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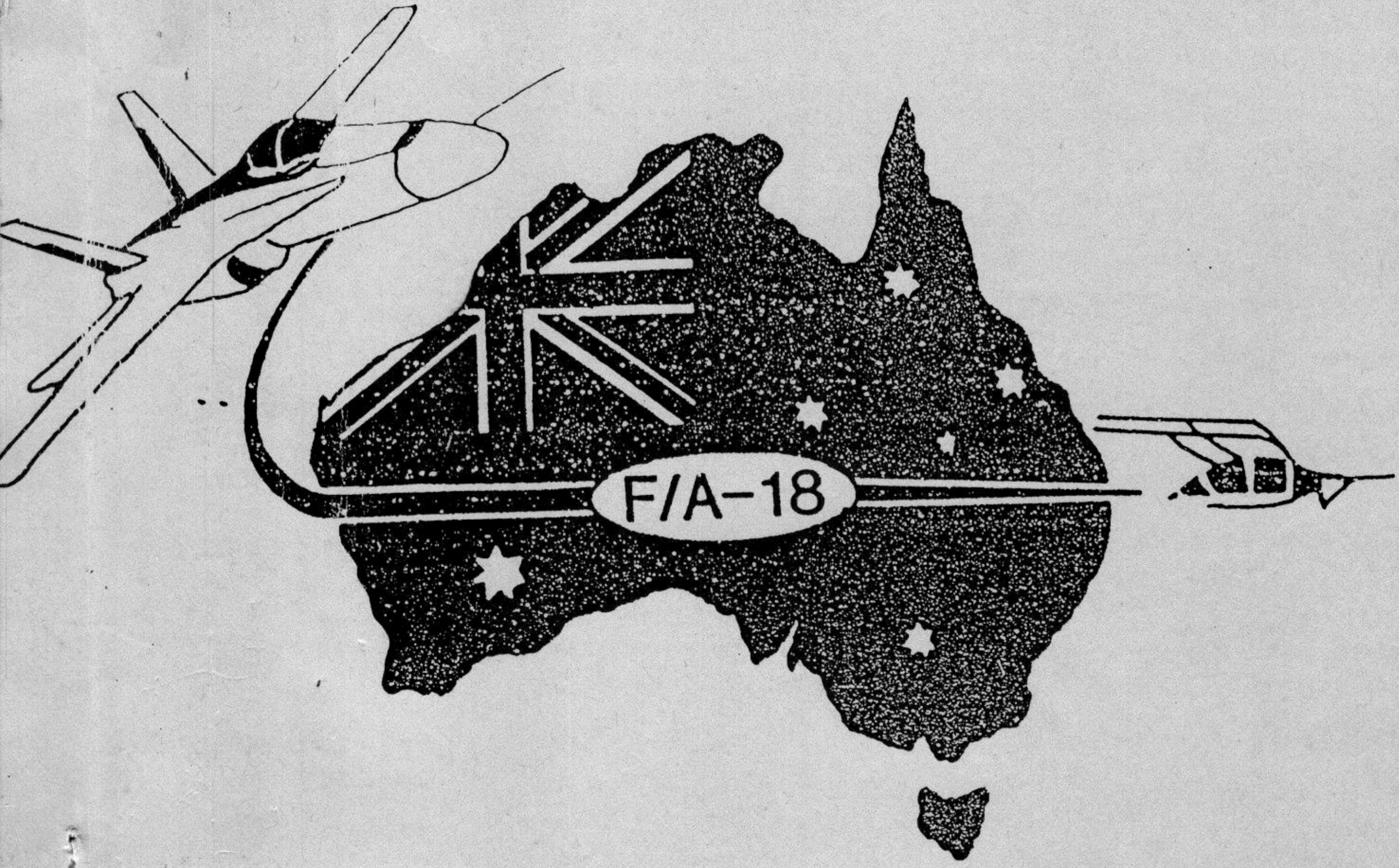


481 WING

Field Training Flight

ENGINE OLM
HANDOUT 1

SECTION 2

ENGINE AIRFLOW

A. GENERAL (See Figure 2-1 through 2-5)

Air enters the F404 engine through the front frame and passes through the fan where is is compressed at a ratio of 4.1 to 1 at one-hundred percent engine speed. The rate at which the air moves through the fan is one-hundred and forty pounds per second. Fan discharge air enters the midframe where it is split at approximately twenty-five percent for bypass air, and the remaining air is used to supercharge the compressor. Air passes through the compressor at a rate of 104.5 pounds per second and at a compression ratio of 6 to 1 at one-hundred percent engine speed. During the compression cycle, air pressure and temperature are increased and the volume is decreased. The overall engine compression ratio is 25 to 1. Approximately twenty-five percent of the air entering the combustor is mixed with the products of combustion to dilute the temperature of the gases entering the turbine to a safe operating level.

The hot combustion gases enter the turbine, where the velocity of the gases is increased, and the turbine rotors extract the necessary power from these hot gases to drive the fan and compressor rotors. The hot gases exiting the turbine area are accelerated into the afterburner area where these gases are allowed to exit the engine through the exhaust nozzle or when in the afterburner operating condition, they are mixed with fuel and ignited, thus producing approximately fifty percent additional thrust.

To permit the turbines to operate at temperatures which are higher than the materials can normally tolerate, air is bled off the compressor for cooling purposes in addition to those cooling functions performed by compressor discharge secondary air. Additional air is required for anti-icing, pressurizing, and sealing.

B. TURBINE COOLING (See Figure 2-4)

1. Balance Piston Chamber. Inner combustor flowpath air is ported through holes in the high-pressure turbine inner nozzle support. This air is then accelerated through an inducer and enters a chamber defined by the inner and outer balance piston seals. This air develops a pressure force within this chamber which acts on the forward face of the outer balance piston rotating seal, creating a rearward force. This force counteracts some of the forward force of the compressor rotor, thereby reducing the axial loading on the number three thrust ball bearing.

2. High-Pressure Turbine Nozzle Cooling. Inner combustor flowpath air is also used for cooling of the high-pressure turbine nozzle. This air passes through holes in the combustion liner support flange and enters each nozzle segment radially through opening in each vane segment. The air cools the nozzle and exits through holes in the convex side of the airfoil. Air directed into other cavities within each nozzle airfoil, discharges through holes in the concave surface and trailing edge of each vane. In this manner, each airfoil is convection, impingement and film cooled. Air directed at the underside of each nozzle segment also serves to film cool the nozzle platform. This air exits through a pattern of holes above and below each platform segment.

3. High-Pressure Turbine Rotor Cooling. As well as providing balance piston pressure, accelerated air exiting the inducer is directed at holes in the outer balance piston rotating seal and is used for cooling of the high pressure turbine rotor forward face, the forward cooling plate and the rotor blades. Air enters each blade root radially, cools the blade and exits through film cooling holes on the convex side and trailing edge of the blade and into the gas stream. The high-pressure turbine shroud cooling is accomplished by air exiting through holes provided in each rotor blade tip.

4. Low-Pressure Turbine Nozzle and Rotor Cooling. The low-pressure turbine nozzle is cooled by fourth-stage compressor bleed air which is directed aft. This air enters the low-pressure turbine area and into a cavity between the HPT shroud support and combustion chamber case. This cooling air then passes through axial holes in the shroud support circumferential flange and enters each low-pressure turbine airfoil tip. The air then passes through radial passages in each vane, thus cooling the vane. Air exiting the root of the vane enters the low-pressure turbine inducer. This air is discharged from the inducer and enters a cavity formed by two labyrinth seals on the low- pressure turbine forward seal and retainer. The cooling air then passes through holes in the underside of the blade dovetail and moves through the blade by means of radially drilled holes. This air cools the blades, and is discharged through holes in the blade tip, thus cooling the low pressure turbine shroud.

C. ANTI-ICING SYSTEM (See Figure 2-2)

Fourth-stage compressor air is bled off from an air manifold welded to the aft compressor casing. This air is ducted forward to the anti-icing valve which regulates the air pressure and enters the front frame. At the front frame, this air enters the anti-icing manifold which circumferentially distributes this air to anti-ice the eighteen hollow struts and inlet centerbody. Air within the hollow struts exits through holes in the trailing edge of each strut and bathes each inlet guide vane, thus anti-icing each vane.

D. SUMP PRESSURIZATION SYSTEMS - (See Figures 2-2, 2-3, and 2-4)

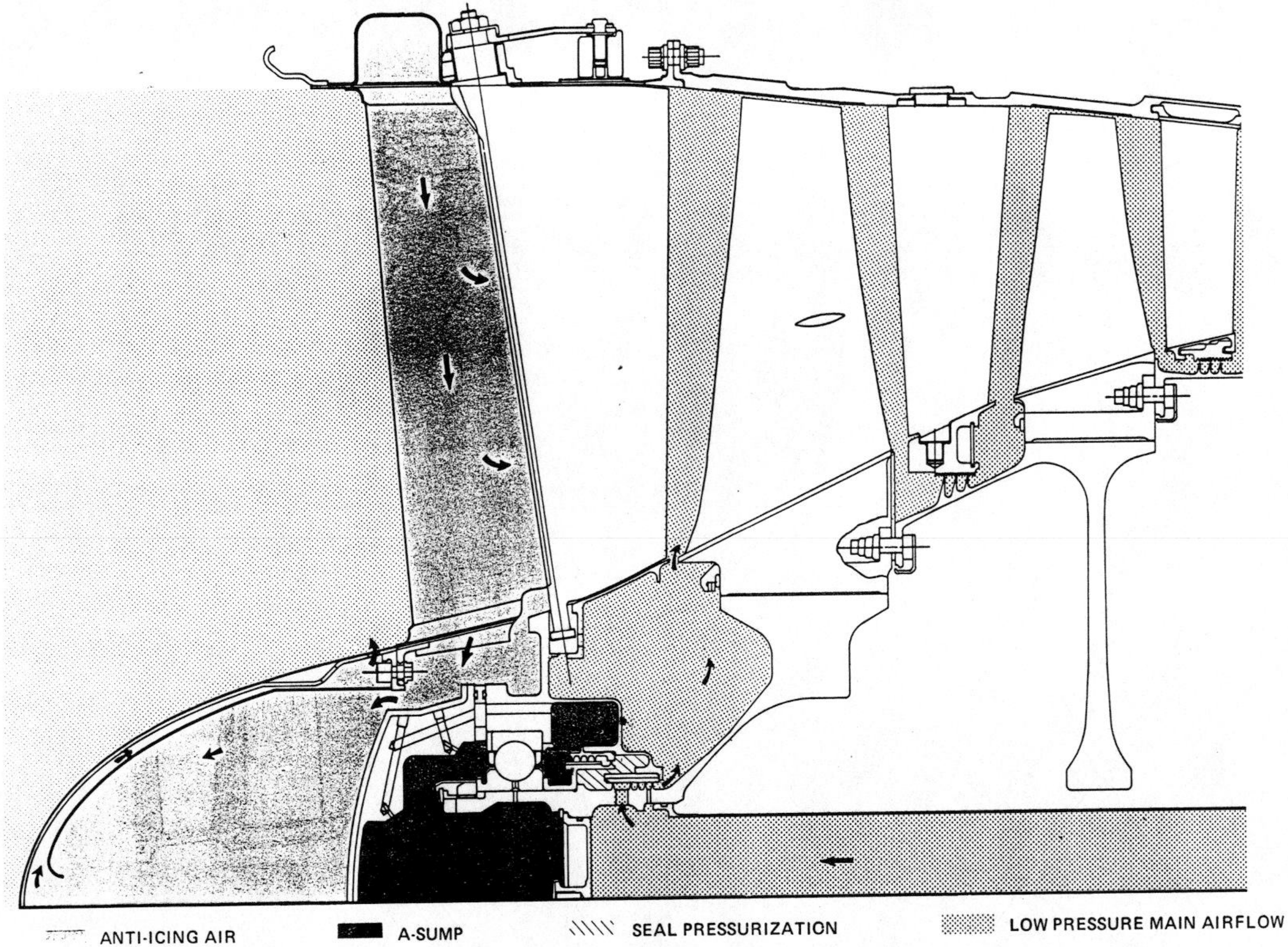
The engine A-sump area which houses the number one ball bearing is defined and sealed on the forward side by the A-sump cover, and on the aft side by a two-step labyrinth seal. In order to prevent oil from leaking out of the sump area, the seals on the aft side are pressurized with fan discharge air which serves to pressurize the area between the two seals. This air enters this cavity from the seal pressurization tube through holes in the fan forward shaft. The seal pressurization tube is pressurized from fan discharge air entering through holes in the fan aft shaft.

The number two and three carbon seals, which define the forward and aft ends of the B-sump, are pressurized by fan discharge air, which is scooped at the midframe and split. A portion of this air is ducted through a tube in the number two bearing support to the number two carbon seal. The other portion of air enters the midframe air duct and pressurizes the number three carbon seal and also enters the compressor rotor cavity through holes in the compressor forward shaft. This air serves to cool the rotor, and exits through holes in the high-pressure turbine aft shaft, through the low pressure turbine disk bore, out through the torque cone, and into the main gas stream.

Outer bypass air is ducted through struts in the exhaust frame and is directed to the number five carbon seal, thus sealing the aft portion of the C-sump. This same air passes through a series of holes in the torque cone and into a cavity formed by the number four seal runner and rotating air seal providing pressurization of the number four carbon seal at the C-sump forward side.

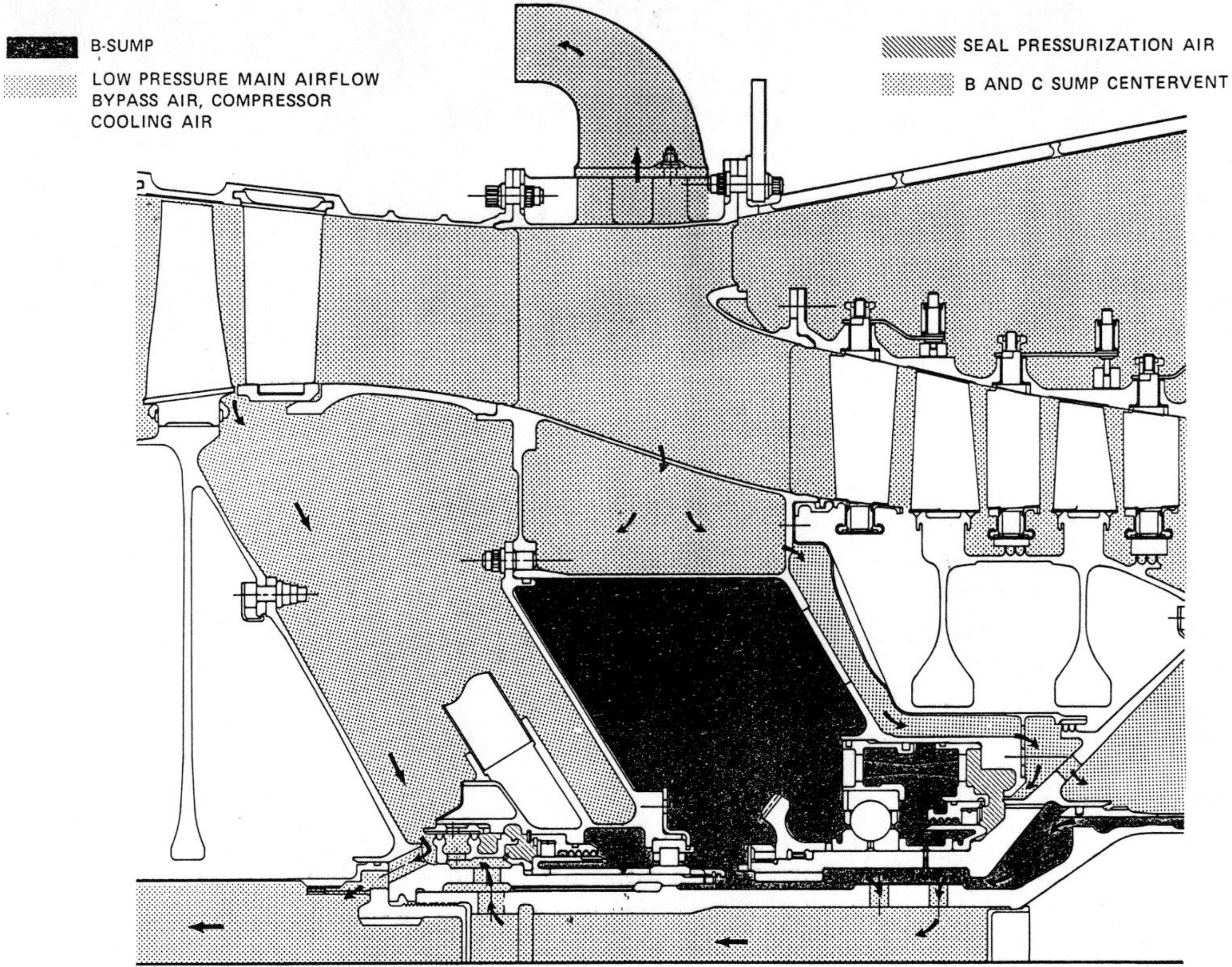
E. CUSTOMER BLEED

Air for customer use can be extracted through the customer bleed air duct located on the forward section of the combustion case at the six o'clock position.



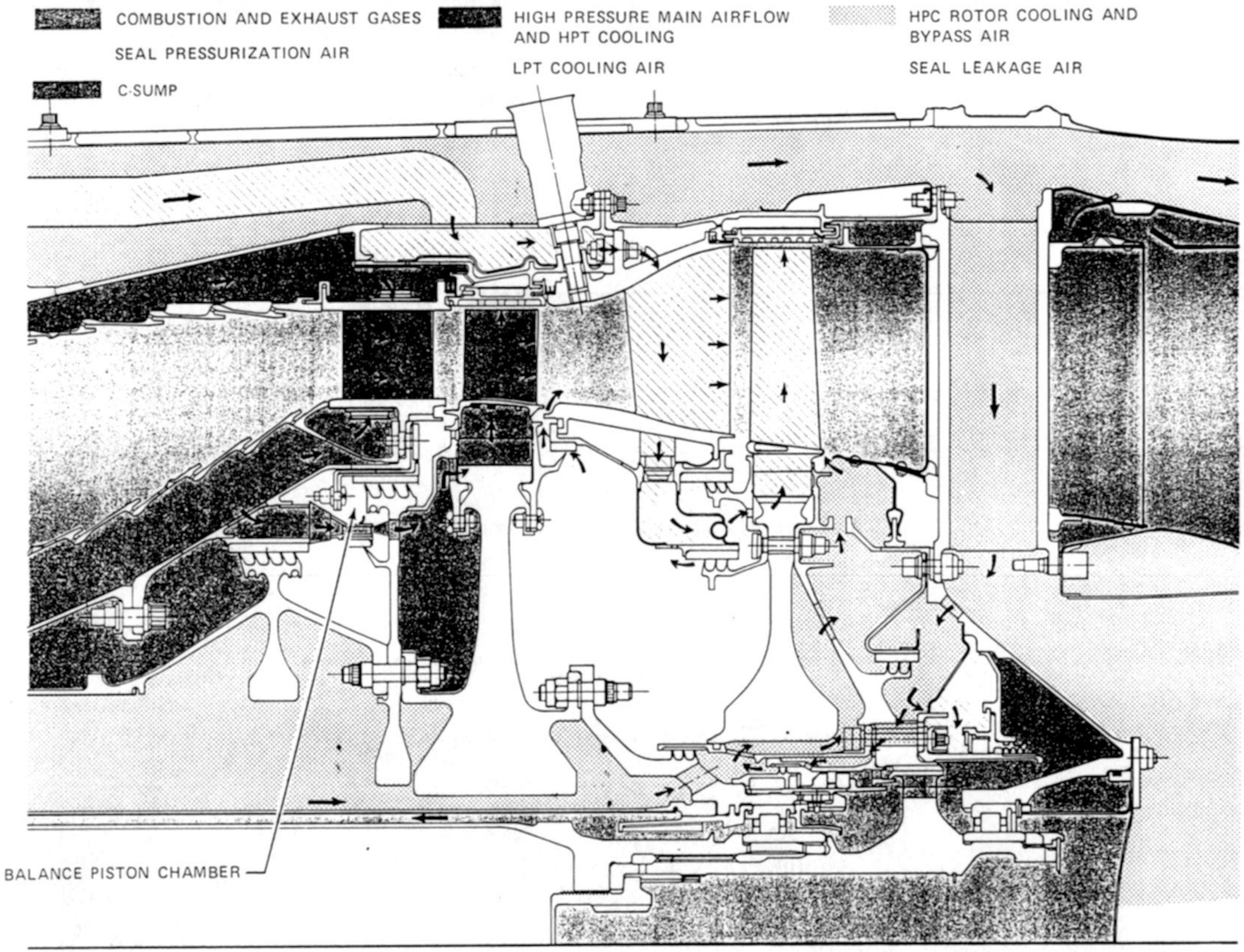
FRONT FRAME AND A-SUMP

Figure 2-2



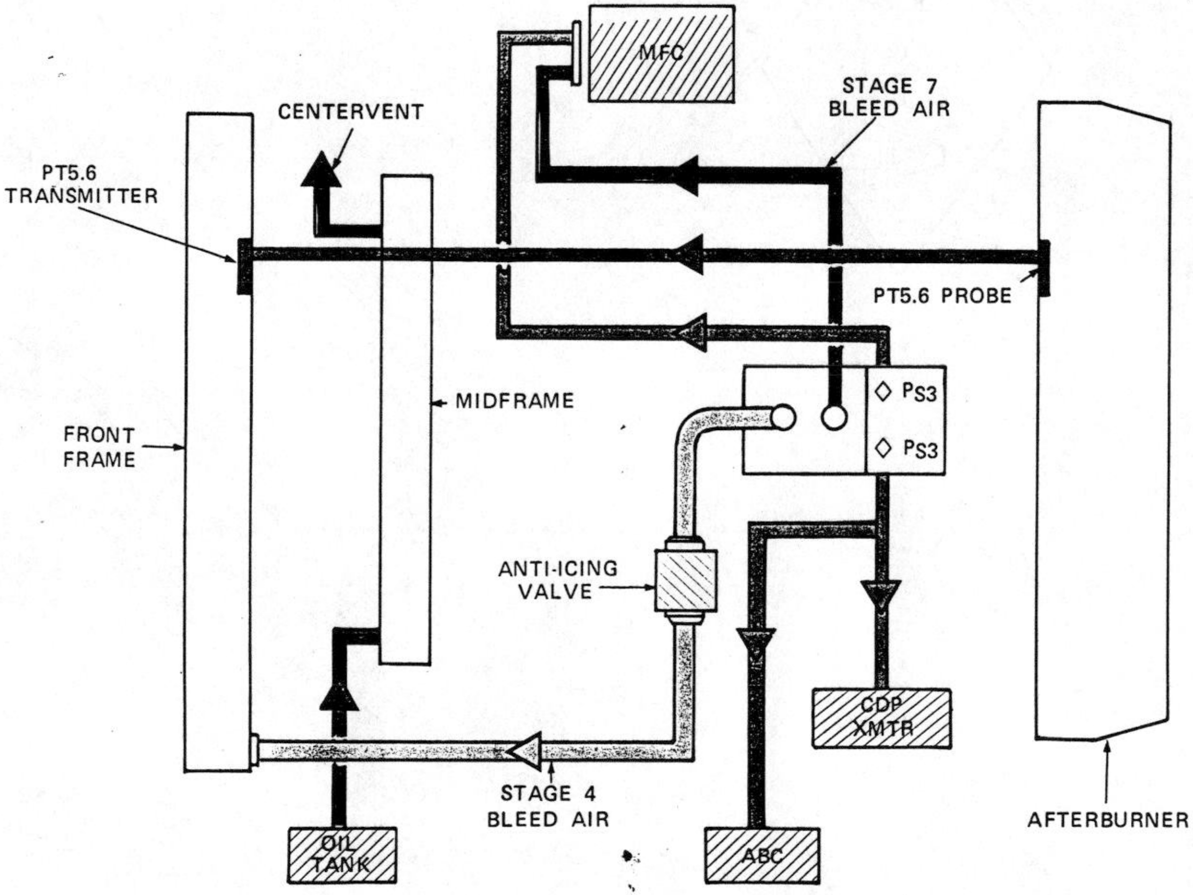
MIDFRAME AND B-SUMP AREA

Figure 2-3



LPT AND HPT COOLING AND C-SUMP AREA

Figure 2-4



AIR SYSTEM SCHEMATIC

Figure 2-5

SECTION 3

LUBRICATION SYSTEM

A. GENERAL

The F404-GE-400 engine lubrication system utilizes a pressurized, closed circuit, recirculating, dry sump system designed to furnish lubricating and cooling oil to the necessary engine rotating components during engine operation. After oil has been supplied to those parts requiring lubrication, it drains to the sumps and gearbox from which it is scavenged by individual elements within the pump and returned to the oil tank. All system components are engine furnished and engine mounted. External oil lines are kept to a minimum by the use of internal lines and cored or drilled passage ways. The major components of the system are the lube and scavenge pump, oil filter, oil tank, oil cooler and oil pressure transmitter.

B. LUBE AND SCAVENGE PUMP (See Figure 3-1)

The lube and scavenge pump is a positive displacement multi-element vane pump. The pump has one pressure element and five scavenge elements and is mounted on the forward left-hand pad of the accessory gearbox. The pressure element supplies oil under pressure to the oil pressure transmitter and to the oil nozzles in the A, B and C-sumps to lubricate the bearings, and supplies oil to the gearbox to lubricate the gear train. The oil supply from this pressure element is rated at eight and one half (8.5) gallons per minute. Incorporated also within the pump are five (5) scavenge elements, one (1) for each sump and two (2) for the gearbox sump area. The combined capacity of the five (5) scavenge elements is thirty-six (36) gallons per minute. A comparison of the pump supply to the scavenge side results in a scavenge to pressure ratio of 4.24:1.

A pad is provided on the pump for mounting the variable exhaust nozzle (VEN) power unit. This VEN power unit is spline driven off the lube and scavenge pump.

To protect the system during cold weather starts, or due to a restriction, a relief valve in the supply side of the system is set to crack at a differential pressure of 200-240 psid, and is fully open at 285 psid.

C. OIL FILTER (See Figure 3-1)

The oil system has a disposable 10-micron nominal filter. The filter assembly, is part of the lube and scavenge pump and has a pressure relief bypass valve which operates when the differential pressure across the filter reaches 41-49 psid. The filter housing has an automatic shutoff to prevent oil drainage when the bowl is removed, and a check valve which prevents oil from flowing through the pump when the engine is shutdown. The filter is equipped with a differential pressure activiated pop-out device. This device provides visual warning of impending bypass with an extended red indicator when the pressure differential across the filter element reaches 22-27 psid. This bypass indicator is equipped with a thermal lockout which prevents the indicator pop-out when the engine oil is below (100°F) 37.8°C. Once activated, the red indicator remains extended until manually reset with the filter bowl inverted.

D. OIL COOLER (See Figure 3-4 and 3-5)

There are two oil coolers supporting the engine systems, the main oil cooler for the basic engine and the VEN oil cooler for the VEN actuation system. Both oil coolers have been fabricated into one unit, however, the two oil systems remain separated. In other words, there are two independent oil coolers within the same housing using the same fuel for cooling the two oil systems. This double oil cooler is mounted on the lower outer bypass duct at approximately the 4 o'clock position.

The double oil cooler has an aluminum shell and tube type, oil to fuel heat exchanger. Each cooler consists of numerous longitudinal passages arranged in a honeycomb pattern. Both fuel (the cooling medium) and oil flow simultaneously through separate passages with an exchange of heat occurring between hot oil and cool fuel. Oil passes over the fuel tubes five times in the main oil cooler and six times in the VEN oil cooler. The fuel flows in series, first through the main oil cooler and then through the VEN oil cooler.

The coolers are the full flow type with no provisions for temperature regulation.

E. OIL TANK (See Figures 3-2, and 3-3)

The oil tank is an elongated spherical enclosure containing a fill tube, a vortex separator, packing chamber, lube pump supply and scavenge return ports, oil tank vent to B-sump, oil level sight gauge, oil level switch, oil sampling valve and a drain with a magnetic chip-detector plug.

As scavenged oil is returned to the tank, excess air is removed by a deaerator inside the tank. Excess air is vented to the B-sump and the deaerated oil enters the packing chamber of the tank which is connected to the lube pump supply port. The packing chamber is maintained full of oil by the scavenged oil plus additional oil from the reservoir surrounding the packing chamber. The additional oil enters the packing chamber by scavenge-oil-driven eductors.

The oil tank sight glass is a prism that reflects the dark color of oil when the tank contains enough oil. When the oil level is 1.5 quarts or more below the full level, the prism reflects light and appears clear. If oil is 1.5 quarts or more below full level, the oil tank must be serviced. The oil level switch located within the tank will indicate low oil through the aircraft IECMS.

F. MAGNETIC CHIP DETECTORS (See Figure 3-6)

Located throughout the engine at various positions are seven magnetic chip detectors. During engine operation the chip detectors are designed to accumulate any magnetic particles within the A, B, and C-sump scavenge lines as well as the oil tank and accessory gearbox. Chip detector inspection is accomplished as part of a periodic engine inspection. The detectors are located as follows: A-sump detector is at the seven o'clock position on the lube and scavenge pump, ninety degrees from the A-sump detector on the lube and scavenge pump is the gearbox aft detector, the B-sump detector is located on the left side of the gearbox front housing, the gearbox forward chip detector is at the six o'clock position of the front housing, the oil tank, another is located within the C-sump scavenge line, and a second C-sump detector within the C-sump gravity drain at six o'clock.

G. OIL PRESSURE TRANSMITTER

The lube oil pressure transmitter is mounted on the forward end of the fan module, near the 6:00 o'clock position. The transmitter measures the engine oil pressure as a differential pressure between engine B-sump vent pressure and lube pump output pressure. Oil pressure is transmitted electrically to indicators in the aircraft cockpit.

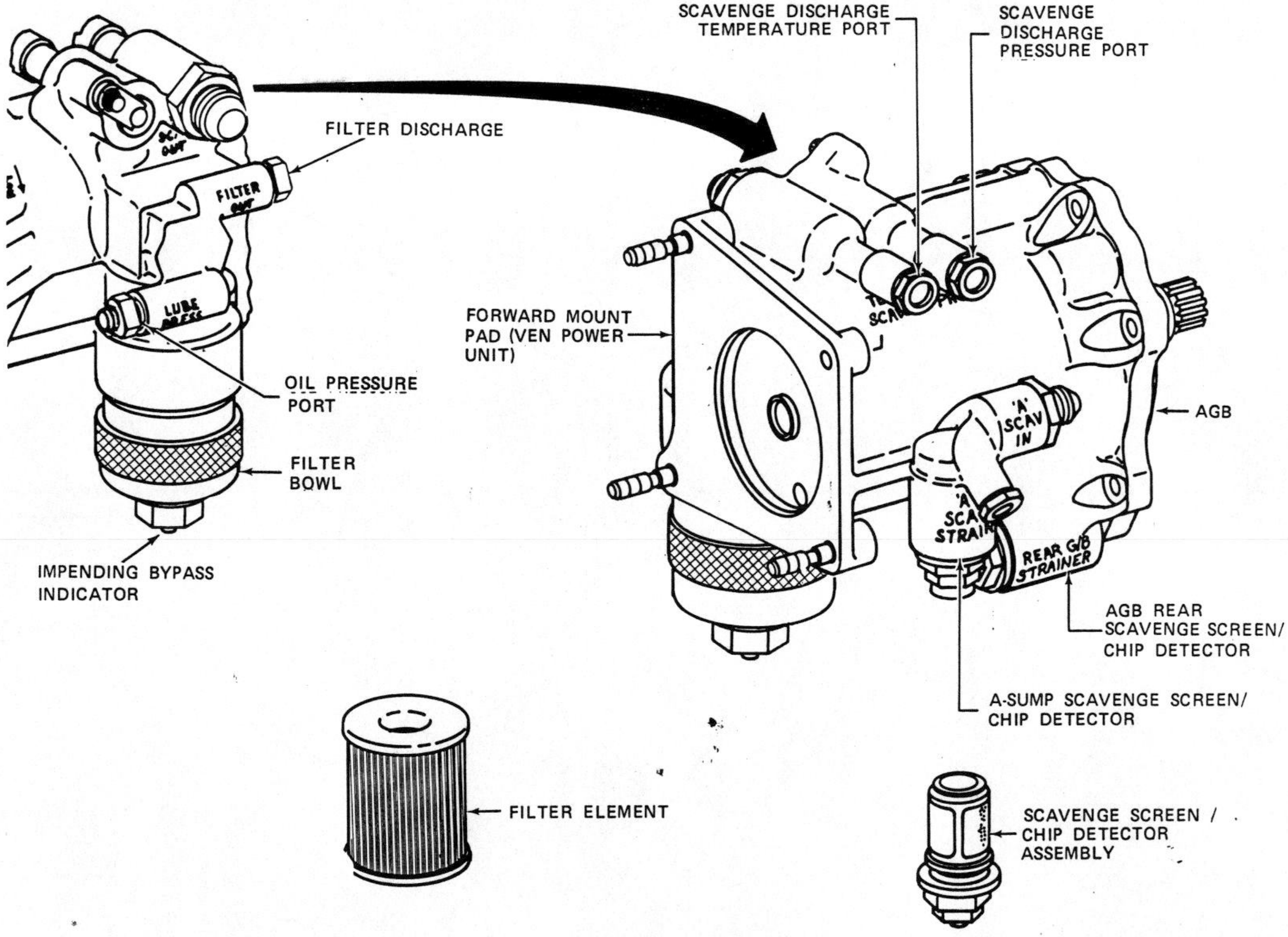
H. VENTING SYSTEM

The oil tank is vented through a pressurizing valve to the B-sump. The C-sump is vented to the B-sump between the fan driveshaft and the C-sump air duct. The B-sump is vented overboard through the twelve o'clock compressor midframe strut. The A-sump is not vented.

J. LUBRICATION SYSTEM OPERATION (See Figure 3-7)

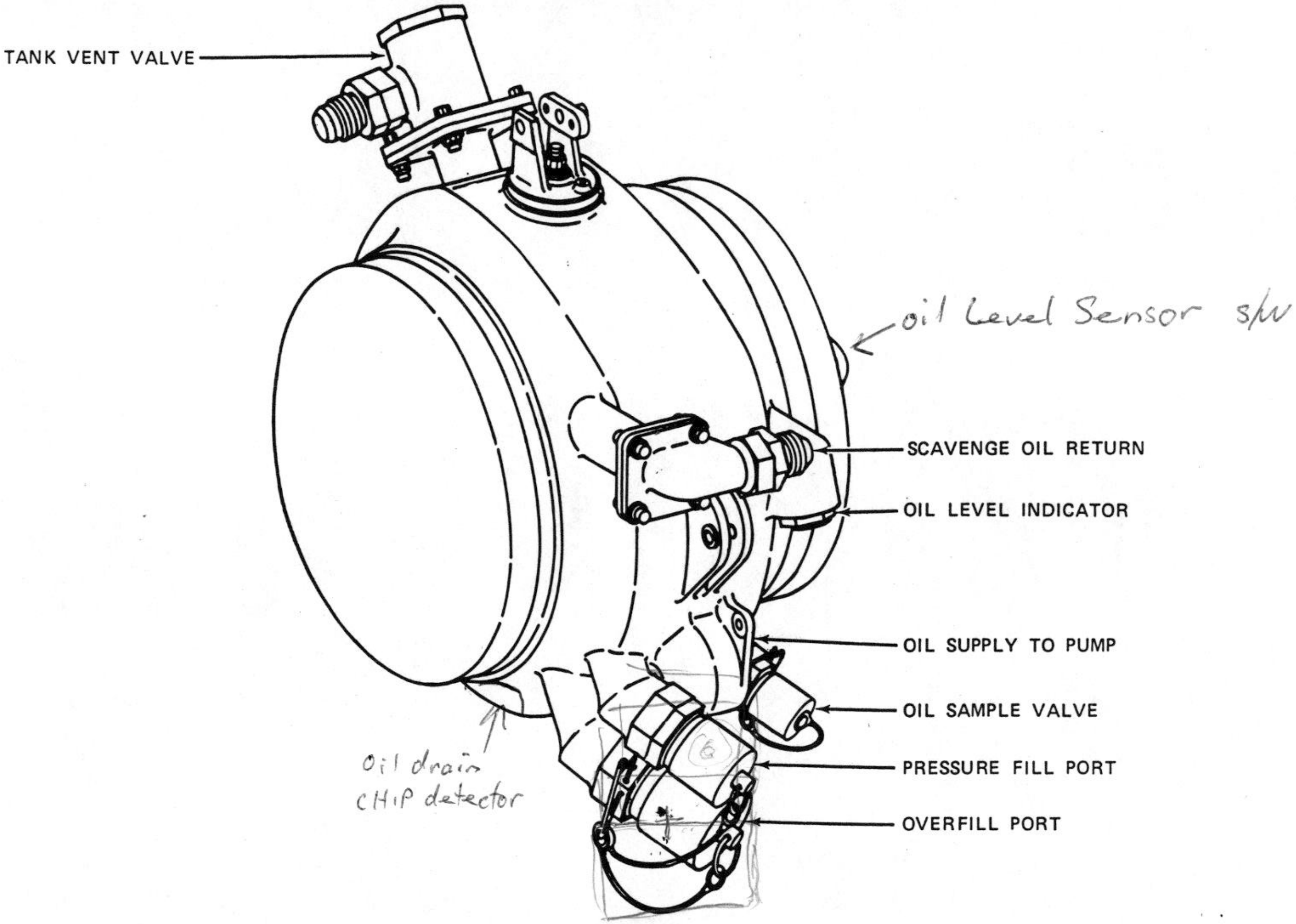
The lube system is self-contained and requires no external connections or inputs. The system consists of a pressure-filled supply tank, lube and scavenge pump, oil filter, oil cooler, gearbox, three engine sumps, oil pressure transmitter and interconnecting piping. Scavenge screens and magnetic chip detectors are provided for all sump and gearbox scavenge lines.

The supply line from the oil tank is connected to the forward end of the gearbox and directs oil to the pump by internal passages within the gearbox. The oil passes through the pump where it is pressurized and is then directed through internal passages to the oil cooler by way of the oil supply line connected to the top right side of the gearbox. Oil passes through the cooler and is then directed to the engine sumps and gearbox. Oil supplied to the A-sump lubricates the number one engine bearing and is returned through a scavenge element in the pump. Oil supplied to the B-sump lubricates the number two and three engine bearings and power takeoff gears and bearings. It is returned by a combination of a scavenge element and the gravity flow of oil from the B-sump past the AXIS-A gear into the gearbox. The C-sump is supplied with oil to lubricate the number four and five engine bearings and the oil is returned through a combination of a scavenge element and a gravity flow return line to the gearbox. Oil is supplied to the gearbox to lubricate the gears and bearings and is returned through two scavenge elements in the pump. All five scavenge elements return oil to a common scavenge manifold and this total scavenged oil is then returned to the oil tank.



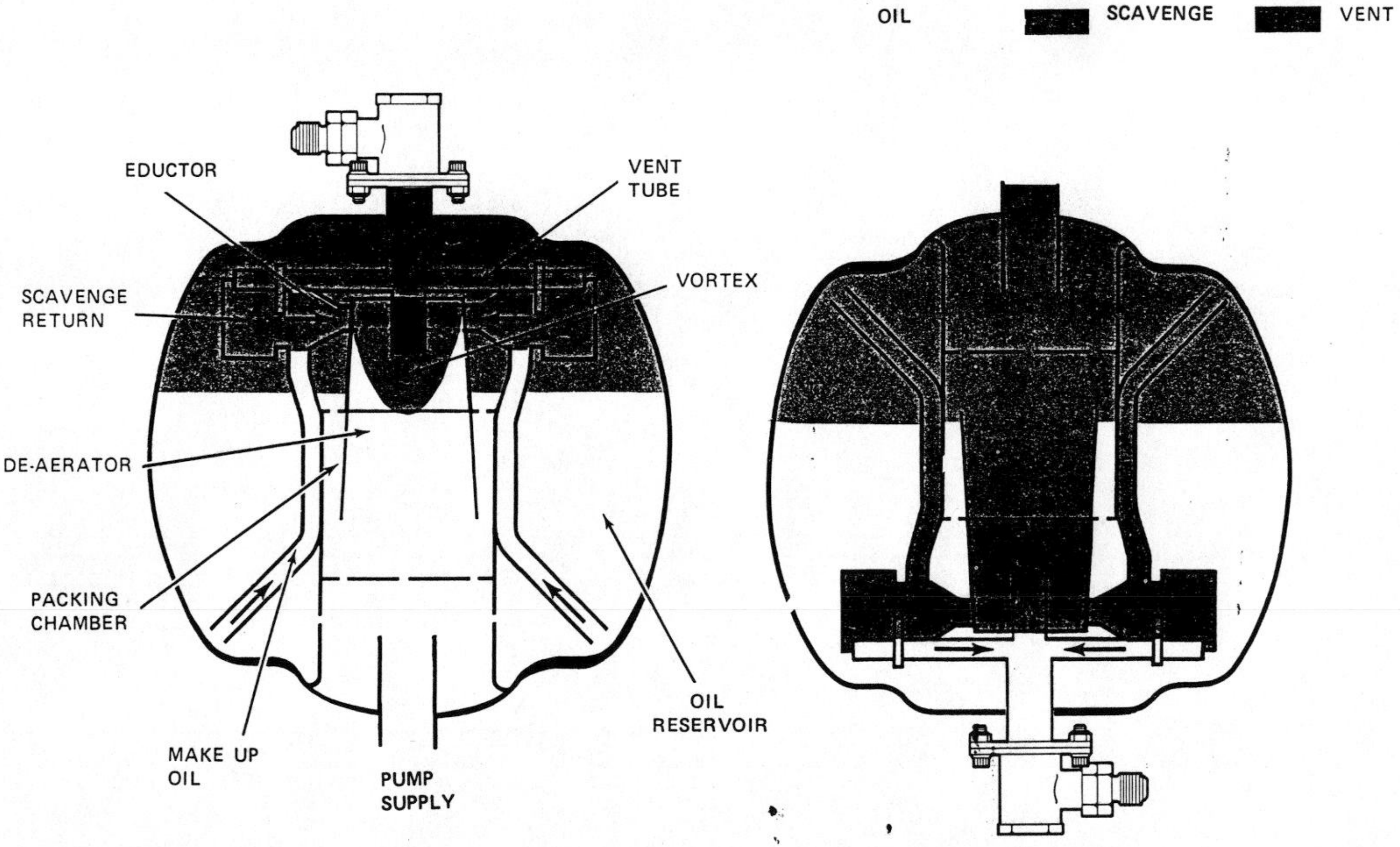
LUBE AND SCAVENGE PUMP

Figure 3-1



OIL TANK

Figure 3-2

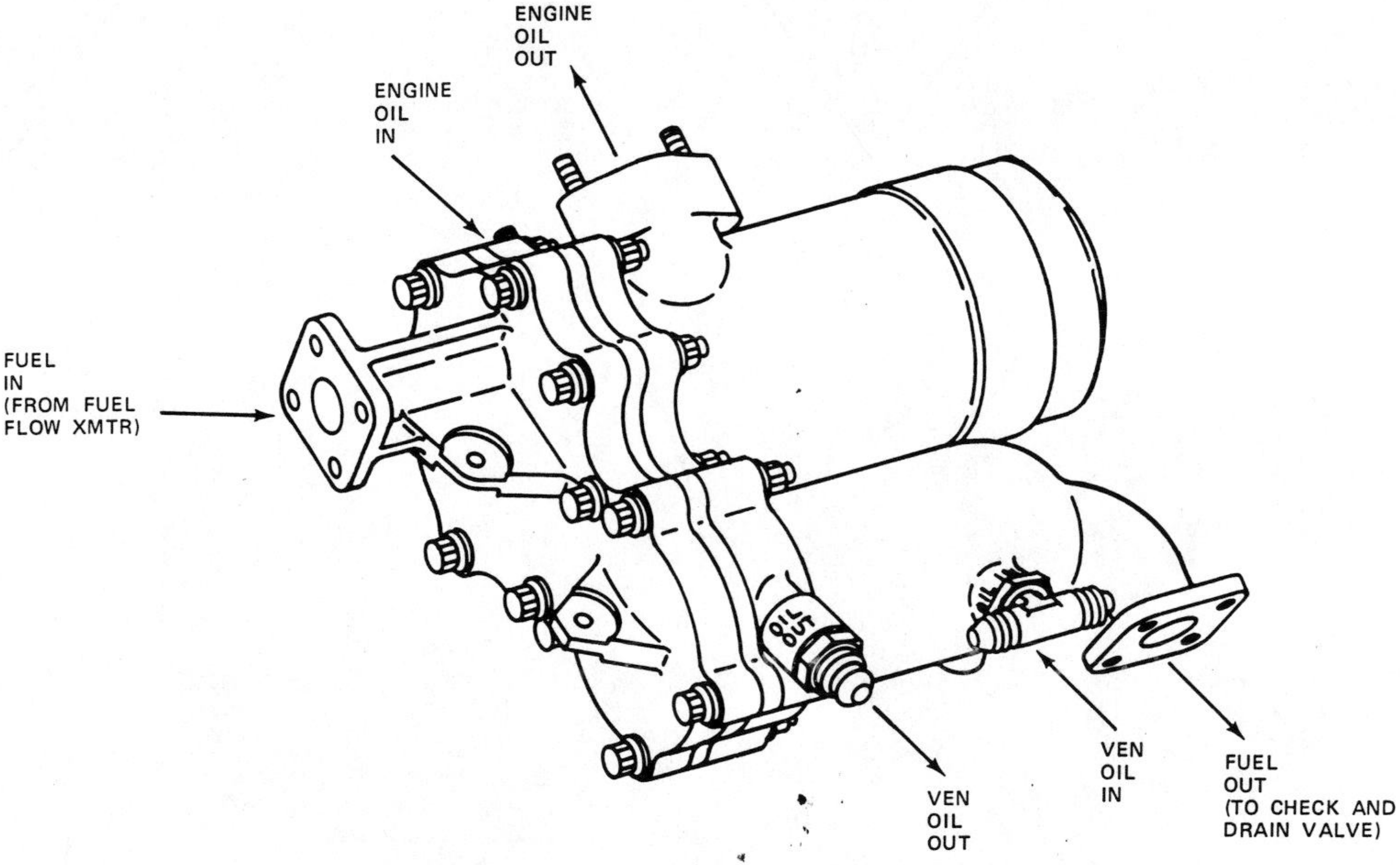


LEVEL FLIGHT

INVERTED FLIGHT

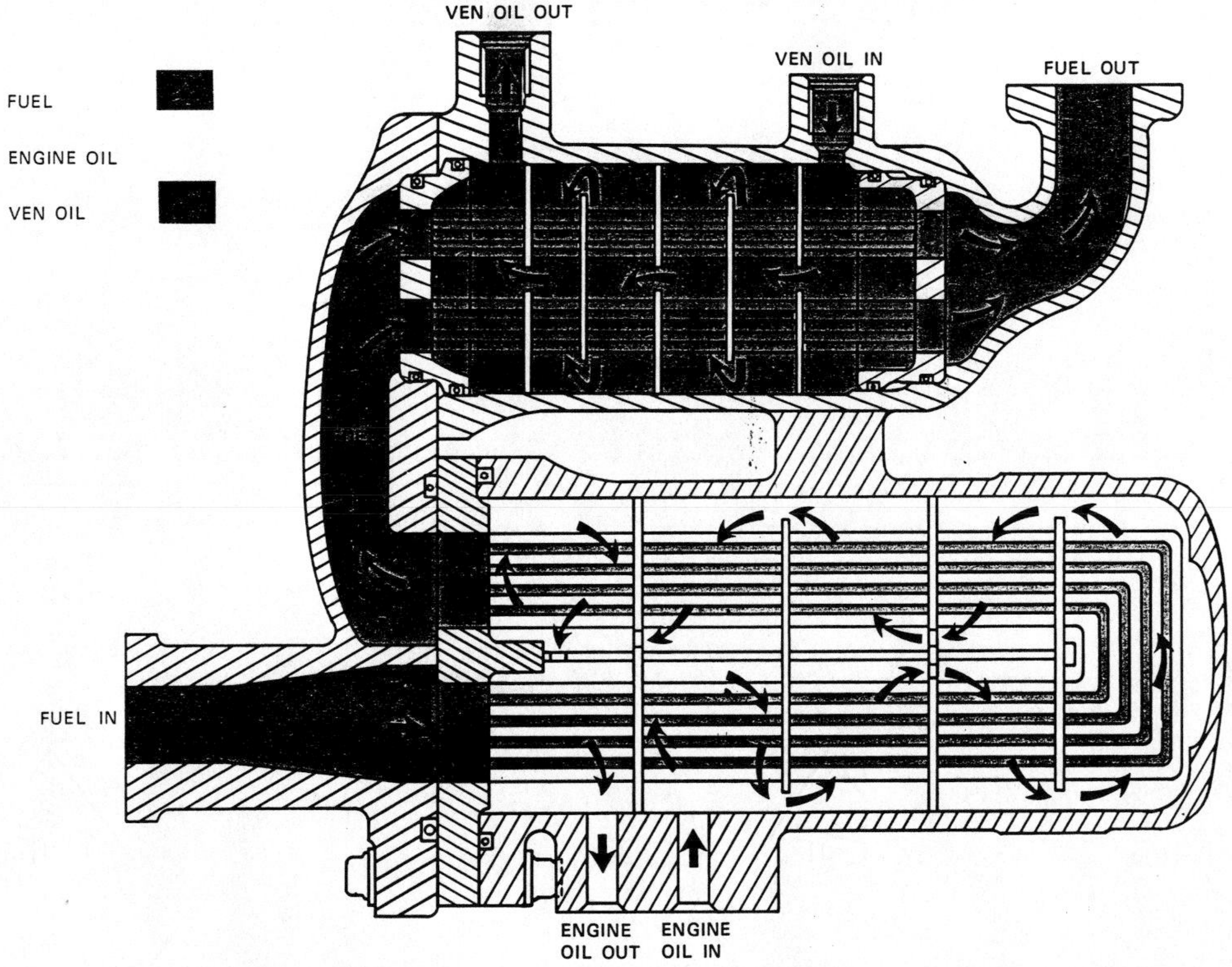
OIL TANK OPERATION

Figure 3-3



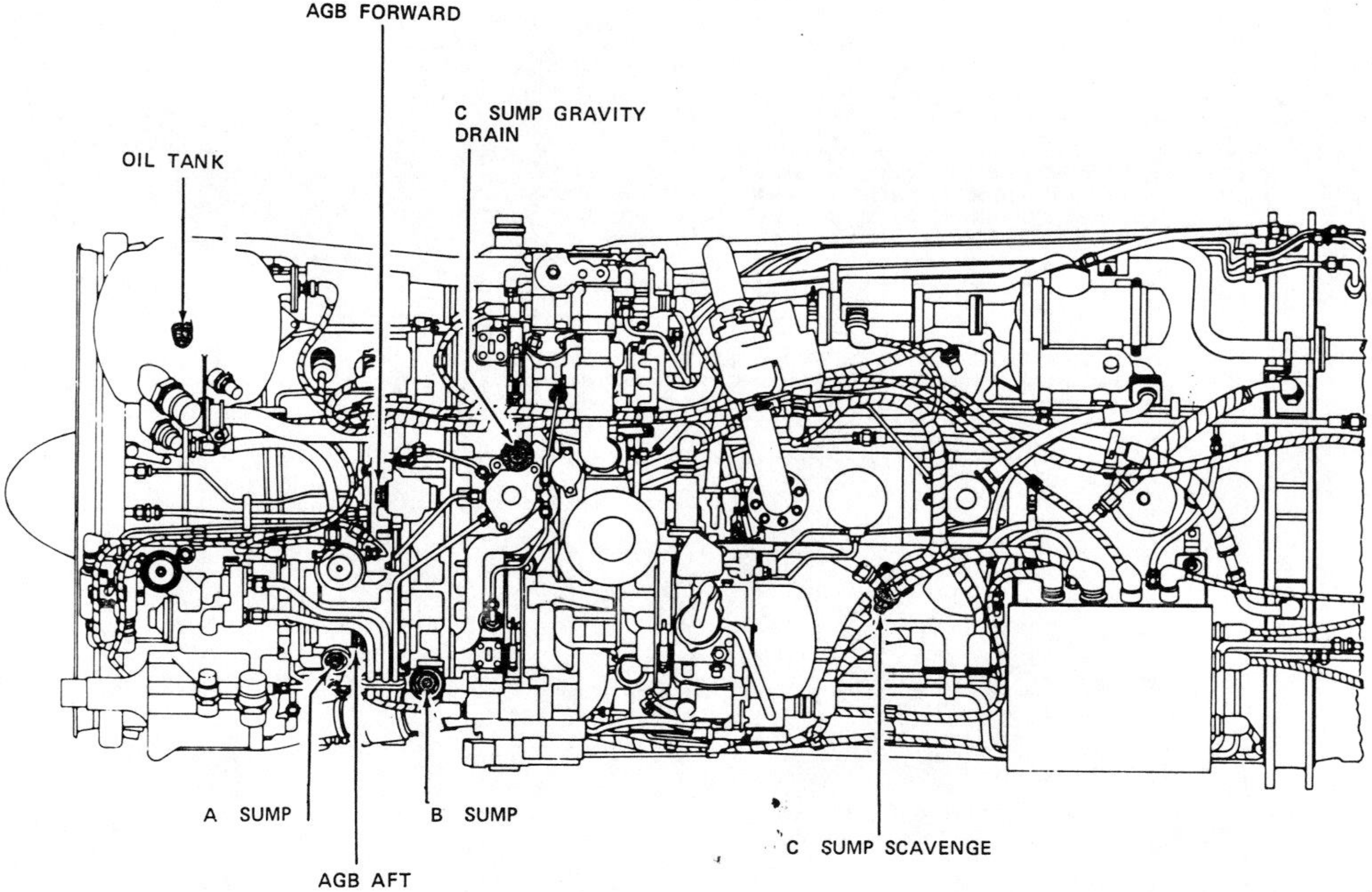
OIL COOLER

Figure 3-4



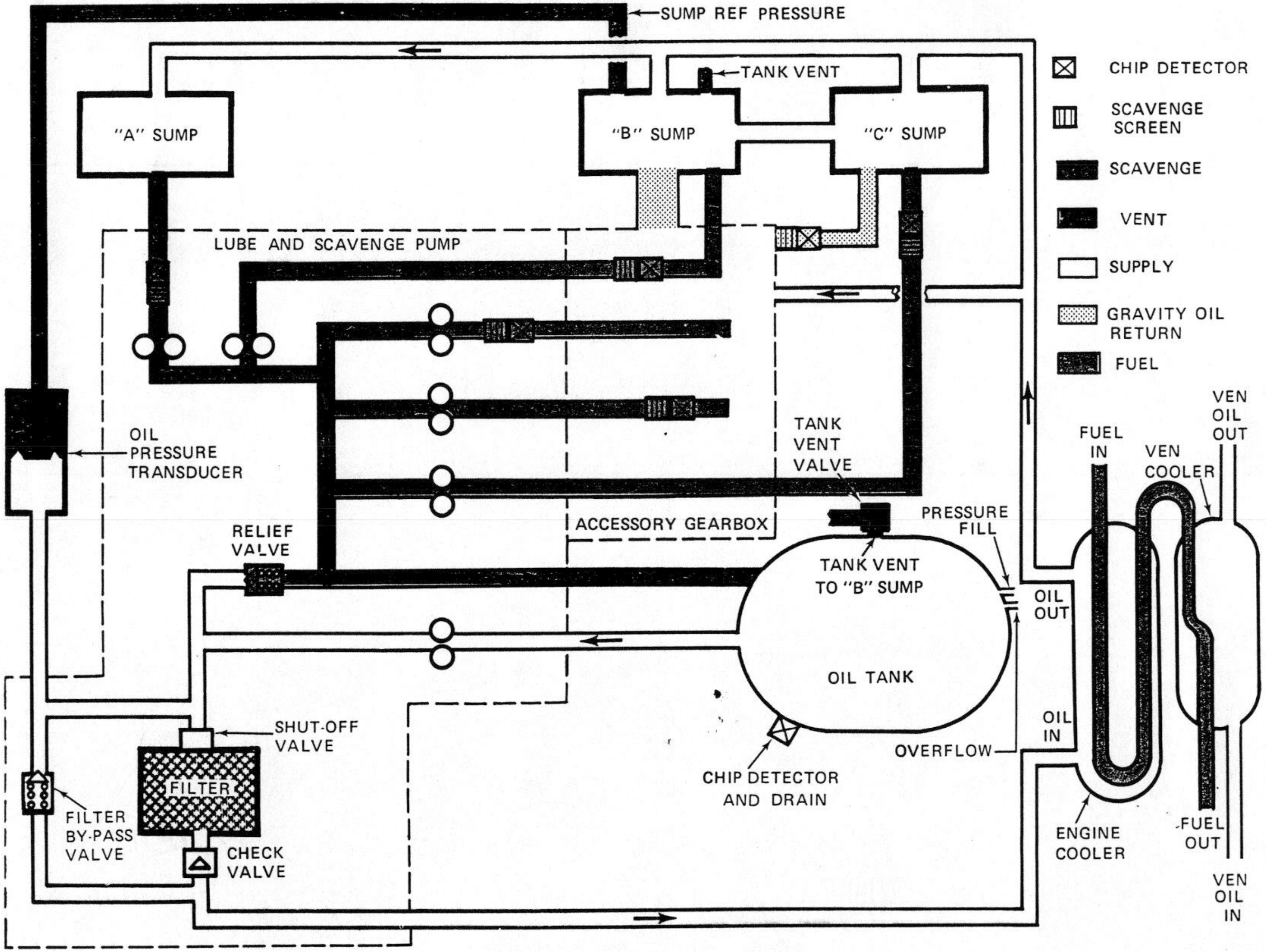
OIL COOLER OPERATION

Figure 3-5



CHIP DETECTOR LOCATIONS

Figure 3-6



LUBRICATION SYSTEM

Figure 3-7

SECTION 4

FUEL SYSTEM

A. GENERAL

The F404-GE-400 fuel system is designed to supply the engine with the proper amount of fuel for operation in all conditions of flight within the flight envelope. In addition to fuel for the main combustor and afterburner, the system provides fuel for operating the fan and compressor variable geometry systems, operation and lubrication of the servomechanisms in the main and afterburner fuel controls and cooling of the electrical control assembly, and lube and VEN hydraulic system oil.

B. MAIN FUEL PUMP (See Figures 4-1 and 4-2)

The main fuel pump (MFP) is mounted on the aft left side of the gearbox, and provides a mounting pad for the main fuel control (MFC). The pump is capable of providing up to 12,000 pounds per hour for main engine fuel flow and 28,000 pounds per hour for afterburner fuel flow requirements. The MFP also provides fuel for cooling flow to the electrical control assembly (ECA), and includes an integral fuel filter with bypass indication. The pump has an inlet and three pumping elements on the same shaft. The three pumping elements are:

1. A low-pressure, total-flow inducer element which minimizes fuel cavitation under loss of aircraft boost pressure.
2. An intermediate pressure, centrifugal, total-flow element which supplies cooling flow to the ECA; and AB flow to the ABC and ABP via a main fuel filter. Filtered flow is also forwarded to the high pressure pump element.
3. A high-pressure, positive-displacement vane element supplies fuel flow to the MFC, the FVG actuator, and the power lever control. Fuel to the MFC is additionally supplied to the AB control (servo only) and to the CVG actuators after filtering through a wash filter.

The fuel filter is a 10-micron nominal, 30 micron absolute disposable type filter. It incorporates both an impending bypass indicator and an actual bypass indicator. The impending bypass indicator is a yellow button that extends at a filter differential pressure of 13 ±1.3 psid. The bypass indicator is a red button that extends when the bypass valve opens. The bypass valve opens at 15.0 psid minimum. Once activated, the indicators will remain extended until manually reset internally after removing the filter element.

C. <u>MAIN FUEL CONTROL</u> (See Figures 4-3)

The main fuel control (MFC), mounted on the aft end of the MFP, is a hydromechanical droop type fuel control. The control's main function is to provide regulated fuel flow to the main engine combustor to satisfy engine operation. Compressor speed below intermediate power is a function of power lever angle (PLA), and compressor inlet temperature ($T_{2.5}$). Fan speed is a function of compressor speed and fan inlet temperature (T_1). At intermediate power and above, fan speed is controlled by a signal from the ECA and is a function of fan inlet temperature (T_1) and altitude. At intermediate power and above, compressor speed remains essentially constant. Only max T_5, max N_1, and max P_{s3} will limit compressor speed.

MFC auxiliary functions are as follows:

1. Schedules compressor variable geometry (BH).
2. Schedules variable exhaust nozzle (VEN) area (A_8) with throttle setting by providing a (PLA) signal to the ECA by a linear variable differential transformer (LVDT) connected to the throttle shaft.
3. Provides a signal to the ABC to initiate afterburner fuel flow in response to throttle setting.
4. Provides an electrical signal to the ECA to intiate afterburner ignition and afterburner lightoff logic.

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5. Provides activation signal for main ignition through a cam operated switch on the throttle lever.
6. Provides acceleration and deceleration fuel flow limits for transients.
7. Provides minimum and maximum compressor discharge pressure (P_{S3}) limits.
8. Provides fuel shutoff in response to PLA.
9. Provides fuel shutoff in response to overspeed conditions.
10. Provides N_2 speed lockup schedule at high aircraft Mach, in response to a signal from the aircraft.

D. AFTERBURNER FUEL CONTROL (See Figure 4-5)

The afterburner fuel control (ABC), mounted on the ABP, schedules fuel flow to the pilot and main spraybars for afterburner operation. Fuel for ABC operation is supplied by the gearbox driven MFP. Total flow is metered in the ABC. Fuel then passes through the ABP and back to the ABC where part of it is separated from the total flow and passes through the pilot spraybar metering valve which is positioned by the compressor discharge servo. A constant pressure drop is maintained by the throttling valve in the main spraybar flow stream. A lockout valve moves in response to the afterburner permission signal from the MFC and switches the ABP inlet valve between the off and modulated positions. This valve also controls the circulating valve which circulates fuel through the main spraybar manifold during non-afterburner operation.

E. AFTERBURNER FUEL PUMP (See Figure 4-4)

The afterburner fuel pump is mounted on the aft right side of the gearbox. It is a vapor-core, centrifugual type pump that receives metered fuel flow from the ABC. Fuel pressure is increased by the pump centrifugal impeller, and the inlet valve maintains a constant pressure differential across the ABC. The MFC provides a hydraulic signal to regulate the inlet valve and turn the ABP on and off. Thus, the pump provides fuel pressure as required for afterburner fuel requirements.

F. POWER LEVER CONTROL (See Figure 4-9)

The power lever control (PLC) is mounted on the left side of the gearbox and is connected to the MFC power lever arm. The PLC consists of an actuator, torque motor, solenoid, RVDT, and a manual mode servomechanism. This component has two purposes. First, it provides a power boost to operate the MFC input lever arm, and second, it positions the MFC input arm when the aircraft is controlled by the approach power control (APC) computer. When activated by the pilot, the APC computer sends a signal that energizes the solenoid in the PLC, this, in turn, activates the hydraulic circuits controlled by the torque motor. The torque motor, commanded by the APC, positions the MFC power lever arm through a pilot valve. The position of the PLC output is fed back to the APC through an RVDT. When the solenoid is not energized, the MFC power lever arm is positioned through the manual mode servomechanism.

G. FUEL FLOW TRANSMITTER (See Figure 4-6)

The fuel flow transmitter is mounted on the right side of the engine at 5 o'clock and measures flow to the main combustor. Afterburner fuel flow is not measured by the flow transmitter.

H. CHECK AND DRAIN VALVE (See Figure 4-6)

The check and drain valve is a small spring-loaded valve located at the bottom center of the engine connected between the oil cooler and combustor manifold. As pressure increases to admit fuel to the manifolds, the valve closes. When the engine is shutdown, fuel pressure is relieved and the spring loaded valve opens, allowing the combustor manifold to drain.

J. MAIN FUEL NOZZLE (See Figure 4-8)

There are eighteen dual-cone type main fuel nozzles, containing a fixed primary orifice and a secondary orifice which opens above 125-150 psig to accommodate large changes in flow rate.

K. AFTERBURNER PILOT AND MAIN SPRAYBARS

There are six afterburner pilot spraybars with a fuel pressure-operated distributor valve in the head of each spraybar. They are insulated to eliminate fuel boiling by incorporating a tube within a tube construction.

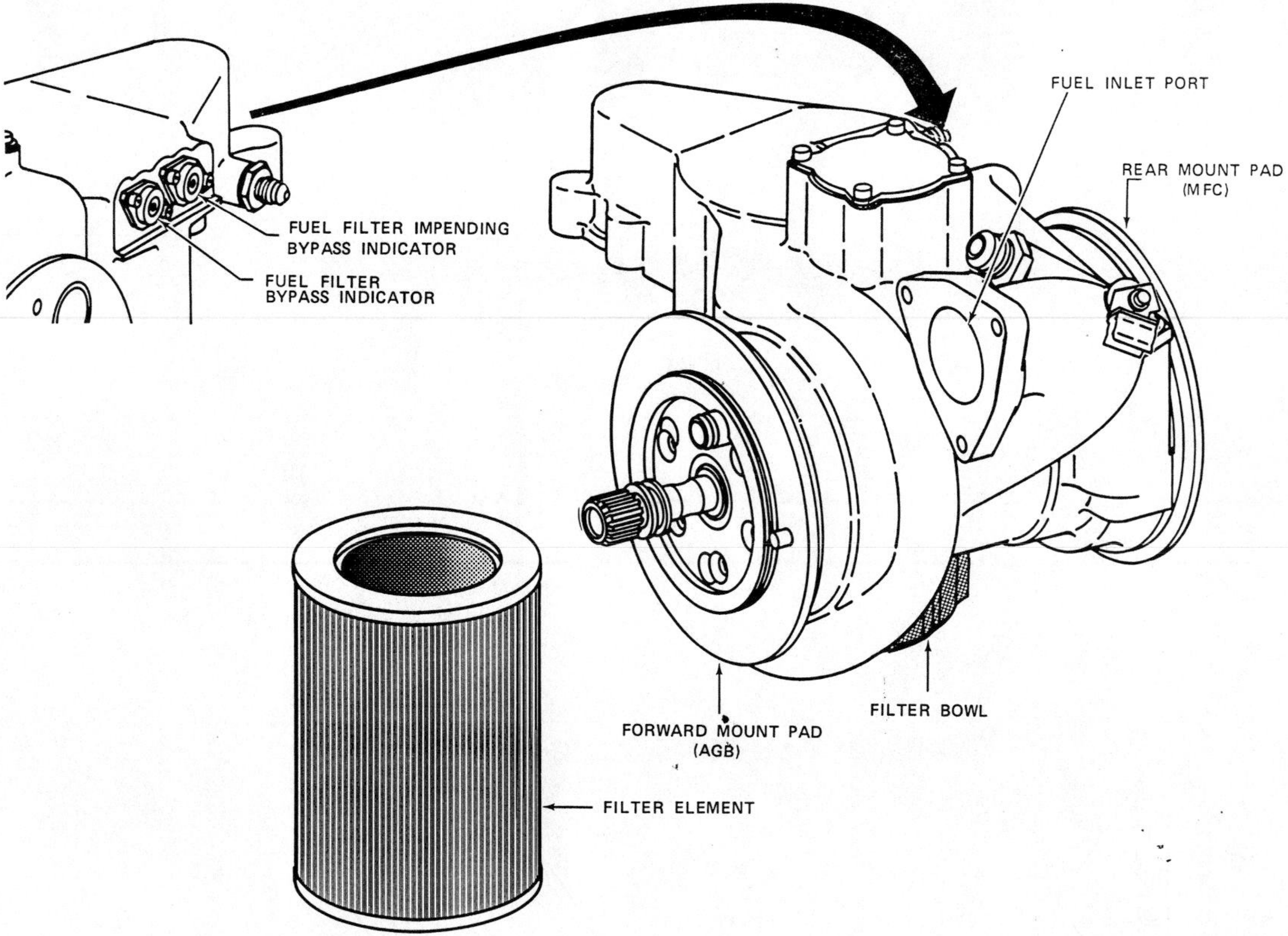
There are 24 main A/B spraybars. Four main spraybars are attached to each of the six distributor valves.

L. FUEL SYSTEM OPERATION (See Figure 4-10)

Fuel is introduced into the engine fuel system through a single inlet connection to the main fuel pump. The fuel passes through the inducer and centrifugal pump elements and then through a 10-micron nominal, 30 micron absolute disposable filter. After the fuel is filtered, the fuel is divided three ways. First, a small amount of fuel is sent to the ECA for cooling purposes and then returned to the inlet of the centrifugal element. Additionally, fuel is supplied for afterburner control use. The balance of the filtered fuel flow is sent to the high pressure vane element of the pump. The high-pressure discharge of the vane element is then sent directly to the main fuel control.

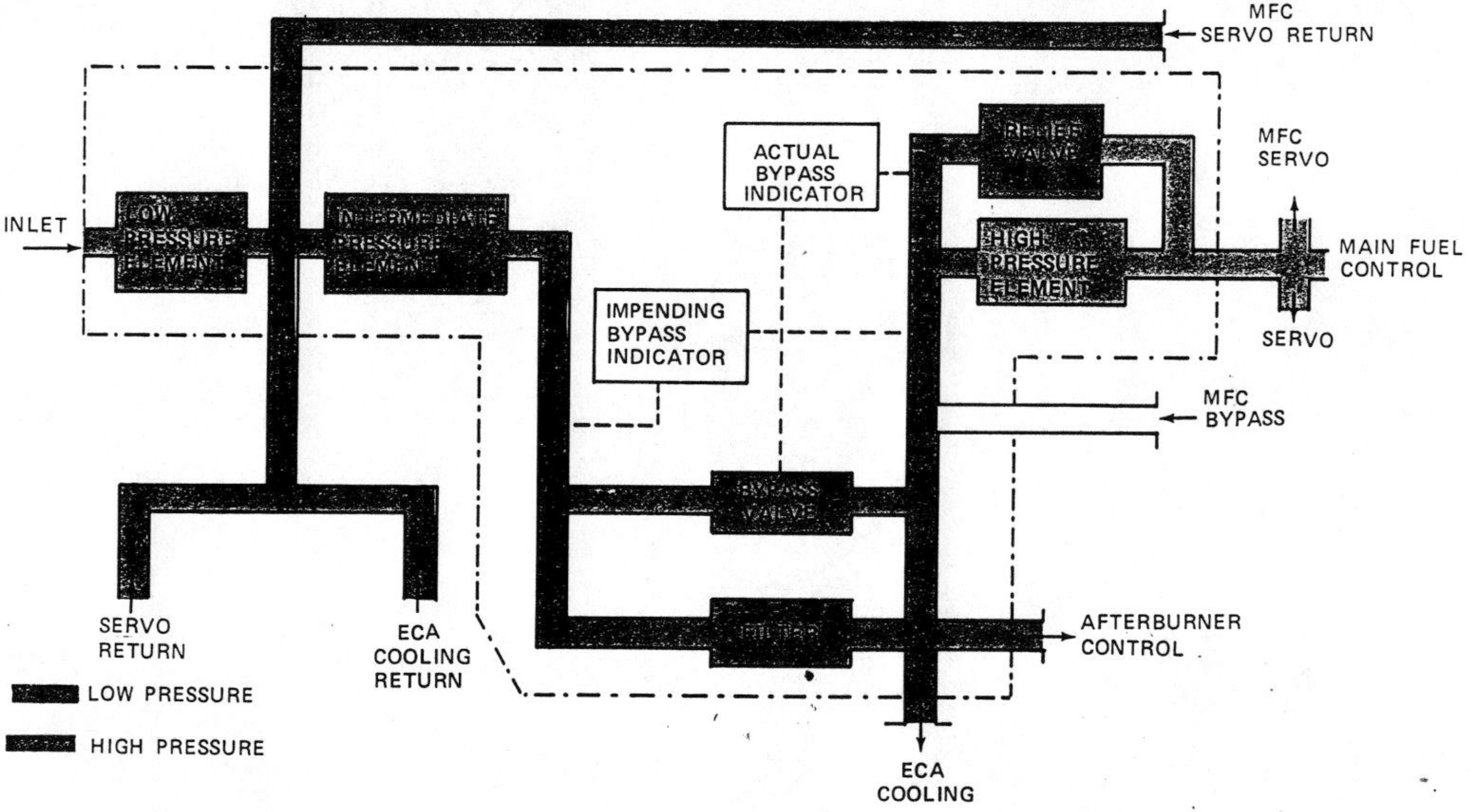
Fuel entering the MFC passes through a mesh screen to protect the MFC from large contaminants. A portion of the screened flow passes through a wash filter and operates the various MFC and afterburner control servomechanisms and powers the FVG, CVG and PLC systems. The remainder of the flow is sent to the metering valve. The metering valve assumes a position, based on the inputs of PLA, N_2, $T_{2.5}$, P_{s3}, and will deliver the correct amount of metered fuel flow to the combustor based on these inputs. The excess fuel delivered to the metering valve above its requirements is bypassed back to the inlet of the high pressure vane element of the pump via the bypass valve. Metered fuel passes through pressurizing valve and a positive fuel shutoff valve before discharging the main fuel control. After leaving the MFC, the fuel passes through the fuel flow transmitter, lube and VEN oil cooler, check and drain valve, the main fuel nozzles and then is ignited in the combustor. The check and drain valve ahead of the manifolds positively shuts off fuel flow when the pressure falls below a set value and allows the manifolds to drain without draining the upstream portion of the system.

To satisfy afterburner fuel requirements, the afterburner metering valve is positioned by an electrical signal from the ECA (W_r/P_3 demand) and rotationally by P_{s3}. The afterburner metered fuel flow is routed to the afterburner pump inlet valve. The inlet valve has two functions: 1) it maintains a constant pressure drop across the A/B main metering valve and 2) provides a shutoff for non-afterburner operation. The afterburner control in afterburner operation divides the afterburner fuel flow from the pump into pilot spraybar and main spraybar fuel flow. The pilot spraybar flow is metered through its own metering valve. The pressure drop across the pilot metering valve is regulated by a regulating valve in the main spraybar flowpath. The regulating valve allows the remainder of the pump flow to pass into the main spraybars while operating to maintain a constant pressure drop across the pilot metering valve. During non-afterburner operation, fuel is circulated through the main spraybar manifold, distributor valves and back to the afterburner pump through the manifold circulating valve. This circulation minimizes afterburner ignition time by eliminating manifold fill time. The distributor valves have a positive shutoff valve, preventing fuel from flowing into the main spraybars during non afterburner operation.



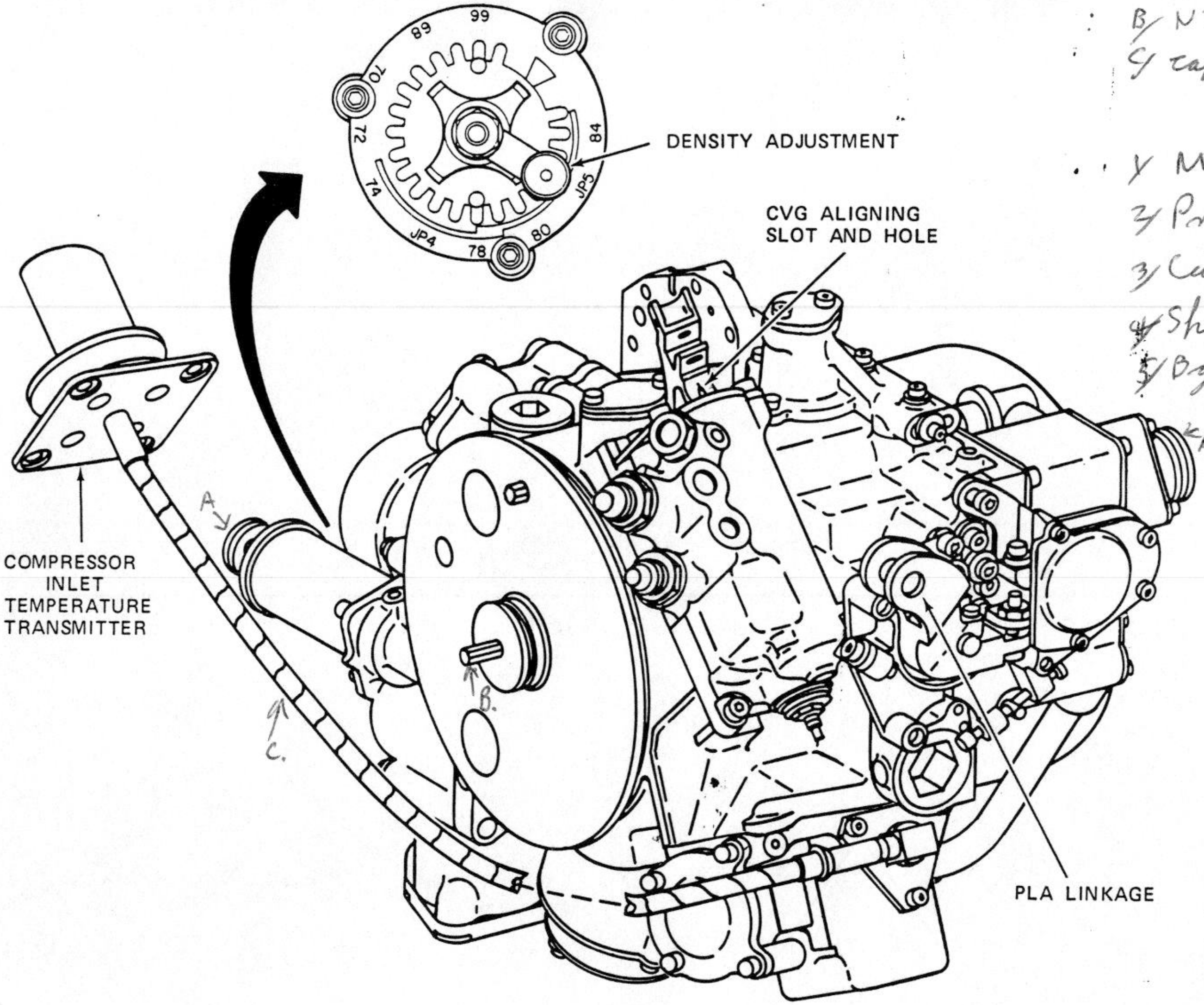
MAIN FUEL PUMP

Figure 4-1



MAIN FUEL PUMP SCHEMATIC

Figure 4-2

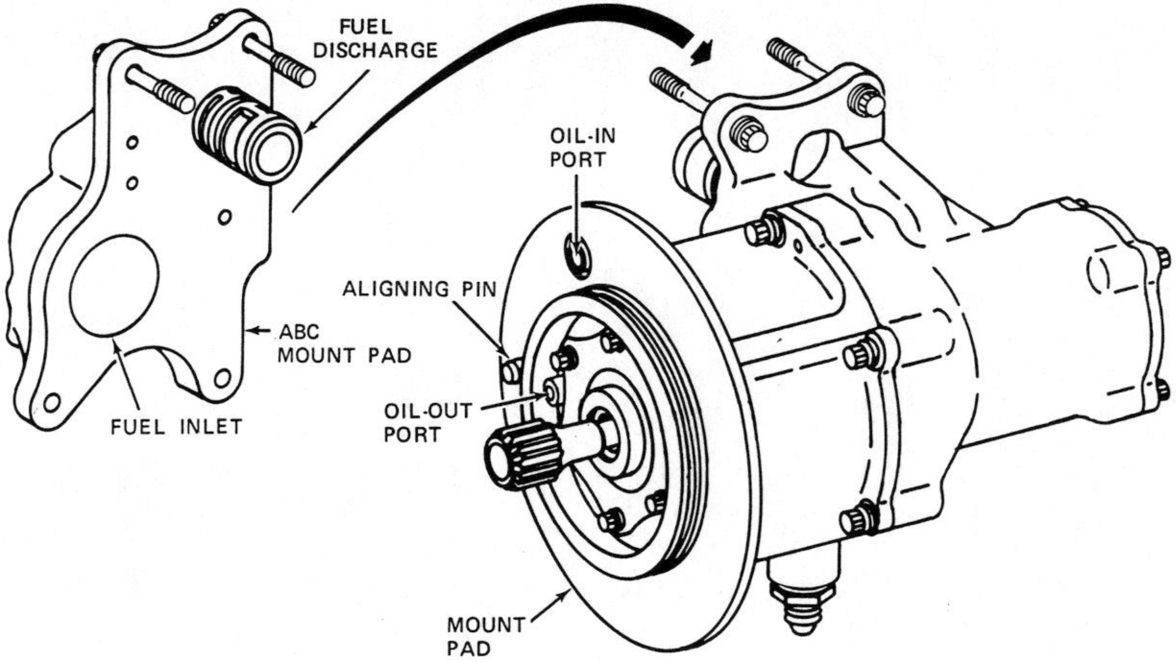


A/ ELEC CONN
B/ N2 drive
C/ capillary tube

1/ Metering valve
2/ Press V.
3/ Cutoff V.
4/ Spec gravity adj
5/ Bypass V.
6/ N1 Overspeed sol

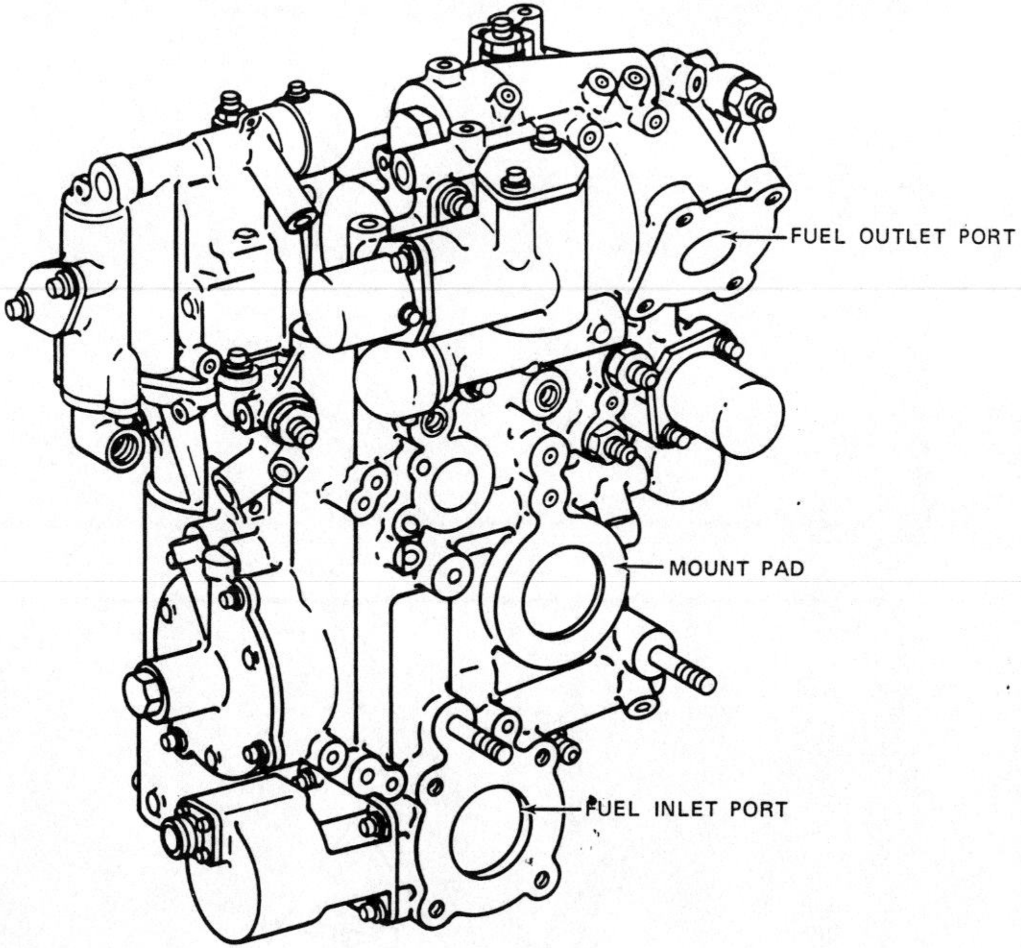
MAIN FUEL CONTROL

Figure 4-3



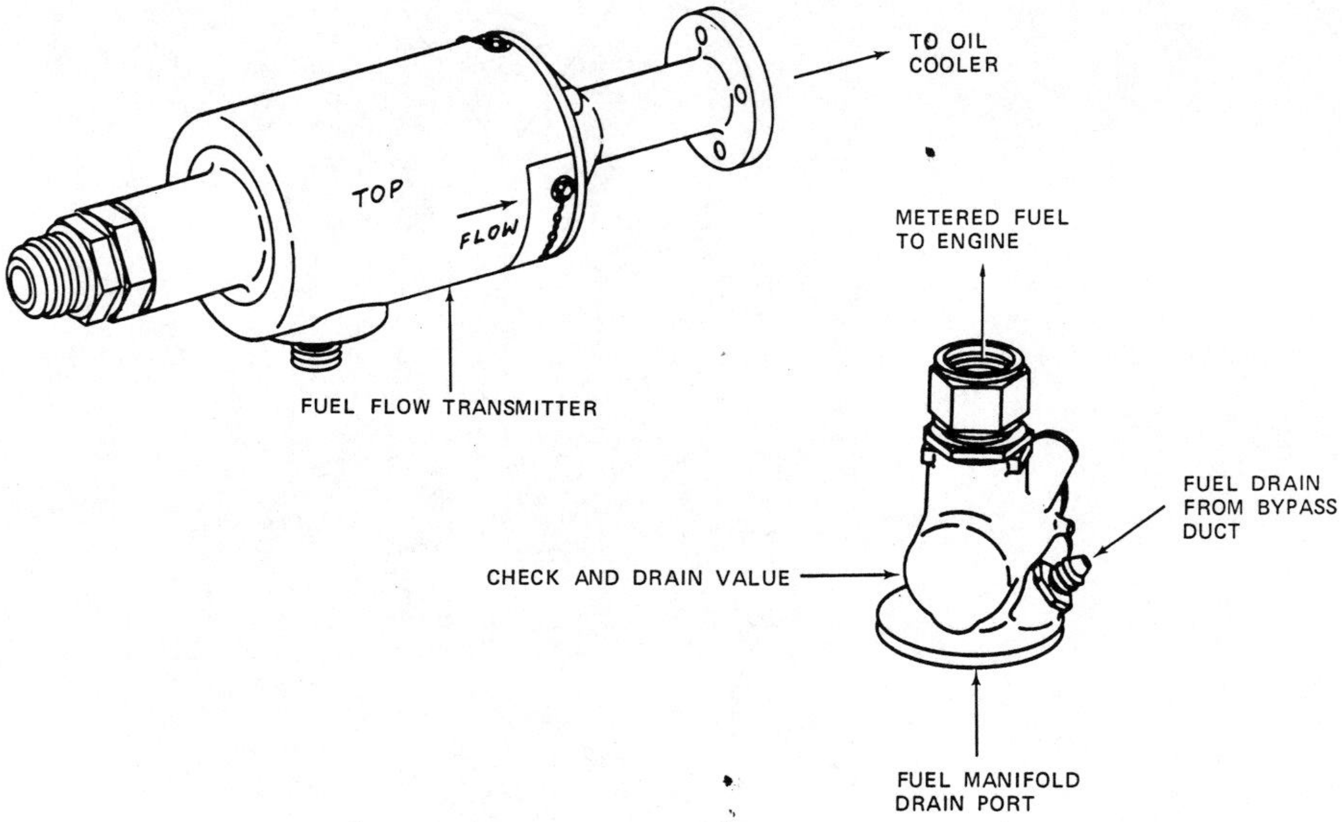
AFTERBURNER FUEL PUMP

Figure 4-4



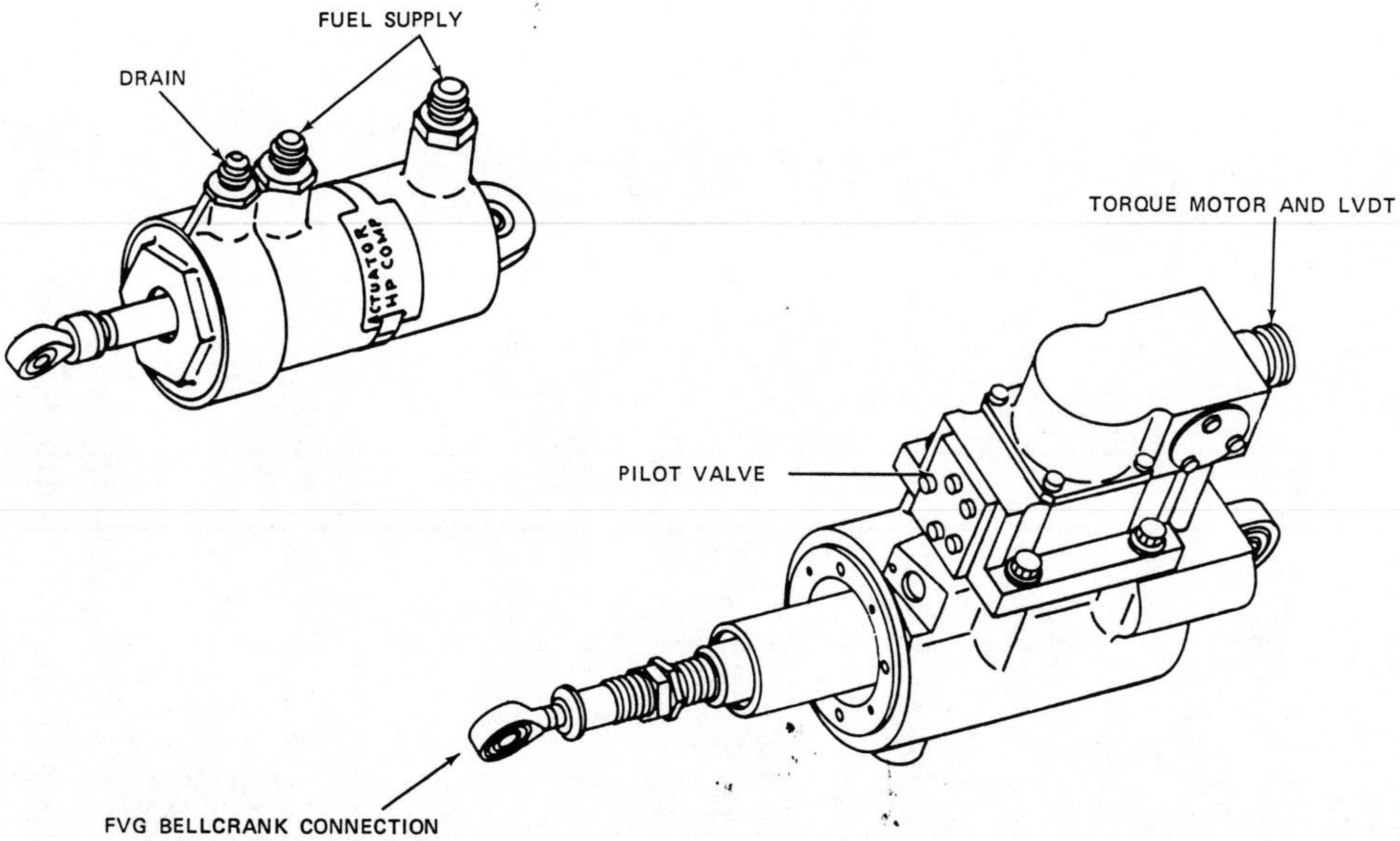
AFTERBURNER FUEL CONTROL

Figure 4-5



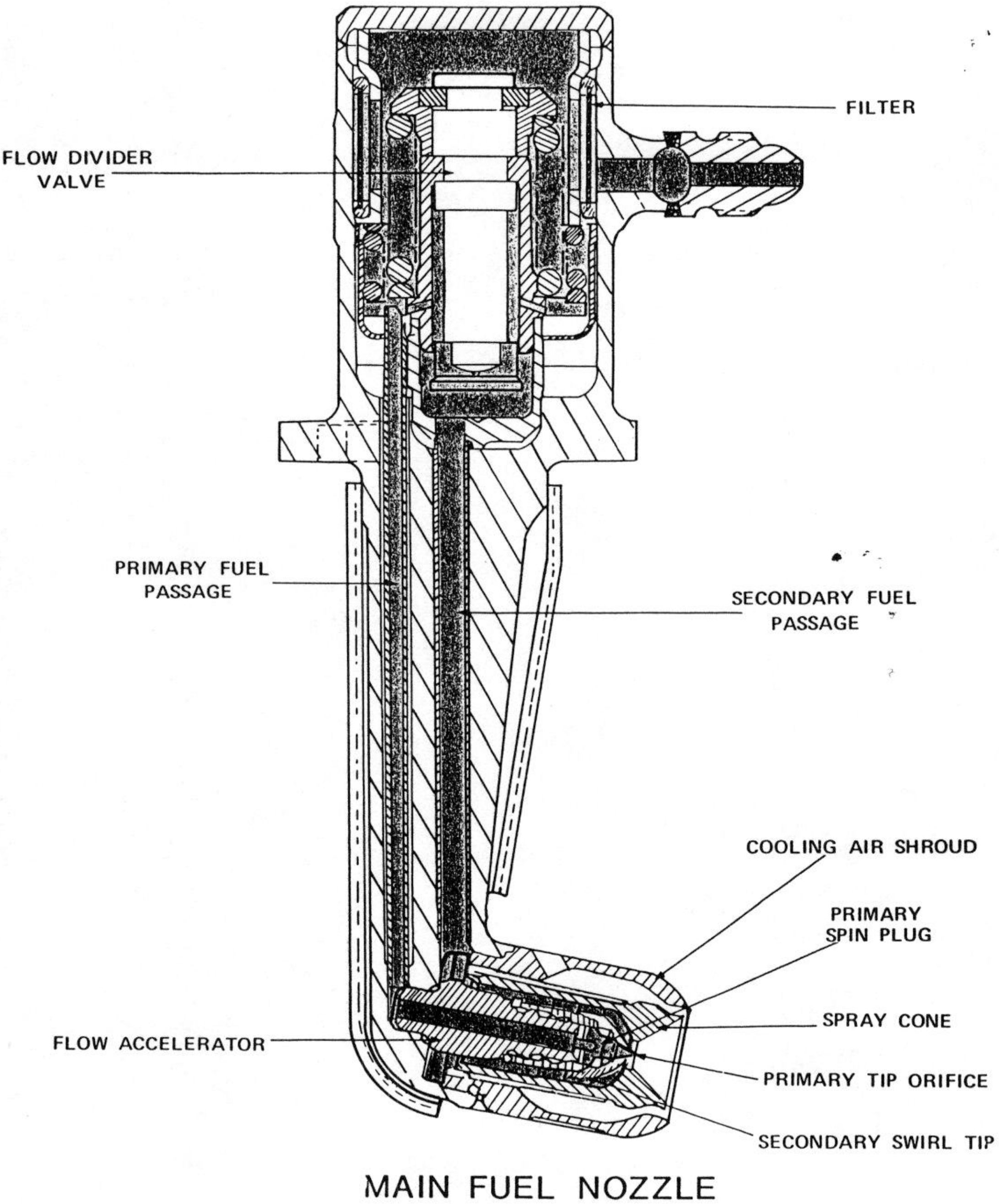
FUEL SYSTEM COMPONENTS

Figure 4-6



FAN AND COMPRESSOR VG ACTUATORS

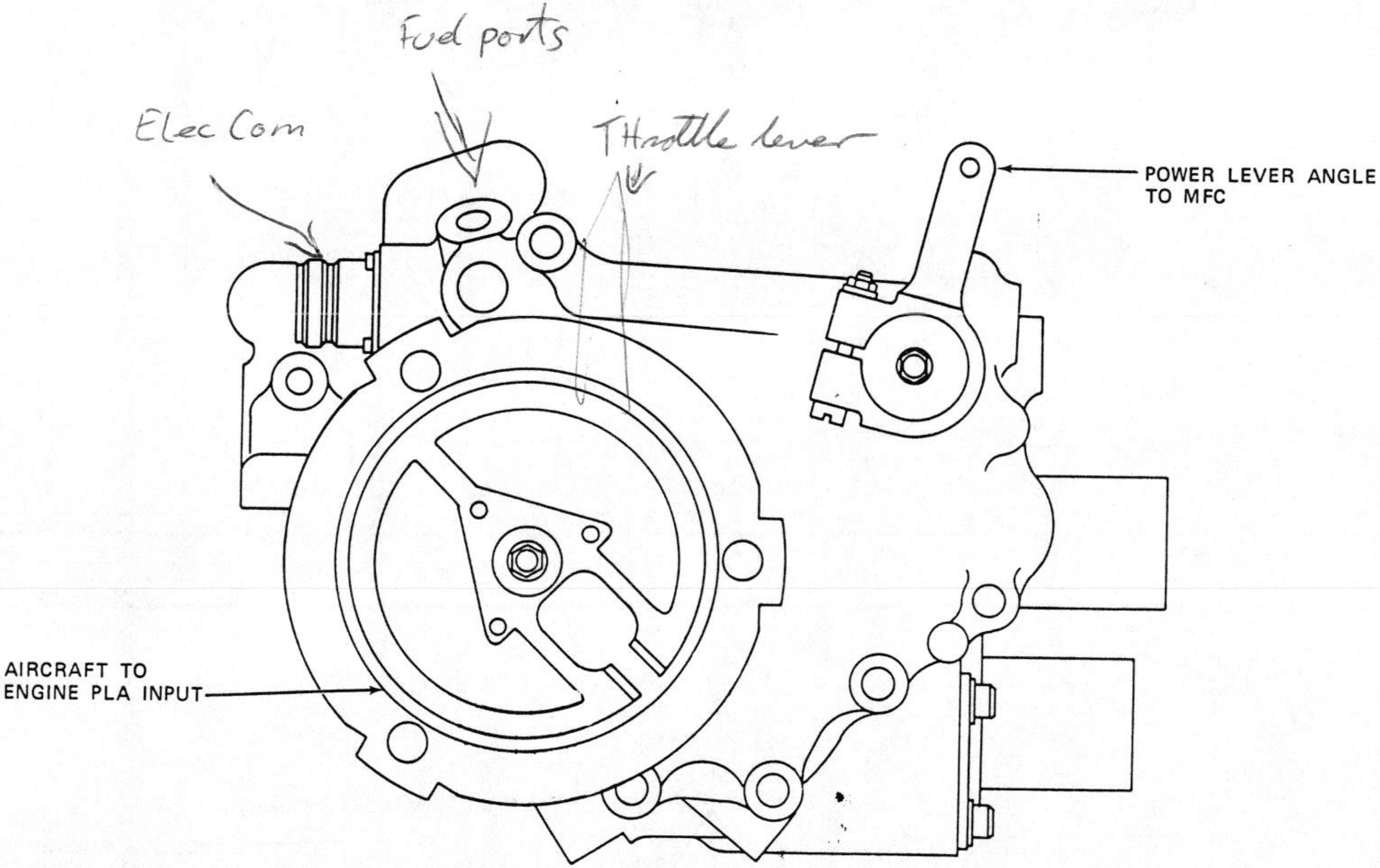
Figure 4-7



MAIN FUEL NOZZLE

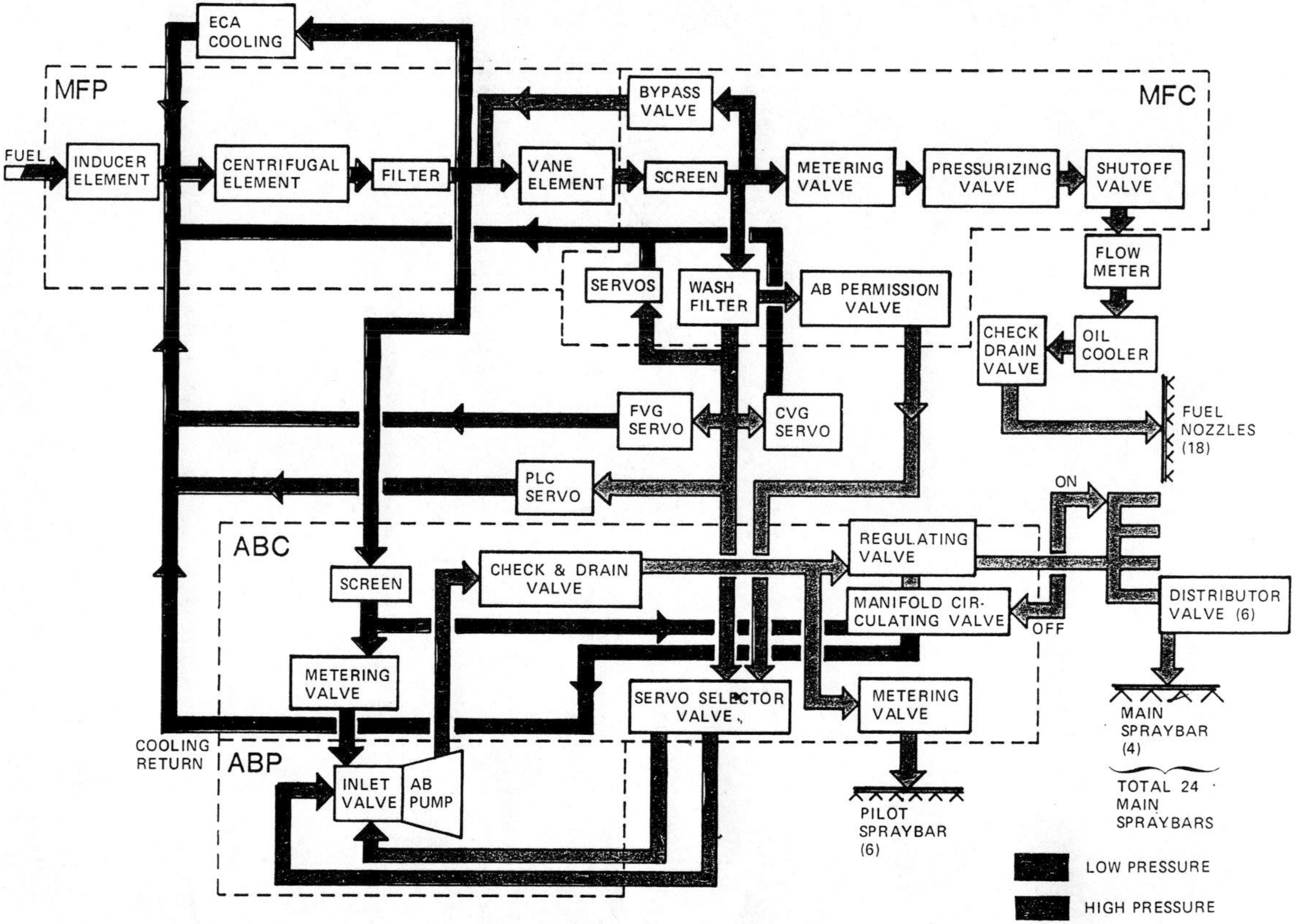
PRIMARY & SECONDARY FLOW

Figure 4-8



POWER LEVER CONTROL

Figure 4-9



FUEL SYSTEM SCHEMATIC

Figure 4-10

SECTION 5

NOZZLE ACTUATION SYSTEM

A. GENERAL (See Figure 5-4)

The hydraulic variable exhaust nozzle (VEN) actuation system is self-contained and supplies oil at high pressure to the three synchronized hydraulic actuators to operate the variable exhaust nozzle.

The system monitors the area of the nozzle and feeds back this position, through an electrical signal from the A_8 LVDT position transmitter, to the electrical control assembly.

The function of the system is to maintain a constant exhaust gas temperature as determined by the electrical control assembly which is sensing T_5 directly from the thermocouple harness. Deviations from the desired exhaust gas temperature will initiate repositioning of the nozzle by a signal from the electrical control assembly (A_8 demand) to the VEN power unit.

The major components of the nozzle actuation system include the electrical control assembly, VEN power unit, VEN oil cooler, three VEN actuators, A_8 position transmitter and the associated electrical and hydraulic lines.

B. VEN POWER UNIT (See Figures 5-1 and 5-2)

The VEN power unit is mounted on and driven through the lube and scavenge pump. The power unit consists of a reservoir/accumulator, a boost pump, a servo pump, and a controlled piston pump. The three pumps are driven by inline shafting. The self-contained reservoir is isolated from the engine oil system. Positive priming for the boost pump is provided by the accumulator. Filtered oil under pressure is supplied to the three synchronized VEN actuators to open and close the variable exhaust nozzle. A feed-back signal from the VEN position transmitter is sent to the electrical control assembly (ECA). The ECA then schedules the position of the VEN. The power unit can produce up to 550 psig to open the nozzle and up to 4000 psig full demand to close the nozzle. Return oil to the power unit and from the actuators passes through the oil cooler and back to the reservoir. The power unit has a relief valve with an overboard drain to protect the system against overpressure. The filter assembly is equipped with a shutoff valve, a bypass valve, and an impending bypass indicator button. The impending bypass indicator activates at a pressure of 51.75 psid. The bypass valve opens at a pressure of 65 psid.

Nozzle area (A_8) is controlled by an output signal from the ECA called A_8 demand. This demand signal provides the nozzle schedule and integrated T_5 control to the VEN power unit torque motor. As a function of this torque motor input, high pressure oil is allowed to flow to either the head end or rod end of the VEN actuators to actuate the nozzle system.

C. VEN ACTUATORS

The VEN actuators are mounted on and supported by the aft end of the afterburner casing. The actuator piston shafts are connected to the actuating ring of the VEN. There are three hydraulic connections on each side of the three actuators. The forward hydraulic connection is called the head end and the middle hydraulic connection is called the rod end. The aft hydraulic connection is for VEN actuator cooling. The function of the actuators is to provide a stroking motion with sufficient force to position the variable exhaust nozzle. The three actuators are synchronized mechanically, by flexible synchronizing cables, and hydraulically to prevent any misalignment of the actuating ring when its position is changed. There are cooling orifices within the actuators which control the cooling flow of oil through the actuators.

Oil pressure supplied to the head end of the actuators will extend the piston shafts and open the nozzle. Oil pressure supplied to the rod end of the actuators will retract the piston shafts and close the nozzle.

D. VEN (A8) POSITION TRANSMITTER (See Figure 5-3)

The A_8 position transmitter is mounted on and supported by the aft end of the afterburner casing at the 6 o'clock location. The A_8 position transmitter is a linear variable differential transformer (LVDT). The core of the transformer is attached to the actuating ring. The movement of the core has a linear relationship to output voltage. Therefore, output voltage from the A_8 LVDT can be measured, converted in the ECA logic and interpreted as nozzle area.

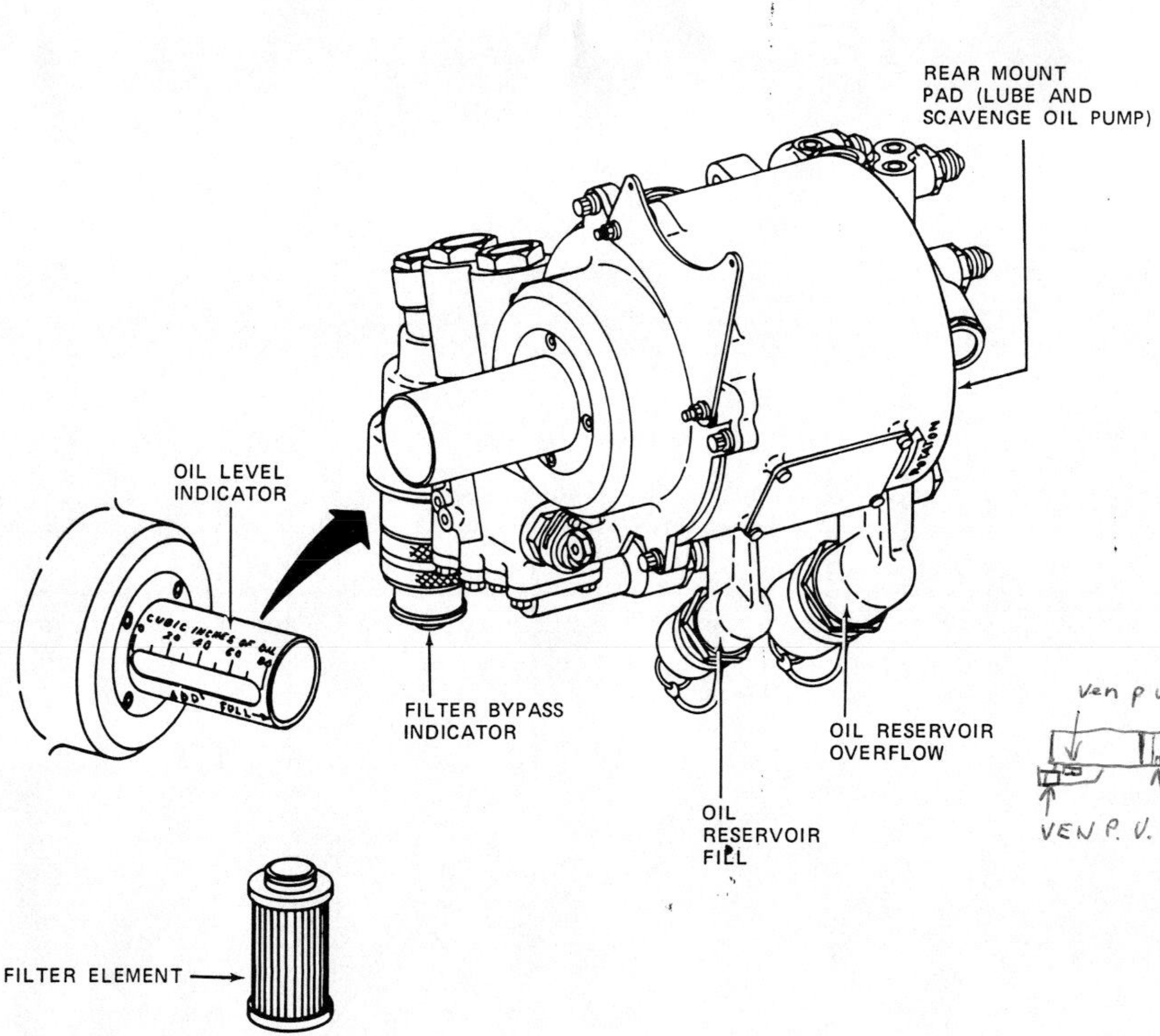
The VEN cooling oil being returned from the actuators is passed through the cooling jacket of the A_8 position transmitter before being returned to the VEN oil cooler and the VEN power unit reservoir.

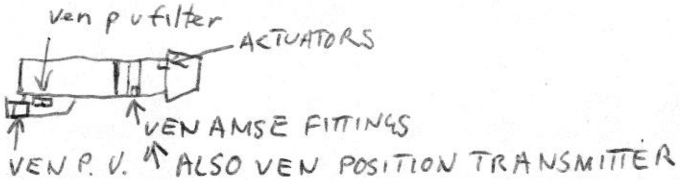
E. ELECTRICAL CONTROL UNIT

Inputs to the ECA controlling the A_8 system:

1. PLA from MFC:
   Provides A_8 demand signal for scheduling A_8.
2. Afterburner permission from MFC:
   Initiates min A_8 area when minimum afterburner is requested.
3. T_1 signal:
   Modifies the A_8 schedule in afterburner operation.
4. N_1 signal:
   Biases part power A_8 schedule.
5. P_0 signal:
   Biases min A_8 schedule.
   Biases the N_1 and T_5 limit schedules.

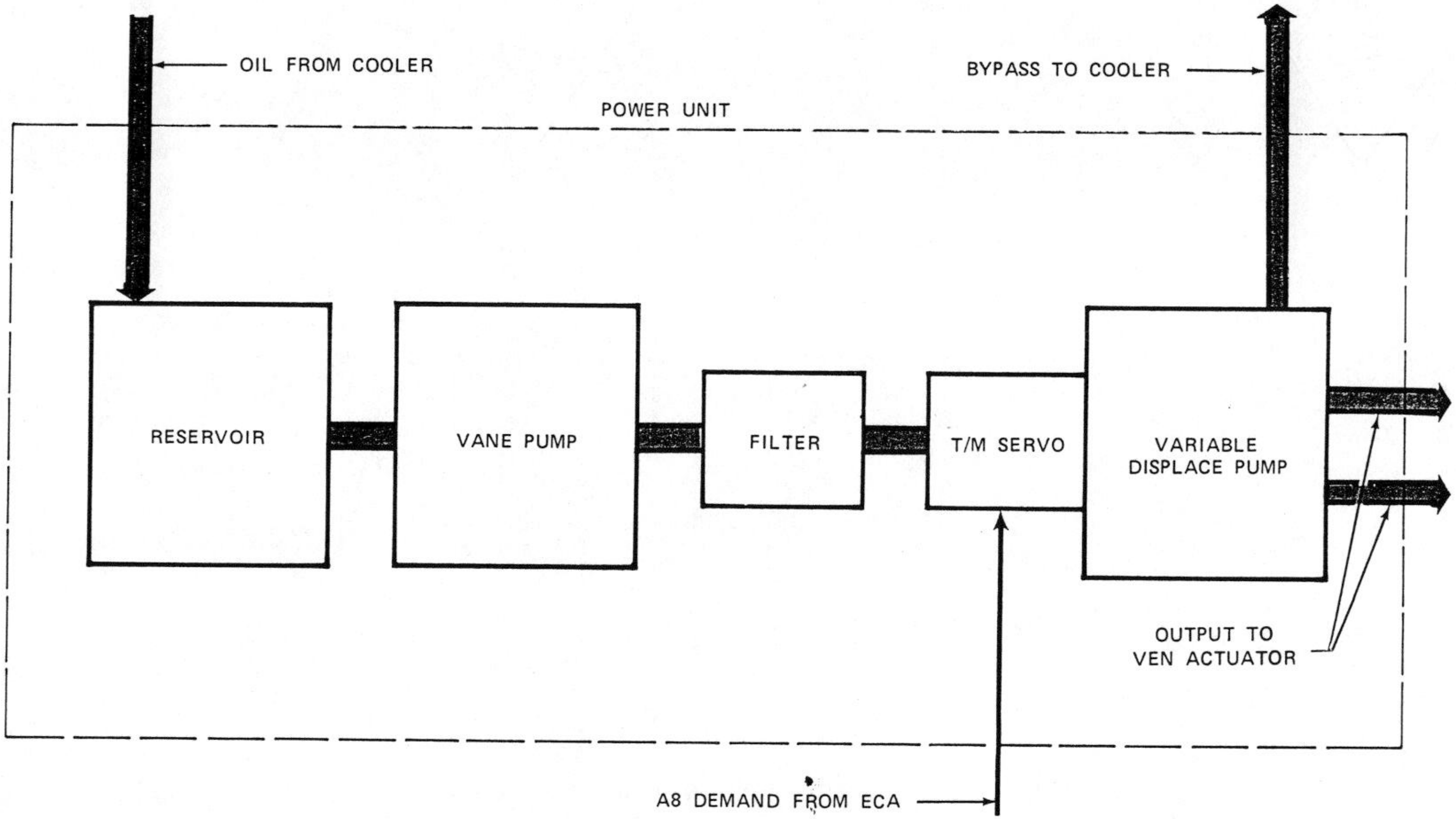
6. T_5 signal from thermocouple harness:
   Provides actual T_5 temperature sensed in engine for control of T_5 by modulating A_8
7. A_8 position feedback:
   Provides actual A_8 position for comparison to desired position requested by ECA.





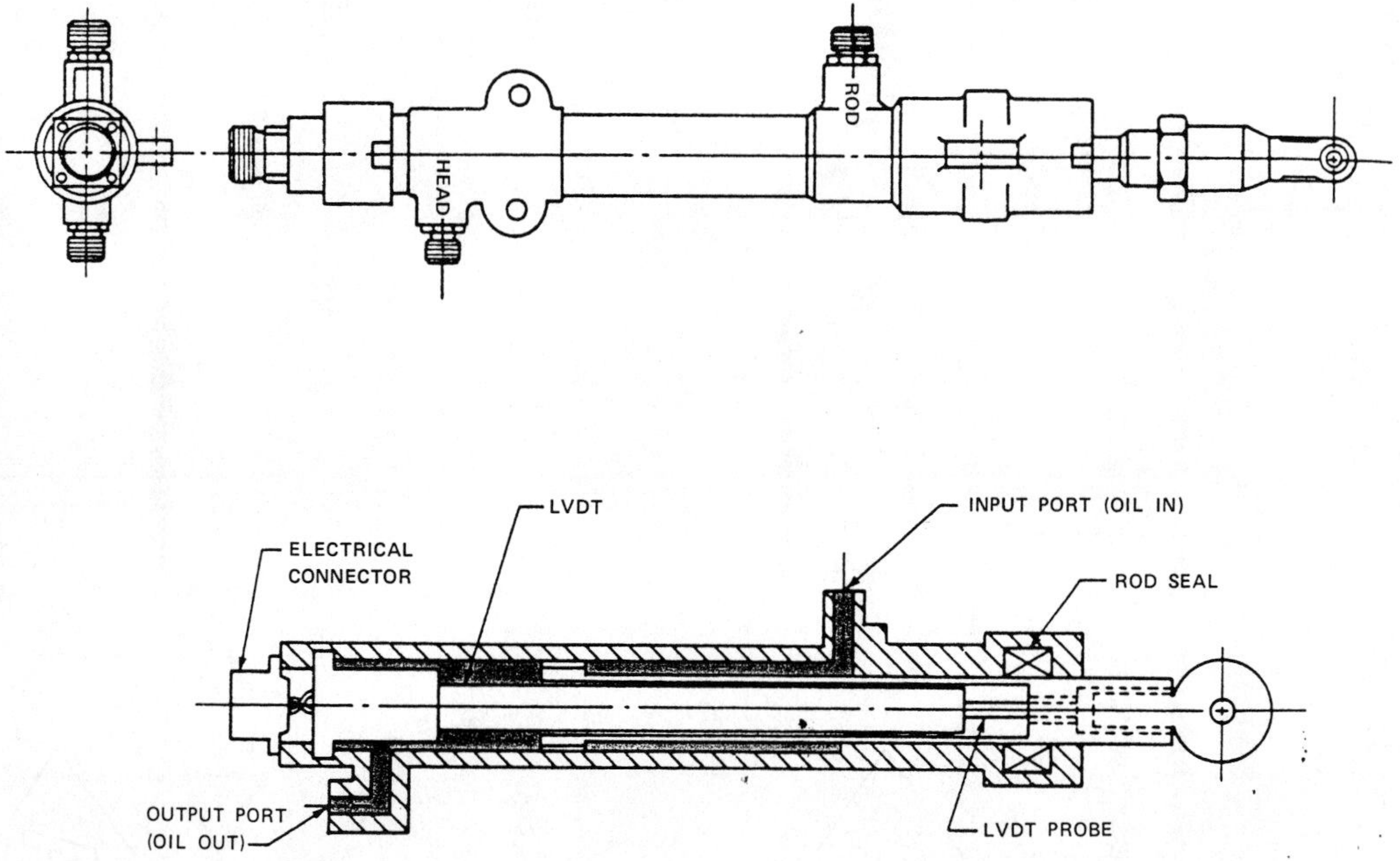
VEN POWER UNIT

Figure 5-1



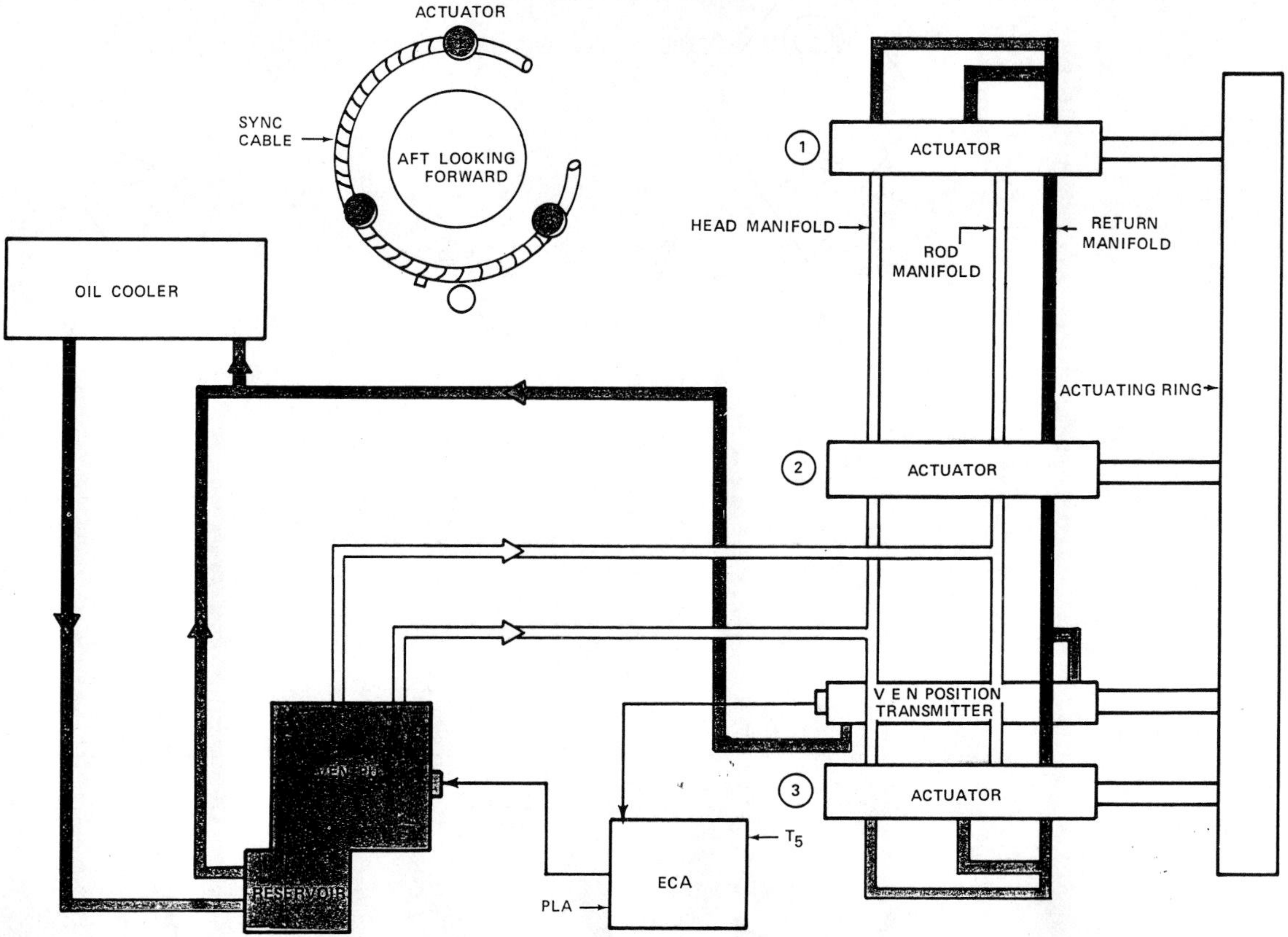
VEN POWER UNIT SCHEMATIC

Figure 5-2



VEN POSITION TRANSMITTER

Figure 5-3



VARIABLE EXHAUST NOZZLE ACTUATION SYSTEM

Figure 5-4

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SECTION 6

ELECTRICAL SYSTEM

A. ELECTRICAL CONTROL ASSEMBLY (See Figures 6-3)

The electrical control assembly (ECA) is a modular solid-state component, mounted on the engine, supplied with power from the engine alternator and cooled by fuel from the MFP. It accepts various engine signals from the engine sensors, computes engine schedules, and establishes and maintains limits. It contains most of the circuitry necessary for steady-state and fast transient responses. The ECA provides the following outputs:

1. A_8 demand torque motor signal to the VEN power unit to schedule A_8 in response to:
   a) PLA from an LVDT demand signal from MFC
   b) Fan speed N_1 sensor input (part power only)
   c) T_5 error computed signal
   d) T_5 limit scheduled by T_1 sensor signal
   e) A_8 feedback position from VEN position transmitter
   f) Altitude ambient pressure (P_0)
   g) Afterburner initiation signal
2. W_F trim torque motor signal limits maximum N_1 in response to N_1 speed error computed from engine sensors:
   a) N_1
   b) Armament firing signal
   c) T_1
   d) MFC metering valve LVDT (stability loop)
3. Afterburner torque motor signal to ABC (WR/P_3 demand) which schedules WR, in response to:
   a) PLA
   b) A_8 feedback
   c) T_1
   d) ABC Metering valve LVDT feedback

4. Main and afterburner ignition signals to ignition exciter which schedules ignition on and off in response to:
    a) PLA
    b) N_2
    c) Afterburner flame sensor signal
    d) Armament firing signal
    e) T_5
    f) A/B initiation logic
5. Cockpit indications for:
    a) N_1 from transmitters
    b) A_8 from A_8 feedback
    c) T_{5C}
6. Schedules fan variable geometry (FVG) in response to:
    a) N_1
    b) T_1
    c) Armament firing signal
7. Excitation voltage for LVDT's and flame sensor.
8. Constant current for T_1 transmitter operation.
9. A/B vapor puff relay signal which holds N_2 in a lock-up condition through the MFC N_2 lock-up solenoid during throttle chops out of A/B if:
    a) There is no A/B initiation signal
    b) A/B flame sensor signal is on

B. IGNITION SYSTEM (See Figures 6-1 through 6-5)

The F404-GE-400 ignition system is an automatic, intermittent duty, AC powered, capacitor discharge system. The ignition circuitry is self-contained on the engine, requiring no electrical power from the aircraft for operation. The system includes the alternator, the electrical control assembly, ignition exciter, one main igniter and one afterburner igniter. The system is shown schematically in Figure 6-5.

B. IGNITION EXCITER (See Figure 6-2)

The ignition exciter mounted on the fan stator case, converts ac power supplied by the engine alternator to 1200-volt dc pulses for ignition. The exciter has two outputs, one for the main igniter and one for the afterburner igniter. Outputs are turned on and off simultaneously with one input from the electrical control assembly.

C. ALTERNATOR (See Figure 6-1)

The alternator consists of a rotor and a stator which are assembled to the forward right-hand pad on the gearbox. The stator has three separate windings which provide electrical power for the following:

a) Ignition exciter for main and afterburner ignition
b) ECA power and N_2 speed frequency
c) N_2 signal for cockpit indication of compressor speed

D. FAN SPEED N1 TRANSMITTERS

The two fan speed transmitters are eddy current devices, mounted on the fan stator lower case, directly over the fan second stage rotor blade tips. Interruption of these eddy currents by movement of the fan rotor blades produces an AC voltage whose frequency is proportional to the fan rotor speed. Two sensor signals are transmitted to the ECA which discriminates out any false low signal. The N_1 signal is used to control maximum N_1, limit fan variable geometry and also as an N_1 overspeed governor. The signal is also transmitted to the aircraft for cockpit indication.

E. T1 TRANSMITTER (Engine Inlet Temperature)

The T_1 transmitter is mounted on the front frame and projects into the fan inlet air stream. The T_1 transmitter is a resistance temperature device (RTD) that transmits a signal to the ECA, which is interpreted as engine inlet temperature.

The ECA accomplishes this by supplying the T_1 sensor a constant current and monitors voltage changes across a feedback resistor. This signal is used to generate schedules for the following:

a) LPT discharge temperature (T_5)
b) Fan speed (N_1)
c) Fan variable geometry (FVG)
d) A/B fuel flow (W_R)

G. AFTERBURNER FLAME SENSOR

The afterburner flame sensor is mounted near the forward end of the afterburner case at the 7 o'clock position, and consists of an ultraviolet sensitive gas-filled tube and associated circuitry. The sensor provides an electrical on/off signal, corresponding to the afterburner pilot light, no-light condition, to initiate afterburner operation.

H. MIDFRAME VIBRATION ACCELEROMETER

The midframe vibration accelerometer is located on the midframe directly below the 3 o'clock split line. Vibrations produced by the engine during operation are detected by the midframe vibration accelerometer, which transmits a vibration signal electrically to the aircraft.

J. EXHAUST GAS PRESSURE PROBE

The exhaust gas pressure probe is mounted on the afterburner case at the 8 o'clock location. The probe is positioned to sample the pressure of air being discharged from the low-pressure turbine (PT5.6). This pressure is transmitted through tubing to the turbine discharge pressure transmitter located just off of 6 o'clock on the front frame.

K. COMPRESSOR DISCHARGE PRESSURE (PS3) TRANSMITTER

The compressor discharge pressure (CDP) transmitter is mounted on a bracket on the accessory gearbox (AGB), at the 5 o'clock position.

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The transmitter measures the compressor discharge static pressure (P_{S3}) and transmits it electrically to the aircraft on board IECMS system.

L. THERMOCOUPLE HARNESS (T5)

The thermocouple harness consists of two separate identical harness assemblies mounted on the afterburner case. Each half contains two shallow probes (20% immersion) and two deep probes (70% immersion) for average temperature sensing. The thermocouple signal is transmitted to the ECA to control temperature (T_5) at intermediate power and above. The signal is also transmitted by the ECA to the cockpit for T_{5C} indication.

M. TURBINE DISCHARGE PRESSURE TRANSMITTER

The turbine discharge pressure transmitter is mounted on the fan module front frame. The function of the transmitter is to convert turbine discharge air pressure, received from the exhaust gas pressure probe, into an electrical signal for IECMS use.

N. AFTERBURNER VAPOR PUFF RELAY

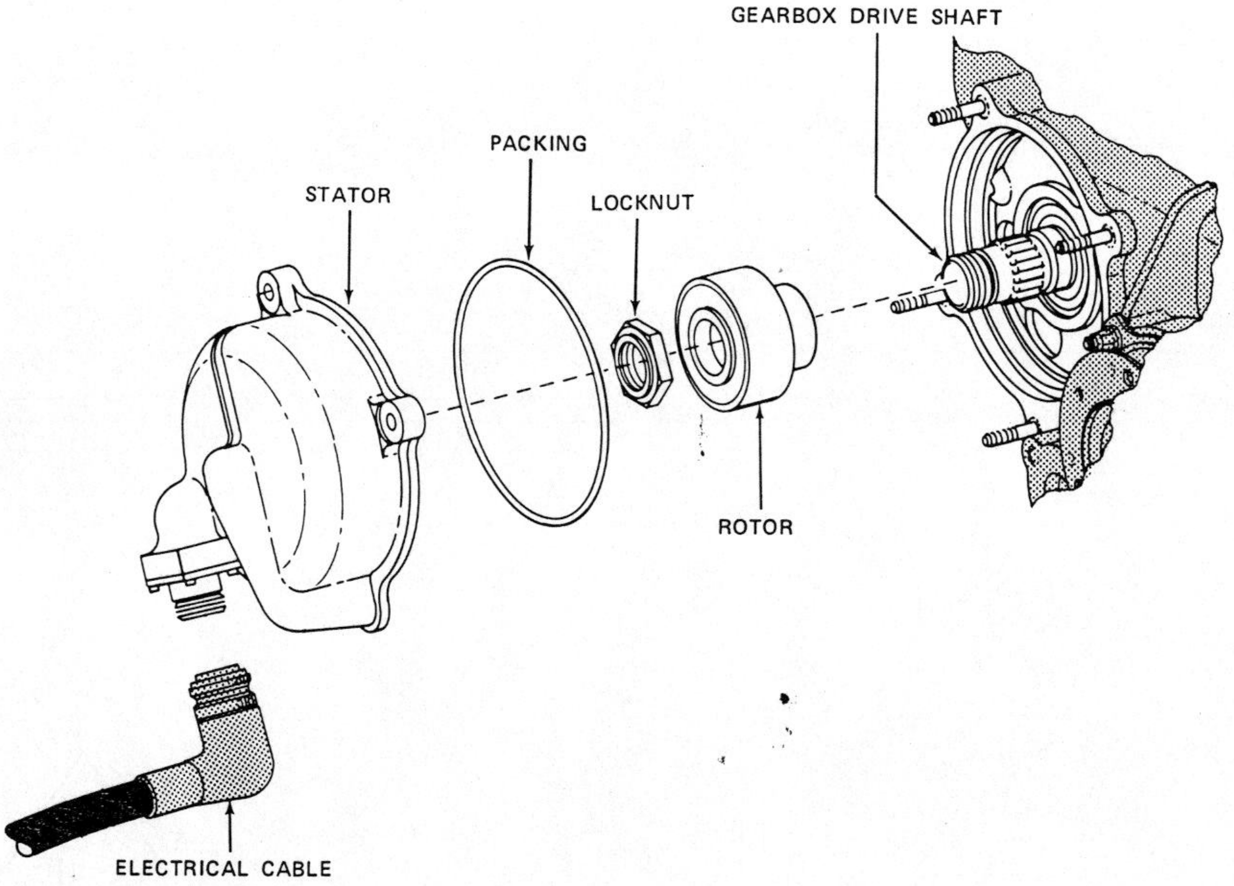
The afterburner vapor puff relay is mounted on the fan module flange at the 5 o'clock position. When commanded by the ECA, the relay energizes the N_2 speed lock-up solenoid in the MFC to briefly hold the engine at intermediate on throttle chops out of A/B. This is to insure the A/B fuel pump is off prior to the rotor speed dropping off too low to sustain an A/B light.

O. LINEAR VARIABLE DIFFERENTIAL TRANSMITTERS (LVDT'S)

The position transmitters are powered by an excitation voltage from the ECA (voltage in). The LVDT's for the ABC, FVG actuator, and MFC, and the RVDT for the PLC are incorporated in the basic functioning component. However, the VEN position trasmitter is a separate component. The output voltage from any of these transmitters is proportional to the position of the piston rod, (voltage out) and this voltage is fed back for closed-loop control of ABC and MFC metering valve, fan variable geometry feedback, PLA to the ECA and nozzle area (A_8).

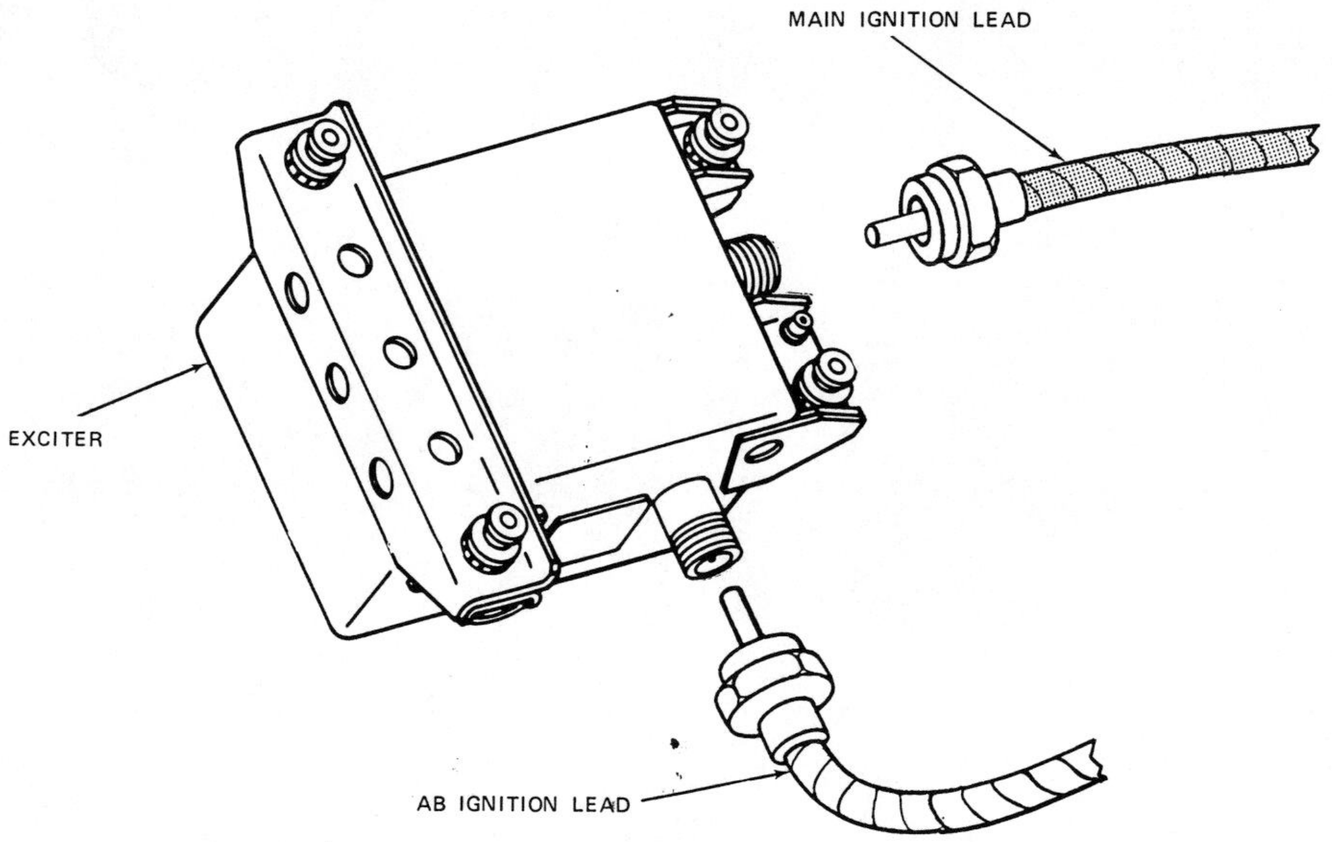
P. ANTI-ICING VALVE

The anti-icing valve is a pressure-regulating shutoff valve that requires external power for operation. If external power is shut off, the valve will open, provided inlet air pressure is 7 psig or greater.



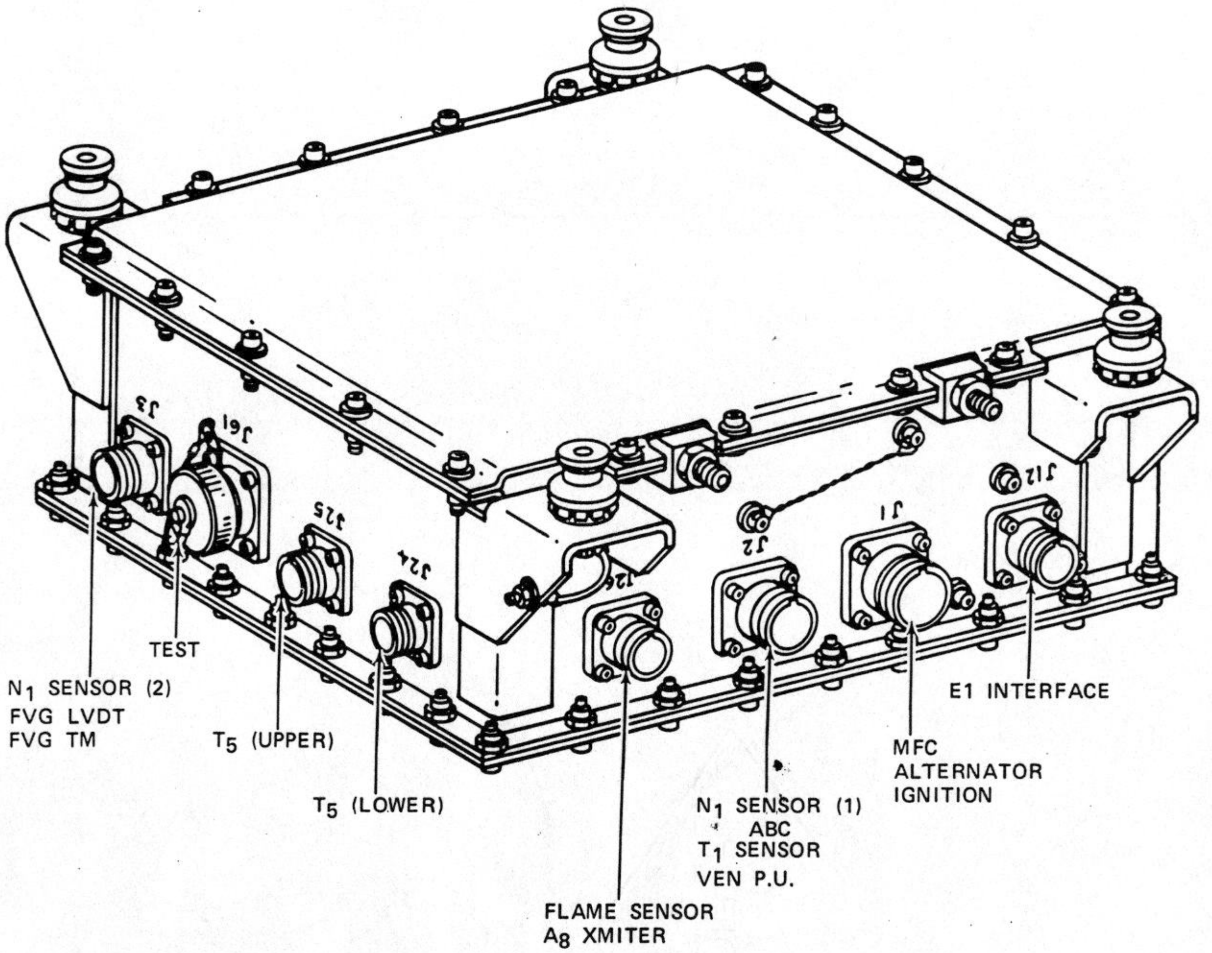
ALTERNATOR COMPONENTS

Figure 6-1



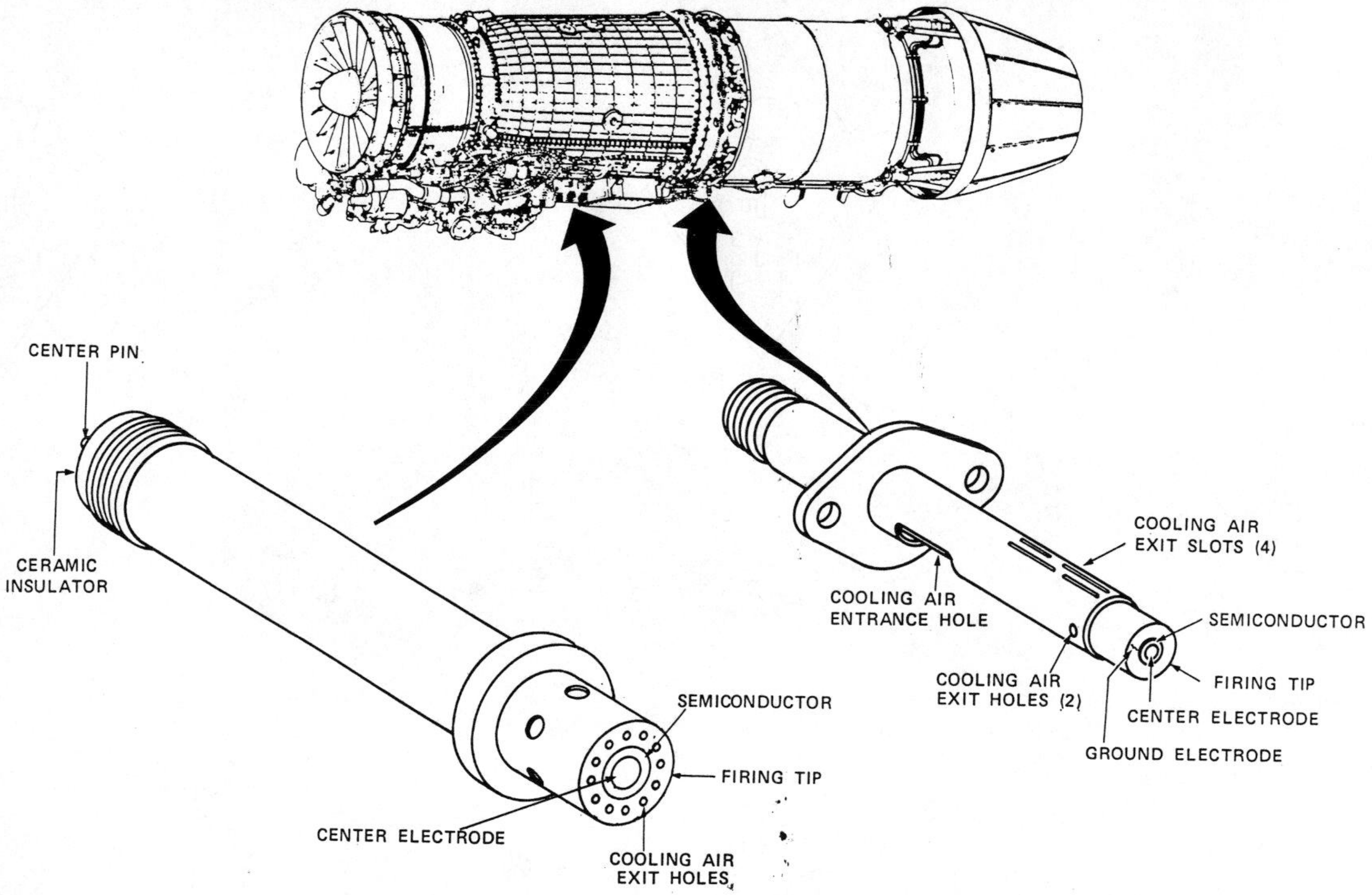
IGNITION EXCITER

Figure 6-2



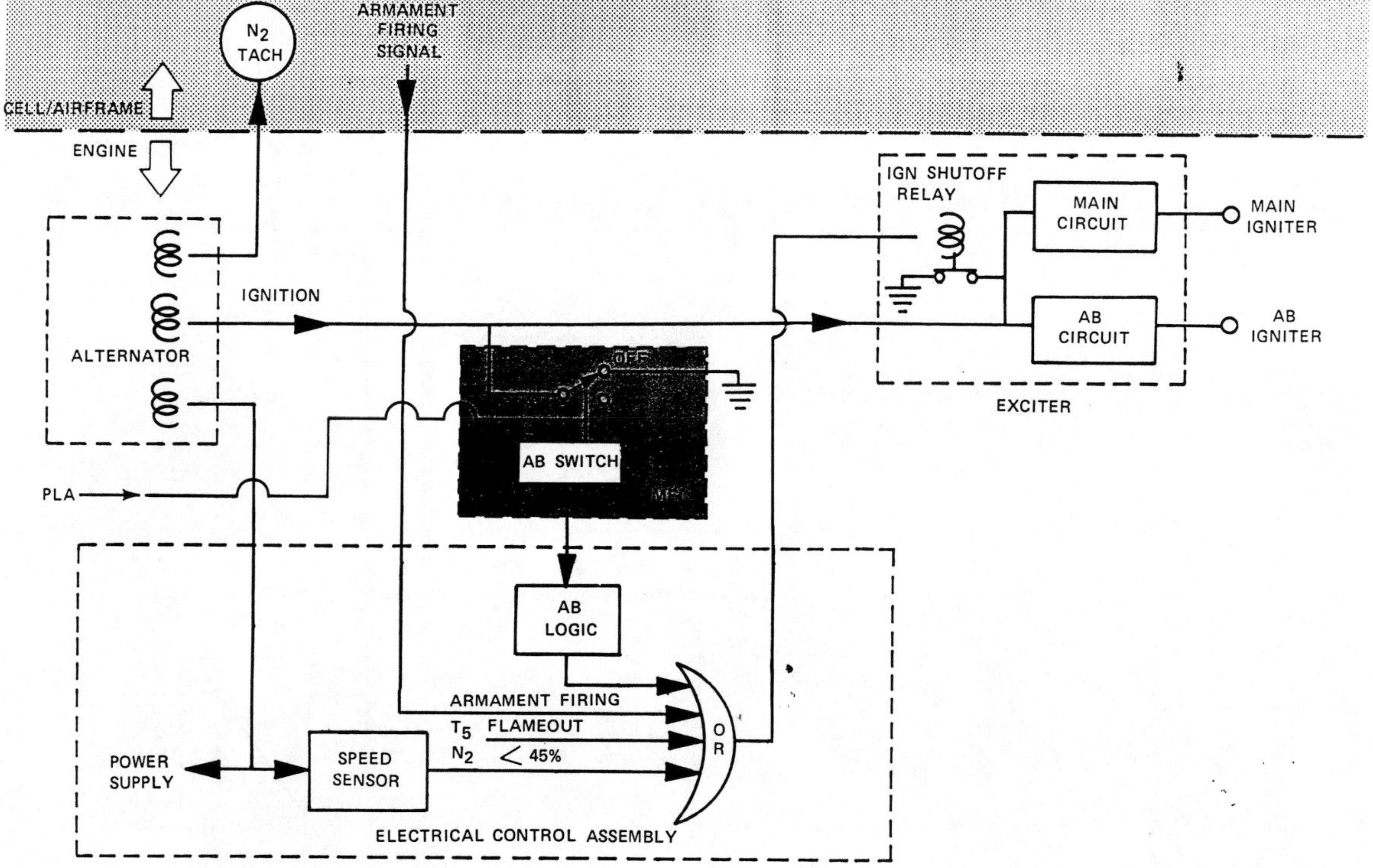
ELECTRICAL CONTROL ASSEMBLY

Figure 6-3



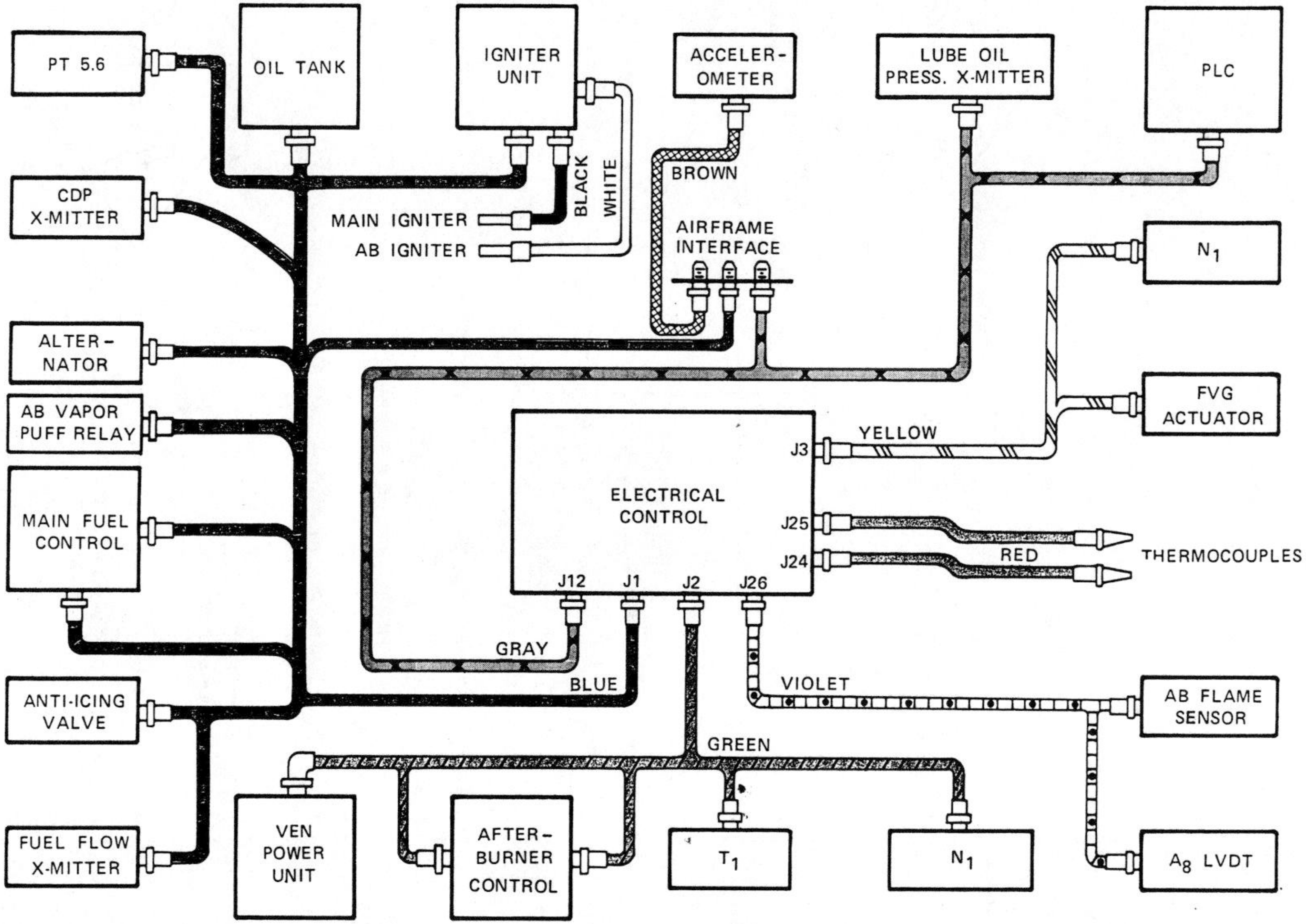
MAIN AND AB IGNITERS

Figure 6-4



IGNITION SYSTEM

Figure 6-5



ELECTRICAL COMPONENTS AND CABLING

Figure 6-6

SECTION 7

ENGINE CONTROL SYSTEM

A. GENERAL (See Figure 7-1 through 7-12)

The F404-GE-400 engine control is an integrated electro-hydromechanical system that provides automatic engine operation throughout its operating range from shut off to maximum afterburner by means of a single power lever.

The control system schedules high pressure compressor rotor speed (N2), low pressure compressor rotor speed (N1), exhaust gas temperature (T5), fan and high-pressure compressor variable geometry (FVG and CVG), variable exhaust nozzle area (VEN, A8) total afterburner fuel (WR), and main fuel flow (WF). It limits minimum and maximum HP compressor discharge pressure (Ps3), maximum fan speed (N1), maximum low pressure turbine discharge temperature (T5) and maximum core speed (N2).

Engine starting, speed governed accel and decel fuel scheduling, CVG scheduling and minimum and maximum Ps3 are completely hydromechanical functions. FVG, A8, WR, N1 and T5 scheduling and limiting of the maximum N1 and maximum T5 are combined hydro-mechanical/electrical functions.

The control system has two basic control operating modes. At part power operation the control system schedules N2 and A8. At intermediate rated power (IRP) and above, the control system schedules maximum N1 and maximum T5. The control system also modulates afterburner power above intermediate PLA. In addition to these basic control modes, minimum and maximum Ps3 limits are controlled under certain power settings and flight conditions.

For engine starting and dry power transients, the control system regulates light-off, acceleration, and deceleration fuel flow to the engine.

For engine afterburner transients, the control schedules a desired A/B light-off flow and VEN position prior to a light. When A/B light-off is detected, WR and A8 holds are released allowing rapid A/B power transients to the desired power lever angle (PLA) schedule of WR and A8. During the transient, A8 is trimmed to limit maximum T5.

For engine/airframe compatibility the control system maintains a high engine N2 speed (N2 lock-up) when the throttle is retarded at high Mach numbers, specifically to prevent airframe engine duct buzz. During armament firing, the control system resets engine N1 speed down 15-17%, resets FVG full closed, CVG closed 20°, and turns on ignition. This function is controlled by an aircraft signal and may not be required as a function of armament compatibility.

The control system provides a means of accepting an aircraft electrical throttle signal (auto throttle control) for automatic modulation of the engine thrust during approach, landing, and during constant airspeed operation.

In the event of an electrical control failure, the hydromechanical control is capable of providing part power thrust modulation with PLA.

In addition, the system is designed to prevent excessive overspeed or overtemperature for any single control system failure.

The control system contains the following major components: power lever control (PLC), main fuel control (MFC), afterburner control (ABC), electrical control assembly (ECA), CVG and FVG actuators, VEN power unit (VPU), main and afterburner pumps, alternator, ignition exciter, HP compressor and fan inlet temperature sensors (T1 and T2.5), T5 sensor (T/C Harness), two fan speed sensors (N1) and an A/B flame sensor.

The PLC is a fuel operated high response power servo system which positions the MFC PLA by accepting either an A/C manual mechanical input (throttle) or electrical input (non-pilot input). Operating in the non-pilot input mode, is activated by an A/C signal to the PLC. An override feature allows the pilot to override the electrical input in the event of an emergency.

The MFC is a basic N2 speed droop type hydromechanical fuel control with an electrical override for maximum N1 limiting. The T2.5 sensor is a high response gas-filled sensor utilizing pressure changes to operate a servo input to the MFC.

The ABC schedules AB main and pilot burner fuel flow in response to an electrical input (WR/Ps3 demand) signal and Ps3. The AB pump is a vapor core centrifugal pump which provides a very high turndown ratio (maximum to minimum flow ratio) capability.

The ECA is an integrated modular electrical control which is engine mounted, fuel cooled, and engine/alternator powered. The ECA accepts various engine signals and computes the engine schedules and limits which are transmitted to the MFC, ABC, VEN hydraulic pump and FVG servo for control of the required engine parameters.

The VEN actuation system contains a gearbox driven, variable hydraulic pump with self-contained oil reservoir unit, a linear variable differential transformer (LVDT) feedback and three synchronized actuators which are scheduled by an electrical input signal (A8 demand) to the hydraulic pump. The pump can produce full demand flow at maximum load in either direction.

The main fuel pump is a gearbox driven unit containing one inlet and three pumping elements on a single shaft. The first element is a low pressure total flow inducer designed for high volume ratio performance. The second element is an intermediate pressure centrifugal type total flow element which supplies AB fuel and ECA cooling flow. The third, and main pumping element is a positive displacement high pressure vane element which supplies flow to the MFC.

The flame sensor consists of an ultraviolet sensitive gas filled tube and associated electronics. The gas ionizes in the presence of ultraviolet light from the pilot flame and generates an electrical signal. This electrical signal, corresponding to a pilot burner light/no-light, properly initiates and sequences AB operation.

The ignition exciter is an engine power device which uses an undirectional discharge characteristic with different plug energies at the main and AB outputs. Both outputs are turned on and off simultaneously with one input from the electrical control assembly.

The engine inlet temperature (T1) sensor is a conventional platinum resistance thermal device (RTD) mounted on the engine front frame. Its output signal is transmitted to the electrical control to generate maximum T5, maximum N1, FVG and WR schedules.

The FVG actuator is a fuel operated actuator containing a torque motor servo and an LVDT feedback to control the fan variable geometry. The servo receives an electrical signal from the ECA to position the actuator. The LVDT generates an electrical FVG position signal which is used for closing the control loop.

The thermocouple harness consists of two identical halves containing a total of eight single junction probes, equally spaced circumferentially with alternate immersions of 20% and 70%. The thermocouple signal is transmitted to the electrical control for maximum engine temperature control and transmitted unmodified for aircraft cockpit indication.

The N1 sensors are eddy current devices mounted on the fan casing which induce eddy currents on the 2nd stage fan blades. The interruption of these eddy currents by moving blades provides an AC voltage whose frequency is proportional to fan rotor speed. The two sensor signals are transmitted to the electrical control which discriminates out any false low signal. The remaining high signal is used for maximum N1 limit control and for a N1 overspeed trip.

The alternator is a gearbox mounted high speed generator (26,740 rpm at 100% N2 speed), consisting of a rotor and stator. The stator has three separate windings which provide electrical power to the ignition exciter, electrical power to the ECA, and a compressor rotor speed (N2) signal to the cockpit. The alternator rotor is assembled to a gearbox output shaft and the stator is bolted to a gearbox pad.

B. CONTROL OPERATING MODES (See Figure 7-2)

1. Starting

Starting the engine is initiated by energizing the starting system and placing the power lever angle (PLA) in the ground idle position (18°) at 15% compressor speed (N2). The main fuel control automatically controls starting flow (430 ± 10 pph) and the electrical system provides ignition. Ignition is available when the PLA is advanced beyond 11° and N2 exceeds 10%. As the engine speed increases the main fuel control automatically schedules acceleration fuel flow, the starter will drop off line at 52% (N2) and ignition will be turned off at 45% (N2), where upon the main fuel control droop governor takes control and governs N2 speed at ground idle. If the PLA is set at a position higher than ground idle (18°+), the main fuel control will automatically accelerate the engine to the speed setting requested. During this entire sequence the fan rotor is free to float and assumes a speed (N1) relative to compressor engine airflow.

Ground idle speed and acceleration fuel flow is automatically and continuously adjusted for compressor inlet temperature (T2.5) by the main fuel control. Compressor inlet temperature is sensed by the T2.5 temperature sensor and fed directly to the main fuel control.

In order to minimize ground idle thrust the PLA also schedules the engine variable exhaust nozzle to an area of approximately 480 in^2 or 75% A8. The A8 position schedule is set by a two-dimensional cam located within the main fuel control and directly connected to the power lever shaft. An A8 position demand signal, from the PLA, LVDT in the MFC, is sent to the electrical control assembly (ECA) which feeds a signal to the VEN hydraulic power unit to demand the A8 position. Once A8 reaches the desired position the VEN (A8) LVDT feeds the position information back to the ECA to close the loop.

2. Flight Idle

Advancing the power lever (PLA) to the flight idle position (31°), from GI, resets main fuel control acceleration and governing control. The main fuel control also begins to control the compressor stator variable geometry (CVG). At higher altitudes, approximately 40,000 ft., a minimum Ps3 function begins to override the governor and establishes flight idle speeds (N2) slightly higher than the governing speed normally established by PLA. This provides engine blowout protection which could otherwise occur at low main combustor flows.

3. Part Power Up to Intermediate Rated Power (IRP)

Advancing the power lever (PLA) into the part power range (flight idle to IRP) continues main fuel control speed governing of the engine with CVG, FVG, and A8 (exhaust nozzle area) scheduled to provide optimum engine performance in this range of operation. The main fuel control droop governor slope provides engine stability, A8 is scheduled to obtain minimum SFC (specific fuel consumption) at cruise and loiter, FVG and CVG are scheduled to provide an optimum tradeoff between stall margin and SFC, and a linear relationship is established between PLA and engine thrust. Transient operation in this range provides good response to small PLA movements due to the MFC droop type governor control. In addition a deceleration schedule is provided to prevent main engine blowouts on throttle chops. Temperature and altitude corrections continue to bias MFC action as required.

4. Intermediate Rated Power (IRP) Operation

As the power lever (PLA) is advanced to IRP and above (102° and above), the main fuel control is overridden by the electrical control assembly via torque motor control of the MFC main metering valve position. Fan speed (N1) is controlled at its optimum level and is controlled isochronously by the electrical control assembly using a signal from the N1 sensors. At the same time exhaust gas temperature (T5) is controlled to its optimum level by modulation of the A8 (exhaust nozzle) area by the electrical control assembly.

The schedule is controlled as a function of engine inlet temperature and biased by altitude. Isochronous governing control of N1, integral T5 control, and accuracy are established and controlled by the electrical control assembly.

5. Afterburner Operation

As the power lever (PLA) is advanced further (above 102°), it enters the range of afterburner operation (106.5° to 130° PLA). All afterburner operation is controlled by the electrical control assembly providing command signals to the afterburner control metering valve torque motor.

The afterburner control has been supplied servo flow from the main fuel control, and A/B fuel flow from the second (intermediate) stage of the main fuel pump. As the power lever (PLA) is advanced to 106.5° the main fuel control provides an "ON" signal (AB permission) to the afterburner control which initiates fuel flow to the afterburner pump at a fixed 5.5 WR/Ps3 ratio units. At this same moment, the electrical control assembly provides ignition and holds the afterburner control at 5.5 units and A8 (exhaust nozzle area) at a pre-open position until a light occurs. The T5 reference schedule is temporarily reset to a lower value during the nozzle pre-open position to minimize the hardness of AB lights. At altitude this function is eliminated in favor of keeping T5 high for improved AB light off. During a rapid throttle advance from below intermediate to max A/B, the A/B vapor puff system is activated to withhold A/B fuel initiation until fan speed (N1) is within 3% of the scheduled fan speed vs T1, (N1 reference schedule). These conditions are maintained until an A/B flame is detected. After the electrical control receives a light-off signal from the flame sensor, it turns off ignition and releases its hold on main A/B fuel flow and A8, and schedules afterburner fuel flow with A8 until the steady state afterburner demand point, established by PLA, is reached. The electrical control assembly then generates a WR/P3 demand signal and schedules steady state afterburner fuel flow as a function of T1 and PLA, and modifies A8 nozzle area to maintain the T5 limit.

6. Miscellaneous System Operations

The control system also provides several other controlling functions to assist engine/aircraft operation:

1. Speed (N2) lock-up

At high aircraft speeds a Mach number signal activates the N2 lock-up solinoid in the MFC to hold N2 speed at a scheduled high level to prevent air inlet buzz from occurring due to low engine speed and high aircraft Mach number.

2. Aircraft bleed

During aircraft bleed operation (PBL) the main fuel control Ps3 function is biased to provide enrichment to the acceleration schedule to prevent slow accelerations or speed hang-ups during aircraft bleed.

3. Max Ps3 bias operation

At high Ps3 levels the main fuel control limits max governing fuel flow to protect the combustor casing structural integrity.

4. Armament firing protection

During armament firing the engine could be subjected to rocket gas ingestion (RGI). To prevent possible uncontrolled power loss the control system resets fan variable geometry to the full closed position, compressor variable geometry to a 20° more closed position, resets fan speed down 15-17%, and turns on the ignition.

5. Failure protection

The control system also provides several failure protection limitations as noted below:

N2 overspeed

a. WF/Ps3 cam cutback at high and low speeds (MFC).
b. N2 overspeed trip when N2 reaches 106% (MFC).

N1 overspeed

a. Redundant speed sensors.
b. A8 close at 105% N1 (ECA).
c. N1 overspeed trip at 114% N1.

Loss of T2.5 sensor

a. All acceleration, N2 governor, and CVG schedules revert to sea level static schedules.
b. Ground idle RPM reset to approximately 72% N2 (normally 63-66%).

T1 sensor failure

a. N1 and T5 schedules shift to -40°F schedule.

N1 sensor failure

a. Exhaust nozzle (A8) goes to minimum area.
b. WF/Ps3 goes to 20 ratio unit electrical floor.

FVG demand signal fails open

a. FVG will close.

A8 feedback fails open

a. A8 goes to minimum area (cockpit indication is 100% A8 area).

Afterburner metering valve stuck open

a. A8 goes to max area.
b. Afterburner fuel WR to off.

Electrical power loss

a. A8 closes.
b. Afterburner fuel to off.
c. FVG close.
d. WF/Ps3 to 20 ratio unit electrical floor.

A8, or ABC torque motor, or A8 LVDT signal loss

a. A8 to minimum area.
b. Afterburner off.

FVG torque motor signal loss

a. FVG to closed position.

FVG LVDT signal loss

a. FVG open at greater than 87% N1.
b. FVG close at less than 87% N1.

WF torque motor signal loss

a. WF/Ps3 ratio units to 20 ratio unit electrical floor.

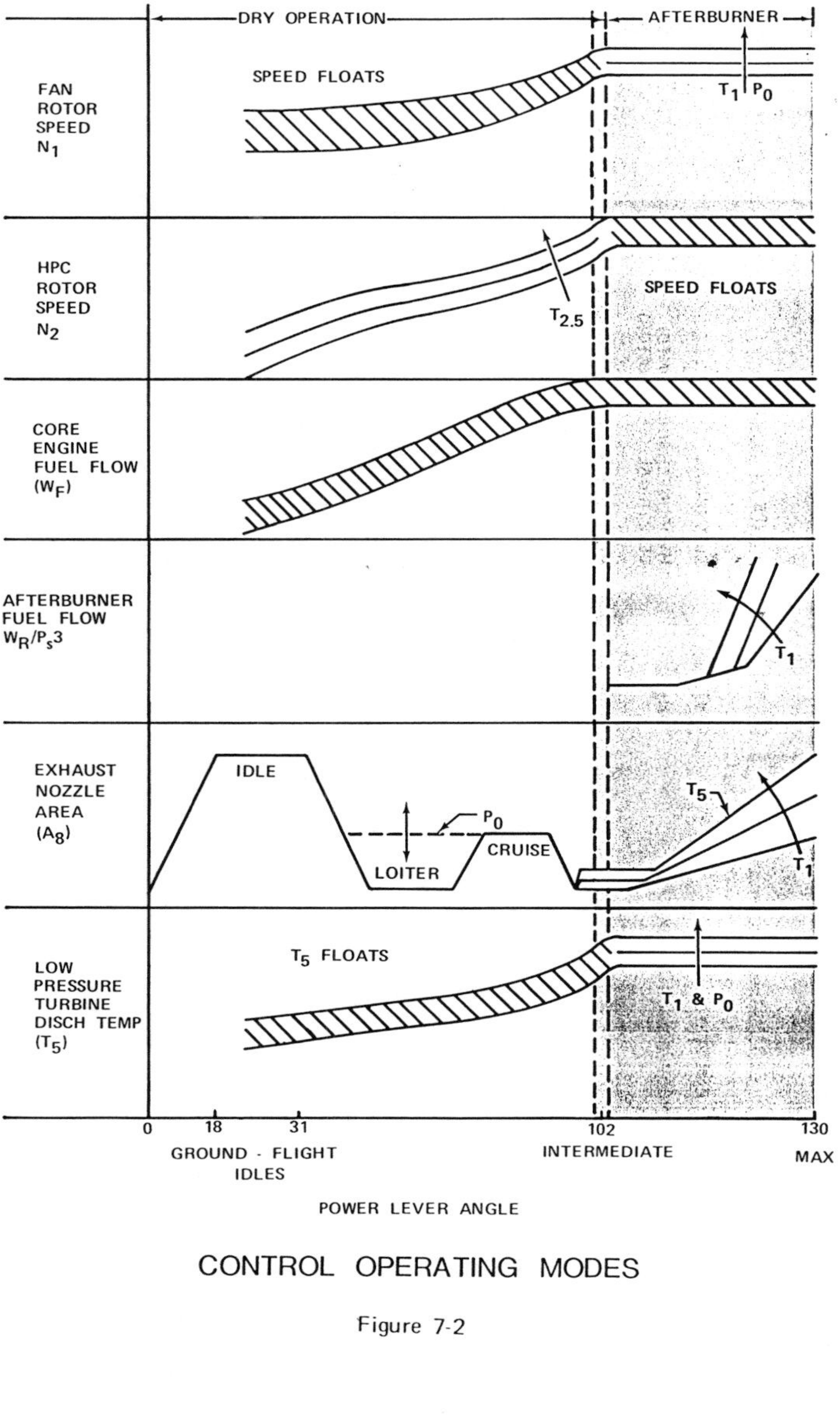
Loss of MFC A8 demand (PLA LVDT)

a. A8 to minimum area.

PARAMETER	SYMBOL	TYPE OF SENSOR
FAN SPEED	N_1	ELECTRICAL
COMPRESSOR SPEED	N_2	HYDROMECHANICAL (MFC) ELECTRICAL (ALTERNATOR)
FAN INLET TEMPERATURE	T_1	ELECTRICAL
COMPRESSOR INLET TEMPERATURE	$T_{2.5}$	HYDROMECHANICAL
FAN STATOR POSITION	B_L	ELECTRICAL
COMPRESSOR STATOR POSITION	B_H	MECHANICAL
COMPRESSOR DISCHARGE PRESSURE	P_3	HYDROMECHANICAL
TURBINE DISCHARGE TEMPERATURE	T_5	ELECTRICAL
AB FLAME SENSOR	–	ELECTRICAL
EXHAUST NOZZLE AREA	A_8	ELECTRICAL
AMBIENT PRESSURE	P_O	ELECTRICAL
N_2 LOCK-UP	M_P	ELECTRICAL
ARMAMENT FIRING	–	ELECTRICAL
CUSTOMER BLEED THROAT PRESSURE	PBL	HYDROMECHANICAL

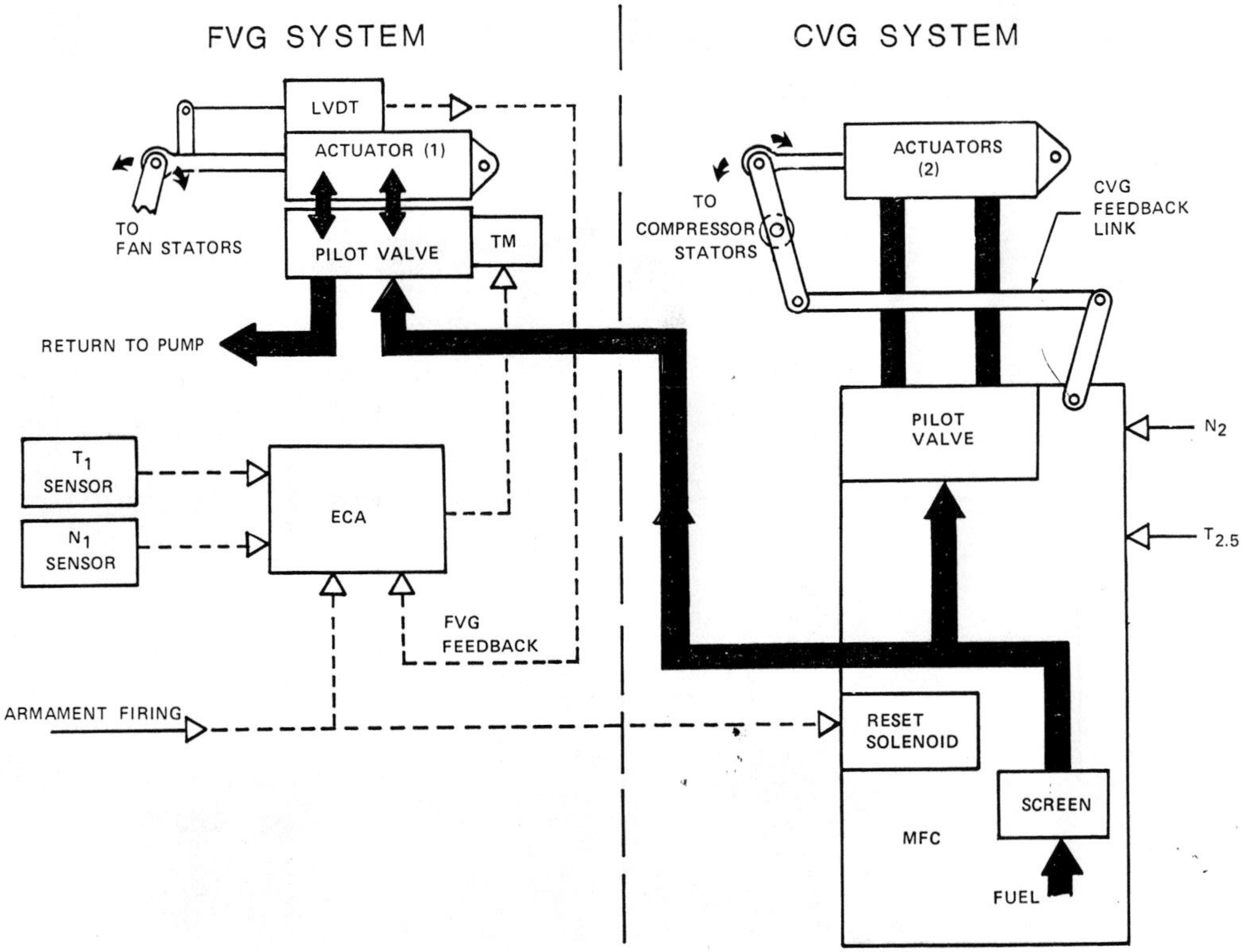
SENSORS

Figure 7-1



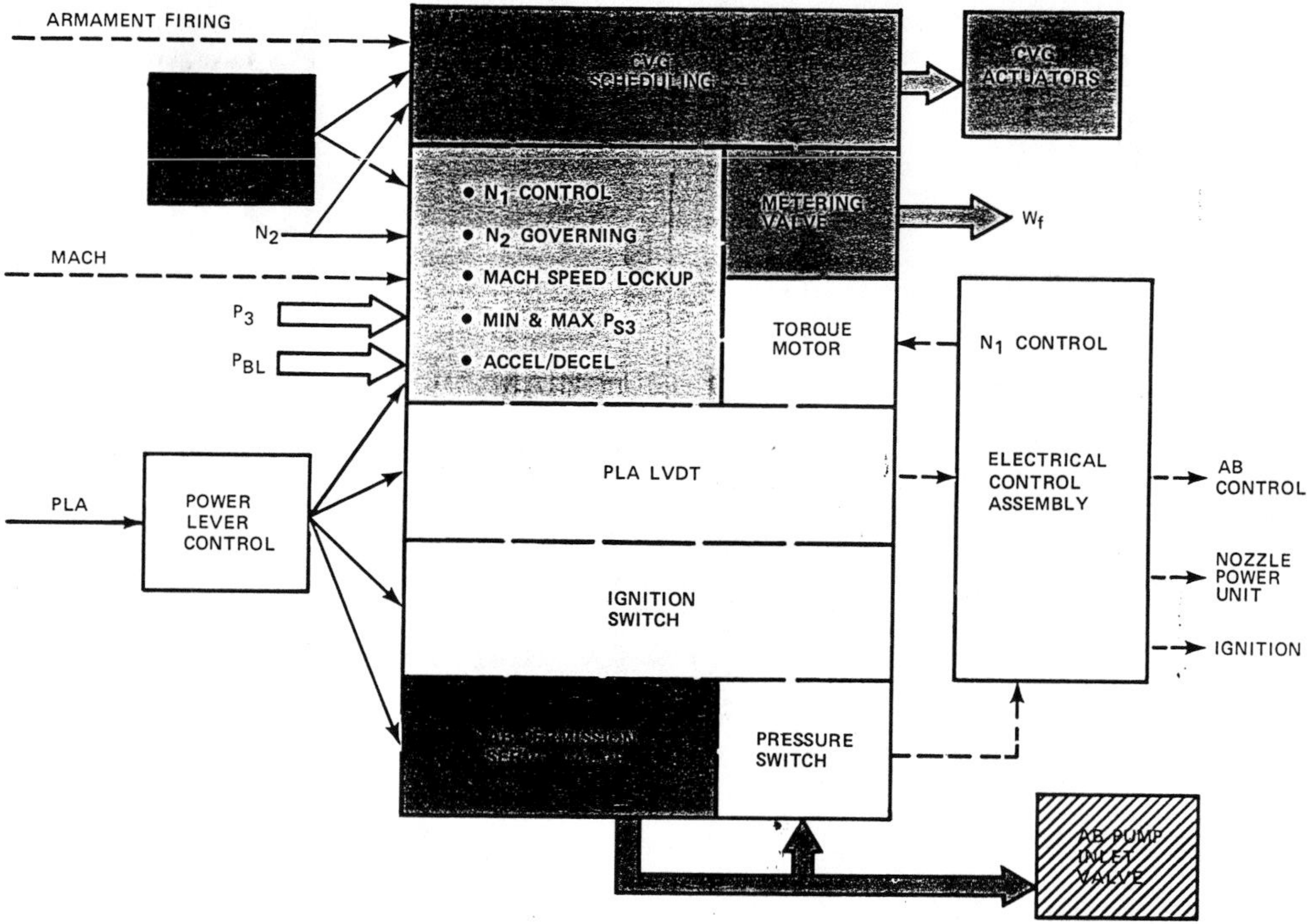
CONTROL OPERATING MODES

Figure 7-2



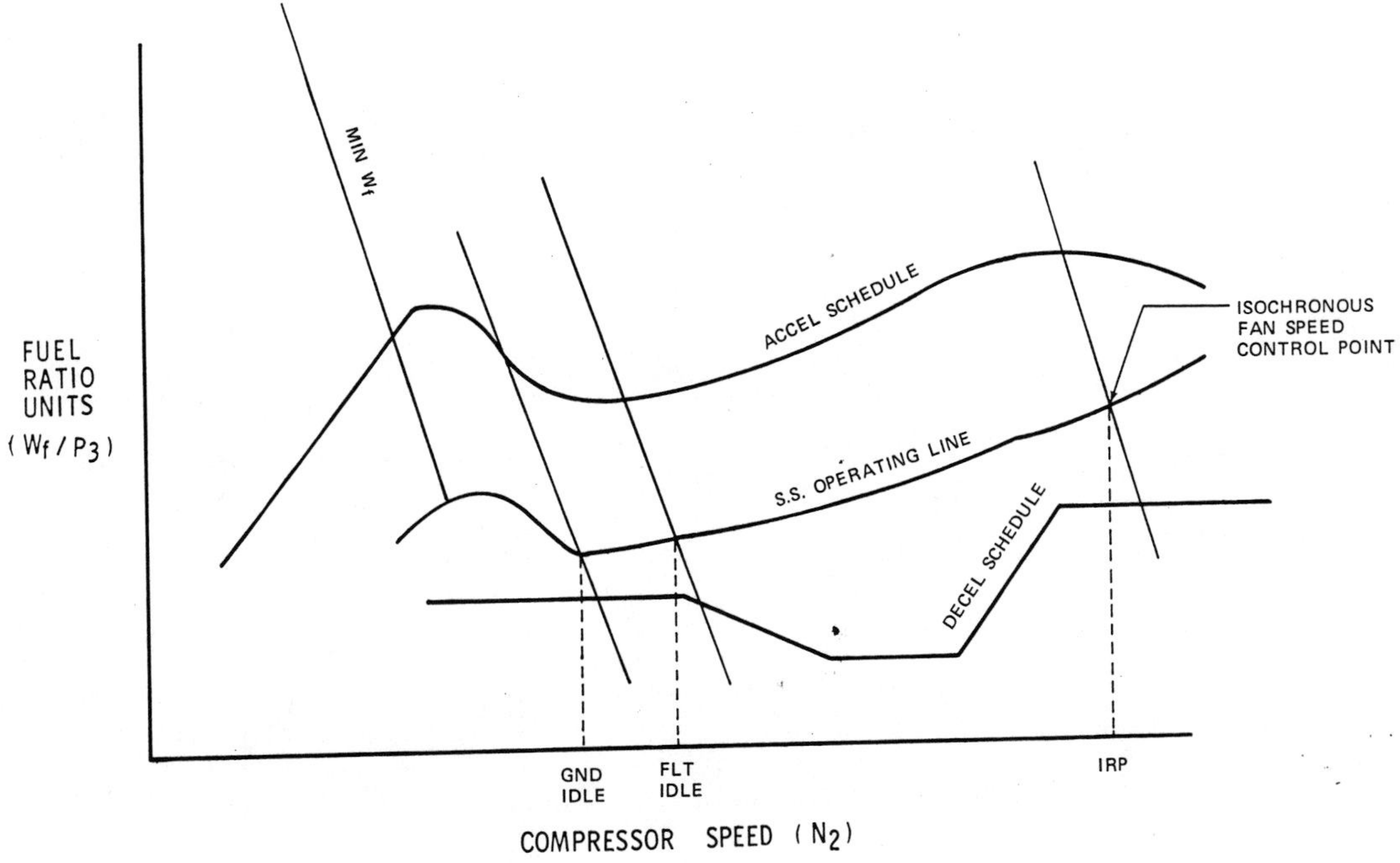
VARIABLE GEOMETRY SYSTEMS

Figure 7-3



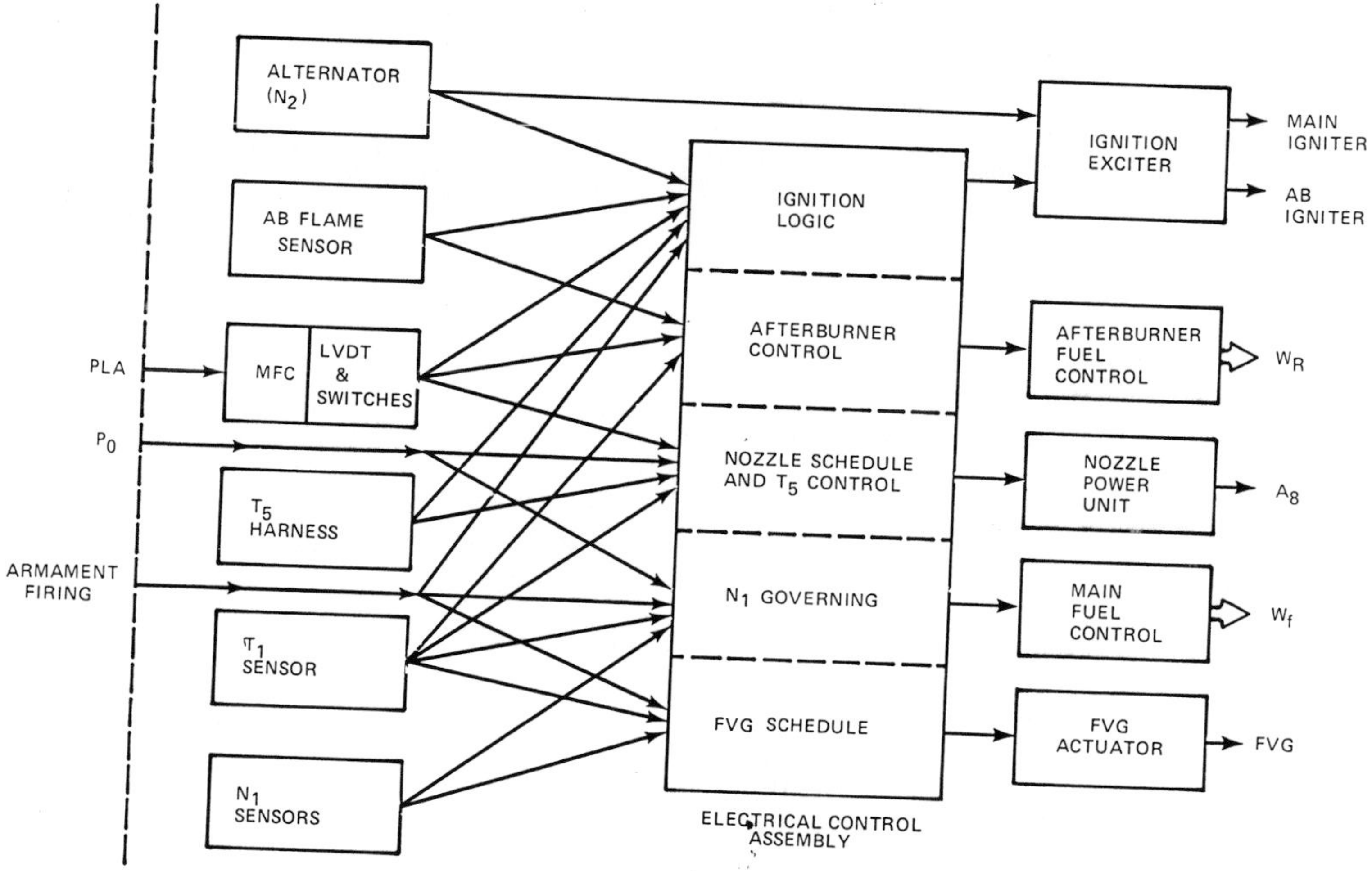
MAIN FUEL CONTROL

Figure 7-4



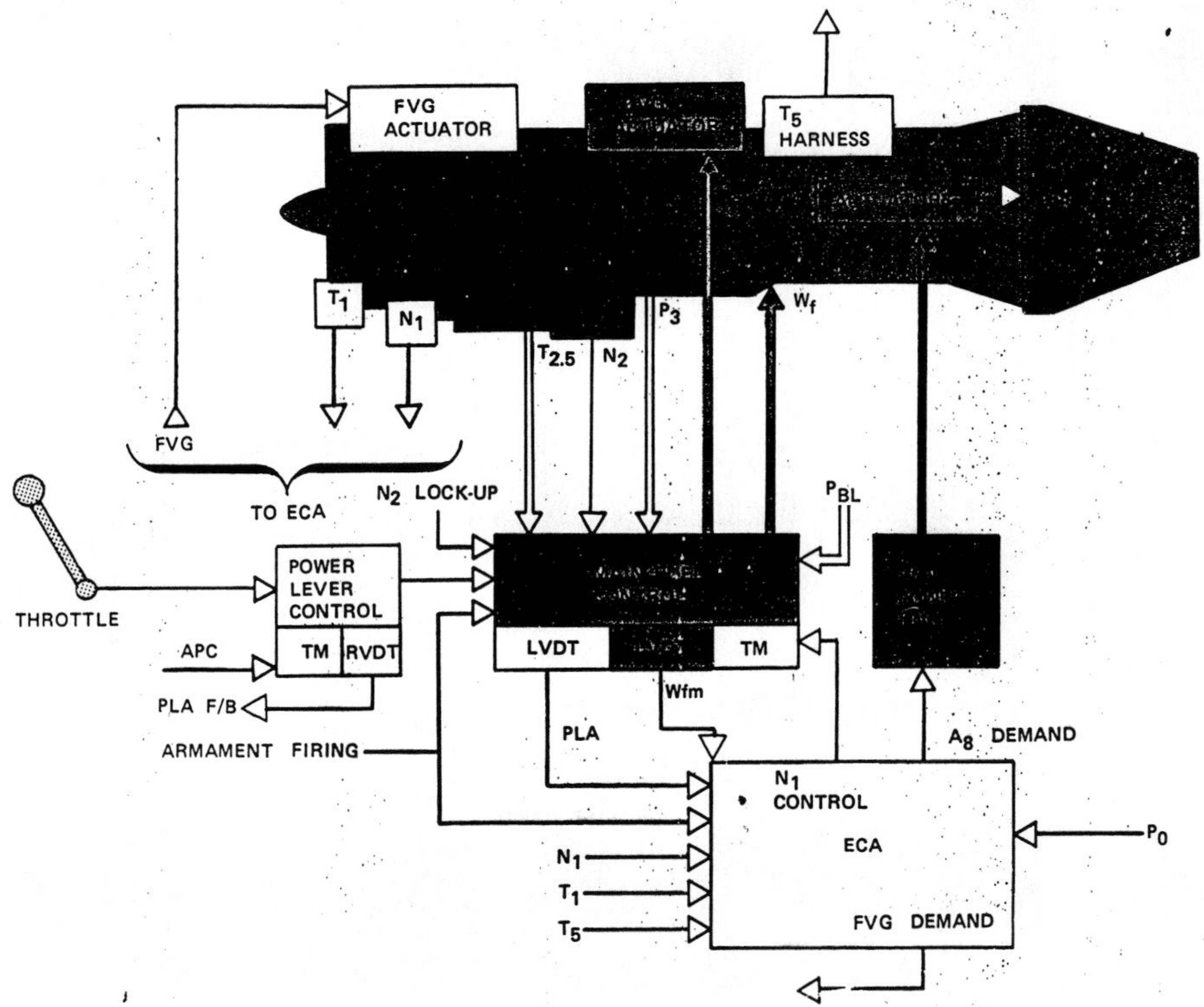
F404 OPERATING CURVE

Figure 7-5



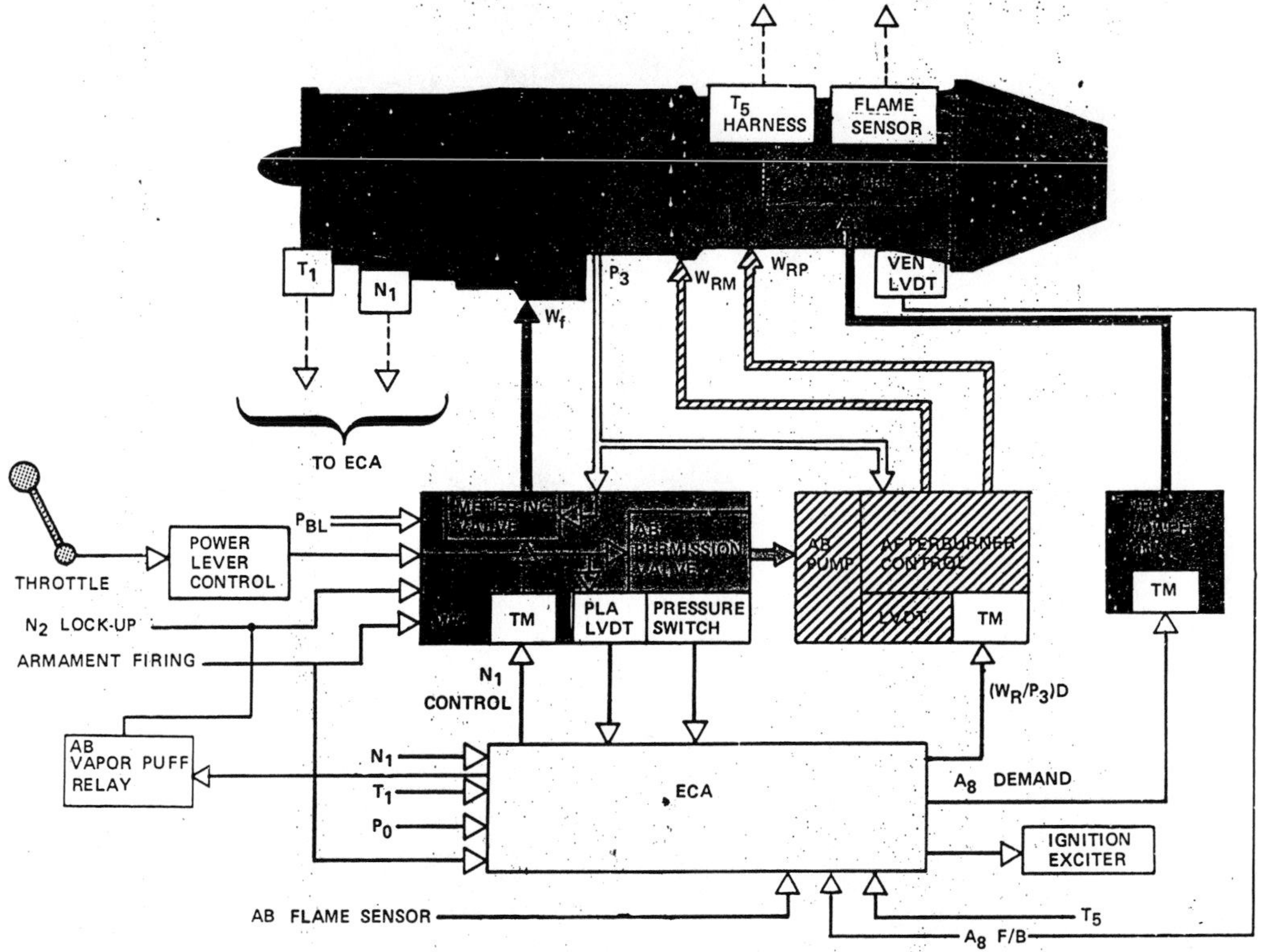
ELECTRICAL CONTROL

Figure 7-6



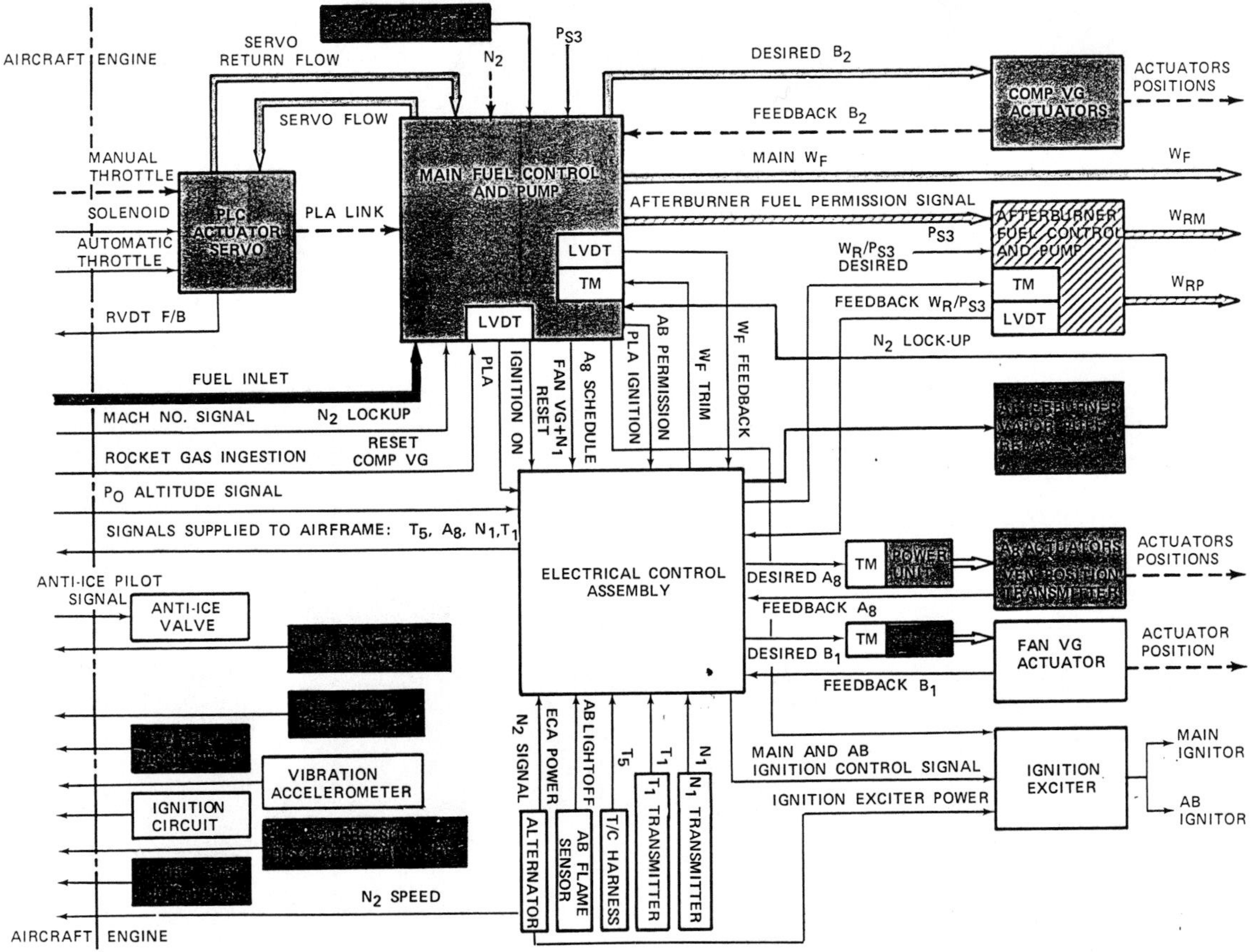
ENGINE CONTROL SYSTEM
(DRY OPERATION)

Figure 7-7



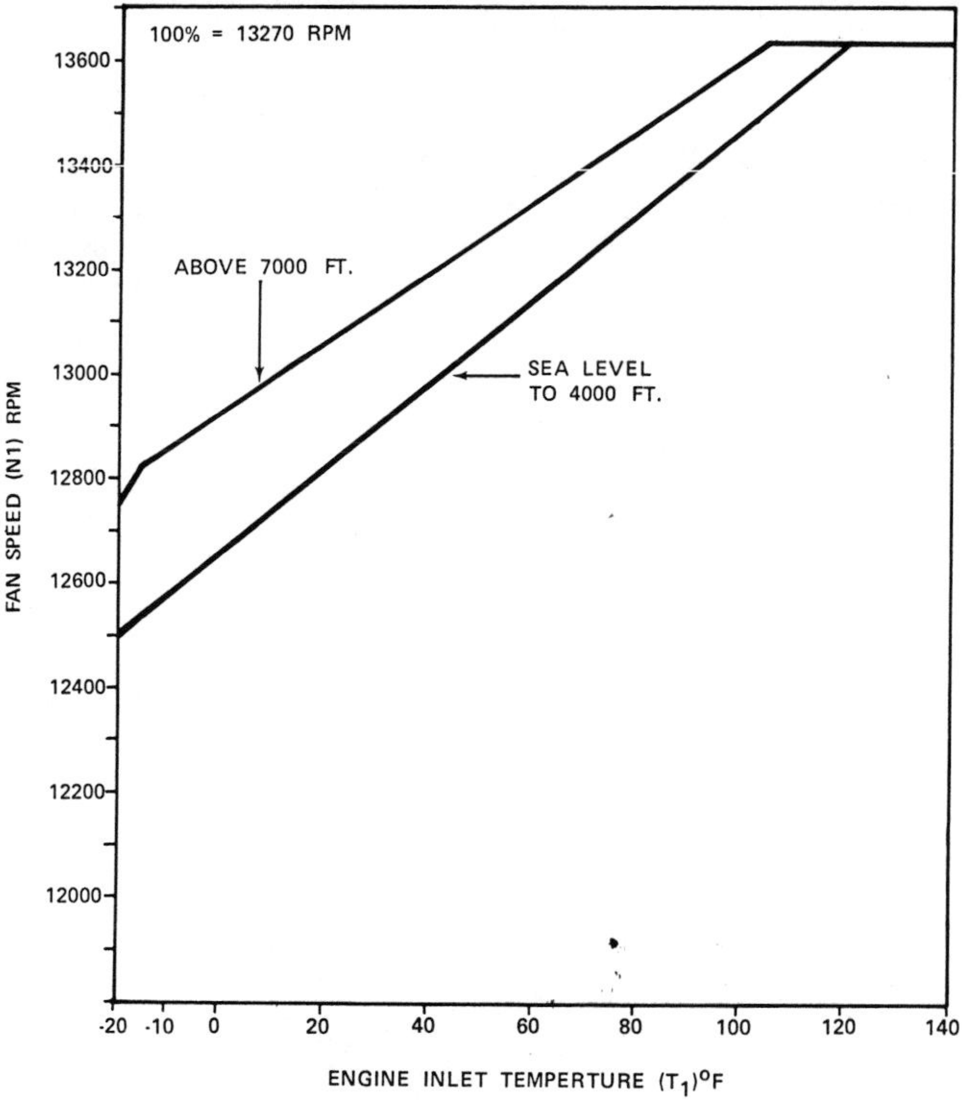
ENGINE CONTROL SYSTEM
(AFTERBURNER OPERATION)

Figure 7-8



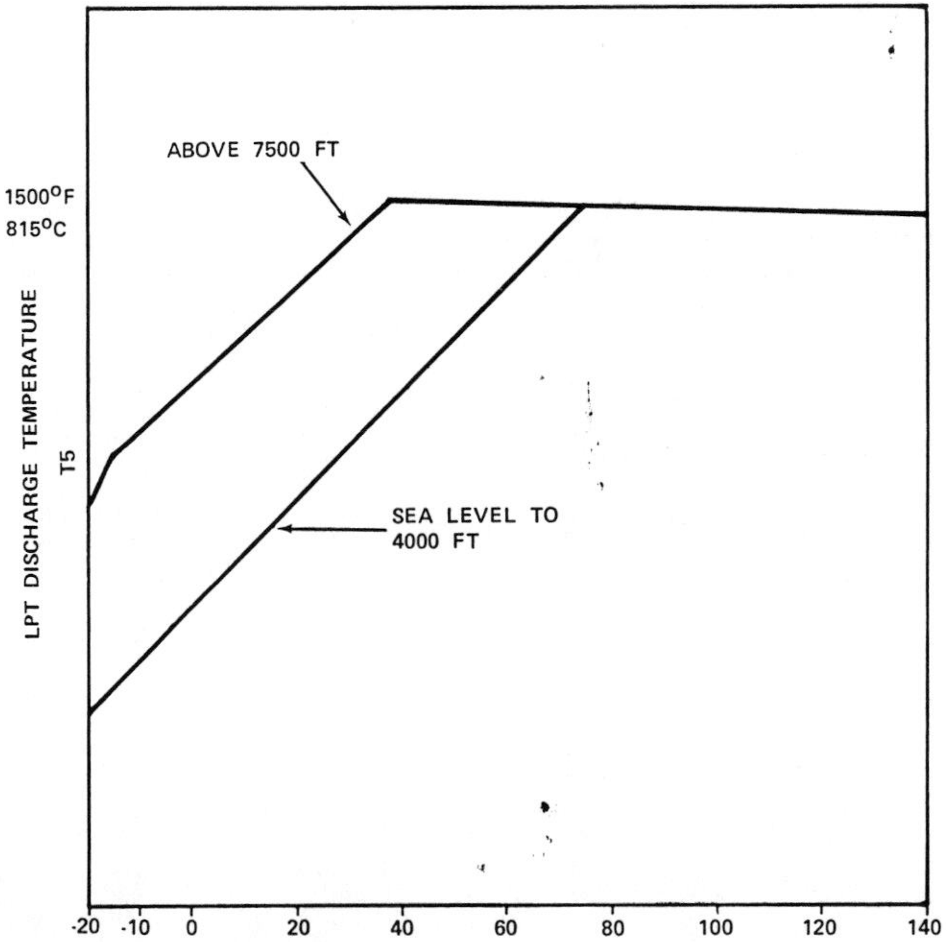
CONTROL SYSTEM INTERFACE

Figure 7-9



N_1 REFERENCE SCHEDULE

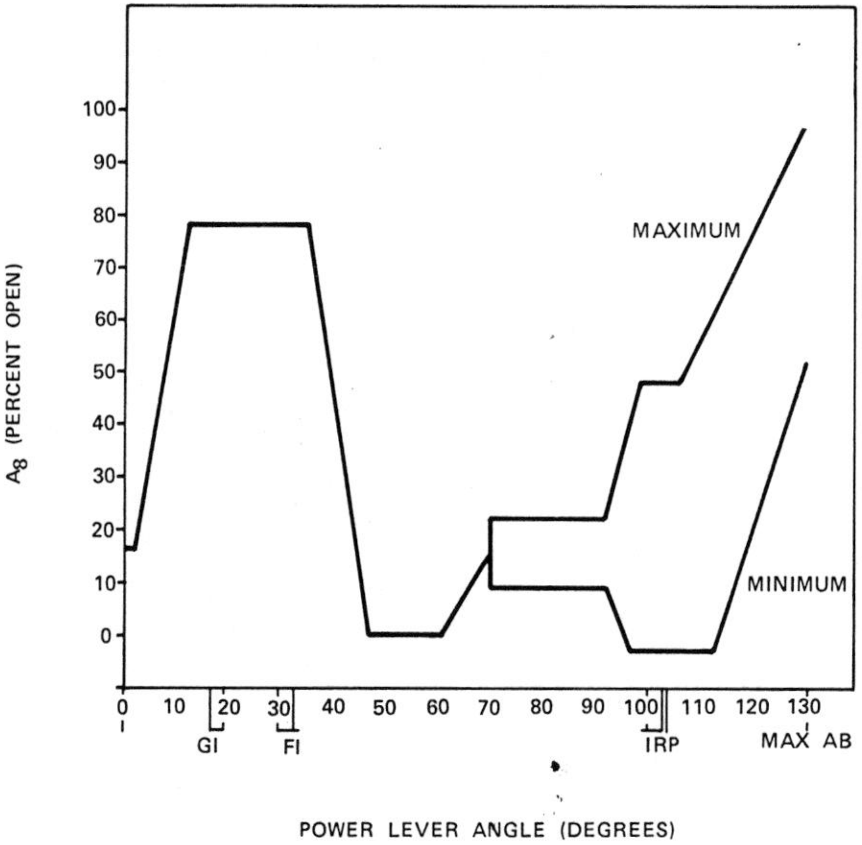
Figure 7-10



ENGINE INLET TEMPERATURE (T_I)° F

T_5 REFERENCE SCHEDULE

Figure 7-11



VEN A_8 VS PLA SCHEDULE

Figure 7-12