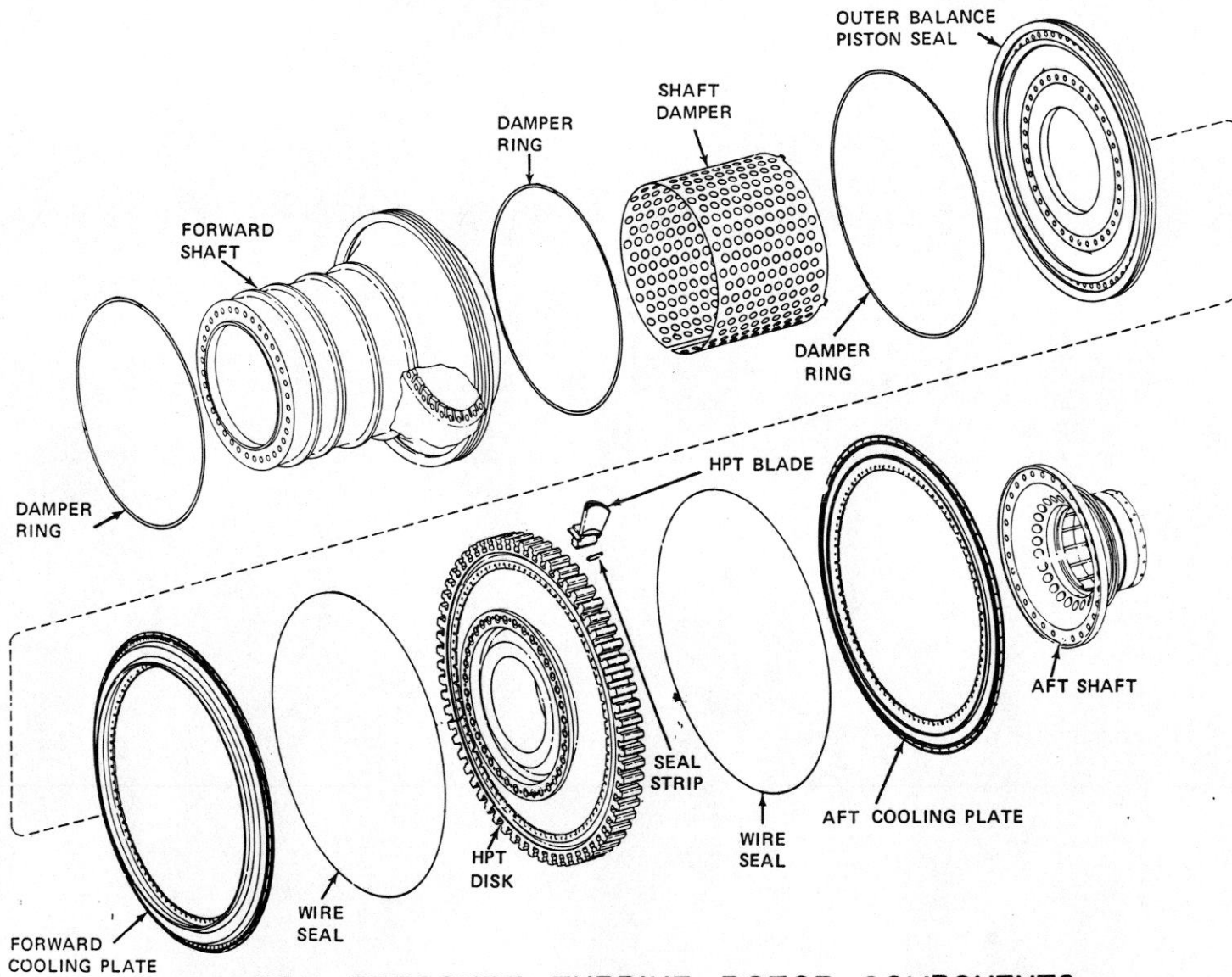
HIGH PRESSURE TURBINE MODULE

Figure 1-33



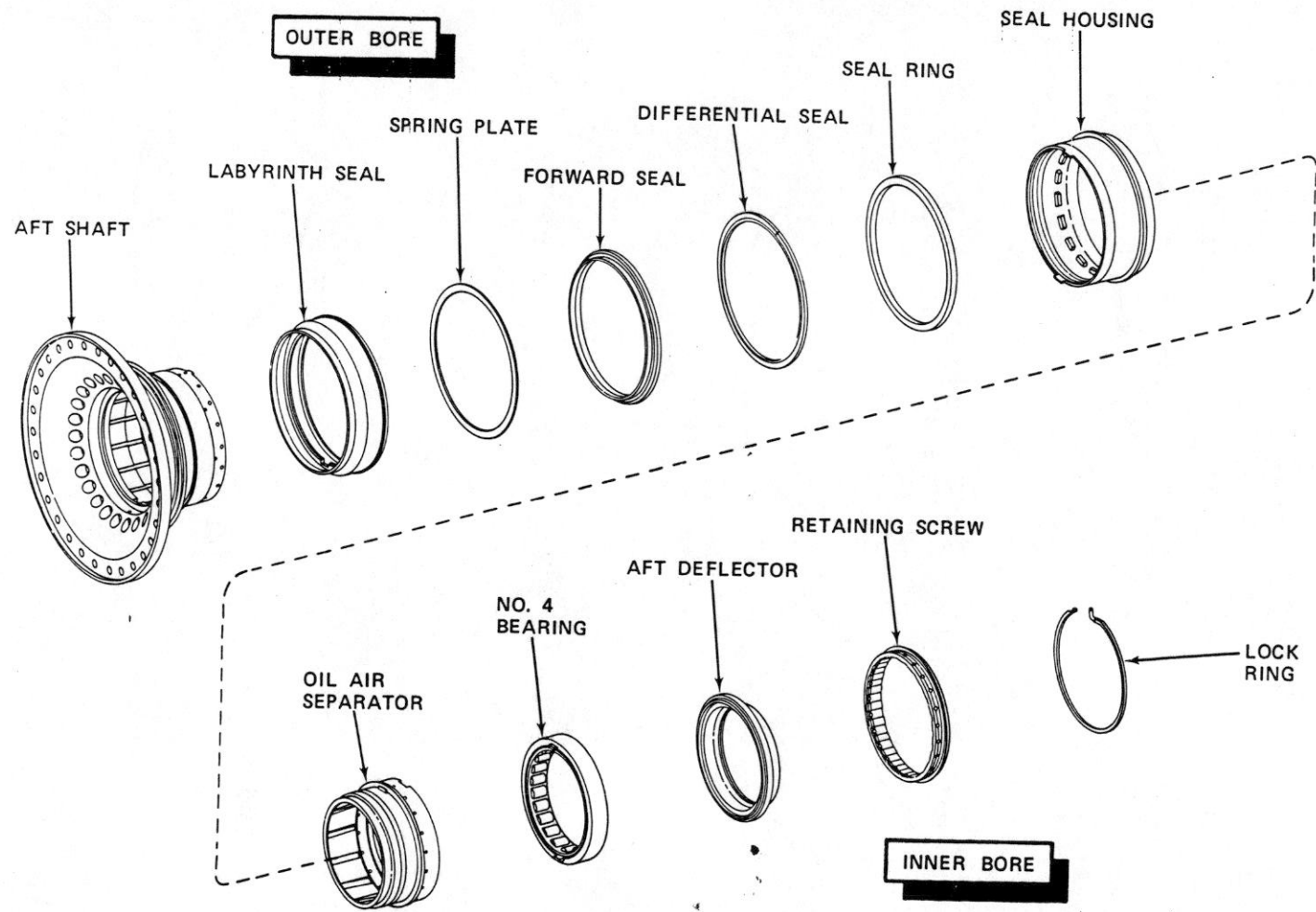
HIGH PRESSURE TURBINE ROTOR (CROSS SECTION)

Figure 1-34



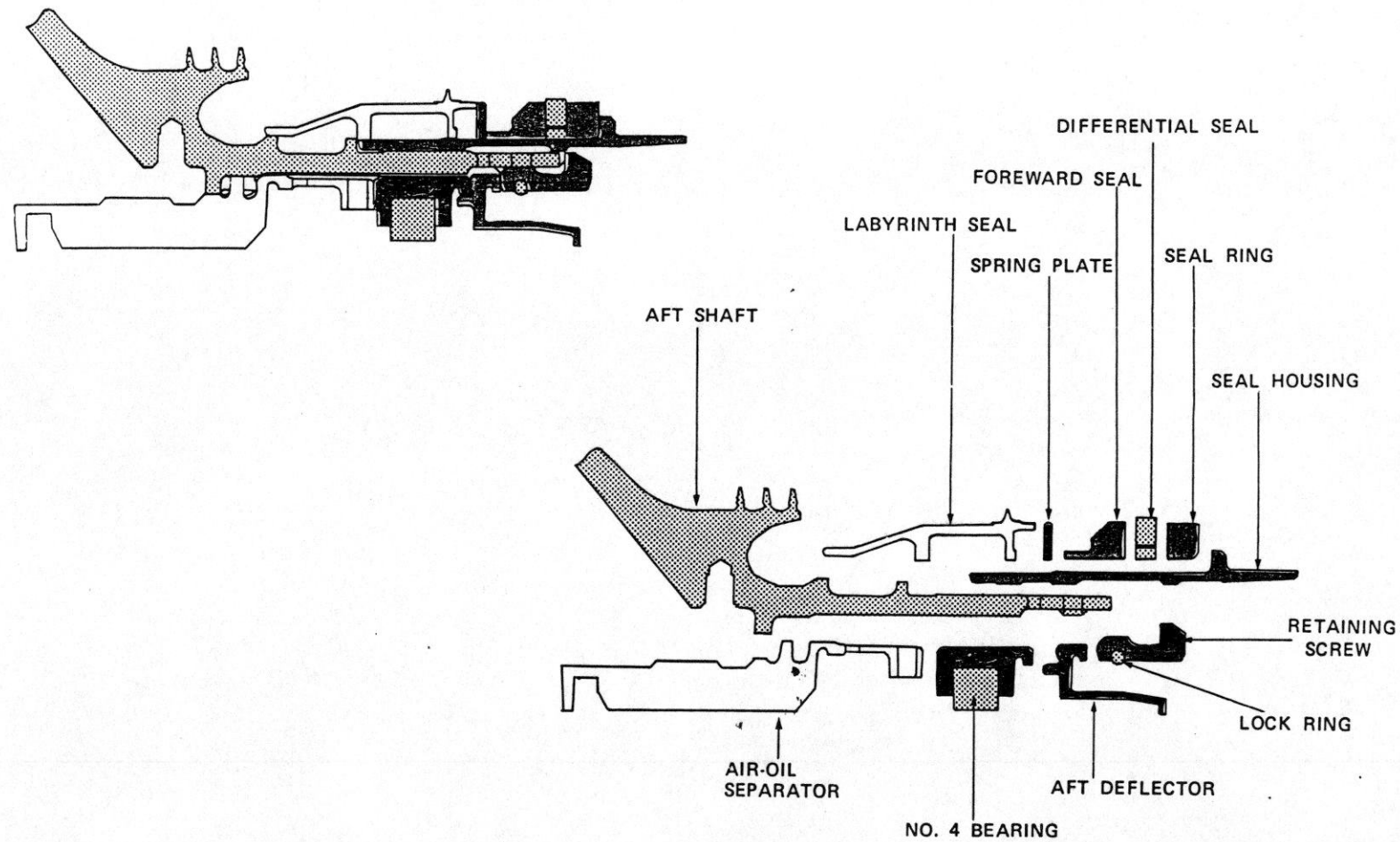
HIGH PRESSURE TURBINE ROTOR COMPONENTS

Figure 1-35



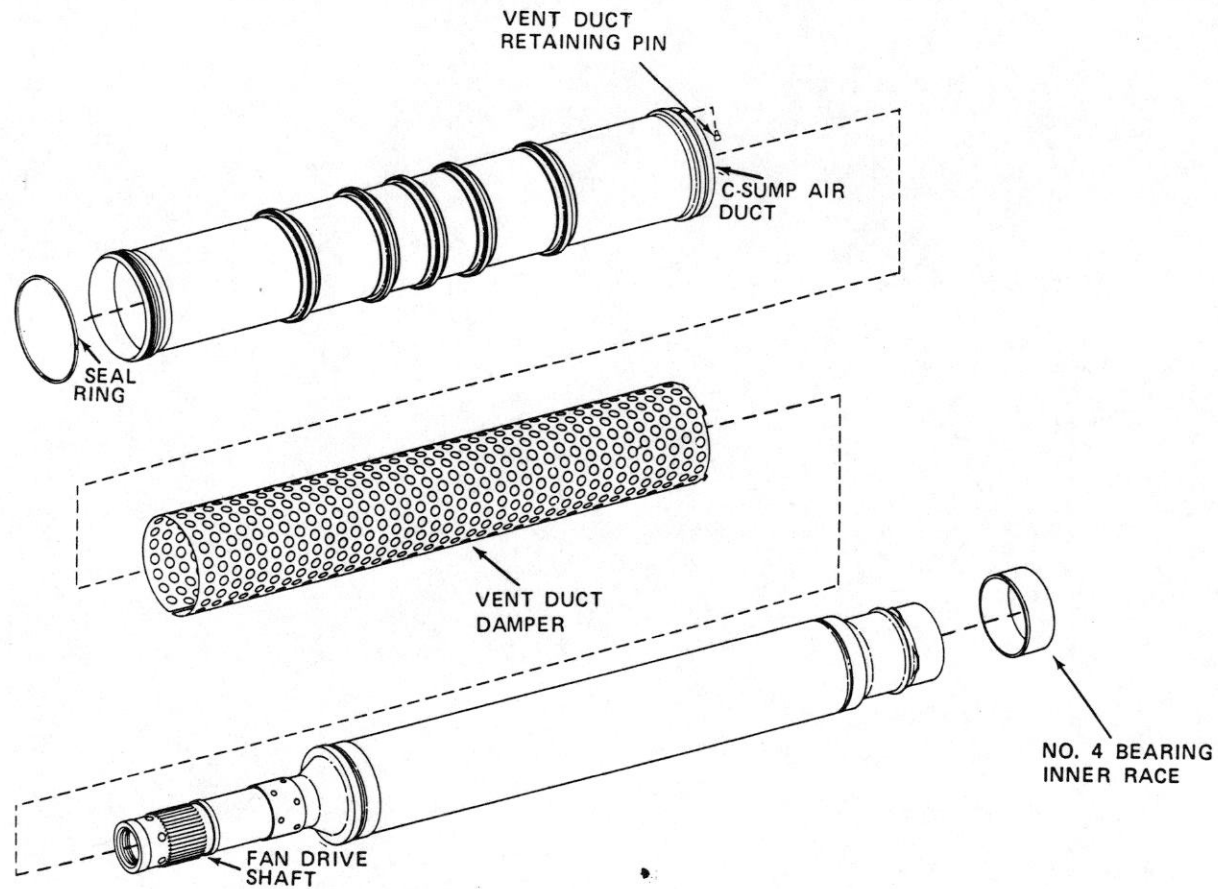
AFT SHAFT COMPONENTS

Figure 1-36



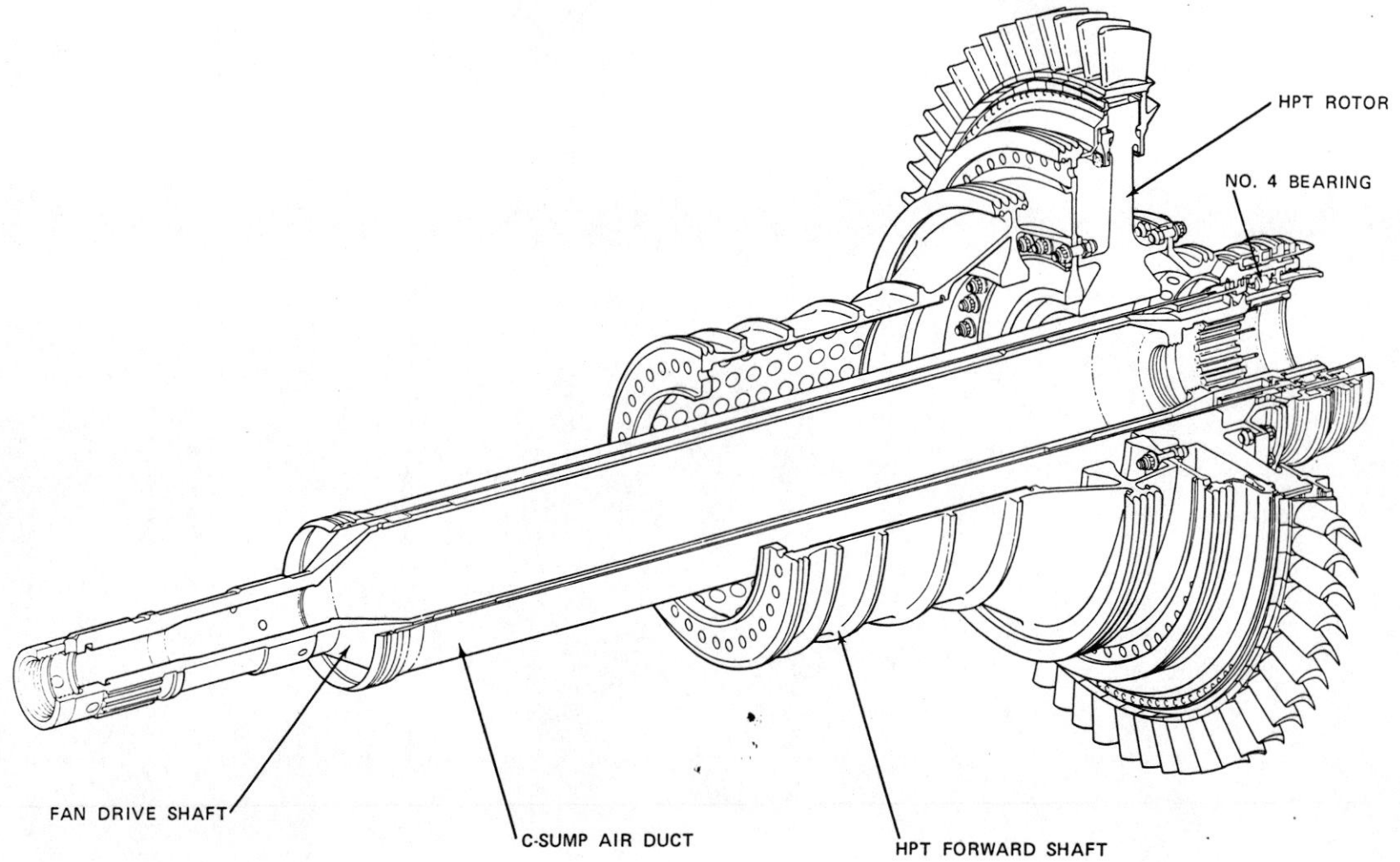
NUMBER 4 BEARING AREA

Figure 1-37



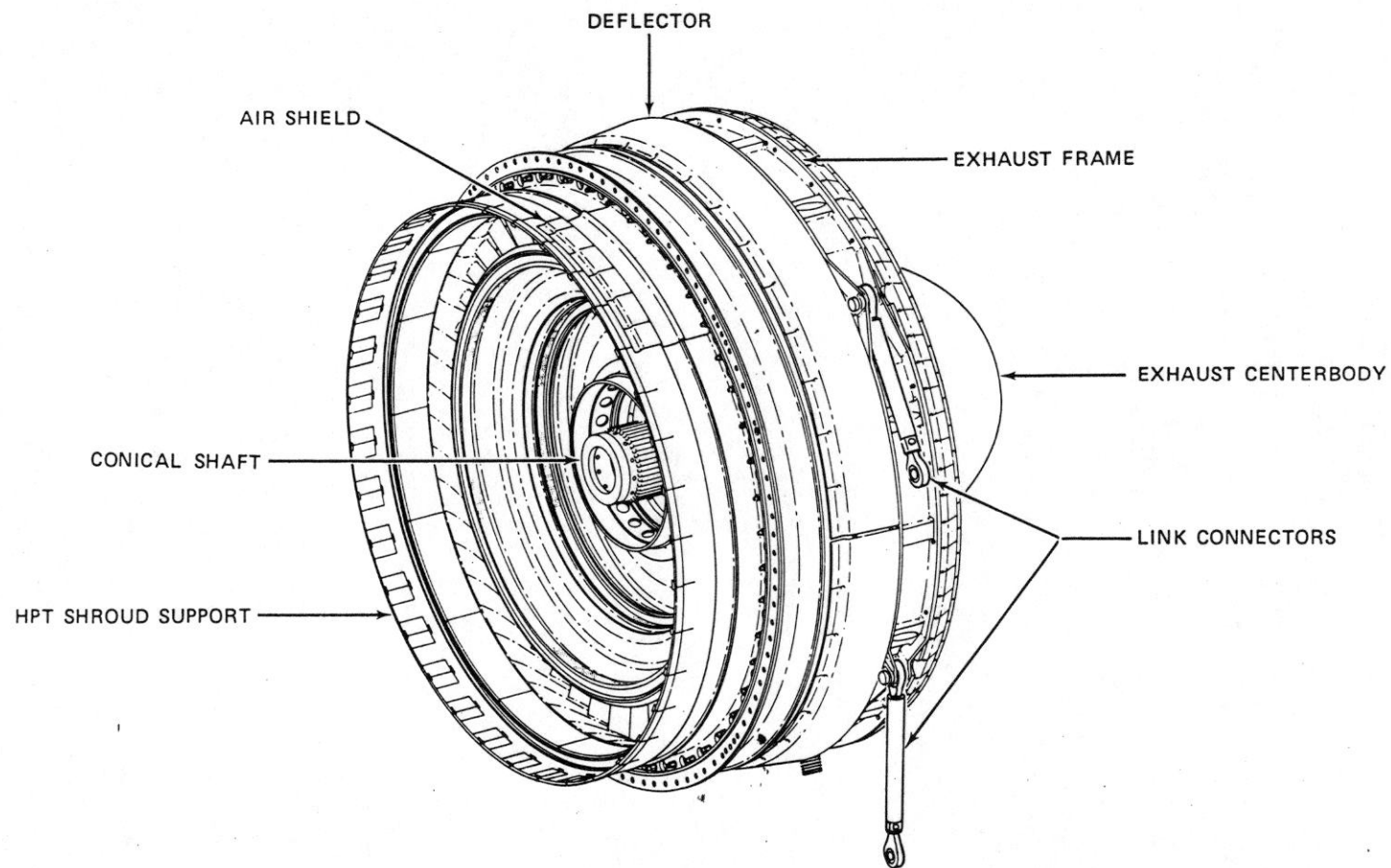
FAN DRIVE SHAFT ASSEMBLY

Figure 1-38



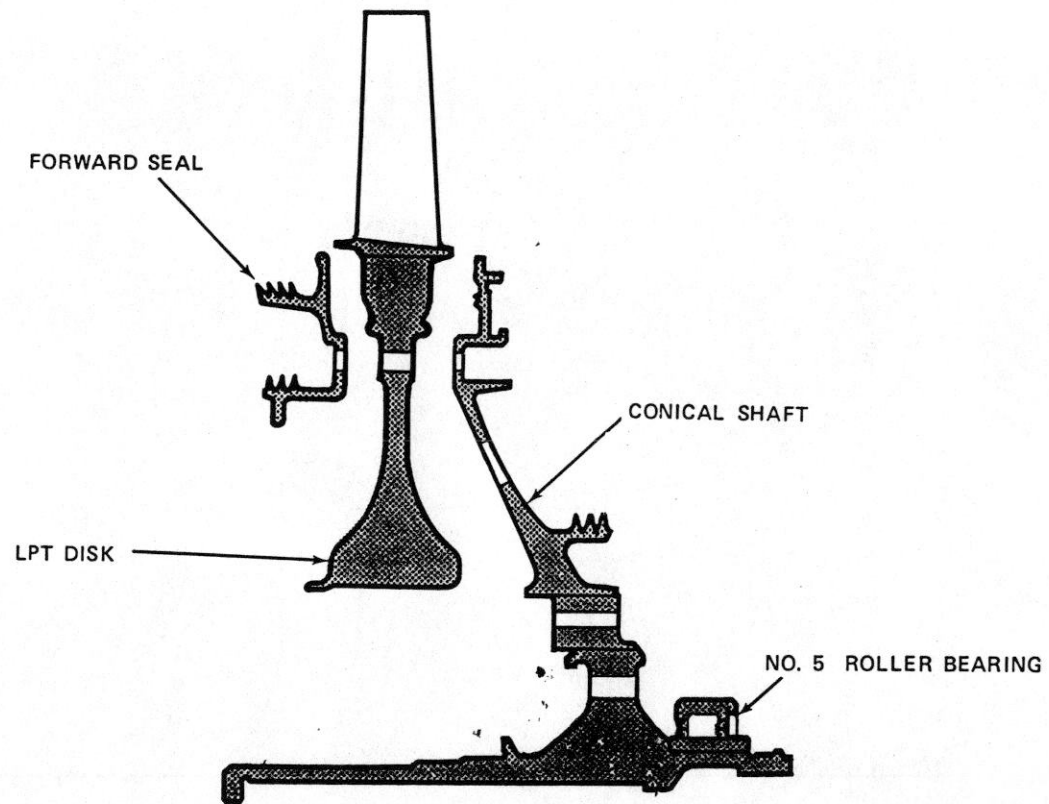
HIGH PRESSURE TURBINE (CUTAWAY)

Figure 1-39



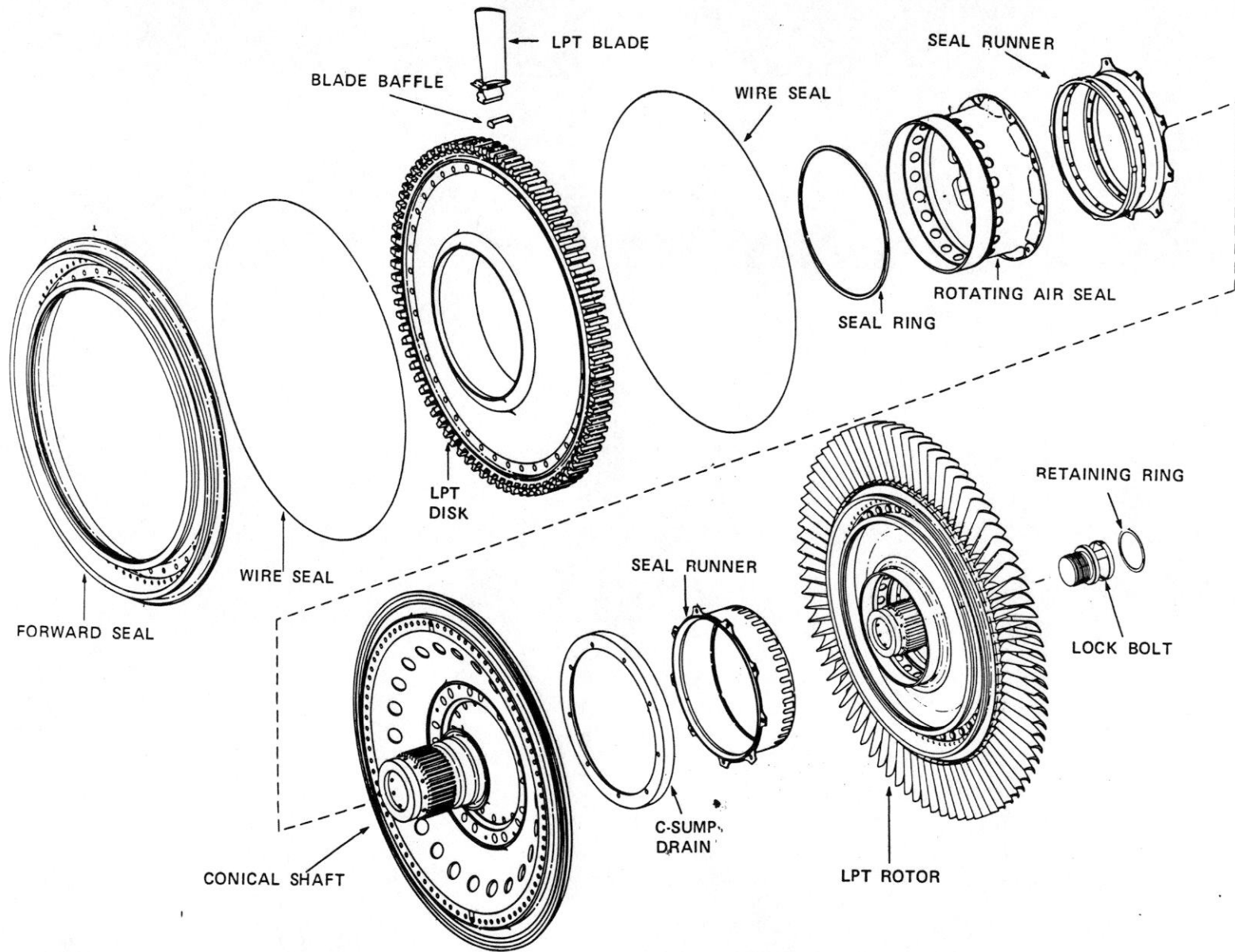
LOW PRESSURE TURBINE MODULE

Figure 1-40



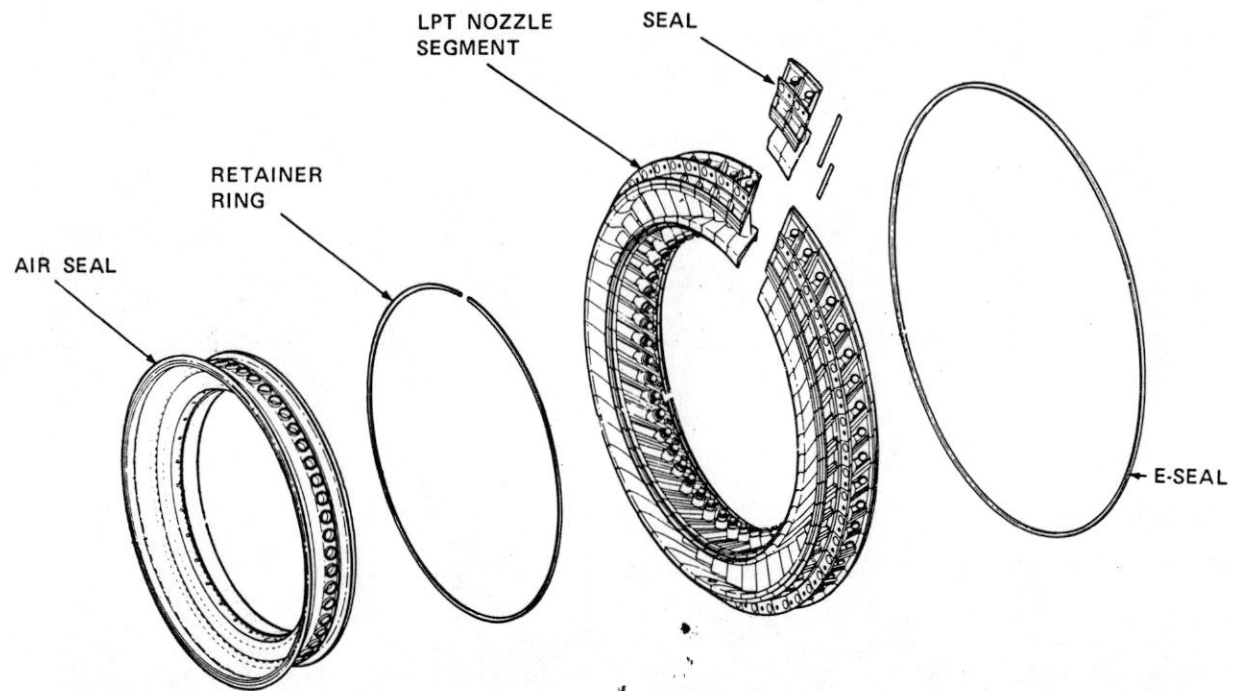
LOW PRESSURE TURBINE ROTOR (CROSS SECTION VIEW)

Figure 1-41



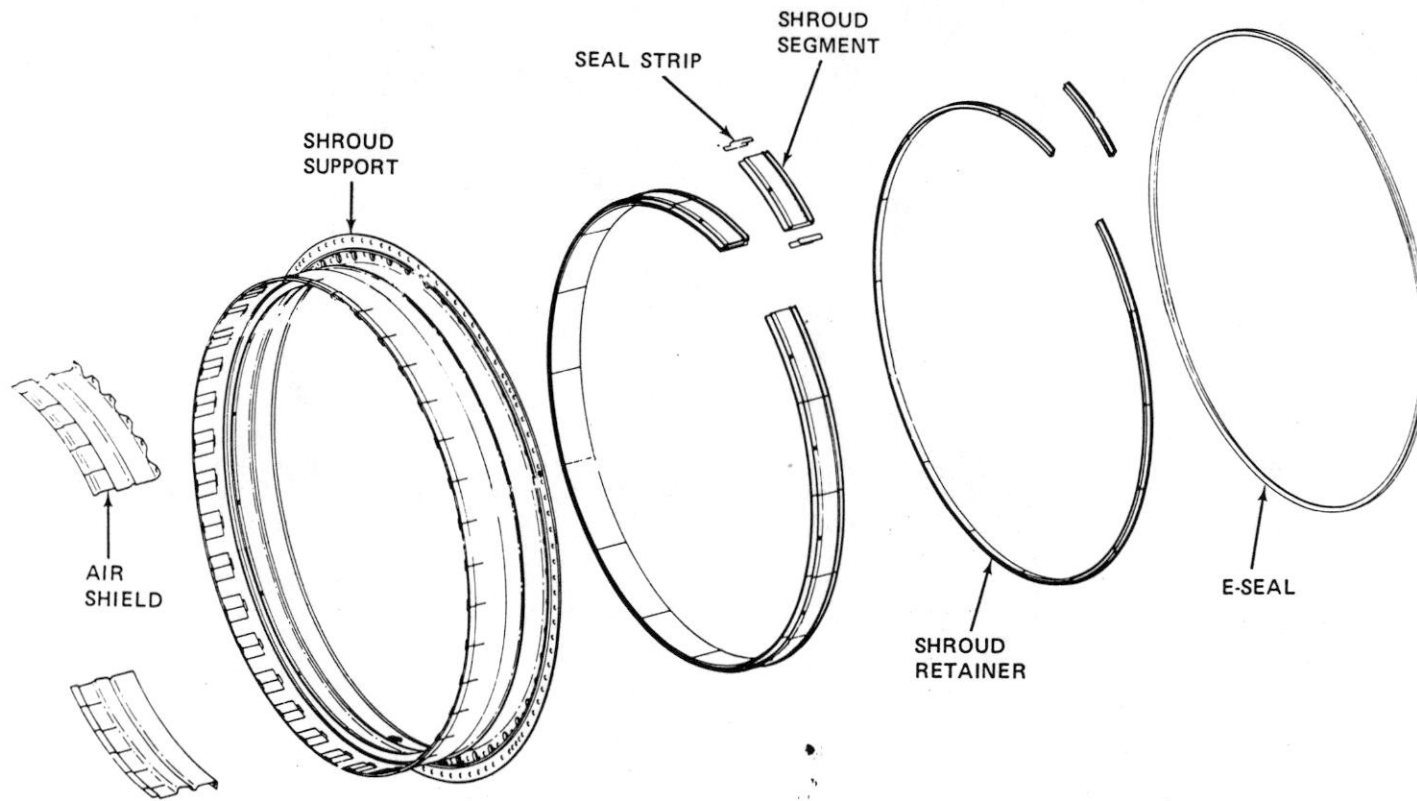
LOW PRESSURE TURBINE ROTOR COMPONENTS

Figure 1-42



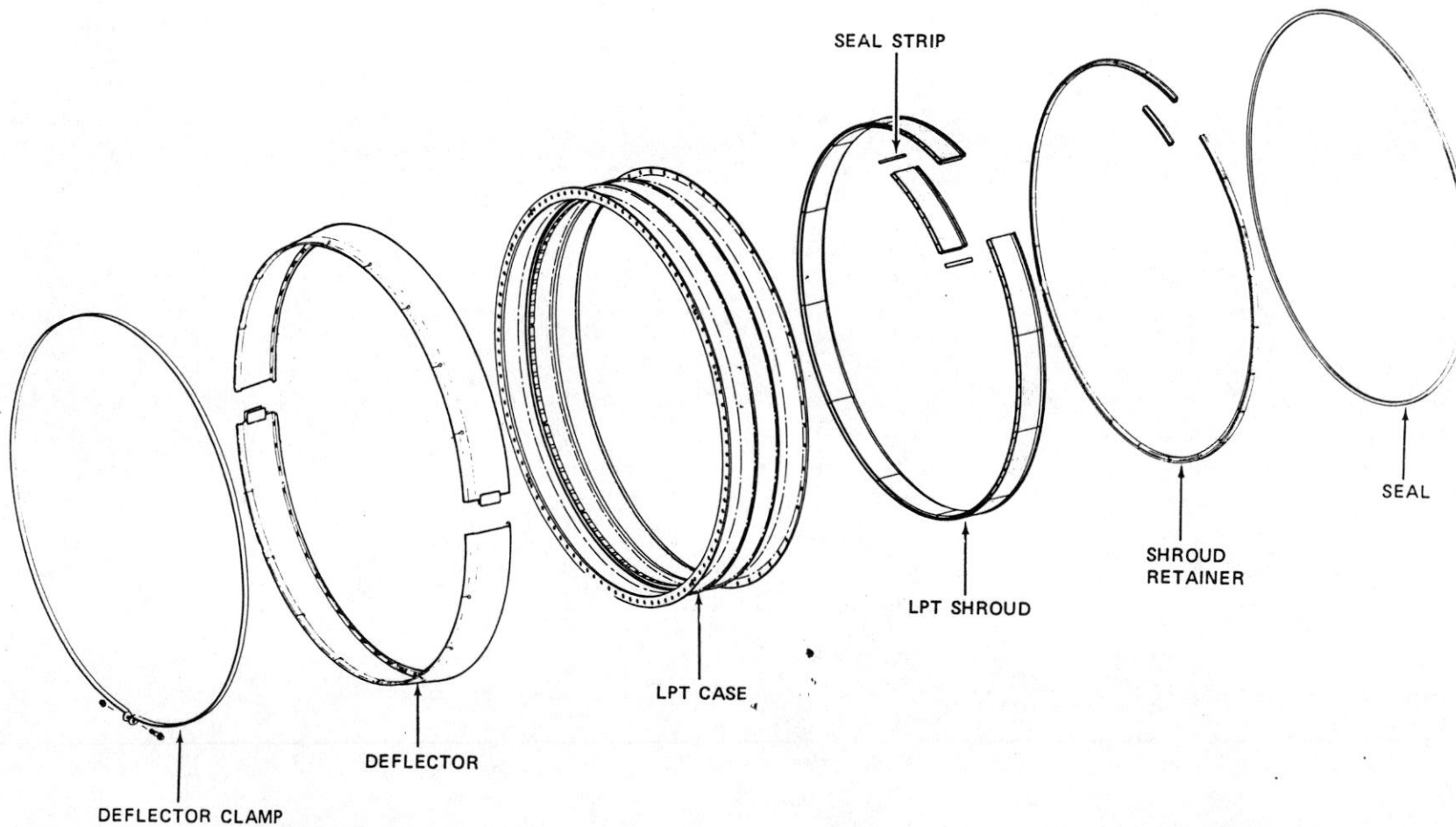
LOW PRESSURE TURBINE NOZZLE COMPONENTS

Figure 1-43



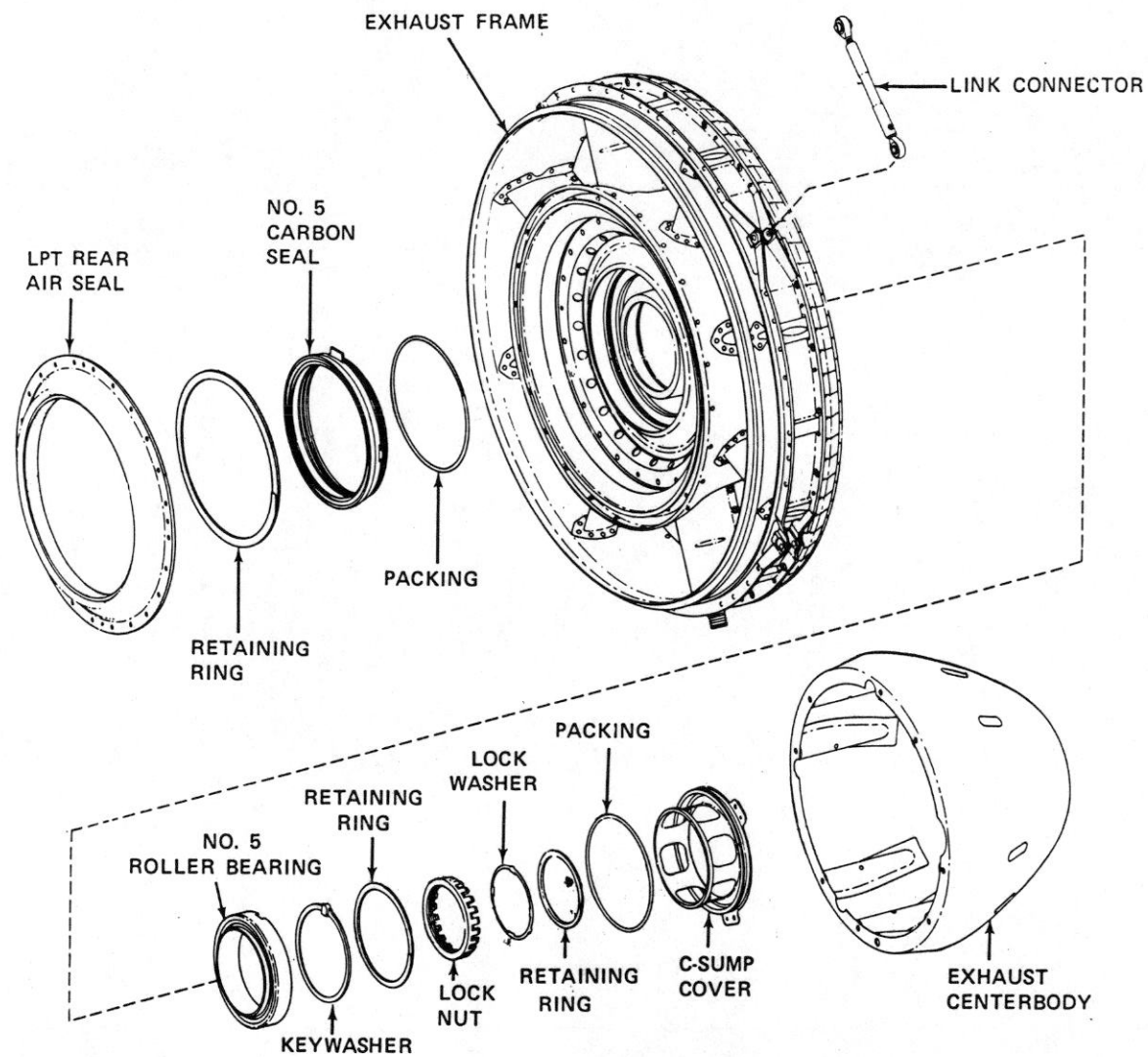
HIGH PRESSURE TURBINE SHROUD COMPONENTS

Figure 1-44



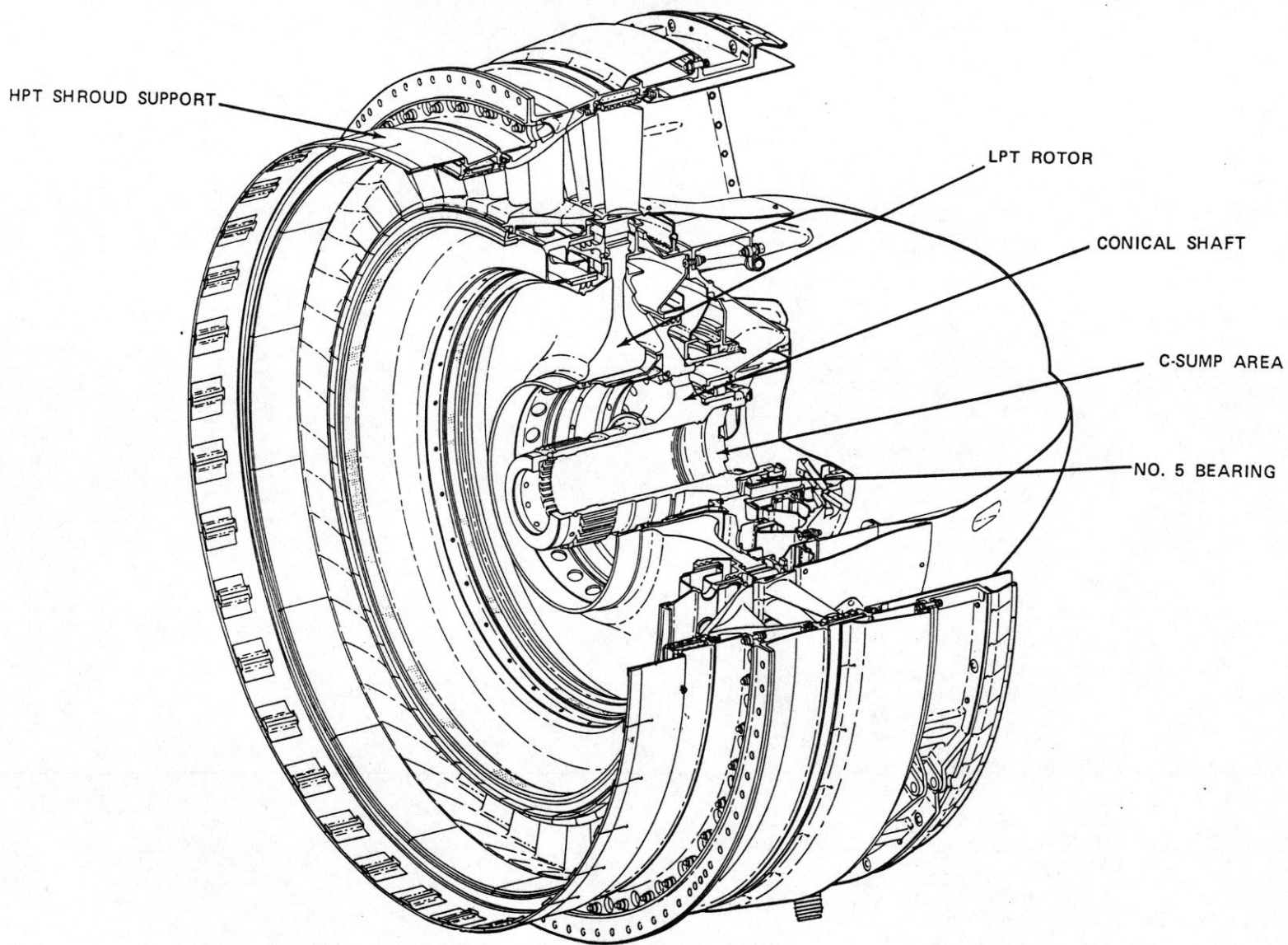
LOW PRESSURE TURBINE CASE AND SHROUD COMPONENTS

Figure 1-45



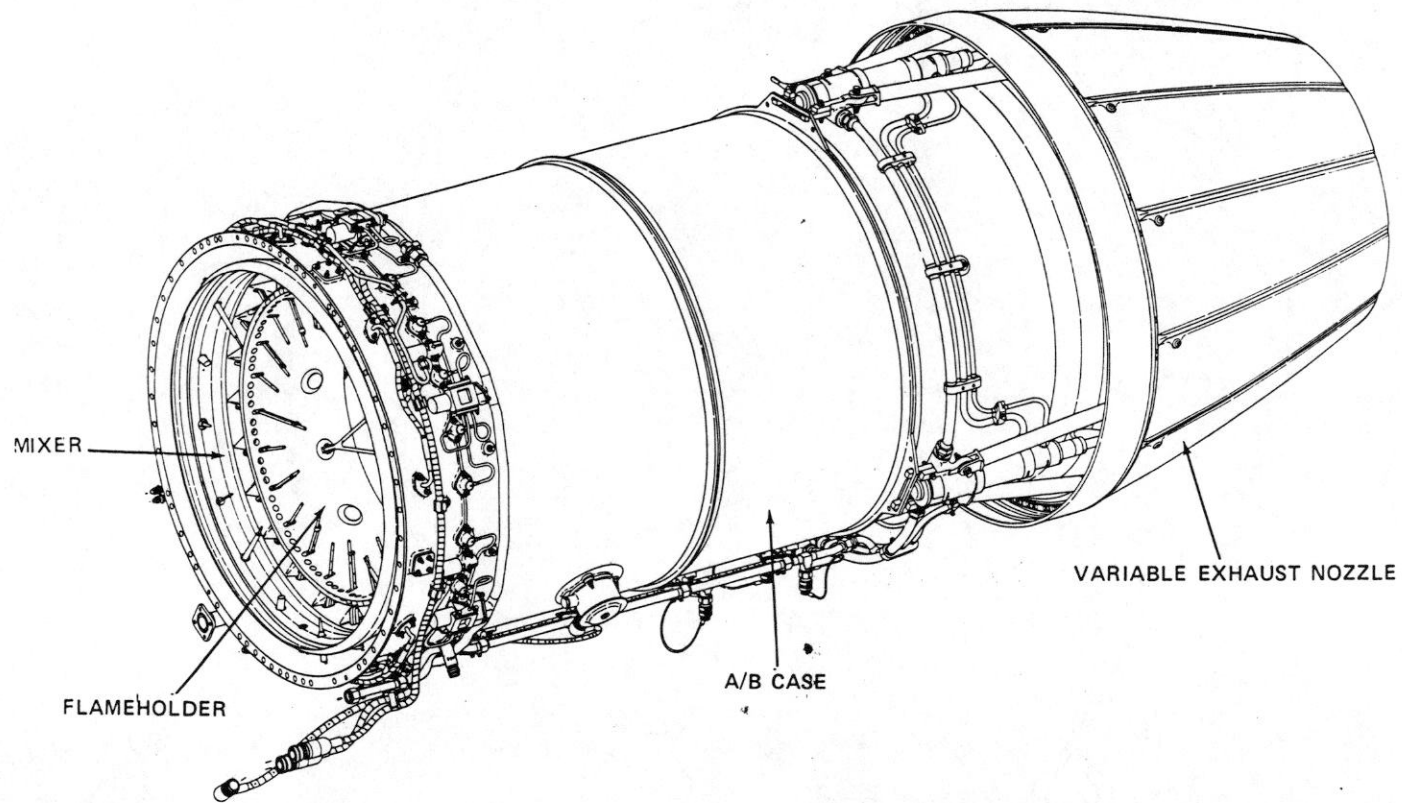
EXHAUST FRAME AND C-SUMP COMPONENTS

Figure 1-46



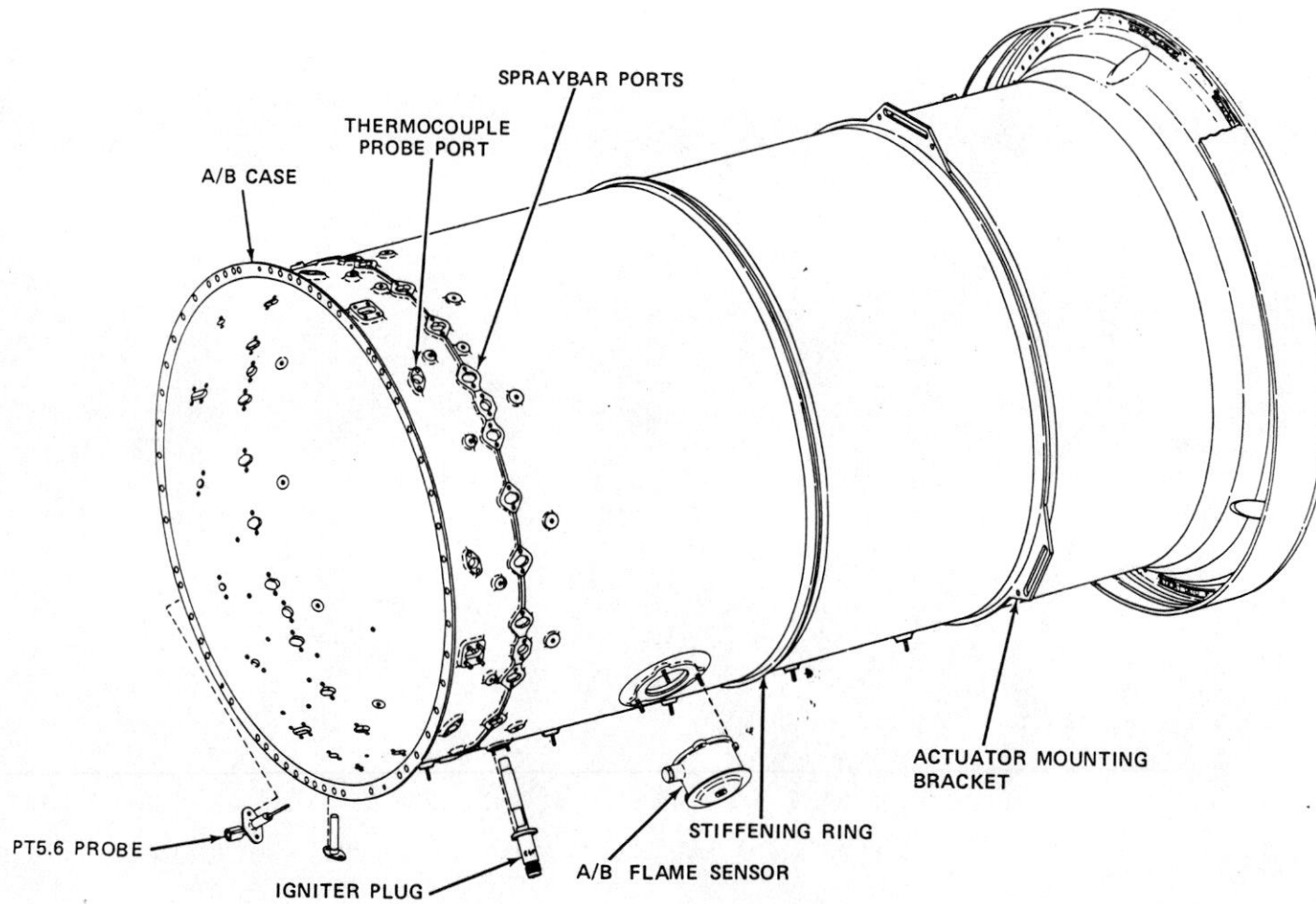
LOW PRESSURE TURBINE MODULE (CUTAWAY)

Figure 1-47



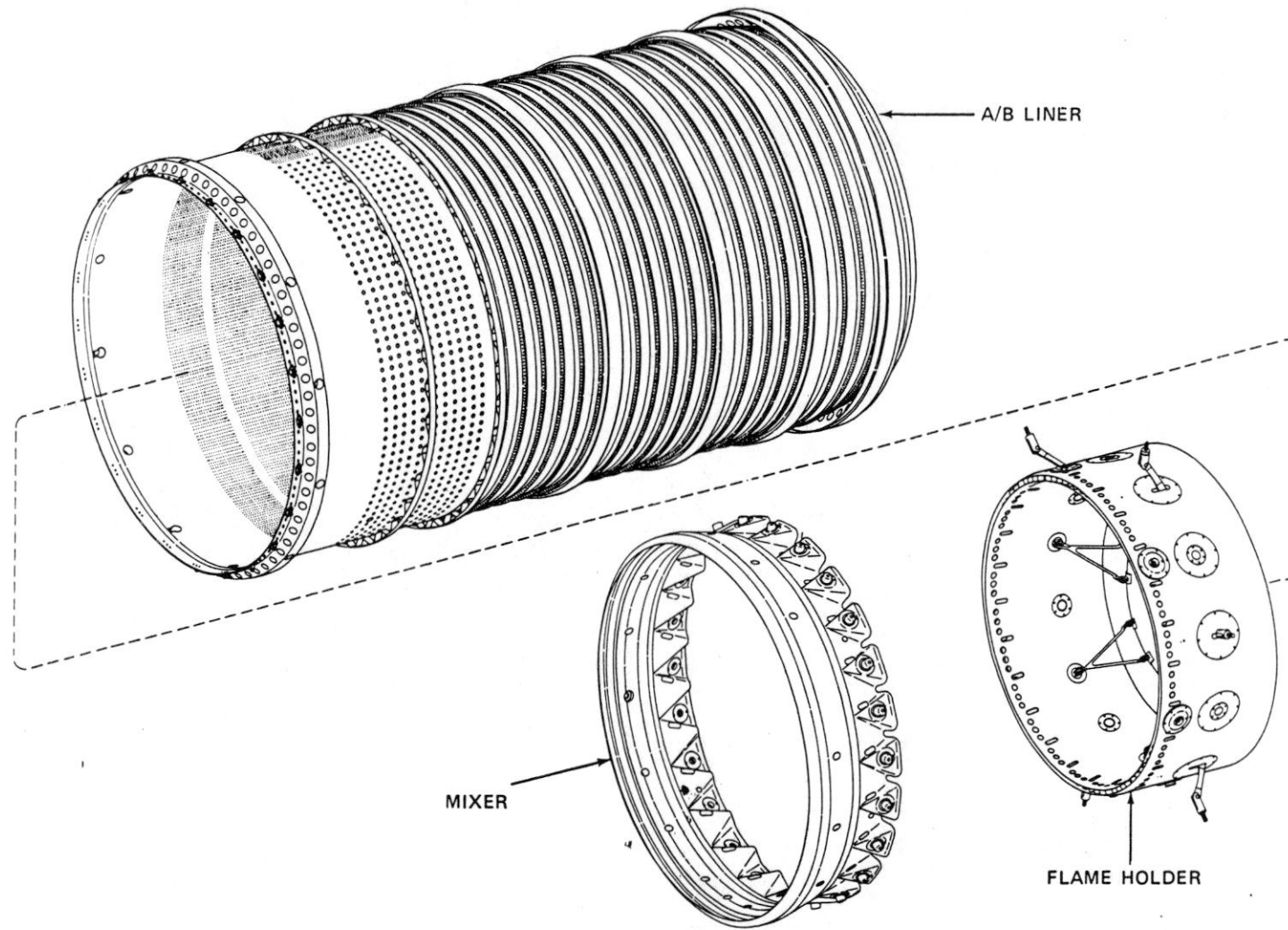
AFTERBURNER MODULE

Figure 1-48



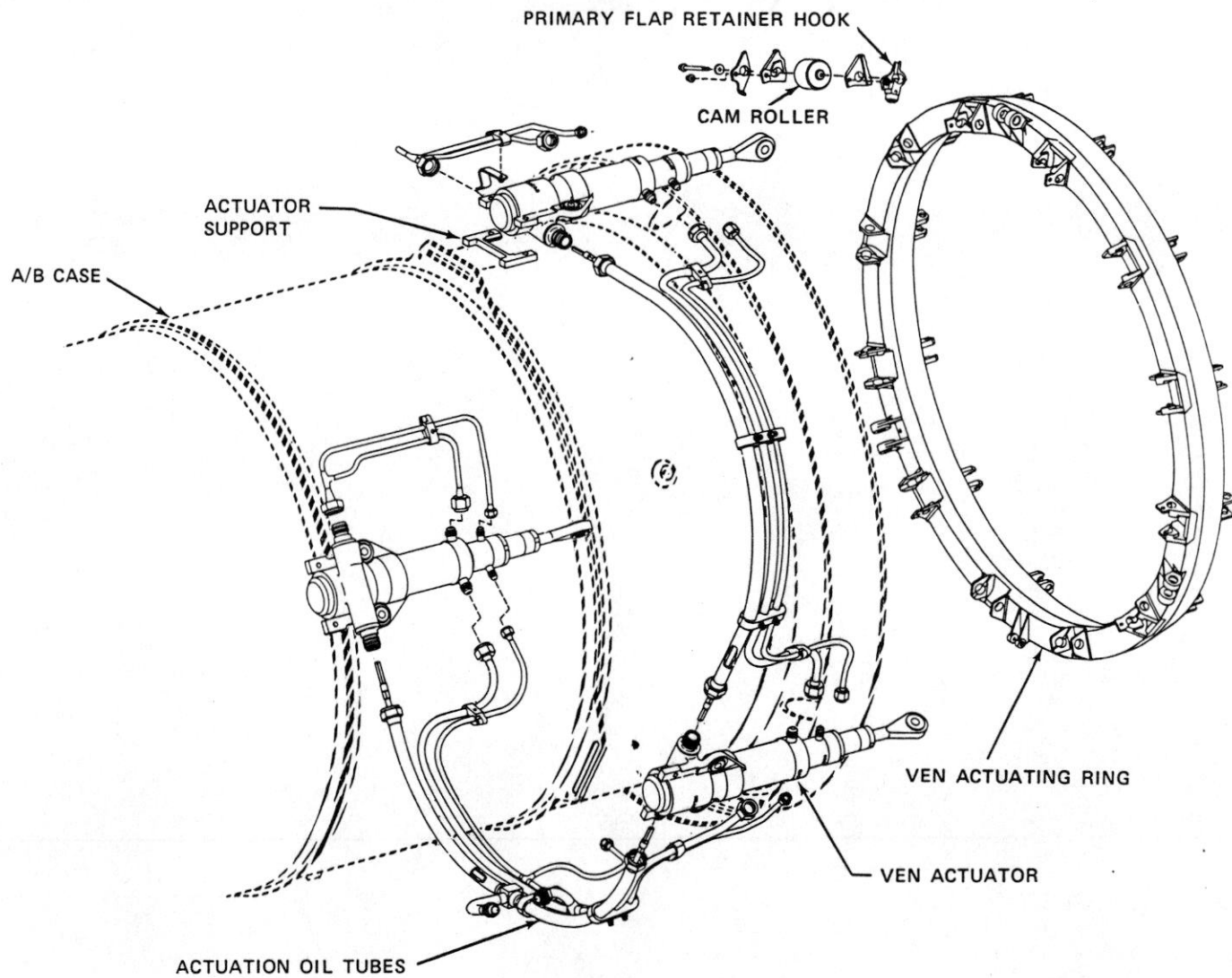
AFTERBURNER CASE

Figure 1-49



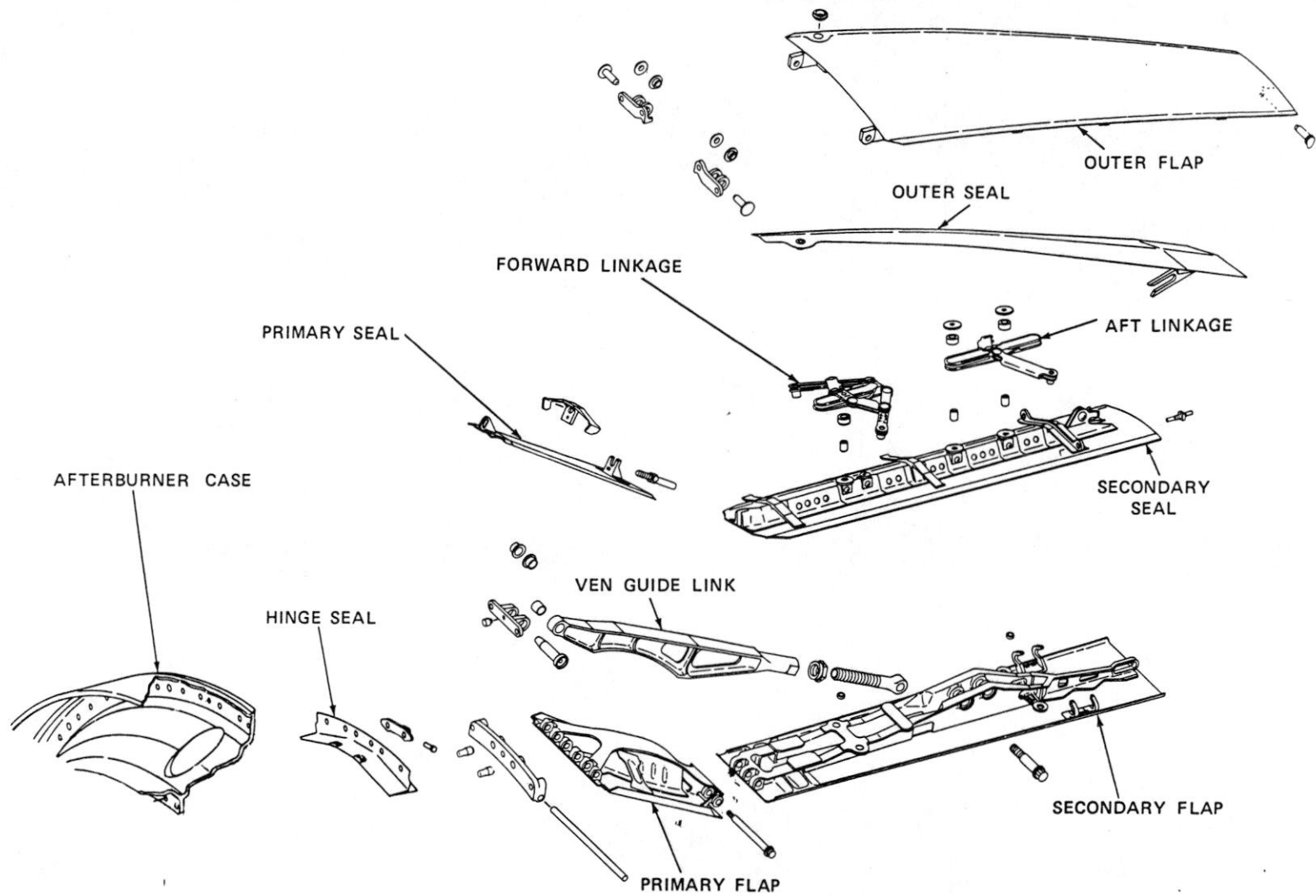
AFTERBURNER COMPONENTS

Figure 1-50



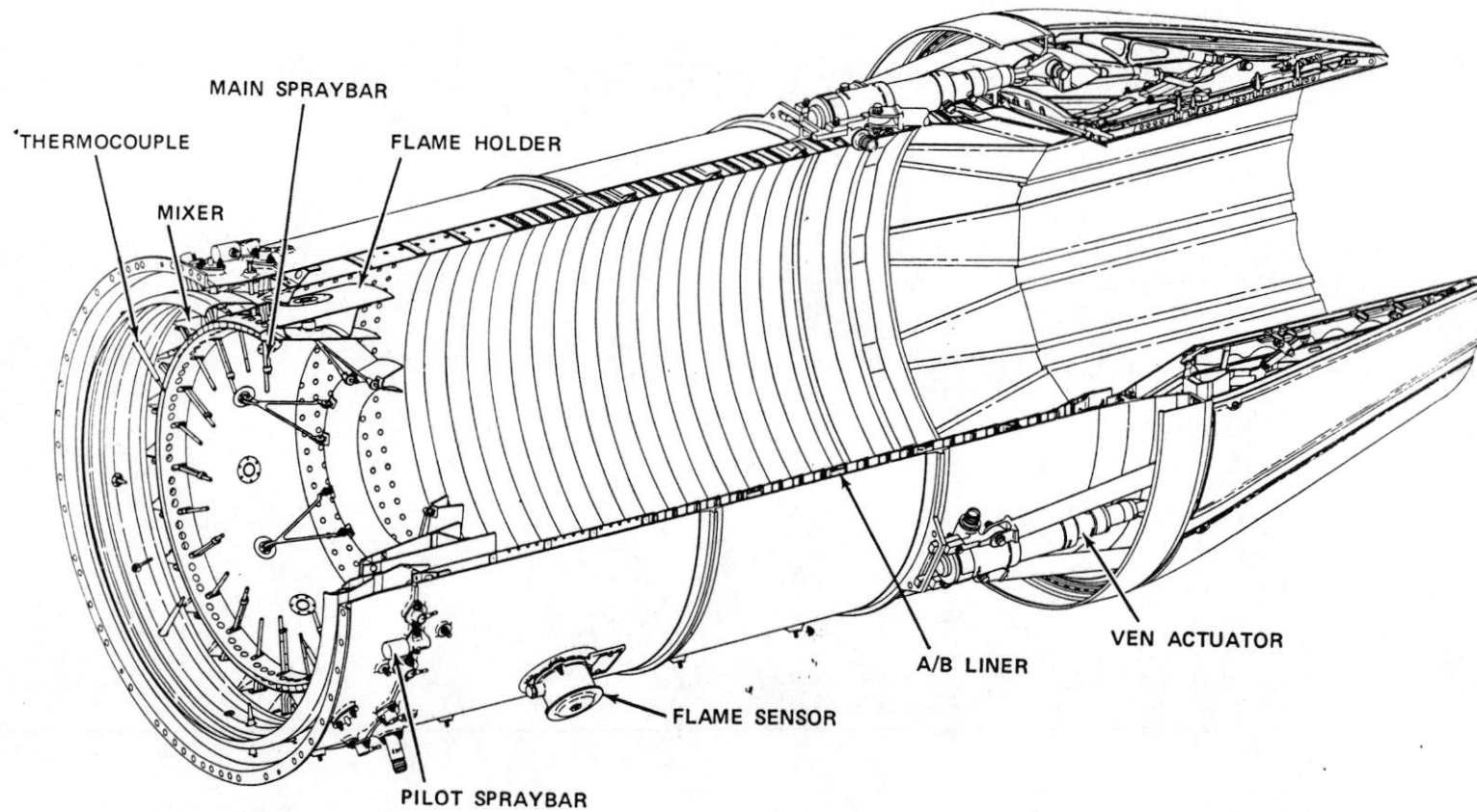
VEN ACTUATION COMPONENTS

Figure 1-51



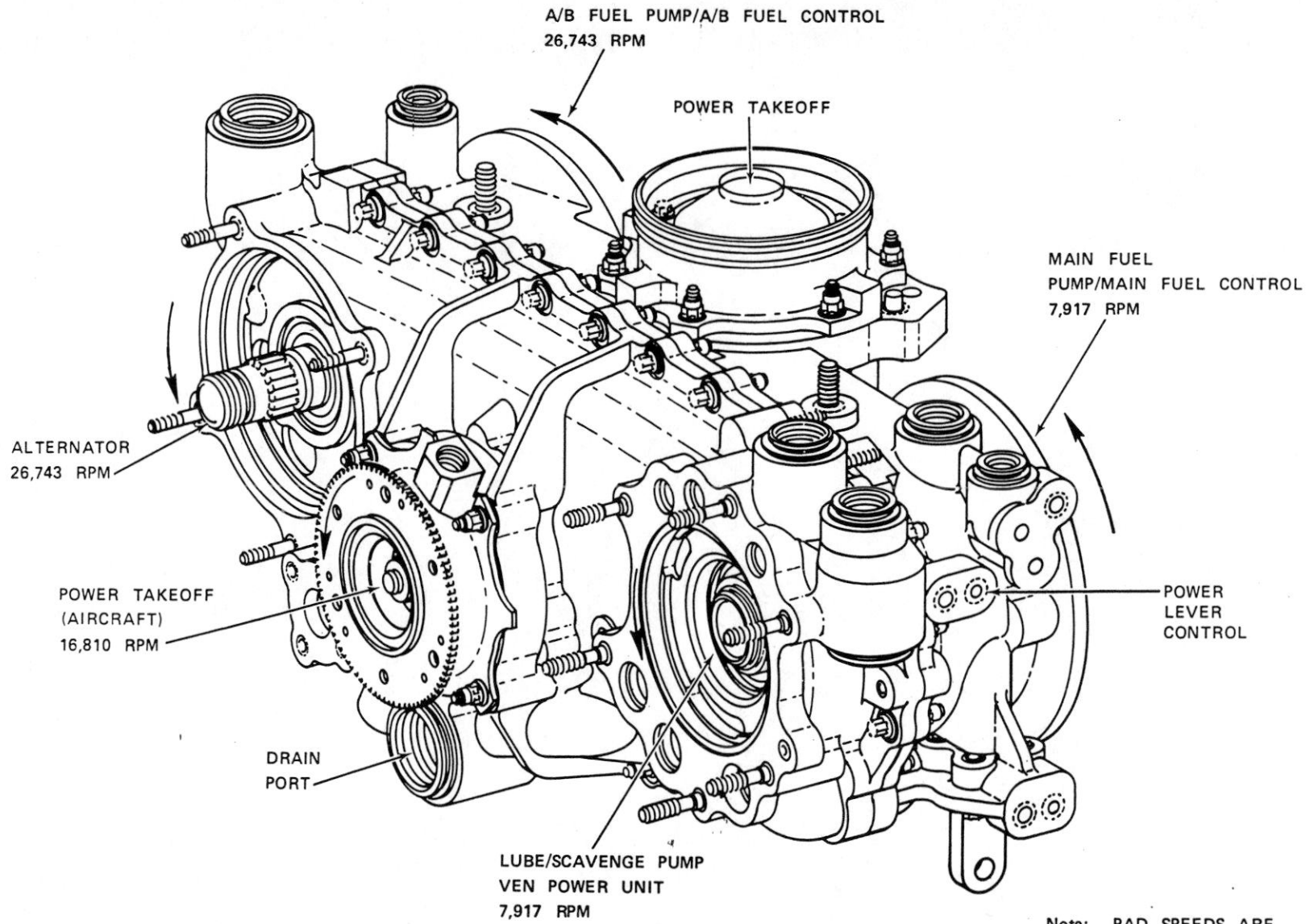
VARIABLE EXHAUST NOZZLE COMPONENTS

Figure 1-52



AFTERBURNER (CUTAWAY)

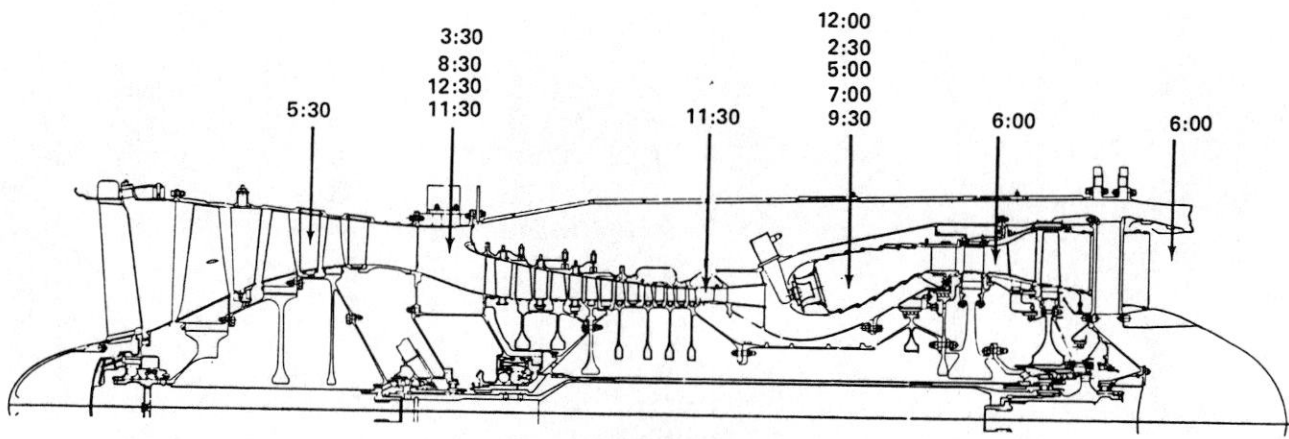
Figure 1-53



Note: PAD SPEEDS ARE GIVEN AT 100% HPC SPEED (N₂)

ACCESSORY GEARBOX

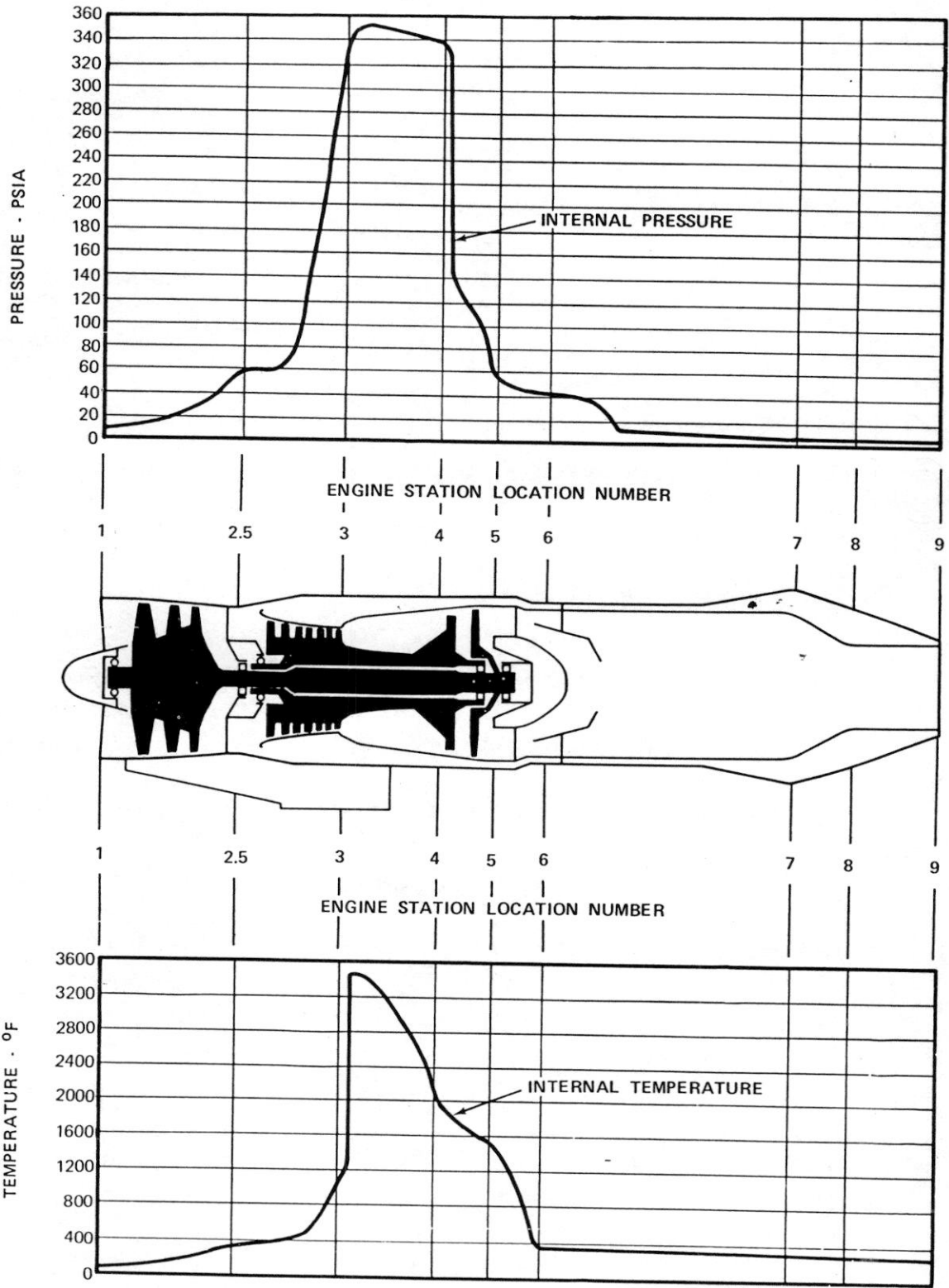
Figure 1-54



CLOCK POSITIONS,
AFT LOOKING FORWARD

BORESCOPE PORT LOCATIONS

Figure 1-55



ENGINE TEMPERATURE AND PRESSURE

Figure 1-56

