# SECTION V

# ENGINES

Section V ENGINES

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# Chapter 1

# ENGINE GENERAL

(Figures 5-1 thru 5-5)

## Design Features

The TF33-P-7A power plant has a sixteen-stage axial-flow split compressor; an eight-can, can-annular combustion chamber; and a four-stage axial-flow type turbine. There are two accessory cases on the engine.

## Engine Sections

The engine is divided into five operating sections: Compressor (including the fan section), diffuser section, combustion section, turbine exhaust, and accessory drive sections.

## Compressor Section

The compressor section supplies air for combustion, internal engine cooling, and operation of the aircraft pneumatic systems.

The engine has a sixteen-stage, axial-flow split compressor. The air in an axial-flow compressor normally continues through the engine without rotating more than 180 degrees.

The axial-flow compressor has alternate rows of rotating blades and stationary vanes. The rotating (rotor) blades are attached to the compressor shaft. The stationary (stator) vanes are attached to the compressor housing. Each rotor blade compresses and pushes the air through the stator vanes. The stator further compresses the air and directs it to the next rotor blade. The combination of one stator vane and one rotor blade is one stage of compression.

The front compressor ($N_1$) consists of nine stages of compression. The first two stages of the front compressor have larger blades than the other stages. These two make up the fan.

The fan is part of the relatively slow-turning front compressor, allowing the fan blades to rotate at the most efficient speed. The outer portion of the fan air is ducted around the engine and exits in a duct surrounding the exhaust nozzle.

The rear or high speed compressor ($N_2$) consists of 7 stages of compression.

## Diffuser Section

The diffuser section, which is secured to the rear flange of the compressor rear case, adapts the air for entry into the combustion chambers. The diffuser section also provides ports for extracting bleed air for use in the bleed air system and in the engine systems.

## Combustion Section

The combustion section is composed of an inner combustion liner, a split outer combustion case, and eight burner cans arranged in an annular pattern inside the outer combustion case. The burner cans are located between the inner combustion liner and outer combustion case. They are numbered one through eight in a clockwise direction as viewed from the rear of the engine starting from the 1 o'clock position.

The burner cans are interconnected by means of crossover tubes. As the spark igniters start the flame in the No. 4 and 5 cans, the crossover tubes carry the flame to the other cans.

A fuel drain is located on the bottom rear of the outer combustion chamber case to drain unburned fuel on engine shutdown.

## Turbine Section

The turbine section contains a four-stage turbine having a set of nozzle guide vanes located ahead of each turbine rotor, a turbine nozzle case and a turbine exhaust case. The first-stage rotor is the high-speed turbine, which drives the $N_2$ high-pressure compressor. The second, third and fourth stages of the rotor are the low-speed turbine, which drives the $N_1$ low-pressure compressor.

## Accessory Sections

The main accessory section gearbox is mounted beneath and secured to the diffuser section. The gearbox is driven by the $N_2$ compressor through a gear train.

Mounted to the accessory section are the:

- Main oil pump
- Engine fuel control
- Engine-driven fuel pump
- CSD
- Starter
- Aircraft hydraulic pump
- Rotary breather
- $N_2$ tachometer generator
- Oil filter
- Thrust reverser hydraulic pump

The front accessory section is located at the front of the $N_1$ compressor and is covered by the nose dome. The $N_1$ tachometer generator and a scavenge pump for the front bearing are mounted on the front accessory section.

# Chapter 2

# ENGINE BLEED AIR SYSTEM

(Figures 5-6 thru 5-16)

## Introduction

Each engine incorporates an engine bleed system which supplies pressurized air for various pneumatically powered systems on the engine and in the aircraft. Each engine has 16 stages of compression with a 16 to 1 pressure ratio. Compressed air is bled from the inner and outer diameter after the 16th stage. Venturies in the bleed struts limit the inner diameter air bleed to a maximum of 4.6% of the air available. The outer diameter air is limited by duct venturies prior to system components.

At sea level on a standard day, and with the engines operating at TRT, each engine can deliver 200 ppm of bleed air at 220 psig and 420°C. This combined bleed air is sufficient to supply the needs of all the pneumatically operated equipment. However, if the engines are running at less than takeoff power, the pressure, temperature, and amount of bleed air are decreased proportionally. At ground idle, for example, the delivered bleed air is about 40 ppm at 15 psig and 88°C. Each subsystem is completely independent of the other three, and each supplies air for specific functions.

1. High Pressure ID Bleed System
2. High Pressure OD Bleed System
3. Compressor Surge Bleed System
4. Fan Duct Bleed System

## High Press ID Bleed System

The function of this system is to supply high pressure heated air for the systems and functions listed below:

1. Environmental System
2. Wing Anti-Icing System
3. Windshield Rain Removal System
4. Engine Starting System
5. Fan Duct Seal Pressurization

ID Air is supplied from:

Two bleed air ports on each side of the engine that manifold together and connect to a collector assembly. A check valve is installed between the collector assembly and each side of the two manifolds from the bleed ports to prevent backflow into the engine. The air then flows through the bleed air shutoff valve into the crosswing manifold which supplies the aircraft systems requiring pneumatic air. The only system on the engine requiring air from the crosswing manifold is the engine ground starting system.

High Pressure OD Bleed System

The function of this system is to provide high pressure heated air for the following functions:

1. Fan duct seal pressurization

2. CSD oil tank pressurization

3. Zone II cooling air ejectors

4. Fuel heater

5. Engine nacelle anti-icing

6. Engine anti-icing

Bleed air from this system is utilized only within each engine, and there is no provision for crossbleeding between engines. Air is taken from two points in the diffusion case just aft of the 16th stage of compression and is branched off to the different components.

One branch is taken off to supply air to the fan duct seal pressure regulator which regulates the pressure to about 24 psig. Another branch is for the CSD oil tank pressure regulator. It maintains a pressure of 7 psig in the CSD tank to prevent foaming of the oil at high altitudes. A third branch supplies air to the Zone II cooling air ejections and a fourth tap-off is for Fuel Heater operation.

Structural and component cooling within zone two is accomplished by ejecting high pressure OD bleed air through ejector ducts located on top of each engine adjacent to the pylons. As air is ejected through these ducts, a low pressure area is formed at the top of each engine which in turn draws ambient air into the zone two area through louvers in the bottom forward section of each engine cowling. This cooling air is then discharged overboard along with the OD air as it circulates upward. The zone II cooling ejectors operate from ground level through 20,000 feet and are controlled by a solenoid-operated shutoff valve which receives power from the Isolated DC bus.

The nacelle and engine anti-icing systems for each engine are referred to as running wet systems, which turn ice to water before it is allowed to accumulate. The pneumatic portions of the two systems are separate, but both are controlled electrically by one switch for each engine, located on the pilot's overhead panel. Both systems for the engines are controlled by the ice detector system when in the automatic mode of operation.

The bleed air supply for the nacelle anti-icing system is extracted from a port on the upper right side of the engine diffusion section. The air flows from the port, through a venturi, to a shutoff regulator valve. The venturi limits the maximum amount of flow that can be extracted from the port. The shutoff regulator valve is solenoid controlled but uses bleed air for operation. The pressure regulator assembly regulates the position of the valve, maintaining a downstream pressure of 17 psig. Should the regulator fail, the pressure limiter will modulate to maintain 40 psig.

The bleed air for the engine anti-icing is also extracted from a port on the diffuser section. Control of the extracted air flow is by means of an air flow regulator and a motor-operated shutoff valve. The purpose of the regulator valve is to provide sufficient air to control icing, with a minimum increase in inlet air temperature. This avoids damage to the inlet guide vanes. The regulator has an internal valve which is controlled by a bimetallic spring. After the regulator valve, the air flows to the shutoff valve. The shutoff valve is a motor-operated butterfly valve.

Compressor Surge Bleed System (Figure 5-17)

The engine compressor surge bleed system controls and operates two surge bleed valves, whose function prevents or minimizes a compressor stall or surge condition by providing an escape port for excessive compressor air. The valves, when open, permit air pressure at the twelfth stage of the engine compressor to escape into the left and right fan ducts. The valves are located on the left and right sides of the compressor intermediate case. The valve on the right side, approximately 6" in diameter, is known as the starting bleed valve. This valve is open whenever the engine is operating below 80% $N_2$ RPM, or during a sudden power reduction from high power operation.

The valve on the left side of the intermediate case is approximately 4 3/4" in diameter and is known as the deceleration bleed valve. This valve opens only when the engine power is suddenly reduced. This valve is controlled and operated by means similar to the 6" bleed valve.

Components used in the system to operate the bleed valves are two bleed valve actuators, a pressure ratio bleed control unit, an accumulator, a 20 psi check valve, and a bleed reset control. During starting or at power settings below 80% $N_2$, 16th stage ID pressure and spring tension is used in the bleed valve actuator to keep the 6" bleed valve open. In the 4 3/4" bleed valve actuator, 16th stage pressure and spring tension keeps it closed. As the $N_2$ RPM increases above 80%, the pressure ratio unit vents shuttle valve pressure from the 6" actuator, allowing it to shift. This action ports 16th stage air to the close side of the power piston in the actuator, closing the bleed valve and preventing 12th stage air from escaping to the bifurcated duct. During slow power reduction below 80% $N_2$, the action is reversed. On rapid power reduction, 16th stage air pressure for operation is reduced. In order for the system to operate efficiently, an accumulator was installed. The accumulator stores air pressure until the Pressure Ratio unit senses a rapid pressure change, as when the power is suddenly reduced. Then air pressure from the accumulator overrides spring tension on a diaphragm in the bleed reset controller, venting the closing signal pressure for both bleed valve actuators to atmosphere. Spring tension in the pilot valve causes the ID air to be ported to the "open" side of the 6" bleed valve. Accumulator pressure is also supplied to the pilot valve in the 4 3/4" bleed valve actuator, shifting it to allow air pressure to be ported to the open side of the actuator. Accumulator pressure flows through the 20 psid check valve when accumulator pressure becomes 20 psi higher than 16th stage air. As the pressure equalizes, the reset controller causes the 4 3/4" valve to go closed.

Fan Duct Bleed System (Figures 5-7 thru 5-9)

Fan duct bleed air is used for cooling the generator, Zone I of the nacelle, and engine and CSD oil. Air for cooling the generator is extracted from the forward fan case. Air for cooling Zone I, CSD oil and engine oil is taken from the aft fan ducts.

The primary purpose of the Zone I cooling system is to maintain structural temperatures below design limits. Air is extracted from the upper areas of each fan duct and distributed within the compartment by piccolo tubes. Flow within each system is continuous as long as the engine is operating. Cooling air is then discharged overboard through louvers on the bottom aft section of the engine cowling.

# Chapter 3

# ENGINE FUEL SYSTEM

(Figures 5-18 thru 5-26)

## General

The engine fuel system provides clean, vapor-free fuel to the fuel nozzles at pressures and flow rates required to develop the correct engine power for all operating conditions. The system compensates for variations in throttle position during flight, limits the acceleration fuel flow to prevent "surging," and establishes a minimum fuel flow to prevent flameout of the engine during deceleration.

The engine fuel system consists of (1) a dual-element engine-driven pump, (2) fuel heater, (3) fuel filter, (4) fuel shutoff actuator, (5) fuel control, (6) fuel flow transmitter, (7) fuel oil cooler, (8) pressurizing and dump valve (9) fuel nozzles and pressure switches.

## Fuel Pump

After the fuel passes the engine fire manual shutoff valve, it enters the engine-driven fuel pump. The pump is a dual-element unit, mounted on the left side of the main accessory drive gearbox. The two elements are driven by a common shaft. The first stage of the pump is an impeller assembly which acts as a boost pump for the second stage. A built-in bypass valve between the first and second stages bypasses fuel directly to the second stage in the event of a first-stage malfunction.

The second stage of the engine-driven fuel pump is a positive displacement gear type pump designed to deliver a flow regardless of the pressure demand. Fuel from the impeller stage passes through the fuel heater and filter assemblies, then enters the gear stage through a second filter installed in the pump. A high-pressure relief valve relieves pump output pressure above approximately 1,050 psi.

## Fuel Pump Out Warning System

Connected across the impeller stage of the engine-driven fuel pump is a differential pressure switch. This pressure switch controls the engine PUMP OUT light on the engineer's fuel management panel. One warning light is provided for each engine. If the output of the impeller stage decreases to 10 psid, the pressure switch will illuminate the warning light.

## Fuel Deicer Heater

Fuel leaving the first stage is ported into the fuel heater through external tubing. The fuel deicing heater is mounted on the left side of the engine compressor case. The heater consists of an air chamber surrounded by a fuel jacket. Engine bleed air is circulated through the air chamber. The heat from the air is transferred to the fuel circulating in the fuel jacket. During engine operation, all of the fuel from the first stage passes through the fuel heater. Airflow through the heater is controlled by a motor-operated valve. The valve is controlled by the fuel heater switch on the engineer's fuel management panel. One switch is provided for each heater. A light above each switch illuminates when the valve opens.

## Fuel Filter

Fuel leaving the fuel heater is directed into the fuel filter. The fuel filter is located on the left side of the compressor intermediate case. Should the filter become clogged, a built-in bypass valve will bypass the fuel around the filter. During a clogged condition, differential pressure across the filter will be sensed by a differential pressure switch. If the differential pressure reaches 8 psid, the switch closes and illuminates the FIL BYPASS light on the engineer's fuel management panel. When the pressure reaches 12 psid, the bypass valve opens and the fuel flows around the filter. If the clogged condition relieves itself, the bypass valve will close and normal operation will resume.

## Fuel Control

After leaving the filter, the fuel flows into the second stage of the engine-driven fuel pump. After leaving the second stage of the pump, the fuel flows through the fuel control.

The fuel control is a fuel flow metering unit which controls engine power under all operating conditions. Control is provided in both the forward and the reverse power ranges.

The control is an engine-driven, hydro-mechanical unit located on the forward right side of the main accessory gearbox. Two levers are provided on each fuel control. The power lever (throttle lever) is used for selecting engine thrust in the range from full reverse, through idle, to takeoff. The second lever is the electrically actuated shutoff lever which controls fuel for engine starting and shutdown.

Also incorporated in the fuel control is a solenoid valve which provides fuel enrichment for cold weather starting.

The fuel control schedules fuel to the engine to (1) control steady-state rpm, (2) maintain a constant turbine inlet temperature for each position of the throttle, (3) prevent over-temperature and compressor "surging" during starting and acceleration, and (4) prevents flameout during deceleration.

The fuel control accomplishes all of this by signals from the following sensors: (1) A burner pressure sensor which reflects airflow in the combustion section of the engine, (2) an RPM sensor which monitors speed of the $N_2$ compressor, and (3) power lever angle sensor which reflects engine power requirements by throttle position.

The metered fuel leaves the fuel control through the minimum fuel shutoff valve, which is indirectly controlled by the fuel and start ignition switch. Then it flows to the fuel flow transmitter and fuel oil cooler, on its way into the engine.

## Pressurizing and Dump Valve

Fuel leaving the fuel-oil cooler flows into the fuel pressurizing and dump valve. This valve consists of a fuel inlet check valve, a self-relieving filter, a manifold dump valve and a pressurizing valve.

The fuel inlet check valve is located in the inlet port of the pressurizing and dump valve. A fuel inlet pressure of eight to ten psi is required to open the inlet check valve. The valve prevents fuel from draining overboard from the fuel-oil cooler when the engine is not operating.

The pressurizing and dump valve is divided into primary and secondary chambers. The fuel manifold feeding the fuel nozzles has primary and secondary manifolds. The primary chamber of the pressurizing and dump valve flows fuel into the primary manifold for engine starting and low power operation. As the engine is accelerated, the fuel pressure increases. At approximately 250 psid, the pressurizing valve opens, allowing fuel flow into the secondary chamber and secondary fuel manifold.

The manifold dump valve is spring-loaded open and closed by fuel pressure from the fuel control. When the engine is shut down, the dump valve opens, draining the primary and secondary fuel manifold overboard.

## Fuel Enrichment

Fuel enrichment is used with alternate grade fuel during ground engine starts with low fuel temperatures, or during air starts at high altitudes with alternate grade fuel. -18°C ON THE GROUND. AIRSTARTS ABOVE 15,000'

When the fuel enrichment switch on the pilot's overhead panel is actuated, extra fuel is added to metered fuel, in the fuel control, for easier engine starting. The system cuts off mechanically when the fuel flow reaches approximately 1,500 pounds per hour, (4,000 $N_2$ RPM), or electrically when the fuel enrichment switch is placed to off.

# Chapter 4

## AUXILIARY POWER UNIT

(Figures 5-27 thru 5-29)

The APU, located in the left wheel well, supplies air for engine starting, air for the environmental systems, and mechanically drives an AC generator, identical to the main generators, for ground operation only. The APU controls receive power from the Isolated DC Bus through circuit breakers on the flight engineer's No. 3 circuit breaker panel.

The APU is started by a hydraulic motor which receives its power from two accumulators. These accumulators are pressurized from Hydraulic System No. 3 and controlled by the APU ACCUM SEL switch which permits selection of No. 1, No. 2, or both accumulators for starting. A 10-cubic-inch surge accumulator is used in the system to absorb the initial surge of pressure, protecting the clutches in the starter adapter.

Speed of the APU is controlled by the fuel governor which regulates the fuel flow to maintain a constant speed under varying load conditions. If a malfunction occurs in the fuel governor and the speed of the APU exceeds 110 percent, a centrifugal speed switch will automatically close the fuel feed valve and shut down the APU.

The APU control switch is a three-position, OFF-START-RUN rotary switch. Placing the switch to START closes the self-holding start relay. This relay will remain closed until the circuit is opened by the centrifugal speed switch at 35 percent. When the switch is released from START, it will move to RUN by spring-action. When the switch is at RUN, all APU controls are energized and controlled by their automatic controls.

The APU door control switch is a three-position, OPEN-OFF-CLOSED switch. The doors must be fully open before the APU can be started. Automatic closing is initiated by pulling the fire control handle or by actuation of the touchdown relays. If the aircraft becomes airborne with the APU running, the APU will shut down. When the APU oil pressure drops below 3.5 psi, the doors close.

The bleed load and flow control valve switch controls the solenoid-operated bleed air valve. The switch is interlocked with a 95 percent speed switch which prevents a bleed load from being applied to the APU until it reaches operating speed. Placing the switch to OPEN will supply air to the crosswing manifold.

There are two FIRE CONTROL handles for the APU, one on the flight engineer's panel and one in the cargo compartment. When either handle is pulled, the APU shuts down, the doors close, and the corresponding fire extinguishing agent discharge switch is armed.

The indicators for the APU consist of three lights and an exhaust gas temperature (EGT) indicator. The START light illuminates to indicate that the starter is operating. The light goes OUT when the APU reaches starter cutout speed. The ON SPEED light illuminates to indicate the APU is operating at 95 percent. The door warning light illuminates to show NOT CLOSED when the APU doors are not closed.

Oil from an externally mounted oil tank is delivered through the oil pump mounted on the accessory case. A relief valve maintains desired oil pressure. Temperature is maintained by an oil cooler. An oil temperature switch automatically shuts the APU down if the temperature exceeds 120°C. A low oil pressure switch automatically shuts the APU down if the pressure drops below 55 psi while operating above 95%. A sequencing switch is actuated at approximately 3.5 psi when starting and completes the circuit to the ignition unit. During APU shutdown, the door closing circuit is completed through the switch when the oil pressure drops to approximately 3.5 psi.

The APU fuel system provides for proper flow during starting, acceleration, and ON-SPEED operation. Fuel gravity flows from the No. 2 main tank surge box. A motor-driven shutoff valve is located in the line at the tank outlet and is energized open whenever the APU control switch is in the RUN or START position. Placing the control switch OFF or pulling the APU fire control handle will close the motor-driven shutoff valve. The acceleration control valve provides the proper fuel metering for starting and acceleration to ON-SPEED RPM. The governor has no control over fuel flow until the APU is at or near ON-SPEED RPM. At this time the governor increases or decreases the fuel flow to keep the turbine speed relatively constant. A solenoid-operated shutoff valve is located in the metered fuel line and provides control of flow to the fuel nozzle during operation and shutdown. The valve is energized open and spring-loaded closed. During the starting sequence, as oil pressure increases above 3.5 psi, this valve becomes energized. Several means are available to deenergize the valve; they include:

- Placing the APU control switch to OFF
- APU overspeed of 110 percent or greater
- Low oil pressure < 55 psi
- High oil temperature > 120°C

# Chapter 5

## STARTER AND IGNITION SYSTEM

(Figures 5-30, 5-31)

Each engine is equipped with a self-contained starting system consisting of the following components:

1. Pneumatic ducting

2. Starter control valve

3. Starter

4. Ignition system

The engine starter is used while the aircraft is on the ground. Air starts are made with the engine windmilling and without the aid of the starter. The starter uses pneumatic air supplied through the crosswing manifold for operation. Any source of air that is normally supplied to the crosswing manifold may be used in the starter system. The electrical power for the starter system is supplied through the Isolated DC Bus.

### Pneumatic Ducting

The ducting is routed from the crosswing manifold, through the engine pylon, to the engine high pressure ID air manifold. Two check valves prevent air from entering the engine and allow it to be supplied to the starter system only.

### Start Control Valve

The starter control valve acts as an air pressure regulator for the starter and as an air shutoff valve when the starter is not being used. The valve regulates the air pressure for the starter to approximately 40 psi. In the event of a valve failure, a pressure relief valve incorporated within the control valve limits the maximum pressure to the starter to approximately 45 psi, when open. A switch on the valve completes an electrical circuit to a "Starter Valve Open" light on the pilots' center instrument panel. The light will remain on until the valve is closed.

### Starter

The starter has its own 11-ounce oil system for lubrication. It is independent of the engine oil system but uses the same type MIL-L-23699 oil. High pressure air, regulated by the starter control valve, enters the starter turbine, causing it to rotate. The air is then discharged into the engine nacelle. The turbine drives a starter shaft to the engine through the starter gear train and clutch assembly. When the starter reaches a predetermined speed, between 35 to 45% $N_2$ RPM, a centrifugal cutout switch on the engine side of the starter clutch will actuate, causing the starter control valve to close. The engine will continue to accelerate, and the starter turbine and gear train will slow to a stop.

At approximately 40% $N_2$ RPM, when the starter control valve closes, the starter turbine speed is about 70,000 RPM. In the event of a malfunction, resulting in turbine failure, a turbine guard ring and an exhaust screen are designed to absorb some of the energy of the metal fragments which result from turbine disintegration.

## Ignition System

The igniter exciter is a single housing unit containing the 20-joule and the 4-joule systems. The 20-joule is an intermittent duty, dual discharge system. The 4-joule is a continuous duty, single discharge system, used after engine start, when necessary. Both sections have independent circuits, requiring a power input for each section and output leads to each spark igniter. There are only two spark igniters, one located in the No. 4 combustion chamber can, the other in No. 5 combustion chamber can.

When the 20-joule is used, 28 volts DC power is supplied to the 20-joule intermittent exciter from the isolated DC bus. From there it is routed through a series of filters to eliminate radio interference during operation. From the filters, power travels to the trigger generator, which increases the voltage to approximately 2,450 volts and applies it to the trigger output circuit. There it is increased to a point where it will ionize the gap of the spark igniters.

When the continuous ignition system is placed on, 115 VAC from the No. 1 essential bus is sent to the continuous duty ignitor exciter, where it is directed through its own set of radio noise filters. From there it goes through a full wave transformer rectifier which increases the voltage slightly and converts it to DC. This increased DC voltage enters a voltage doubler which boosts the voltage to approximately 300 VDC and sends it to the trigger generator which also increases the voltage. This power is then supplied to the trigger output circuit which will ignite the spark igniter in the No. 4 combustion chamber can.

### NOTE

> The 20-joule ignition system and the 4-joule continuous ignition system share a common trigger output. To prevent damage to the trigger output circuit, do not energize both ignition systems simultaneously.

# Chapter 6

# ENGINE OIL SYSTEM

(Figures 5-32 thru 5-37)

The TF33-P-7 engine is lubricated by a high-pressure, self-contained, dry sump oil system. It provides lubrication for engine bearings, bearing seals, accessory drive shaft and accessory gear housing. Components included in the system are:

1. Oil tank
2. Oil temperature indicator
3. Pressure pump
4. Pressure relief valve
5. Oil filter
6. Oil coolers
7. Scavenge pumps and vent system

## Oil Tank

The oil tank is a steel saddle-type located on the upper forward right side of the engine and is serviced through a cowling access panel. The tank capacity is 7.8 gallons but can be serviced to only 6.0 gallons, due to the filler neck being placed in a position to prevent overservicing. This leaves approximately 1.8 gallons of total tank volume for air expansion. The tank contains internal baffles and plates to prevent the oil from sloshing, a can-type de-aerator to prevent aeration of the oil returning to the tank, and near the one-gallon usable level, a float-operated switch. If the oil quantity in the tank decreases to approximately one gallon of usable oil, the float switch will complete an electrical circuit to a "Low oil quantity" light on the flight engineer's panel.

## Oil Temperature

The oil temp bulb is located downstream of the filter in the pressure passage on the filter housing. It senses temperature of the oil going to the engine bearings and accessory drive gears. This signal is then routed to the temp indicator on the flight engineer's panel.

## Oil Pump

The pressure pump is a dual-element, positive-displacement pump located in the accessory gear housing. The two elements are the main pressure pump and a scavenge pump. The speed of the pump will vary with $N_2$ RPM. At 100% $N_2$ RPM, the pump speed is approximately 3,300 RPM, with a pressure output of about 80 psi. This pressure is regulated to prescribed limits by a pressure relief valve.

## Pressure Relief Valve

The oil pressure relief valve is a continuous bypass, pressure relief valve, located on the accessory gear housing adjacent to the oil pump. The valve will open and close to maintain desired system pressure by spring tension against a valve seat. System pressure may be adjusted by a screw which changes the amount of tension on the valve spring. When the oil pressure increases above normal, the valve will open and bypass oil back to the inlet side of the pressure pump. The oil pressure is sensed by an oil pressure transmitter and a low oil pressure switch. The oil pressure transmitter sends a signal to a pressure indicator located on the flight engineer's panel. Should the oil pressure drop below 33 psi, the low oil pressure switch will complete an electrical circuit to a "Low Oil Press" light on the pilot's center instrument panel. The light will remain on until the pressure increases to approximately 38 psi.

## Oil Filter

The main oil filter is located in the accessory housing above the oil pump. It is constructed with a series of screens between wafer disks, designed to trap contaminants and supply clean oil to the engine components. At the bottom of the oil filter housing is a spring-loaded poppet valve. Under normal operation, oil flows through the filter with enough pressure to overcome the spring tension on the poppet valve, allowing clean oil to flow to the engine bearings. Under static conditions, spring tension will close the valve and will not allow oil flow from the tank into the accessory housing, causing an overflow of oil out the housing vent.

The second valve in the oil filter housing is a bypass valve. In the event the filter becomes clogged, pressure on the inlet side becomes greater than pressure from the outlet. When this differential pressure reaches 50 psid, the bypass valve will open and a differential pressure switch will actuate and complete a circuit to the "Low Oil Pressure" light on the pilot's center instrument panel. The system pressure gage should indicate normal if the filter is clogged.

## Scavenge and Vent System

The engine oil system is a dry sump type, unlike the wet sump system because it doesn't allow the oil to pool at the bottom of the engine. The engine has 5 gear-type scavenge pumps that pick the oil up from the bearing compartments and accessory housing and send it back to the oil tank. The combined output of the 5 scavenge pumps is approximately twice the output of the pressure system. As the scavenge system picks up oil and air from the housings, the two are mixed together. This mixture of air and oil goes through the system until it gets to the can-type de-aerator in the tank, where the air is removed to the vent system. As oil is being sprayed on the bearings, some of it becomes vaporized with the air in the bearing housing. This air-oil mixture is too light to be picked up by the scavenge system, so it escapes into the vent system that collects vapor-ized oil from all the bearing housings. It then goes to the air-oil separator in the main accessory housing. The air-oil separator removes the air from the oil, venting the air overboard and leaving the oil to be picked up by the scavenge pump in the accessory housing.

## Oil Coolers

The scavenge system takes the oil from the bearing and accessory housing and sends it through two oil coolers before it is returned to the tanks.

### Air Oil Cooler

The air-oil cooler is a radiator-type, located in the right side of the engine fan discharge duct. Fan discharge air flows across the radiator to cool the oil. The cooler is equipped with a pressure relief and temperature bypass valve. If the cooler becomes clogged, the pressure relief valve is designed to open at 23 psid and allow the flow to continue. The temperature bypass valve controls the amount of oil flowing through the cooler by opening at 60°C or below so no oil flows through the cooler. As the oil temperature increases, the valve closes, sending an increasing amount of oil through the cooler until the temperature reaches approximately 77°C, when the valve closes fully, sending all oil through the cooler.

### Fuel Oil Cooler

The fuel oil cooler is located on the forward right side of the engine. It works on the same principal as the air oil cooler, with the exception that fuel is used as the cooling agent, instead of air.

It contains a pressure relief and temperature bypass valve similar to the air oil cooler. The main differences are the bypass pressure will be 40 psid should the cooler become clogged and the oil temperature must rise to 90°C before all oil passes through the cooler.

# Chapter 7

# THRUST REVERSER SYSTEM

(Figures 5-38 thru 5-49)

Each engine is equipped with an independent thrust reverser system, operated through the throttle quadrant. The system permits reverse thrust application of engine power after touchdown and during rejected takeoff.

Each thrust reverser system consists of a hydraulic pump, filter, two actuators, two doors and a mechanical linkage, a control assembly, a flow regulator, a mechanical lockout and indicator lights.

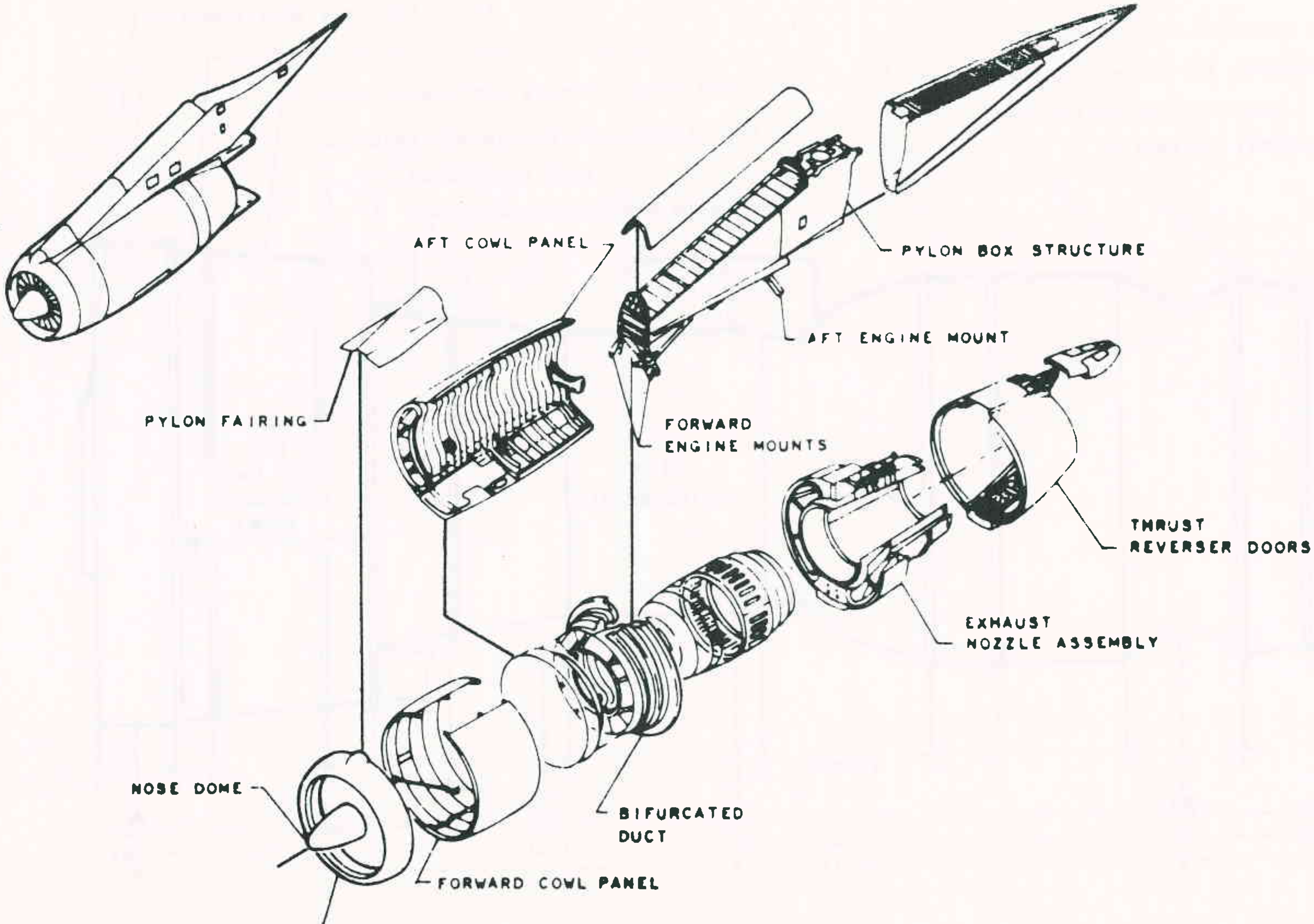
Oil for actuation of the system is taken from the CSD oil tank. The oil is circulated through the thrust reverser system, then ported through the CSD oil cooler and back to the reservoir.

A dual element engine-driven hydraulic pump provides hydraulic pressure for operation of the thrust reverser system. The pump assembly consists of a high-volume pump, a low-volume pump, an unloading valve, an unloading pilot valve and check valves. The high- and low-volume pumps are attached to a common shaft so both will operate at the same speed. Both are fixed displacement, gear-type pumping units. At idle speed, the high-volume pump will deliver approximately 5.5 gallons per minute at 2,500 psi. The low-volume pump will deliver .5 gallons per minute at 3,000 psi. The electric bypass valve permits both pump outputs to be ported to a return line when the thrust reversers are stowed and locked. This is to ensure rapid operation of the thrust reverser doors. The output of the pumps is used to cool the system while the doors are in the closed and locked position. This is a small amount of oil flow as most of the oil is being bypassed thru the electric bypass valve. The control assembly determines the system pressure and direction of flow for thrust reverser door operation.

Two hydraulic actuators are used to supply the force and motion necessary to retract and extend the target-type thrust reverser doors. The actuators are located at the top and bottom on the aft end of the nacelle. The actuators operate both doors, and are connected to a common oil pressure source.

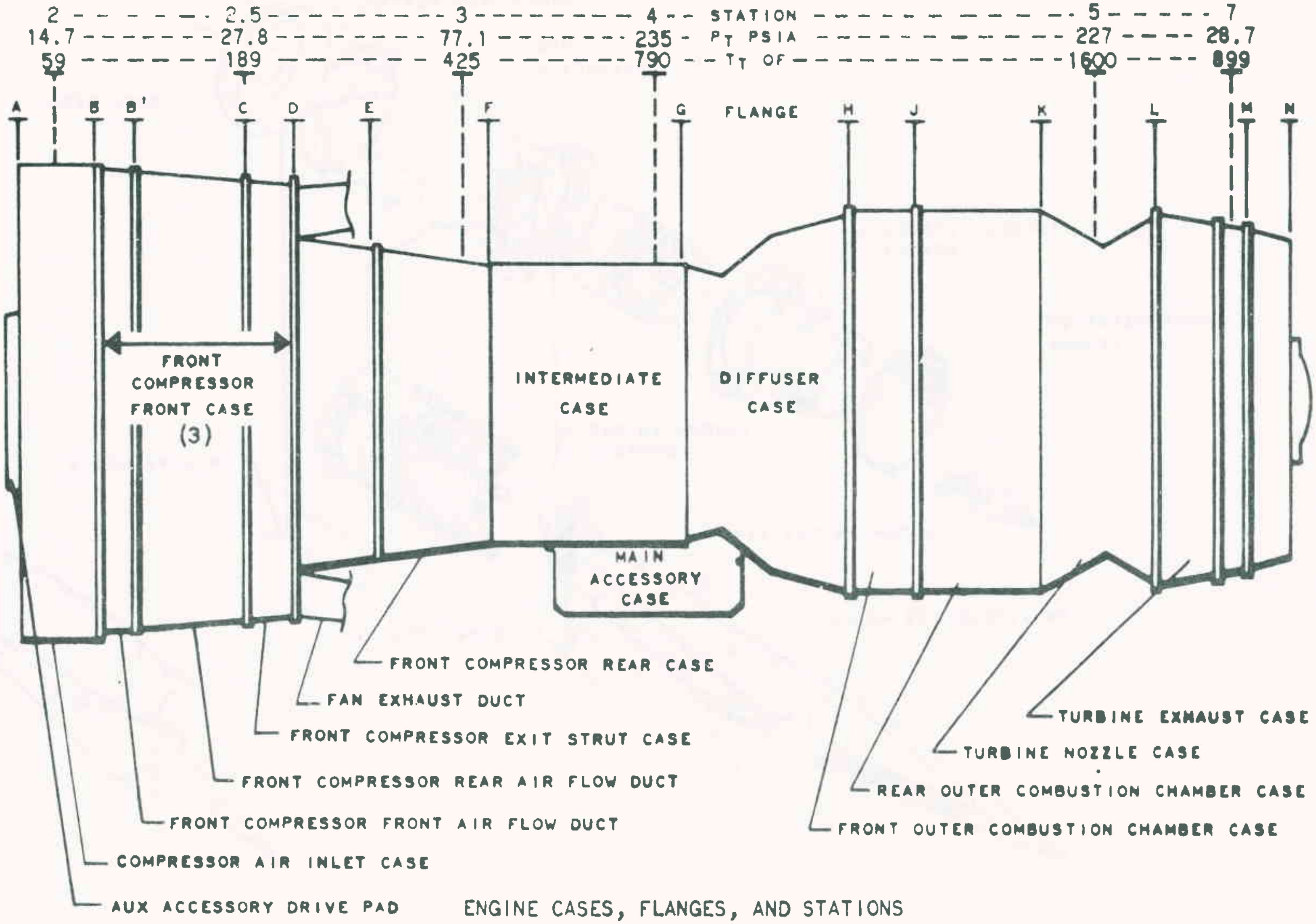
To monitor thrust reverser operation, there are three indicating lights per engine, a PRESSURE light located on the engineer's panel, a THRUST REVERSER NOT LOCKED light, and a THRUST REVERSER EXTENDED light on the pilot's center instrument panel. The PRESSURE light will come ON when the pressure in the control assembly reaches approximately 1,000 psi. The THRUST REVERSER NOT LOCKED light, located on the pilot's panel, will come ON at the first movement of the doors out of the locked position. The EXTENDED light will come ON when the doors have fully extended.

An interlock system is installed to prevent throttle movement if the thrust reverser doors are not fully extended. The mechanical linkage to the fuel control will be blocked until the thrust reverser doors are fully extended.



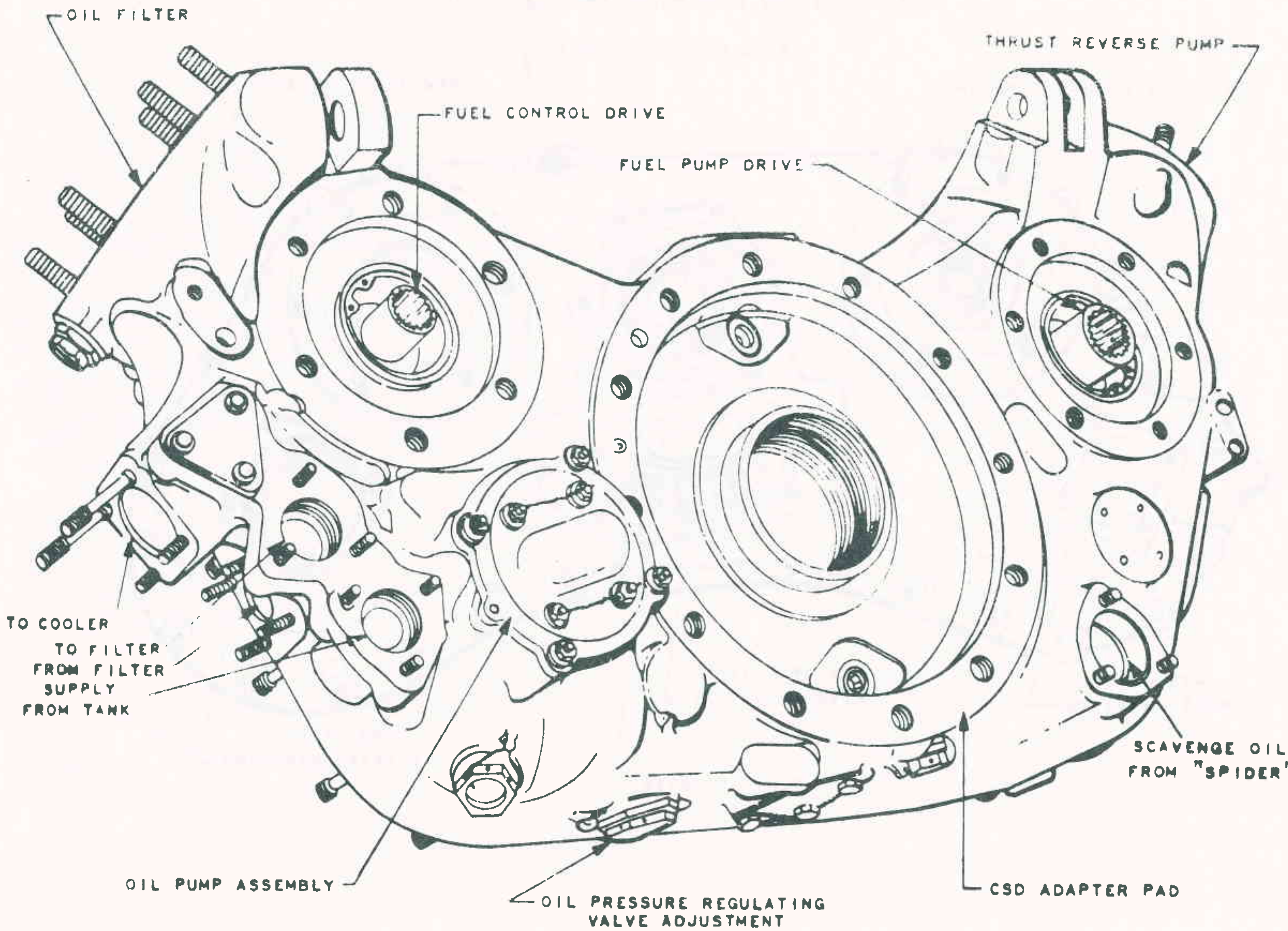

NACELLE CONSTRUCTION

Figure 5-1



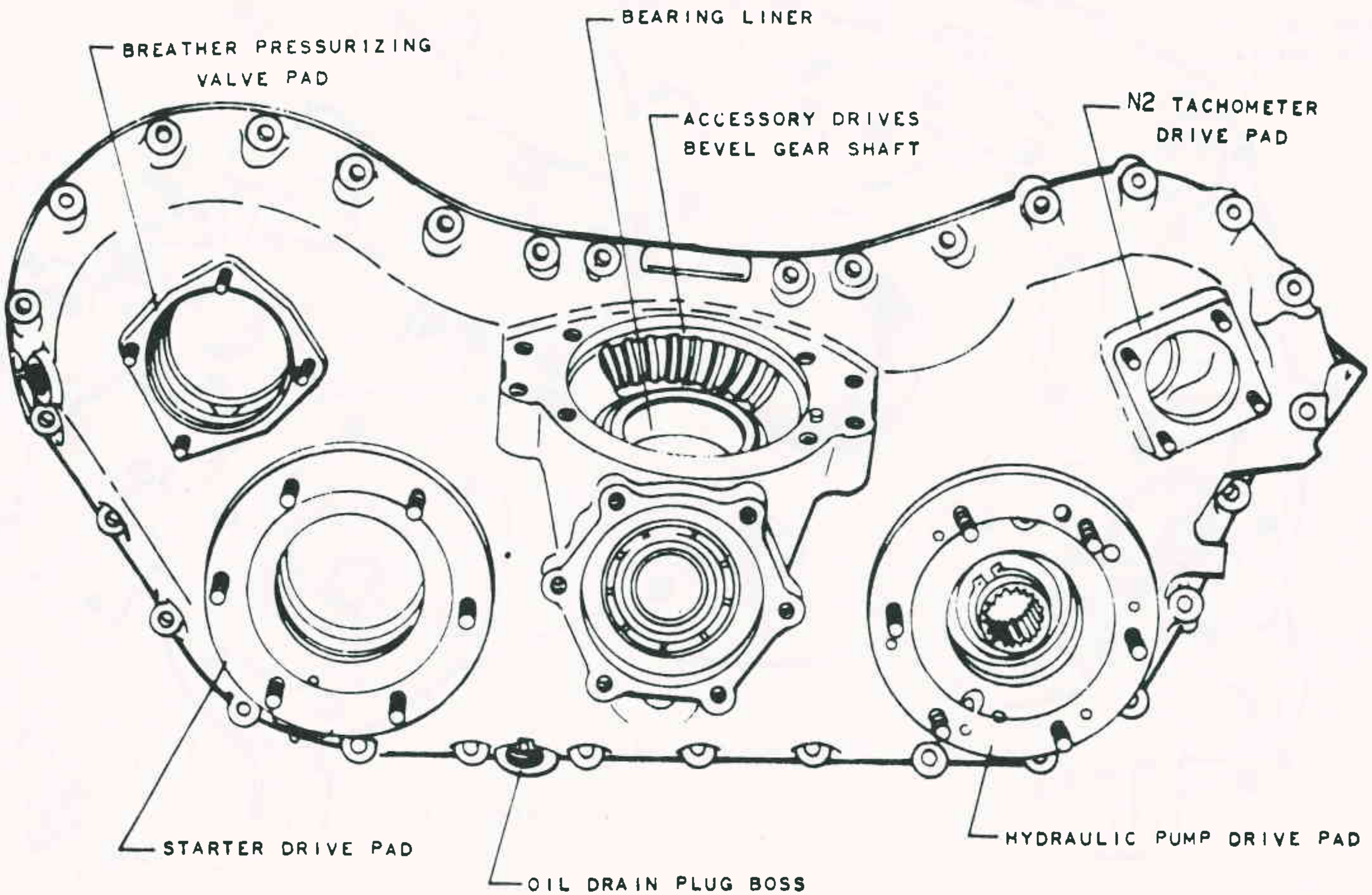

ENGINE CASES, FLANGES, AND STATIONS

Figure 5-2



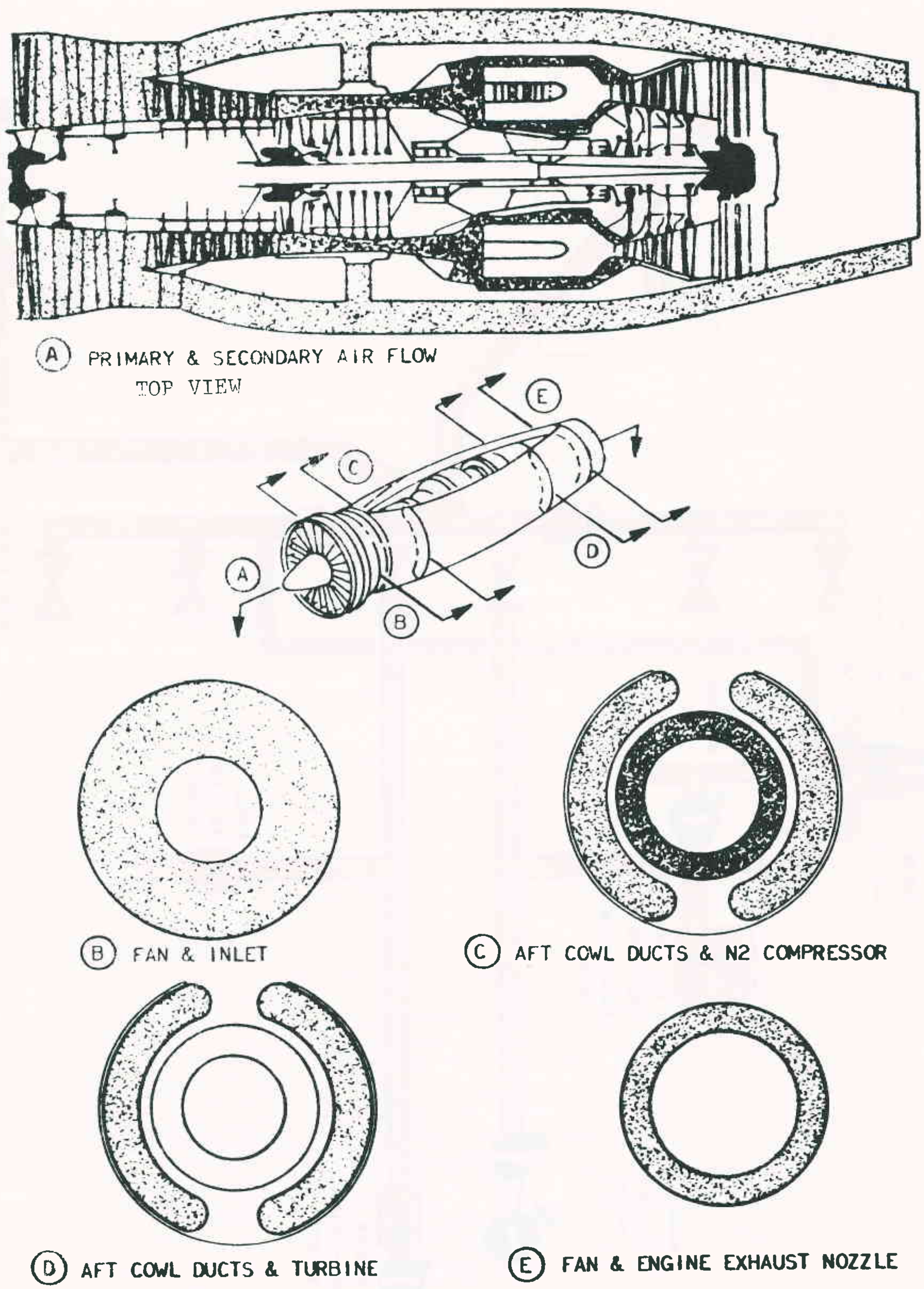

ENGINE ACCESSORY DRIVE GEAR BOX (FRONT VIEW)

Figure 5-3



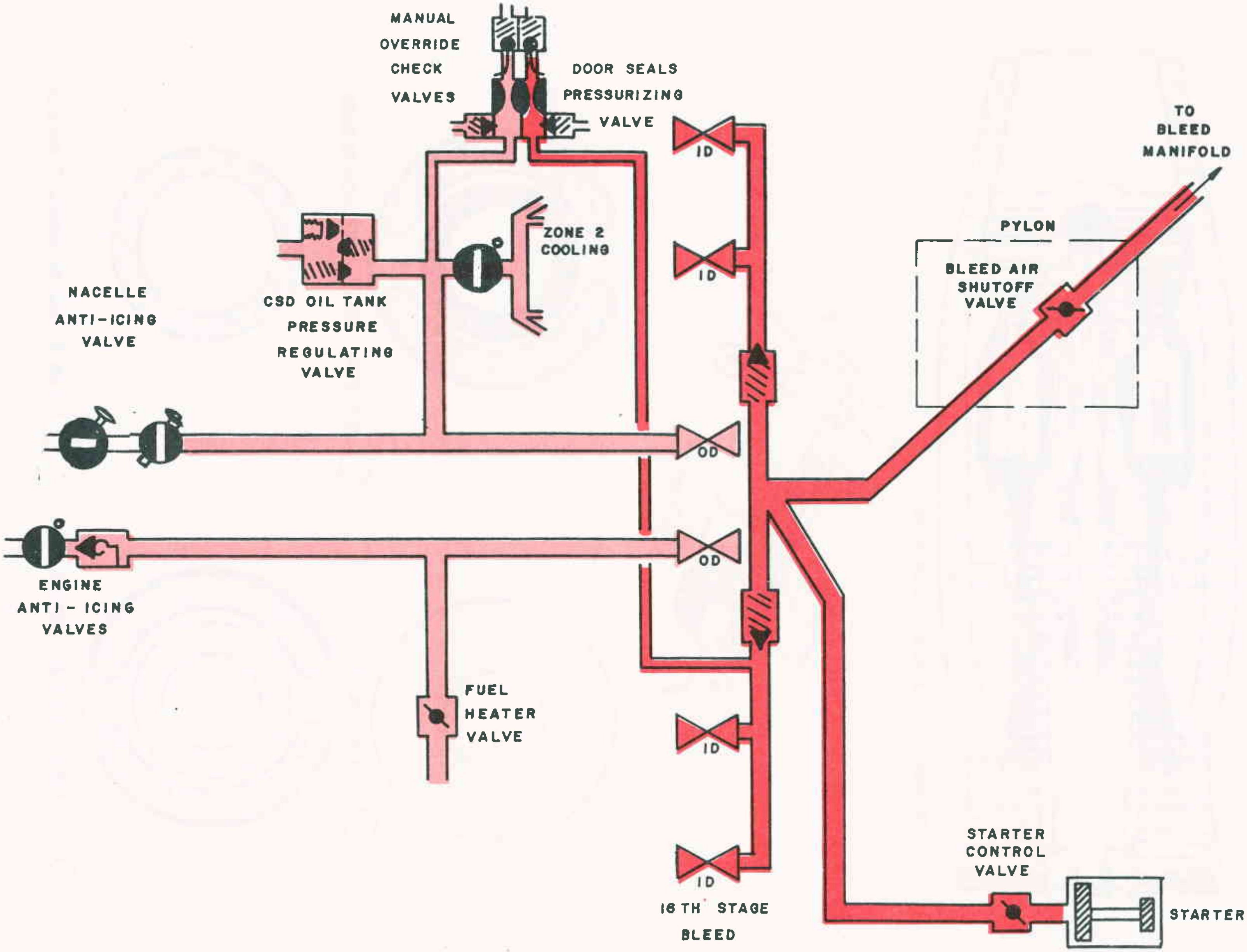

ENGINE ACCESSORY DRIVE GEAR BOX (REAR VIEW)

Figure 5-4



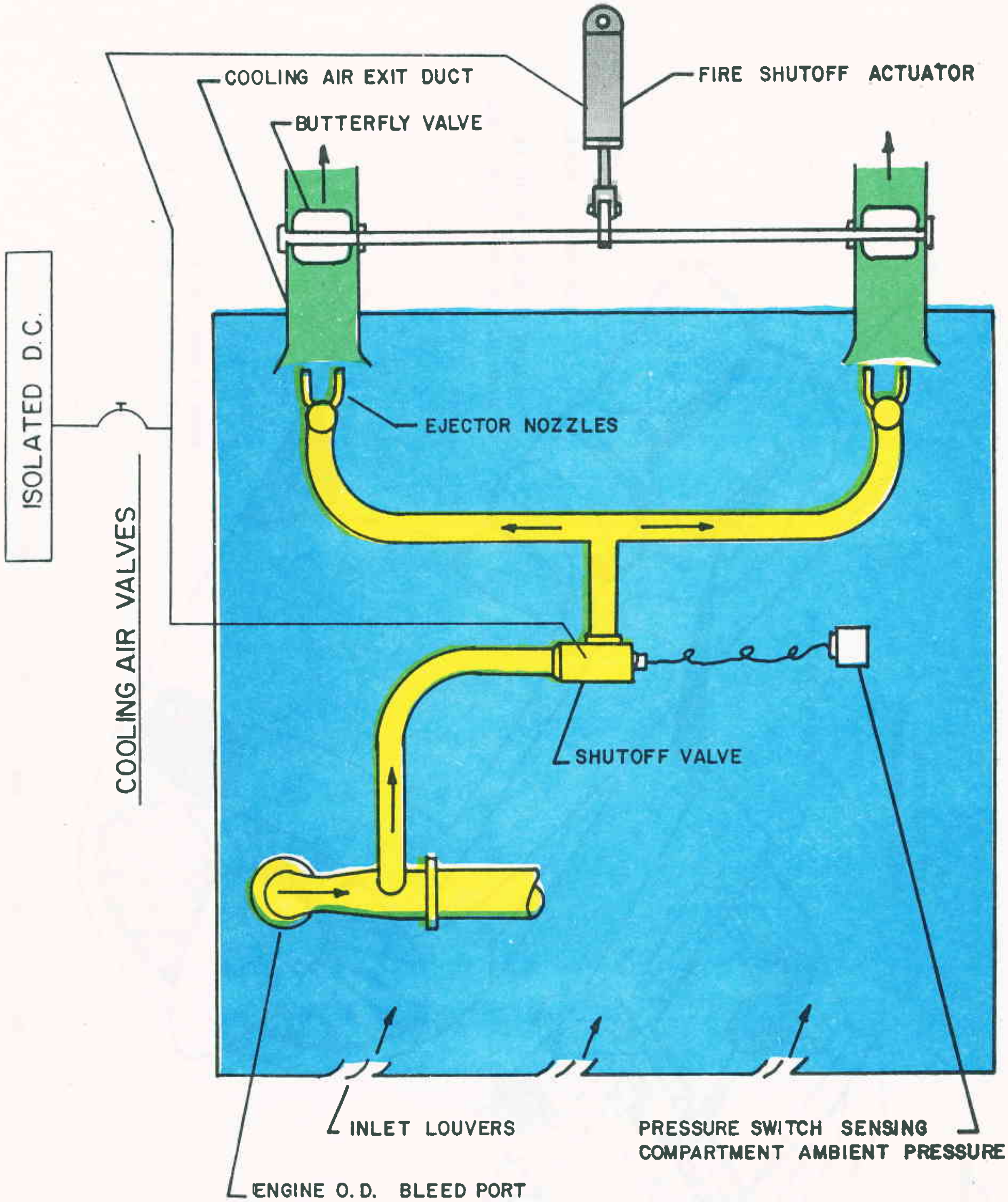
A PRIMARY & SECONDARY AIR FLOW
TOP VIEW
E
C
D
A
B
B FAN & INLET
C AFT COWL DUCTS & N2 COMPRESSOR
D AFT COWL DUCTS & TURBINE
E FAN & ENGINE EXHAUST NOZZLE


Figure 5-5



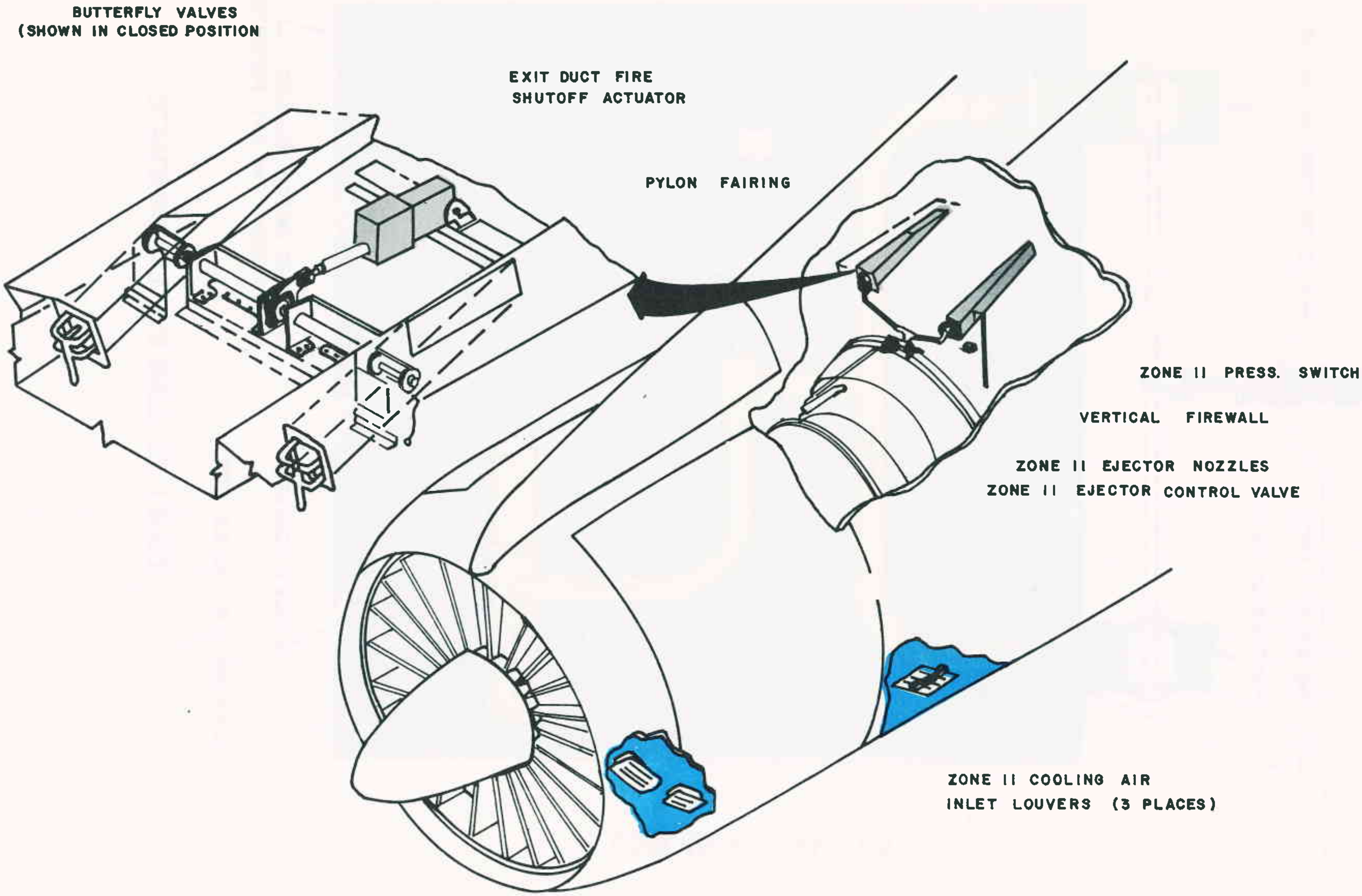

ENGINE BLEED SYSTEM SCHEMATIC

Figure 5-6



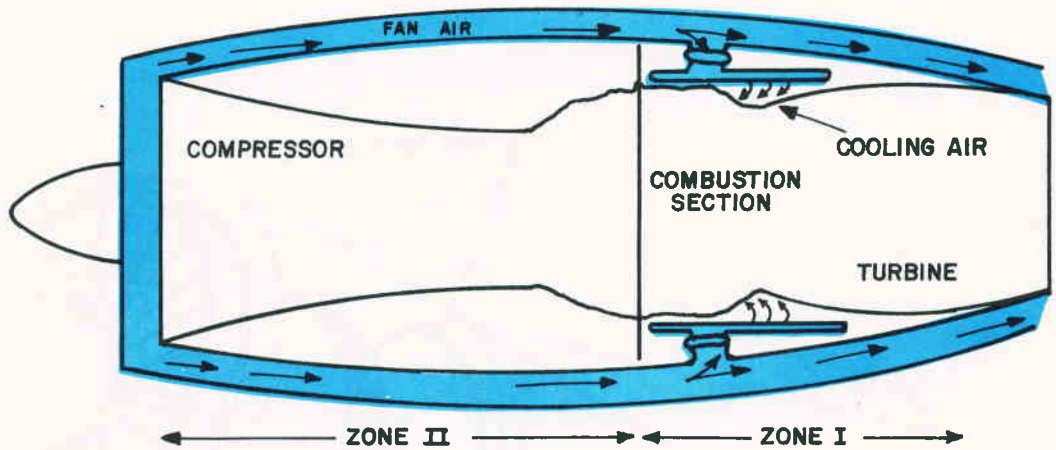

ZONE II COOLING SYSTEM SCHEMATIC

Figure 5-7




ZONE II COOLING SYSTEM COMPONENT LOCATIONS

Figure 5-8




As viewed from the top of the engine

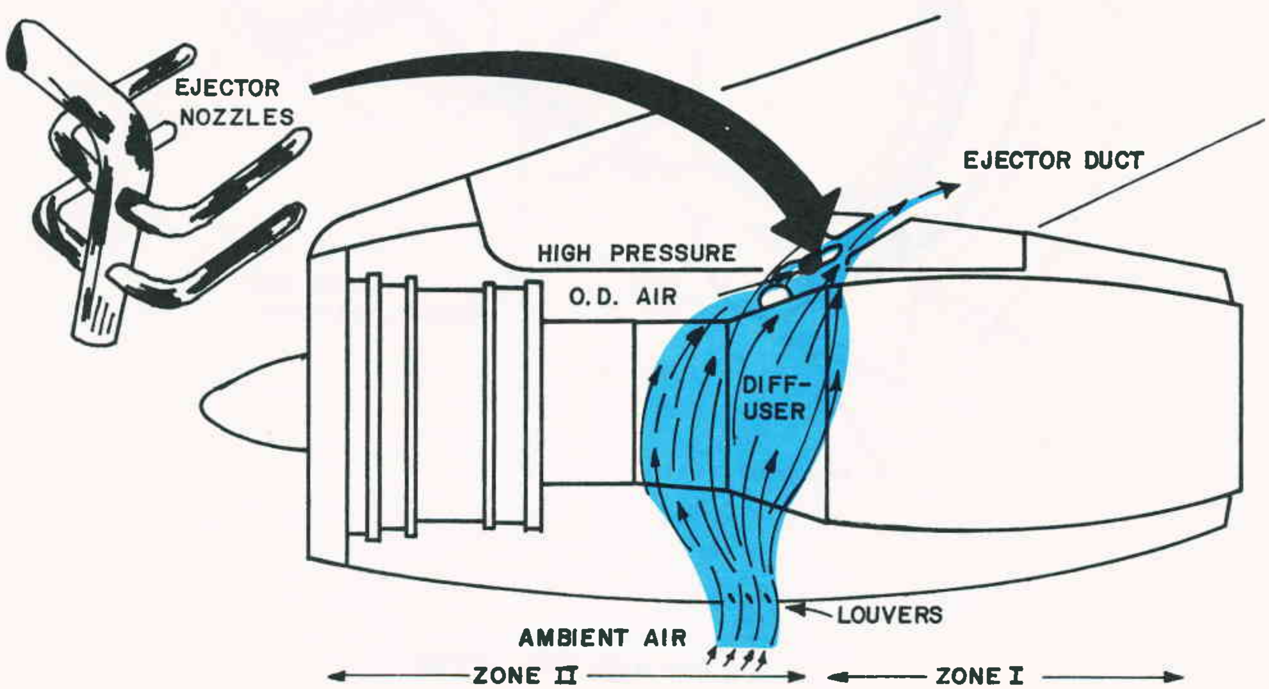
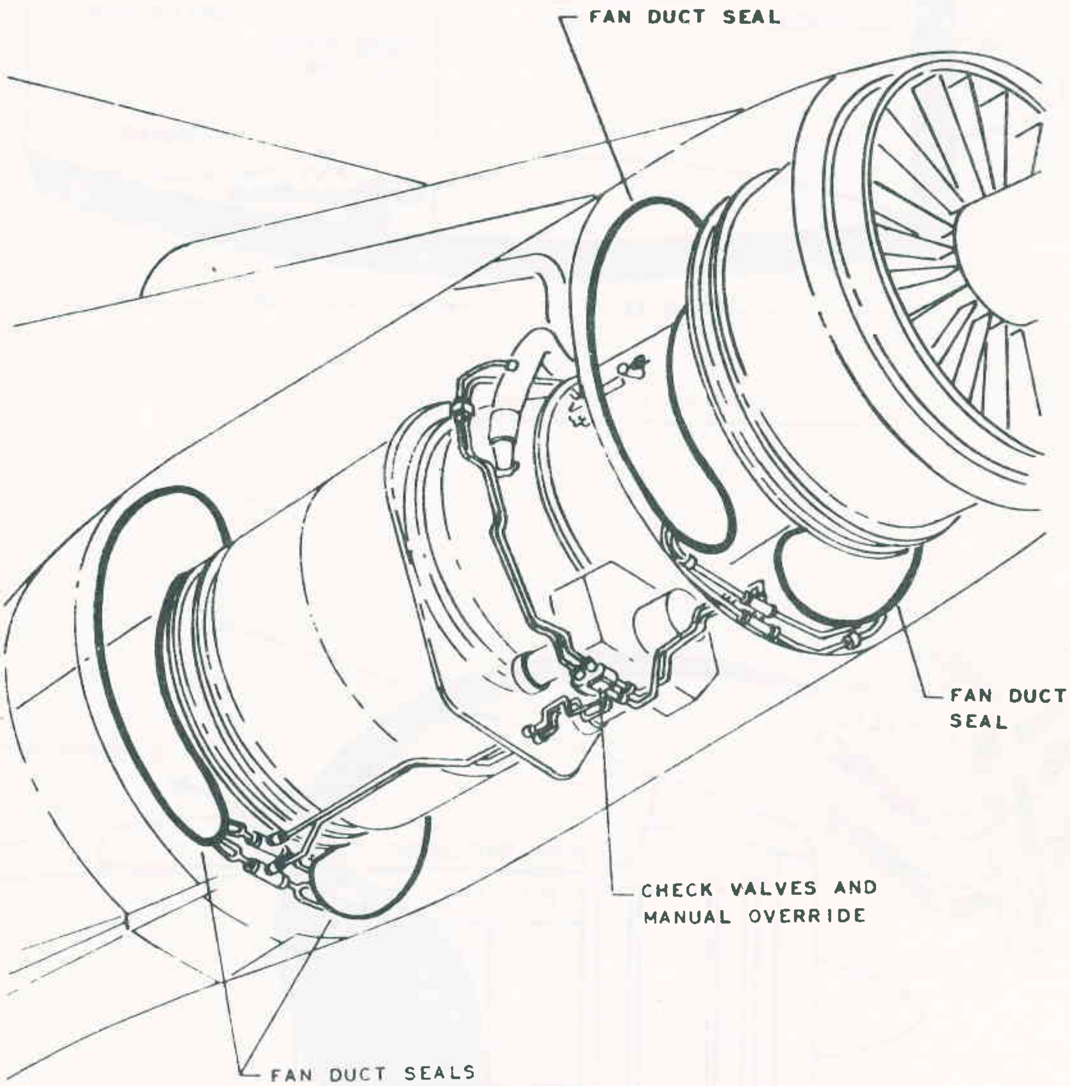
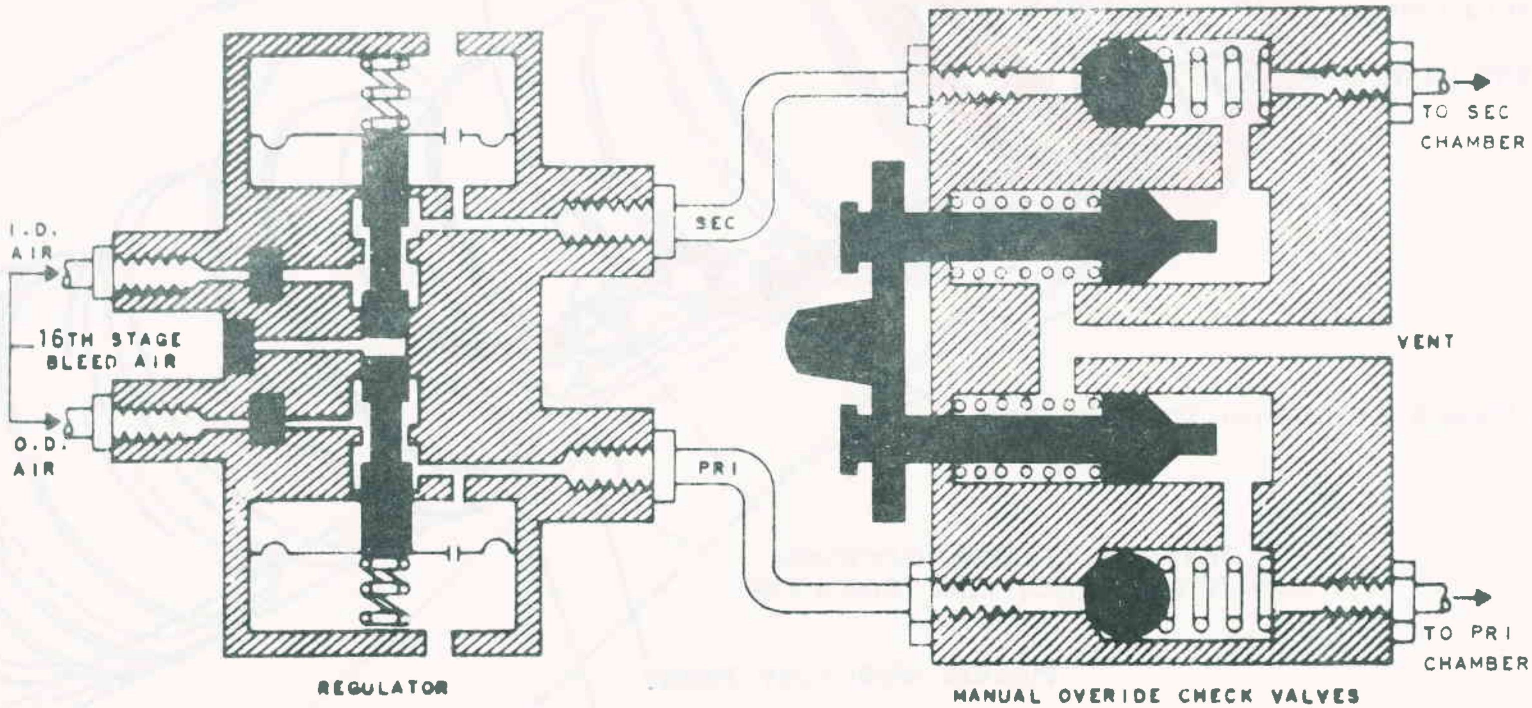



Figure 5-9



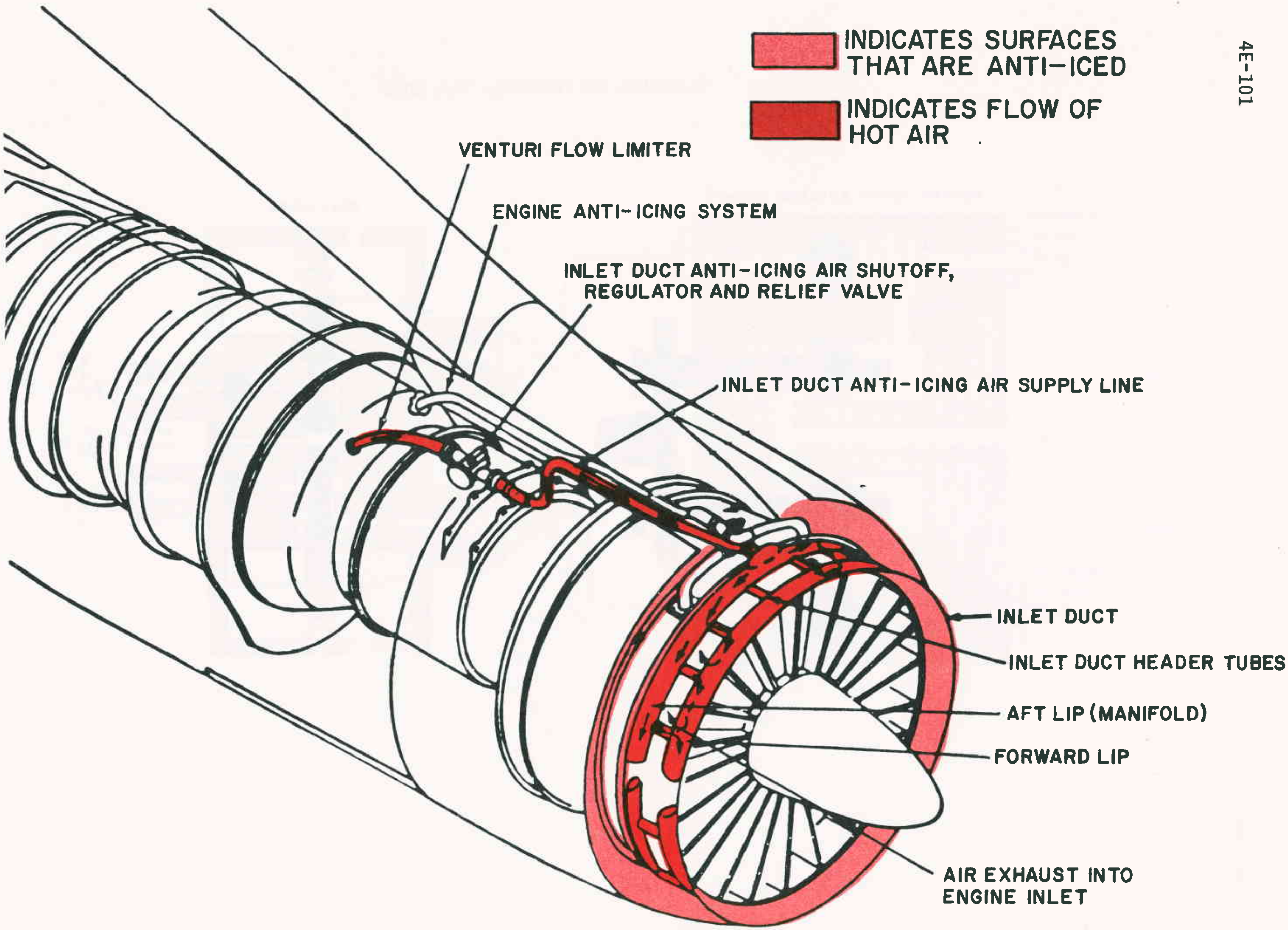

FAN DUCT SEAL SYSTEM

Figure 5-10




DOOR SEAL PRESSURIZING SCHEMATIC

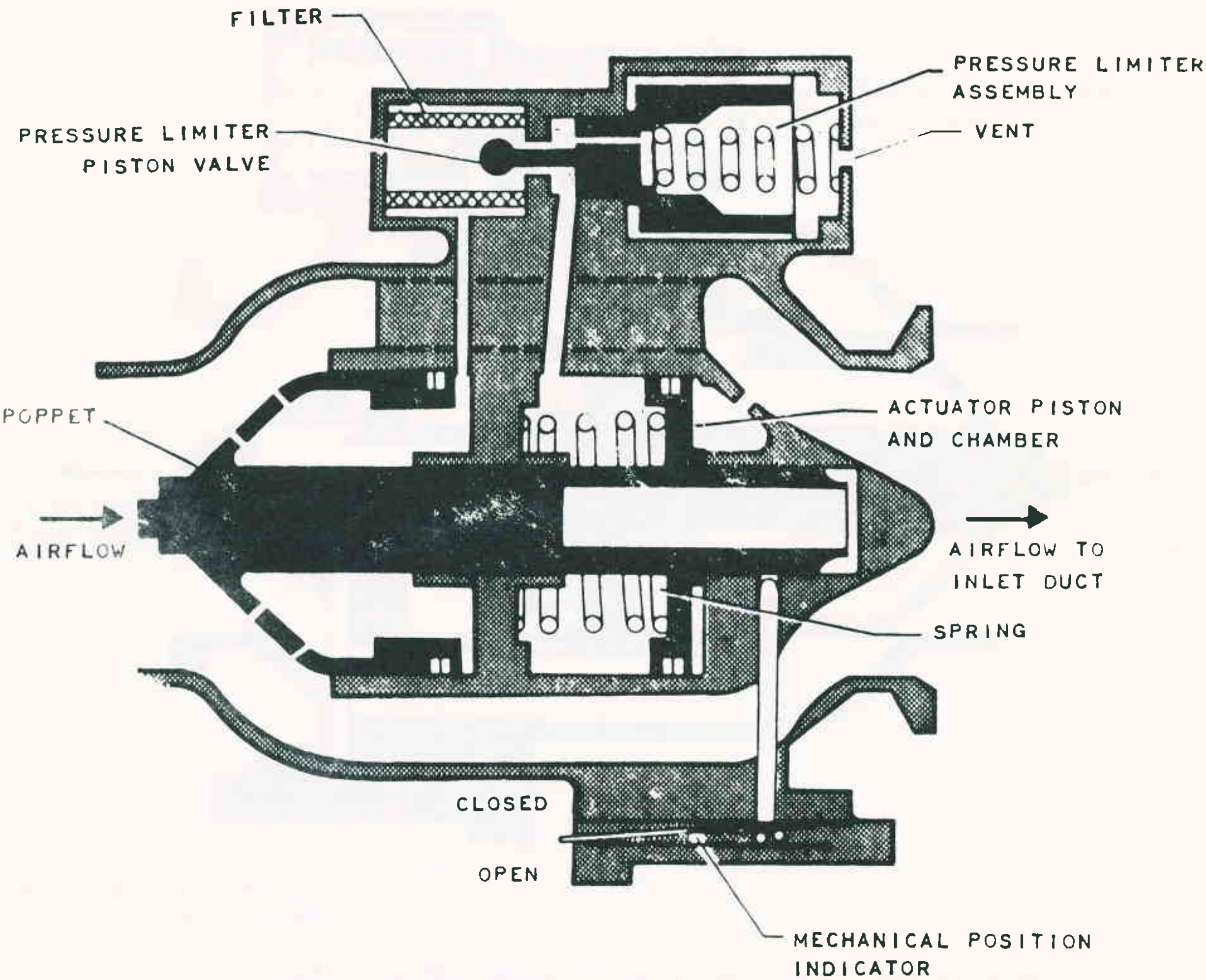
Figure 5-11




4E-101

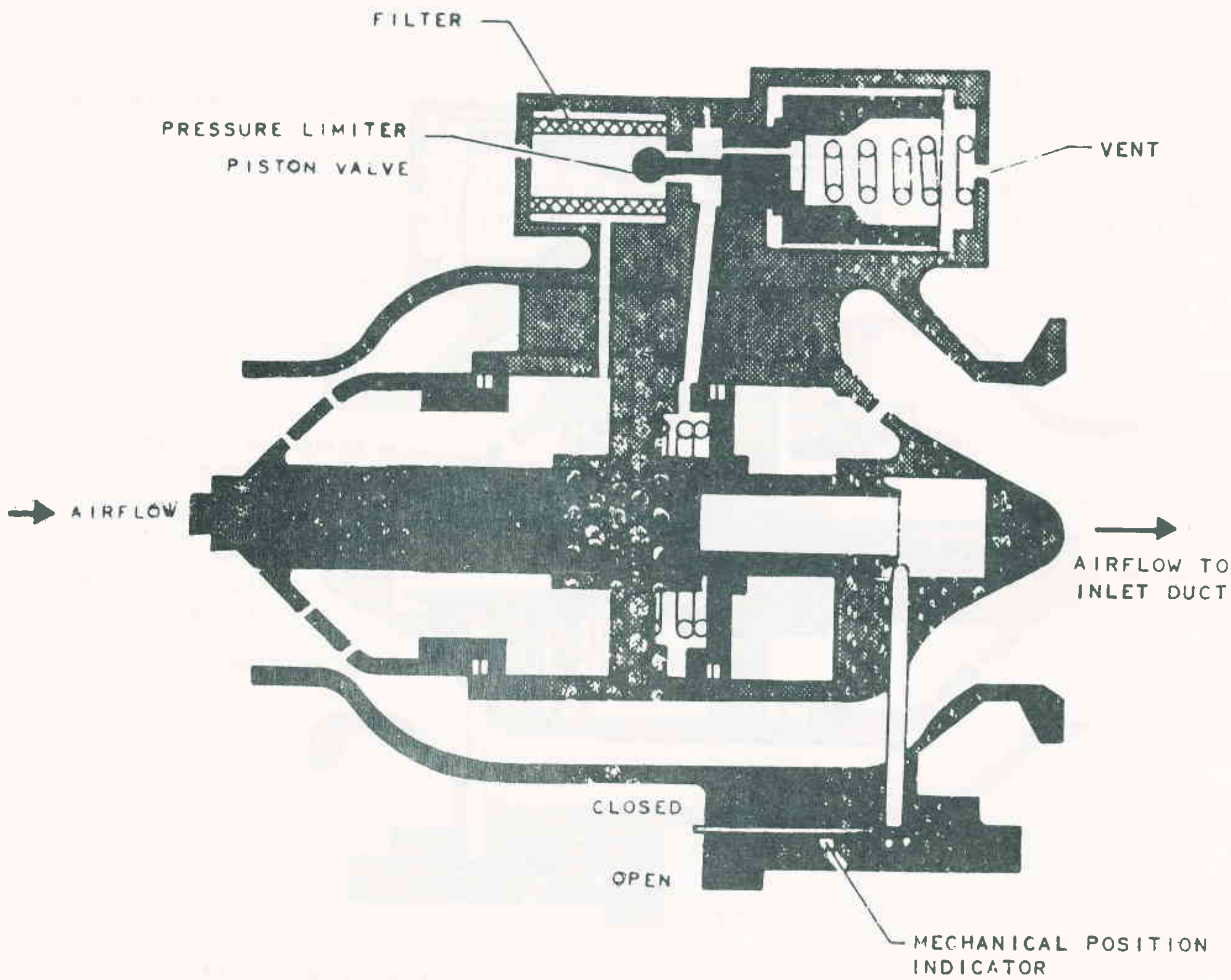
NACELLE ARRANGEM^F THE INLET DUCT ANTI-ICING SYSTEM

Figure 5-12



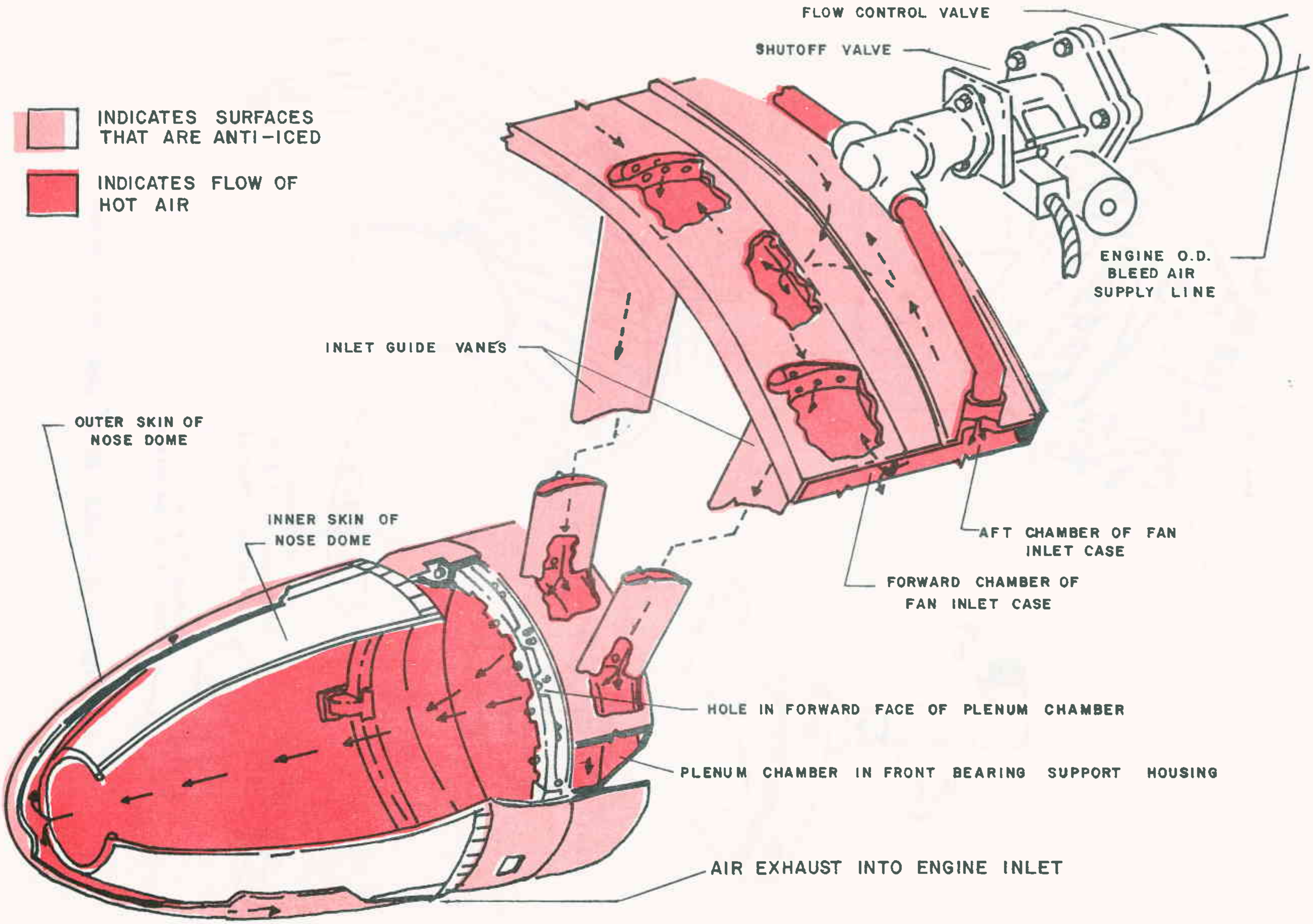

NACELLE INLET PRESSURE LIMITER VALVE (OPEN)

Figure 5-13



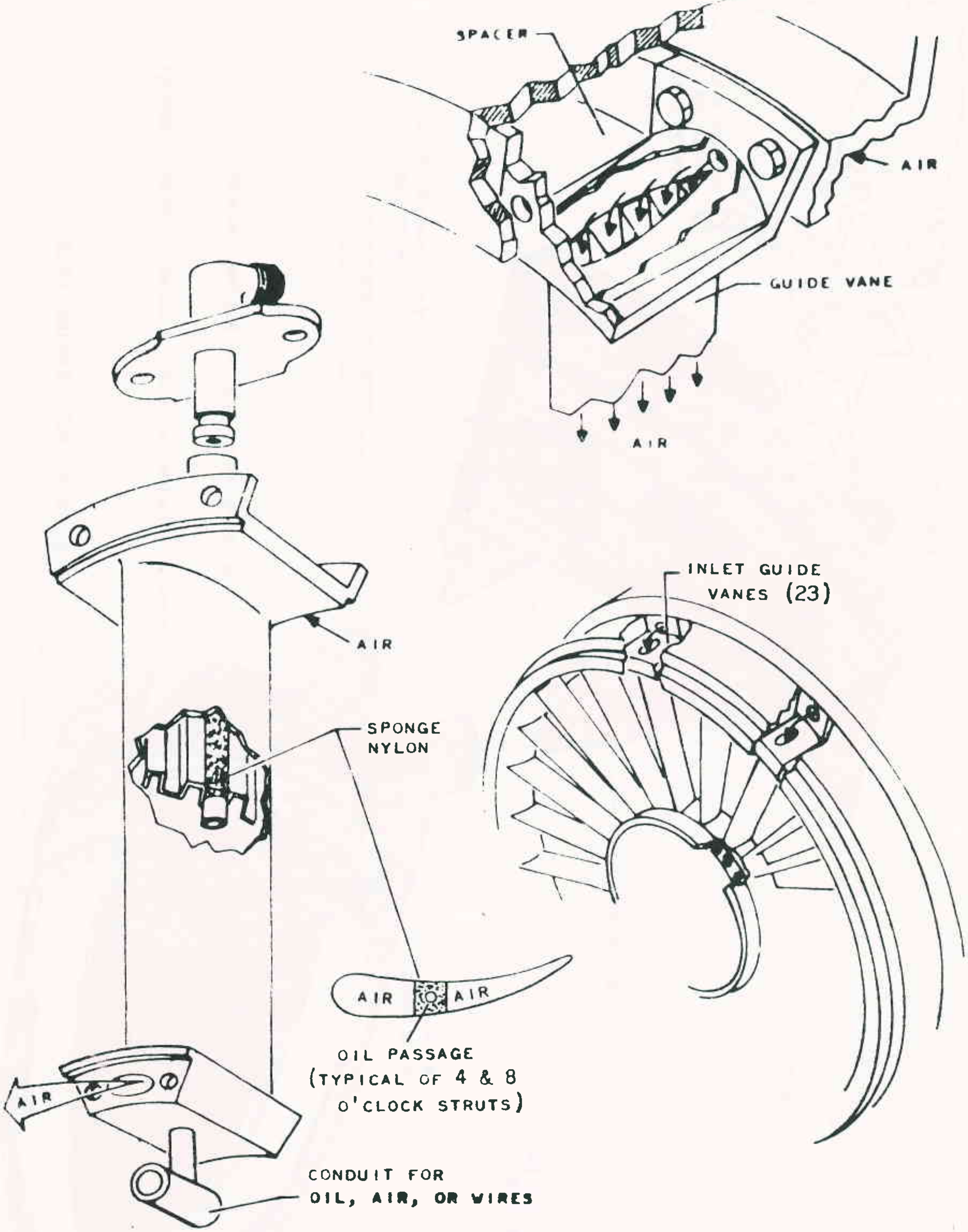

NACELLE INLET PRESSURE LIMITER VALVE (REGULATING)

Figure 5-14



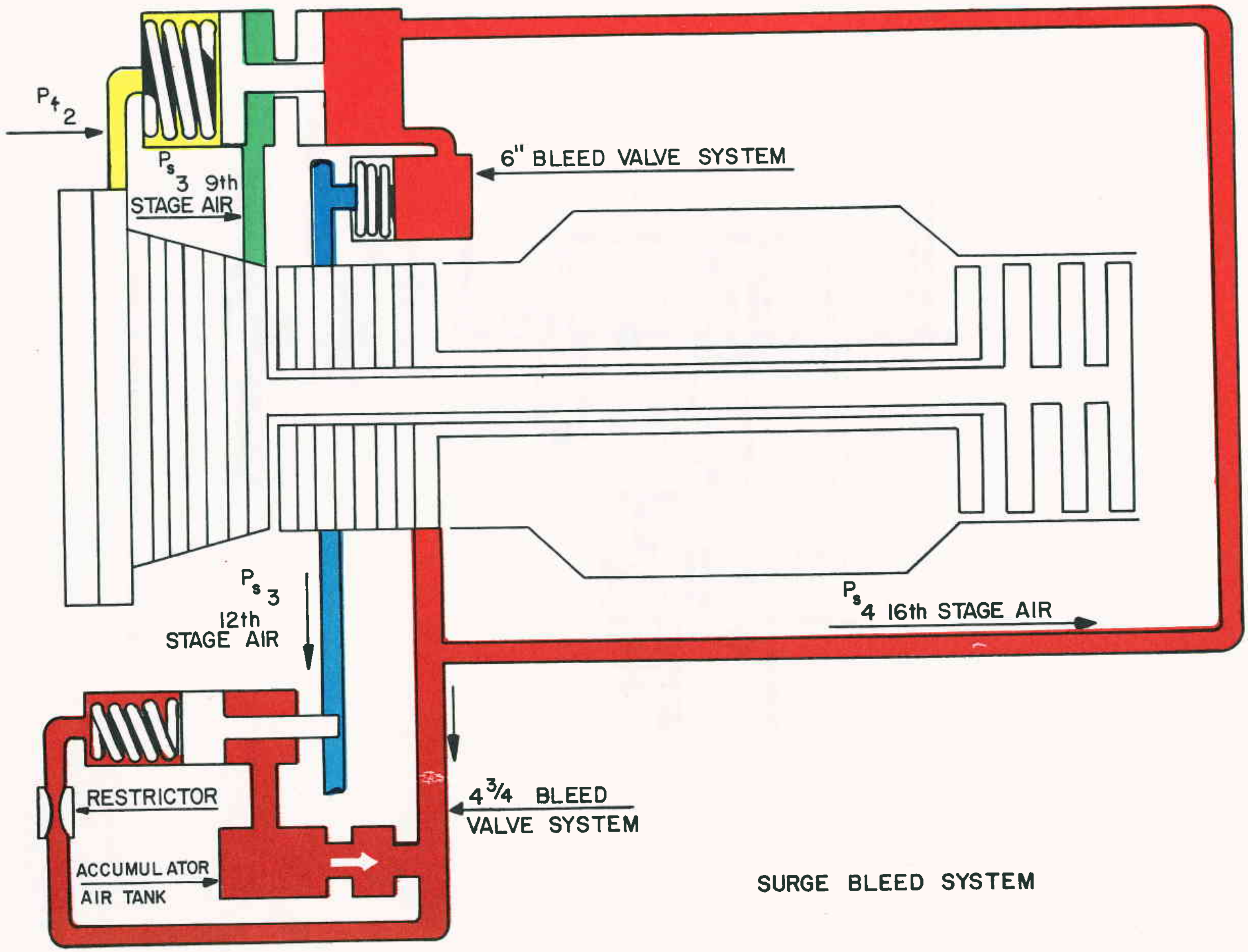

ENGINE ANTI-ICING SYSTEM AIRFLOW

Figure 5-15



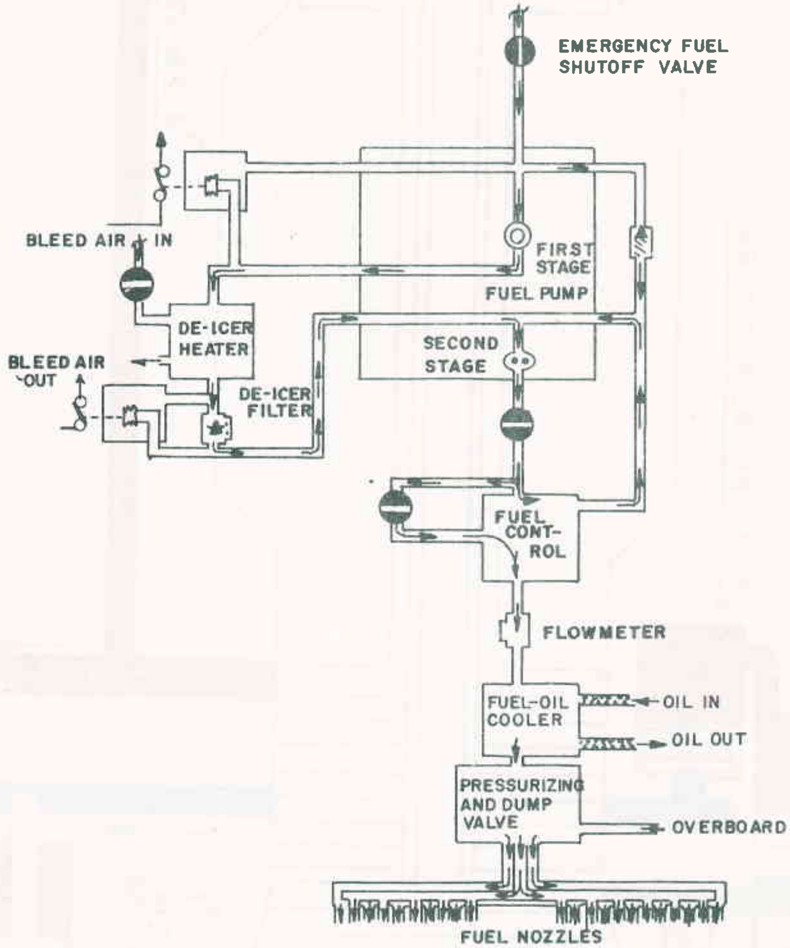

AIR INLET CASE - INLET GUIDE VANE INSTALLATION

Figure 5-16




SURGE BLEED SYSTEM

Figure 5-17




ENGINE FUEL SYSTEM SCHEMATIC DIAGRAM

Figure 5-18

4E-101

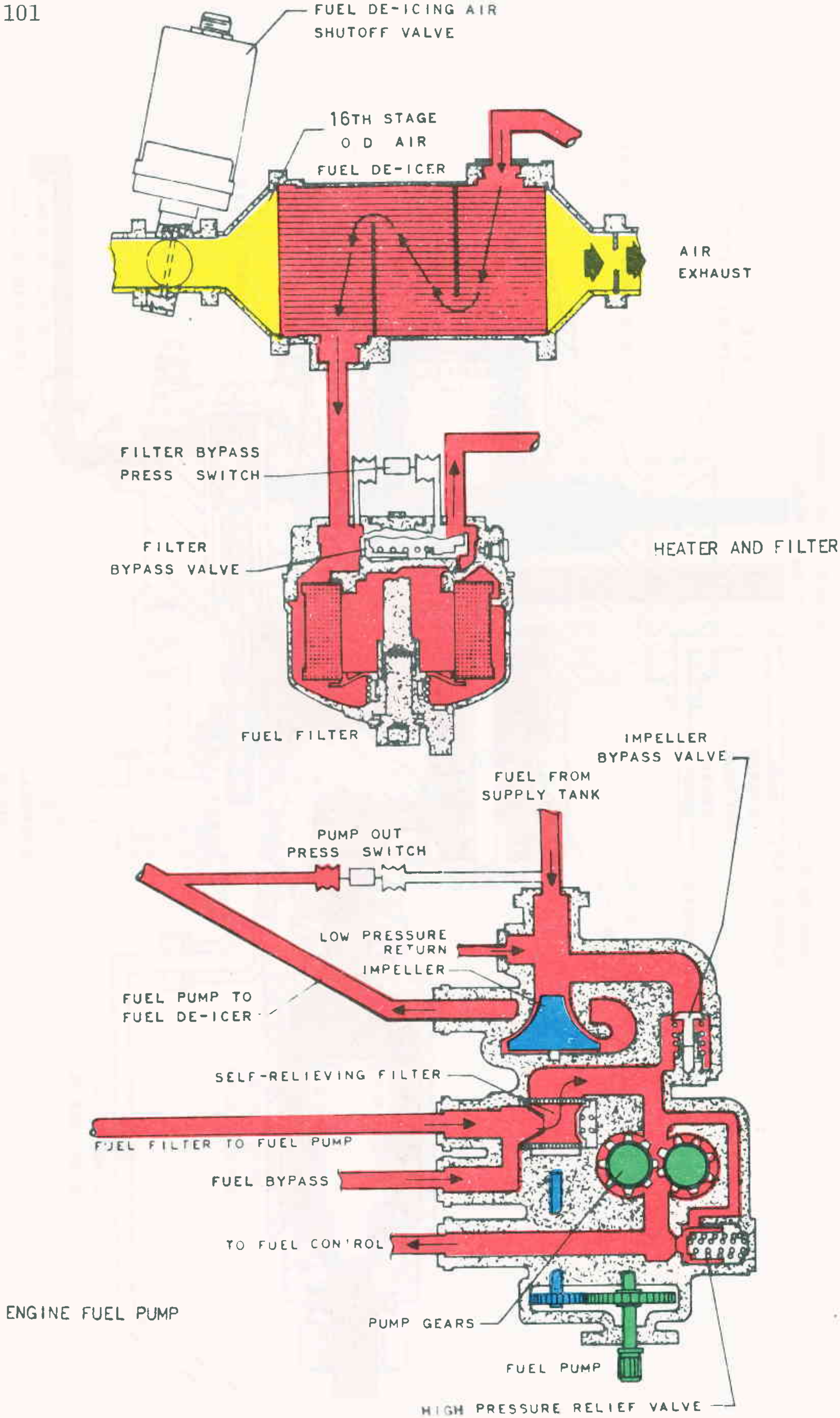
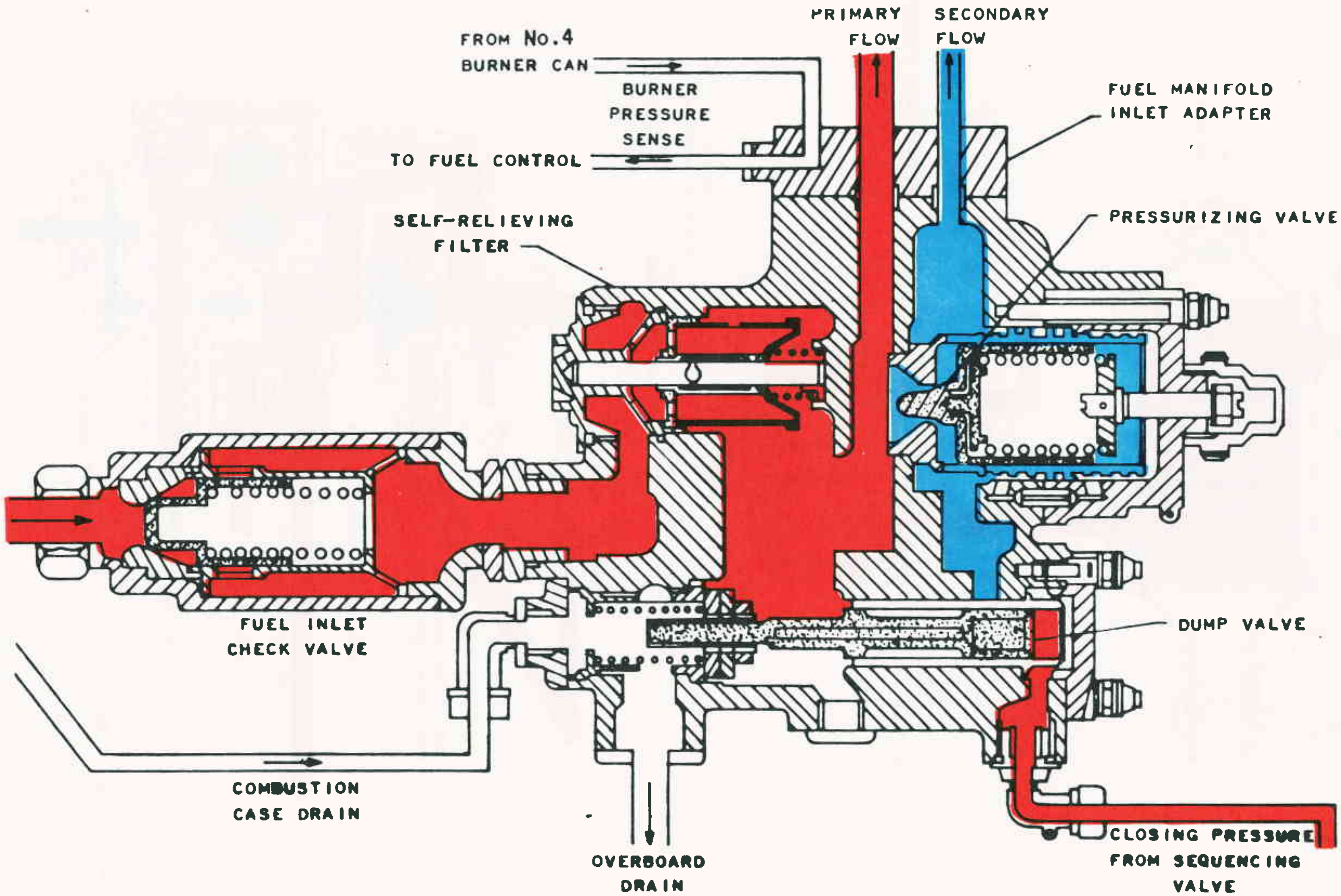
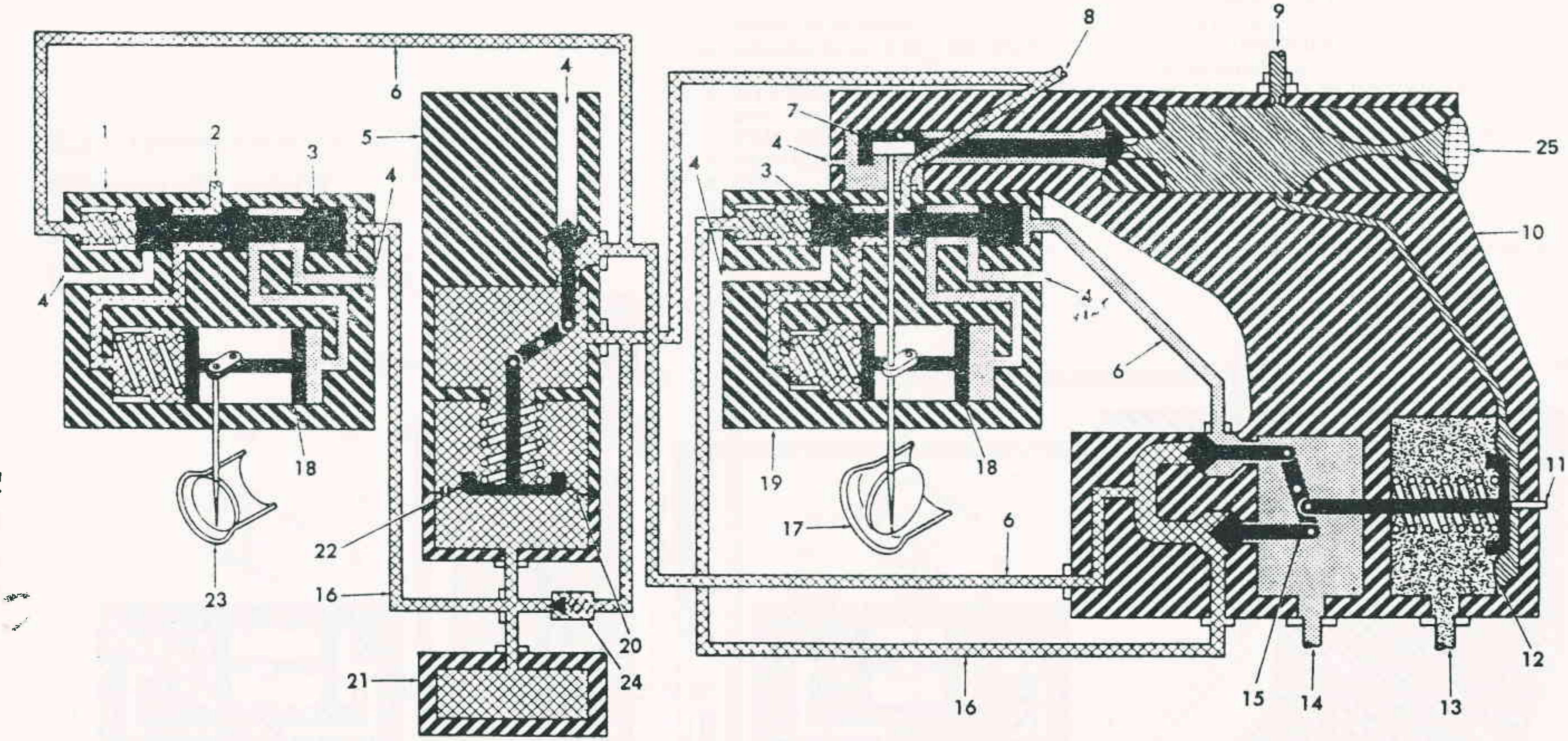



Figure 5-19




ENGINE FUEL PRESSURIZING AND DUMP VALVE

Figure 5-20



PT$_0$ P$_{amb}$ OR NACELLE PRESSURE

PT2 PRESSURE

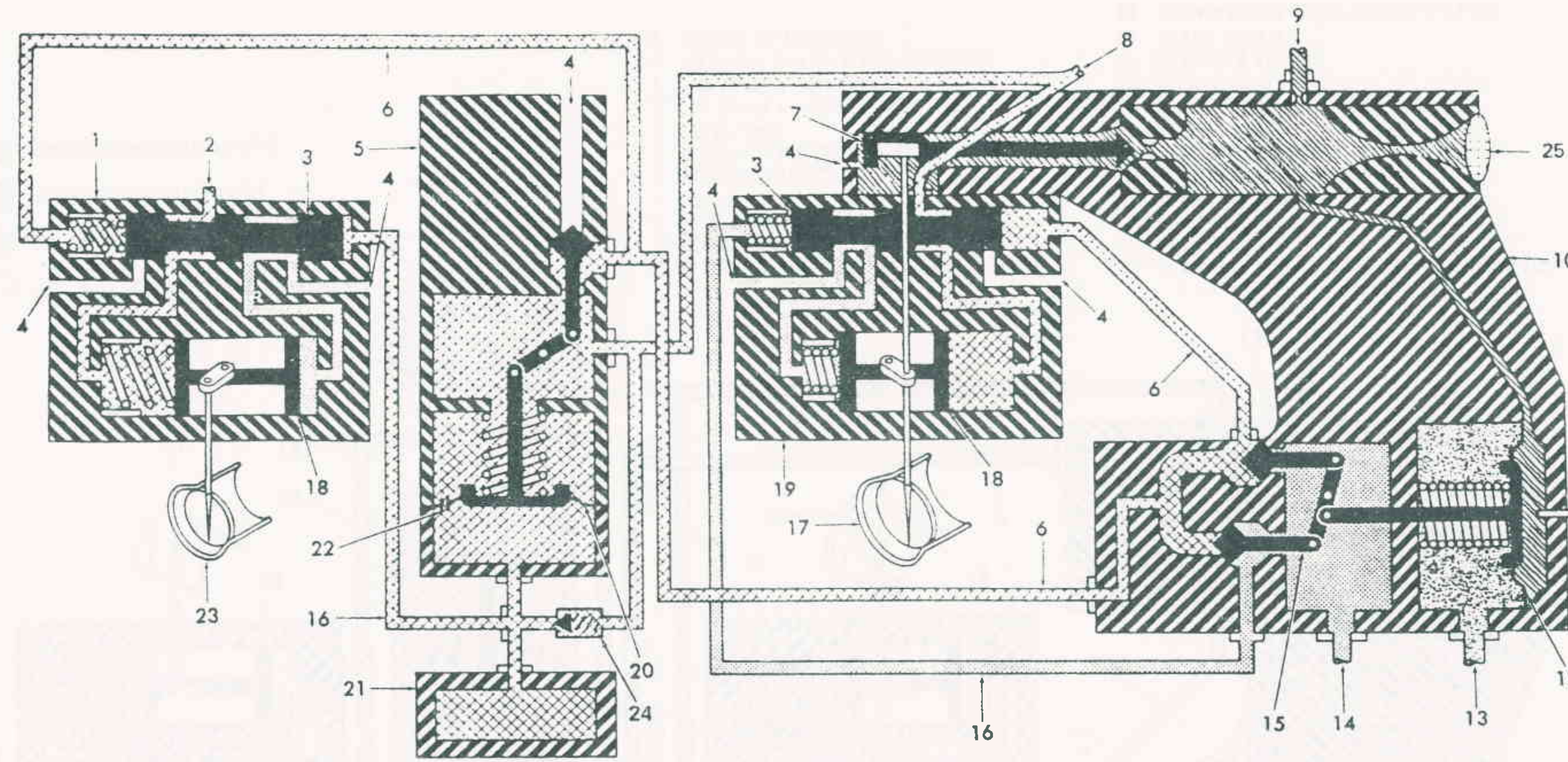
PS3 PRESSURE 9TH STAGE

PS4 PRESSURE 16TH STAGE

1. BLEED VALVE ACTUATOR , 4.74 IN.
2. PS4 SUPPLY 16TH STAGE
3. PILOT VALVE
4. VENT
5. BLEED RESET CONTROL
6. BLEED CLOSE SIGNAL LINE
7. RESET CAM
8. PS4 SUPPLY 16TH STAGE
9. PS3 SUPPLY 9TH STAGE
10. PRESSURE RATIO BLEED CONTROL
11. BENCH ADJUSTMENT
12. TRANSFER VALVE ACTUATING DIAPHRAGM
13. PT2 SUPPLY
14. EXHAUST
15. TRANSFER VALVE ASSEMBLY
16. BLEED OPEN SIGNAL LINE
17. COMPRESSOR BLEED VALVE 6.00 IN.
18. POWER PISTON
19. BLEED VALVE ACTUATOR , 6 IN.
20. DIAPHRAGM
21. ACCUMULATOR
22. BLEED ORIFICE
23. COMPRESSOR BLEED VALVE, 4.74 IN.
24. BLEED RESET CHECK VALVE, 20 PSID
25. PRBC ORIFICE VENT

**START AND IDLE**

Figure 5-21



PT$_0$, P$_{amb}$ OR NACELLE PRESSURE

PT2 PRESSURE

PS3 PRESSURE 9TH STAGE

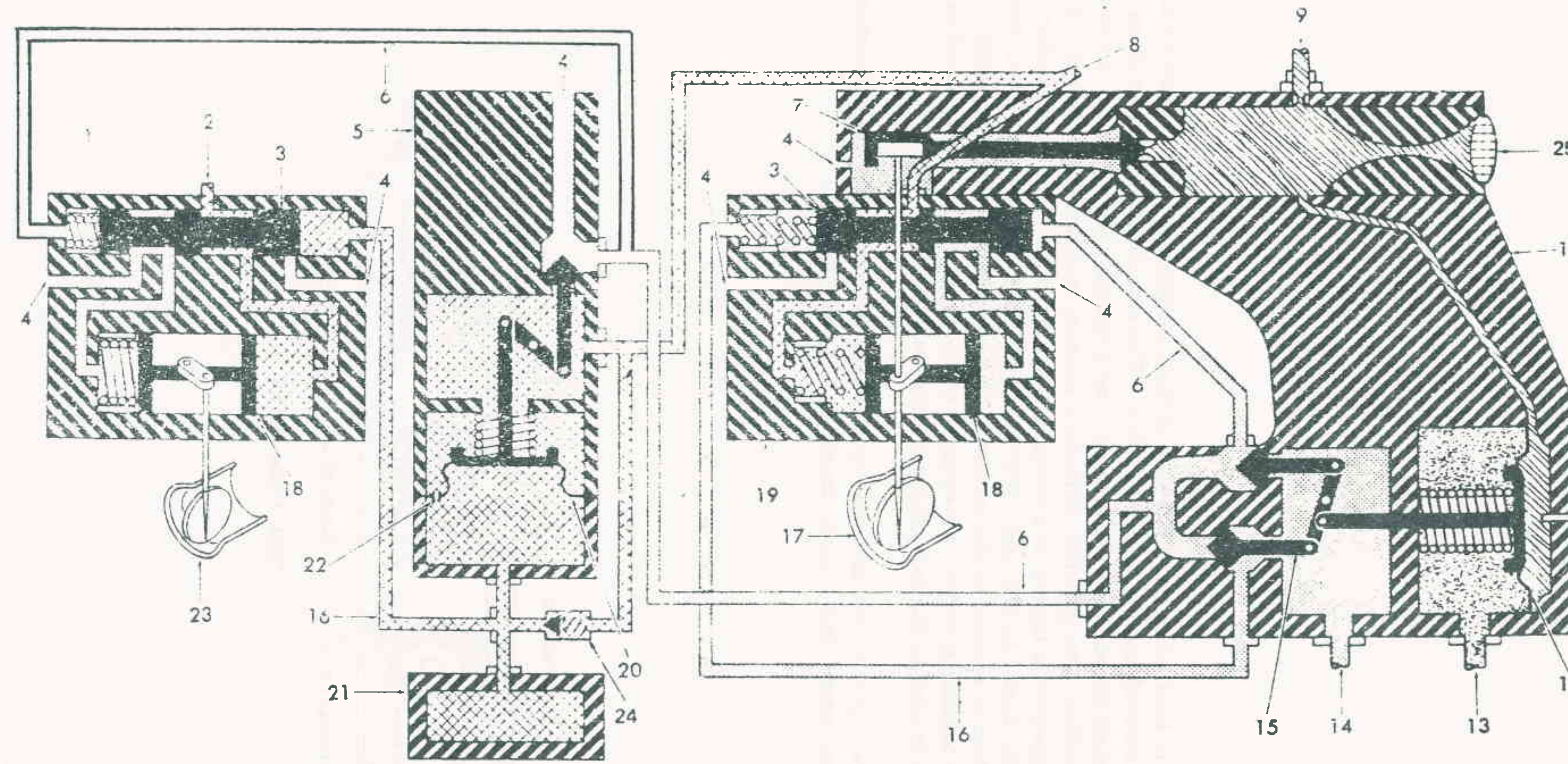
PS4 PRESSURE 16TH STAGE

1. BLEED VALVE ACTUATOR, 4.74 IN.
2. PS4 SUPPLY 16TH STAGE
3. PILOT VALVE
4. VENT
5. BLEED RESET CONTROL
6. BLEED CLOSE SIGNAL LINE
7. RESET CAM
8. PS4 SUPPLY 16TH STAGE
9. PS3 SUPPLY 9TH STAGE
10. PRESSURE RATIO BLEED CONTROL
11. BENCH ADJUSTMENT
12. TRANSFER VALVE ACTUATING DIAPHRAGM
13. PT2 SUPPLY
14. EXHAUST
15. TRANSFER VALVE ASSEMBLY
16. BLEED OPEN SIGNAL LINE
17. COMPRESSOR BLEED VALVE, 6.00 IN.
18. POWER PISTON
19. BLEED VALVE ACTUATOR, 6 IN.
20. DIAPHRAGM
21. ACCUMULATOR
22. BLEED ORIFICE
23. COMPRESSOR BLEED VALVE, 4.74 IN.
24. BLEED RESET CHECK VALVE, 20 PSID
25. PRBC ORIFICE VENT

TAKE-OFF AND CRUISE

Figure 5-22

4E-101



- $PT_2$, $P_{amb}$ OR NACELLE PRESSURE
- PT2 PRESSURE
- PS3 PRESSURE 9TH STAGE
- PS4 PRESSURE 16TH STAGE

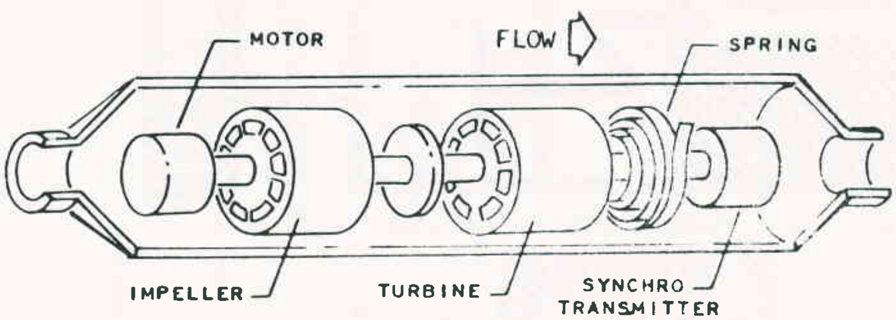
1. BLEED VALVE ACTUATOR, 4.74 IN.
2. PS4 SUPPLY 16TH STAGE
3. PILOT VALVE
4. VENT
5. BLEED RESET CONTROL
6. BLEED CLOSE SIGNAL LINE
7. RESET CAM
8. PS4 SUPPLY 16TH STAGE
9. PS3 SUPPLY 9TH STAGE
10. PRESSURE RATIO BLEED CONTROL
11. BENCH ADJUSTMENT
12. TRANSFER VALVE ACTUATING DIAPHRAGM
13. PT2 SUPPLY
14. EXHAUST
15. TRANSFER VALVE ASSEMBLY
16. BLEED OPEN SIGNAL LINE
17. COMPRESSOR BLEED VALVE, 6.00 IN.
18. POWER PISTON
19. BLEED VALVE ACTUATOR, 6 IN
20. DIAPHRAGM
21. ACCUMULATOR
22. BLEED ORIFICE
23. COMPRESSOR BLEED VALVE, 4.74 IN.
24. BLEED RESET CHECK VALVE, 20 PSID
25. PRBC ORIFICE VENT

**RAPID DECELERATION**

Figure 5-23

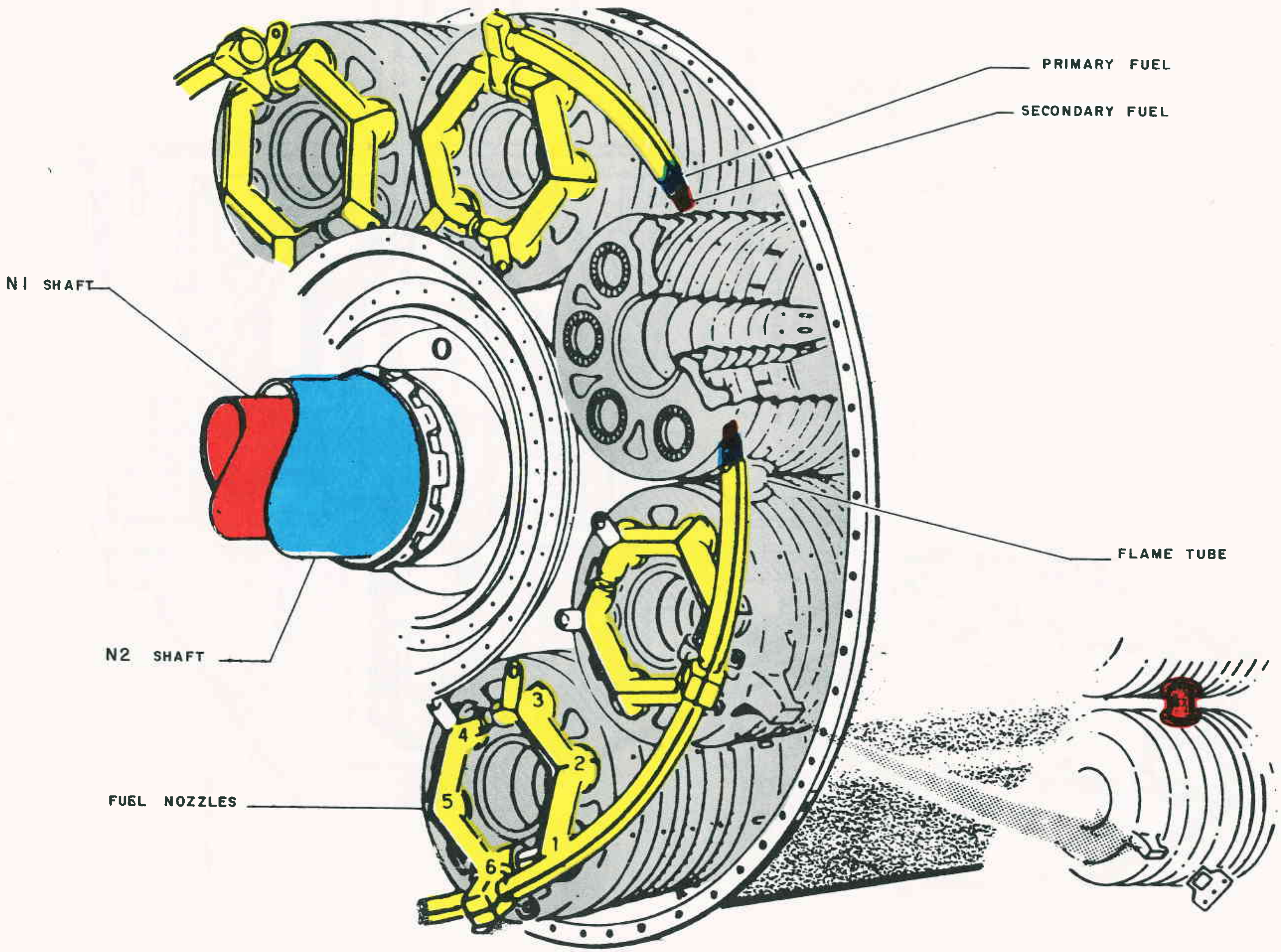
The transmitter is located on the right side of the compressor intermediate case between the fuel control and the fuel-oil cooler. The transmitter consists of an impeller, a constant speed motor, a turbine, and a transmitter synchro. As fuel enters the transmitter, the impeller imparts a twisting motion, or torque, to the fuelflow. The impeller is driven at a constant speed by a constant speed motor. Power to drive the motor is 115-volt, 400-Hertz AC from the Essential A-C Bus. The twisting motion is applied to the turbine which causes it to deflect against the spring. The angular position is measured by the transmitter synchro and an electrical signal is sent to the indicator and data converter.

Since the fuelflow signal to the indicator is of a synchro-type, the data converter serves as a power supply and a servo amplifier for the indicator.



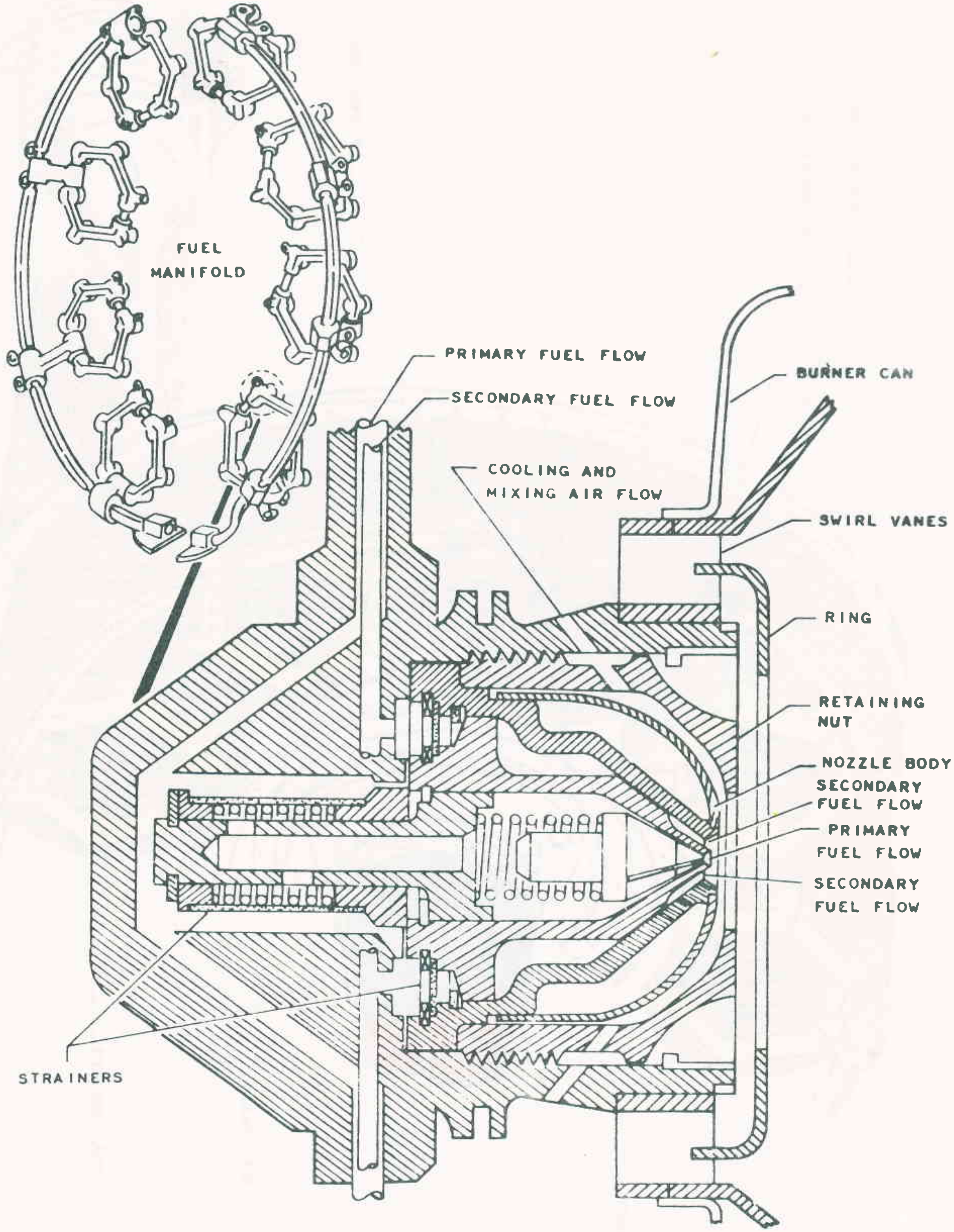

FUEL FLOW METER

Figure 5-24




CAN ANNULAR COMBUSTION CHAMBER

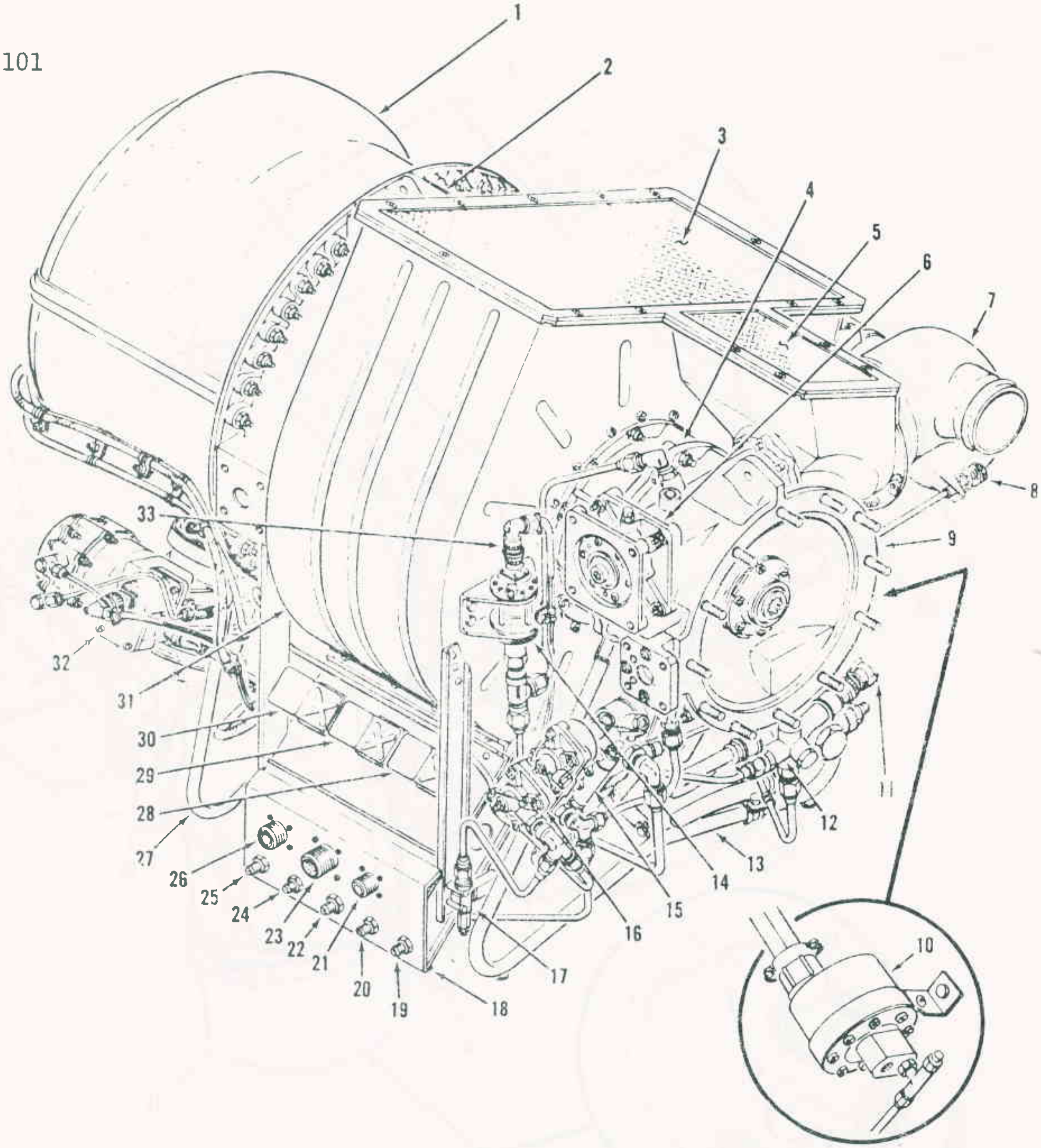
Figure 5-25




FUEL NOZZLE

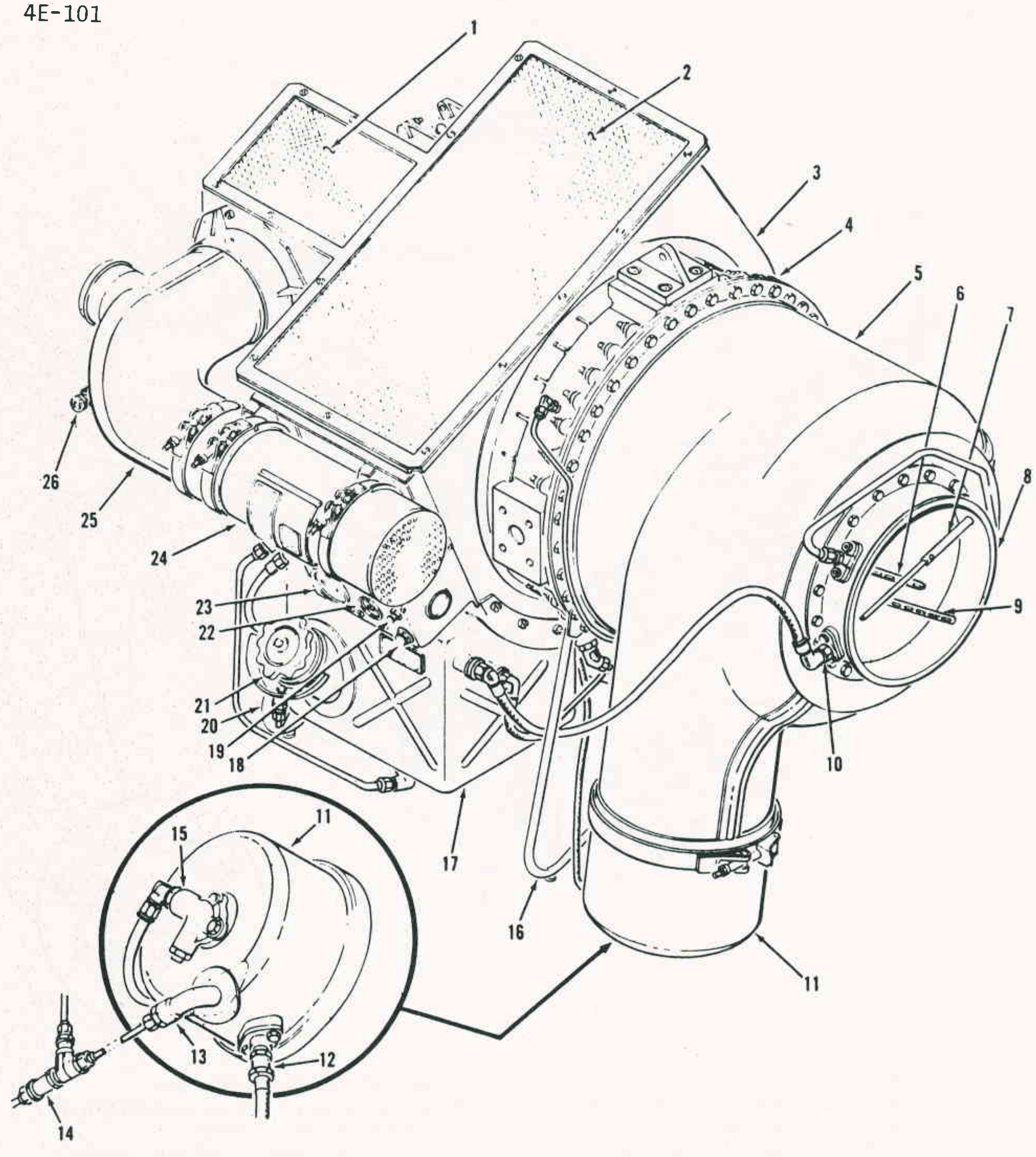
Figure 5-26

4E-101



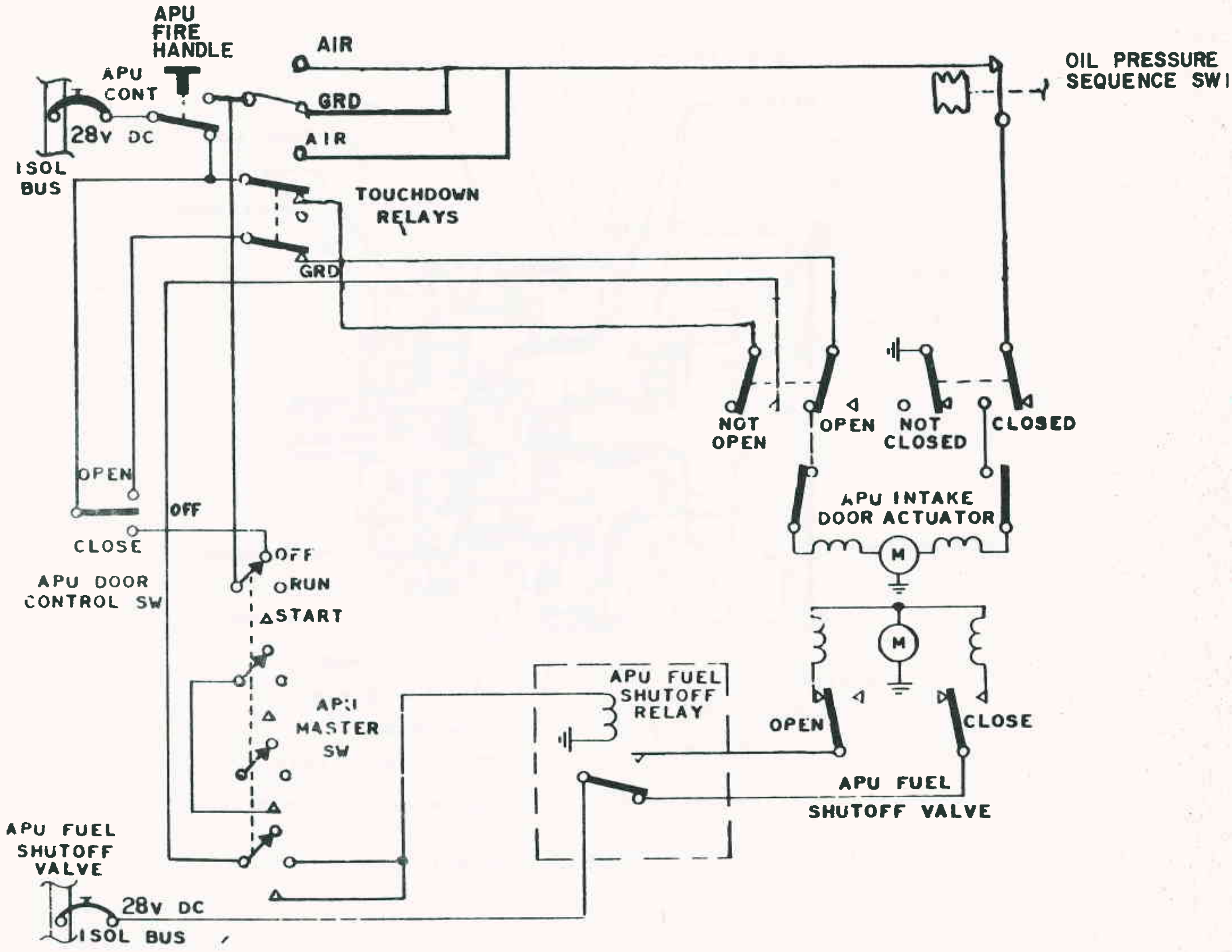

1. TURBINE PLENUM ASSY
2. COMPRESSOR AND TURBINE ASSY
3. COMPRESSOR AIR INLET SCREEN
4. PLANETARY GEAR HOUSING ASSY
5. COOLING AIR INLET SCREEN
6. STARTER MOTOR ADAPTER ASSY
7. FAN COOLING AIR DISCHARGE PIPE ASSY
8. CENTRIFUGAL SWITCH OVERSPEED TRIP BUTTON
9. ACCESSORY DRIVE SECTION
10. OIL PRESSURE SEQUENCING SWITCH
11. OIL TEMPERATURE SWITCH
12. OIL PUMP ASSY
13. FRONT SUPPORT ASSY
14. LOW OIL PRESSURE SWITCH
15. FUEL SHUTOFF SOLENOID VALVE
16. FUEL CONTROL UNIT
17. ACCELERATION LIMITER SOLENOID VALVE AND ADJUSTABLE ORIFICE
18. MOUNTING BRACKET ASSY
19. HYDRAULIC STARTER MOTOR/PUMP DRIVE DRAIN FITTING
20. FUEL METERING CONTROL DRAIN FITTING
21. TACHOMETER-GENERATOR CONNECTION RECEPTACLE
22. FUEL INLET FITTING
23. ENGINE CONTROL CONNECTION RECEPTACLE
24. OIL TANK SCUPPER DRAIN FITTING
25. COMBUSTOR FUEL DRAIN FITTING
26. EXHAUST GAS TEMPERATURE RECEPTACLE
27. REAR SUPPORT ASSY
28. OIL TEMPERATURE RELAY
29. LOW OIL PRESSURE PROTECTION RELAY (HR 2)
30. ENGINE CONTROL RELAY (HR 1)
31. COMPRESSOR INLET PLENUM ASSY
32. PNEUMATIC SHUTOFF BUTTERFLY VALVE
33. WIRING HARNESS ASSY

Figure 5-27



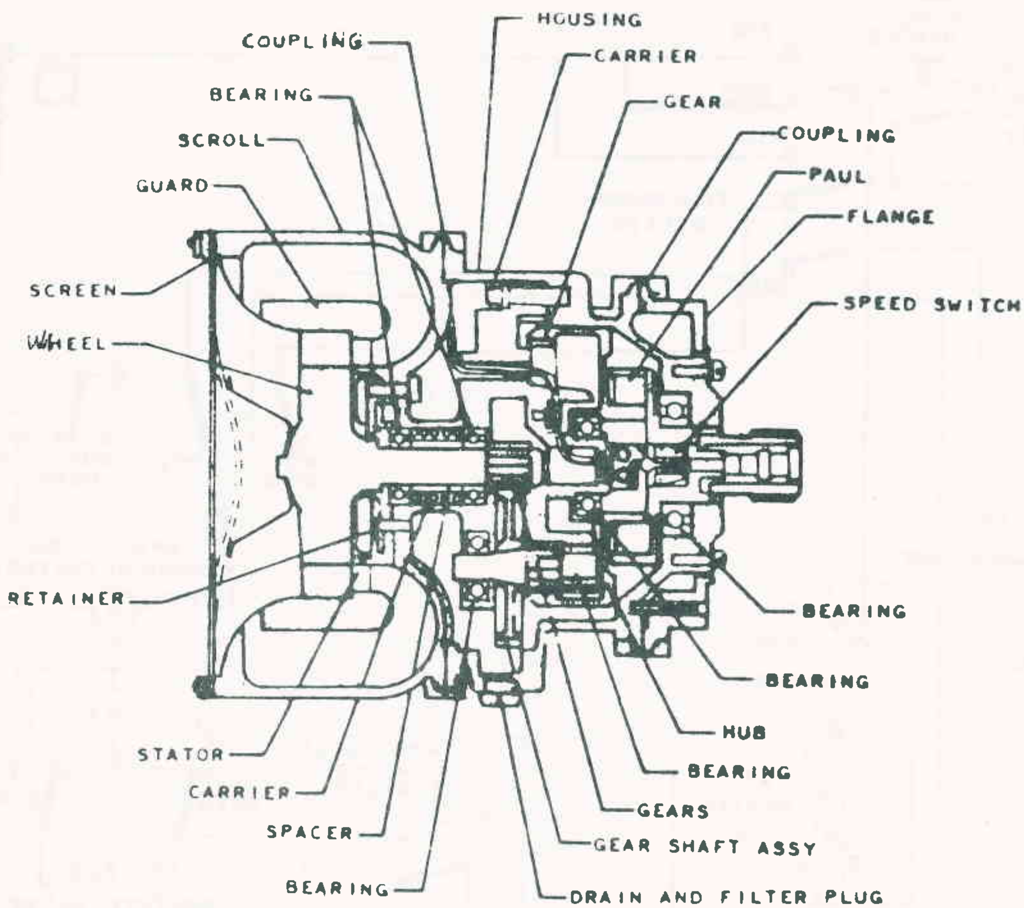

1. COOLING AIR INLET SCREEN
2. COMPRESSOR AIR INLET SCREEN
3. COMPRESSOR INLET PLENUM ASSY
4. COMPRESSOR AND TURBINE ASSY
5. TURBINE PLENUM ASSY
6. LOAD CONTROL THERMOSTAT
7. THERMOCOUPLE
8. TURBINE DISCHARGE FLANGE
9. ACCELERATION AND OVERTEMPERATURE CONTROL THERMOSTAT
10. OIL TANK VENT FLANGE
11. COMBUSTOR CAP ASSY
12. IGNITOR PLUG
13. DRAIN FITTING
14. DRAIN CHECK VALVE
15. FUEL ATOMIZER ASSY
16. REAR SUPPORT ASSY
17. OIL TANK ASSY
18. OVERSPEED TEST LIGHT
19. CIRCUIT BREAKER
20. FRONT SUPPORT ASSY
21. OIL TANK FILLER CAP
22. START COUNTER
23. TIME TOTALIZING METER
24. OIL COOLER ASSY
25. FAN COOLING AIR DISCHARGE PIPE ASSY
26. CENTRIFUGAL SWITCH OVERSPEED TRIP BUTTON

Figure 5-28



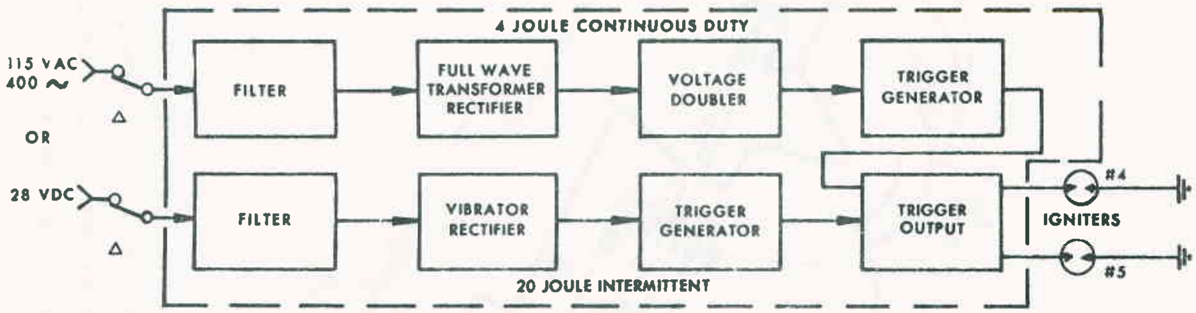

APU VALVE FUEL CONTROL

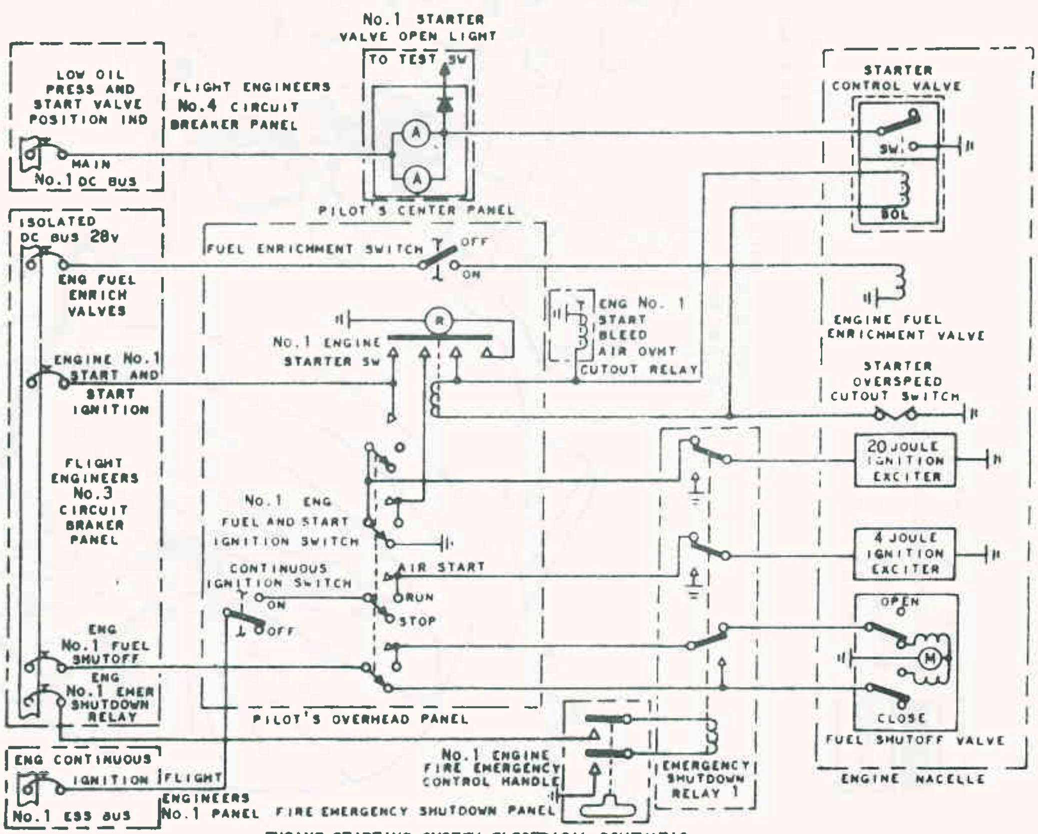
Figure 5-29




STARTER SCHEMATIC

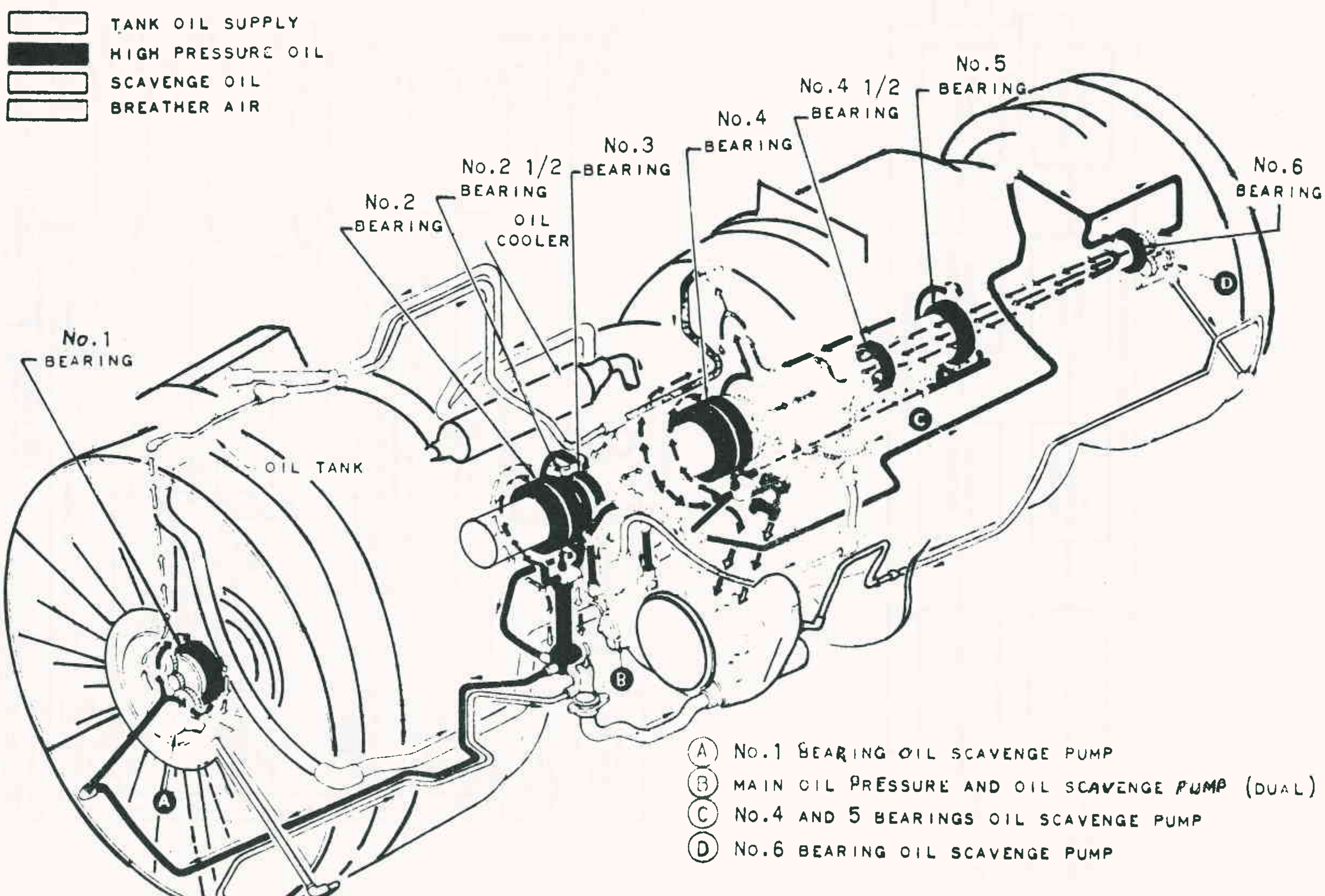
Figure 5-30



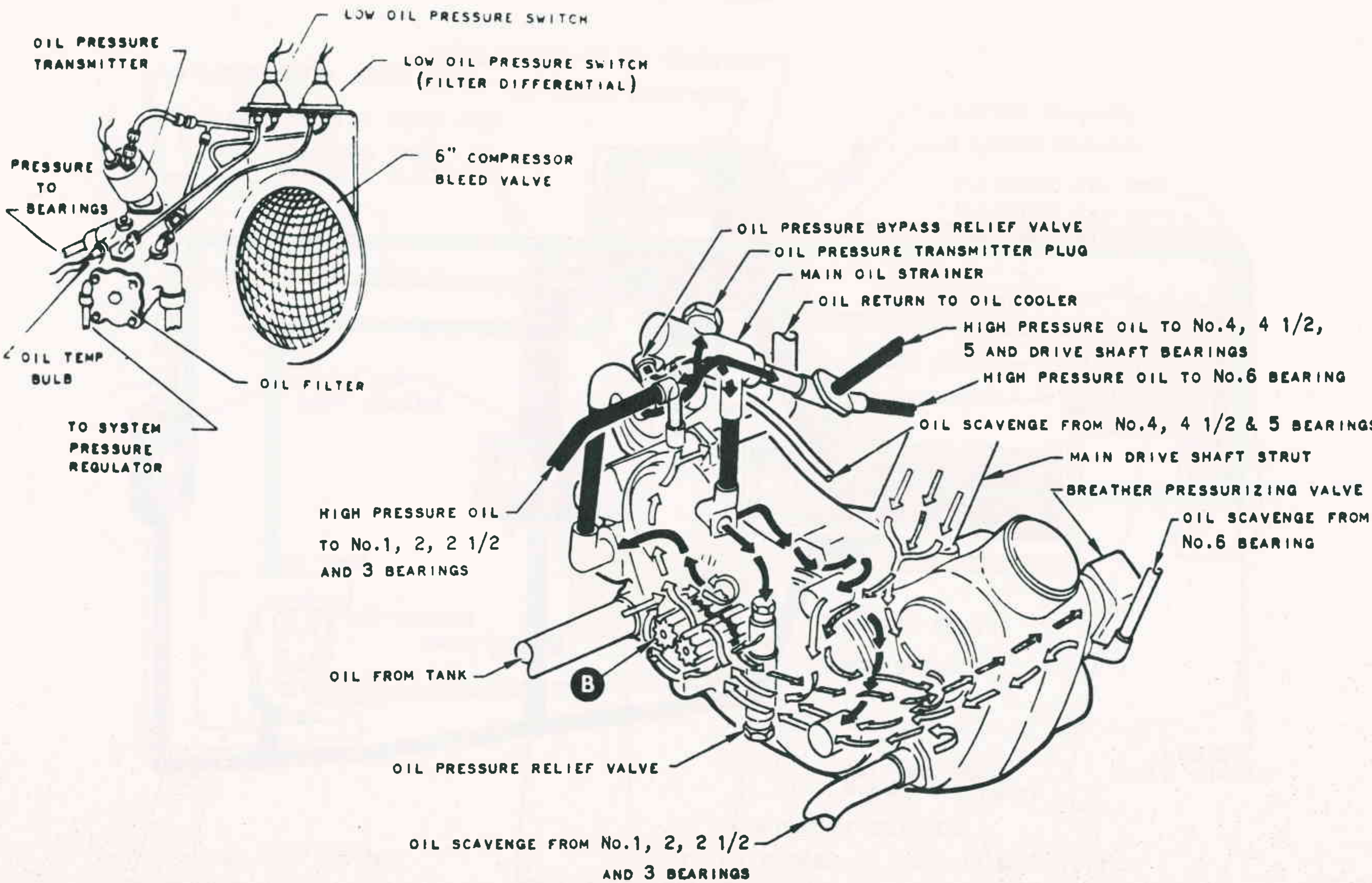

ENGINE STARTING SYSTEM ELECTRICAL SCHEMATIC

Figure 5-31



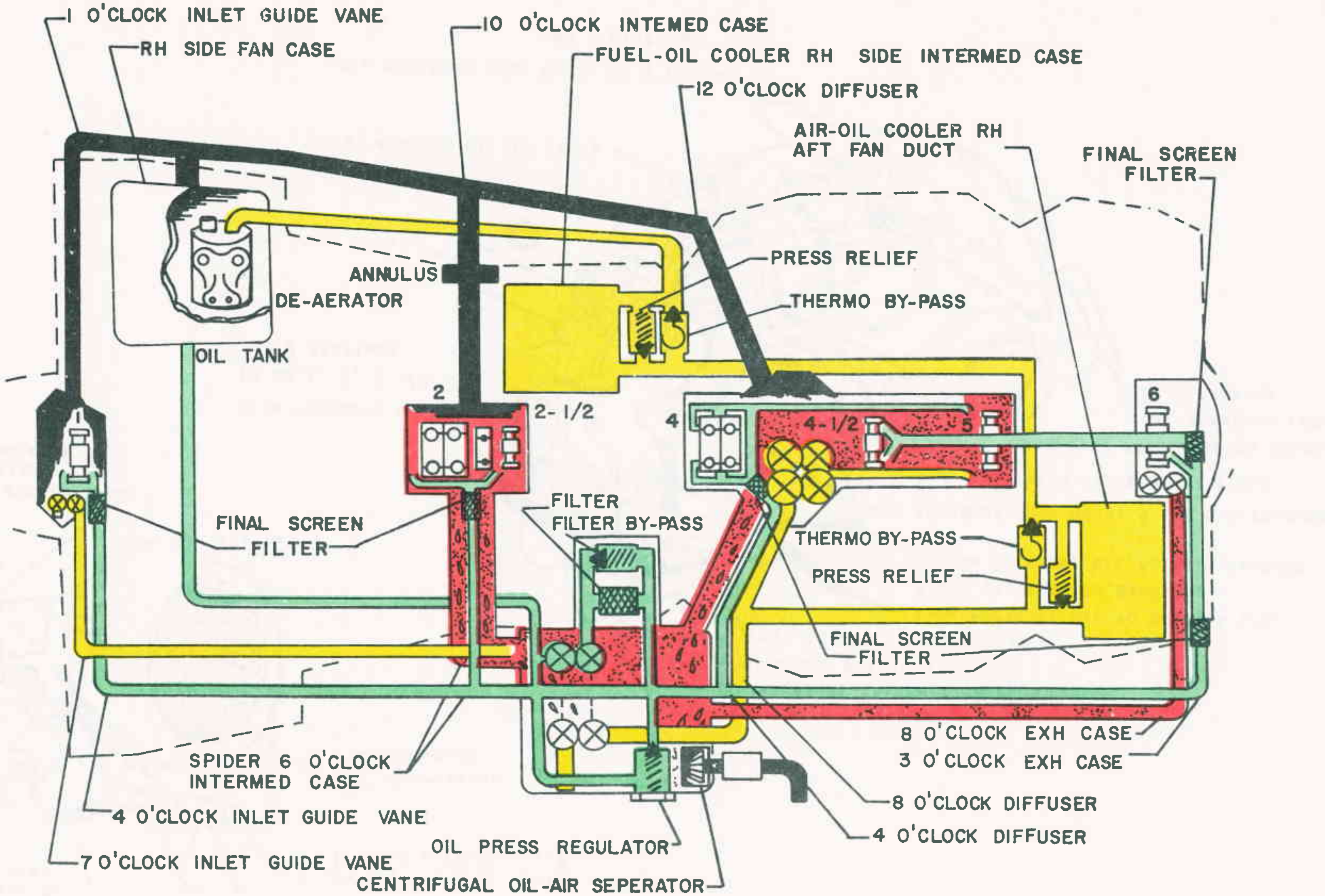

ENGINE OIL SYSTEM

Figure 5-32



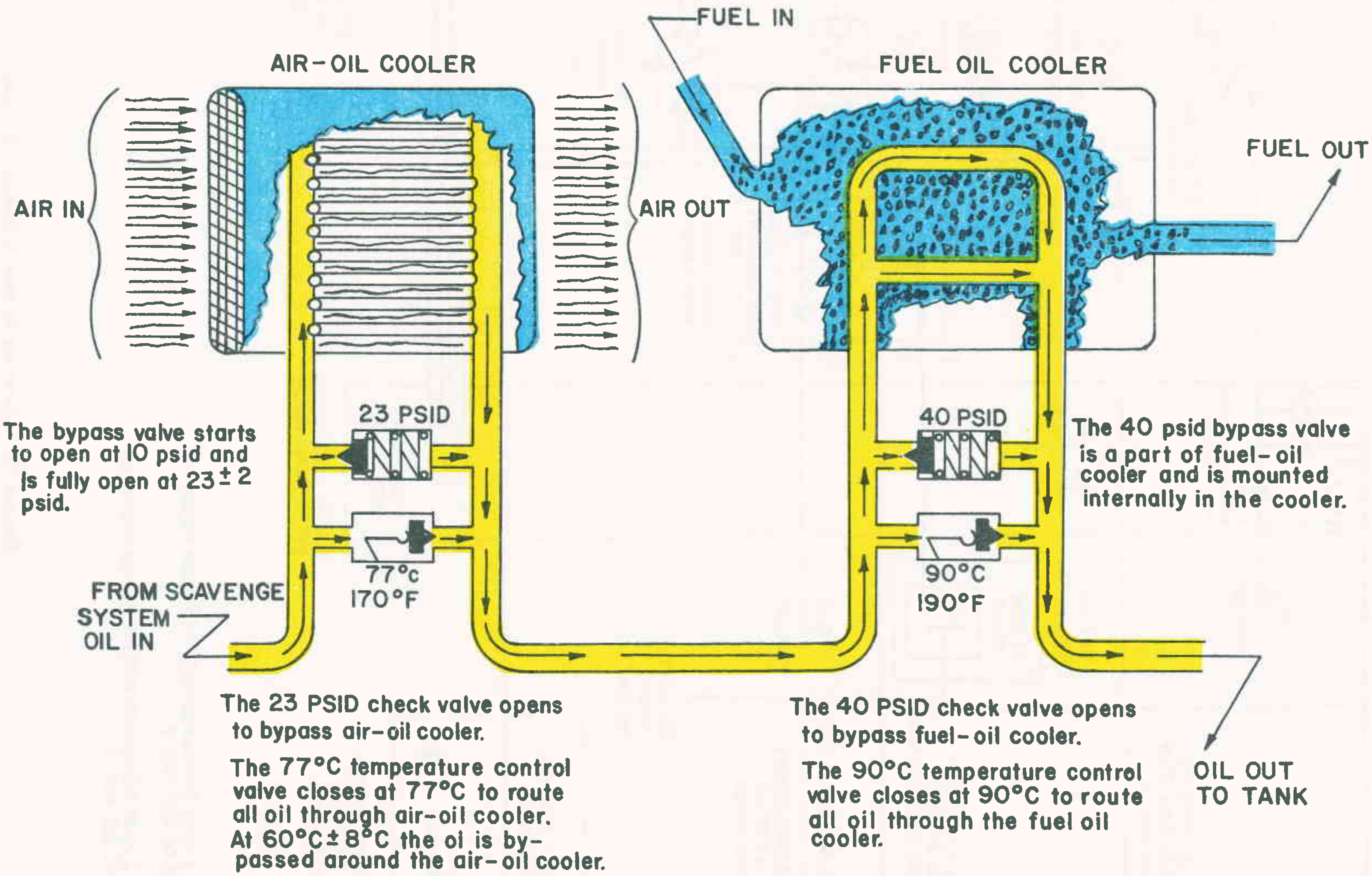

OIL SYSTEM SCHEMATIC

Figure 5-33



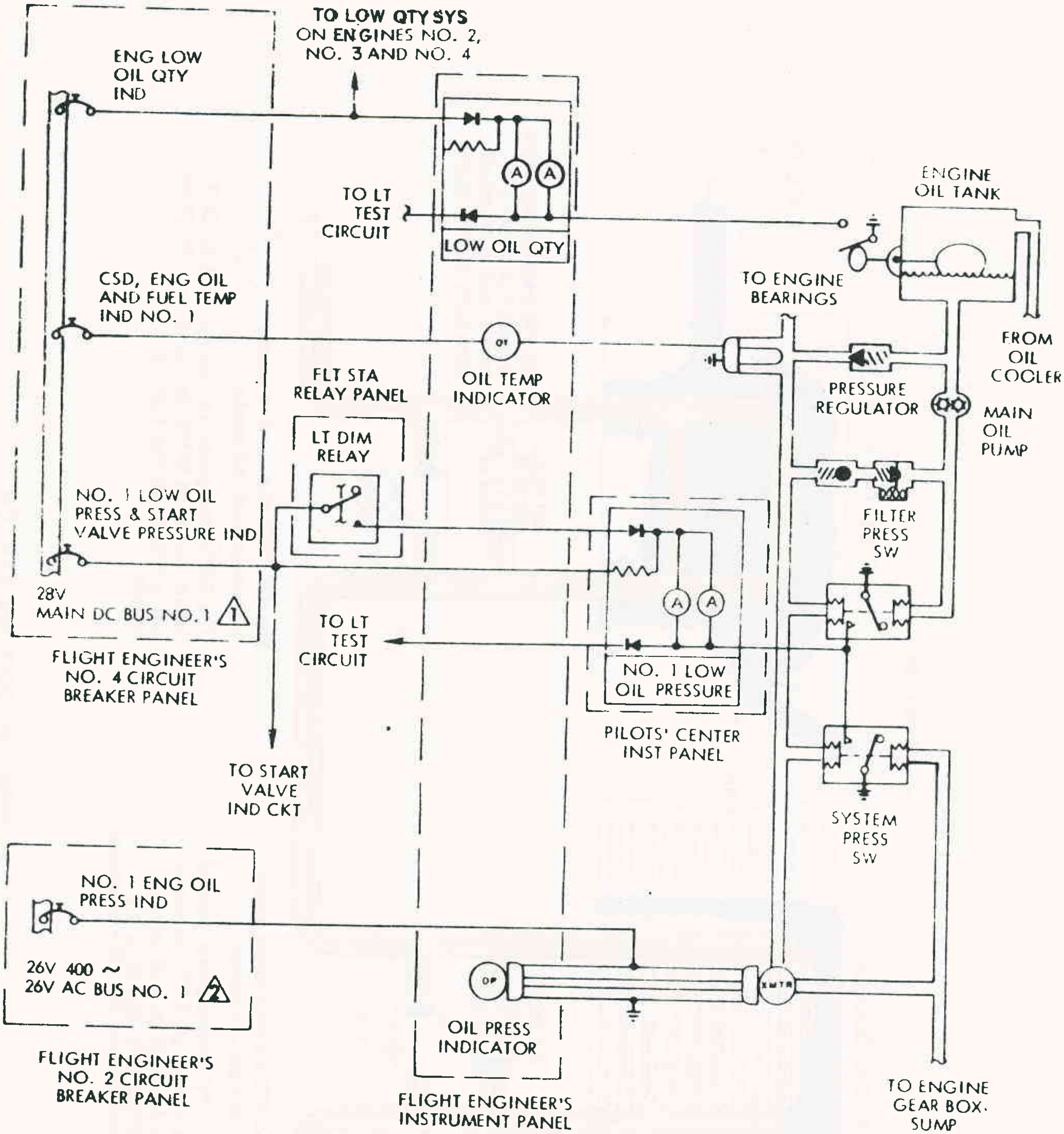

VENT SYSTEM

Figure 5-34




C-141A ENGINE OIL COOLING SYSTEM

Figure 5-35




**NOTE**

⚠1 NO. 2 AND 3 ENGINES RECEIVE POWER FROM THE MAIN DC BUS NO. 2

⚠2 NO. 2 AND 3 ENGINES RECEIVE POWER FROM THE 26V AC BUS NO. 2

***Engine Oil Indicating System Schematic Diagram***

Figure 5-36

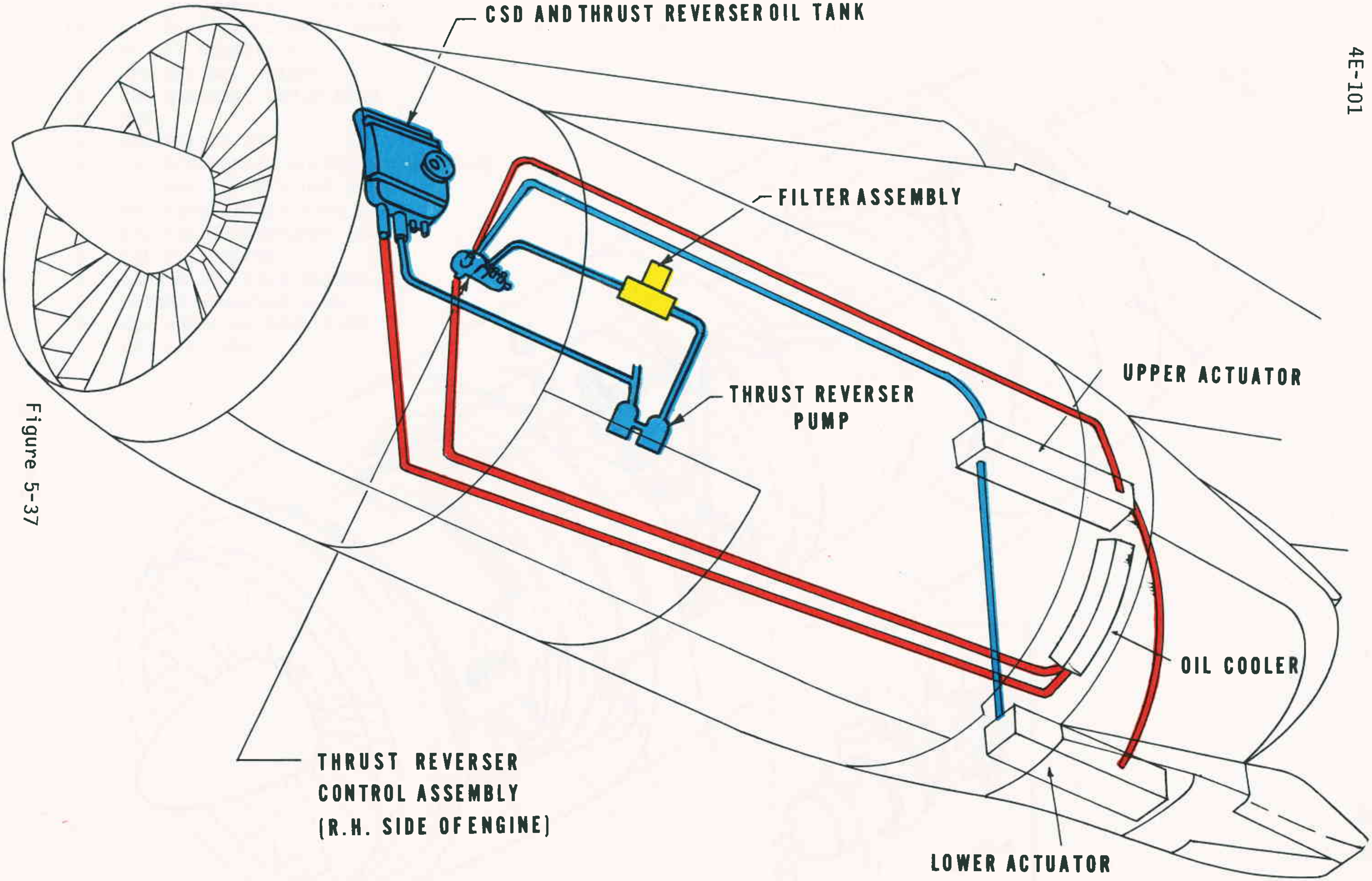
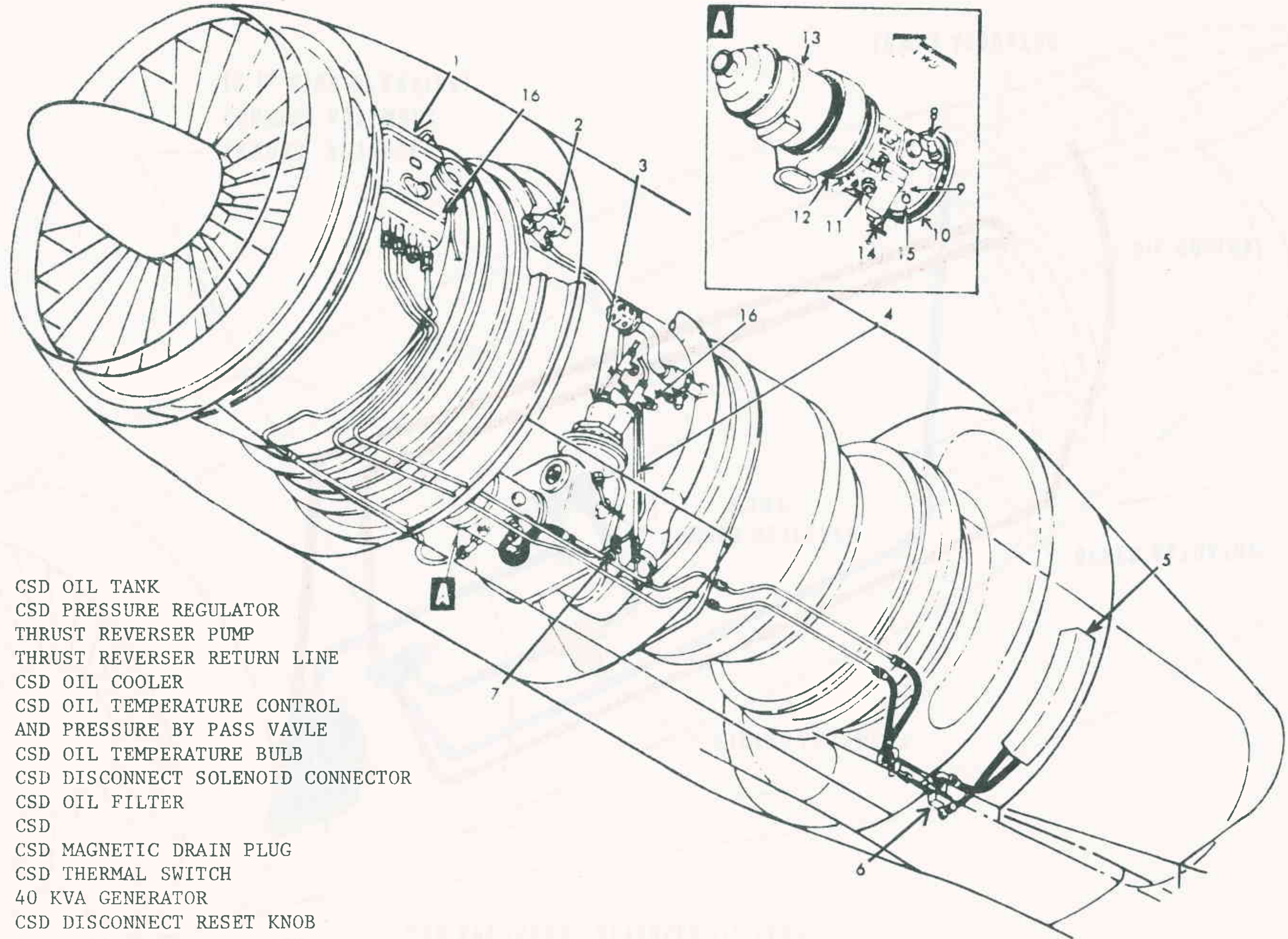

CSD AND THRUST REVERSER OIL TANK
FILTER ASSEMBLY
UPPER ACTUATOR
THRUST REVERSER PUMP
OIL COOLER
THRUST REVERSER CONTROL ASSEMBLY (R.H. SIDE OF ENGINE)
LOWER ACTUATOR

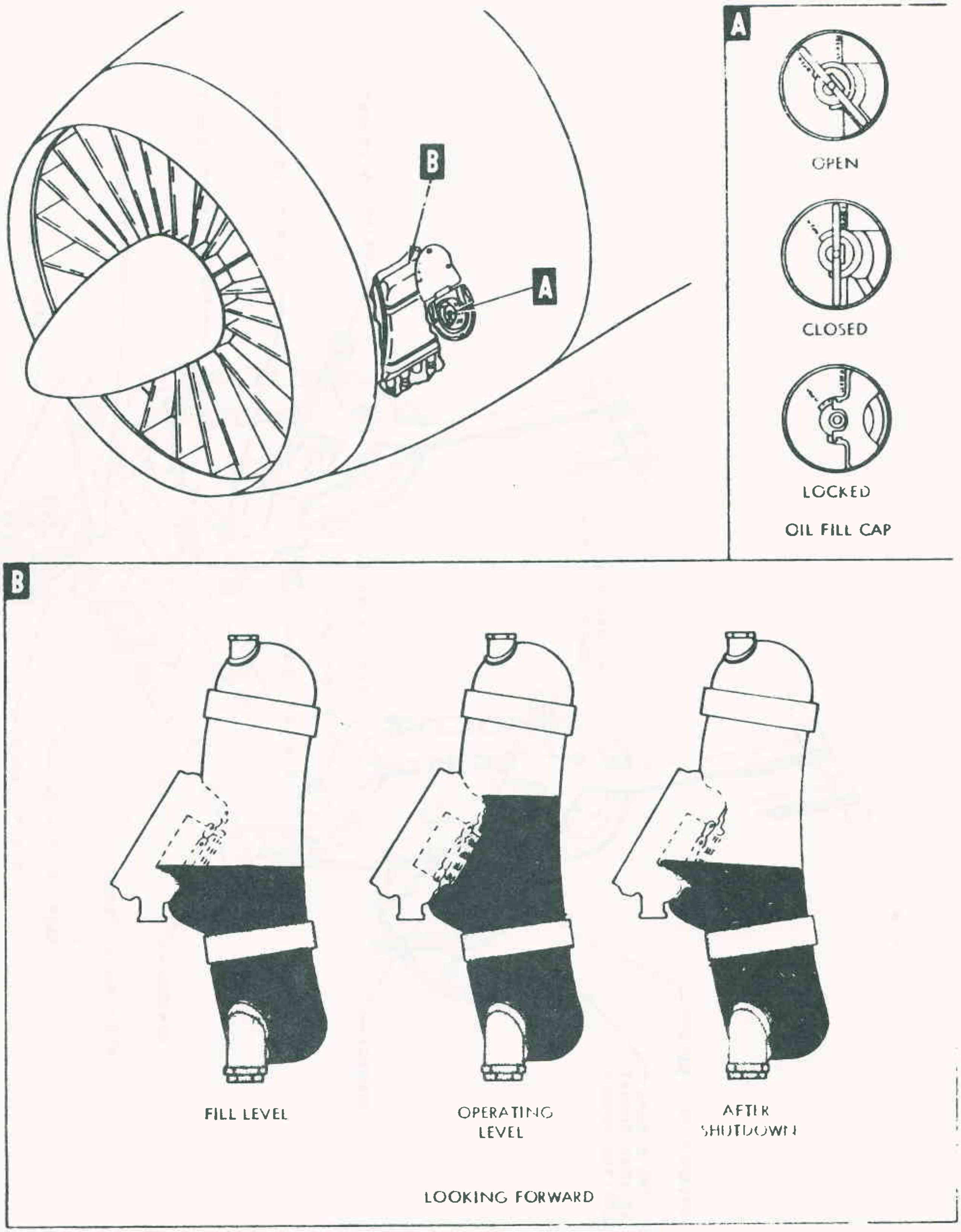
Figure 5-37




1. CSD OIL TANK
2. CSD PRESSURE REGULATOR
3. THRUST REVERSER PUMP
4. THRUST REVERSER RETURN LINE
5. CSD OIL COOLER
6. CSD OIL TEMPERATURE CONTROL AND PRESSURE BY PASS VAVLE
7. CSD OIL TEMPERATURE BULB
8. CSD DISCONNECT SOLENOID CONNECTOR
9. CSD OIL FILTER
10. CSD
11. CSD MAGNETIC DRAIN PLUG
12. CSD THERMAL SWITCH
13. 40 KVA GENERATOR
14. CSD DISCONNECT RESET KNOB
15. CSD DISCONNECT OIL DRAIN
16. TEST STAND COUPLINGS

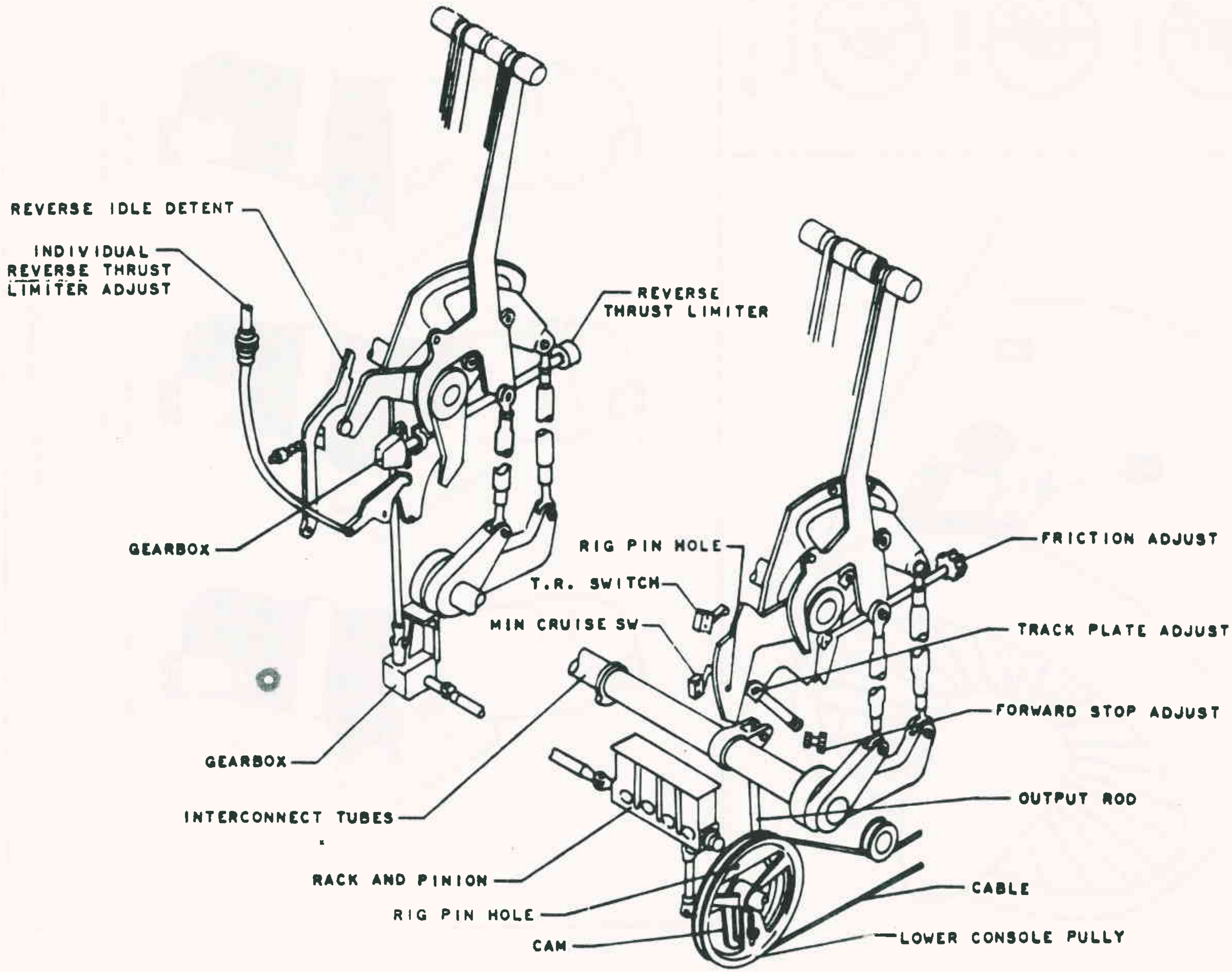
**CSD System Compoi ents Locations**

Figure 5-38



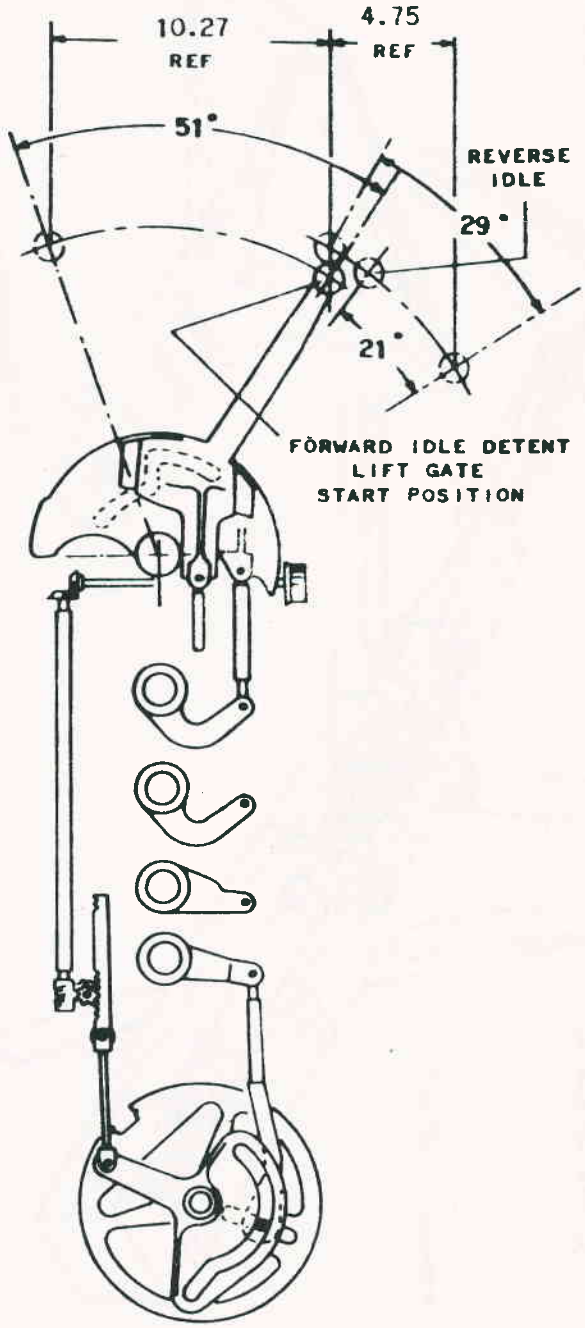

***CSD Oil Tank Servicing***

Figure 5-39



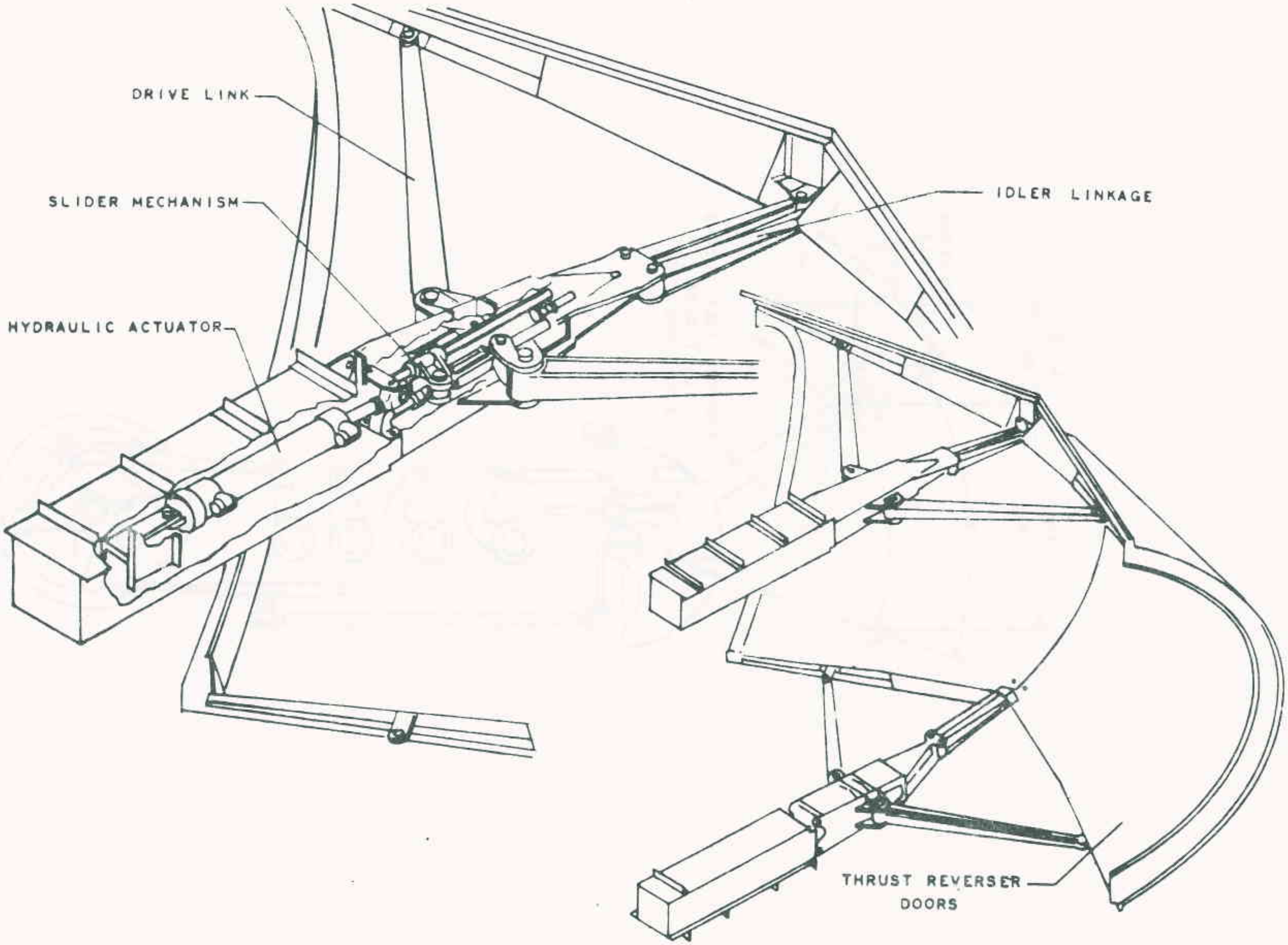

PILOT'S AND COPILOT'S THROTTLE

Figure 5-40



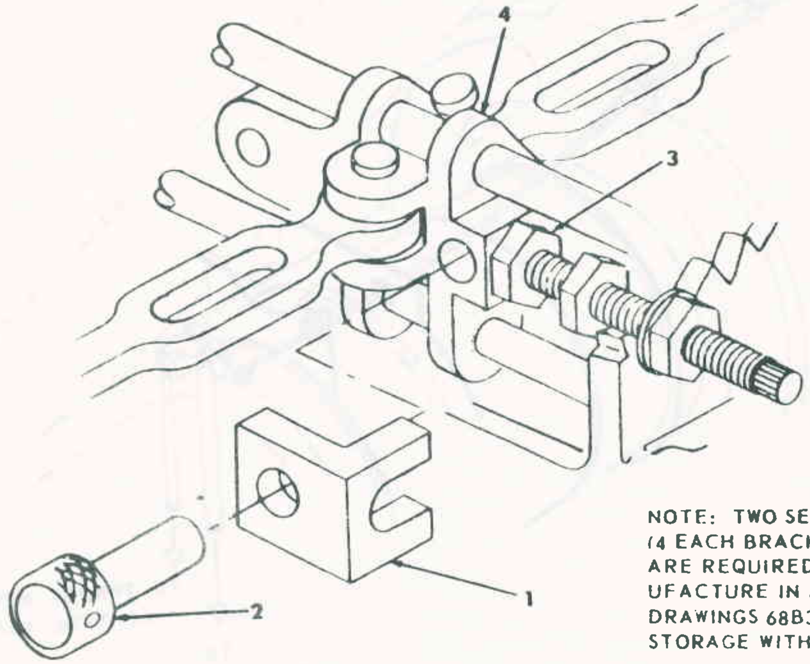

THRUST REVERSER LIMITER

Figure 5-41




THRUST REVERSER DOORS AND ACTUATORS

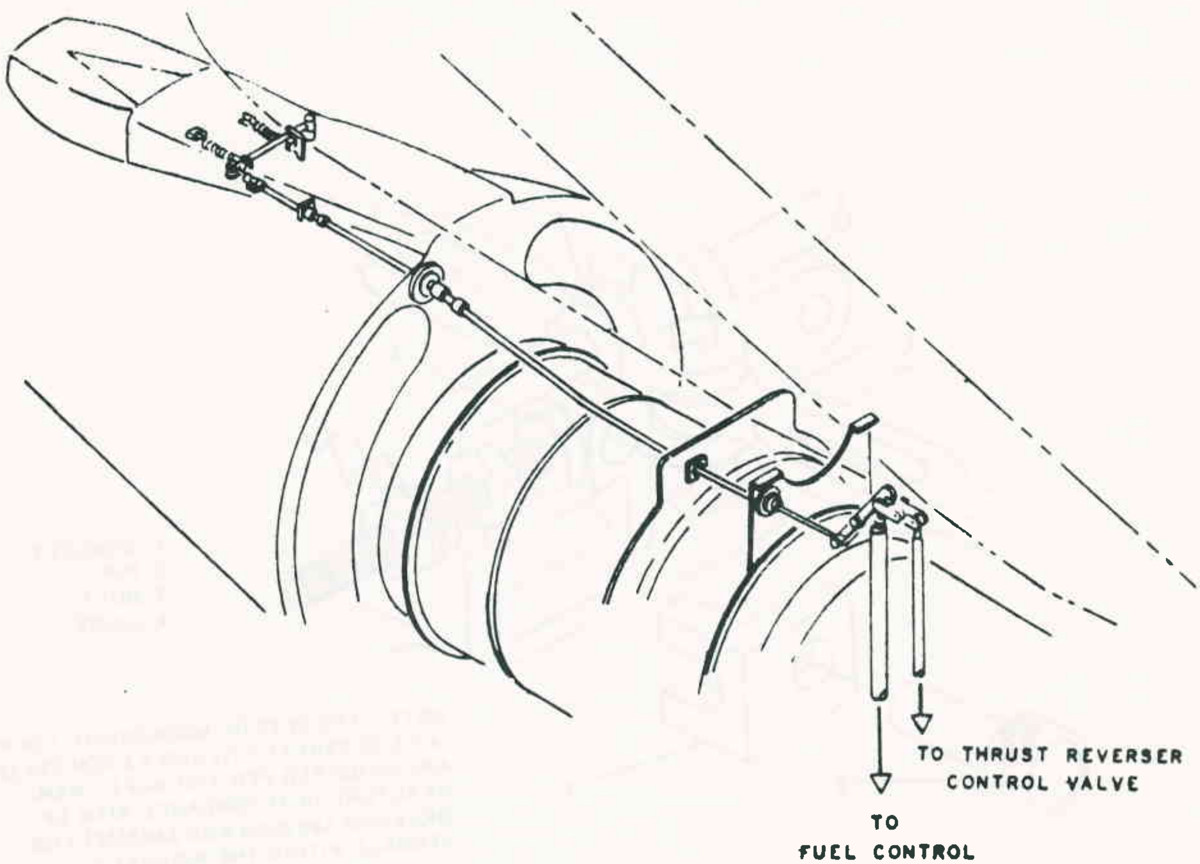
Figure 5-42




1. BRACKET
2. PIN
3. BOLT
4. GUIDE

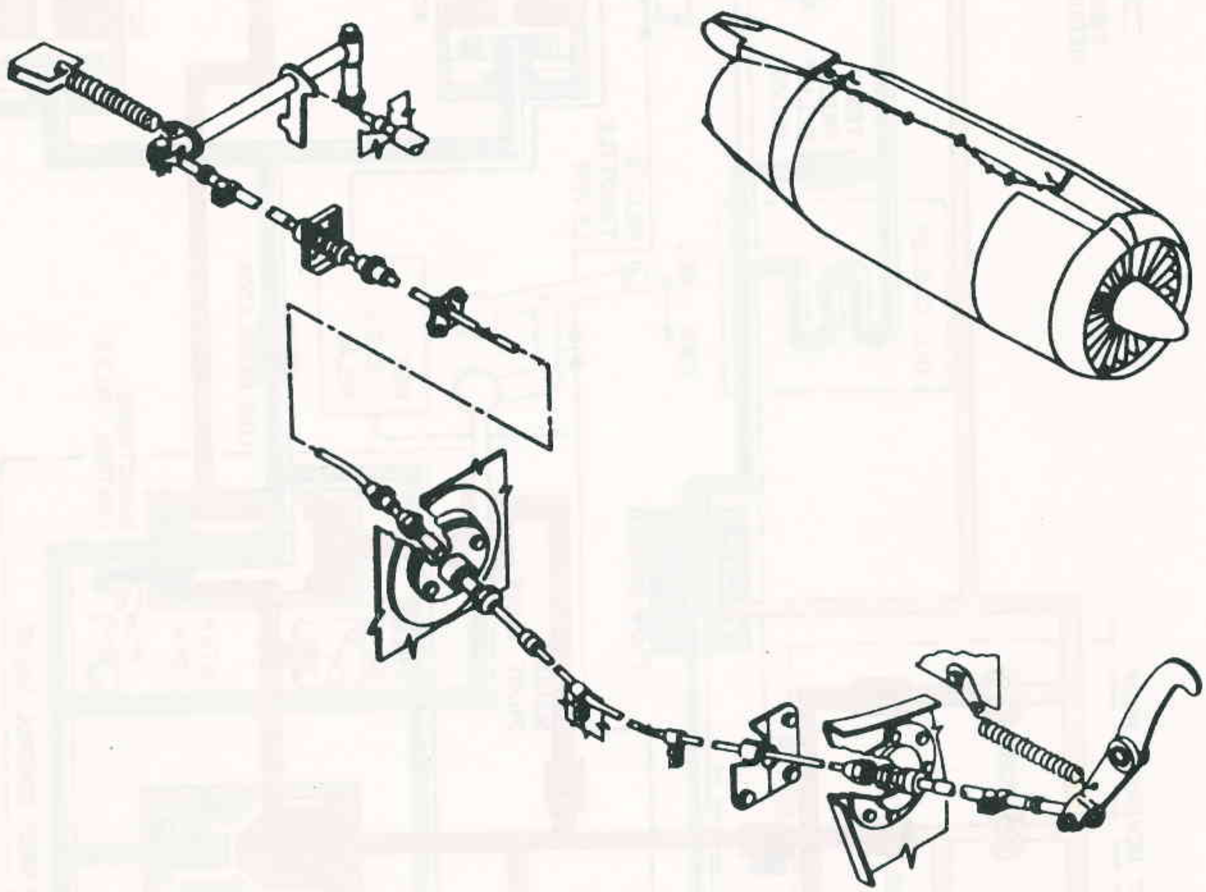
NOTE: TWO SETS OF MECHANICAL LOCKS (4 EACH BRACKET (1) AND 4 EACH PIN (2) ARE REQUIRED PER AIRCRAFT. MANUFACTURE IN ACCORDANCE WITH AF DRAWINGS 68B35580 AND 68B35581 FOR STORAGE WITHIN THE AIRCRAFT.

Figure 5-43



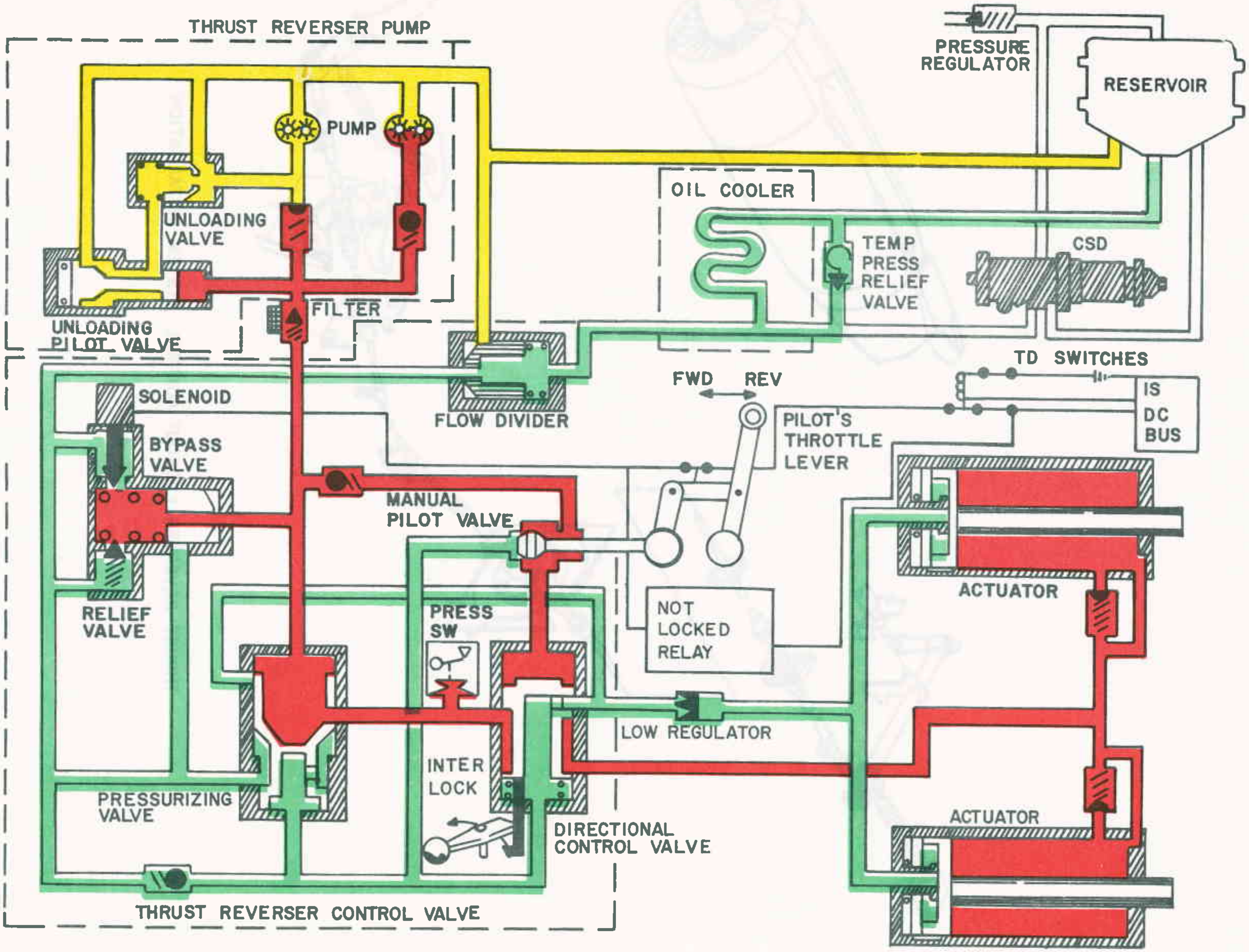

THRUST REVERSER MECHANICAL LOCKOUT

Figure 5-44



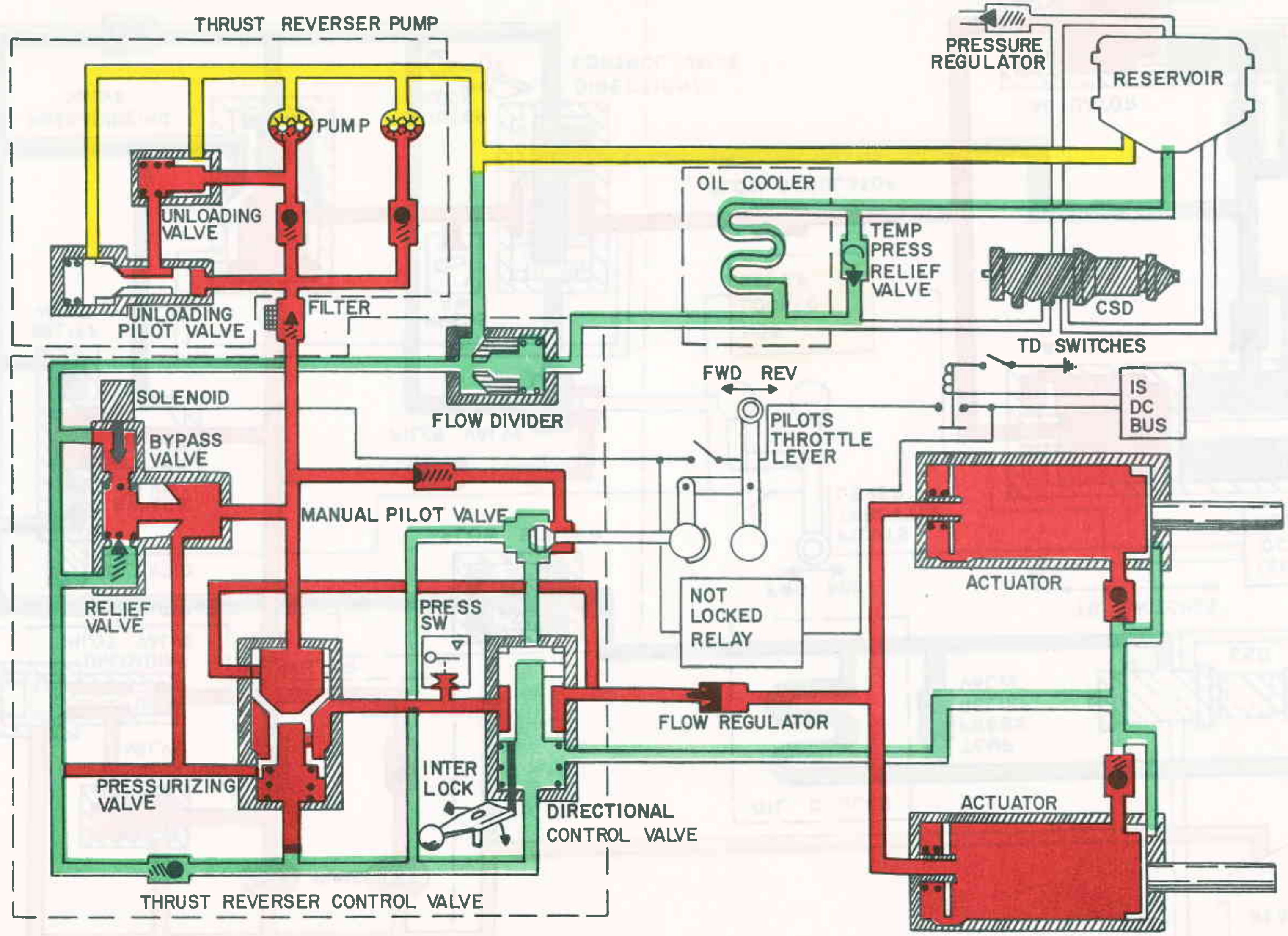
THRUST-REVERSER LOCKOUT CONTROL SYSTEM INSTALLATION

Figure 5-45



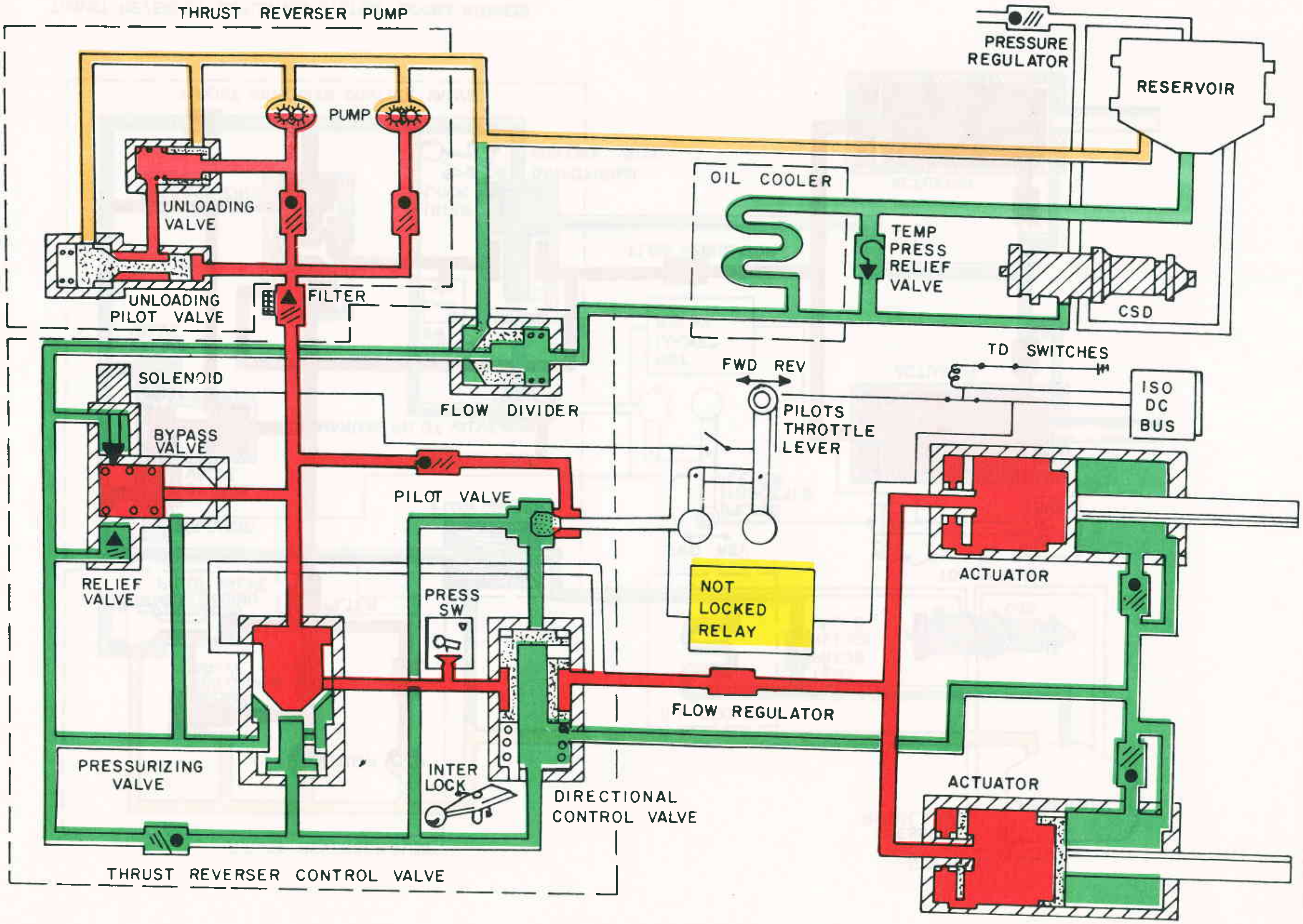

THRUST REVERSER (EXTENDED)

Figure 5-46




THRUST REVERSER ACTUATION SYSTEM (DOORS STOWED)

Figure 5-47




THRUST REVERSER CLOSING

Figure 5-48

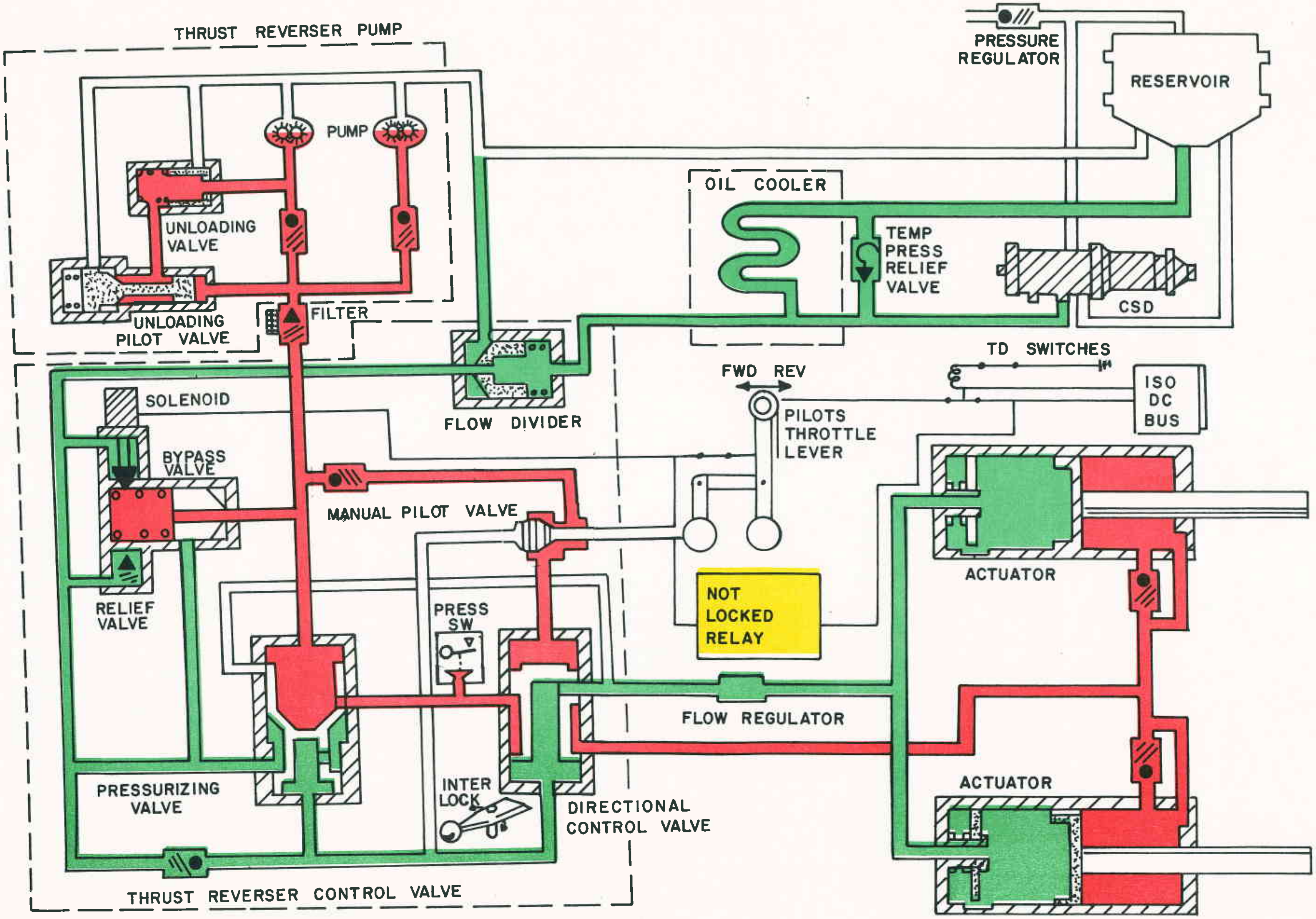



Figure 5-49

THRUST REVERSER OPENING