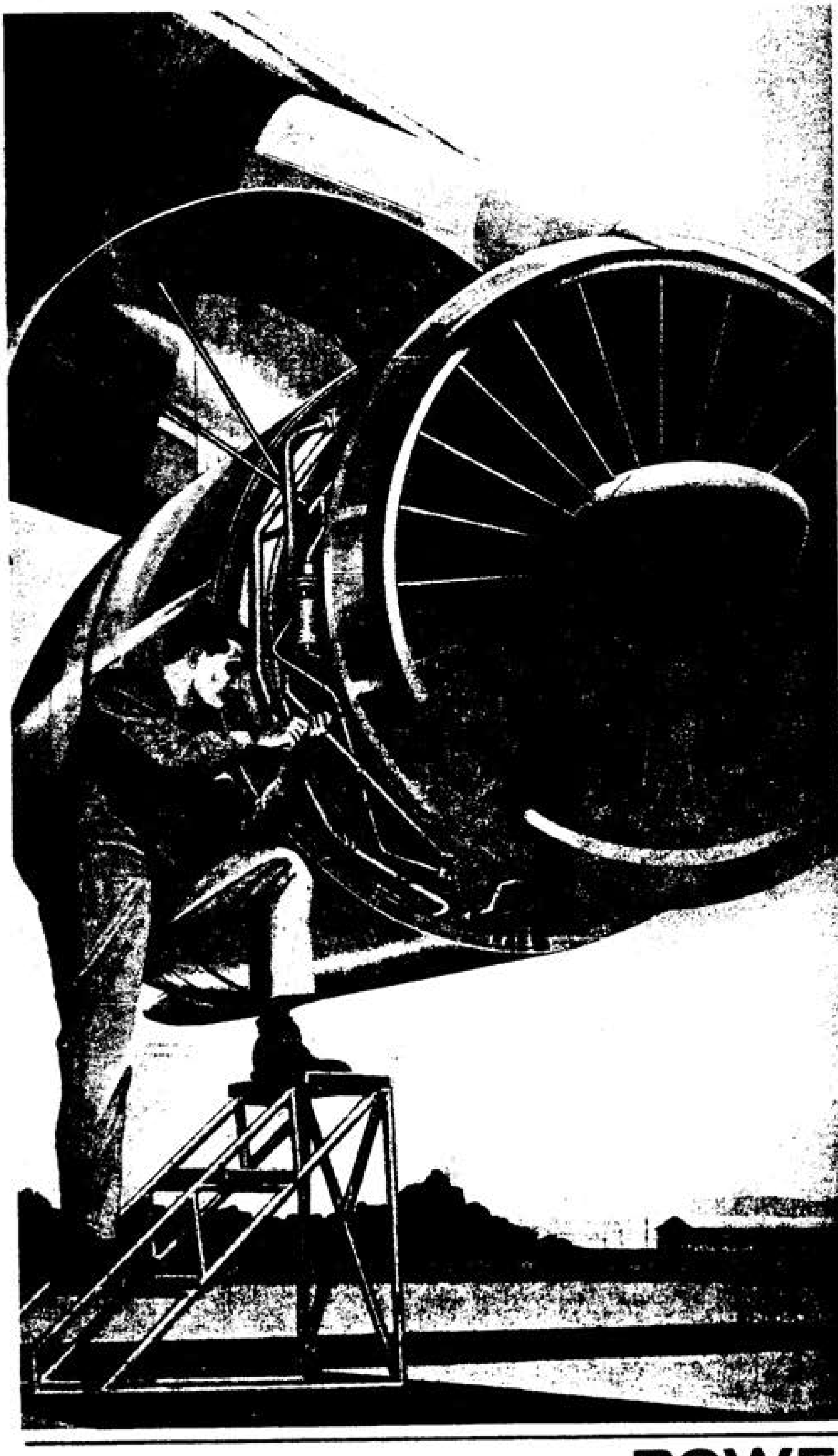
STARLIFTER TRAINING MANUAL • VOLUME II



POWER PLANT

Customer Training Department • Lockheed – Georgia Company • Marietta, Georgia 30060

VOLUME II

POWER PLANT

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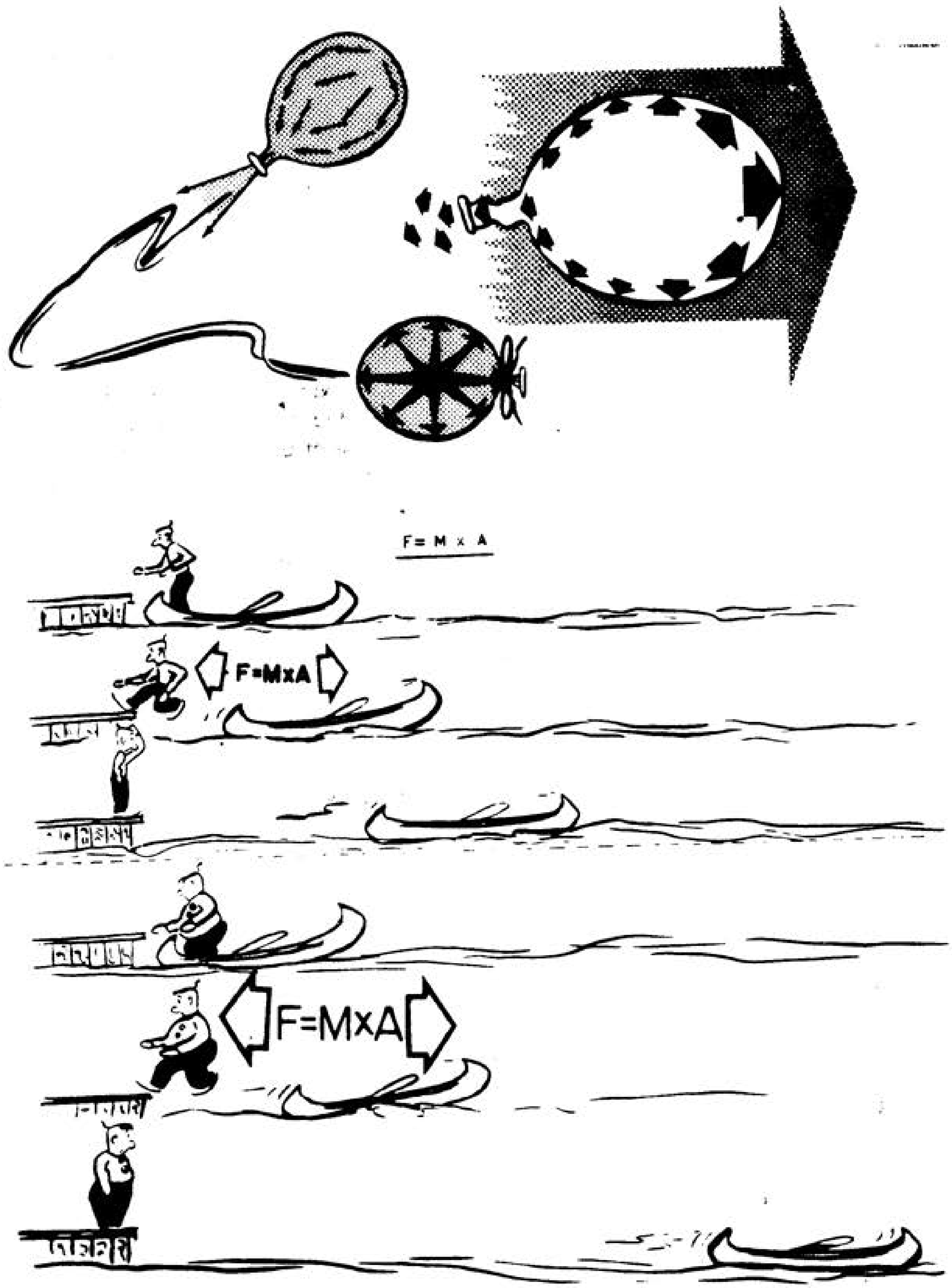
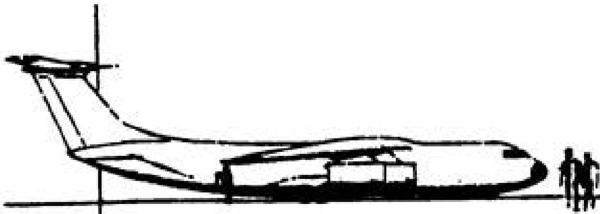


JET PROPULSION



FUNDAMENTALS OF JET PROPULSION

INTRODUCTION.

Down through the pages of aviation history many ideas have been advanced on the possibility of adapting the known principles of jet propulsion to aircraft. Devices depending upon this type of propulsion have been used for centuries either for instruments of war or for the amusement of man. The basic principles of jet propulsion, therefore, are not new.

In the late 1600's, Sir Issac Newton developed the laws of motion which account for the principles by which all reaction engines operate. The basic principles common to jet propulsion are expressed in Newton's second and third laws of motion.

The second law states,

> An unbalanced force acting on a body causes the body to accelerate in the direction of the force, and the acceleration is directly proportional to the unbalanced force and inversely proportional to the mass of the body.

Stated mathematically, the law may be written as

$$F = M A$$

where

F = force

M = mass

A = acceleration.

It is only logical, then, that of two identical objects, the one acted upon by the larger force experiences the greater acceleration. Again, if equal forces can be applied to objects of unequal mass (weight), unequal rates of acceleration result and the lighter object receives the greater acceleration.

Newton's third law states,

> For every action (force), there is an equal and opposite reaction.

The term "action" (or force) means the force one body exerts on a second body, while reaction force means the force the second exerts on the first. There can never be a force acting in nature unless two bodies are involved, one exerting the force and one on which the force is exerted. The second law indicates the magnitude of thrust and the third law explains why thrust is obtained from the ejection of mass through a nozzle. A given thrust forward can be produced by ejecting rearward either a large mass of material at low velocity during a given period of time, or a smaller mass of material at higher velocity in the same time period.

These facts can be demonstrated with a toy balloon that has been inflated. As long as the stem is kept closed, the air inside the balloon exerts static pressure. This means the pressure is pushing out in all directions with equal force. If the stem is released, there is less force pushing on the stem side of the balloon than on the opposite side. The larger force moves the balloon in the direction opposite the stem. The movement is erratic because the nozzle is not stabilized in any direction. If a supply of air could be stored under pressure in the balloon, the balloon would continue to move. Basically, that is what happens in gas turbine engines.

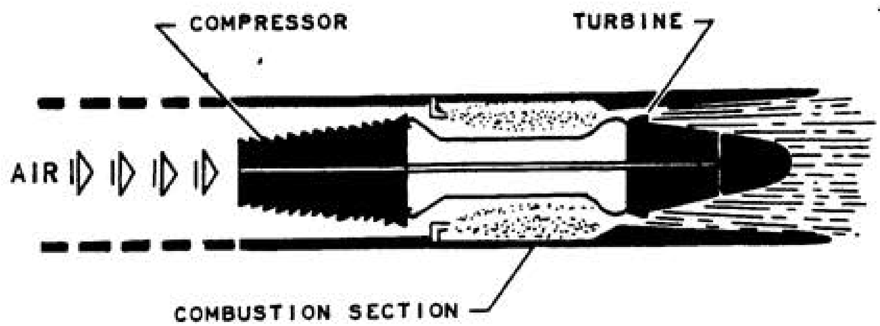
During operation, the gas turbine engine draws in air and compresses it. Fuel is added to the compressed air and then ignited. The rapid release of energy is accomplished by a process of combustion. Energy (in the form of heat) is transferred to the air passing through the engine to create the force necessary to accelerate the airflow. Thrust, then, is the reaction of the acceleration of the mass of air and burning gases.

TURBOJET ENGINE OPERATION.

The basic gas turbine engine is made up of three primary sections: the compressor section, the combustion section, and the turbine section. Atmospheric air is drawn through the engine air inlet into a compressor which increases the pressure many times above atmospheric value. Theoretically, the greater the mass of air inducted, the greater is the thrust produced by the engine. The increase in air pressure ratios, however, is limited by compressor efficiency.

From the compressor the air enters the combustion chamber where a portion of it is mixed with fuel injected into the combustion chambers through spray nozzles. The release of the heat energy of the fuel causes the air to expand.

The heated gases accelerate toward the rear and enter the turbine section at high velocity. A part of the energy of the gasses is transformed by the turbine into mechanical energy to drive the compressor and accessories.

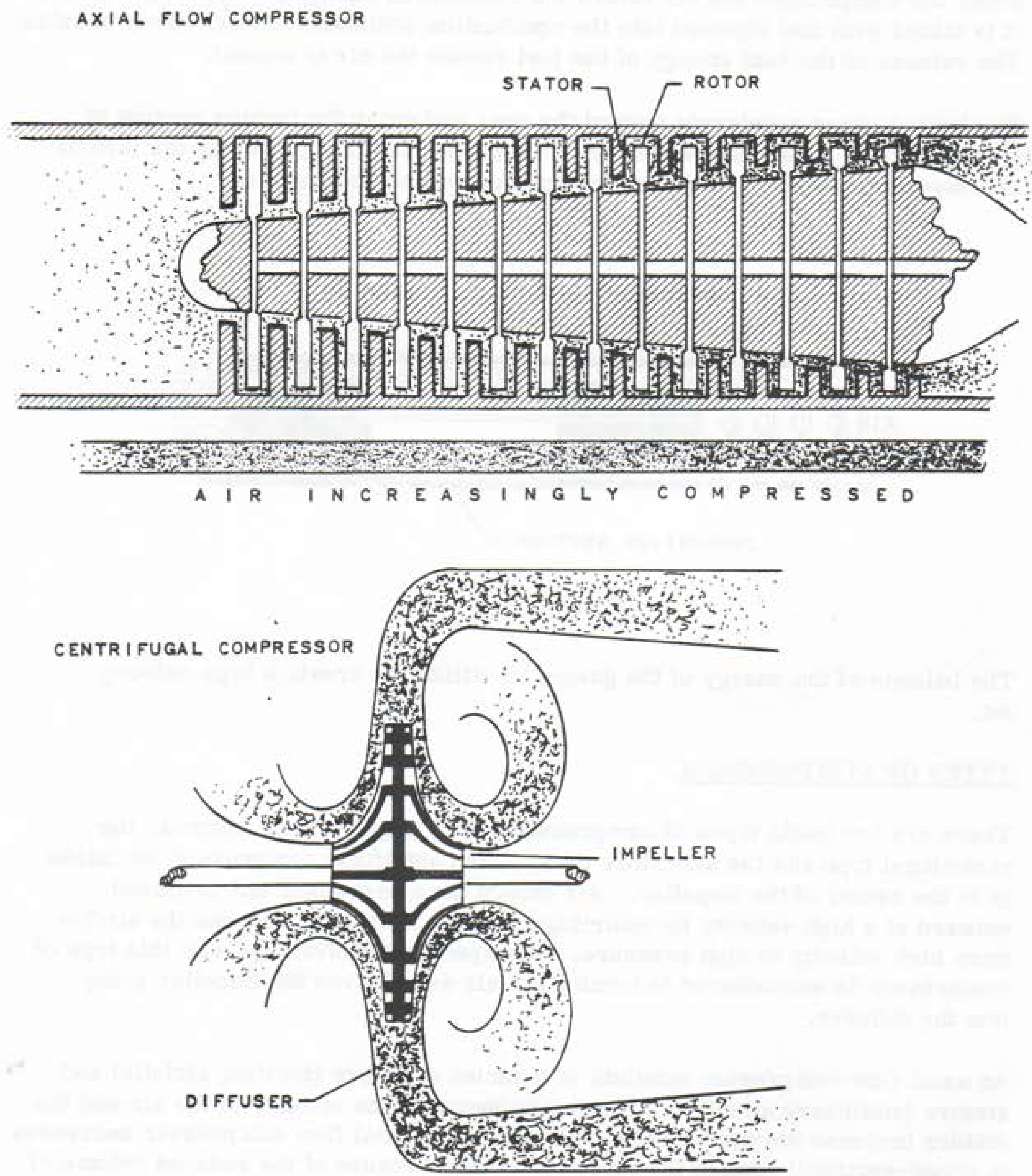


The balance of the energy of the gasses is utilized to create a high-velocity jet.

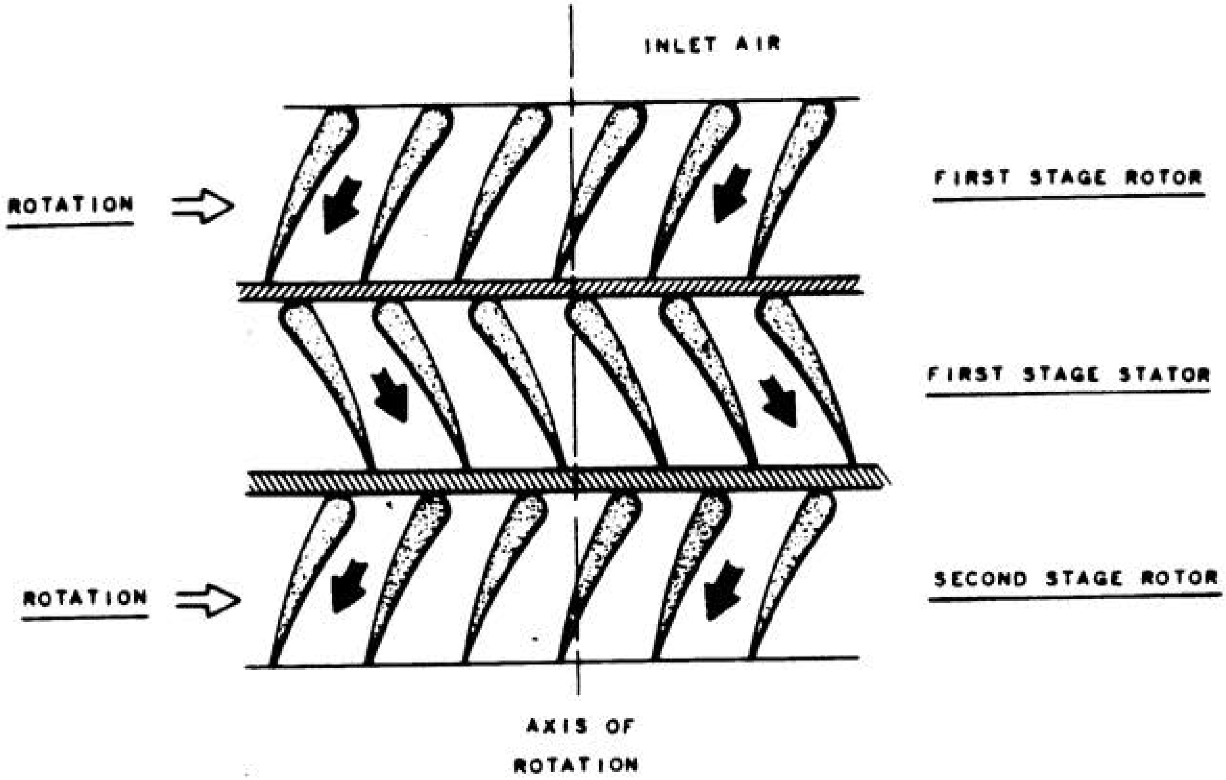
TYPES OF COMPRESSORS.

There are two basic types of compressors used in gas turbine engines, the centrifugal type and the axial flow type. The centrifugal compressor air intake is at the center of the impeller. Air enters the compressor and is moved outward at a high velocity by centrifugal force. A diffuser changes the airflow from high velocity to high pressure. The specific disadvantage with this type of compressor is encountered in turning the air as it leaves the impeller going into the diffuser.

An axial flow compressor consists of a series of rotors (rotating airfoils) and stators (stationary airfoils). The rotors increase the velocity of the air and the stators increase the pressure by diffusion. The axial flow compressor decreases in cross-sectional area in the direction of flow because of the reduced volume of air as compression progresses from stage to stage.



TYPES OF COMPRESSORS



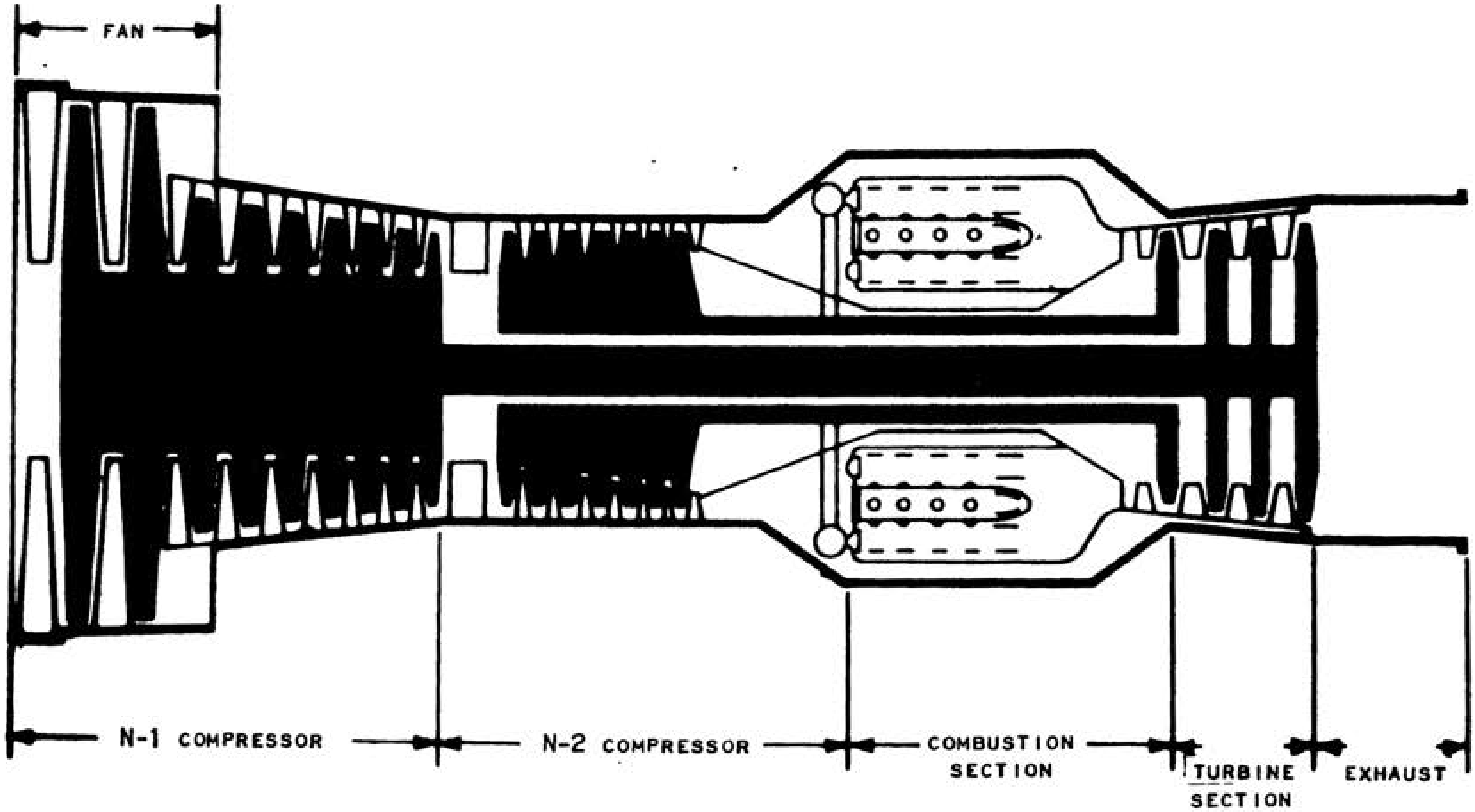
COMPRESSOR AIRFLOW

Dual-spool axial flow compressors operate on the same principles as single-spool axial compressors. The main advantage is that higher pressure ratios are attained with minimum total compressor weight and frontal area.

For example, if a single axial-flow compressor were built of as many stages as necessary to produce a required pressure ratio, at specific rotor speeds, the rearmost stages of the compressor would operate inefficiently, and the forward stages would be overloaded. This condition would produce compressor stall. Stalling could be prevented by unloading or bleeding air from the compressor, but this action would be excessively wasteful.

For greater compressor efficiency with high pressure ratios and with less weight, dual type compressors are used.

The high pressure compressor (N2) has shorter blades than the low pressure compressor (N1) and is lighter in weight. The N2 compressor rotor is speed-governed by fuelflow to the engine. With the N2 compressor turning at governed speed the N1 compressor is rotated by its turbine at whatever speed



TURBOFAN ENGINE

will ensure optimum airflow through the compressor. With the compressors working in harmony, increased pressure ratios are obtained without decreasing efficiency. The compressors also adjust themselves to lower power settings (fuel flows) with a minimum of interstage or compressor bleeding (unloading) to prevent stalls.

COMPRESSOR STALL.

There are many different types of compressor stall that can be experienced by turbojet engines. Compressor stall is the breakdown or interruption of airflow through the compressor. Since the compressor blades are tiny airfoils similar to those of an aircraft wing, stalls can occur when operating at too high an angle of attack. Any change or variation in airflow or distribution of airflow to the compressor will change the angle of attack on the blades and cause compressor stall. Examples of this are turbulence at the inlet of the engine, increased airflow into the engine, and abrupt and sharp changes in maneuvering the aircraft.

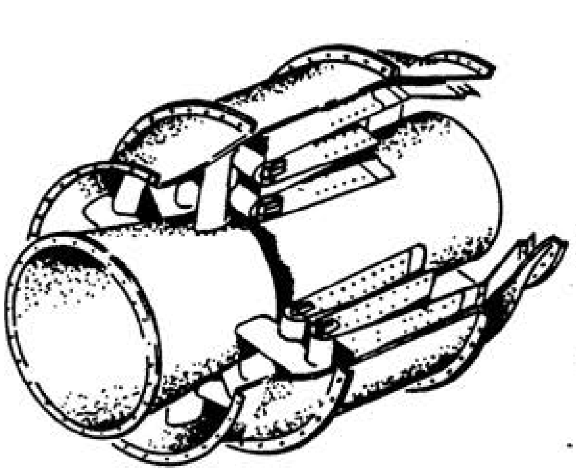
Many different types of engine malfunctions can cause a stall. Compressor blade damage, damage to engine components or accessories, and improper fuel scheduling are a few causes. During engine acceleration, if fuel scheduling is too great for compressor airflow, combustion pressure will increase and interrupt the airflow through the compressor, and a stall will occur.

The means for preventing or avoiding compressor stall are proper fuel scheduling and a means for unloading the compressor. Proper fuel scheduling, handled by the fuel control will be discussed in the section on engine fuel system. By unloading or bleeding air from the compressor, increased air flow results which prevents pressure buildup and reduces the pressure ratio across the compressor. This minimizes the tendency of compressor stall. Both of the above mentioned methods are used on the JT3D (TF-33).

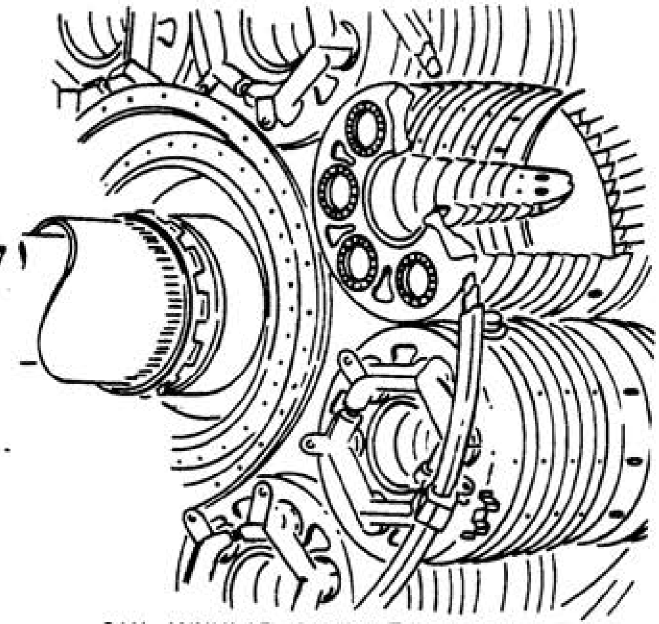
COMBUSTION SECTION TYPES.

The combustion section of an axial flow engine usually uses can-annular type burner cans. The multiple can-type used with centrifugal-type compressors has the advantage of short flame length. The annular type used in some axial flow engines has the advantage of even temperature distribution. In the JT3D (TF-33), by combining the two types into a can-annular combustion section, the advantages of short flame length and even heat distribution are obtained. Fuel nozzles fit into the front of the can and spray fuel toward the rear of the can. Air to be used for combustion is admitted into the can through slots and holes. To prevent the can from damage due to high temperatures, cooling air is vented through a series of baffles. This cooling air forms a blanket along the sides of the liner, keeping the flame centered and away from the sides of the can. Satisfactory fuel-air mixture is gained by baffling on the inlet end of the can. A fuel-air mixture for combustion is about 15:1.

Another important advantage of can-annular combustion sections is their ease of maintenance. Parts are also easily removed and replaced.

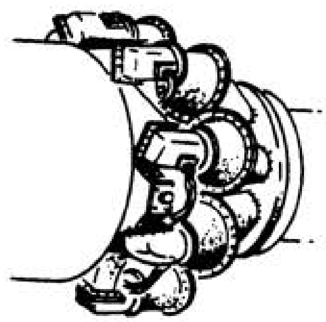


ANNULAR COMBUSTION CHAMBER



CAN-ANNULAR COMBUSTION CHAMBER

Ignition of the fuel-air mixture is accomplished by use of ignitor plugs. Usually there are two plugs placed opposite each other in the ring of burner cans. After initial ignition takes place, the flame is spread to remaining burner cans by cross-over tubes which interconnect the cans.

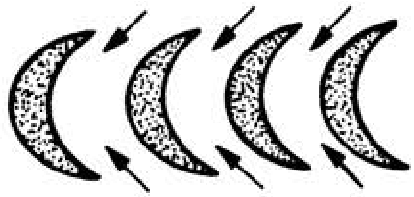


MULTIPLE-CAN-TYPE COMBUSTION CHAMBER

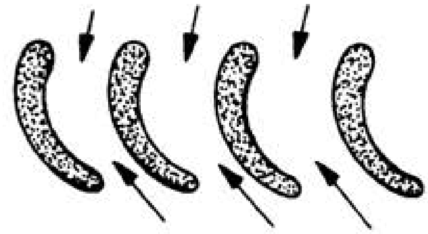
TURBINE SECTION.

The exhaust gasses from the combustion section are directed to the turbine inlet. Several stages can be used in the turbine; however, the number of turbine stages depends on compressor and accessory power requirements. On turbojet and turbofan engines, approximately three-fourths of the generated power is used to drive the compressor.

High-velocity exhaust gas from the combustion section is directed through stationary guide vanes at the entrance to the turbine section. These stationary nozzle guide vanes increase gas velocity and direct flow to the turbine blades. This convergent nozzle vane decreases the width of the gas stream and increases the gas velocity. The high-speed gas stream is directed onto the turbine blades which are designed so that they extract energy from the gas stream in two ways: impulse and reaction.



IMPULSE TURBINE - BLADE ROOT



REACTION TURBINE - BLADE TIP

Each blade is cup-shaped towards the root. Then the gas stream strikes the root section, it tends to push the blade. This is known as impact force.

The contour of the blade changes towards its tip. When the gas stream strikes this portion of the blade, the gases are directed in such a way that a lower pressure is developed on the opposite side of the blade and causes airfoil "lift." This is known as reaction force.

Turbine blades usually have shrouded tips. A shroud is a metal flange built into the tip of the blade. The shrouds interlock forming a continuous band around the outside diameter of the turbine wheel. This continuous band reduces blade vibration and improves airflow characteristics. Turbine blades can be made thinner because of the additional support provided by the shroud.

ENGINE COMPARISONS.

A turbojet engine gets its thrust by accelerating a mass of air through the engine. A high velocity of gases escaping from the engine is necessary to develop proper thrust. To maintain high velocity at the exhaust nozzle, the turbine is designed to extract only enough energy to drive the compressor and accessories. All thrust produced by a turbojet occurs within the engine.

Turboprop propulsion combines the thrust developed by the propeller and the thrust produced by exhaust gases at the exhaust nozzle. The turboprop turbine extracts the maximum possible energy from the gas stream. This energy is converted into shaft horsepower to drive the compressor, propeller and reduction gear, and accessories. The remaining energy, approximately 10 percent, produces jet thrust as the gases are forced out of the exhaust nozzle.

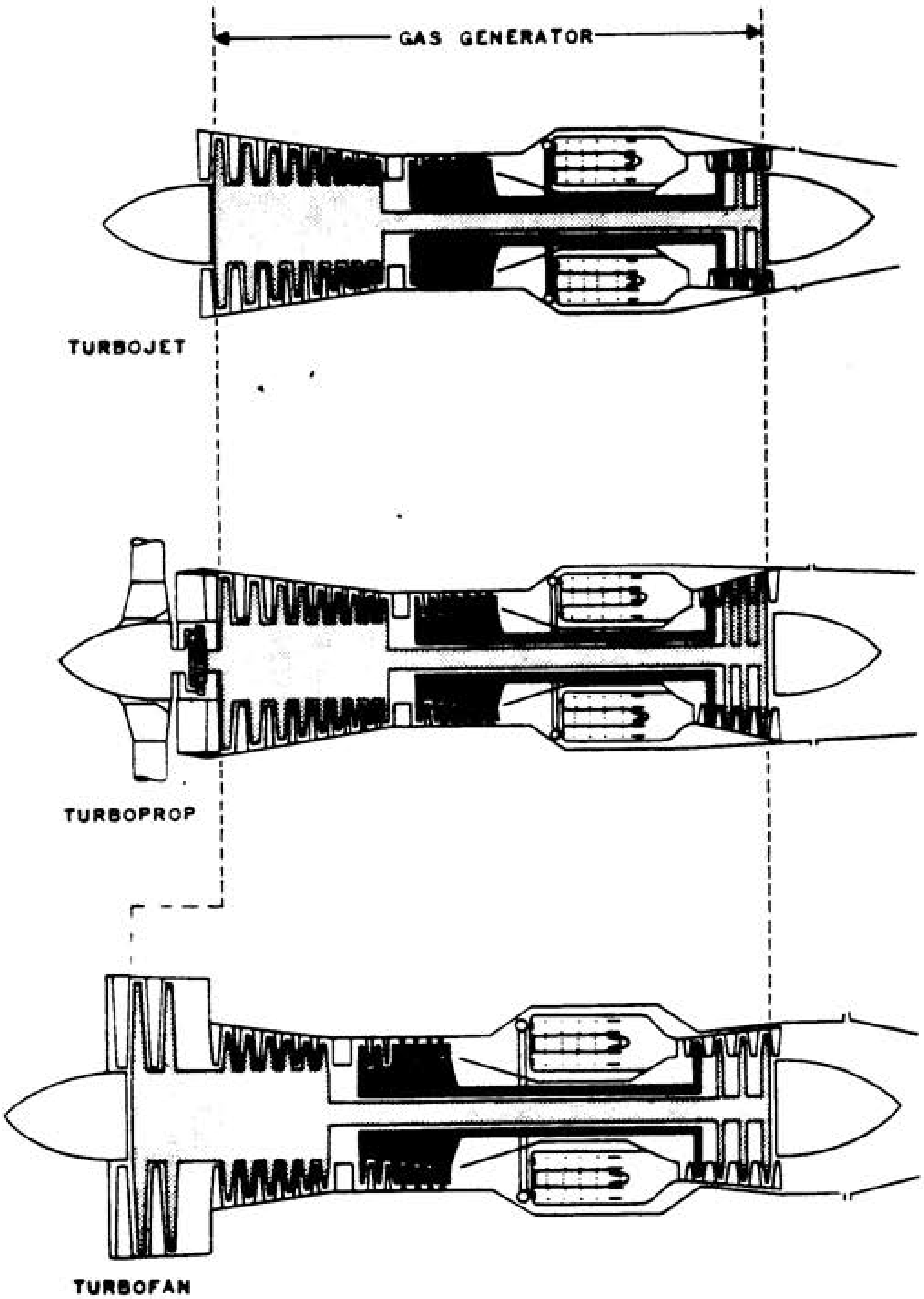
The turbofan is similar to the turboprop, except that the ratio of secondary airflow to primary (combustion airflow) is much lower. The geared propeller is replaced in the turbofan by an enclosed, axial-flow fan. The fan consists of one or more stages of extra large blades.

These fan blades are on the same shaft as the low pressure compressor (N1) and turn at N1 speed. The exhaust from the outer edge of the fan is directed through ducts along the outside of the compressor case. Inner diameter air flows rearward through the compressor of the engine. The fan provides extra thrust by accelerating a large mass of air.

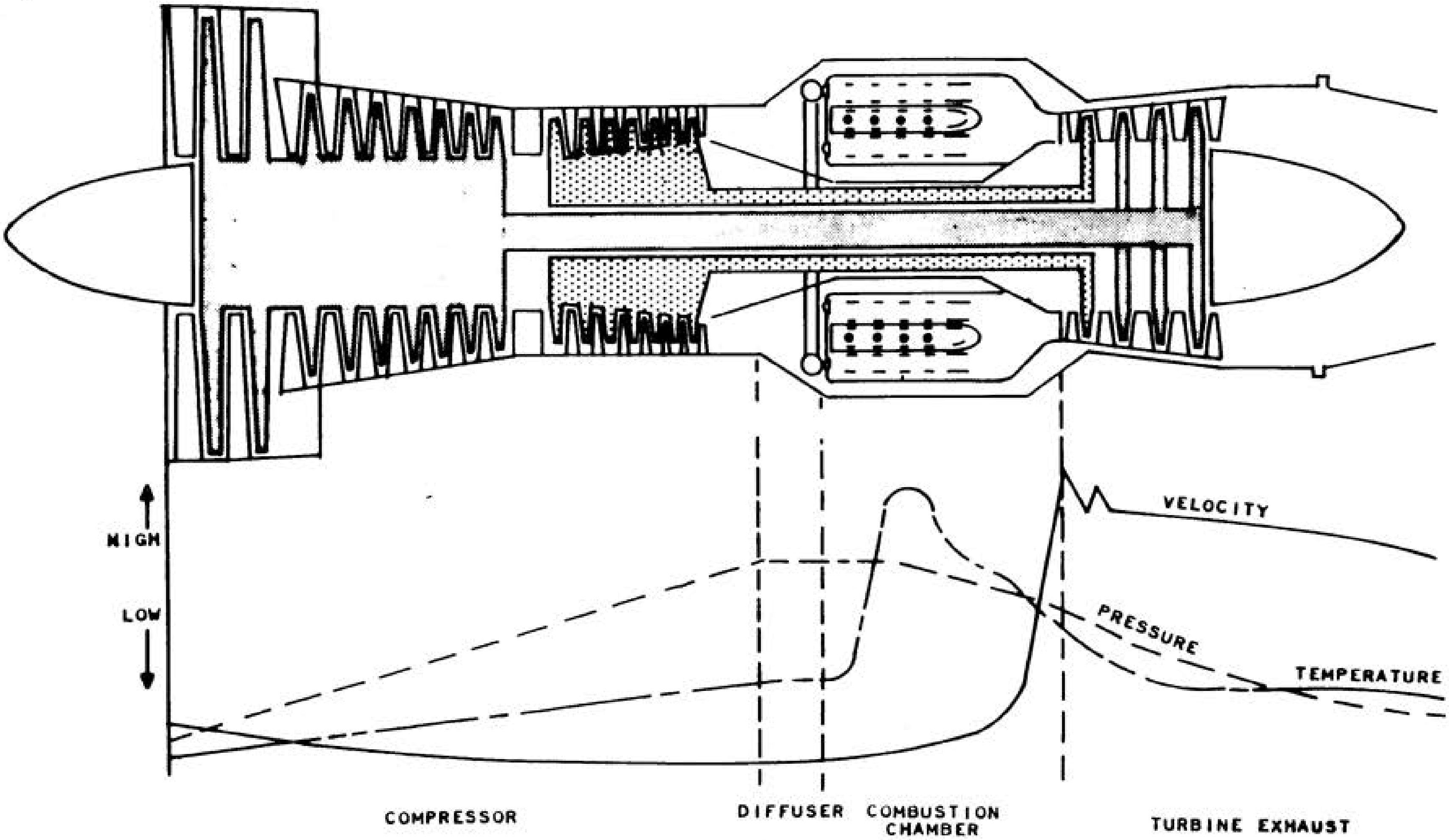
Each of the three configurations has its limitations and advantages. Turbojet engines provide sustained power efficiency at high altitude and high airspeed. When used on long range aircraft it makes the climb to altitude worthwhile. Exceptionally high thrust at low airspeed and low altitude is not characteristic of turbojet engines. Therefore, they require long runways for take-off. Fuel consumption, compared with turboprop or turbofan engines, is high, although it decreases with an increase in altitude and airspeed.

The turboprop engine combines the gas turbine with the good propulsive characteristics of a propeller at low airspeeds. The turboprop can develop high thrust at low airspeeds and altitude which is possible because the propeller can accelerate large quantities of air. This ability makes turboprops ideal for short and medium-length runways. Also, the turboprop has a low fuel consumption at low airspeed. Propeller efficiency falls off at higher airspeeds. With its advantages and limitations the turboprop is best suited for short and medium takeoff runs, heavy loads, and airspeeds under 400 knots.

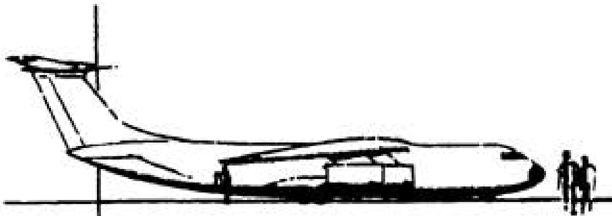
The turbofan performance falls between that of the turboprop and turbojet. While it is true that the turboprop loses performance with increase of airspeed, it is not true with the turbofan. Generally, the turbofan is not penalized by high speeds. It combines other features such as lower weight, increased ground clearance, and more economical flight speeds. Compared with the turbojet, a fan version of the same engine has higher static thrust at takeoff, more climb thrust, more cruise thrust, and lower fuel consumption at cruise. It is also somewhat quieter at takeoff.



GAS TURBINE ADAPTIONS



VELOCITY, TEMPERATURE, PRESSURE RELATIONSHIPS



GENERAL DESCRIPTION AND SPECIFICATIONS

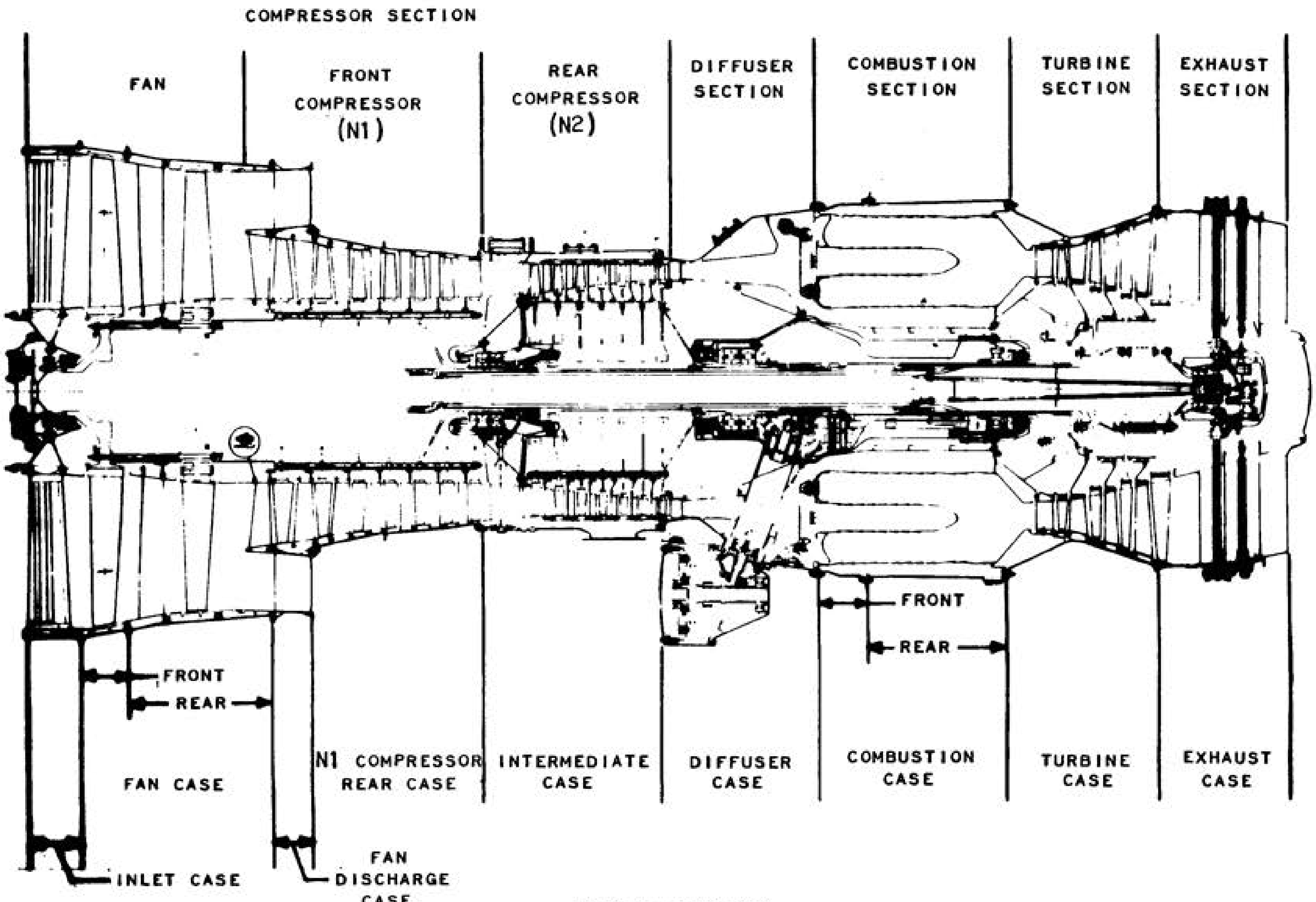
Lockheed's StarLifter has four Pratt and Whitney JT3D (TF-33) turbofan engines. Each engine has a sixteen-stage dual compressor, an eight-can, can-annular combustion section, and a four-stage axial flow, dual-type turbine. Each engine also carries two accessory gear boxes: one mounted on the bottom of the engine and the other on the front of the N1 compressor front hub. The engine is composed of five operating sections:

- o Compressor
- o Diffuser
- o Combustion
- o Turbine
- o Accessory

COMPRESSOR.

The twin spool compressor delivers air for combustion, internal cooling, and the airplane's pneumatic systems. The compressor section includes the air inlet case, front compressor rotor case, fan discharge case, front compressor rear case, compressor intermediate case, and the rear compressor case.

The first two stages of the nine-stage N1 compressor have relatively large blades which make up the fan. The inner portion of the two-stage fan is part of the first two stages of the N1 compressor. The outer portion of these large fan blades delivers air into ducts around the engine. The N1 compressor and fan are relatively slow turning in relation to the N2 compressor which allows the fan to rotate at its most efficient speed. The fan develops approximately 10,000 pounds of thrust at maximum power settings.



ENGINE SECTIONS

The seven-stage N2 compressor is the high-pressure compressor. N2 compressor speed is higher than N1 and is the controlled speed compressor. The speed of N2 is controlled by fuelflow. Fuel control establishes desired thrust according to speed and airflow through the N2 compressor.

As discussed in Chapter 1, compressor stall is a breakdown or interruption of airflow through the compressor. To aid in preventing stalls, the JT3D compressor is protected by a compressor bleed system. There are two valves mounted right and left on the compressor intermediate case that allow the compressor to unload during starting, acceleration, and deceleration.

The compressor air inlet of each engine is protected from ice formation in icing conditions by an ice detection and anti-icing system. Should ice form on the inlet and restrict airflow to the engine, the automatic ice detection system will turn on anti-icing. Anti-icing is accomplished by sixteenth-stage air from the diffuser. Hot air flows through the inlet guide vanes and lip duct, breaking up the ice and preventing reformation.

DIFFUSER.

The diffuser case attaches to the rear flange of the N2 compressor's rear case. The diffuser maintains the high pressure-low velocity air from the sixteenth stage and adapts the air for entry into the combustion section. Internally, the diffuser case provides support for the dual-split type fuel manifold and fuel nozzles. Externally, the case provides support for mounting the accessory gearbox and bosses for attaching the air ducts for the pneumatic systems.

COMBUSTION.

The combustion section is composed of an outer combustion case, eight burner cans, and an inner combustion case liner. The inner liner is a heat shield for the N1 and N2 turbine shafts.

At the front of each burner can are six holes for mounting the fuel nozzles. Each burner can has slots and perforations to allow air to mix with the fuel for proper burning and for cooling airflow.

The outer combustion case serves as a heat shield and a container for the combustion section.

TURBINE.

The turbine section houses the four-stage, twin-spool turbine. The first stage of turbine rotor is used to drive the N2 high speed compressor. Second, third, and fourth stages drive the N1 compressor and fan.

The turbine exhaust case attaches to the rear of the turbine section and is used to collect and straighten the exhaust gases as they leave the turbine. The rear opening of this convergent duct is critical in the respect that if the size of the opening is changed, a change in the velocity of exhaust gases will directly affect thrust produced by the engine. The exhaust case also supports the thrust reverser assembly.

ACCESSORY GEARBOX.

The main accessory gearbox, on the bottom of the engine, mounts the main oil pump, fuel control, fuel pump, constant speed drive, thrust reverser pump, hydraulic pump, tachometer generator, and a pneumatic starter. Power to drive the engine accessories is taken from the rear hub of the N2 compressor. The other accessory gearbox is mounted in the air inlet housing, forward of the No. 1 bearing. It is driven by a gear from the N1 compressor's front hub. The N1 tachometer generator and the No. 1 bearing oil scavenge pump are mounted on this forward accessory gearbox.

ENGINE SPECIFICATIONS

Model	JT3D-5a (TF33-P-7)
Type	Axial Flow, Turbofan Gas Engine
Compressor	Axial Flow
Fan	Two Stage
N1 (Low Speed-Low pressure)	Seven Stage
N2 (High Speed-High pressure)	Seven Stage
Turbine	
1st Stage	Drives N2 Compressor
2nd, 3rd and 4th Stages	Drives N1 Compressor
Direction of Rotation	Clockwise
Number of Combustion Cans	Eight
Type of Combustion Cans	Can-annular - Straight Flow

ENGINE SPECIFICATIONS (Continued)

Dry weight (including standard equipment)	4605 pounds
Installed on Pylon	6700 pounds
Dimensions - room temperature	
Length	142.26 inches
Diameter	54.06 inches
Dimensions - operating temperature	
Length	142.86 inches
Diameter	54.12 inches
Fuel	
Specification	MIL-F-5624
Grade	JP-4 or Commercial Equivalent
Lubrication	
Oil Specification	MIL-L-7808E (latest MIL Spec.)
Oil Consumption (30 hours average)	0.234 gal/hr

ENGINE OPERATING LIMITS
(Sea Level, Standard Day - Static Thrust)

Thrust Setting	Rated Engine Thrust (pounds)	Time Limit (3)	Max. Observed E.G.T. (°C)	Oil Pressure PSIG (Normal)
Takeoff (1)	21,000	5 min.	555	45 ± 5 (4)
Max. continuous (5)	18,000	continuous	488	45 ± 5
Starting	Not applicable	-	454 (2)	-
Engine acceleration	Not applicable	2 min.	555	45 ± 5

(1) To be used for takeoff only. EPR settings are limiting.

(2) Temperature is time-limited to momentary - not to exceed 15 seconds.

(3) If E.G.T. exceeds 555° C at anytime - shut down engine.

(4) Oil pressure may exceed 50 PSI but not 55 PSI for takeoff only.

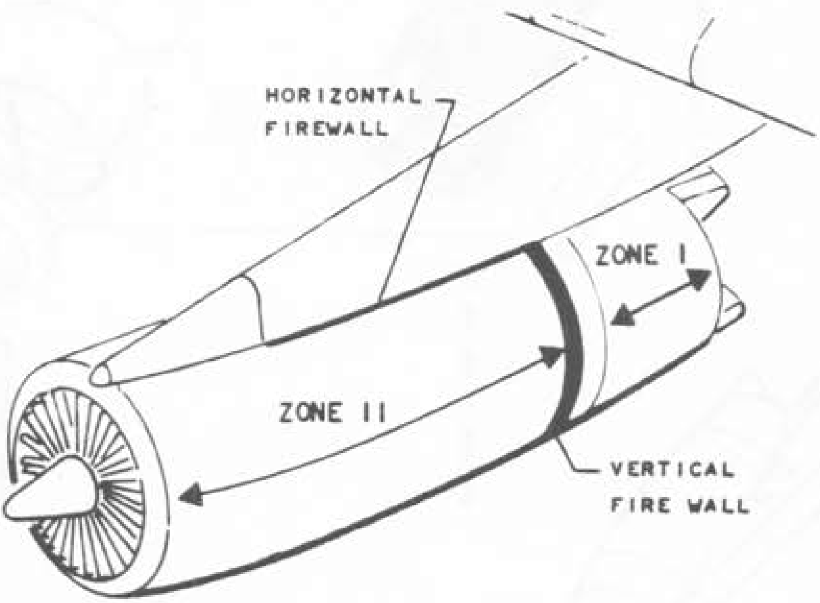
(5) EPR settings are limiting (Takeoff Thrust EPR Setting Charts)

ENGINE CONSTRUCTION AND RELATED COMPONENTS

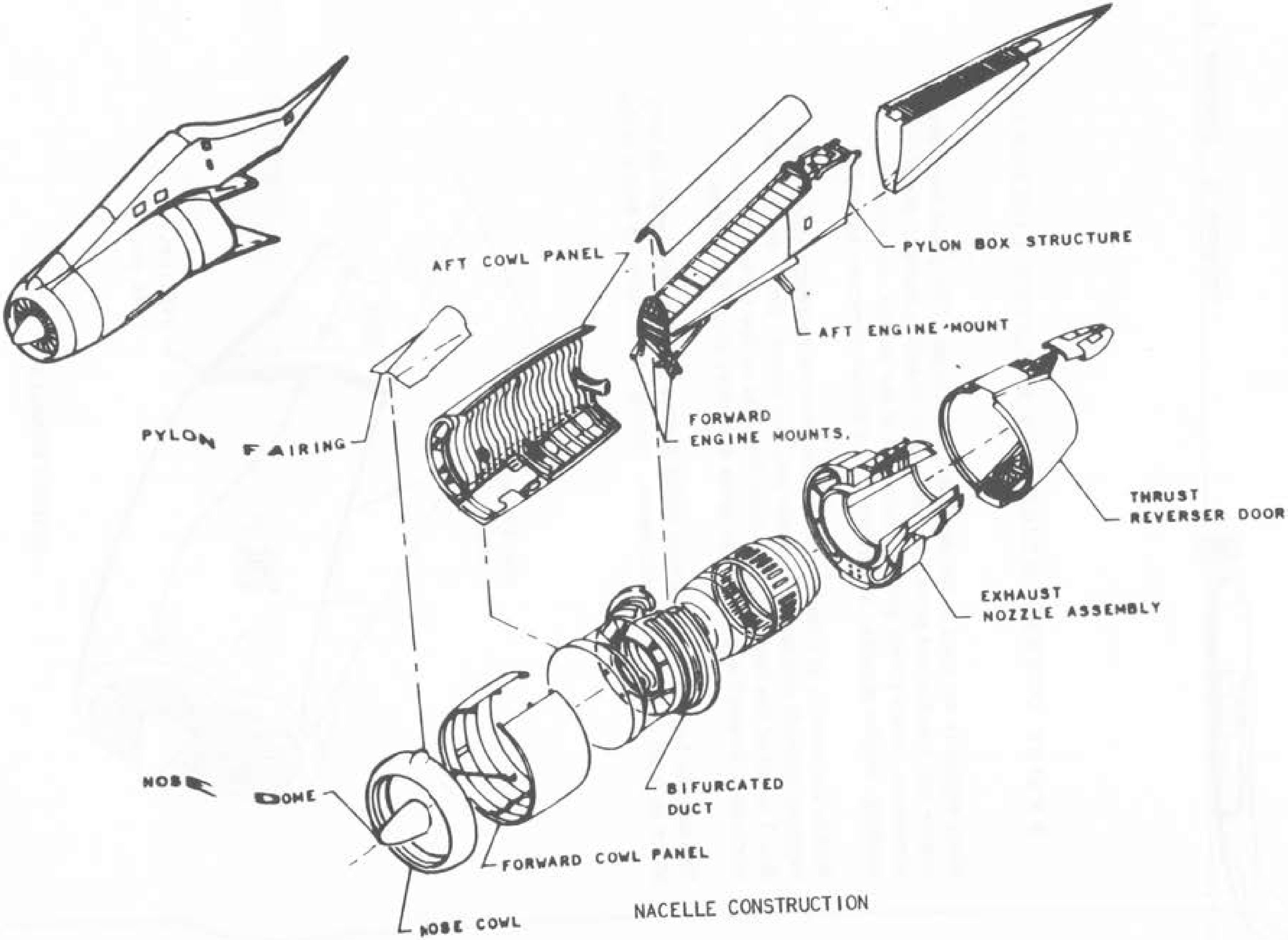
Each engine is encased in its own nacelle package. The pylon supports the engine and nacelle and provides a means of attaching them to the aircraft structure. Each power package consists of the engine, accessories, cowling, engine mounts, and exhaust duct-thrust reverser assembly.

Within the nacelle are two firewalls of corrosion resistant steel. The vertical firewall divides the nacelle into two zones, No. 1 and 2. Zone No. 1 is aft of the firewall, and Zone No. 2 is on the forward side. A horizontal firewall separates the pylon structure from the engine.

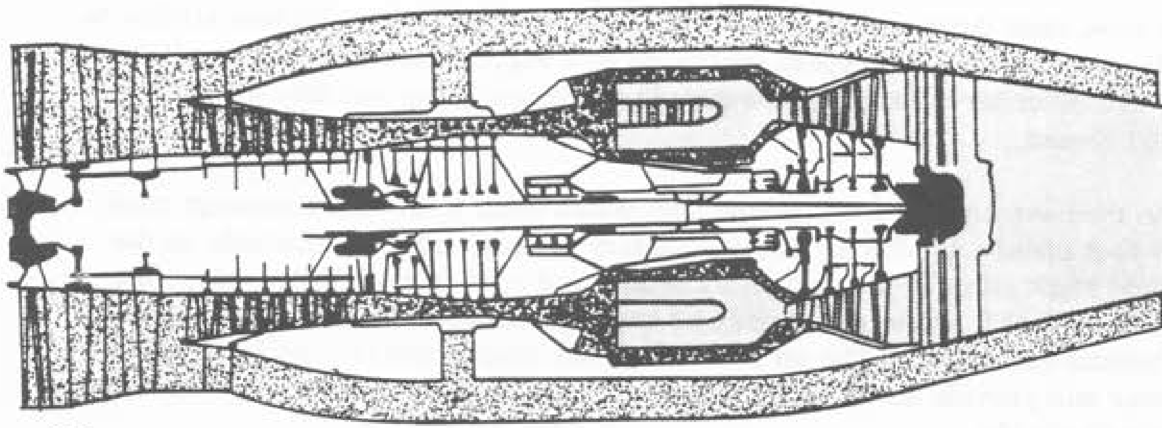
The nacelle has a zero inlet duct which means that the duct length is very short in front of the inlet guide vanes. Spring-loaded blow-in doors in the



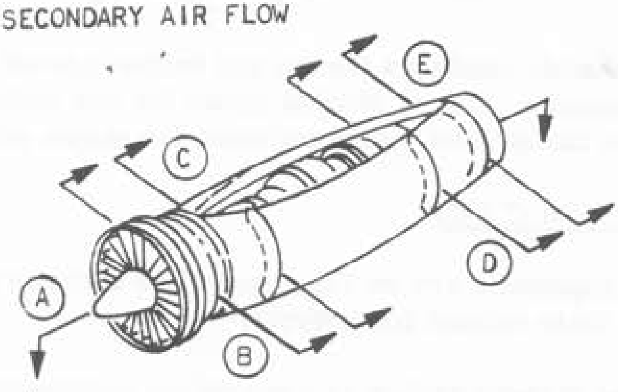
ENGINE FIREWALLS

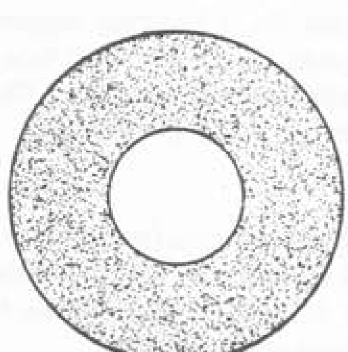


NACELLE CONSTRUCTION

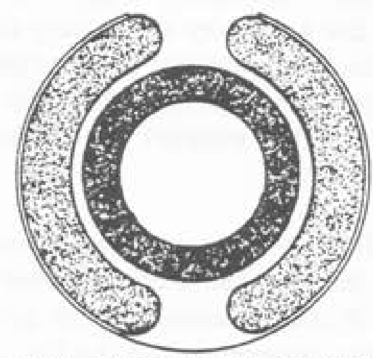


(A) PRIMARY & SECONDARY AIR FLOW

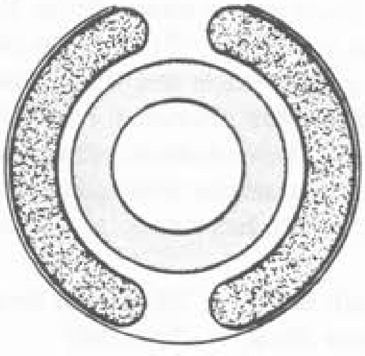




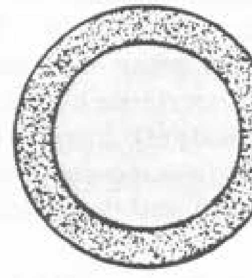
(B) FAN & INLET



(C) AFT COWL DUCTS & N2 COMPRESSOR



(D) AFT COWL DUCTS & TURBINE



(E) FAN & ENGINE EXHAUST NOZZLE

nose cowl open during starting and low airspeed to provide sufficient airflow to the fan rotors. When airspeed increases to a value where ram air supplies airflow needs, differential pressure across the doors drops and they are spring-loaded closed.

Aft of the nose cowl is a bifurcated duct which bolts to the fan discharge case. This duct directs the fan airflow (secondary airflow) into two channels on the left and right sides of the engine. The forward cowl doors which enclose the bifurcated duct hinge on the upper left and right sides of the engine and latch on the bottom centerline. The aft cowl doors are hinged and latched in a like manner and provide an integral duct which guides fan discharge air to the exhaust nozzle assembly.

The exhaust nozzle assembly combines the fan and engine exhaust nozzles and the thrust reverser assembly. These nozzles direct fan and engine exhaust gases aft and overboard. The fan exhaust nozzle encloses the engine exhaust nozzle.

N1 COMPRESSOR SECTION (FAN):

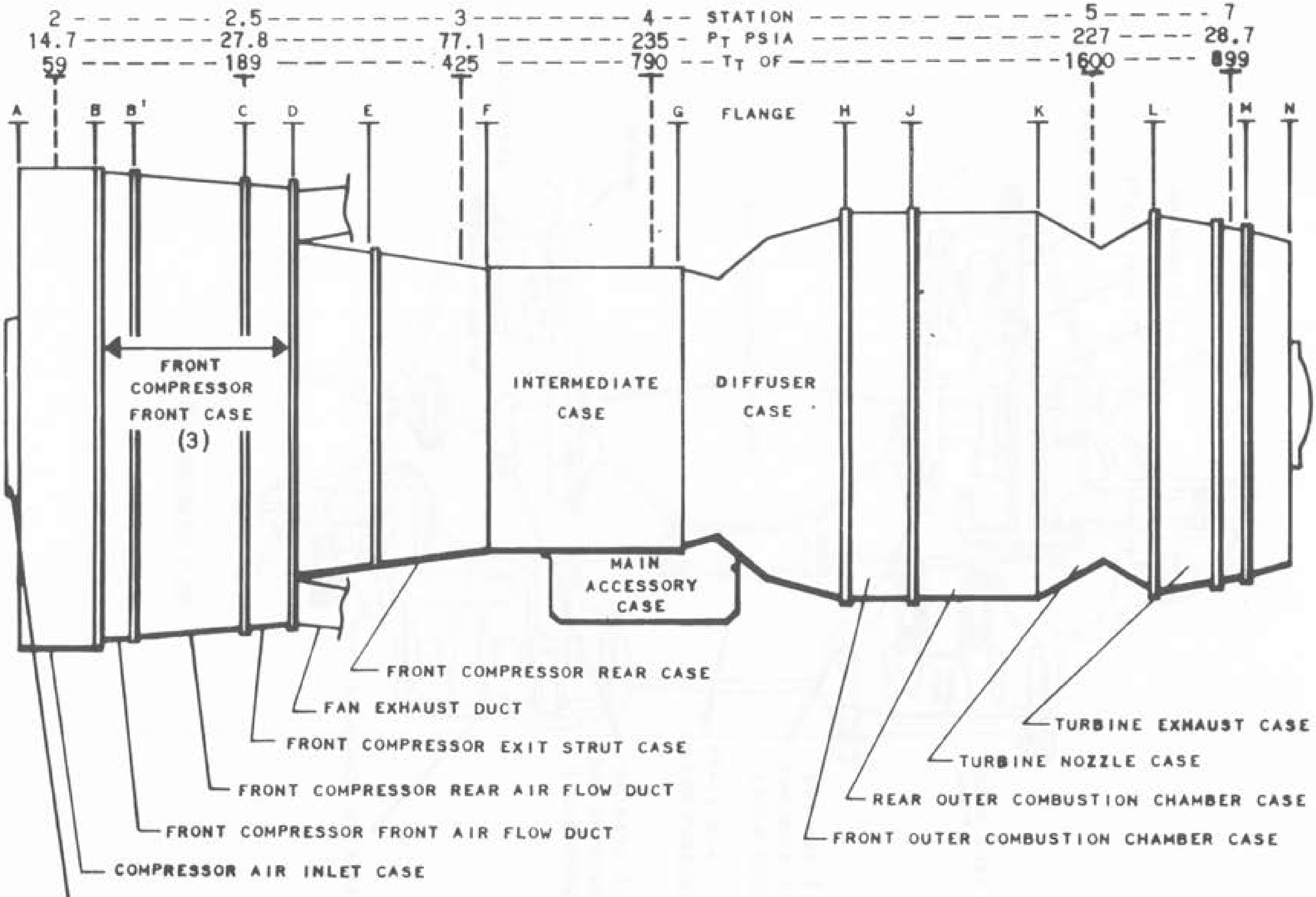
Since the fan and N1 compressor are on a common shaft they are discussed under this section along with their related components.

The auxiliary accessory support section is a one-piece magnesium casting. It supports the auxiliary accessory drive and bolts into the No. 1 bearing support. The auxiliary accessory support provides two mount pads on the forward face, but only one is used. It drives the N1 compressor tachometer generator. The lower face of the support section provides a mount for the No. 1 bearing oil scavenge pump.

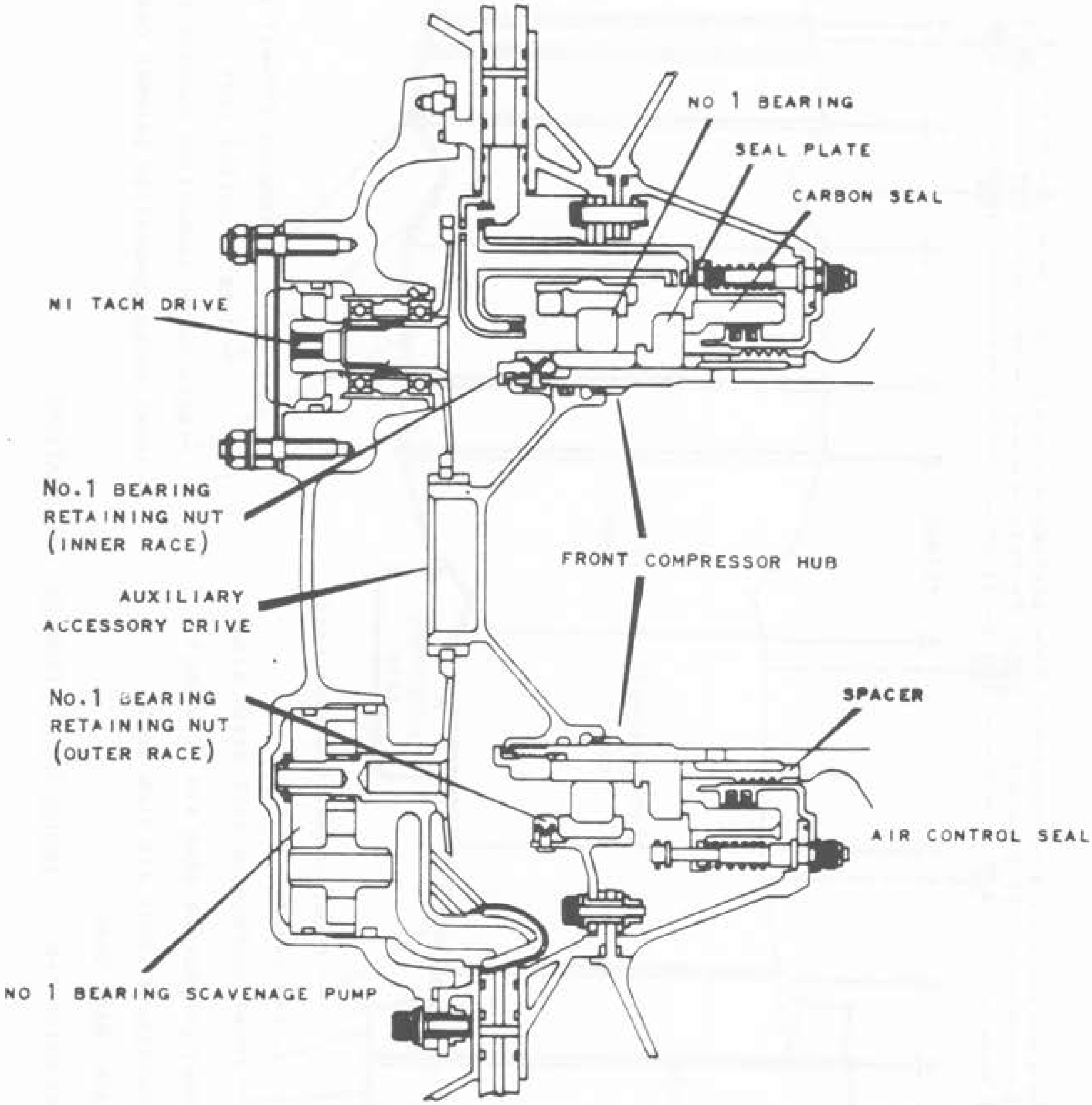
The auxiliary accessory drive gear is externally splined and installed with an "O" ring into the front compressor hub. The hub has an internal spline which mates with the accessory drive gear. The accessory drive gear powers the N1 tachometer generator and the No. 1 bearing oil scavenge pump.

The compressor air inlet duct, A-B, bolts to the front compressor front airflow duct (front fan case), B-B. The outer case wall is titanium. Fitted into the inner diameter of the outer case are 23 hollow titanium guide vanes and their spacers. These guide vanes are bolted to the case wall on the outer diameter and riveted to the No. 1 bearing support on the inner diameter. These hollow vanes have an internal webb bracing and a sponge nylon filler which absorbs vibrations. All the vanes carry anti-icing air. In addition, some struts have special functions:

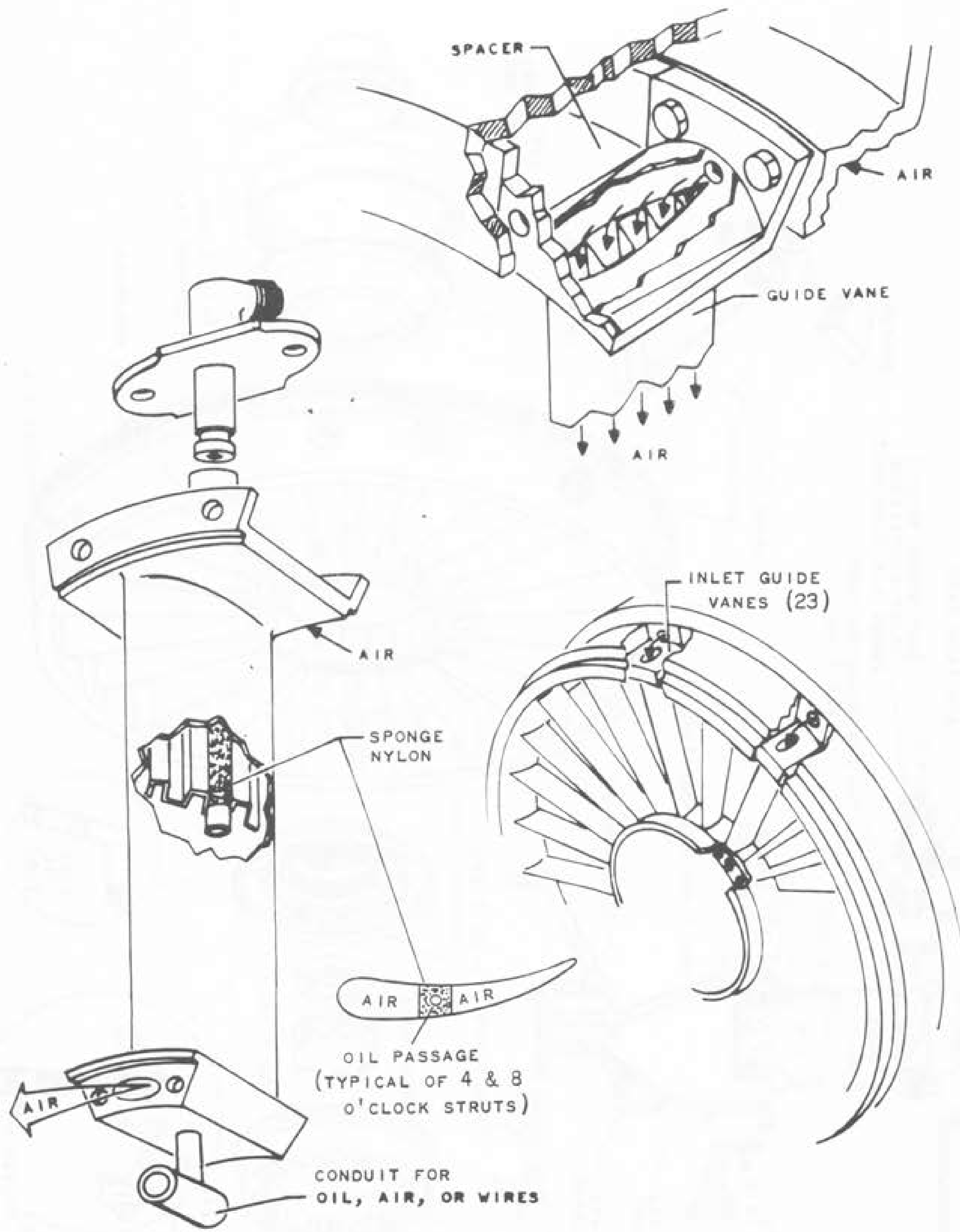
1 O'clock Strut - Air Sensing
4 O'clock Strut - Oil Pressure
8 O'clock Strut - Scavenge Oil
9 O'clock Strut - N1 TACH Gen Wire
11 O'clock Strut - Breather



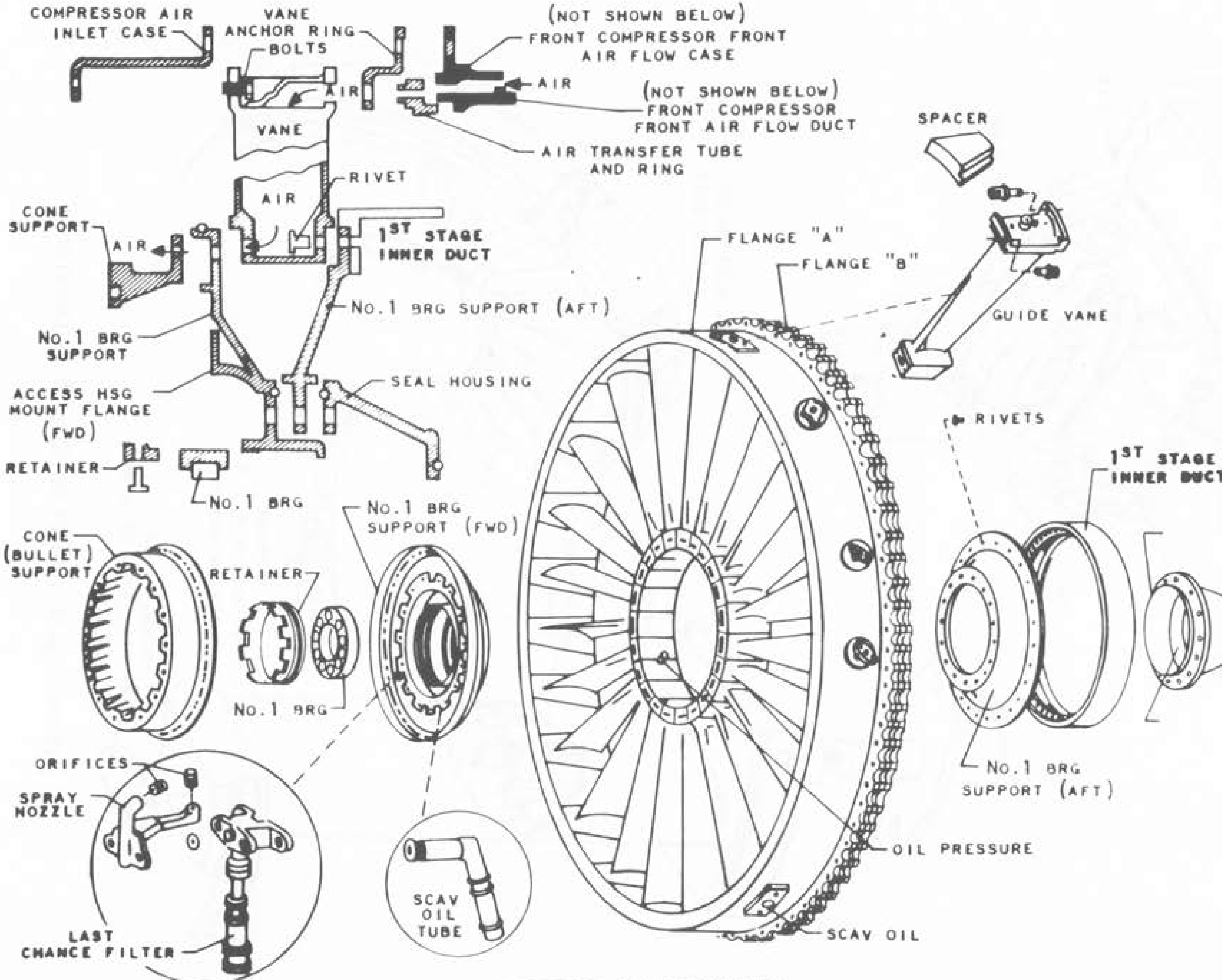
ENGINE CASES, FLANGES, AND STATIONS



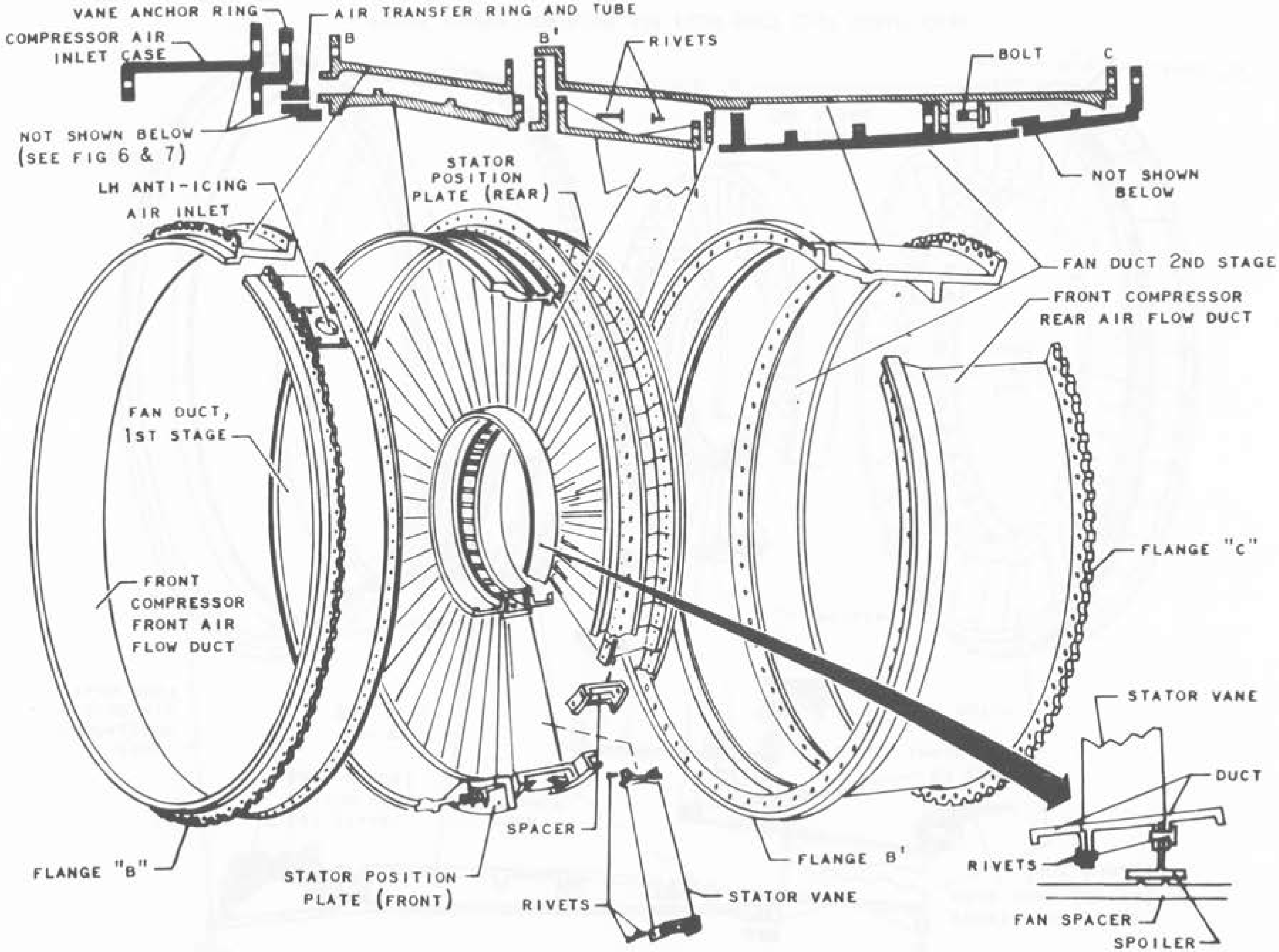
NO.1 BEARING AND SEAL



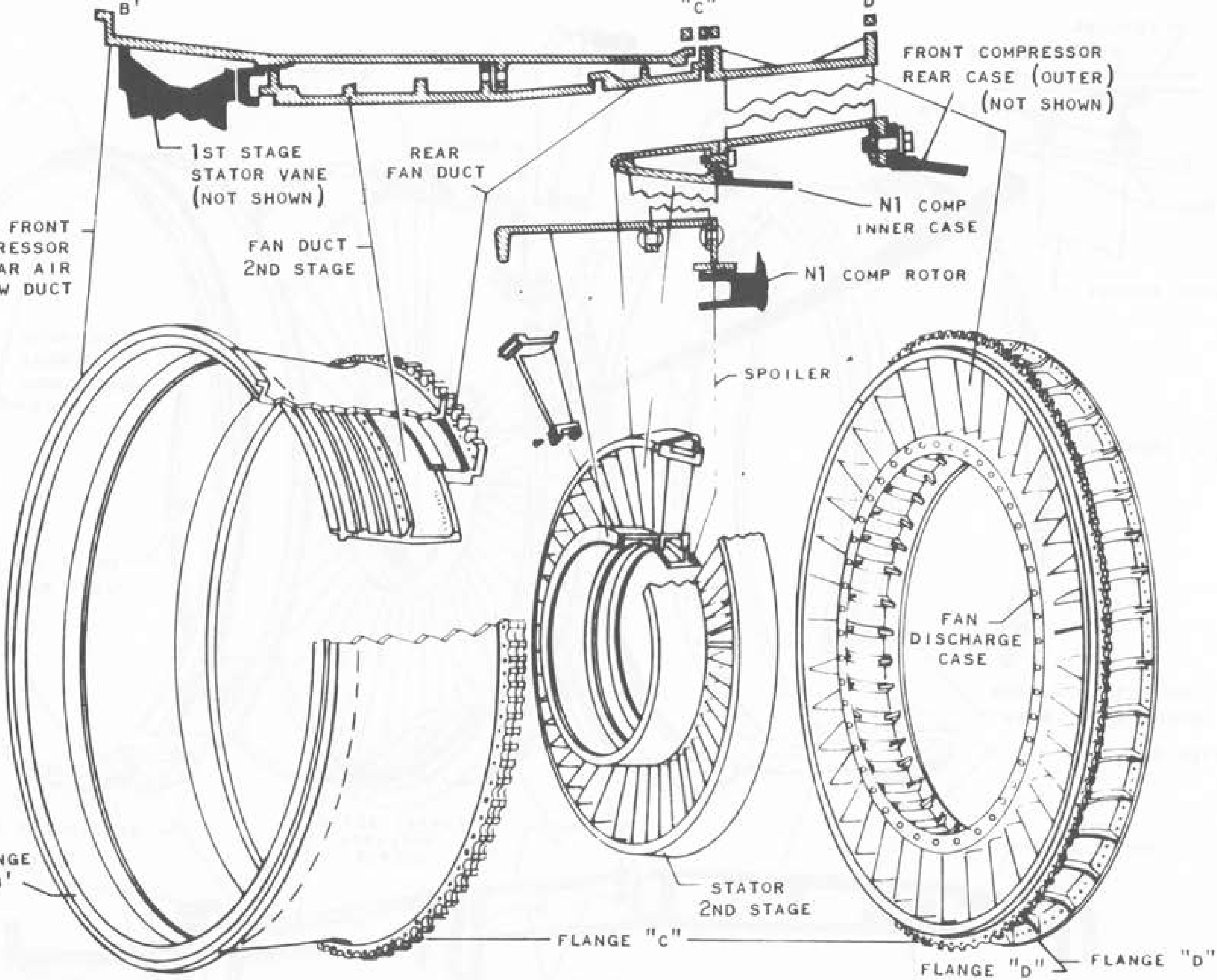
AIR INLET CASE - INLET GUIDE VANE INSTALLATION



COMPRESSOR AIR INLET CASE



FRONT COMPRESSOR - FRONT & REAR AIR FLOW DUCTS AND FIRST STATOR



FRONT COMPRESSOR REAR AIR FLOW DUCT EXIT STRUT CASE

These special functions are discussed in later chapters under related subsystems.

The purpose of the inlet guide vanes is two-fold: First, they direct incoming air onto the rotors at the best angle for compression. Second, they distribute the No. 1 bearing support load to the outer case. On the inner diameter of the vanes, the fore and aft No. 1 bearing support shells are riveted. These components form the No. 1 bearing scavenge sump.

The front compressor front airflow duct (front fan case) B-B, bolts to the rear of the air inlet duct and to the front flange (B1) of the front compressor rear airflow duct (rear fan case). The front airflow duct (front fan case) is aluminum and fits over the first-stage fan duct. The first-stage rotor of the N1 compressor rotates inside this fan duct. Riveted to the first-stage fan duct and to front and rear stator position plates are 48 aluminum alloy stator blades. These blades help provide compression and serve to guide fan airflow onto the second-stage rotor. At the inside diameter of the stator blades is a spoiler, which rides on the knife edge of the rotating fan spacer. The purpose of this spoiler is to prevent air leakage around the inner diameter of the stators. Should leakage occur, engine efficiency would decrease. The stator blades are replaceable. For easy maintenance, they slip into the rear airflow duct (rear fan case).

The front compressor rear airflow duct (rear fan case) shown as B-C in the illustration is aluminum and houses the first-stage (fan) stator assembly as noted above. The second-stage fan duct slips into the rear airflow duct and bolts to an internal flange. This duct houses the second-stage rotor. During disassembly, this fan duct must be removed from the forward end.

The rear fan duct slips into the rear airflow duct at flange C. The leading edge lip fits over the aft lip of the second-stage fan duct making a streamlined passage to the front compressor exit case and the N1 inner case inlet. The rear fan duct bolts into position with the front compressor exit case at flange C.

In summary, the front compressor front case (fan case) is divided into two parts: the front (fan) and rear (fan) airflow ducts, which house the first two stages of the low pressure (N1) compressor. These first two stages, then, are the fan.

The front compressor exit strut case (fan discharge case) shown as C-D, divides fan airflow into two paths: primary and secondary. The secondary air flows into the bifurcated duct, as shown earlier in this chapter; primary air flows into the N1 compressor via second-stage stator vanes.

The exit case is stainless steel and supports 38 steel exit guide vanes on its outer circumference. The inner circumference houses the second and third stator assemblies and the third-stage rotor.

The second-stage stator is bolted to the forward inside diameter of the exit case and extends forward into the rear airflow duct. The 48 aluminum alloy vanes are individually replaceable and form a continuous ring. At their inside diameter they are riveted to a shroud which forms an air seal on the inner end of the vanes. The second-stage stators are pinned to the third stage for alignment and to prevent the stator sections from rotating within the case.

The third-stage stators are a two-piece assemblies which pin to the second-stage stator on the forward end and to the fourth-stage stator on the aft end. The 56 vanes are made of aluminum alloy and riveted to a spoiler shroud on the inner diameter. This spoiler serves as an air seal to prevent air leakage on the inner end of the stators. The outer circumference of the third stage rivets to an inner compressor duct on the forward end. The inner duct and the spoiler shrouds are two-piece units to allow ease of maintenance. The stator vanes are replaceable.

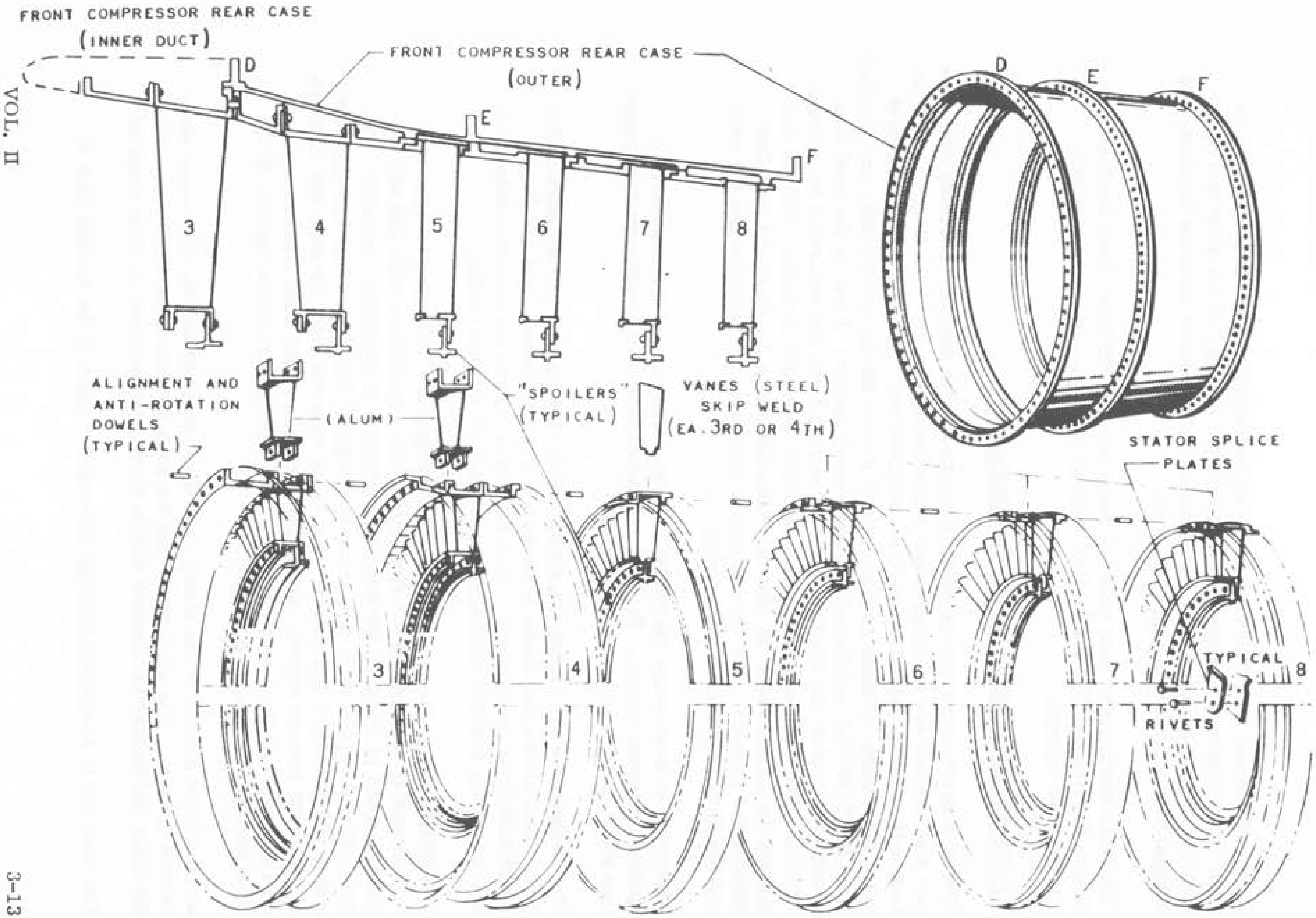
N1 COMPRESSOR SECTION (COMPRESSOR).

The front compressor rear case (N1 compressor case), D-F in the illustration, is a one-piece aluminum structure. It bolts to the front compressor exit strut case (fan discharge case) at flange D and to the intermediate case at flange F. There is a dummy flange, E, at mid-case. The front compressor rear case (N1 compressor case) houses the remaining five stages of the compressor. Each stator stage is constructed in halves.

The 66 fourth-stage vanes are made of replacable aluminum alloy. The outer circumference is riveted to the compressor inner duct on the forward end. The inner circumference is riveted to an air seal spoiler shroud. The compressor inner duct serves as a spacer between stator sections and is pinned for alignment and to prevent rotation within the case.

The fifth-stage stator is a two-piece steel assembly. The 96 stator vanes are all welded on the inner diameter. Every sixth vane on the outer diameter is welded. This provides flexibility and room for expansion without putting undue strain on the case. The fifth-stage is not attached to a compressor inner duct but assemblies between the fourth and sixth stage ducts which act as spacer and pin to the fifth stage.

The sixth through eight stages are of two-piece steel construction. The vanes, of which the sixth stage has 96 blades, the seventh stage, 106 blades, and the eighth stage, 120 blades, are welded on the inner diameter and strap welded on the outer diameter. In addition, the vane segments are assembled with and pinned to inner ducts which act as spacers. Each stage is pinned to the one in



N1 COMPRESSOR STATORS AND CASE

front and the one aft. The vanes h ve an aluminum spoiler shroud riveted on their inner diameter. These spoi. rs form an air seal on the inner end of the stators. Stator splice plates, which fasten the two-piece sections together, are staggered 90 degrees during installation.

The front compressor rear case (N1 outer case) is installed from the rear. It tapers from flange D to flange F to conform to decreasing blade size and compressor volume.

N1 COMPRESSOR SECTION (ROTOR ASSEMBLY).

The N1 compressor rotor assembly consists of nine stages. The front compressor disk and hub are an integral unit supported by the No. 1 bearing. The hub is internally splined and drives the front accessories. The disk mounts the first-stage fan blades. Sixteen tie rods, which secure the fan rotor stack, are inserted from the front disk and thread into the second spacer. A nut on the front disk provides torque on the stack. The front and aft disks are separated by a spacer which has two knife-edge air seals used with the stator shrouds. The aft disk mounts the second-stage fan blades. Snap flanges on the front and rear face receive the spacers. The second spacer separates the second-stage fan rotor and the third stage of the compressor.

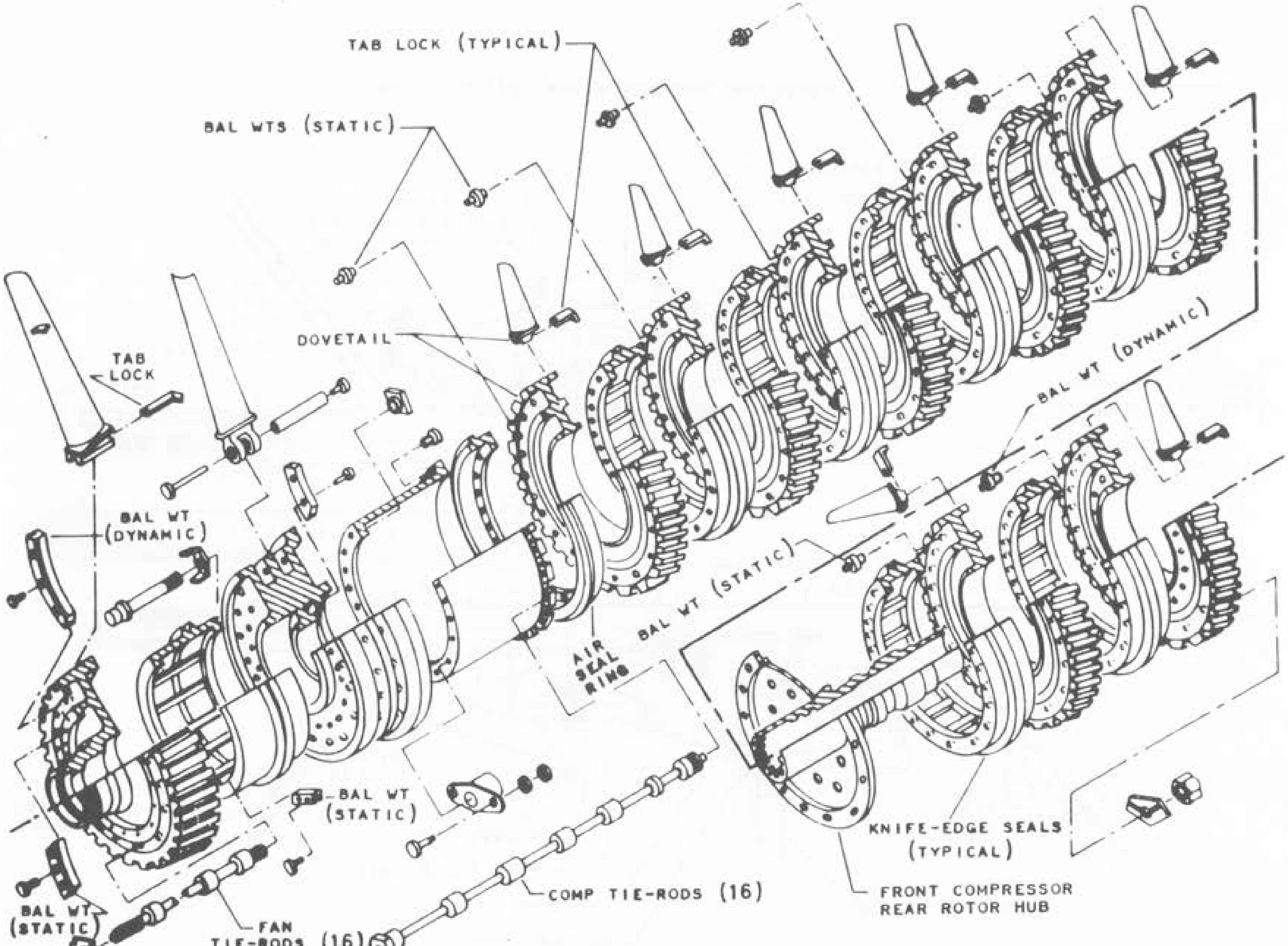
There are 34 first-stage fan blades. These blades are of steel and have a stellite mid-span shroud. This shroud locks the blades together during operation which helps to strengthen the blades.

The 30 second-stage blades are also made of steel but are pin-mounted to the disk. This allows the blades to move 1 1/2 inches radially and 1/4 inch longitudinally at the blade tip. This movement allows the blades to take their best operating position and helps compensate for uneven loading.

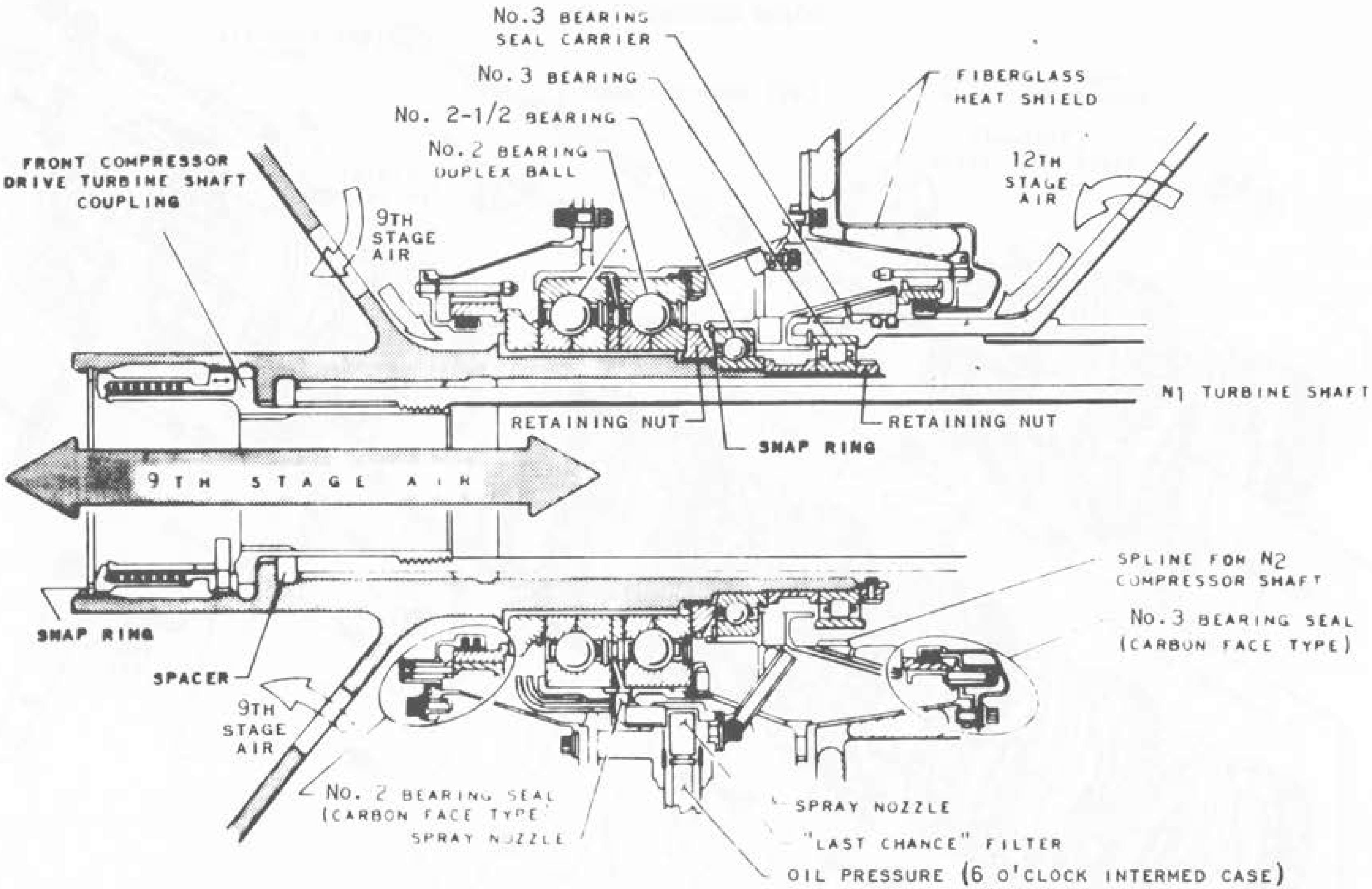
The rotor disks in the third through ninth stages are of varying weights and thicknesses to compensate for vibration levels experienced with this engine. Each segment is designed for maximum strength at maximum operation. On the front and rear of each disk are snap flanges. The third stage forward side mates with the No. 2 fan spacer. The third stage aft side, the fore and aft sides of the fourth through eighth, and the forward side of the ninth disks accept the disk spacers. At the seventh disk aft side, just in front of the spacer, is the front compressor rotor rear hub.

Air seals are formed by the stator vane inner shrouds and the knife-edge seals on disk spacers. The spacers fit into the snap flanges of the disks separating the disks and helping to transmit torque from rotor segment to rotor segment.

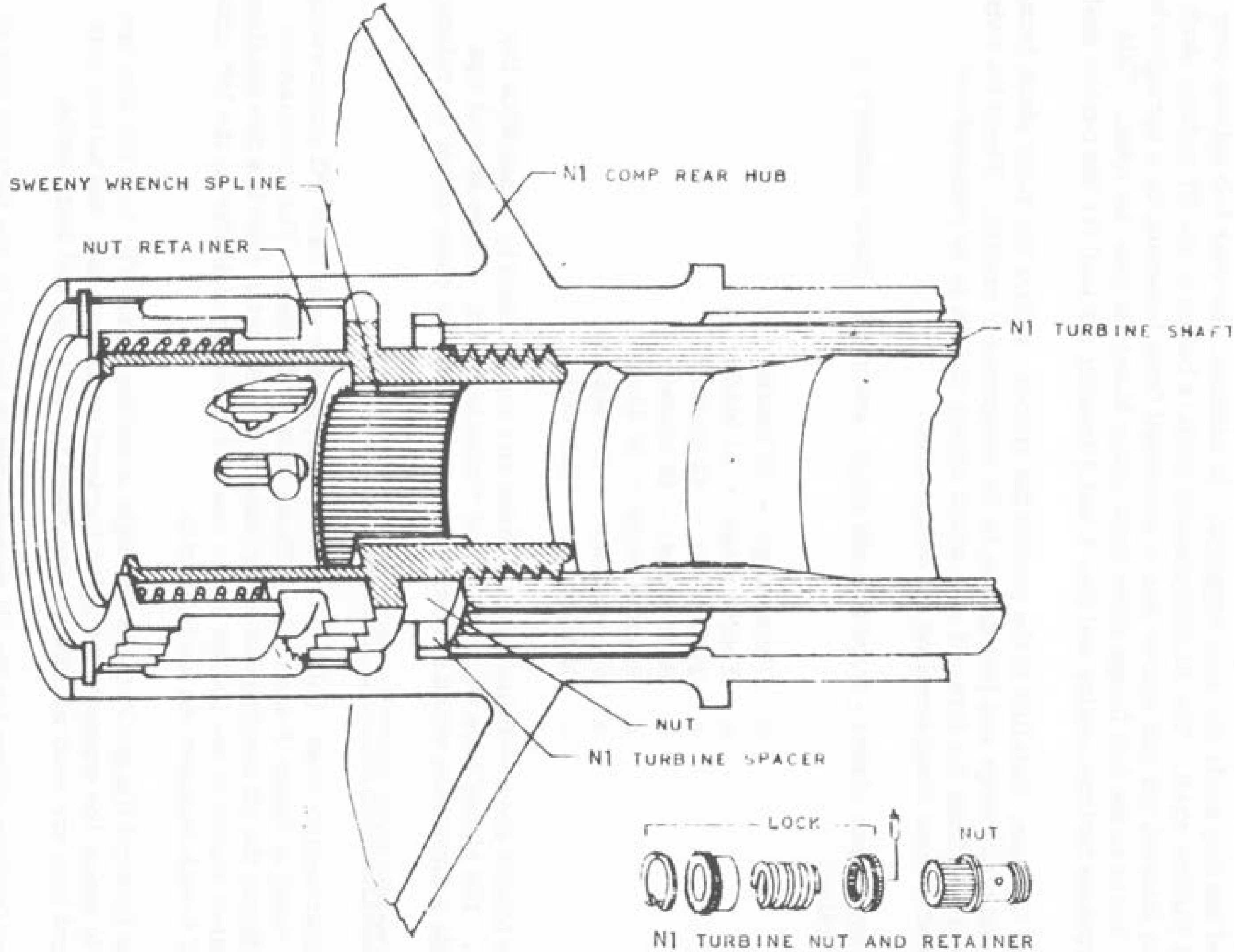
The rear hub is assembled into the disk-spacer stack at the seventh disk to



N1 COMPRESSOR ROTOR



No. 2, 2 1/2, AND 3 BEARINGS AND SEALS



N1 TURBINE SHAFT NUT AND RETAINER

to lessen the effect of vibrations and to keep the total engine length to a minimum. The rear hub is supported by the No. 2, 2 1/2, and 3 bearings and mounts the related bearing seals and seal supports. In addition, the rear hub splines over the N1 turbine shaft. The N1 compressor shaft is bolted to the N1 turbine shaft with an internal nut and spacer and is prevented from loosening by a springloaded lock. Holes in the hub flange allow ninth-stage bleed air into the rotor. This air provides turbine cooling and No. 1 and 2 bearing air load for the carbon seals.

Sixteen tie rods, installed in the second fan spacer, secure the rotor stack from third and ninth stage and join the fan to the compressor section. These tie rods are removed from the forward side which allows the fan to be removed and replaced without disassembling the compressor.

The compressor blades - third to ninth stage, are steel. Blade numbers by stage follow:

- o Third stage - 36 blades
- o Fourth stage - 51 blades
- o Fifth stage - 62 blades
- o Sixth stage - 62 blades
- o Seventh stage - 82 blades
- o Eighth stage - 100 blades
- o Ninth stage - 102 blades

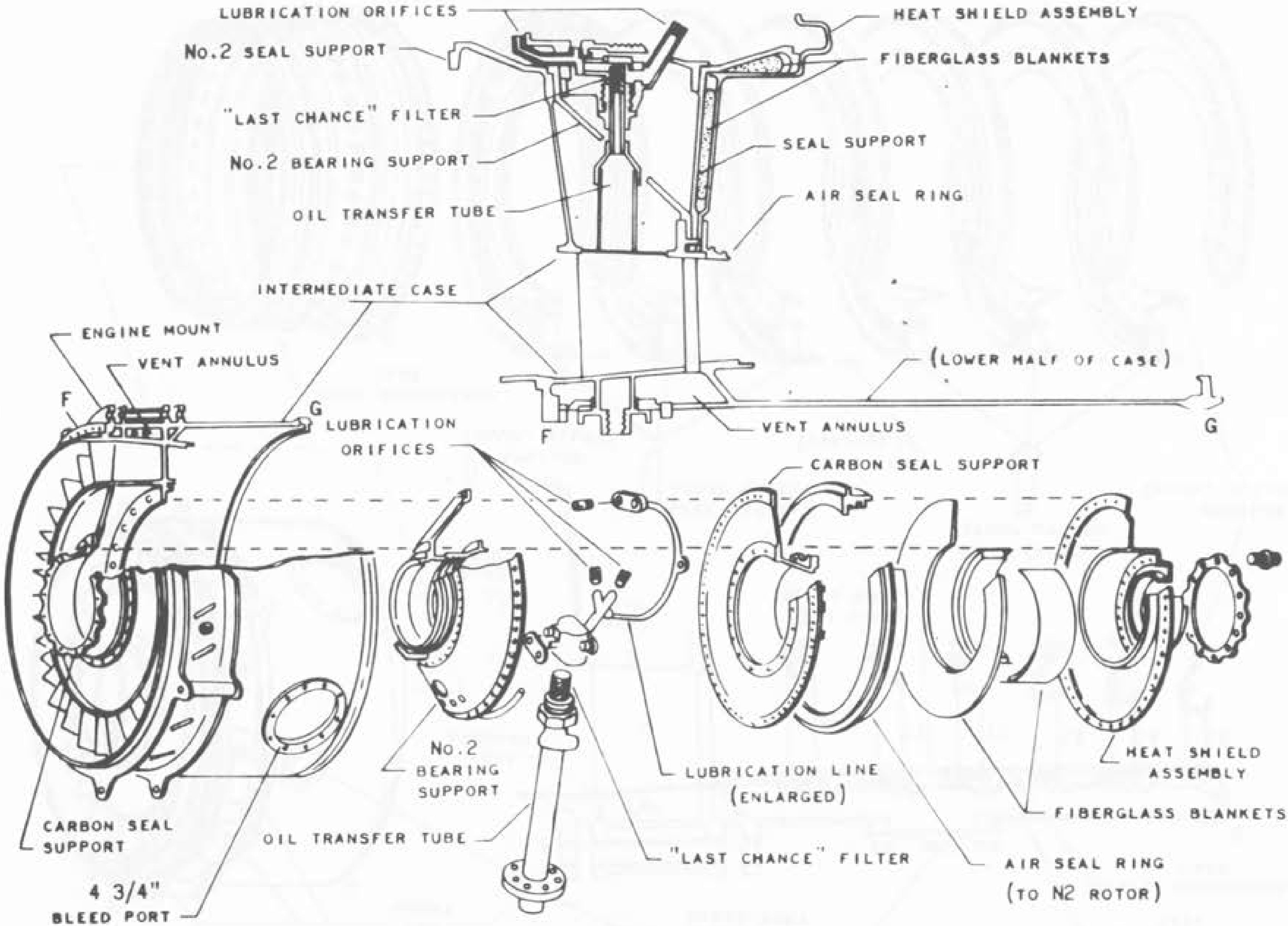
These blades are dovetailed to their disks and are retained by expandable tab locks. The blades have what are called "squeeler" tips. These special tips provide a turbulence which minimizes air leakage on the outer end of the rotors.

N2 COMPRESSOR SECTION (INTERMEDIATE CASE).

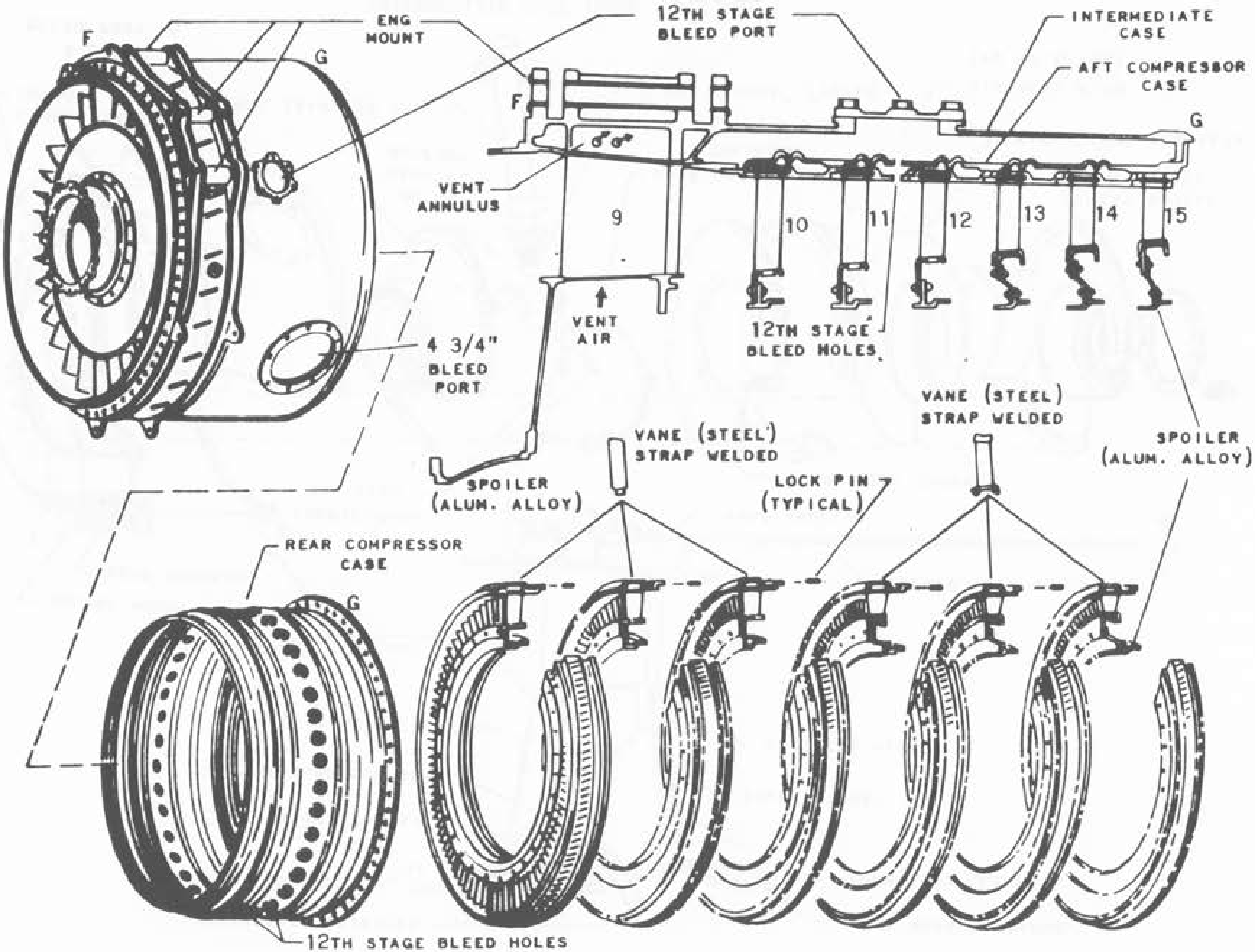
The intermediate case, bolts to the front compressor rear case (N1 compressor outer case) at flange F and to the diffuser case at flange G. The intermediate case forms the N2 compressor outer case. The N2 outer case has two acceleration bleed valves at the twelfth stage: one of 4 3/4-inch diameter on the left side, one of 6-inch diameter on the right side.

On the forward flange (F) there are eight mounting lugs. The four top lugs are used to mount the engine to the pylon (forward engine mount), the bottom four forward lugs are used with the engine stand for removal and installation.

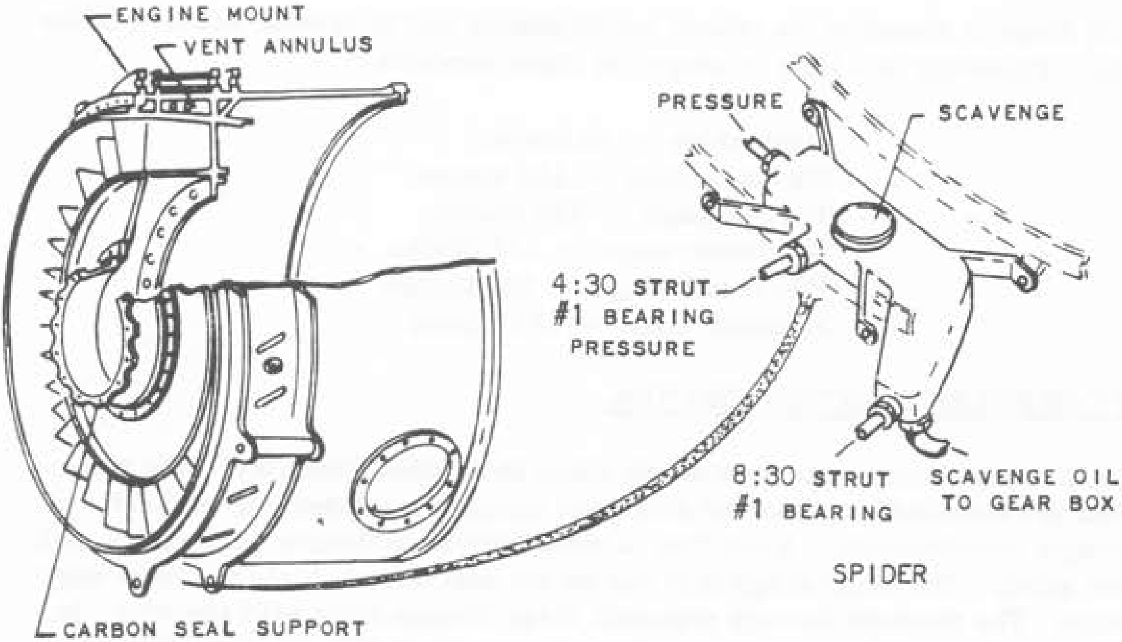
The ninth-stage stator for the N1 compressor is formed by the forward part of the intermediate case. The outer circumference of the case forms a bearing vent manifold. A vent adapter tube in the 6 o'clock strut connects the bearing cavity and the vent annulus.



INTERMEDIATE CASE INNER STRUCTURE



N2 COMPRESSOR CASE AND STATORS



A spider on the bottom of the 6 o'clock strut combines the fittings for the vent adapter, pressure line from the pump, and the scavenge line from the accessory case.

The No. 2 bearing seal support is welded into the inner periphery of the intermediate case. The No. 2 bearing seal housing bolts to the forward face of the seal support and supports the forward heat shield. The No. 2 bearing housing bolts between the ninth-stage stator and the aft face of the bearing support. The No. 3 bearing seal support and seal housing bolts to the No. 2 bearing housing. In addition, the No. 3 seal support bolts to the inner stator flange. The seal housing supports a fiberglas heat shield assembly.

Assembled with the No. 3 seal support is an air seal ring. This ring contacts the N2 rotor and prevents air leakage across the front of the N2 compressor.

The rear compressor case (inner) is of one-piece steel construction. It slips into the intermediate case on the forward end and is flanged and bolted at the diffuser end (flange F). The N2 stator vane assemblies nest inside this case. The twelfth-stage bleed holes circle the case just over the twelfth-stage rotor stage. These bleed holes port twelfth-stage air between the inner and outer cases.

The six stator assemblies are of steel, continuous-ring construction. The stator blades are all welded on the inner diameter. The outer diameter is strap welded. At the inner diameter an aluminum alloy spoiler shroud is riveted to prevent air leakage. Assembled with the stator sections is an integral duct which serves as a spacer between segments. The stator segments nest into the inner case. The tenth stage butts against a flange; the fifteenth stage is secured by four screws.

Each stage is pinned to the others for alignment and to prevent rotation in the case. Following is a list, by stage, of blade numbers.

Tenth stage - 96 blades
Eleventh stage - 122 blades
Twelfth stage - 128 blades
Thirteenth stage - 140 blades
Fourteenth stage - 150 blades
Fifteenth stage - 174 blades

N2 COMPRESSOR SECTION (ROTOR).

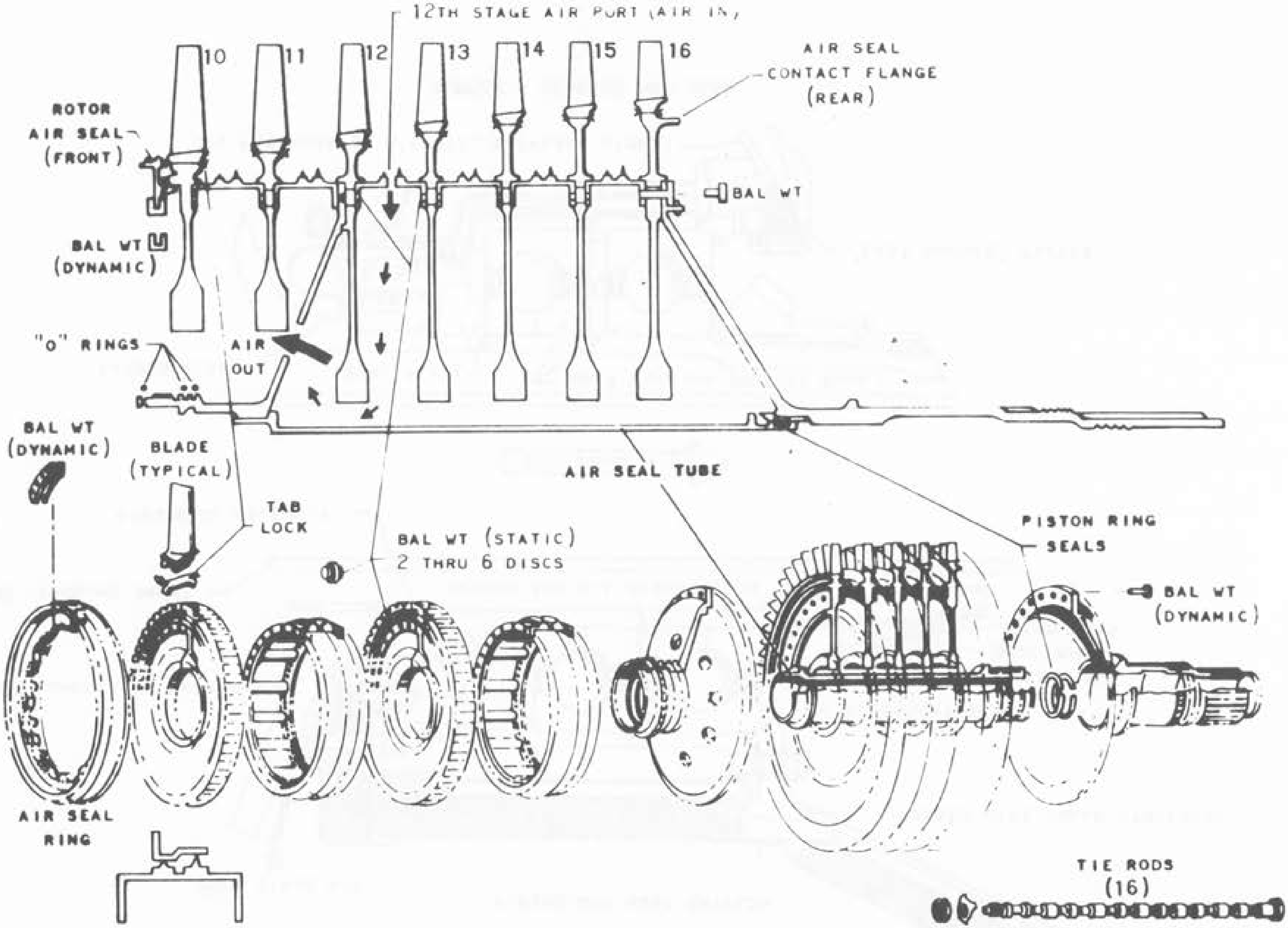
The N2 compressor rotor is a seven-stage steel alloy assembly. The rotor disks are machined in assorted sizes and thicknesses depending on their strength requirements. Each disk is made with snap flanges on the front and rear sides. The tenth-stage disk has an air seal mounted into the front snap flange. The eleventh through sixteenth stage flanges mate with spacers. In addition, the twelfth stage accepts the N2 rotor front hub; the sixteenth stage accepts the rear hub.

The six spacers are separate steel disks with machined knife-edge seals on their rims. They separate the rotor segments and shrink fit into the rotor snap flanges. When assembled into the rotor stack the spacers help transmit torque. The knife-edge seals mate with the stator spoiler shrouds and form air seals.

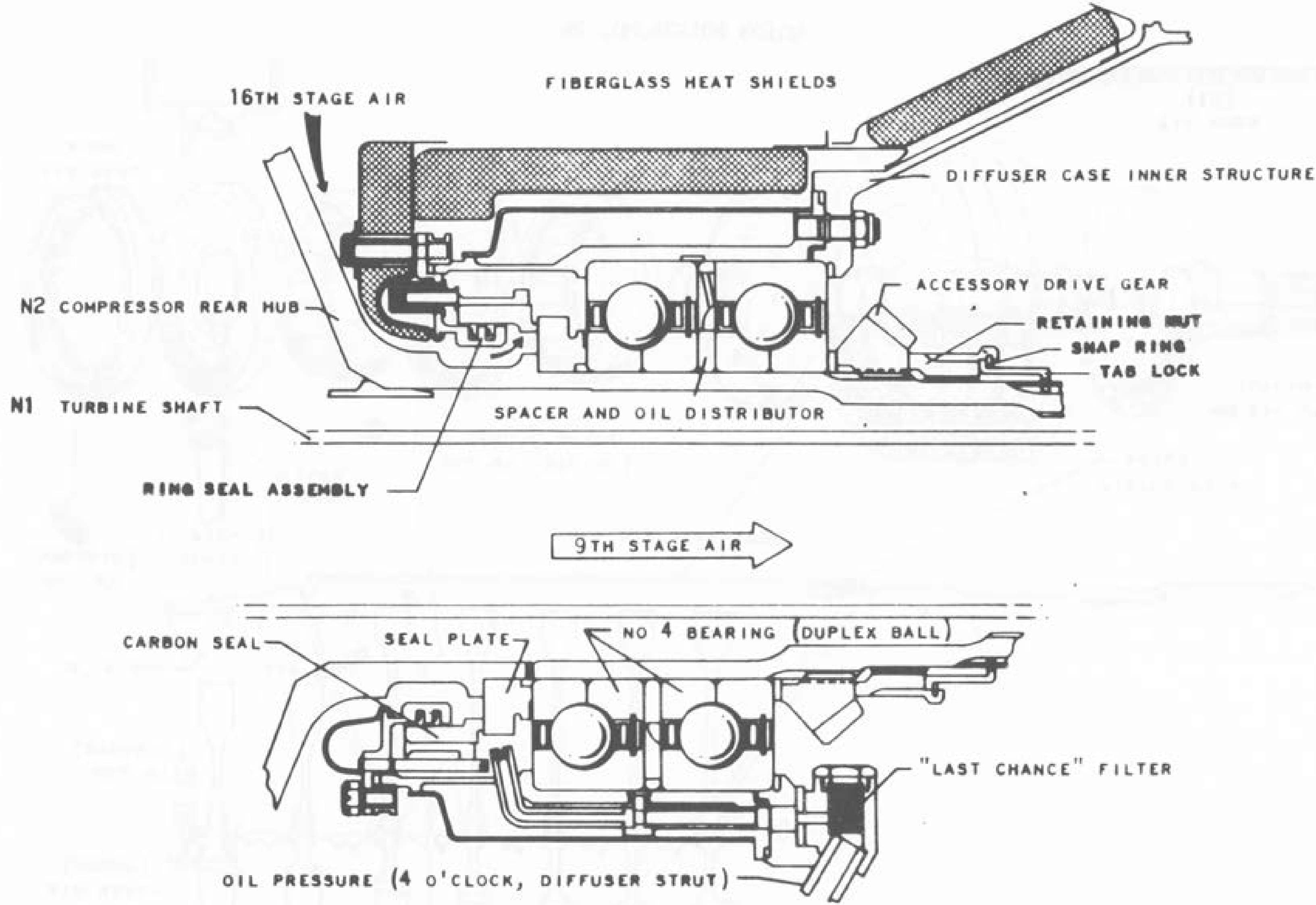
The front hub assembly mounts into the forward flange of the twelfth-stage rotor which reduces overall engine length and the effects of vibrations. The N2 front hub is supported by the No. 3 bearing, and also drives the No. 3 seal carrier. The air seal tube which is shrunk fit into the front hub prevents N2 rotor air from leaking down the shaft. The front hub flange has exit holes which allow twelfth-stage air to exhaust forward, creating approximately 4,000 pounds thrust to offset the engine thrust load on the No. 4 bearing.

The rear hub is flanged to the aft side of the sixteenth-stage rotor. Just above the hub flange is an air seal contact flange which mates with N2 rotor air seals. The rear hub is installed over the air seal tube with piston ring type seals. The rear hub also mounts the No. 4 bearing, No. 4 seal plate, and the accessory drive gear. The aft end of the N2 hub splines into the N2 turbine shaft with a spacer. Left and right-hand threaded nuts secure the assembly.

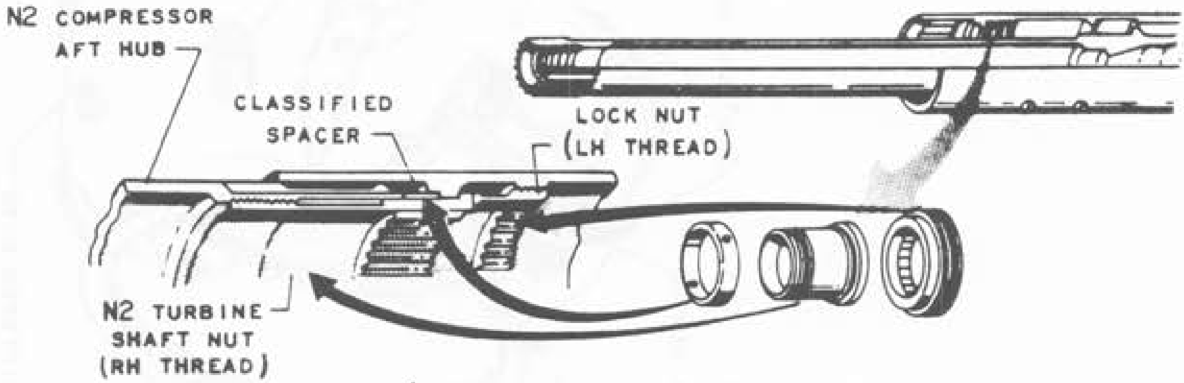
The 16 N2 compressor tie rods are installed from the rear (sixteenth-stage rotor) thus securing the rotor stack. The forged steel compressor blades dovetail into the rotors. The blades are secured by expandable tab locks. In addition, the blades are "squeeler" tipped.



N2 COMPRESSOR ROTOR



NUMBER 4 BEARING AND SEAL



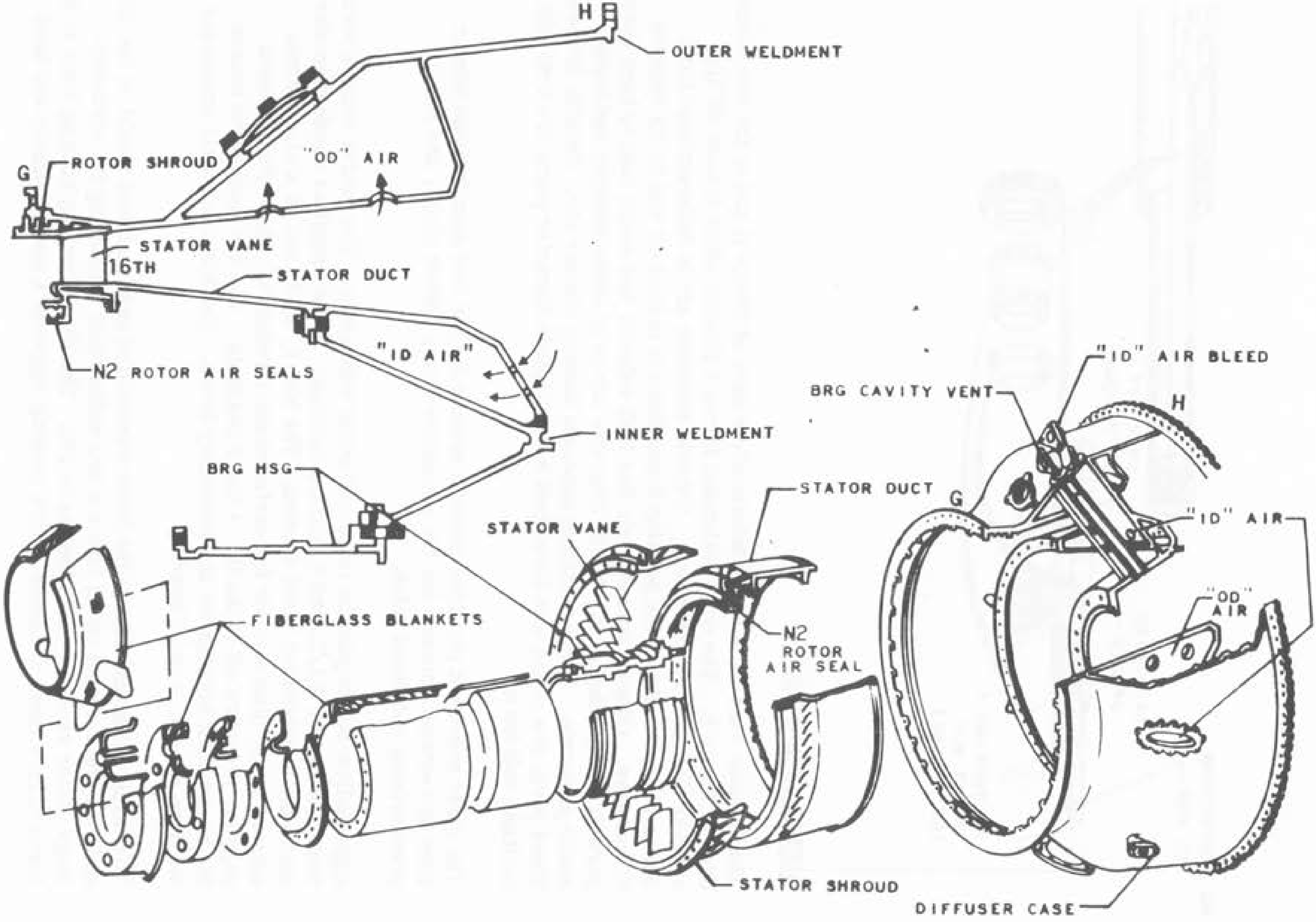
DIFFUSER SECTION.

The diffuser case bolts to the intermediate case at flange G and to the combustion case at flange H. The outer weldment forms a plenum which bleeds off high velocity "outside diameter" air. Outside diameter air is differentiated from inside diameter air by the position from which it is bled off and by its relative cleanliness. Outside diameter air has high velocity and would tend to keep heavy particles suspended in it. Inside diameter air is of lower velocity and higher static pressure. Large particles separate leaving cleaner air. Outside diameter bleed ports are round with three bolt holes; inside diameter ports are oval with multiple bolt holes.

The outer weldment provides internal mounts for the fuel manifold and burner cans and external mounts for the accessory case, igniter plugs, and the pressurizing and dump valve.

Eight hollow struts join the inner and outer weldments. The twelve o'clock strut vents the No. 4, 4 1/2, and 5 bearing cavities. It also supplies inside diameter air to the acceleration bleed control. The No. 1, 3, 9, and 10 o'clock struts extract inside diameter air for environmental systems. The 4 o'clock strut supplies pressure oil to the No. 4 and 5 bearings. The 6 o'clock strut houses the tower shaft housing for the accessory drive. The 8 o'clock strut scavenges oil from the No. 4 and 5 bearing.

The inner weldment bolts to the inner combustion case and heat shield on the aft end. On the forward end it forms a two walled duct supporting the sixteenth-stage stator vanes of which there are 130. The No. 4 bearing housing bolts to the forward face inner diameter. This housing supports a seal assembly and head



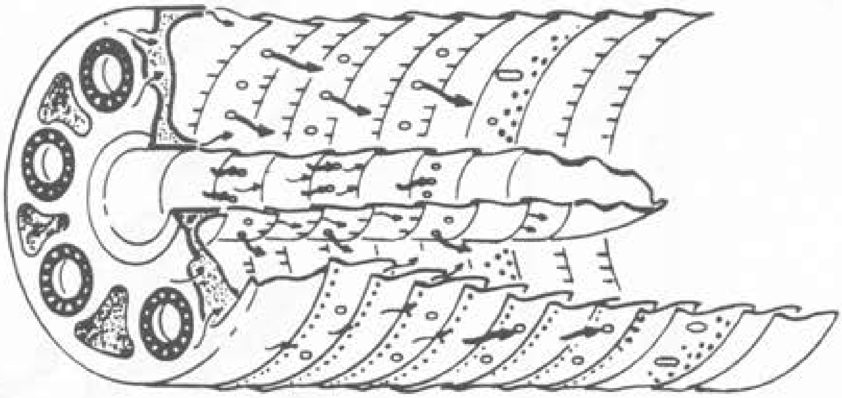
DIFFUSER ASSEMBLY

shield. A bracket on the aft inner diameter helps support the fuel manifold.

COMBUSTION SECTION.

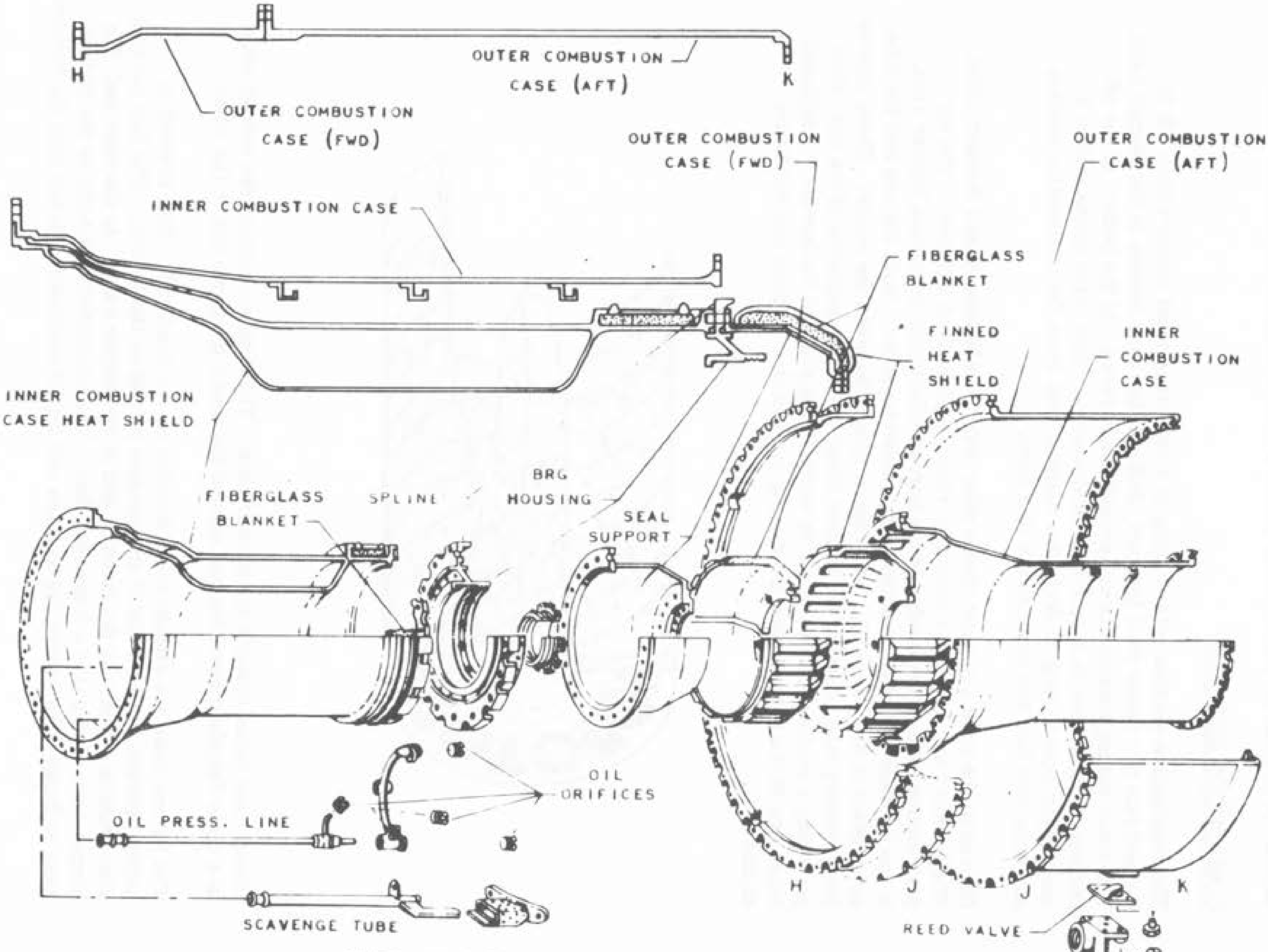
The combustion section outer casing is a two piece steel construction. It is formed into two cases (H-J forward, J-K aft) for easy access to the burner cans. The outer casing retains the air around the burners. In the bottom of the aft portion of the casing is a reed type drain valve. This valve opens at 2 to 4 pounds per square inch to drain the residual fuel from the combustion section any time raw fuel has collected in this area.

Housed in the case are eight nickel alloy steel combustion liners (burner cans). The burners are made of a series of rings, roll-welded together. The air distribution tube in the center of the burner effectively increases burner area. It too is made of ringed sections roll-welded together. Both the can and the tube are welded in such a manner as to leave spaces between the welds. These spaces form cooling tabs allowing air to flow along the inside surfaces of the can, thus providing a cooling blanket of air to insulate the sides of the burner. Additional holes are in the burner cans for mixing the fuel-air mixture and for flame dilution.

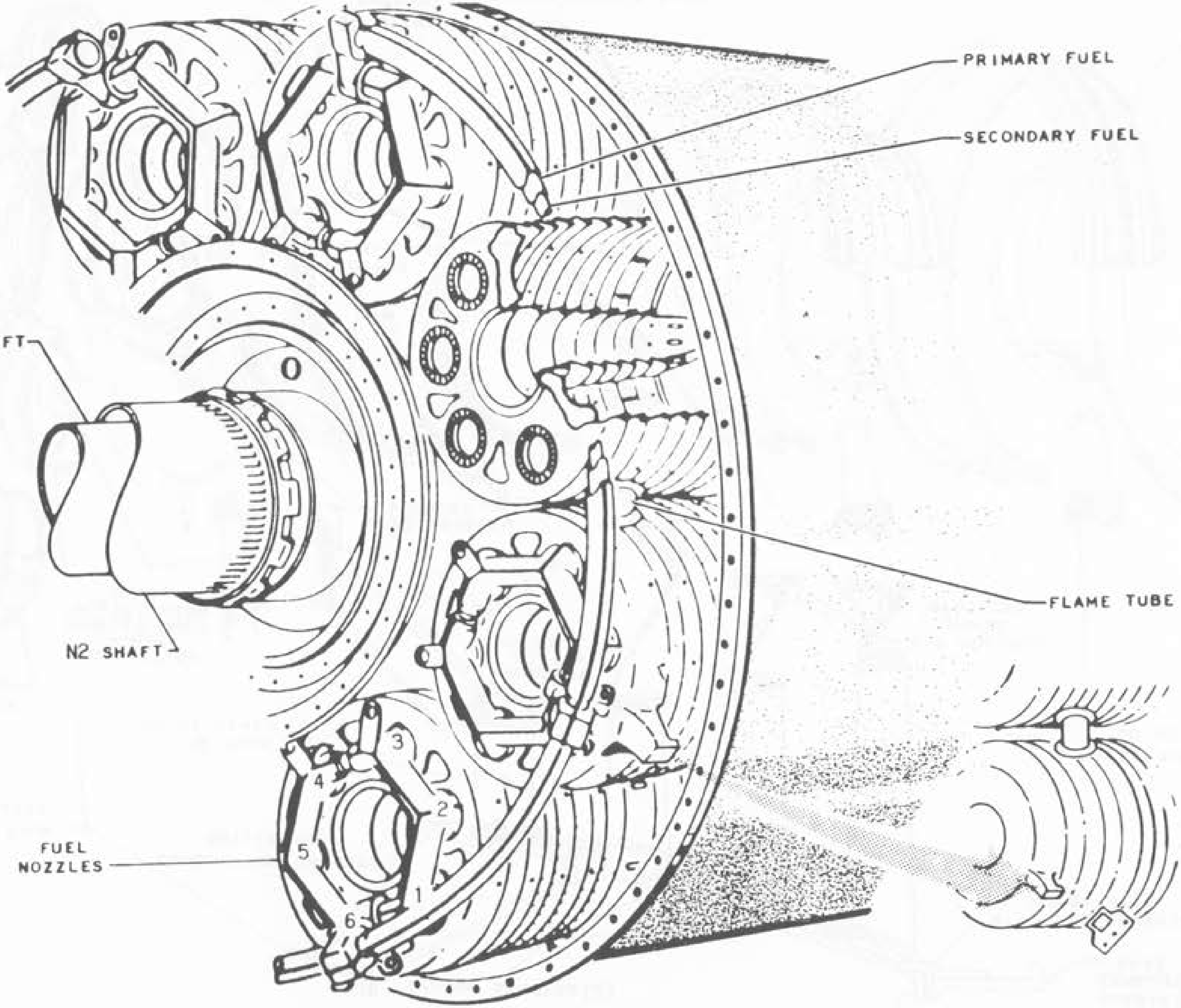


Cross-over tubes connect the burner cans. These tubes connect the burner cans in a male-female connection and spread the flame from one can to the other.

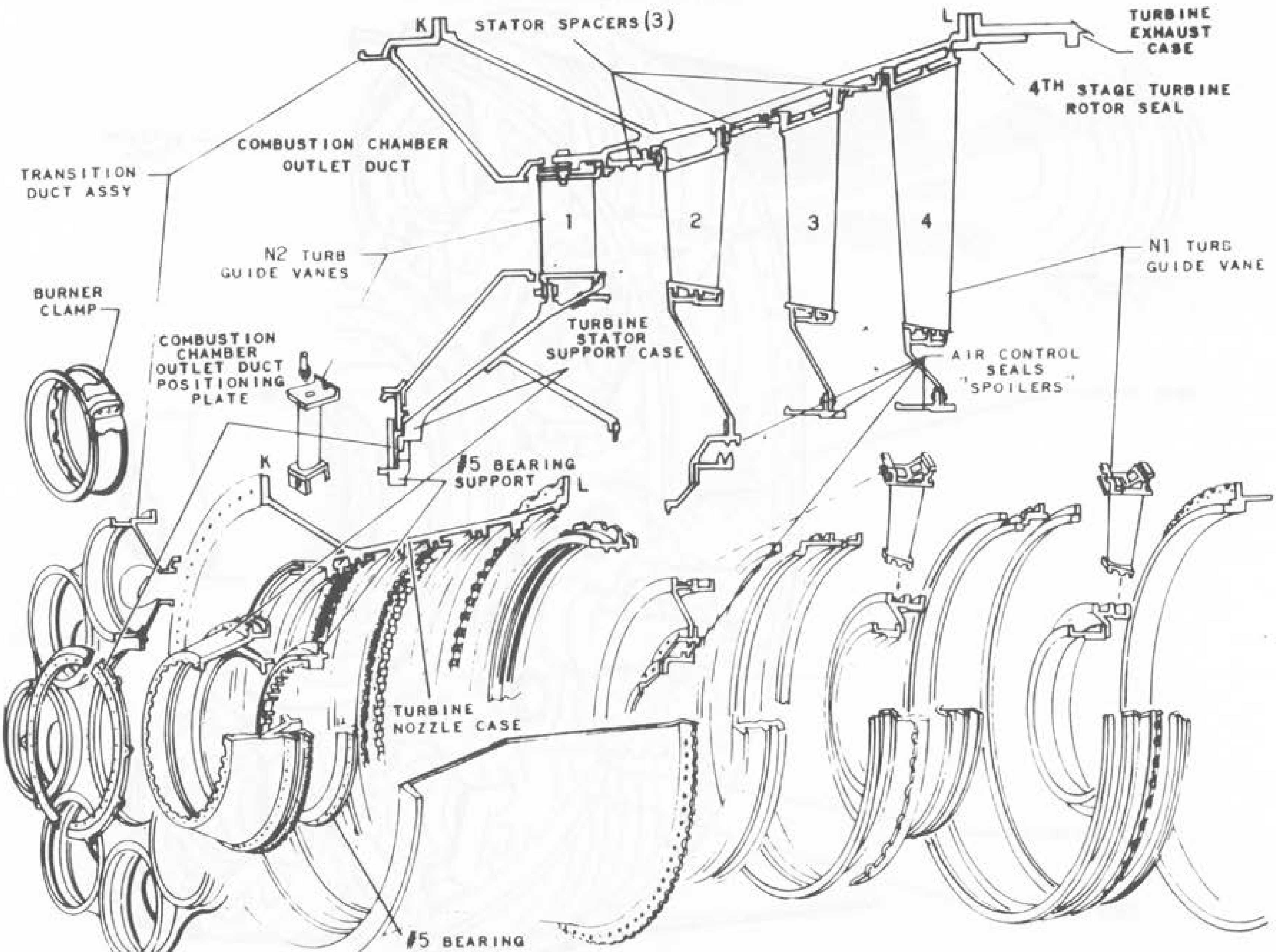
The burner cans are attached to a bracket on the front end. This bracket is bolted between flange G and H and accepts a hook on the burner. The fuel nozzles also provide support on the forward end of the burner cans. At the rear end, the burner cans clamp into a transition duct. The transition duct bolts to the turbine case at flange K to secure the burners and direct combustion gases onto the turbine.



INNER AND OUTER COMBUSTION CASE ASSEMBLY



CAN ANNULAR COMBUSTION CHAMBER



TURBINE NOZZLE CASE

A three-walled combustion inner case houses and protects the turbine shafts. It also encloses the pressure and scavenge oil tubes for the No. 3 bearing. A dual scavenge pump is also housed in the inner case. In addition to the above, the inner case forms a vent cavity and scavenge sump for the No. 4, 4 1/2, and 5 bearings.

TURBINE SECTION.

The turbine nozzle case, K-L, is a one-piece steel structure. It encloses the N1 and N2 of the turbines. Each stage consists of a stator assembly located in front of a rotor assembly.

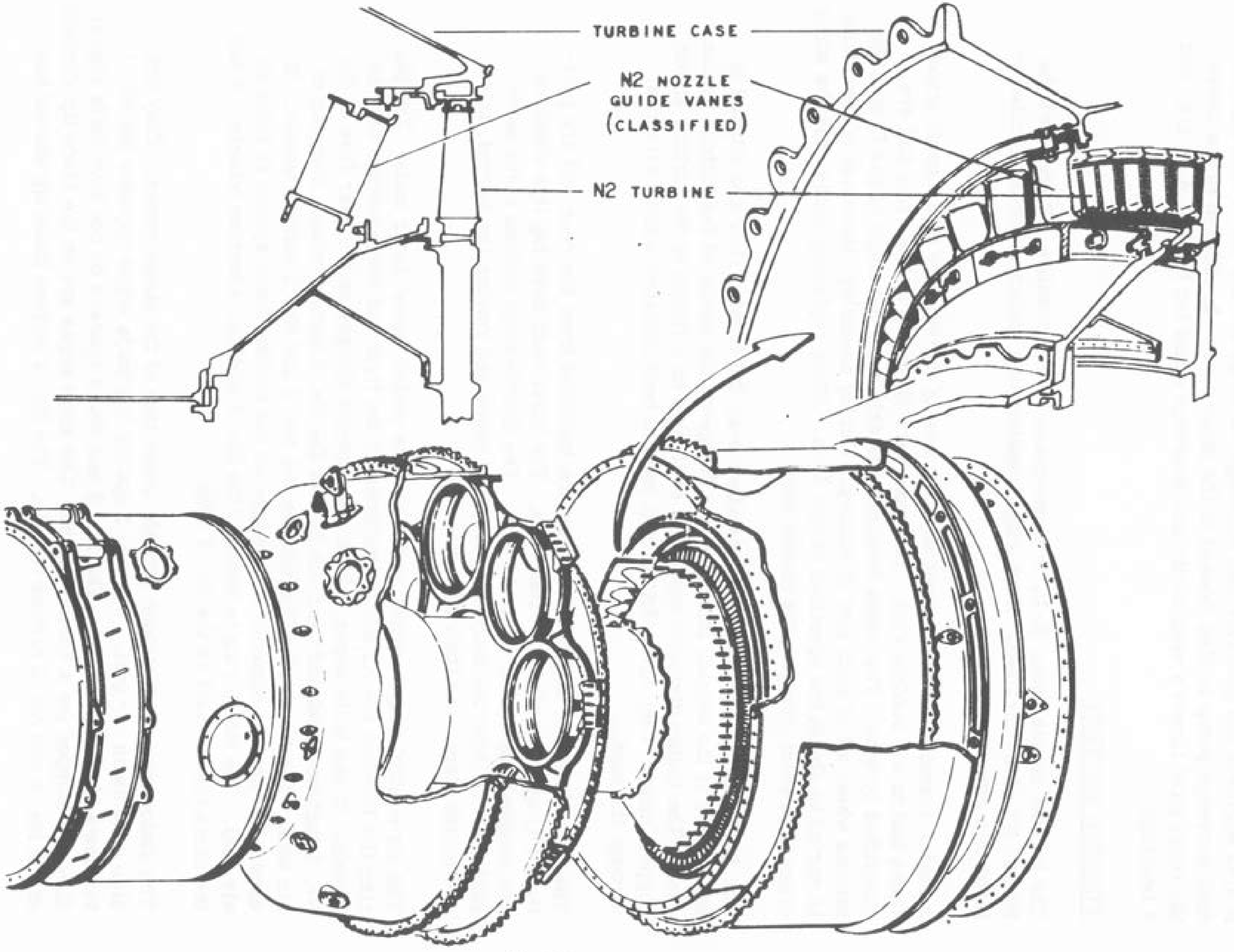
A stator assembly consists basically of a row of individually replaceable stator vanes and an air control ring. The vanes are shrouded at their tips and are classified by size. The vanes determine nozzle area and angle of gas flow to the turbine wheel aft of each row of stators. During assembly, the class of the vanes is varied to obtain the specified nozzle area. When replacing vanes, use the same class to prevent changing the nozzle area.

The first-stage stator vanes are installed from the front. They are slipped in and pinned at the outside diameter to a flange on the inside of the turbine nozzle case. The inside diameter blades fit over lugs on a flange of the turbine stator support case. They are safetied by a special heat resistent safety wire run through the lugs.

The second, third, and fourth stages are installed from the rear and are positioned by spacers at their outer ends. The inner ends have lug tips which fit into channels in the air control rings. The fourth-stage turbine rotor outer seal fits in behind the fourth-stage stator vanes and retains the second, third, and fourth stages and their spacers.

The air control rings control airflow at the stator vanes' inner ends. The No. 1 ring fits between the N1 and N2 turbines or the first and second-stage turbine wheels. It has knife edges, which are opposite flanges on the rear face of the No. 1 turbine wheel and the front face of the No. 2 turbine wheel, forming an air seal. The No. 2 ring fits between the No. 2 and No. 3 turbine wheels. It uses a flat spoiler opposite knife edges on the turbine rotor spacer to form an air seal. The No. 3 ring is between the No. 3 and No. 4 turbine wheels. It has the same type of seal as the No. 2 ring.

The stator spacers interlock with the outer tips of the stator vanes. They are also used as an air seal. The No. 1 spacer has knife edges opposite the No. 1 turbine's blade tip shroud. The No. 2 and No. 3 spacers do not have knife edges; they are stepped for a spoiler effect. The knife edges are on the blade tip shrouds of the No. 2 and No. 3 turbine wheels. The No. 4 turbine blade tip shroud has



N2 TURBINE INSPECTION

the knife edges opposite the stepped fourth-stage rotor seal. These seals contain the diverging gas flow minimizing the leakage around the outside of the blade tip shrouds.

A combustion chamber outlet duct is positioned by a plate to the rear flange on the inner combustion case. The plate has an inner bolt ring and eight tabs which extend around the outer edge. Locating pins extend rearward from four of these tabs. It is on these locating pins the outlet duct is correctly positioned.

The center opening of the outlet duct is larger in diameter than the forward flange on the stator support case. The forward flange extends through the opening and mates to the bolt ring on the outlet duct positioning plate. The No. 5 bearing support mates to the rear face of the front flange on the stator support case. From the rear, bolts are inserted in every other hole around the bearing support. Then from the other side, i.e. the positioning plate side, bolts are placed in the remaining holes. In this manner the positioning plate, combustion case rear flange, stator support case front flange, and the No. 5 bearing support are all joined together.

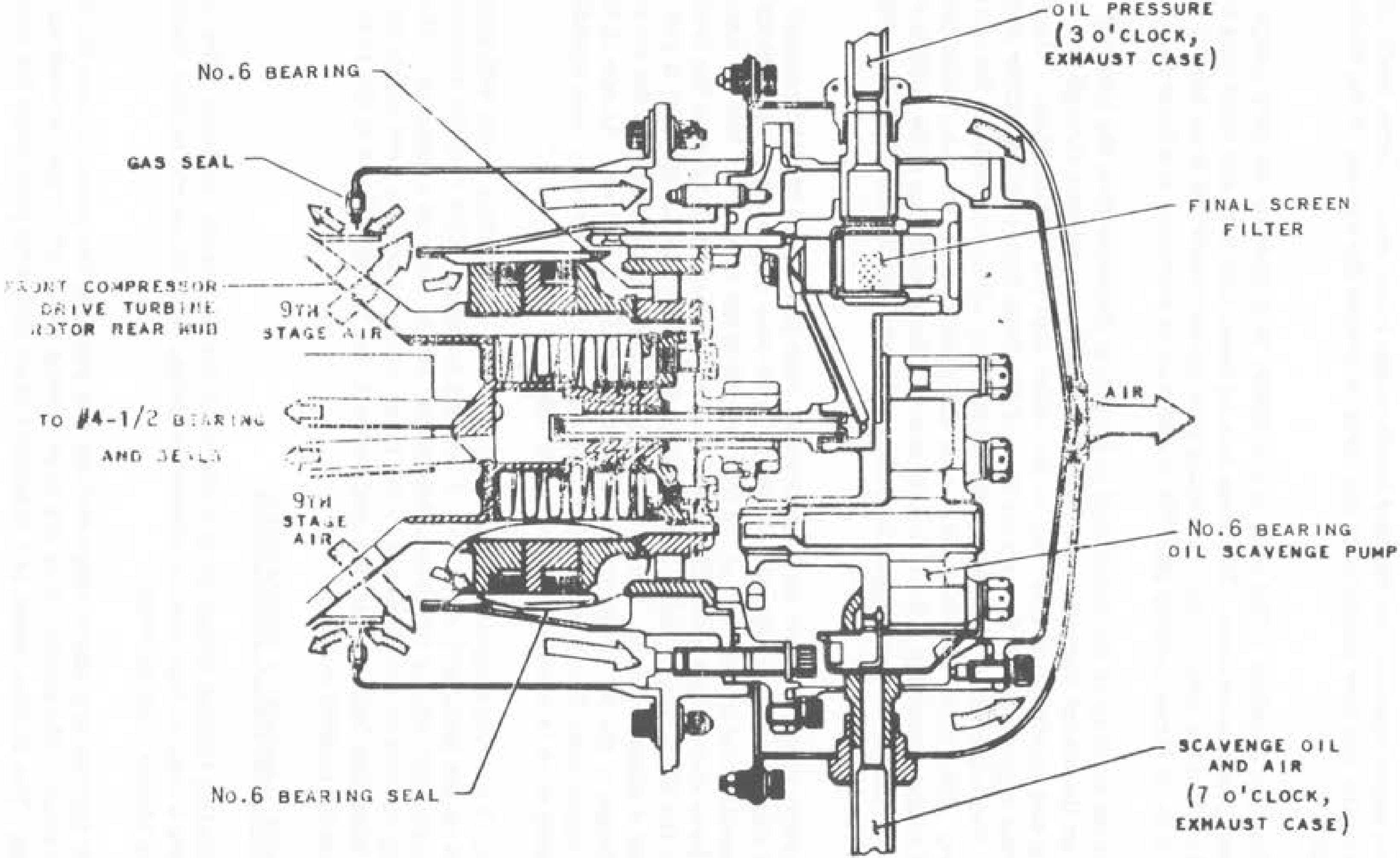
The turbine stator support or inner turbine case provides a mounting means for the N2 stators and two air control seals. It is cone shaped and, as previously mentioned, bolts to the rear of the inner combustion case. The two air control seals have knife edges extending inward towards opposite flanges on the front face of the N2 turbine wheel. Mounting for the stators is provided by a row of lugs and a stepped flange. The stepped flange and a similar one on the inner rear flange of the N2 stator vanes provide a seat for the vanes. An eye in the stator inner front flange passes over the lug. After the row has been installed the safety wire is used for retaining the vanes.

The No. 5 bearing support is internally splined. The splines mesh with similar splines on the periphery of the No. 5 bearing housing. This radially positions the housing and allows for growth lengthwise due to thermal expansion. The bearing housing is also fastened to the inner combustion case heat shield by the same bolts that hold the bearing seal support and the heat shield to the rear of the bearing support housing.

TURBINE ASSEMBLY (ROTATING).

The rotating turbine assembly is made up of the N1 and N2 turbines. The turbines consists a total of four turbine wheels or disks, two concentric turbine shafts, turbine blades, and tie rods.

The N2 turbine is a single stage turbine that supplies the power to turn the N2 compressor. Physically, it is the first turbine wheel aft of the combustion section. The turbine wheel is a machined steel disk with provisions for attaching



NUMBER 6 BEARING SEALS AND OIL SUMP

the turbine blades to its outer circumference.

The blades are classified by weight in pairs and then installed diametrically opposite each other. They are fir-treed to the wheel. The broached openings in the wheel are not perpendicular to the face of the disk but are at about a 10-degree angle to the wheel. They are offset as a method of manufacturing and assembly that reduces the width of the base of the blade allowing more blades to be installed around the turbine wheel. On their outer tips, the turbine blades are shrouded to cut down airflow losses. The shrouds are interlocked in a "Z" shaped joint for added strength.

On the rear face of the No. 1 trubine wheel, one seal flange is opposite the knife-edge fastened to the bottom of the No. 2 stator air control ring.

The front face of the N2 turbine is cooled by sixteenth-stage air that has passed aft between the inner combustion case and the case liner. The cooling air can pass outward along the face of the wheels through the knife seals and finally mix with the gas flow just forward of the N2 turbine blades. Part of the cooling air can pass down through holes in the mounting flange to the area between the N2 and N1 shafts. From here it flows forward through the shaft bearings and seals or rearward under the N2 wheel and up its rear face and the front face of the No. 2 turbine wheel to mix with the exhaust flow.

The inner diameter of the N2 turbine wheel has a snap flange on the forward face for mounting to the N2 turbine shaft flange. The N2 turbine shaft extends forward through the combustion section coupling the N2 turbine to the N2 compressor. At its aft end, just forward of the turbine section, it is supported by the No. 5 bearing. At the forward end, just aft of the diffuser, it is splined to and supported by the N2 compressor rear hub. At the midpoint it is supported by the No. 4 1/2 bearing.

The N2 turbine shaft coupling consists of a spacer, attach nut, and lock nut. The N2 compressor rear hub has external splines and the N2 turbine shaft has internal splines. The spacer fits between the end of the rear hub and an internal shoulder inside the turbine shaft when the two are splined together. On the rear face of the same shoulder, an attach nut mates when it is threaded into the internal threads of the rear hub. Once the attach nut is seated, a lock nut threads into the inside of the turbine shaft and seats against the attach nut. The two nuts have opposite threads, e.g. the attach nut is right hand and the lock nut is left hand, to provide a locking system for the N2 compressor and turbine shaft. The nuts themselves have internal splines to match those on the tool used to remove them. They are accessible from the rear end or the turbine after the N1 turbine shaft has been removed.

Just forward of the No. 4 1/2 bearing, the N2 shaft has a series of small holes to allow oil to be scavenged by centrifugal force into the void between the N2 shaft and the combustion case heat shield and into the No. 4 bearing sump.

The N1 turbine is a three-stage assembly consisting of the No. 2, No. 3, and No. 4 turbine wheels, their seals, a spacer, and ten tie rods.

A turbine rotor seal is between the No. 2 and No. 3 turbine wheels and another between the No. 3 and No. 4 wheels. The spacer is concentrically mounted inside the rotor seal between the No. 3 and No. 4 wheels. It determines the stacked dimension after assembly and is available in many different thicknesses for this reason.

Ten tie rods hold the N1 turbine assembly together. The No. 2 wheel bolts to a flange on the rear of the N1 turbine shaft. On the rear of the No. 2 wheel, there is an integral turbine shaft extension flange that is sometimes called the "flower pot." The rest of the turbine assembly, consisting of turbine rotor seal, the No. 3 turbine wheel, another rotor seal and the spacer, and the No. 4 turbine wheel and a flange, is fastened to the flower pot by the ten tie rods. Special nuts lock into the flower pot and then the tie rods thread into the nuts from the rear of the turbine. Then, on the rear end of the tie rods, the assembly is secured by nuts and tab locks. The turbine wheels have close tolerance snap flanges for the stacking of the wheels, seals, and spacer.

The rear flange or hub narrows and extends rearward forming a mounting surface for the No. 6 bearing, bearing spacer, and seal assembly.

The rear hub is internally threaded for a plate to which an oil transfer tube assembly and a pinion drive gear attach. The transfer tube passes engine lubrication oil to the trumphets going to the No. 4 1/2 bearing. The pinion drive gear drives the No. 6 bearing oil scavenge pump.

A housing attached to the No. 6 bearing support encases the oil scavenge pump. A cup-shaped heat shield fastens over this area. Ninth-stage cooling air, passing through the inside of the N1 turbine shaft, flows between the pump housing and the heat shield. It then passes out a hole in the tip of the heat shield and back along the inside of the tail cone. At the junction of the tail cone and the turbine assembly, it mixes with the exhaust gas flow. Some ninth-stage air passes through the air seal at the rear inner face of the No. 4 turbine wheel and out along the rear face cooling it and then mixes with the exhaust gas flow near the turbine blade base.

The turbine blades are fir-treed and rivet retained in the rim of the turbine wheels the same way as the N2 turbine blades. Knife-edge air seals are used on the outside of the blade tip shrouds and each blade's shroud interlocks with the ones on each side of it. The interlocking face is Z-shaped. Above 9,000 revolutions per minute, centrifugal twisting force acting on the blades locks the tips firmly together. As previously mentioned, the blades are classified by weight and are installed in pairs diametrically opposite each other.

The N1 turbine shaft couples the N1 turbine to the N1 compressor. The rear hub of the N1 compressor is splined internally, and the N1 turbine shaft has external splines. They slip together and then an attach nut is inserted in from the compressor side.

The turbine attach nut and a lock (retaining) assembly are held inside the rear hub by a snap ring. The lock consists of two splined collars and a spring. The attach nut is internally splined to receive a Sweeney wrench. The lock is designed to be released by the Sweeney wrench allowing the attach nut to turn. The nut threads into the inside of the turbine shaft. As it is threaded in, a shoulder on the nut tightens down against the other side of the flange in the hub pulling the turbine shaft into position. For disassembly, the attach nut acts against the lock and functions as a puller, thus backing the shaft out of the compressor hub. The attach nut is silverplated to prevent seizing and galling.

The N1 turbine shaft is supported at its forward end by the N1 compressor rear hub. Further aft in the combustion area, the N1 shaft and the forward end of the turbine rotor are supported by the No. 4 1/2 bearing. The aft end of the N1 turbine rotor is supported by the No. 6 bearing. No. 4 1/2 bearing inner race and retaining nut are on the N1 turbine shaft and the oil tubes are inside the shaft.

TURBINE EXHAUST CASE.

The turbine exhaust case, L-M, attaches to the rear of the turbine nozzle case. The fourth-stage turbine outer seal is flanged between the rear flange of the turbine nozzle case and the front flange of the exhaust case. Two heavy external flanges near the center of the exhaust case provide the necessary strength and rigidity for engine mounting and the fastening of the outer ends of the turbine exhaust strut rods. The rods position and hold the No. 6 bearing support, the No. 6 sump and heat shield assembly, and the turbine exhaust fairing assembly.

Six Pt7 probes mount on bosses between the front flange L and the heavy flanges. The bosses are at the 1:30, 3:30, 5:30, 7:00, 8:30, and 10:30 o'clock positions. The probes sample the exhaust gas pressure which is averaged out in the pressure manifold. The manifold, in turn, is connected to the corresponding EPR transmitter.

Just forward of the rear flange N, six thermocouple mounting bosses are located. They are at the 12:30, 3:00, 5:00, 6:30, 9:15, and 11:30 o'clock positions. Six dual thermocuples are mounted on the bosses. The thermocouples provide the exhaust gas temperature electrical signal for the engine EGT system.

The six support rods are secured at their outer ends by a dual locknut arrangement. The locknut arrangement secures the rods to the strut support mounts between the engine mount flanges. Strut support mounts are at the 12:00, 2:00, 5:00, 7:00, and 10:00 o'clock positions on the exhaust case.

At their inner ends, the rods are bolted to ears on the No. 6 bearing support. With the same bolts, a gas seal assembly is fastened to the forward side of the No. 6 bearing support. To the aft side of the bearing support is fastened the sump adapter and No. 6 bearing oil scavenge pump. The entire sump area is enclosed in a heat shield also fastened to the sump adapter.

A pressure oil line enters the exhaust case at the 3:00 o'clock position. It runs parallel to the 3:00 o'clock support rod and enters the No. 6 bearing housing and heat shield just aft of the 3:00 o'clock support.

The exhaust fairing assembly consists of an inner cone and fairing and five hollow streamline struts. The struts fair-in the support rods and oil lines. The inner cone and fairing fairs-in and encloses the No. 6 bearing housing and heat shield assembly. In addition, it forms an inner nozzle wall and maintains proper nozzle area.

MAIN ACCESSORY DRIVE AND GEARBOX.

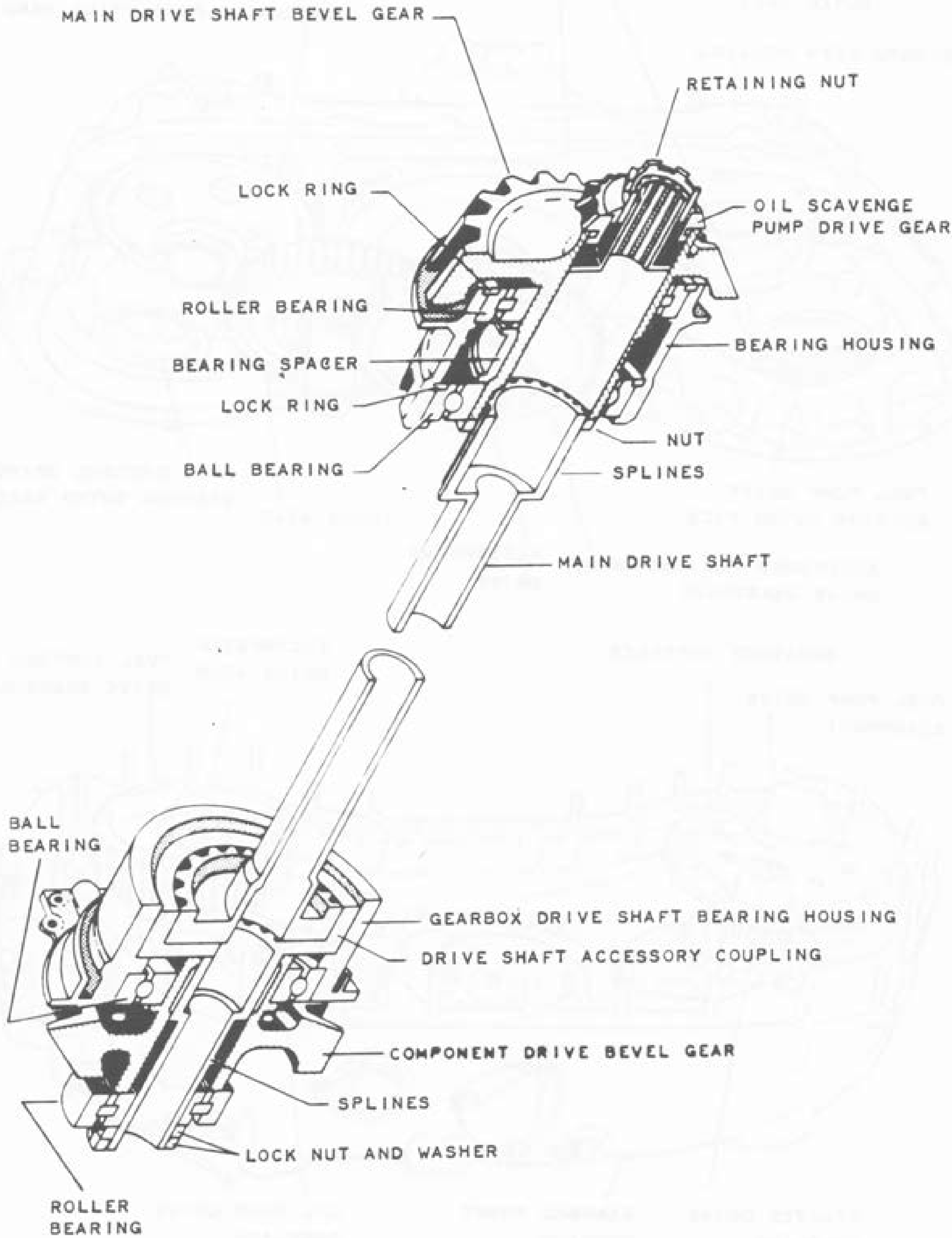
The main accessory drive and gearbox is located at the 6:00 o'clock position on the diffuser case. The accessory drive gearbox consists of front housing, rear housing, and reduction gear assembly.

The reduction gear assembly is driven by a hollow steel tower shaft extending down through the 6:00 o'clock strut. The upper end of the tower shaft splines into the main drive shaft bevel gear and coupling. This gear meshes with the bevel gear on the rear hub of the N2 compressor.

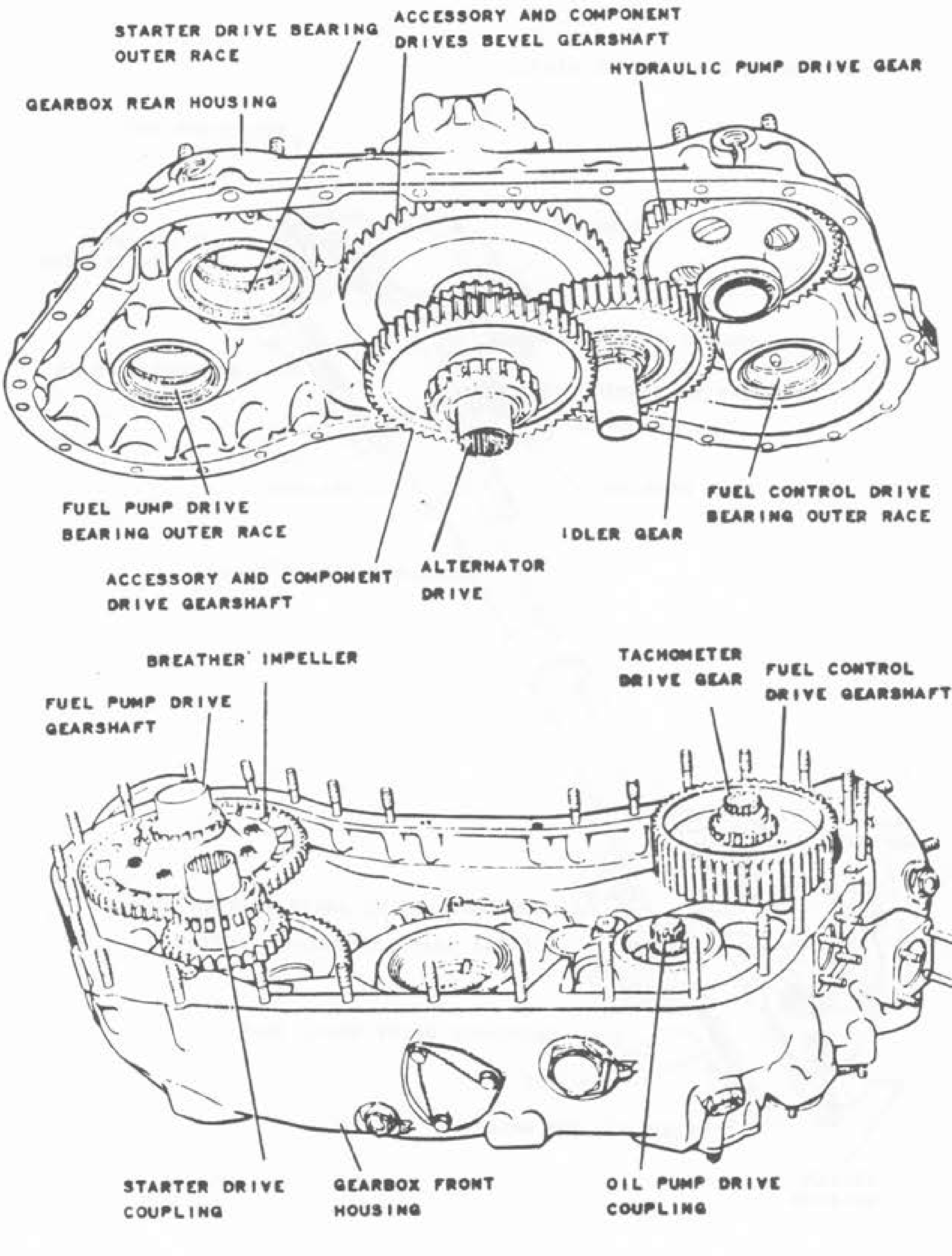
The upper end of the tower shaft is supported by two bearing assemblies, housed in the main component drive coupling. The upper bearing is a roller type and accepts radial loads from the coupling. The other, also a ball bearing, accepts both radial and thrust loads imposed on the coupling by the compressor drive gear.

At its lower end, the tower shaft has a gear that meshes with a ring gear inside the lower coupling. This coupling is, in turn, splined into the inside of a bevel gear that meshes with a bevelled accessory drive gear in the gearbox.

The lower coupling and tower shaft assembly is supported by two bearing


MAIN DRIVE SHAFT BEVEL GEAR
RETAINING NUT
LOCK RING
OIL SCAVENGE PUMP DRIVE GEAR
ROLLER BEARING
BEARING HOUSING
BEARING SPACER
LOCK RING
NUT
BALL BEARING
SPLINES
MAIN DRIVE SHAFT
BALL BEARING
GEARBOX DRIVE SHAFT BEARING HOUSING
DRIVE SHAFT ACCESSORY COUPLING
COMPONENT DRIVE BEVEL GEAR
SPLINES
LOCK NUT AND WASHER
ROLLER BEARING

TOWER SHAFT



GEAR BOX GEAR TRAIN

assemblies located in the gearbox bearing adapter. The ball bearing accepts radial and thrust loads from the tower shaft while the lower roller bearing receives radial loads from the bevel gear.

The gearbox fastens to the diffuser with four mounting lugs, a positioning bracket, and two guide pins.

Mounting lugs are in pairs: one pair on the forward upper left corner, and the other on the upper right corner. Each pair slips over each side of a mounting link attached to the diffuser. When properly aligned, a pin can then be slipped through the lugs and the link. A clip retainer is used to lock the pin in position.

On the top center of the gear case, the positioning bracket slips between two lugs on the bottom of the diffuser case. Just aft of the positioning bracket are the two guide pins. When the case is mounted, the guide pins slide into matching holes in the diffuser case properly aligning the gearbox.

The gearbox is then properly mated to the tower shaft and bevel drive gear assembly. Machined mating surfaces around the tower shaft assembly compress an "O" ring type seal when the gear case is properly attached to the diffuser.

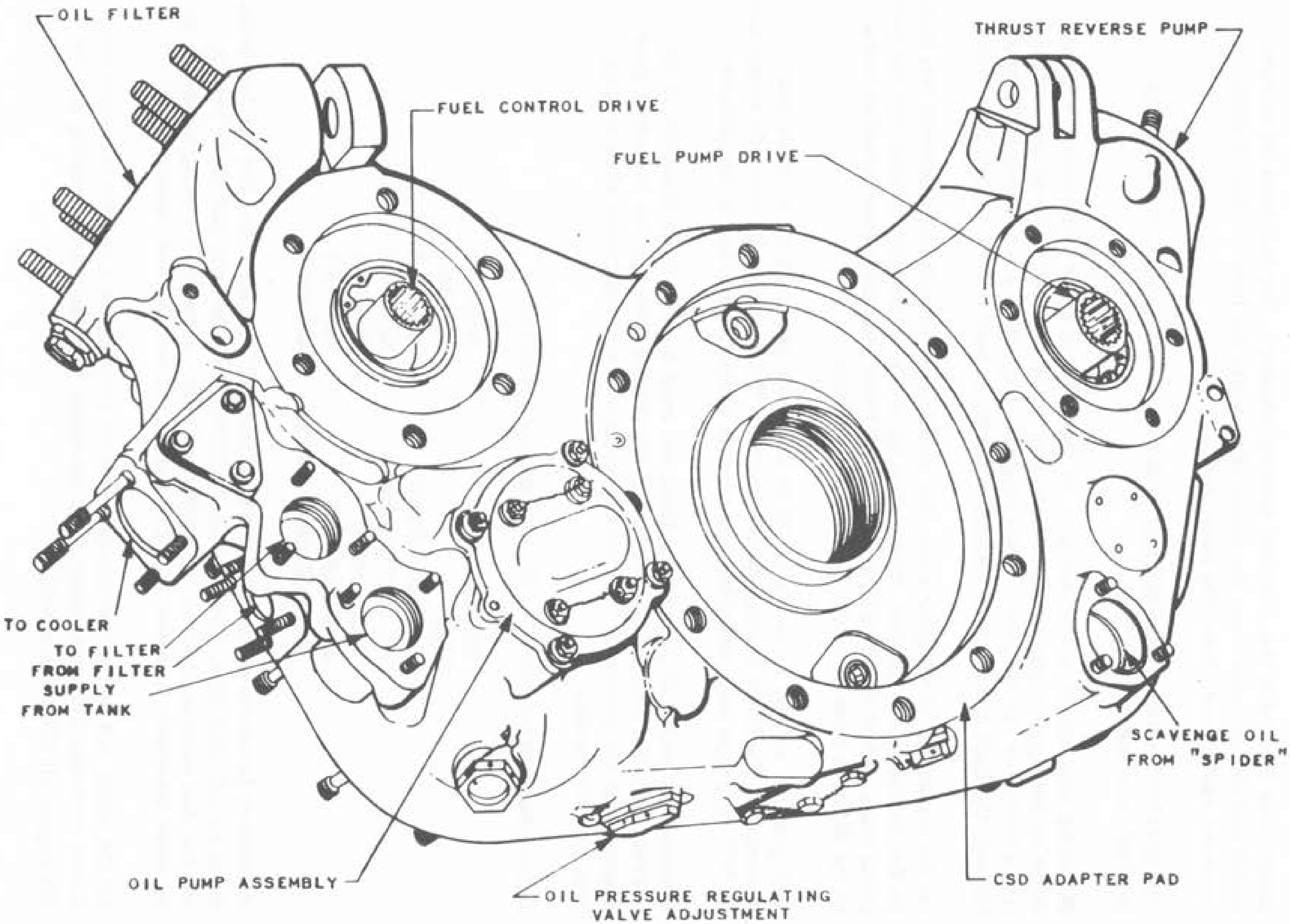
Accessories mount to pads on the front and rear faces. When mounted on the correct pad, the accessory is driven at the proper speed by the reduction gear assembly in the gearbox. All accessory drives are right hand when looking into the drive pads.

Drive ratios as compared to N2 compressor speed follow:

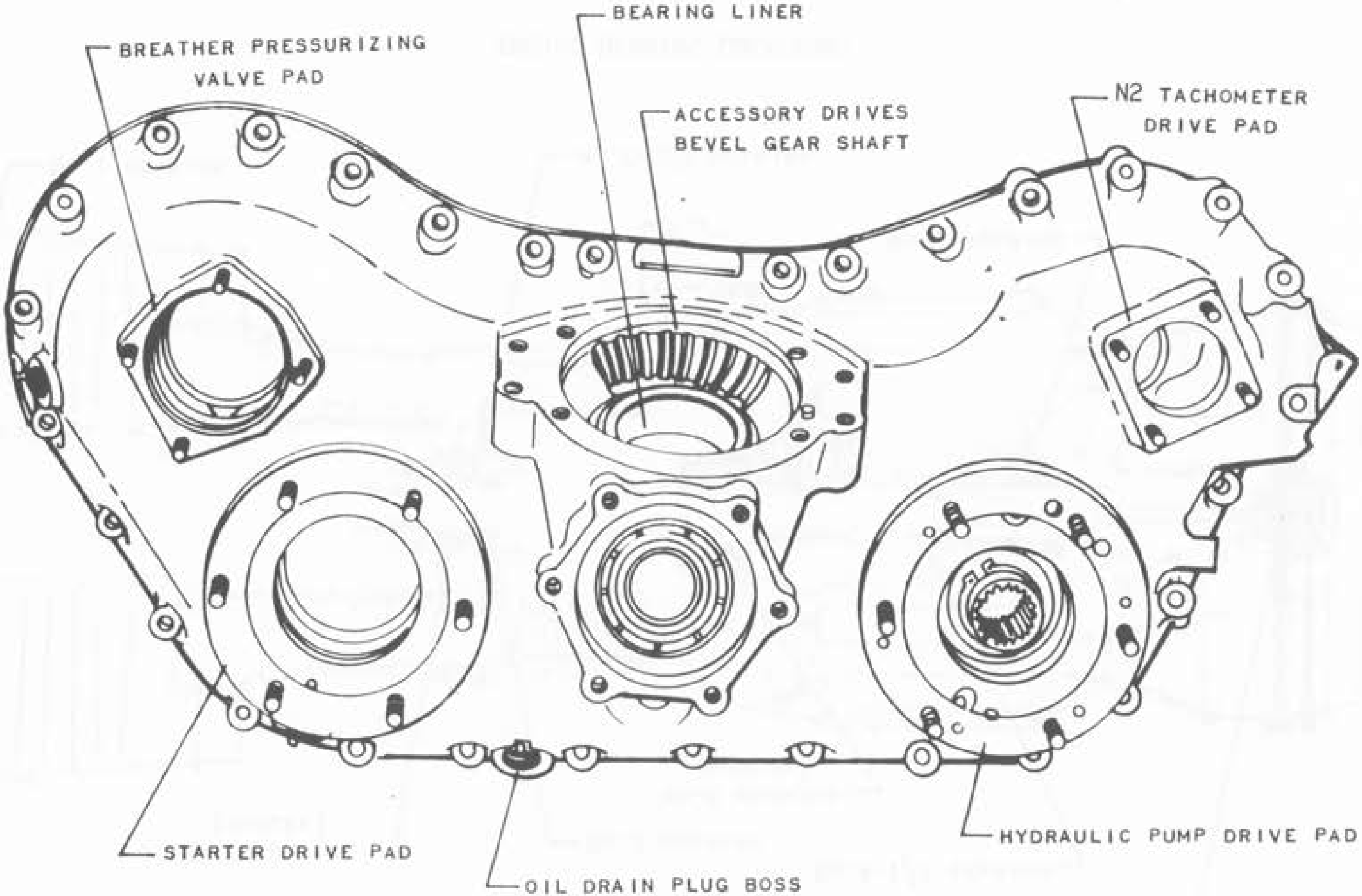
Starter	0.7000:1
CSD	0.8020:1
Hydraulic Pump	0.3420:1
N2 Tach Generator	0.4350:1
Fuel Control	0.3480:1
Fuel Pump	0.3440:1
Thrust Reverser Pump	0.7000:1

Accessory locations on the forward face (viewed from the rear) are the fuel pump drive on left hand side, Constant Speed Drive (CSD) adapter pad in the center, and the fuel control drive on the right hand side. A duplex oil pump assembly is mounted internally between the CSD adapter pad and the fuel control drive.

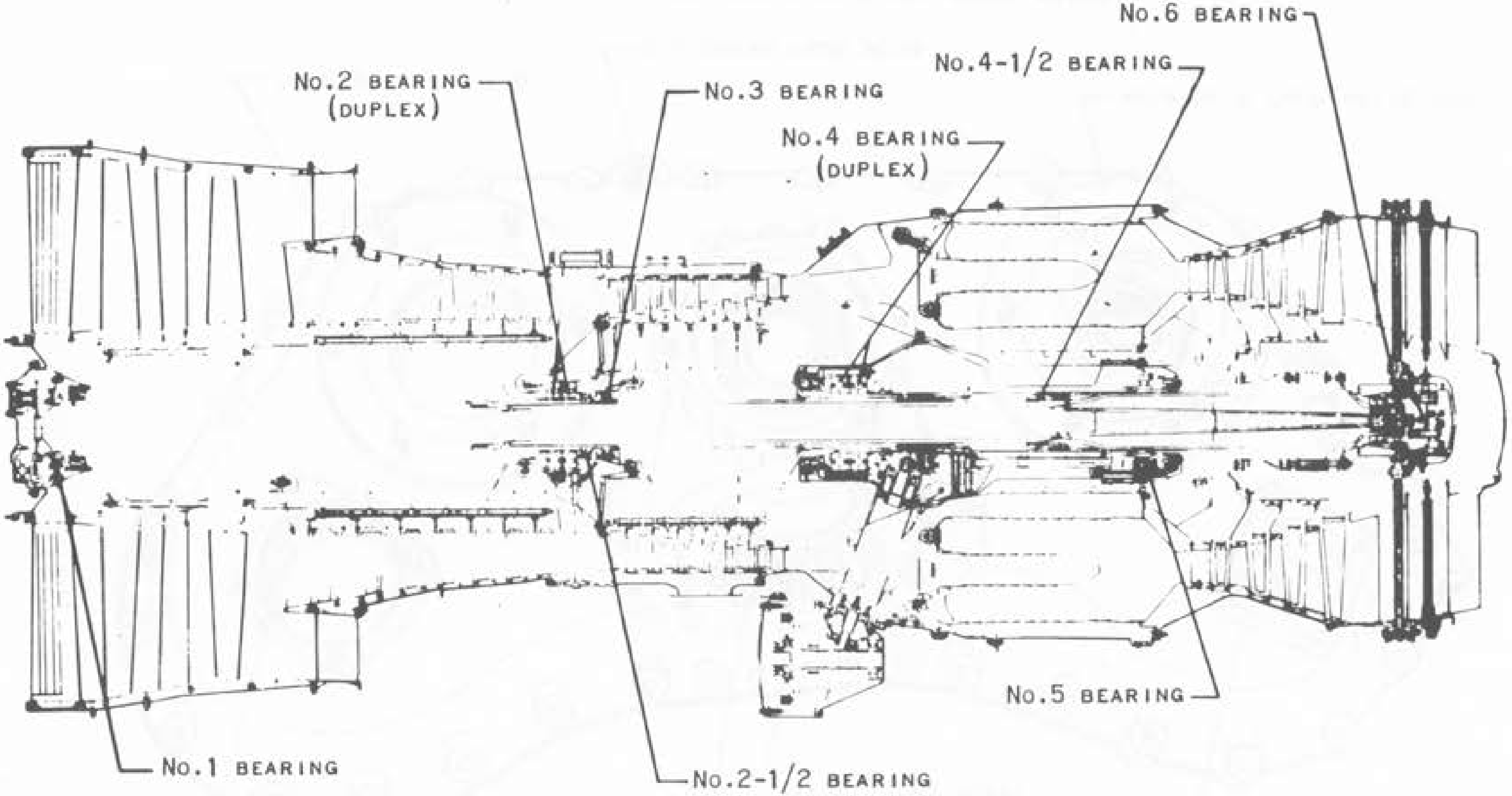
On the upper left end of the accessory drive gearbox is a pad for mounting the thrust reverser hydraulic pump. On the upper right end is a mounting pad for the engine oil filter (undriven).



ENGINE ACCESSORY DRIVE GEAR BOX (FRONT VIEW)



ENGINE ACCESSORY DRIVE GEAR BOX (REAR VIEW)



ENGINE BEARING LOCATIONS

On the aft face of the accessory drive gearbox the following accessory drives or mounts are located. On the upper left hand side is the breather pressurizing valve pad and on the lower left hand side is the starter drive pad. The hydraulic pumps drive pad is on the lower right hand side and on the upper right hand side is the N2 compressor tach generator drive pad. An oil drain plug is provided in the lower rear case just left of center.

ENGINE BEARINGS.

The rotating mass of the JT3D (TF33) engine, consisting of the compressor rotors, turbines, and turbine shafts, is supported by eight bearings. The No. 2 and 4 bearings are actually dual ball bearing units with each dual unit being considered as one bearing. By numerical reference, the bearings are the No. 1, 2, 2 1/2, 3, 4, 4 1/2, 5, and 6. The No. 2, 2 1/2, and 4 bearings are ball type used as thrust bearings. Ball bearings are used as thrust bearings as they can absorb both radial and axial loads. Remaining bearings are of the plain roller type as they absorb mainly radial loads.

NO. 1 BEARING.

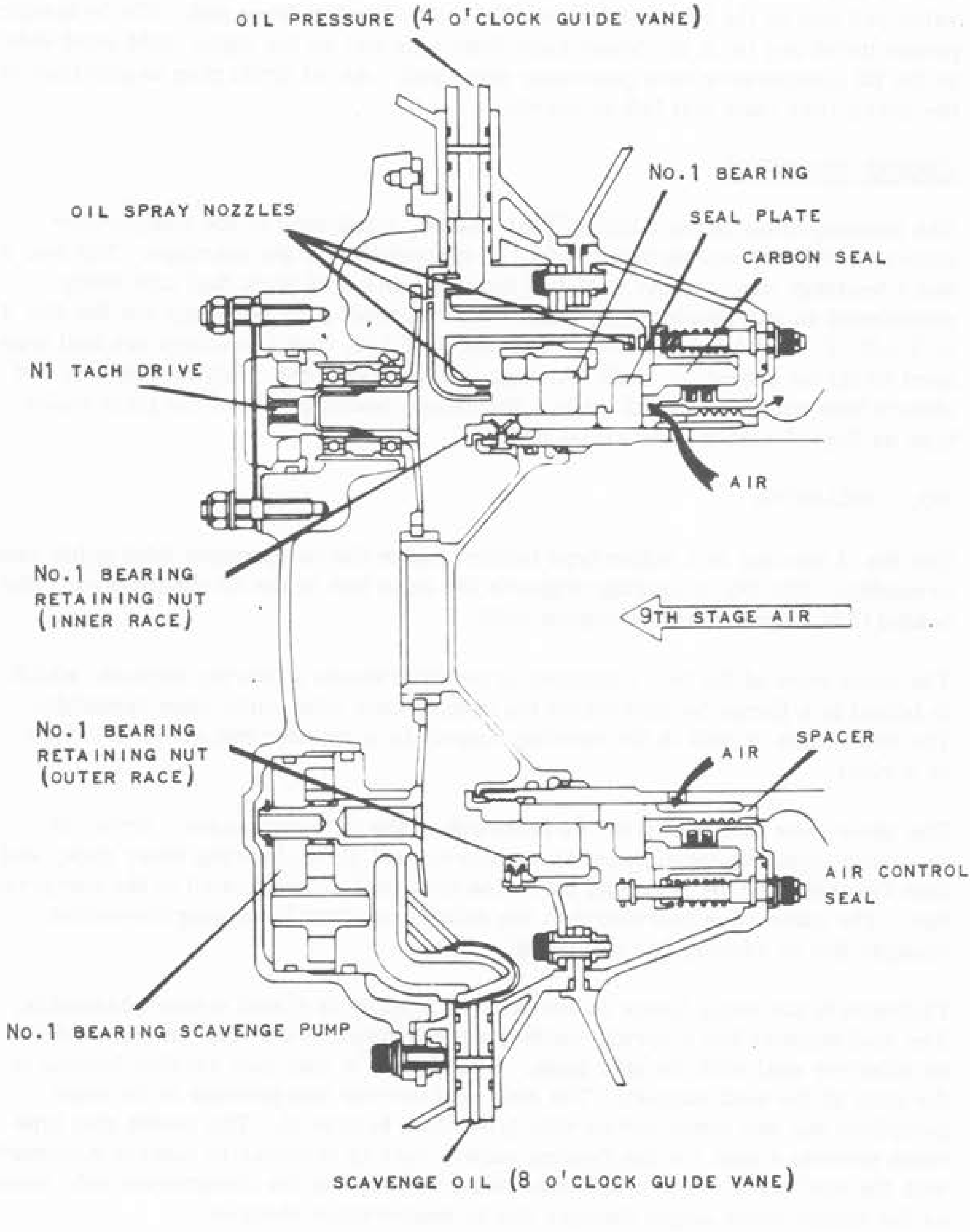
The No. 1 bearing is a roller type located inside the compressor inlet guide vane assembly. The No. 1 bearing supports the front hub of the N1 compressor, and behind it is a spring-loaded carbon seal.

The outer race of the No. 1 bearing is mounted inside a bearing support, which is bolted to a flange located inside the compressor inlet guide vane assembly. The outer race is held in the bearing support by a spanner nut which is locked by a rivet.

The inner race is mounted on the front hub of the N1 compressor. Order of assembly from the hub forward is a spacer, seal plate, bearing inner race, and then the spanner type retaining nut. The retaining nut is riveted to the compressor hub. The inner race is wider than the rollers to allow for enging dimension changes due to varying temperatures.

Fastened to the same flange as the bearing support is a seal support assembly. The seal support has a spring-loaded, carbon-faced seal riding on pins to make an effective seal with the seal plate. In addition, a ring seal carrier fastens to the rear of the seal support. The ring seal carrier has grooves in its outer periphery for two metal piston-ring type seals to ride in. The piston ring type seals provide a seal for the floating carbon seal as it moves to remain in contact with the seal plate. The seal plate, being mounted on the compressor hub, moves as the engine rotor length changes due to temperature changes.

A seal between the compressor hub and seal support is provided by multiple



NUMBER 1 BEARING AND SEAL

knife edges on the bearing spacer opposite the inside surface of the ring seal carrier, forming a type of labyrinth seal. Ninth-stage air is bled through holes in the front hub and bearing spacer to a small cavity between the seal plate, the carbon seal, and the bearing spacer. This ninth-stage air pressurizes the carbon seal so that if any seal leakage occurs, it is air-to-oil. Some bleed air passes through the labyrinth seal, up the front face of the first N1 compressor rotor wheel and is reingested. Air bled through the ring seals, and the carbon seal enters the No. 1 bearing cavity and passes out the No. 1 bearing vent.

The bearing front face is lubricated by an oil jet. The carbon seal and seal plate also are lubricated by another oil jet.

NO. 2, 2 1/2, AND 3 BEARINGS.

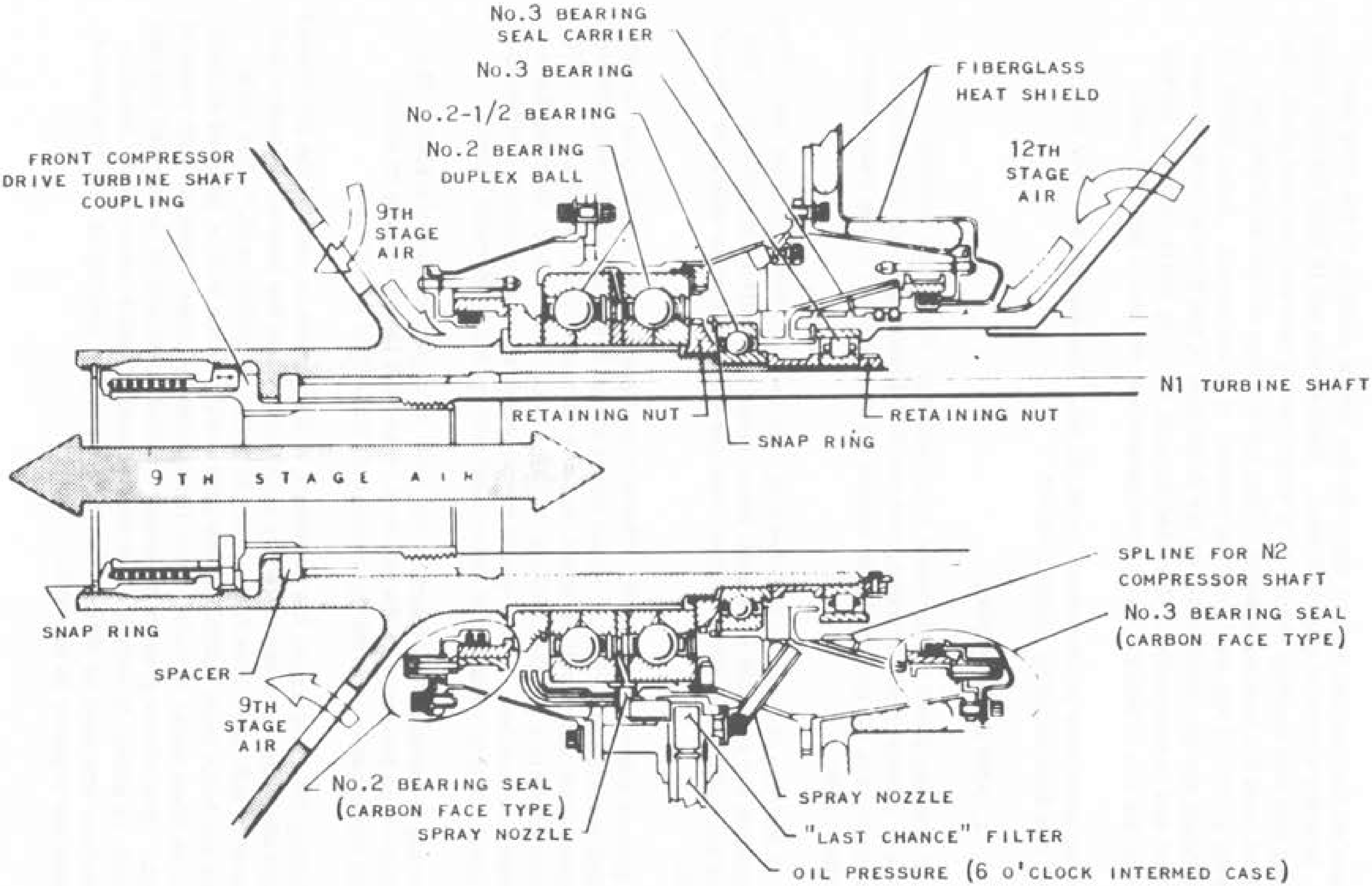
The No. 2 bearing (front compressor rear bearing), No. 2 1/2 bearing (compressor intermediate bearing), and the No. 3 bearing (rear compressor front bearing), are all located in the center section in front of the compressor intermediate case.

The No. 2 bearing is a duplex ball bearing, the two bearings acting as one. They are a matched set and both have split inner races to facilitate installation. The design of the split inner-race, duplex, annular-type bearing is unique in several respects.

A deep groove outer race is used. There is no tendency for a ball to be damaged under high centrifugal forces or under heavy thrust loads due to the elimination of a counter bore which will be found on some non-separable bearings. A split inner race permits a greater number of balls to be used without the need for a counterbore or notches. A one-piece machined retainer of maximum strength can be used. It may be inner or outer land riding, but preferably inner.

The bearing is completely separable for ease of inspection and cleaning. The split-inner-race bearing has the ability to take high thrust loading in either direction while heavy momentary radial overloads may be carried.

In producing the inner race, the curvature of the groove in each of the two halves is ground while they are separated by a spacer. When the bearing is assembled, the spacer is left out. This forms what is called a "gothic arch." The arch prevents the balls from rolling on the split itself. If the ball is pressed radially inward, as when under a radial load, it contacts the inner races on both sides of the split. This allows greater monentary radial overloads to be carried besides axial loads in either direction. For these reasons, split-inner-race, annular-type bearings are used as thrust bearings. A duplex bearing of this type would give twice the capacity in one unit.



NUMBER 2, 2 1/2, AND 3 BEARINGS AND SEALS

The inner races of the bearing are separated by an oil baffle. In front of the bearing, proper position is maintained by a seal plate used as a spacer. The seal plate sets against the shoulder of a sleeve that has been slipped over the rear hub. The No. 2 bearing races, seal plate and oil baffle all ride on the sleeve. They are held on the sleeve by a retaining nut that threads onto the rear hub of the N1 compressor.

The outer race of the dual bearing is carried in a bearing support that, in turn, is bolted to a flange of the compressor intermediate case. The outer race is retained by a retaining nut that threads into the bearing support.

Extending forward from the bearing support is a heat shield and seal assembly. The seal is comprised of a springloaded, floating carbon seal and seal plate with piston ring type seals. Again, the piston ring type seals provide an air seal for the carbon seal as it moves to maintain contact with its seal plate. Ninth-stage air off of the rear of the N1 compressor pressurizes the carbon seal to prevent oil leakage.

Aft of the No. 2 bearing, the No. 2 1/2 and 3 bearing assemblies sit on steps in the rear hub of the N1 compressor.

The inner races of the No. 2 1/2 and 3 bearings and a spacer are retained on the hub by a spanner-type retaining nut. The nut, in turn, is locked to the hub by a rivet.

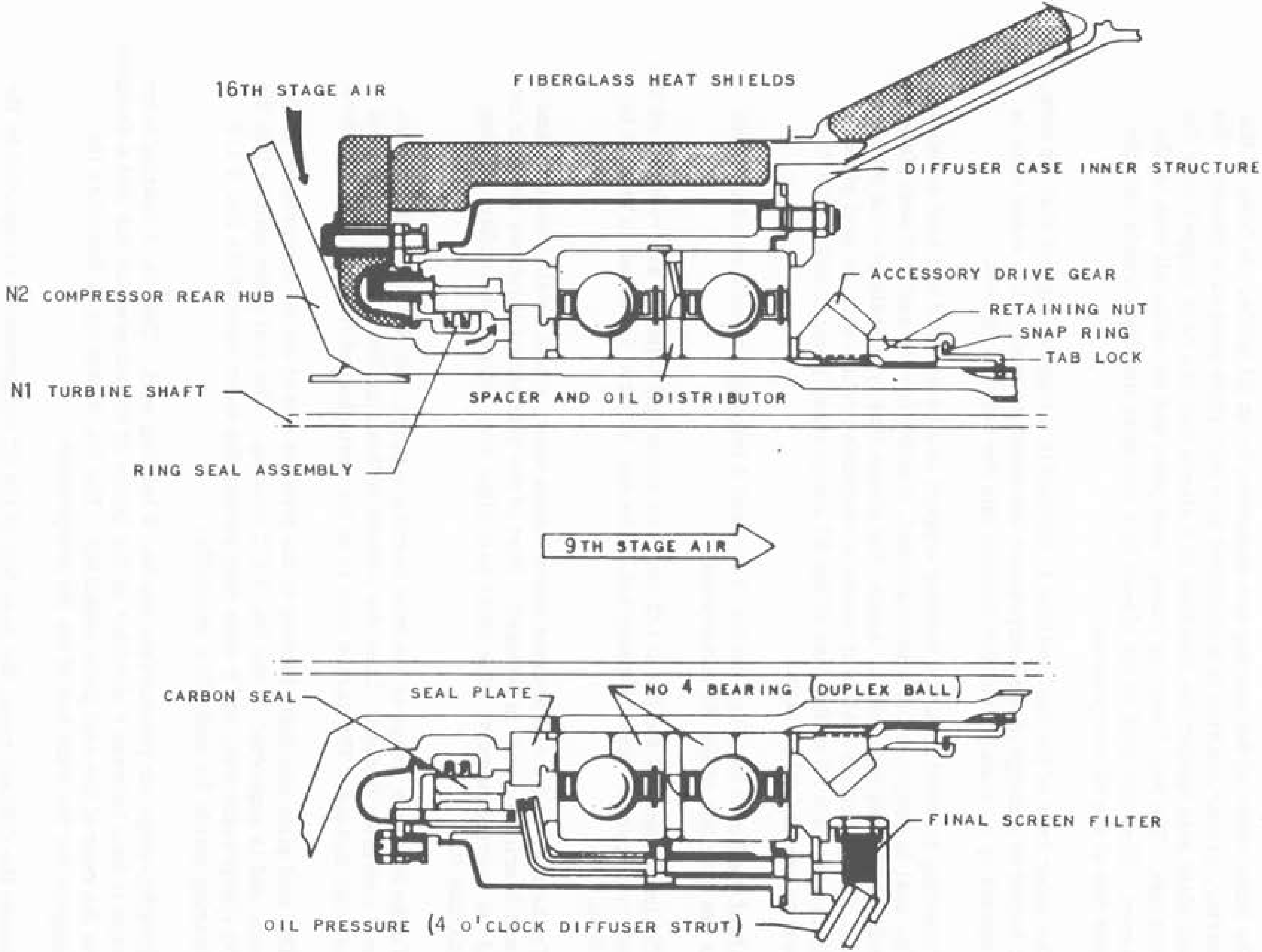
To the rear of the compressor intermediate case, a heat shield assembly and a rear bearing support is fastened. Part of the heat shield insulates the rear face of the bearing support. The other part slips over the seal assembly, helping insulate it.

To the aft inner flange of the rear bearing support, the No. 3 bearing carbon seal assembly fastens. Over the outside of this, the No. 3 bearing ring seal carrier fastens. The carbon seal is of the springloaded floating type as before.

The seal plate assembly fastens to the forward end of the N2 compressor front hub, and is supported by the No. 2 1/2 bearing. The seal plate splines into the N2 compressor hub, and a snap ring retains the outer race of the No. 2 1/2 bearing inside the seal plate assembly.

Twelfth-stage air pressurizes the No. 3 bearing seal. The No. 3 bearing outer race is held between a shoulder on the inside of N2 compressor hub and a shoulder on the rear of the seal plate assembly. The No. 3 bearing is therefore the support for the front hub of the N2 compressor.

Inside the diffuser case, the rear hub of the N2 compressor is supported by the



NUMBER 4 BEARING AND SEAL

No. 4 bearing. The No. 4 bearing is a duplex ball type similar to the No. 2 bearing.

The inner races of the No. 4 bearing are of the split type and slip over the outer diameter of the rear hub of the N2 compressor. From a shoulder on the rear hub aft, the order of assembly is a seal plate, dual bearing inner races separated by an oil baffle-spacer, spacer ring, bevel gear, and a retaining nut. The retaining nut is safetied to the rear hub by a splined locking sleeve and a snap ring to keep it engaged.

The outer race of the No. 4 bearing is mounted in a bearing support-seal carrier fastened to a flange of the inner diffuser case structure. To the forward end of the bearing support-seal carrier, the No. 4 bearing heat shield fastens. Just below this, the springloaded floating carbon seal is located. Piston ring seals are again provided to seal the carbon seal as it moves to stay in contact with the seal plate during engine dimension changes.

Sixteenth-stage air passes down the rear face of the N2 compressor hub, around and under the heat shield, pressurizing the carbon seal so any leakage is air into the No. 4 bearing cavity.

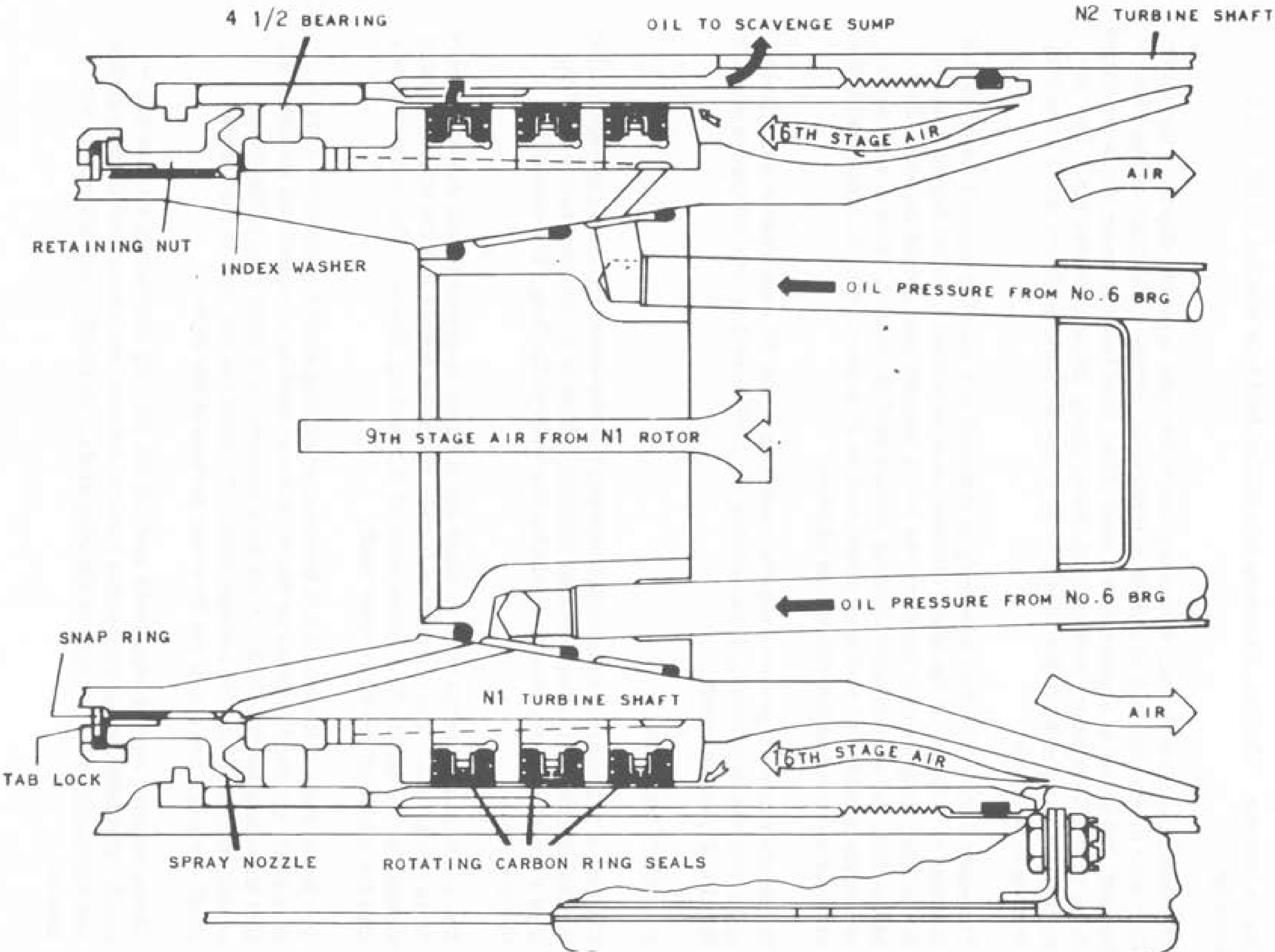
NO. 4 1/2 BEARING.

The No. 4 1/2 bearing is mounted between the low speed (N1) and high-speed (N2) turbine shafts, and is located approximately midway in the combustion section. It is a roller bearing used to minimize the whip of the long, low-speed (N1) turbine shaft.

The outer race is extra wide to allow for changes in engine length due to temperature variations. The outer race is held against a spacer and the spacer against a shoulder inside the N2 turbine shaft by a retaining sleeve. The sleeve threads into the inside of the N2 turbine shaft.

The inner race of the No. 4 1/2 bearing, a bearing spacer, and three carbon ring seals are held in place on the N1 turbine shaft by a castellated retaining nut that threads onto the shaft. A tab lock retained by a snap ring locks the castellated nut to the N1 turbine shaft. To index the tab lock to the turbine shaft, grooves are cut in the threaded portion of the shaft.

Three rotating carbon ring seals seal off the bearing preventing oil flow rearward. Sixteenth-stage air passes forward between the concentric turbine shafts and pressurizes the aft side of the ring seals. Normally, any leakage is air-into-oil.



NUMBER 4 1/2 BEARING AND SEAL

NO. 5 BEARING.

The No. 5 bearing is a roller type, located just forward of the N2 turbine in the front center of the turbine nozzle case. This bearing supports the high-speed (N2) turbine.

The outer race and rollers are mounted in the bearing support housing. The bearing support housing splines into the bearing support and is also bolted to the inner combustion case heat shield. The inner race is retained in the bearing housing by a spanner type retaining nut that is locked by a rivet to the bearing housing.

Against a shoulder on the N2 turbine shaft rides a spacer, seal plate, and the No. 5 bearing inner race. They are held against the shoulder by a castellated retaining nut that threads onto the turbine shaft. The retaining nut is safetied by a tab lock that locks the nut to the turbine shaft. The tab lock is retained inside the nut by a snapring.

Oil flow aft is prevented by a springloaded floating carbon seal. The carbon seal assembly mounts to the seal support. The carbon seal is sealed by two, metal, ring-type seals. The ring seals and their carrier bolt to the aft inner flange of the seal support.

Knife edges on the bearing spacer provide additional seal on the inner circumference of the ring seal carrier. Sixteenth-stage air pressurizes the ring seals and the carbon seal so leakage is air into the No. 5 bearing cavity.

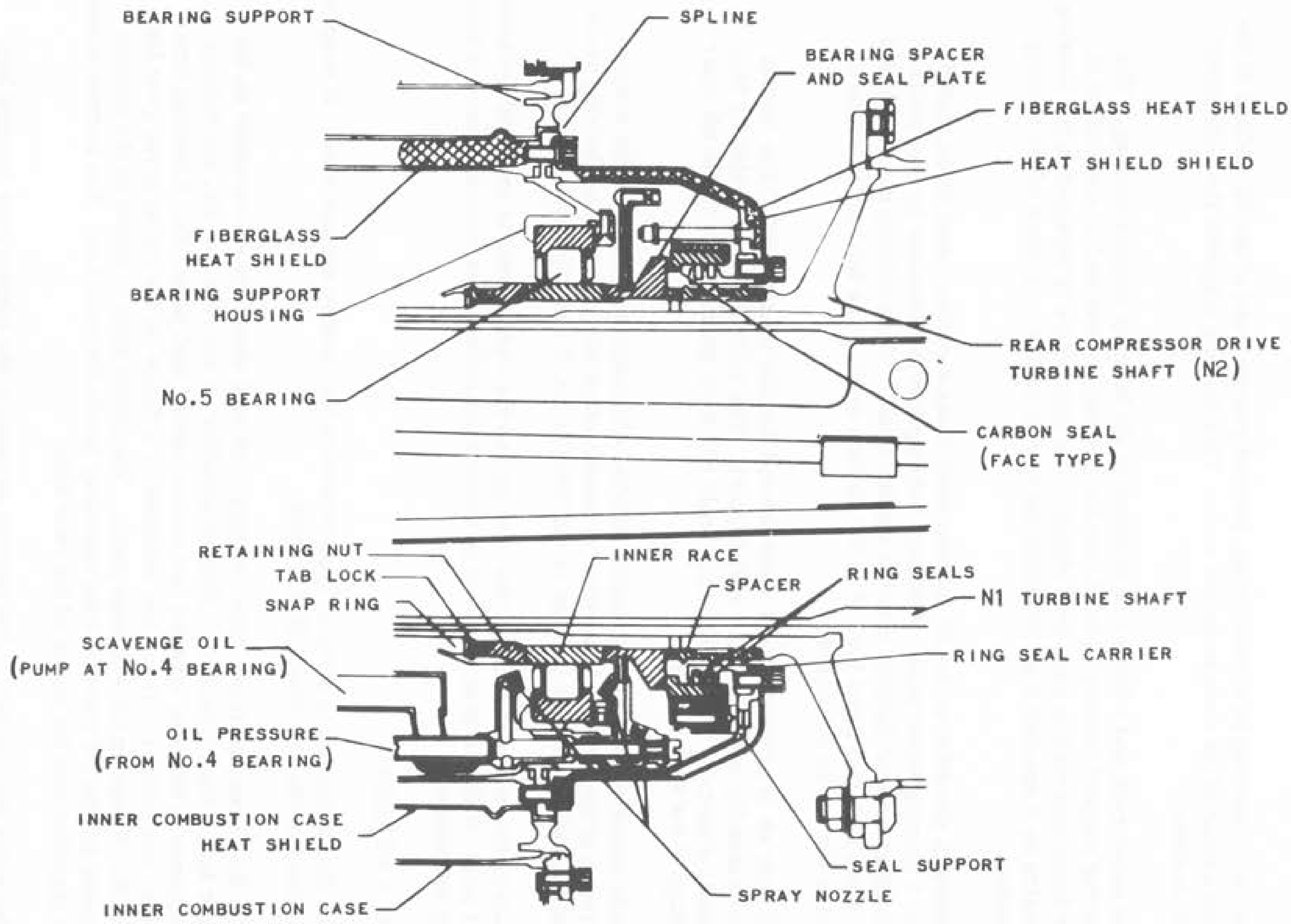
Lubrication for both faces of the bearing and the carbon seal is provided by three oil jets. A finned heat shield of swandwich construction is fastened over the bearing assembly.

No. 6 BEARING.

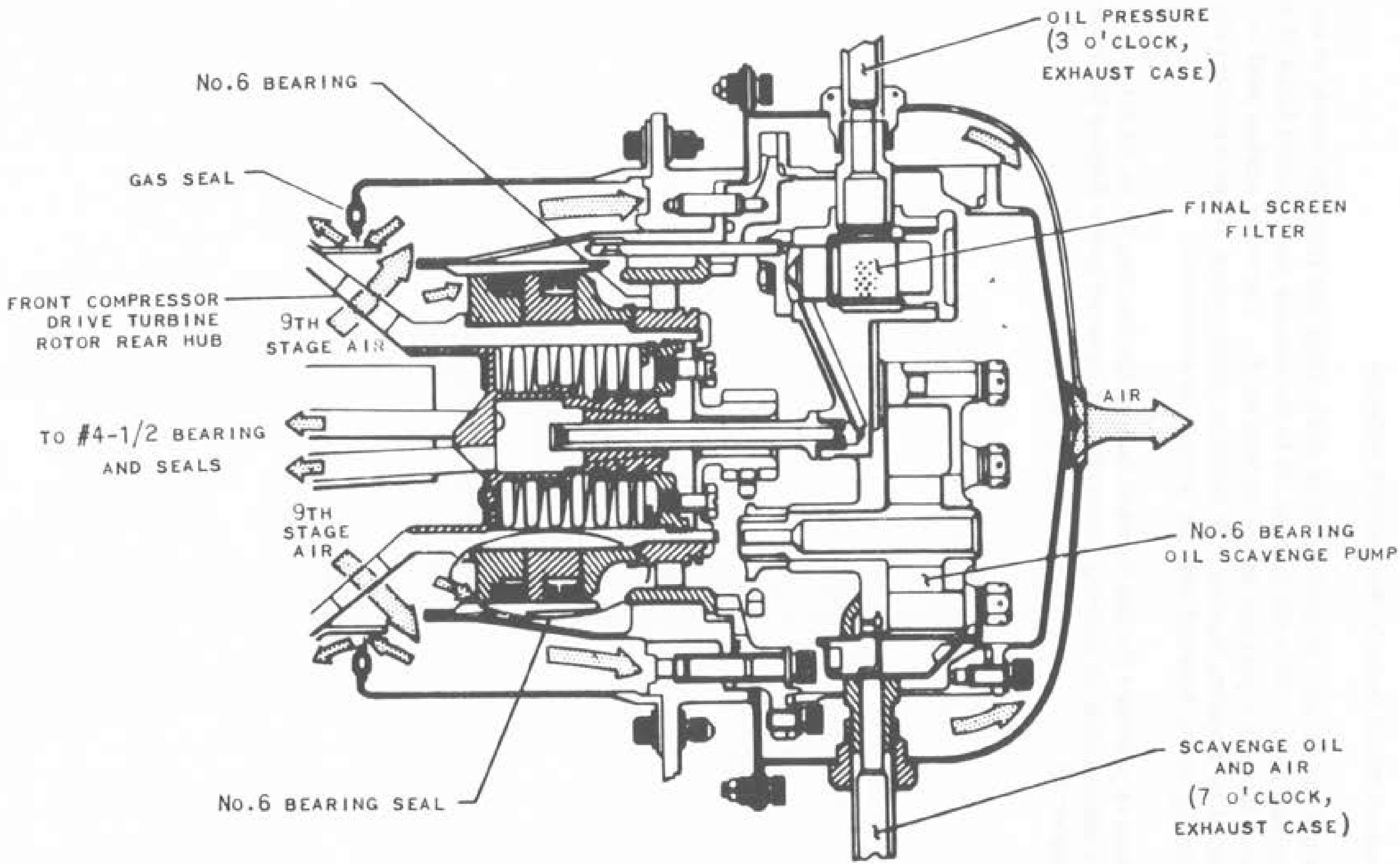
The No. 6 bearing is a roller type located in the turbine exhaust case. It supports the rear of the low-speed (N1) turbine.

The No. 6 bearing inner race, rollers, and seal assembly are mounted on the rear hub of the N1 turbine. From a shoulder on the rear hub aft, the buildup sequence is two seal spacers and carbon seals, seal plate, No. 6 bearing inner race, and rollers. These are retained by a flange on the pinion drive gear for the No. 6 bearing oil scavenge pump. The pinion gear is bolted to the carrier sleeve for the oil transfer tube assembly inside the rear hub. The carrier sleeve is threaded into the inside of the rear hub.

The outer race is held in the bearing support by the turbine rear bearing heat



NUMBER 5 BEARING AND SEAL



NUMBER 6 BEARING SEALS AND OIL SUMP

shield support which bolts to the bearing support.

The forward carbon seal is preloaded by ninth-stage air from the inside of the hollow turbine shaft. This air is bled off to the outside and forward faces of the carbon seal through a passage in the turbine shaft. The other carbon seal is springloaded by a spring washer. In addition, ninth-stage air pressurizes the seal assembly on its forward side so leakage is air-to-oil.

Lubrication is provided for the forward face of the bearing by an oil jet. Complete information on bearing lubrication is covered under Engine Lubrication, Chapter IV.

ENGINE SYSTEMS

COOLING AIR SYSTEM.

A cooling system is necessary on the JT3D (TF33) to cool the vital operating components. Of the mass airflow through the engine, approximately 20 percent is used for combustion and 75 percent used in cooling. The large surplus of air serves to cool the hot sections of the engine to help eliminate unacceptable temperatures. The conductivity of the metal in the case carries the heat directly to the outside skin, but with adequate internal cooling the external temperatures can be held to an acceptable level. The remaining 5 percent is used for other purposes such as operation of various pneumatic systems and pressurizing the main bearing carbon oil seals.

Airflow into the engine passes through the first two stages of the fan where it divides and flows into the engine and fan ducts around the engine. The fan air passes through the ducts and is exhausted in the tail pipe along with the engine exhaust gasses.

Airflow in the nine-stage N1 compressor is increased approximately 5.25 times. If standard day conditions exist (15°C* and 15 PSIA) the pressure and temperature of the air through the N1 compressor is then 79 PSIA at 220°C at the ninth stage.

Ninth-stage air is bled off at the blade rear platform and enters the N1 compressor rotor assembly through holes in the N1 rear hub. A small amount of the air pressure inside the rotor assembly is bled at a controlled rate across the No. 1 bearing carbon seal. Some of this air also passes

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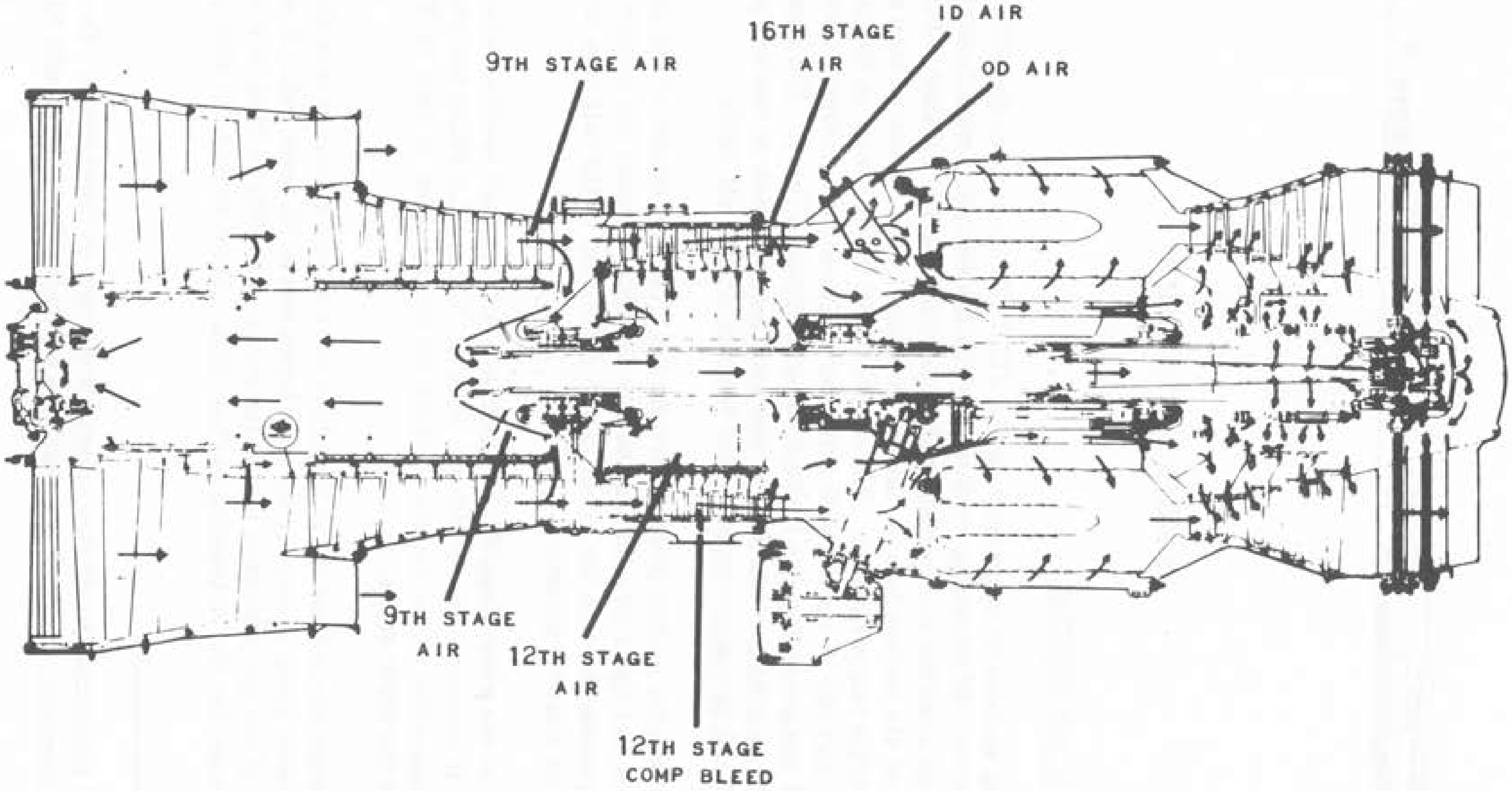
* All temperatures in this volume are given in Centigrade. To convert to Fahrenheit, multiply the Centigrade reading by 9/5 and add 32.



ENGINE COOLING AIR FLOW

over an air control seal at the No. 1 bearing and is re-injested into the intake of the engine just aft of the inlet guide vane assembly.

Ninth-stage air inside the N1 rotor flows down the hollow N1 turbine shaft to the area formed by the N1 turbine wheel disks, the wheel disk spacers, and the turbine rear hub. Air flows through holes in the disk spacer between No. 2 and No. 3 turbine wheel. As it flows, it cools the aft side of the No. 2 turbine wheel and the forward side of the No. 3 wheel. Air passes through the air seal ring and cools the base of the No. 3 turbine stator assembly and is then exhausted into the exhaust gases passing out of the engine.

The aft side of the No. 3 turbine wheel and the forward side of the No. 4 wheel are cooled in the same manner. Cooling air passes through the seal ring between the No. 3 and No. 4 wheels and cools the base of the No. 4 turbine stator assembly. This air is also exhausted into the gas stream.

Airflow through the turbine at the rear hub takes several paths. First, the aft side of the No. 4 wheel, the inner exhaust cone, and the base of the No. 6 bearing support struts are cooled by the flow. Second, the heat shield assembly (cup) surrounding the No. 6 bearing is hollow with openings fore and aft which permit cooling airflow around the bearing shield assembly. The ninth-stage air is also bled at a controlled rate across the No. 6 bearing seal.

From the ninth stage, airflow continues on into the seven stages of the N2 compressor. Sixteenth-stage air at the diffuser case has now reached 235 PSIA at 421°C. The total pressure ratio through the engine is 16 to 1.

At the twelfth-stage rotor of the N2 compressor air is bled off for two purposes:

1. The N2 compressor inner case has holes at the twelfth stage to allow air off of the twelfth-stage rotor to flow out into the chamber formed by the inner case and the compressor intermediate (outer) case. The air in this chamber is bled off for compressor unloading to aid in preventing compressor stall. This bleed air is dumped directly into the fan ducts from the compressor bleed valves.

2. The rotor seal spacer between the twelfth and thirteenth stage of the compressor rotor has holes which allow twelfth-stage air to bleed inside the N2 compressor rotor assembly. This air bleeds out forward through the N2 front hub. By bleeding off this twelfth-stage air, approximately 4,000 pounds of thrust against the No. 4 bearing is offset. The twelfth-stage air passing out of the N2 rotor hub supplies air across the No. 3 bearing seal. Excess air is re-injested at the tenth stage.

At the rear compressor, sixteenth-stage air bleeds past the rotor seal and enters the diffuser case inner cavity forward of the No. 4 bearing heat shield. Sixteenth-stage air is bled at a controlled rate across the No. 4 bearing seal. From the inner cavity, the air passes through holes into the area formed by the combustion chamber inner heat shield and liner. Air flows aft to the No. 5 bearing housing support where it is bled at a controlled rate across the No. 5 bearing carbon seal. Sixteenth-stage air in the chamber flows up to cool the base of the turbine nozzle guide vanes and the front face of the No. 1 turbine wheel. Air flows down past air seal rings to cool the base of the No. 1 wheel, then back up between the No. 1 and 2 wheels to cool forward and aft sides of these turbine wheels. As air passes out into the exhaust stream, it cools the base of the No. 1 stage turbine stators.

The air passing through the engine serves to cool the combustion chamber liners and aid combustion. The burner cans are constructed with holes and slots which serve to induce a thin, fast-moving film of air over both inner and outer surfaces. A center tube is installed in each can to lead cooling air into the center to promote high combustion efficiency and rapid dilution of the hot gases.

LUBRICATION SYSTEM.

The JT3D (TF33-P-7) engine is lubricated by a high-pressure, self-contained oil system. Lubrication is provided for the engine bearings, bearing seals, accessory drive shaft, and gear train in the accessory gearbox.

Synthetic lubricating oil is used in the engine lub system and must conform to P&WA specification 521D or MIL-L-7808E. It is recommended that types of synthetic oils not be mixed and should never be mixed with petroleum base oils.

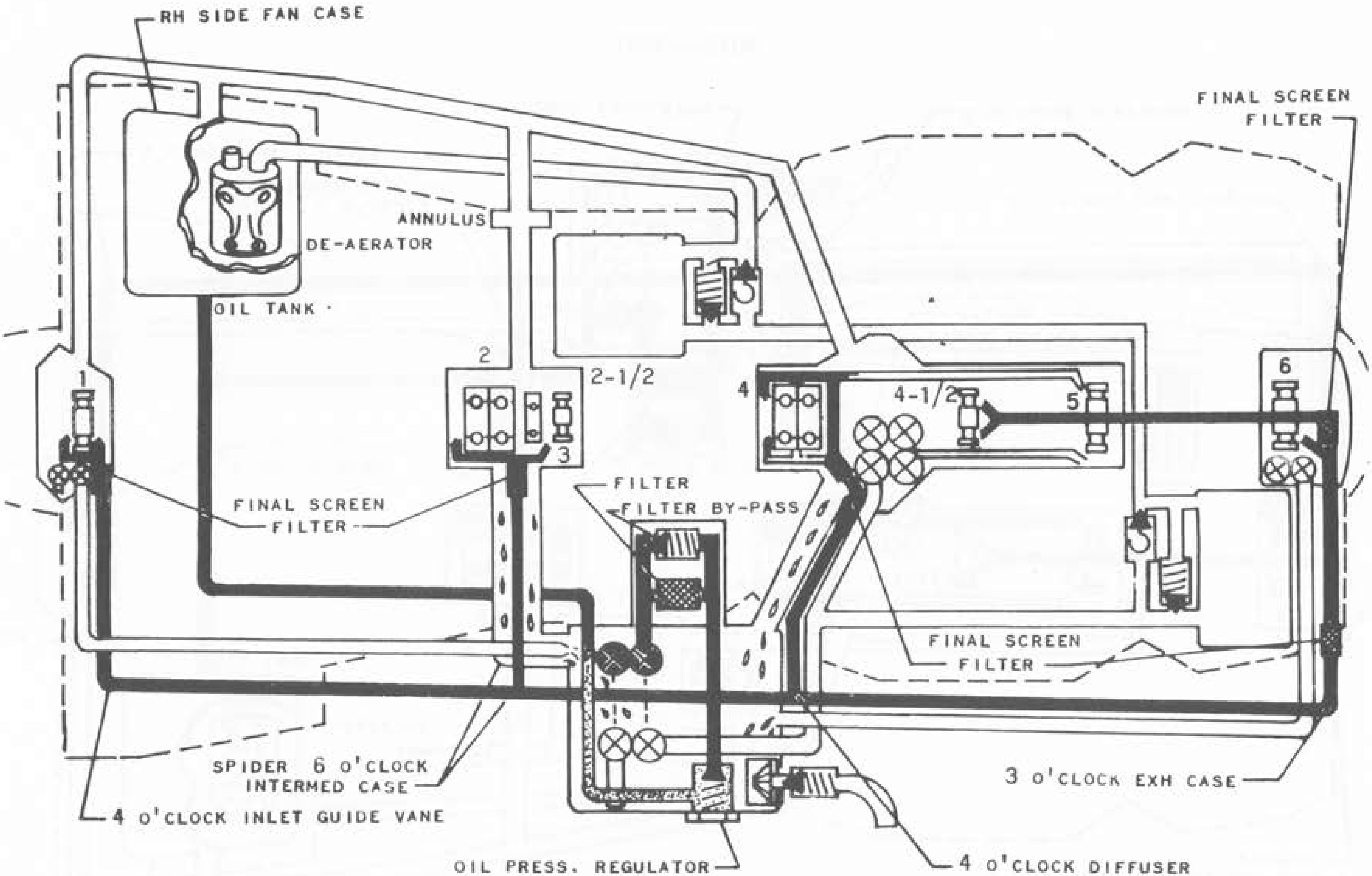
CAUTION

> When synthetic oil is hot, it produces toxic fumes which cause irritation to the eyes and nose.

COMPONENTS.

The major components include an oil tank, pressure pump, oil filter, pressure relief valve, scavenge pumps, air-oil cooler, fuel-oil cooler, rotary breather, and a breather pressurizing valve. In addition to the major components, a low oil quantity warning light, an oil pressure indicator, a low oil pressure warning light, and an oil temperature indicator are included for monitoring the engine oil system.

Most of the engine lubrication components are located on the right hand side of the engine.



LUBRICATION

PRESSURE SYSTEM AND COMPONENTS.

The pressure system provides lubrication for engine bearings, bearing seals, and accessory drives. Components included in the pressure system are an oil tank, a pressure pump, an oil filter, a pressure relief valve, a low oil quantity warning light, an oil pressure indicator, a low oil pressure warning light, an oil temperature indicator, and all external/internal lines and oil spray nozzles.

OIL TANK.

The engine oil is contained in a steel, saddle-type tank. It is located around the top, upper right hand quadrant of the engine. The tank is secured by two straps to the flanges of the front and rear fan rear case assembly.

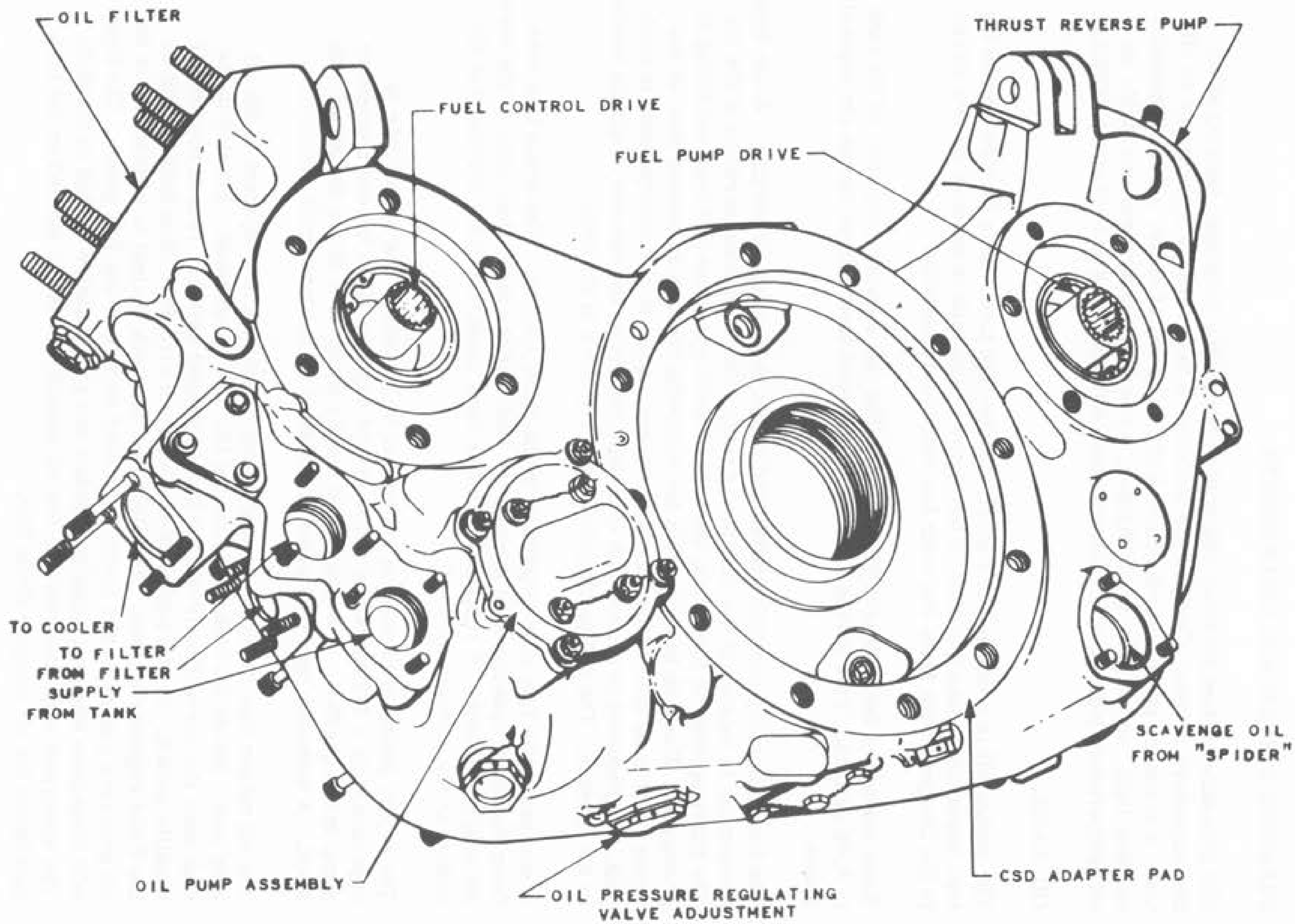
Total volume of the tank is 7.77 gallons. The full servicing capacity of the tank is 6.09 gallons. This leaves 1.68 gallons of total tank volume for an air expansion space.

The tank internally contains baffles and plates to prevent oil surging. A can type de-aerator is located in the tank at the return line to prevent aeration of the oil. The filler opening is located on the tank in such a position that over servicing is prevented. The tank is accessible for servicing through an access door on the upper right hand side of the forward cowling. A dip stick, incorporated in each tank, is graduated in quarts with markings indicating the number of quarts needed in the system. The full mark indicates 6.1 gallons in the tank.

A scupper drain line is incorporated in the filler opening. The drain line runs from the filler opening down through the inside of the tank, then exits at the lower aft side of the tank. A scupper drain line runs down to a drain provision at the bottom of the forward fan case.

The supply fitting is located on the bottom of the tank. The supply line is approximately 1 1/2 inches in diameter and supplies oil to the main pressure pump in the gearbox. Next to the oil supply fitting is a fitting for an oil tank drain. A manually operated valve is installed on the tank drain connection.

The oil return line fitting is located on top of the tank and adjacent to the oil tank vent. Inside the tank at the return line is a de-aerator. Located in the tank near the one-gallon level is a float-operated switch. This is the low oil quantity switch. It will complete an electrical circuit to illuminate a light on the flight engineer's panel. The light (one for each engine) is located above the oil pressure guages on the lower right hand corner of the F/E panel. The light will illuminate when oil quantity reaches one gallon usable oil left in the tank. The electrical connection for the low oil quantity switch is located on the tank just below the oil scupper drain line.

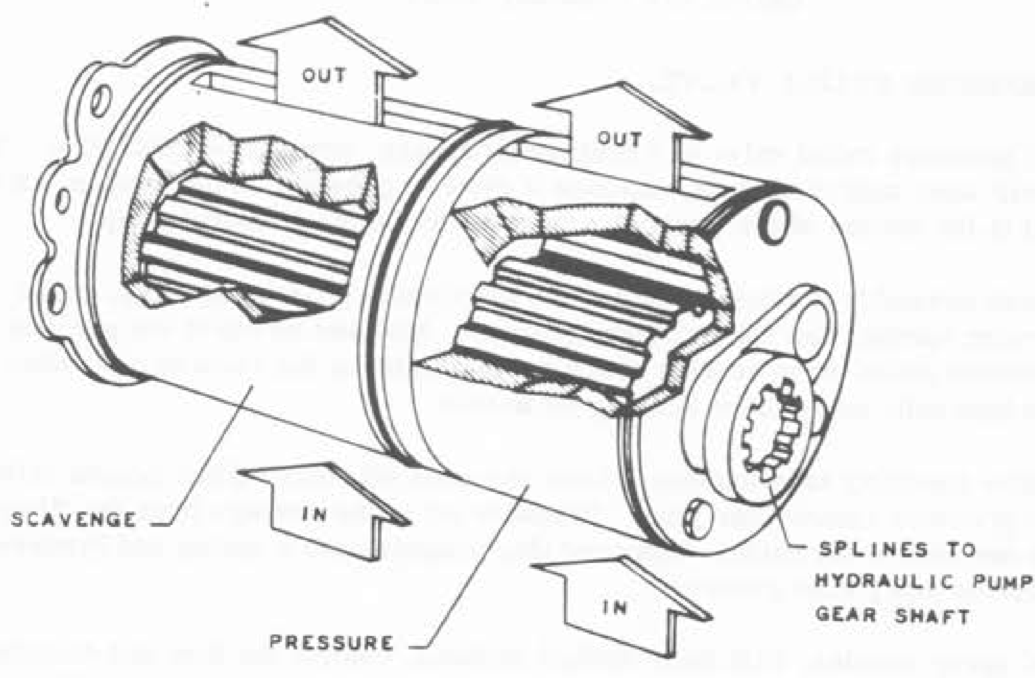


ENGINE ACCESSORY DRIVE GEAR BOX (FRONT VIEW)

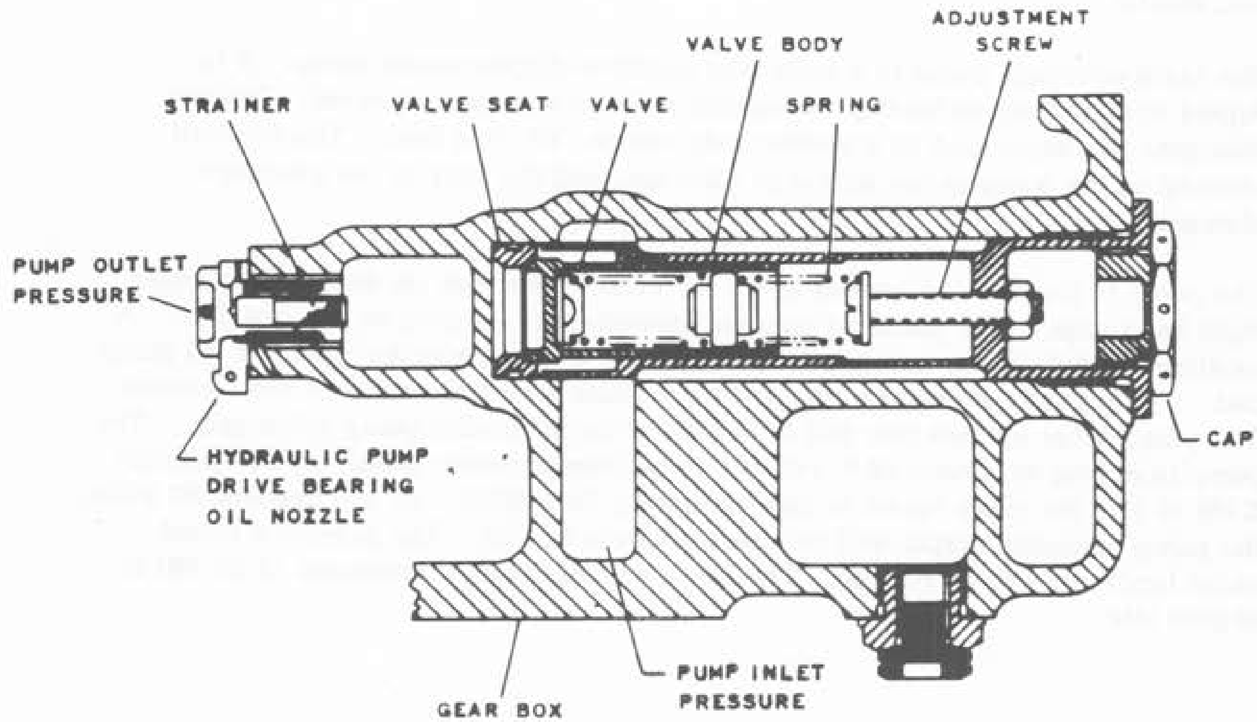
OIL PUMP.

The main pressure pump is a gear type positive-displacement pump. It is duplex in construction having a pressure and one scavenge element. The two elements are separated by a center body and an "O" ring seal. The forward element of the pump is the scavenge element, and the rear is the pressure element.

The pump is located and housed in the accessory gearbox on the forward lower right hand side. It is installed into the smooth-bore opening in the gearbox. A locating pin hole in the pump front body aligns with a pin in the gearbox oil pump pad. The pump is secured to the gearbox studs with four washers and locknuts. The pump drive splines into and is driven by the hydraulic pump drive gear. The pump is driven at a ratio of 0.342 to 1 to N2-compressor speed. At 100 percent RPM of N2, the pump speed is approximately 3300 RPM. At 100 percent N2 RPM, the pump pressure output will be approximately 80 PSI. The pressure relief valve limits this to 45 ± 5 PSI. The pump will maintain a minimum of 35 PSI at engine idle.



ENGINE OIL PUMP



. ENGINE OIL PRESSURE VALVE

OIL PRESSURE RELIEF VALVE.

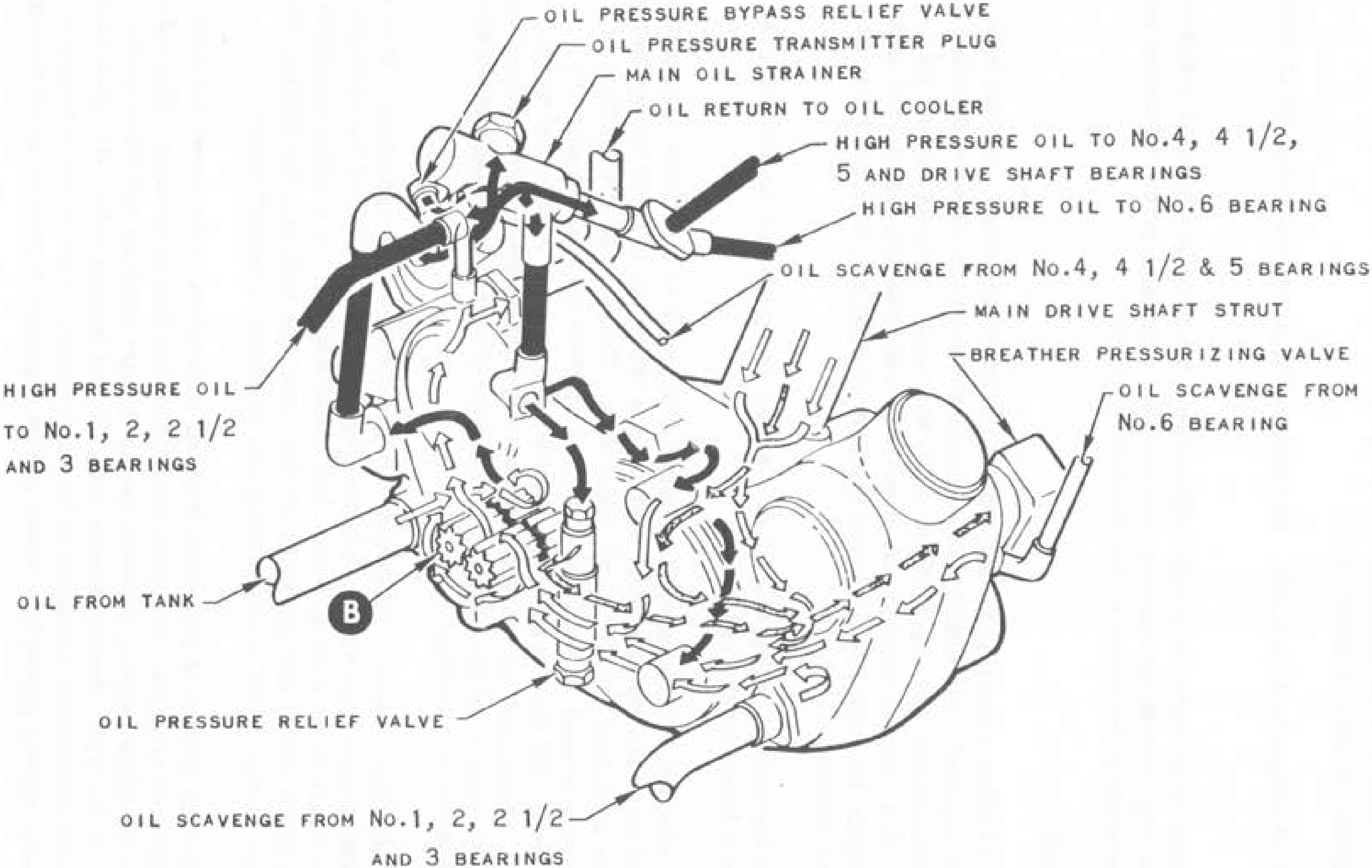
The oil pressure relief valve is a continuous bypass, pressure-relief valve. The valve will open and/or close to maintain a desired pressure in the system. It is located in the bottom of the gearbox, adjacent to the oil pressure pump.

The valve assembly is made up of a valve body which houses the valve, valve seat, valve spring, and valve adjusting screw. Mounted on top of the gearbox oil pressure relief valve housing at the presure inlet to the valve is a strainer and the hydraulic pump drive bearing oil nozzle.

The valve assembly is downstream from the main oil filter, filter bypass valve, and oil pressure transmitter plug. Pressure oil in the passage from the filter is felt on one side of the valve. Opposing this pressure are a spring and bypassed pressure or pump inlet pressure.

The oil spray nozzles, with their drilled orifices, control the flow and distribution of oil to the bearings. The pressure relief valve maintains a constant differential pressure across the spray nozzles.

When the engine is operating at 100 percent the pump supplies more pressure than is required for normal bearing lubrication. To reduce oil pressure to the desired



OIL SYSTEM SCHEMATIC

level, and to maintain the differential, the pressure relief valve opens and bypasses some oil back to pump inlet.

Normal oil pressure is 45 ± 5 PSI. At engine idle, pressure should be at least 35 PSI.

The pressure relief valve is ground adjustable. In order to adjust oil pressure, remove the cap, loosen the locknut, and turn the adjusting screw clockwise or counterclockwise to increase or decrease oil pressure.

OIL FILTER.

The main oil filter assembly is mounted on the main gearbox, top right hand side. It is angularly positioned on the gearbox. Purpose of the main filter is to trap contaminants and supply clean oil to the engine components and main bearings. The filter is downstream from the main pressure pump. Oil under pressure from the main pump travels through internal and external lines directly to the filter housing assembly.

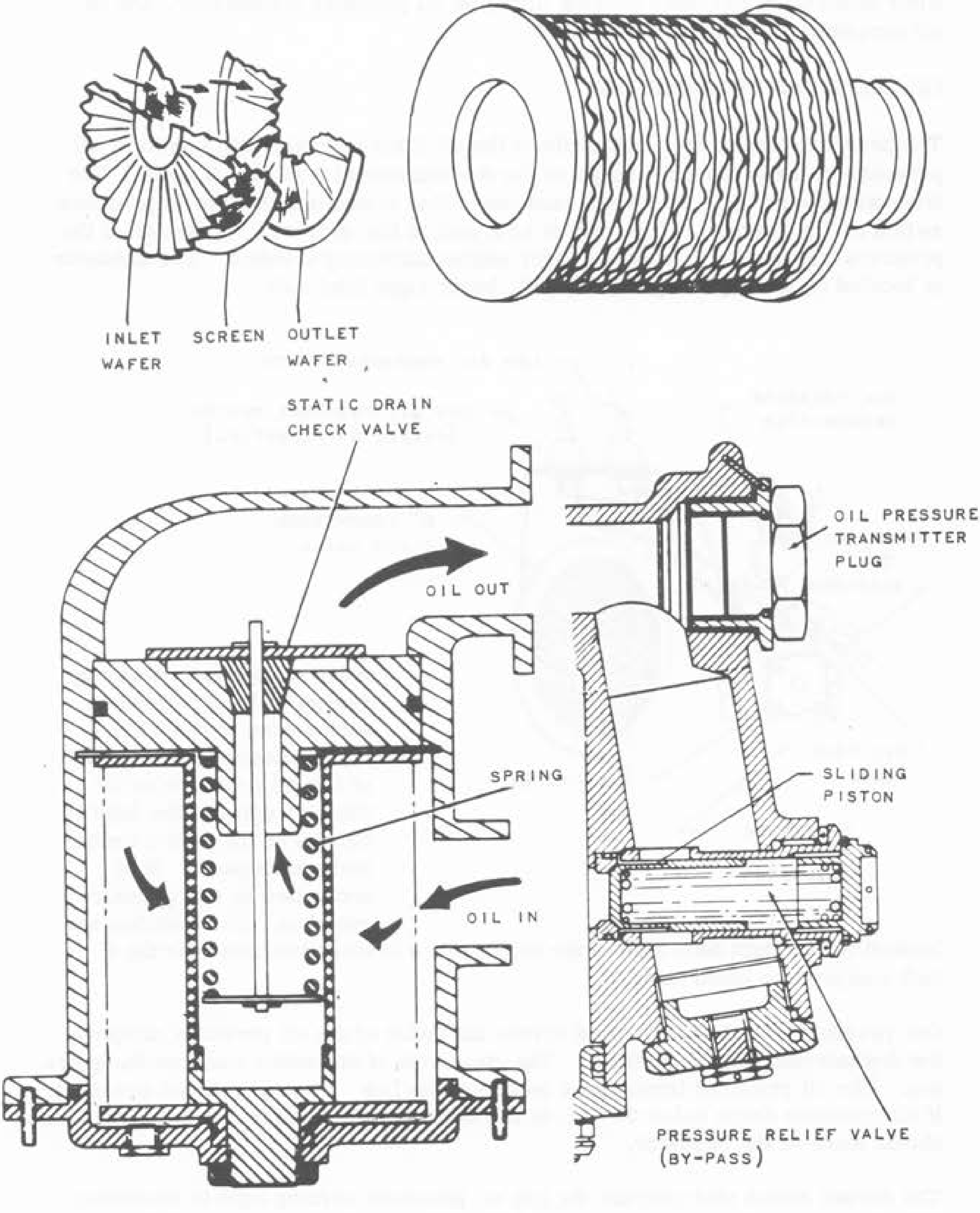
Located in the filter housing is a filter element assembly, an oil filter check valve, and a filter bypass valve.

The filter element is composed of a series of screens in disk form, separated by stamped inlet and outlet spacer disks. The assembly is made up by alternately stacking an inlet disk, screen, and outlet disk. These disks are stacked on a cylindrical perforated support and squeezed together and held in place by a retaining plug. Oil flow is from the outside of the disks, to the inlet wafer, through the screen and out an outlet wafer, and through the cylindrical perforated support to the center of the element. This type of element is easily accessible for replacement or cleaning.

The oil filter check valve is located at the end of the screen assembly. It is a springloaded poppet type valve. Oil pressure from the center of the element forces the check valve open allowing flow to the system. In a static condition, the check valve closes and prevents oil flow from the tank into the engine, thus avoiding an excess of oil in the bearing and accessory compartments.

The lubrication system is protected from oil starvation in the event the main oil screen becomes clogged. A bypass valve provides this protection. The valve is located in the filter housing between the filter inlet passage and filter outlet passage. If the filter should become clogged, the bypass valve will open when an approximate differential pressure of 50 PSID exists. This valve is simply a springloaded sliding piston type which can be replaced in part or as an assembly.

Located adjacent to and on the oil filter assembly are the low oil pressure and

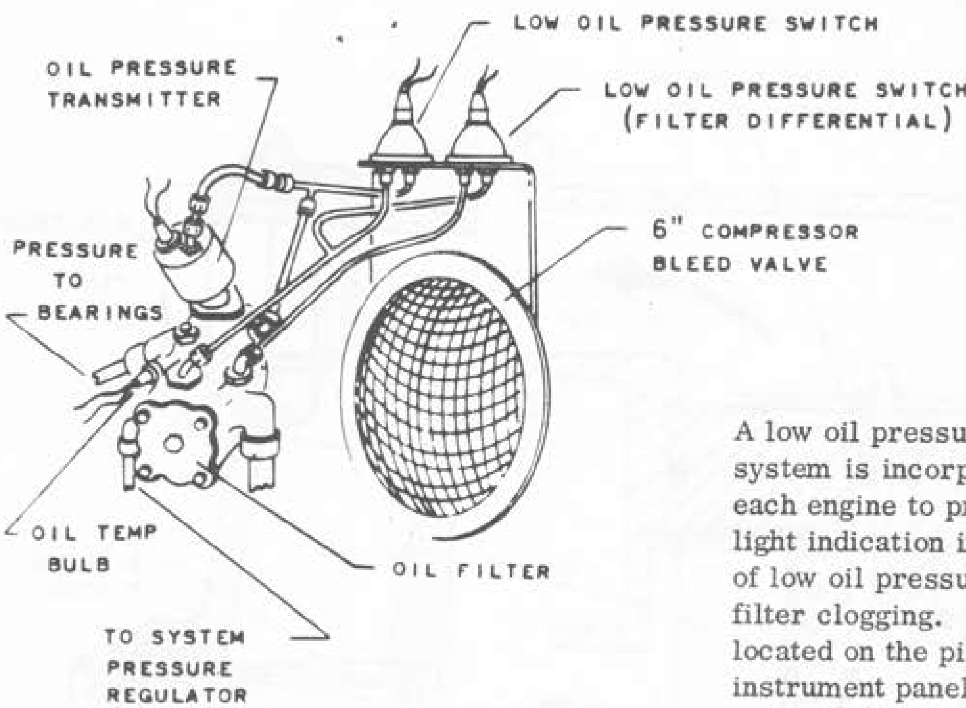


ENGINE OIL FILTER ASSEMBLY

filter differential pressure sensing lines, an oil pressure transmitter, and an oil temperature bulb.

OIL PRESSURE TRANSMITTER.

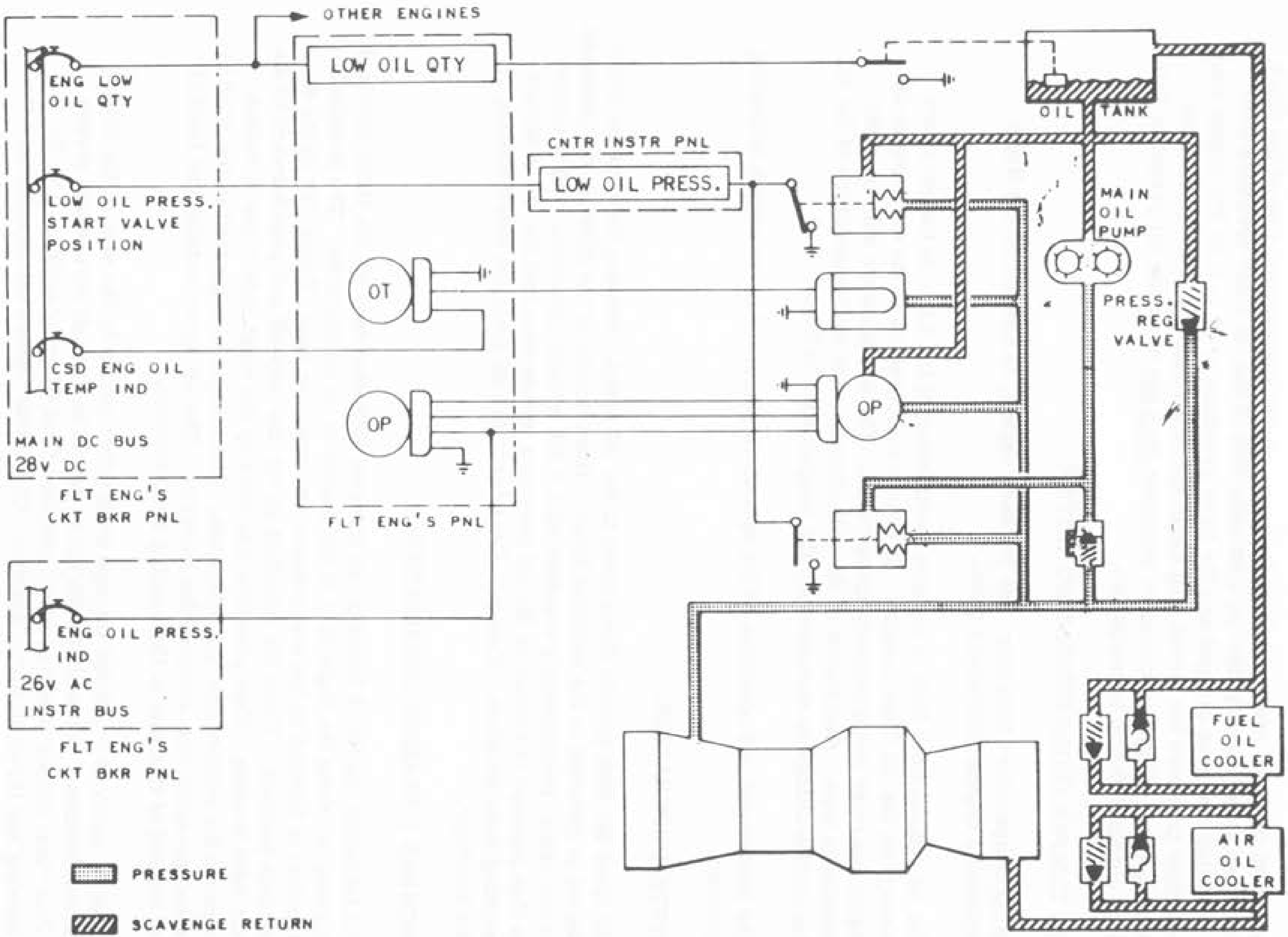
The pressure transmitter is just above the oil filter assembly and monitors oil pressure in the pressure passage on the downstream side of the oil filter. The transmitter also has a line which tees into a line connecting the low oil pressure switch to the gearbox. This serves as a vent to the gearbox. Operation of the pressure transmitter is covered under engine indicating systems. The indicator is located on the flight engineers panel, lower right hand side.



A low oil pressure warning system is incorporated on each engine to provide a light indication in the event of low oil pressure or oil filter clogging. The light is located on the pilot's center instrument panel. It is controlled by two pressure switches. The switches are located on the right hand side of the engine, on a bracket attached over the 6 inch compressor bleed valve.

One pressure switch is connected across the outlet of the oil pressure pump on the downstream side of the filter. The other side of the switch ties into the gearbox. The oil pressure transmitter tees into this line, sensing gearbox pressure. If oil pressure drops below 33 (± 1.5) PSI the light will come on. Low oil pressure should show on the indicator.

The second switch that controls the low oil pressure warning light is connected across the main oil filter. One side of the differential pressure switch is



ENGINE OIL SYSTEM ELECTRICAL SCHEMATIC

connected to outlet pressure from the pump on the downstream side of the filter. The other side connects into the upstream side of the oil filter pressure line. If the filter becomes clogged and the input pressure is 50 (± 1.5) PSI higher than the output pressure the switch will close and illuminate the low oil pressure warning light. If the oil pressure indicator <u>does not</u> show low oil pressure then filter clogging should be suspected.

OIL TEMPERATURE INDICATING SYSTEM.

An oil temperature indicator, one for each engine, is located on the flight engineer's engine instrument panel.

The oil temperature bulb is located downstream of the filter in the pressure passage on the oil filter housing. It senses temperature of the oil going to the engine bearings and accessory drive gears. The temperature bulb is of the resistance type. Resistance of the bulb changes with the temperature of the oil. Resistance change is measured by the temperature indicator.

The instrument and operation of the system is discussed under engine indicating systems.

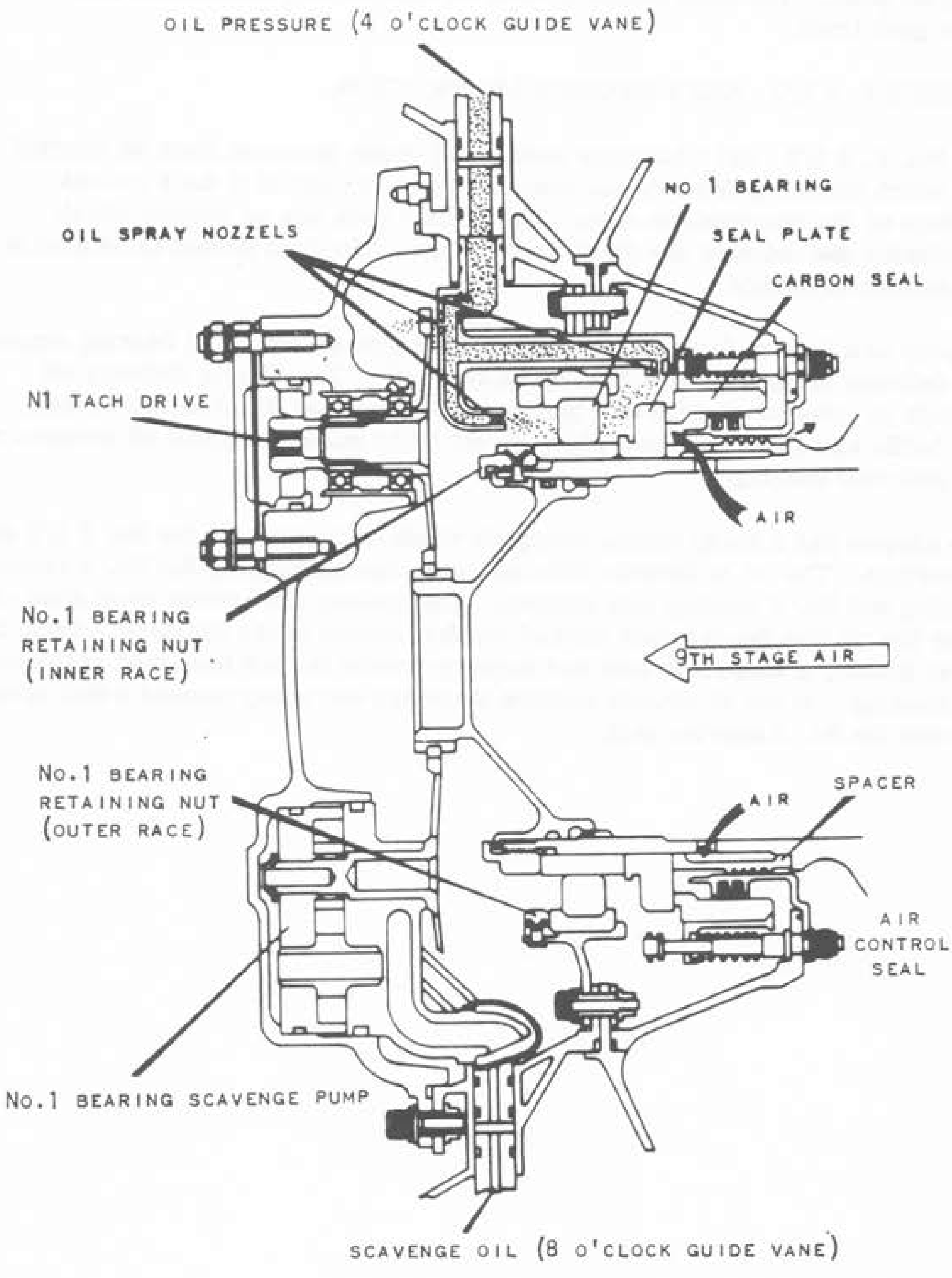
SYSTEM OPERATION.

Oil from the tank gravity flows down to the oil pump. Passing through the pump, the oil is directed to the main oil filter. Downstream of the filter is the pressure relief valve, maintaining a constant 45 ± 5 PSI system pressure. Oil pressure in this passage is sensed by the oil pressure transmitter and low oil pressure warning light switches. External lines carry the oil from the filter housing to the bearings.

NUMBER 1 BEARING LUBRICATION.

To lubricate the No. 1 bearing, an external line (that tees off the filter housing) directs oil along the right side of the engine to an oil manifold. The manifold (spider) is located on the compressor intermediate case, flange "F" in the 6 o'clock position. From the manifold an oil line tees off and goes forward to the air inlet housing. This pressure line runs up the right side to the 4 o'clock strut in the compressor air inlet case. The oil line is supported in the strut by a sponge-nylon type composition material. The oil spray nozzles are located at the end of this line in the bearing compartment.

The oil spray is regulated through each spray nozzle by the size of the drilled nozzle orifice. Located at each spray nozzle is a small wire-mesh screen. This "last chance (final) screen" provides final filtering action. The No. 1 bearing has three oil spray nozzles. One nozzle sprays oil directly onto the



NUMBER 1 BEARING AND SEAL

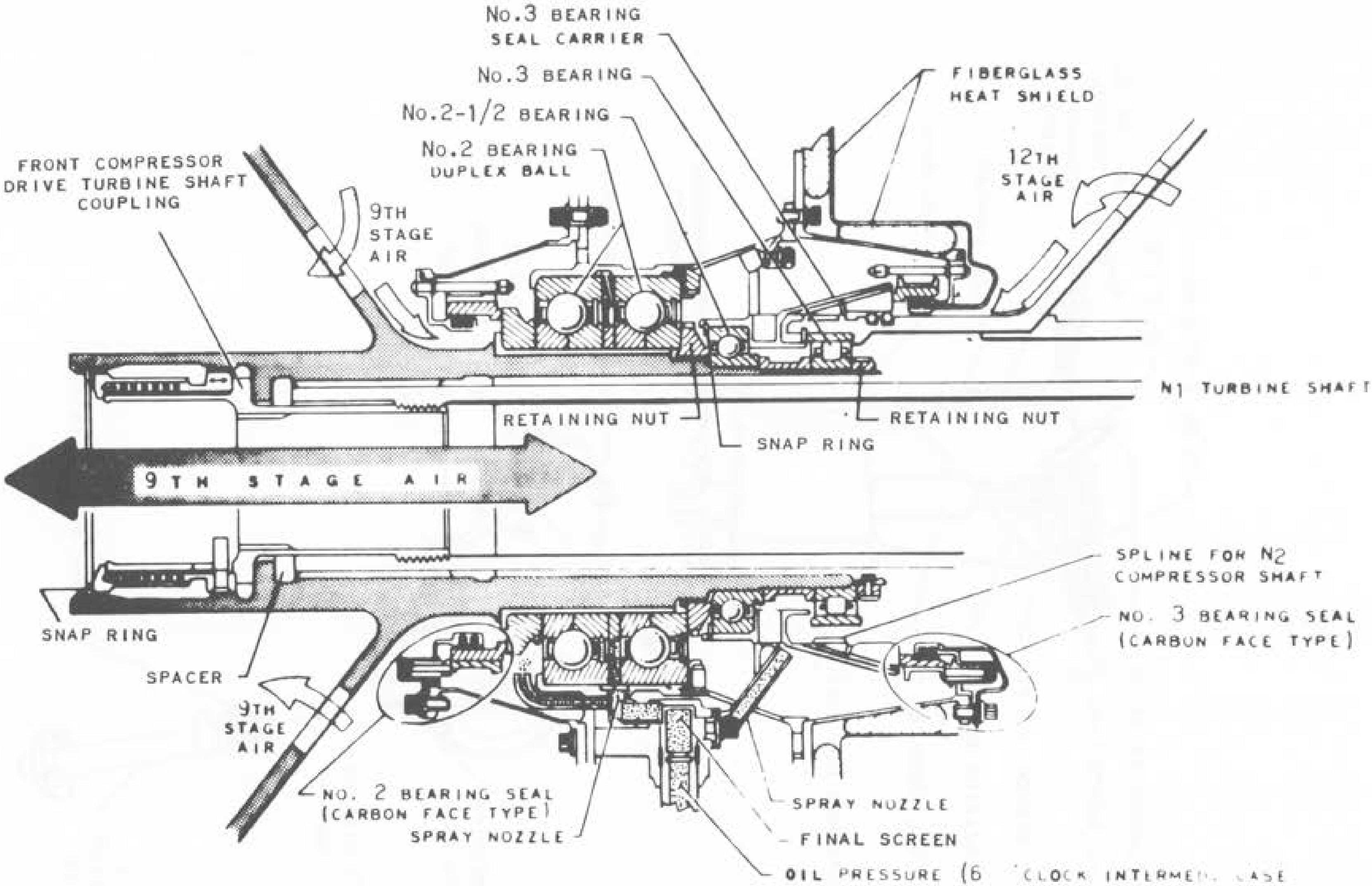
front face of the bearing. A second nozzle sprays oil down onto the carbon seal and seal plate. The third nozzle directs oil onto the N1, tachometer generator drive gear train.

NUMBER 2, 2 1/2, AND 3 BEARING LUBRICATION.

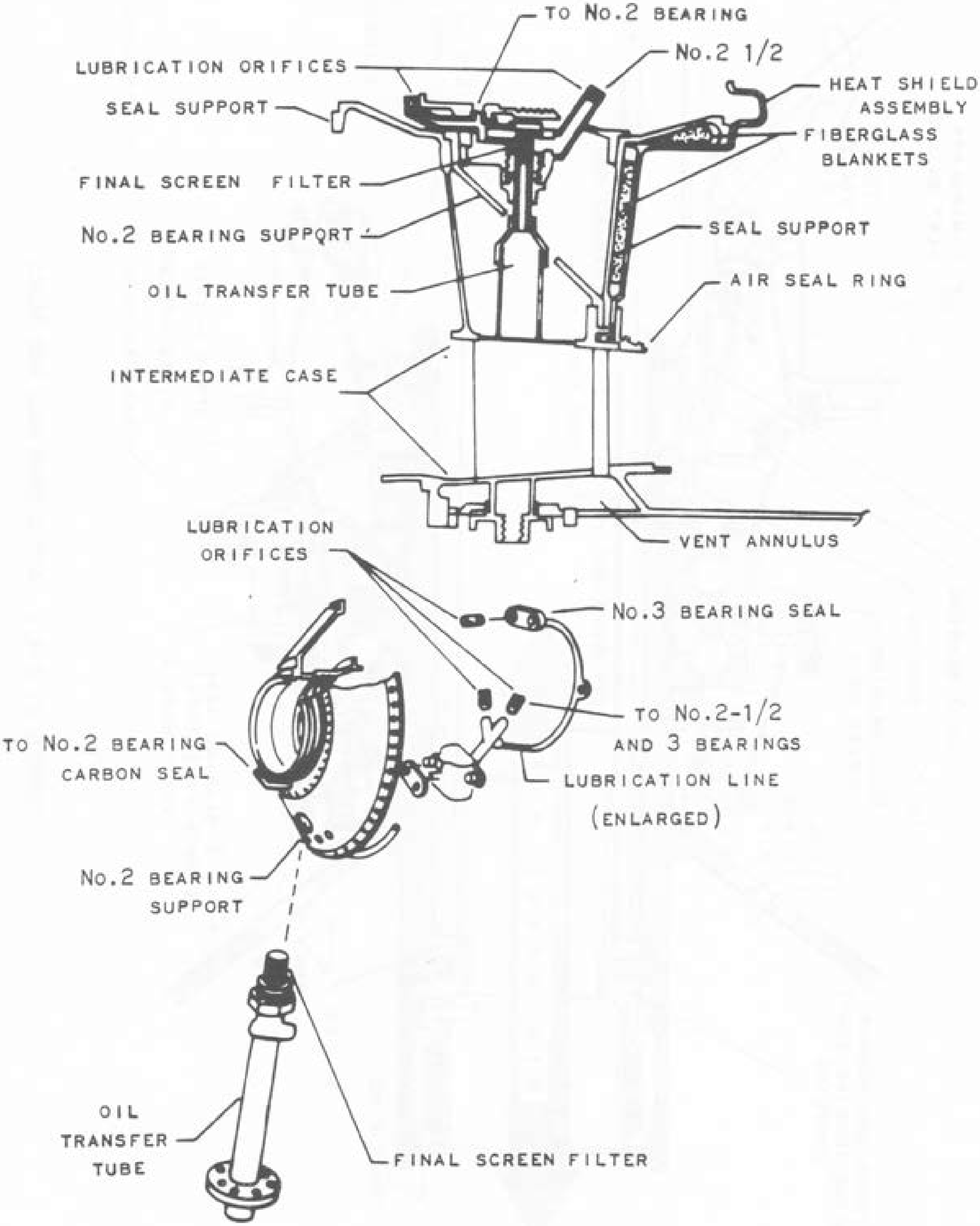
The No. 2, 2 1/2, and 3 bearings receive oil under pressure from an internal line which comes up from the oil manifold (spider) located at the 6 o'clock position on the intermediate case. The oil line goes into an adapter which distributes and delivers the oil to the bearings. The final screen is located in the adapter assembly.

A spray nozzle goes from the adapter forward through the No. 2 bearing support and delivers oil to the No. 2 bearing carbon seal. The adapter delivers oil through an internal passage to a baffle ring between the No. 2 duplex bearing. The baffle has drilled orifices which direct oil to the forward and aft sections of the dual-ball bearing.

The adapter has a spray nozzle facing aft which delivers oil to the No. 2 1/2 and 3 bearings. The oil is directed fore and aft to the bearings by the No. 2 bearing housing and No. 3 bearing seal carrier. The housing and carrier have slots which allow the oil into the chamber formed for the location of the bearings. From this spray nozzle, a small line tees and loops up around the left hand side of the bearing housing. At the 12 o'clock position there are two spray nozzles which spray oil onto the No. 3 bearing seal.



NUMBER 2, 2-1/2, AND 3 BEARINGS AND SEALS



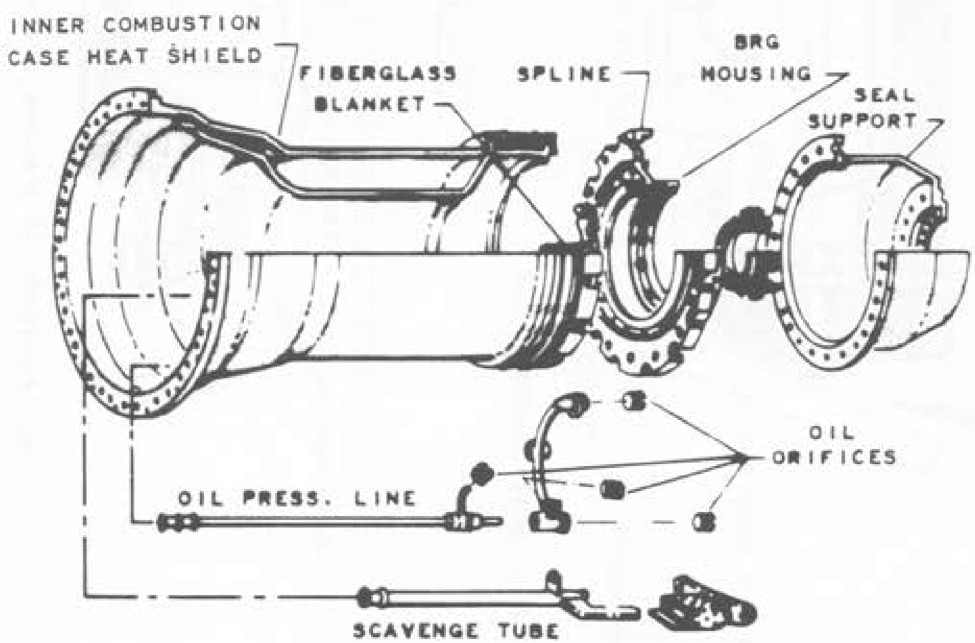
INTERMEDIATE CASE

NUMBER 4 AND 5 BEARING LUBRICATION.

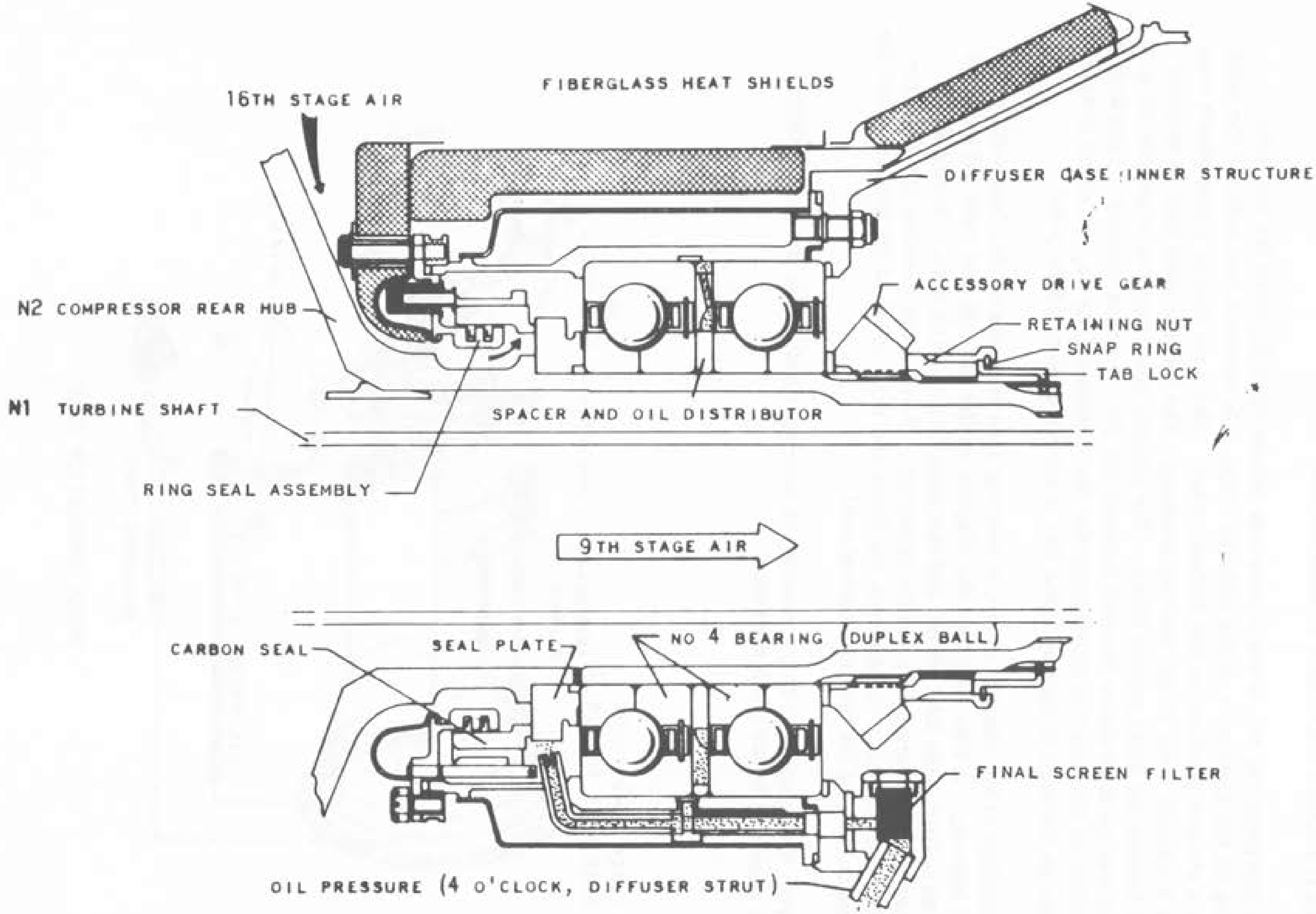
Oil to lubricate the No. 4 and 5 bearings comes directly from the oil filter housing on the right side of the diffuser case. An external line bolts to the boss at the 4 o'clock position on the diffuser case. The boss ties to a line which runs up the 4 o'clock strut to the bearing housing. The oil line goes into an adapter which houses the final screen filter. The adapter tees forward to supply oil to a spacer and oil distributor located between the No. 4 duplex bearing. Lubrication is similar to that used in lubricating the No. 2 duplex bearing. A spray nozzle extends on forward to lubricate the No. 4 carbon seal and face plate.

Oil supplied to the adapter at No. 4 bearing also supplies oil for lubricating the No. 5 bearing. A line tees into the adapter on the aft side and runs aft between the combustion case heat shield and the inner combustion case. At the No. 5 bearing, oil enters a spray nozzle assembly. Four spray nozzles are incorporated in the assembly to lubricate the front and rear sides of the bearings and the top and bottom of the bearing carbon seal.

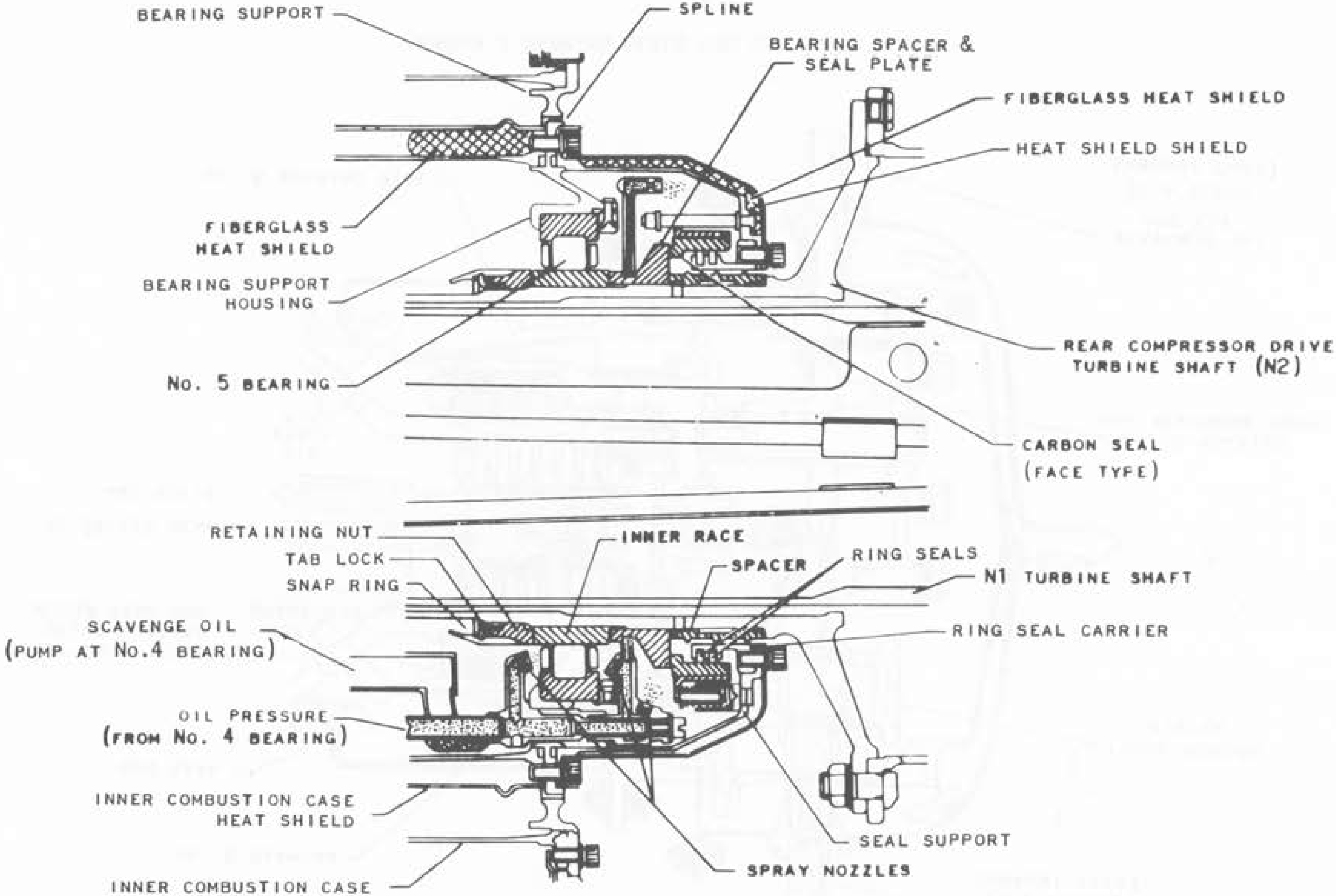
Oil from the adapter at No. 4 bearing is also sprayed on the accessory drive bevel gear and tower shaft bearings.



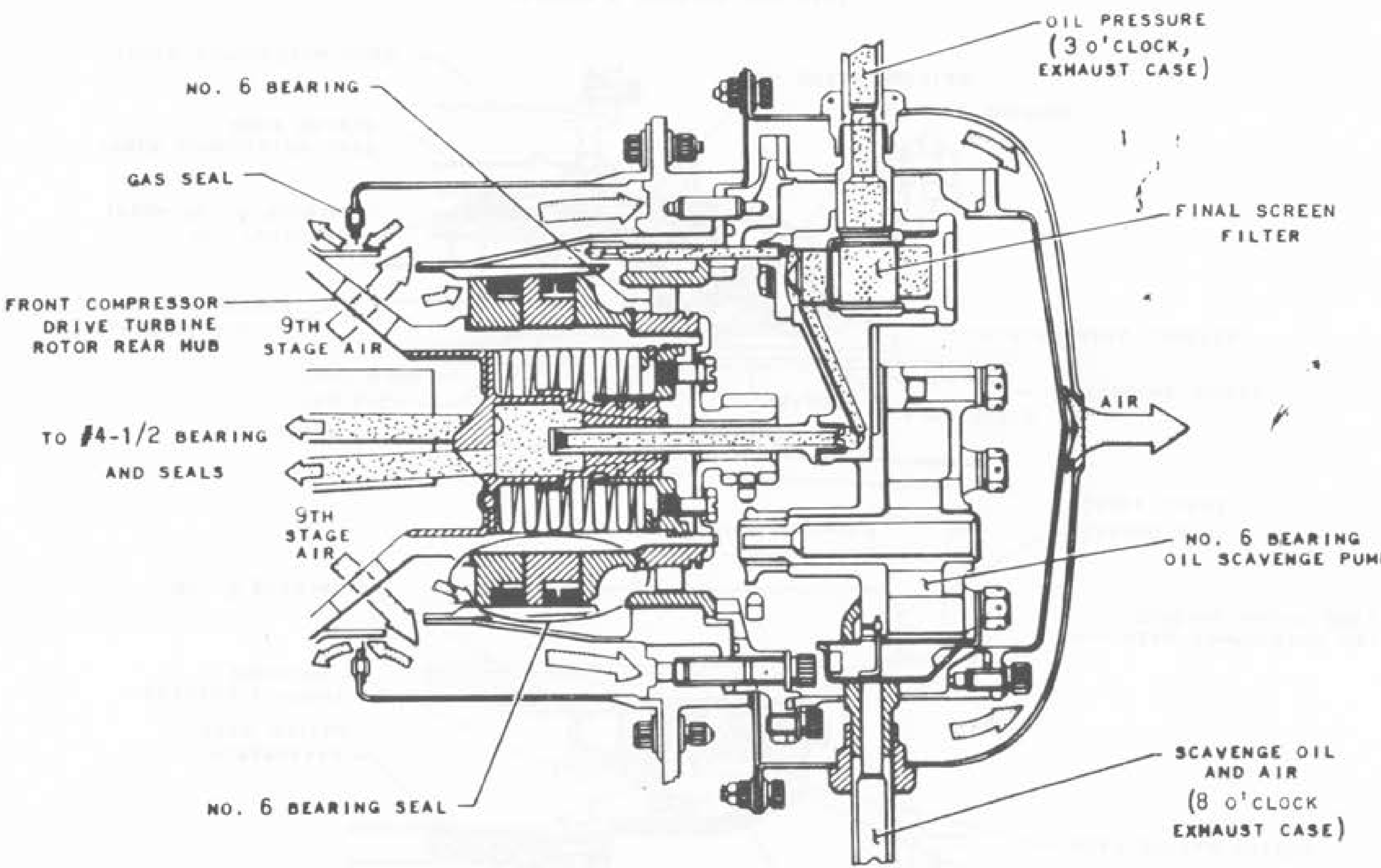
INNER COMBUSTION CASE



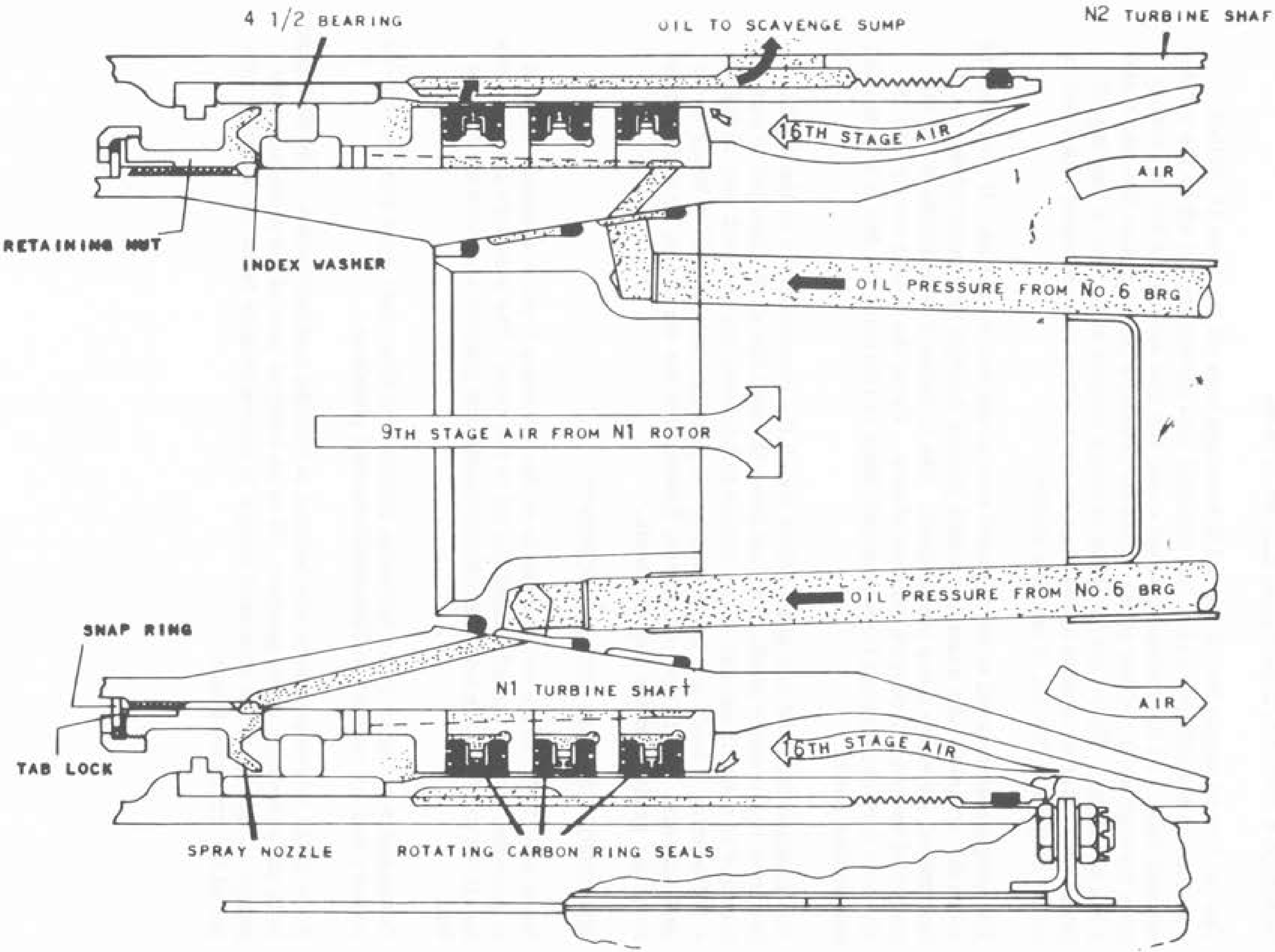
NUMBER 4 BEARING AND SEAL



NUMBER 5 BEARING AND SEAL



NUMBER 6 BEARING SEALS AND OIL SUMP



NUMBER 4-1/2 BEARING AND SEAL

NUMBER 6 AND 4 1/2 BEARING LUBRICATION.

The oil line to supply No. 6 and 4 1/2 bearings tees off the boss (4 o'clock position) on the diffuser case. An external line directs the oil aft to the turbine exhaust case. At the turbine exhaust case, the line enters the No. 6 bearing area through the 3 o'clock strut. This oil pressure line supplies the No. 6 and 4 1/2 bearings. There are two final screens located in the No. 6 bearing oil line. One filter is located at the boss on the turbine exhaust case; the other is in the adapter at the No. 6 bearing nozzle.

The adapter directs oil to the forward side of the No. 6 bearing. It also directs oil to the transfer tube assembly which passes through the center of the No. 6 bearing oil scavenge pump pinion gear. The transfer tube supplies oil to the center of the No. 6 bearing oil seal sleeve. From the center cavity, oil is directed forward through three trumpet tubes to lubricate the No. 4 1/2 bearing and carbon seals.

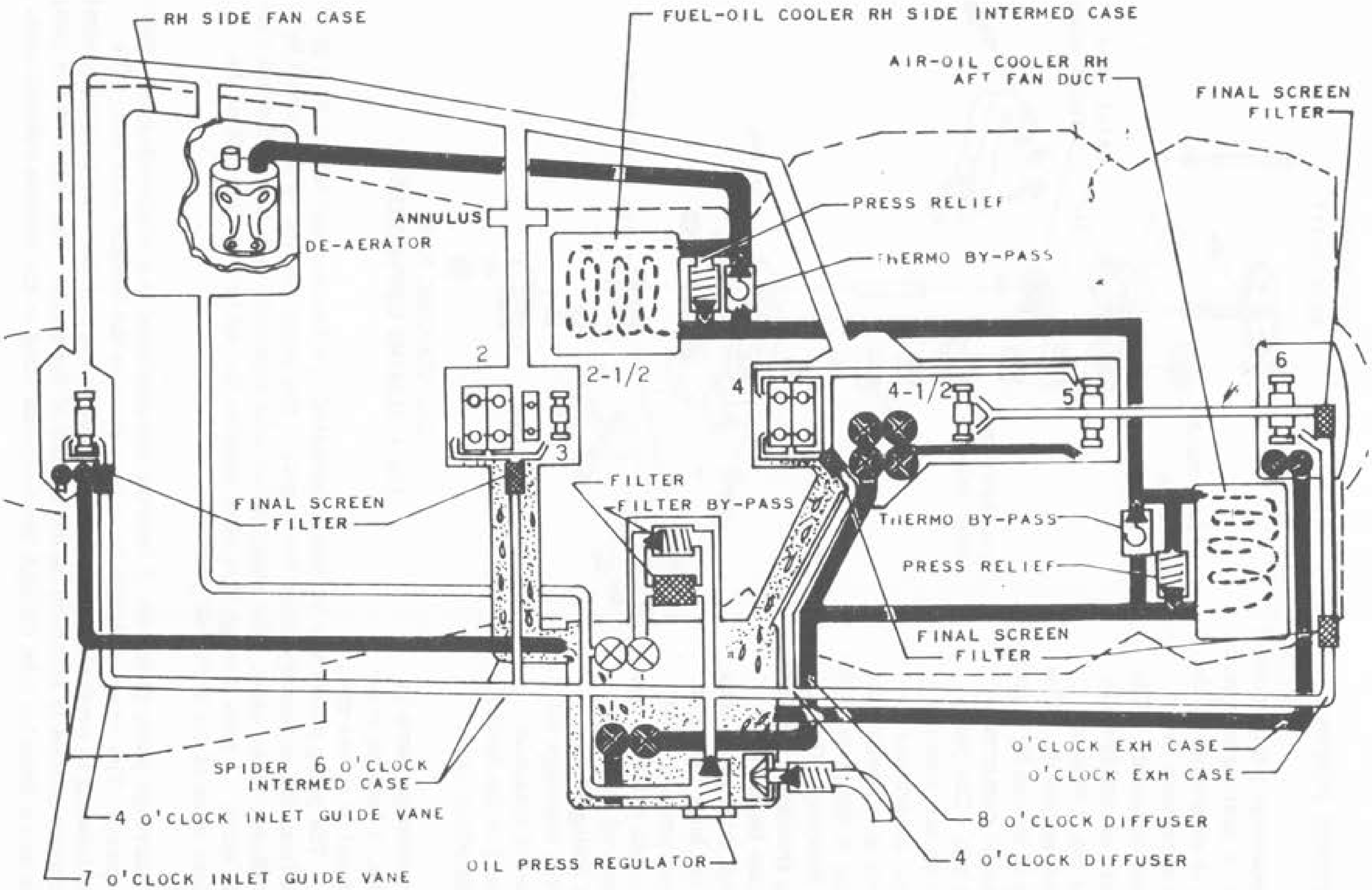
The trumpet tubes fit into seals which match the internal taper of the inside of the front compressor shaft. Drilled holes through the shaft allow oil to run out forward to a small annular spray nozzle to lubricate the forward side of the No. 4 1/2 bearing. Seals are lubricated by oil passing through drilled holes in the seal spacers. Oil is prevented from flowing into the airstream by a sixteenth-stage air preload on the bearing seals.

SCAVENGE SYSTEM AND COMPONENTS.

Since the JT3D (TF33-P-7) engine is of the dry sump type, a scavenge system is provided to pick up and return the oil to the tank. The scavenge system picks up all the oil from the bearing compartments and gearbox and returns it to the tank.

Components included in the scavenge system are five, gear-type pumps; air-oil cooler; fuel-oil cooler; and internal/external plumbing.

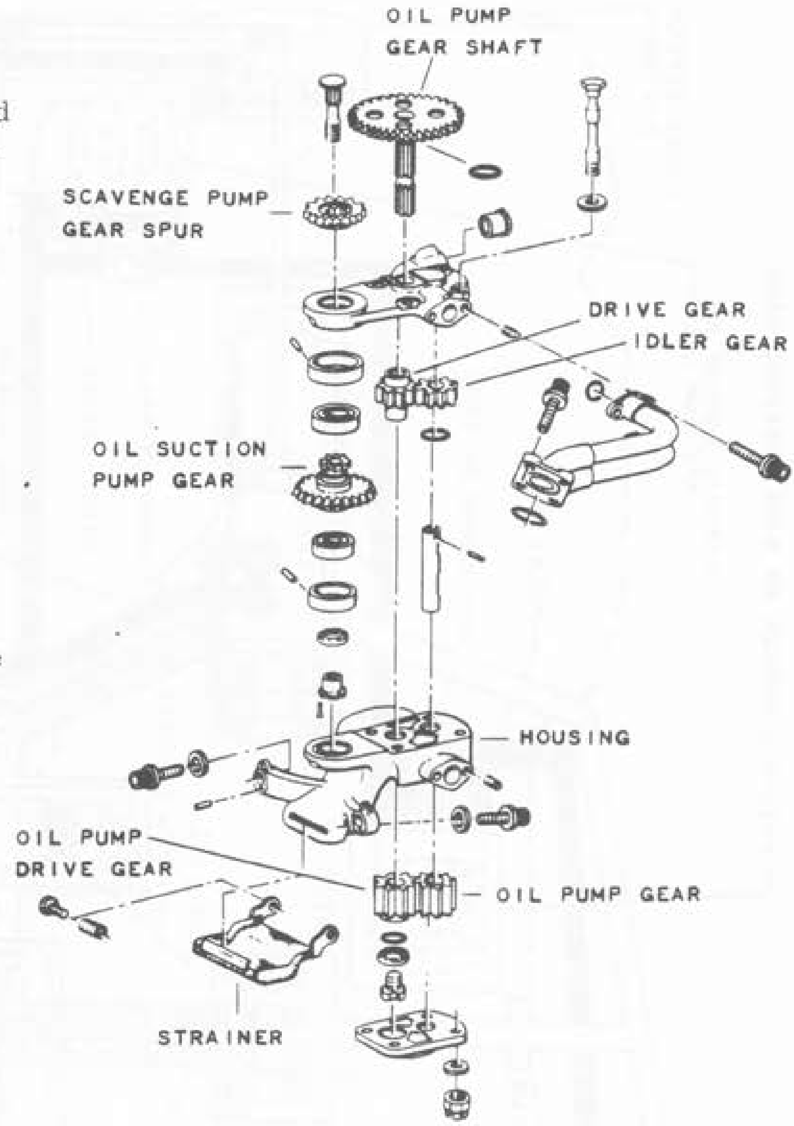
Four of the scavenge pumps are located in bearing compartments. The fifth pump is in the accessory drive gearbox. It is an integral part of the main pressure pump. Capacity of the combined pumps is approximately twice the quantity output of the pressure pump.



SCAVENGE SYSTEM

SCAVENGE PUMPS.

The scavenge pump located in No. 1 bearing compartment is supported by the front accessory drive support assembly. The support assembly bolts to the No. 1 bearing support assembly. The pump is driven by a gear off the N1 compressor front hub. The pump picks up oil from the sump. A strainer screen is located at the bottom of the pump pick-up. Scavenge oil from the pump travels to a transfer tube inside the 8 o'clock inlet guide vane to a tee boss fitting on the compressor inlet case. An external line is secured to the tee boss fitting which carries scavenge oil to the oil manifold (spider) at the bottom intermediate case.



OIL SCAVENGE PUMP
(No.4 BEARING COMPARTMENT)

The scavenge pump in the No. 4 bearing compartment is a dual-gear type. The pump shafts are vertically mounted in a housing and driven by a gear train from the accessory drive bevel gear. The pump housing is supported by the diffuser inner case. The pump outlet tube assembly is bolted to the left side of the strut. A tube through this strut carries the oil to a pad outside of the diffuser case of the 8 o'clock position.

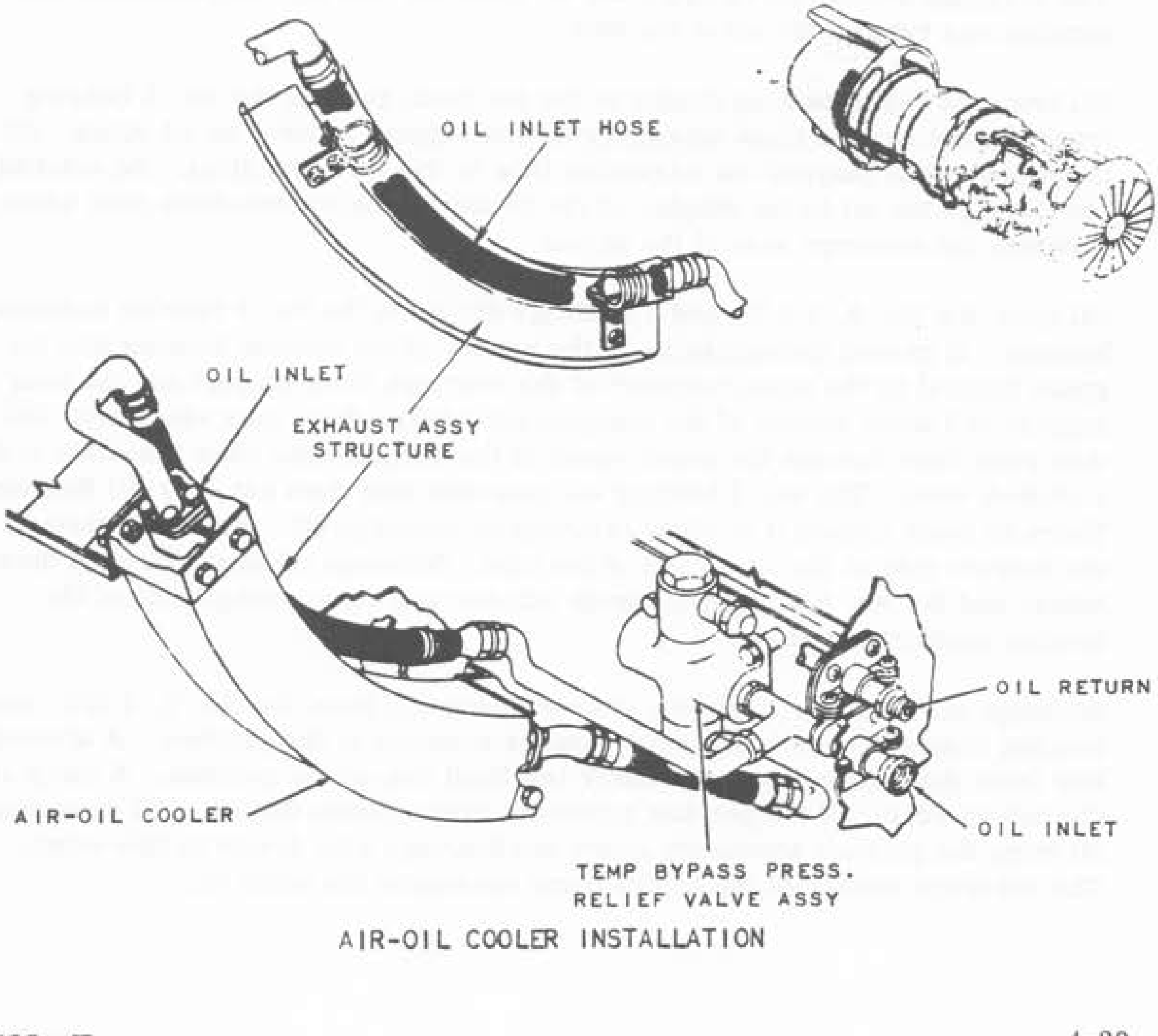
The scavenge pump in the No. 6 bearing compartment is a single-element, gear-type pump. The pump is driven by a spur gear on the turbine rear hub. The pump housing is supported through an adapter to the turbine rear bearing assembly. A strainer screen is installed on the bottom of the pump. The outlet on the pump exits into a transfer tube through the 8 o'clock strut in the turbine exhaust case.

The scavenge pump in the main gearbox is part of the main pressure pump. It is driven through splines from the hydraulic pump drive gear. The pump will scavenge oil from the No. 2, 2 1/2, and 3 bearing compartments. Oil draining down the accessory drive tower shaft and oil from the accessory drive gears and bearings in the gearbox is scavenged by the main scavenge pump.

AIR-OIL COOLER.

The air-oil cooler is a radiator-type heat exchanger. It supplements the fuel-oil cooler to keep the temperature of the oil within the desired limits. Under certain engine operating conditions the fuel-oil cooler is not capable of maintaining the oil temperature within limits.

The air-oil cooler is located on the right side of the exhaust assembly of the fan discharge duct. The oil is cooled by fan exhaust air flowing around the cooler case.



AIR-OIL COOLER INSTALLATION

Heat from the hot oil is transferred to the colder air, thereby reducing the oil temperature. The unit employs a temperature-pressure controller bypass valve which protects the cooler radiator case it clogs.

FUEL-OIL COOLER.

The fuel-oil cooler is a radiator-type heat exchanger, similar in principle of operation to the air-oil cooler. The cooler has a cylindrical oil chamber surrounded by a jacket. Fuel passes through the cooler core and oil circulates around the core. It is located on the right side of the N2 compressor case.

A temperature-pressure controller bypass valve is incorporated in the unit. The temperature-pressure controller also acts as a pressure relief valve which opens if the core becomes clogged. The temperature control bypass valve regulates the temperature of the oil returning to the tank.

SYSTEM OPERATION.

The scavenge system picks up all the oil from the bearing compartments and gearbox and returns the oil to the tank.

Oil from the No. 1 bearing drains to the low point between the No. 1 bearing front support and the front accessory drives support to form an oil sump. Oil is picked up and pumped out a transfer tube in the 8 o'clock strut. An external line carries the oil to the adapter at the bottom of the intermediate case where it enters the scavenge side of the spider.

Oil from the No. 2, 2 1/2, and 3 bearings drains in the No. 2 bearing assembly housing. It passes through holes in the bottom of the bearing housing into the space formed by the center support of the bearings front support and the rear support and inner shroud of the compressor intermediate case assembly. Oil then runs down through the lower vanes of the intermediate case assembly to the 6 o'clock vane. The No. 2 bearing oil pressure tube does not fully fill this vane. There is room around it to allow drainage of scavenge oil. Holes are through the support ring at the lower end of the tube. Scavenge oil drops through these holes, and the No. 2 bearing oil drain adapter into the scavenge side of the adapter (spider) assembly.

Scavenge oil from No. 1 bearing joins scavenge oil from the No. 2, 2 1/2, and 3 bearing compartments at the spider and is returned to the gearbox. A scavenge line from the spider enters the lower left hand side of the gearbox. A sump at the bottom center of the gearbox assembly case collects the oil. All scavenge oil from the gearbox accessory gears and bearings also drains to this sump. The scavenge section of the duplex pump scavenges the sump oil.

Scavenge oil from the 4, 4 1/2, and 5 bearings is picked up by the dual scavenge pump in the No. 4 bearing compartment. Pressure oil is discharged from the front of the forward and the rear of the rear bearing (No. 4). A space in the seal housing allows oil from the front to drain back to the rear of the No. 4 bearing support structure in the diffuser case. Oil from the rear bearing drains directly to the same place. Splash from the rear bearing provides lubrication for the gears and scavenge pump idler bearings in this area. All scavenge oil then drains to a sump formed where the No. 5 bearing support joins the No. 4 bearing support structure.

The lower section of the dual scavenge pump draws oil from the sump. The oil scavenge tube for this pump is a passage in the pump housing casting. Output goes into a common manifold.

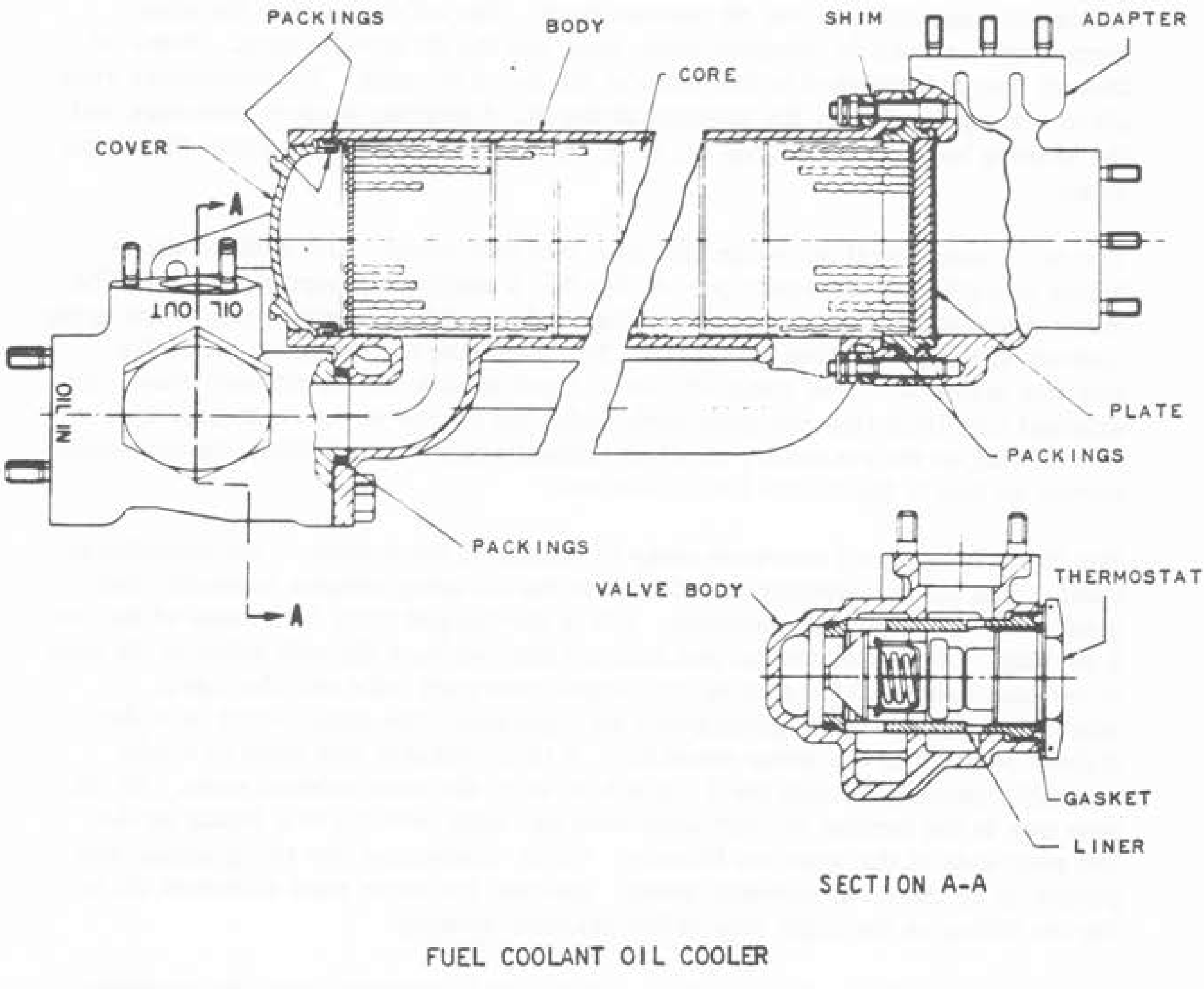
Scavenge oil from the 4 1/2 bearing is discharged from the rear side of the rollers through holes in the N2 turbine shaft. The oil drains into the area formed by combustion chamber inner liner and the N1 turbine shaft. Some of this oil may run forward to the sump at the No. 4 bearing. The remainder runs aft to a sump formed by the junction of the No. 5 bearing support structure and the bearing housing. Scavenge oil from the No. 5 bearing drains into this same sump.

The no. 5 bearing oil scavenge tube dips into this sump. The pickup tube is bolted into place in the lower part of the No. 5 bearing support structure. The forward end of the tube fits into the inlet of the upper scavenge pump. The upper element of the pump picks up oil from No. 5 bearing and pumps it out to the common manifold. The manifold ties to a pad outside on the diffuser case. An external line from this pad goes down under the engine to the right hand side to a tee fitting on the accessory gearbox directly under the oil filter element which serves as this is the return line to the tank.

The No. 6 bearing oil scavenge pump is located in the bottom of the cylindrical sump. The sump assembly is mounted to the oil sump adapter assembly and covered by a heat shield assembly. Oil is discharged from both sides of the No. 6 bearing. Oil that is discharged forward can run back through holes in the rear of the seal housing. Oil that is discharged rearward falls into the sump, lubricating the scavenge pump gears as it passes. The pump outlet is at the 7 o'clock position of the sump assembly. A tube connects this point to a tube assembly passing through the 7 o'clock strut to the outer exhaust case. An oil tube ties to the turbine exhaust case boss and runs forward to a fitting on the left rear side of the gearbox housing. Oil is discharged into the gearbox and picked up by the main scavenge pump. Internal passages pass scavenge oil to the tee fitting on the right side of the gearbox housing.

From the tee fitting, oil from the 4, 4 1/2, and 5 bearings joins the scavenge oil from the gearbox. Oil return lines run aft on the right side of the engine to the fan discharge duct in the exhaust nozzle assembly. The air-oil cooler is located in this duct.

Fan exhaust air is used for cooling the oil. The oil cooler is equipped with a pressure relief and temperature bypass valve. The pressure relief valve is designed to open at a pressure of 23 PSID if the cooler core becomes clogged. The temperature bypass valve is designed to limit the amount of oil cooling by permitting more or less oil to flow through the cooler. When the temperature of the oil is 60°C or below, the bypass valve is fully opened, bypassing oil around the cooler. When oil temperature increases the temperature bypass valve begins to close. At 76.7°C the bypass valve is fully closed, allowing oil to pass through the cooler.



FUEL COOLANT OIL COOLER

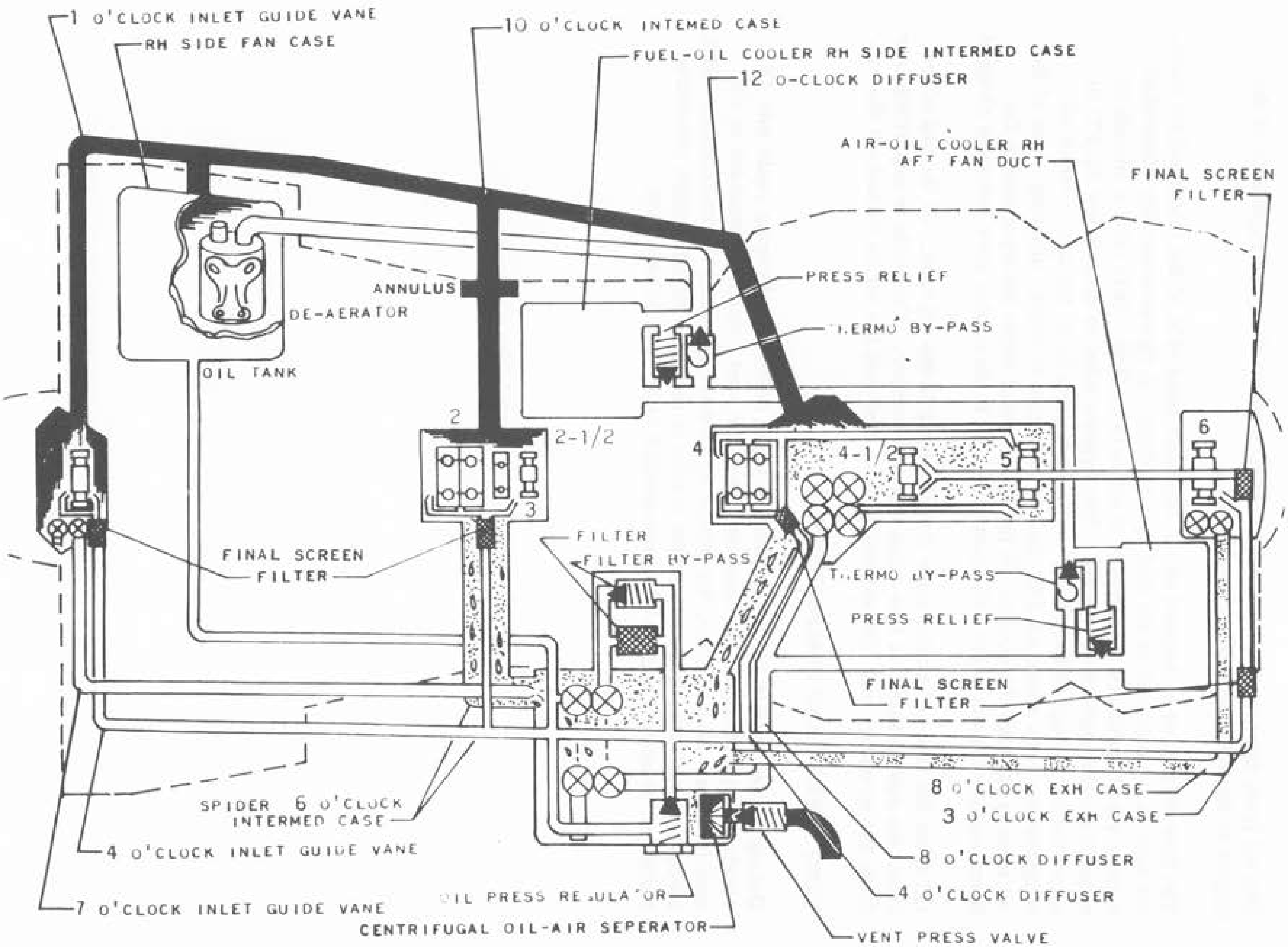
The oil from the air-oil cooler is directed forward along the right side of the engine to the fuel-oil cooler.

The fuel-oil cooler is located on the top right hand side of the intermediate case. Oil heat is transferred to the fuel by radiation. A thermostatically controlled bypass valve regulates the amount of oil to be cooled. Only oil hot enough to require cooling enters the cooler. The bypass valve is open below 93.3°C to allow the oil to bypass the cooler and return directly to the tank. When oil temperature goes above 93.3°C, the valve begins to close, allowing some of the oil to pass through the cooler. A pressure relief valve incorporated in the thermostatic bypass valve will open at 60 PSI if the cooler core becomes clogged.

Oil from the fuel-oil cooler goes directly back to the oil tank. At the top of the tank, the return line ties into a can type de-aerator. This aids in separating air from the scavenge oil. Oil settles into the tank and the air is vented out the top.

VENT SYSTEM AND COMPONENTS.

During engine operation, air constantly leaks across the bearing seals into all bearing compartments. Pressurization in the vent system is provided by the seal leakage. At sea level, the entire oil system is vented to atmosphere. With increasing altitude, the vent system works to maintain an oil system pressure sufficient to assure engine oil flows similar to oil flow at sea level.


1 O'CLOCK INLET GUIDE VANE
RH SIDE FAN CASE
10 O'CLOCK INTEMED CASE
FUEL-OIL COOLER RH SIDE INTERMED CASE
12 O-CLOCK DIFFUSER
AIR-OIL COOLER RH AFT FAN DUCT
FINAL SCREEN FILTER
PRESS RELIEF
THERMO BY-PASS
ANNULUS
DE-AERATOR
OIL TANK
2
2-1/2
3
4
4-1/2
5
6
FINAL SCREEN FILTER
FILTER
FILTER BY-PASS
THERMO BY-PASS
PRESS RELIEF
FINAL SCREEN FILTER
8 O'CLOCK EXH CASE
3 O'CLOCK EXH CASE
SPIDER 6 O'CLOCK INTERMED CASE
4 O'CLOCK INLET GUIDE VANE
8 O'CLOCK DIFFUSER
4 O'CLOCK DIFFUSER
7 O'CLOCK INLET GUIDE VANE
OIL PRESS REGULATOR
CENTRIFUGAL OIL-AIR SEPERATOR
VENT PRESS VALVE

VENT SYSTEM

COMPONENTS.

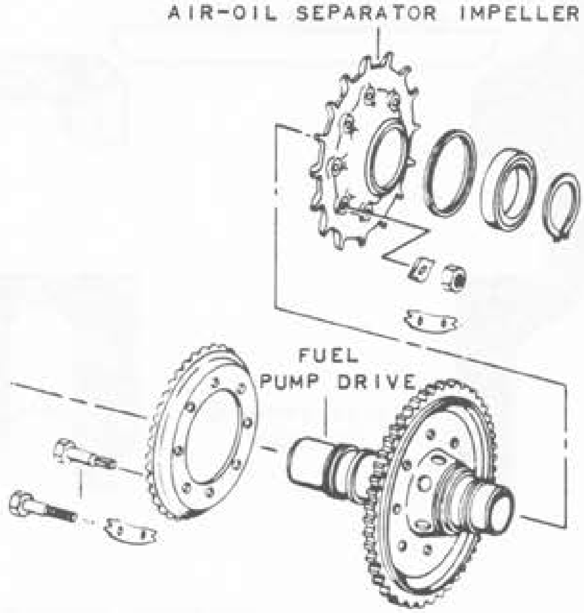
Components included in the vent system are a breather pressurizing valve, a centrifugal type air-oil separator, and all external lines.

External Lines.

External lines interconnect each bearing compartment to the oil tank and main accessory gearbox.

Air-Oil Separator.

The air-oil separator is a centrifugal device used to remove oil particles from the air. It is located in the gearbox and driven by the fuel pump drive shaft.

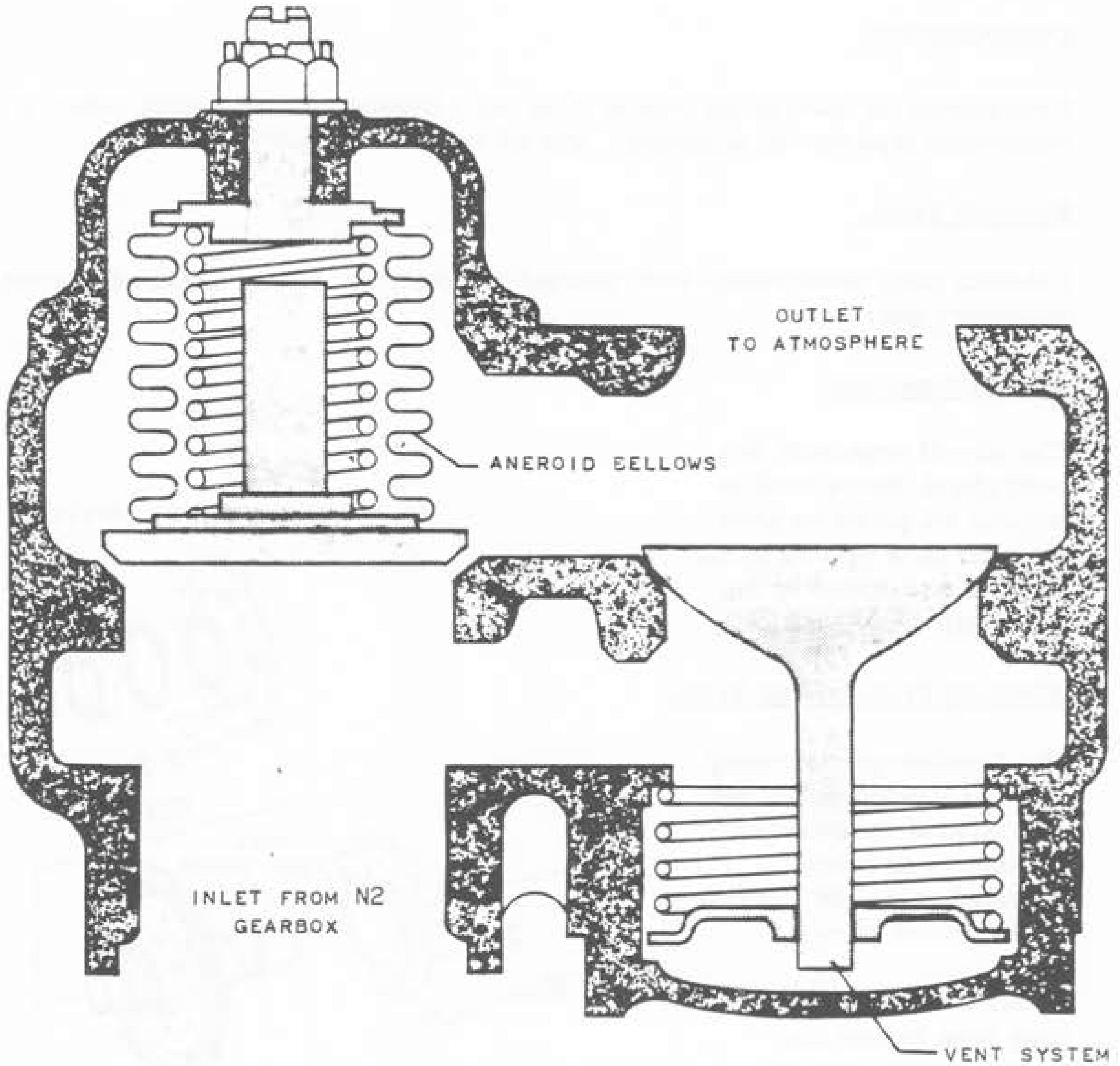


ROTARY BREATHER

Breather Pressurizing Valve.

The breather pressurizing valve is located on the left rear side of the gearbox. It contains an aneroid-operated valve and a spring-loaded relief valve.

At sea level, the valve is fully open to vent the system to atmosphere. With increasing altitude, the aneroid bellows expands gradually closing off the vent to atmosphere. The valve will reach a fully closed position at an altitude of approximately 30,000 feet. The spring-loaded relief valve acts as a pressure relief for the entire breather system and will open if the pressure differential exceeds approximately 7 PSID.

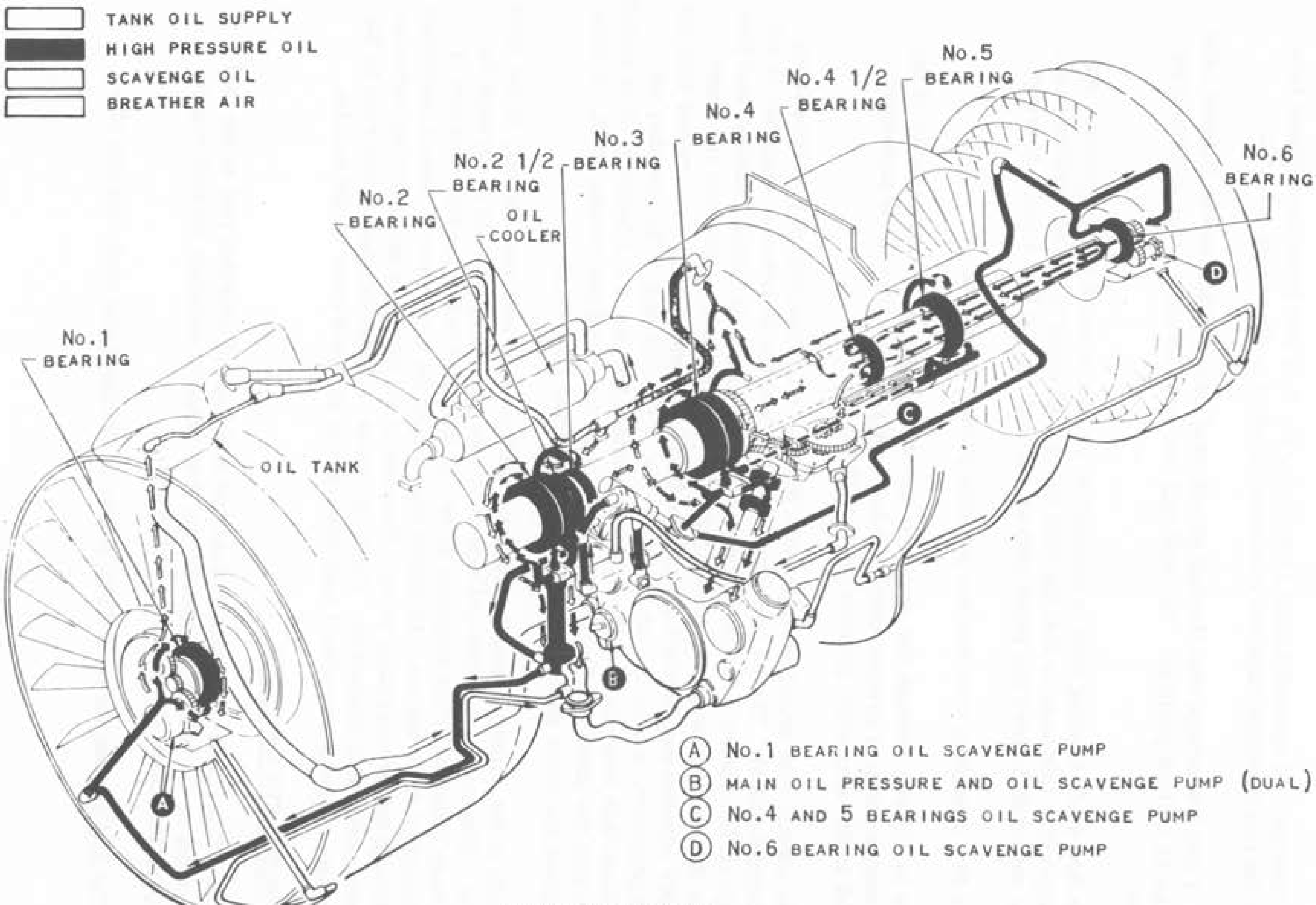


BREATHER PRESSURIZING VALVE

SYSTEM OPERATION.

The No. 1 bearing is vented by means of a transfer tube through the 1 o'clock inlet guide vane to a fitting on the outer case. A line connects the bearing compartment to the top of the oil tank. The vent line tees at the top of the oil tank and runs aft along the top of the engine to a fitting on the intermediate case. The annulus in the intermediate case serves as a common vent manifold for the No. 2, 2 1/2, 3, 4, 4 1/2, and 5 bearings.

The No. 2, 2 1/2, and 3 bearing compartments in the intermediate case vent to



ENGINE OIL SYSTEM

the annulus. At approximately 11 o'clock, the vent line from the diffuser tees into the intermediate case and continues forward to the engine oil tank.

No. 4 and 5 bearings vent through an external line attached on the diffuser case in the 12 o'clock position. The external line runs forward to the intermediate case.

The No. 4 1/2 bearing vent is common to the No. 4 and 5 bearing vents. An exception in this case is that the vent is through holes in the N2 turbine shaft. The vent then follows the same path as did vent for the No. 4 and 5 bearings.

The No. 6 bearing area has two possible paths for venting:

One is directly through the scavenge system. Since the output capacity of the scavenge pump is greater than oil inlet supply, some air will be scavenged back to the accessory gearbox along with the oil.

The second vent provision is through the No. 4 1/2 bearing oil pressure tubes (trumpet tubes). The jet tube that feeds oil into the distribution chamber is not tight on the sleeve. Air in this area can enter the distribution chamber and flow into the trumpet tubes along with bearing lubrication oil. Because the tubes taper outward and forward toward the bearing, centrifugal force, rather than the oil pressure, moves the oil out to the No. 4 1/2 bearing. The breather air follows this same path. When the air reaches the No. 4 1/2 bearing, it is vented out into the inner combustion chamber inner liner and the turbine shaft. It then follows the same path as vent air for No. 4 and 5 bearings.

Each of the separate bearing compartments and oil tank vent directly to the gearbox. The common overboard vent from the accessory gearbox is through the rotary breather. The majority of the oil particles in the breather system is separated from the air. Breather air leaving the separator is vented overboard through the pressurizing valve. Purpose of the breather pressurizing valve has been previously discussed. From the valve, a large overboard line runs to the bottom of the engine where vent pressure is relieved clear of the nacelle.

ENGINE FUEL SYSTEM.

The JT3D (TF33-P-7) fuel system and fuel control provides fuel to the fuel nozzles at the proper pressures and flow rates to maintain correct engine operation under all operating conditions.

The fuel system for each JT3D engine is identical and each consists of a combination of the following units. Units are listed in the order of fuelflow:

- o Firewall Shutoff Valve
- o Engine Low Pressure Warning Switch
- o Dual-Element Engine Driven Fuel Pump
- o Engine Pump-Out Pressure Switch
- o Fuel Heater
- o Fuel Filter
- o Filter Bypass Pressure Switch
- o Fuel Shutoff Actuator
- o Fuel Control
- o Fuel Flow-meter
- o Fuel-Oil Cooler
- o Pressurizing and Dump Valve
- o Fuel Manifold
- o Fuel Nozzles

SYSTEM AND COMPONENTS.

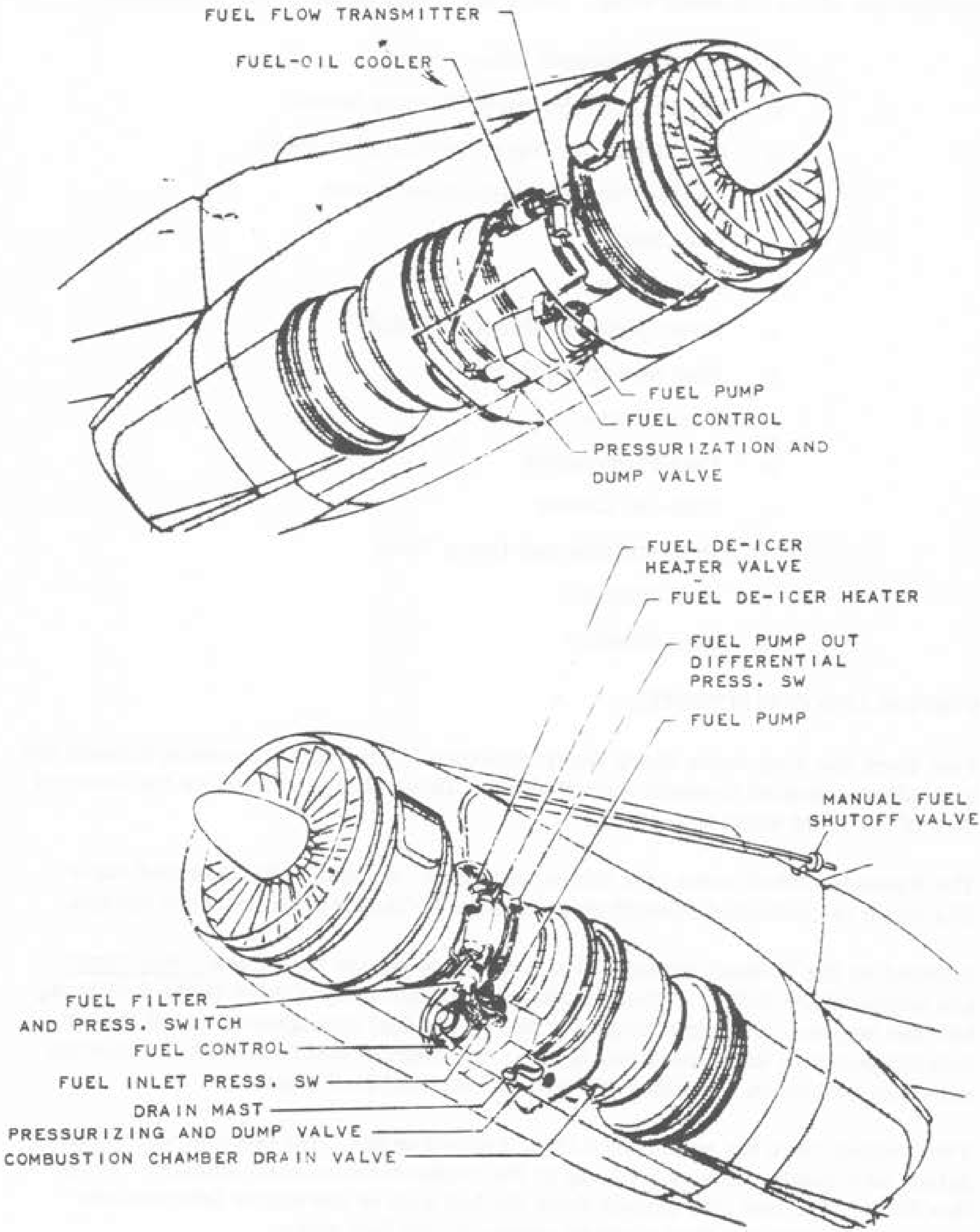
Fuel from the wing tanks flows under pressure to the engine, passing through the manually controlled firewall shutoff valve. This valve is located on the forward face of the front wing main beam.

The firewall shutoff valve is a sliding gate type, mechanically operated valve. The valve is controlled through cable linkage by the fire handle in the cockpit.

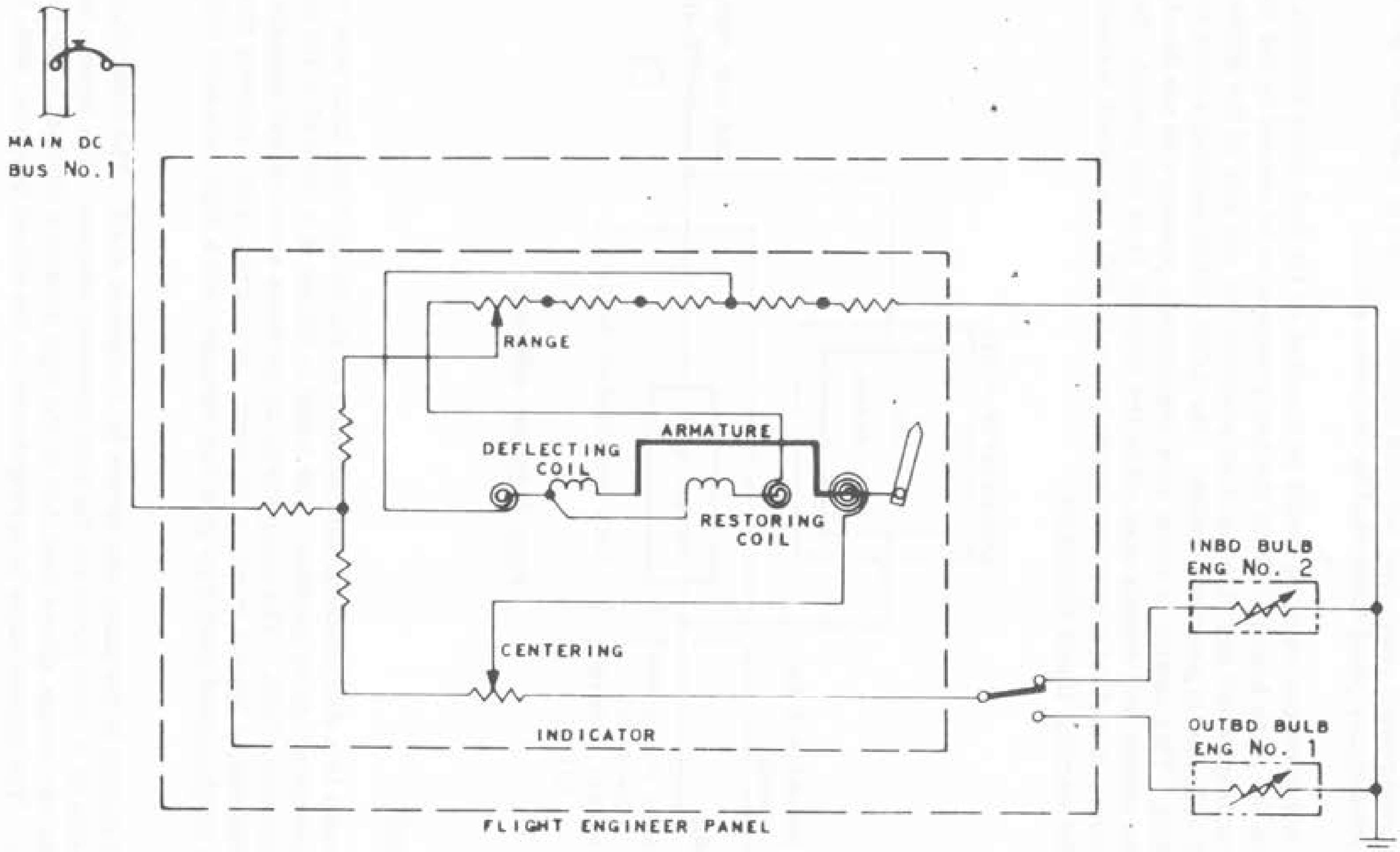
Located on the firewall shutoff valve housing on engine feed lines 1 and 2 only are temperature bulbs. These bulbs monitor the temperature of the fuel going into the engines. A single gauge located on the fuel management panel indicates fuel temperature in degrees centigrade. A selector switch is used, permitting selective indication for either inboard or outboard feed lines.

Fuel passes down the engine feed line, located on the front beam of the engine pylon, to a quick disconnect fitting at the engine forward cowl support. From this fitting, the fuel line passes down the left side of the engine intermediate case directly into the dual element engine driven fuel pump.

At this point, inlet fuel pressure is sensed by the engine low pressure warning

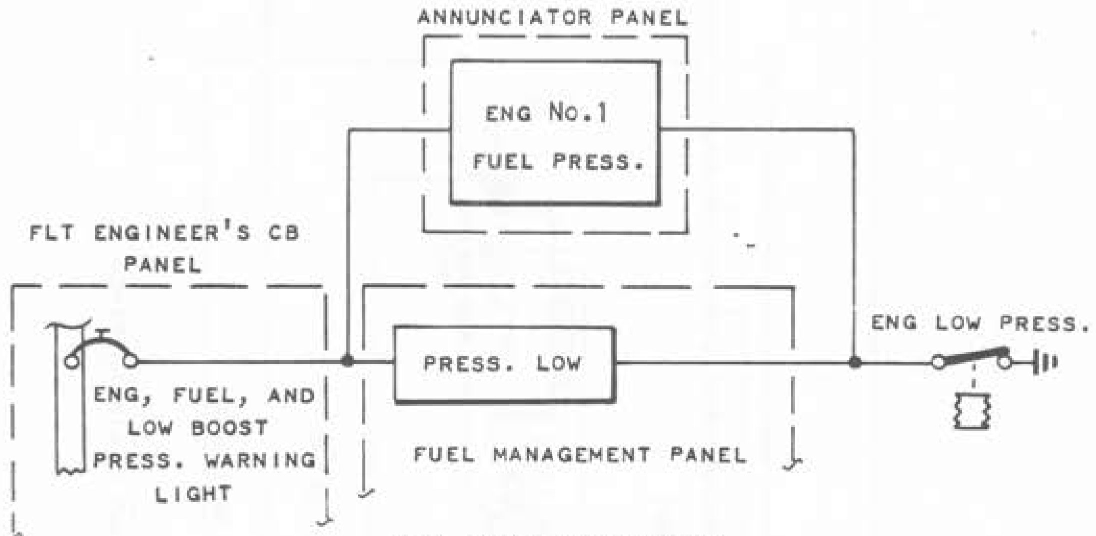


ENGINE FUEL SYSTEM COMPONENTS LOCATION



FUEL TEMPERATURE INDICATING SYSTEM SCHEMATIC switch. This switch controls the PRESS LOW warning light on the flight engineer's fuel management panel (one for each engine). There is also one light on the pilot's annunciator panel controlled by the same switch.

The engine low pressure warning switch is mounted on the fuel pump housing. A tee fitting on the pump housing allows the fuel pressure to be sensed by the low-pressure warning switch and also supplies pressure for one side of the engine PUMP OUT differential pressure switch. The LOW PRESS warning switch is set at 12 PSIA. This setting is lower than atmospheric pressure at sea level; therefore the switch will remain open while the aircraft is on the ground. During flight, however, if fuel inlet pressure drops below 12 PSIA the switch contacts close and the warning lights illuminate.

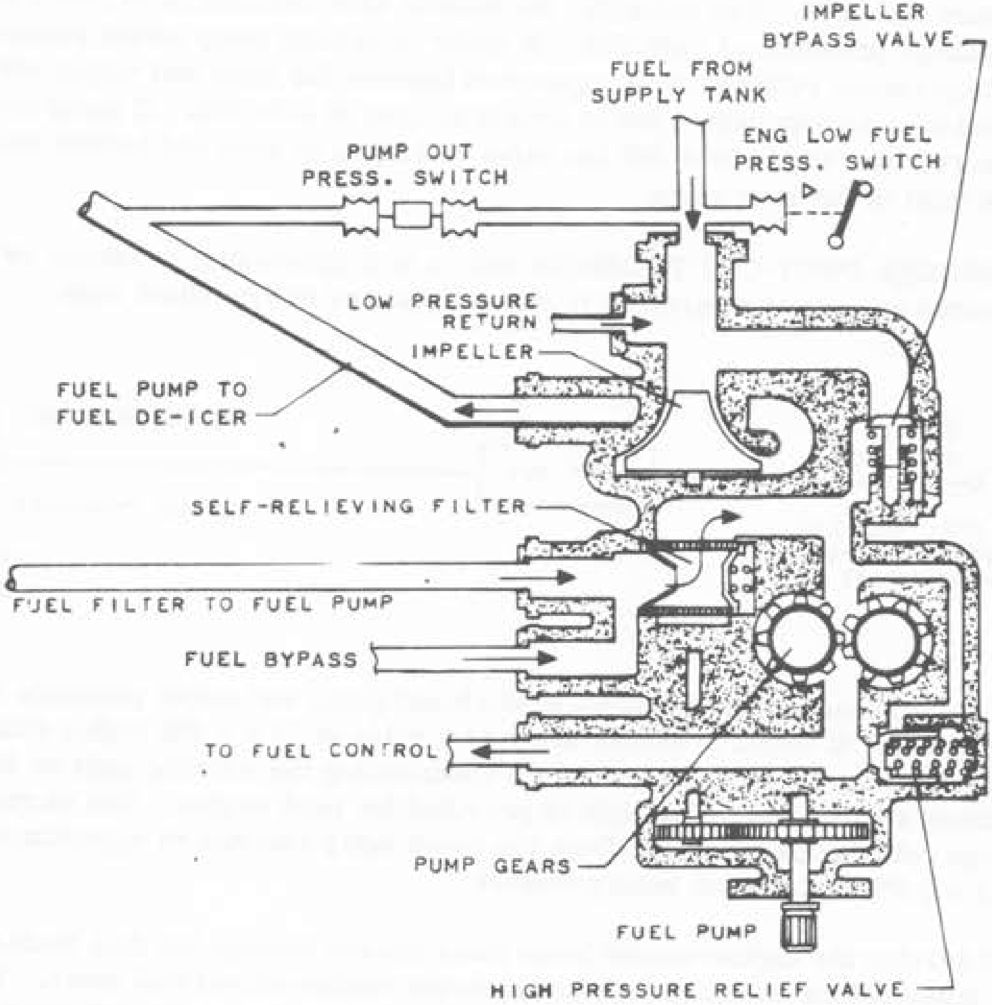


FUEL PRESSURE WARNING

FUEL PUMP.

The fuel pump is a dual-element unit mounted on the forward left hand side of the main accessory drive gearbox. The pump is driven at a ratio of 0.708 to 1 of N2 Compressor RPM. The pump assembly includes a centrifugal impeller pumping element; a bypass valve; a 40-mesh, 10-micron, self-relieving filter; a positive displacement gear type pumping element; and a high-pressure relief valve.

The two elements in the pump are driven by a common shaft. The centrifugal impeller acts as a boost pump for the high pressure element. The bypass valve between the two pumps allows fuel flow to the high pressure element if the boost stage fails. The bypass valve is spring-loaded to the closed position, and, if



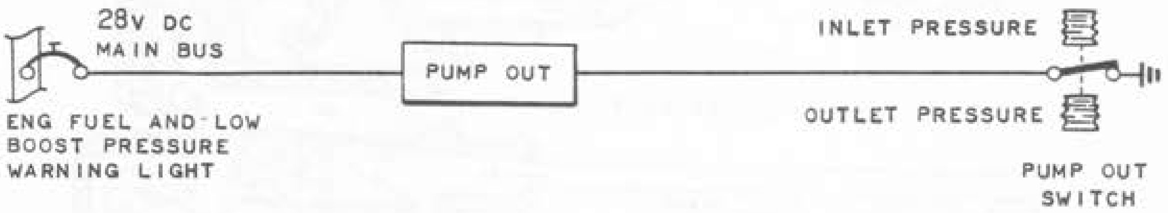
ENGINE FUEL PUMP

input pressure to the impeller rises approximately 5 PSI above the output of the impeller boost pump, the bypass valve will open porting fuel to the high pressure pump.

Fuel from the impeller boost pump flows through external lines to the fuel heater and fuel filter and then on into the the high-pressure stage of the pump. At the inlet to the high pressure pump is a self-relieving filter. The filter assembly is actually a filter within a filter. The larger outer filter is a 40-mesh type which houses a 10-micron inner filter element. If the filter element should become clogged and a differential pressure of approximately 60 PSID builds up, the relief valve opens allowing fuelflow to continue on to the gear type pump.

The gear-type pump is designed to deliver a flow capacity regardless of the pressure demands. For example, the normal flow capacity is 19,000 PPH at a discharge pressure of 1000 PSI. In order to relieve pump output pressure, a high-pressure relief valve is connected between the input and output ports. The valve is spring-loaded and is preset to open at 1050 PSI. If pump output pressure rises above 1050 PSI the valve will begin to open and bypass fuel back to the inlet of the gear pump.

The ENGINE PUMP OUT PRESSURE switch is a differential pressure switch. It is located on a bracket mounted to the compressor intermediate case.



The switch senses inlet pressure to the boost pump and output pressure from the boost pump. If output pressure drops to a value of 10 ± 2 PSI higher than the input pressure the contacts will close illuminating the warning light on the flight engineer's fuel panel. One light is provided for each engine. The warning light will go out if output pressure from the boost pump reaches an approximate value of 15 ± 2 PSI higher than input pressure.

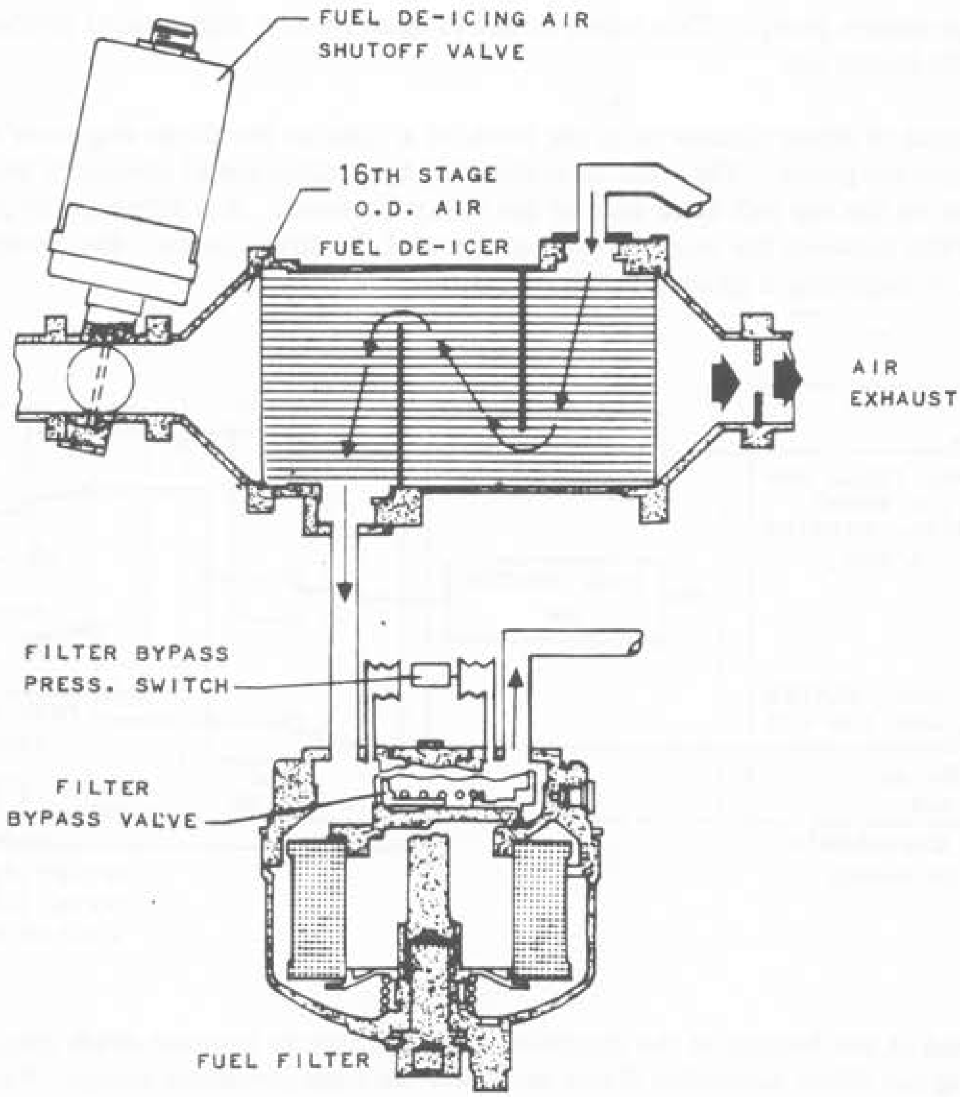
Fuel leaving the engine-driven boost pump passes through the fuel heater and fuel filter before entering the high-pressure engine-driven fuel pump. The fuel heater is a radiator type heat exchanger. It is mounted on the left-hand side of the N1 compressor rear case.

FUEL HEATER.

Fuel passing through the heater during engine operation is heated by engine bleed air when the hot air is circulated through the core of the radiator. Airflow through the heater is controlled by a motor-operated valve. When the valve is opened, hot bleed air from the Outside Diameter (O. D.) ports on the diffuser case is allowed to enter the heater core.

The control for the valve is a fuel heater switch, one for each engine, located on the flight engineer's fuel management panel. A light is also provided for indicating valve operation on each engine.

Fuel heat should be used when fuel temperature is below 0°C. Heat should also



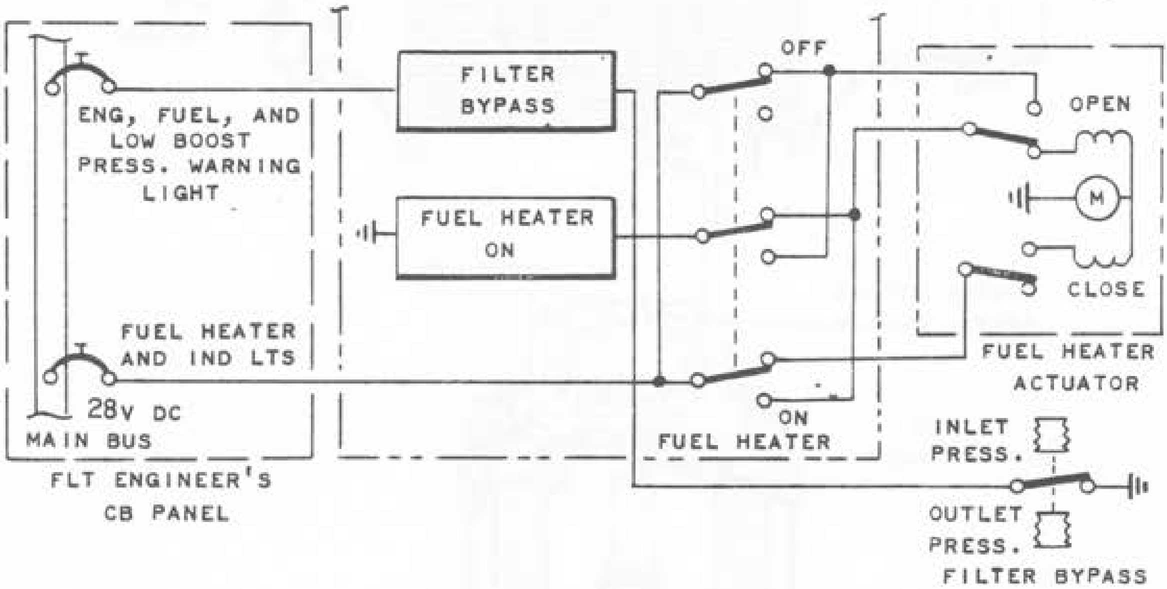
HEATER AND FILTER

be used anytime ice is suspected in the fuel or when a fuel filter bypass light illuminates.

FUEL FILTER.

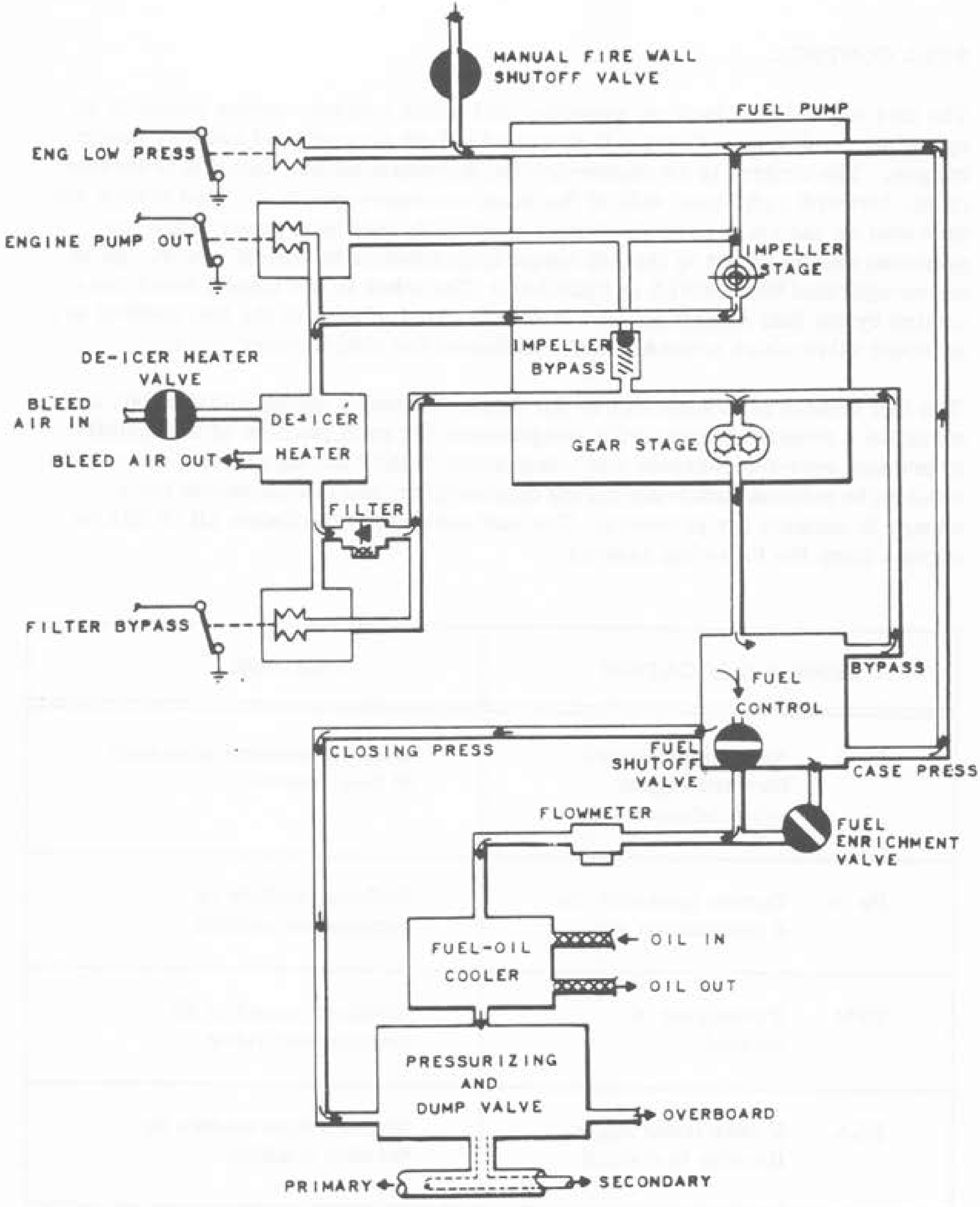
From the fuel heater, fuelflow is directly into the fuel filter. The filter is a 10-micron, disposable paper element, contained in a large canister mounted under the heater on the left side of the N1 compressor rear case. All the fuel will normally pass through the filter, except when the filter becomes clogged. If clogging occurs, a built-in bypass valve opens allowing fuel to flow on to the high-pressure pump. This valve is set to open when a differential pressure of 12 PSID builds up.

Indication of filter bypass is in the form of a light on the flight engineer's fuel management panel. The light is controlled by a differential pressure switch located on the top left hand side of the filter canister. If a differential pressure of 8 PSID between the inlet and outlet ports of the filter exists, the switch contacts close, completing a ground for the light.



Located at the bottom of the canister filter housing is a water drain plug. Fuel leaving the filter assembly flows back into the high-pressure pump. From the pump, an external line carries the fuel under the engine to the inlet of the fuel control.

Located on the fuel control at the inlet line from the fuel pump is a fuel shutoff valve. The shutoff valve is actuated by the fuel shutoff actuator motor, which controls fuelflow to the engine. The actuator motor is controlled by the FUEL AND START IGNITION switch. This switch is located on the pilot's overhead panel. There is one switch for each engine. Fuel flows into the metering section of the fuel control from the shutoff valve.



ENGINE FUEL SYSTEM SCHEMATIC

FUEL CONTROL.

The fuel control is a fuelflow metering unit which controls engine power in all operating conditions. Control is provided in both forward and reverse power ranges. The control is an engine-driven, hydromechanical unit. It is located on the forward right-hand side of the main accessory gearbox. Two levers are provided on each fuel control: One is a manually operated power lever for selecting engine thrust in the full range from reverse to takeoff power. (It is servo-operated when AWLS is installed.) The other is the shutoff lever controlled by the fuel shutoff actuator motor. Also included 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 control steady-state RPM; to maintain a constant turbine inlet temperature for each position of the throttle; to prevent over-temperature and compressor "stall" during starting and acceleration; to prevent flame-out during deceleration; and to reschedule for a change in ambient air pressure. The fuel control accomplishes all of this by signals from the following sensors:

SENSOR & LOCATION		PURPOSE
Pt 0	Ambient pressure forward engine pylon inboard side	Reflects ambient pressure at fuel control
Pb 4	Burner pressure No. 4 combustion can	Reflects airflow in combustion section
RPM	Flyweights in control	Monitors speed of N2 compressor rotor
PLA	Power lever angle throttle in cockpit	Power requirements by throttle position

For understanding operation, the fuel control may be considered as consisting of a fuel metering system and a computing system. The metering system regulates pump discharge fuel to provide the engine thrust output demanded by the pilot but is subject to engine operating limitations as sensed and scheduled by the computing system. The computing system senses and combines various operational conditions to govern the output of the metering system during all ranges of engine operation.

METERING SYSTEM. The fuel control's primary metering system consists of the following components:

- Fuel Filter
- Pressure Regulating Valve
- Throttle Valve
- Minimum Pressure and Shutoff Valve

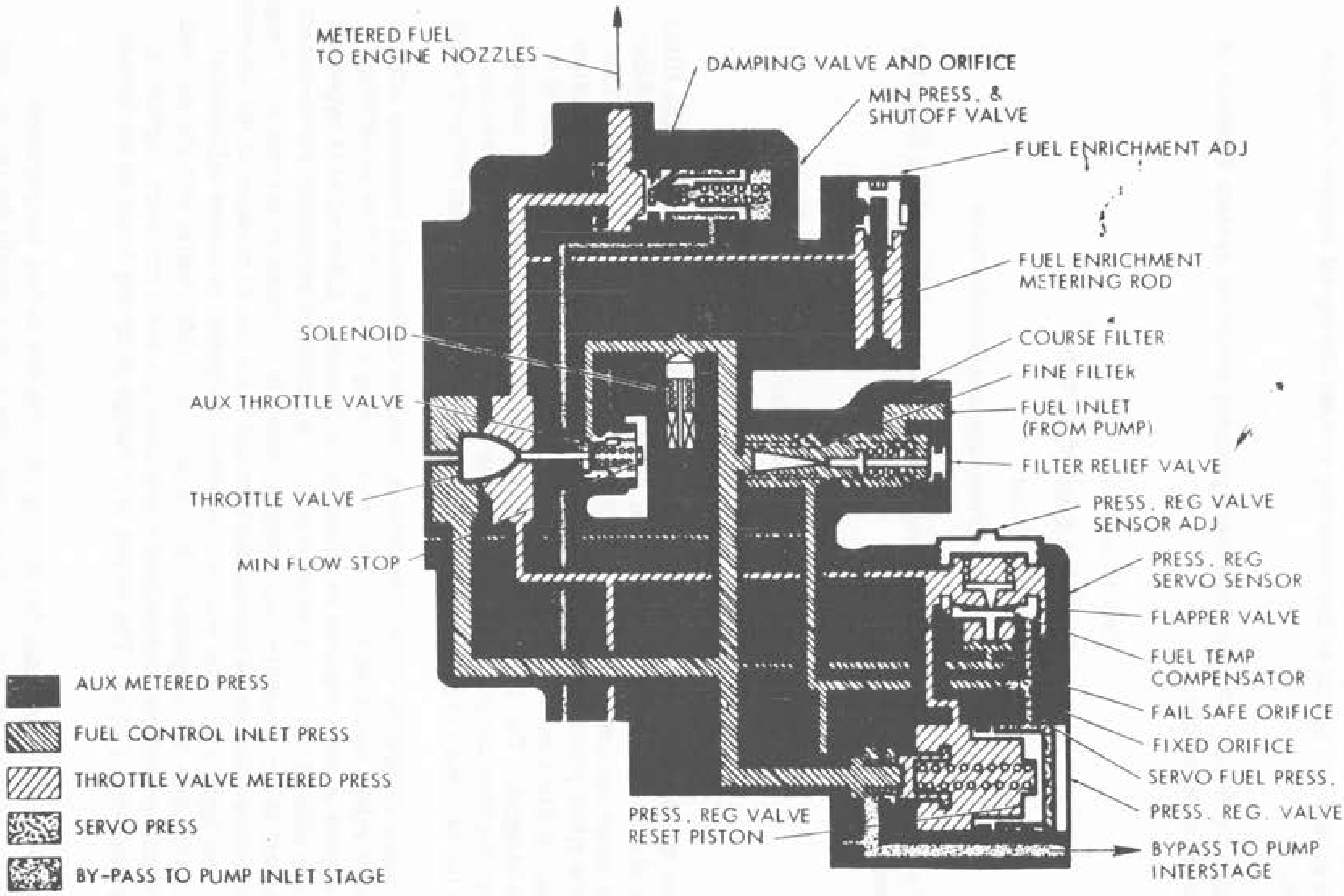
The fuel control secondary or fuel enrichment system consists of the following components:

- Solenoid Valve
- Auxiliary Throttle Valve
- Fuel Enrichment Metering Valve

Fuel from the pump enters the fuel control at a dual-filter assembly. The filter consists of a 80-mesh screen and a fine, 40-micron filter. The 80-mesh filter prevents large contaminants from passing through the metering system. The 40-micron filter prevents the computing system from being clogged by smaller particles. A filter relief valve allows fuel to bypass the 80-mesh screen if it becomes clogged. The 40-micron filter is a self-cleaning type. It is constantly washed by fuelflow across it. The main flow of fuel goes out of the 40-micron filter to the pressure regulating valve, throttle valve, and fuel enrichment valve.

The pressure regulating valve maintains a constant differential pressure across the throttle valve, assuring accurate fuel metering during all flow conditions. Fuel in excess of that required to maintain the pressure differential is bypassed back to the inlet of the high-pressure pump. A pressure regulating servo-sensor, which is part of the pressure regulating system, is provided to prevent any change in the pressure differential across the throttle valve due to changes in the amounts of fuel being bypassed. The sensor measures the actual pressure differential across the throttle valve opening. It compares this differential with the desired pressure differential and hydraulically positions the main pressure regulating valve spring reset piston. The result is a change in spring force on the bypass valve.

The sensor also compensates for density changes due to fuel temperature variations. As fuel temperature increases, the volume weight decreases, and



FUEL CONTROL - METERING SYSTEM

the sensor resets the pressure regulating valve spring reset piston to decrease the fuel being bypassed. This action results in a greater pressure drop across the throttle valve, thus allowing increased flow of metered fuel.

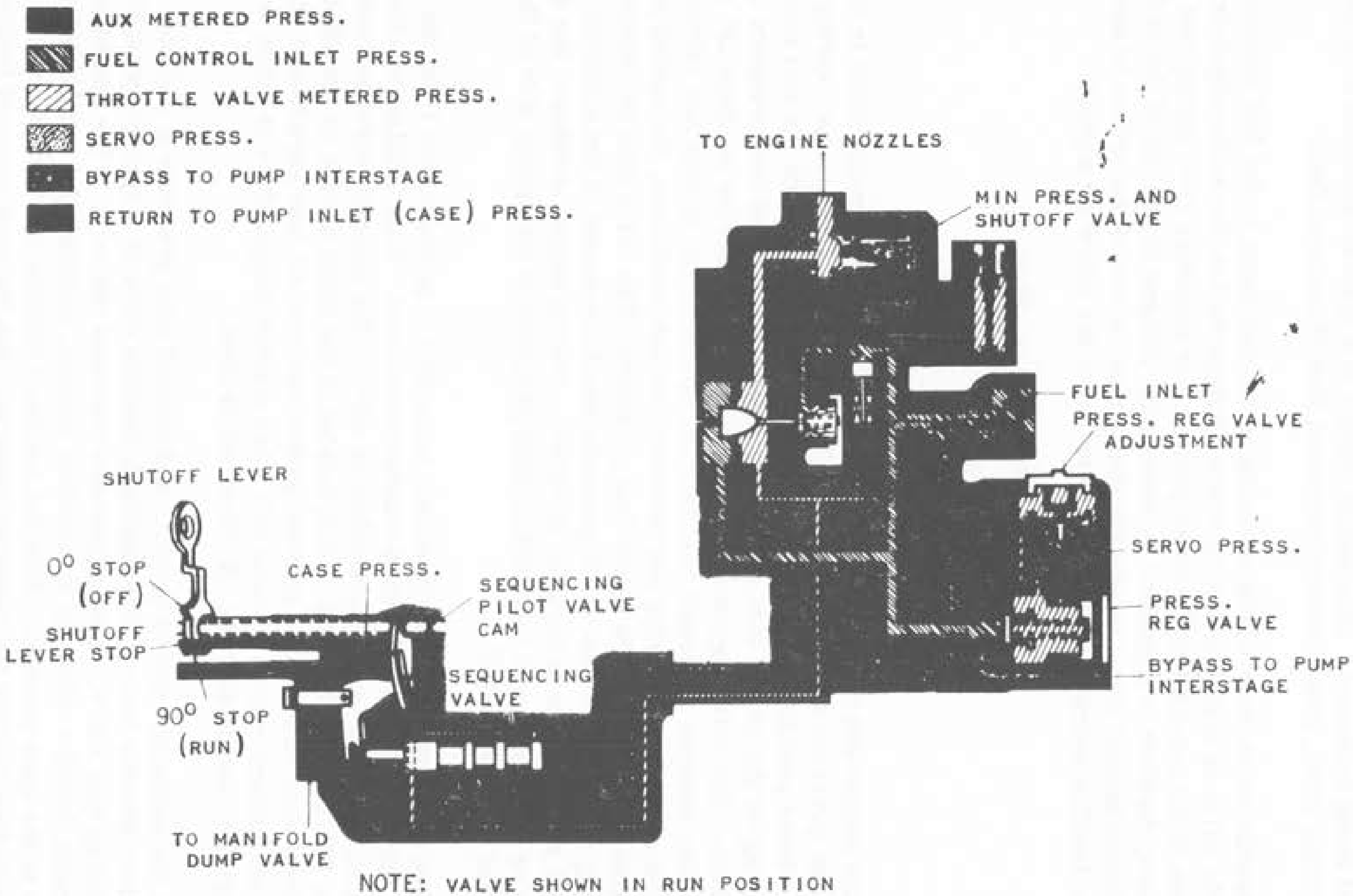
The throttle valve does all the metering of the fuel going to the fuel nozzles. Throttle valve is made up of a contoured plunger within the knife-edged orifice. Because of the constant differential pressure or pressure drop maintained across the valve, fuelflow is regulated by moving the plunger in and out of the orifice. A hydromechanical servo moves the plunger in and out of the orifice to assure proper fuelflow according to the combination of the following signals:

- Ambient Pressure - Pt 0
- Burner pressure - Pb 4
- Throttle setting - PLA

The last component in the flow of metered fuel from the throttle valve is the minimum pressure and shutoff valve. The valve is a plunger type, spring-loaded to the closed position. It maintains minimum pressure inside the fuel control by the spring on the closed side of the valve opposing metered fuel pressure on the open side. The valve begins to open when metered pressure reaches 130 to 150 PSI. This assures sufficient pressure for operating the servos and valves at low flow conditions. During low metered fuelflow conditions, the spring positions the valve proportionally to meter fuel pressure. The valve also incorporates a damping valve and orifice which prevents rapid movement of the minimum pres-ure and shutoff valve in the open direction. During engine shutdown, the sequencing valve will port fuel control inlet pressure to the spring side of the valve, ensuring position shutoff.

The fuel enrichment is used to supply extra fuel to primary flow from the throttle valve during starting under cold weather conditions. This fuelflow is added by energizing the fuel enrichment solenoid valve. The solenoid valve is controlled by the FUEL ENRICHMENT switch located in the flight station on the pilot's overhead start panel. One guarded switch controls all four enrichment valves. Fuel enrichment should be used only when outside temperature is below freezing or anytime, during starting, if JP-5 fuel is used.

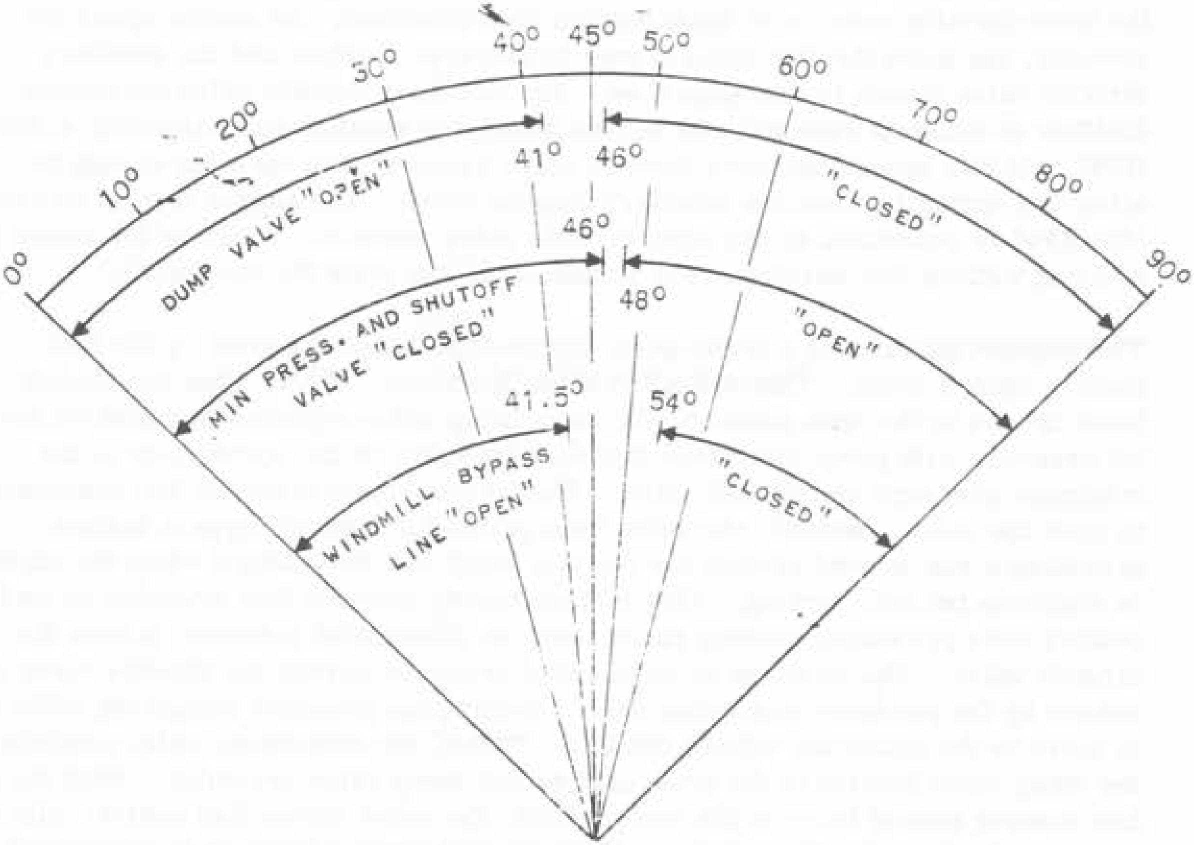
When the solenoid valve is opened, fuel control inlet pressure is directed to the auxiliary throttle valve. The auxiliary throttle valve is a spring-operated regulating type valve. Spring pressure positions the valve to the closed position. The main throttle valve, by mechanical linkage, positions the auxiliary throttle valve to the open position. With the auxiliary throttle valve in the open position, fuel will flow through the metering valve and into the main metered fuelflow passage between the throttle valve and the minimum pressure and shutoff valve.



FUEL CONTROL - SEQUENCING VALVE OPERATION

The metering valve consists of an orifice and a metering rod. The metering rod is adjusted to meter extra fuel required for starting the engine during cold-weather conditions. The metering valve meters fuel when the auxiliary throttle valve is full open. This condition occurs at the beginning of the start cycle when the main throttle valve is in the minimum flow condition. As engine speed increases, the main throttle valve moves to increase fuelflow and the auxiliary throttle valve moves to decrease flow. The auxiliary throttle valve decreases fuelflow at constant rate until the engine speed has reached approximately 4,000 RPM. At this speed, the main throttle valve has moved to open far enough to allow the spring to close the auxiliary throttle valve. The engine accelerates to idle RPM as scheduled by the main throttle valve position. Fuelflow for engine starting without fuel enrichment is scheduled by the main throttle valve.

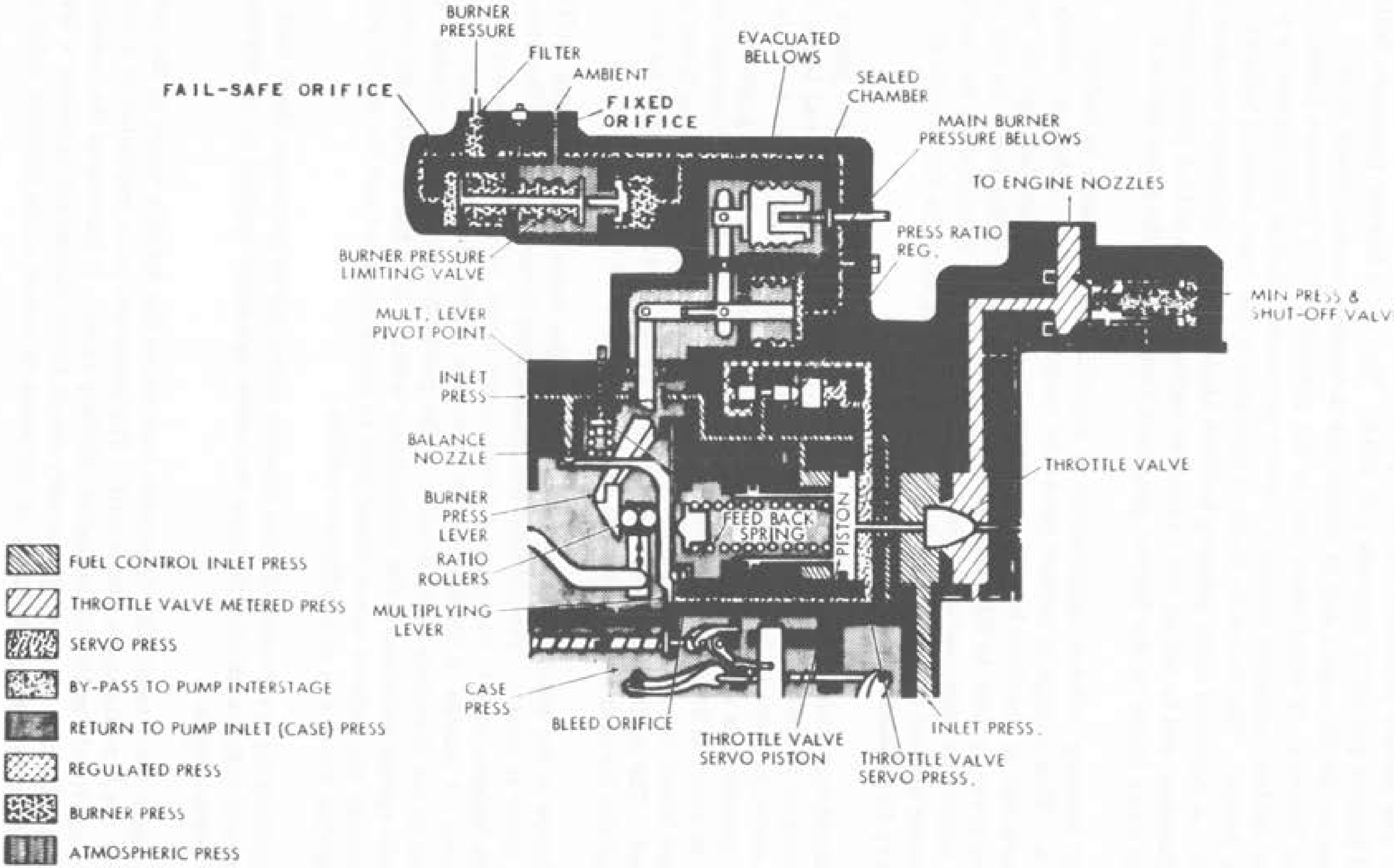
The sequencing valve is a multi-port, piston-type valve operated by the fuel control shutoff lever. This valve has three functions: First, when the shutoff lever moves to the open position, the sequencing valve replaces fuel control inlet pressure with pump interstage (bypass) pressure on the spring side of the minimum pressure and shutoff valve. This action allows metered fuel pressure to open the valve. Second, the valve incorporates a windmill bypass feature, providing a run-around system for the fuel pump and fuel control when the engine is shutdown but still turning. This feature bleeds metered fuel pressure to fuel control case pressure, causing an increase in differential pressure across the throttle valve. The increase in differential pressure across the throttle valve is sensed by the pressure regulating valve, causing the pressure regulating valve to move to the maximum bypass position. Third, the sequencing valve controls the dump valve located in the pressurizing and dump valve assembly. With the fuel control shutoff lever in the run position, the valve allows fuel control inlet pressure to close the dump valve. When the fuel control lever is in the shutoff position, the sequencing valve ports the dump valve pressure to the fuel control case pressure, allowing the dump valve to open. The fuel control shutoff lever has a 90-degree travel from the stop or shutoff position to the run or open position. The fuel control shutoff lever positions the sequencing valve functions at the following degrees of travel:



SEQUENCE VALVE FUNCTIONS IN DEGREES OF SHUTOFF LEVER TRAVEL

THE COMPUTING SYSTEM. The computing system of the fuel control receives signals from the ambient pressure probe (Pt 0), burner pressure probe (Pb), speed governor (RPM), and throttle position (PLA- power lever angle) and resolves these signals into one resultant throttle valve position. This assures a correct ratio of fuelflow to burner pressure.

Burner pressure indicates the actual pressure of the air passing through the engine. A steel tube routes combustion chamber pressure (Pb) from the No. 4 combustion can directly into the fuel control. The burner pressure signal enters the fuel control and is internally parted to the main burner pressure bellows and the burner pressure limiter assembly. The main burner pressure bellows, which is a metallic pressure sensing bellows, maintains a force on the burner pressure lever, proportional to absolute pressure in the engine combustion



FUEL CONTROL - BURNER PRESSURE SENSOR

section. The burner pressure limiter operates to vent the Pb signal to atmosphere if burner pressure exceeds 255 PSIA. The main burner pressure bellows is exposed to the Pb signal and is connected through a pivoted lever to an evacuated bellows, of equal size, and to the pivoted burner pressure lever. The evacuated bellows assures absolute burner pressure sensing and serves as a fail-safe device. The fail-safe feature operates if the main sensing bellows ruptures. A ruptured main sensing bellows allows burner pressure to enter the sealed chamber and to act on the evacuated bellows. This action gives essentially the same force on the burner pressure lever as did the main bellows.

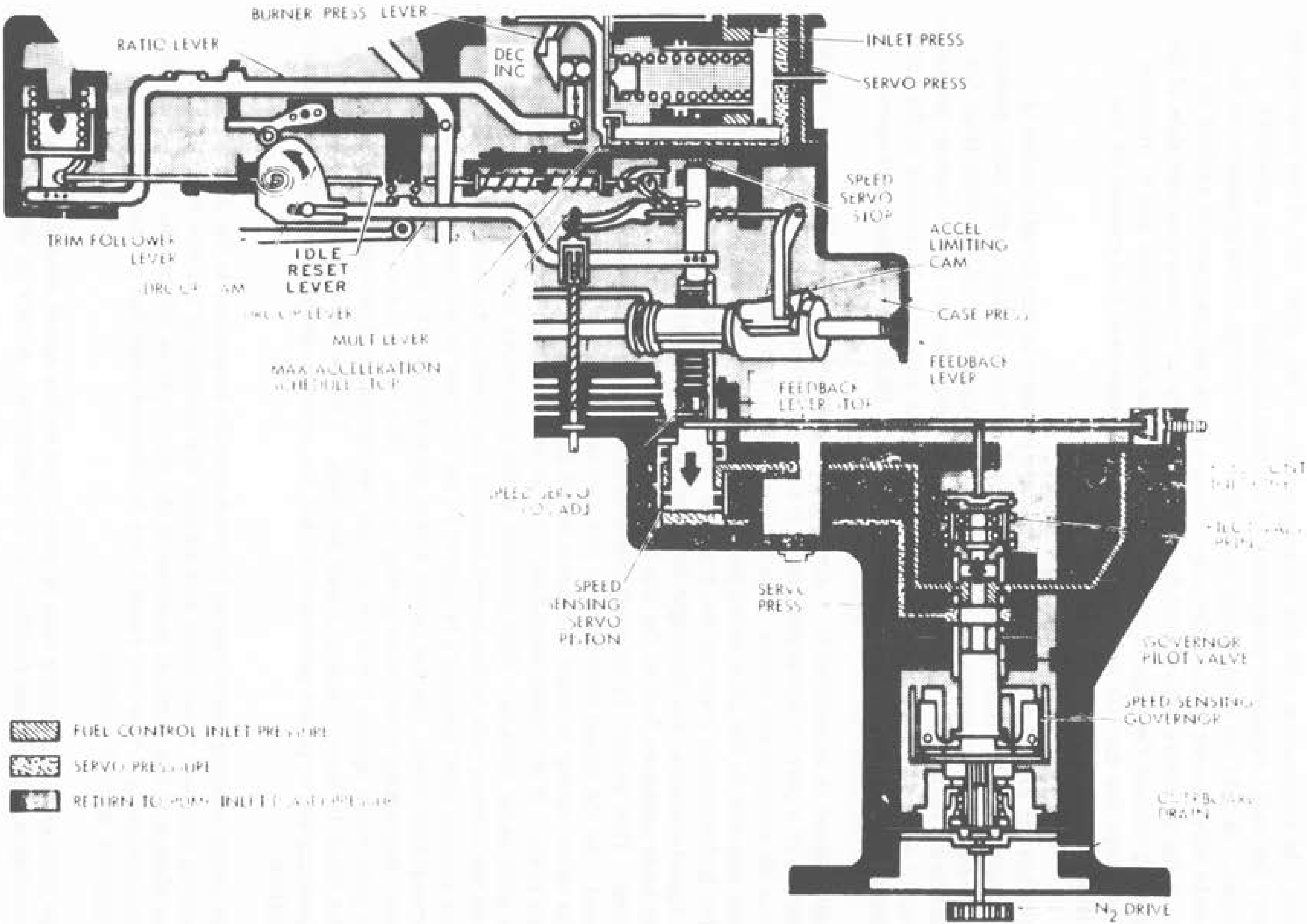
The main sensing bellows compresses or expands with a change in burner pressure. This change in burner pressure causes a net force change, which is proportional to absolute burner pressure, to be transmitted through the burner pressure lever system to the ratio rollers. Any change in the force on the ratio rollers causes an unbalancing of the multiplying lever. Unbalancing the multiplying lever causes the throttle valve servo piston to move in the direction necessary to rebalance the multiplying lever.

The multiplying lever controls the position of the throttle valve servo piston by increasing or decreasing the servo pressure bleed rate. The normal bleed rate allows servo pressure, acting on the large side of the servo piston, to be reduced, resulting in a force equal to the force exerted by fuel inlet pressure which, in turn, is acting on the other side of the piston. When the normal servo pressure bleed rate is established, the forces across the multiplying lever are balanced. The multiplying lever is balanced by the ratio roller force on the left side and the throttle servo feedback spring on the right side.

If the force of the ratio rollers should change, the force balance of the multiplying lever is upset. This causes the multiplying lever to move in the direction of force balance upset, causing a change in the bleed rate of throttle servo pressure. A change in throttle servo pressure allows the throttle servo piston to move in the direction of less force. The piston moves until the throttle servo feedback spring rebalances the multiplying lever. With the multiplying lever rebalanced, the normal servo bleed rate is re-established and the servo piston and throttle valve are at a different setting.

The multiplying lever controls the throttle valve servo pressure bleed rate, but a pressure ratio regulator controls the servo pressure applied to the throttle valve servo piston.

A pressure ratio regulator is located just above the throttle valve in the pressure line for the throttle valve servo unit. The pressure ratio regulator is a hydraulically operated, normally balanced, sliding valve. It increases the sensitibity of the multiplying lever so that a very small lever movement provides a large servo pressure change, causing an increase in travel of the throttle valve servo



FUEL CONTROL - SPEED SENSOR

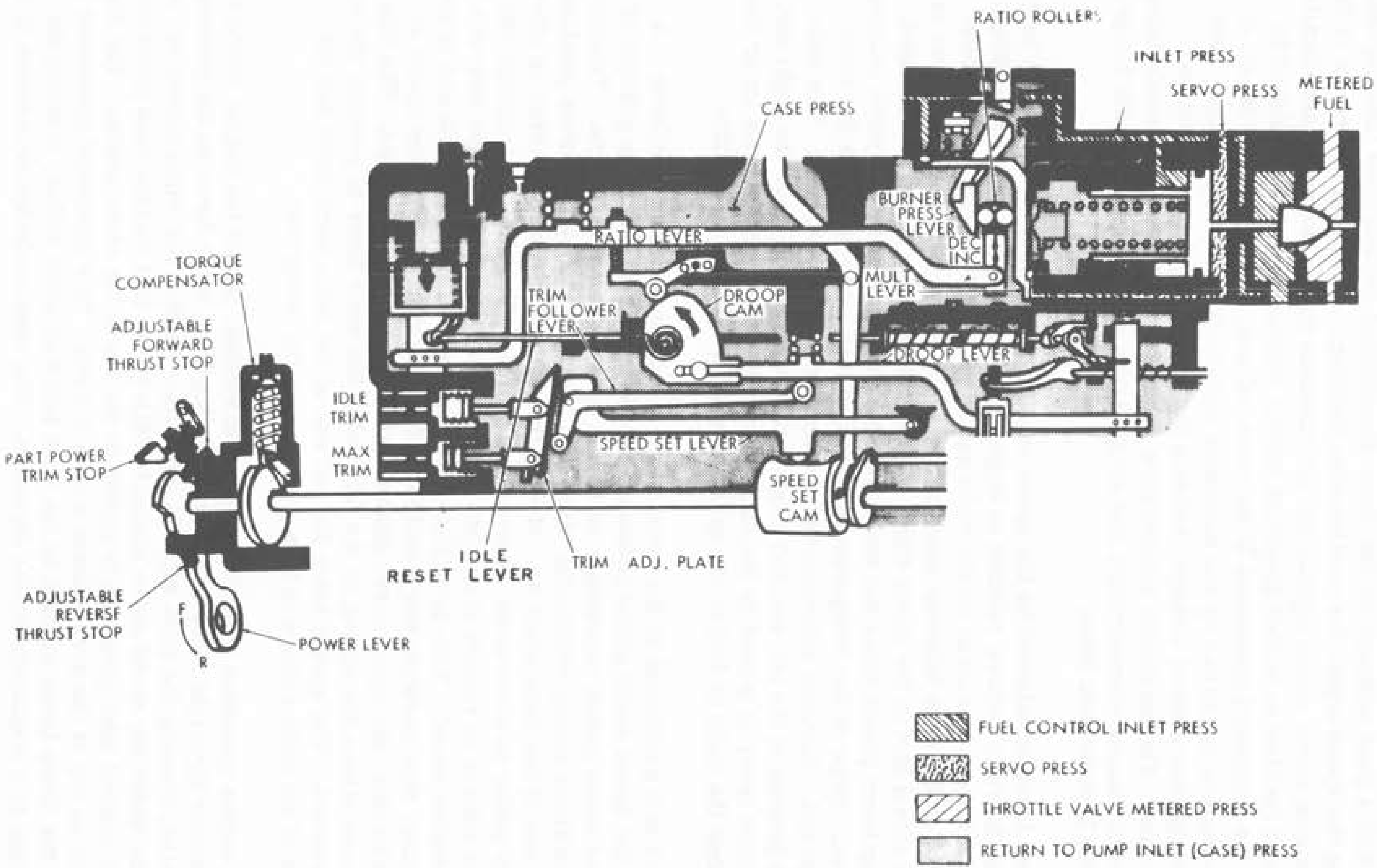
piston. In conjunction with the balance nozzle on the upper end of the multiplying lever, the ratio regulator compensates for control inlet and case pressure changes. Should the multiplying lever move and change servo pressure on the throttle valve servo piston, the same change in servo pressure is applied to one side of the pressure ratio regulator. This change in pressure on one side of the regulator causes the regulator sliding valve to be repositioned and to increase or decrease the throttle valve servo pressure more than that caused by the multiplying lever alone.

In the burner pressure sensing system, the position of the throttle valve is determined by the force of the burner pressure lever acting on the ratio rollers. As the ratio rollers move vertically, they are closer or farther away from the multiplying lever pivot point. Thus, the net force exerted by the burner pressure lever is varied by the actual position of the ratio rollers. Movement of the ratio rollers is controlled by a combination of RPM, PLA, and ambient pressure.

Engine speed is monitored by a speed-sensing governor unit. The unit assembly consists of a pair of flyweights and a spring-loaded pilot valve. The flyweights sense N2 compressor speed. During operation, flyweight speed generates a force opposite to the pilot valve spring force. The speed sensing governor pilot valve hydraulically controls the position of a speed sensing servo piston. When N2 speed changes, the flyweight force varies and the pilot valve is positioned to port high-pressure fuel to the top or to the top and bottom of the speed servo piston. This results in an exact position of the speed servo piston for every N2 speed. As the speed servo piston position changes, it changes the force of the pilot valve spring to equal the force of the flyweights through a mechanical feed-back lever. If N2 speed increases, the increased speed of the flyweights moves the pilot valve upward. This position of the pilot valve then allows servo pressure from the bottom side of the speed sensing servo piston to relieve to case pressure. Fuel control inlet pressure is ported to the top side of the piston, moving the servo piston down. As the servo piston moves down, the feedback lever moves down, increasing pilot valve spring force. The servo piston moves down until the pilot valve spring force overcomes the increased flyweight force and the pilot valve is moved back to a null position. The null position of the pilot valve maintains servo piston pressure so that the speed sensing servo stays in the new position.

The speed sensing servo piston is mechanically connected to the acceleration limiting cam and droop lever and adjusts the position of the idle reset lever. Any change in the vertical position of the servo piston affects the first two units simultaneously. The idle reset lever is affected when the piston reaches its maximum upward position.

The acceleration limiting cam is positioned by the speed sensing servo. The cam establishes a maximum fuelflow for acceleration. A rack on the servo piston



FUEL CONTROL - POWER LEVER SENSOR

meshes with a gear segment on the three-dimensional acceleration limiting cam. providing the speed signal for acceleration limiting. A vertical movement of the speed sensing servo piston rotates the acceleration cam. Maximum acceleration schedule of fuelflow to burner pressure versus engine speed is established by limiting the downward movement of the ratio rollers. The downward travel of the ratio rollers is limited by the maximum acceleration schedule stop. This stop, through mechanical linkage, reflects the contour of the acceleration limiting cam. The maximum acceleration schedule permits engine accelerations which avoid the over-temperature and surge limits of the engine without compromising the acceleration time.

The droop lever is actuated by the speed sensing servo piston. The droop lever positions the ratio rollers relative to engine speed through mechanical linkage. The droop lever is attached on the right end to the speed sensing servo piston and pivots on the trim follower lever roller. The left end of the droop lever is inserted into a slot in the droop cam. As the speed servo piston moves down, the droop lever pivots about the roller, causing the droop cam to rotate counterclockwise. Slope of the droop cam is such that this rotation moves the ratio lever upward. Reverse action occurs as the piston moves upward. The ratio lever is pivoted at the left end and coupled to the ratio rollers on the right end. As the ratio lever is moved by the droop cam, the ratio rollers move up or down and change the ratio of fuel to air by increasing or decreasing fuelflow.

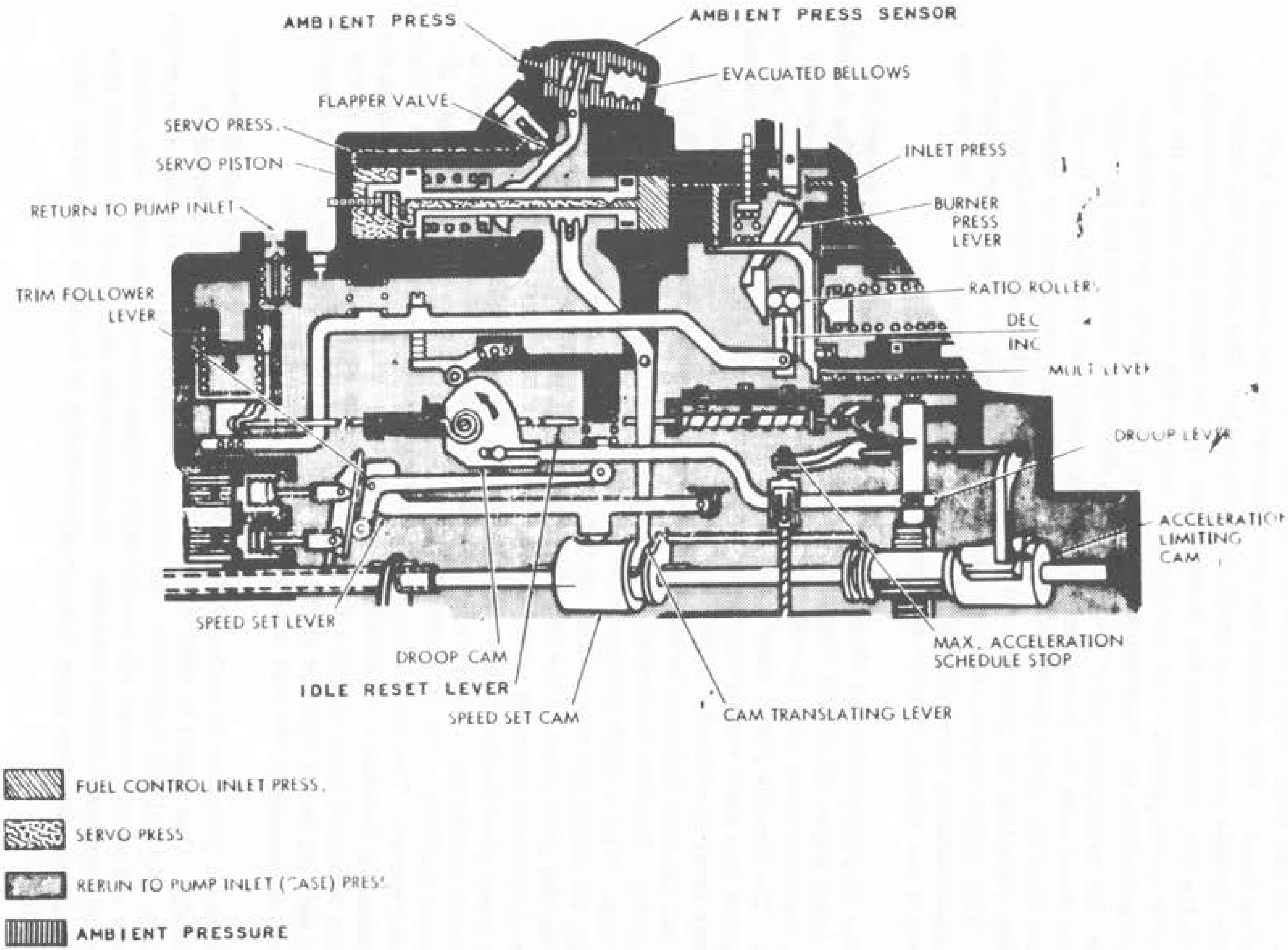
The third unit positioned by the speed servo piston is the idle reset lever. A cam on the speed servo piston rotates the backlash spring when the position of the speed servo piston represents an engine speed below idle to zero. Tension of the backlash spring rotates the idle reset lever. Rotating this lever positions the left end of the ratio lever up. Moving the left end of the ratio lever up allows the ratio roller to move down, increasing fuelflow. The idle reset linkage causes the ratio rollers to remain in contact with the maximum acceleration stop to a higher engine speed. This provision allows more fuelflow toward the end of the start cycle, thus reducing the possibility of a hung start. As engine speed increases to idle, the speed servo piston continues to move downward. The idle reset lever allows the spring on the left end of the ratio lever to position the left end downward. The spring holds the left end of the ratio lever down and the position of the ratio rollers is then governed by the droop cam.

During engine operation with a fixed throttle setting, should the engine overspeed, the governor flyweight force unbalances the feedback lever force on the governor pilot valve, causing the pilot valve to move up. As the pilot valve moves up, servo pressure under the speed servo piston is relieved to fuel control case pressure, and fuel control inlet pressure is ported to the top of the servo piston. The higher pressure on top of the servo piston moves it down. This downward movement causes the droop lever to pivot on the trim follower lever roller, rotating the droop cam in a counterclockwise direction. The counterclockwise rotation of the droop cam lifts the ratio lever and, in turn, causes the ratio rollers to move upward. As the ratio rollers move up, they move nearer to the pivot of the multiplying lever. This changes the force balance on the multiplying liver, giving the throttle servo spring force more leverage. The multiplying lever moves to the left, increasing the bleed orifice and decreasing servo pressure on the throttle servo piston. The servo piston and throttle valve moves to the right, decreasing fuelflow and feedback spring force. As feedback spring force decreases, the multiplying lever moves back to the right, decreasing the servo pressure bleed until the forces are rebalanced across the multiplying lever. At the same time the speed servo piston was moving down, the governor feedback lever was resetting the governor spring force to equal the increased flyweight force. This action repositioned the governor pilot valve to control the movement of the speed sensing servo piston movement, fuelflow was decreased and N2 was restored to the original steady-state speed.

When the throttle position is changed in the cockpit, the fuel control senses the power lever angle (PLA) and schedules the desired fuel to the engine. The throttle can be operated from idle, forward for forward thrust, or rearward for reverse thrust. The throttle signal enters the fuel control through the power lever, which is attached to a shaft supporting the speed set cam. The speed set cam is rotated by power lever movement. Rotation of the speed set cam moves the speed set lever and the trim follower lever, thus raising or lowering the pivot point of the troop lever. Throttle movement affects the position of the droop lever pivot point only. With a slight movement of the throttle toward an increased power setting, the speed set cam rotates so that the speed set cam follower drops, lowering the pivot point of the trim follower lever. This action allows the lower roller on the trim follower lever to roll down the trim adjust plate, causing the droop lever pivot roller to move down. Moving the droop lever down rotates the droop cam clockwise, causing a downward movement of the ratio rollers and an increased fuelflow. The increased fuelflow increases engine speed, thereby increasing thrust. The speed set cam is contoured to schedule an increase in fuelflow when the throttle is retarded beyond idle into reverse, the same as when the throttle is moved from idle to a forward thrust setting. The flat position of the speed set cam is the idle, or minimum power, setting. This flat portion allows throttle movement in the idle range without an increase in fuelflow.

Ambient air pressure is ported into the fuel control to a pressure-sensing servo assembly. This signal is used to reset fuelflow scheduling with changes in altitude. As altitude increases, the ambient pressure signal, through appropriate linkage and cams, causes the steady-state engine speed to increase and resets the maximum acceleration schedule. Because of the decreased air density this speed and acceleration reset feature is necessary to maintain the correct fuel-air ratio.

The pressure-sensing servo assembly consists of an evacuated bellows and a



FUEL CONTROL - AMBIENT PRESSURE SENSOR

spring-loaded piston exerting opposing forces on a pivoted lever. As pressure increases in the sensor chamber, the evacuated bellows contacts and the lever pivots in a clockwise direction. When altitude increases, pressure in the sensor chamber decreases causing the bellows to expand and pivot the lever in the counterclockwise direction. The lever performs two functions: First, it actuates a flapper valve, which controls servo pressure acting on one side of a servo piston. Second, it maintains spring tension on the servo piston, thus ensuring a proper force-balance across the servo piston. As ambient pressure increases, the lever movement closes the flapper valve, causing servo pressure to increase. As servo pressure increases, the servo piston moves to the right against fuel control inlet pressure. As the piston moves, the spring force on the lever increases, moving the lever back to the original position. This movement causes the flapper valve to open, allowing servo pressure to decrease. This decrease limits the servo piston movement proportionally to the changed ambient pressure.

A pivoted cam translating lever is attached to the ambient pressure servo piston. The lever transmits servo piston movement to the speed set cam and the acceleration limiting cam. If ambient pressure increases, the servo piston movement to the right causes the speed set cam and acceleration limiting cam to move to the left. This movement of the speed set cam repositions the speed set lever, trim follower lever, droop lever, and the droop cam. The movement of the droop cam moves the ratio lever and rollers upward, reducing the amount of fuelflow increase that the burner pressure sensor is scheduling. Simultaneously, the acceleration limiting cam is moved to the left causing the maximum acceler-stop to move up. The movement of this stop provides more movement of the ratio rollers at lower ambient pressures. This action is necessary to establish the same rates of fuelflow during acceleration at altitude. Function of this system is minor at sea level and low altitudes.

During engine operation, there is a continuous flow of fuel through the valves and orifices into the case of the fuel control. The case in connected into the inlet of the engine driven fuel pump through a pressure drain valve. The fuel control case contains fuel under all operating conditions. The drain pressure valve is normally open, but does maintain a case pressure slightly higher than pump inlet pressure.

Two adjustments are provided on the JFC25-18 fuel control. These are idle trim speed and maximum power trim speed. The adjustment screws change the effective droop cam position with respect to the speed set cam position. This is accomplished by the adjustments rotating the trim follower lever about the pivot point on the left end of the speed set lever. The effect of this inside the fuel control is the same as a slight throttle movement.

FUELFLOW TRANSMITTER.

A fuelflow transmitter, installed between the fuel control and the fuel-oil cooler, is located on the right-hand side of the compressor's intermediate case.

The system uses mass flow measurement to indicate fuel comsumption in pounds-per-hour. There is one fuelflow indicator unit on the pilot's center instrument panel and flight engineer's engine instrument panel. Each unit contains four, tape-type indicators, one for each engine. A complete discussion of the fuelflow transmitter and indicator system is included under engine indicating systems.

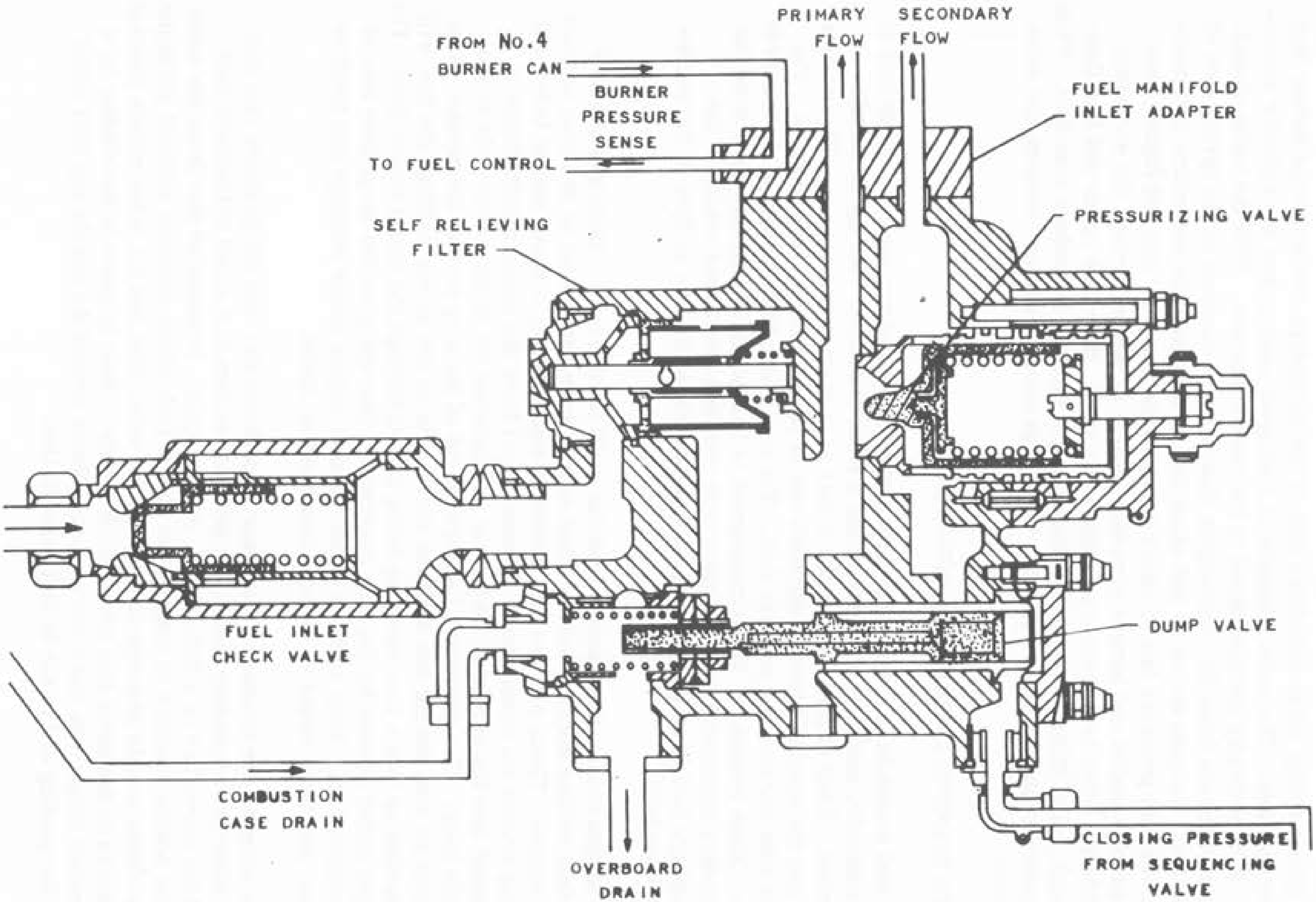
FUEL-OIL COOLER.

Fuel leaving the fuelflow transmitter is directed into the fuel-type oil cooler. The cooler is mounted on the right-hand side of the N2 compressor case, just above the compressor bleed valve. A discussion of the fuel-oil cooler is covered under the engine lubricating system.

FUEL PRESSURIZING AND DUMP VALVE.

Fuelflow leaving the fuel-oil cooler is directed down the right-hand side of the engine to the bottom of the diffuser case. The P&D valve is located on the diffuser case in the 6 o'clock position. The P&D valve assembly consists of a fuel inlet check valve, a self relieving filter, a manifold dump valve, and a pressurizing valve. The fuel inlet check valve in the inlet prot prevents fuel drainage from the fuel-oil cooler during engine static conditions. The valve is spring-loaded closed but requires an inlet pressure of 8 to 10 PSI to open. The 200-mesh fuel inlet screen filters all the fuel before its entry into the primary and secondary manifolds. If the filter should become clogged, a differential pressure buildup of 10 to 20 PSID opens the built-in relief valve, bypassing fuel directly into the primary and secondary manifolds.

The manifold dump valve is a two-sided, nylon-disk, poppet valve that is spring-loaded to the open position. The dump valve drains the primary fuel manifold during engine shutdown. Opposing the spring tension is a piston which receives pressure from the fuel control during engine starting and operating conditions. When the fuel and start ignition switch is placed in the "ON" position, the sequencing valve movement opens a port which directs fuel pressure from the engine-driven pump through the fuel control and to the piston side of the dump valve. The fuel pressure overrides the spring tension and the dump valve is closed. After the dump valve closes, the fuel pressure in the pressurizing and dump valve assembly aids in keeping the dump valve closed. When the engine is shutdown, the fuel pressure to the piston side of the dump valve is cutoff. Pressure in the primary manifold keeps the dump valve seated until the fuel pressure in the manifold decreases to a value below the minimum operating pressure.



ENGINE FUEL PRESSURIZING AND DUMP VALVE

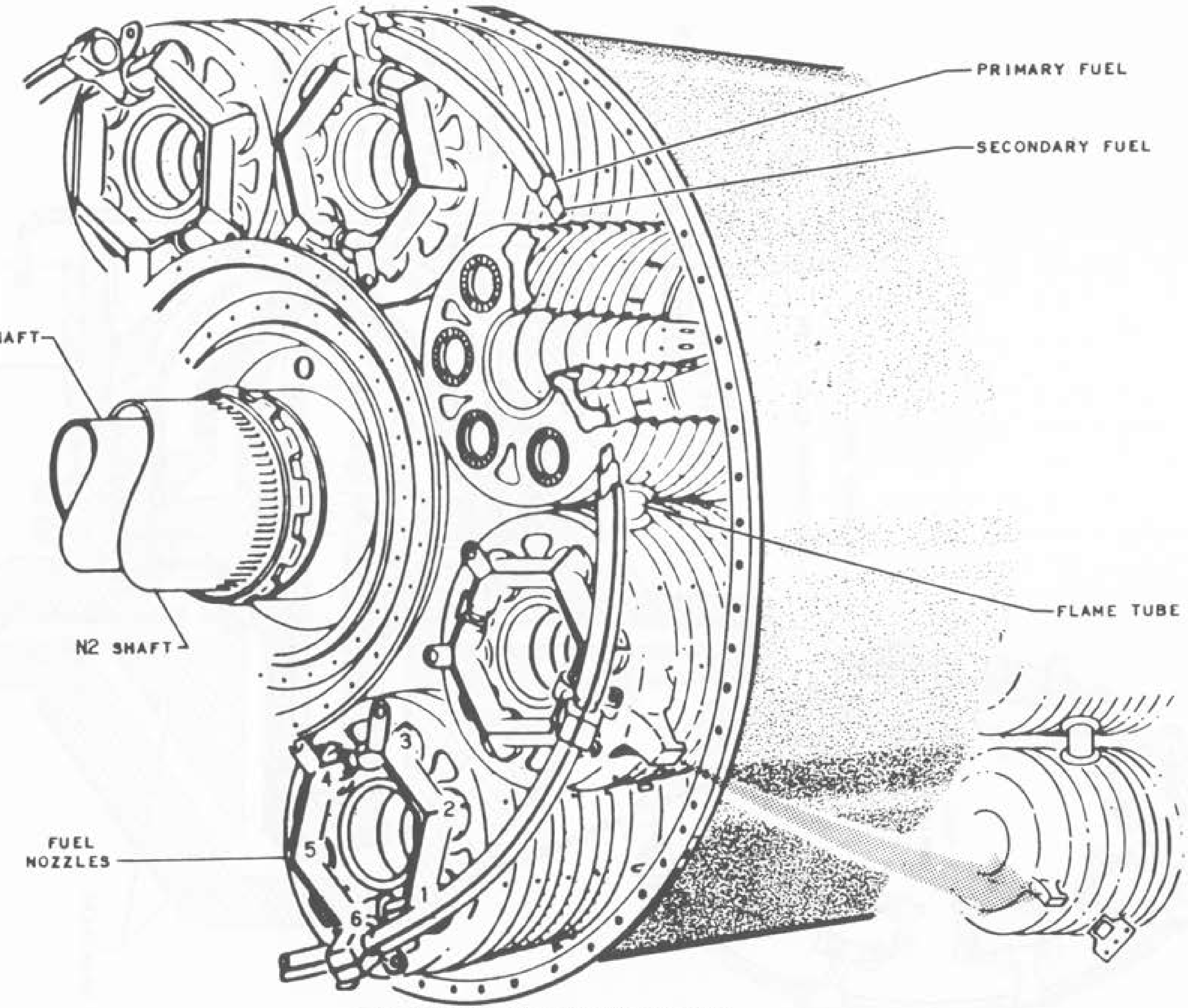
The pressurizing valve schedules fuel to the secondary fuel manifold during high power settings. The valve consists of a stepped-area piston and cylinder assembly. It is normally spring-loaded to the closed position. With the valve closed, burner pressure from the combustion chambers is directed to the spring side of the valve. To open the valve and allow fuel to flow into the secondary fuel manifold, the fuel pressure has to reach a point approximately 250 PSI higher than the spring tension and burner pressure, which is vented through the secondary manifold. When fuel pressure reaches this point, the valve opens and fuel flows through radial slots in the valve assembly and into the secondary manifold. When the power requirement is reduced, the fuel pressure reduces, causing the valve to close.

FUEL MANIFOLD AND FUEL NOZZLES.

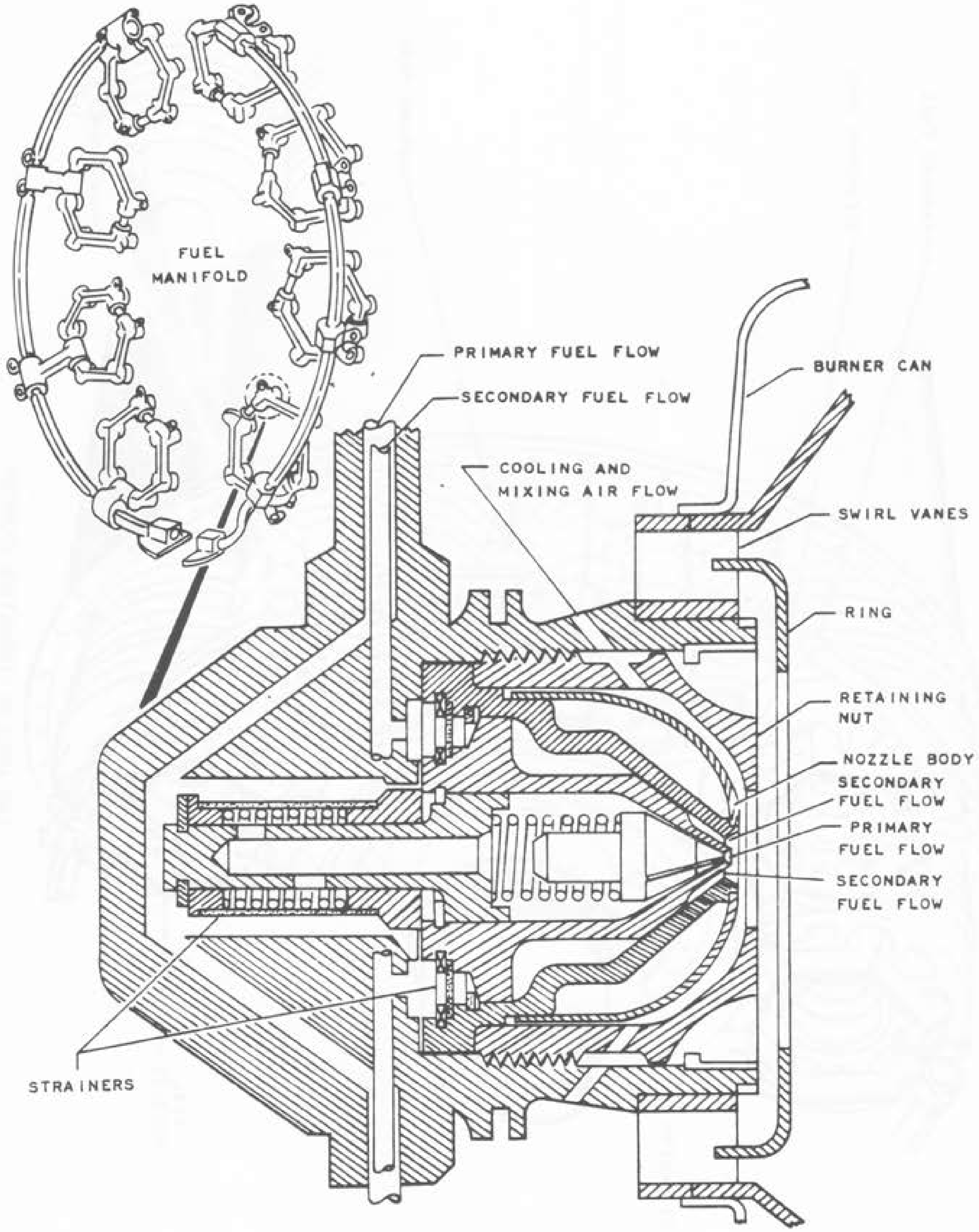
The fuel manifold is a split type with a right and left-hand section. Each half of the manifold, made up of a tube within a tube, leads into four spray nozzle clusters. Each nozzle cluster has a pair of concentric tubes in it. These tubes tap into the manifold tubes, and each one of the pair feeds three nozzles. The outer tube carries the primary fuel. The secondary fuel is carried in the inner tube. Main reason for this arrangement is that primary fuel flowing around the secondary manifold keeps the inner tube cool and eliminates coking of the secondary fuel when the engine is hot and there is little or no flow in the secondary manifold.

The engine combustion section includes eight burner cans. Each can contains six dual orifice spray nozzles. This means there are a total of 48 spray nozzles per engine. There are two fuel outlets in each nozzle, a small center hole, and a ring around the center hole. Primary fuel from the outer manifold tube is directed into the center of the nozzle and sprayed out of the center hole of the nozzle body. The secondary fuel sprays out of the ring around the center. This is done so that during low fuelflow during idle or low power settings the fuel will be broken up into a fine spray by being forced through the small center hole. The larger outlet formed by the ring generates a fine spray on the large flow rate of secondary fuel. Both orifices deliver fuel at higher power settings and fuelflow rates, and their output is blended into a single spray.

Two screens are mounted in the rear of each nozzle: one for primary fuel and the other for secondary fuel. The primary screen is a small cylindrical type, and the secondary is a flat, round, washer type. Transfer of fuel from the tubes in the nozzle clusters is done by the nozzle body which contains internal passages. The center nozzle passage connects to the outer tube and the outer nozzle passage connects to the inner fuel tube. Each nozzle is held in place in the cluster by a threaded nozzle cap and a tab washer. Holes around the nozzle cap wall admit air for cooling and to aid in fuel vaporization.



CAN ANNULAR COMBUSTION CHAMBER


FUEL
MANIFOLD
PRIMARY FUEL FLOW
SECONDARY FUEL FLOW
BURNER CAN
COOLING AND
MIXING AIR FLOW
SWIRL VANES
RING
RETAINING
NUT
NOZZLE BODY
SECONDARY
FUEL FLOW
PRIMARY
FUEL FLOW
SECONDARY
FUEL FLOW
STRAINERS

FUEL NOZZLE

COMPRESSOR BLEED SYSTEM.

Compressor stall can range from a mild form with no sound or motion to one that causes a very loud noise. Stalls may be recognized by compressor pulsations felt through the aircraft structure. Stalls also may sometimes only be known by the inability of the engine to accelerate properly or by the engine decelerating when the throttle has not been moved.

Compressor stall is the breakdown or interruption of airflow through the compressor. Many conditions can cause compressor stall. Engine malfunctions, faulty fuel controls, damaged components, and icing conditions are just a few of the conditions which might cause a stall.

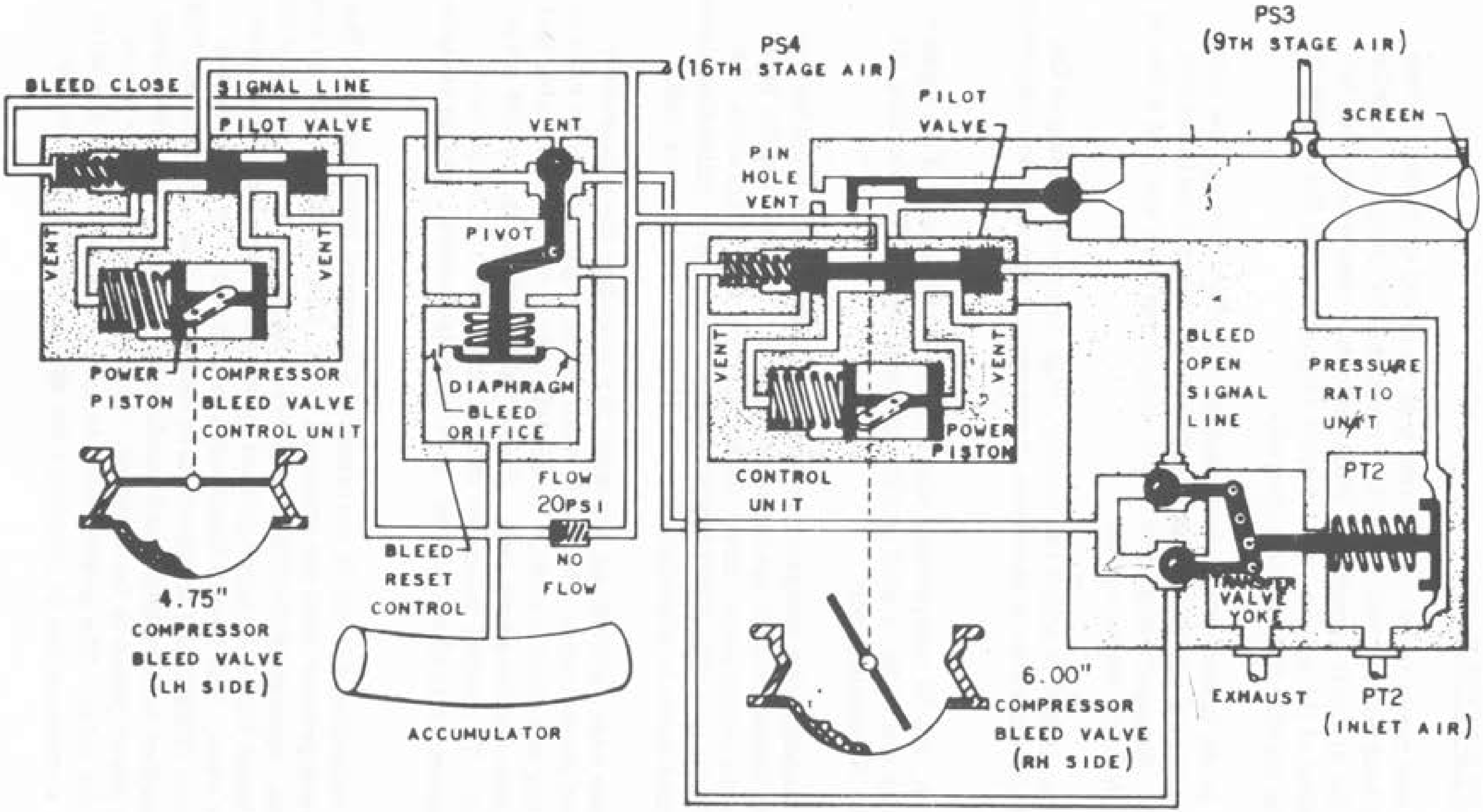
During acceleration, if fuel is added too rapidly, high-pressure buildup in the combustion chambers can cause a slowdown of air coming through the compressor and cause a stall.

During deceleration, the N2 compressor slows down first because of its lighter mass. If conditions are right, a stall can be produced by the N2, blocking the airflow through the N1 compressor.

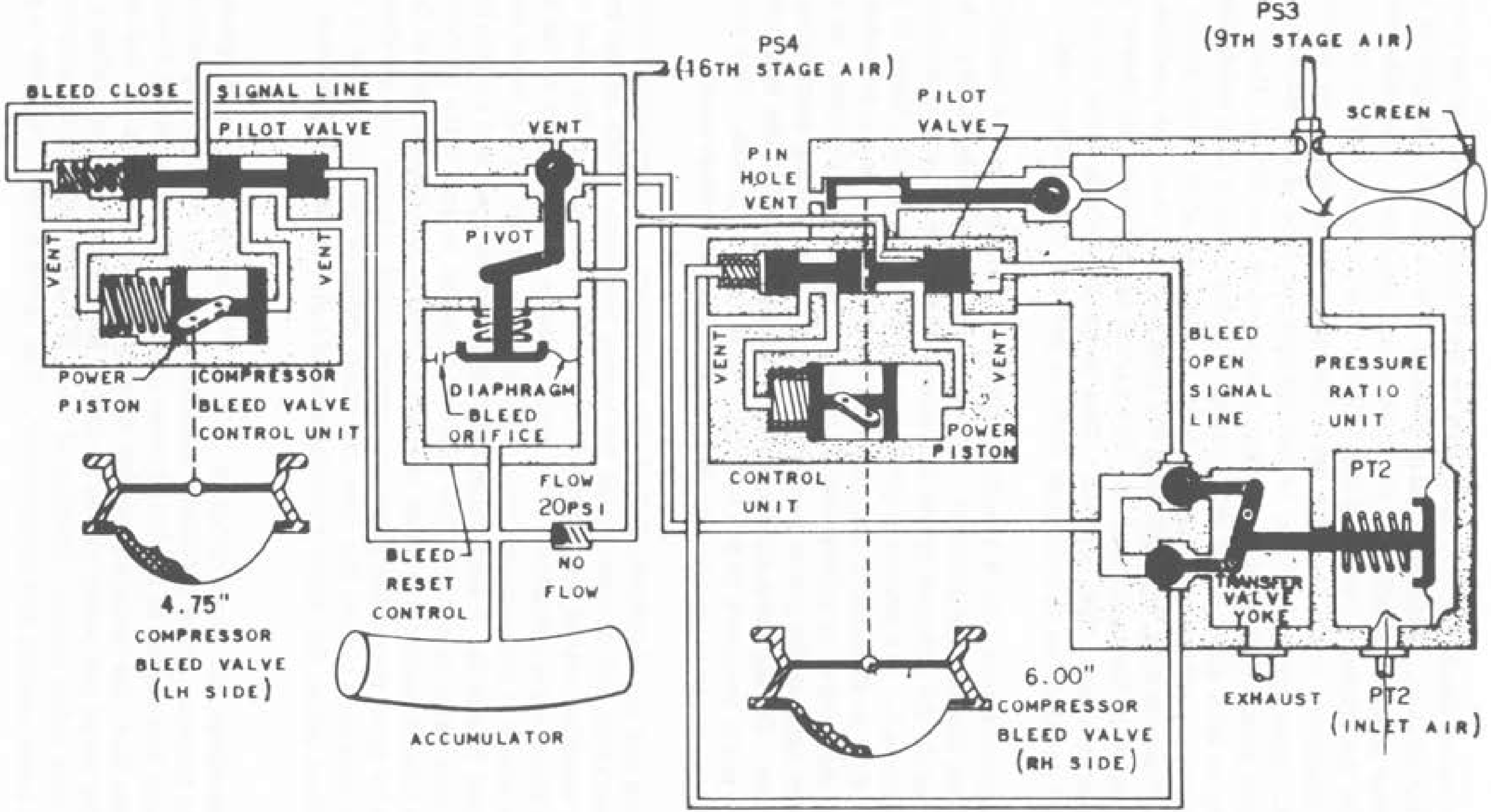
To minimize the tendency of a compressor stall, the compressor must be frequently "unloaded" during certain operating conditions. By reducing the pressure ratio across the compressor during engine starting or deceleration, the stall tendency is reduced. The JT3D (TF33) uses a compressor (unloading) bleed system as described below to eleminate the possibility of compressor stall.

On the intermediate case, provisions are made for unloading the compressor during starting and deceleration. A 6-inch valve on the right side of the case is used during starting and deceleration. On the left side is a 4.75-inch valve that operates during snap decelerations only. These valves unload the twelfth stage of the compressor. To control these two valves, there are two bleed valve actuators, a pressure ratio bleed control, a bleed reset control, and an accumulator.

The compressor unloading system is operated by a pressure ratio control. The ratio is between compressor inlet air pressure (Pt2), plus spring tension on one side of a diaphram, against ninth-stage compressor air (Ps3) on the opposite side. Actuation of the bleed valves is accomplished by sixteenth-stage air (Ps4) bled from the diffuser case. The 6-inch bleed valve is controlled by the pressure Ratio Bleed Control (PRBC) and its bleed valve actuator. The actuator and PRBC are connected together both by tubing and mechanical linkage. The valve itself if connected to a power piston in the actuator. Movement of the power piston opens or closes the valve. The power piston is spring-loaded to keep the valve open; therefore a pressure has to overcome the spring tension to close the



COMPRESSOR BLEED SYSTEM SCHEMATIC (STARTING AND LOW THRUST)

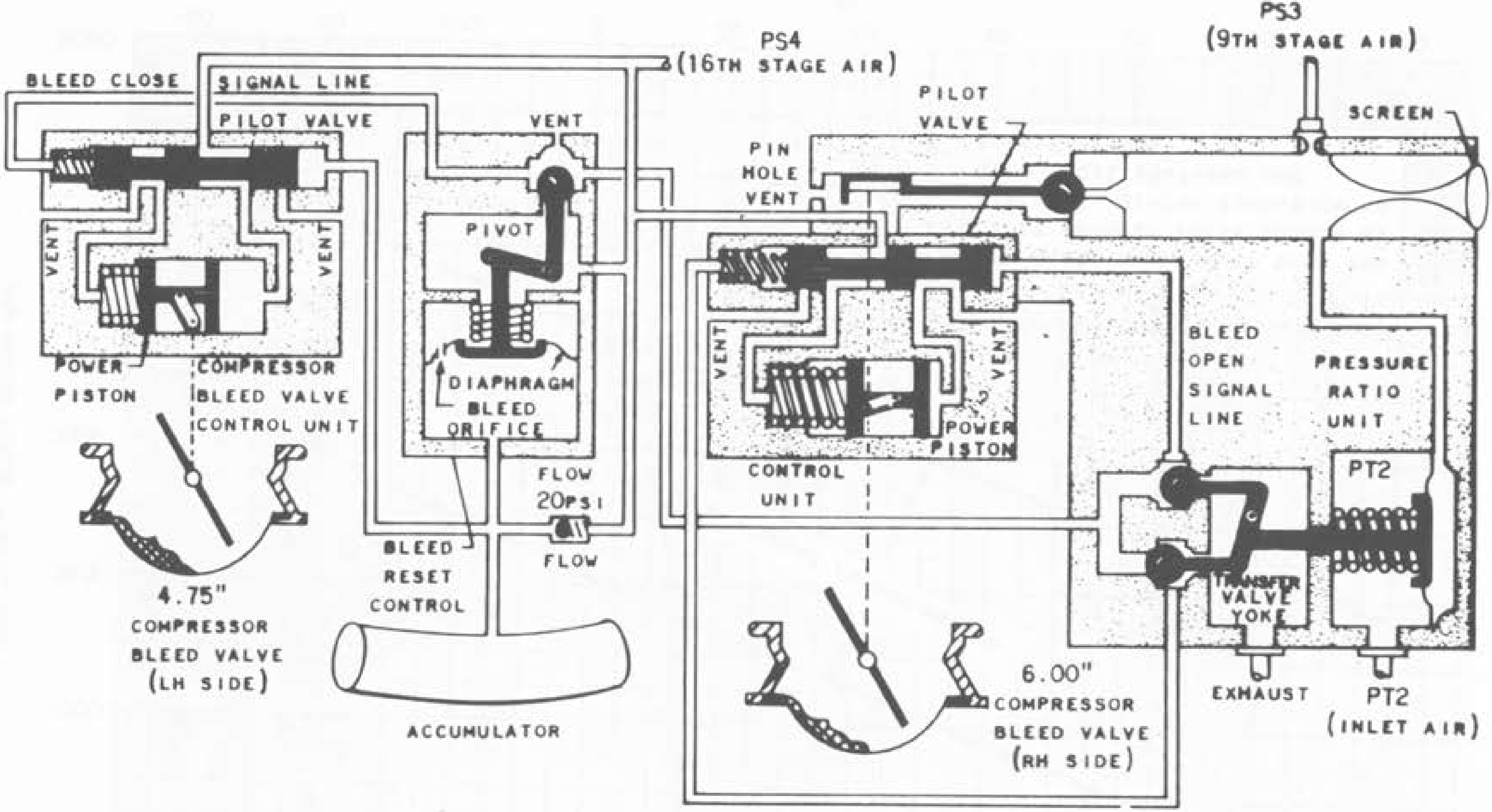


COMPRESSOR BLEED SYSTEM SCHEMATIC (HIGH THRUST) valve. A pilot valve inside the actuator directs Ps 4 (sixteenth-stage air) to the power piston for closing. This pilot valve directs PS4 to either the open or closed side of the power piston depending on the differential pressure. The pilot valve is controlled by the transfer valves in the PRBC. The transfer valves are mechanically connected to the transfer valve actuating diaphragm. As previously mentioned, Pt2, plus spring tension, is felt against one face of the diaphragm and Ps3 on the other side. With engine at static condition or low thrust, there is equal pressure on both sides of the diaphragm. Spring tension then holds the transfer valves in a position to allow Ps4 to go to the open side of the power piston. Spring tension aids in positioning the pilot valve to the open position. With the pilot valve in the open position, Ps4 cannot be ported to the closed side of the power piston sooner than desired. This keeps the 6-inch bleed valve open until the engine accelerates to sufficient RPM to prevent compressor stall.

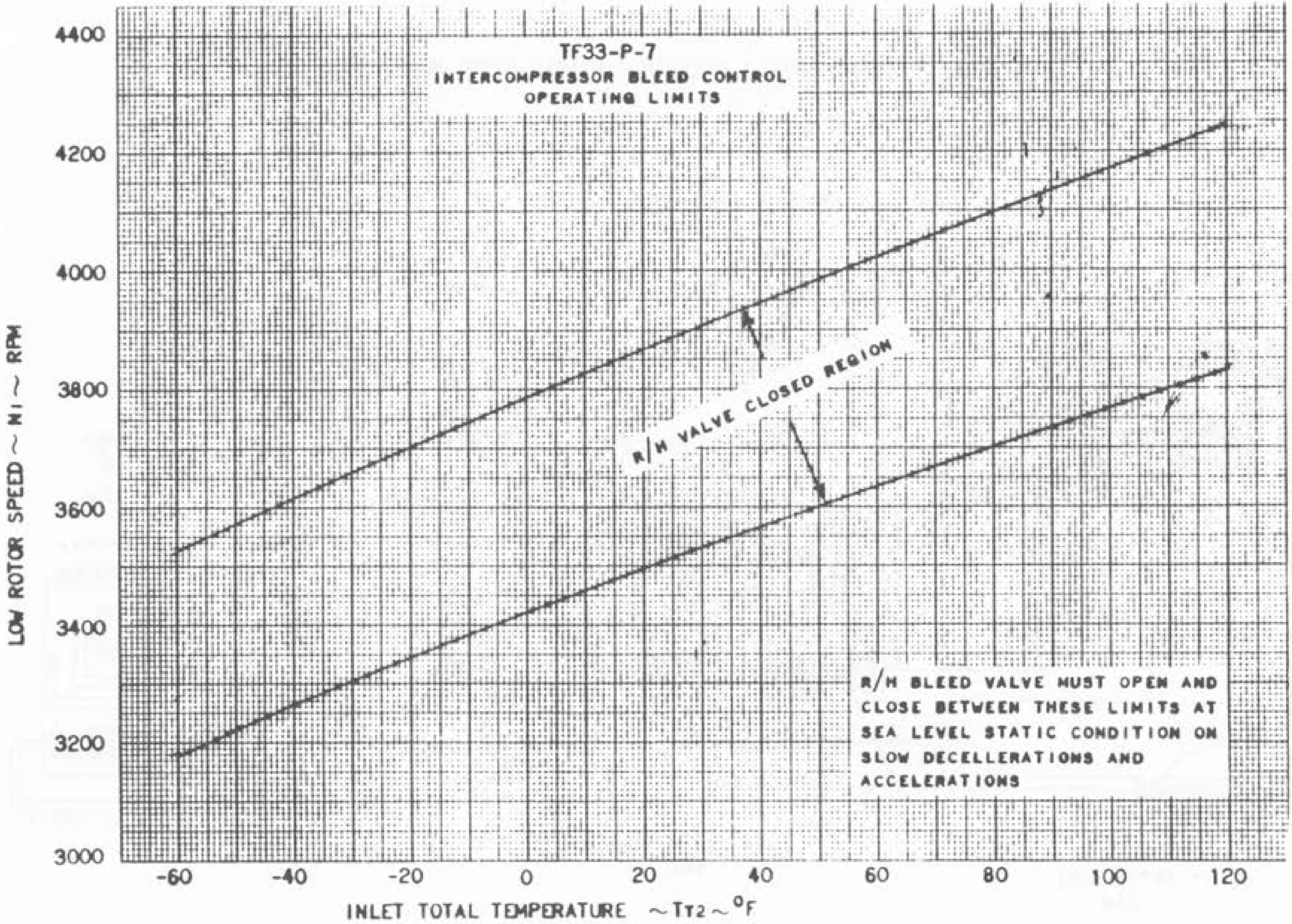
During snap decelerations, the 4 3/4-inch bleed valve is used and is controlled by the PRBC and its bleed valve actuator. The two are connected by tubing. A power piston inside the actuator opens and closes the valve, which is normally spring-loaded closed. Air pressure (Ps4) has to overcome spring force to open the valve. Airflow is directed to the piston by the pilot valve in the actuator. Normally, the pilot valve is spring-loaded closed to direct air pressure to aid spring pressure against the power piston to keep it closed during starting and steady operation. During snap deceleration, pressure ported to the open side of the pilot valve ports pressure to the open side of the power piston. This action allows twelfth-stage air to be bled overboard to unload the compressor.

During starting and acceleration, Ps3 slowly increases. At a predetermined point, Ps3 overrides Pt2 pressure plus the spring pressure. This action repositions the transfer valves and shuts off Ps4 to the open side of the pilot valve in the 6-inch bleed valve actuator. This action allows Ps4 pressure to the bleed reset control where it pressurizes both sides of a diaphragm in the reset control, the close signal line to the 6-inch valve actuator, and the open and closed lines of the 4 3/4-inch valve actuator. The pilot valve in the 6-inch valve is then moved to the closed position, porting pressure (Ps4) to the closed side of the power piston to drive this valve closed as engine speed reaches idle or above. With the Ps4 pressure to both the open and close sides of the pilot valve of the 4 3/4-inch bleed valve, the valve remains closed because of spring tension on the close side.

During deceleration, the rapid decay of Ps3 and Ps4 allows Pt2, plus spring tension in the transfer valve actuating diaphragm, to override and reposition the valves to close Ps4 supply to the bleed reset control. When the bleed reset control senses this, the close signal line to both actuators is shut off and vented. Since the pilot valve and power piston no longer have Ps4 opposing spring pressure, the 6-inch valve opens. Opening of the 4 3/4-inch valve is accomplished by the bleed reset control and accumulator. The accumulator pressure is ported



COMPRESSOR BLEED SYSTEM SCHEMATIC (SNAP DECELERATION)



COMPRESSOR BLEED VALVE OPERATING LIMITS

to the open side of the pilot valve by the reset control. When the pilot valve moves to the open side, Ps4 is then directed to the open side of the power piston. This action opens the 6-inch bleed valve and unloads the compressor by allowing twelfth-stage air to be dumped into the fan duct. The 6-inch valve remains open until open signal pressure drops below 8 PSI higher than spring tension plus pressure on the close side of the valve.

Mechanical linkage which connects the 6-inch valve to the actuator also connects it to a reset valve in the PRBC. With the 6-inch valve closed, the reset valve is open. When the 6-inch valve is open, the reset valve is closed. This allows the opening and closing of the 6-inch valve at a predetermined point. Assuming the power setting is above this point, the valve is open. The reset valve is open. When the power setting is decreased, the open reset valve allows Ps3 in the PRBC to rapidly decrease. This allows instant operation and presents the predetermined point of opening and closing.

NACELLE AND ENGINE INLET ANTI-ICING SYSTEM.

Each engine inlet and nacelle is protected from ice formation by a pneumatic anti-icing system. This system is composed of two separate sub-systems: a valve and regulator for the nacelle inlet duct, and a second valve and regulator for the compressor guide vanes in the engine. Both valves are controlled simultaneously by an automatic ice detector or manually by a single switch (for each engine).

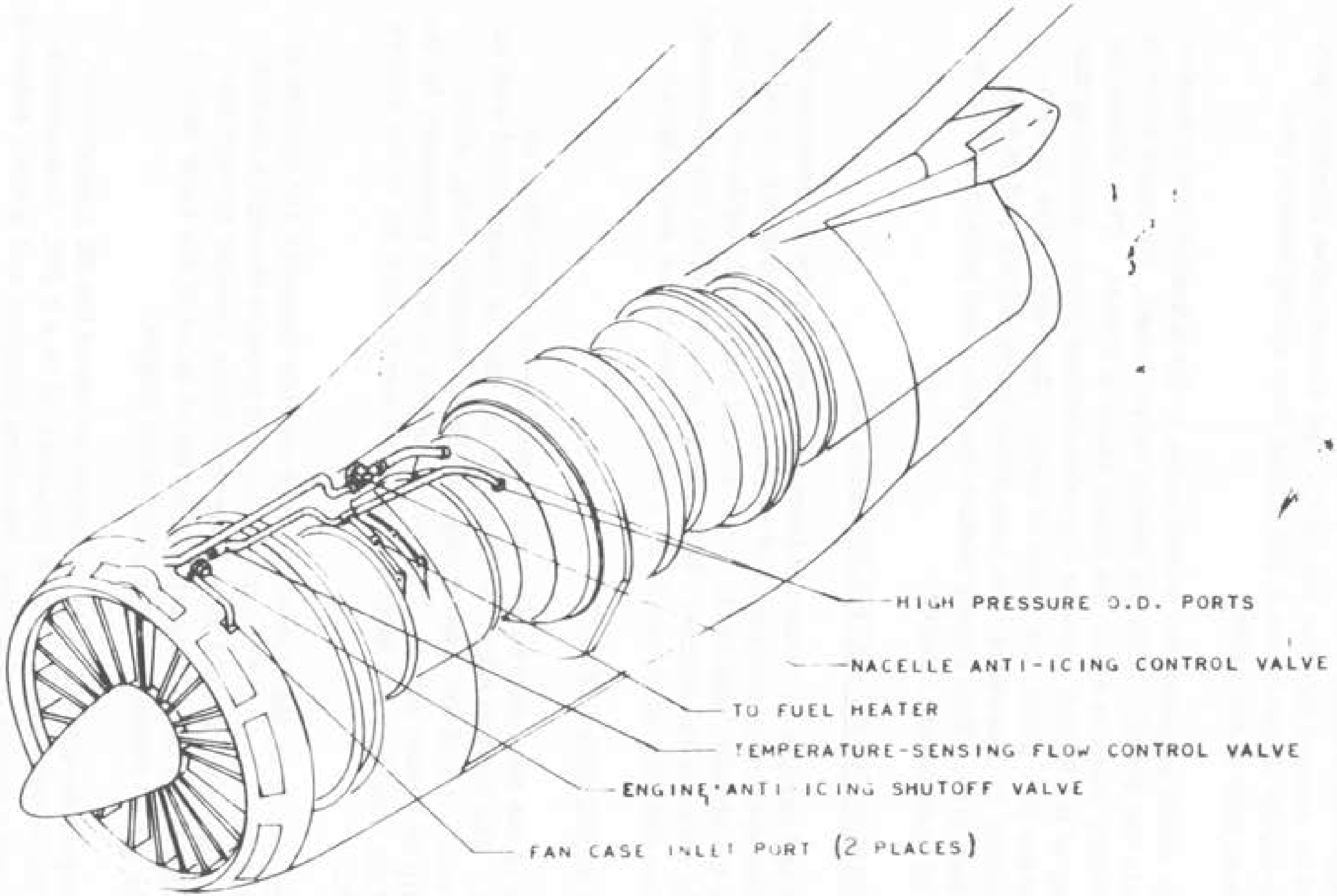
NACELLE ANTI-ICING SUB-SYSTEM.

The leading edge of the inlet duct to the engine has hot-air, anti-icing as mentioned above. The leading edge, or "lip," of the duct is constructed with an inner and outer wall. Aft of the leading edge is the aft manifold ring, which connects to the lip by header tubes. This arrangement is made necessary by the incorporation of the auxiliary air inlet doors which admit extra air to the engine at low air speeds.

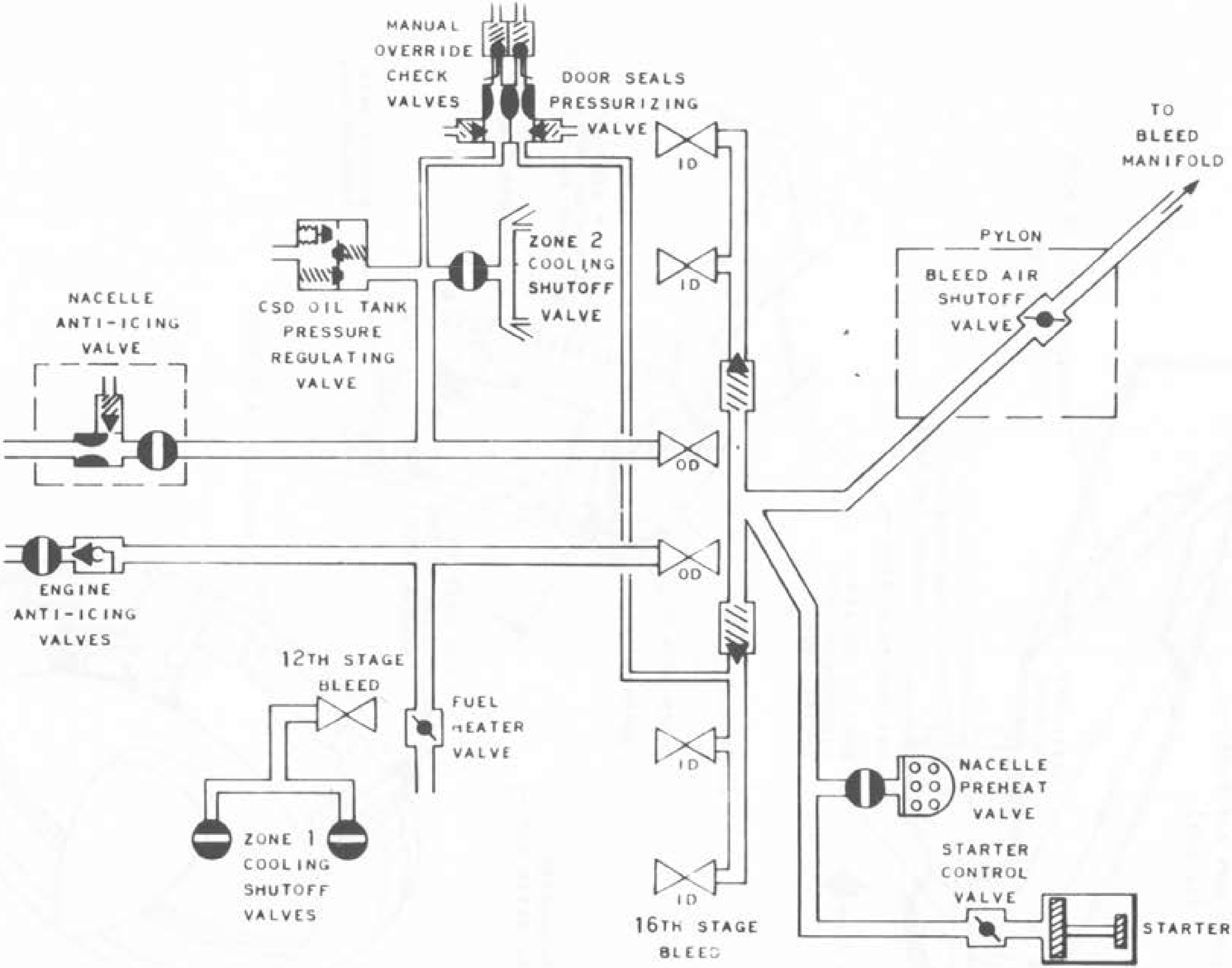
Bleed air is extracted from the sixteenth-stage outside diameter air system at approximately 235 PSIA and 421°C of the engine and brought through a shutoff-regulator valve to the aft manifold ring. Air then flows forward through the header tubes to the lip of the inlet duct. A series of holes in the inner skin of the lip allows the air to escape into the inlet of the engine.

A poppet-type regulator-shutoff valve, mounted on top of the N2 compressor, supplies air to the nacelle inlet duct at a pressure of 16 ± 2 PSI. Components of the valve inclued a poppet and spring, actuating chamber and piston, solenoid shutoff, filter, pressure regulator, and indicator light switch.

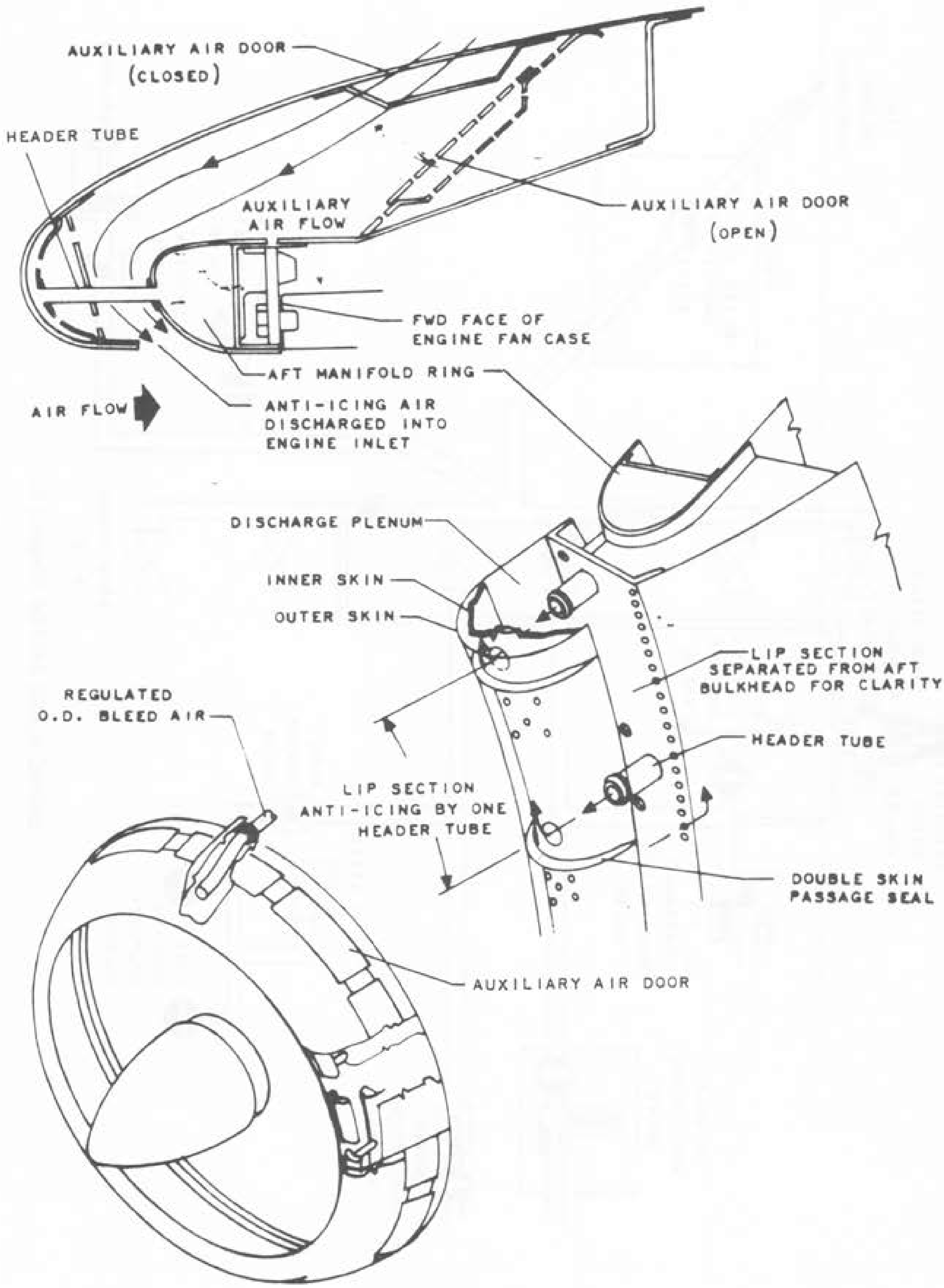
When the valve is off, airflow is blocked by the poppet being held against its seat



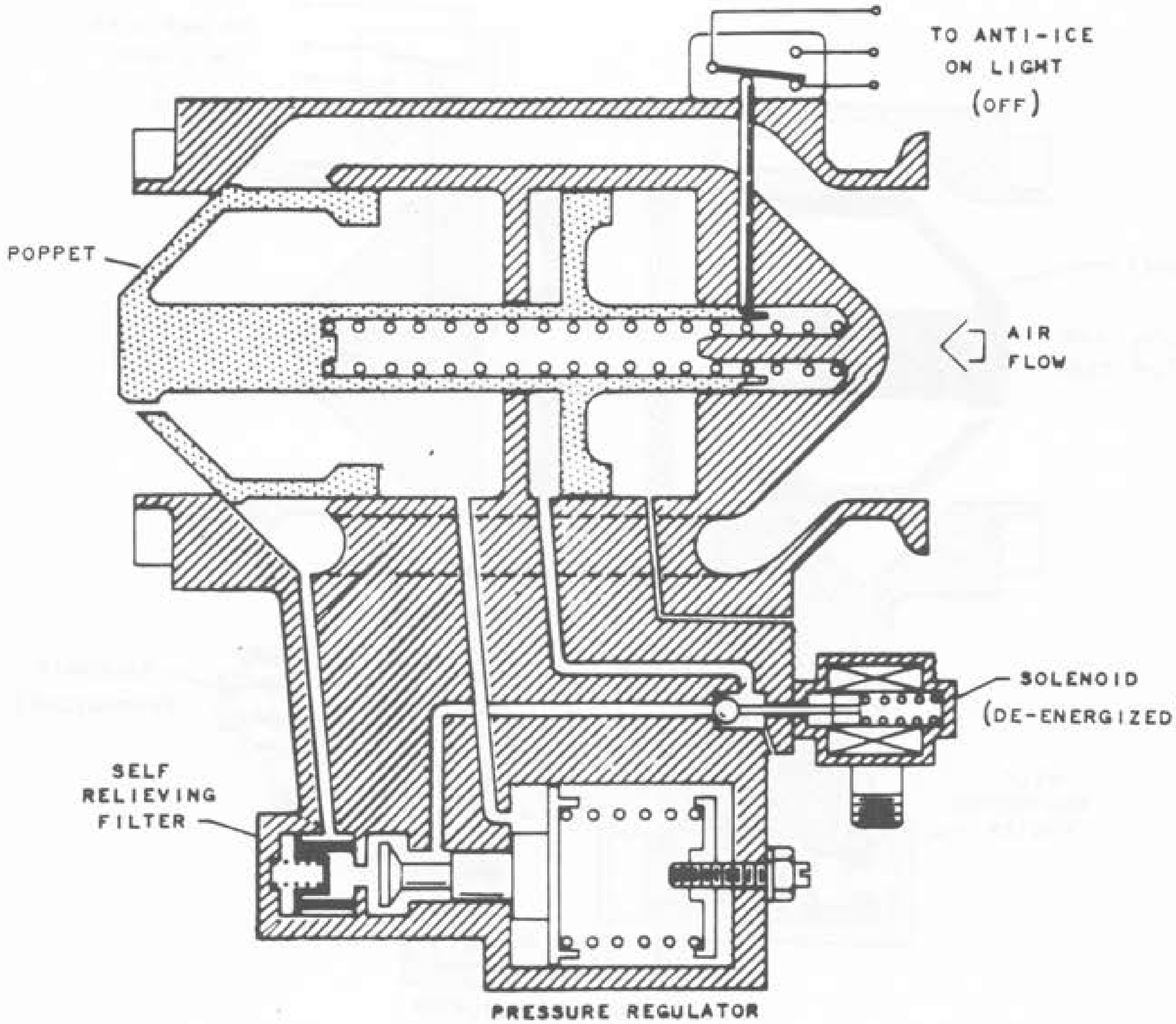
ENGINE ANTI-ICING SYSTEM COMPONENT LOCATIONS



ENGINE BLEED SYSTEM SCHEMATIC



NACELLE ANTI-ICING AIR FLOW SCHEMATIC

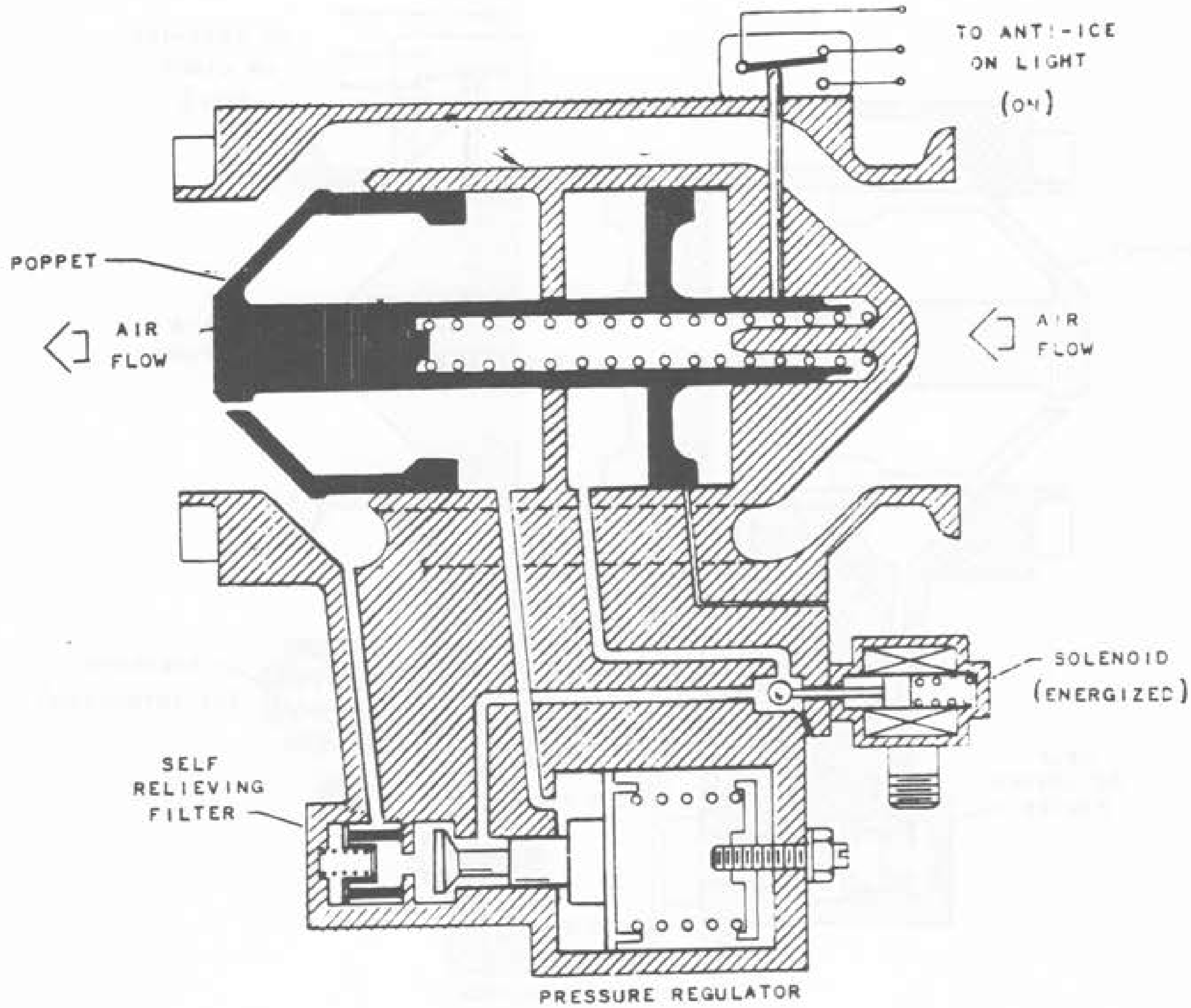


NACELLE ANTI-ICING VALVE (CLOSED)

by the poppet valve spring. A passageway leads from upstream pressure to the filter, the regulating valve orifice, and to the solenoid operated shutoff valve. The filter is relieved when a differential pressure is felt across the filter.

From the filter, airflows to the pressure regulator orifice which is full open whenever the valve is closed. From the regulator, air goes to the solenoid-operated shutoff valve. When the anti-icing system is off, the solenoid is de-energized, blocking airflow to the actuating chamber of the valve.

When the system is on, the solenoid is energized, opening a path of flow to the actuating chamber and piston. Pressure felt on the face of the piston moves the



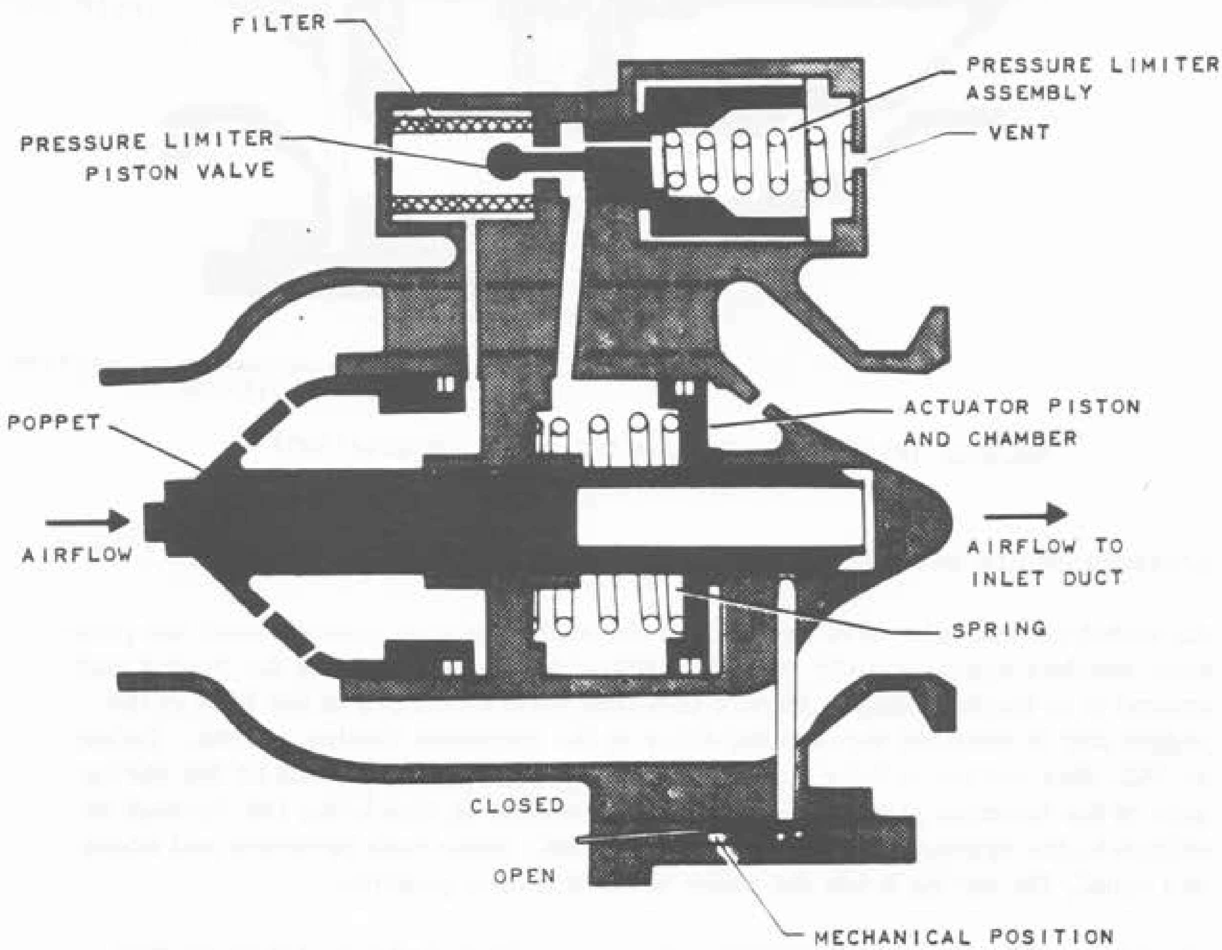
NACELLE ANTI-ICING-VALVE (OPEN)

poppet against spring tension, thus opening the valve. The anti-icing light switch cam will be forced outward, completing the anti-icing "on" indicating circuit to the engine inlet valve switch which is in series with the switch.

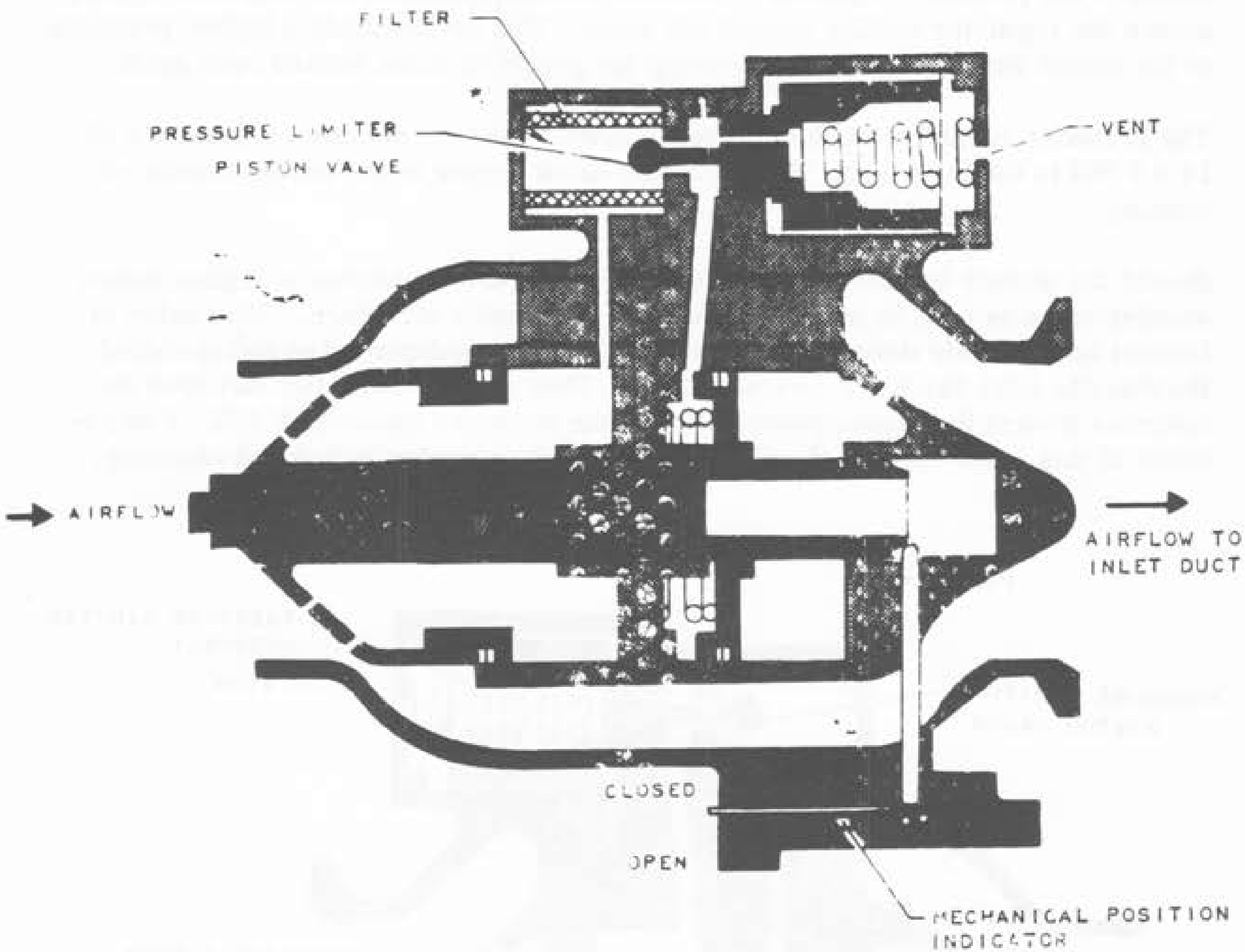
When the poppet opens to allow pressure to the downstream side of the valve, an orifice in the face of the poppet admits air to the actuating chamber of the pressure regulator. Pressure felt on the piston of the regulator tends to compress the spring, narrowing the orifice leading to the poppet actuating chamber. As this passage is restricted, pressure going to the poppet actuator decreases. As pressure decreases in the poppet actuator, the valve spring tends to drive the poppet closed. As the poppet goes toward closed, downstream pressure is decreased. This decrease in pressure is felt through the face of the poppet to the piston of the pressure regulator. With decreased pressure, the regulator spring drives the regulator orifice toward full open. This action sends a higher pressure to the poppet actuator chamber, causing the poppet to drive toward open again.

The pressure regulator modulates as described above to maintain a pressure of 16 ± 2 PSI to the inlet duct. Shutoff of the valve occurs in the reverse order of opening.

Should the shutoff-regulator fail to function and pressure to rise to higher value, another valve is used to prevent damage to the nacelle structure. This valve is located immediately downstream from the shutoff-regulator valve and is called the Nacelle Inlet Pressure Limiter Valve. This valve is normally full open and operates toward the closed position only when pressure exceeds 40 PSI. Components of this valve consist of a poppet and spring, actuator piston and chamber,



NACELLE INLET PRESSURE LIMITER VALVE (OPEN)



NACELLE INLET PRESSURE LIMITER VALVE (REGULATING)

pressure limiter assembly, filter, and a mechanical position indicator.

As stated above, this valve remains in the normally open position until the pressure reaches approximately 40 PSI. Upstream air flows across the poppet and around it to the inlet duct. Part of this flow enters orifices in the face of the poppet and is directed through the filter to the pressure limiter orifice. Below 40 PSI, this orifice is fully open, allowing air pressure to be felt on the spring side of the actuator piston. Downstream pressure is also being felt through an orifice to the opposite side of this same piston. Since both pressure and areas are equal, the spring holds the valve in the full open position.

Should pressure rise above 40 PSI, air passing through the pressure limiter orifice causes the pressure limiter piston to begin compressing its spring. As the piston moves against spring tension, the limiter orifice is narrowed, decreasing the pressure felt on the spring side of the actuator piston. Since downstream pressure is now greater on the opposite side of the actuator piston, the poppet moves toward closed against spring tension.

As the poppet moves toward closed, downstream pressure is decreased. This action allows the poppet valve spring to move the actuator piston and poppet toward the open position. The valve modulates in the above manner to maintain a downstream pressure of approximately 40 PSI.

The inlet pressure limiter valve cannot close completely since the pressure limiter orifice must continue to pass a high pressure against the face of the pressure limiter piston. It is obvious that the limiter piston eventually cuts off its own pressure source as the spring is compressed. Modulation toward closed is adequate to maintain a maximum pressure of 40 PSI as mentioned above.

ENGINE ANTI-ICING SUB-SYSTEM.

As mentioned previously, the engine inlet guide vanes and nose dome have hot air anti-icing which operates simultaneously with the nacelle inlet duct system.

The nose dome has a double-skin construction which forms a cavity for air to flow through during anti-icing operation. Each inlet guide vane is hollow to allow anti-icing airflow. The case which supports the guide vanes at their outer periphery and the case immediately aft of the vanes form a plenum for distribution of anti-icing air. This also means that the outer periphery of the engine inlet case is anti-iced as well as the guide vanes.

Airflow is as follows: sixteenth-stage outside diameter air is brought forward to the outer case immediately aft of the inlet guide vanes. Air enters at two points here and is distributed around the case and moves forward to the case supporting the outer ends of the inlet guide vanes. Again, air is distributed throughout this case, entering the inlet guide vanes at their outer ends. Air flows inward through the inlet guide vanes to their inner support case where the air again is distributed evenly around the support.

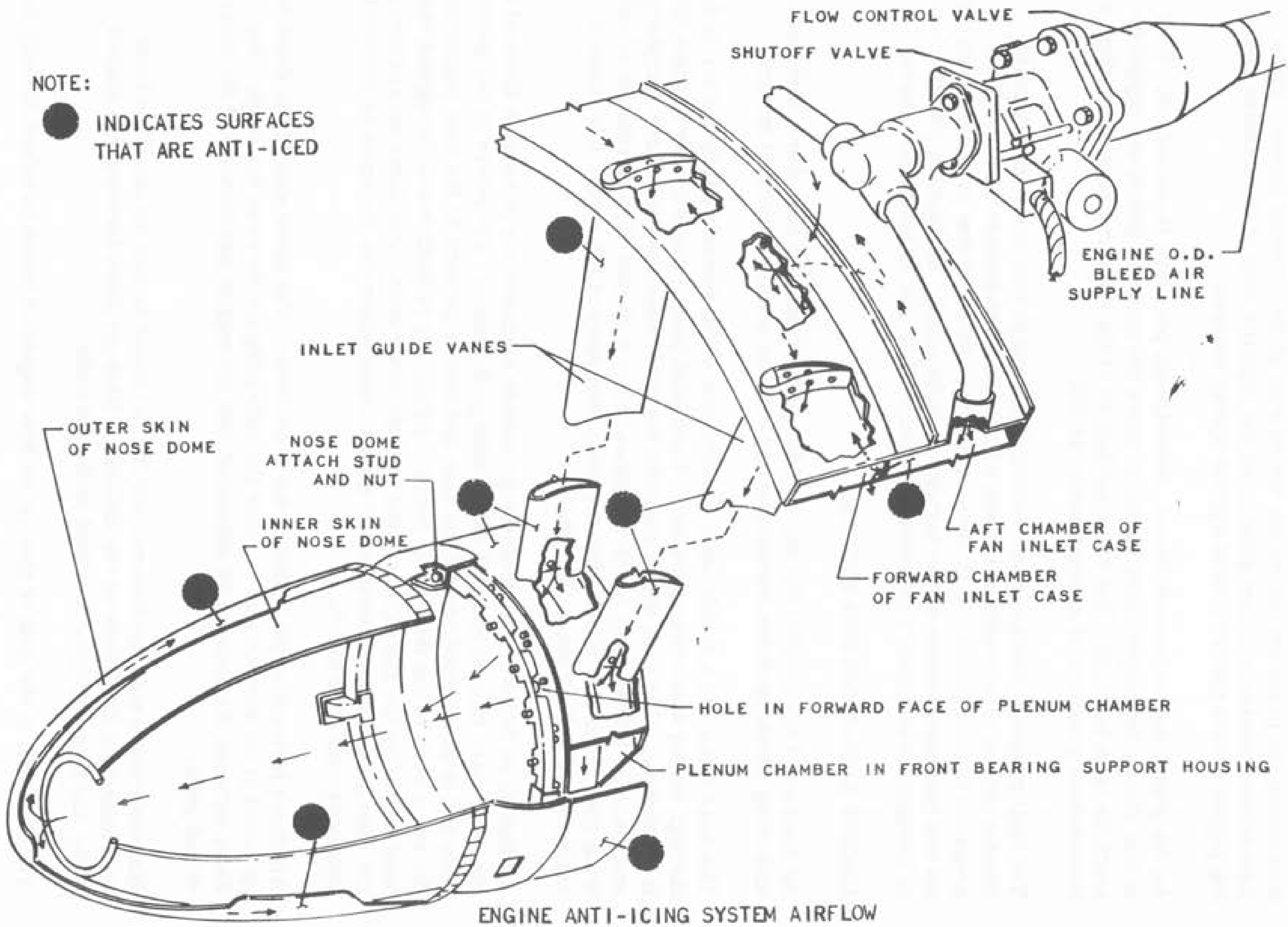
Air flows forward to the inside of the nose dome. The inner skin of the dome has an outlet at its forward end to route the anti-icing air between the skins. Air flows between the skins to be exhausted into the engine just forward of the dome attach point.

Sixteenth-stage outside-diameter air for the above system is extracted from approximately 11 o'clock on the diffuser. This air flows forward to a shutoff valve and flow regulator mounted on the fan case.

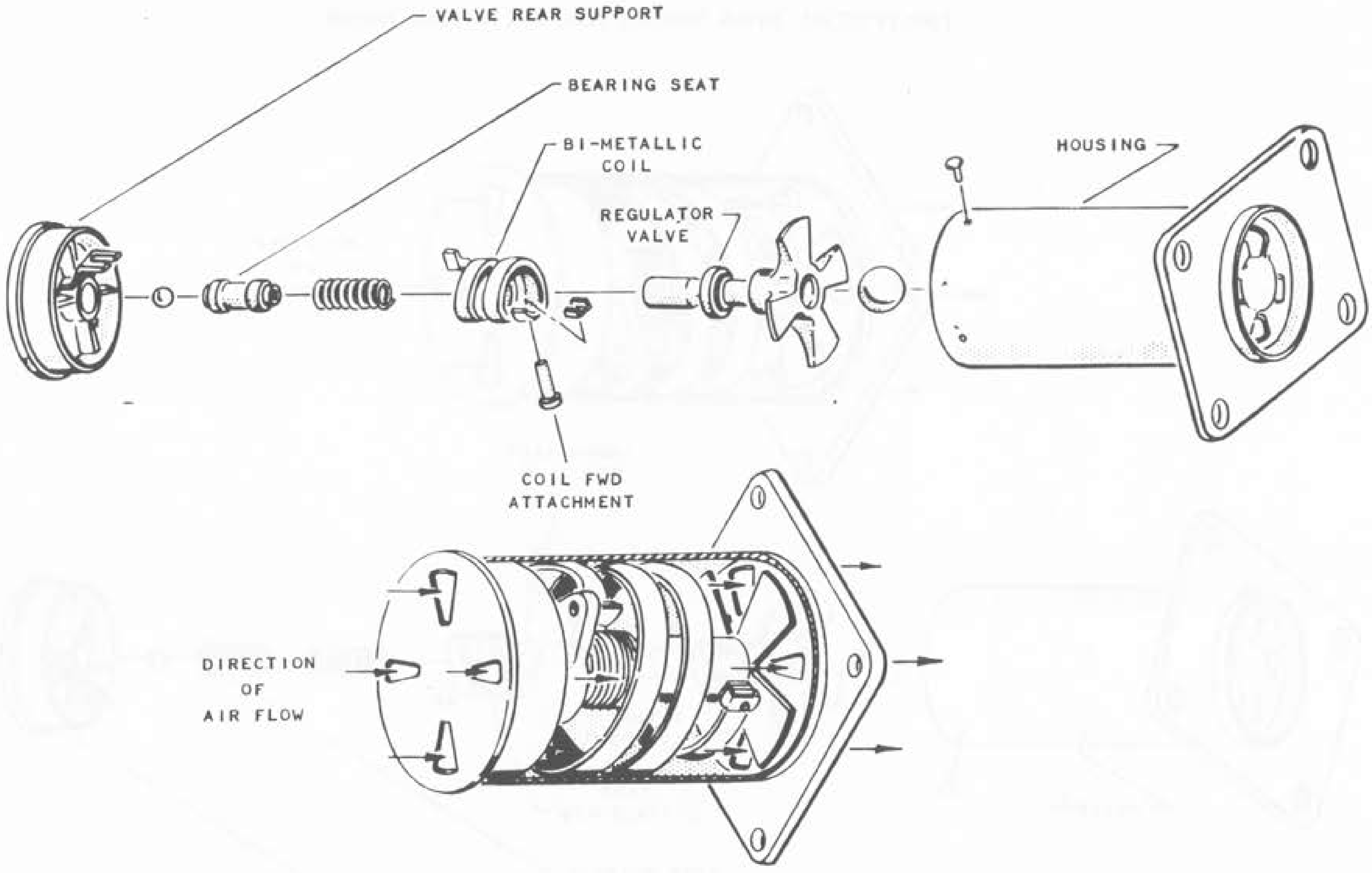
The first unit in the path of flow is the flow regulator which is bolted directly to

NOTE:

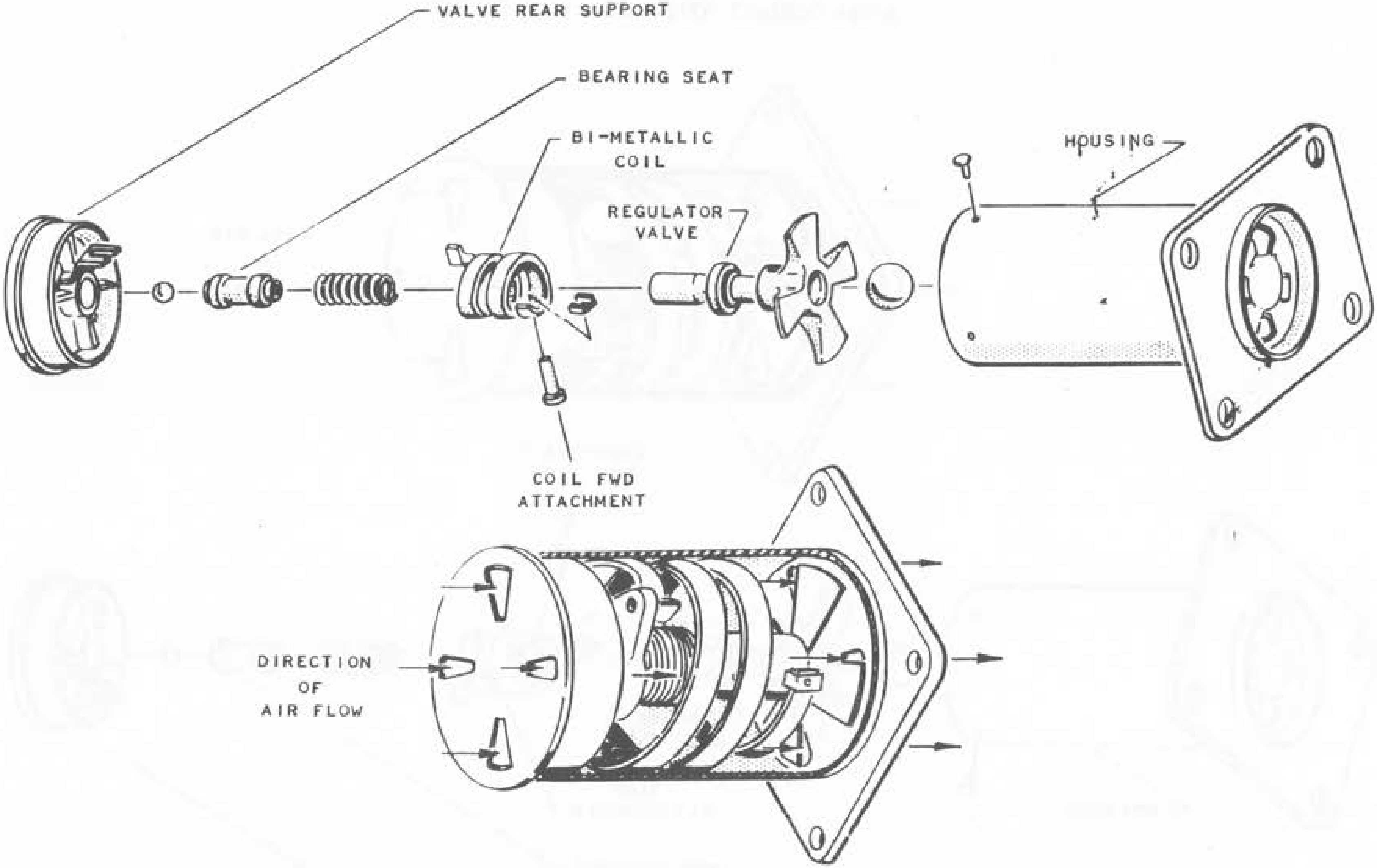
● INDICATES SURFACES THAT ARE ANTI-ICED



ENGINE ANTI-ICING SYSTEM AIRFLOW



ENGINE ANTI-ICING FLOW CONTROL VALVE



ENGINE ANTI-ICING FLOW CONTROL VALVE (REGULATING) the butterfly-type shutoff valve.

The flow regulator valve consists of a housing, regulator valve, bimetallic coil, spring, bearing seat, and rear support.

The valve housing has four "windows" in its downstream end. The regulator valve has four "paddles" which are spaced to coincide with the windows of the housing. The regulator valve is mounted at each end by a ball, which forms bearings. They are kept in contact with the housing by a spring which bears against the bearing seat. The bimetallic coil is anchored to the valve rear support at one end and attached to the rotating regulator valve at the other.

When heat is applied to the coil, it becomes longer, rotating the paddles of the regulator valve across the windows of the valve housing. As the area of the openings decreases, flow of anti-icing air diminishes to the engine inlet guide vanes. The resultant decrease in flow tends to cool the coil, causing the regulator valve to be driven toward open again. In the above manner, the valve modulates to control flow (and relevant temperature) to the engine inlet. The valve has internal stops to prevent total closure during operation.

A butterfly type, motor-driven shutoff valve is bolted to the downstream side of the flow regulator. This valve is opened by the individual engine anti-icing switches in the "ON" position or by the automatic ice-detection system when the above switches are "OFF." The valve contains an ANTI-ICE ON indicator microswitch which is in series with the nacelle inlet valve switch (as mentioned earlier).

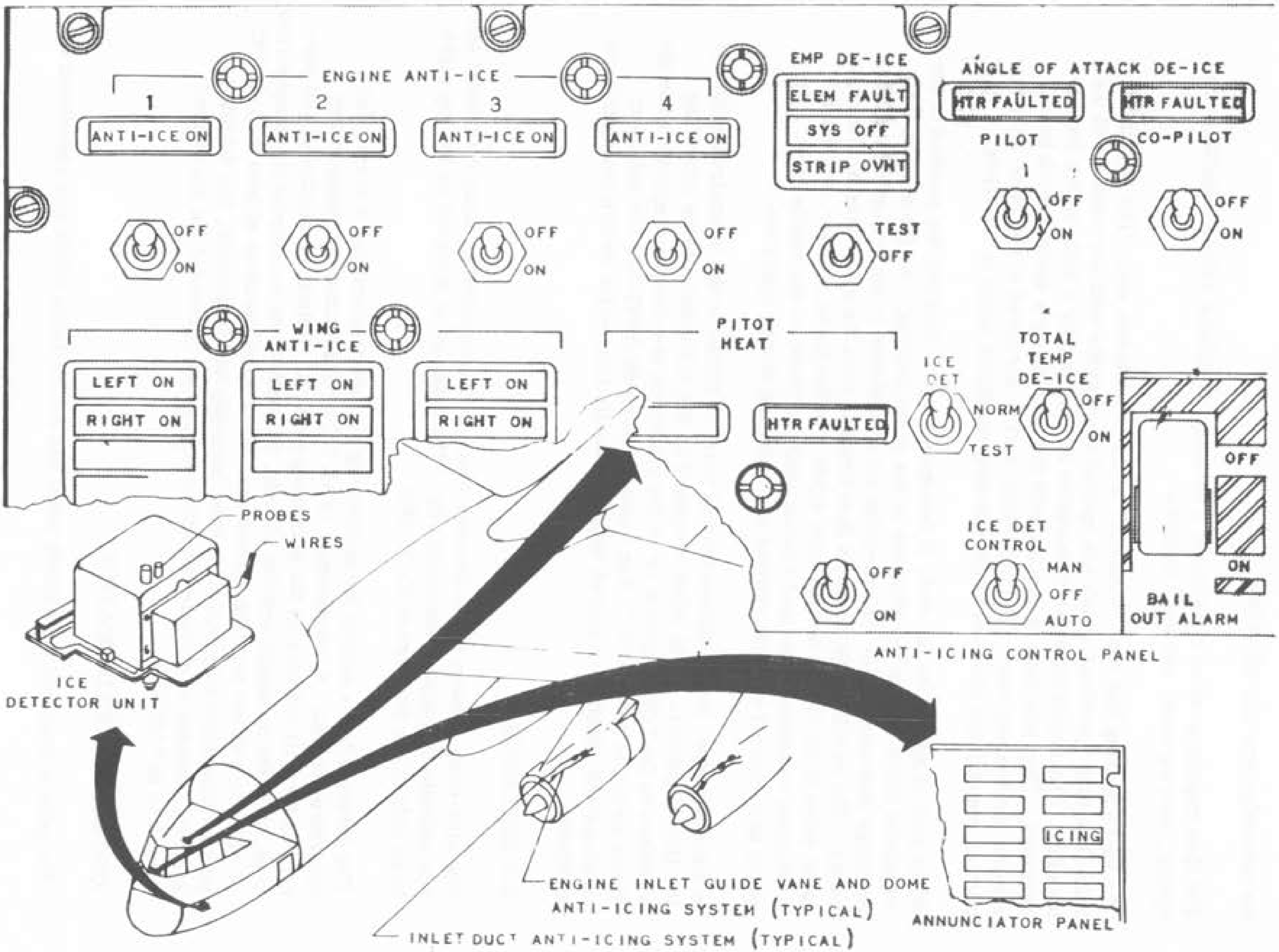
ICE DETECTOR.

The anti-icing system has a detector which senses impending icing conditions and can activate the system automatically. The detector is mounted on the top right-hand side of the fuselage at F. S. 265.

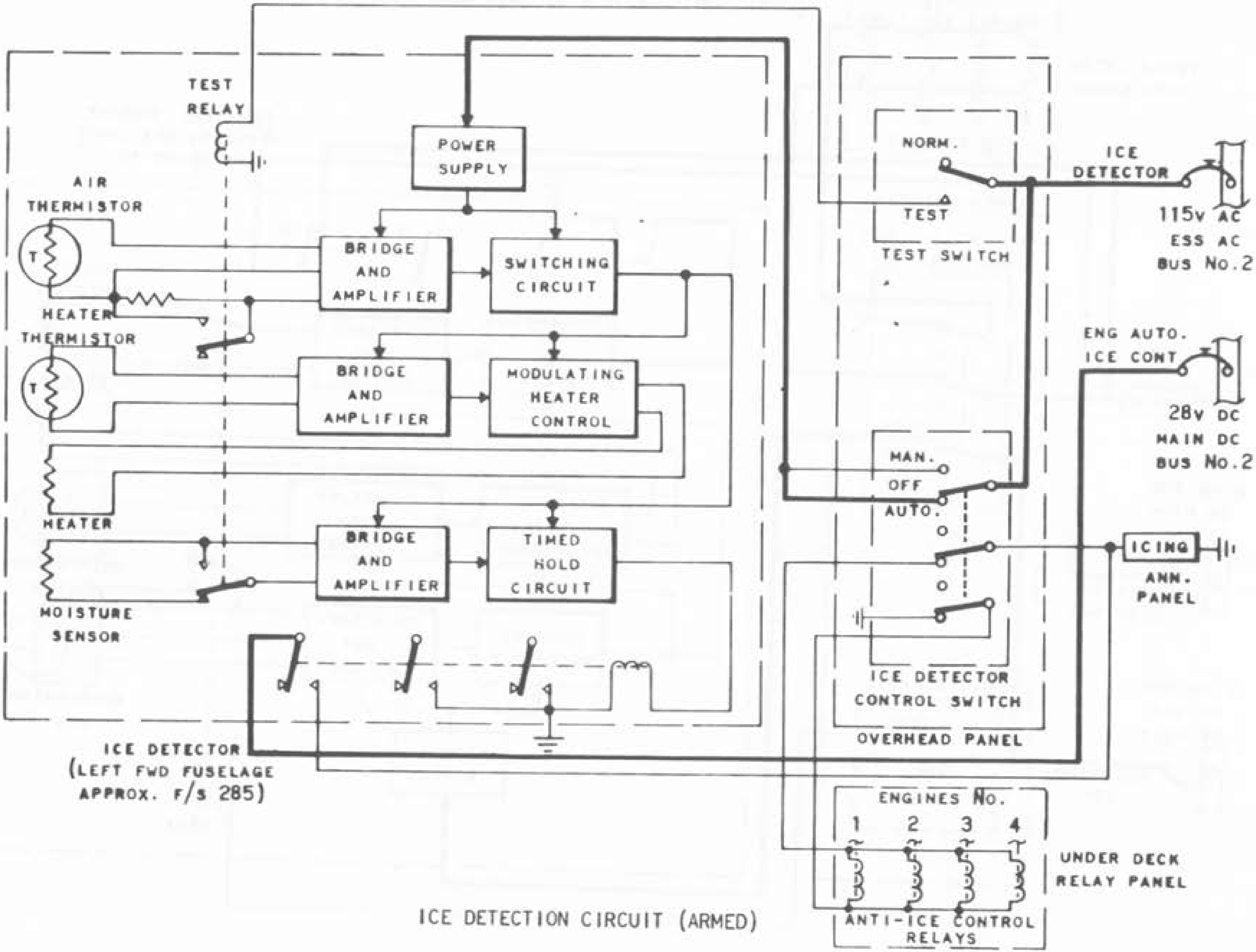
The detector has a sensor for monitoring air temperature and a sensor for moisture content. A temperature of +1.7°C or less arms the temperature circuit but will not turn on the anti-icing system. Relative humidity of 100 percent arms the moisture sensing circuit, but without an accompanying temperature of +1.7°C, will not turn the system on. When a temperature of less than +1.7°C occurs simultaneously with a relative humidity of 100 percent, the detector circuits combine to activate the anti-icing system (provided the ice control switch is in "AUTO").

OPERATION AND INDICATION.

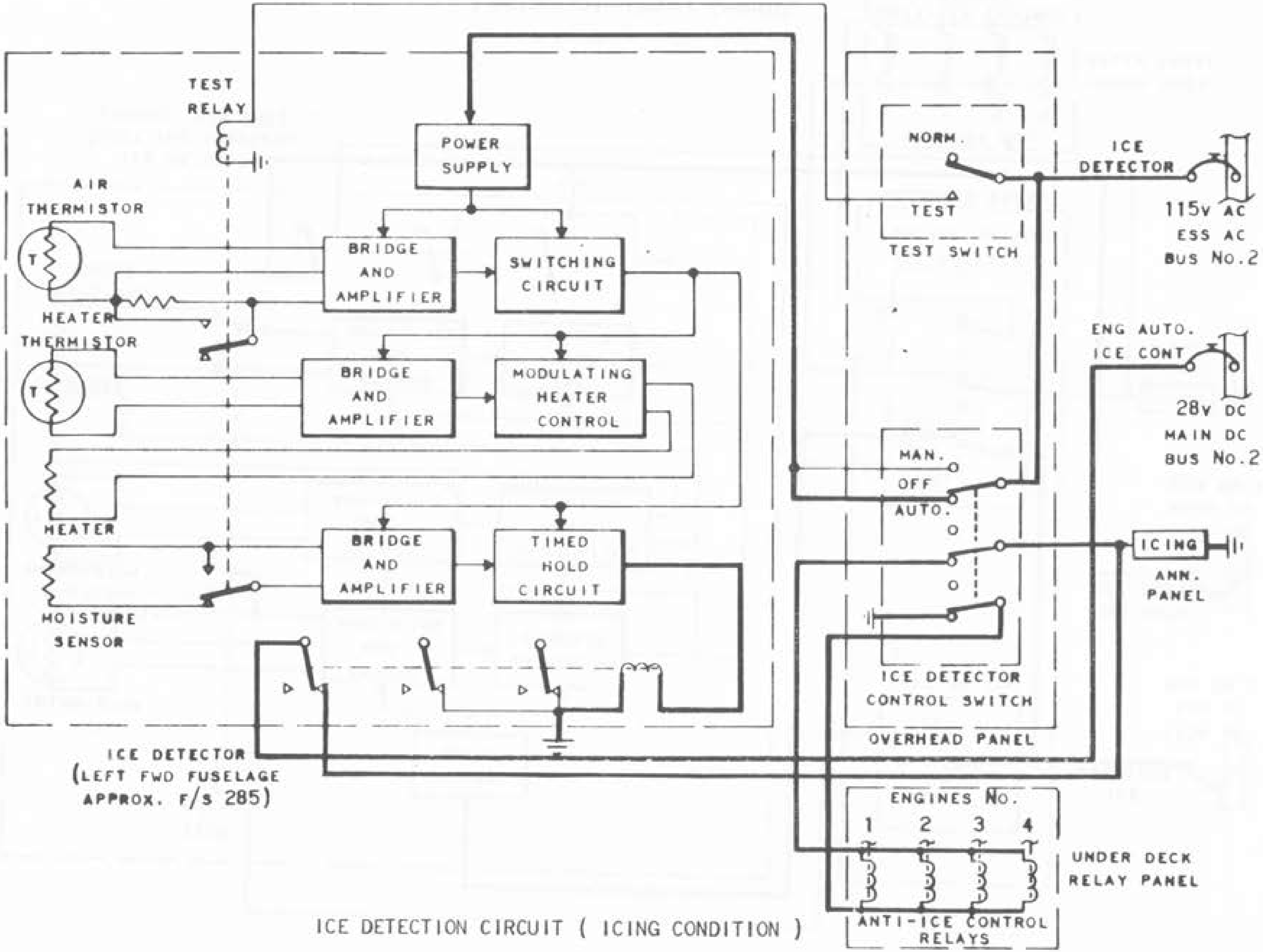
The pilot's overhead ice control panel has six switches which are associated with



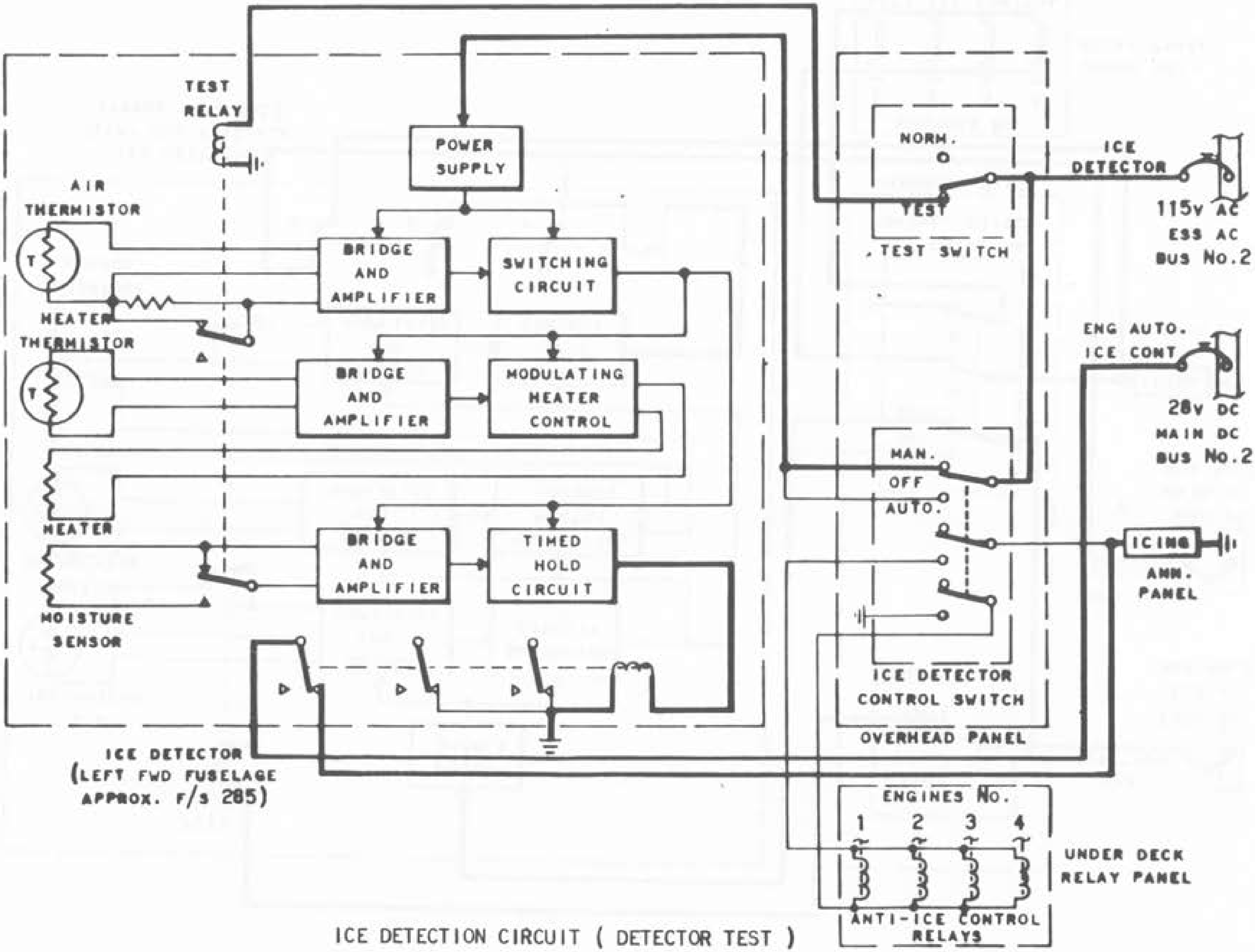
ENGINE AND NACELLE ICE CONTROL COMPONENTS



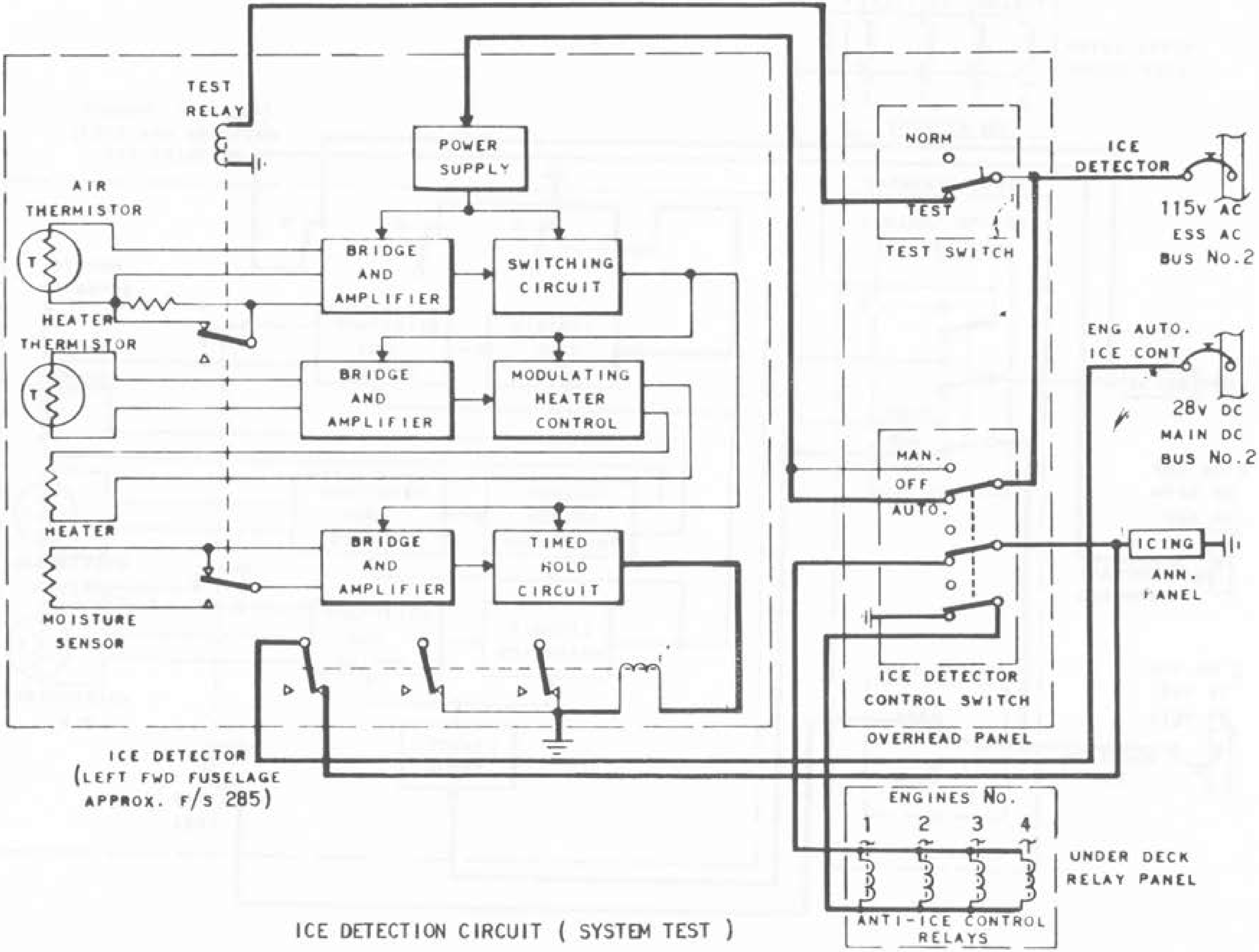
ICE DETECTION CIRCUIT (ARMED)



ICE DETECTION CIRCUIT (ICING CONDITION)



ICE DETECTION CIRCUIT (DETECTOR TEST)



ICE DETECTION CIRCUIT (SYSTEM TEST)

nacelle and engine anti-icing. Each engine has an individual anti-icing control switch.

The Ice Detector Control switch (lower right) could be considered as the "master" switch. The ice detector switch provides a menas of testing the ice detection system. For normal operation, the engine anti-ice switches are placed to "OFF," the ice detector switch to "NORM," and the ice detector control switch to "AUTO." This arms the system for automatic operation should icing conditions be encountered.

Should icing conditions be encountered, the amplifier interprets the signal and furnishes a current output to the triple-contact relay. This relay, in turn, energizes the anti-icing control relays for the individual engines. The icing light on the annunciator panel is also illuminated.

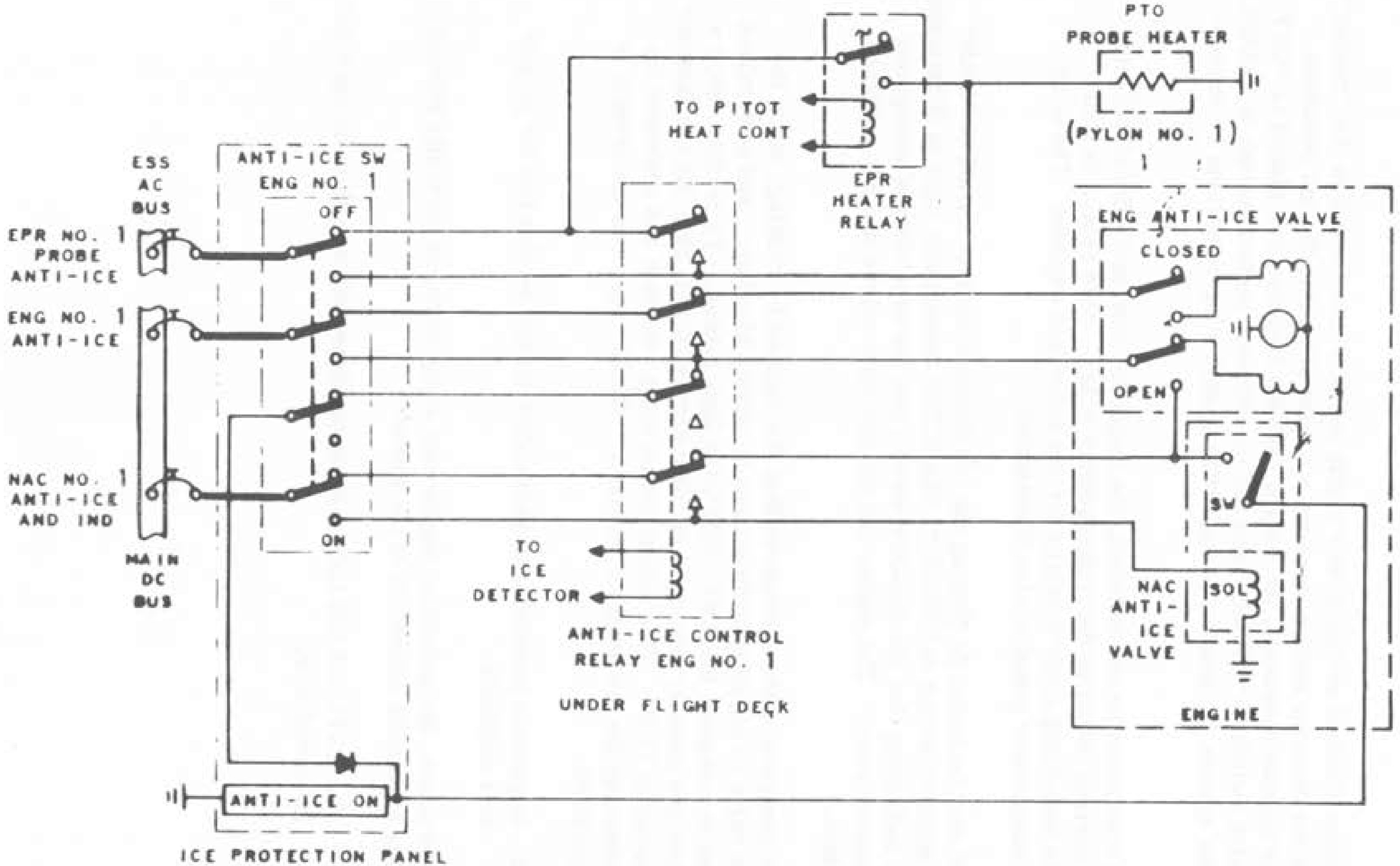
The detector may be tested by placing the ice detector control switch to "MAN" and the ice detector switch to "TEST." The ICING annunciator light is illuminated during test, indicating that the detector circuit has the capability of energizing the triple-contact relay. The engine and nacelle inlet valves are not energized during this test.

A test of the complete system requires that the engines be running, since the nacelle inlet valve is pneumatically opened by engine bleed air; and both valves must be open to complete the ANTI-ICING ON light circuit. To perform such a test, switches are initially arranged as for a normal flight, then the ice detector switch is moved to TEST. This simulates an icing condition and activates the system. Returning the ice detector switch to "NORM" restores the system to flight configuration.

NOTE: Applicable maintenance publication should be checked for proper test sequence.

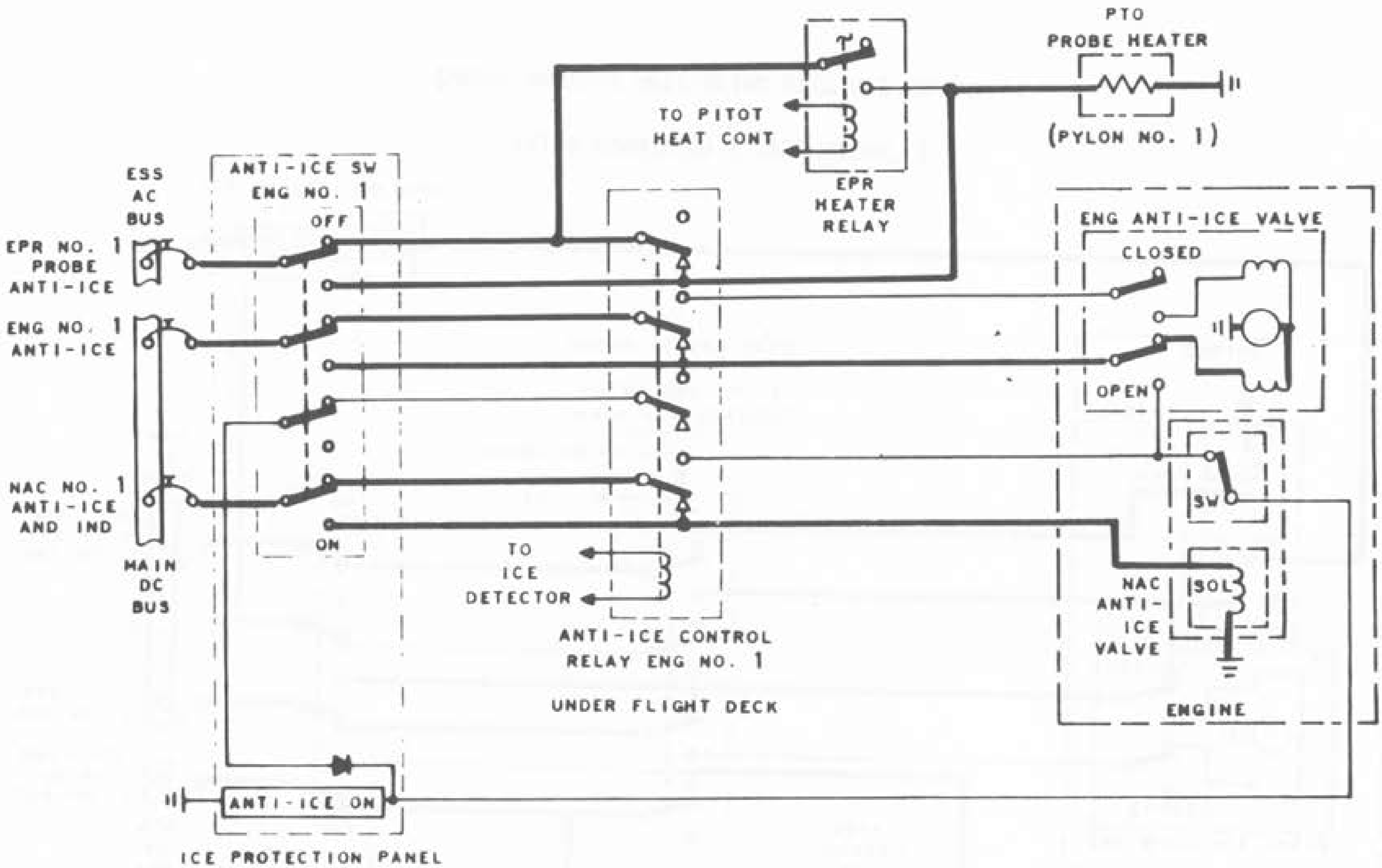
As mentioned above, the individual engine anti-icing switches normally remain "OFF" during automatic activation of the system.

NOTE: The ANTI-ICE ON light circuit requires both valves to be open for its completion.



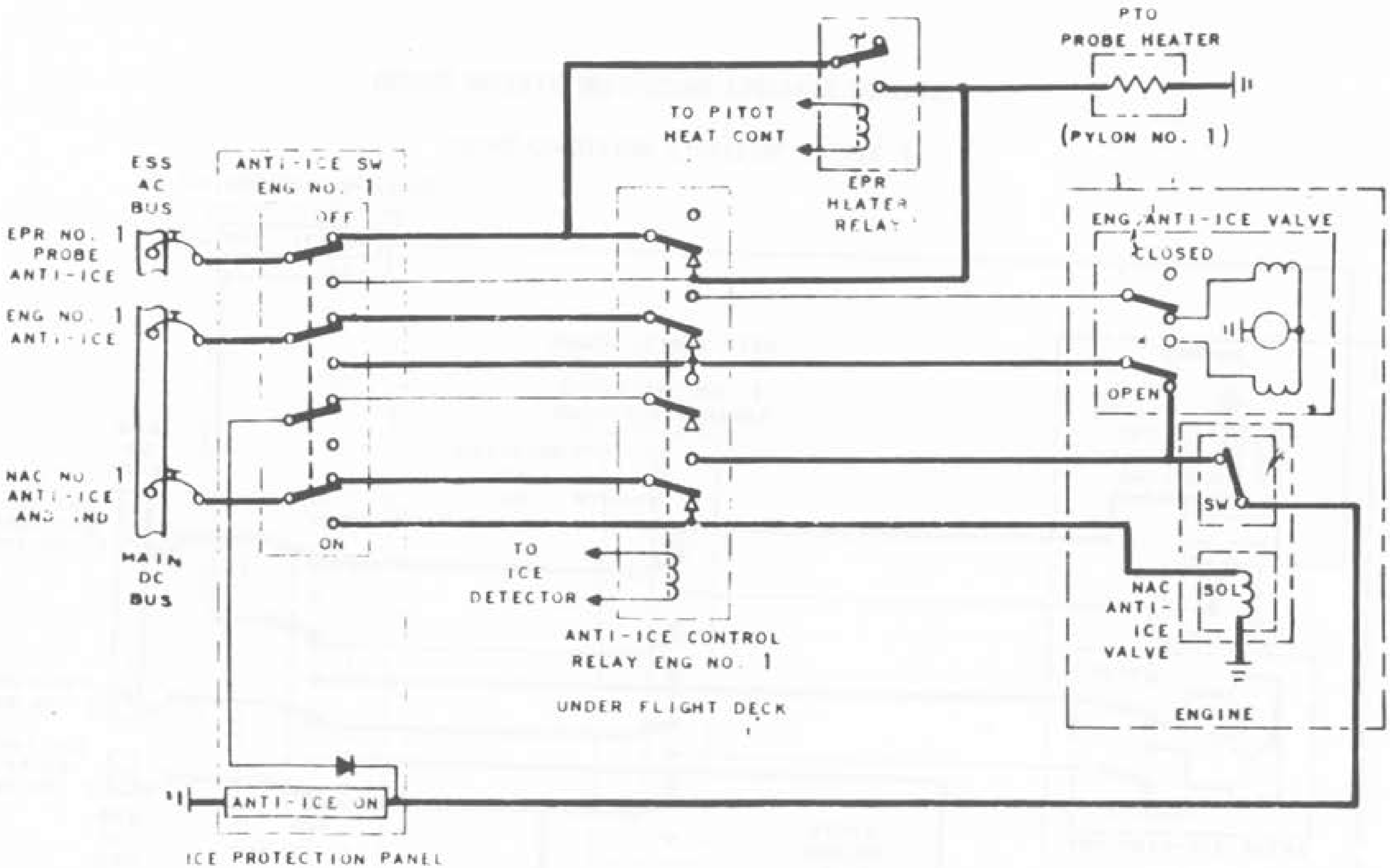
ARMED (ICE DETECTOR CONTROL SW IN "AUTO")

ENGINE NACELLE ANTI-ICING ELECTRIC SCHEMATIC



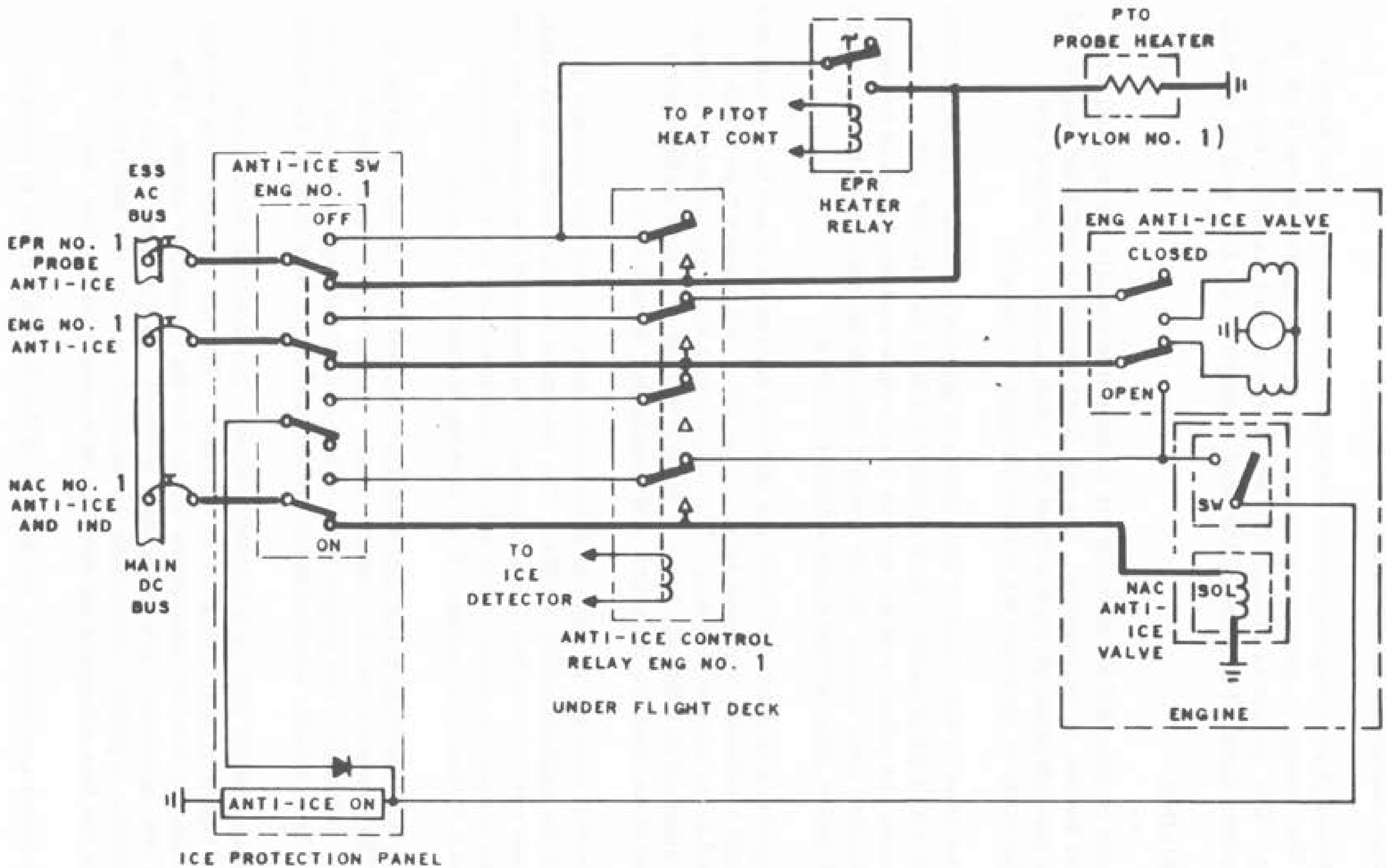
ICING CONDITION (INITIAL SIGNAL)

ENGINE NACELLE ANTI-ICING ELECTRIC SCHEMATIC



ICING CONDITION (SYSTEM "ON")

ENGINE NACELLE ANTI-ICING ELECTRIC SCHEMATIC



MANUAL "ON" (INITIAL SIGNAL)

ENGINE NACELLE ANTI-ICING ELECTRIC SCHEMATIC

NACELLE AND COMPONENT COOLING.

A cooling system is provided for cooling the engine, accessories, and nacelle structure. The cooling is designed primarily for ground operation and flight at low altitudes. The system is divided into two zones in each nacelle: the area aft of the vertical firewall is Zone I; the area forward of the fire seal is Zone II.

ZONE II COOLING.

Zone II cooling is provided by allowing air to enter the nacelle through louvers located on the bottom of the nacelle. The air flows upward around the engine and is exhausted through ports on each side of the pylon fairing. Ejectors are located at this point to increase the airflow through the nacelle.

Located in the front of each ejector duct are four ejector nozzles. These nozzles direct streams of high pressure, high velocity air into the ejector ports. This action increases the velocity in the ejector duct with a resultant drop in pressure. This low pressure area causes the air flowing through the nacelle to rush through the duct at a faster rate, giving more effective cooling.

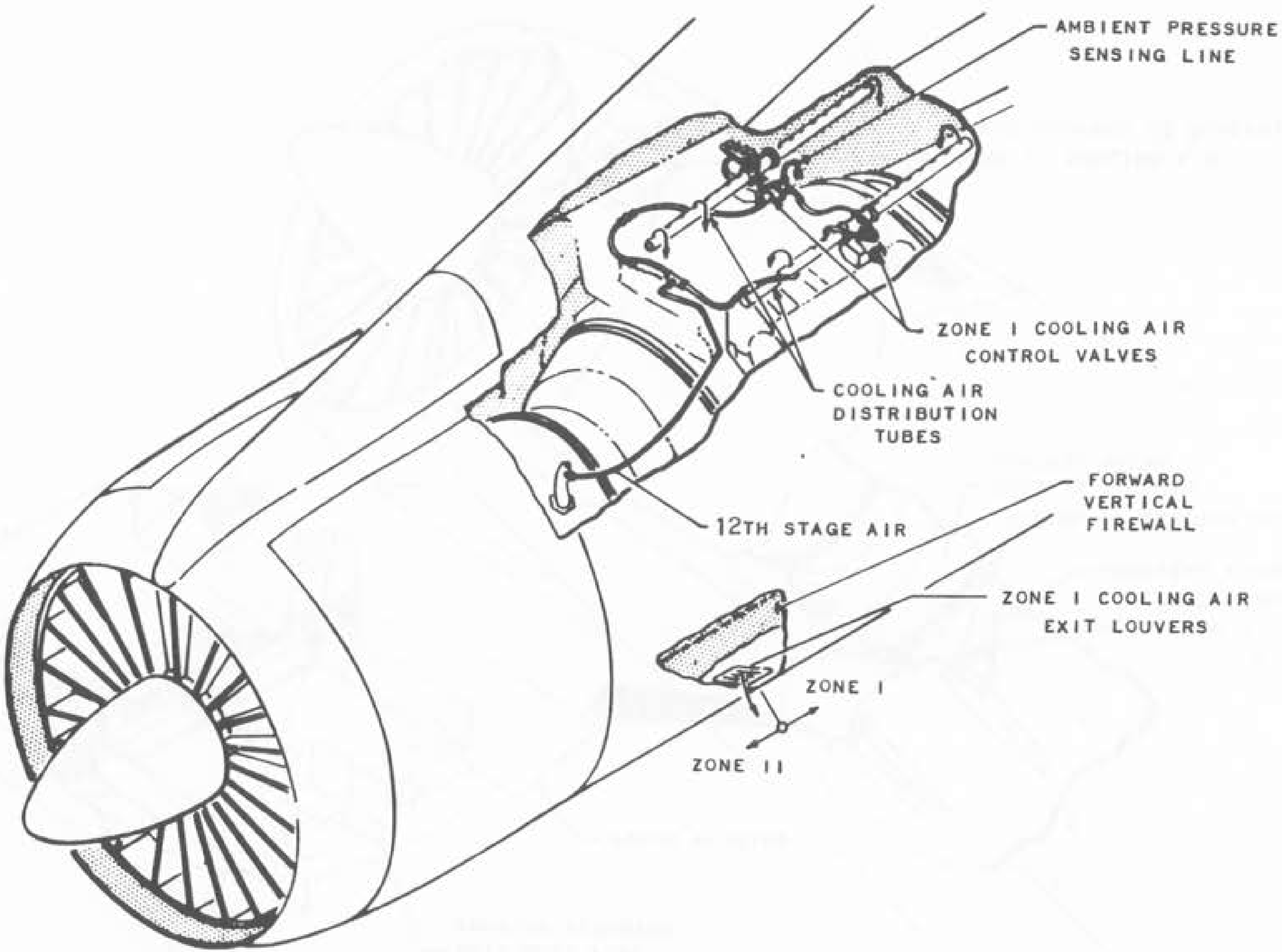
Air for the ejectors is extracted from the diffuser (sixteenth-stage O. D. air) and passes through a solenoid operated valve. The valve is a poppet type which is spring-loaded to the closed position. The valve opens when the solenoid is energized. The solenoid is controlled by a normally closed pressure switch which is set to open at an absolute pressure of 6 pounds per square inch.

When the aircraft reaches an altitude of approximately 20,000 feet ambient air pressure will be approximately 6 PSIA. The pressure switch contacts then open, which removes power from the solenoid valve. The solenoid deenergizes and the spring closes the poppet valve. This cuts off high pressure air to the ejector nozzles, which reduces the volume of air flowing through the nacelle.

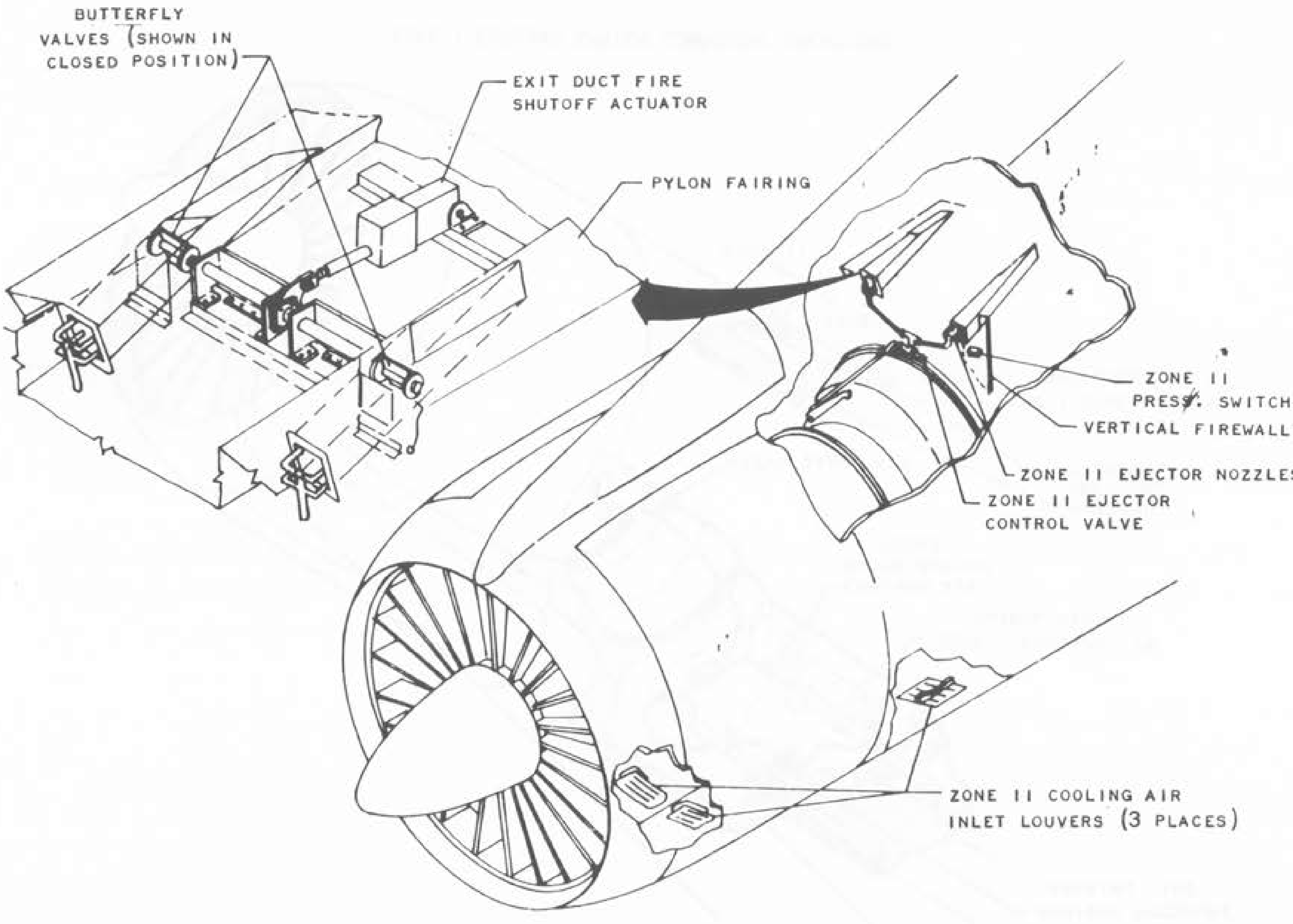
When the aircraft descends below approximately 20,000 feet the above action is reversed. The pressure switch contacts close, completing a circuit which energizes the solenoid. The poppet valve opens and allows high-pressure air to flow through the ejectors, causing more air for cooling to flow through the nacelle.

Located in each ejector duct is a butterfly valve. The butterfly valves are connected through common linkage to an actuator. The actuator is motor-driven and is controlled by the fire emergency handle for its respective engine. The butterfly valves, normally, are in the open position. In the event of fire the emergency handle is pulled, energizing the actuator to close the butterfly valves. This permits the fire extinguishing agent to be concentrated on the fire.

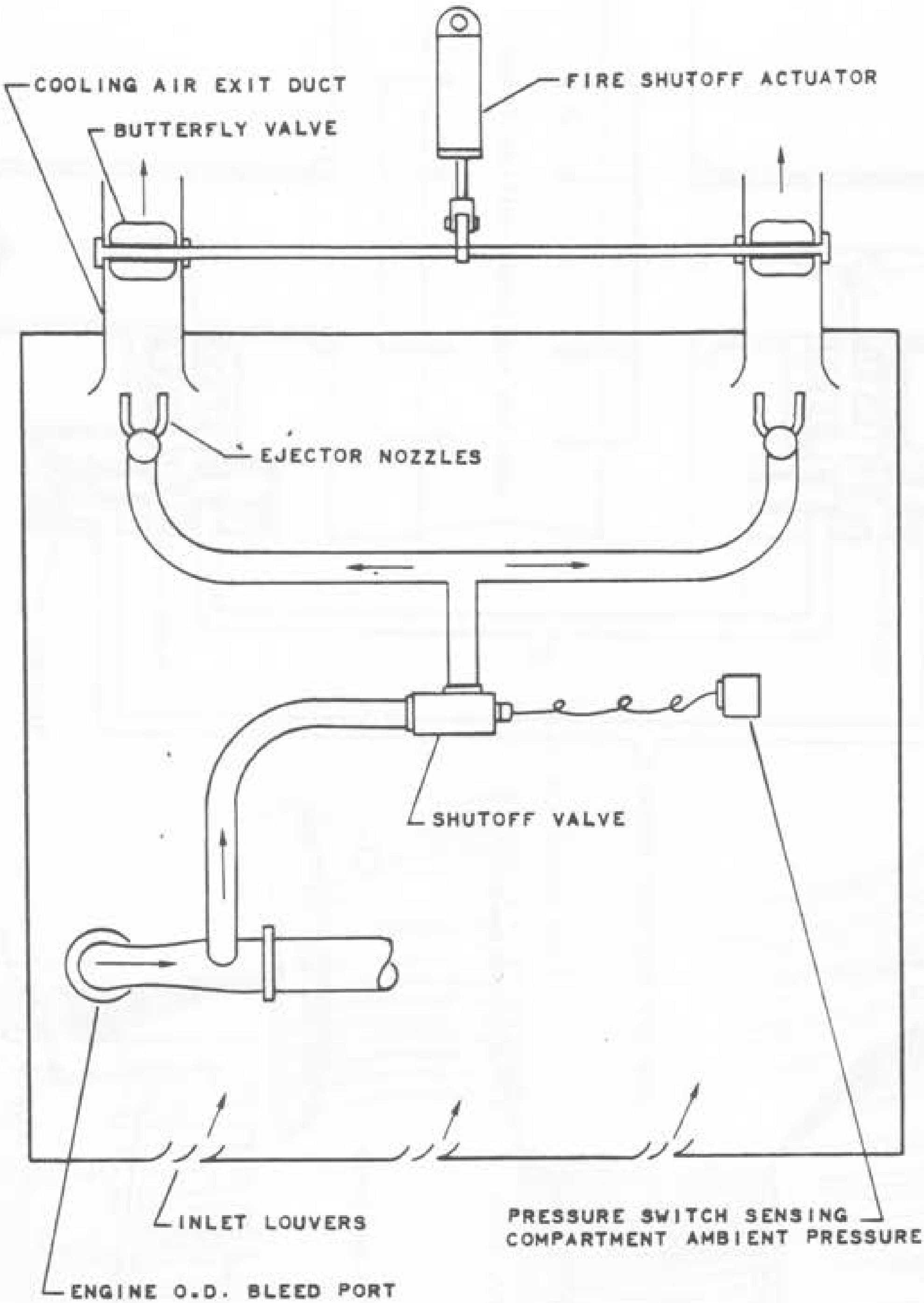
Two blowout doors are located in the bottom of the Zone II nacelle to provide



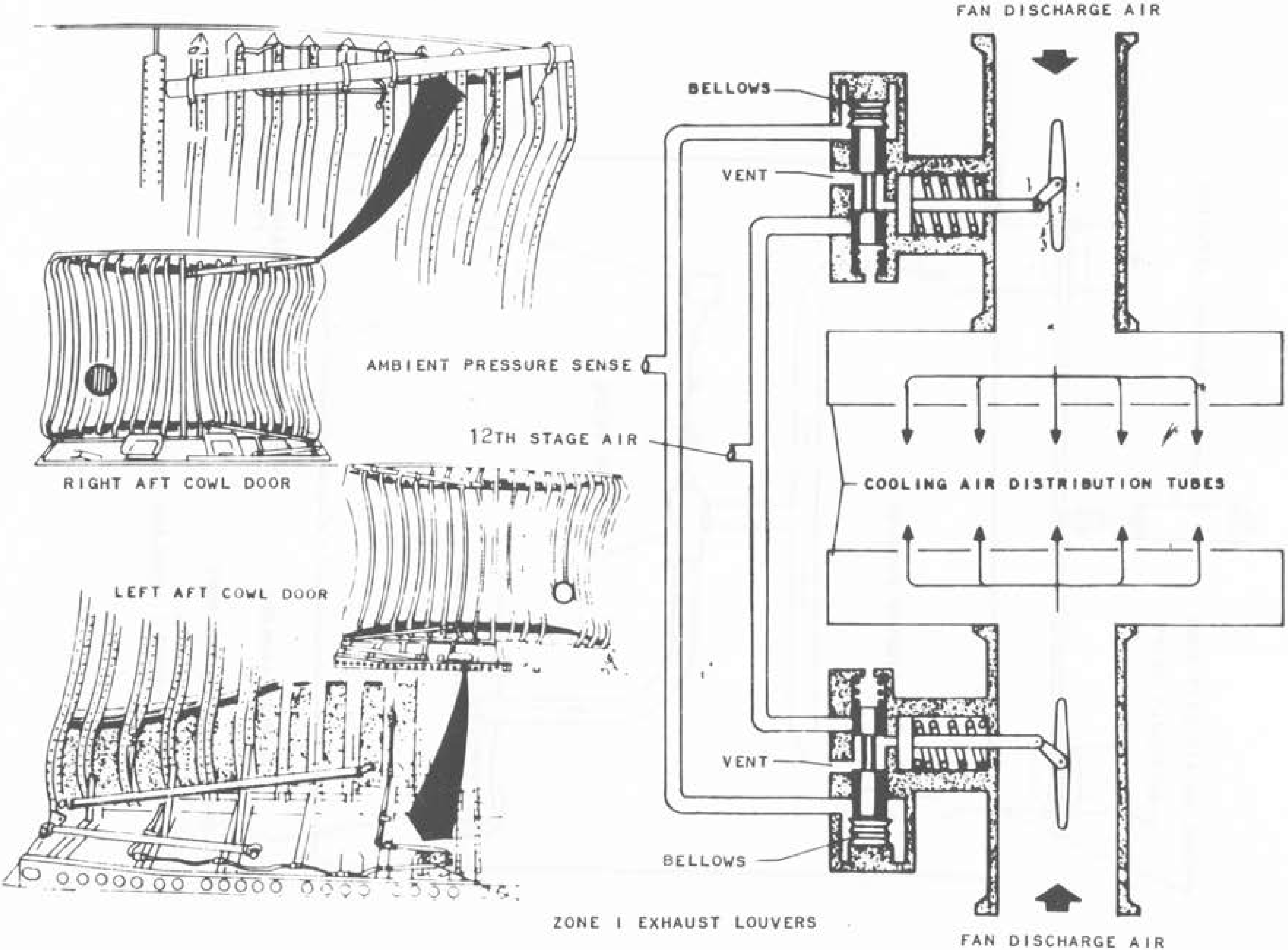
ZONE I COOLING SYSTEM COMPONENT LOCATIONS



ZONE II COOLING SYSTEM COMPONENT LOCATIONS



ZONE II COOLING SYSTEM SCHEMATIC



ZONE I COOLING SYSTEM SCHEMATIC

relief should cooling air pressure become excessive. These doors are normally spring-loaded closed.

ZONE I COOLING.

Zone I cooling is provided to reduce the temperature in the "hot" section of the engine nacelle. Cooling air for Zone I is bled from the upper side of both fan ducts. This air flows through two pneumatically controlled valves into two perforated tubes attached to the aft cowl doors. Air is distributed from these tubes into Zone I. Flow is downward through the Zone I area and out louvers located on the bottom of the cowl doors.

The two pneumatic valves which control Zone I cooling air consist basically of a butterfly valve connected to a piston. Air pressure for operation is extracted from the twelfth stage of the engine. Control of the actuator is accomplished by a shuttle selector valve connected to an evacuated bellows.

Below 10,000 feet altitude the bellows will be compressed allowing the shuttle valve to block twelfth-stage air from entering the actuator chamber. At this time the actuator spring will be extended, holding the butterfly open to admit cooling air to Zone I.

Above 10,000 feet altitude the bellows expands, allowing the shuttle valve to admit twelfth-stage air to the actuator chamber. The actuator spring will be compressed, holding the butterfly valve closed. This cuts off cooling air to Zone I.

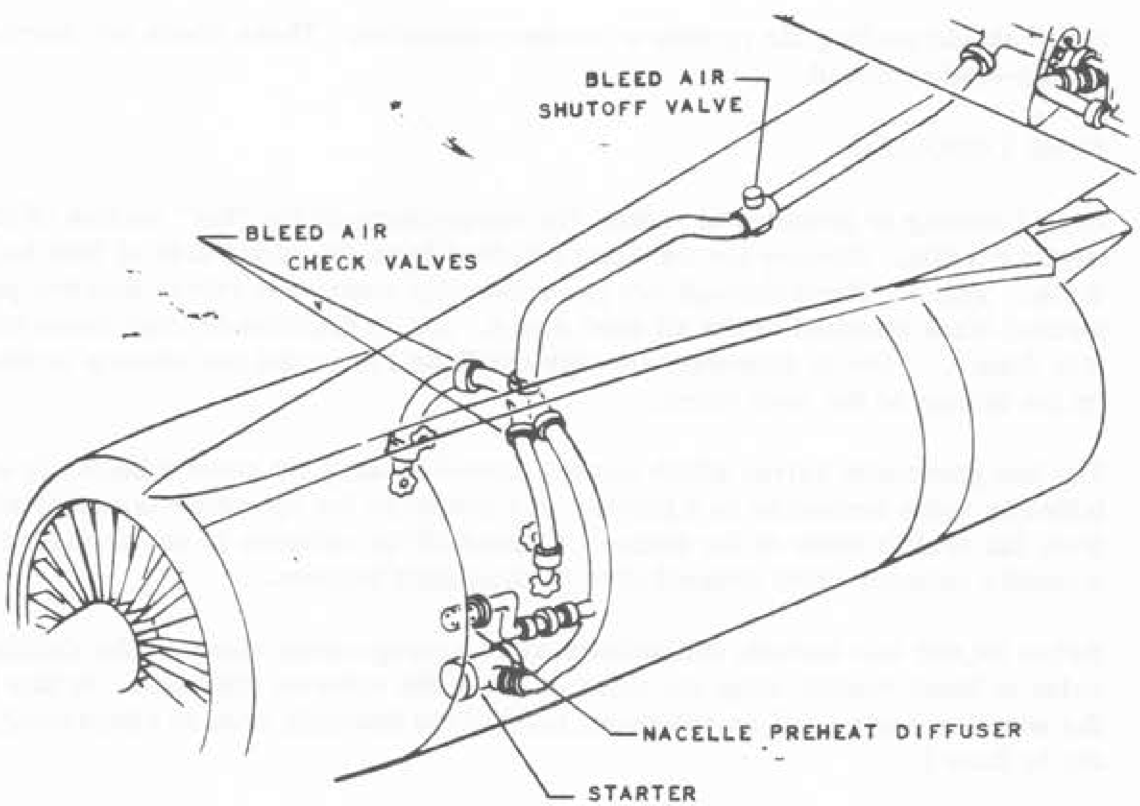
Two blowout doors are located in the bottom of the Zone I nacelle to provide relief should cooling air pressure become excessive. These doors are normally spring-loaded closed.

NACELLE PREHEAT SYSTEM.

A nacelle preheat system is provided for preheating the engine and accessories in extremely cold conditions. The system conducts air from the aircraft bleed air system through a shutoff valve and a nacelle preheat valve into each nacelle. Preheating air may be supplied from the Auxiliary Power Unit (APU), an external compressor, or any engine which is operating.

The preheat valves are poppet type, solenoid-controlled. The valve consists principally of a spring-loaded poppet and a switcher ball controlled by a solenoid.

When the valve is closed, upstream air flows around the poppet and is blocked at the valve outlet by the poppet being held against its seat. A small port delivers upstream air to the switcher ball which in connected to the solenoid. In the "OFF" (deenergized) position, the spring causes the switcher ball to block the ambient

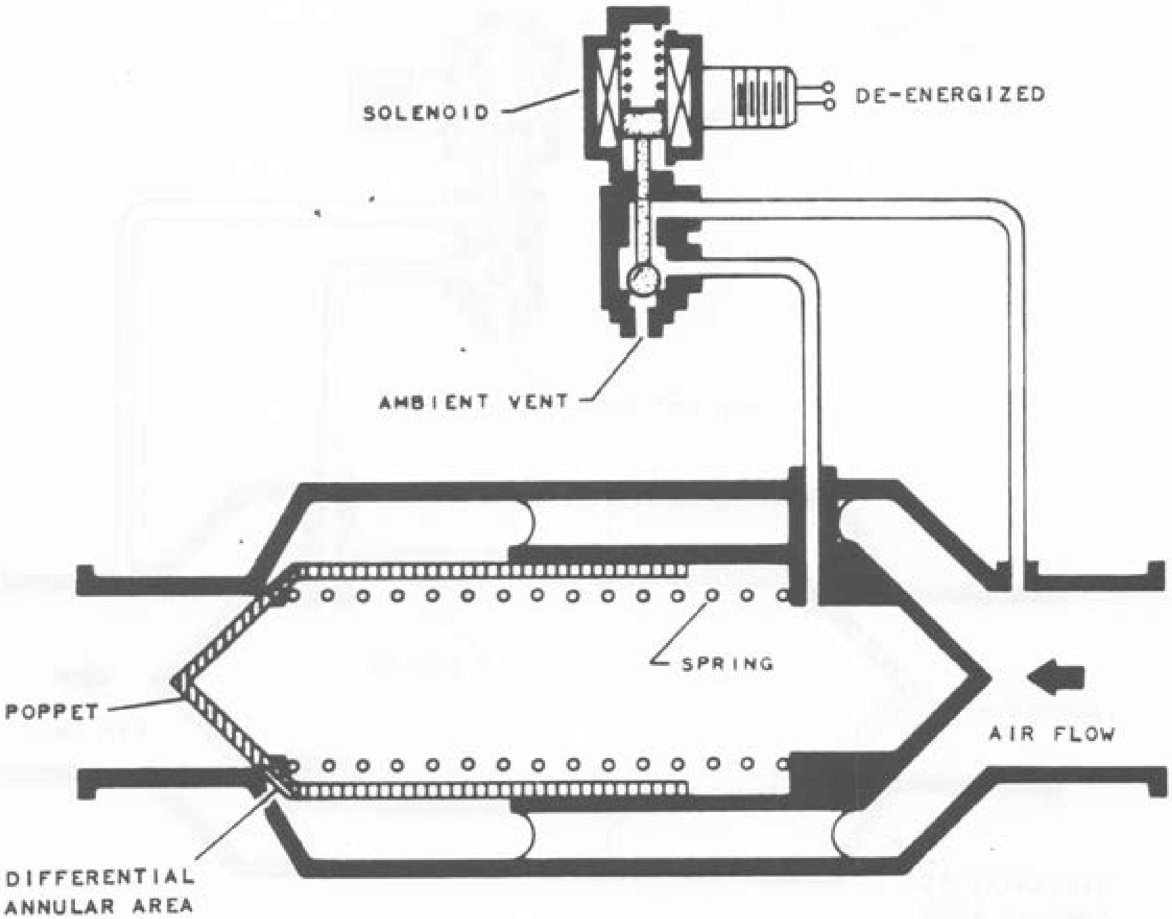


ENGINE BLEED AIR LINES

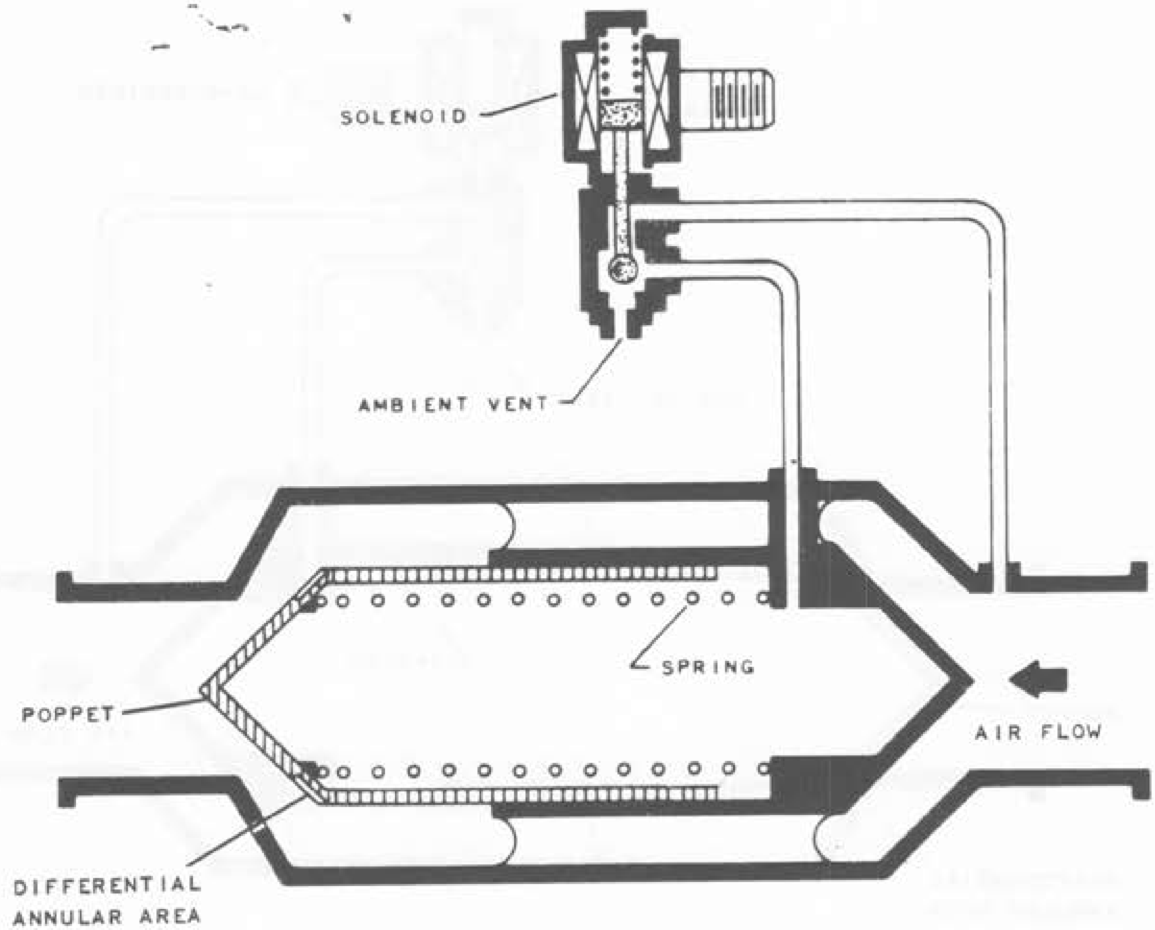
vent, thereby routing air into the spring side of the poppet valve. Since the area exposed to upstream pressure on the inside of the poppet is much greater than that exposed at the poppet seat, the spring holds the valve firmly against its seat.

When the valve is selected to open, the solenoid is energized, causing the switcher ball to block the upstream air port and to open the poppet piston port to ambient pressure. Pressure inside the poppet becomes much less than that felt on its downstream face, causing the poppet to compress the spring and move to the open position.

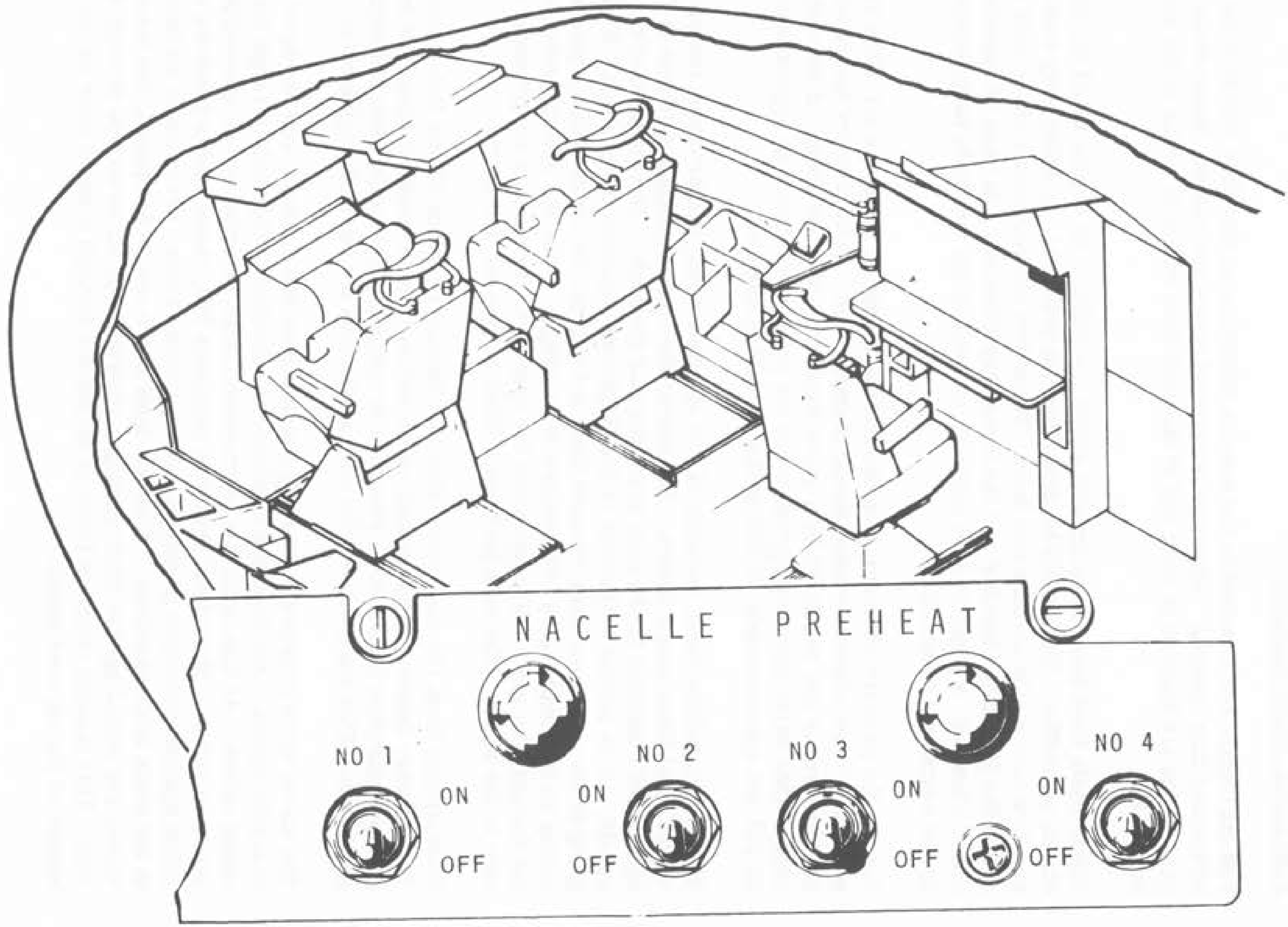
The NACELLE PREHEAT switches, located on the flight engineer's panel, control the nacelle preheat valves. When a particular nacelle is to be heated, the bleed air shutoff valve for that engine must be opened to allow air to flow to the preheat valve. The NACELLE PREHEAT switch for the same engine can then be placed "ON" to accomplish the preheating. The nacelle preheat system does not operate in flight since the valves receive their power only when the touchdown relay contacts are closed.



PREHEAT SHUTOFF VALVE (CLOSED)



PREHEAT SHUTOFF VALVE (OPEN)


NACELLE PREHEAT
NO 1
ON
OFF
NO 2
ON
OFF
NO 3
ON
OFF
NO 4
ON
OFF

FAN DUCT SEAL SYSTEM.

Fan duct seals are attached to the nacelle structure so that they encircle the bifurcated duct opening. When the large cowl doors are closed, these seals prevent fan air leakage at each end of the cowl door where it mates to the nacelle structure.

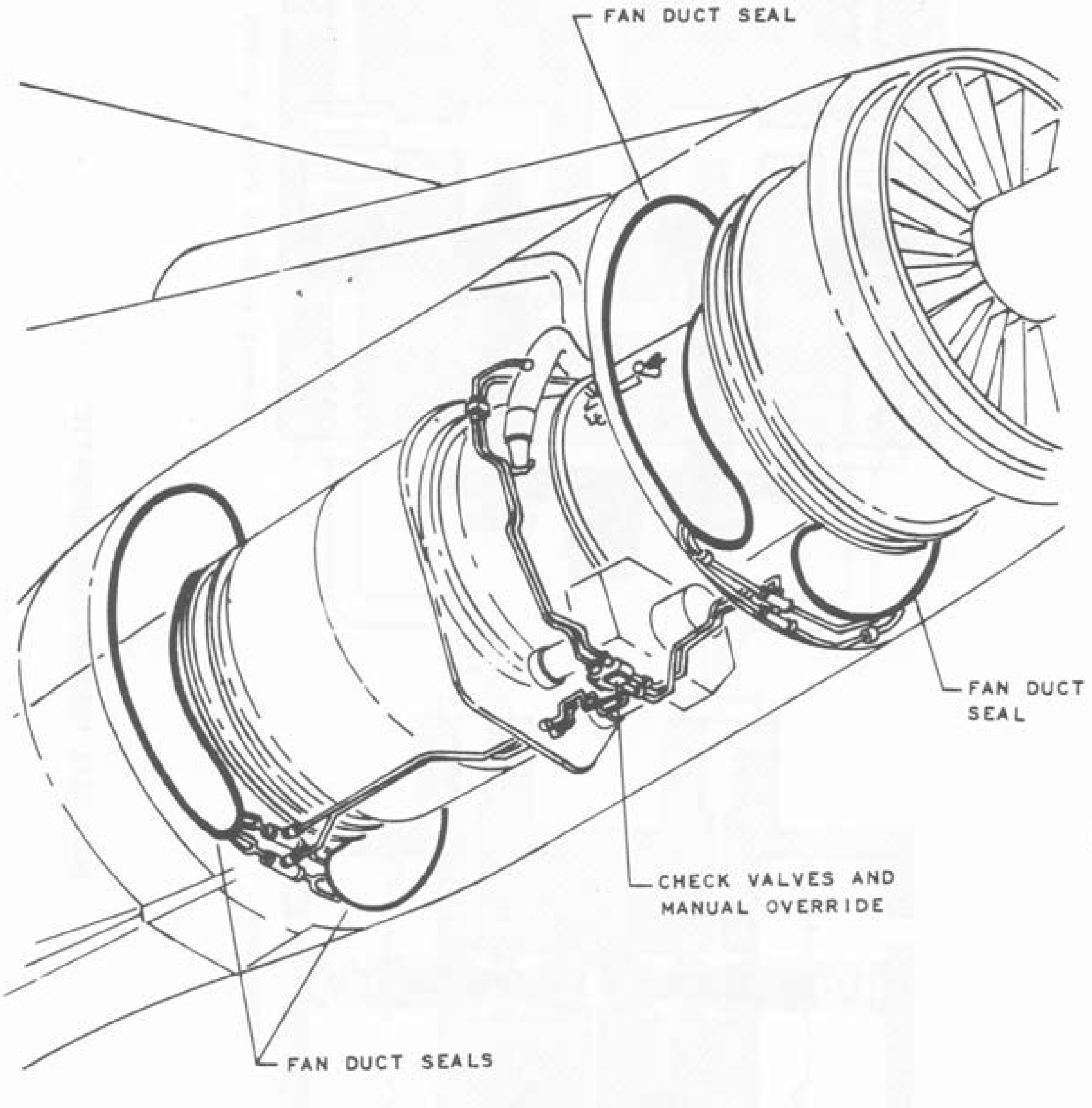
These seals have two compartments which are inflated by engine bleed air during engine operation. They could be described, in principle, as being very similar to a tire tube inside another tire tube. These two compartments of the seal are called the Primary Chamber and the Secondary Chamber. In case of rupture of either chamber, a positive seal between sections of the fan ducts is maintained by the remaining chamber.

Air for the primary chamber is sixteenth-stage outside diameter air while the secondary uses sixteenth-stage inside diameter air. Both primary and secondary seal pressures are regulated by a valve located on the rear flange of the diffuser case. This valve maintains pressure in the primary chamber at approximately 24 PSI and approximately 21 PSI in the secondary chamber.

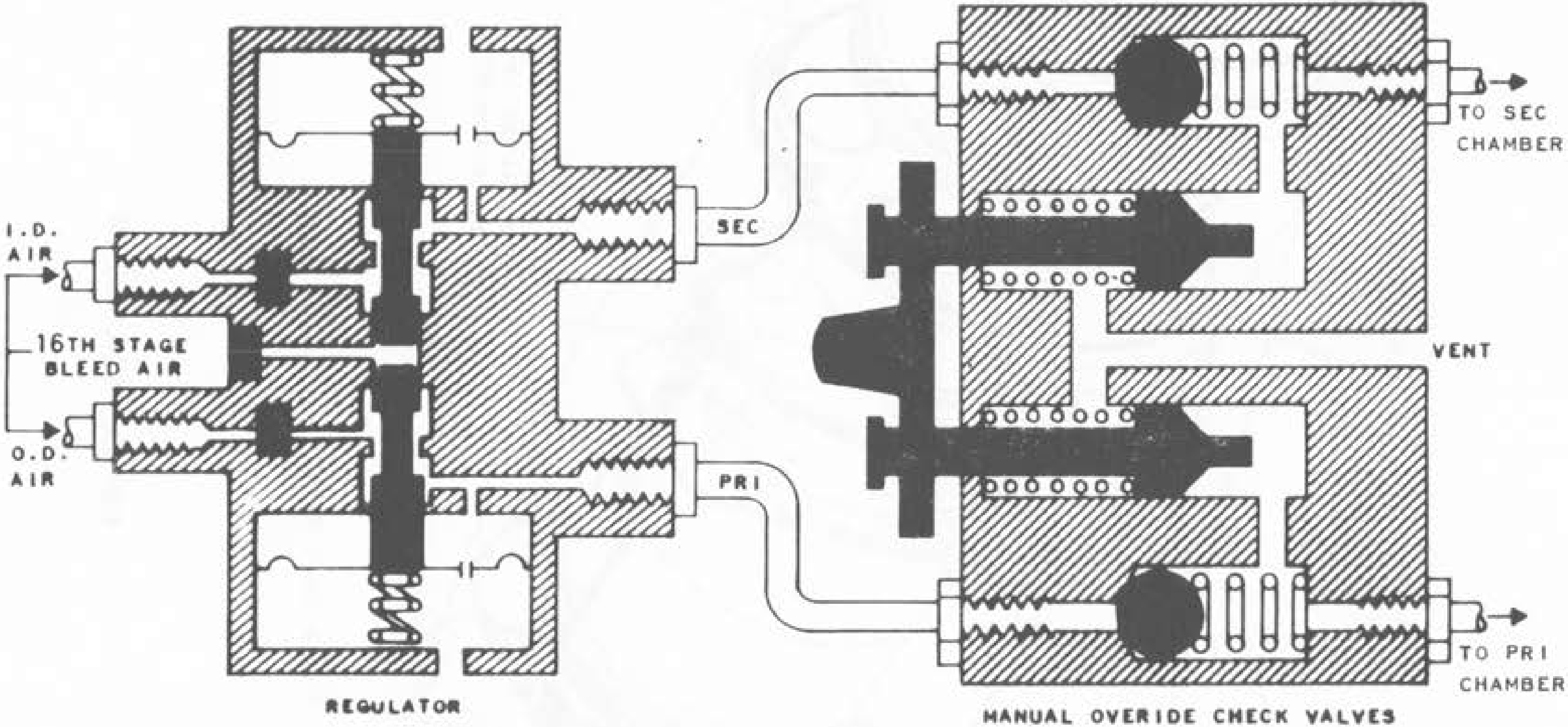
The dual regulator valve consists of two spring-loaded, diaphragms, two spool valves, and three small filters. Air enters the valve through the filters to the spools and continues to the next assembly and the seals. Downstream of the spools, air is ported to the side of the diaphragm opposite the springs. If air going to the seal chambers exceeds their set values, the increased air pressure acting on the diaphragms compresses the springs. When the springs compress far enough, the spool valve uncovers the vent port, decreasing air pressure being sent to the seals. The vent port has a filter to prevent dirt entry.

Downstream from the regulator valve is a Manual Override Check Valve assembly. The primary function of these dual check valves is to prevent reverse flow in the seal pressurizing lines, e.g. pressure is trapped in the seals when the engine is shut down. This ensures that the seal is effective for the next engine start.

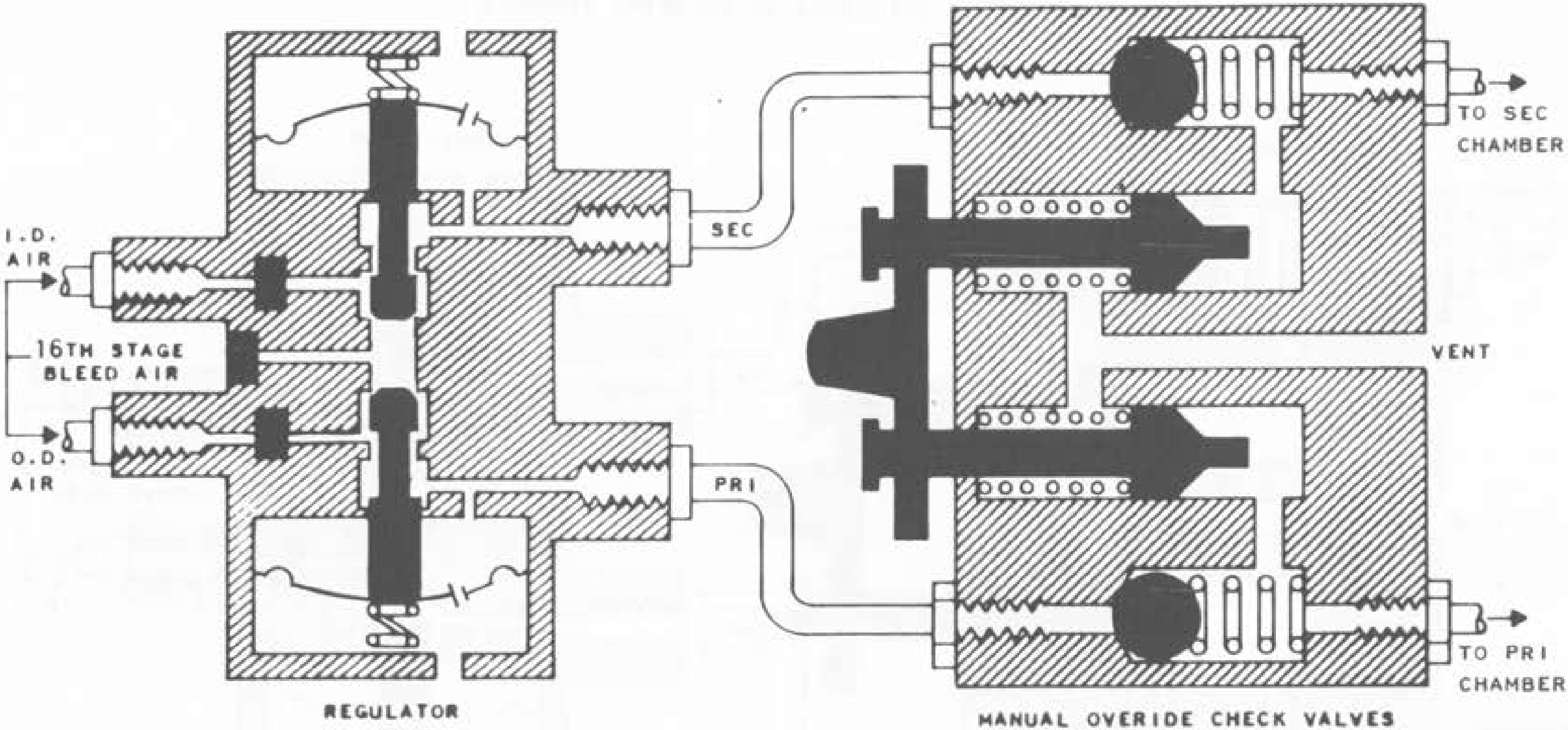
The above valve consists of two ball check valves and springs, and two spool-type override valves. Air from the regulator is admitted to the seals through the ball check valves. At this time, air is prevented from escaping by the spool-type override valves. Should the pressure regulator fail, these spools provides a relief against excessive pressure. As mentioned above, pressure is maintained in the seals after shutdown. When the cowl doors are to be opened, the spool valves are pulled against their springs, allowing seal air to escape through the vent. This manual override lever is accessible through a small door on the bottom of the aft cowl panel.



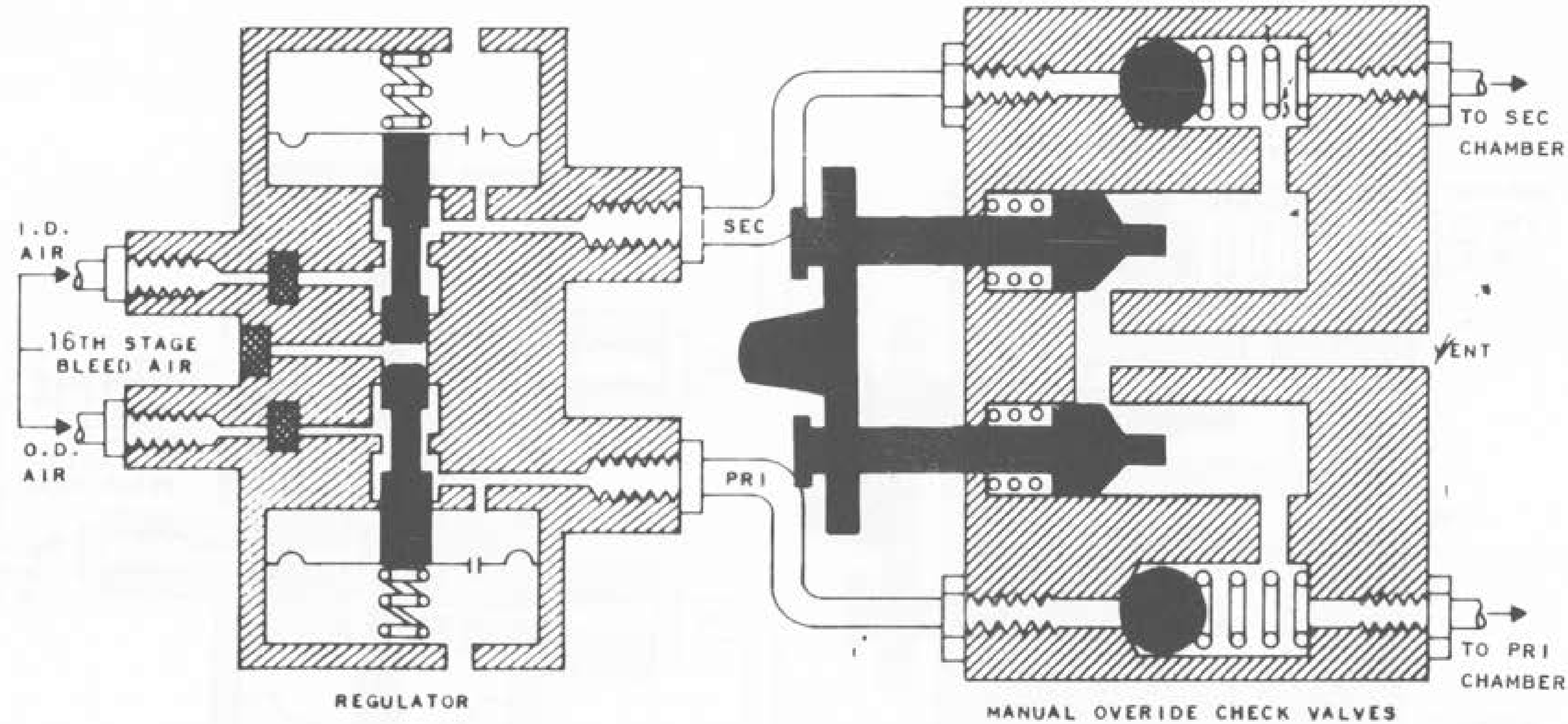
FAN DUCT SEAL SYSTEM



DOOR SEAL PRESSURIZING SCHEMATIC



DOOR SEAL PRESSURIZING SCHEMATIC (REGULATING)

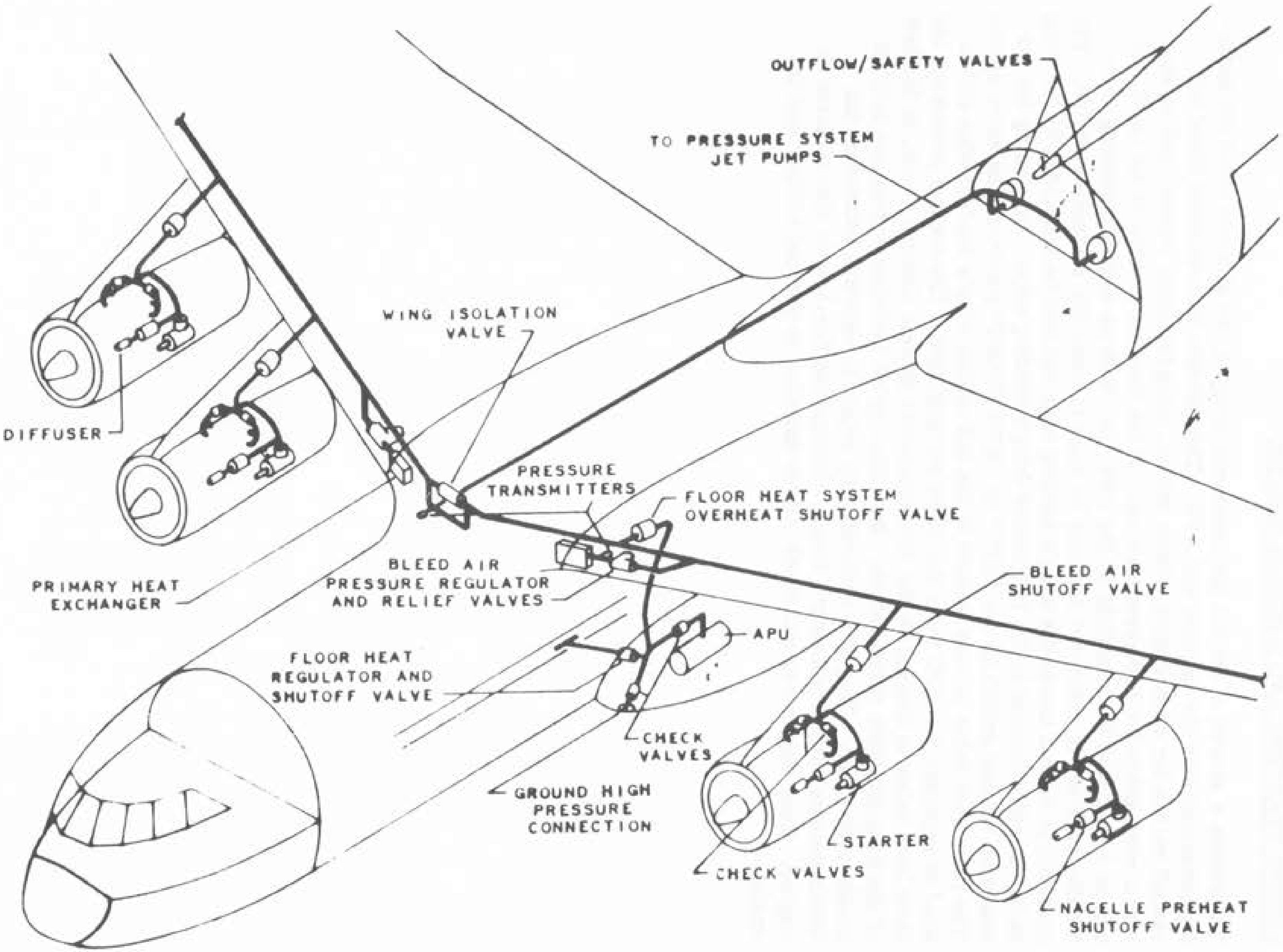


(MANUAL OVERRIDE OR EXCESSIVE PRESSURE)

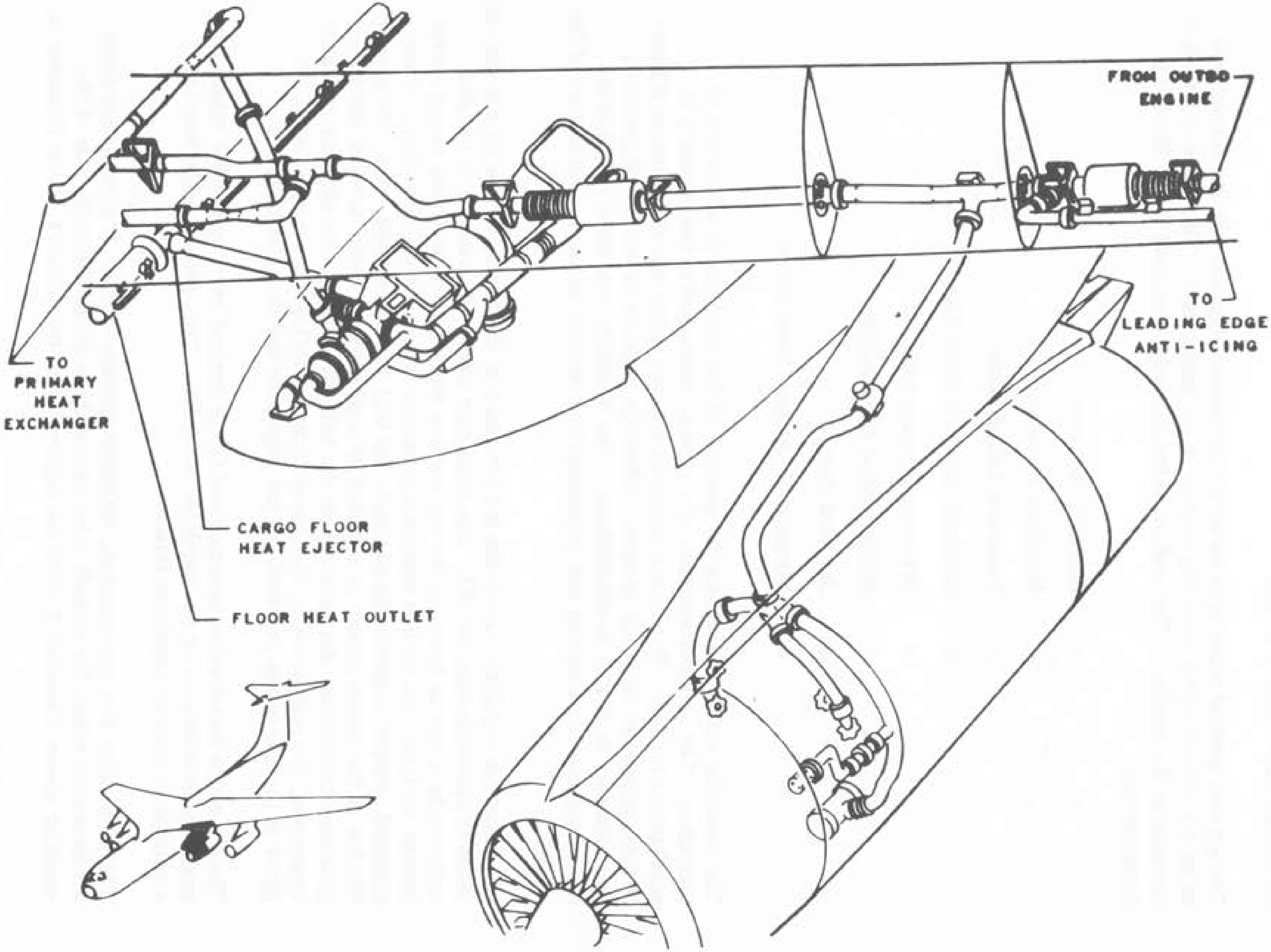
DOOR SEAL PRESSURIZING SCHEMATIC

ENGINE STARTING AND IGNITION SYSTEM.

To provide a source of air for the pneumatic starter, an aircraft bleed air manifold interconnects the engines and APU. This system incorporates bleed air shutoff valves for each engine, check valves, wing isolation valves, and an external connection for high-pressure air. If the external source is not used, air can be supplied to the manifold by the APU, or, with an engine operating, sixteenth-stage air is extracted and may be used to start any remaining engine. The manifold is routed inside the wing's leading edge and can be separated by the wing isolation valve located in the left center wing's leading edge. By placing the air condition master switch in the "APU" or "ENG START" position, the valve opens. The floor heat valve is also located in the left center wing's leading edge and is used to separate the APU from the bleed air manifold. The control switch for the floor heat valve is located on the Environmental System Control Panel, to the left of the wing isolation valve switch. Individual pylon isolation valves are located inside each pylon. They are controlled by separate switches located on the Environmental Systems Control Panel. Pulling the fire handle also isolates an engine. Each engine has two check valves installed to prevent airflow into the engine.



BLEED AIR SYSTEM COMPONENTS



ENGINE BLEED AIR COMPONENT LOCATIONS

STARTER 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 is attached directly to the starter. The control valve assembly consists of the following components:

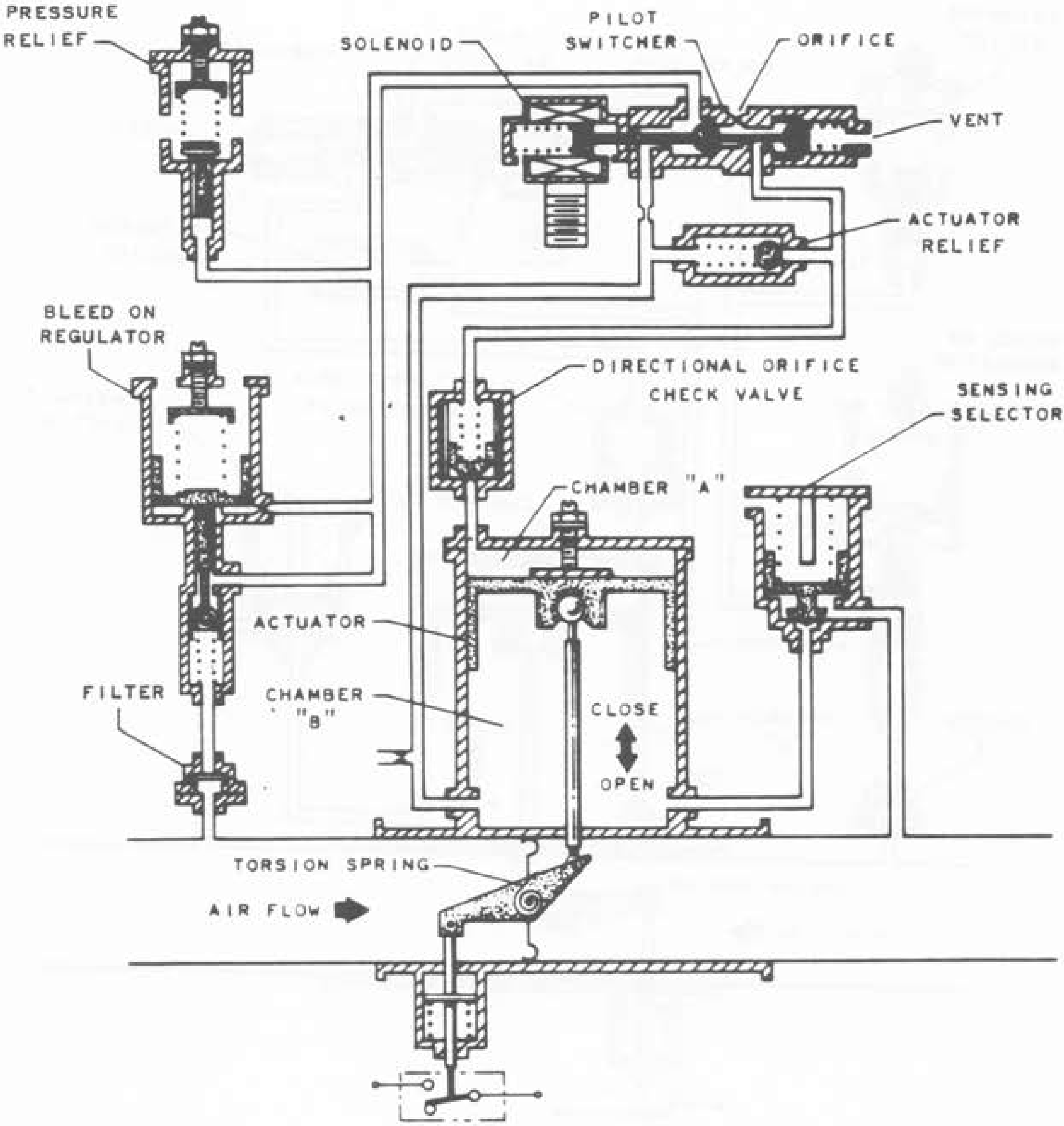
- o Butterfly Actuator
- o Bleed-on Regulator
- o Pressure Relief Valve
- o Solenoid-Actuated Pilot Valve
- o Pressure Sensing Selector
- o Starter Valve Open Switch
- o Actuator Relief
- o Directional Orifice Check Valve

The butterfly actuator controls the position of the butterfly in all modes of operation. The actuator consists of a piston, connected to the butterfly by mechanical linkage. Pneumatic pressure applied to the top of the piston (Chamber A) causes the butterfly to open. When the valve is in the closed position, this chamber is vented to atmosphere. The butterfly is normally held in the closed position by a spring and by pneumatic pressure acting on the bottom of the piston.

The bleed-on regulator limits the air pressure in the regulator line to a maximum value of approximately 40 PSI. The regulator assembly consists of a piston actuated by a spring force on the top surface and inlet air pressure acting on the bottom surface. An orifice dampens pressure surges during operation. A mechanical plunger connects the piston to the ball of a ball-check valve. Proper tension of the piston spring is adjusted by a setscrew. Under no-flow and no-pressure conditions, the piston holds the ball off its seat. As inlet air pressure increases, the piston rises, thus permitting the ball to approach its seat. A filter is located in the line between the regulator and the inlet manifold.

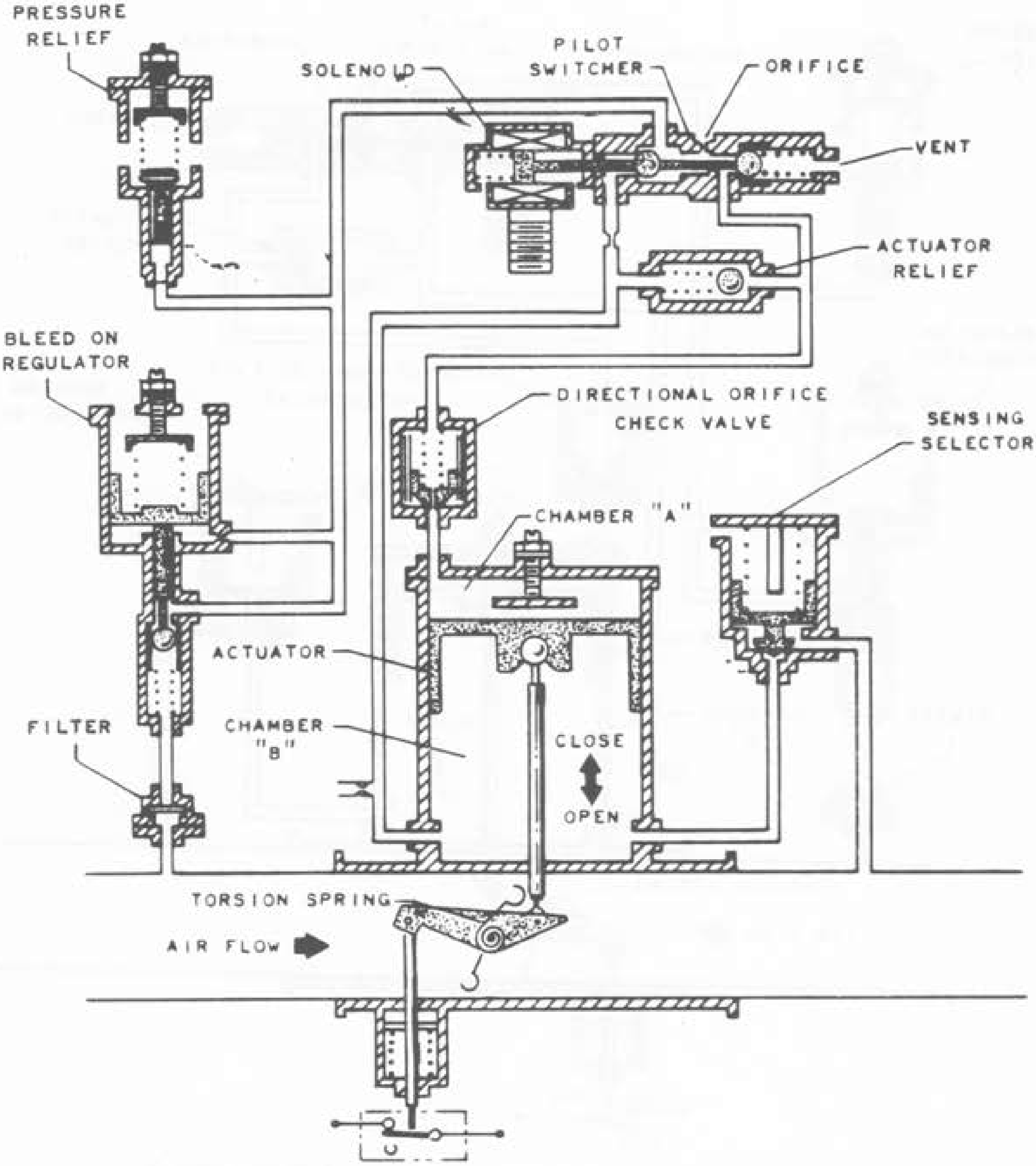
The pressure relief valve incorporated in the control valve limits the maximum pressure downstream of the regulator to 45 PSI. This pressure limiting is available in case of regulator failure.

The pilot valve is a two-position, solenoid-actuated valve. It directs regulated air pressure within the shutoff valve assembly to either the underside of the actuator piston Chamber B or to the upper side of the actuator piston Chamber A.



AIR PRESSURE REGULATOR & SHUTOFF VALVE (BLEED OFF)

The valve consists of a dual ball valve which is held in a normal position by a spring-loaded plunger. When the pilot valve solenoid is energized, it causes the plunger to move against the spring. The second ball is also moved by the piston. The two balls are thereby positioned by the solenoid to permit regulated air pressure to be ported to Chamber A. The lower area Chamber B is vented to atmosphere. The butterfly is then open. When the solenoid is deenergized, the dual-ball valve permits regulated pressure to flow to Chamber B. At the same



AIR PRESSURE REGULATOR AND SHUTOFF VALVE (INITIAL ACTUATION)

time, Chamber A is vented to atmosphere. The butterfly is then closed.

The actuator relief valve is located in the pressure line between the pilot valve and Chamber A. It is a ball-check valve which is spring-loaded against regulated pressure. It relieves regulated pressure to Chamber A momentarily as the butterfly begins to open. The actuator relief ensures that opening regulating pressure is allowed to rise very little above Chamber B pressure, ensuring that the initial rate of the opening of the butterfly is relatively slow.

STARTER SYSTEM.

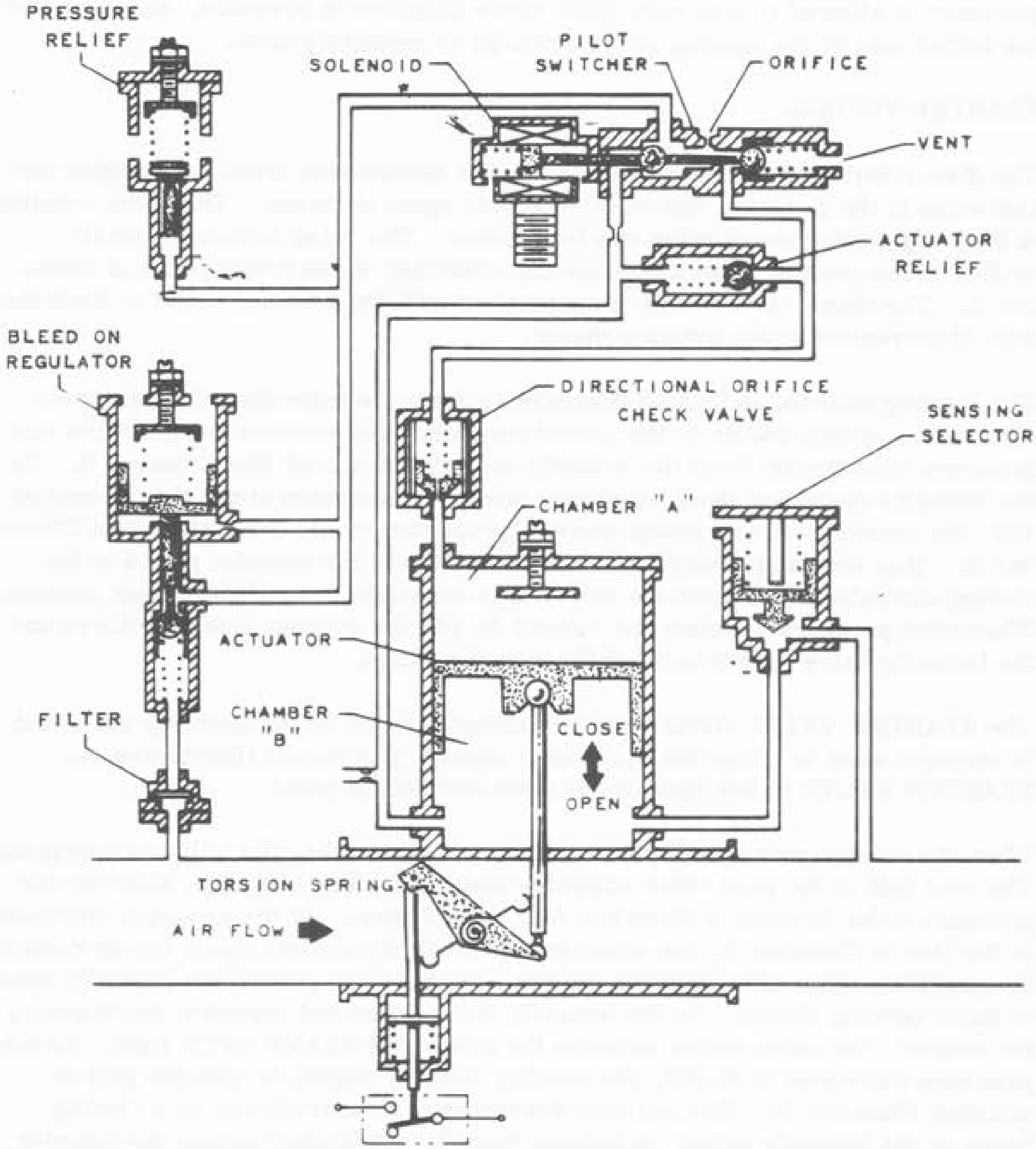
The directional orifice check valve is located downstream from the actuator relief valve in the pressure line to the actuator upper chamber. The valve consists of a spring-loaded check valve and its housing. The valve contains a small orifice which permits restricted flow into Chamber A and freeflow out of Chamber A. The check valve works in conjunction with the actuator relief to limit the rate of movement of the actuator piston.

The sensing selector is located downstream from the butterfly. It is a piston-type valve, spring-loaded to the closed position. The selector permits flow and pressure downstream from the butterfly valve to be ported into Chamber B. As the butterfly opens and the downstream pressure increases above the desired 40 PSI, the sensing selector piston moves upward and allows the airflow into Chamber B. This action applies downstream pressure to the actuator piston in the closing direction and causes the butterfly to modulate at a partially open position. When inlet pressure is below the desired 40 PSI, the sensing selector closes and the butterfly valve moves to the fully opened position.

The STARTER VALVE OPEN switch is linked directly to the butterfly valve and is spring-loaded to follow the valve as it opens. The switch illuminates the STARTER VALVE OPEN light on the main instrument panel.

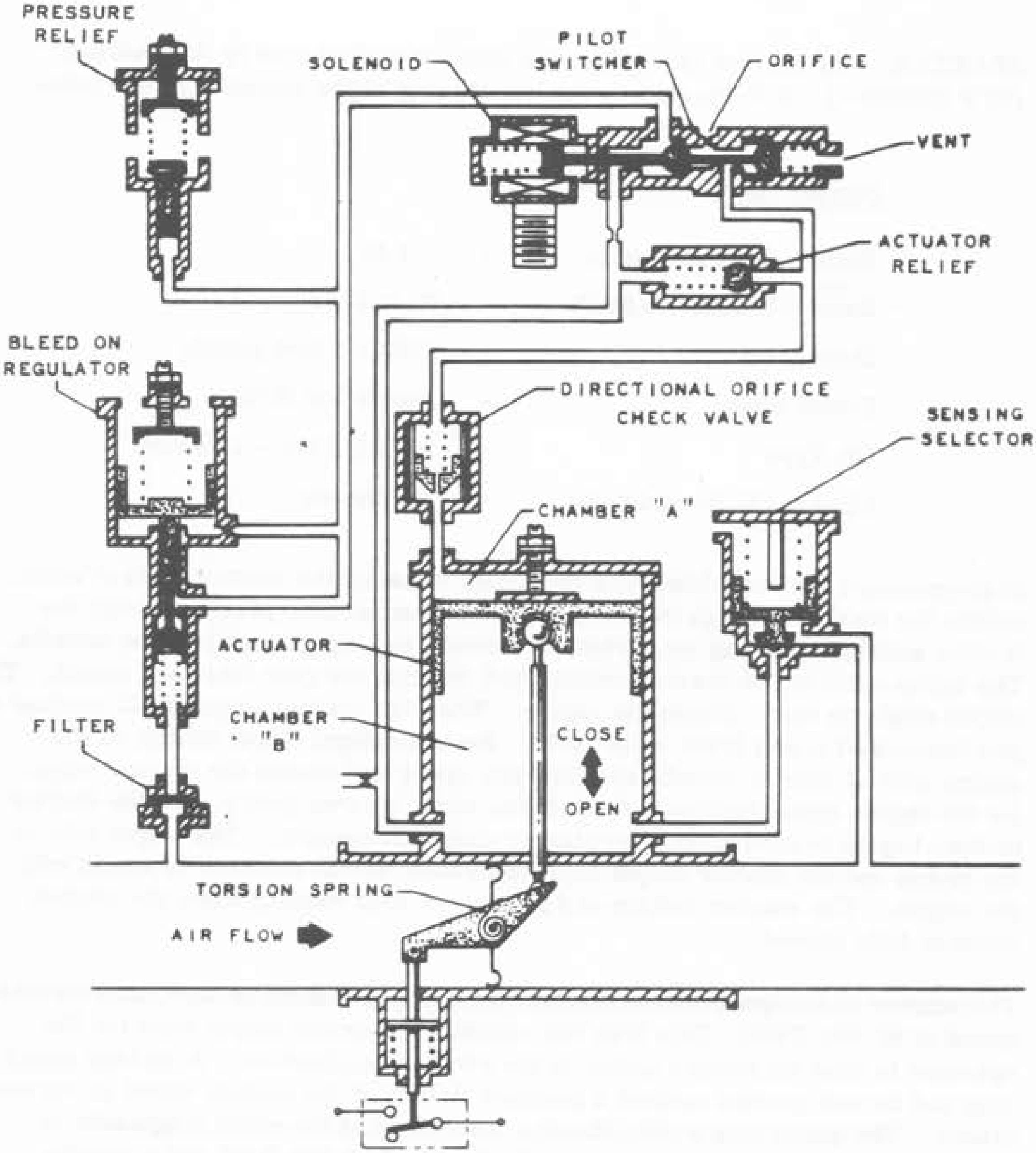
When the starter switch is depressed, the solenoid in the pilot valve is energized. The vent ball in the pilot valve assembly then closes the vent port, allowing air pressure to be directed to Chamber A of the actuator. As the pressure increases in the line to Chamber A, the actuator relief and directional check valves reduce the pressure differential between the two chambers and permit the butterfly valve to begin opening slowly. As the butterfly valve opens and pressure increases to the starter, the valve switch actuates the STARTER VALVE OPEN light. As the pressure increases to 40 PSI, the sensing selector begins to open the port to actuator Chamber B. This permits downstream pressure to act as a closing force on the butterfly valve. A balance force is established across the actuator, which causes the butterfly valve to modulate between fully open and fully closed.

The valve closing sequence begins when the starter speed switch actuates at a predetermined RPM and opens the circuit to the pilot valve solenoid and the starter switch. When the solenoid is deenergized, the plunger moves the directional ball valve to a position which directs regulated pressure to Chamber B. At the same moment, the vent ball valve is moved to the open position. As pressure is directed to Chamber B, the actuator moves upward. The directional orifice moves off its seat and allows Chamber A pressure to be vented to atmosphere



AIR PRESSURE REGULATOR AND SHUTOFF VALVE (MODULATING)

quickly. The butterfly valve closes rapidly. As downstream pressure drops, the sensing selector closes and Chamber B pressure rises, thus helping the torsion spring to close the valve completely.



AIR PRESSURE REGULATOR AND SHUTOFF VALVE (CLOSING)

STARTER. The starter is a pneumatic type, manufactured by AiResearch (P/N 356660-1). It is located on the left aft side of the accessory gear case.

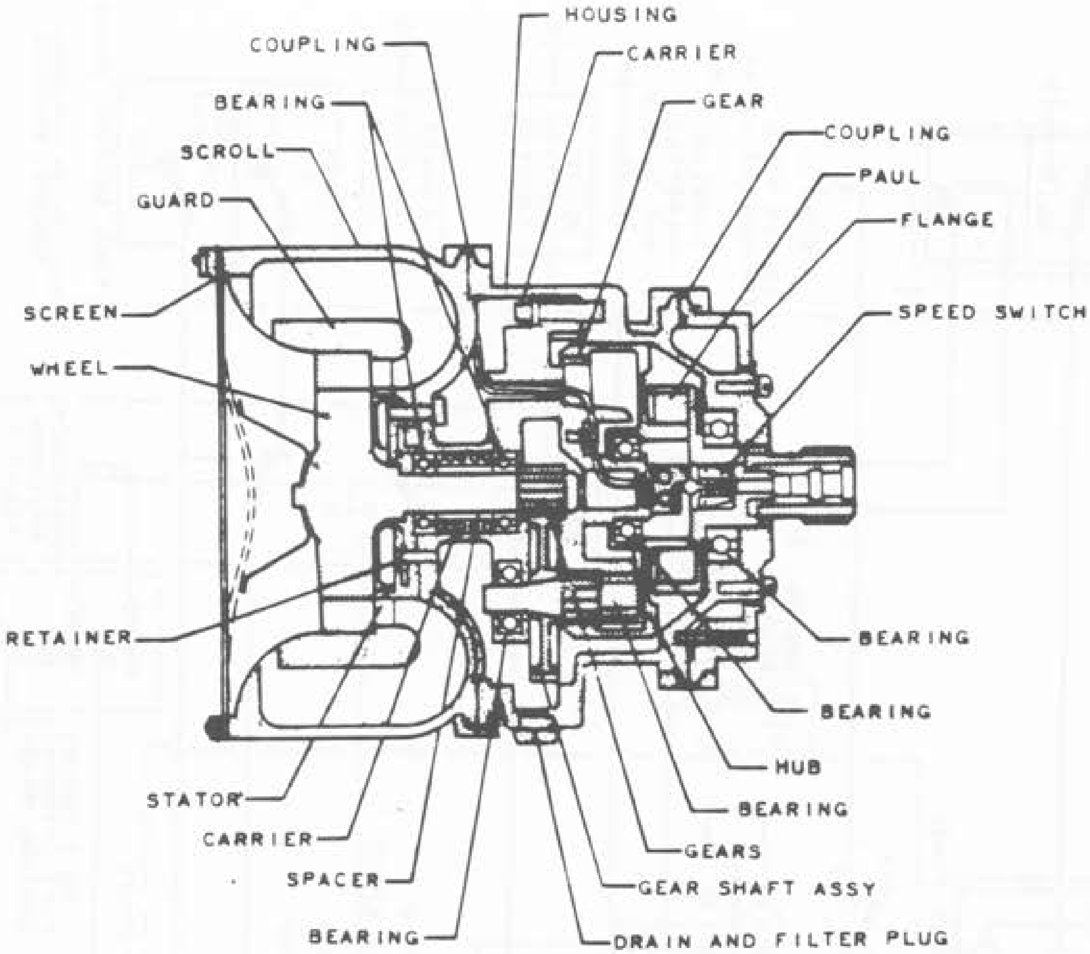
Starter Data:

Ratio - Shaft to Engine	-	0.7 to 1
Ratio - Turbine to Shaft	-	23 to 1
Shaft Shear	-	1050 + 5 foot pounds
Cutout Speed	-	2900 + 100 RPM
Oil Type	-	MIL-L-7808 - 11 ounce
Change Oil Periodically	-	No Checks

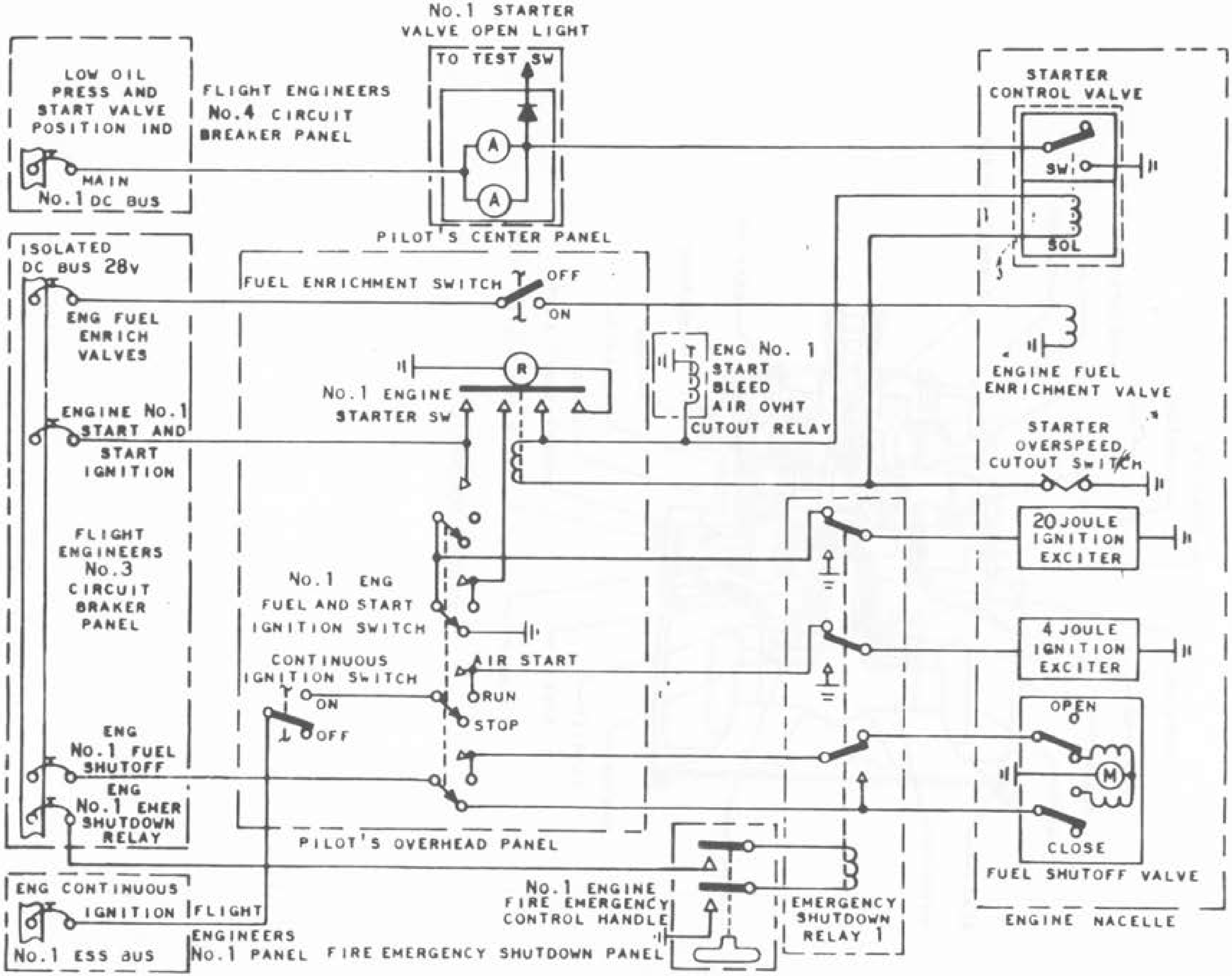
High-pressure air, regulated to a maximum value by the starter control valve, enters the starter through the inlet on the turbine scroll; passes through the turbine nozzles, causing the turbine to rotate; and discharged into the nacelle. The turbine drives the starter output shaft through the gear train and clutch. The output shaft, in turn, drives the engine. When the starter output shaft reaches a predetermined speed (2900 + 100 RPM), the centrifugal cutout switch on the engine side of starter clutch automatically opens and closes the starter valve. As the engine speed continues to increase under its own power, and the starter turbine begins to slow down, the starter clutch disengages. The output side of the clutch and the starter output shaft and cutout switch continue to rotate with the engine. The starter turbine and gear train stop rotating when the control valve is fully closed.

The starter is designed to free run for one minute, without failure, at a turbine speed of 95,000 RPM. This free run capability provides ample time for the operator to take corrective action in the event of malfunction. A turbine guard ring and screen protect against a possible failure of the turbine wheel or turbine blades. The guard ring safely absorbs the energy of the metal fragments resulting from turbine wheel failure up to speeds of 86,000 RPM and a turbine blade failure up to speeds of 117,500 RPM. The exhaust screen absorbs energy from any turbine failure which results in fragments discharged in an axial direction.

For installation and removal the starter incorporates a Quick Attach-Detach (QAD) feature. No major nacelle components components must be removed in order to install or remove the starter.



STARTER SCHEMATIC



ENGINE STARTING SYSTEM ELECTRICAL SCHEMATIC

IGNITION SYSTEM.

The ignition system consists of an ignition exciter, two high-tension ignition leads, and two spark igniters. The spark igniters are located in combustion chambers No. 4 and 5. The high-tension ignition leads carry the high-tension voltate from the ignition exciter to the spark igniters.

Two separate systems are incorporated in the ignition exciter. A 20-joule intermittent system is used for engine starts, and a 4-joule continuous system used for air starts and continuous ignition. When there is a possibility of upset air conditions at the engine inlet, the 4-joule ignition system may be used to prevent an inadvertent engine flameout. If one or both of the engine igniters are operating for the duration of the condition, a flameout can usually be prevented.

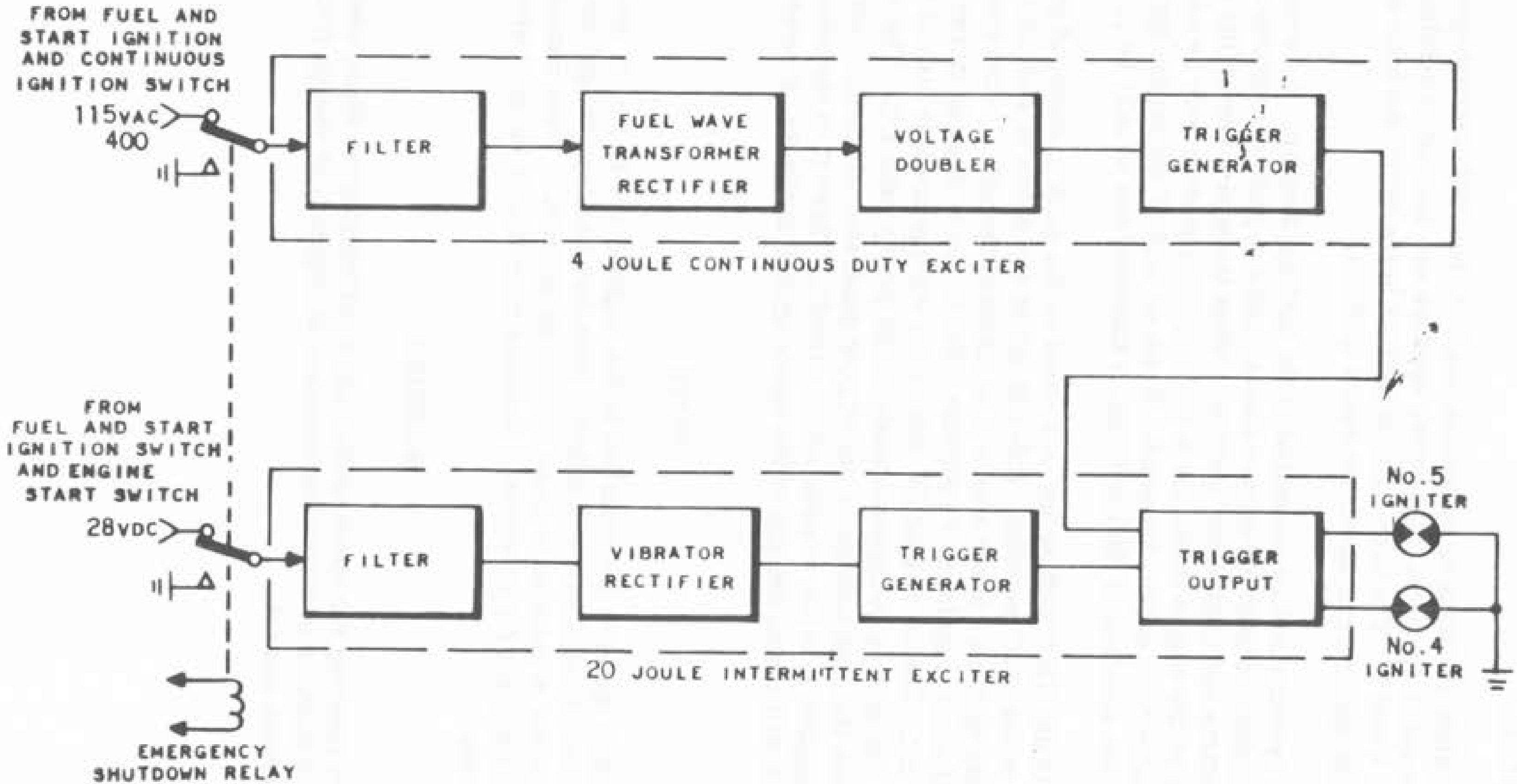
The CONTINUOUS IGNITION switch is located on the pilot's overhead panel. When placed in the "ON" position, 115-volt AC at 400 Hertz is sent into the continuous duty ignition exciter where it is directed through a radio noise filter and to the full wave transformer-rectifier. Here, the voltage is increased and converted to DC. The increased DC enters the voltage doubler circuit which, in turn, boosts the voltage to approximately 3,050 (±100) volts DC. The voltage doubler applies the high voltage to the trigger generator which increases the voltage and applies it to the trigger output circuit. There it is increased to a point where it will ionize the gap of the spark igniter in the No. 5 combustion chamber.

NOTE

Two spark igniters are installed in the engine: one in No. 4, and one in No. 5 combustion chamber. Both fire on 20-joule ignition, but only No. 4 fires on 4-joule continuous ignition. When removed, visually inspect for condition. Extreme care should be used when removing.

WARNING

Before touching the spark igniter after performing the firing check, allow 3 minutes to elapse for complete dissipation of energy from the ignition system.



ENGINE IGNITION SYSTEM BLOCK DIAGRAM

OPERATION AND INDICATION.

When the starter switch is depressed, power is supplied through the switch, to energize the solenoid in the starter control valve; to one of the contacts in the FUEL & START IGNITION switch, and through the "RUN" position of that switch to the 20-joule ignition exciter. Power is also supplied through the starter switch to a holding coil, which holds the switch in the depressed position; and to the indicator light in the switch, indicating the starter circuit is energized. For cold-weather starting, a fuel enrichment switch is provided.

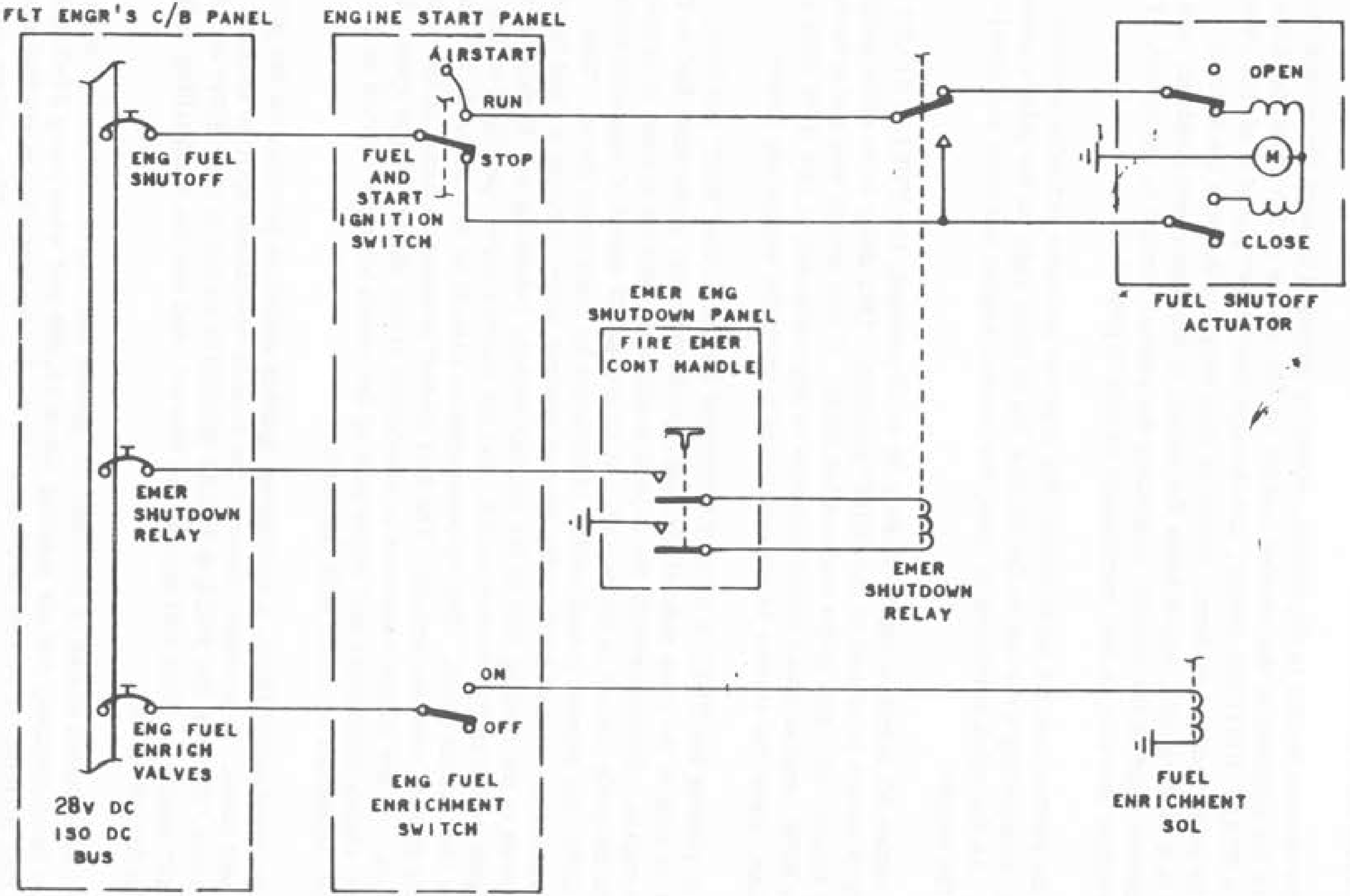
When the starter control valve opens, the position indicator actuates a micro-switch, completing a circuit to the Starter Valve Open light on the pilot's center panel. As the valve continues to open, the starter begins to rotate and accelerate the engine.

When engine N2 speed is approximately 13 to 18 percent, the FUEL & START IGNITION switch is placed to the "RUN" position. This delay is to allow purging of any fumes, etc. that might cause a hot start. If this switch was not actuated at this RPM, engine speed would increase to approximately 2,200 RPM (N2) and stabilize, since the starter is not capable of turning the engine any faster.

Also by placing the FUEL & START IGNITION switch to the "RUN" position, power is sent to the open side of the fuel shutoff actuator, permitting fuel to flow to the engine. Simultaneously the 4-joule continuous ignition system is armed, and the 20-joule circuit is energized. At an engine N2 speed of approximately 4150 RPM, the starter cutout switch is actuated by centrifugal force. This deenergizes the circuit back to the starter control valve, closing it, and breaks the circuit to the holding coil of the starter switch, releasing it. At this time, the lights go out in the starter switch, and the starter valve open light on the center instrument panel. The 20-joule ignition circuit is deenergized, but the 4-joule system remains armed. The fuel shutoff actuator remains in the open position. As the engine continues to accelerate above starter cutout speed, the starter clutch disengages and output side of the clutch which is splined to the engine, continues to rotate with the engine.

For air start capabilities, a continuous ignition switch is provided on the pilot's overheat panel. It provides power to the 4-joule continuous ignition exciter, with the switch "On" and the FUEL & START IGNITION switch to the "RUN" or "AIR START" position. This will bypass the starter, and use the windmilling of the engine for air starts.

A fuel enrichment switch is provided for ground starting of cold soaked engines at low temperatures, and air starting above 15,000 feet when using JP-5 fuel. The fuel enrichment system is designed to do this by supplying more fuel than normally required to the engine, through the fuel control. This system was



ENGINE FUEL SYSTEM ELECTRICAL CONTROL SCHEMATIC designed for use when fuel temperature is below freezing or anytime, during starting if JP-5 fuel is used. The FUEL ENRICHMENT switch is located on the pilot's forward overhead panel, near the FUEL & START IGNITION switch. When the fuel enrichment valve is actuated open, additional fuel bypasses the computing section of the engine fuel control unit and flows through the fuel shutoff valve to the burner nozzles. The system is designed so that enrichment fuel is automatically cut off when fuelflow reaches 1500 PPH. It should be turned off as soon after start as possible, to eliminate possible damage to the solenoid.

FIRE EMERGENCY SHUTDOWN HANDLE.

When the fire emergency shutdown handles are pulled, power is sent to the emergency shutdown relay which sends power to the close side of the fuel shutoff valve, closing it, and simultaneously removing power from both the 20-joule and 4-joule ignition exciters.

MISCELLANEOUS ENGINE SYSTEMS

The following systems, which are necessary for the proper operation of the JT3D (TF33) power plant, are included in this chapter:

- o Fire Protection System
- o Engine Indicating System
- o Constant Speed Drive
- o Thrust Reverser System

The fire protection system provides the ultimate in fire detection and fire extinguishing if such an emergency should occur. It also provides adequate protection to prevent the spread of fire to other aircraft systems and the airplane structure.

The engine indicating system is installed to ensure safety during engine operation and it serves as a means of monitoring engine performance.

The Constant Speed Drive (CSD) mechanically couples each engine to a 40/50 KVA generator which supplies 200/115-volt, three-phase, 400 Hertz AC. The CSD converts variable engine speed to maintain generator frequency output at 400 Hertz under changing conditions of electrical load.

The thrust reverser system permits reverse thrust application of engine power during landing, after touchdown. They are mechanically and electrically actuated and hydraulically operated.

FIRE PROTECTION SYSTEM.

The fire protection system is a combination of an overheat warning system, a fire detection system, and a fire extinguishing system. The APU fire warning and fire extinguishing system is covered under APU systems.

OVERHEAT WARNING AND FIRE DETECTION SYSTEM.

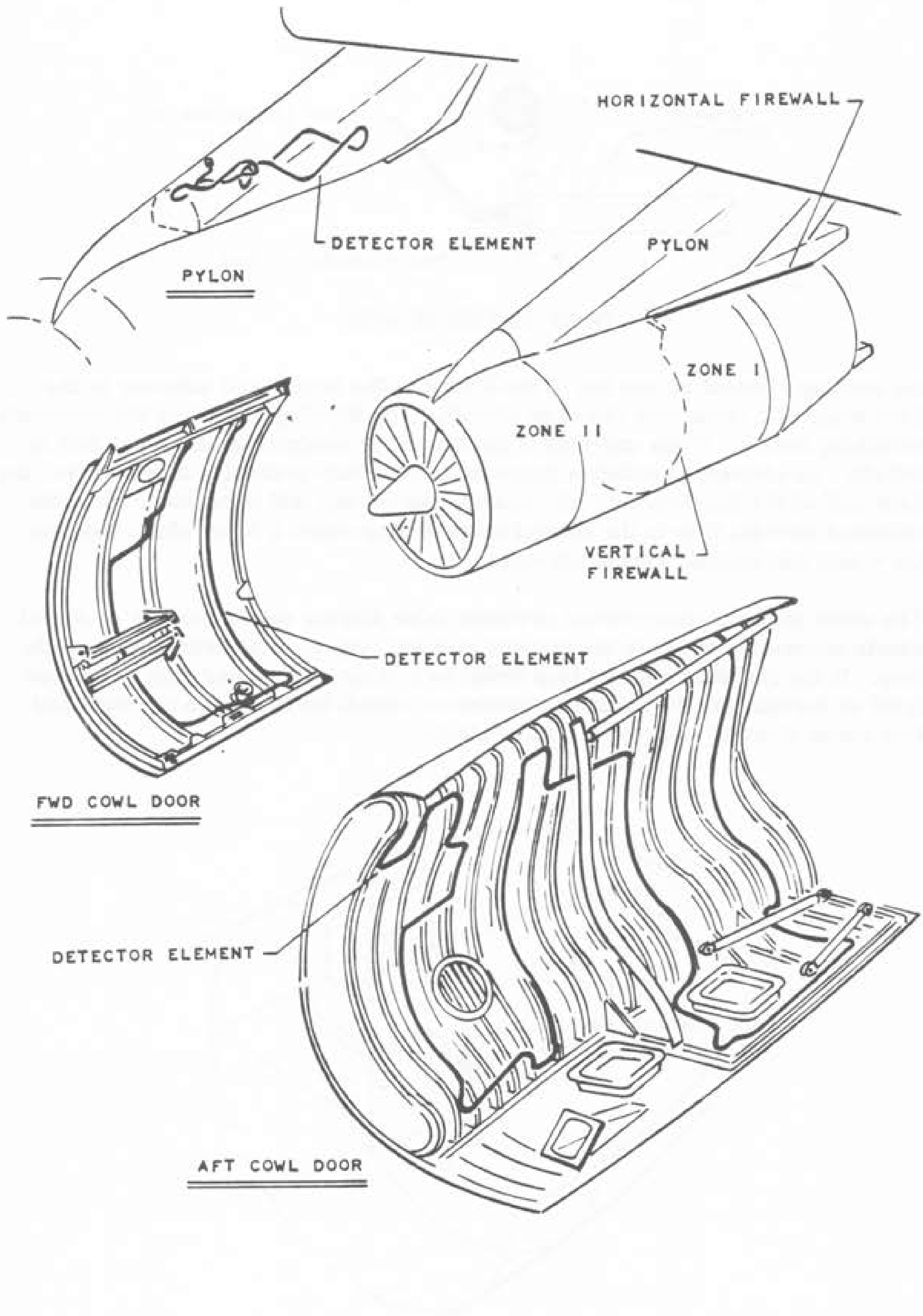
The engine, nacelle, and pylon of each power plant assembly are protected by a fire and overheat warning system. The system is composed of a continuous-loop, wire-like element routed through the areas where a fire or overheat condition could occur. The wire is a temperature-sensing element which is connected to a control unit. The control unit detects change in the resistance of the wire loop caused by a fire or an overheat condition and gives a visual and an audible warning to the flight crew.

Each power plant has three sections which are constantly monitored. They are Zone No. 1, which is aft of the vertical firewall; Zone No. 2, which is forward of the firewall; and the engine plyon. The pylon is separated from the other areas by a horizontal firewall. These firewalls prevent combustibles in one area from entering another area to prevent the spread of fire. Components in the power plant overheat warning and fire protection system include a temperature sensing wire loop, a control unit for each engine, and the visual and audible warning devices. The sensing element is mounted on the inside of the left and right engine cowl panels. The elements are attached to the cowl by asbestos impregnated teflon clamps. An access door on the right side of the pylon provides access to the sensing element in the pylon.

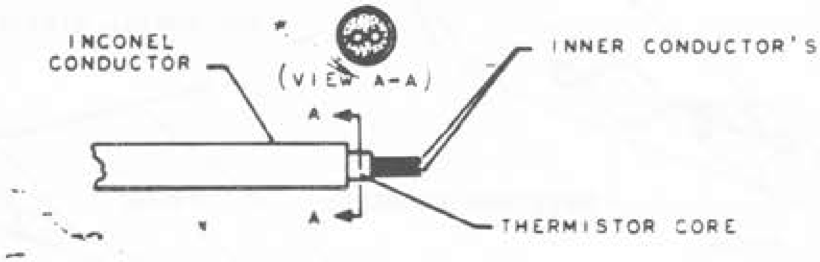
The element consists of several lengths of inconel metal tubing. Inconel has properties similar to stainless steel, but it cannot be hardened by heat treatment. The tubing serves as a protector for the internal thermistor core. The core is a ceramic material containing two wires. Resistance between the two wires is the resistance of the thermistor core. In this application, the thermistor core has a negative temperature coefficient of resistance. This means that its resistance decreases as its temperature increases. During normal engine temperatures, the resistance of the thermistor is very high. Voltage dropped across the sensing element produces a very small current flow, but the current is not sufficient to trigger the warning circuit. Only when the resistance decreases to a predetermined level, will current flow through the circuit be high enough to trigger the warning circuit. There are approximately 107 feet of detector element installed in each engine nacelle and pylon. Care should be taken when handling the sensing element. It is fairly rugged and continues to operate even when broken. Resistance between the two conductors can be changed, however, if they are kinked or squeezed together.

Resistance of the sensing element is constantly monitored by one control unit. There is one unit for each engine. The units are mounted on the electrical rack under the flight station.

Each control unit contains an automatic switching circuit, a short discriminator circuit, and a test circuit. The automatic switching circuit is a bridge type with



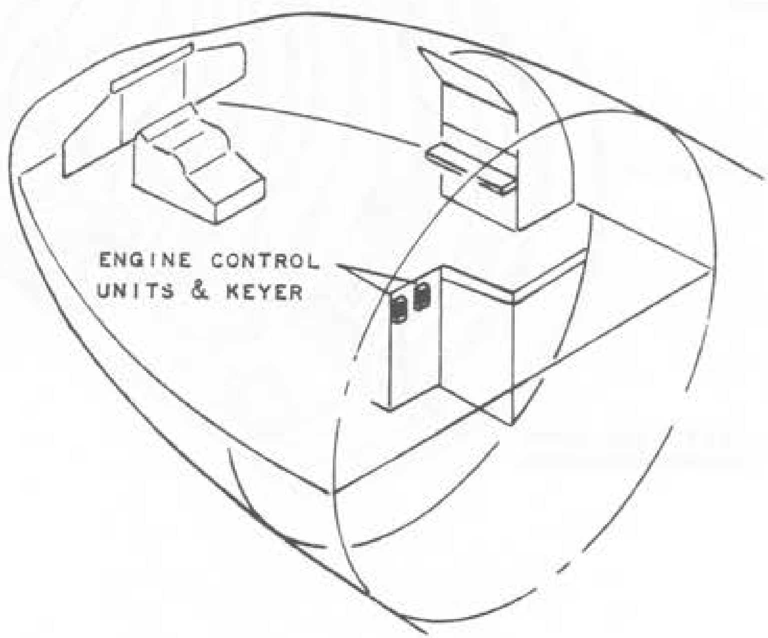
HORIZONTAL FIREWALL
DETECTOR ELEMENT
PYLON
PYLON
ZONE I
ZONE II
VERTICAL FIREWALL
DETECTOR ELEMENT
FWD COWL DOOR
DETECTOR ELEMENT
AFT COWL DOOR

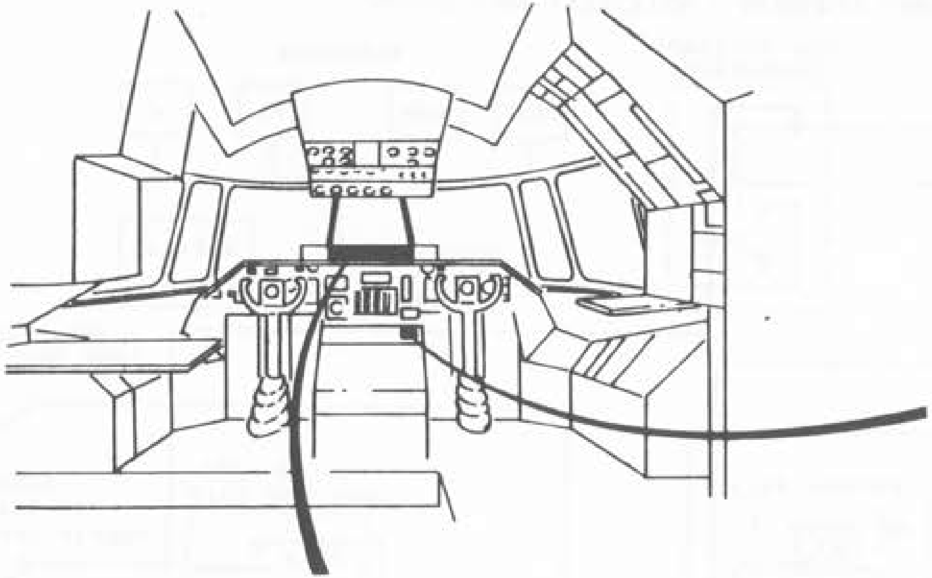


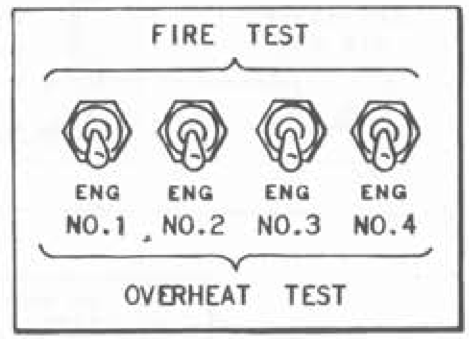
CROSS SECTION OF WIRE

the sensing element as one leg of the bridge. The bridge null detector is the first stage of a transistor flip-flop circuit. The flip-flop circuit is the automatic switching device. When one-half of the circuit is conducting, the other half is cut off. As element resistance decreases to the null-producing alarm valve, the first half of the flip-flop cuts off, causing the second half to conduct. It is the collector current flow in the second stage that operates a relay which turns on the visual and audible warning devices.

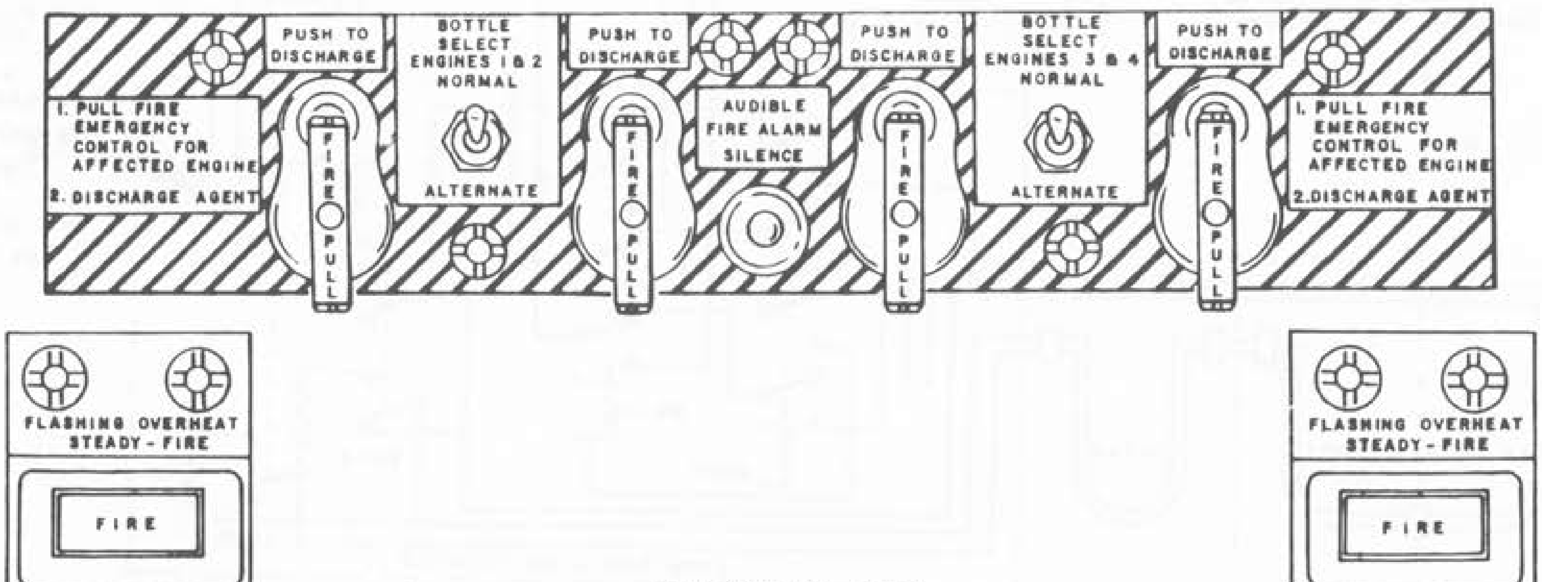
The short discriminator circuit prevents false alarms due to grounds or direct shorts across the wires in the sensing element loop or to aircraft wiring to the loop. If the resistance of the loop drops to a value much lower than the preset level of resistance, the short discriminator circuit locks out the overheat and fire alarm circuits to prevent a false alarm.



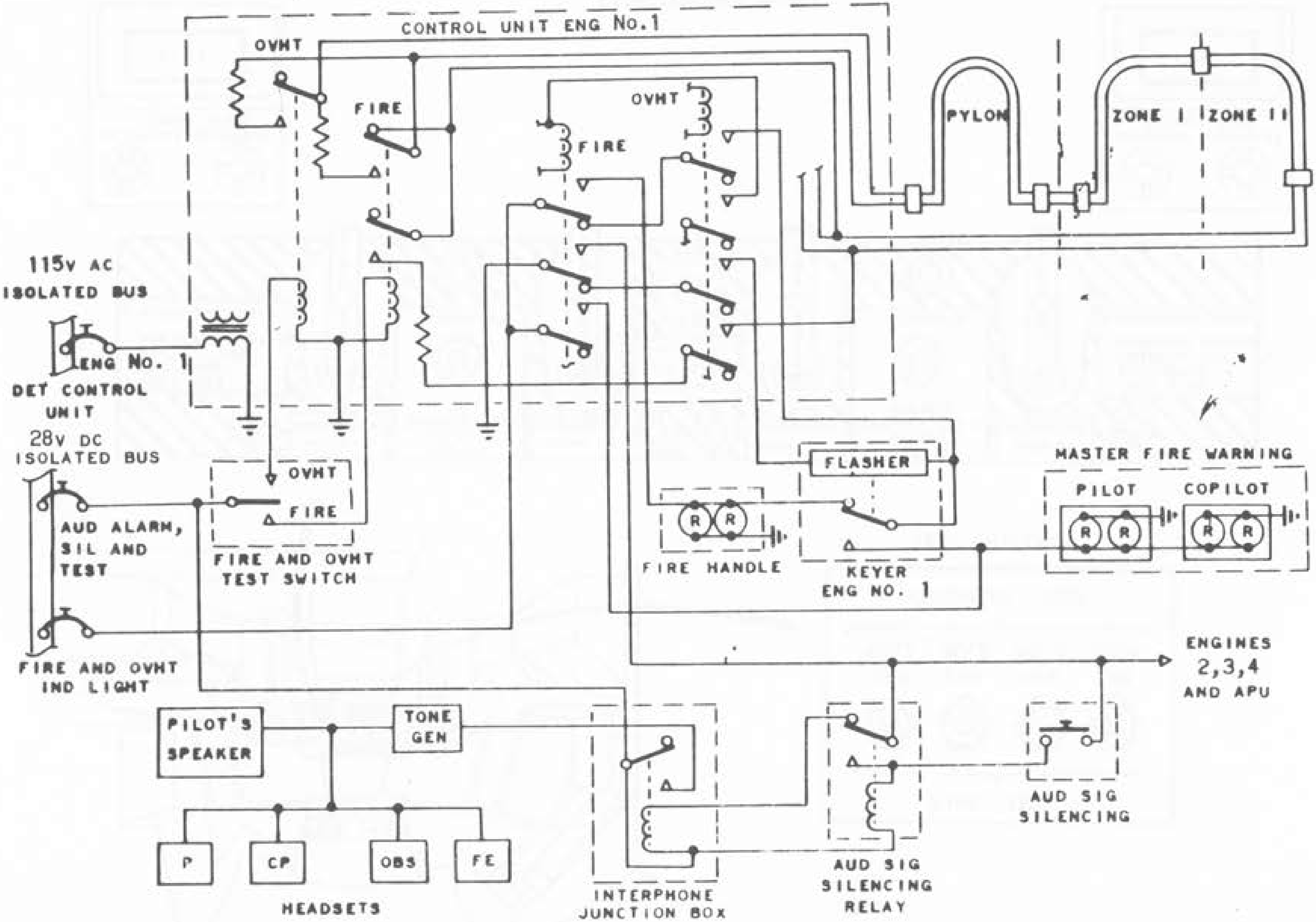




TEST SWITCHES



FIRE CONTROL PANEL



ENGINE FIRE DETECTION - OVERHEAT WARNING SCHEMATIC

The overheat and fire warning test circuit is controlled by four switches located on the copilot's side of the center console. For each engine and pylon overheat and fire warning circuit there are three positions for each test switch, "OVER-HEAT TEST," "FIRE TEST," and "OFF." All four test circuits are identical.

When one of the test switches is moved to the "OVERHEAT TEST" position, the resistance of the circuit is reduced to the overheat warning level. This allows the overheat warning relay in the control box to be energized completing the circuit to the warning lights through a flasher.

The "FIRE TEST" position reduces the resistance of the circuit to the fire warning level, which allows the fire warning relay in the control box to be energized. The warning lights are illuminated and the audible tone warning circuit is energized. The system will not operate when the test switch is actuated if there is a break in the sensing element loop or a double ground in the loop.

Indication of a fire or an overheat condition is in the form of a red light in the affected fire emergency handle. For an overheat condition, a flashing light comes on in the fire handle and the pilot's and copilot's master fire warning lights are illuminated. For a fire condition, a steady light illuminates in the affected handle. The master warning lights also come on, and a warning horn sounds in the pilot's overhead speaker and also in the pilot's, copilot's, flight engineer's, and observer's head sets.

When actuated, an audible fire alarm silencing switch on the fire emergency panel completes a circuit to the audible fire alarm silencing relay. With this relay energized, the circuit to the fire warning relay is broken and the audible fire warning stops. The silencing relay remains energized until the fire condition is corrected.

OPERATION.

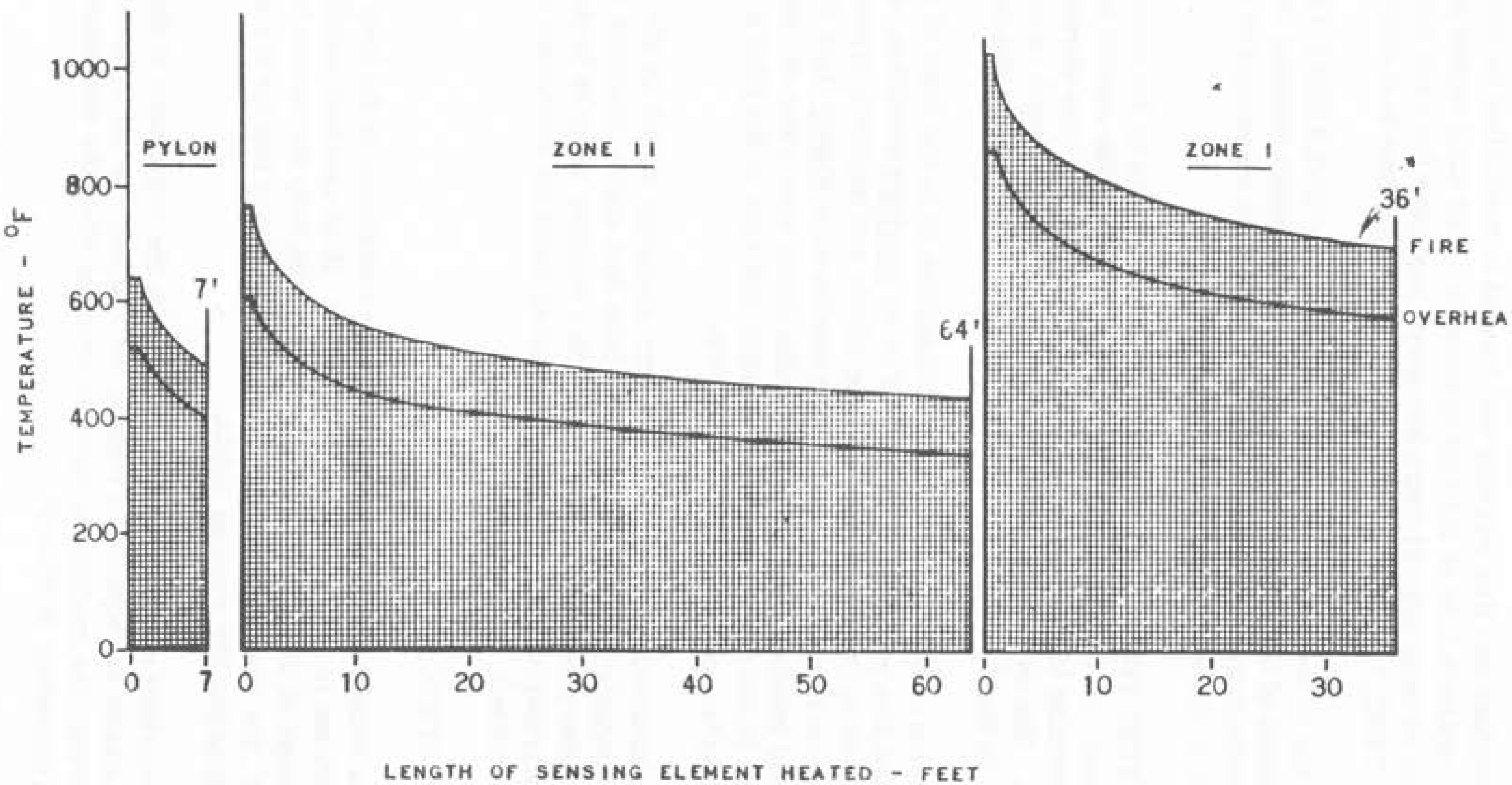
In the nacelle and pylon wire loop, the resistance of the loop under normal conditions is approximately 2629 ohms. If an overheat condition (207°C±16°) develops in the pylon, the resistance of the loop decreases to 1061 ohms. At this point, the overheat warning relay in the control box for the affected pylon energizes, illuminating the warning lights.

An overheat condition in Zone 1 reduces the resistance of the element. The same resistance is required to trigger the warning circuit in Zone 2 as in the pylon. However, the resistance value is reached when the temperature in Zone 1 is approximately 310°C±16°.

An overheat condition in Zone 2 is reached when the temperature is approximately 176.7°C±14°. The resistances of the warning, reset, and discriminator circuits

COMPARTMENT ALARM TEMPERATURES

COMPARTMENT	FIRE	OVERHEAT
PYLON		405 ± 30°F
ZONE II	440 ± 30°F	350 ± 30°F
ZONE I	705 ± 45°F	590 ± 35°F



ALARM TEMPERATURES - ENGINE FIRE AND OVERHEAT are the same as for the pylon and for Zone 1.

The nacelle fire warning circuit is triggered at a higher temperature. If fire occured in Zone 1, the temperature would rise rapidly, decreasing loop resistance. When the temperature reaches 374.1°C±26.2°, the loop resistance drops to approximately 237 ohms. This resistance drop causes the fire warning relay in the control box to energize, illuminating the warning lights and energizing the warning horn. When the fire is extinguished, the resistance of the loop increases; when it reaches 592 ohms, the circuit resets and turns off the warning lights.

Zone 2 fire warning temperature is approximately 226.7°C±14°. The resistance of the loop is the same as for Zone 1. There is no fire warning for the pylon.

FIRE EXTINGUISHING SYSTEM.

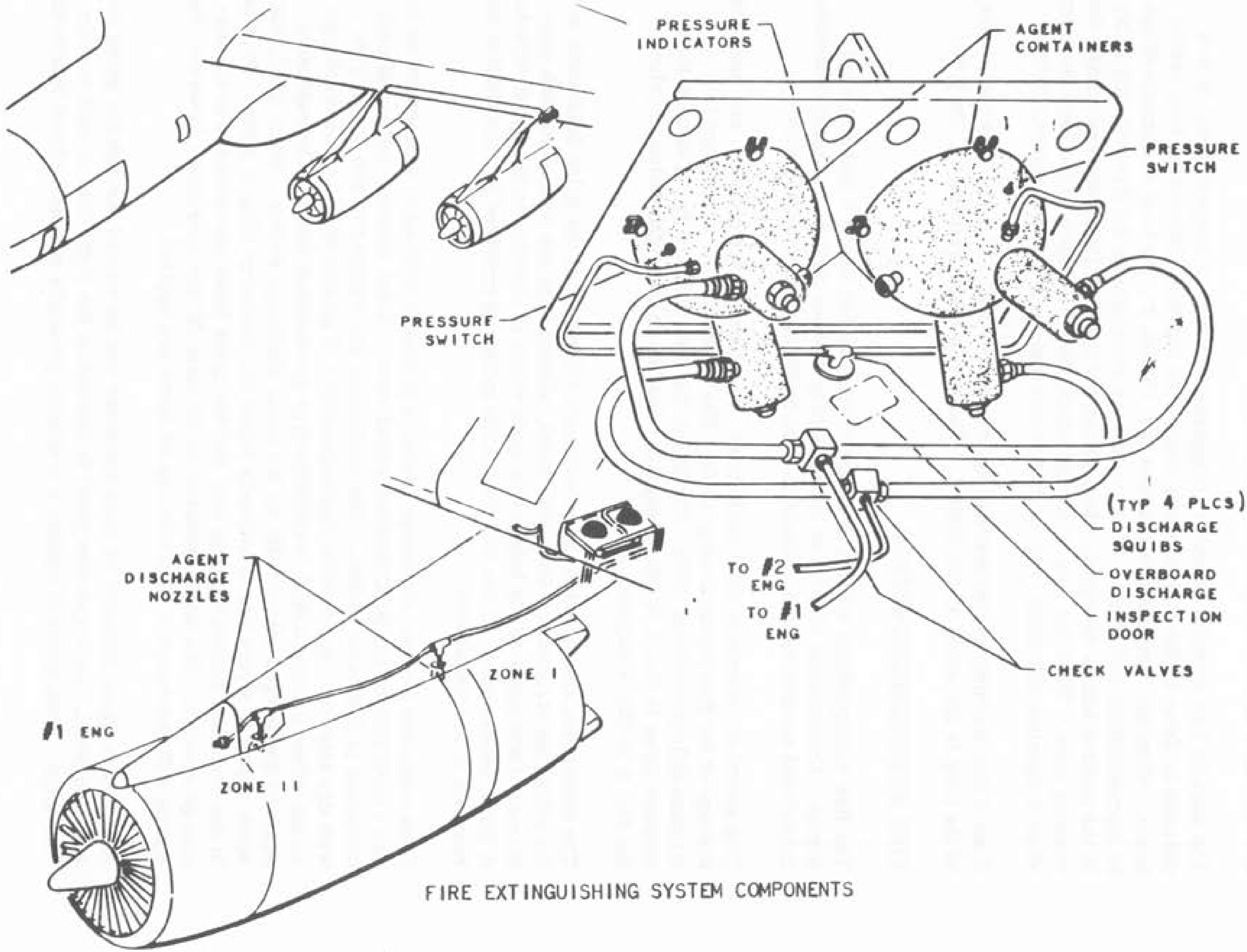
The fire extinguishing system provides protection for Zones 1 and 2 of each engine. Components of the fire extinguishing system include the agent containers, directional control valves, plumbing, and indicating and control units.

Two sperical, stainless steel containers, in each outboard nacelle, are used for storage of the fire extinguishing agent. The extinguishing agent used is dibromodifluoromethane (DB). The DB in the left outboard pylon is used to extinguish fires in No. 1 or No. 2 engines; the DB in the right outboard pylon is for No. 3 or No. 4 engines.

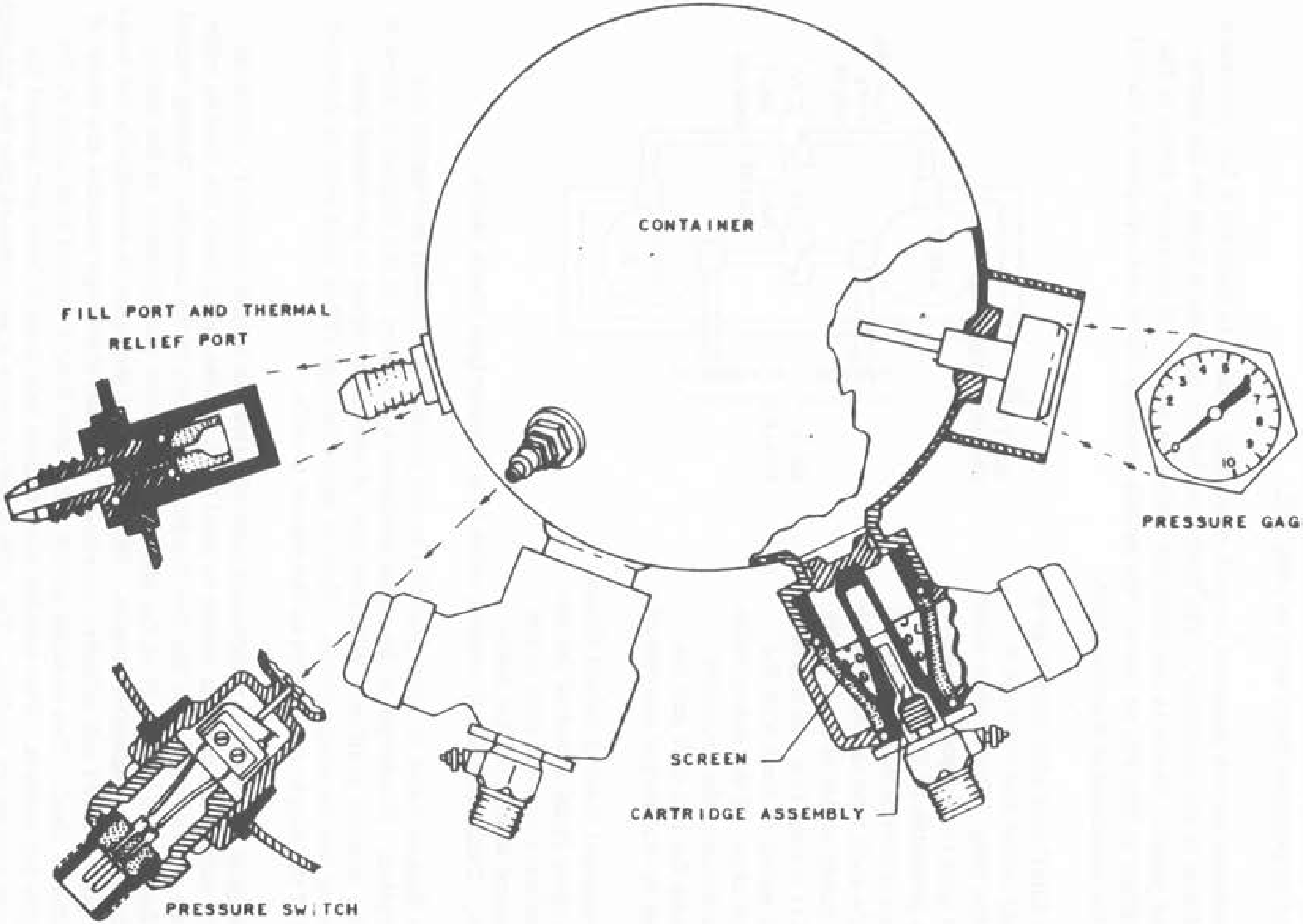
The containers are mounted in the outboard pylons aft of the pylon bulkheads in the pylon box structure. Four horizontal, slotted lugs are welded to each container. Each container is bolted to a rack which is attached to the pylon structure. A large access panel on the left side of the pylons is provided for installation and removal of the containers.

Each container has two discharge heads, a pressure indicator, a pressure switch, and a combination fill port/thermal relief valve. Total internal volume of each container is 378 cubic inches. The containers are charged to 600 PSI at 27°C with dry nitrogen, and contain approximately 6.5 pounds of DB. The discharge outlet valves contain a dual, cartridge-type pyrotechnic squib. The explosive squib is discharged electrically by the agent discharge switch. When fired, the squib reptures a post which normally holds the discharge plug in place. Pressure in the container forces the plug out, and the agent flows unrestricted to the discharge nozzles. The squib requires 18-30 volts DC for operation; however, the squibs will discharge if 35 milliamps or more are applied.

A pressure gage mounted on each container can be viewed through the pylon inspection panel. An inspection panel is located on the right side of each nacelle. The gage, when checked against a container pressure versus ambient temperature



FIRE EXTINGUISHING SYSTEM COMPONENTS

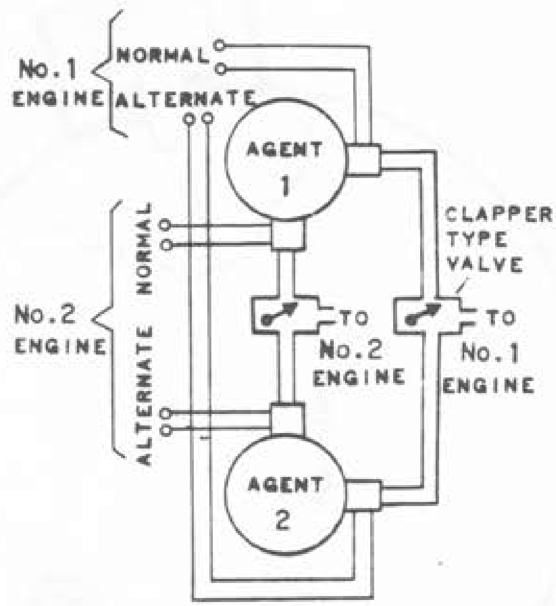


ENGINE FIRE EXTINGUISHING CONTAINER

chart, reveals whether the container is charged. Each gauge is marked in 50-pound increments from zero to 1000 PSI.

A pressure switch mounted on each container is used to indicate a low-pressure condition in the container. The pressure switch controls a light on the annunciator panel. There is one light for each fire bottle. If pressure drops in the container to 225 PSI or lower, the switch contacts close and complete a circuit for the annunciator warning light.

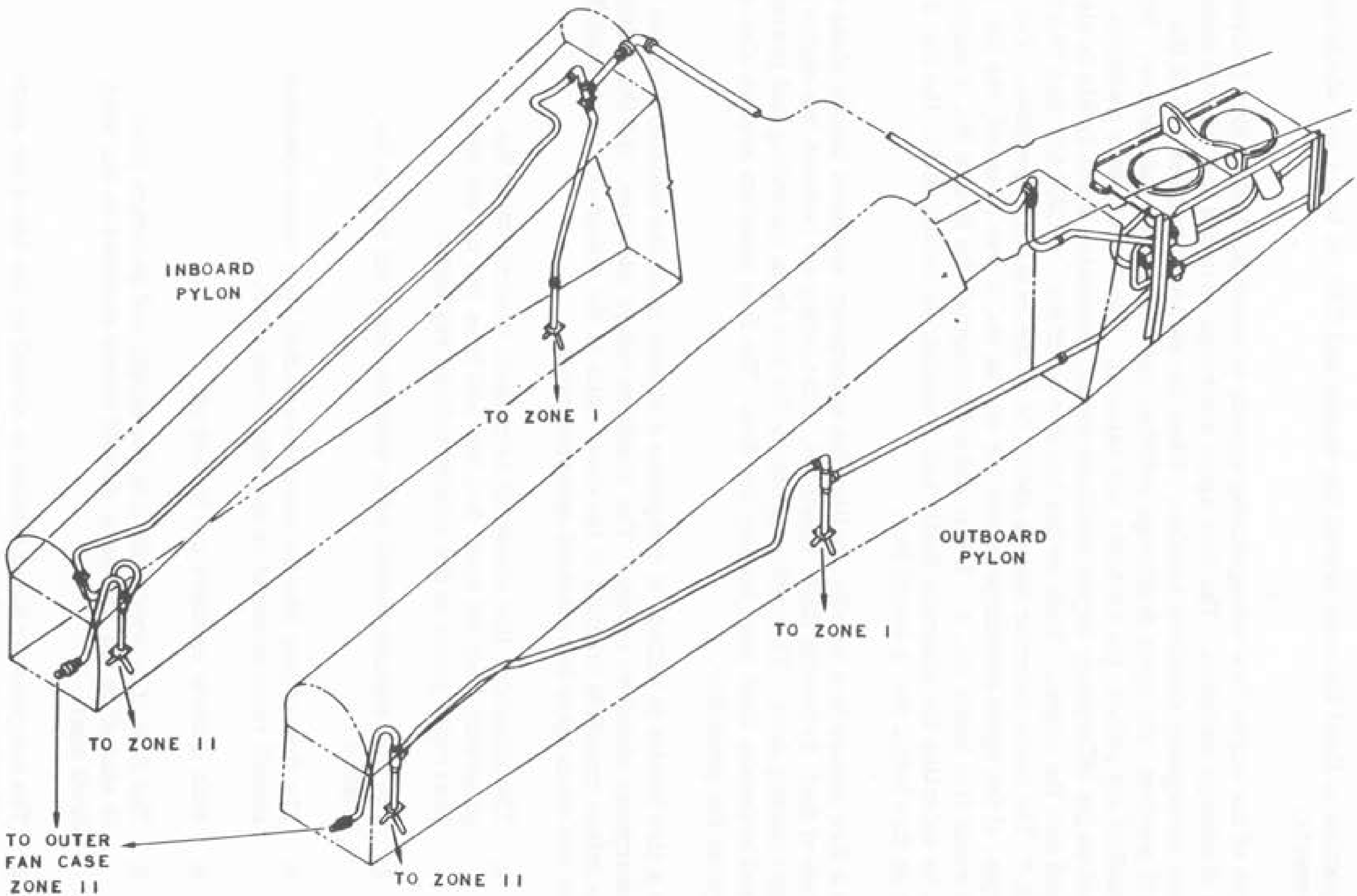
The filler port also serves as a safety outlet and contains a fusible plug. The fusible-alloy-type plug is designed to relieve at a pressure of 775 PSI or a temperature of 93.3°C-107.2°. A 1/4-inch tube is connected to the safety outlet of each bottle and is routed to a red indicator disk which is flush with the pylon skin. If the safety valve is activated, the pressure breaks the red disk and the agent is discharged overboard.



Directional control valves direct the agent from either of the two containers on each side to the selected engine on that same side. Each directional control valve is a flapper-type check valve.

The flapper valve is spring-loaded to one position to prevent movement and vibration. Discharge of the agent produces a pressure on the flapper to move it to the desired position. With this type of valve, the agent is prevented from flowing into an empty bottle. Flow of agent through either inlet port is directed out of the single outlet port to the engine nacelle.

Plumbing between the directional control valves is 1-inch diameter, stainless steel tubing. Aluminum tubing is used to direct the agent down the leading edge of the outboard pylon to the five discharge nozzles in the nacelle. Tubing routed to the inboard nacelle is of the same type material and diameter as the tubing utilized in the outboard nacelle. Distribution of the agent is essentially the same for both inboard and outboard nacelles. The five discharge nozzles are made of stainless steel. Two nozzles direct agent into Zone 1 around both sides of the engine hot section. Two nozzles direct agent into Zone 2 down and around the engine accessory section. The fifth nozzle sprays agent forward into the bifurcated



FIRE EXTINGUISHER PLUMBING ARRANGEMENT

duct section to flood the area around the engine and CSD oil tanks and electrical disconnects.

Control of the engine fire extinguishing system is accomplished by four individual agent discharge switches. The four agent discharge switches are located under the four emergency shutdown handles. When the shutdown handles are in the normal position, the agent discharge switches are covered by the handles. When the handles are pulled, the switches are exposed. The two selector switches, located on the emergency engine shutdown panel, determine which bottle is discharged into the engine. Each switch has two positions, "NORMAL" and "ALTERNATE." The bottle selector switch should be in the NORMAL" position. For example, if the agent discharge switch for engine No. 2 was pressed, the No. 2 squib would fire bottle No. 2. If this did not extinguish the fire in No. 2 engine, then, by selecting the alternate bottle and pressing the switch again, the No. 2 squib on fire bottle No. 1 would fire.

When a fire occurs in a nacelle, pulling the emergency shutdown handle shuts off the flow of fuel, hydraulic fluid, bleed air, and cooling air between the engine and the surrounding area. This action prevents the fire from spreading and prevents fuel and hydraulic fluid from feeding the fire. The fire isolation system also deenergizes the generator.

When a fire handle is pulled, it completes a circuit from the isolated D-C bus to the emergency shutdown relays. The shutdown relays energize, and the contacts of the relays complete circuits to the close coils of the motor-operated shufoff valves and deenergize the solenoid operated valve.

1. The generator line contactor is opened, disconnecting the generator from its main A-C bus and from the tie bus and interrupts power to the related voltage regulator.

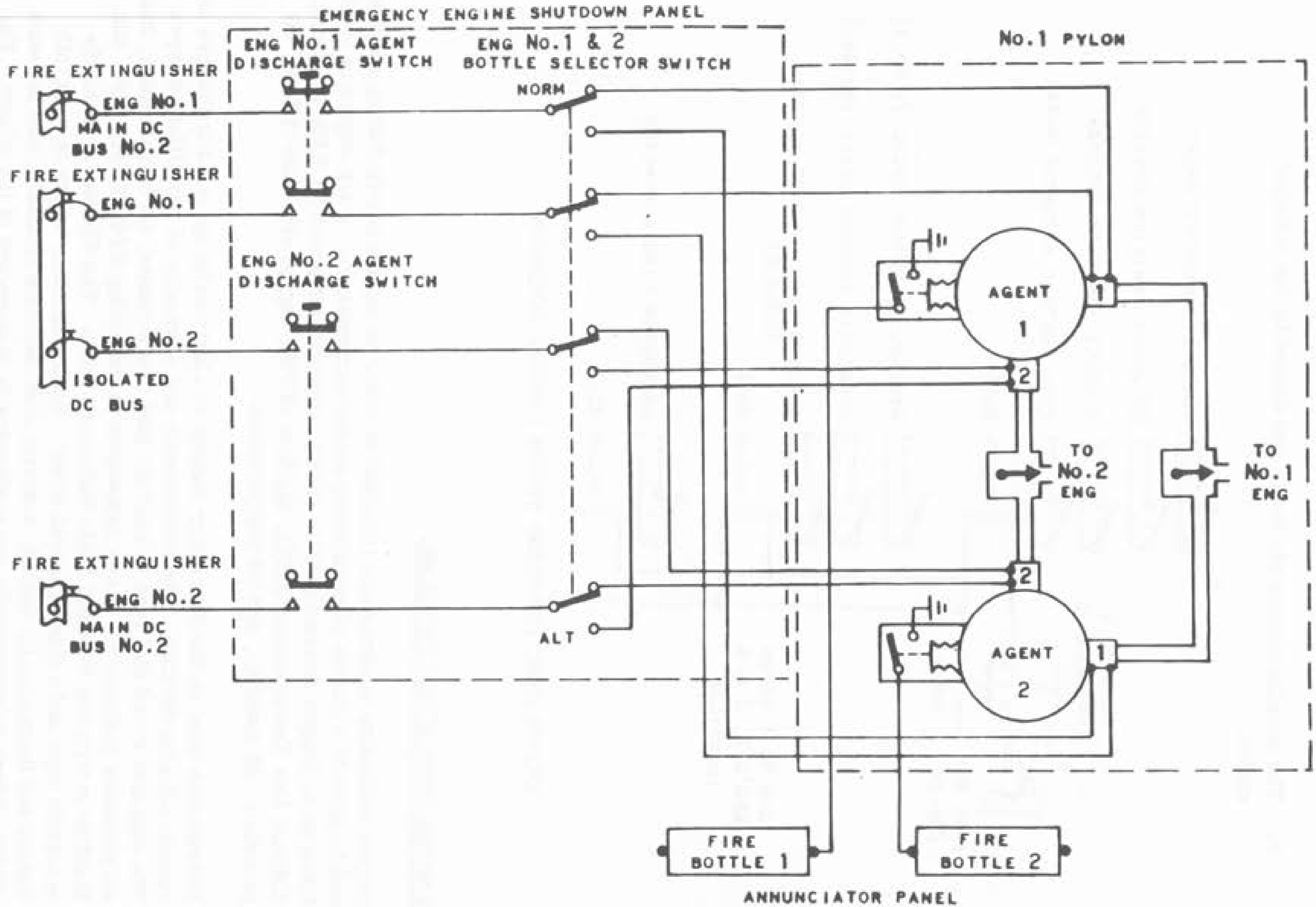
2. The fuel control shutoff valve actuator shuts off fuel to the control.

3. The flow of fuel into the nacelle is shutoff by a cable-operated shutoff valve mounted on the wing front spar.

4. Both ignition exciters are turned off.

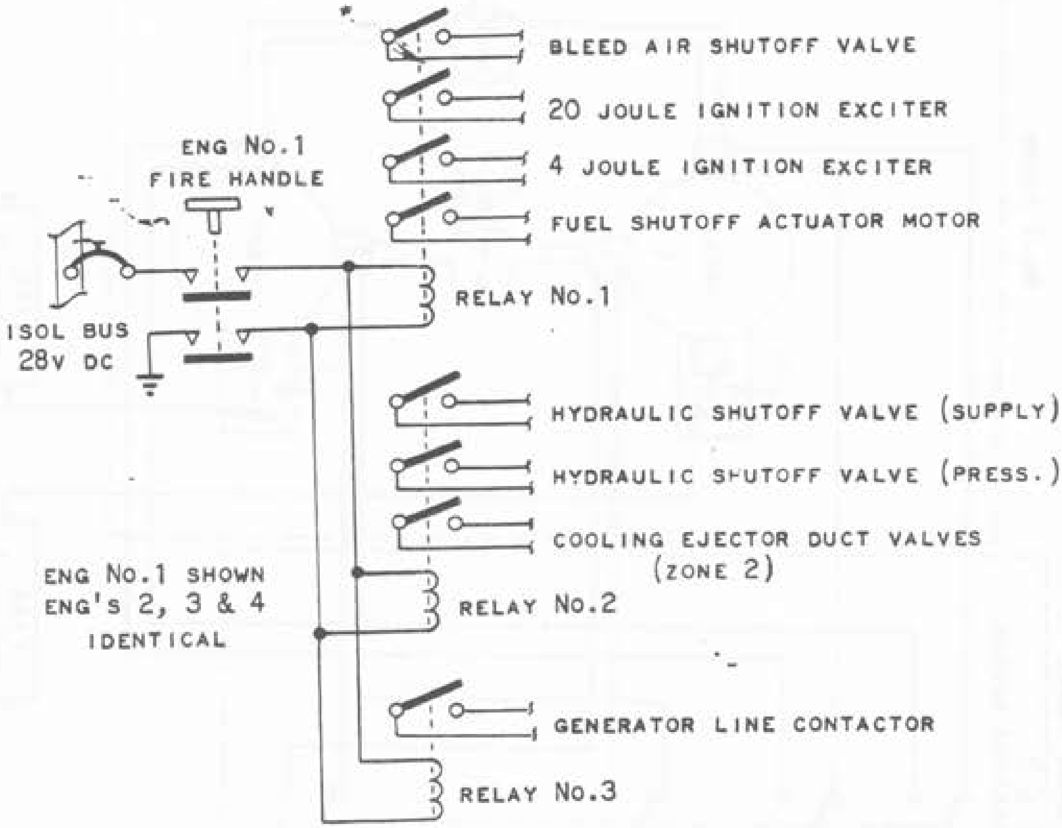
5. The flow of hydraulic fluid in the supply and pressure lines is shutoff by the hydraulic shutoff valves mounted on the wing front spar.

6. The compressor bleed airflow is shutoff by the bleed air shutoff valves mounted in the pylon structure.



FIRE EXTINGUISHING SYSTEM SCHEMATIC

7. The nacelle cooling air doors are closed by the actuator motor.

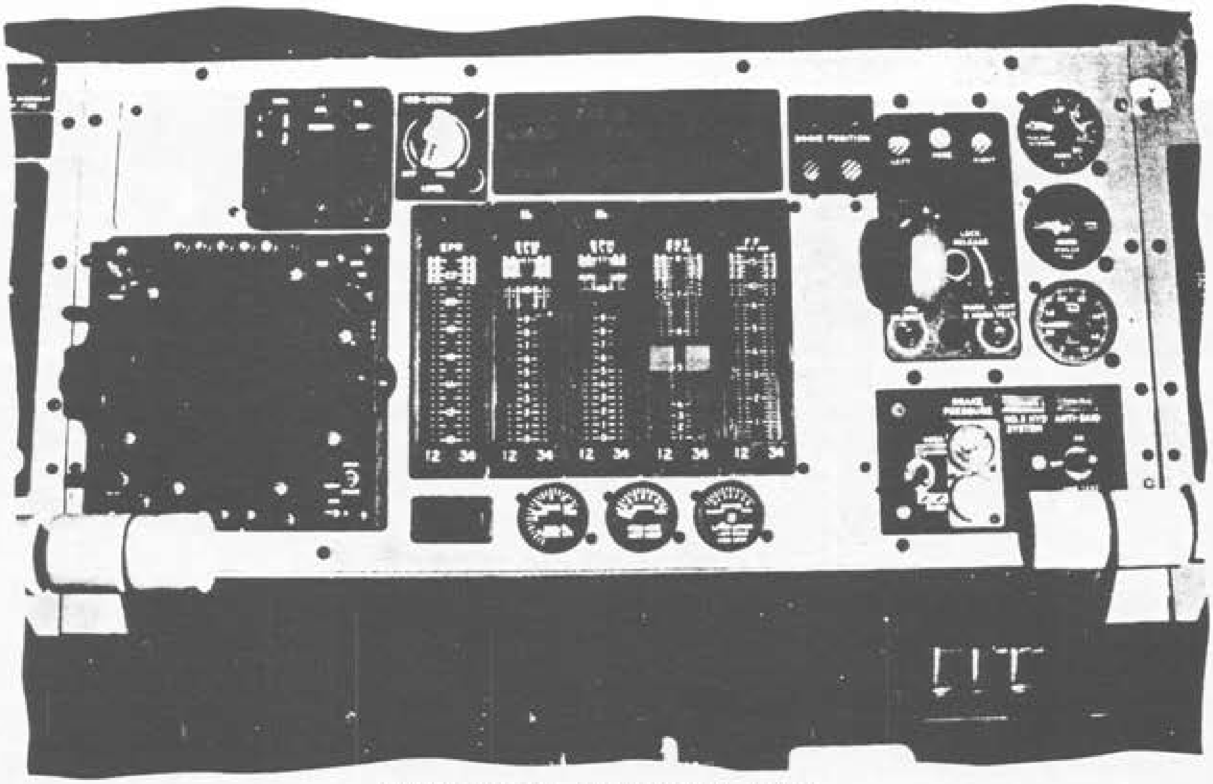


ENGINE FIRE ISOLATION SYSTEM CIRCUIT SCHEMATIC

ENGINE INDICATING SYSTEMS.

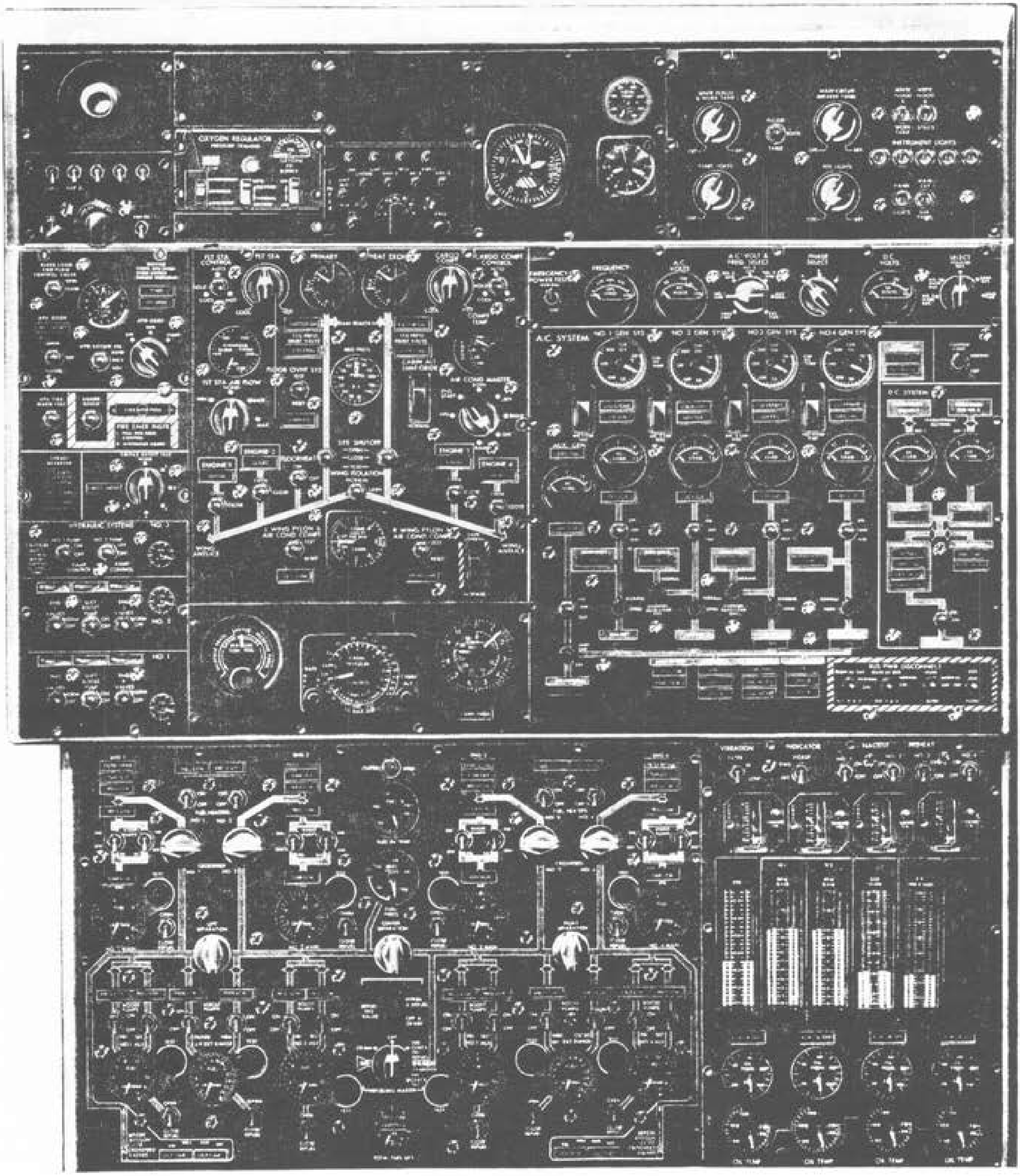
Engine indicating systems are installed in order to ensure safety during operation and to provide a means of monitoring engine performance. Each engine is monitored as to Engine Pressure Ratio (EPR), compressor speed N1 RPM (percent), Exhaust Gas Temperature (EGT), fuelflow (PPH), engine vibration (MILS), oil pressure, oil quantity, and oil temperature.

Instruments used on the StarLifter consist of electrically operated indicators and remote sensing devices. The instruments are primarily of two different types. The common round dial type is used for fuel temperature, oil temperature, and oil pressure indicators. A new innovation in indicating EPR, RPM, EGT, and fuelflow is with the Vertical Scale Indicators (VSI). The VSI has a vertically moveable tape and a fixed vertical scale. Each indicator, which is integrally lighted and hermatically sealed, contains four separate channels, one for each engine, which is electrically and mechanically independent of the others. The

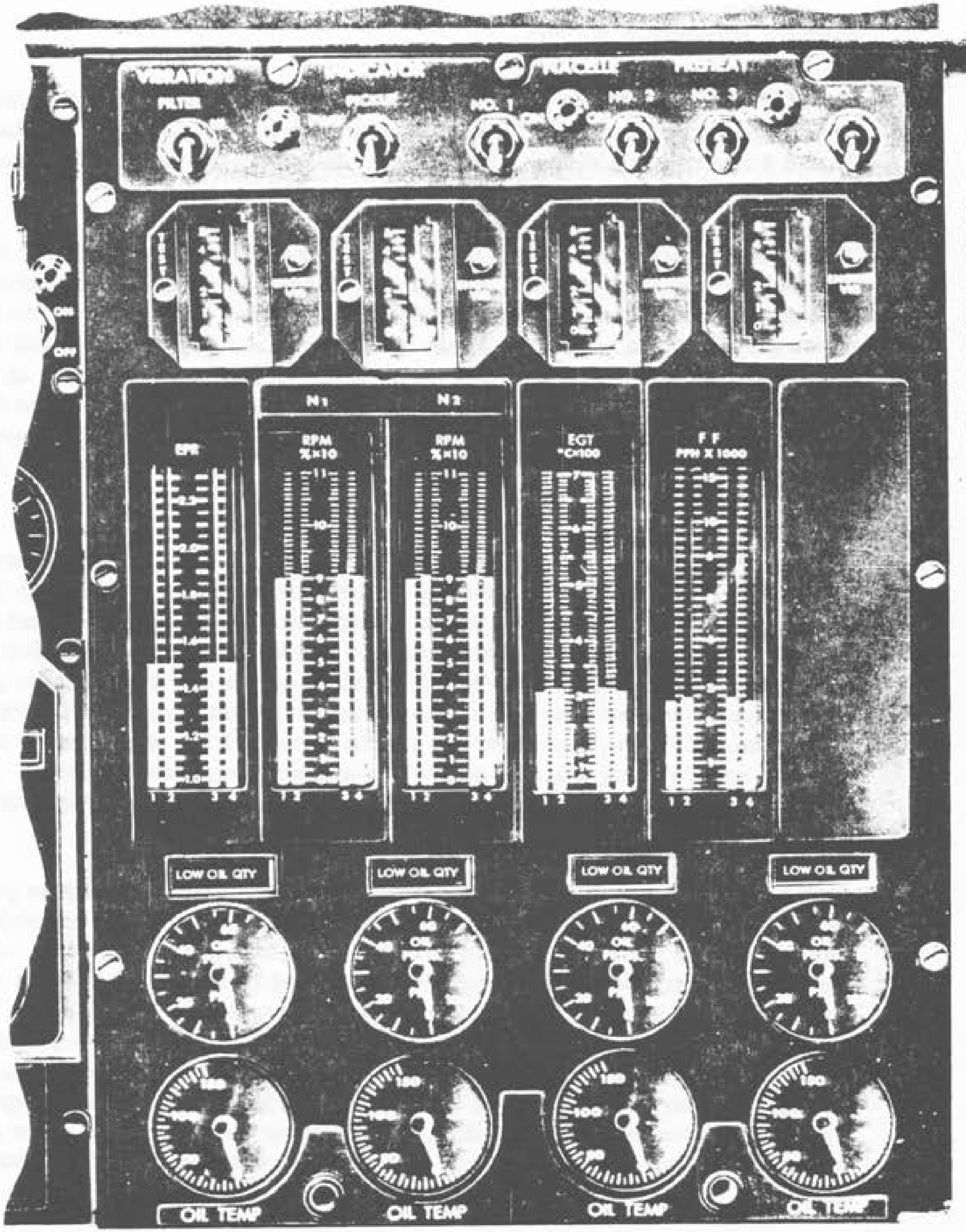


MAIN ENGINE INSTRUMENT PANEL

tapes are spring-loaded down and driven by servo motors. When power is on, a black "OFF" is displayed against a red fluorescent portion of the tape indicating a power-off condition. The indicators are mounted on the pilot's center instrument panel and on the flight engineer's panel.



FLIGHT ENGINEER'S PANEL



FLIGHT ENGINEER'S ENGINE INSTRUMENT PANEL

ENGINE PRESSURE RATIO.

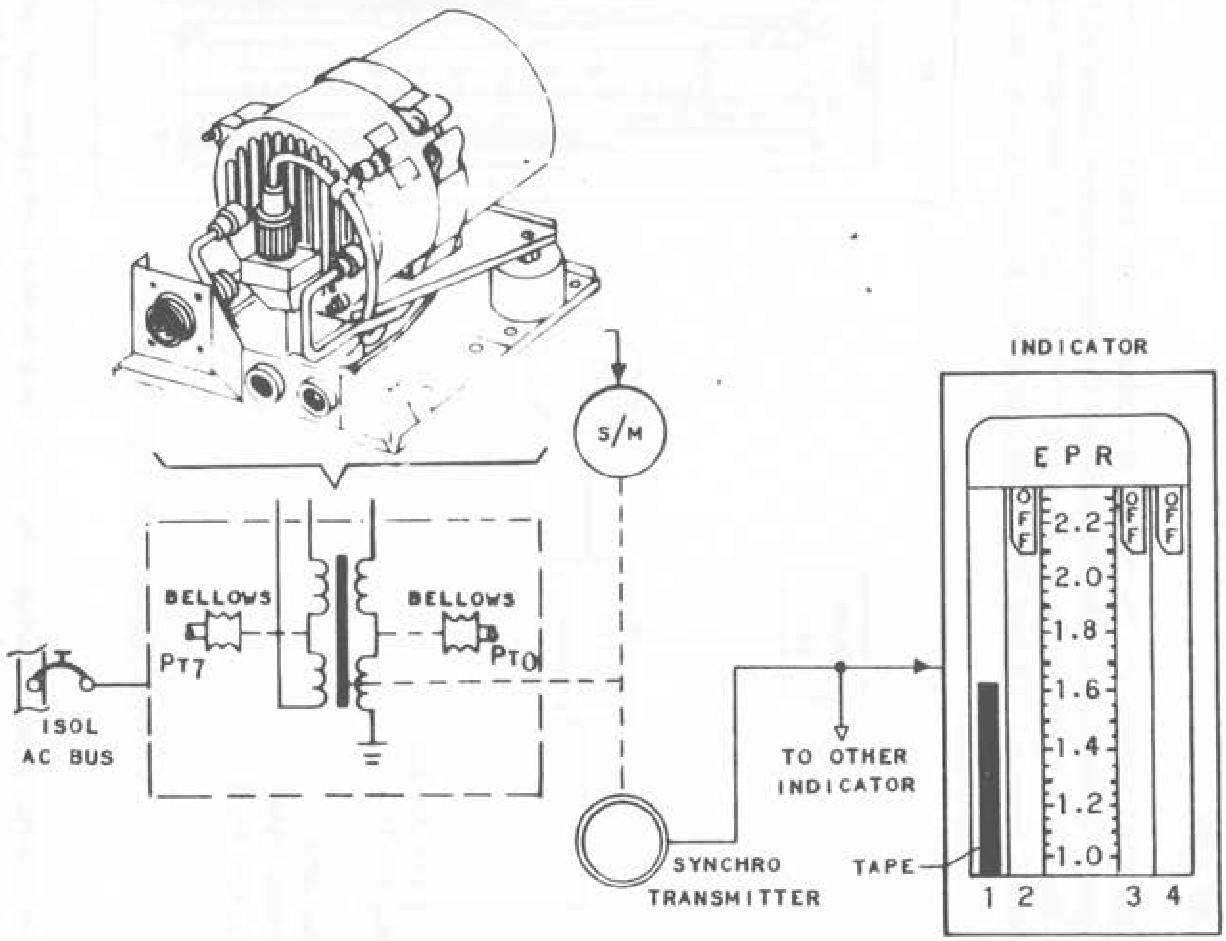
The EPR indicator is the first VSI (left to right) on the pilot's and flight engineer's instrument panel. The VSI monitors all four engines and is labeled 1, 2, 3, and 4 from left to right. The vertical scale is marked in 0.05 increments with a range from 1.0 to 2.3.

The turbojet engine draws in air and compresses it. Fuel is added to the compressed air and then ignited. The rapid release of energy is accomplished by a process of combustion. Energy (in the form of heat) is transferred to the air passing through the engine to create the force necessary to accelerate the air. Thrust is then the reaction of this force which accelerated the mass of air and burning gases. If the pressure of these gases changes, the developed thrust of the engine also changes. Since changes in RPM, temperature, pressure, and air speed affect thrust, it is necessary to consider these variables in determining the propulsive force of the engine.

The most accurate means of indicating thrust output is by the difference in pressures or the pressure ratio between engine inlet pressure and turbine discharge pressure. Inlet pressure is true barometric pressure, corrected and computed for the variables of airspeed and pressure altitude, versus the turbine discharge pressure for EPR. Engine RPM, EGT, and fuelflow are improtant to proper engine operation, but they are not as accurate in indicating thrust developed by the engine. EPR is proportional to engine thrust. RPM indication is used to monitor speed during starting and to indicate an overspeed condition. RPM does vary with compressor-inlet temperature and must be corrected for ambient air temperature when accurate RPM indications are required.

On the StarLifter engine, inlet pressure (Pt 0) and turbine discharge pressure (Pt 7) are compared to develop an engine pressure ratio. Inlet pressure is taken from pitot type probes which are located on the forward inboard side of each engine pylon structure. Each probe is anti-iced by electrical heaters which are controlled by the engine and nacelle anti-icing system. Pt 0 pressure is routed to the interior of the engine pylon, where the EPR transmitter is located. Turbine discharge pressure (Pt 7) is total pressure taken at engine station No. 7. The six pressure pickup probes in the exhaust case are manifolded together. A flexible hose connects the manifold to a fitting in the base of the pylon structure. A small coupling and an aluminum tubing is connected to the EPR transmitter inside the pylon.

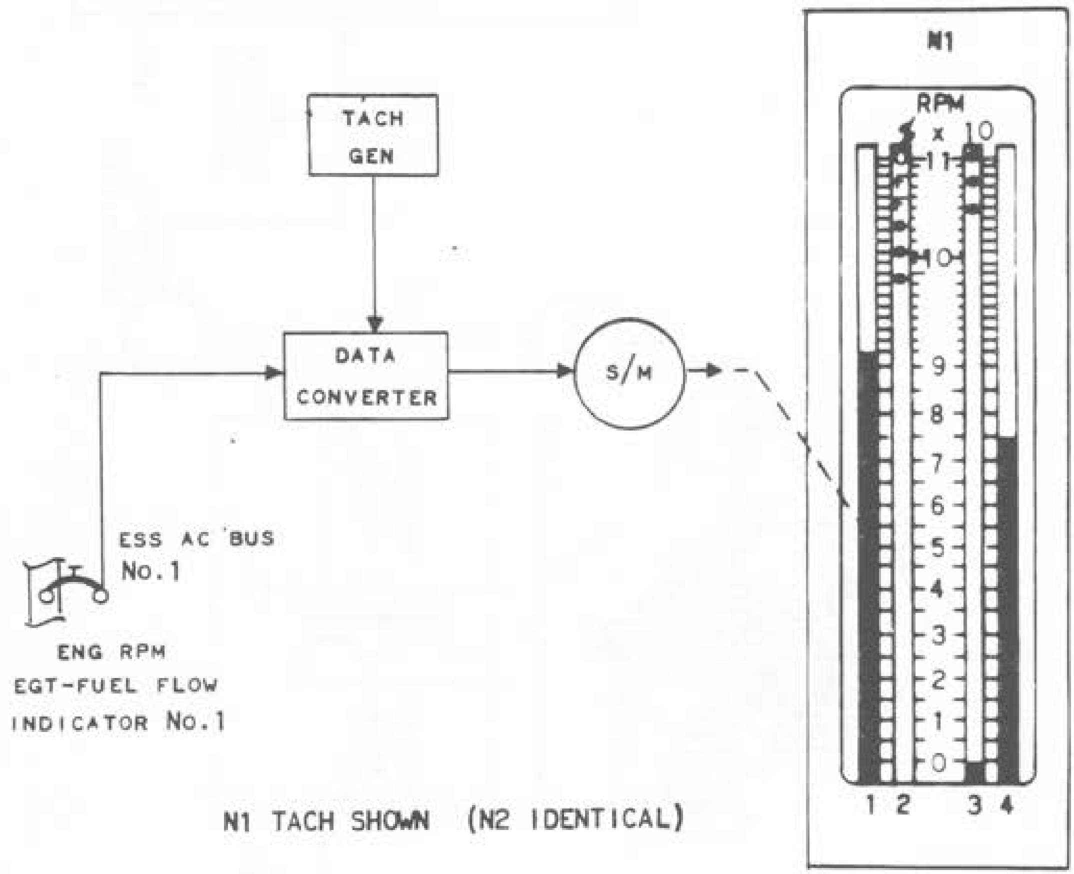
The transmitter senses Pt 0 and Pt 7 pressures through a bellows pickup assembly and converts the mechanical movement of the bellows into an electrical signal. The signal is sent directly to the VSI, where it is amplified and used to drive the servo motor connected to the tape.


INDICATOR
E P R
OFF
OFF
OFF
2.2
2.0
1.8
1.6
1.4
1.2
1.0
1 2 3 4
TAPE
S/M
BELLOWS
BELLOWS
PT7
PT0
ISOL
AC BUS
TO OTHER
INDICATOR
SYNCHRO
TRANSMITTER

The power to operate the transmitter units is supplied through the EPR circuit breaker from the isolated A-C bus.

N1 AND N2 RPM.

Two engine RPM indicators, located on the pilot's main instrument panel and the flight engineer's panel, indicate the speed of the low-pressure compressor rotor (N1) and the high-pressure compressor rotor (N2). The N1 indicator monitors the individual speeds of all four engine low-pressure compressors, and the N2



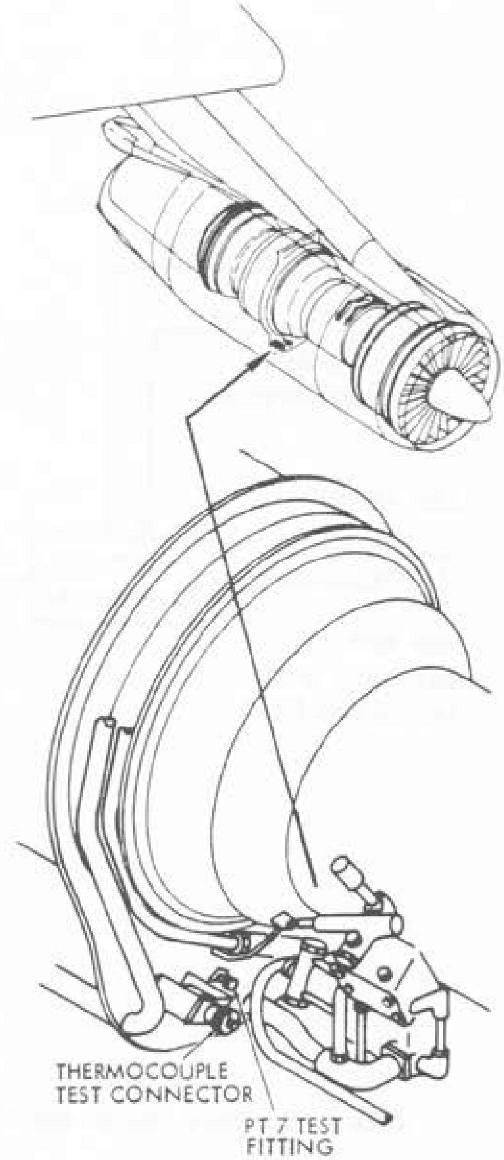
N1 TACH SHOWN (N2 IDENTICAL)

indicator monitors individual speeds of all four engine high-pressure compressors. Both indicators are vertical tape types, four scales each, calibrated from 0 percent to 110 percent RPM. Graduations of scales are 0.5 below 9.0 and 0.1 above 9.0. Scale numbers represent "% x 10." Electrical power to the indicator is provided by essential A-C bus No. 2 through four ENGINE EGT, RPM FUEL-FLOW circuit breakers located on the flight engineer's No. 2 circuit breaker panel. One-hundred percent of N1 compressor speed is equal to 6796 rotor RPM, and 100 percent of N2 compressor speed is 9655 rotor RPM. The tachometer generator transmitting RPM of the low speed compressor (N1) is mounted on the forward accessory drive case. The second generator is mounted on the main accessory drive gearbox and transmits RPM of the high speed compressor (N2). Both signals are fed into the data converter and then sent to their respective indicators.

EXHAUST GAS TEMPERATURE.

In the operation of a jet engine, it is necessary to know the temperature of the gases leaving the engine. If the EGT is allowed to rise above certain limits, serious damage to engine components will result. EGT is also important in its interrelationship with fuelflow, RPM, and EPR. These indications will be used for analysis and forecast of probable engine trouble or an actual engine malfunction.

The exhaust gas temperature indicating system consists of a vertical scale type indicator. It is the fourth VSI (left to right) on the pilot's and flight engineer's panel. The VSI monitors all four engines and is labelled 1, 2, 3, and 4. The range on the indicator scale is marked from 0 to 2 in 50° increments and from 2 to 7 in 10° increments. EGT is read in degrees centigrade times one-hundred (℃ x 100).

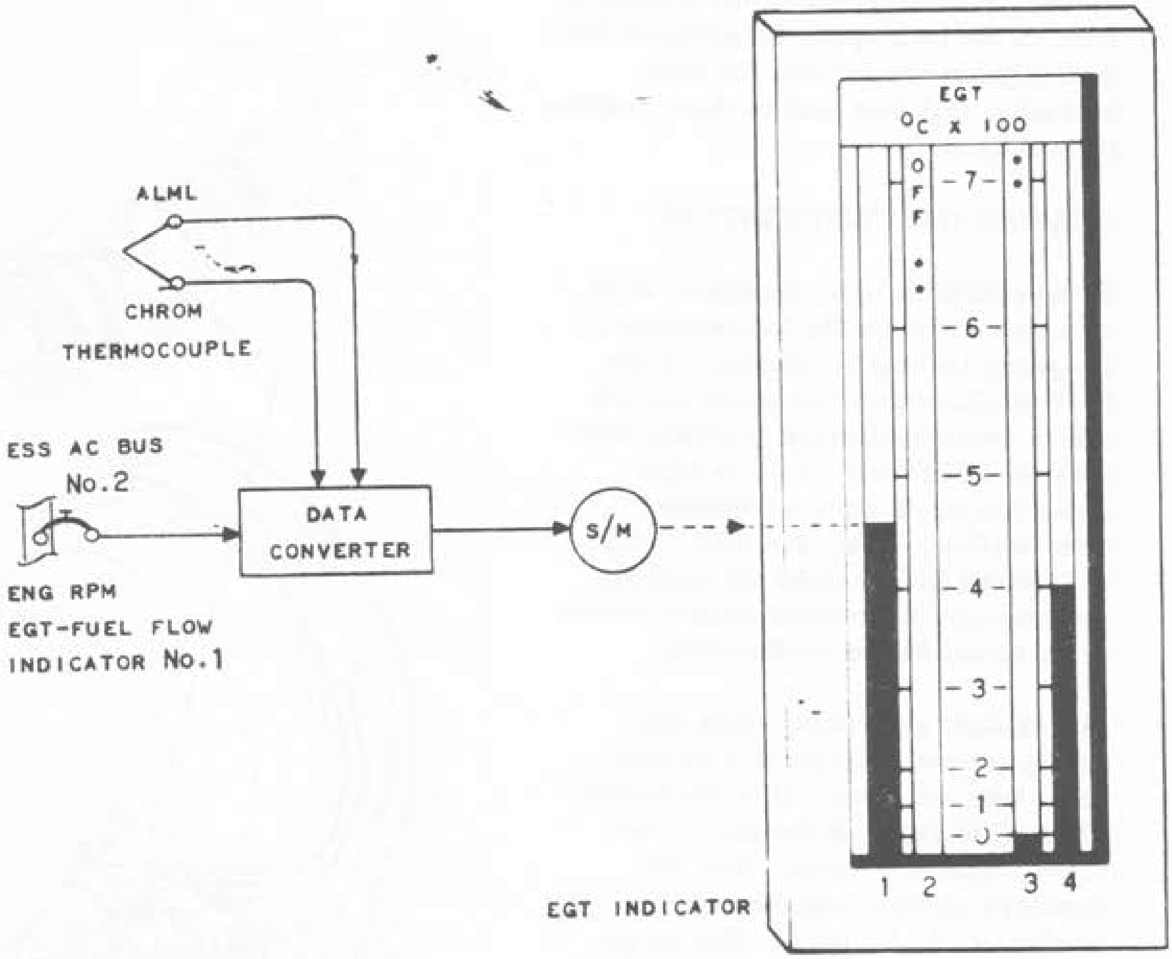


THERMOCOUPLE AND
PT7 TEST CONNECTIONS

Six dual-junction thermocouples are located around the engine exhaust case at engine station 7. The thermocouple junction is made of alumel and chromel material. Connections from one of the junctions of each thermocouple are wired in parallel with the other thermocouples to obtain an average temperature indication.

The other junction is wired into a test connector. The test connector for EGT and Pt 7 are both located on the lower right hand side of the engine vertical firewall.

The electrical signal from the thermocouples is sent to the data converter and



then to the EGT VSI in the cockpit.

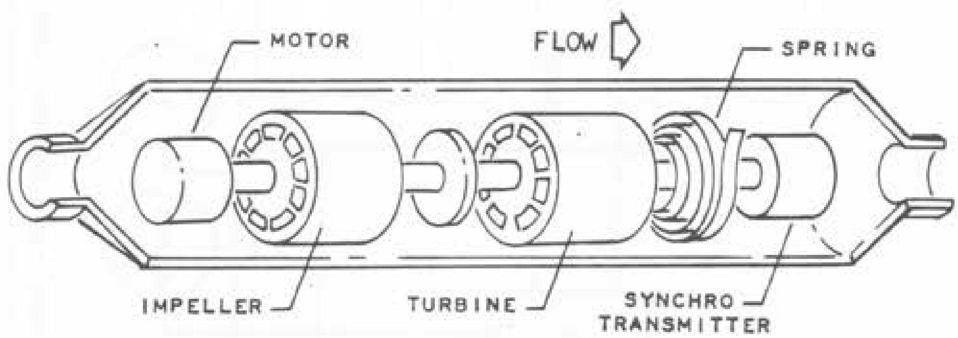
FUELFLOW.

As stated earlier, the interrelationship of all engine instruments is important for forcasting probable or actual engine malfunction. Knowing the exact amount of fuel flowing to the engine not only serves as an aid in determining fuel consumption versus flight time, but also is a means of detecting an engine malfunction. As a general rule of troubleshooting, when only one of the primary engine instruments, by itself, indicates an abnormal reading, the probable cause is most likely an instrument system malfunction.

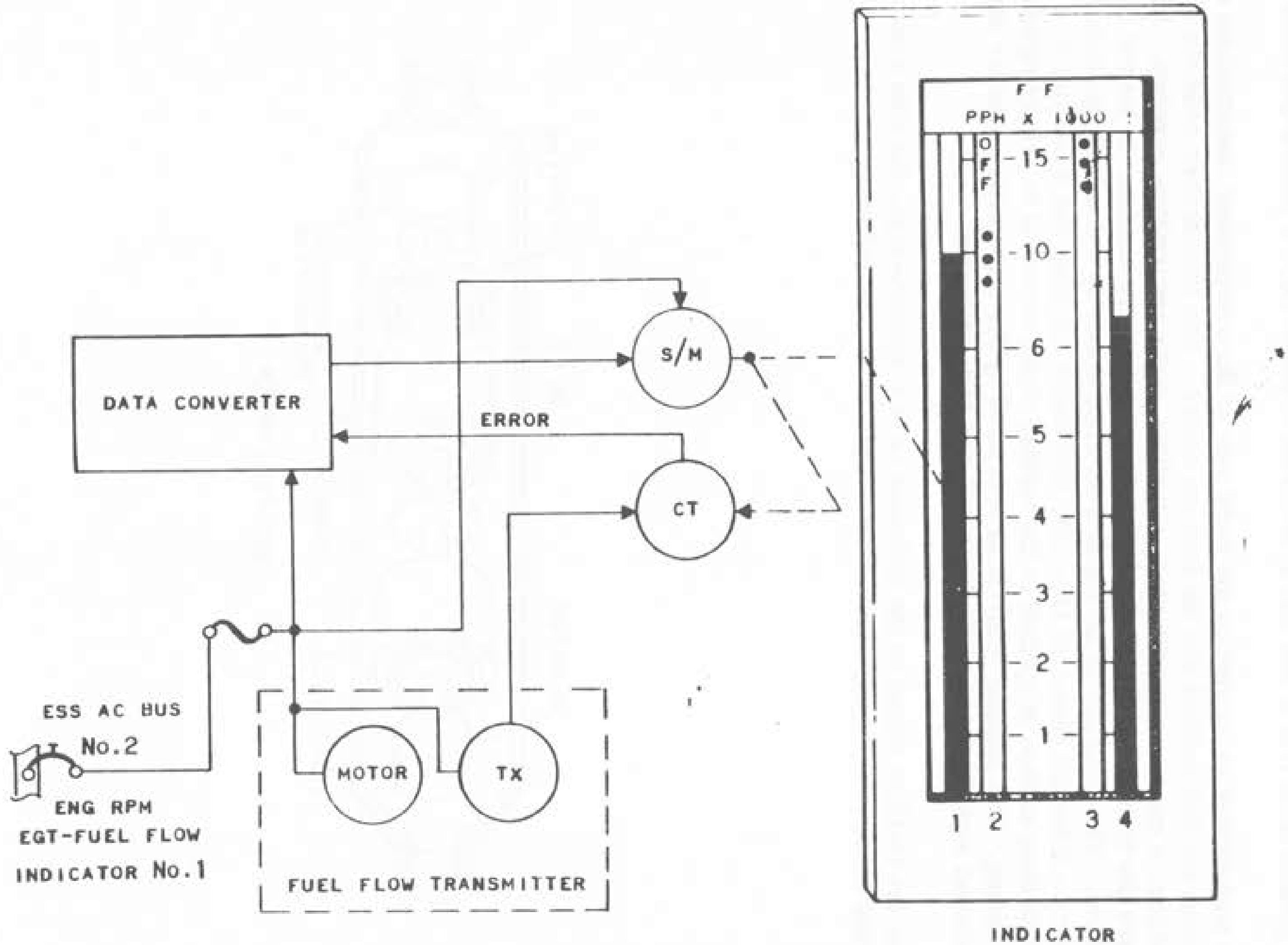
The fuelflow transmitter and indicator monitors fuel which is leaving the fuel control and going to the fuel nozzles. The indicator is the last VSI in the row of engine instruments, one on the pilot's panel and the other on the flight engineer's panel. Both are single indicator, four scale-type vertical scale indicators. The scale reads 0 to 16 pounds per hour times 1000 (PPH x 1000) in increments of 200 pounds from 0 to 6,000 and 1,000 from 6,000 to 16,000 pounds-per-hour.

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.

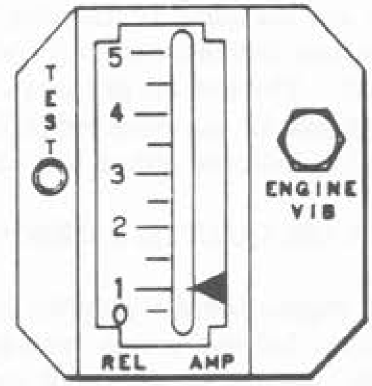


FUEL FLOW METER



ENGINE No.1 SHOWN (2,3, & 4 IDENTICAL)

ENGINE VIBRATION.



ENGINE VIBRATION INDICATOR

Four vertical-scale type indicators are provided on the aircraft to supply the flight engineer with indications of engine vibrations and to aid in isolations of engine vibrations. Each of the engine vibration indicating systems consists of an integrally lighted, vibration amplitude, indicator-amplifier and two vibration sensing devices. A vibration filter selector switch and an indicator pickup selector switch maintains control over all four indicating systems. The four indicators and two selector switches are located on the flight engineer's lower instrument panel. There are two vibration sensors on each engine, one on the forward end and one on the aft end. The forward vibration pickup is located on the left side of the compressor section and the aft pickup is located on the bottom left side of the turbine section. Operation of each of the vibration indication systems is identical. The two vibration sensing devices on the engine sense the amplitude of engine vibration. One is operative at all times depending on the "FWD-AFT" switch position. Vibration signals are amplified in the indicator and position the indicator pointer to register the average vibration displacement on a zero to 5-mill scale. The scale is graduated in one-half mill increments.

The vibration sensing system is capable of sensing both high and low-frequency vibrations. The HI-LOW vibration filter selector switch is spring-loaded to the low position; in this position the amplitude of the total frequency range of vibrations is presented on the indicator. Positioning the filter switch to "HI" allows only the high frequency vibrations to be presented on the indicator. The indicator incorporates a PUSH-TO-TEST switch to check the continuity of the wiring and vibration sensors. When the switch is actuated, the indicator pointer should move to approximately 3.5 mills. Electrical power for system operation comes from two separate sources: The 115-volt, 400-Hertz A-C power for indicator-amplifier operation is received from the "ISOLATED AC BUS" and through the ENGINE VIBRATION INDICATOR circuit breaker. The 28-volt, D-C power is for relay operation and comes from the "ISOLATED DC BUS" and through the ENGINE VIBRATION INDICATOR circuit breaker. Both circuit breakers are located on the flight engineer's No. 3 circuit breaker panel.

OIL SYSTEM INDICATION.

To correctly monitor the oil system operation, each engine has a low oil quantity warning light, an oil pressure indicator, a low oil pressure warning light, and an oil temperature indicator.

The low oil quantity warning light, the oil pressure indicator, and the oil temperature indicator are all located on the flight engineer's engine instrument panel. The low oil pressure warning light is located on the pilot's center instrument panel. As covered in lubrication, the low oil pressure warning light is used to indicate either low oil pressure or filter clogging.

LOW OIL QUANTITY INDICATION.

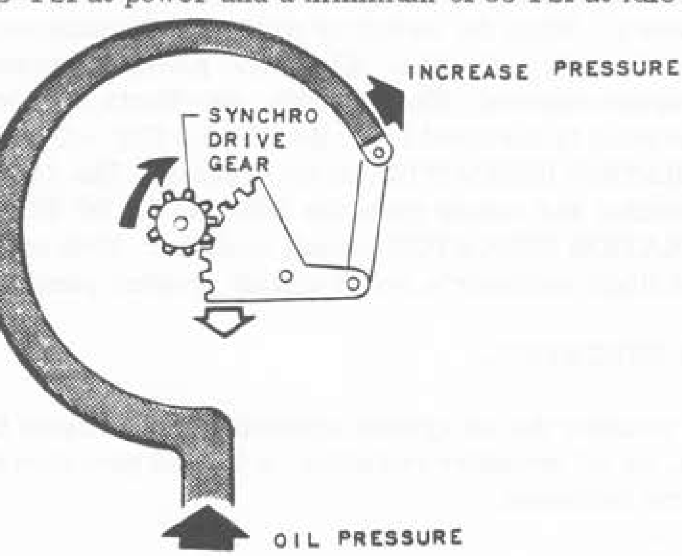
The engine low-oil quantity indicating system consists of an oil tank float-type switch, located inside each engine oil tank, and one low oil quantity indicator light, located on the flight engineer's instrument panel. When the oil level reaches one gallon of usable oil remaining, the float switch completes a circuit to ground and illuminates the red rectangular light on the flight engineer's engine instrument panel.

OIL PRESSURE INDICATION.

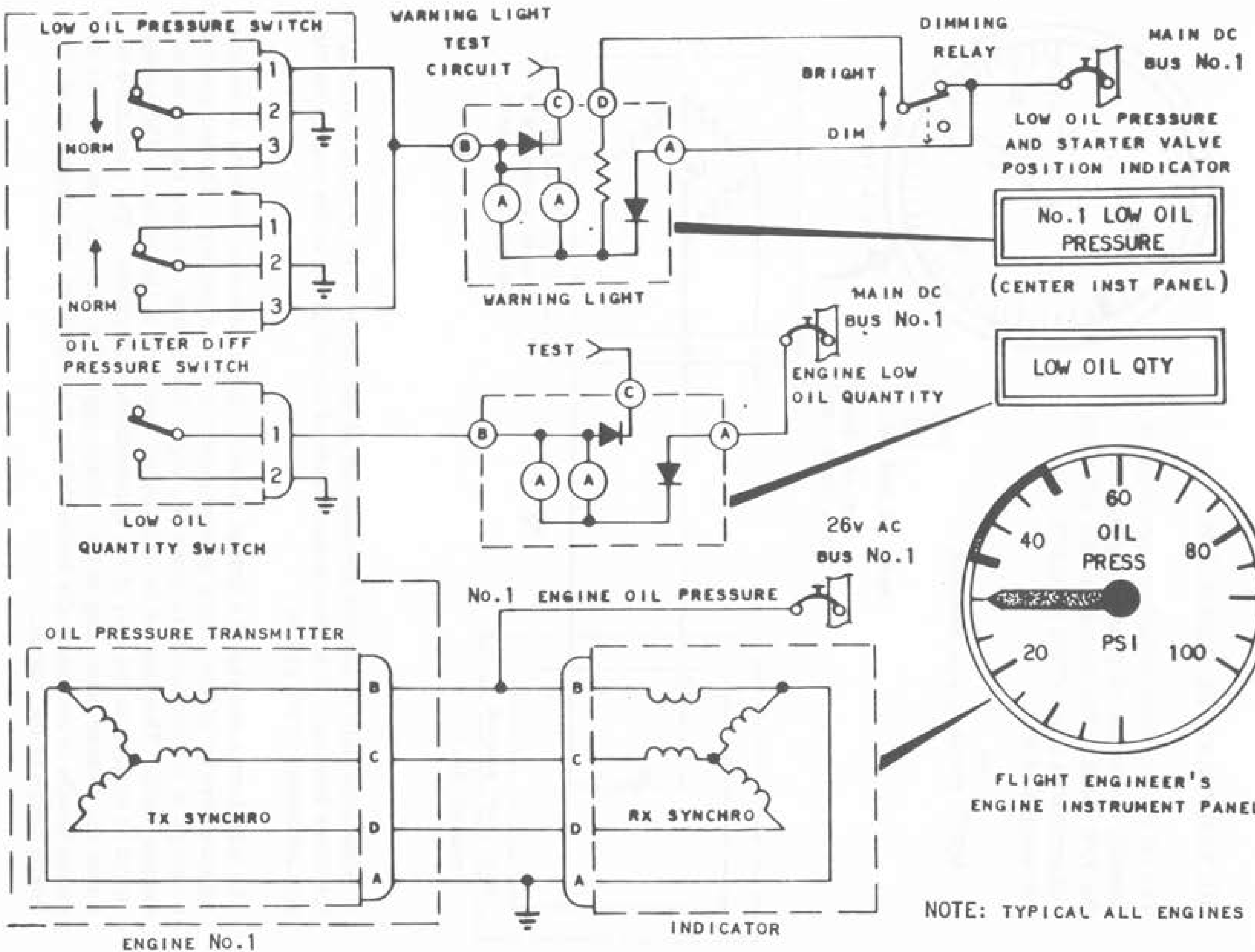
The oil pressure indicating system consists of a pressure transmitter and a pressure indicator. The system is identical for all engines on the aircraft. The transmitter is located just above the oil filter housing assembly and monitors oil pressure in the pressure passage on the downstream side of the oil filter.

The transmitter contains a transmitter syncho actuated by a bourdon tube assembly. As the oil pressure increases, the bourdon tube attempts to straighten. This movement positions the synchro transmitter and sends an electrical signal to the indicator.

The indicator contains a receiver synchro which is mechanically connected to the pointer. It is located on the flight engineer's panel, lower left-hand corner. The dial of the indicator is calibrated from 0 to 100 PSI in 5-PSI increments. Normal oil pressure is 45 ± 5 PSI at power and a minimum of 35 PSI at idle RPM.



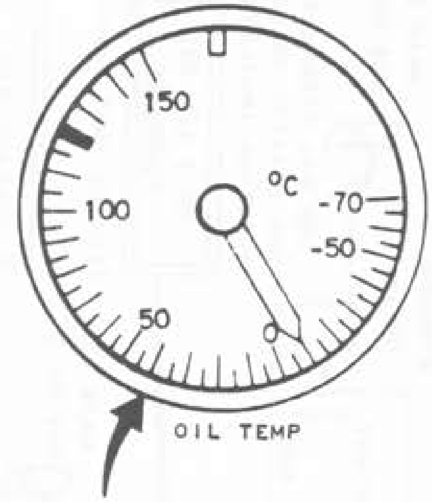
BOURDON TUBE OPERATION

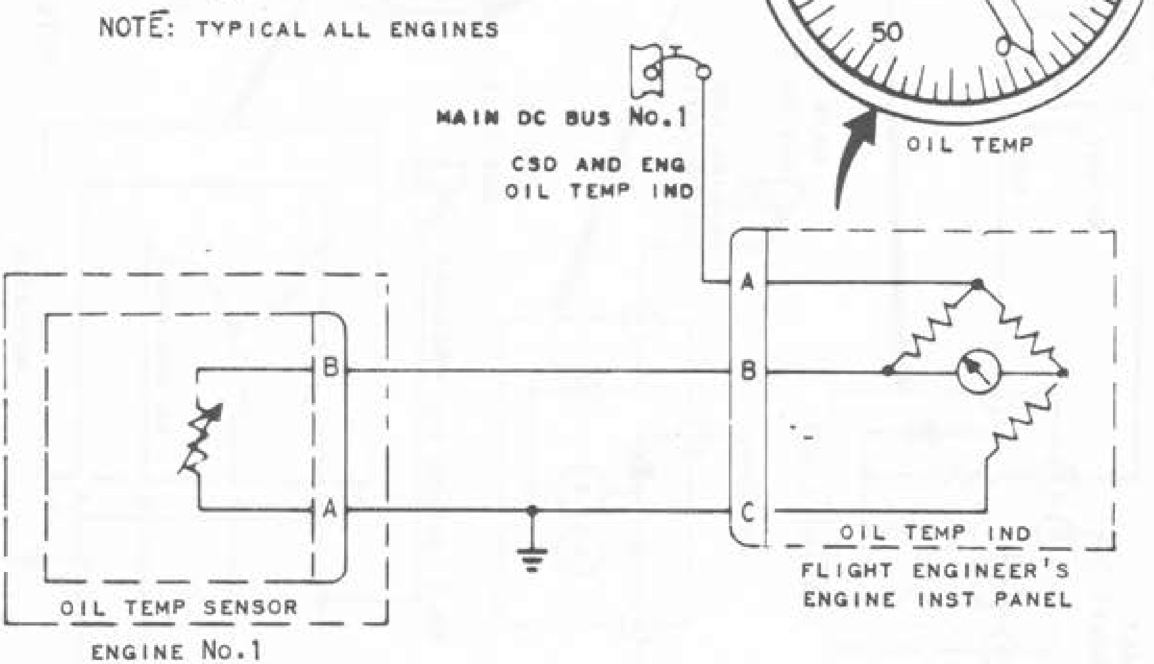


ENGINE OIL PRESSURE INDICATOR AND WARNING

OIL TEMPERATURE INDICATION.

The oil temperature indicators are located directly under the oil pressure guages on the F/E panel. The indicator dial indicates temperatures from -70°C to +150°C with increments of 5°C.





A resistance 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.

The bulb forms one leg of a bridge circuit. Each indicator consists of an unbalanced bridge circuit and a galvonometer-actuated pointer. The bridge detects a change in oil temperature since one leg of the bridge is in the temperature sensing bulb. This causes an unbalanced condition of the bridge. The bridge output is applied to the coil of the galvonometer armature. The armature deflects the pointer according to the voltage applied to the coil. Because the indicating needle is mechanically connected to the armature, an indication of oil temperature is the result.

CONSTANT SPEED DRIVE.

The Constant Speed Drive (CSD) is a hydraulic differential transmission driven at variable speeds by the jet engine accessory gearbox. Two different types are being used on the StarLifter. On earlier models, the General Electric "Model 2CLKH40D5" was installed, and on later aircraft a Sundstrand unit "Model 40AGD04" was installed. These completely interchangeable units are discussed individually:

GENERAL ELECTRIC MODEL 2CLKH40D5.

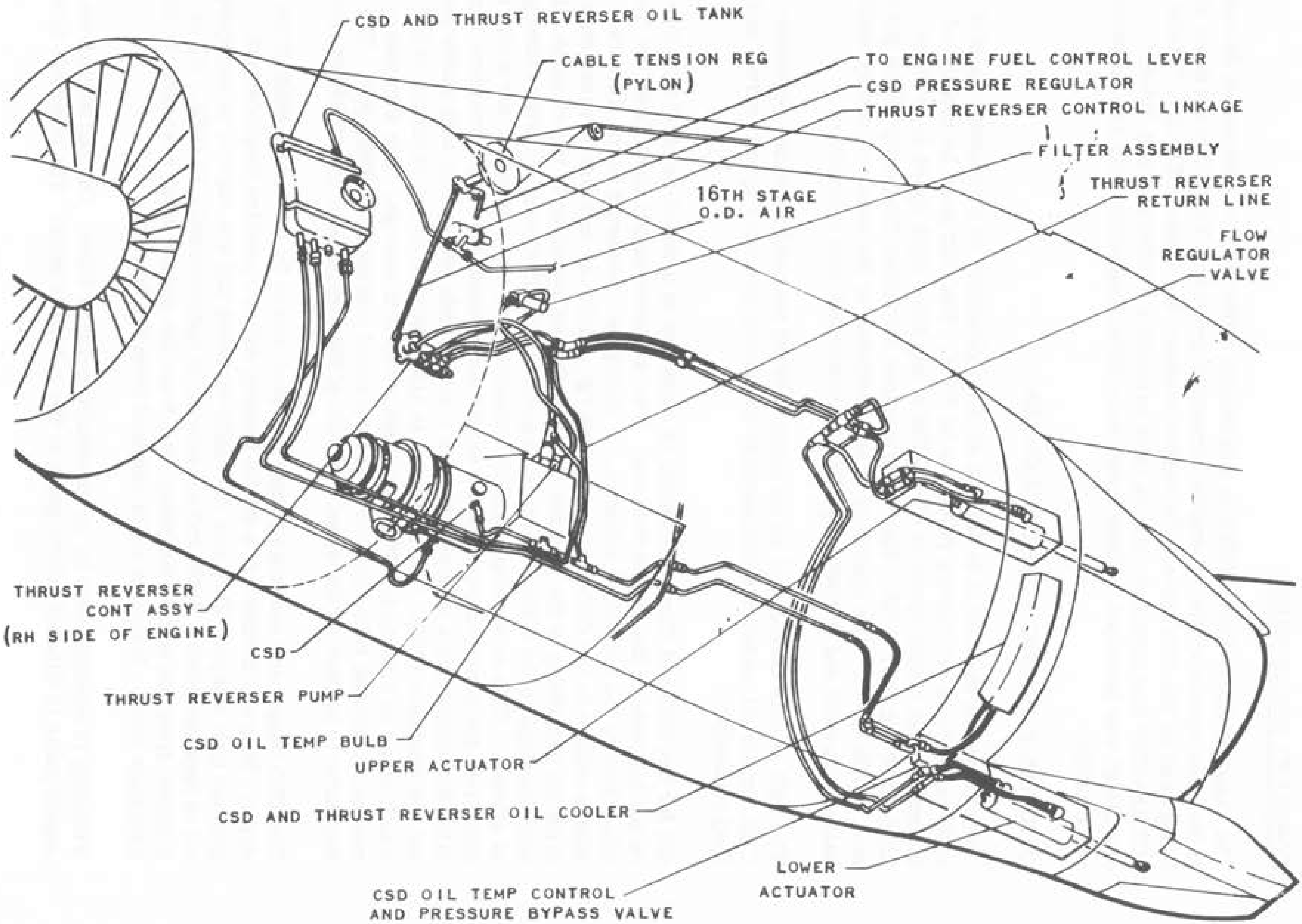
The purpose of the CSD is to drive a 40-KVA generator at a constant speed of 6000 revolutions per minute (RPM), ± 60 RPM. The CSD must be capable of maintaining an output speed of 6000 RPM at any time input speed is between 4100 RPM and 8500 RPM. This RPM ensures a constant frequency of the generator of 400 Hertz. The operation is accomplished by the action of two hydraulic ball piston units and is controlled by a governor and load controller.

The CSD system consists of an oil supply, an oil tank and pressure regulator, a CSD, an air oil cooler and temperature regulating pressure bypass valve, and a load controller.

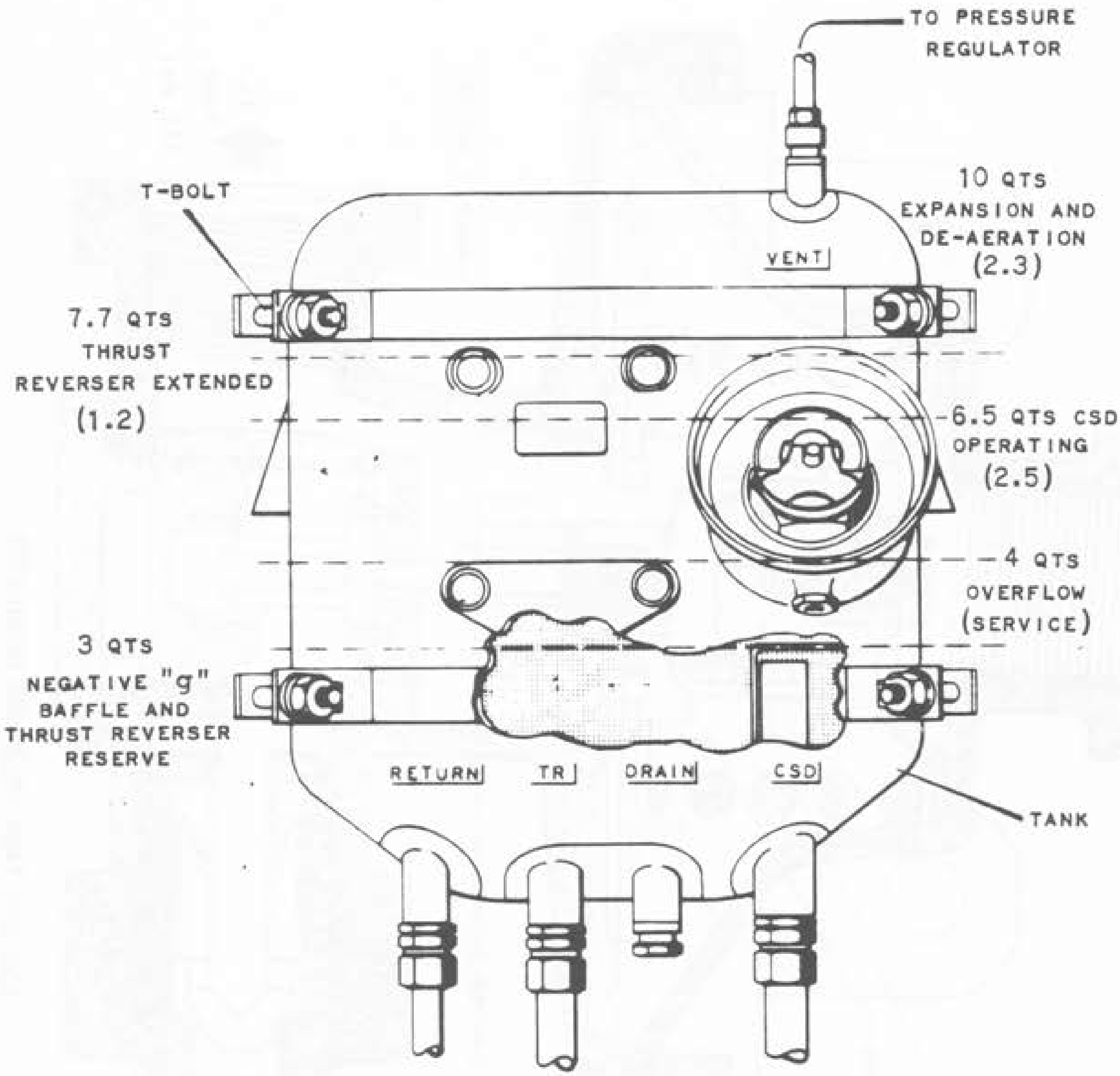
Oil for the CSD and Thrust Reverser is contained in a stainless steel tank located on the left side of the engine fan case. Two separate supply lines from the tank allow flow to the individual systems. A standpipe, connected to the CSD line, allows oilflow to the CSD during negative "g" conditions and also ensures sufficient oil remaining in the tank for thrust reverser operation in the event an oil leak develops in the CSD. The tank is pressurized to prevent oil from foaming at altitude. This is accomplished by high-pressure outer diameter air which is bled from the sixteenth stage of the engine compressor through a pressure regulator that maintains a tank pressure of 7 (±1) pounds per square inch above ambient air pressure (PSI). The regulator is also equipped with a pressure relief which opens at 8.25 to 9.5 PSI to prevent structural damage. For this same reason, a vacuum relief feature is incorporated and set at -2 PSIG (±1). The regulator is located on the upper left side of the compressor intermediate case.

The CSD supply and scavenge pumps are gear driven by the output shaft of the drive. Both are mounted in a single housing and are positive displacement gerotor type pumps. They are internally mounted and are capable of supplying oil at approximately 7 GPM and scavenging at approximately 11 GPM. Oil is supplied from the tank to the pump, and from the pump, under pressure, to the hydraulic units. Scavenge oil is obtained from the housing.

Filtering is accomplished by an externally mounted filter. Oil delivered from the supply pump is filtered before going to the hydraulic units. The complete filter



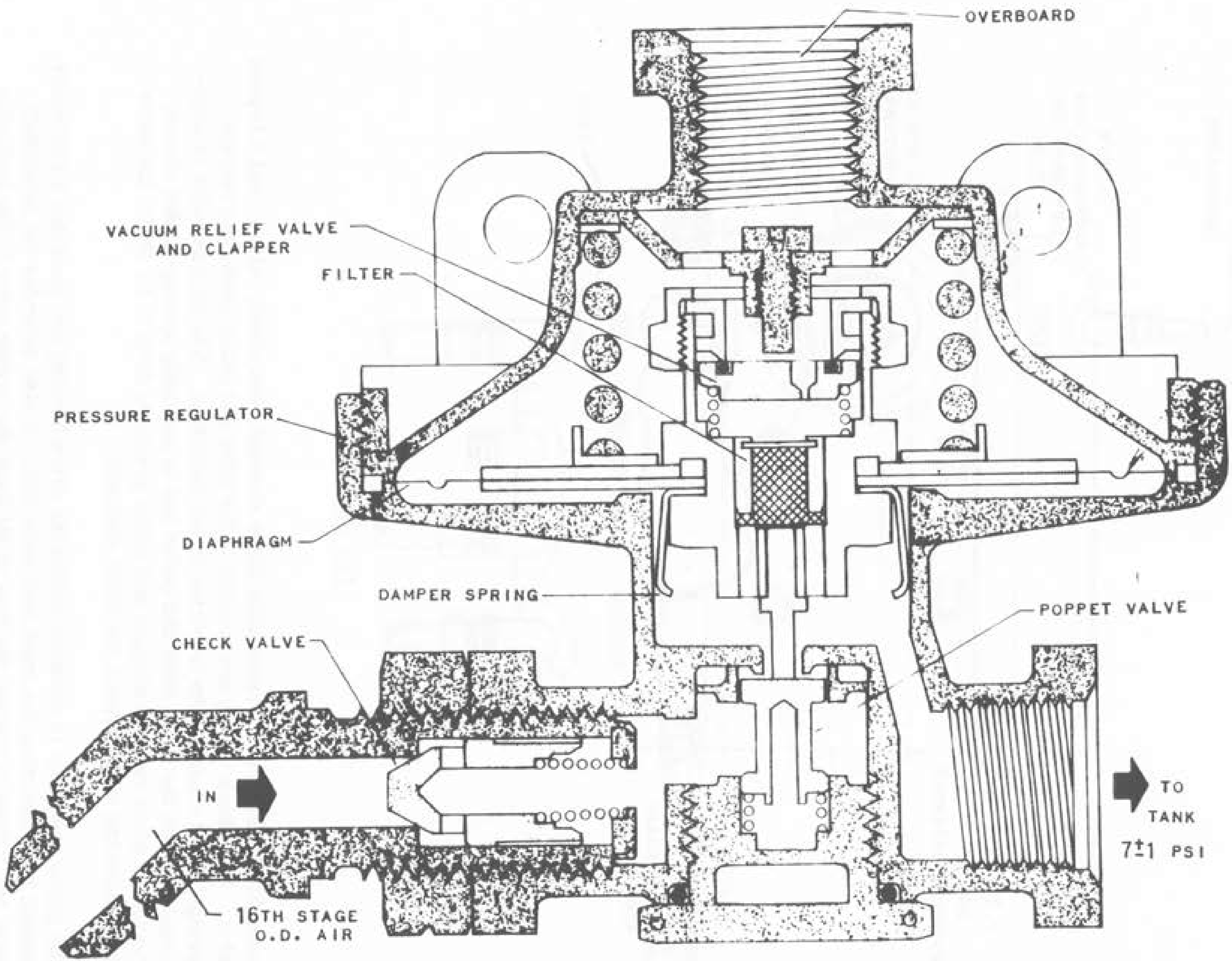
THRUST REVERSER AND CSD COMPONENTS LOCATION



CSD OIL TANK

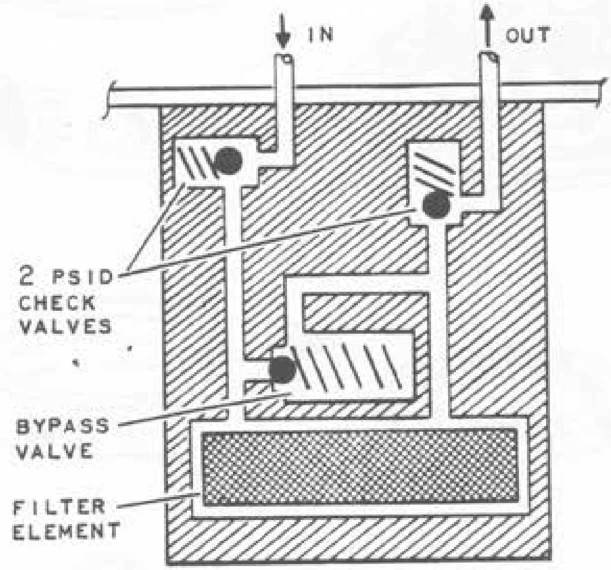
assembly consists of a replaceable filter element, two check valves, and a bypass valve. The check valves are located in the inlet and outlet ports and remain spring-loaded closed when the drive is not operating. The bypass valve is positioned between the filter inlet and outlet and is normally spring-loaded closed. Should the filter become clogged and outlet pressure drop to 18 PSID, the valve opens allowing oil to bypass the filter element.

The pintle assembly is mounted within the drive housing and provides a stationary journal for supporting the input hydraulic unit. It also provides the necessary ports and valves to control the flow of oil from the supply pump to the hydraulic units and from the units to the governor assembly. Two selector valves in the



CSD OIL TANK PRESSURE REGULATOR

pintle assembly allow oil to flow to the side of the hydraulic unit that has the lower pressure.



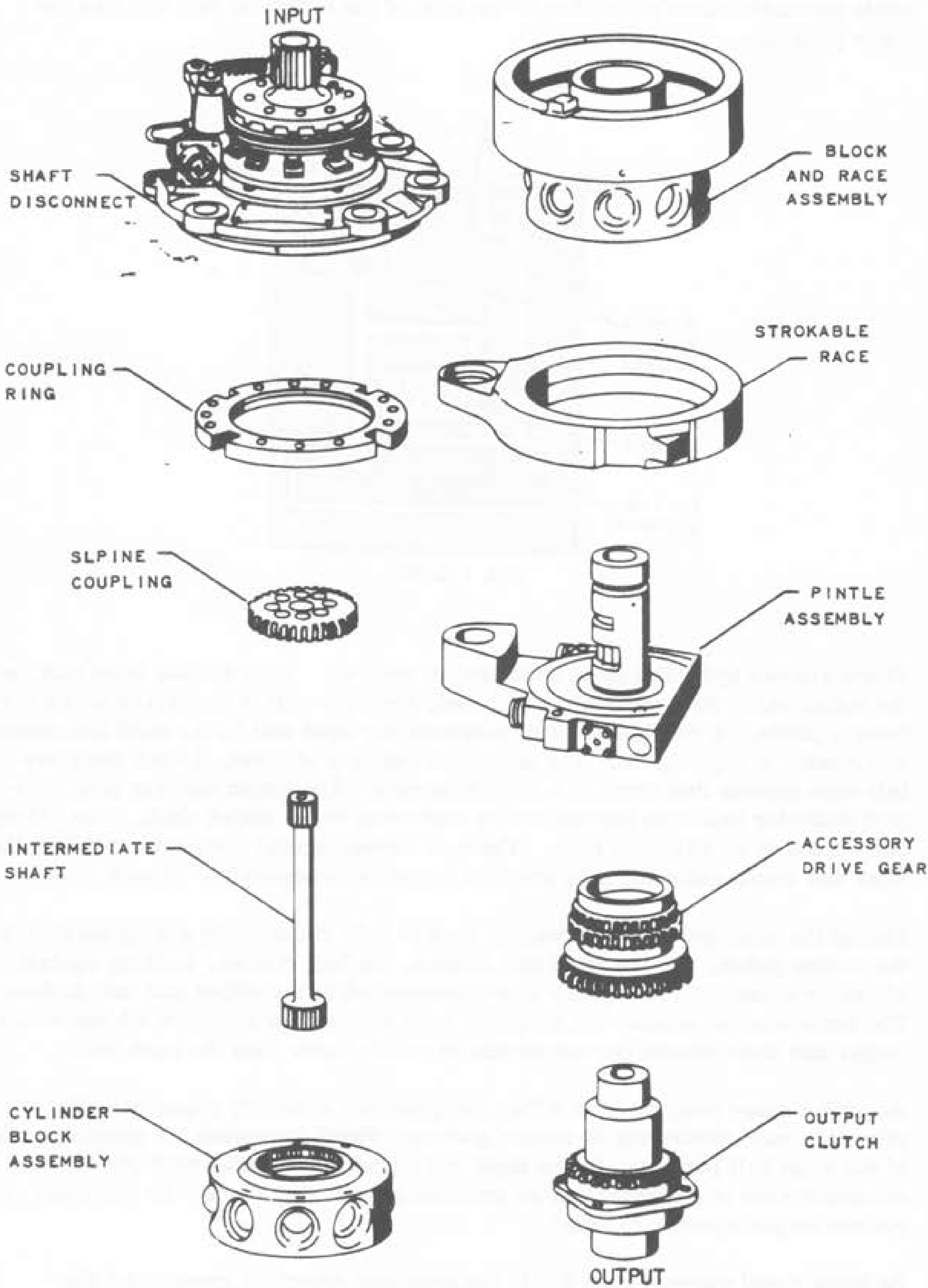
OIL FILTER

There are two hydraulic units contained in the CSD. They are the input unit, and the output unit. As previously mentioned, the input unit is supported by the stationary pintle. A flexible coupling connects the input unit to the shaft disconnect and rotates at input speed. The input unit consists of seven, 1-inch diameter ball-type pistons that track in a strokable race. The output unit has nine, 7/8-inch diameter ball-type pistons and is connected to the output shaft. The 7/8-inch balls track in an elliptical race. There is no mechanical connection between the input and output units and both are free to rotate independently of each other.

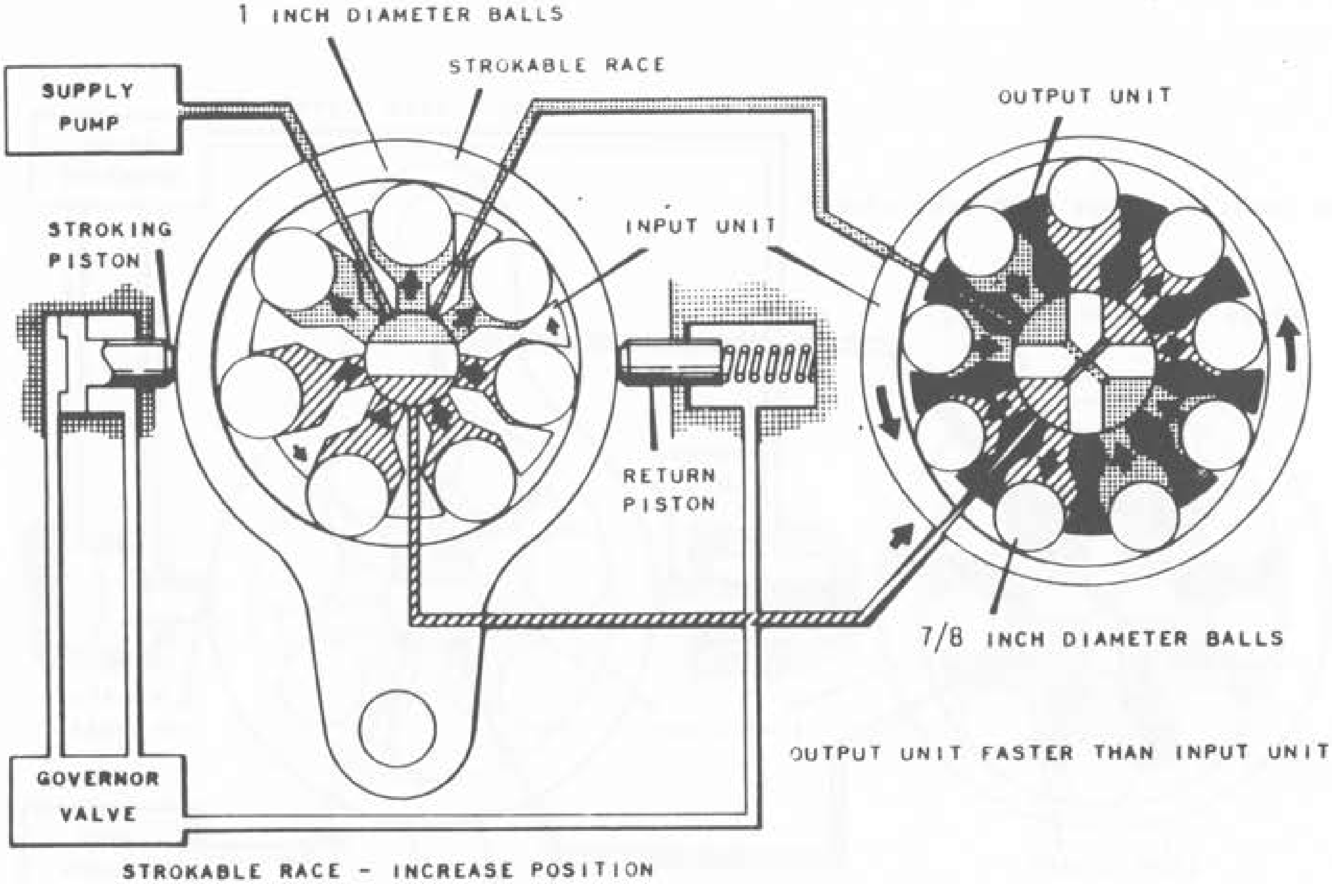
During the start cycle, the strokable race is held offcenter by spring tension of the return piston. As the input unit rotates, the ball pistons, working against the offcenter strokable race, pump high-pressure oil to the output unit ball pistons. The force exerted against the elliptical race by the high-pressure oil behind the output unit balls causes the output unit to rotate faster than the input unit.

As output speed reaches 6000 RPM, the governor assembly repositions the strokable race toward the on center position, which decreases the pumping action of the input ball pistons. As the input and output speed reach 6000 RPM, the strokable race is on center and no pumping action takes place. At this point, input and output speeds are equal.

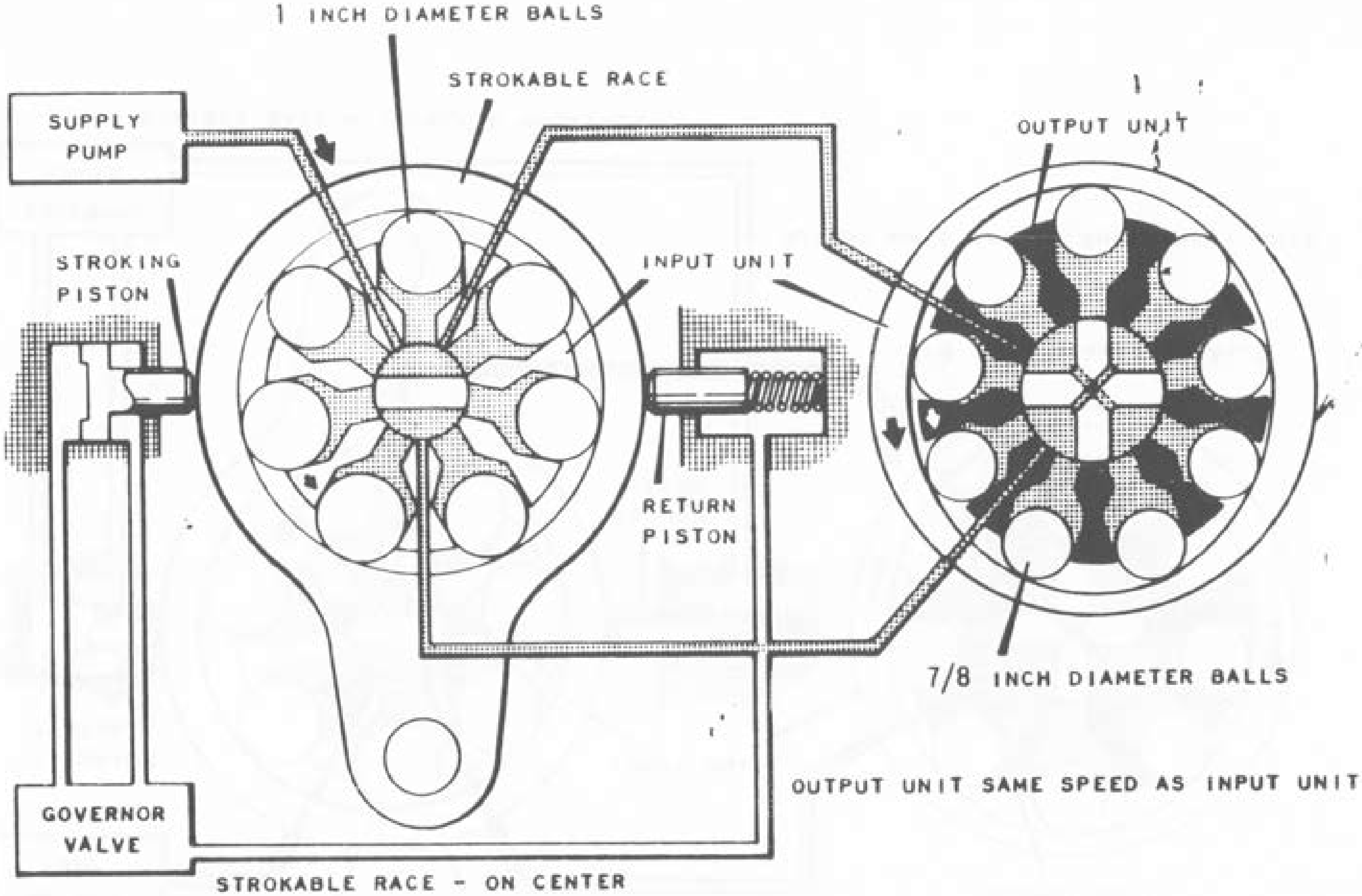
As input speed exceeds 6000 RPM, the governor assembly repositions the



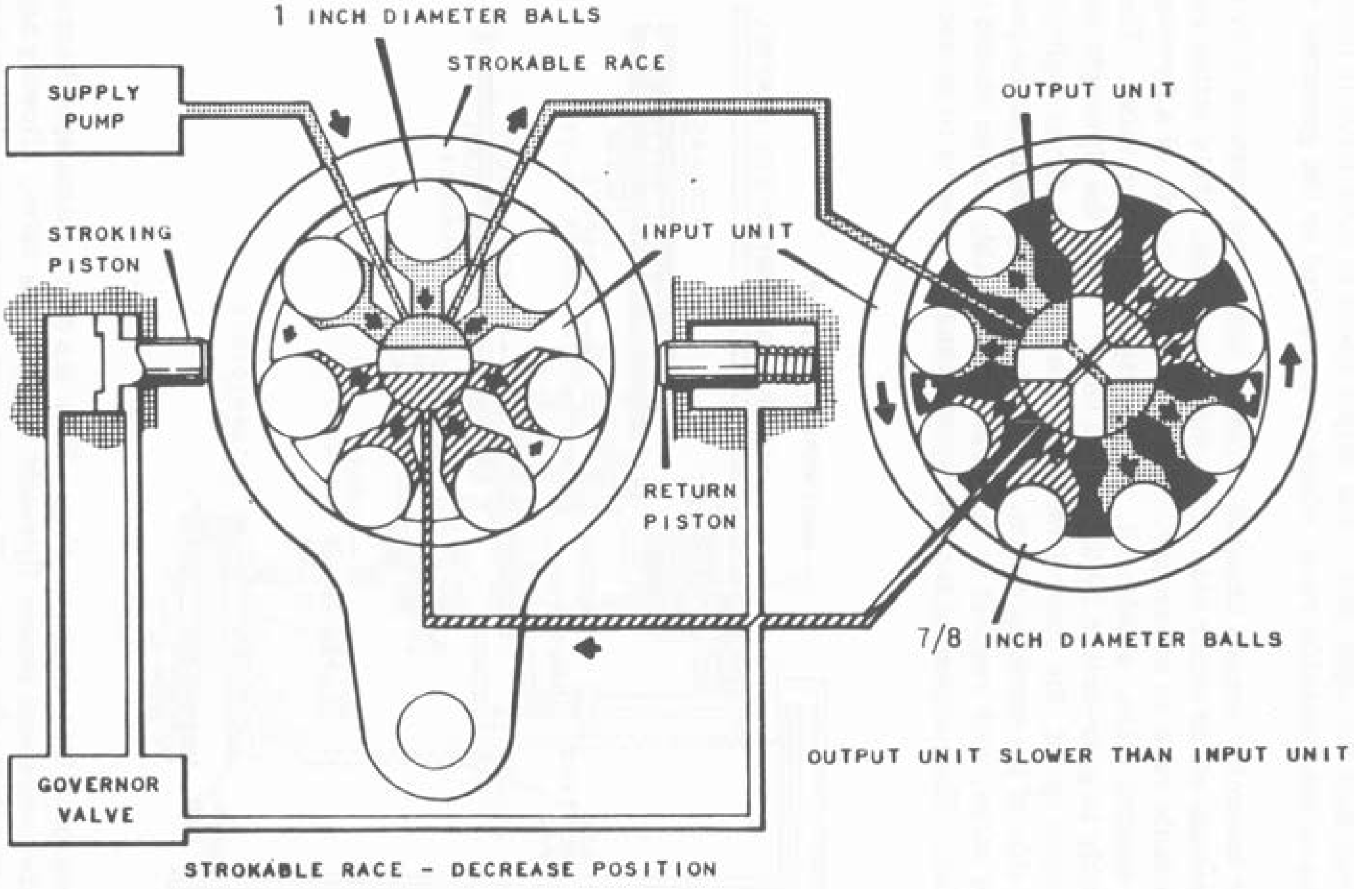
CSD MAJOR COMPONENTS



CDS OPERATION - STEP UP RATIO



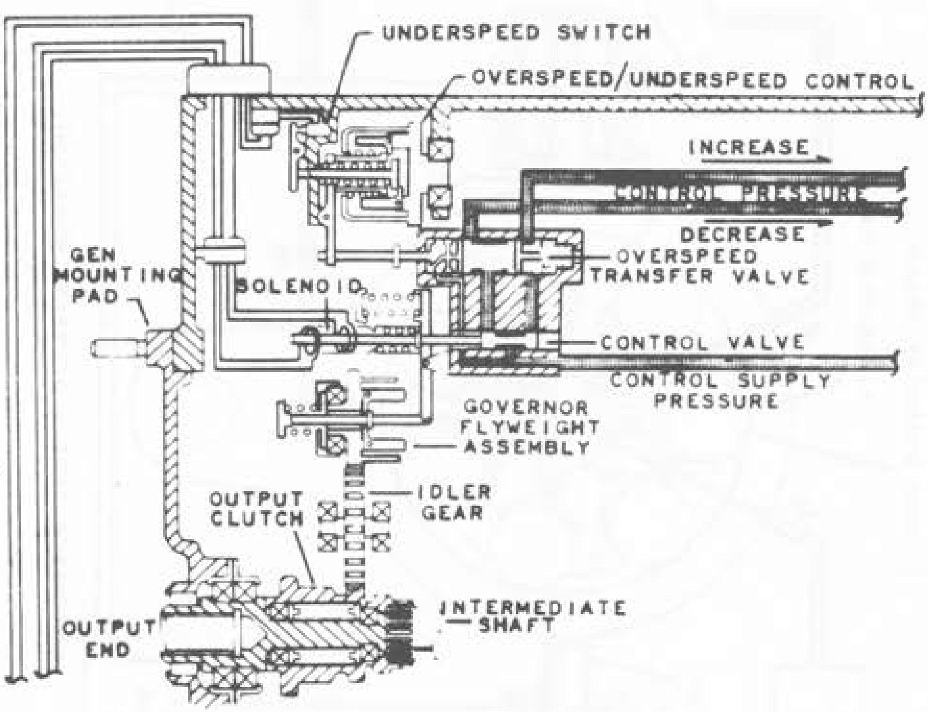
CDS OPERATION - THROUGH RATIO



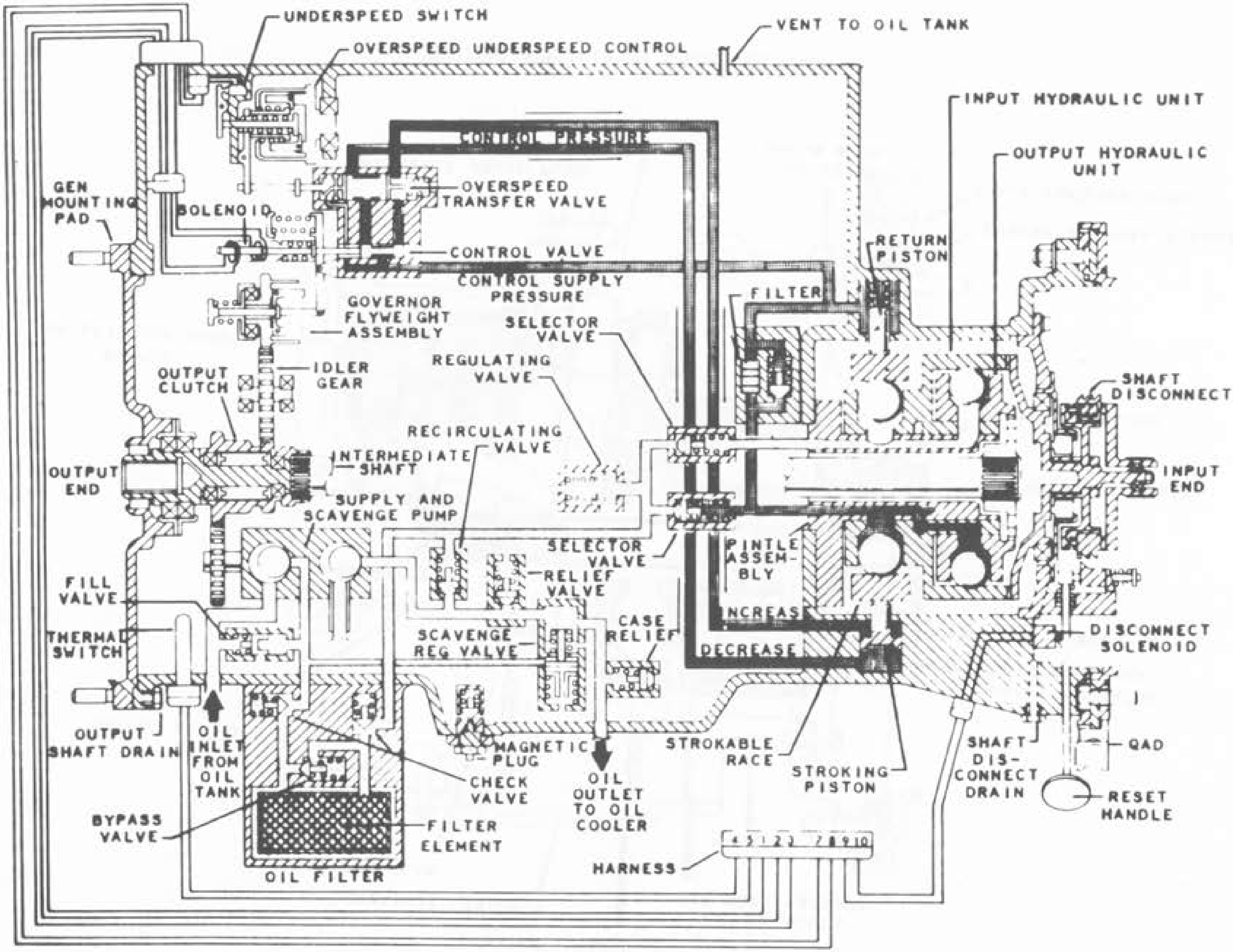
CDS OPERATION - STEP DOWN RATIO

strokable race offcenter toward the decrease position. When the strokable race is in this position, the flow of high-pressure oil is reversed and the output unit ball pistons function as a pump. The flow of oil from the output unit to the input unit, as controlled by the position of the strokable race, permits the output unit to rotate slower than the input unit. The output speed of 6000 RPM is maintained by the position of the strokable race, which is controlled by the governor assembly.

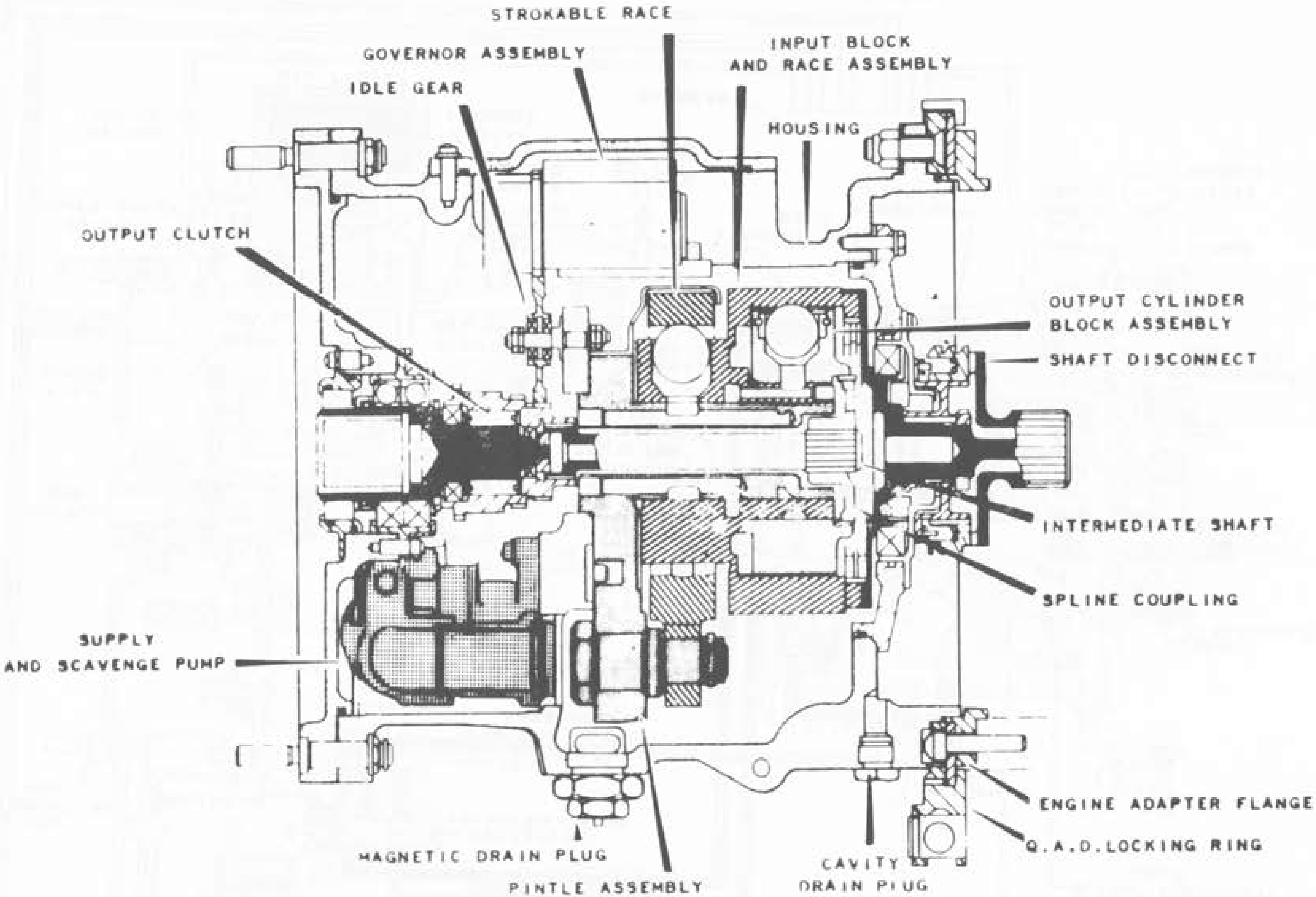
The governor assembly senses changes in output speed and corrects it by directing high-pressure oil to either side of the stroking piston. This action repositions the strokable race as necessary. The governor consists of a flyweight assembly, a control valve, a solenoid, and overspeed transfer valve. The flyweight assembly is gear-driven by the output shaft. When the flyweight senses changes in output speed, the control valve is repositioned to direct high-pressure oil to either side of the stroking piston. The solenoid also changes the position of the control valve, with respect to the flyweight assembly, when biased by the load controller. The purpose of the overspeed transfer valve is to protect the



drive and generator from overspeeding. When the drive output speed exceeds 7200 RPM, the overspeed sensor flyweight triggers the valve, allowing high-pressure oil to actuate the valve. The valve snap-actuates and directs high-pressure oil to the decrease side of the stroking piston. Once actuated, the valve remains in this position until all pressure has decayed. Approximately one minute at zero RPM is required for this decay; then the valve automatically resets.



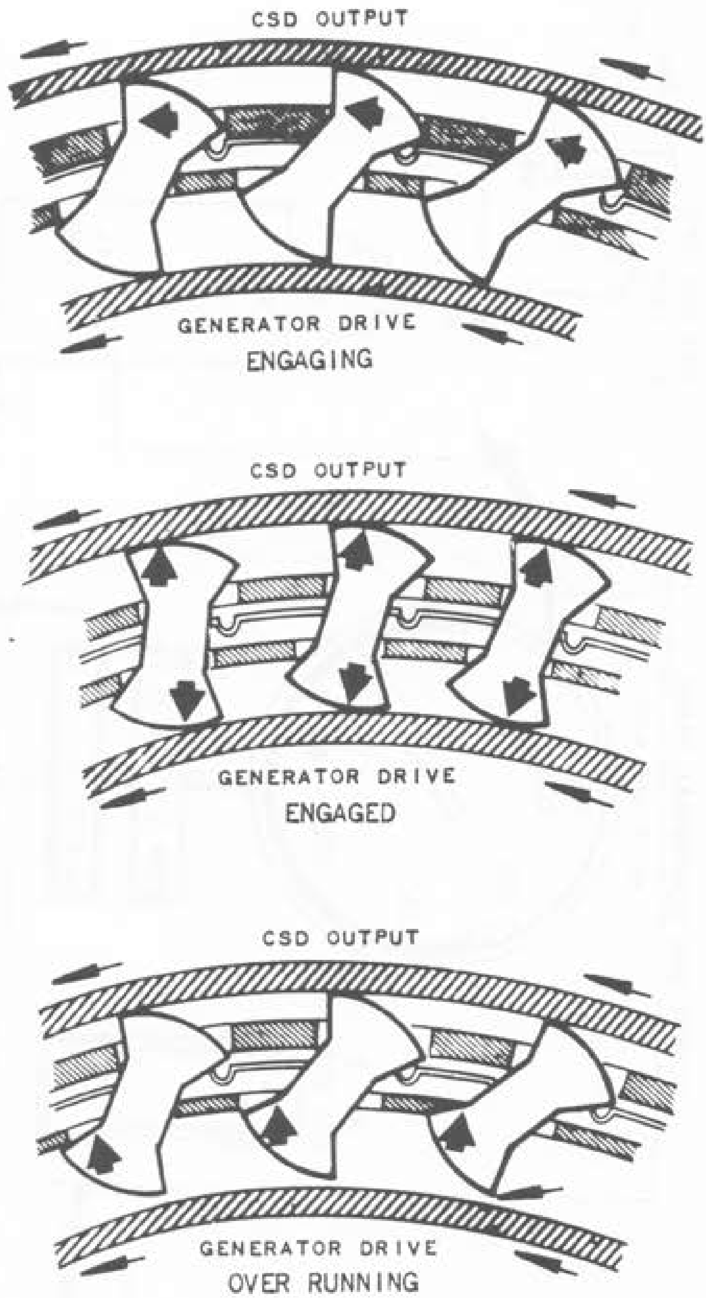
CONSTANT SPEED DRIVE OIL SYSTEM SCHEMATIC



CONSTANT SPEED DRIVE CROSS-SECTION

A load controller, used in conjunction with each drive, is located inside the Star-Lifter fuselage, at the right-hand underdeck equipment rack. Purpose of the load controller is to sense an unbalanced load between its generator and the average load of the generators on the line. Correction for an unbalance is accomplished by sending an increase or decrease signal to the governor solenoid of the drive.

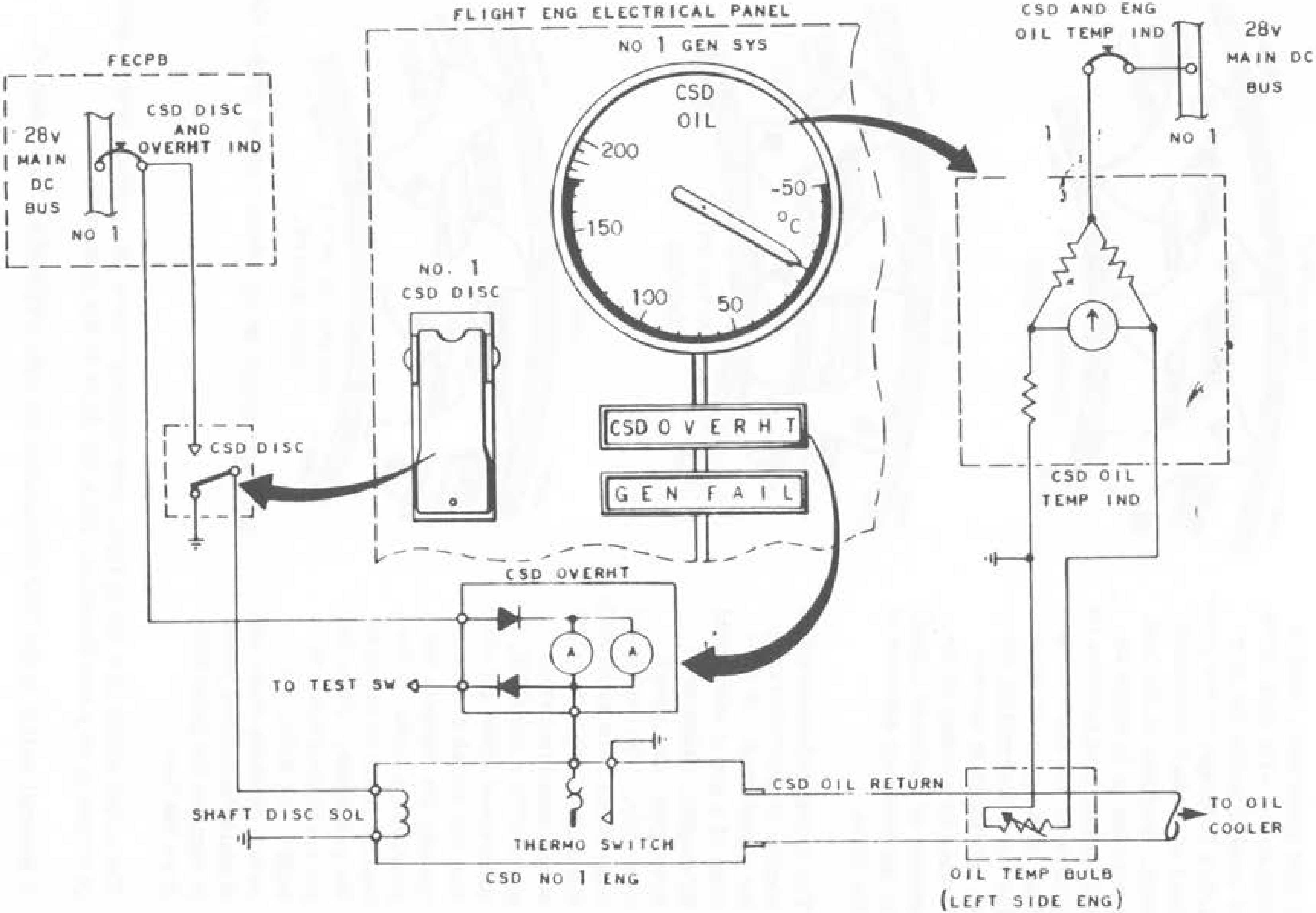
The overspeed-underspeed control is gear-driven by the output shaft. It consists of a set of overspeed flyweights, underspeed flyweights, and switch assembly. The overspeed control has been previously discussed. When the CSD output speed increases above 5700 ± 120 RPM, the underspeed flyweight actuates the switch assembly, opening the contacts and providing a signal to the control panel to energize the generator. When output speed decreases to 5400 ± 120 RPM, the switch contacts close and signals the control panel to remove the generator from the line.



CONSTANT SPEED DRIVE SPRAG CLUTCH OPERATION

The output clutch is a sprag type, over-running clutch that permits transmission of torque in only one direction, from the drive to the generator.

A thermal switch in the CSD illuminates the CSD OVERHEAT light when oil



CSD OIL TEMPERATURE INDICATING SYSTEM

temperature reaches 185°C. When the temperature of the CSD oil drops below 174°C, the contacts open and the light goes out.

The input shaft disconnect is mounted on the input end of the CSD housing. It couples the output drive of the engine accessory gearbox with the input hydraulic unit of the CSD. The disconnect, solenoid-operated and controlled by CSD DISCONNECT switch on the flight engineer's panel, provides rapid means of disengaging the CSD and generator from the engine drive. The drive may be disconnected either during flight or ground operation by positioning the CSD DISCONNECT switch, which energizes the disconnect solenoid. Once disengaged, the drive can be reset mechanically only on the ground. To prevent damage to the disconnect assembly, reset is accomplished by pulling the reset handle while the engine is stopped.

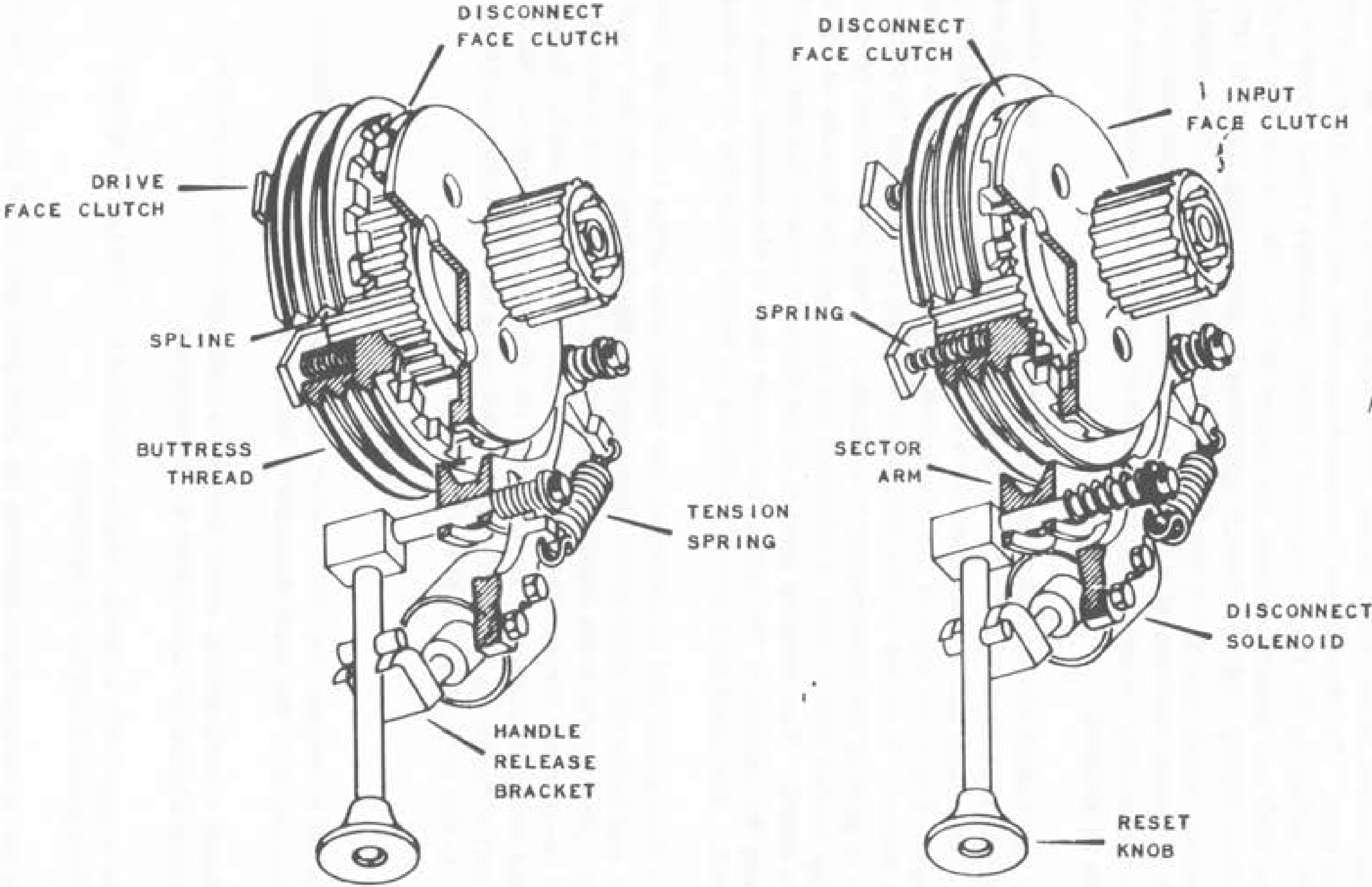
The CSD input shaft disconnect consists primarily of a rotating-face clutch assembly and a stationary housing. The rotating-face clutch assembly contains an input face clutch and a disconnect face clutch, both splined and held engaged by springs. The outer edge of the disconnect face clutch contains a course buttress thread. Mounted on the stationary housing is a pivoted thread sector arm that is part of the disengaging mechanism. When the solenoid is energized, the spring-loaded sector arm is released and engages the threads on the disconnect face clutch. The rotating motion of the threads causes the disconnect to slide along the splines of the drive face clutch until it disconnects from the input face clutch. The input face clutch continues to rotate while the drive decelerates.

When the disconnect unit is actuated, the sector arm drops below the thread shoulder and holds the disconnect clutch against the spring until the reset handle is pulled. Pulling the reset handle allows spring tension to overcome the disconnect and re-engages the splines of the input and disconnect clutch. Simultaneously, the thread sector mechanism is cocked to the disconnect solenoid. Should the splines fail to mate, as the next engine rotation is accomplished (starting, motoring, etc.), the assembly restores itself to normal.

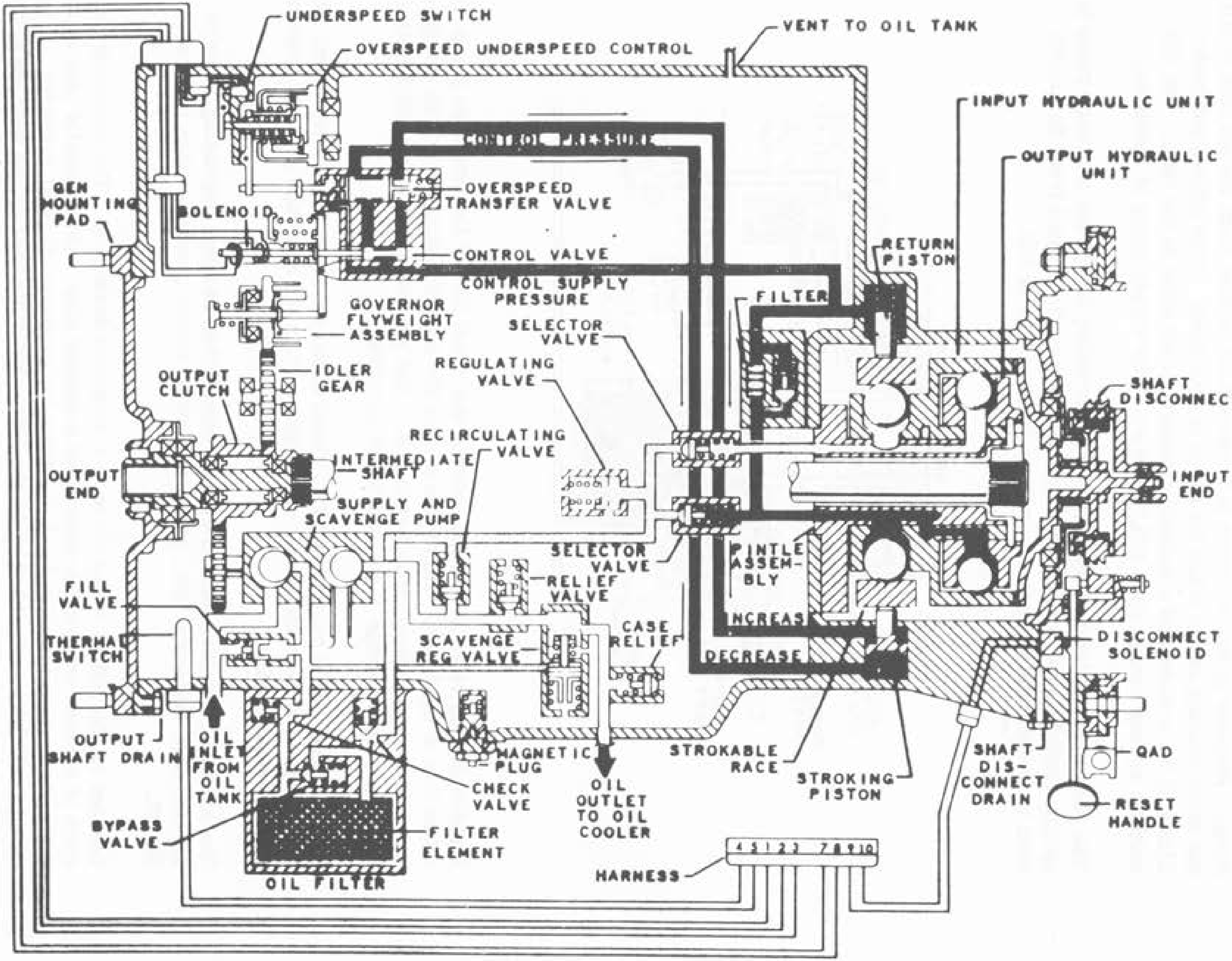
CAUTION

> Do not disengage the drive under static conditions because damage may occur to the shaft disconnect during engine start.
>
> Should a malfunction occur during system operation, corrective action should be taken prior to re-engaging.
>
> Re-engage only at static engine conditions. Damage of splines takes place if engine is operating.

A fill valve is incorporated between the inlet port and outlet port of the oil supply



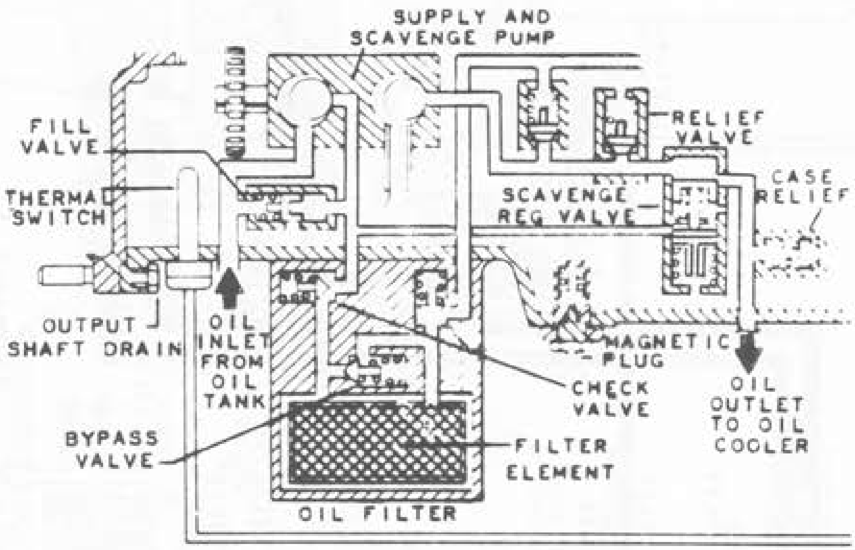
CONSTANT SPEED DRIVE OIL SYSTEM SCHEMATIC



CSD OIL SYSTEM SCHEMATIC

pump. Purpose of the fill valve is to permit oil to flow from the oil tank to fill the drive housing cavity when the drive is shut down. This allows complete filling of the system and a definite measurable oil level in the tank. The fill valve is spring-loaded open and closes when the supply pump is operating.

The scavenge regulating valve located in the outlet line of the scavenge pump is spring-loaded closed and prevents oil from being discharged from the cavity back to the oil tank whenever supply pump pressure is lost.

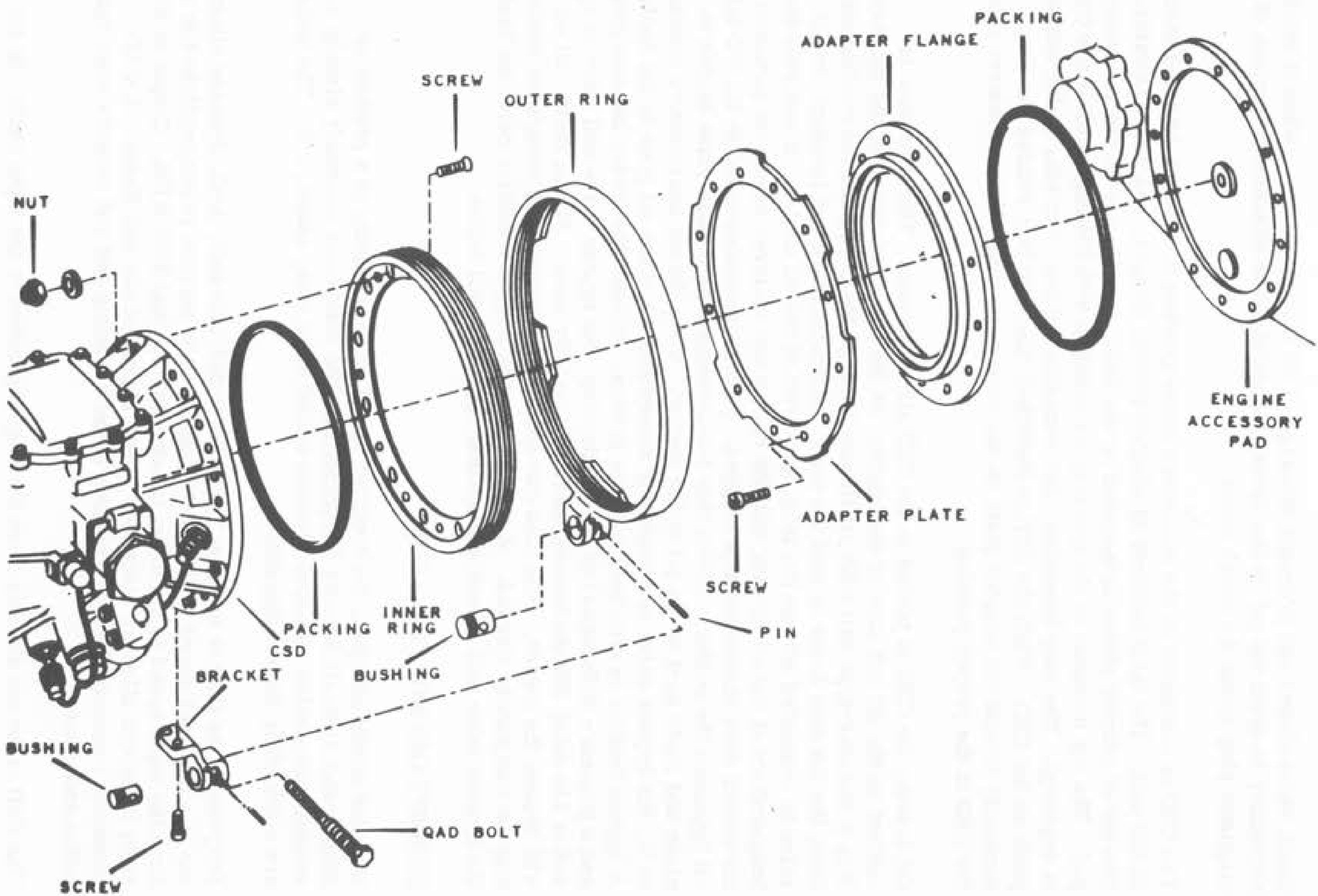


A recirculating valve is located between the outlet line of the scavenge pump and outlet line of the filter. This valve allows the scavenge pump to act as a supply pump when supply pump pressure is lost. The recirculating valve will function only when the scavenge regulating valve is closed.

The scavenge relief valve is located ahead of the scavenge regulating valve. Its purpose is to relieve excessive oil pressure when the scavenge pump is functioning as a supply pump.

The case relief valve, located downstream of the scavenge regulating valve in the scavenge discharge line, relieves housing cavity pressure when it exceeds 50 PSI.

Located on the bottom of the drive is a magnetic drain plug. The assembly consists of a check valve and a removable magnetic plug. The magnetic plug makes it possible to electrically check the drive for evidence of metal particles. If any metal particles were picked up by the plug, continuity then exists between ground and the center threaded post on the plug. When the magnetic plug is removed, the



CONSTANT SPEED DRIVE QAD

check valve closes and prevents drainage of oil from the drive. When it becomes necessary to drain the oil in the drive, a special drain attachment in place of the megnetic plug opens the check valve.

The CSD is connected to the accessory drive gearbox by a Quick Attach-Detach (QAD) unit. The QAD consists of adapter plates, flanges, and ring assembly. One set of adapter plates is mounted on the CSD, the other is on the accessory pad. The set mounted on the pad may be retained with the engine after the CSD is replaced. The ring assembly, that connects the two, remains on the adapter plate on the CSD. When the CSD is installed, the QAD bolt rotates the ring assembly around the adapter plate on the accessory pad. This movement secures the CSD in the proper position.

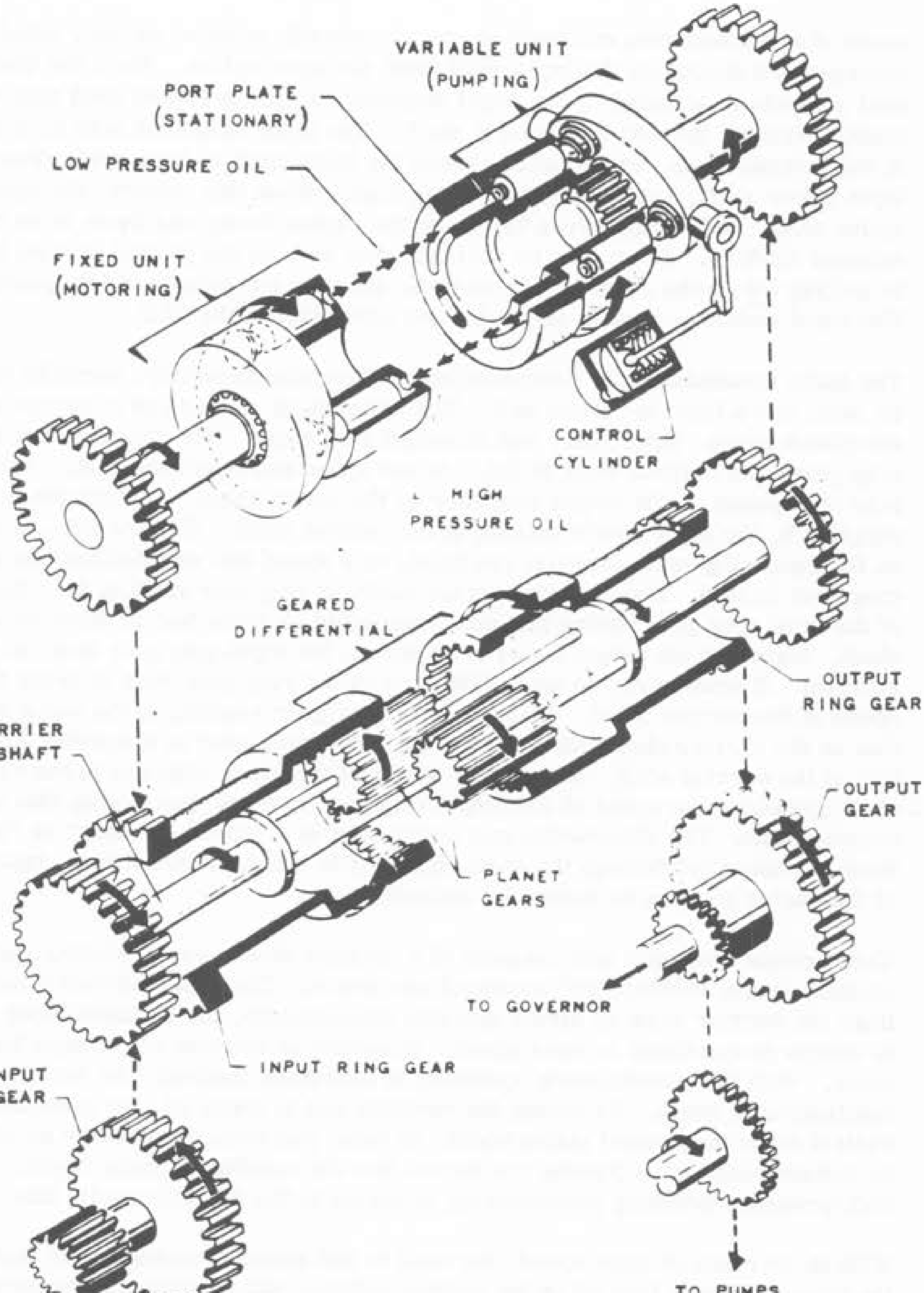
Oil leaving the CSD is ported to the CSD air-oil cooler. The oil cooler is located on the aft left side of the engine, on the outer periphery of the fan duct. It is a radiator-type unit with oil flowing through the core, and the cooling air from the fan duct flows around the core. A temperature and pressure relief valve is connected across the inlet and outlet of the oil cooler. It controls the temperature of the oil flowing into the cooler and relieves excessive pressure if the cooler core should become clogged. At oil temperatures below 73.9°C all oil bypasses the cooler. Above this temperature, the bypass valve begins to close and route part of the oil to the cooler. When the oil temperature reaches 85°C, the bypass valve is completely closed and all of the oil goes to the cooler. A bypass feature is also built into the system. Should the cooler become clogged, and a pressure differential of 65 PSI develop, the bypass valve will start to open, and at 110 (±10) PSI the bypass valve will be fully open. At this point, all oil will bypass the cooler. The CSD can continue operation even though the cooler may be completely clogged. If at any time the clogged condition relieves itself, the bypass valve will reseat and normal operation will follow.

SUNDSTRAND MODEL 40AGD04.

On later model aircraft, the constant speed drive assembly is a product of Sundstrand Aircraft Service Corporation. The completed assembly closely resembles the earlier General Electric model as to size, shape, etc. The units are completely interchangeable.

Purpose of the CSD is to drive a 400-Hertz 208/120-volt, A-C, 3-phase alternator at a constant speed of 6000 RPM (±60). This purpose is accomplished at anytime the input speed to the drive is between 4100 and 8500 RPM. Output of 6000 (±60) RPM will allow an electrical power supply of 400 (±4) Hertz. A QAD assembly connects the transmission to the mounting pad and permits easy installation and removal.

The CSD is driven directly from the engine gearbox to the input shaft. In the

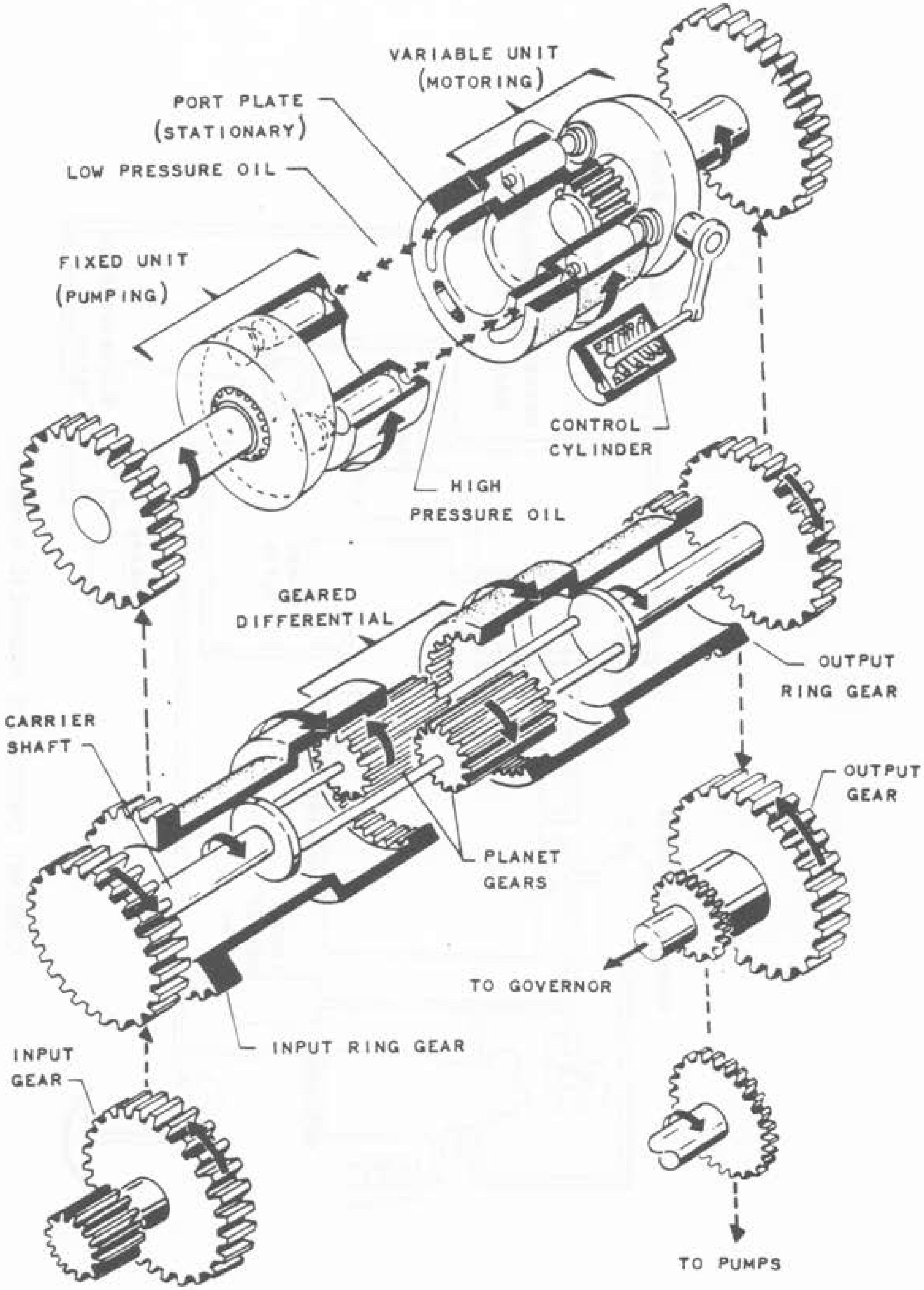


OVERDRIVE PHASE (STEP UP) CONSTANT SPEED DRIVE event of a transmission malfunction, an electrically actuated device, which is incorporated decouples the input shaft from the input spline. When the disconnect solenoid is actuated by the flight engineer, a spring-loaded pawl moves into contact with the threads on the input shaft. The input shaft then acts as a screw in the threaded hole, and rotation causes the input shaft to move away from the input spline shaft, separating the driving dogs. When this occurs, the input spline shaft, still being driven by the engine, spins freely and there is no transmission rotation. Reset may be accomplished only on the ground at zero RPM, by pulling out on the reset handle until the solenoid pin pops back into position. The reset handle is located on the bottom centerline of the CSD.

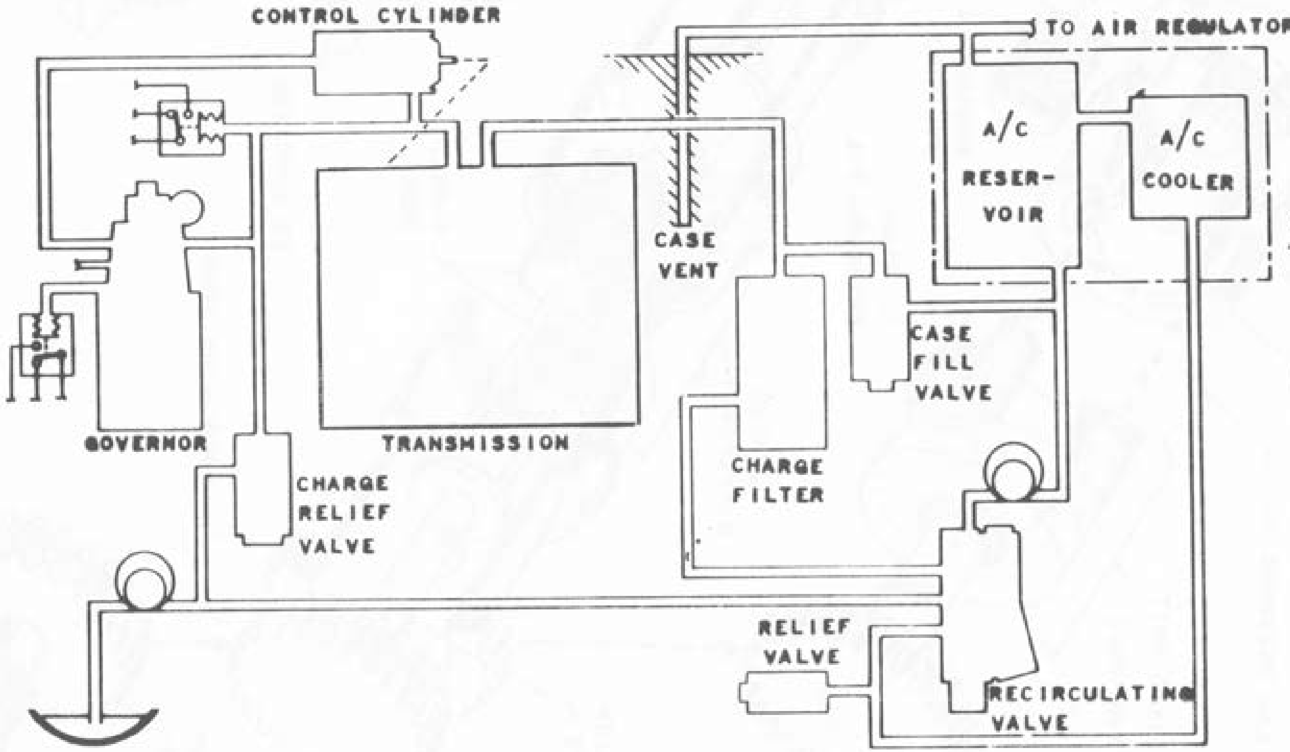
The basic transmission is composed of a differential assembly, variable hydraulic unit, and a fixed hydraulic unit. The differential consists of a carrier shaft, two planet gears, input gear, and an output ring gear. The ratio between the ring gears and carrier shaft is 2:1. At any speed and load condition, a torque load is imposed on the output ring gear by the output gear. Input torque is supplied by the input gear's turning of the carrier shaft. If there were no torque on the input ring gear, it would run freely at a speed that would allow the output ring gear to stop. Because the carrier shaft-to-ring gear ratio is 2:1, the speed of the input ring gear during this condition would be twice that of the carrier shaft. Since a given output speed is required, the input ring gear must be constrained. If constrained to zero RPM, the output ring gear runs at twice the speed of the carrier shaft. With the input ring gear rotating in the same direction as the carrier shaft, the speed of the output ring gear is somewhat less than that of the carrier shaft. Rotation of the input ring gear opposite to the carrier shaft increases the speed of the output ring gear to more than double that of the carrier shaft. The differential unit action then is a "speed summer" or "adding" device, controlled through the input ring gear to add or subtract from input speed of the engine gearbox to obtain the desired output.

The variable hydraulic unit consists of a cylinder block, reciprocating pistons, a variable-angle wobbler, and a control unit piston. The unit is driven directly from the carrier shaft by direct gearing; consequently, the cylinder block speed is always proportional to input speed. Direction of rotation will always be the same. With the transmission operating in overdrive (adding), the variable unit functions as a pump. To enable the variable unit to pump oil, the governor ports control oil to the control piston which, in turn, positions the wobbler so oil will be compressed as the pistons are forced into the rotating cylinder block. This high-pressure (working pressure) oil is ported to the fixed hydraulic unit.

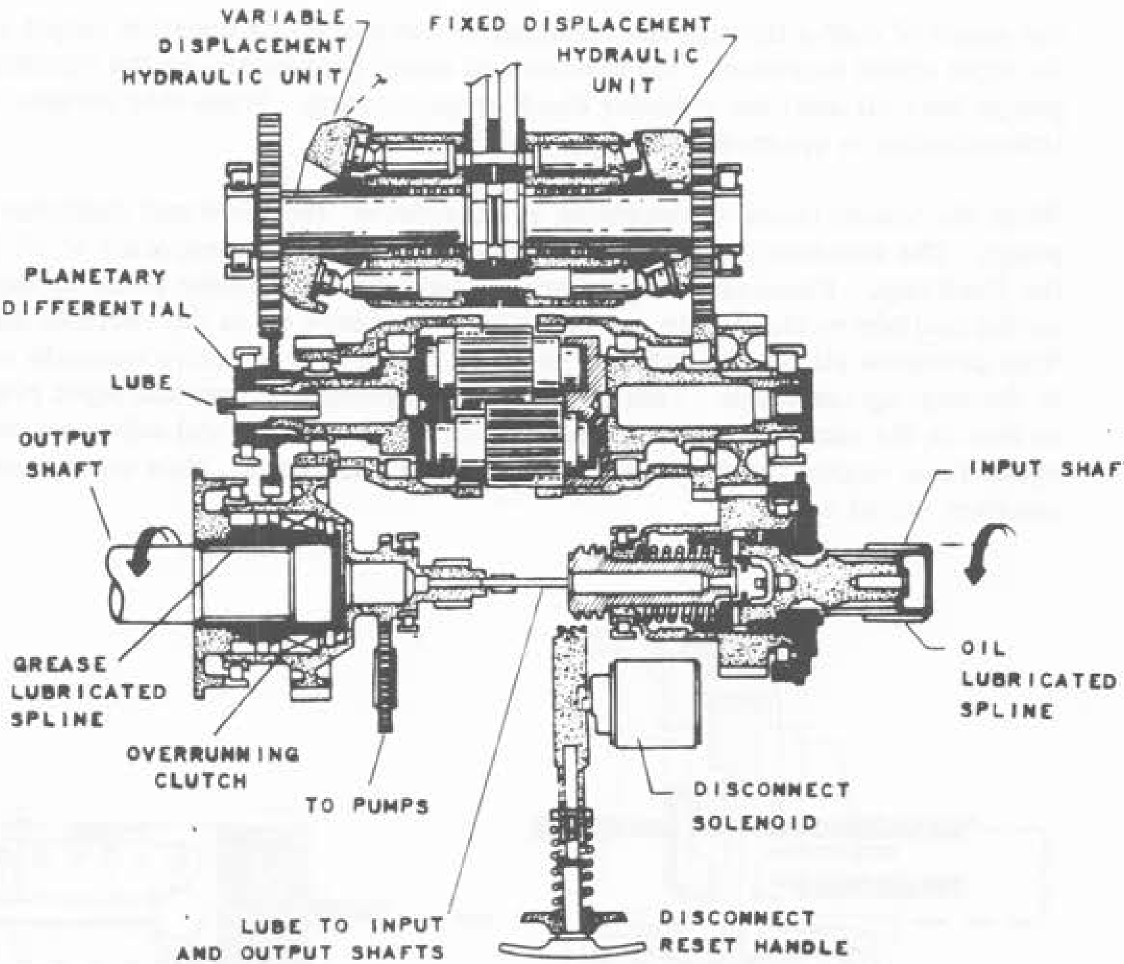
With an increase of input speed, the need to add speed decreases. As this occurs, the governor ports less oil to the control cylinder and repositions the variable unit until the face of the variable wobbler is approximately perpendicular to the pistons; no oil is pumped or received by the variable unit. The input ring gear is stopped and the transmission is operating in straight-through drive.



UNDERDRIVE PHASE (STEP DOWN) CP CONSTANT SPEED DRIVE



CONSTANT SPEED DRIVE HYDRAULIC SCHEMATIC

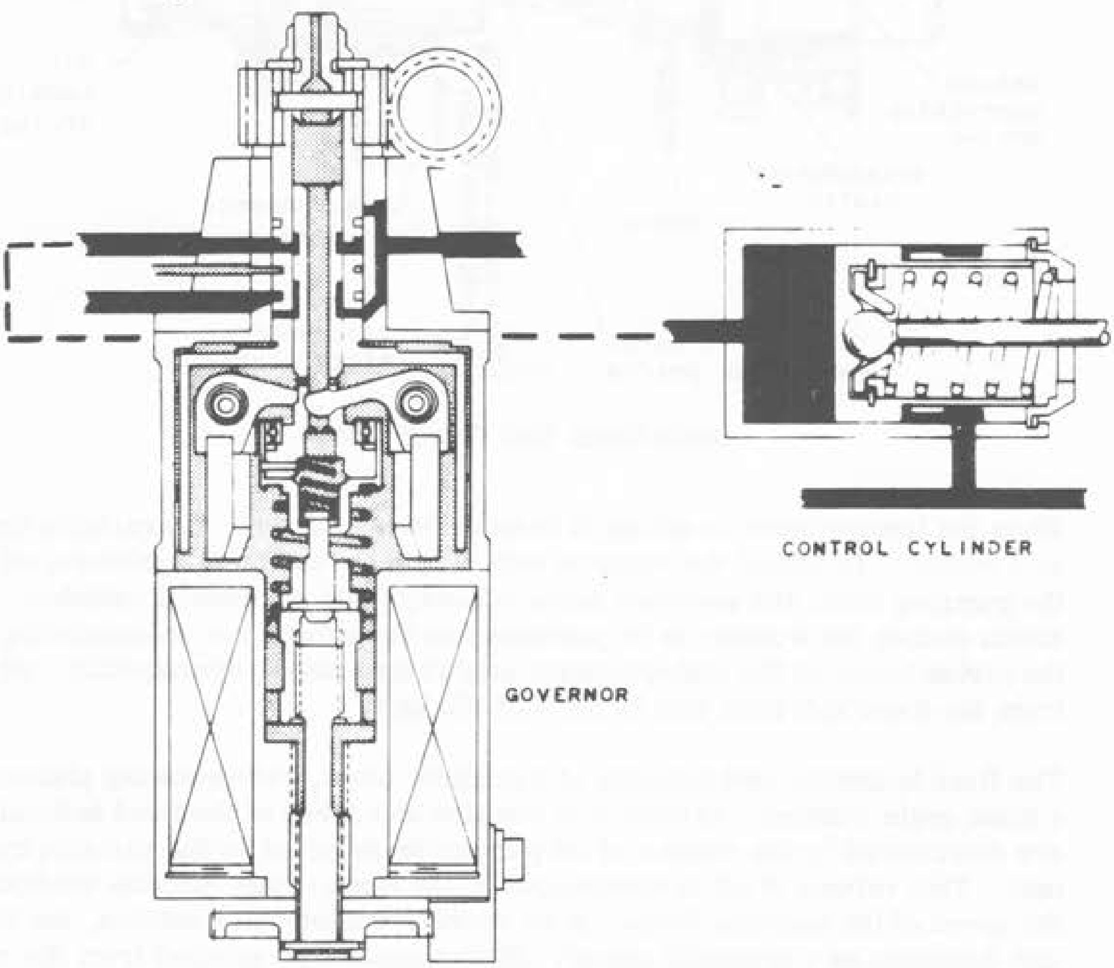


SUNDSTRAND CSD TRANSMISSION

When the transmission is acting in underdrive (step down), the variable unit acts as a motor. To enable the variable unit to operate as a motor (receive oil from the pumping unit), the governor ports oil away from the control cylinder. This action causes the wobbler to be positioned so the volume for accomodating oil in the piston bores on the high-pressure side is increased; consequently, oil flows from the fixed hydraulic unit to the variable unit.

The fixed hydraulic unit consists of a cylinder block, reciprocating pistons, and a fixed angle wobbler. Direction of rotation and speed of the fixed hydraulic unit are determined by the volume of oil pumped or received by the variable hydraulic unit. This volume of oil is determined by the angle of the variable wobbler and the speed of the variable block. In an overdrive (step-up) condition, the fixed unit functions as a hydraulic motor. High-pressure oil pumped from the variable unit forces the fixed-unit pistons to slide down the inclined wobbler face, causing the cylinder block to rotate. The block rotation causes the input ring gear to rotate in the opposite direction to that of the carrier shaft. This action adds to the speed of output through the differential and maintains constant output speed. As input speed increases, the need to add speed decreases, so the variable unit pumps less oil until the cylinder block stops rotating. When this occurs, the transmission is operating in straight-through drive.

When the transmission is operating in underdrive, the fixed unit functions as a pump. The variable unit wobbler is positioned to act as a receiver of oil from the fixed unit. Fixed unit pistons are forced into the cylinder block as they slide up the inclined wobbler face, pumping high-pressure oil to the variable unit. This pressure allows the cylinder block to rotate in a direction opposite to that in the step-up condition. This opposite block rotation allows the input ring gear to turn in the same direction as the carrier shaft rotation and subtracts output speed from engine gearbox speed, through the differential, thus maintaining constant output speed.



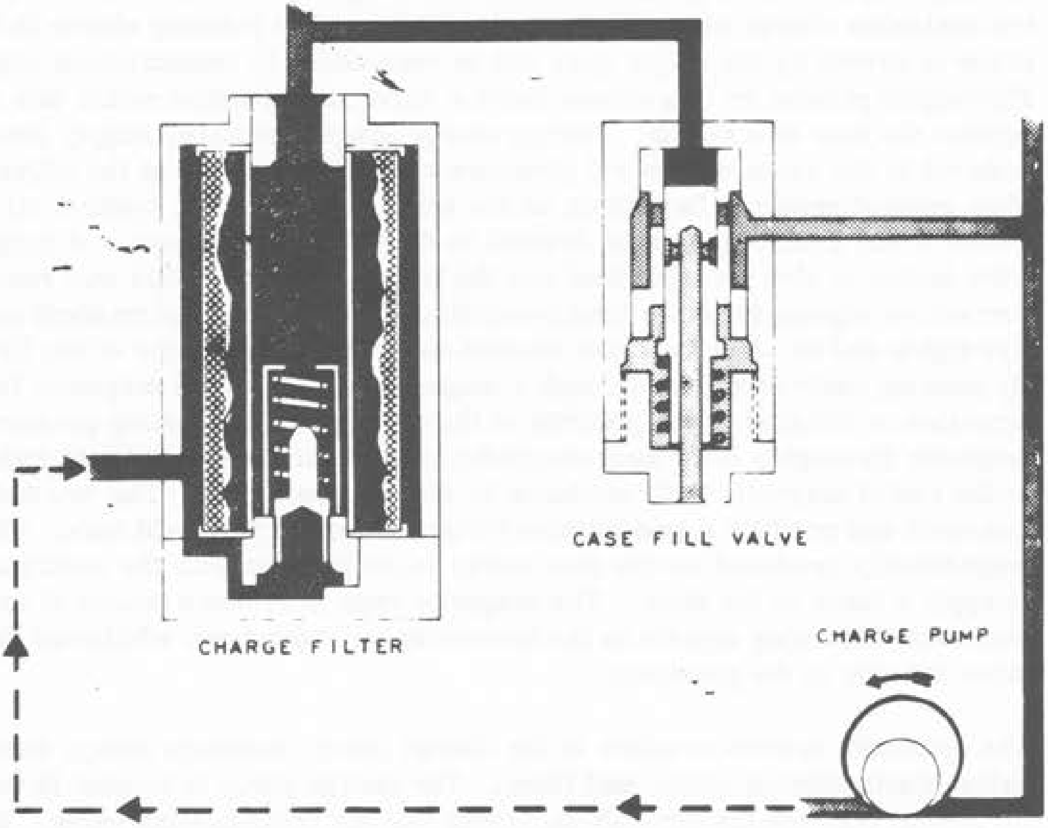
SUNDSTRAND CSD GOVERNOR AND CONTROL CYLINDER

This unit also incorporates a governor. The basic governor is a spring-biased, flyweight-operated, hydraulic control valve. Its function is to control porting of transmission charge oil to the control cylinder. The rotating sleeve in the governor is driven by the output gear and is responsive to transmission output speed. Flyweights pivoted on this sleeve move a valve stem located within this sleeve against the bias of a spring. During steady-stage operation, supply pressure is reduced to the required control pressure by orificing action at the edges of the stem control groove. Depending on the value stem position, control oil is either ported to the control piston or drained to the transmission case. A magnetic trim device is also incorporated into the basic governor. This unit receives corrective signals from the load controller. It consists of permanent magnetic flyweights and an electromagnet located above the rotating tips of the flyweights. By passing controlled D-C through a magnetic coil, a radial magnetic field direction is dictated by the polarity of the current. The rotating permanent magnetic flyweights have their magnetic axis oriented essentially at right angles to the radial magnetic field produced by the electromagnet. The two fields intersect and produce a controllable torque above the flyweight axis. This magnetically produced torque then works in conjunction with the centrifugal torque to apply a force to the stem. The magnetic trim provides a means of introducing electrical trimming signals to the transmission without any additional parts above those already in the governor.

The hydraulic system consists of the charge pump, scavenge pump, charge relief valve, recirculating valve, and filter. The charge pump is located in the hydraulic circuit between the aircraft reservoir and the recirculating valve. It supplies oil to the cylinder blocks, governor, differential, and control piston. The scavenge pump is located in the hydraulic circuit between the transmission sump and the recirculating valve. The pump picks up lubrication oil and internal leakage and, except when the transmission is operating in recirculation, pumps it through the recirculating valve and aircraft cooler into the aircraft reservoir. During recirculation, the scavenge pump functions as the charge pump and supplies oil to the cylinder blocks, governor, differential, and control piston.

The charge relief valve is installed to regulate the operating pressure of the system charge oil. This is accomplished by metering the discharge of oil from the charge system to maintain the preset charge pressure. The following figure illustrates the same principal as used in the transmission.

The recirculating valve is installed to provide protection from malfunctions of the external oil circuitry. Improper servicing, loose fittings, or ruptures of external lines are typical malfunctions that may occur. Should one of these malfunctions occur, and inlet oilflow is interrupted, the recirculating valve acts to retain the oil supply already in the transmission rather than return scavenge flow to the reservoir, thereby possible saving the transmission from damage. Initial oil supply is from the transmission sump by the scavenge pump through



SUNDSTRAND CSD CHARGE FILTER AND CASE FILL DRAIN VALVE

the de-actuated recirculating valve. When sufficient charge pressure is reached, the recirculating valve actuates. At this time, scavenge oil is routed to the cooler and reservoir, and the charge pump is supplying oil to the charge circuit. Any interruption in charge pressure would be felt by the recirculating valve and it would de-actuate, allowing scavenge oil to be ported back into the charge oil system. Recirculation would continue until the charge pump could develop enough pressure to actuate the recirculating valve.

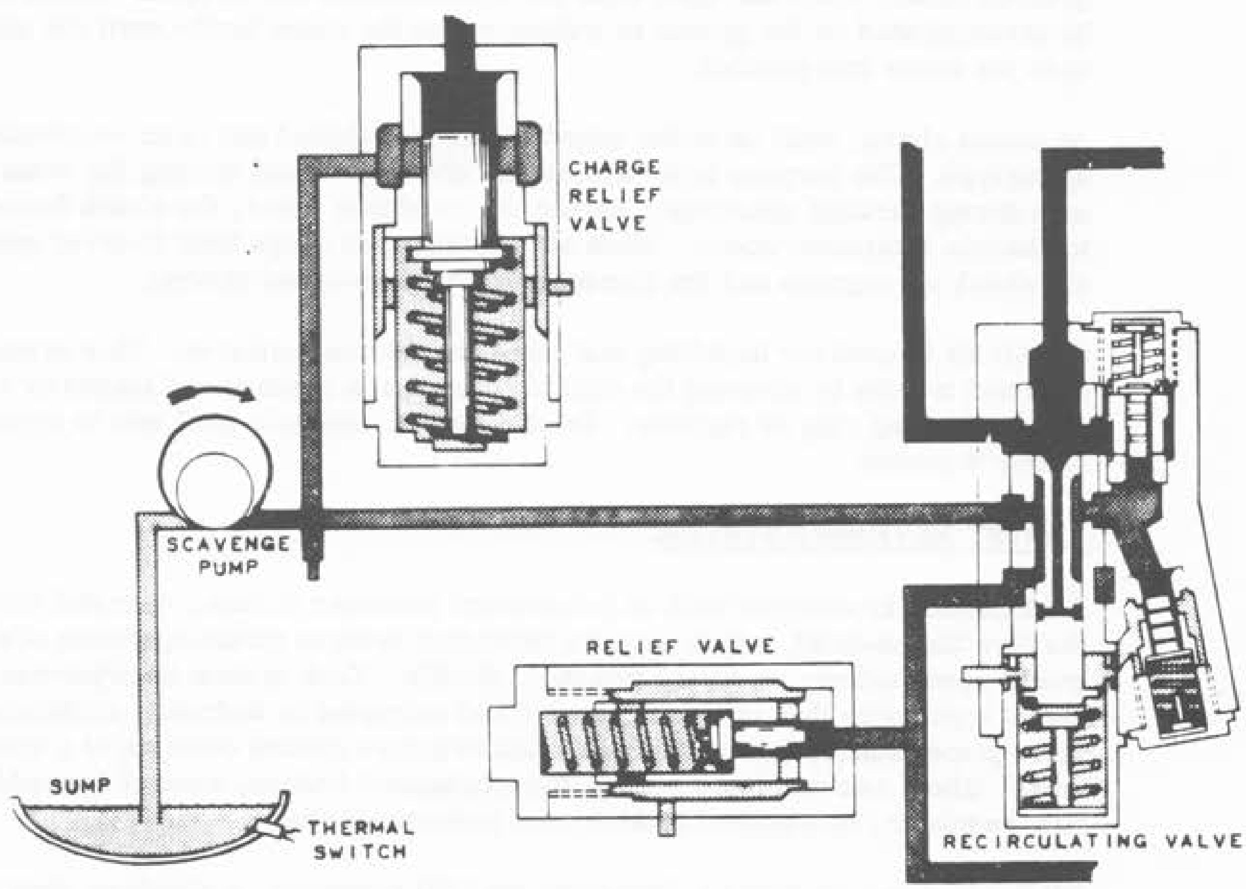
The filter assembly consists of a 20-micron stainless steel mesh filtering element. Its purpose is to remove contamination from the oil before it is ported to the hydraulic units. A bypass valve is incorporated to prevent damage from oil starvation should the element become clogged.

Additional transmission components are an underspeed pressure switch, charge pressure switch, case fill valve, relief valve, thermal switch, disconnect device, and an output clutch. The underspeed pressure switch actuates and provides a signal to the control panel when transmission output speed is allowing 355 to

385 Hertz (5325 - 5775 RPM). The charge pressure switch actuates and provides a signal to the flight engineer's control panel when charge pressure is not sufficient for continued operation. A red light, marked CSD MALFUNCTION, illuminates. The temperature bulb for CSD overheat is also connected to this light.

The case fill valve is installed to assure an initial oil supply for the transmission. When the transmission is shut down, the case fill valve actuates and allows approximately two quarts of oil to drain into the transmission. When the next start of the transmission occurs, sufficient oil is available to the scavenge pump until charge pressure can override. At this point, the case fill valve is deactuated.

The relief valve is installed to permit return oil to flow back to the transmission case in the event the oil cooler is temporarily restricted. When the restriction is removed, the valve deactuates as pressure again decreases to normal, and oil is ported to the cooler.



SUNDSTRAND CSD RECIRCULATING VALVE & CHARGE RELIEF VALVE

A thermal switch is installed in the system sump to provide a signal to the flight engineer in the event the transmission overheats. On earlier aircraft, this light was labled CSD OVERHEAT. All aircraft using the Sundstrand CSD units are marked as CSD MALFUNCTION. The indicator illuminates when either an overheat condition exists or charge pressure is insufficient. When the transmission is being operated and this light illuminates, the CSD should be disconnected to prevent further damage.

The disconnect is an electrically actuated device which decouples the input shaft from the input spline shaft. The disconnect should be used only when the transmission is in operation and reset only at zero RPM. Disconnect can be accomplished only at the flight engineer's panel by operation of a red guarded switch labeled CSD DISCONNECT. When this switch is actuated, a solenoid is energized, which releases a spring-loaded pawl and allows the pawl to contact threads on the input shaft. Rotation of the input spline shaft causes the input shaft to move away from the input spline shaft, which separates the driving dogs. When these dogs have been separated, the input spline shaft rotates freely with engine gearbox speed, while the input shaft and transmission are stopped. Reset may be accomplished on the ground by pulling out on the reset handle until the solenoid nose pin snaps into position.

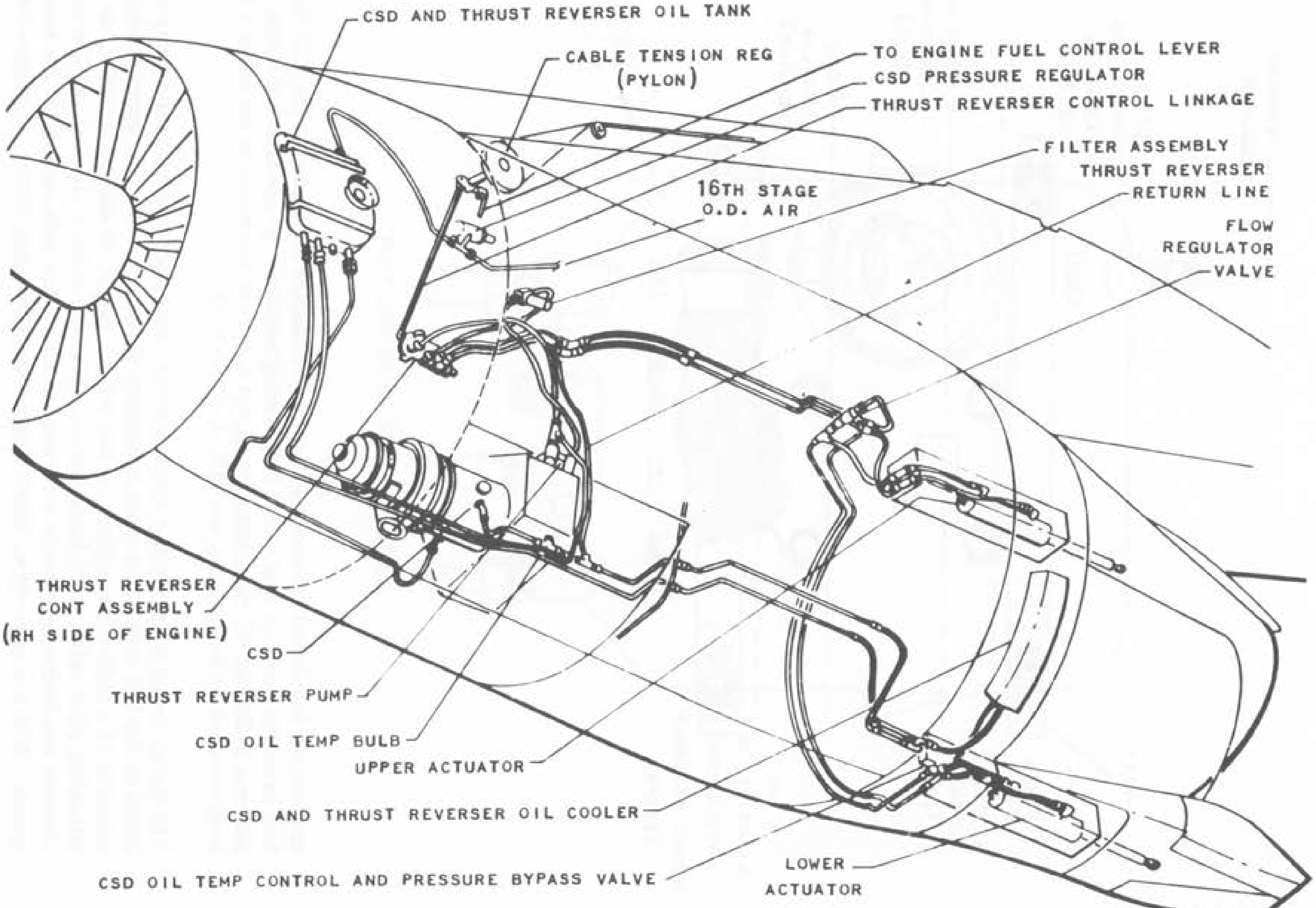
An output clutch, built on to the output shaft, is installed and is an overrunning sprag type. The purpose is to prevent the alternator from driving the transmission during parallel operation. Should this condition occur, the clutch freewheels to absorbe alternator speed. When alternator speed drops back to drive speed, the clutch re-engages and the transmission again does the driving.

A QAD kit is used for installing and removing the transmission. This saves both time and trouble by allowing the CSD to be placed in position and locked by rotating a locking ring 30 degrees. Total weight of complete QAD unit is approximately 3 pounds.

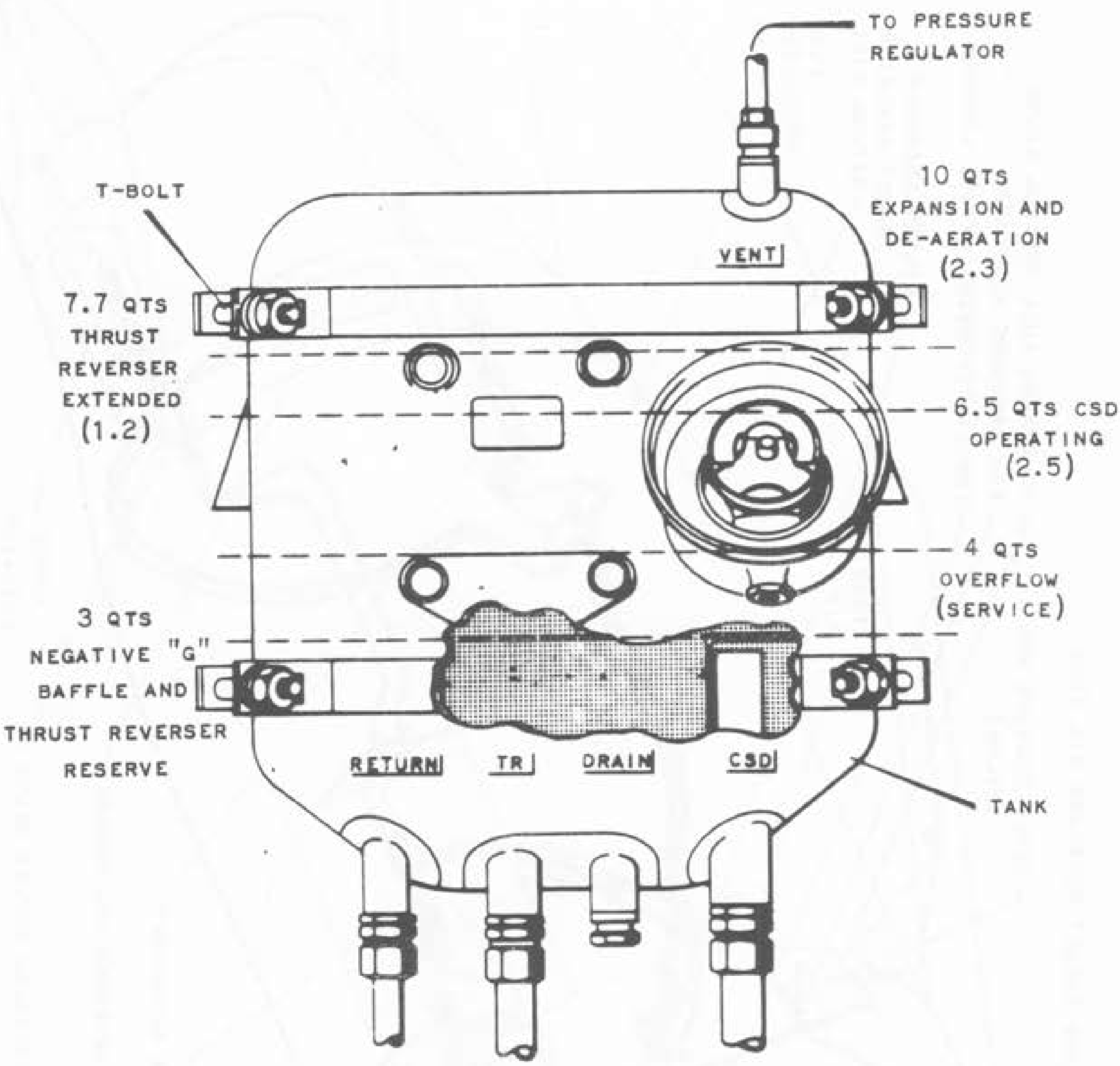
THRUST REVERSER SYSTEM.

Each nacelle is equipped with an independent reverser system, operated through the throttle quadrant, which permits individual reverse thrust operation of engine power upon landings or during rejected takeoffs. Each system incorporates two target type doors that are both extended and retracted by hydraulic actuators through mechanical linkage. Each thrust reverser system consists of a hydraulic pump, filter, two actuators, doors and mechanical linkage, control assembly, flow regulator, mechanical lockout, and indicator lights.

Oil for system actuation is taken from the CSD reservoir, a stainless steel tank with approximately a 10-quart capacity and is located on the left side of the engine fan case. There are two separate supply lines from this tank: one for the CSD,



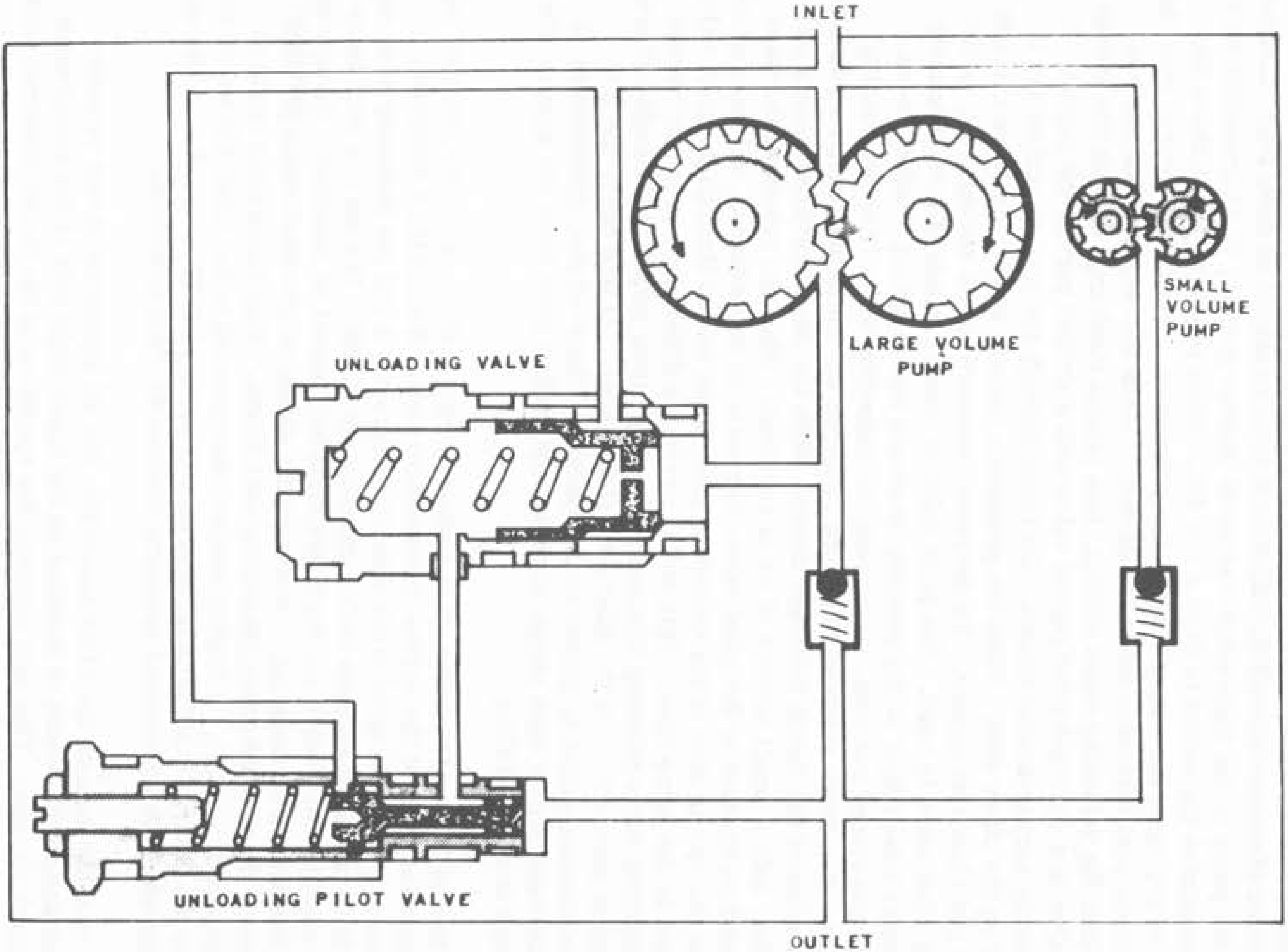
THRUST REVERSER AND CSD COMPONENTS LOCATION



CONSTANT SPEED DRIVE OIL TANK

and one for the thrust reverser system. A standpipe connected to the CSD supply line provides positive flow to the CSD during negative "g" operation and also ensures sufficient oil remaining for thrust reverser operation in the event a CSD leak occured. The systems use MIL-L-7807-E oil.

The thrust reverser pump is a dual-element, engine-driven hydraulic pump located on the left side of the main accessory drive gearbox. 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 volume element and low volume element are both connected to a common shaft so that both operate at the same speed. Both are gear-type, fixed-displacement pumping units. At engine idle

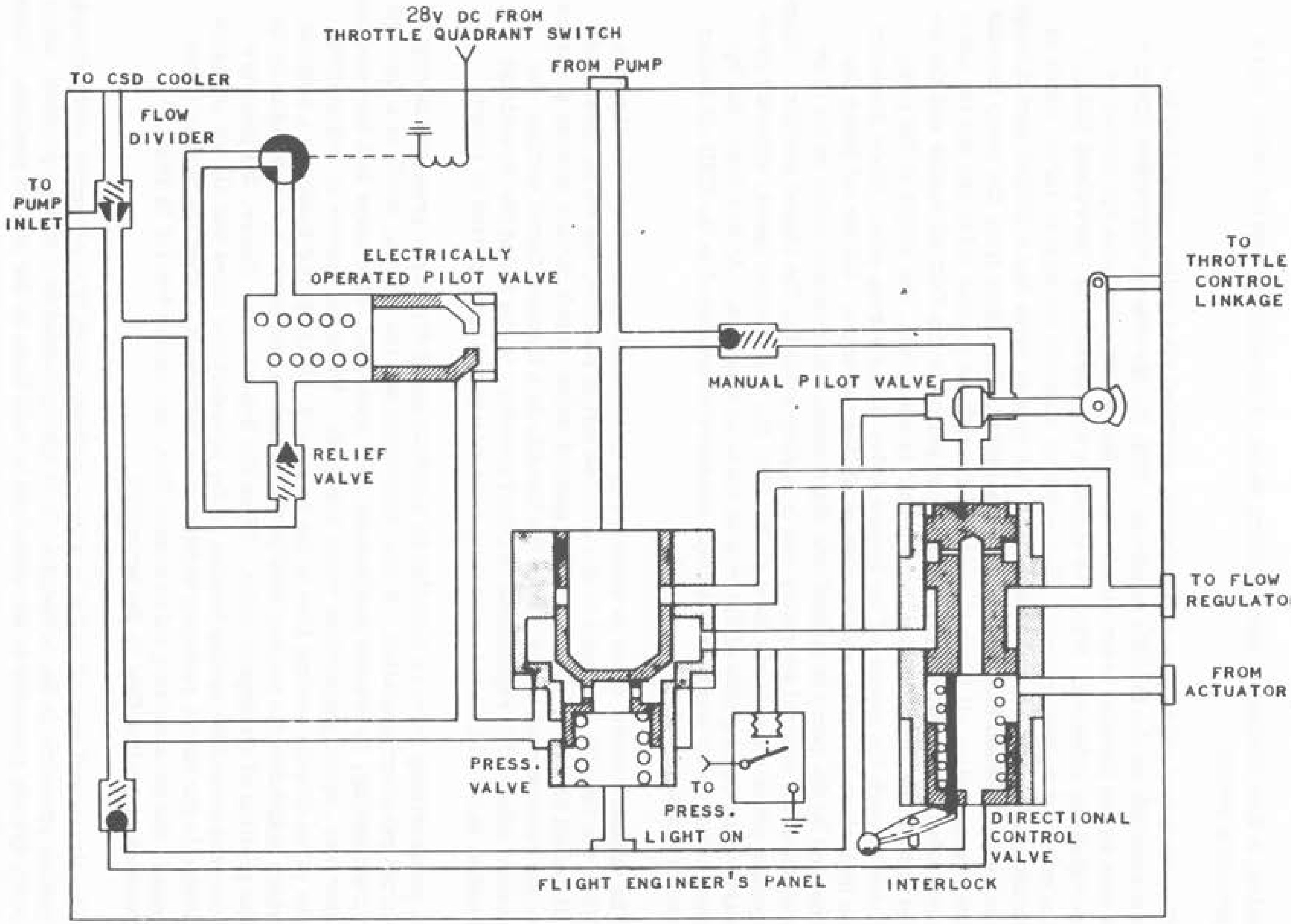


THRUST REVERSER PUMP SCHEMATIC

speed, the pump operates at approximately 3600 RPM. The high-volume pump displacement is approximately 5.5 GPM at a rated pressure of 2500 PSI. The low-volume element delivers 0.5 GPM at a rated pressure of 3000 PSI. Located inside the pump at the high-volume element discharge port, is an unloading valve, which regulates the output to 2100 ± 100 PSI. When pressure rises above this, the valve bypasses the output back to the pump inlet. When this occurs, only the low-volume port furnishes oil to the system. When the output of the pump is lower than the unloading valve setting, both pumps discharge oil into the system. This valve is a spring-loaded poppet valve with a drilled port in the poppet. It is normally spring-loaded closed. Oil flows through the drilled orifice and is sensed on the other side. When the pressures remain equal, the valve remains seated and allows no bypass. To decrease pressure on the spring side, an unloading pilot valve is used. The pilot valve is located inside the pump housing and senses total output of the pumping elements and is spring-loaded closed. When in the closed position, it prevents the unloading valve from decreasing pressure when large volumes of oil are required for operation, such as retraction or extension of the thrust reverser doors. With the thrust reverser doors fully extended, only a small volume of oil is required. When the pressure increase is sensed on the face of the pilot valve, the valve is repositioned, allowing pressure on the spring side of the unloading valve to be ported through the pilot valve and back to the pump inlet. This action creates a differential pressure across the unloading valve allowing it to unseat, and the total output of the high-volume element is ported back to the inlet side of the pump. At this time, the low-volume element output is ported to the system. Check valves, downstream of each element isolate each pump, also prevent oilflow back from the system when the pump is not operating.

After the oil leaves the pump, it is ported through a filter assembly, located on the upper left side of the engine intermediate case. It contains a reusable, 33-micron, stainless steel mesh filtering element. A red pin indicator pops out when inlet pressure exceeds outlet pressure by 70 PSI. The pin can only be reset manually, but when it is, the filter must be cleaned or replaced. To prevent false indications of clogging, a thermostatic detent is provided which prevents release of the red indicator pin during cold starts. This thermostat is set at approximately -1.1°C. A bypass feature incorporated in the filter allows oil to bypass the filter if a differential pressure of 100 ± 10 PSID is reached. The value reseats when the differential pressure reaches 65 PSID minimum.

After passing through the filter assembly, the oil enters the thrust reverser control assembly, which is mounted on the upper right side of the compressor intermediate case. This unit controls the operation of the thrust reverser doors by controlling the direction of flow to the reverser actuators in response to manual and electrical input from the throttle. It also regulates flow to the CSD oil cooler and provides for cooling flow to the actuators when the reverser is not operating. The assembly consists of an electrical pilot valve, a manual pilot



THRUST REVERSER CONTROL VALVE

valve, a flow divider, a pressurizing valve, a directional control valve, and a pressure switch.

The electrical pilot valve is a solenoid-operated pilot valve, controlled by a microswitch on the throttle quadrant. With the throttle in "REVERSE IDLE," a cam on the throttle lever closes the switch which completes the circuit to energize the solenoid. When the throttles are forward of "REVERSE IDLE," the solenoid is deenergized. This solenoid controls the bypass valve, which is located inside the control assembly. The bypass valve has a drilled port through the center. When the solenoid is deenergized, the output from the pump unseats the bypass valve; oil flows around and through the bypass valve and out the solenoid valve to the flow divider where it is ported to the CSD oil cooler and the inlet side of the pump. When the solenoid is energized, the output of the pump flows through the center of the bypass valve to the spring side. Since pressure on both sides is equal, spring tension closes the valve. All the oil being discharged by the pump is ported into the system. A pressure relief valve is installed in the control assembly and is spring-loaded to the closed position. When system pressure exceeds 3000 (±100) PSI, the relief valve opens, allowing pressure on the spring side of the bypass valve to decrease. At this time, the bypass valve opens and allows excess pressure to be ported to the CSD oil cooler and to the pump inlet.

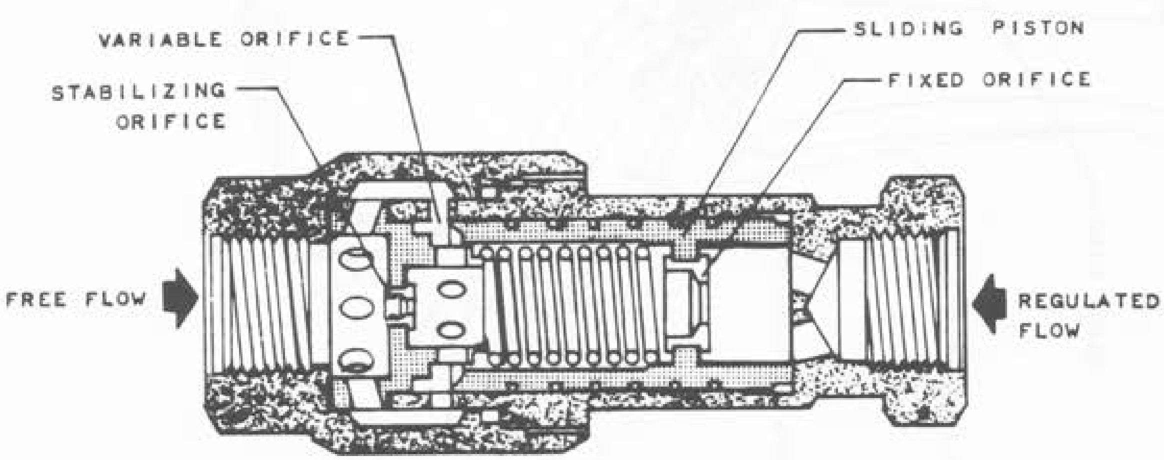
The manual control valve is operated by mechanical linkage from the throttle. When the throttle is moved to the reverse thrust position, the valve opens and allows oil to flow to the directional control valve, which directs system pressure to the reverser actuators. With the throttle in a forward thrust setting, the manual pilot valve repositions to cutoff pressure to the top of the directional control valve and allows remaining pressure on top to be ported to return.

A pressurizing valve is installed to maintain pump discharge pressure during thrust reverser operation. It also depressurizes the system, while in a forward thrust setting, to prevent inadvertent door openings. This valve is a two-position, four-way, spool poppet-type valve assembly. When the system is inoperative, the valve directs cooling flow to the actuators. It is spring-loaded to a position which maintains the cooling flow to the actuators and controlled hydraulically by the position of the bypass valve. When the bypass valve closes, the pressure increase overrides spring tension of the pressurizing valve and allows pressure available for thrust reverser extension or retraction. When the bypass valve opens, the pressurizing valve senses this, and spring tension is reset to a position of cooling flow to the actuators.

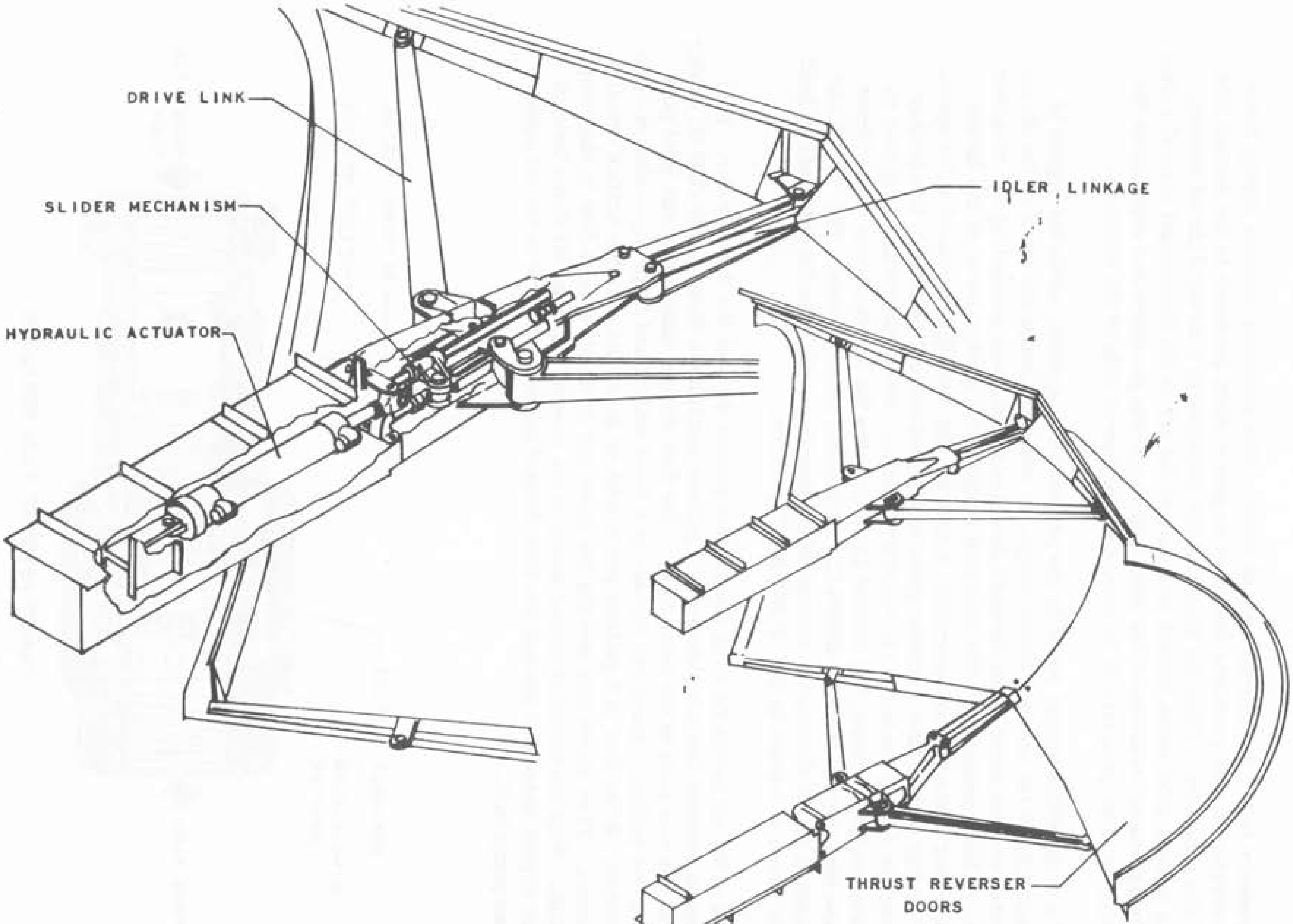
The directional control valve is a two-position, spool type assembly which directs system pressure to the actuators. It is spring-loaded to a stowed position, which ports system pressure to the actuators to hold them in the stowed position. When the throttle is in a reverse thrust setting, the manual pilot valve ports system pressure to the directional control valve. This pressure opposes spring force, overrides it, and positions the valve to port system pressure to the extend side of the actuators. When the throttles are returned to a forward thrust setting, the manual pilot valve cutsoff pressure to the top of the directional control valve. Spring tension overcomes the reduction in system pressure and repositions the valve to allow pressure to be ported to the stowed side of the actuators.

If a malfunction should occur in the pressurizing system, while the engine is operating in the forward thrust range, an interlock keeps the spool of the directional control valve in the forward thrust position, thus preventing the reverser doors from extending. The interlock consist of a striker lever on the thrust reverser control valve assembly, a lock for the directional control valve spool, a striker button, and a striker plate on the fuel control pushrod. The striker lever is spring-loaded to the "LOCK" position. When the throttle is moved to reverse thrust range, the striker plate actuates the striker lever of the thrust reverser control valve to unlock the directional control valve. The "LOCKED" position of the directional control valve directs pressure to the actuators to hold the doors retracted to the "FORWARD" position.

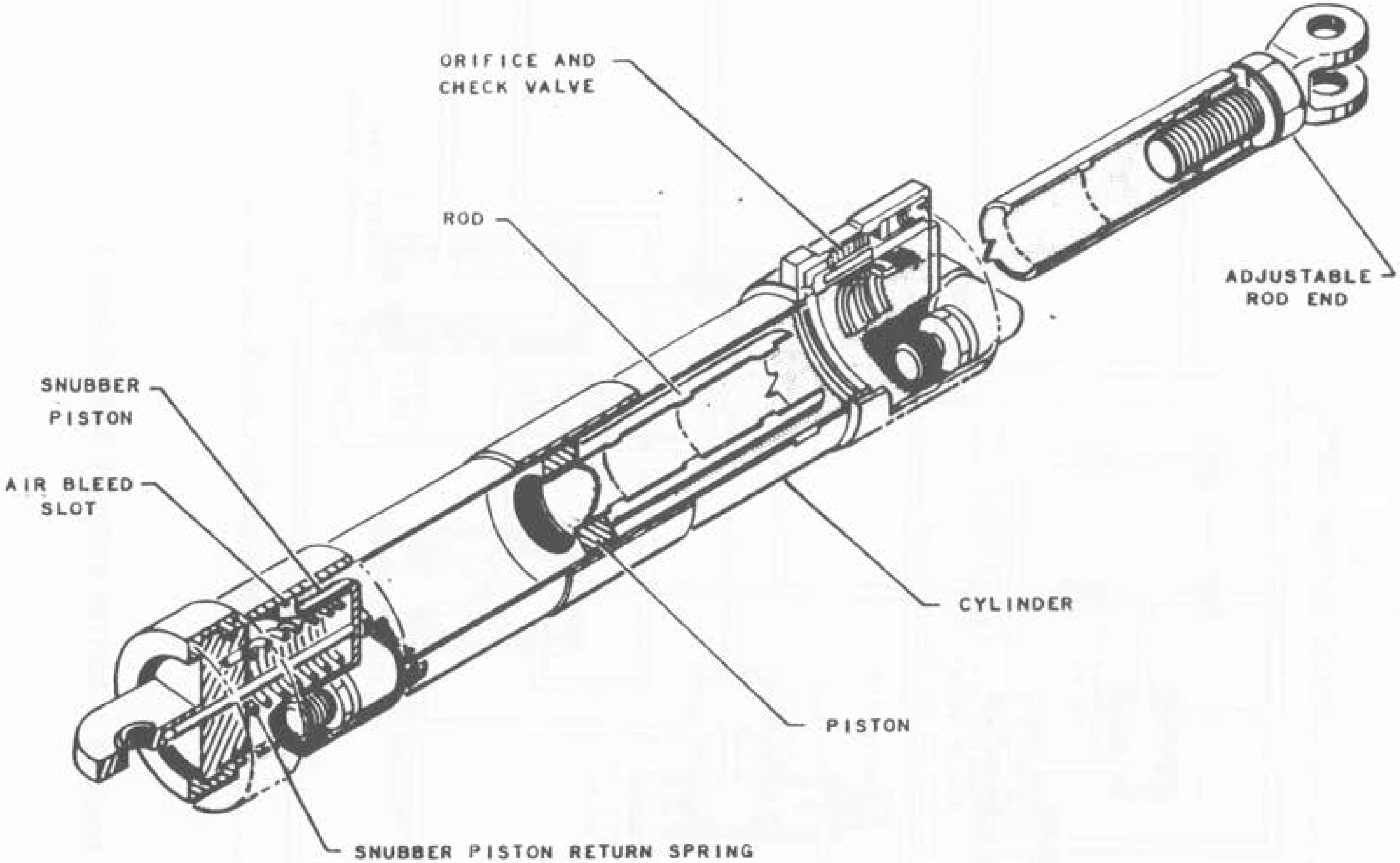
All of the oil returning from the system passes through the flow divider. This action ensures that a maximum of 2 gallons per minute flows to the CSD oil cooler and the rest back to the pump inlet. The flow divider consists of one inlet port and two outlets. Inside the divider is a fixed orifice and a spring-loaded variable orifice. If the flow is 2 gallons per minute or less, the variable orifice remains closed. Flow above that unseats the valve and ports all excess flow to the pump inlet. With the thrust reverser doors in the stowed position, oil flows through the bypass valve and through the flow divider before returning to the oil cooler and pump inlet.



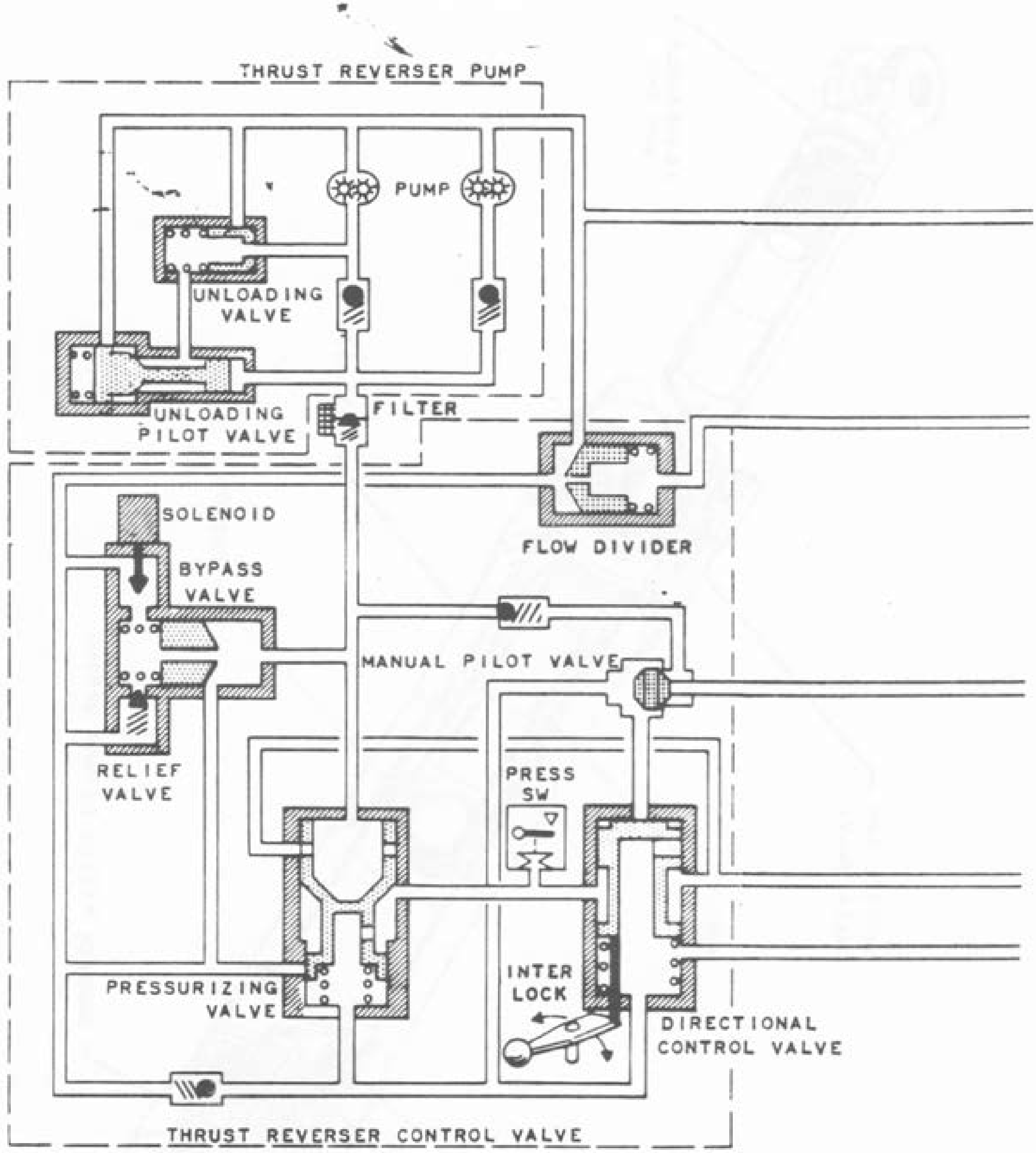
THRUST REVERSER FLOW REGULATOR



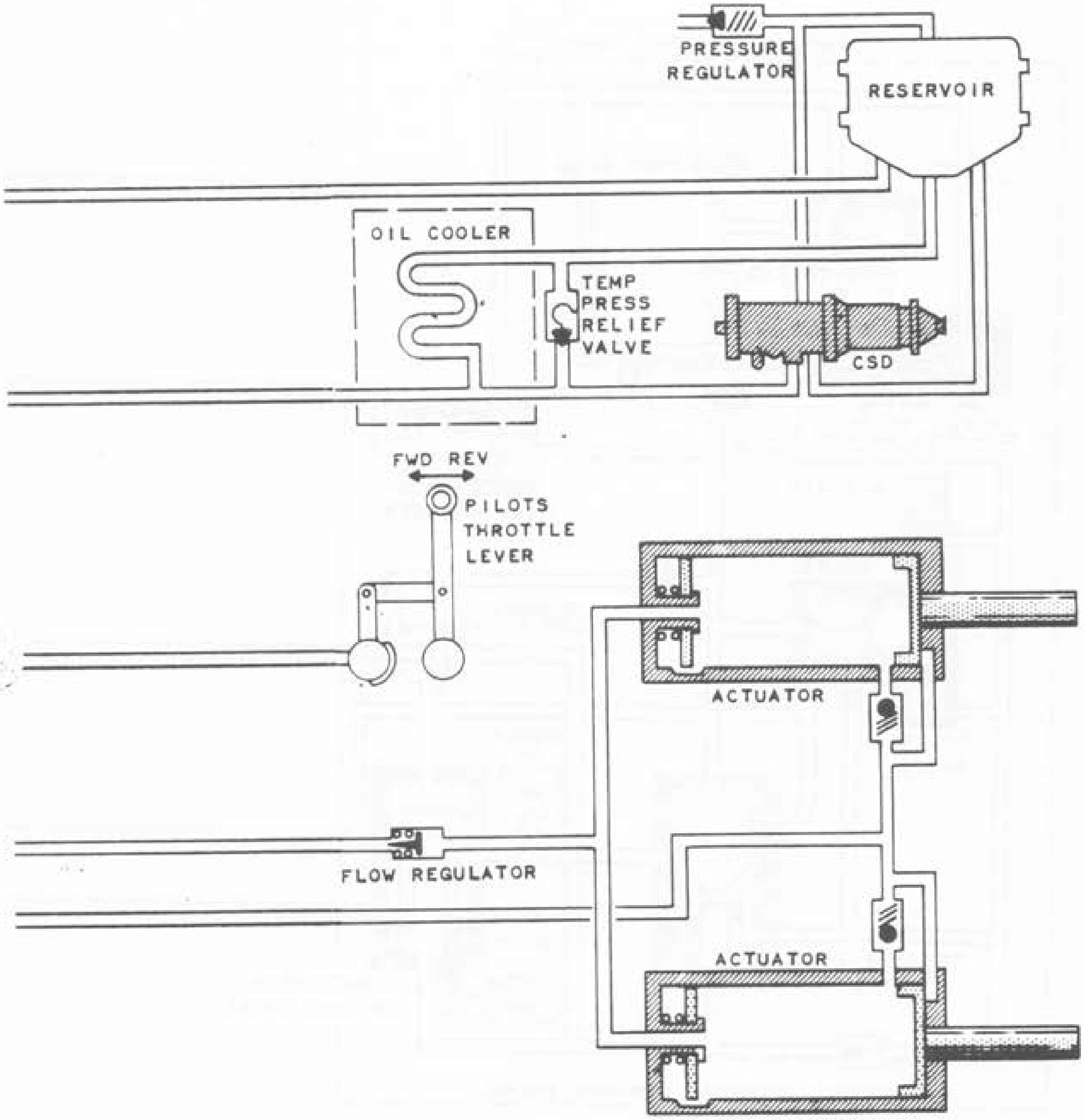
THRUST REVERSER DOORS AND ACTUATORS

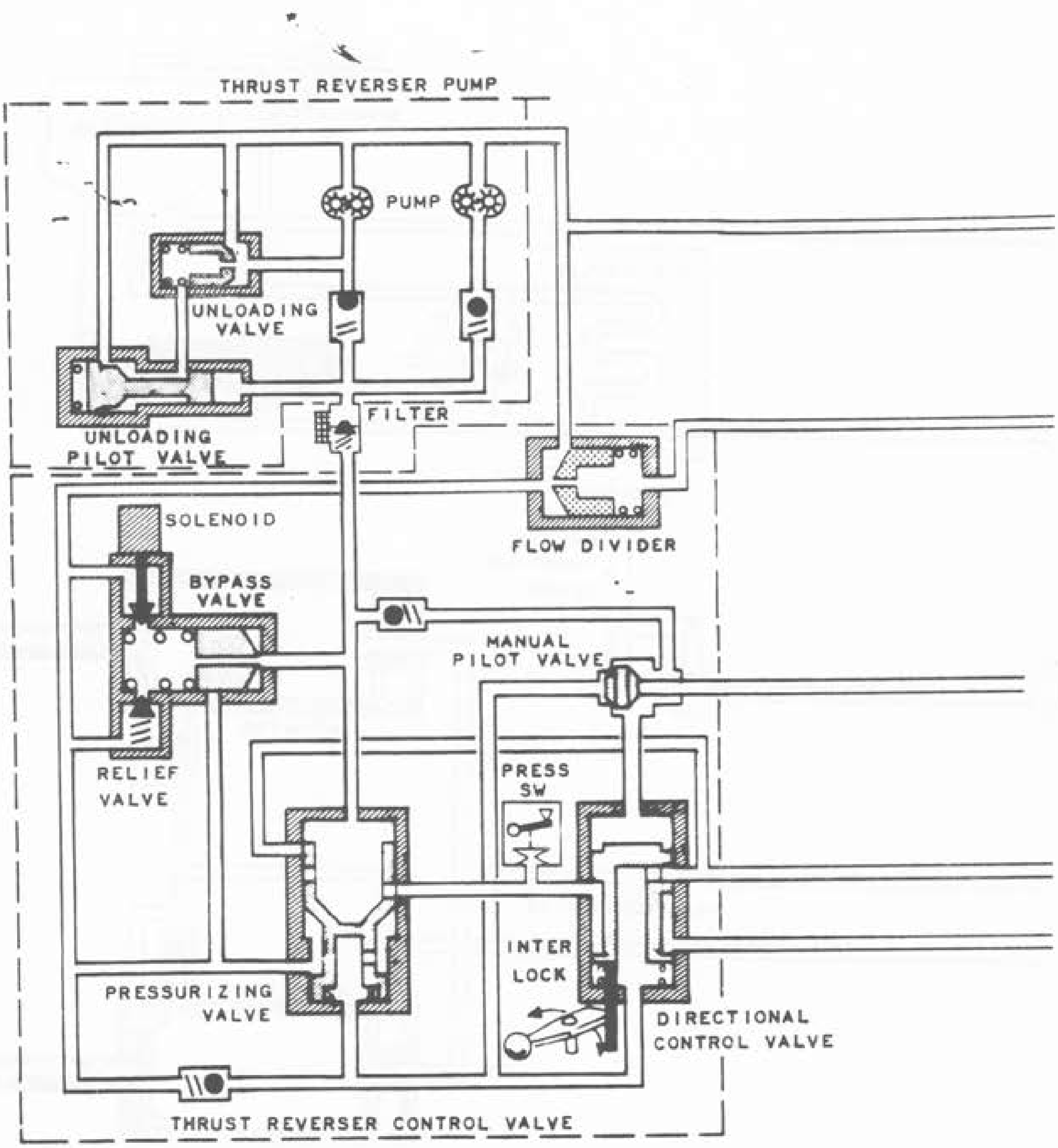


THRUST REVERSER ACTUATOR

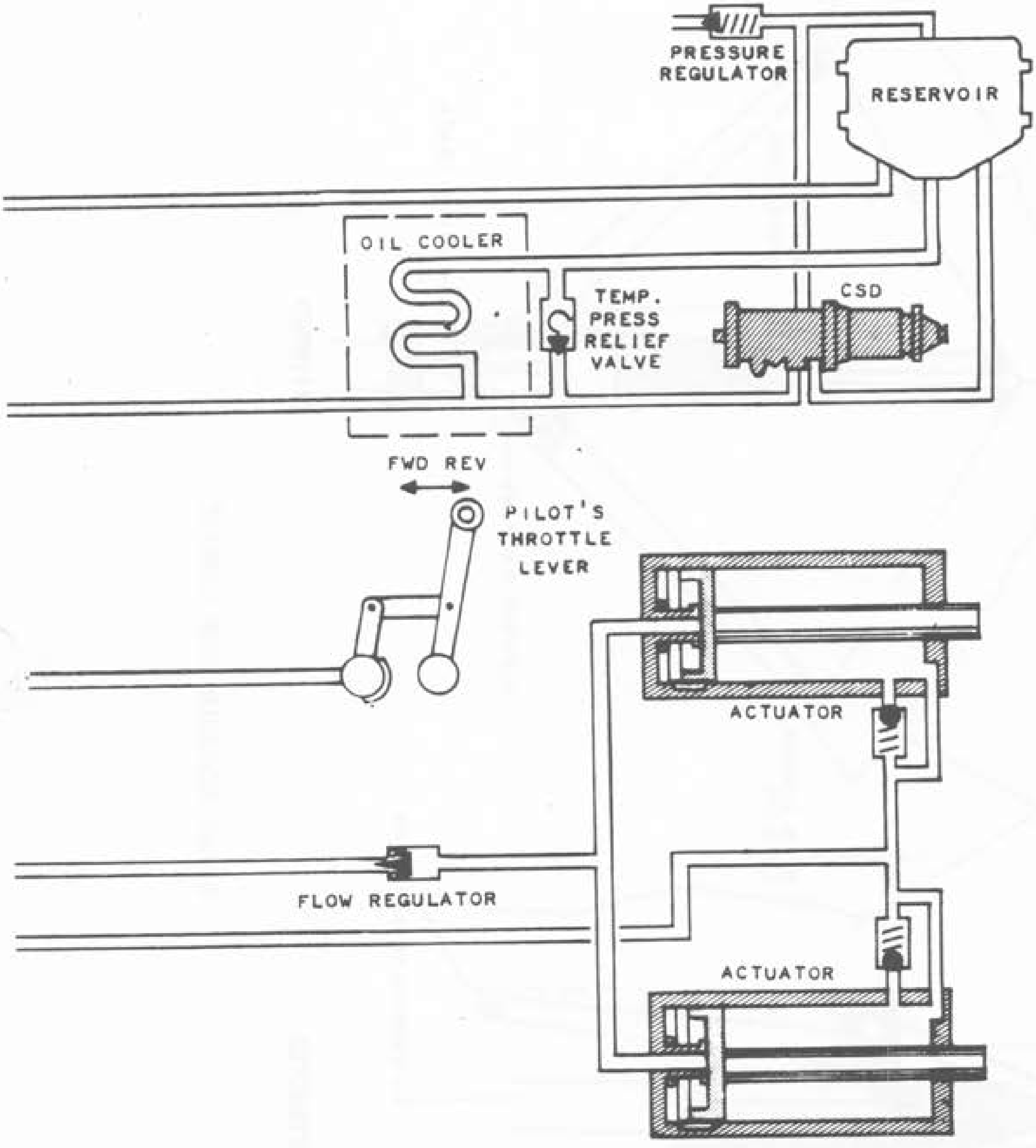


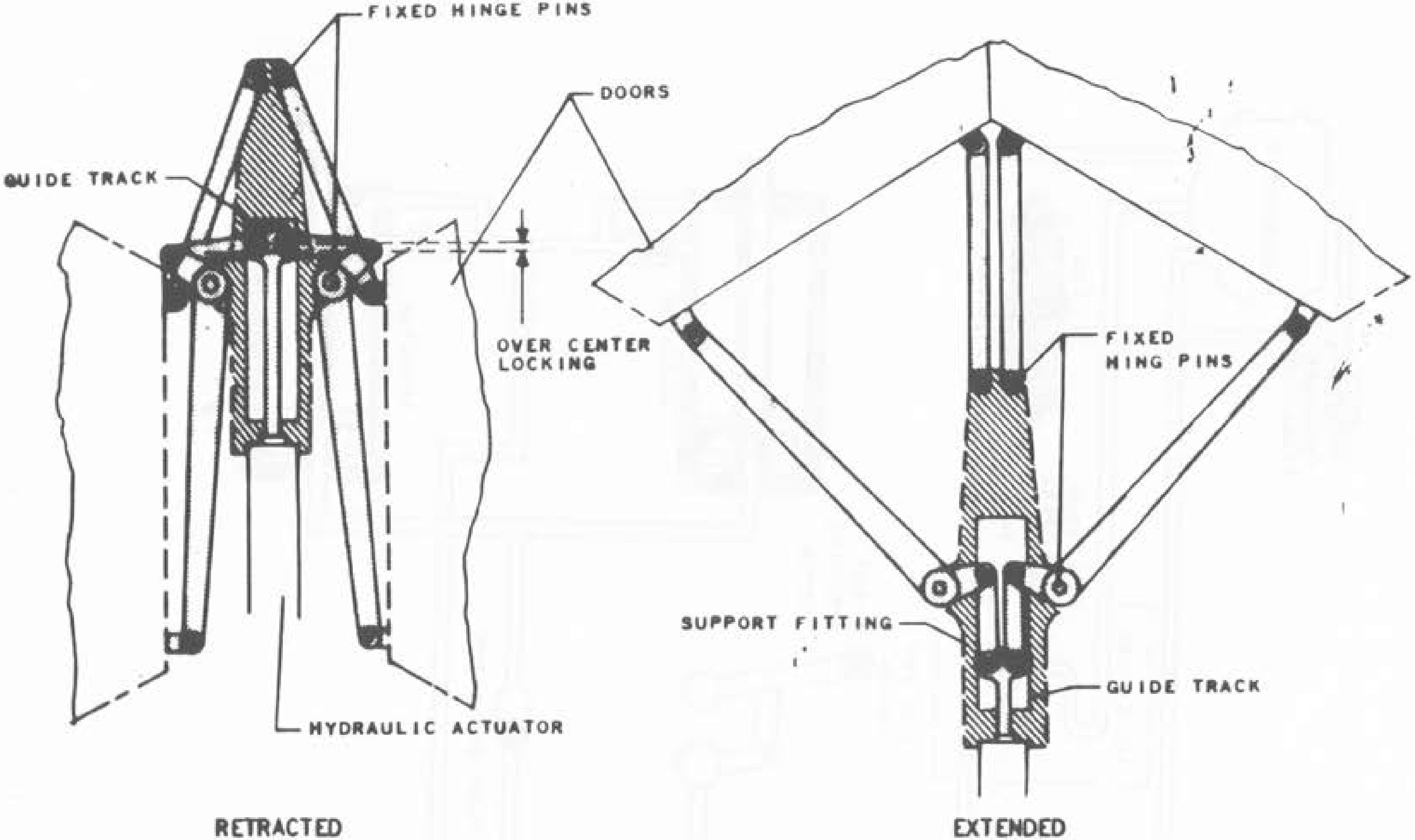
THRUST REVERSER ACTUATION SYSTEM (DOORS STOWED)


PRESSURE REGULATOR
RESERVOIR
OIL COOLER
TEMP PRESS RELIEF VALVE
CSD
FWD REV
PILOTS THROTTLE LEVER
ACTUATOR
FLOW REGULATOR
ACTUATOR



THRUST REVERSER ACTUATION SYSTEM (DOORS EXTENDED)


PRESSURE REGULATOR
RESERVOIR
OIL COOLER
TEMP. PRESS RELIEF VALVE
CSD
FWD REV
PILOT'S THROTTLE LEVER
ACTUATOR
FLOW REGULATOR
ACTUATOR



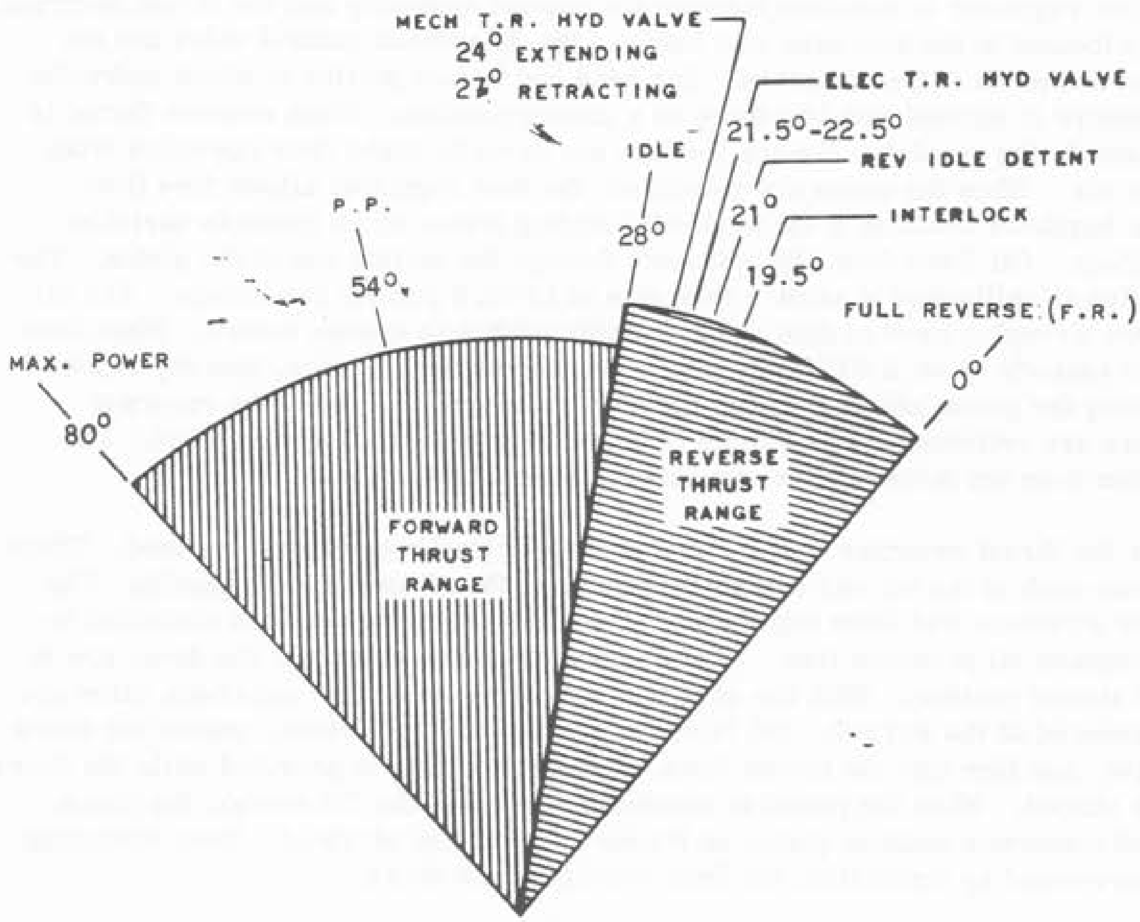
THRUST REVERSER DOOR LINKAGE

A flow regulator is installed between the control assembly and the thrust reverser. It is located in the hydraulic line between the directional control valve and the head end ports of the actuators. The head end is that portion to which hydraulic pressure is applied with the doors in a stowed position. When reverse thrust is selected, the regulator meters the flow and actually snubs door operation from ram air. When the doors are retracted, the flow regulator allows free flow. The regulator contains a spring-loaded sliding piston which controls variable orifices. Oil flows from the actuators through the orifice end of the piston. The orifice is calibrated to allow a flow rate of 10 ±0.5 gallons per minute. The oil flows through a fixed orifice and a variable orifice to system return. When flow rate exceeds 10 ±0.5 GPM, the piston overcomes spring force, thereby repositioning the piston and decreasing the size of the orifice. When the reverser doors are retracted, the oil flows in the same direction as spring force. The piston does not move and the variable orifices remain open.

For the thrust reverser door operation, two hydraulic actuators are used. There is one each at the top and bottom centerline at the aft end of each nacelle. The door structure ties them together mechanically, and they are both connected to a common oil pressure line. When the actuators are extended, the doors are in the stowed position. With the actuators extended, an orifice and check valve are uncovered at the rod end. Oil is allowed to flow out the orifice, unseat the check valve, and flow into the return lines. Constant cooling is provided while the doors are stowed. When the piston is retracted (extending the TR doors), the piston head contacts a snubber piston as it nears completion of travel. Door slamming is prevented by controlling the final velocity of the doors.

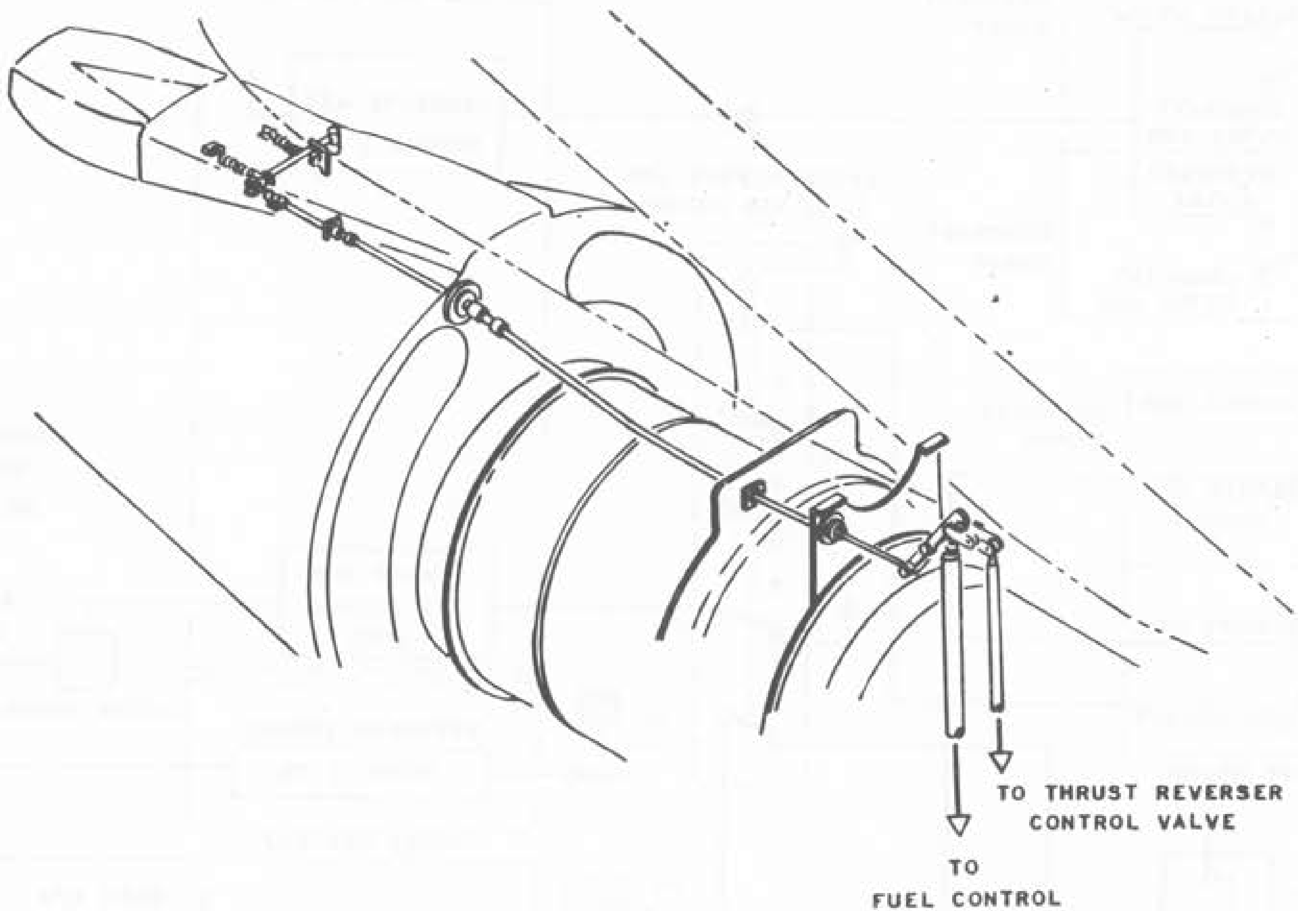
Target-type thrust reverser doors were selected, mainly for the weight savings as compared to other thrust reverser configurations. Simplicity of design also contributes to the reliability of the system. The material selected for their manufacture consists of an inner surface of stainless steel and an exterior skin of 2024-clad, annealed aluminum. Stainless steel is used because inner surface temperatures during thrust reverser operation can reach 480°C. An over-center link provides the driving connection between the actuator and the drive links. When the reverser is in the retracted position, the over-center links are driven to a position where drive link loads, caused by air loads tending to extend the reverser doors, force the mechanism against the stop. When stowed, the doors form part of the nacelle contour.

Operation of the thrust reversers is through the pilot's or copilot's throttle lever. To extend thrust reverser, retard the appropriate throttle from idle, up, and aft to the reverse thrust interlock position. This motion first unlocks the directional control valve as the striker on the fuel control linkage rotates the lock-out lever from the locked to unlocked position. The directional control valve is now free to move in response to the hydraulic control system command. A mechanical control system command opens the manual pressure pilot valve, and a microswitch

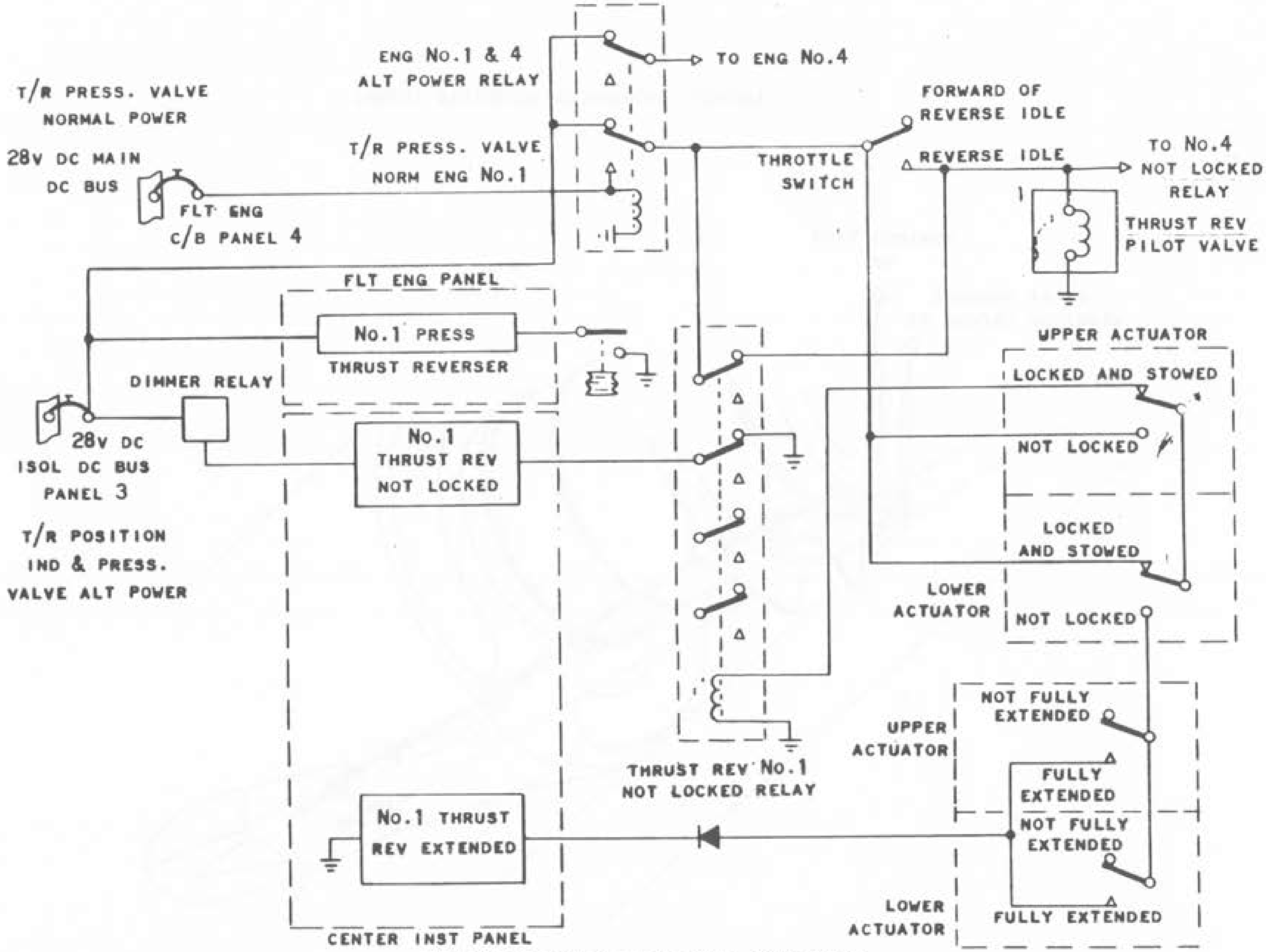


THROTTLE QUADRANT SCHEMATIC

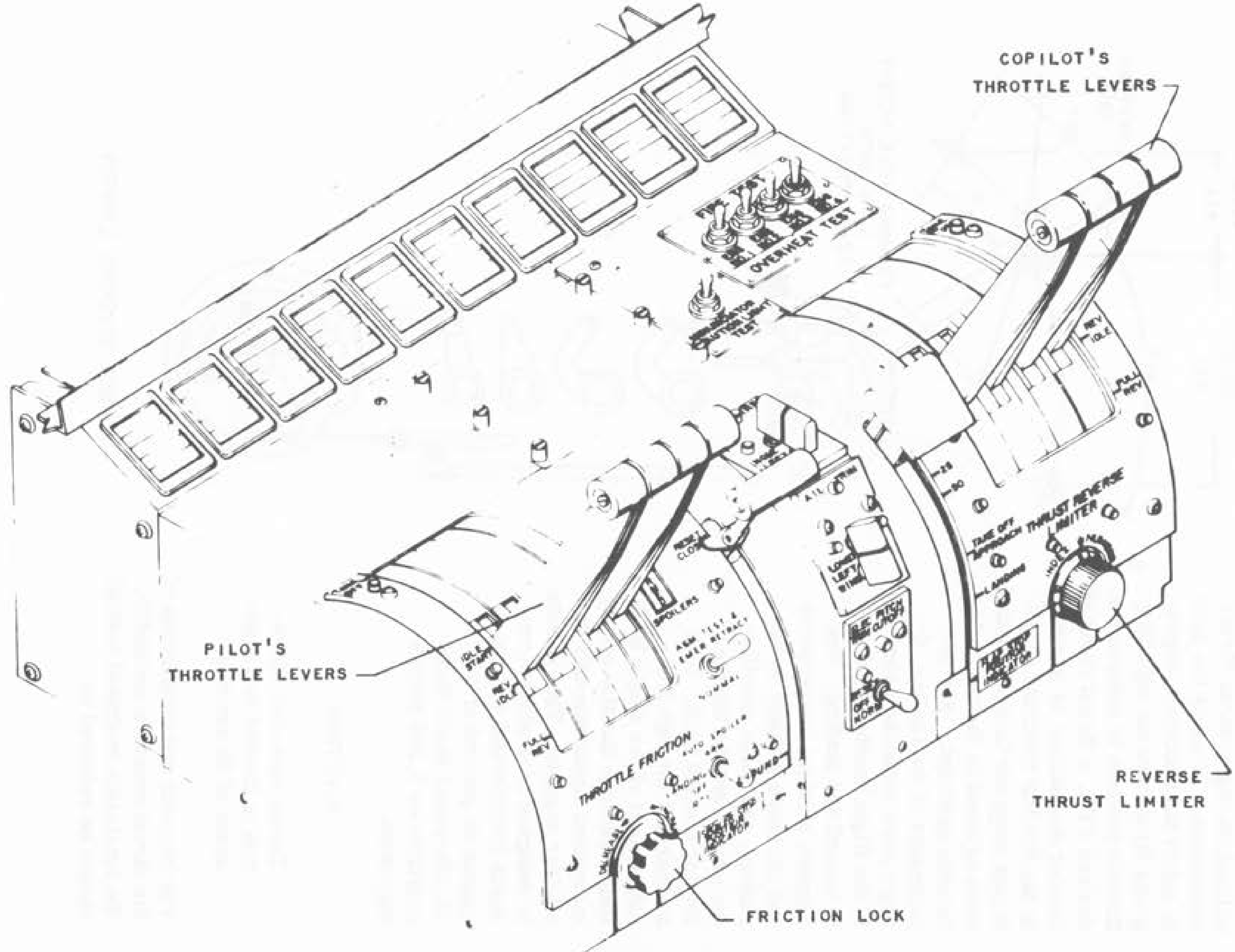
on the throttle quadrant energizes the solenoid valve in the control assembly to the closed position. This pressurizes the thrust reverser hydraulic system. Pressure causes the directional control valve to shift to the extend position and closes contacts of a pressure switch at approximately 1000 PSI. A circuit is completed to the PRESSURE light on the flight engineer's panel, causing it to illuminate. Pressure to the door extend side of the actuator extends the thrust reverser doors. As the doors move from the stowed and locked position, microswitches are actuated and complete a circuit to the NOT LOCKED light on the main instrument panel which illuminates it. This light remains illuminated whenever the doors are in any position except stowed and locked. The doors should reach the fully extended position within 2 seconds. At that time the fully extended microswitches actuate to illuminate the EXTENDED light on the main instrument panel. Also when the doors reach the full extended position, the engine mechanical lockout is released and the throttle lever may be moved farther aft to increase thrust. Fuel control travel is limited by the reverse thrust limiter. This system is incorporated to limit the engine to the maximum gross thrust which can be



THRUST REVERSER MECHANICAL LOCKOUT



THRUST REVERSER ELECTRICAL SCHEMATIC



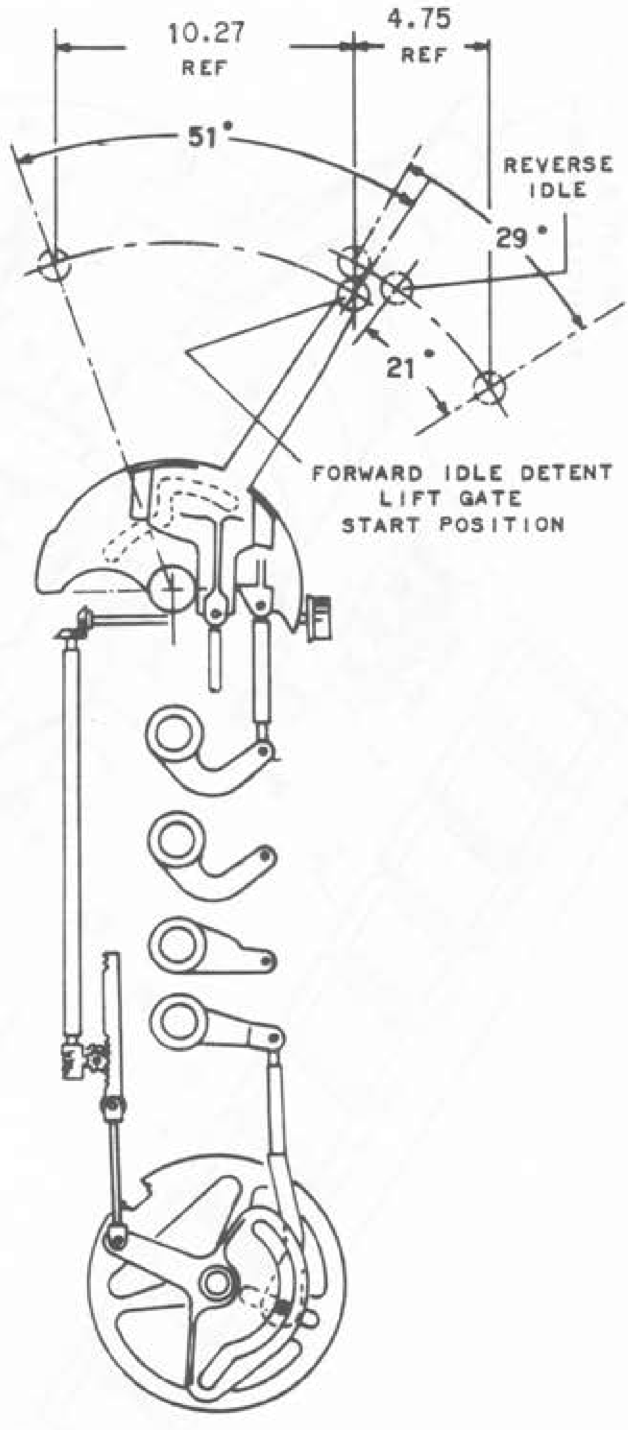
CENTER CONSOLE

utilized during reverse thrust operations. To allow the pilot to select the maximum engine gross thrust without adjusting throttle position to achieve the desired EPR, a thrust reverser limiter mechanism is provided in the throttle quadrant with a thrust reverser limiter control knob adjacent to the copilot's throttle quadrant. For adjustments of the limiter, the flight crew consults a chart in the flight handbook prior to takeoff and landing. For a known ambient temperature and pressure altitude on the runway, the chart specifies the proper setting for the limiter control knob. It is numbered 1 through 12. Adjustment of the single knob limits reverse throttle output movement simultaneously on all four engines. This system is designed to produce a reverse thrust which approximates 40 percent of the 18,000-pound static thrust available or 7,200 pounds maximum.

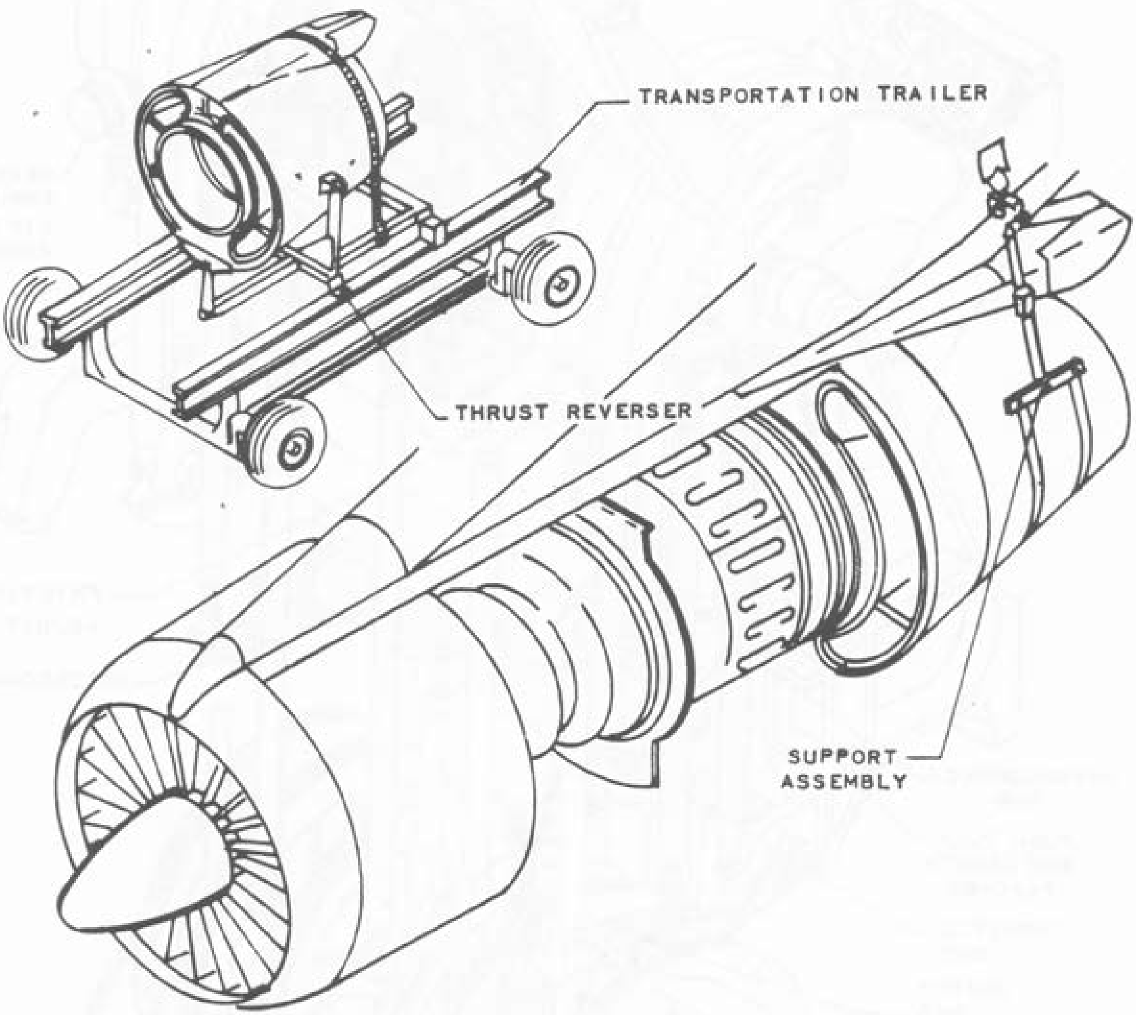
CAUTION

> Thrust reverser operation is limited to a maximum of 30 seconds.

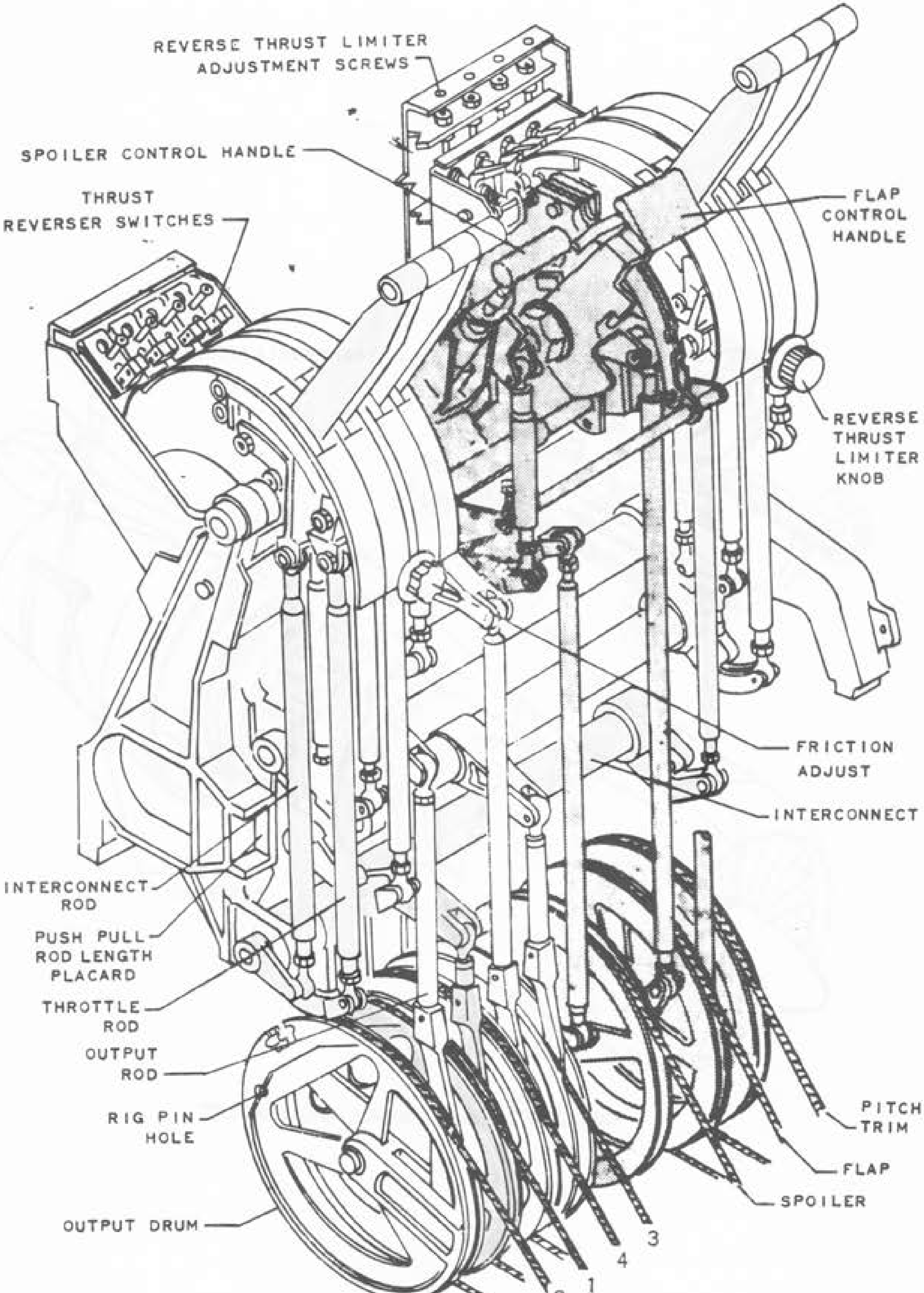
For removal and installation of the thrust reverser assembly, the applicable technical manual should be referred to.



THRUST REVERSER LIMITER



THRUST REVERSER CRADLE AND SUPPORT



THROTTLE QUADRANT

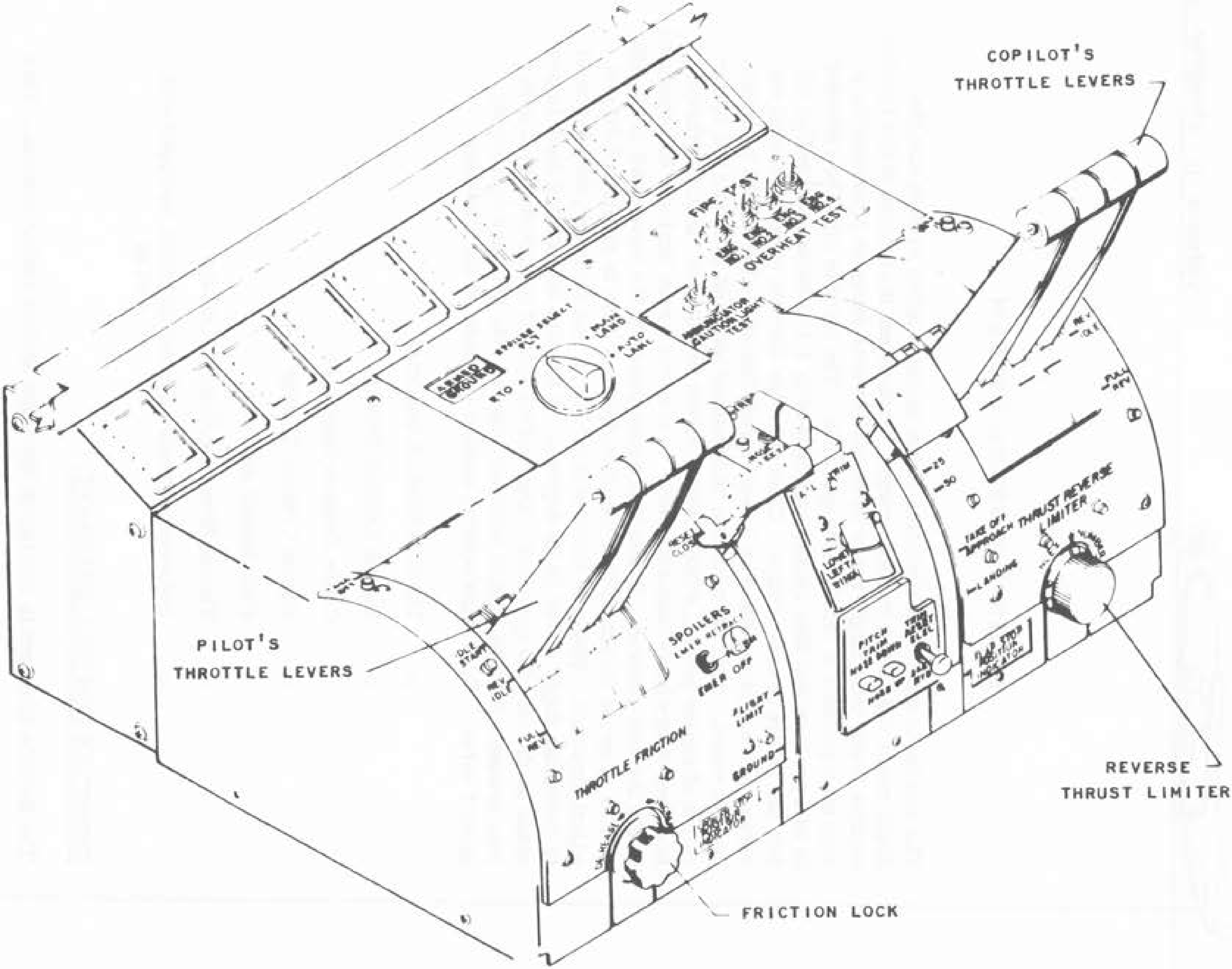
ENGINE CONTROL SYSTEM

The two basic ranges of operation of the engine control system are the flight range and thrust reverse range. Inadvertent movement of the throttle control lever from flight range to thrust reverse range is prevented by a cam incorporated in the throttle quadrant. The throttle must be retarded to idle position and then raised approximately 1 1/8 inches and pulled aft into the thrust reverse range. Control by the throttle over the thrust reverser system is provided by a mechanical linkage to the thrust reverser control valve. A thrust reverser mechanical lock-out prevents the application of engine power, when reverse thrust is selected, until the thrust reverser doors have been extended. A reverse thrust limiter, incorporated in the throttle quadrant, limits the engine power to the equivalent of 18,000 pounds of gross thrust so that the pilot does not have to monitor EPR and adjust throttles. Range of throttle travel from full reverse (zero degrees) to maximum flight power is 80 degrees. A friction adjustment knob is provided on the throttle quadrant. Engine fuel shutoff is provided by a separate system, the fuel shutoff actuator, and a cable actuated fuel supply shutoff valve. The engine control system consists of the following:

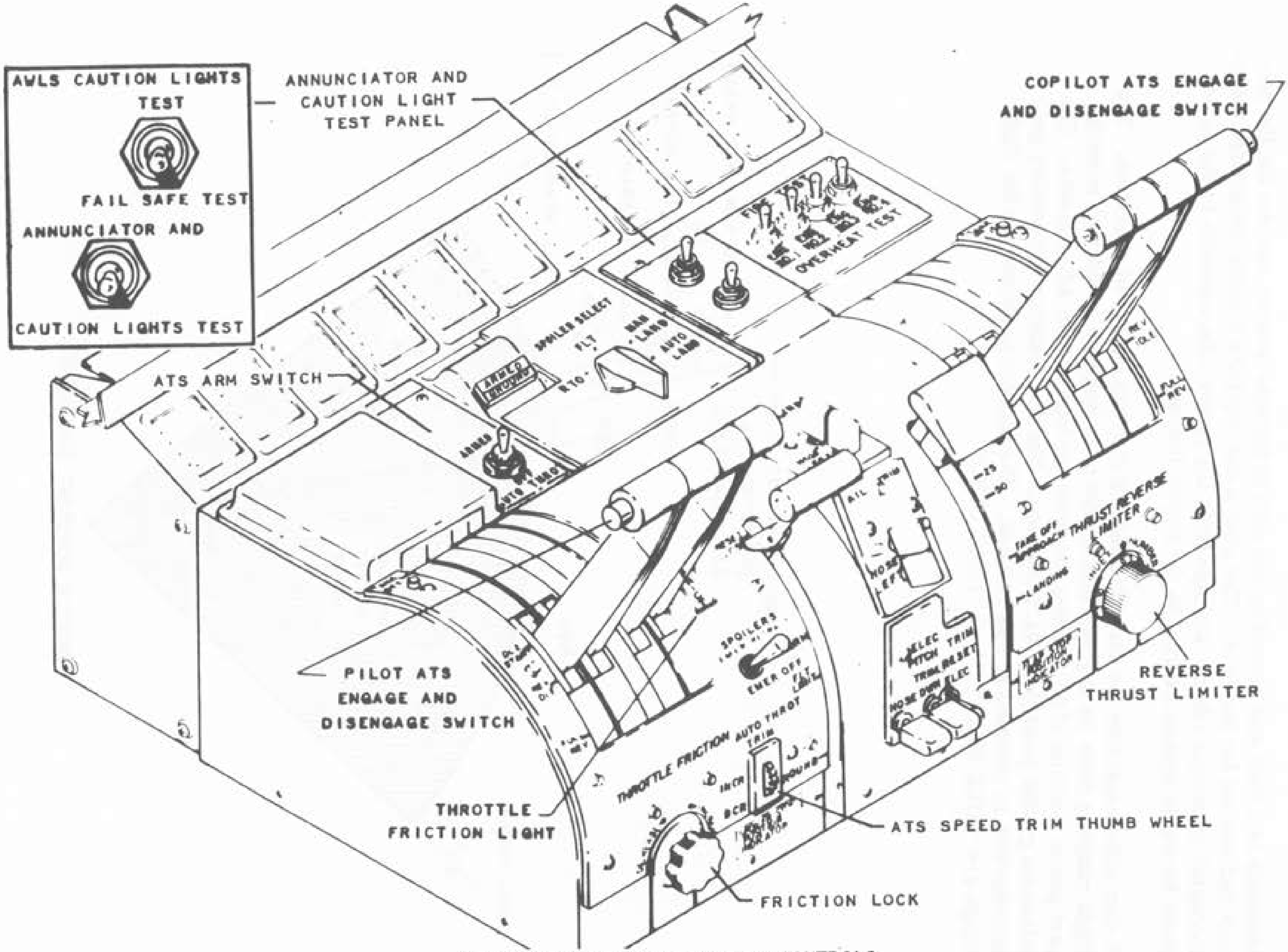
- Throttle Control Quadrant
- Engine Control Cables
- Cable Tension Regulator
- Engine Control Linkage
- Fuel Shutoff Actuator
- Thrust Reverser Control Linkage
- Automatic Throttle System (aircraft equipped with AWLS)

THROTTLE CONTROL QUADRANT.

The throttle quadrant is located on the flight station center console. This



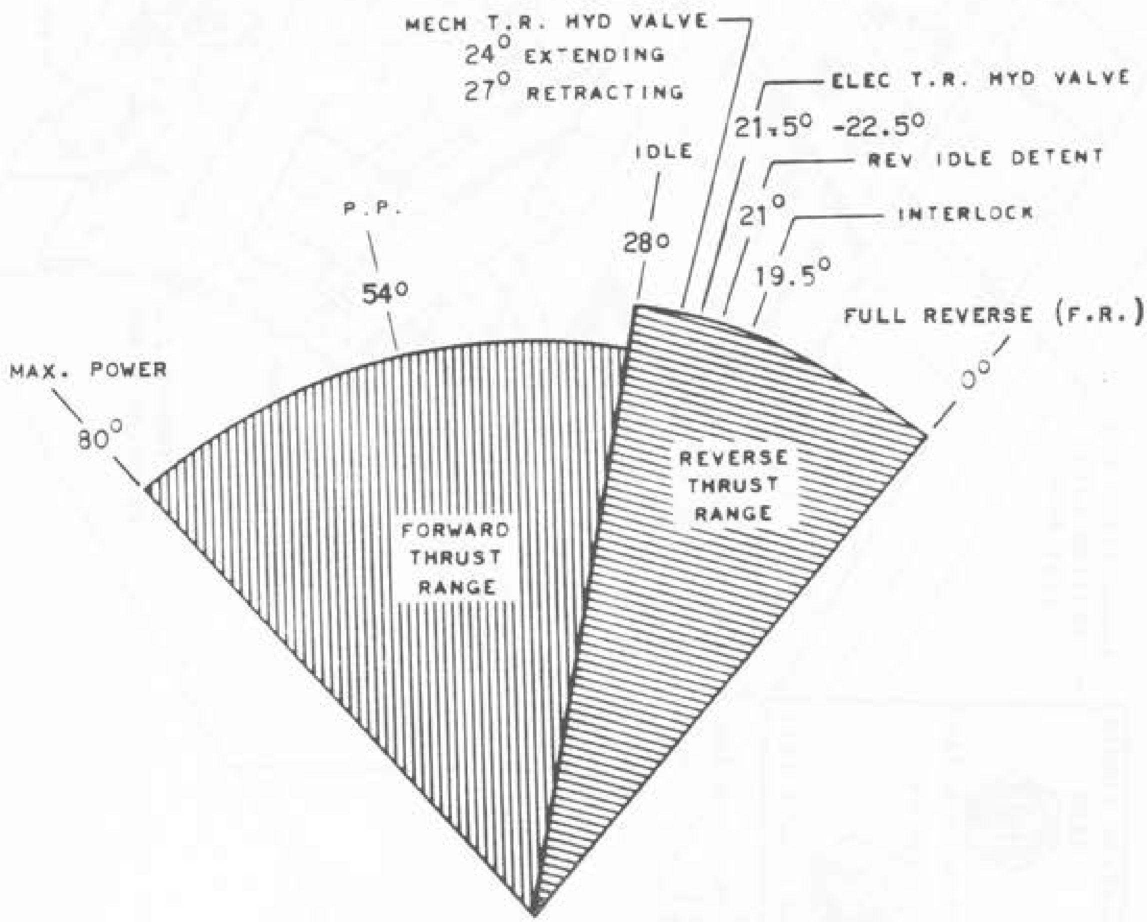
COVER ASSEMBLY - CENTER CONSOLE



AUTOMATIC THROTTLE SYSTEM CONTROLS

assembly is a dual unit providing two sets of throttle levers: one set for the copilot and one set for the pilot. The pilot's and copilot's throttle levers are interconnected by torque tubes. Linkage from the torque tube connects to the cable drum for cable system control to the engine linkage.

A cam plate separates the throttle quadrant into two ranges of operation. The flight range is from 28 degrees (idle start) to 80 degrees (maximum power). A part power position of 54 degrees provides for engine trim adjustments. The minimum cruise position is 41.5 degrees. The flap warning and landing gear microswitch is actuated at this position. The placard positions for the flight range are "IDLE START" and "TAKE OFF."



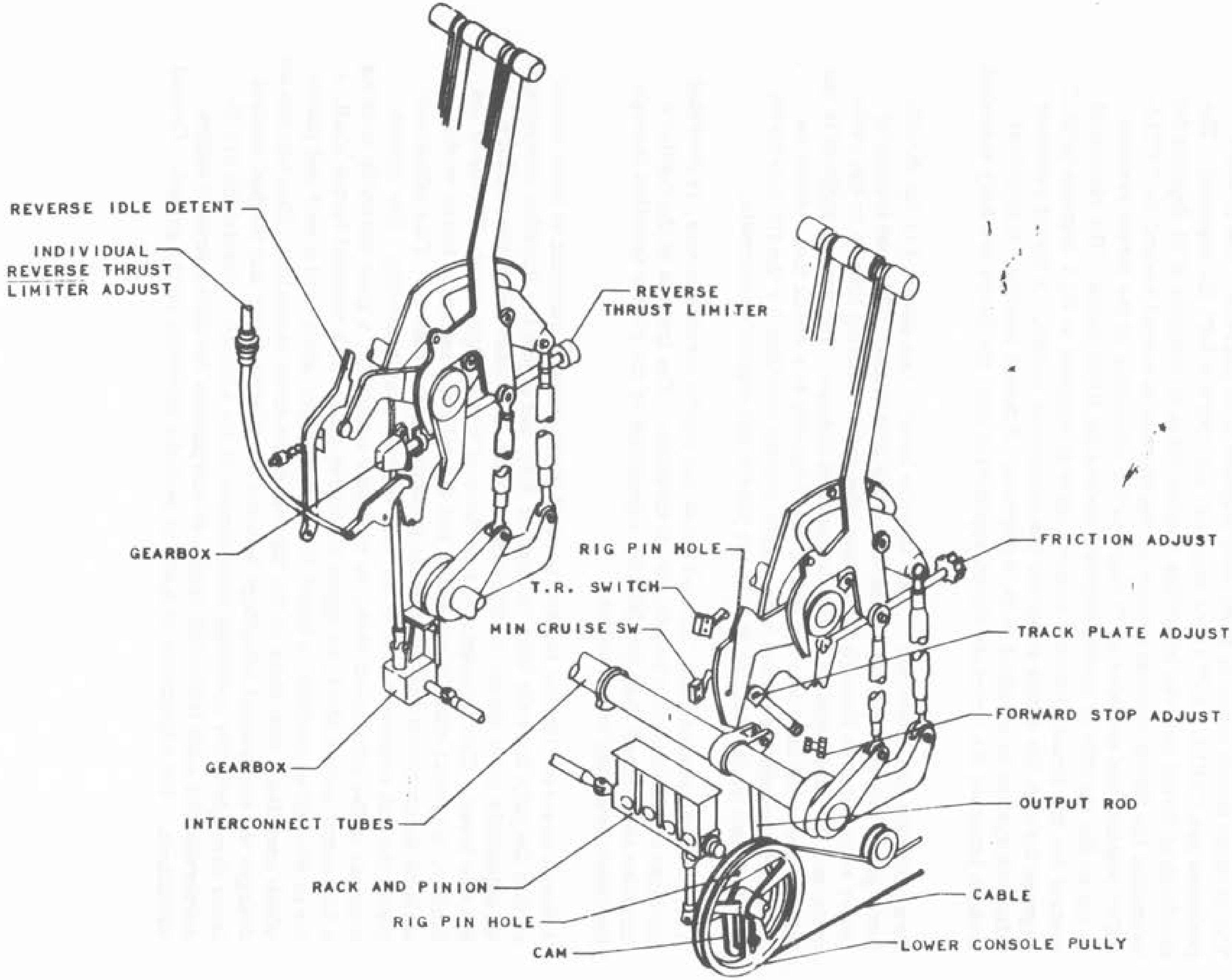
THROTTLE QUADRANT SCHEMATIC

The reverse thrust range is from zero degrees to 28 degrees. The placard positions are "FULL REV" (zero degrees) and "REV IDLE" (21 degrees). The mechanical thrust reverse hydraulic control valve is actuated at 24 degrees for extending the thrust reverser doors as the throttle is moved toward the "FULL REV" position and actuated at 27 degrees for retraction of the thrust reverse doors as the throttle is moved forward toward the flight range. The electrical control for the thrust reverser control valve is actuated at 21.2 degrees to 22.2 degrees through the thrust reverser pressurization switch. A thrust reverser interlock system is actuated at 19.5 degrees. A thrust reverser mechanical lockout prevents the reverser thrust application until the doors are fully extended.

Two pushrods are connected to each throttle lever. One pushrod is the throttle lever power interconnecting rod to the torque tube crank. This rod transmits power requirements through the torque tube and connecting linkage to the cable drum and the cable system to the fuel control linkage. The second pushrod is the throttle lever lift interconnecting rod that connects to a crank that rotates an intershaft through the torque tube. This system provides for the lift movement of 1 1/8-inch of the throttle at both the pilot's and copilot's quadrants.

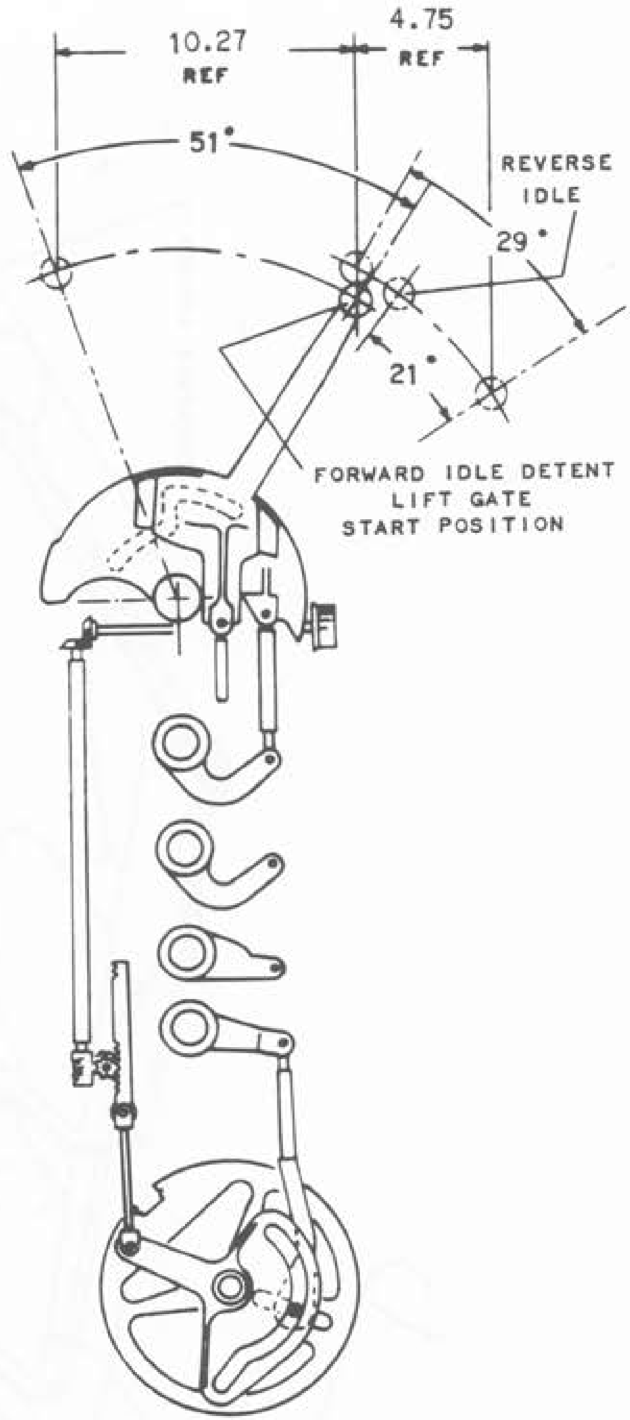
A friction adjustment knob, located below the pilot's throttle levers, is provided for desired friction adjustments for all throttles. The friction in the copilot's throttles is obtained from the friction adjustment of the pilot's throttles through the interconnecting torque tubes.

A thrust reverser limiter is incorporated in the throttle quadrant to limit thrust so that the pilot does not have to monitor EPR and adjust his throttles accordingly. An adjustable index thrust limiter control knob is located below the copilot's throttle lever. This adjustment is performed by the flight crew. To adjust the limiter, a special chart is consulted and the selected setting is based on the ambient temperature and barometric pressure on the runway. This adjustment limits the full reverse thrust of all four engines simultaneously. The system consists of the adjustment knob, an indicator assembly, a gear assembly rotating a horizontal torque shaft, an upper 90-degree gearbox, a vertical torque shaft, a lower 90-degree gearbox, a lower horizontal torque shaft, and a rack and pinion which operates a cam plate on the throttle cable drum assembly. This adjustment changes the mechanical advantage between the throttle lever and the fuel control lever throughout the operating environment of the aircraft. Provisions are incorporated for each individual engine to compensate for differences in engine variations. The adjustment is made at periodic intervals on the ground. Ground



PILOT'S AND COPILOT'S THROTTLE

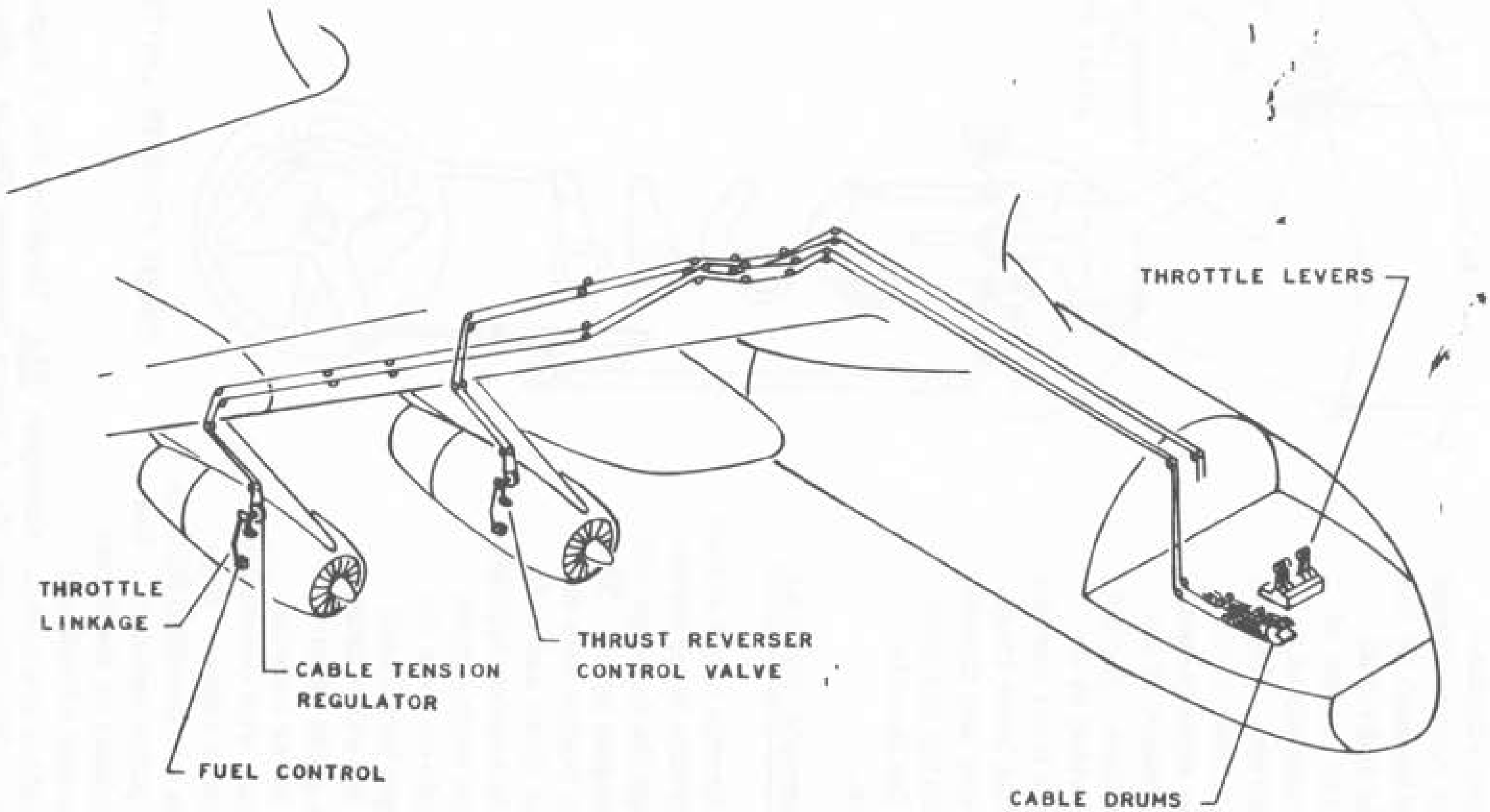
adjustments provide for the accomplishment of adjusting all four engines simultaneously by the reverse thrust limiter adjusting knob by the aircrew. The individual thrust reverser limiter of each engine consists of a adjustment screw, a flexible shaft, and a master stop lever. These adjustments are located forward of the copilot's throttles. Rig pin holes are provided in the pilot's throttle lever carrier and the throttle lever track. An inclinometer and throttle bracket assembly are used to establish the throttle lever position.



THRUST REVERSER LIMITER

ENGINE CONTROL CABLES.

The engine throttle cable system transmits throttle lever movements through the fuselage and wing to the engine pylon. The cable system begins with the throttle cable drum and ends with the cable tension regulator located on the engine pylon strut. A pushrod from the throttle torque tube crank connects to the cable drum crank. The cable drum consists of the lower console pulley and cam with connecting upper and lower cables. Rigging pin holes are provided through the console pulley and cam. The cam is positioned by the thrust reverser limiter adjustment knob. All cables are coded. Example: TIA Throttle, No. 1 Engine, Increase Thrust Cable. TIB Throttle, No. 1 Engine Decrease Thrust Cable. No. 2 Engine Cables would be T2A, and T2B etc. These 3/16-inch flexible steel cables are



ENGINE CONTROL GENERAL ARRANGEMENT

routed below the floor of the flight crew compartment, then up the 436.5 bulkhead to the top of the fuselage, and back to the front beam of the wing. The cable system then extends out the leading edge of the wing to the pylon, where it is routed down the leading edge of the pylon to a tension regulator. The tension regulator is the termination point of the cable and pulley system.

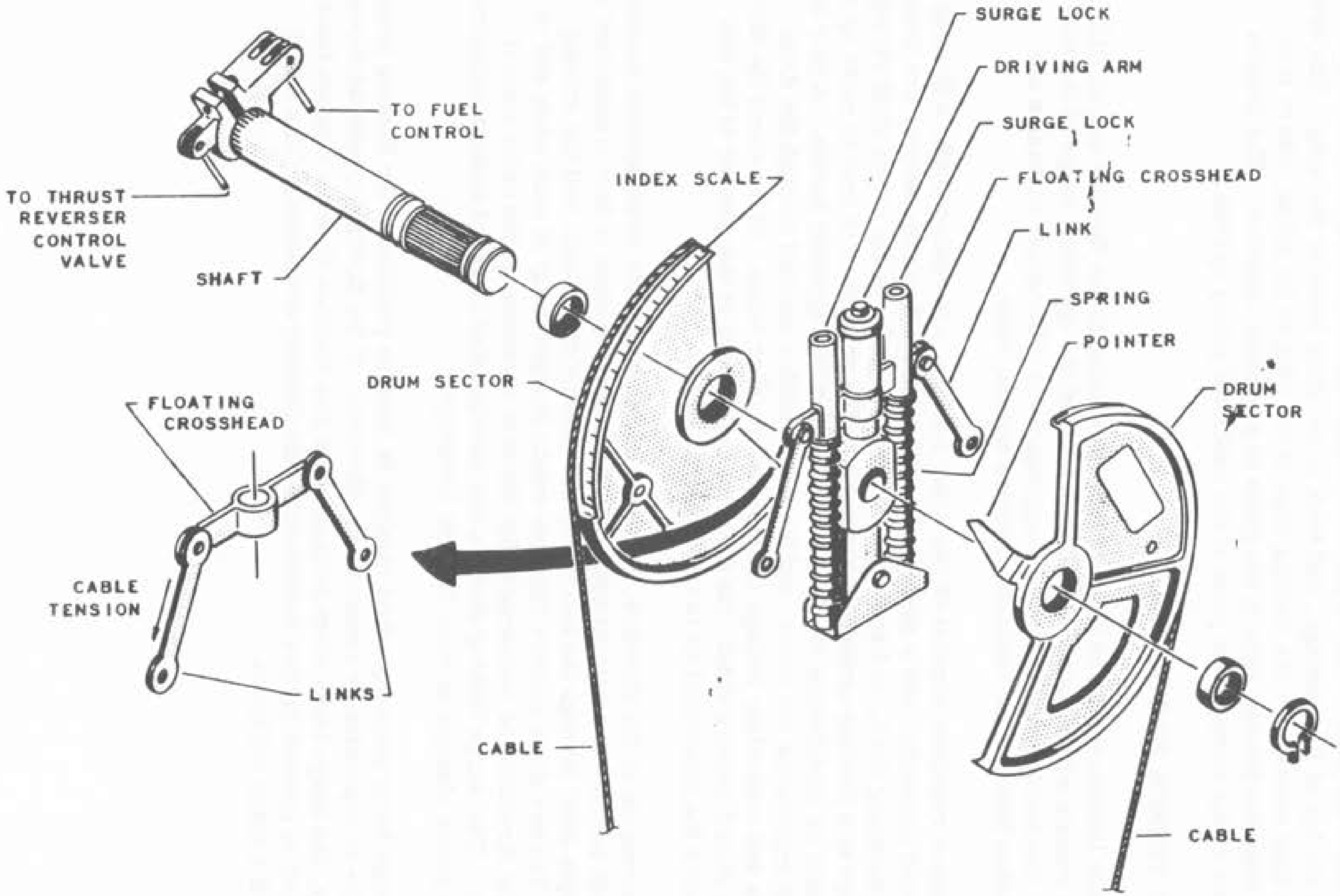
CABLE TENSION REGULATOR.

The cable tension regulator ensures that the tension in the throttle cables will always remain within required limits throughout the operating range of the aircraft. The tension regulator will compensate for differential expansion and contraction between the aircraft structure and the cable.

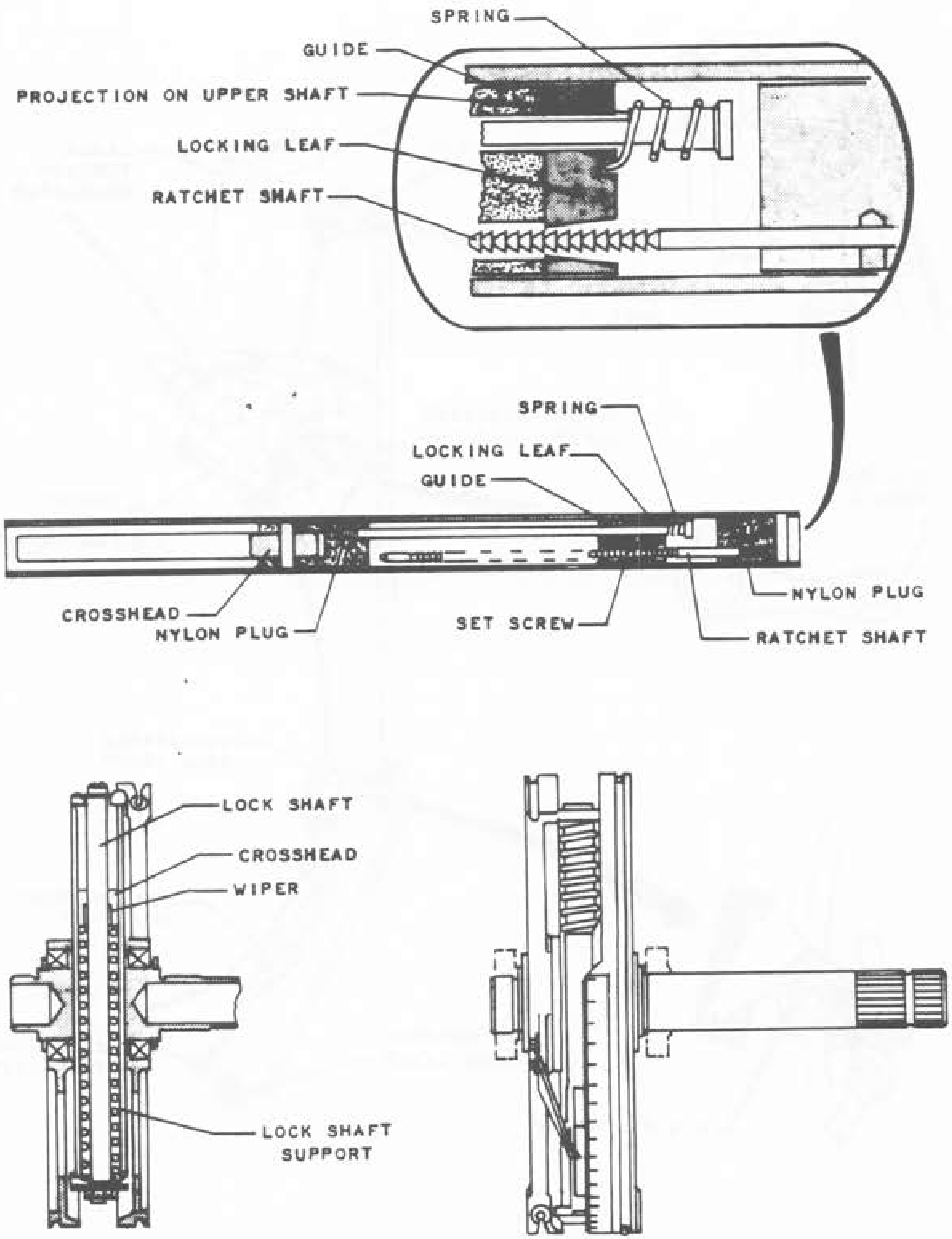
The tension regulator consist of two drum sectors, a mounting shaft, a floating crosshead assembly, and a surge lock mechanism. The drum sectors are located on the mounting shaft, and are connected mechanically to the output shaft through a linkage to a floating crosshead assembly. The crosshead is free to move up or down until an equilibrium is established between two opposing forces. A pair of springs represents one force, and the cable tension exerted through the drum sectors and connecting linkage represents the other force. In the event the throttle cables should become slack, the force on the springs is the greater of the two and moves the crosshead up to re-establish tension.

With movement of the throttles, increase or decrease, the cable system causes the drum sectors to rotate as one unit. The rotary motion is then transmitted to the output shaft through the two links, the floating crosshead, and the driving arm. The two drum sectors can also rotate independently of each other and in opposite directions to compensate for thermal expansion in the cable control system. Two surge locking devices are incorporated to guard against undesirable engine power changes in case of cable breakage.

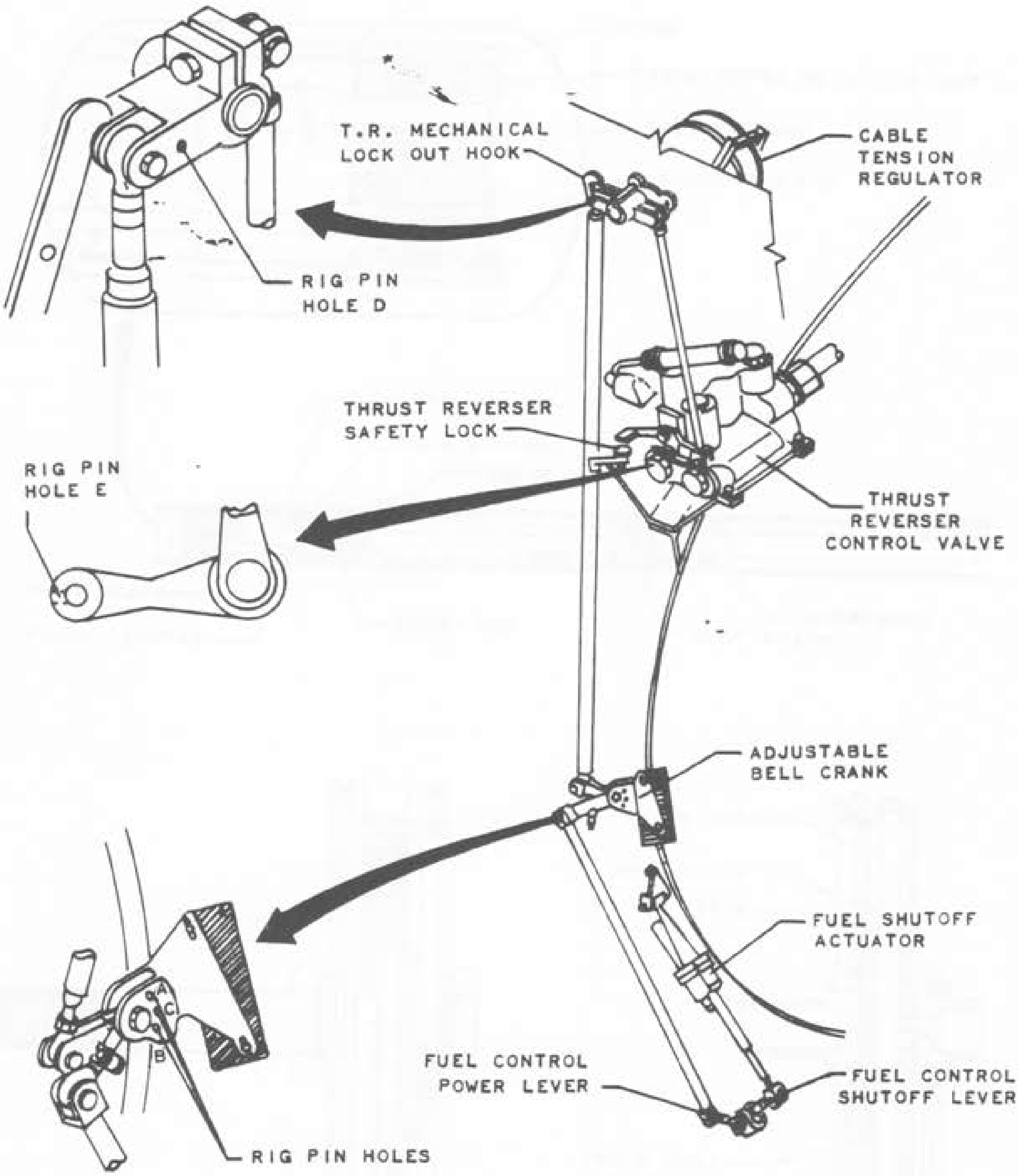
The surge locks permit gradual changes in relative position of the floating crosshead due to expansion or contraction. However, if the floating crosshead moves rapidly, the surge locks allow no more than five degrees of drum rotation before they lock to prevent further movement of the floating crosshead. This would occur if a cable did break.



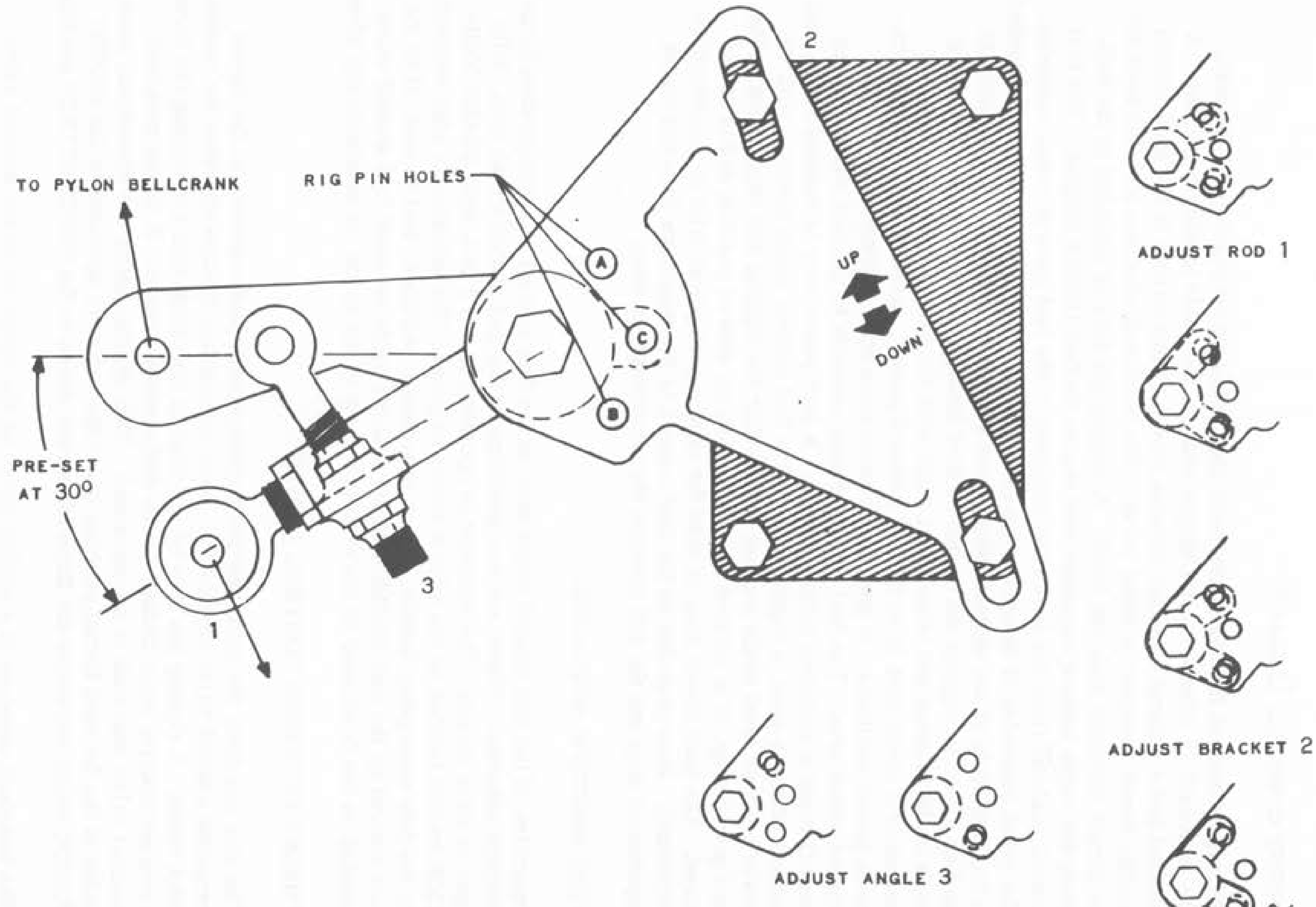
CABLE TENSION REGULATOR



TENSION REGULATOR SURGE LOCK



NACELLE THROTTLE LINKAGE



THROTTLE LINKAGE ADJUSTABLE BELLCRANK

ENGINE CONTROL LINKAGE.

The engine control linkage begins with the cable tension regulator bellcrank. The bellcrank is attached to the output shaft of the cable tension regulator. A pushrod and a linkrod transmit throttle power requirements to the fuel control and the thrust reverser control valve. The bellcrank also has a roller hook for the thrust reverser lock-out latch. A rigging pin hole is provided in the bellcrank for cable tension regulator and engine control linkage rigging. The fuel control pushrod from the bellcrank connects to the fuel control crank assembly. The crank assembly is mounted to a serrated plate and bracket which is attached to the right side of the engine compressor section at flange G. Serrations are used as an aid in rigging the engine control linkage. There are three rigging holes in the bracket and plate which align with the lobe of the crank when the fuel control crank arm is in the full forward power, partial power, and full reverse power positions. A push rod connects the crank assembly to the fuel control crank arm. The fuel control crank connects to the fuel control power shaft through a serrated mating device. A part power stop is located on the fuel control which is used in rigging the engine fuel control crank position with the use of a power level angle rigging tool. After the rigging and adjustment of the part power stop, it is rotated 180 degrees to its stowed position and is safety wired. The part power stop is used for engine part power trim by maintenance personnel. Also provided on the fuel control is the maximum forward thrust adjustment stop and the full reverse thrust adjustment stop.

FUEL SHUTOFF ACTUATOR.

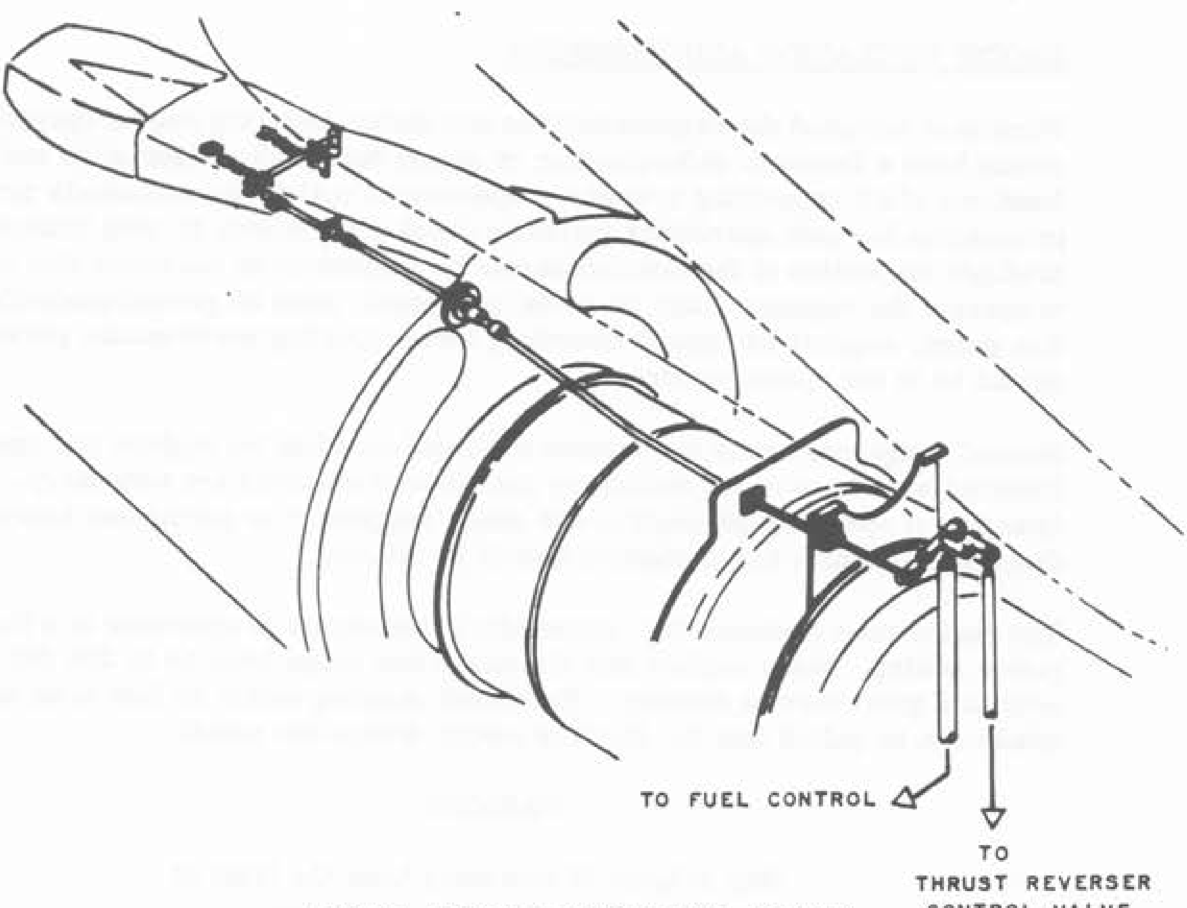
Operation of the fuel shutoff crank arm on the fuel control is accomplished by an electric actuator. There are two positions of the fuel shutoff crank arm, fully open or fully closed. The actuator is operated by the FUEL AND START IGNITION switch located on the pilot's overhead panel. The actuator is also controlled by the fire emergency handle. When this handle is pulled, fuel is shut off at the fuel control by the fuel shutoff actuator and the cable actuated fuel shutoff valve, located on the front spar of the wing at the top of the pylon, is mechanically closed.

THRUST REVERSER CONTROL LINKAGE.

The link rod from the cable tension regulator bellcrank connects to the thrust reverser control valve crank arm. This mechanical linkage operates the manual pilot valve. A rigging pin lobe is provided at the crank arm for rigging the thrust reverser control valve linkage to the fuel control linkage. A thrust reverser control valve interlock is incorporated. This system keeps the directional control valve in the forward thrust position while the engine is operated in the FLIGHT RANGE which maintains the thrust reverser doors in the "RETRACTED" position.

The interlock consists of a striker lever on the thrust reverser control valve assembly, a lock for the directional control valve spool, a striker lever, and a striker button attached to the fuel control upper pushrod. The striker lever is spring-loaded to "LOCK." When the throttle is moved to the thrust reverse range, the thrust reverser interlock is actuated and unlocks the spool of the directional control valve so that hydraulic power is ported to the thrust reverser target door actuators on the extend end.

A thrust reverser lock-out mechanism is provided to prevent the application of engine power in the "REVERSE THRUST" range until the thrust reverser target doors are extended. This system consists of a teleflex cable assembly connected to the actuating linkage on the thrust reverser target doors and to a lock-out latch at the cable tension regulator bellcrank. The mechanism is spring-loaded to the "LOCK" position. Quick disconnects are provided in the cable and conduit assembly so that the engine exhaust assembly can be changed without disturbing the rigging of the thrust reverser system.



THRUST REVERSER MECHANICAL LOCKOUT

AUTOMATIC THROTTLE SYSTEM (ALL WEATHER LANDING SYSTEM ONLY).

The major components of the Automatic Throttle System (ATS) are the computer/amplifier unit, servomotor assembly, clutch pack assembly, and speed trim assembly. The ATS uses the airspeed hold signal from the Central Air Data Computer (CADC) as the airspeed source. A clutch-operated synchromotor is used to present a zero error signal to the computer until the ATS is engaged. When the pilot engages the system, a CADC signal engages the synchroclutch to the indicated airspeed shaft. Thereafter, until disengaged, the signals through the computer/amplifier to the servomotor are proportional to aircraft speed changes.

The servomotor positions the throttles to maintain the speed of the aircraft at the time the system was engaged. The pilot, by adjusting the speed trim signal, can command a change in aircraft speed up to ± 5 knots of the original engaged speed without disconnecting the ATS system. Additional information is shown in Chapter 5, Volume IX of the StarLifter manual series.

ENGINE OPERATION AND TRIMMING.

Personnel assigned the responsibilities and duties involving engine operation should have a thorough understanding of engine design characgeristics and the functions of all supporting systems. Operational maintenance manuals provide procedures for safe operations including check lists of step by step functions. A preflight inspection of the aircraft should be performed to ascertain that it is safe to operate the engines. Only essential personnel, such as ground controller, fire guard, support equipment operator, and supporting maintenance personnel, should be in the operating vicinity.

Several dangerous areas and factors are involved when jet engines are operated. Knowledge of these areas and safety precautions required are necessary. Noise intensity of operating jet engines can cause temporary or permanent hearing damage. Adequate ear protection should be utilized.

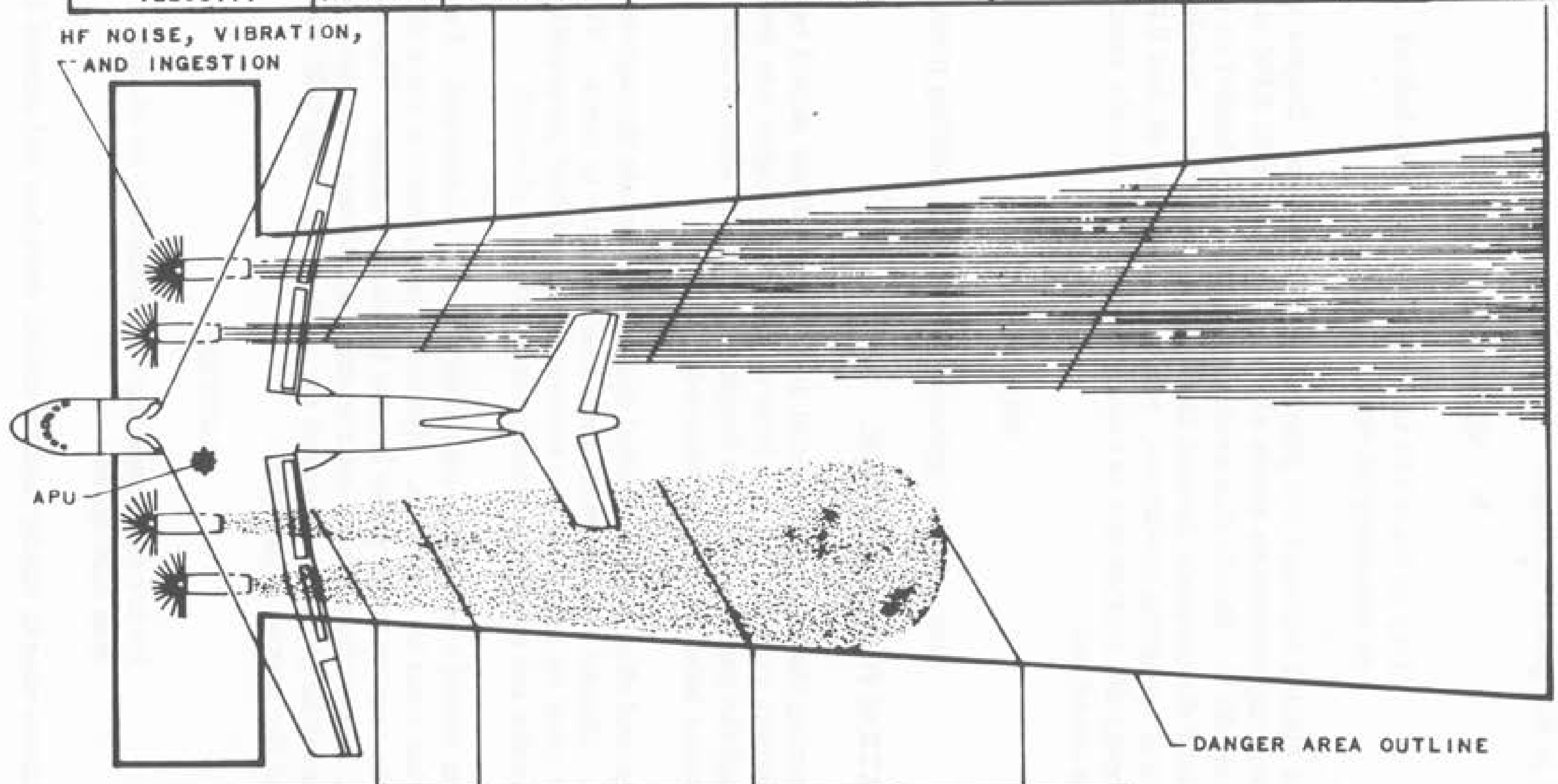
The engine inlet is dangerous, especially if the engine is operating at a high, power setting. Mass airflow into the intake can range from 50 to 300 PSI and acts as a giant vacuum cleaner. Personnel standing within 25 feet of an engines intake can be pulled into it: Death is nearly always the result.

WARNING

Stay at least 35 feet away from the front of the intake of an operating jet engine.

Similarly, high-velocity gases are ejected through the exhaust nozzle of the

DISTANCE FROM EXHAUST	20 FT	45 FT	100 FT	200 FT	300 FT
VELOCITY	1000 MPH	500 MPH	200 MPH	100 MPH	50 MPH



DISTANCE FROM EXHAUST	15 FT	40 FT	100 FT	150 FT
TEMPERATURE	920°F	400°F	200°F	150°F

DANGER AREAS - MAXIMUM POWER

engine. These gases usually have a temperature of 500°C and a flow velocity of 1000 MPH at full power settings.

WARNING

Stay at least 150 to 200 feet away from behind an operating jet engine.

Engine and starter turbines are potential hazard areas. Engine turbines under normal operating conditions rotate at approximately 8000 RPM at temperatures in excess of 500°C. Should this assembly become overheated or should it overspeed, it may disintegrate through the side of the engine. Turbines of starters, under normal operating conditions, rotate in excess of 60,000 RPM's before cutoff. Should the starter fail to cutoff, an overspeed would result; consequently, the turbine could fail.

WARNING

Stay out of alignment with turbine rotating planes.

PREPARATION FOR ENGINE RUN.

Before starting the engines, several safety precautions should be observed. Foreign objects around or in the inlet of a turbojet engine are detrimental. The area around the engine should be inspected, and any objects that may be drawn into the engine inlet should be removed.

A static ground should be connected and should remain throughout entire ground operation. Checks and tiedowns should be securely in place. Firefighting equipment must be available and manned with qualified personnel. Aircraft status records and engine servicing should also be checked.

Prior to an initial run, engine oil quanity should be checked. Fuel from any tank to the engine must be available. Hydraulic pump suction lines must be pressurized by using the suction boost pump for the applicable engine. The electrical, fire detection, fire extinguishing, instrumentation, thrust reverser, and bleed air systems must be properly prepared for engine run. The CSD disconnect should be checked for proper connection.

CAUTION

Do not disengage the CSD statically or at less than idle speed.

With the above checks accomplished and all switches and circuit breakers engaged, the aircraft and engines are in a ready-state for an engine run.

ENGINE LIMITATIONS.

Engine limitations are established by the manufacturer and must be applied to ensure the integrity of the engine. Engine operators must be capable of quickly recognizing normal and adnormal conditions.

All abnormal conditions must be recorded in the applicable forms for maintenance disposition. Engine operating conditions are measured by engine pressure ratio, engine RPM, exhaust gas temperature, fuelflow, oil pressure, oil temperature, and engine vibration.

ENGINE LIMITATIONS

Duration of Power Setting

Power Setting	Acceleration	Takeoff	Climb	Normal Rated
Duration	2 minutes	5 minutes	30 minutes	Continuous
EGT °C (max indicated)	554*	554*	510	488

Engine Speed Limits

Low-Pressure Compressor (N1)	Overspeed is 101.1%
High-Pressure Compressor (N2)	Overspeed is 104.5 %

*Whenever the gas temperature exceeds 565°C for 5 seconds or longer, the engine throttle should be retarded to idle power for 5 minutes and then shut down. Maintenance directives must be consulted for required inspections.

When an overspeed is experienced, the indicating system should be checked for accuracy. If overspeed is confirmed, maintenance directives must be checked for subsequent action.

START LIMIT - If the engine's EGT exceeds 455°C on starting for any length of time, the start should be discontinued and recorded as a "Hot Start." An over-

TF33-P-7 JT3D-5A FUEL GRADE JP-4

OPERATING CONDITION		OPERATING LIMITS		
THRUST SETTING	(MINUTES)	MAXIMUM OBSERVED EXHAUST GAS TEMPERATURE (°C) (4)	OIL PRESSURE (PSIG) NORMAL	MAXIMUM OIL TEMPERATURE (°C) (5)
TAKE-OFF (1)	5	555	40-50 (6)	121
MILITARY	30 (8)	510	40-50	121
NORMAL RATED	(7) CONTINUOUS	488	40-50	121
IDLE	CONTINUOUS	340 (2)	35 MINIMUM	121
STARTING	—	455	—	—
ENGINE ACCELERATION	5	555	40-50	121

(1) TO BE USED FOR TAKE-OFF ONLY.

(2) THIS TEMPERATURE IS NOT A LIMIT. IT IS GIVEN AS A GUIDE TO INDICATE THE EGT, WHICH, IF EXCEEDED, MAY SIGNIFY AN ENGINE MALFUNCTION. THE EGT LIMITS FOR THROTTLE SETTINGS BELOW NORMAL RATED THRUST ARE THE SAME AS THE TEMPERATURE LIMIT FOR NORMAL RATED THRUST.

(3) DELETED.

(4) WHENEVER THE EGT EXCEEDS 565°C FOR ANY TIME, EITHER THE ENGINE SHOULD BE SHUT DOWN OR A LANDING SHOULD BE MADE AS SOON AS POSSIBLE. WHEN SHUTTING THE ENGINE DOWN FOR THIS REASON, ALLOW A COOLING PERIOD OF 5 MINUTES AT IDLE PRIOR TO SHUTDOWN IF ENGINE CONDITIONS AND FLIGHT CIRCUMSTANCES PERMIT.

(5) PROVIDING ENGINE OPERATION IS OTHERWISE NORMAL, NO MINIMUM OIL INLET TEMPERATURE NEED BE OBSERVED BEFORE TAKE-OFF.

(6) THE OIL PRESSURE MAY EXCEED 50 PSIG BUT NOT 55 PSIG, DURING TAKE-OFF ONLY.

(7) ANY POWER SETTING ABOVE NRT WILL BE LIMITED TO 30 MINUTES.

(8) ANY POWER SETTING ABOVE MRT WILL BE LIMITED TO 5 MINUTES.

ENGINE OPERATING LIMITS

temperature inspection must be performed before a restart is attempted.

FALSE START - If an engine ignites normally but does not accelerate, the start must be discontinued and a second start attempted. If the second start is unsatisfactory, the engine must be shut down and an investigation made.

A false start may be the result of insufficient power to the starter or early starter cutout. The starter must assist the engine up to 35 percent speed for a successful start. (The indication of the starter valve light during the second start should be noted.)

NOTE

> After a false start, rotate the engine with the starter for 10 to 15 seconds to remove accumulated fuel or vapor from the engine before attempting a restart.

STARTER DUTY CYCLE - The starter duty cycle follows:

One minute "ON," 30 seconds "OFF"

One minute "ON," 30 seconds "OFF"

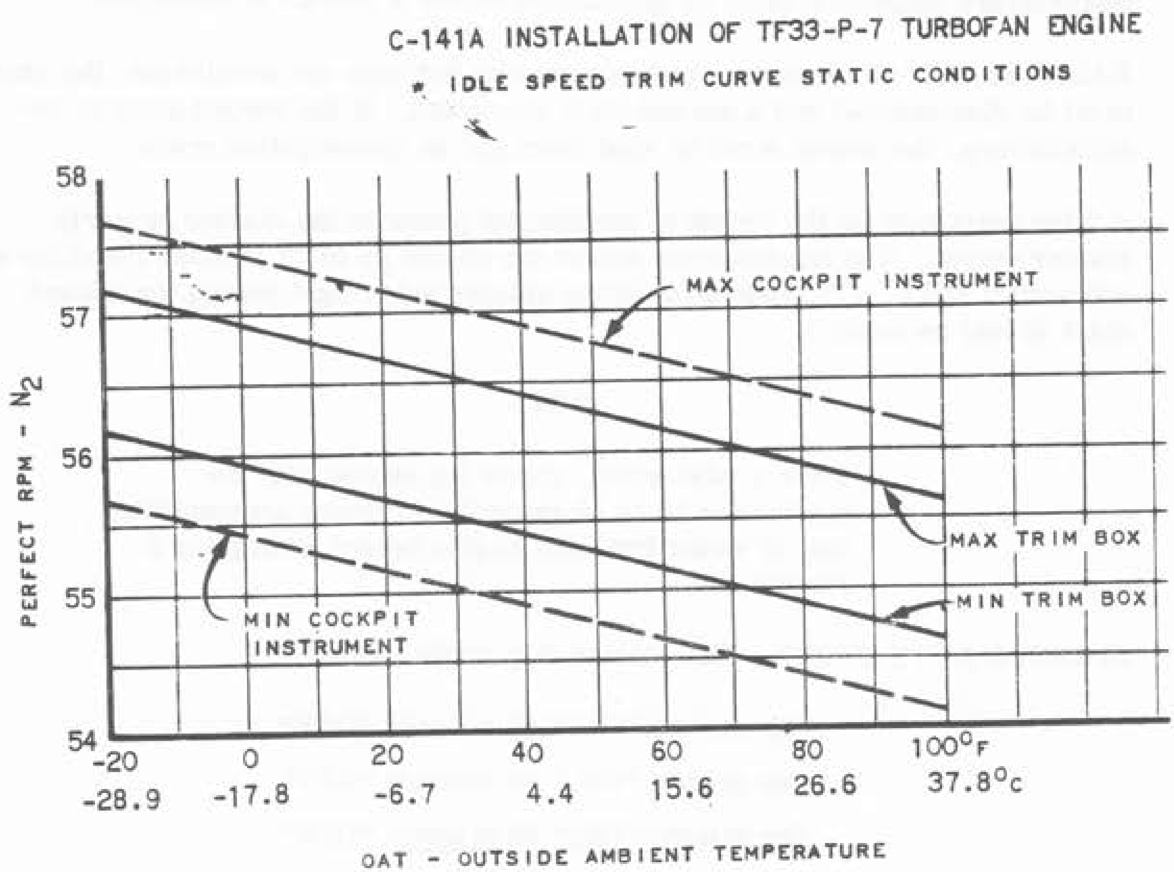
One minute "ON," 30 minutes "OFF"

The starter may be operated for 1.5 minutes "ON," and 10 minutes "OFF" for any number of duty cycles.

FUEL AND OIL LEAKAGE - During engine operation, the drain mast and lower cowl area must be observed for liquid leakage. If any leakage is observed, the engine should be shut down and an investigation made. After engine run, the nacelle cowling must be inspected for leakage.

ENGINE STARTING.

Before the starting operation is begun, the parking brakes should be set by using the No. 3 hydraulic system pump until the engine is started. The pump need not be run continuously, but accumulator pressure must be kept above 2000 PSI. With the fuel and ignition switch in the "STOP" position, the throttle lever is placed in "IDLE START." The pylon bleed air duct and the APU valves, if required, should be opened. The fuel boost pump should then be turned on and the corresponding low-pressure fuel light should go out. Thrust reverser lights should be "OFF." If the thrust reverser NOT-LOCKED light is "ON," the reverser should LOCK as the engine is started.



IDLE SPEED TRIM CURVE

The engine start button should now be depressed. The button will hold in and the button and starter valve light will illuminate. If oil pressure and N1 RPM do not indicate within 20 seconds, the engine must be shut down.

Only the N2 rotor section is driven by the starter. Air is pumped into the engine through N1 which results in N1 rotation. The engine must be rotated by the starter to approximately 10 percent RPM to provide sufficient airflow for combustion. At 10 percent N2 RPM, the ignition and fuel switch should be positioned to "RUN." Fuelflow and EGT will be indicated and the N2 RPM will continue to accelerate.

NOTE

Maximum EGT at start is 455°C not to exceed 15 seconds. If EGT does exceed these limits, shut down the engine immediately.

The engine's RPM will continue to accelerate by both starter power and heat energy driving the engine's turbines. The fuel control provides the fuel metering in accordance with the changing engine parameters.

At 35 to 45 percent RPM, the starter button will pop out, and the button and starter valve position lights will go out. If the button does not pop out by 45 percent RPM, the button should be pulled manually and the starter system checked. The engine's operation is now self-sustaining. The fuel control provides for the continued acceleration to idle speed, 54 to 58 percent depending on the ambient air temperature. The following table shows the normal engine idle configuration:

NORMAL ENGINE IDLE CONFIGURATION

ITEM	CONDITION
N2 RPM	54 to 58 percent
N1 RPM	25 to 30 percent (reference only)
Oil Pressure	35 to 45 PSI
Oil Temperature	40 to 121°C
Hydraulic Pressure	3000 PSI ± 150
Generator	400 Hertz ± 4
EPR	Bottom of scale
Fuelflow	700 to 1500 PPH (reference only)
CSD Oil Temperature	40 to 150°C

ENGINE SHUTDOWN.

If the engine has been operated at normal rated power or above for 1 minute or more, the engine must be run at "IDLE" for 5 minutes to allow the enging to cool and to prevent possible rotor seizure during coastdown. The engine throttle should be moved to "IDLE" and, after sufficient cooling, the fuel and ignition switch should be positioned to "STOP." The fuel boost pump switch should also be positioned to "OFF." Engine RPM, EGT, and engine oil pressure should decrease. Fuel should drain from the drain mast immediately thus indicating that the fuel dump valve has opened.

N1 and N2 RPM gages should indicate free deceleration of the compressors. N1 will require approximately 2 to 3 minutes to reach zero RPM.

ENGINE TRIM.

The primary purpose of engine trimming is to ensure that the engine produces its rated thrust within a wide range of atmospheric conditions. Trimming is based upon the measurement and adjustment of exhaust nozzle pressure (P+7). The adjustments on the fuel control enable the governed speed to be varied within specified limits. Varying the engine RPM results in a proportional change in engine exhaust gas pressure and thrust. A manifold pressure gage is used in trimming the engine, as are the EPR gage, RPM and EGT indicators. Trimming should be accomplished whenever a new or overhauled engine is installed on the aircraft and when a fuel control has been replaced or rerigged.

The aircraft must be headed directly into the wind and wind velocity must not exceed 8 to 10 knots. Trimming should never be attempted when icing conditions prevail. It is also necessary that all engine controls be properly rigged or checked before engine trimming is attempted. The appropriate maintenance directives should be consulted for proper throttle rigging procedure.

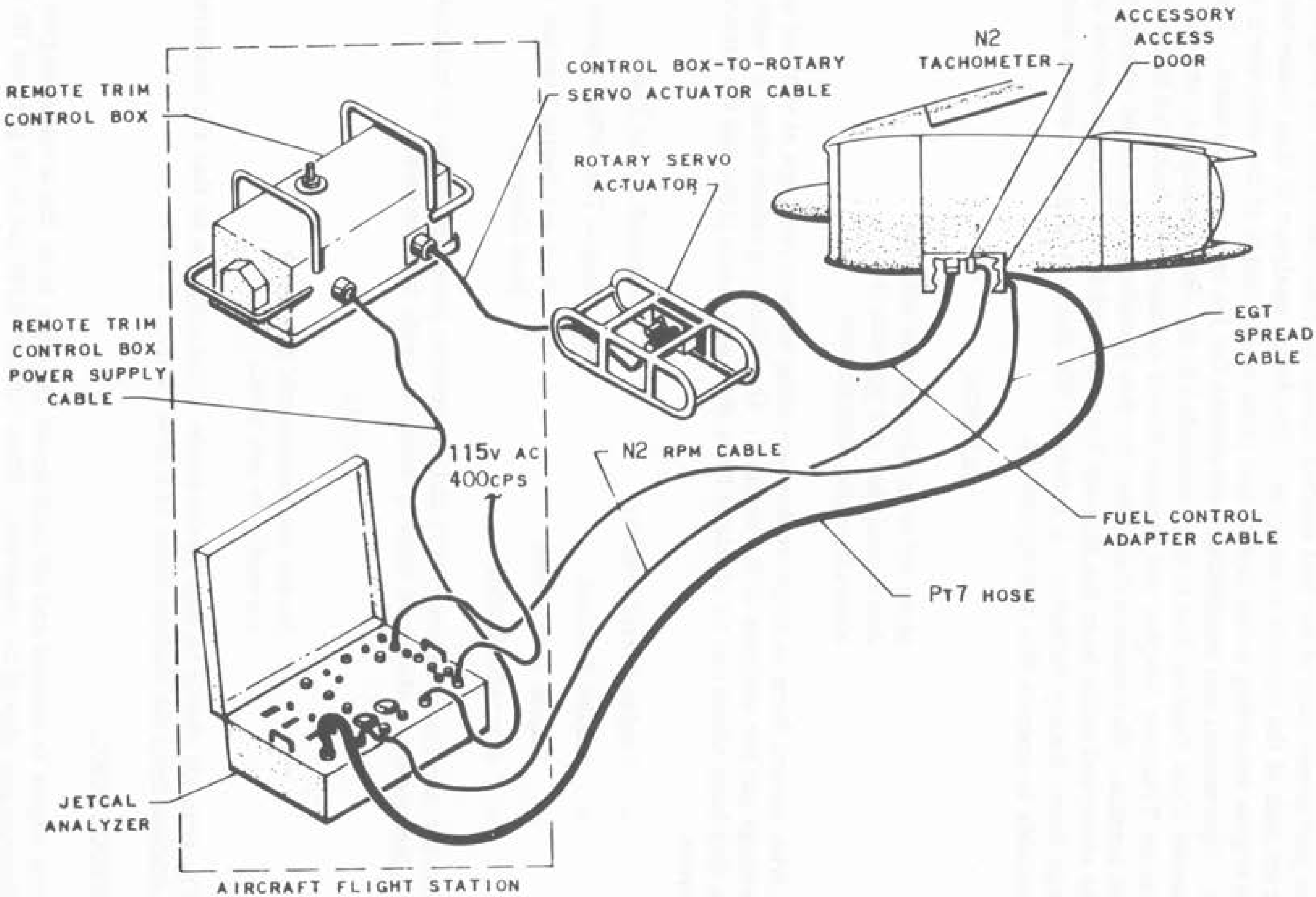
Testing equipment needed for engine trim follows:

- o Jetcal Analyzer (Howell Instruments Inc.) (H120-5119) — This unit is used to measure EGT, RPM and pressures during engine trim. The unit checks out the engine instrument system as well as the engine's performance.

CAUTION

Do not use aircraft instruments for trimming.

- o Remote Trim Control Box (FSN 4920-589-9624) — This box is used to remotely adjust the fuel control trim screw.
- o Remote Trim Servo Rotary Actuator (FSN 4920-654-8434) — This unit is used in conjunction with the remote trim control box to provide power to adjust the fuel control trim screws.
- o Remote Trimmer Adapter (FSN 4920-344-3027) — This unit connects the remote trim servo rotary actuator to the fuel control.



REMOTE ENGINE TRIMMING EQUIPMENT

PREPARATION.

The part power stop of the fuel control should be positioned with the stop in the direct path of the throttle crank arm. The Jetcal analyzer is then connected to the engine according to the instruction plate on the inside of the analyzer's cover lid. Operational and maintenance directives for the unit must be used. The Remote Trim Control Box is then connected to the Jetcal analyzer, and the Remote Trimmer Adapter and Remote Power Actuator are installed to the engine's fuel control. Maintenance directives for this installation should be consulted. The electrical cable from the Remote Trim Control Box is then connected to the Trim Servo Rotary Actuator. A 115-volt, 400 Hertz A-C power source must be available to operate this test equipment.

CAUTION

Make all trim adjustments with the Jetcal analyzer and not with the aircraft engine instruments.

A trim record form is required for recording all test readings at various power settings and for analysis of the results. The following information is required on this form which can be obtained from the engine data plate and the aircraft forms.

- Engine Serial Number
- Engine Position
- Engine Total Time
- Aircraft Number
- Aircraft Total Time
- Engine Data Plate Speed
- Part and Serial Number of Fuel Control

Outside Air Temperature (OAT) and barometric pressure within 30 minutes of engine trimming should be read by using accurate instruments.

NOTE

Do not use barometric pressure corrected to sea level.

The trim kit should be kept in the shade of the airplane so that the temperature obtained from the thermometer is a true reading of OAT.

PROCEDURE.

The engine is started and all instrument readings from the aircraft engine instruments should be observed. When "IDLE" RPM (54 to 58 percent N2 RPM) is reached, all engine instruments must be checked for correct reading. The throttle should then be advanced to the part power stop to fully inflate the fan seals. The throttle is then retarded to "IDLE." The fan discharge ducts and pneumatic ducts must be checked for leakage in all accessible areas with the engine running at "IDLE" prior to the trim procedure. Air bleed must be "OFF." Accessory loads must be reduced to a minimum.

With the engine idling, the N2 RPM should be read from the analyzer and should be recorded on the Engine Trim form. COLD IDLE RPM is the initial reading after the engine start before the engine has been stabilized and trimmed.

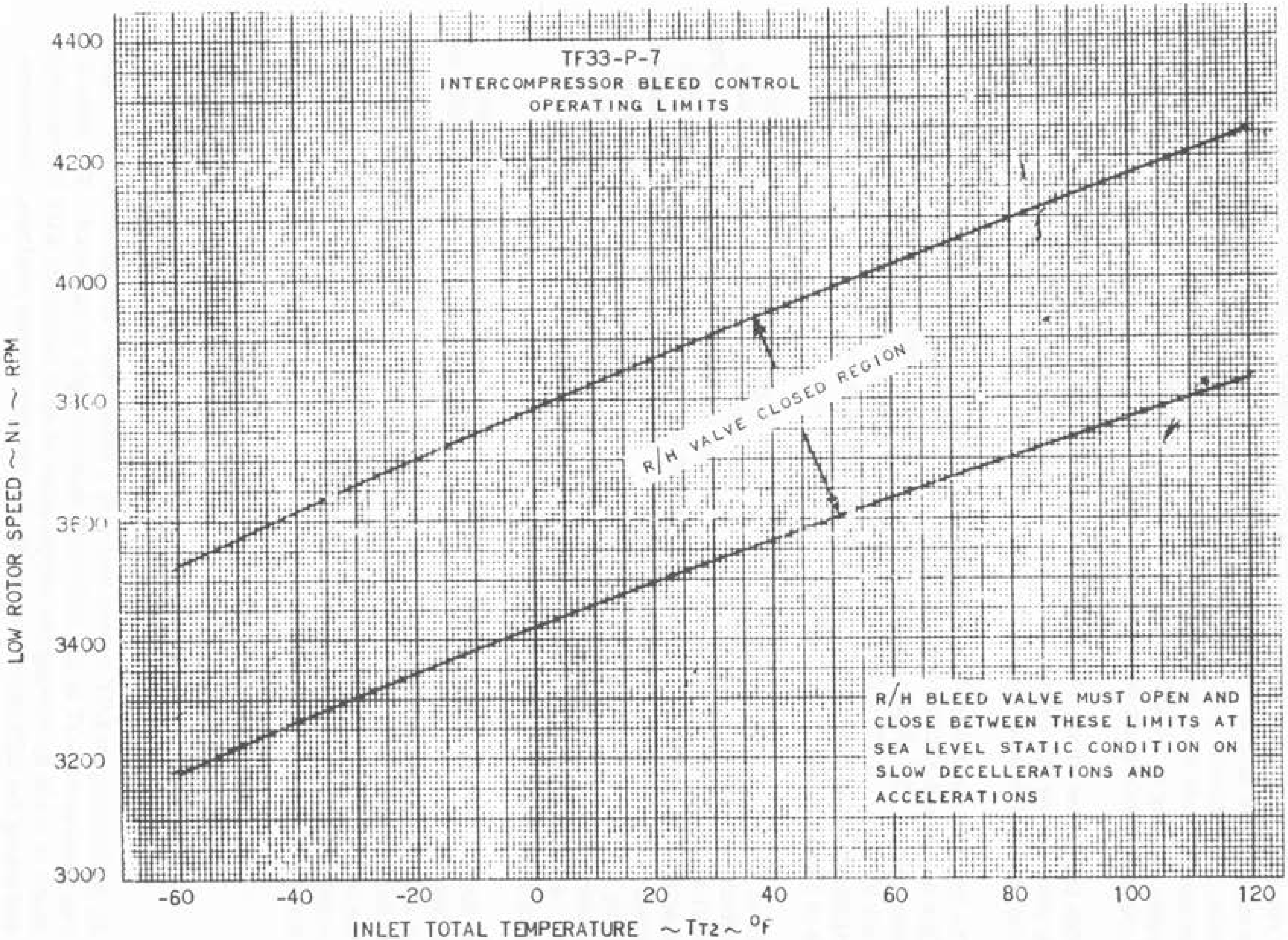
The throttle control is then moved slowly rearward through the throttle gate. This movement should be stopped when the RPM stops decreasing and begins increasing. The change indicates that the throttle control is on the fuel control cam idle flat. If N2 RPM should drop more than 2 percent, the throttle control rigging must be checked. If the throttle rigging is correct, the fuel control unit is at fault and should be replaced.

From the idle position, the throttle should be moved until the N2 tachometer indicates 80 percent. At this point, the throttle is moved forward very slowly until an increase in EPR is observed. If this increase is observed, the N1 RPM should be recorded. Advancing the throttle to the part power stop at this time ensures full inflation of the nacelle seals. While the throttle is slowly retarded from the part power position toward 80-percent N2 RPM, the EPR should be observed closely. When EPR drops, the N1 RPM should be recorded. This check determines the closing and opening range of the right-hand Bleed Control Function chart.

A stabilization period allows the engine to expand until the engine parts stop expanding and hold steady. This action is accomplished by the throttle being set at the part power position and being held there for a minimum of 5 minutes. Stabilization is indicated by a constant EGT and EPR. Status of the engine during the transition is classified as a change of the engine from cold to hot. When the engine reaches a steady stabilized condition, the following must be read and recorded on the work sheet:

- EPR
- EGT, Fuelflow
- Pt 7 (inches of mercury)
- N1 and N2 RPM
- Oil Pressure and Temperature
- Vibration, High and Low

By performing an EGT spread test with a Jetcal Analyzer during a "hot" engine run, excessive EGT of any individual thermocouple is indicated. The spread check is made by reading the temperature of each individual EGT thermocouple and noting the difference between the lowest and highest readings. Excessive



COMPRESSOR BLEED VALVE OPERATING LIMITS

EGT spread can be an indication of defective fuel nozzles. A stabilization period of 1 minute is required for the engine to stabilize at idle RPM before the N2 speed is recorded. This is the Hot Idle RPM. If the recorded readings obtained during the engine run are within the limits of the trim charts, idle RPM charts, and bleed valve charts, the engine is properly trimmed.

TRIM ADJUSTMENTS.

If trim adjustments are necessary, the "MIL PWR" adjustment screw on the fuel control is turned either to increase or decrease Pt 7 while the engine is running at part power speed. The actual Pt 7 should be within the limits of the desired Pt 7 for the existing ambient conditions of the day. When Pt 7 is changed, the idle RPM changes. Necessary adjustments should be made to correct the N2 idle RPM.

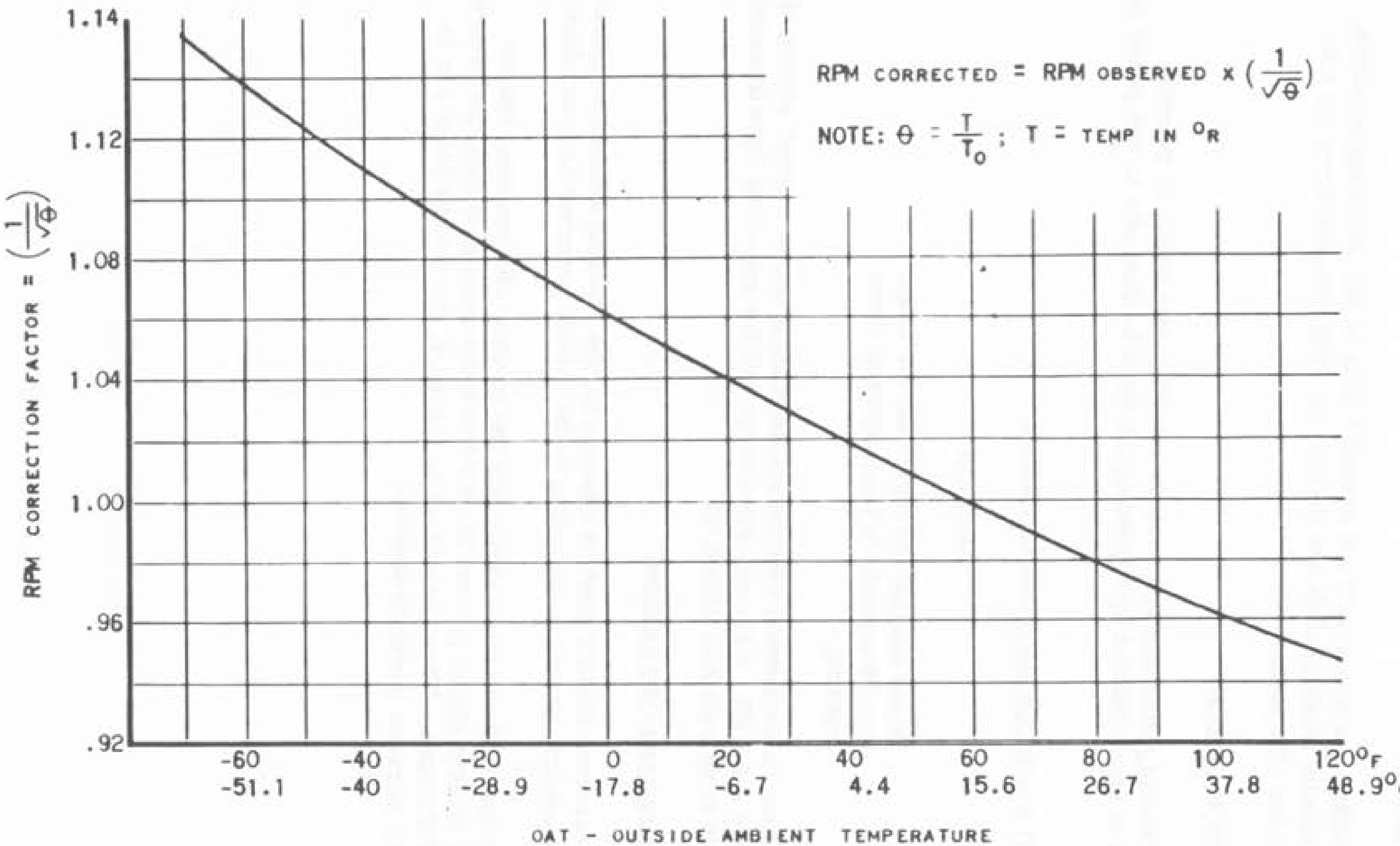
Before a takeoff power check can be made, the part power stop on the fuel control must be removed and safetied in the stowed position. The OAT and barometric pressure must be obtained and used to determine the correct EPR for the takeoff power check. The EPR is set to 1.48 and engine speed is allowed to stabilize. By reading the N2 EPM from the Jetcal Analyzer, the value observed should be within 2.1 percent of the engine data plate speed. The takeoff power check should be within the limits of EPR, EGT, and RPM.

BAR. PRESSURE IN. HG ABSOLUTE	TEMP DEG F	116.0	117.0	118.0	119.0	120.0		
		HOT DAY						
24.5	EPR	1.272	1.268	1.265	1.261	1.258		
	TRIM PT7	31.15	31.07	30.99	30.90	30.82		
24.6	EPR	1.272	1.268	1.265	1.261	1.258		
	TRIM PT7	31.28	31.20	31.11	31.03	30.95		
24.7	EPR	1.272	1.268	1.265	1.261	1.258		
	TRIM PT7	31.41	31.32	31.24	31.16	31.07		
24.8	EPR	1.272	1.268	1.265	1.261	1.258		
	TRIM PT7	31.54	31.45	31.37	31.28	31.20		
24.9	EPR	1.272	1.268	1.265	1.261	1.258		
	TRIM PT7	31.66	31.58	31.49	31.41	31.32		
25.0	EPR	1.272	1.268	1.265	1.261	1.258		
	TRIM PT7	31.79	31.70	31.62	31.53	31.45		

BAR. PRESSURE IN. HG ABSOLUTE	TEMP DEG F	53.0	54.0	55.0	56.0	57.0	58.0	59.0
		STANDARD DAY						
29.8	EPR	1.502	1.498	1.493	1.489	1.485	1.481	1.477
	TRIM PT7	44.75	44.63	44.51	44.38	44.26	44.14	44.02
29.9	EPR	1.502	1.498	1.493	1.489	1.485	1.481	1.477
	TRIM PT7	44.90	44.78	44.66	44.53	44.41	44.29	44.17
30.0	EPR	1.502	1.498	1.493	1.489	1.485	1.481	1.477
	TRIM PT7	45.05	44.93	44.80	44.68	44.56	44.44	44.31
30.1	EPR	1.502	1.498	1.493	1.489	1.485	1.481	1.477

BAR. PRESSURE IN. HG ABSOLUTE	TEMP DEG F	-66.0	-65.0	-64.0	-63.0	-62.0	-61.0	-60.0
		COLD DAY						
30.9	EPR	1.935	1.935	1.935	1.935	1.935	1.935	1.935
	TRIM PT7	59.79	59.79	59.79	59.79	59.79	59.79	59.79
31.0	EPR	1.935	1.935	1.935	1.935	1.935	1.935	1.935
	TRIM PT7	59.98	59.98	59.98	59.98	59.98	59.98	59.98
31.1	EPR	1.935	1.935	1.935	1.935	1.935	1.935	1.935
	TRIM PT7	60.18	60.18	60.18	60.18	60.18	60.18	60.18
31.2	EPR	1.935	1.935	1.935	1.935	1.935	1.935	1.935
	TRIM PT7	60.37	60.37	60.37	60.37	60.37	60.37	60.37
31.3	EPR	1.935	1.935	1.935	1.935	1.935	1.935	1.935
	TRIM PT7	60.57	60.57	60.57	60.57	60.57	60.57	60.57
31.4	EPR	1.935	1.935	1.935	1.935	1.935	1.935	1.935
	TRIM PT7	60.76	60.76	60.76	60.76	60.76	60.76	60.76
31.5	EPR	1.935	1.935	1.935	1.935	1.935	1.935	1.935
	TRIM PT7	60.95	60.95	60.95	60.95	60.95	60.95	60.95
31.6	EPR	1.935	1.935	1.935	1.935	1.935	1.935	1.935
	TRIM PT7	61.15	61.15	61.15	61.15	61.15	61.15	61.15

PART POWER TRIM DATA



RPM CORRECTION CURVE

VIBRATION CHECK.

Vibration at either position should not exceed 4 mils at any operating condition. Vibration is usually checked while the throttle is being retarded from the take-off position to the idle position.

ACCELERATION CHECK.

Each engine should accelerate from idle to takeoff power within 12 seconds. Acceleration is accomplished by advancing the throttle from idle to full power in 1 second.

ENGINE AND NACELLE ANTI-ICING CHECK.

CAUTION

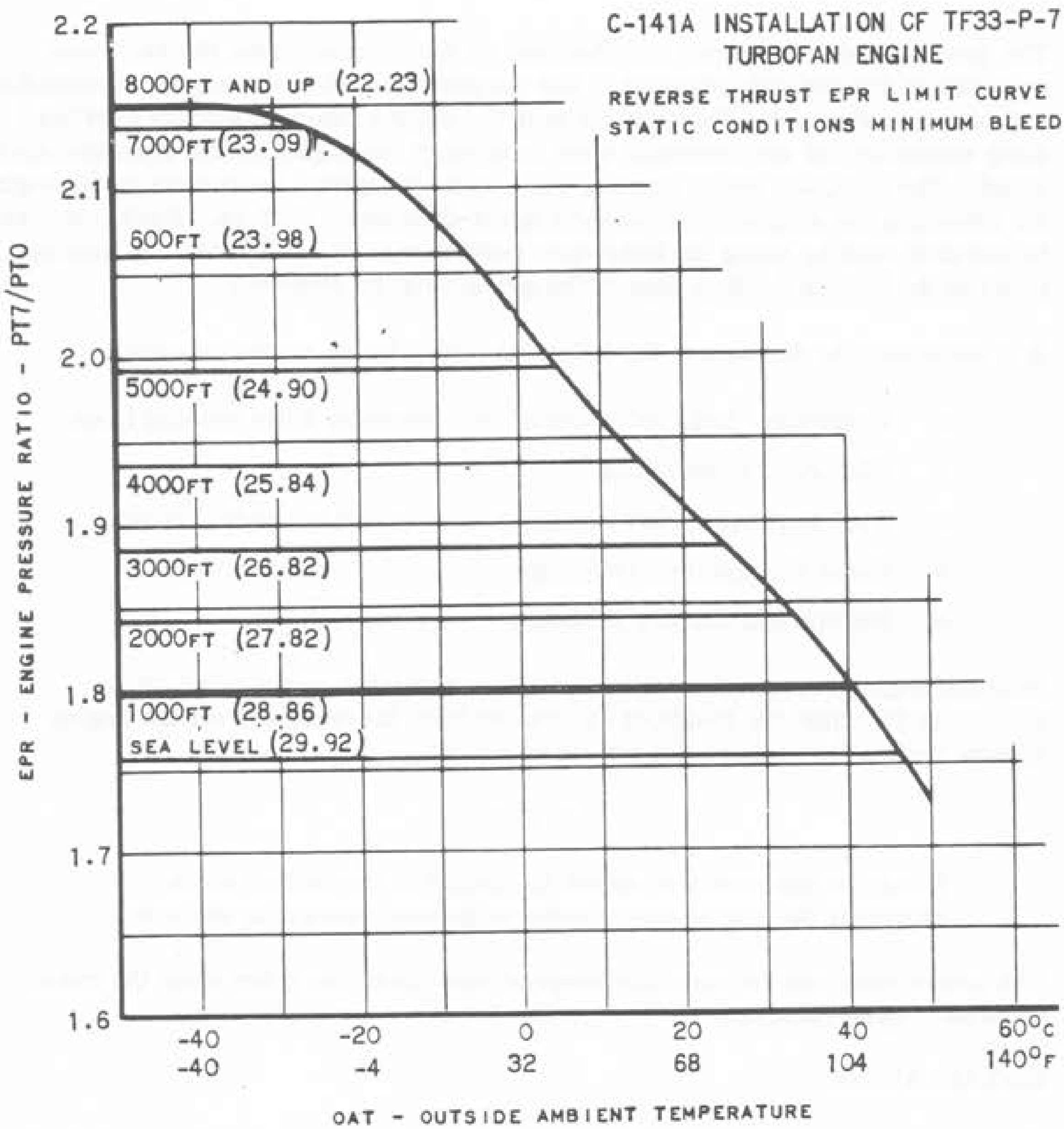
> Do not operate the anti-icing for longer than 10 seconds at temperatures above freezing.

This check must be performed with the engine running and at a power setting of approximately 1.5 EPR. EPR indication drops and the anti-icing light illuminates when the anti-icing switch is turned on.

THRUST REVERSER OPERATION.

The thrust reverser limiter must be adjusted for the existing ambient temperature and field barometric pressure according to the Thrust Reverser Limiter chart.

The throttle lever should move easily into the reverse idle position, but the mechanical lockout should prevent the throttle from moving aft until the reverser doors are fully open. When the lockout is released, the throttle lever can be moved aft to increase power as desired.



REVERSE THRUST EPR LIMIT CURVE

POWER PLANT REMOVAL AND INSTALLATION.

REMOVAL.

The power plant is removed and installed on the aircraft using the removal/installation trailer with adapters. The adapters mount to the engine intermediate and turbine out cases. They can be used for engine removal with an overhead sling assembly but are normally used to support the engine on the transportation stand. The side cool doors and fan ducts must be opened for access to the engine for attaching the adapters and several quick-disconnect fittings. Each door can be secured open by using the hold-open rods stowed on each door. An access panel at the bottom leading edge of the pylon must be removed.

It is necessary to disconnect the following items for an engine removal:

- o Hydraulic, fuel, pylon drain, and pressure ratio sensing lines
- o Electrical connections
- o Fuel control, thrust reverser, and feedback control linkage
- o Bleed air manifold couplings
- o Nacelle and cooling air hoses

With the engine removal/installation trailer under the power plant, it is necessary to adjust the height of the trailer until the weight is off the engine mounts before the mount bolts can be removed.

CAUTION

> It may be necessary to adjust the height of the trailer while removing the engine mount bolts to prevent damage to the bolts.

The power plant can be carefully lowered away from the pylon after the mount bolts have been removed.

INSTALLATION.

Prior to engine installation, all mount bolt thread surfaces must be coated with anti-seize compound, and the thread protectors from the engine mount bolt installation kit must be installed. When the power plant is in place, the bolts, washers, and nuts can be installed in their proper position in the mounts.

NOTE

> The gap between the links of the left and right forward mounts and aft mount is intended and should not be shimmed.

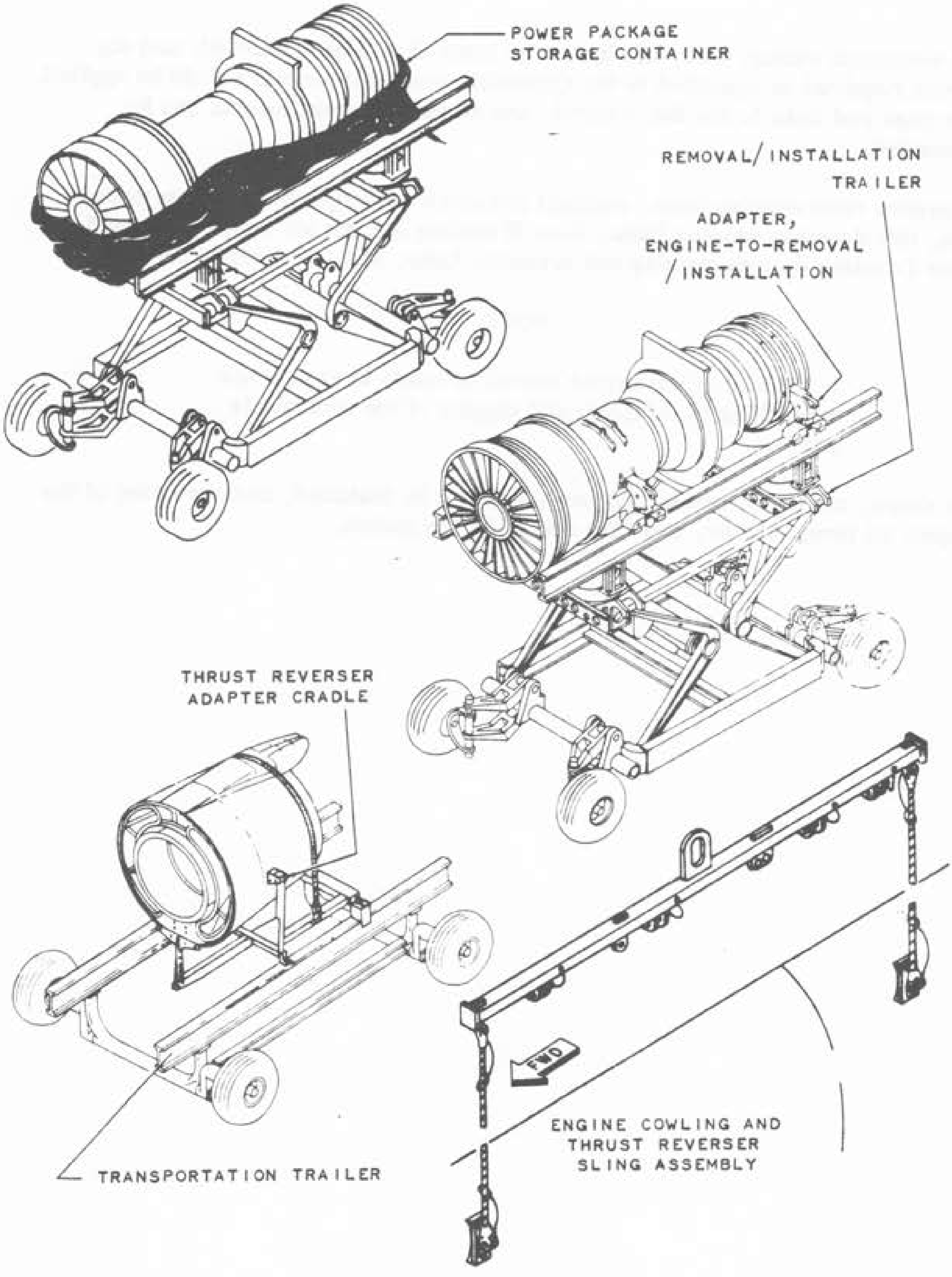
All electrical wiring, fuel, and hydraulic lines should be connected, and any torque required as specified in the applicable technical manual should be applied. The push rod links to the fuel control, and thrust reverser lockout can be connected.

Pressure ratio sensing lines, ambient pressure sensing line and pylon drain line, fire detector sensing lines, Zone II cooling ejector air supply line, and Zone I cooling system sensing and pressure lines, can all be connected.

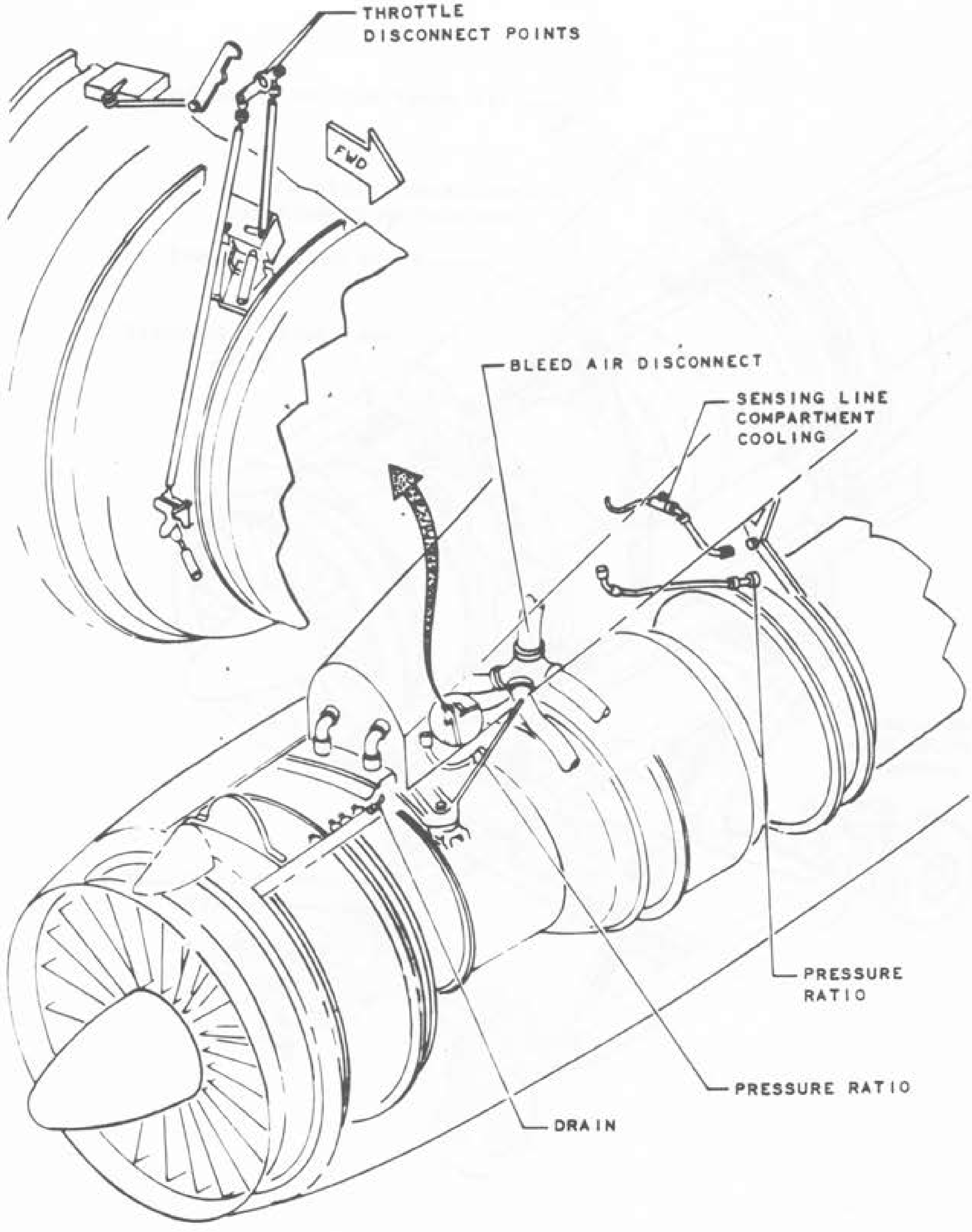
NOTE

> A recheck of the engine should be made to ensure that everything is complete and rigging of the controls is correct.

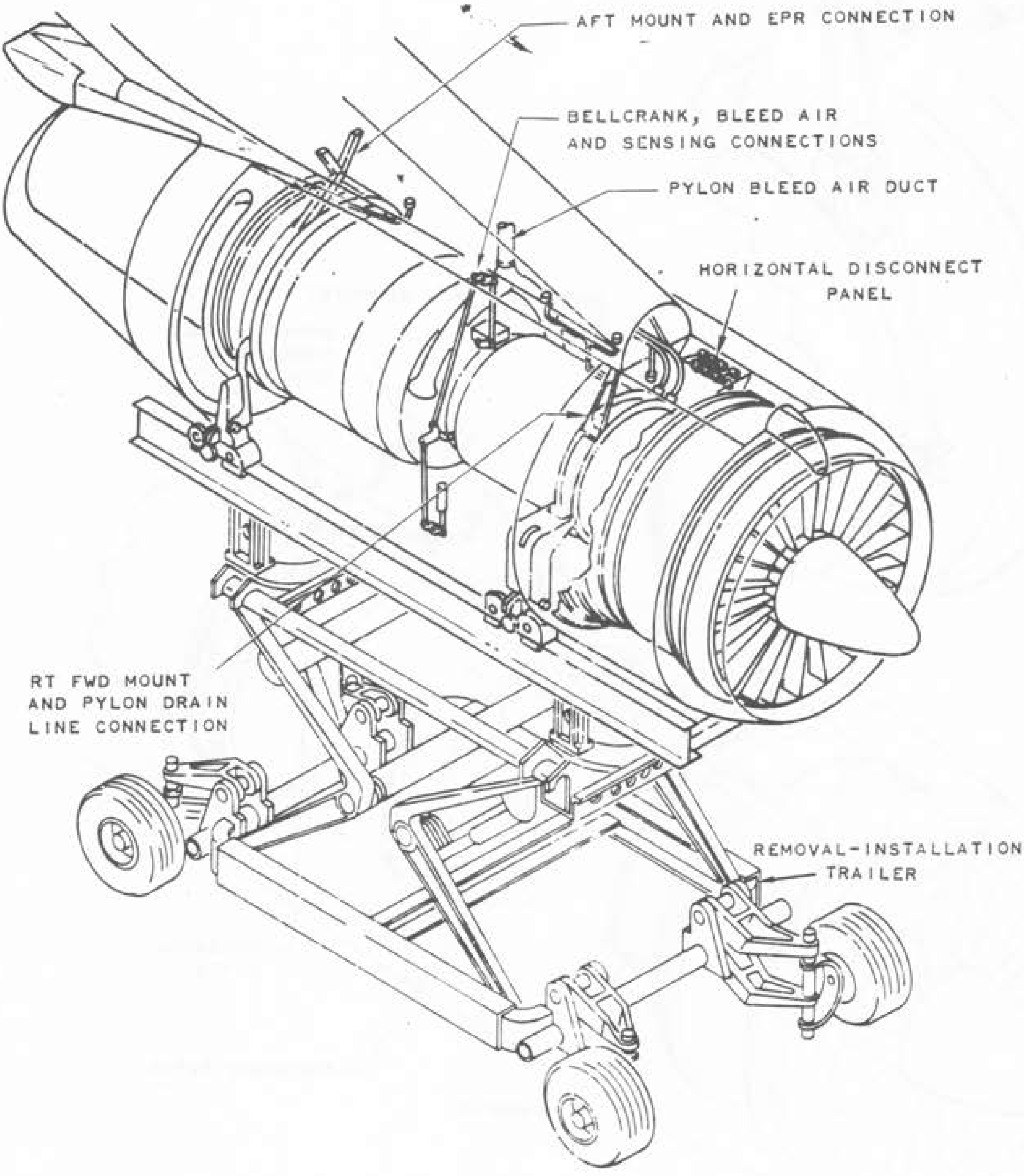
All doors, cowlings, and access panels should be installed, and servicing of the engine oil tank, starter, and CSD should be completed.



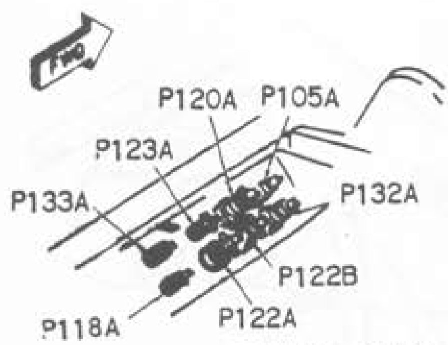
GROUND SUPPORT EQUIPMENT



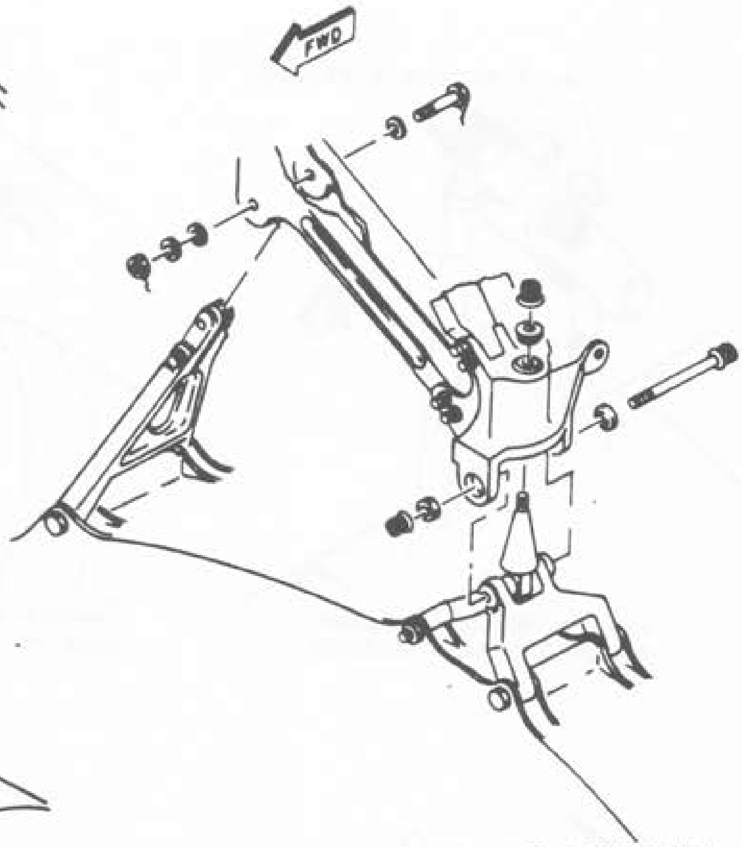
ENGINE TO PYLON THROTTLE AND DUCT DISCONNECTS



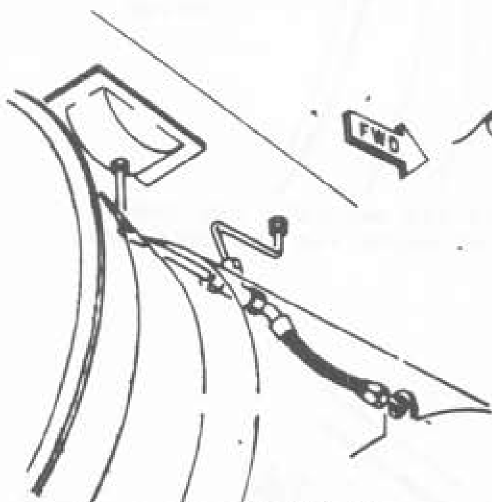
POWER PLANT INSTALLATION



ELECTRICAL DISCONNECT PANEL

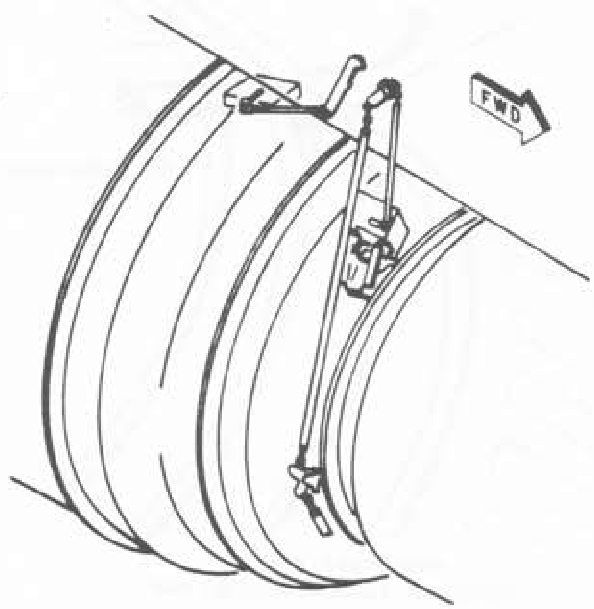


FORWARD ENGINE MOUNT CONNECTION



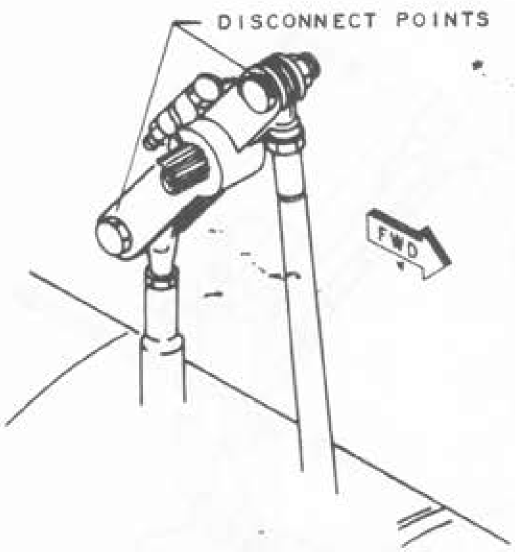
PYLON DRAIN LINE

PRESSURE RATIO SYSTEM, LINE CONNECTION



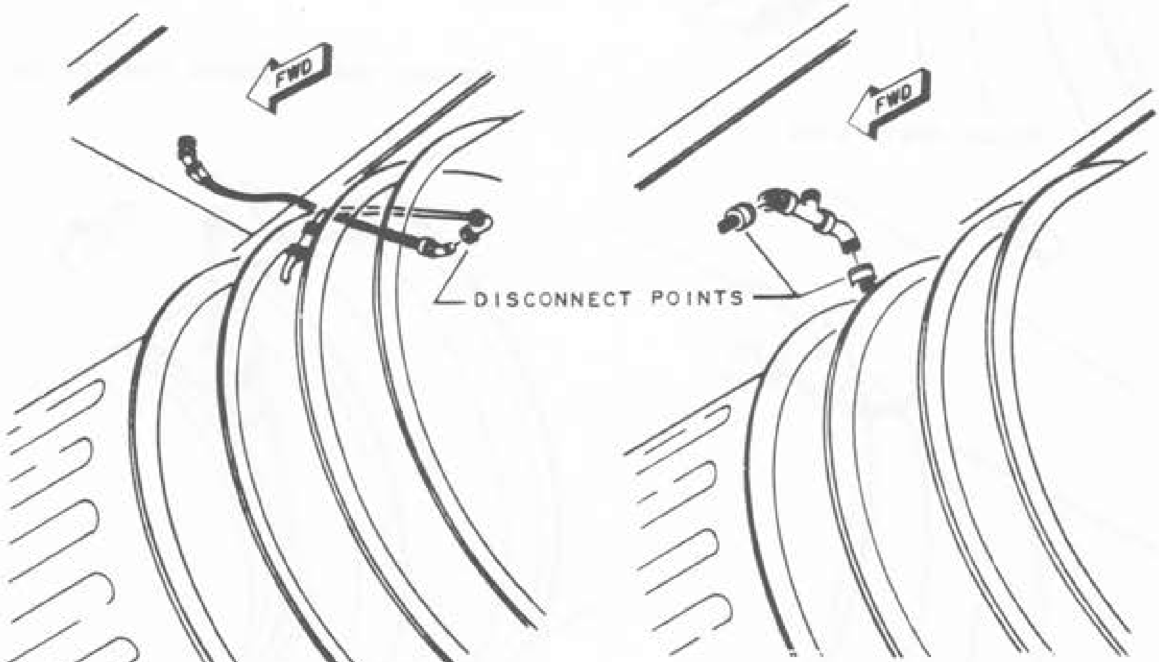
ENGINE CONTROLS CONNECTIONS

POWER PLANT REMOVAL AND INSTALLATION



THRUST REVERSER VALVE
PUSHROD SAFETY WIRING

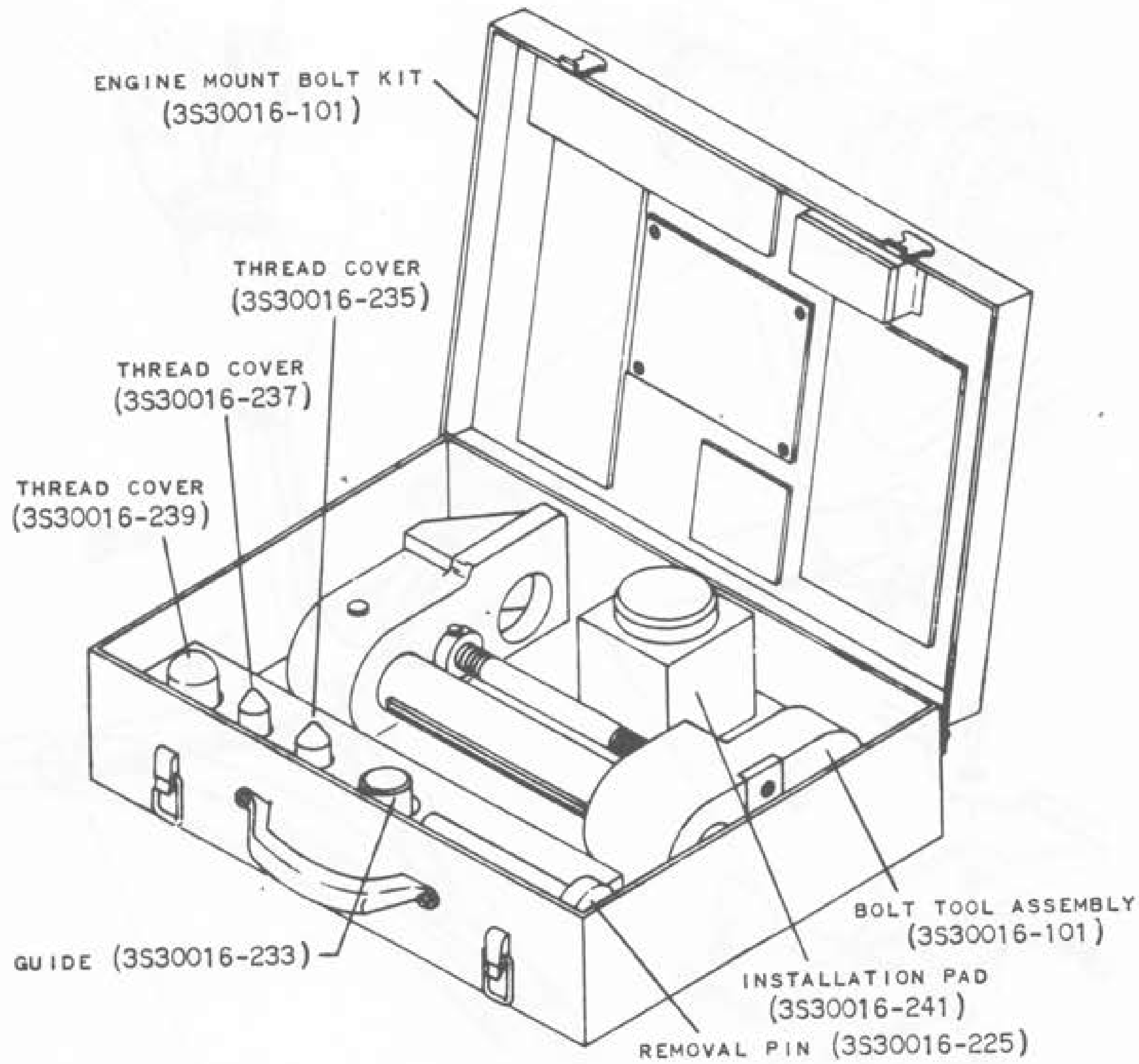
BLEED AIR MANIFOLD AND ZONE I
COOLING VALVE AIR PRESSURE LINE



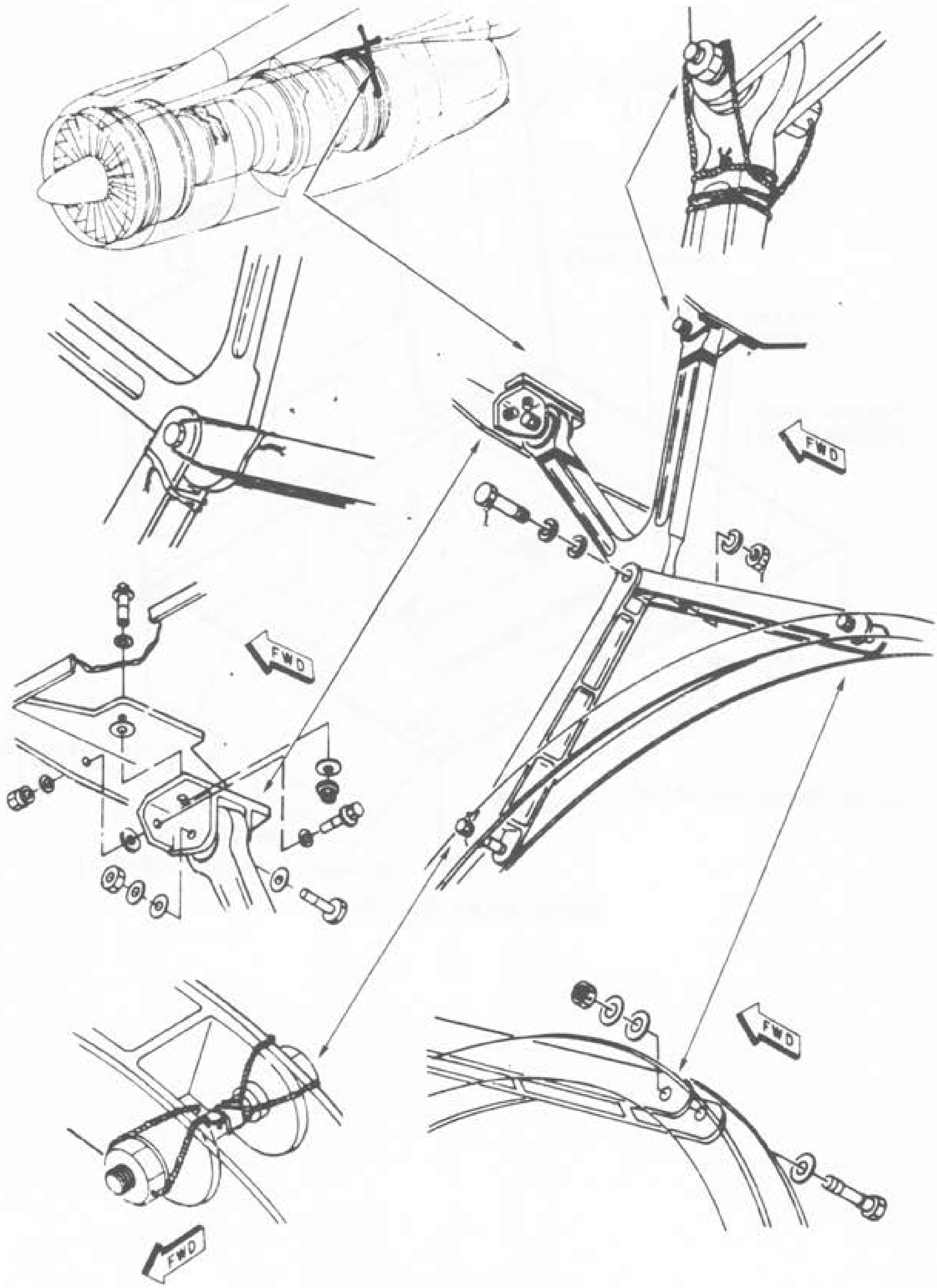
PRESSURE RATIO
SENSING LINE CONNECTION

ZONE I COOLING SYSTEM
SENSING LINE CONNECTION

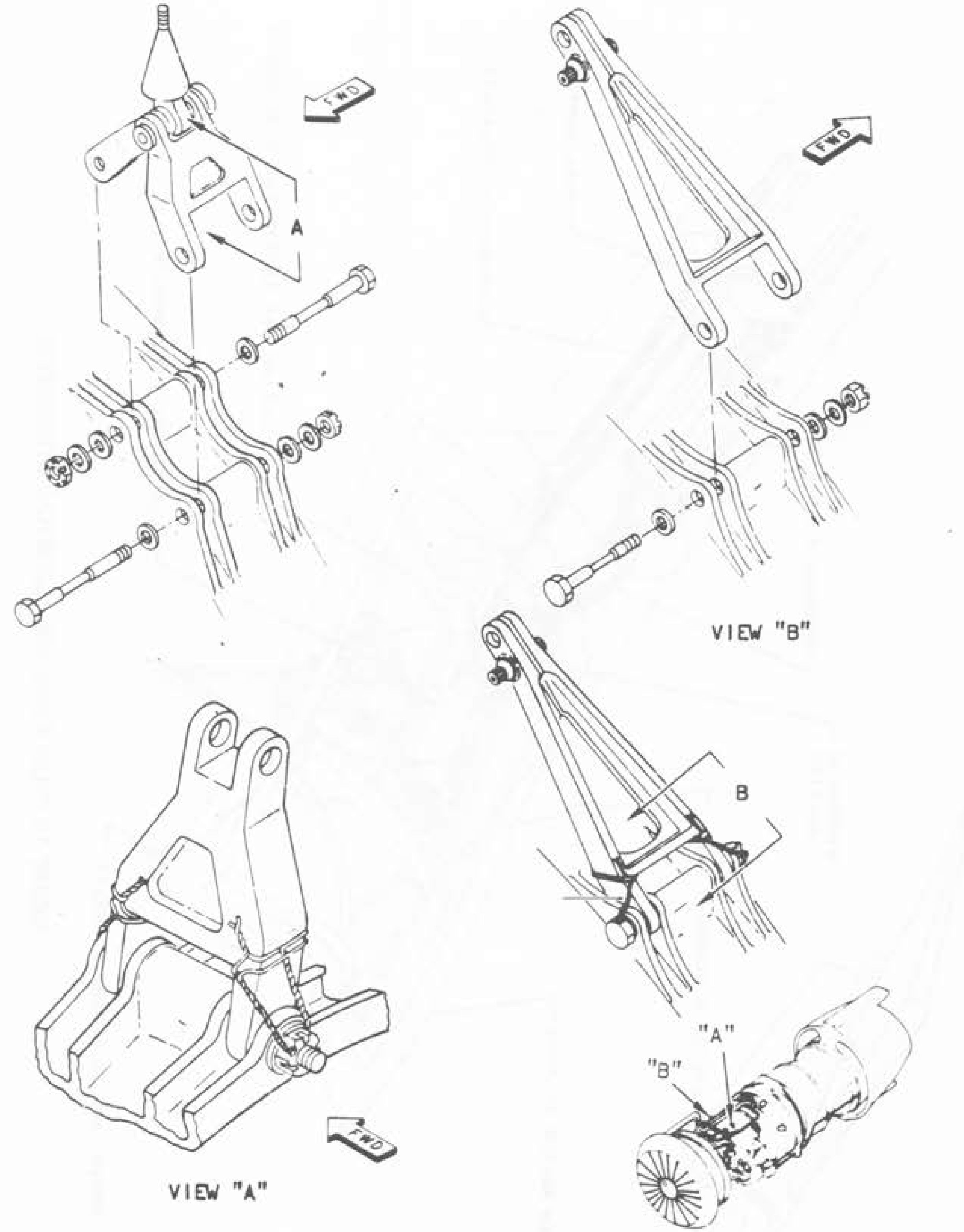
POWER PLANT REMOVAL AND INSTALLATION



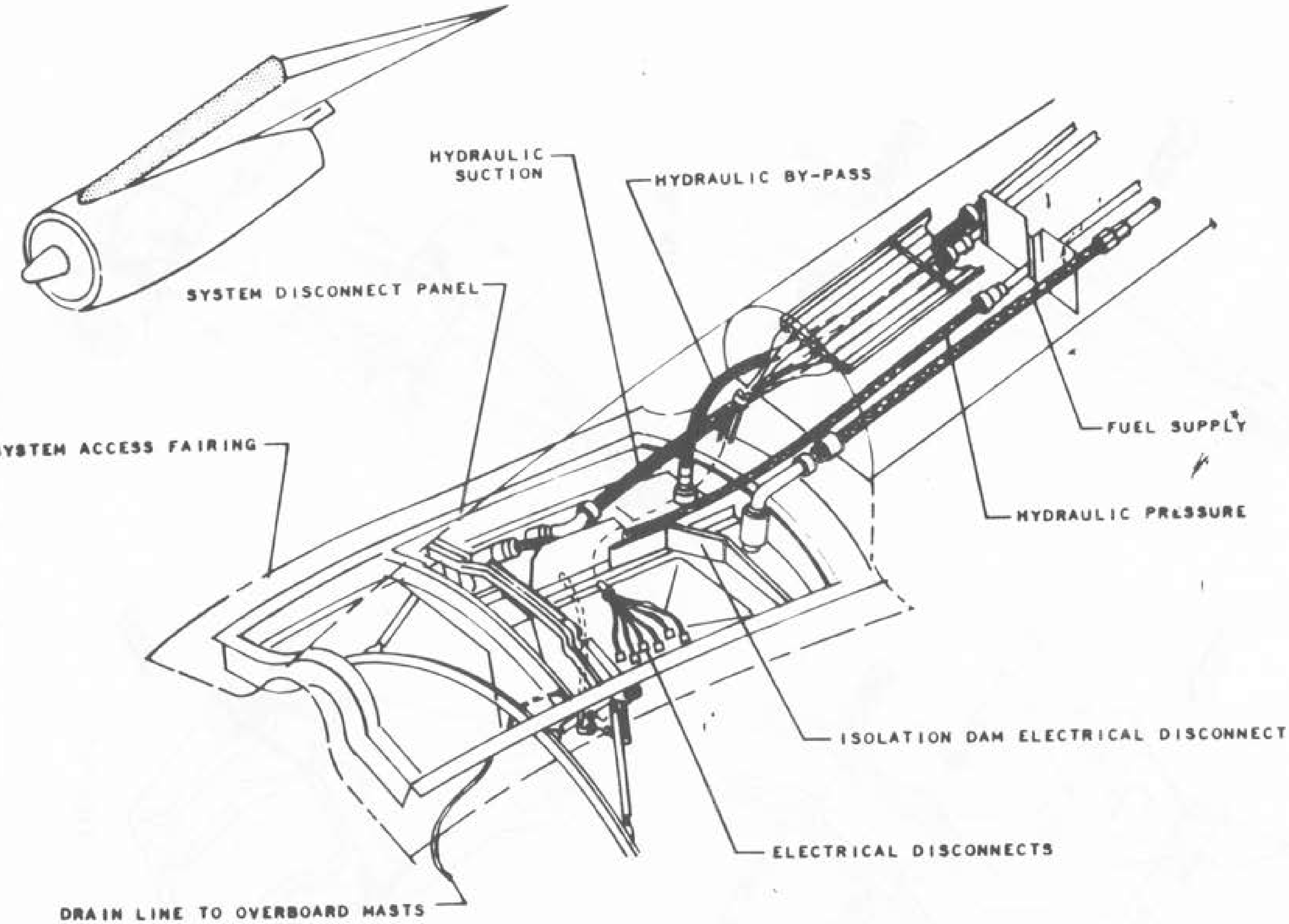
ENGINE MOUNT BOLT KIT



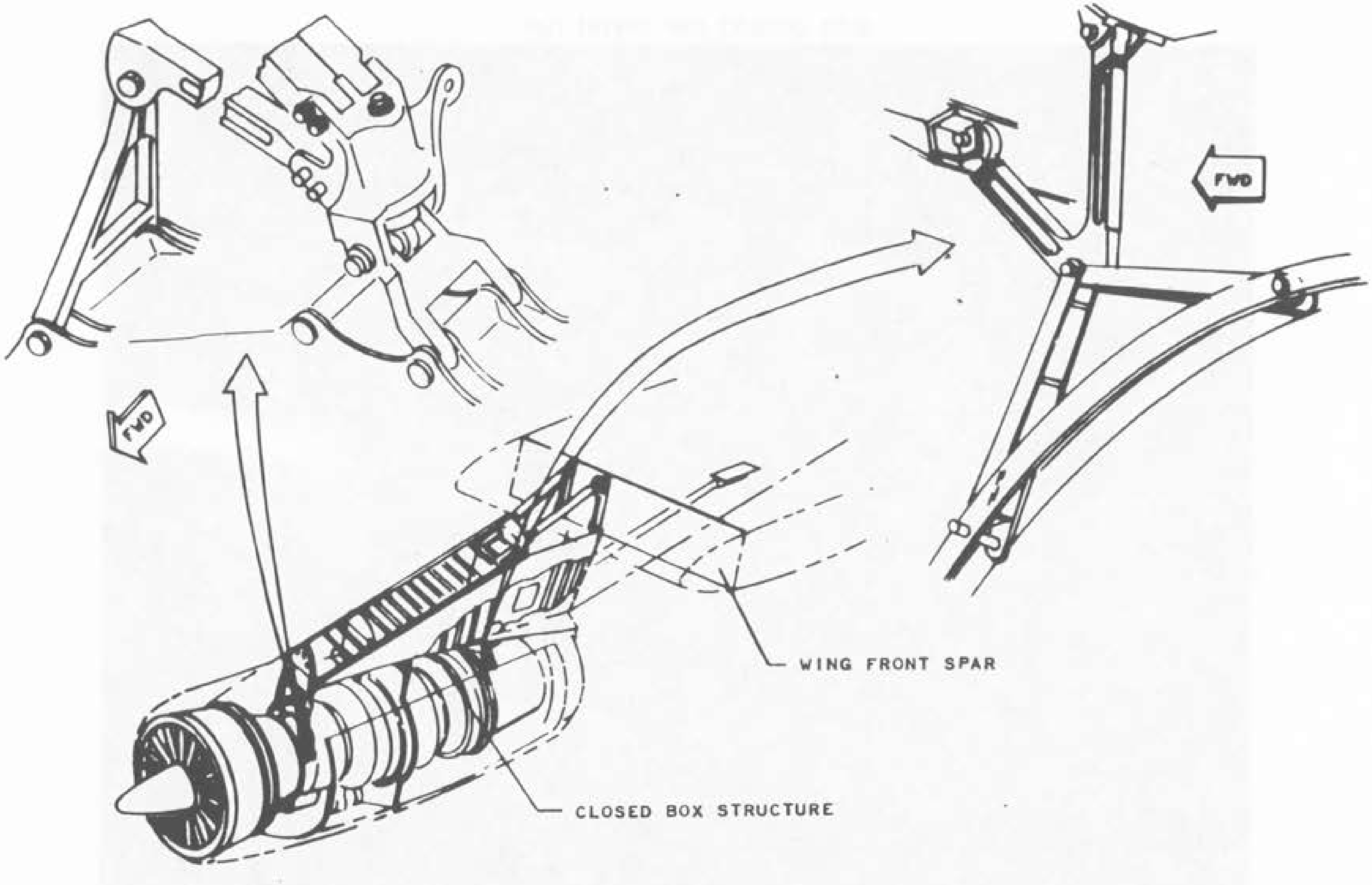
AFT ENGINE MOUNT INSTALLATION



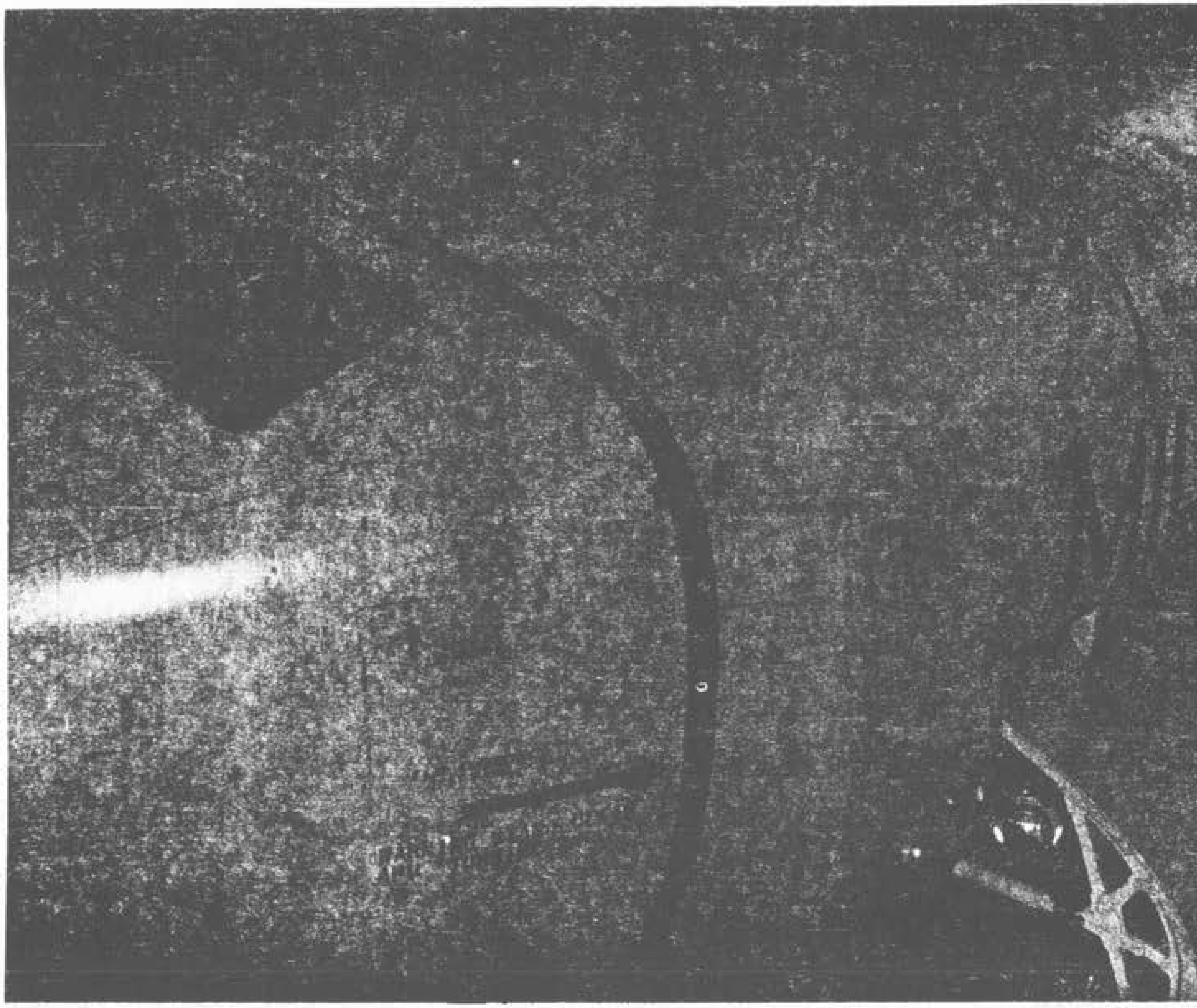
FORWARD ENGINE MOUNT INSTALLATION



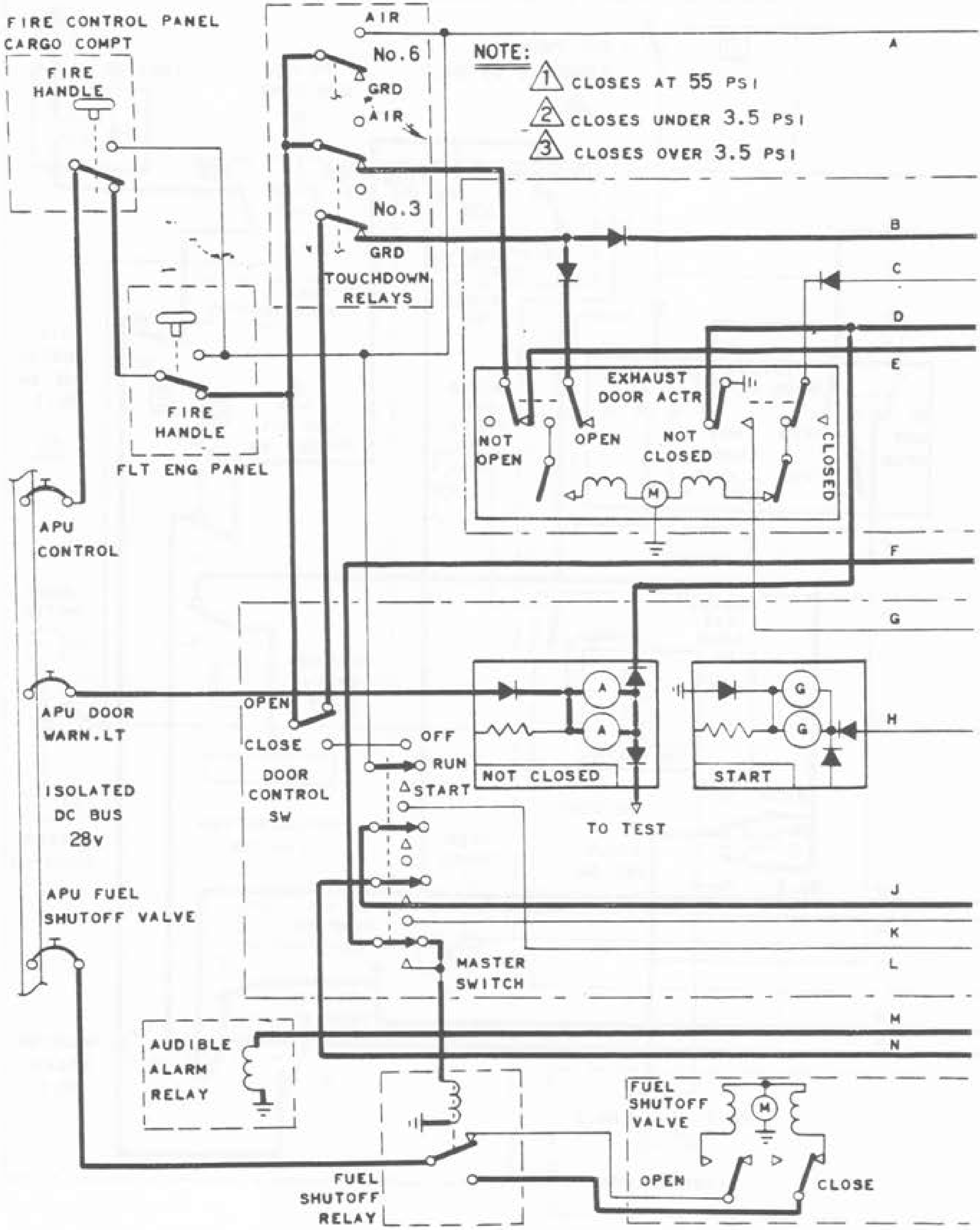
ENGINE TO PYLON FLUID AND ELECTRICAL DISCONNECTS



PYLON STRUCTURE AND ENGINE MOUNT



APU INTAKE AND EXHAUST DOOR



CONTROL SWITCH "RUN" ABOVE 35%
(OIL PRESSURE BELOW 55 PSIG)

AUXILIARY POWER UNIT

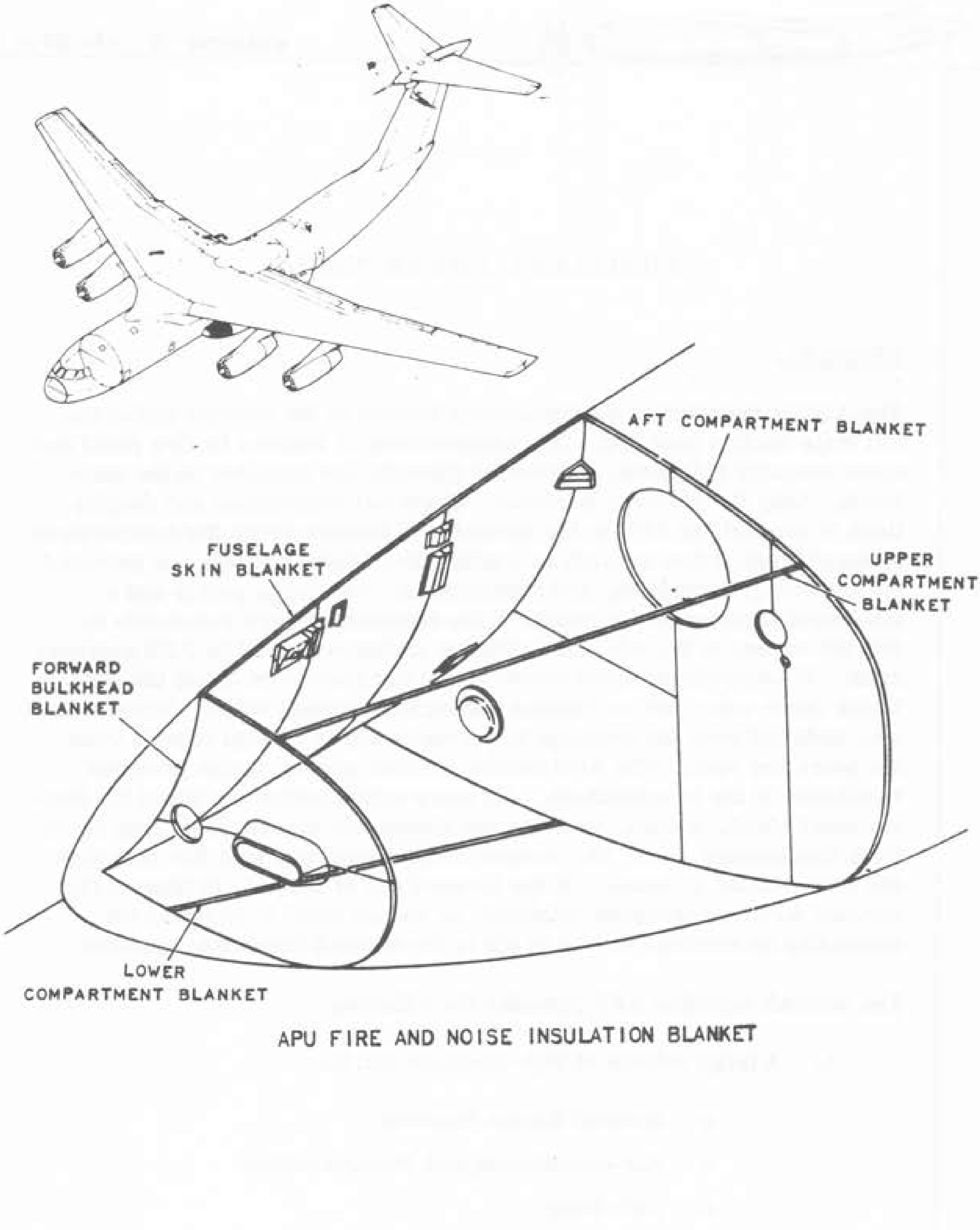
GENERAL.

The APU is installed in a compartment located at the forward end of the left main landing gear pod. The compartment is isolated by fire proof and noise isolating bulkheads. Insulating blankets are installed on the bulkheads. Only the required hardware, electrical connections and flexible lines to connect the APU to the aircraft are located within the compartment to keep potential fire hazards to a minimum. Access panels are provided for servicing, inspection, and maintenance. Two large panels and a structural member at the bottom of the compartment are removable to provide access to the APU for extensive maintenance and/or APU replacement. Electrically actuated louver doors are located on top of the pod. These doors cover the air intakes and turbine exhaust outlet. Screens are also installed over the openings to prevent entry of foreign objects when the doors are open. The APU turbine exhaust ejector design provides ventilation of the compartment. Jet pump action pumps air out of the compartment which, in turn, removes any flammable vapors which may occur from line leakage, etc. The compartment is equipped with fire detection and extinguisher systems. At the forward end of the pod, in front of the forward APU compartment bulkhead, an access panel is provided for connecting an external source of air to the aircraft pneumatic systems.

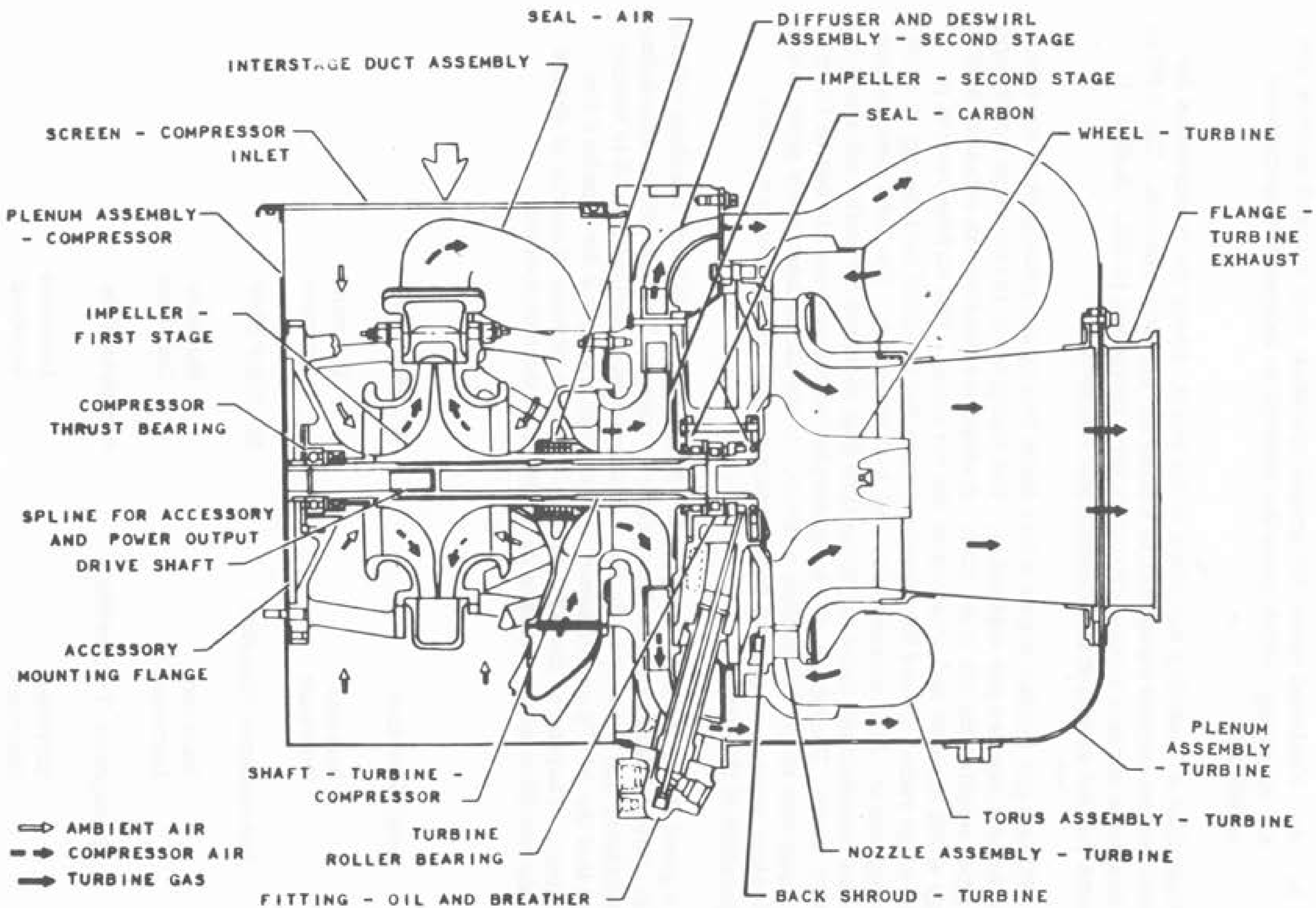
The aircraft installed APU provides the following:

1. A large volume of high-pressure air for

    - o Aircraft Engine Starters
    - o Air-conditioning and Pressurization
    - o Anti-icing
    - o Nacelle Pre-heat



APU FIRE AND NOISE INSULATION BLANKET



APU SCHEMATIC

2. A-C electrical power for ground operation when aircraft engines are not operating, which gives the aircraft an independent operational capability.

The capability of operating any place in the world without the requirement for external ground support equipment is a must for this type aircraft. The APU is not intended to replace normal ground support equipment (AGE). Rather, it supports routine or major maintenance and inspections.

The APU is a gas turbine engine where basic theory and principles of operation of gas turbine engines are applicable. The compressor (a two-stage centrifugal flow type) supplies the air mass flow. A single combustion can releases heat energy which expands and accelerates the air mass. The turbine section (a single-stage radial inward flow type) extracts the required heat energy to drive the compressor, APU accessories, and A-C generator. The APU compressor provides considerably more air mass flow than required for sustained speed of the APU itself. Therefore, the large surplus of compressed air can be taken away upstream of the combustion process. Bleed air is taken away prior to the combustion process to prevent contamination. The air is also at a usable temperature at this point.

For a given RPM, the APU compressor discharges a relatively constant volume of air. Several factors cause the density to change: field elevation, atmospheric temperature, and pressure. In the manufacturers specifications, it is usually stated that the APU's performance is at certain minimums for Standard Day conditions. Therefore, the APU has the ability to provide bleed air to change with any condition which changes the inlet air to the compressor.

Field Elevation	Air Mass Flow
Increase	Decrease
Decrease	Increase
Atmospheric Pressure	**Air Mass Flow**
Increase	Increase
Decrease	Decrease
Atmospheric Temperature	**Air Mass Flow**
Increase	Decrease
Decrease	Increase

(APU Comp. at Constant Speed)

These factors limit bleed air under extreme conditions and, in some cases, adversely effect the ability of the aircraft engine pneumatic starter to function normally. Any change of the compressor output also results in more or less torque required to drive the compressor. This means the APU fuel system must have a design feature to automatically vary fuelflow in relation to varying loads on the compressor rotor, which is accomplished by using compressor discharge pressure as a variable to control fuel metering. All of the variables that affect the compressor output change the discharge pressure so this can be used as a direct relationship to the necessary fuelflow to maintain constant speed of the compressor rotor.

The turbine assembly is designed to convert heat energy to torque in proportion to the load imposed on it. To keep the APU running at a relatively constant speed, there has to be a definite relationship between the heat energy converted to torque and required torque to drive the APU compressors, accessories, and A-C generator. Mass airflow across the turbine wheel decreases and increases with or without bleed air use, respectively. A change in the mass airflow through the turbine must be compensated for by burning more or less fuel to keep the turbine wheels extraction of energy relatively constant. The fuel system makes these compensations of fuelflow.

RELATIONSHIP OF MASS AIRFLOW TO FUEL		
	Mass Airflow Through Turbine Wheel	Fuelflow
Bleed Air "ON"	Decrease	Increase
Bleed Air "OFF"	Increase	Decrease

The APU gas turbine, like any turbine engine, has limitations of safe operating temperatures of gases through the turbine section. Both the fuel control system and bleed air control have features designed to provide over-temperature protection automatically. Excessive bleed air results in low mass airflow through the combustion section in relation to fuelflow. An increase in the fuel-to-air ratio would result in excessive turbine exhaust gas temperatures. When turbine exhaust temperatures reach a predetermined point as a result of excessive bleed air, the bleed shutoff and load control valve automatically reduces the amount of bleed air which increases the air mass flow through the turbine. This limits the turbine discharge gas temperature by increasing the airflow in relation to fuel. The fuel system has a similar feature designed into it which operates at a slightly higher turbine discharge gas temperature. It reduces fuelflow to limit the temperature. This feature acts as a back-up system in the event the bleed valve fails to throttle. It also provides over-temperature protection during APU starting and acceleration to ON-SPEED RPM.

The APU receives its fuel from the surge box of the No. 2 main tank. A motor-driven shutoff valve is located in the line at the tank outlet. Fuel is supplied to the APU by gravity flow. The APU fuel system provides the proper flow for starting, acceleration, and ON-SPEED operation with or without air bleed from the APU. The governor has no control over fuelflow until the APU is at or near ON SPEED RPM. At that time, the governor bypasses more or less fuel to keep the turbine speed relatively constant. The acceleration control valve provides the proper fuel metering for starting and acceleration to ON-SPEED RPM. The acceleration control valve bypasses fuel in relation to a balance of forces; pump discharge pressure on one side is opposed by a spring and controlled compressor discharge air pressure. Spring tension opposing pump output establishes the starting fuel pressure. The spring tension aided by controlled APU compressor discharge pressure opposes pump discharge pressure to establish desired fuel-flow for acceleration. Fuel pump output and compressor discharge air are relative to RPM so it is desirable to utilize these two for establishing the desired acceleration fuelflow curve. The fuel system is automatic and electrically controlled.

The APU lubrication system is a combination pressure and spray type. One pressure pump and a duplex scavenge pump are used. The system is a dry-sump type with the oil tank mounted on the outboard side of the APU. The tank filler cap is reached through an access panel on the outboard side of the compartment. An oil cooler is installed in the scavenge return. It is mounted on the outboard side of the APU and receives its cooling airflow from an APU-driven fan. Specification oil used in the APU is the same as that for the aircraft engines. Oil temperature and pressure are utilized in the automatic control of the APU. Oil pressure must be sensed or ignition and fuelflow cannot be obtained for starting. After the APU is operating, a loss of oil pressure results in automatic shutdown of the APU. Excessive oil temperature also causes automatic shutdown or prevents the APU from being started.

The bleed air shutoff and load control valve serves two functions. Bleed air from the APU can be selected. When bleed air is being taken away from the APU, the valve protects the APU from excessive bleed airflow by operating as an automatic throttle valve. The throttling action is controlled by turbine discharge temperature. Excessive bleed airflow results in excessive turbine discharge temperatures and/or APU compressor stalls.

The APU control system is electrical and automatic. The control panel located at the flight engineer's station is very simple. It has three, toggle-type switches; bleed load and flow control valve, APU door control, and APU start accumulator selector. The APU control switch is a rotary-type, three-position switch with "OFF," "RUN," and "START" positions. It is spring-loaded from the "START" to the "RUN" position. Three lights, mounted on the panel indicate the following:

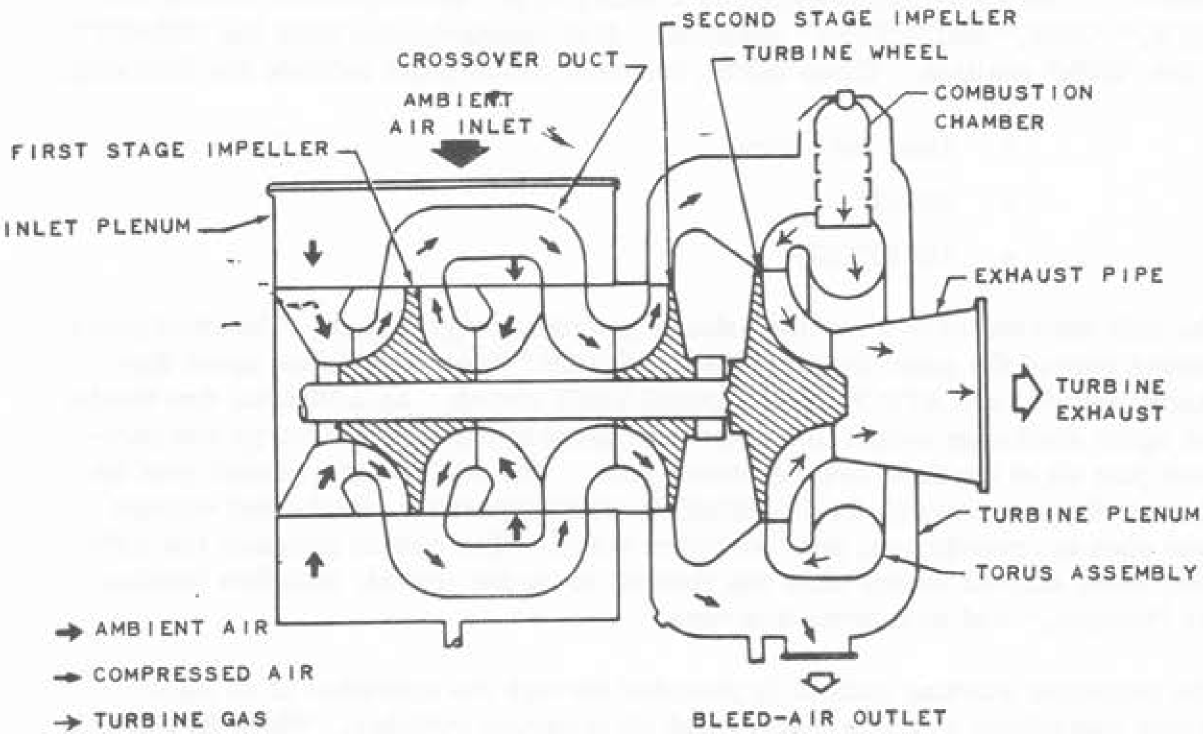
- Door not closed
- START
- ON SPEED

The only instrument is a turbine exhaust gas temperagure gage. The emergency control part of the panel includes the fire handle, fire extinguishes agent discharge switch, and APU FIRE WARNING TEST switch. An additional fire handle and agent discharge switch is located on a panel mounted in the cargo compartment just aft of the front crew entrance door. The APU control circuit gets its electrical power through the fire handle's normal position, intake and exhaust door open microswitches, and touchdown relay. This circuit prevents the APU from being started except when the aircraft is on the ground, both fire handles are "normal," and both doors are open.

The automatic starting control is provided through the operation of an APU-driven centrifugal switch assembly and oil pressure switches. When the control switch is placed to "START," the starting system functions but, ignition and fuelflow do not begin until an oil pressure switch closes. The 35 percent centrifugal switch terminates the starter. The START light is on below 35 percent. The 95 percent switch arms the bleed air control switch and the APU generator control circuit. It also turns on the ON SPEED light and terminates ignition. It also operates the start counter and completes the circuit to the hour-meter. Holding relays to keep the APU operating are provided to aid automatic shutdown in the event of (110 percent) APU overspeed, excessive oil temperature, or loss of oil pressure. After the APU is in operation, any means of shutdown (fire handle pulled, control switch placed to "OFF," or automatic) results in the fuel solenoid being deenergized which stops fuelflow to the nozzle and places power to the close side of the fuel shutoff valve.

AIRFLOW.

Atmospheric air is drawn through the intake doors and screen into the compressor inlet plenum. The plenum surrounds the compressor section and allows relatively free flow to the throat of both sides of the first-stage compressor wheel. Centrifugal force throws the air radially off the blade tips at extremely high speed into the first-stage diffuser. The diffuser is a divergent duct which slows the velocity down with a resultant increase of pressure. The diffuser also divides the airflow into seven interstage ducts which direct the air to the second-stage compressor wheel inlet. The second-stage compressor wheel accelerates the air again to a high velocity by centrifugal force, and the air passes off the blade tips into the



AIR FLOW SCHEMATIC DIAGRAM

second-stage diffuser. The diffuser slows down the airflow which increases pressure and directs the air into the turbine plenum. Bleed air is extracted from the plenum case. This is done upstream from the combustion gases to prevent contamination of the bleed air. The combustion chamber is in the path of airflow from the plenum to the turbine torus assembly. Design of the comustion liner provides for the proper mixing of air and fuel for combustion. It also dilutes the airflow. The airflow aids in containing the flame within the liner. Hot gases from the combustion liner enter the torus, which is an annular cavity with the exit being through the turbine nozzle. The turbine nozzle is a convergent duct which accelerates the gasflow to very high velocity. The angle of the turbine nozzle vanes directs the gasflow onto the turbine wheel blades at the desired angle. Efficiency of the turbine section is dependent on the velocity of the gases and the angle at which they strike the turbine blades. From the turbine wheel, the air flows out of the exhaust pipe and flange into the exhaust ejector. The ejector is bellmouth shape with a larger diameter than the exhaust pipe flange. Exhaust gasflow through this area functions as a jet pump. The low-pressure area pulls air from the APU compartment into the ejector pipe and discharges it with the exhaust gasflow into the atmosphere.

Item	Specification
DIMENSIONS	
Length	36.22 inches
Width	28.125 inches
Height	29.84 inches
Weight (dry)	263 pounds
ENGINE SPEEDS	
Turbine and Compressor (maximum) (no bleed, steady state)	43,000 RPM
Turbine and Compressor (full load)	41,900 to 42,100 RPM
Output Drive Shaft (to A-C generator)	6,000 RPM
Tachometer Generator Drive Shaft (nominal)	4,182 RPM
Turbine Wheel to Tachometer Generator Ratio	10.043 : 1
35 Percent Switch	15,000 to 16,970 RPM
95 Percent Switch	39,000 to 40,600 RPM
110 Percent Switch	44,000 to 44,500 RPM
FUEL SYSTEM	
Fuel	Kerosene, JP-4, JP-5, Aviation Gasoline 115/145
Fuel Inlet Pressure (aircraft gravity flow)	4 to 6 PSIG
Fuel Acceleration Control Valve Cracking Pressure	33 to 35 PSIG

continued

Item	Specification
LUBRICATION SYSTEM	
Lubricant (same as for aircraft engines)	MIL-L-7807
Operating Pressure	80 to 100 PSIG
Oil Tank Capacity	1 U. S. gallon
Operating Temperature	124°C (255°F)
Oil Temperature Switch (automatic shutdown)	118 to 124°C (245 to 255°F)
Oil Pressure Switch -	
To Open Fuel Solenoid and Energize Ignition	3. 5 PSIG
To Deenergize Holding Circuit (shutdown)	Under 55. 0 PSIG
To Complete Doors Close Circuit	Under 3. 5 PSIG
Oil Cooling Fan Output -	Standard NASA Day
Airflow	16. 85 PPM
Temperature Rise of Air	20. 6°C (69°F)
Air Pressure (minimum)	14. 6 inches H_2O (0. 53 PSI)
ELECTRICAL SYSTEM	
Power Supply	24 to 28 volts, DC
Fuel Shutoff Solenoid Valve (spring-loaded closed)	11 to 30 volts, DC
Ignition Unit -	
Input	14 to 30 volts, DC
Output (nominal)	18,000 volts, DC
Bleed Air Control Solenoid	11 to 30 volts, DC

continued

APU SPECIFICATIONS (cont)

Item	Specification
OPERATING TEMPERATURES	
Compressor	Standard NASA Day
Bleed Air	199 to 223°C (390 to 434°F)
Maximum Inlet	54.4°C (130°F)
Turbine Exhaust Discharge, Maximum Allowable (continuous operation)	709°C (1310°F)
Load Control Thermostat* (cracking setting)	670 to 676°C (1240 to 1250°C)
Acceleration Control Thermostat (cracking setting)	704 to 709°C (1300 to 1310°F)
NOMINAL COMBINED POWER OUTPUT RATINGS (Standard NASA Day Conditions)	
Shaft Power	32 horsepower
Bleed Air -	
Flow	133 PPM
Pressure	112 inches Hg ABS (44 PSIA)
Temperature	199 to 223°C (390 to 434°F)

* Must be at least 22°C (40°F) lower than acceleration control thermostat

CONSTRUCTION.

The APU consists of two major sections:

- o Compressor and Turbine Assembly
- o Accessory Assembly

These two major sections can be procured and replaced separately or the entire unit may be overhauled. All repairs requiring disassembly of the APU requires removal from the aircraft. Extent of APU disassembly and field repair is determined by several factors. With adequate spare parts and special tools, many major repairs can be accomplished in the field. Disassembly of the turbine wheel and shaft assembly is not recommended in the field because of balancing problems, but the assembly can be replaced.

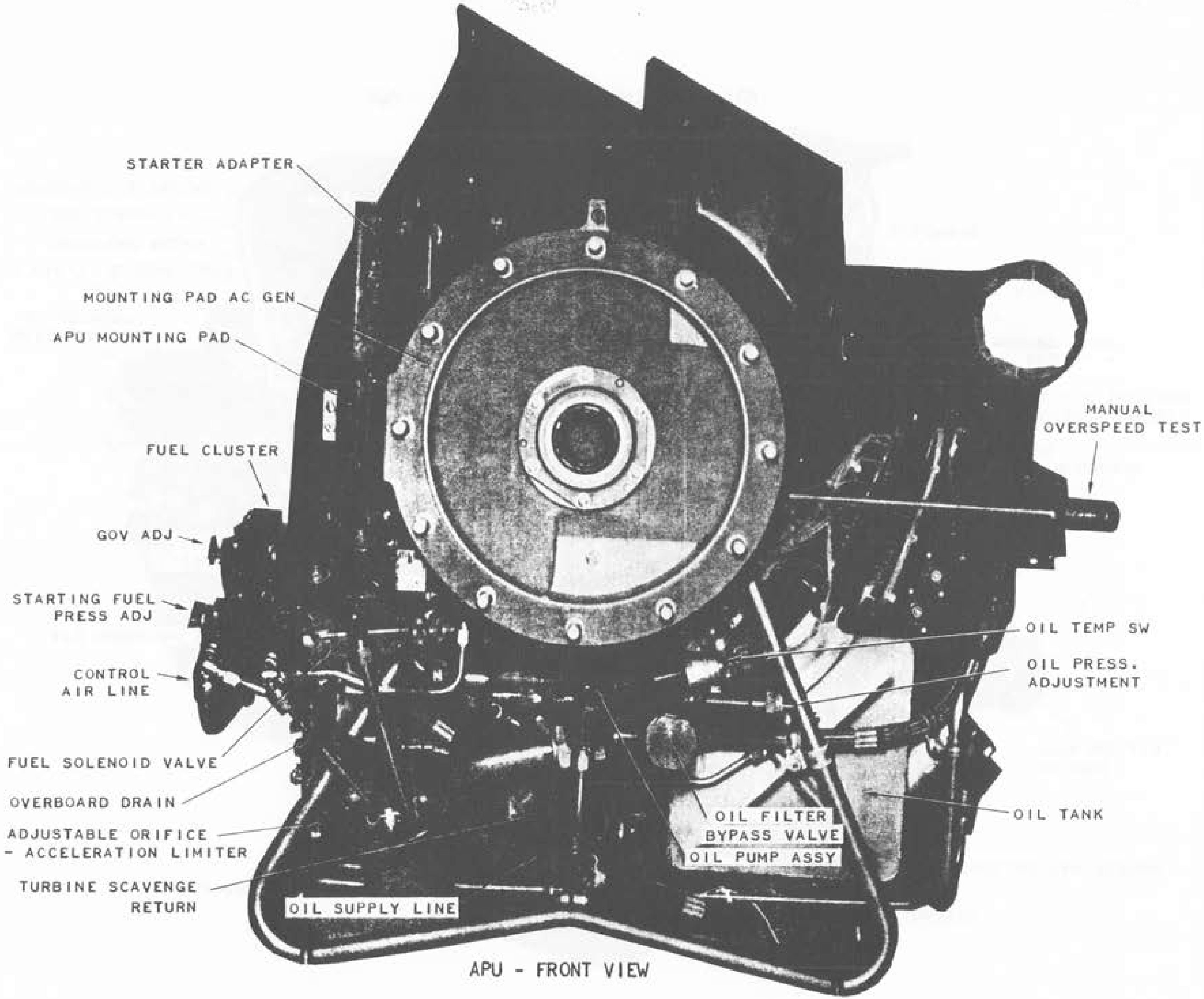
COMPRESSOR AND TURBINE ASSEMBLY.

MAIN BEARINGS.

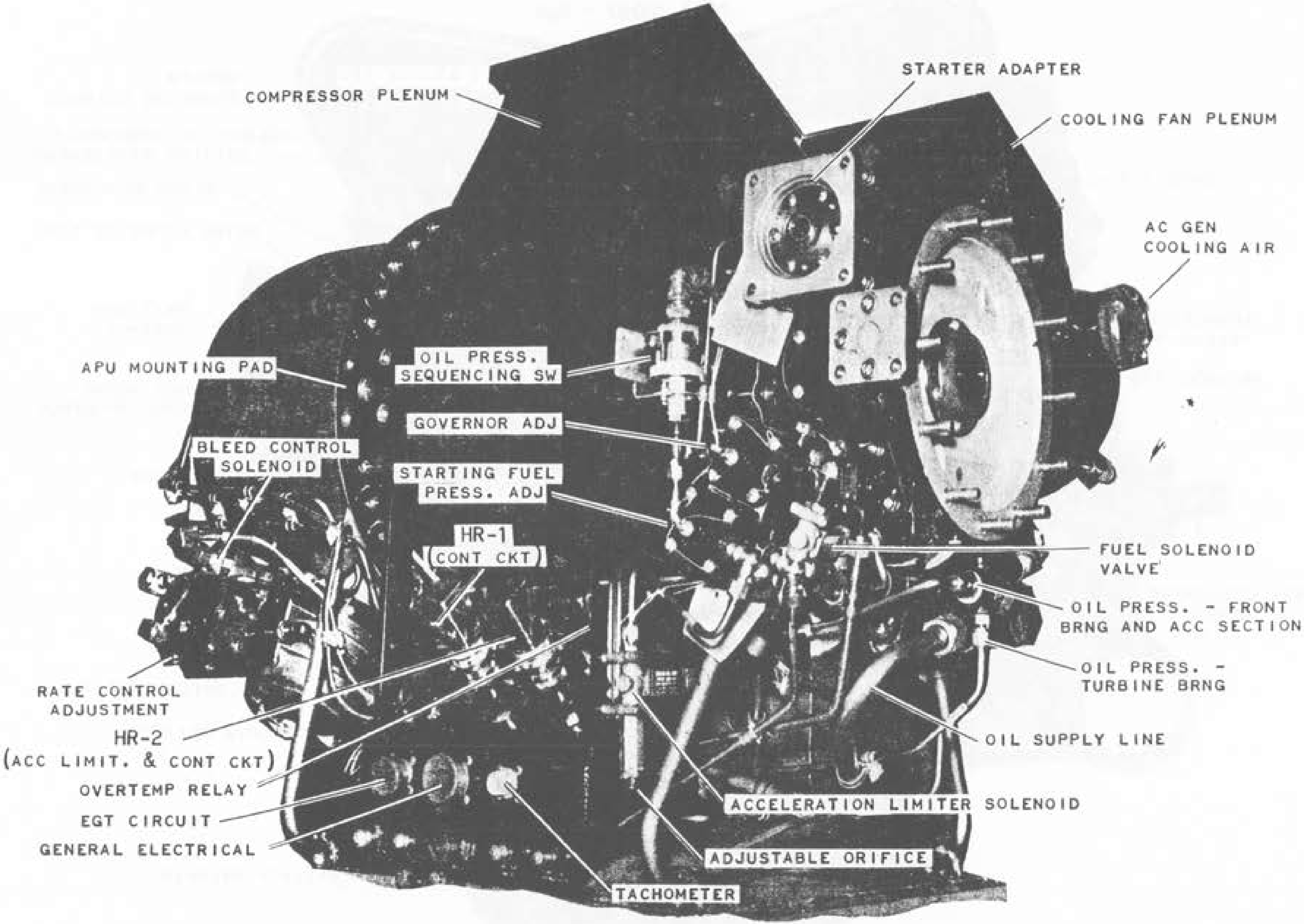
Two main bearings are used to support the compressor and turbine rotor assembly. A ball bearing (thrust), located in front of the first-stage compressor, absorbs axial and radial loads. A roller bearing, located between the turbine wheel and second-stage compressor, absorbs only radial loads.

COMPRESSOR INLET PLENUM.

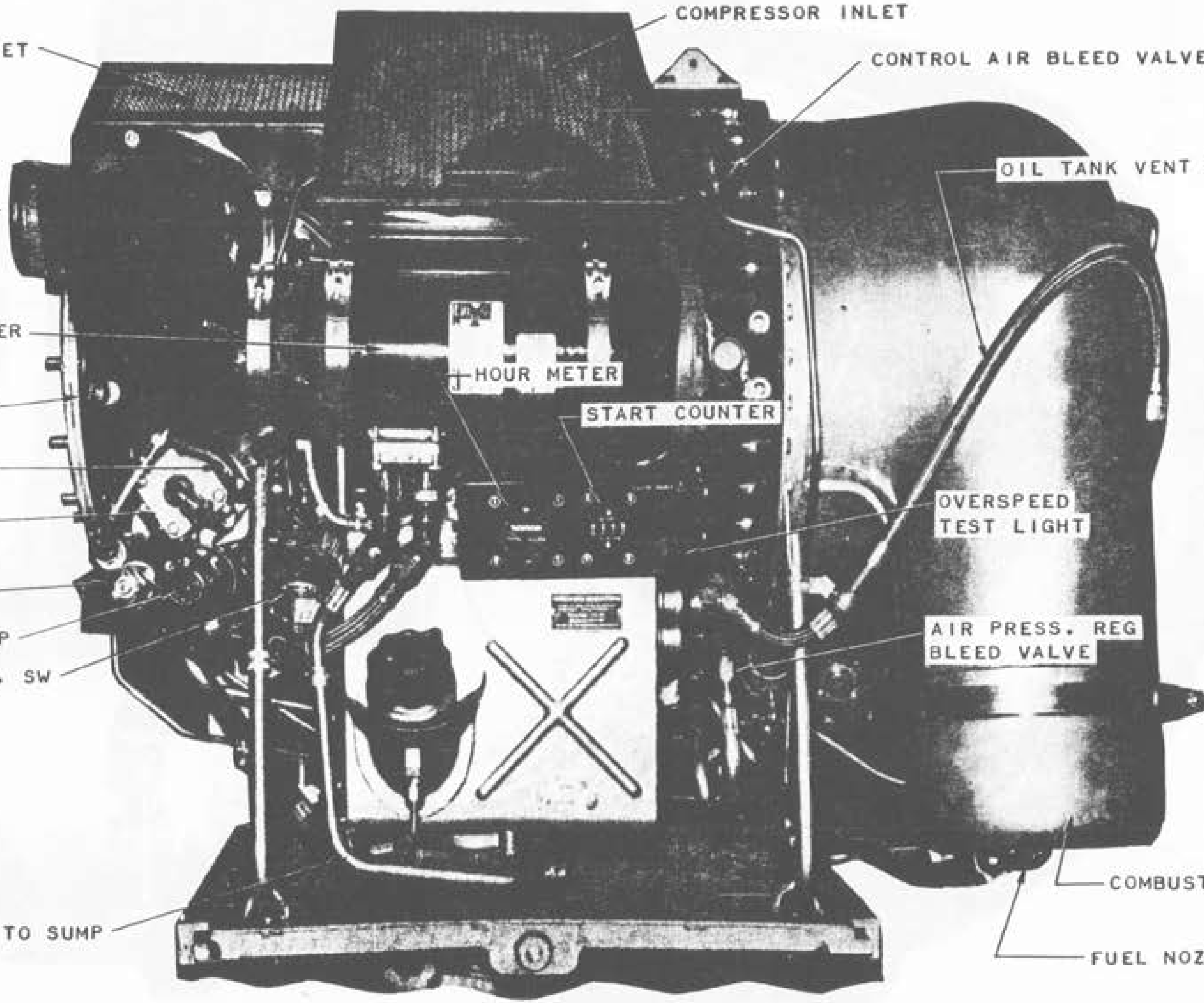
This unit is attached to the first-stage compressor inlet and the second-stage diffuser housing. It surrounds the first-stage compressor inlets with the rectangular opening mating to the intake door opening at the pod structure. A screen is mounted over the rectangular opening to prevent large foreign objects from entering the first-stage compressor intakes. The accessory assembly has to be removed before the plenum can be taken from the APU. The outside of the plenum is used to mount several items. On the right side are the electrical cannon plug connections to the aircraft, fuel supply line, drain lines, and the holding relays of the control circuit. The low oil pressure switch is mounted on the right front side. The oil cooler and oil tank are mounted on the left side. The hour meter and start counter are located between the oil cooler and oil tank on a shock-mounted panel. This same panel also includes the overspeed test light and a circuit breaker which is in the circuit to the hour meter and start counter.



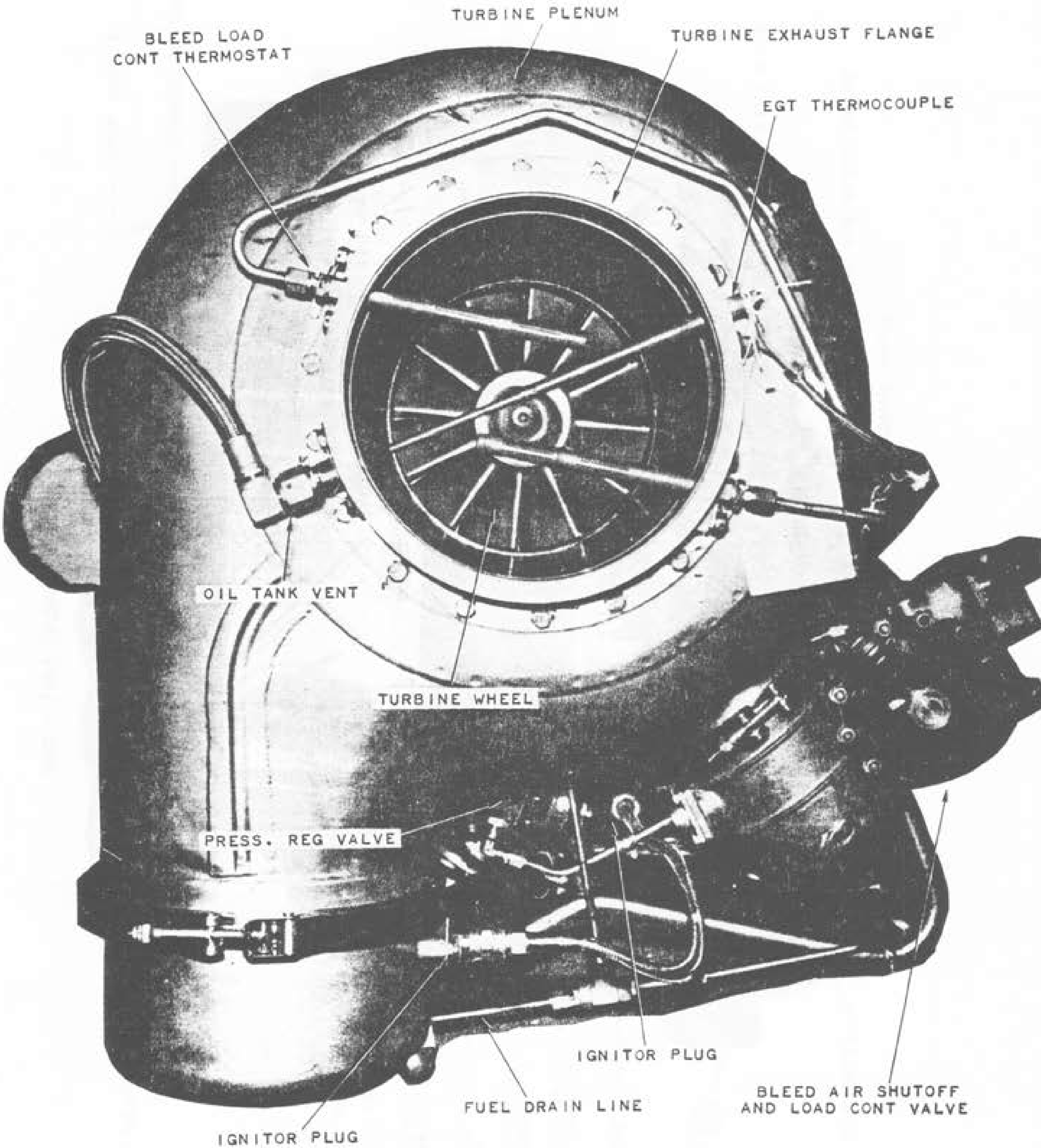
APU - FRONT VIEW



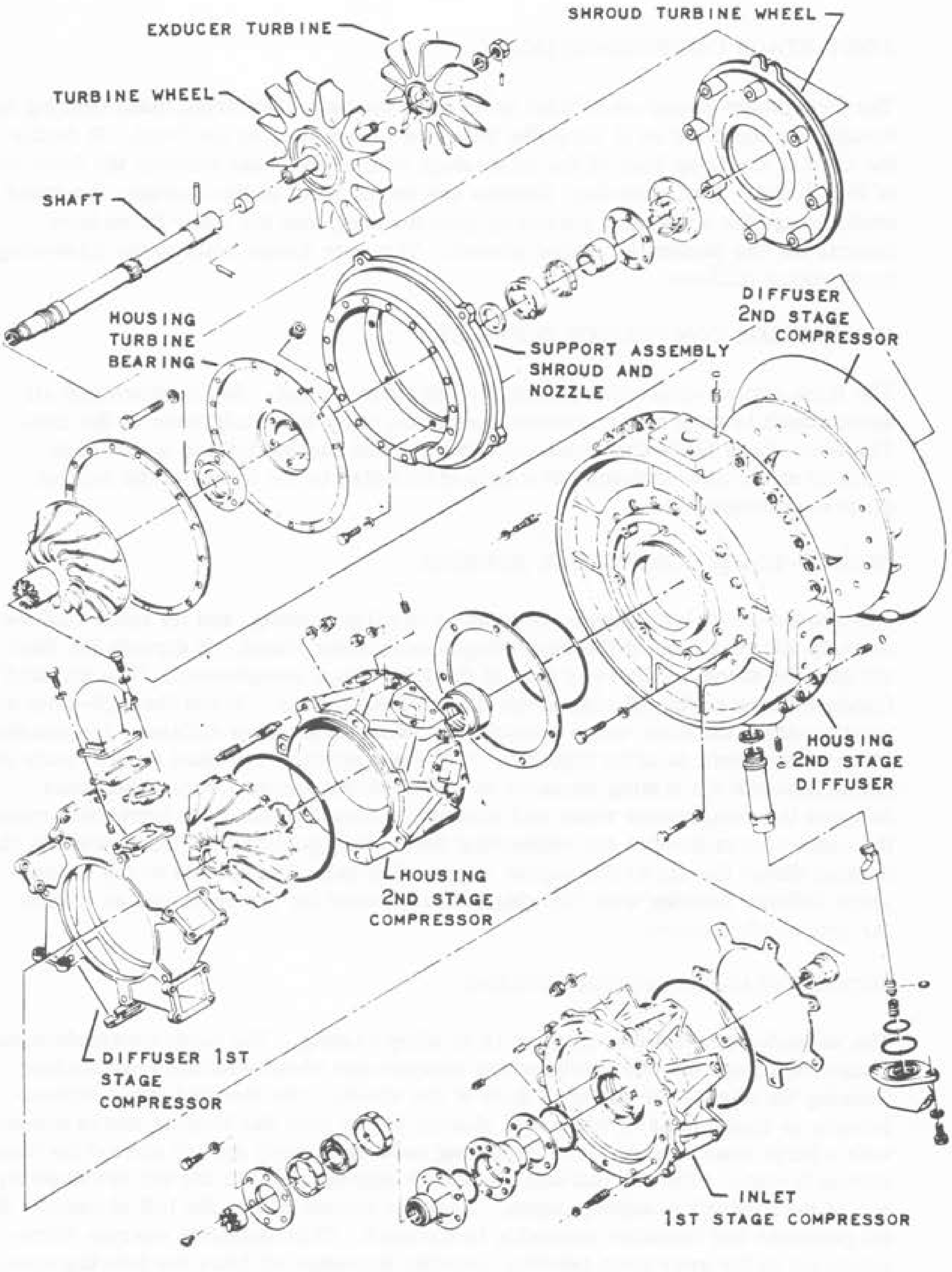
APU - 3/4 FRONT AND RIGHT SIDE VIEW



APU - LEFT OUTBOARD VIEW



APU - REAR VIEW



GAS TURBINE ENGINE COMPRESSOR AND TURBINE ASSEMBLY

FIRST-STAGE COMPRESSOR INLET.

The first-stage compressor inlet is an alloy casting. The front main bearing is mounted in the front so it supports the rotor assemblies at the front. It forms the inlet to the front face of the first-stage compressor and shrouds the front side of the blades. Two mounting flanges are on the front of the casting: the inner studs mount the accessory planetary gear housing, and the outer holes have inserts for the plenum attaching screws. The rear flange bolts to the first-stage compressor diffuser.

FIRST-STAGE COMPRESSOR DIFFUSER.

The first-stage compressor diffuser is an alloy casting. Seven interstage air ducts attach to pads evenly spaced around the outer circumference of the unit. The first-stage blade tips rotate within the inner circumference so the high velocity air is slowed down and evenly distributed to the throat of the second-stage compressor wheel.

SECOND-STAGE COMPRESSOR HOUSING.

The second-stage compressor housing is an alloy casting, and its front surface shrouds the rear face of the first-stage compressor wheel. It directs the inlet air into the throat of the rear face of the first-stage compressor. The forward flange secures to the aft side of the first-stage diffuser. Seven through-bolts are used to attach the first-stage compressor inlet, first-stage diffuser, and second-stage compressor housing together. "O" ring packings are used for air seals and shims between the mating surfaces to establish the desired axial clearances between the compressor rotor and housings. Mounting pads are provided around the outer circumference for connecting the interstage ducts. Passageways in the casting direct the air to the second stage. The rear flange bolts to the second-stage diffuser housing with "O" ring packings used for air seals and as a shim for proper clearances.

SECOND-STAGE DIFFUSER HOUSING.

The second-stage diffuser housing is an alloy casting. The inner circumference forms the throat for the second-stage compressor wheel with the rear surface forming the shroud for the front face of the wheel. The forward outer circumference is smooth and is where the plenum slides over the housing and is secured with a large hose clamp. Four mounting pads are evenly spaced around the outer circumference. The top pad and the one 90 degrees right of the top are used for two of the aircraft mounting points. Near the bottom and to the left of center, the oil pressure and breather assembly is mounted. This assembly carries lubricating oil to the rear main bearing, returns scavenge oil from the bearing area, and vents the area to the oil tank. Two lines connect to the housing for pickup of compressor discharge air. One line is used for control air to the bleed shutoff and control valve and the other for control air to the acceleration and control valve in the fuel system. The turbine plenum attaches to the outer circumference on the aft side. The second-stage compressor diffuser attaches to the rear face.

SECOND-STAGE COMPRESSOR DIFFUSER.

The second-stage compressor wheel blade tips will rotate within its center. In addition to diffusing the high-velocity air from the second-stage compressor wheel, the curved surface of the diffuser and the diffuser housing turns the airflow 90 degrees aft into the plenum.

TURBINE BEARING HOUSING.

The turbine bearing housing is located immediately aft of, and attaches to, the aft side of the diffuser. A shim is used between its attaching surfaces to establish desired axial clearances. The center of this housing supports two radial-type carbon seals and the main roller bearing between them. This roller bearing supports the aft end of the compressor and turbine shaft.

TURBINE SHROUD AND NOZZLE SUPPORT ASSEMBLY.

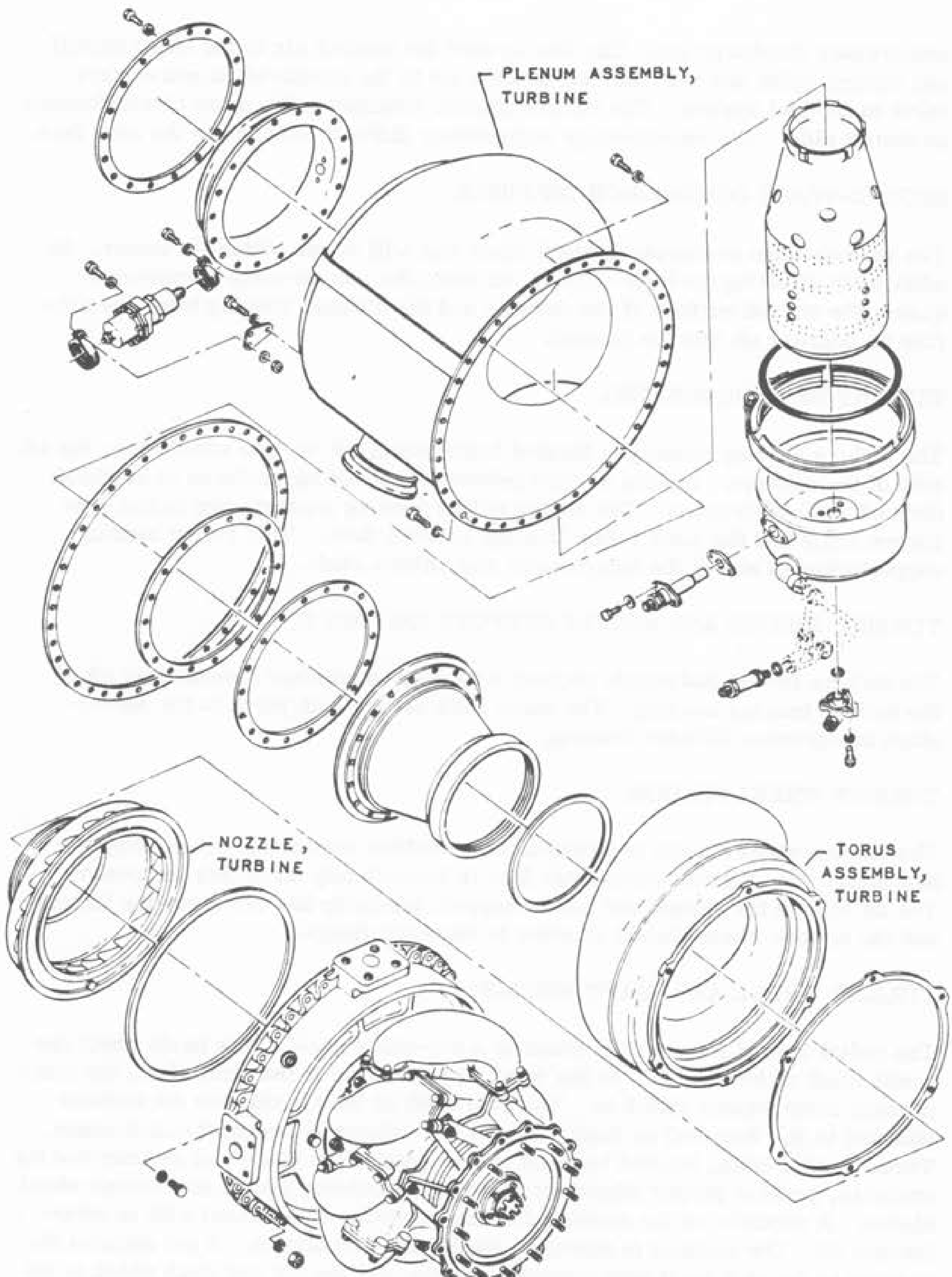
The turbine shroud and nozzle support assembly is attached immediately aft of the turbine bearing housing. The same bolts secure both parts to the second-stage compressor diffuser housing.

TURBINE WHEEL SHROUD.

The turbine wheel shroud is attached to the turbine shroud and nozzle support assembly. The turbine wheel front face is immediately aft of this component. The aft side of the shroud and nozzle support assembly has two mounting flanges and the turbine wheel shroud attaches to the inner flange.

TURBINE WHEEL AND SHAFT ASSEMBLY.

The radial inward flow turbine wheel is a two-piece wheel. The basic wheel has a stub shaft on both sides. At the front, it is secured to the shaft which the compressor rotor wheels attach to. The stub shaft on the aft side has the exducer attached to it. Removal or installation of the exducer is overhaul maintenance. Three special balls, located between indentations in the wheel and exducer mating surfaces, provide proper alignment between the exducer blades and turbine wheel blades. A shoulder on the exducer fits into a groove of the wheel with an interference fit. The exducer is therefore chilled for installation. A nut secures the exducer to the stub shaft with a straight pin through the nut and shaft which is set in the center to lock the pin in position. (The exducer may be secured in a different manner on some models.)



PNEUMATIC AND SHAFT POWER GAS TURBINE ENGINE

TURBINE NOZZLE.

The turbine nozzle is located around the turbine wheel. The forward flange has a dowel which positions the nozzle to the turbine wheel shroud. When the torus assembly is bolted to the shroud and nozzle support, it locks the nozzle in place. A shim is used on the front side of the nozzle flange to establish desired clearances. The aft side of the nozzle is cone-shaped and dorms a shroud around the turbine wheel.

TURBINE TORUS ASSEMBLY.

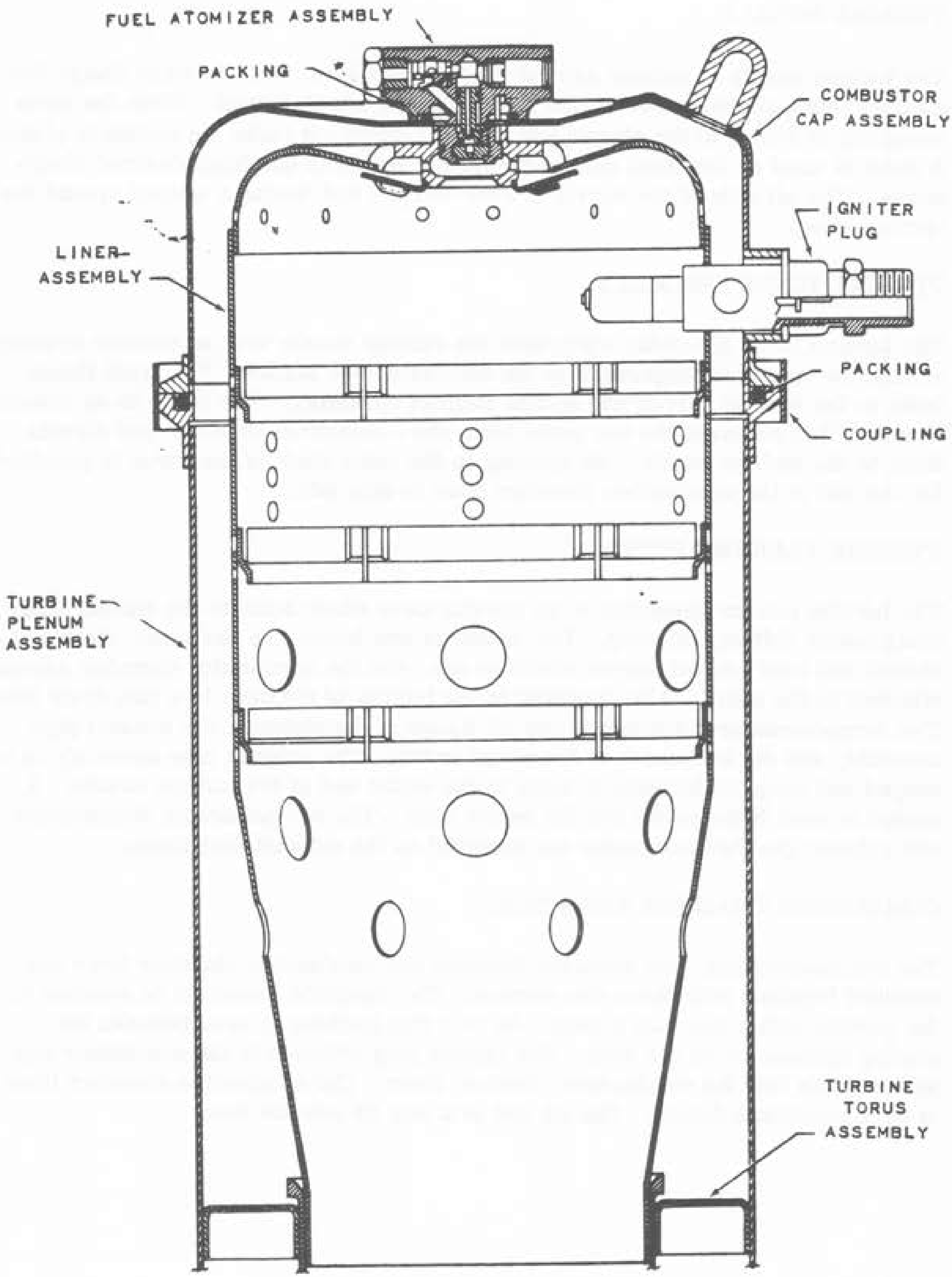
The turbine torus assembly surrounds the turbine nozzle with an annular opening around the outer circumference of the turbine nozzle blades. The front flange bolts to the turbine shroud and nozzle support assembly. The torus is an annular chamber that receives the hot gases from the combustion chamber and directs them to the turbine nozzle. An opening in the outer shell of the torus is provided for the end of the combustion chamber liner to slip into.

TURBINE PLENUM ASSEMBLY.

The turbine plenum assembly is an annular case which bolts to the second-stage compressor diffuser housing. Two openings are located on the case: the bleed shutoff and load control valves attach to one, and the combustion chamber assembly attaches to the other. Also mounted to the bottom of the case is a fuel drain line. Two components are attached to the aft flange of the plenum: the exhaust pipe assembly and the exhaust duct flange assembly. The exhaust pipe assembly is cone shaped and projects forward to mate to the outlet end of the turbine nozzle. A gasket is used between the two for an air seal. The two pneumatic thermostats and exhaust gas thermocouples are mounted on the exhaust duct flange.

COMBUSTION CHAMBER ASSEMBLY.

The combustion cap, fuel atomizer (nozzle) and combustion chamber liner are attached together with three cap screws. The complete assembly is secured to the plenum with a marmon clamp. An "O" ring packing is used between the mating surface for an air seal. The igniter plug attaches to the combustor cap and projects into the combustion chamber liner. The combustion chamber liner is of conventional design. The aft end is a slip fit into the torus.



COMBUSTION CHAMBER AND RELATED COMPONENTS

ACCESSORY ASSEMBLY.

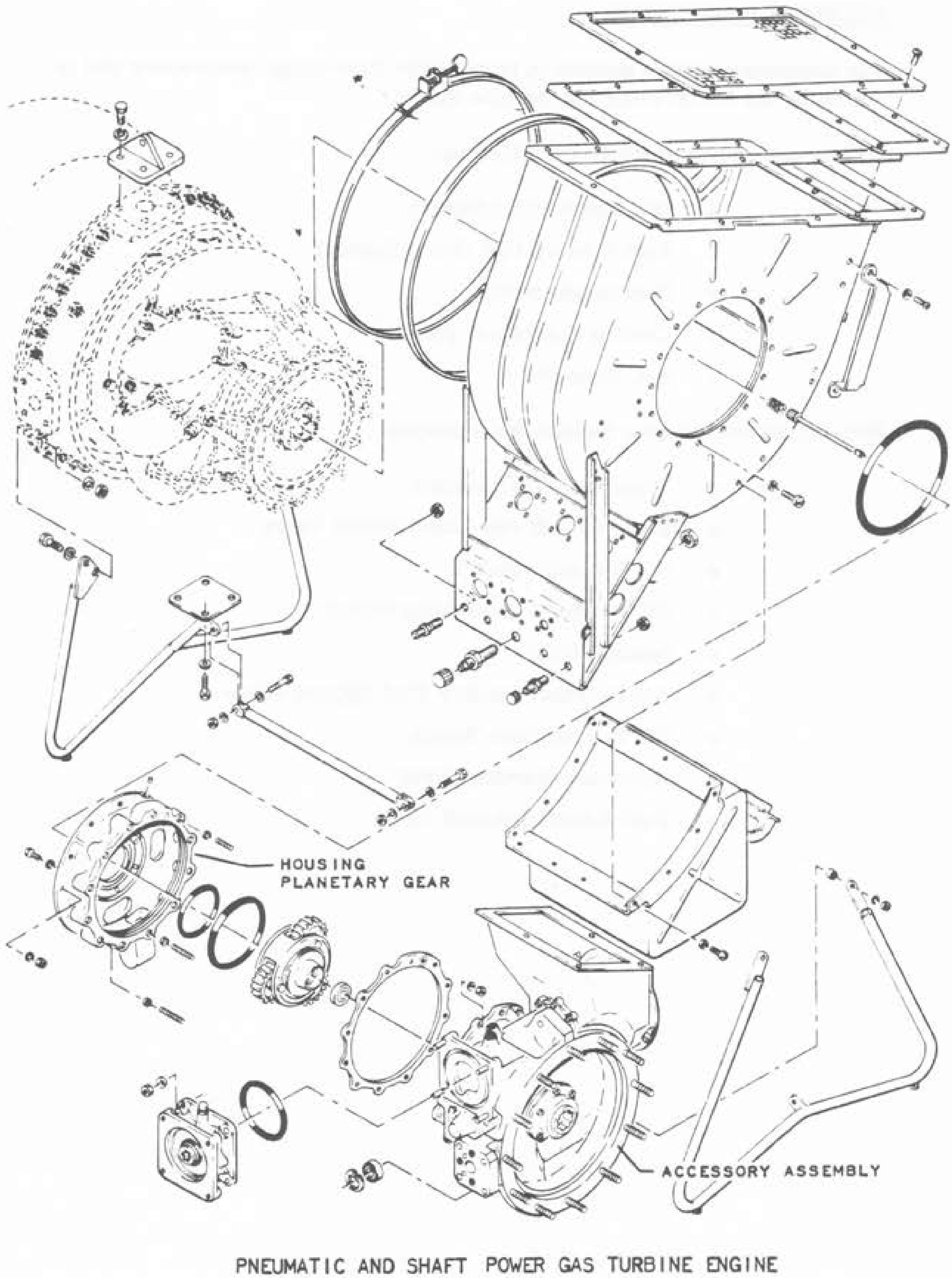
The accessory section mounts in front of the first-stage compressor and is driven by the compressor and durbine shaft.

Driven accessories include the following:

- Oil Pumps (Oil Cluster)
- Fuel Control Unit (Fuel Cluster)
- Centrifugal Switch
- Cooling Fan (Axial Flow)
- A-C Generator

Non-driven accessories include the following:

- Pneumatic Thermostats
- Bleed Shutoff and Load Control Valve
- Oil Pressure Switch
- Oil Pressure Sequencing Switch
- Ignition Unit
- Acceleration Limiter Fuel Bypass Valve
- Oil Temperature Switch
- Hydraulic Starting Motor
- Fuel Solenoid Shutoff Valve



PNEUMATIC AND SHAFT POWER GAS TURBINE ENGINE

PLANETARY GEAR HOUSING ASSEMBLY.

The planetary gear housing assembly attaches to the front of the first-stage compressor inlet housing. It houses the planetary gear reduction assembly which drives the accessory gear train. The planetary gear carrier is attached to the housing. The sun gear is mounted on two ball bearings in the center of the stationary carrier. A small torque shaft splines to the compressor and turbine shaft and to the sun gear. The sur gear drives three stationary planetary gears which, in turn, drive the ring gear. The hub of the ring gear is attached to the main accrssory drive shaft. The main drive shaft is supported in the rear by a bearing mounted between it and the planetary carrier.

ACCESSORY HOUSING.

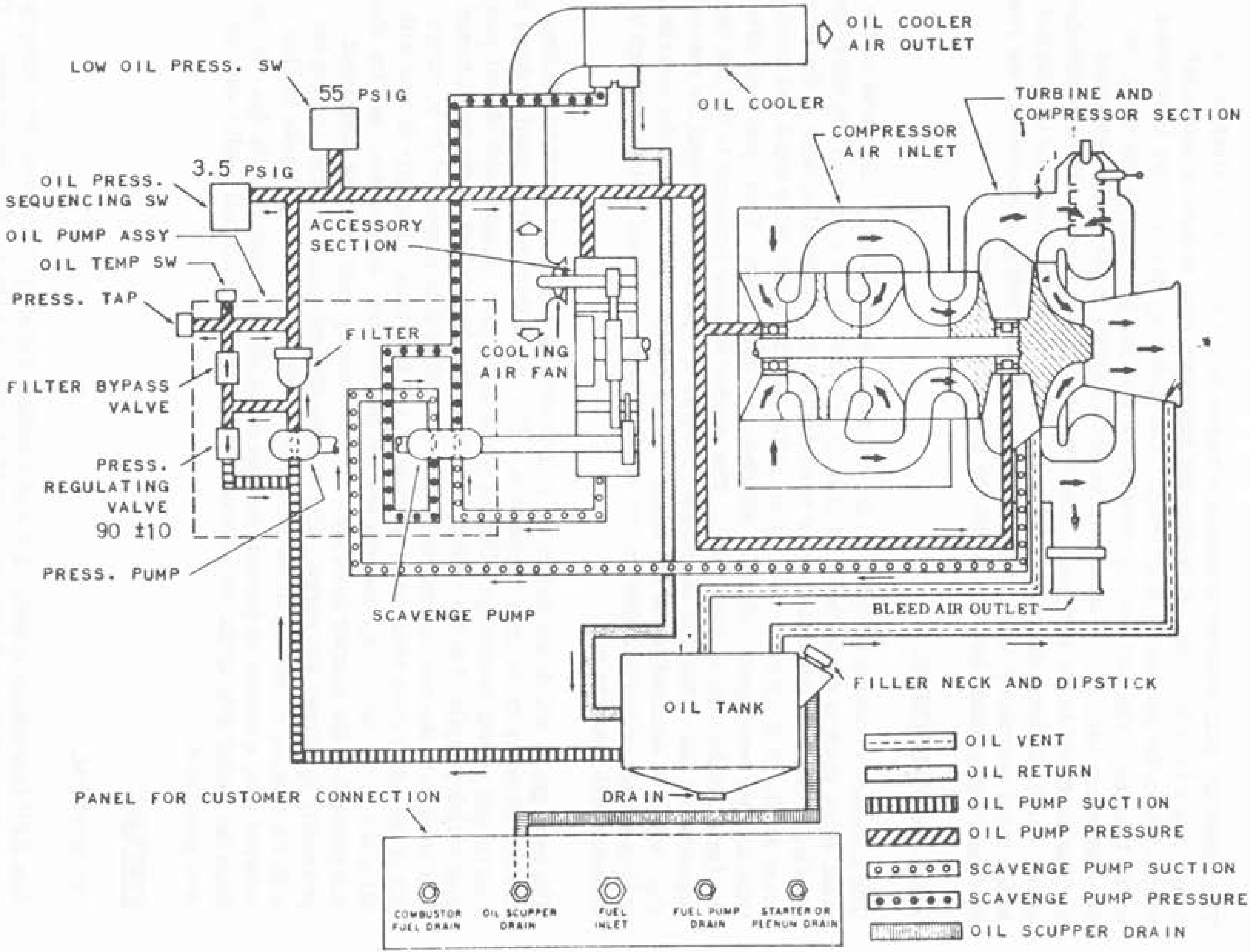
The accessory housing attaches to the planetary gear housing. The front of the main drive shaft is supported by a bearing mounted in the center of the accessory housing. The A-C generator drive shaft splines into internal splines of the main drive shaft. A main drive bevel gear splines on the main drive shaft and meshes with another bevel gear, which is attached to a spur gear. This spur gear drives the fan shaft through an idler gear. The starter adapter connects to the fan shaft opposite the fan. Pawls of the starter adapter are positioned around the ratchet dog, which is secured to the fan shaft. The main spur gear drives the remaining driven accessories (fuel cluster, oil cluster, and centrifugal switch) through a conventional gear train.

The spur gear, which meshes to the main gear, is keyed to a shaft which also has the oil pump drive gear keyed to it. The end of this shaft is used to drive the centrifugal switch assembly. The oil pump drive gear meshes with the oil pump gear which is splined in the center to receive the drive shaft of the fuel cluster. The shaft with the two intermediate gears keyed to it is supported by bushings. All of the other gear train is supported by ball bearings. The only drives with oil seals in the accessory housing are the fuel cluster, cooling fan, and fan shaft end inboard of the starter pawl jaw. The accessory gear train is lubricated primarily by splash and spray. The cooling plenum surrounds the cooling fan with its opening extending to the intake doors on the pod. This intake is also covered with a screen to prevent foreign material from entering the fan. A duct from the outlet side of the fan carries the cooling air to the oil cooler and the A-C generator.

SYSTEMS.

OIL SYSTEM.

The APU lubricating system is a self-contained positive pressure, dry sump type oil system. Military Specification MIL-L-7808 is to be used in the system. The



LUBRICATION SYSTEM

system provides lubrication for two main bearings and the accessory drive section. Several of the system components are combined in one assembly, the oil pump assembly also referred to as the oil cluster. Components of the oil cluster may be repaired, replaced and/or the completed assembly replaced. Components of the oil cluster are pressure pump, duplex scavenge pump, filter, filter bypass valve, pressure regulating valve, and oil temperature switch. All of the above come with the oil pump assembly except the oil temperature switch.

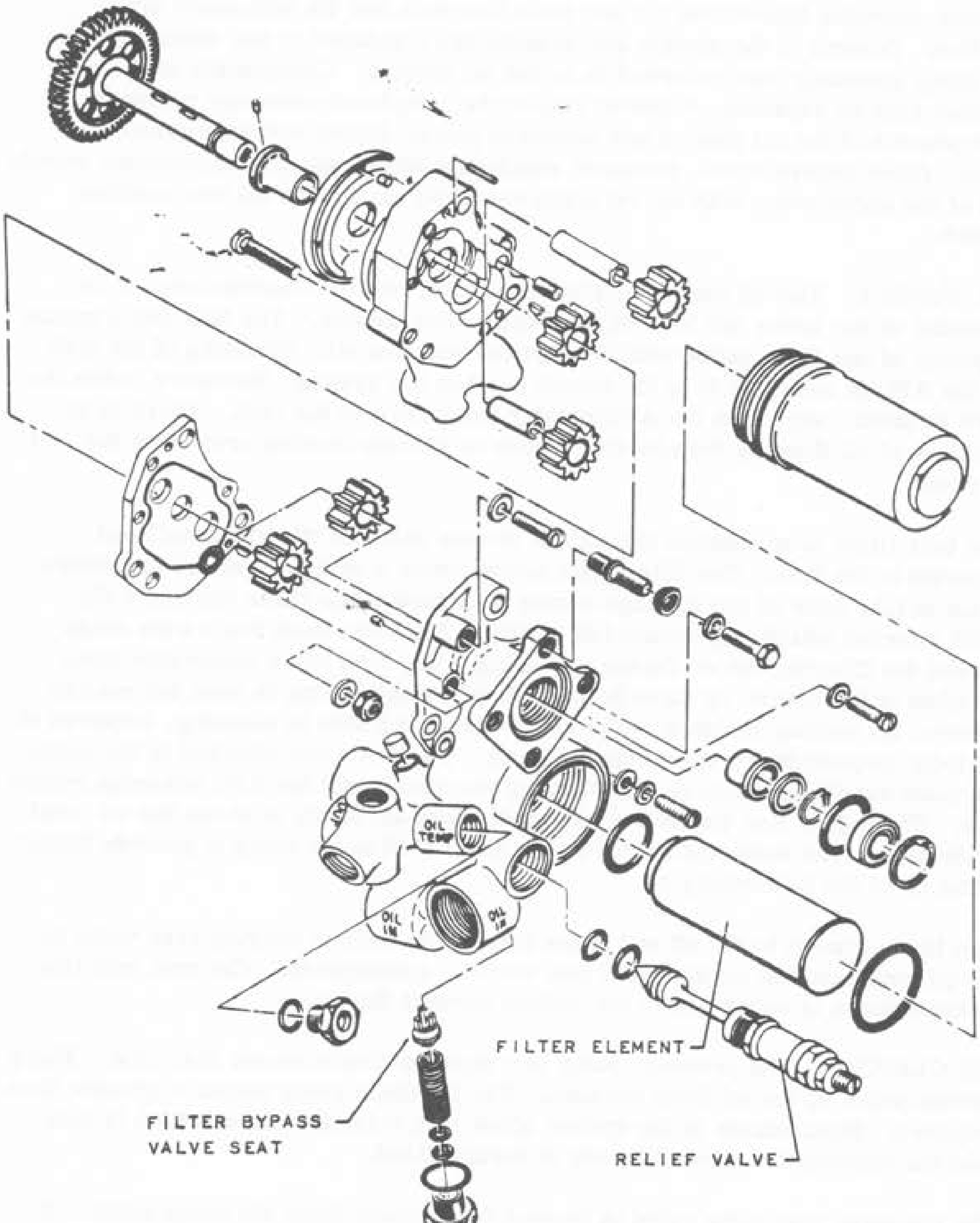
OIL SUPPLY. The oil tank is of stainless steel, welded construction. It is mounted on the lower left side of the compressor plenum. The tank has a usable capacity of one U. S. gallon with 0. 45 gallon residual oil. Mounting of the tank on the APU is such that it is the lowest point in the system; therefore, when the APU is static, any oil in the APU gravity flows back to the tank. There is no problem of oil flooding the accessory case or turbine bearing area when the APU is static.

The tank filler is accessible through an access panel on the wheel well pod adjacent to the tank. The filler neck incorporates a scupper with an overboard drain to take care of any spillage during servicing. The filler cap has a dip stick attached which is graudated in quarts. The filler neck has a wire mesh screen for filtering the oil during servicing. The tank has a removable sump attached at the bottom by three bolts. An "O" ring packing is used for sealing between the mating surfaces. The removable sump aids in cleaning, required at periodic inspections or when contaminated. Two lines are attached to the sump, the main supply inlet line to the oil pump assembly, and the APU scavenge return line. The supply line connection at the oil pump assembly is above the oil level in the tank. The scavenge return line is connected to the sump to provide faster warm up of the lubricating oil.

Two lines connect to the aft end of the tank. The turbine bearing area vents to the oil tank, and the oil tank vent line vents to apmosphere. The tank vent line to atmosphere is connected to the turbine exhaust flange.

OIL CLUSTER. The pressure pump is a positive displacement gear type. Pump suction picks up the oil from the tank. The pressure pump output is greater than required. Restrictions in the system allow less volume to flow, which is less than the capacity the pump delivers at normal RPM.

The pressure regulating valve is located downstream from the pump outlet. It is a poppet-type valve that uses spring tension to oppose pump pressure. The spring tension is adjustable, and is adjusted to maintain an oil pressure of 80 to 100 PSIG to the system. The adjusting screw is external and is accessible with the APU installed in the aircraft. It is located adjacent to, and forward of, the oil filter cap. The pressure regulating valve can be removed for maintenance



OIL PUMP ASSEMBLY

and/or replacement.

The oil filter is downstream from the pressure regulating valve. It is a micronic paper filter mounted in a screw-on case and is accessible on the outside of the oil cluster. The paper element is discarded and replaced with a like item when dirty or at specified intervals. Two "O" ring packings seal the filter element in the case and should be replaced each time the element is replaced. All pressure oil to the system is normally filtered.

In the oilflow path, and parallel to the filter element, is a filter bypass valve mounted in the oil cluster. In the event a filter element should become clogged, it is desirable to use any available oil for lubrication rather than none. The bypass valve opens at 55 PSID, at which point the pressure oil is allowed to bypass the filter element. The bypass valve is not field adjustable. If the bypass valve is removed for any reason, be sure to reinstall all the shims in their respective location.

As the pressure oil is routed out of the oil cluster housing, it passes across the oil temperature switch. This switch is set to close its circuit when the oil temperature reaches 118 to 124°C (245 to 255°F). Lubricating oil at or above 121°C (250°F) does not provide adequate lubrication of the bearings and accessory gear train. The oil temperature switch is wired in the APU electrical control circuit to prevent APU start when the switch is closed. It also automatically shuts down the APU in the event the oil temperature reaches the switch setting during operation.

Adjacent to the oil temperature switch, the oil cluster has three oil pressure outlets. One outlet is normally plugged and used for test purposes or for adjusting oil pressure when required. The other two outlets transfer the lubricating pressure to the required areas. One line is routed to the oil jet assembly, mounted on the lower left side of the second-stage compressor diffuser housing. The oil jet assembly transfers the oil into the turbine bearing support and has a jet to spray lubricating oil on the turbine (roller) bearing. The other outlet from the oil cluster is routed to the top of the accessory case housing where the oil is transferred through drilled passages to lubricate the main front (ball) bearing and all the other components of the accessory drive gear train.

OIL JET ASSEMBLY. The oil jet assembly performs three functions:

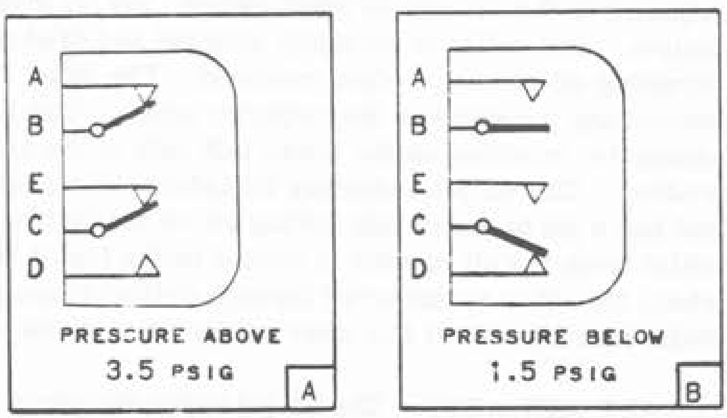
- Transfer lubricating oil into the APU to the turbine
- Allow scavenge oil to gravity flow to the outside of the APU where a line is connected to the oil cluster
- To vent the turbine bearing area to the oil tank

OIL SCAVENGE SYSTEM. The oil pump assembly (oil cluster) has a duplex scavenge pump driven by the same shaft as the pressure pump. The turbine bearing scavenge oil gravity flows down the oil jet assembly and is picked up by one element of the duplex scavenge pump through an external line. All of the lubricating oil for the front bearing and accessory drive gear train drains to a sump at the bottom of the planetary gear housing. From this sump, an external line is connected to the other element of the scavenge pump. Both scavenge elements are combined together and routed by an external line to the oil cooler.

The air oil cooler is strap mounted on the compressor plenum, above the oil tank. It is a tubular-type cooler with airflow from the APU-driven fan directed through the tubes. Airflow is continuous with the APU operating. As a heat exchanger, the air oil cooler is rated at 225 BTU per minute. Scavenge oil, from both elements of the duplex scavenge pump, is carried to the air oil cooler by an external line. Oil flows through the cooler and is carried to the sump of the oil tank by an external line.

The only protection built into the cooling system is the oil temperature switch. Normally the cooling capacity of the air oil cooler keeps the oil temperature below the setting of the temperature switch. Any condition which results in excessive oil temperature results in automatic shutdown of the APU.

OIL PRESSURE SWITCHES. Two oil pressure switch assemblies are attached to the oil pressure system. Both of the switch assemblies are connected to the lubricating oil pressure line which transfers the oil from the oil cluster to the accessory case housing. The low-oil pressure switch is mounted on the right front side of the compressor plenum, and the oil pressure sequencing switch is mounted adjacent to the upper forward end of the oil tank on the left side of the APU.



OIL PRESSURE SEQUENCING SWITCH ELECTRICAL

The oil pressure sequencing switch has two control circuits through it. The switch is set to actuate with oil pressure increasing at 2.5 to 3.5 PSIG. With oil pressure decreasing, it resets when the oil pressure is at a minimum of 1.5 PSIG. Operation of the switch is normally considered to be 3.5 PSIG.

The electrical circuits are as follows:

- o Terminal B - 28-volt, D-C
- o Terminal A - Circuit to Ignition Unit and Fuel Solenoid
- o Terminals C and D - APU Door Close Circuit
- o Terminal E - Not Used

When oil pressure reaches 3.5 PSIG during the starting cycle, the circuit between A and B closes to complete a circuit to energize the fuel solenoid shutoff valve open. The circuit between C and D is open, which keeps the APU intake and exhaust door from being closed while the APU is operating.

When the oil pressure decreases below 1.5 PSIG, circuit C and D closes which makes it possible to close the APU intake and exhaust doors only after the APU is shutdown.

When performing some maintenance and/or trouble analysis of the APU, it may be desired to motor the APU without a normal start. This can be accomplished by disconnecting the electrical cannon plug from the oil pressure sequencing switch.

FUEL SYSTEM.

The fuel supply system to the APU consists of a fuel line routed from the surge box in the No. 2 main tank to the APU. An electrically operated, motor-driven shutoff valve is located in the supply line at the tank outlet. This valve is controlled by the APU control switch and is open only when the APU is operating. Emergency fire handles also close the motor-driven shutoff valve. If either handle is pulled, the shutoff valve cannot be opened electrically until both fire handles are in their normal positions.

Fuel is gravity fed to the APU. Fuel pressure required at the APU pump inlet ranges from a minimum of 2 PSI below altitude ambient to a maximum of 20 PSIG. With an inlet fuel pressure within that range, the APU fuel system functions normally, and APU operation meets the minimum requirements.

The APU fuel and control system is designed to be controlled electrically. The automatic control features will start the APU, accelerate it up to the normal "ON" speed RPM, and maintain a relatively constant RPM with varying bleed air loads and A-C generator loads. The system must provide the desired fuelflow in relation to mass airflow and RPM for all operating conditions. Fuelflow to the fuel nozzle is determined by controlling the bypass of the fuel pump output. Two components control the pump output bypass the governor, which is APU driven, and the acceleration limiter valve.

The acceleration limiter valve establishes the required fuel pressure for starting and provides a fuelflow curve in relation to APU compressor output as the APU accelerates. This fuelflow curve establishes the desired APU acceleration characteristics. A pneumatic thermostat, that senses turbine exhaust gas temperature, is connected to the acceleration limiter valve and provides overtemperature protection. The governor is an on-speed type. It is driven by the APU and does not bypass any fuel or affect the fuelflow to the fuel nozzle until the APU is at or near its "ON" speed RPM. The governor attempts to maintain its adjusted RPM by increasing or decreasing fuel bypass with a respective increase or decrease in RPM. Varying load conditions, which affect the RPM of the RPM of the turbine, are sensed by the governor. The result is automatic fuel compensation.

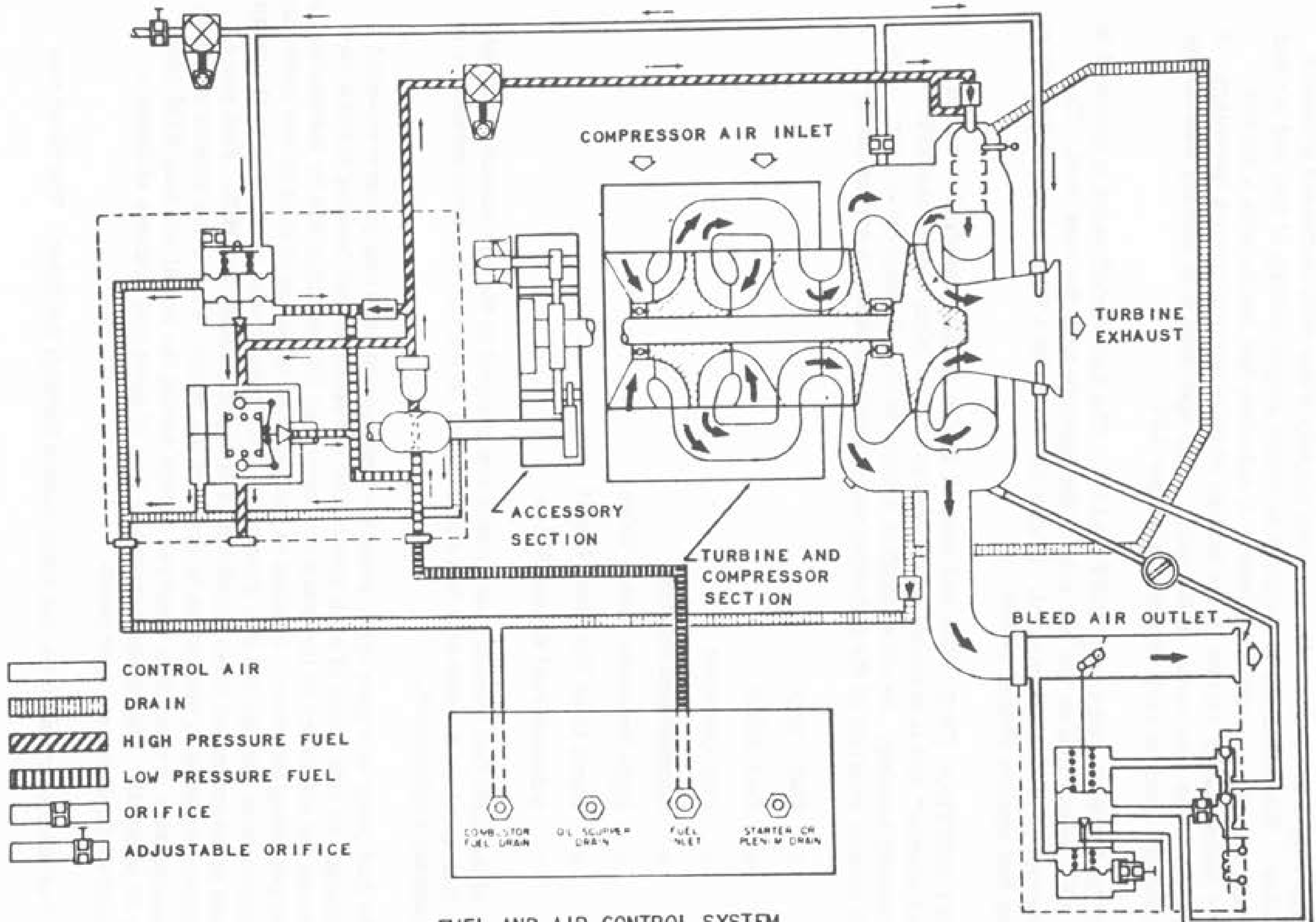
The system has a pressure relief valve which limits the maximum fuel pressure within the system. At 400 PSIG, it opens, thus bypassing pump output back to the inlet of the pump.

A high-pressure fuel filter is provided to remove any contamination from the fuel before it passes through any of the metering components and fuel nozzle. The filter element is a paper, throw-away type.

A solenoid-operated fuel shutoff valve is located in the metered fuel line. This valve provides control of fuelflow to the fuel nozzle for starting fuelflow and shutdown of the APU. The valve is energized open and spring-loaded closed. When starting the APU, the valve solenoid is not energized until the oil pressure sequencing switch senses 3.5 PSI oil pressure. After the APU is operating, several things can deenergize the valve, which stops fuelflow and thus, the APU. They include the following:

- Placing the APU control switch to "OFF"
- APU overspeed of 110 percent or greater
- Low oil pressure (below approximately 55 PSIG)
- High oil temperature (121 to 126.6°C) (250 to 260°F)
- RPM drops below 95 percent after reaching "ON SPEED"

The fuel nozzle is a dual orifice type. At low pressures during starting, it provides a wide spray angle for good mixing efficiency. As fuel pressure increases, a spring-loaded valve (flow diverter) introduces fuel into the secondary orifice, which is a larger orifice, and allows the amount of fuelflow to increase respectively with fuel pressure increases. The fuel nozzle must discharge the fuel producing a desired spray angle and conical shaped pattern. To produce efficient combustion, the spray pattern must retain a conical shape with no discontinuities, solid jets of fuel, or fizzing. The spray angle must also stay within desired



FUEL AND AIR CONTROL SYSTEM

limits throughout the range of operating fuel pressures. The angle should change very little and usually becomes slightly wider with increased pressure and flow. This condition is required to obtain proper mixing of fuel and air and to contain the flame within the liner. A defective fuel nozzle with a narrow spray angle usually results in the turbine wheel's burning through (torching). A bad pattern can also result in the same. Any operation with burning outside the combustion liner is very detrimental to the APU.

MOTOR-DRIVEN FUEL SHUTOFF VALVE. The fuel shutoff valve is mounted in the APU supply line on the left side of the fuselage near the wing root. The valve can be manually operated. It also incorporates a thermal relief feature as most fuel system shutoff valves.

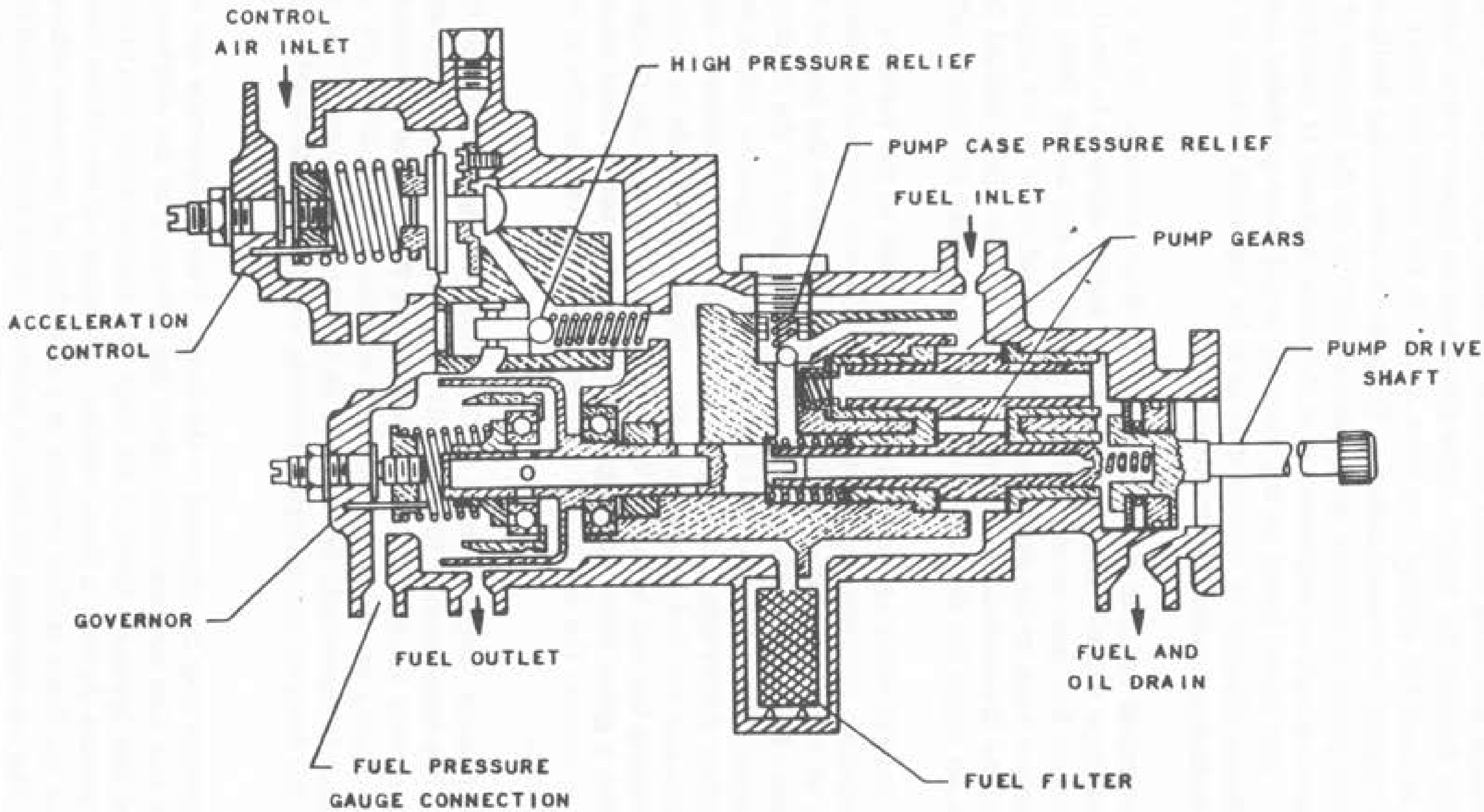
FUEL CONTROL UNIT. The fuel control unit is usually referred to as the "fuel cluster" and is mounted on the forward lower right side of the APU accessory housing. Its drive shaft is splined to the oil pump drive gear. The fuel cluster consists of the following components, grouped in one assembly:

- o Fuel Pump
- o Fuel Filter
- o Fuel Governor
- o Acceleration control
- o High-Pressure Relief Valve
- o Pump Case Pressure Relief
- o Solenoid Fuel Shutoff Valve

All of the APU fuel system components are grouped in the one assembly except the fuel nozzle. Adjustments and maintenance on the unit are premissable as is assembly replacement.

The fuel pump is a gear type, positive displacement utilizing pressure-loaded bushings on both sides of each gear. The pressure-loaded bushing feature improves the efficiency of the pump and increases its operating life by automatically compensating for wear. Loading of the bushings is accomplished by two methods: compression springs and fuel pressure. Fuel pressure is controlled by the pump case pressure relief valve which opens at approximately 25 PSID. Fuel pump volume output is in proportion to speed of the pump. Fuel pump volume output is considerably greater than required except during the initial starting RPM (zero to 35 percent). This characteristic is true of most fuel systems utilizing a positive displacement type pump.

All of the fuel output from the pump passes through the filter. The filter cap



APU FUEL CLUSTER

screws into the fuel cluster housing and is accessible with the APU installed. Two "O" ring packings are used to seal the filter element at both ends to ensure all of fuel's passing through the filter. This filter has no bypass valve feature because the APU is used for ground operation only. In the event the filter element becomes clogged or contaminated to the point of restricting fuelflow, APU operation could produce various symptoms depending on the amount of fuel restriction. Inspection and/or replacement of the filter element is required at specified periods. Any metal found on the element would most probable come from the pump. Some deposits of bronze dust is to be expected because of the pressure-loaded bushings against the rotating gears.

The high-pressure relief valve is downstream of the filter element. It is a spring-loaded, ball type valve. The function of this relief valve is to limit the maximum pump output fuel pressure. It is set to open at 490 to 540 PSIG to bypass pump pressure back to the pump inlet. This relief valve is not adjustable in the field. It can be disassembled, however. If it is, the shims behind the spring must be reset since the thickness of shims establishes the relief setting.

The acceleration limiter valve is a poppet-type. The stem of the valve is attached to two separate diaphragms. Both diaphragms are exposed to atmospheric pressure on one side. The fuel diaphragm, adjacent to the poppet valve, senses fuel pressure behind the valve. Fuel pressure applied to the diaphragm forces the valve open to increase the fuel bypass. On the opposite end of the valve stem, the other diaphragm has a spring in addition to compressor discharge pressure which opposes the fuel pressure force. This action tends to close the valve, thus decreasing the fuel bypass. The combined forces acting in opposite directions establish a given valve opening, which bypasses the desired amount of fuel pump output to control the volume of fuelflow out of the fuel nozzle in relation to APU requirements.

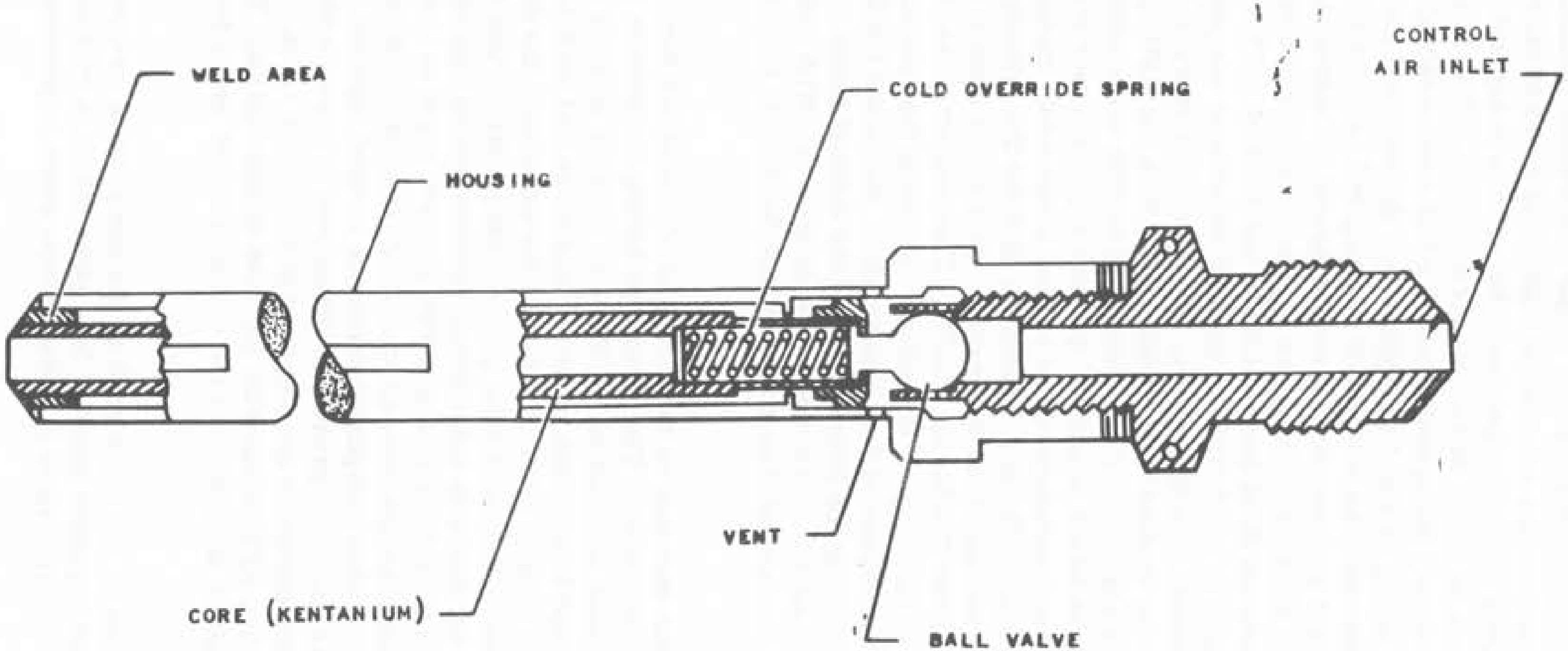
During the starting phase, the fuel pump output is low, and all its volume is needed initially. The acceleration limiter valve is closed, and the pump output pressure must overcome the spring tension before any fuel can be bypassed. Adjustment of this spring provides the required starting fuel pressure (34 PSIG ± 1). This pressure is commonly referred to as cracking pressure. The pressure establishes the desired spray angle, pattern, and fuelflow to obtain combustion.

The cracking pressure may be adjusted in the field. Two components are used in the control air line that automatically affect the pressure on the diaphragm and the amount of fuel bypass. Control air from the second-stage compressor diffuser housing passes through a fixed orifice. Bleeding off any of the control air downstream of the fixed orifice results in a reduction of pressure acting on the diaphragm. The acceleration limiter, a solenoid valve with an adjustable orifice on the outlet side, provides the desired APU acceleration characteristics.

It is mounted on the forward lower right side of the compressor plenum. The valve is spring-loaded open and the solenoid is controlled automatically by the APU control circuit. From zero to 35 percent, the valve is energized closed so the adjustable bleed has no effect on control air pressure. This is a critical period of operation; therefore, the system needs the full compressor discharge output control pressure acting on the diaphragm to get the required fuelflow. From 35 percent to 95 percent, the solenoid is deenergized, and the adjustable bleed will affect the control air pressure on the diaphragm. Control air pressure is a function of APU RPM; therefore, the adjustable orifice can establish a desired relationship between RPM (mass airflow) and fuelflow. This adjustment provides acceleration of the APU to on speed RPM without compressor stalls within 15 to 20 seconds. At 95 percent, the solenoid is energized closed and full control pressure is applied to the diaphragm. With the APU operating on speed, with or without bleed air, the acceleration control valve senses a direct full control pressure which is a direct product of compressor mass airflow. The acceleration and overtemperature control thermostat, mounted on the exhaust pipe flange, can bleed off control pressure anytime the exhaust gas temperature exceeds the setting of the thermostat. It is set to open at an exhaust gas temperature of 704 to 709°C (1300 to 1310°F). This unit provides overtemperature protection by bleeding off control air, reducing the pressure on the diaphragm, increasing the volume of fuel bypass which decreases fuelflow through the fuel nozzle, and decreasing the temperature of the exhaust gases. The system, as its name implies, serves for overtemperature protection. With normal operating systems, the thermostat does not affect the fuelflow to the APU fuel nozzle.

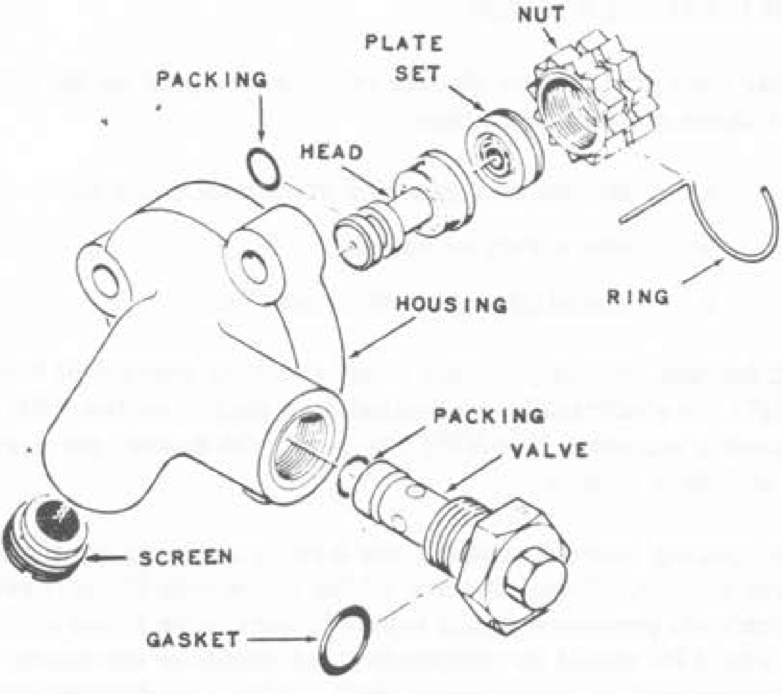
The pneumatic thermostat operates on the principle of dissimilar metals having different coefficients of expansion. The metal tube having the greater rate of expansion has the valve seat attached to it. The tube with the smaller rate has a spring-loaded ball attached to it. Both tubes are slotted so that each is exposed to the same temperature exhaust gases. Opposite the valve end, the dissimilar tubes are welded together. The outer tube grows in length faster than the inner; therefore, the inner is carried with outer which relieves spring tension from the ball. This action allows the ball to unseat at 704 to 709°C (1300 to 1310°F). The shims used for setting the thermostats operating temperature determine the compression of the spring when component parts are torqued together. With smaller thickness shims used, the greater is the amount of spring compression; therefore, more heat and expansion are required to unseat the valve. The base of the thermostat is etched AFT on one side for ease of installation. The slots must be positioned properly in relation to the turbine exhaust gases for satisfactory operation.

The fuel governor, driven by the same shaft as the pump, is an on-speed type governor. The governor bypasses more or less pump output in relation to APU RPM. The governor controlled valve is a sleeve type which is positioned by two



APU PNEUMATIC THERMOSTAT

forces: spring tension opposing APU-driven centrifugal flyweights. As the APU reaches on speed, the acceleration control valve is closed and the governor opens. This action causes bypass of the required volume to maintain the adjusted RPM. On-speed, no-load RPM is 43,000 RPM, maximum. With a 32 horsepower shaft load and bleed air load with EGT at 671°C (1240°F), the governor must maintain 42,000 RPM ± 100. Therefore, the governor is the primary control of fuelflow at on-speed operation, but the acceleration control valve reverts to fuelflow control should the exhaust gas temperature reach the setting of the thermostat 704°C (1300°F). The governor adjustment can be made in the field.



FUEL ATOMIZER ASSEMBLY

The fuel nozzle is a single-entry, dual orifice type. It is attached to the combustor cap assembly. All of the fuel entering the nozzle passes through a screen filter. This filter prevents clogging of the small passages in the nozzle. The primary orifice is the smaller of the two paths for fuelflow. It provides the required spray angle and pattern for starting and low flow. The secondary orifice being larger, allows the greatest volume to flow. The fuel nozzle has a flow divider (spring-loaded valve) which controls the volume of flow through the secondary orifice in relation to the fuel pressure delivered to the nozzle. The flow divider is set to open at 40 PSIG ± 1. It continues to increase the size of the opening as fuel pressure increases.

The fuel nozzle may be disassembled in the field. Special tools must be used, especially for torquing the atomizer nut during assembly. Over-torquing or under-torquing this nut can cause a distorted spray pattern or spray angle. Approved chemical cleaning and/or carbon removal may be used.

NOTE

> Do not use wire brush, metal scrapes, or similar items for cleaning the head of the nozzle.

BLEED AIR CONTROL SYSTEM.

The bleed air load control and shutoff valve is mounted on the turbine plenum. It performs three distinct functions:

- Serves as a positive shutoff of bleed air
- Has a rate of opening
- Modulates to control bleed air

The shutoff feature, which provides positive cutoff control of bleed airflow away from the APU, is electrically controlled by a switch on the APU panel at the flight engineer's station. The APU has to be "On Speed" (95 percent or above) before the switch is armed.

The rate of opening feature protects the APU from being overloaded when the valve is first opened. Rapid opening of the valve with the aircraft pneumatic system at ambient pressure would result in excessive bleed airflow away from the APU. The APU would be overloaded and result in excessive turbine exhaust gas temperature and/or compressor stall. With a controlled rate of opening, the aircraft manifold is pressurized without a radical pressure drop in the APU plenum.

The valve's automatic modulation feature also serves as an overload protection for the APU. When the APU turbine exhaust gas temperature reaches a selected point, the valve automatically drives toward a closed position. By reducing the bleed airflow away from the APU, the turbine exhaust gas temperature is limited to a selected point. This system operates when the use of bleed air exceeds the capacity of the APU. Taking bleed air away from the APU reduces the air mass flow across the turbine. To sustain operation, more fuel is added to the reduced airflow which, in turn, results in increased turbine exhaust gas temperatures. There is a temperature limit that the turbine components can be subjected to. A point would also be reached where combustion pressure would exceed compressor discharge pressure which would stall the compressors.

Functional operation of the bleed air load control and shutoff valve provides the necessary protection for the APU with a minimum of operator controls or monitoring by the operator. Use of the APU at extremely high atmospheric temperatures and/or elevations will be limited in the systems that can be supported at one time. For example, an engine start may not be satisfactory if the APU-driven A-C generator were under full load and the aircraft air conditioning system were in operation simultaneously on a hot day. It should be remembered that the APU airflow decreases with an increase in elevation or atmospheric temperature.

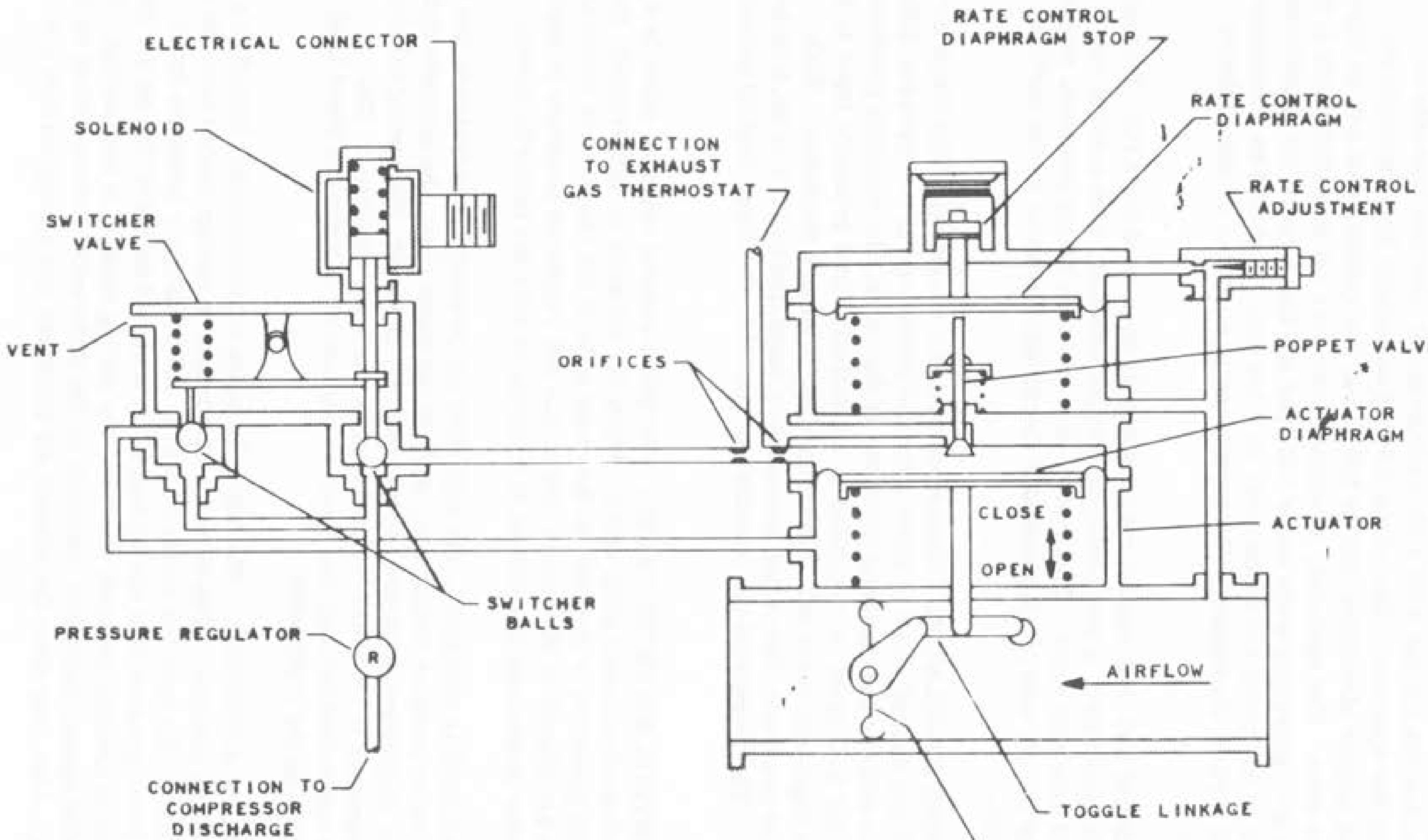
The bleed shutoff and load control valve assembly is part of the APU. It consists of a butterfly type valve, a pneumatic-type valve actuator, rate control valve, and bleed control solenoid valve. The system also includes an air pressure regulator located aft of the oil tank and a pneumatic thermostat mounted on the turbine exhaust flange.

AIR PRESSURE REGULATOR. Compressed air for operation of the bleed air load control and shutoff valve is taken from the second-stage compressor diffuser housing. To achieve the designed functions of the valve, the variable pressures taken from the APU must be regulated to a relatively fixed pressure input to the valve. The regulator valve is a diaphragm-type pressure regulator. With variable inlet pressure, the output pressure is regulated to 41.5 to 42.5 inches of mercury. This regulated air pressure is routed to the bleed control solenoid valve.

BLEED CONTROL SOLENOID VALVE. The bleed control solenoid valve is a two-position, solenoid-actuated pilot valve. When the solenoid is deenergized, the regulated air pressure is directed to the close side of the bleed valve actuator. No orifices are placed in the closed line so the full regulated pressure is applied to the actuator diaphragm in addition to a spring to hold the butterfly closed.

When the solenoid is energized, the regulated air pressure is directed to the open side of the valve actuator diaphragm, and, at the same time, the opposite side of the actuator diaphragm is vented to atmosphere. However, the spring tension must be overcome to move the valve towards the open position. The solenoid is controlled through the above 95 percent switch and the bleed load control switch on the APU panel.

BLEED VALVE ACTUATOR. The butterfly valve is mechanically linked to a diaphragm-type actuator. The actuator diaphragm is spring-loaded towards the closed position. To open the butterfly valve, the control air pressure must produce a force greater than spring tension. It should be noted that as the diaphragm moves towards the open position, the spring tension is increasing. How fast the valve opens, therefore, depends on the differential forces acting on the diaphragm. Also, any time the control air pressure and spring tension are



APU BLEED AIR LOAD CONTROL VALVE

balanced, the actuator diaphragm holds its position until the forces are out of balance.

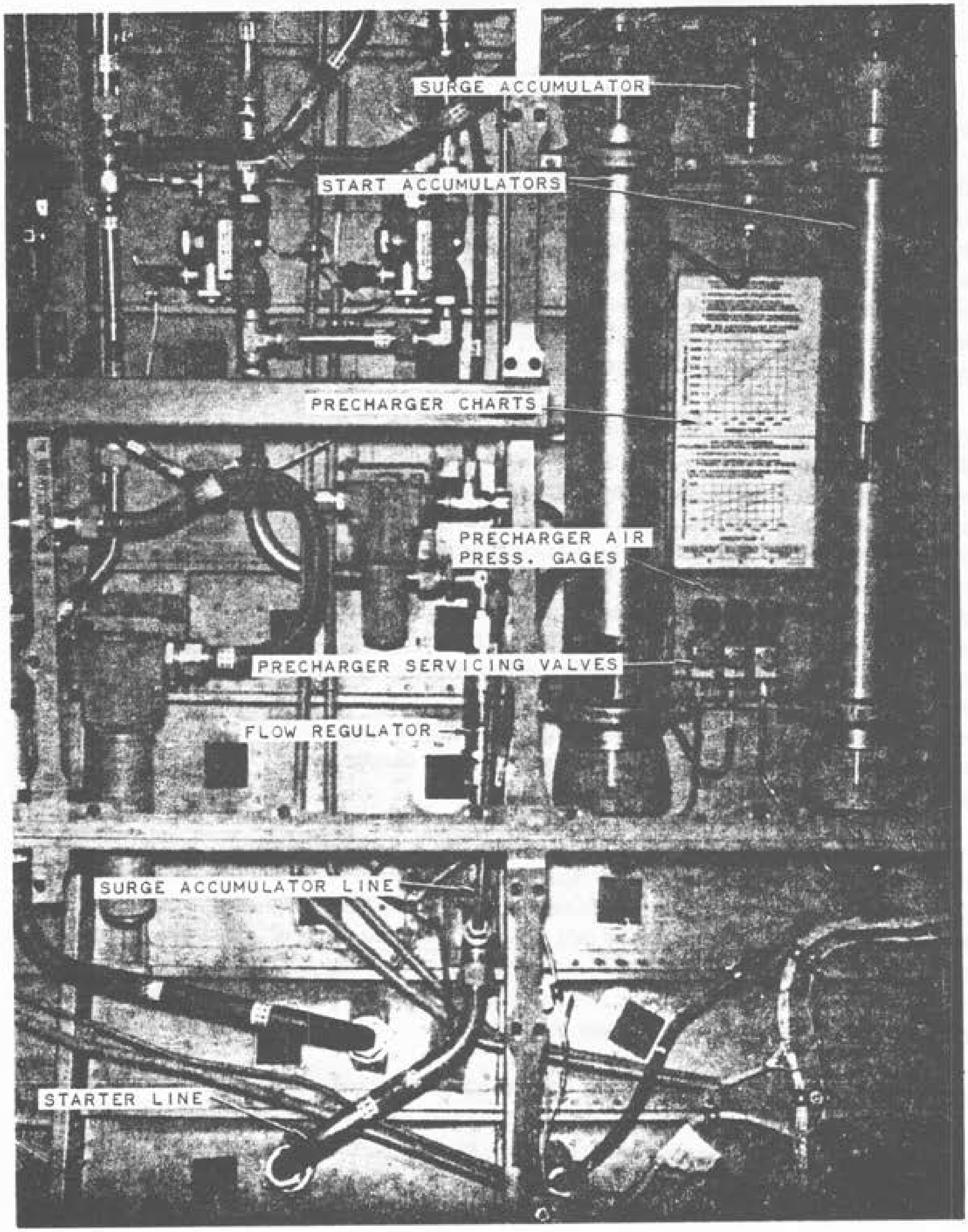
RATE CONTROL VALVE. This part of the bleed air shutoff and load control valve prevents the butterfly valve from being opened too rapidly when the valve is initially energized for bleed air "ON." When bleed air is selected and the butterfly valve starts to open, air pressure upstream from the butterfly valve decreases. This pressure drop controls the buildup of control air pressure on the actuator diaphragm. The poppet valve, located in the actuator chamber, can be unseated to allow some of the control air to leak out to the atmosphere. Control air enters the chamber through an orifice; therefore, the relationship between the size of the orifice and the opening of the poppet valve determines the pressure buildup on the actuator diaphragm.

The poppet valve is spring-loaded to the closed position. Movement of the poppet valve depends on movement of the rate control diaphragm. The rate control diaphragm is spring-loaded towards the poppet valve's closed position. Both sides of the rate control diaphragm are connected to the pressure sensing line. An adjustable orifice is located in the sensing line connected to the diaphragm chamber opposite the spring side. With equal pressure on both sides of the rate control diaphragm, the poppet valve is closed. As the butterfly valve opens and a pressure drop occurs upstream, it is sensed immediately on the spring side of the rate control diaphragm. The adjustable orifice causes a delay in the pressure drop on the other side of the diaphragm. The differential pressure applied to the rate control diaphragm overcomes spring tension and opens the poppet valve which, in turn, decreases the air pressure on the actuator diaphragm. This action controls the rate of opening of the butterfly valve.

The rate control adjustment (adjustable orifice) is a field adjustment. The smaller the orifice the greater the differential pressure across the rate control diaphragm which causes more movement of the poppet valve and an increase in time for the butterfly valve to drive full open. The rate control adjustment must be set to allow the butterfly valve to open and fully load the APU in no less than 9 seconds or more than 10 seconds. The rate allows the APU to fill the aircraft pneumatic system without overloading the unit.

BUTTERFLY VALVE MODULATION. Modulation of the butterfly valve occurs when the valve takes a position other than full open as a result of overloading the APU. Moving the butterfly valve towards the closed position decreases the bleed airflow away from the APU. This action is desired when a predetermined turbine exhaust gas temperature is reached.

A pneumatic thermostat mounted on the turbine exhaust flange is connected to the control air pressure line. This thermostat functions identically to the one used in the fuel system acceleration and overtemperature control. The only difference



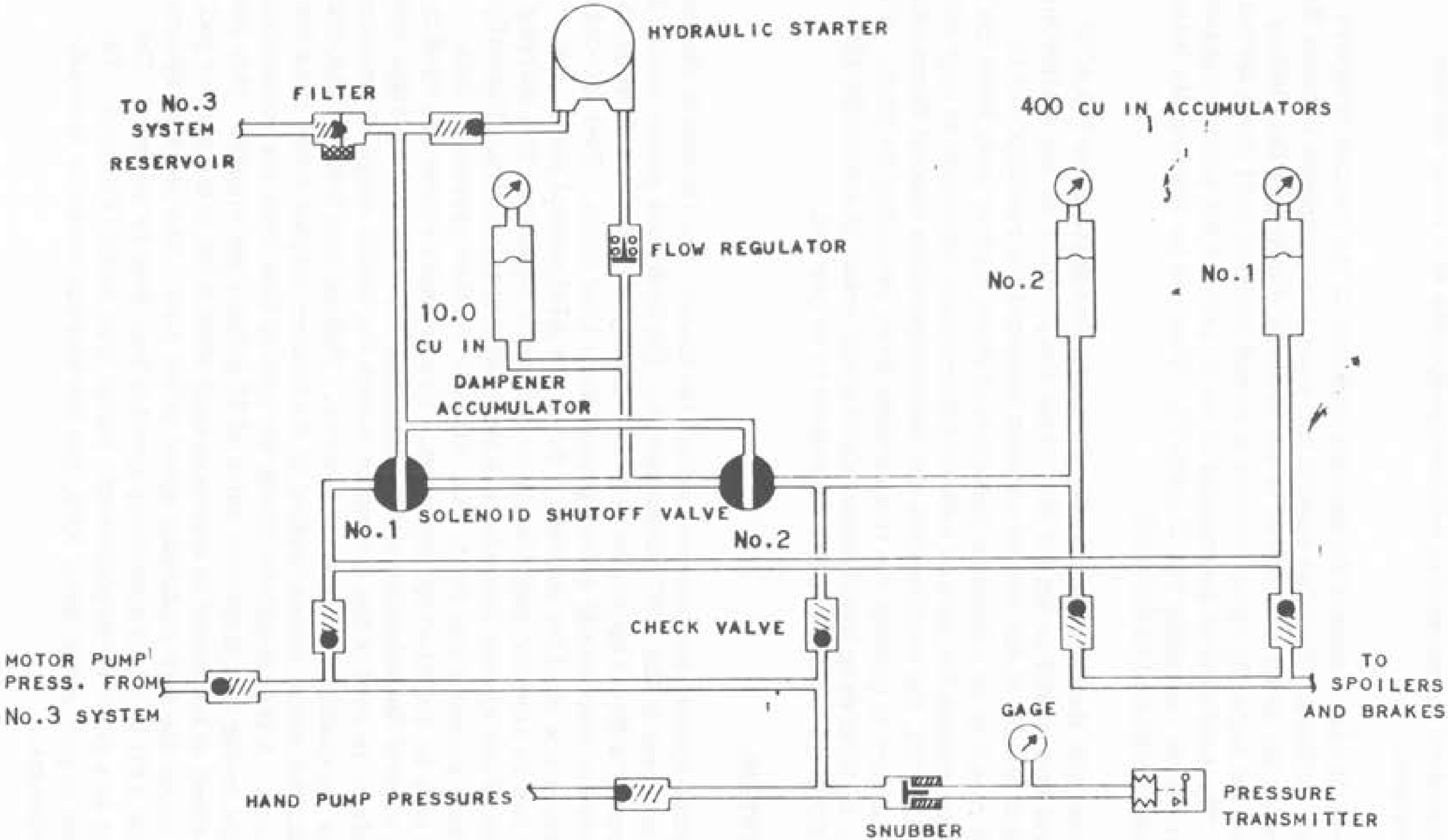
APU - HYDRAULIC STARTING SYSTEM - CARGO COMPARTMENT - LEFT SIDE is that the load control thermostat is adjusted to operate at a lower turbine exhaust temperature.

The air line from the load control thermostat connects to the control pressure line between two orifices. Bleeding control air away to atmosphere between the orifices decreases the pressure applied to the actuator diaphragm thus letting the spring drive the butterfly valve towards a closed position until those forces are balanced. The load control thermostat is set to prevent the turbine exhaust gas temperature from exceeding 675°C (1250°F). This can be functionally tested and the thermostat adjusted in the field.

Both of the pneumatic thermostats function as protective devices for the APU. The load control thermostat is set for the lowest temperature so any malfunction or operation that results in the turbine exhaust temperature reaching 675°C (1250°F) would result in an automatic reduction of bleed airflow away from the APU. If, for any reason the turbine exhaust temperature increased to approximately 705°C (1247°F), the acceleration and overtemperature control thermostat would reduce fuelflow to prevent the temperature from exceeding its limit. If the later occured, an RPM drop would occur which could result in automatic shutdown of the APU in the event the RPM decreased to 95 percent.

STARTING SYSTEM.

All of the starting system components, except the motor, are located in the cargo compartment adjacent to the APU compartment. The hydraulic power source is part of the aircraft's No. 3 hydraulic system. The system has two sources of hydraulic pressure: electrically driven pumps and a hand pump. Two 400-cubic inch accumulators are used for starting. From the APU control panel, the accumulators can be selected individually or both used together. The starting characteristics of the system depends on atmospheric temperature. Normally, each accumulator provides one start, but, for cold weather operation, both accumulators may be required for one start. Two solenoid valves are used in the system to control the selection of the accumulators. A small 10-cubic inch surge accumulator is used in the system to absorb the initial surge of pressure which protects the clutch in the starter adapter. Without this feature, the clutch would slip from the initial torque applied to the starter adapter every time the starter was used. A flow regulator limits the rate of flow from the accumulators to the hydraulic motor to a maximum value of 16 gallons per minute. This limits the cranking speed of the motor to approximately 9000 RPM at the starter pad. This RPM is above the self-sustaining speed of the APU. The starting system accelerates the APU to a self sustaining speed in less than 10 seconds. The starting motor is a positive-displacement, piston type pump (Vickers). The starter adapter is part of the basic APU, but the starting motor is aircraft-furnished equipment.



APU TWO START SYSTEM (6006 & UP)

SOURCES OF PRESSURE. The No. 3 system can be pressurized by electric, motor-driven pumps which pressurizes the accumulators to 3000 PSI. This pressure provides a start from each accumulator at atmospheric temperatures above -17.7℃ (0°F). At atmospheric temperatures from -29 to -17.7℃ (20 to 0°F) it is necessary to use the hand pump to place a full charge of 3560 PSI in the accumulators to provide a two-start capability. At temperatures below -29℃ (20°F), the system should be used as a one-start system with the accumulator selector switch in the "BOTH" position.

CHECK VALVES. Check valves are located between the pressure source and the accumulators to prevent the pressure from bleeding off back through the pumps.

ACCUMULATORS. Two, 400-cubic inch piston-type accumulators are used in the system. Each accumulator's capacity is adequate for one start under normal conditions. They require an air charge of 2140 PSI at 33.3℃ (100°F) ambient temperature. A chart is located in the aircraft between the two accumulators which reflects the required precharge in relation to atmospheric temperature. Air used for the precharge must be clean dry air or nitrogen. The hydraulic system pressure must be zero when checking the air charge or when servicing. Precharge pressure gages and servicing valves are located between the accumulators.

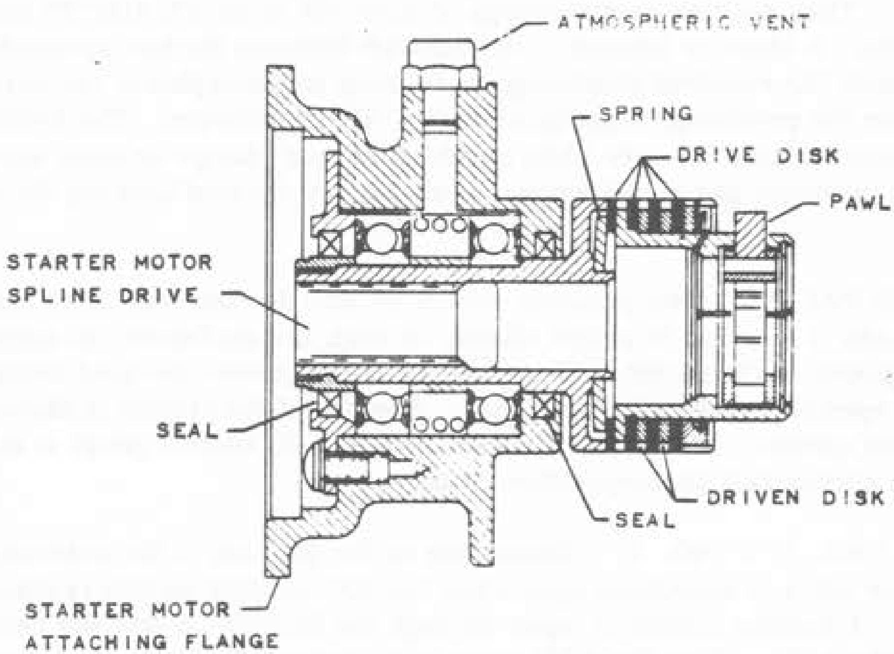
SELECTOR VALVES. Two selector valves located downstream from each accumulator make it possible to select either, or both accumulators, to supply hydraulic power to the motor. These valves are solenoid-operated being energized open and spring-loaded closed. Control of the circuit is through the APU control circuit. The selector switch on the APU control panel at the flight engineer's station is a three-position switch.

"BOTH" - "NO. 2" - "NO. 1." Depending on the position of the selector switch, the selector valve is energized open when the APU control switch is placed to "START." A holding circuit is made through the BELOW 35 percent centrifugal switch on the APU. When the APU exceeds 35 percent RPM, the selector valve is deenergized.

FLOW REGULATOR. The flow regulator is downstream from the two selector valves. It automatically limits the flow to 16 gallons per minute. Because the starter motor is a positive displacement type, the maximum RPM that it can be rotated is directly proportional to the rate of flow. When the starter is used to moter the APU, the limit on the rate of flow determines the maximum cranking RPM.

SURGE ACCUMULATOR. The surge accumulator is a 10-cubic inch accumulator provided in the system to absorb the initial surge of pressure applied to the starter when the selector valve is energized open. It allows the starter motor to get the APU rotating without exceeding the torque limit of the clutch. Without the surge accumulator, clutch slippage would probably occur each time the APU is started and would decrease the serviceable life of the starter clutch.

STARTER MOTOR. The starter motor is aircraft-furnished equipment and has to be installed on an APU before installation in the aircraft. The motor is a series of pistons which converts hydraulic power to mechanical rotation of the output shaft. For each revolution of the pump, the total piston displacement is a given amount; therefore, the maximum cranking speed of the starter motor is normally limited by the flow regulator limit of 16 gallons per minute. Fluid is returned from the motor through a filter to the No. 3 system reservoir. The starting system plumbing is of large diameter to keep the line drop of hydraulic pressure to a minimum. The starter motor output shaft splines to the starter adapter.



STARTER MOTOR ADAPTER ASSEMBLY

STARTER ADAPTER. The starter adapter is located on the APU accessory section at the top right hand side, opposite the cooling fan. The gear train from the adapter to the APU rotor assemblies is a reverse drive through the cooling fan drive gears. The adapter contains the clutch assembly and the starter driven pawls. The input shaft, which the starter motor splines into has the clutch housing opposite the splined drive end. It is supported in the adapter housing by two ball bearings. The area between the two bearings and seals is packed with grease. This area is also vented to atmosphere. The clutch is a spring-loaded disk type clutch. Spring tension is set so that clutch slippage occurs at approximately 230 to 250 inch-pounds. The clutch driven spider has three pawls attached to it. Centrifugal force engages the pawls with the dog which is attached to the fan shaft.

The clutch is a protective device which allows slippage in the event the APU has a mechanical defect and would not rotate or required too much torque for rotation.

The pawls and dog have no direct mechanical connection which allow the APU to overrun the pawls. Normally, when the starter is cutout at 35 percent, the pawls loose their centrifugal force which disengages them from the dog. Should the starter remain in operation, the APU gear train would turn the dog faster than the pawls and the pawls would ratchet around the dog. This arrangement prevents the APU from driving the starter motor.

The starter adapter is field repairable. A parts kit is supplied which contains the components most subject to wear.

EGT INDICATING SYSTEM.

The turbine exhaust gas temperature indicating system used on the APU is similar to that for the aircraft engines. The system uses one thermocouple with the standard alumnel-chromel circuit to the indicator mounted on the APU control panel. An integrated type indicator is used in the system. The amplifier is built into the instrument case. The thermocouple generates a voltage in direct proportion to the temperature of the turbine exhaust gas. This voltage, applied to the amplifier, results in the amplifier output directing the indicator to indicate the temperature of the exhaust gas in degrees centigrade. The indicator is calibrated, to indicate correctly, by applying accurate heat values to the system. The face of the indicator has a flag which warns the operator of a loss of A-C power input to the indicator.

The thermocouple is mounted on the turbine exhaust flange. It is mounted in a case which has three holes. The thermocouple is installed with the two small holes directed upstream and the one large hole directed downstream. The electrical connections are color-coded. In addition, the terminals are of a different size to ensure that proper connections are made. The terminal studs are also identified with the abbreviations CHR and AL etched on the base of the thermocouple.

IGNITION SYSTEM.

One ignitor plug and one ignition unit are used on the APU for igniting the fuel air mixture during the starting cycle. The system is energized and deenergized by the APU electrical control system. The oil pressure sequencing switch must have 3.5 PSI pressure to close its contacts before the ignition unit is energized. The below 95 percent switch, of the centrifugal switch assembly, makes a holding circuit and deenergizes the ignition unit when the APU exceeds 95 percent RPM.

The ignition unit is mounted on the lower right side of the compressor plenum. It is a capacitor-discharge type unit. Repairs on the unit are not recommended. It operates normally with an input of 14 to 30 volts, DC. The voltage is stepped up to approximately 18,000 volts DC.

The duty cycle of the ignition unit must not be exceeded since it is designed for intermittant duty only. The limits are 2 minutes on, 3 minutes off, 2 minutes on, and 23 minutes off. During a normal start, the system is only energized for approximately 20 seconds.

The minimum voltage for operation of the ignition unit is one of the functions that establishes minimum volgage supply to the APU for operation. A high-tension lead from the ignition unit connects to the ignitor plug which is attached to the combustor cap assembly.

The ignitor plug is similar to any other plug used in gas turbine engines. It may be cleaned and inspected for cracked or missing insulation material. The center electrode must protrude a minimum of 0.04 inches above the insulation to continue in service. The plug is self gapping. It is recommended that the plug not be disassembled. When it fails to function, it should be replaced with a like item.

ELECTRICAL CONTROL SYSTEM.

The electrical power supply for the APU control circuits is taken from the aircraft's insolated D-C bus; therefore, no external electrical power is required for APU operation. It is only necessary that the aircraft batteries supply at least 14 volts DC to the system. The APU control circuit has many safety features and a minimum of electrical control switches. Once the automatic start is initiated, the operator is only required to monitor, exhaust gas temperature; select bleed air when indicator light indicates APU is ON SPEED, check for normal bleed air pressure, and be alert for atuomatic shutdown.

The following electrical control system components are installed in the aircraft and are not part of the basic APU:

- Emergency Fire Handles
- Touchdown Relays
- Intake and Exhaust Door Actuators and the Related Microswitches
- APU Fuel Shutoff Relay and Motor Driven Valve

- o Hydraulic Starting Selector Solenoid Valves
- *o APU Door Control Switch
- *o APU Control Switches
- *o Door Light (amber)
- *o Start Light (green)
- *o On-Speed Light (green)
- *o Bleed Airload and Flow Control Valve Switch
- *o APU Accumulator Selector Switch

* Located on APU control panel

The following components are mounted on the APU and are component parts of the APU:

- o Bleed Air Valve Solenoid
- o Fuel Solenoid Shutoff Valve
- o Ignition Unit
- o Start Counter
- o Hour Meter
- o Acceleration Limiter Solenoid
- o Oil Pressure Sequencing Switch
- o Low Oil Pressure Switch
- o High Oil Temperature Switch
- o Centrifugal Speed Switch
- o High Oil Temperature Relay
- o Holding Relay No. 1
- o Holding Relay No. 2
- o Overspeed Test Light

APU CONTROL PANEL - FLIGHT ENGINEER STATION

APU FIRE EXTINGUISHING PANEL - CARGO COMPARTMENT

FIRE HANDLES. There are two fire handles: one located in the cargo compartment just aft of the crew entrance door and the other at the bottom of the APU control panel. The APU control circuit from the isolated D-C bus passes through the normal position of both fire handles in a series circuit; therefore, both fire handles must be in their normal position to obtain a complete circuit to the APU electrical system for starting and operation. Pulling either fire handle when the APU is operating results in automatic shutdown of the APU (deenergize the fuel solenoid valve - deenergize the APU fuel shutoff relay), and complete a door close circuit which will close the intake and exhaust doors when the APU oil pressure drops below 3.5 PSI.

APU DOOR CONTROL SWITCH. The switch is in series with the fire handles normal position. The door open circuit is through the ground position of No. 3 touchdown relay to the open microswitch of both the intake and exhaust doors and their respective actuators. The normal door close circuit passes through the "OFF" position of the APU control switch to the oil pressure sequencing switch. It then goes through intake and exhaust doors closed microswitches and their respective actuators.

To open the APU intake and exhaust doors, the fire handles must be in their normal position and the aircraft must be on the ground.

To close the doors normally, the APU control switch must be in the off position and the oil pressure sequencing switch actuated (APU oil pressure below 3.5 PSI). Two other circuits that are wired parallel to the door control switch and the APU control switch may be used to close the intake and exhaust doors. One of the circuits is energized when either fire handle is pulled. The other is energized by the No. 6 touchdown relay if an aircraft takes off with the doors open. The oil pressure sequencing switch is always in the door CLOSE circuit.

TOUCHDOWN RELAYS. The No. 6 relay is in the APU intake and exhaust door close circuit and ensures that the doors will be closed for aircraft flight. The No. 3 touchdown relay serves two functions. The power circuit to the APU control switch passes through one set of ground position contacts and the door open circuit through the other.

The aircraft must be on the ground to open the APU doors and also to supply power to the APU control switch. Should an aircraft take off with the APU operating, the No. 3 touchdown relay deenergizes the APU control circuit (APU shutdown), and the No. 6 touchdown relay closes the doors.

INTAKE AND EXHAUST DOOR MICROSWITCHES. The two OPEN switches are parallel to each other and in series with their respective actuator open windings.

The two NOT CLOSED switches are parallel to each other and in series with the door NOT CLOSED light. As soon as either door moves out of the closed position, the light is grounded by these switches. Because the two switches are in parallel, both doors must be fully closed to extinguish the NOT CLOSED light. When the doors are closed, the NOT CLOSED switches ground both start valve circuits for an additional safety feature to prevent APU starter operation and possible APU operation with either door not open.

When the doors are open, the intake and exhaust door NOT OPEN switches complete the circuit supplying D-C power to the APU control switch. Both switches are in series: if either door fails to open the power circuit to the APU control switch is open and the APU cannot be started.

CENTRIFUGAL SWITCH ASSEMBLY. The centrifugal switch assembly is an APU mechanically driven accessory mounted on the left side of the accessory housing adjacent to the oil cluster. It consists of APU driven flyweights which operate three microswitches in sequence at 35 percent, 95 percent and 110 percent. It controls the sequence of operation of the various APU control units at the appropriate operating speeds. The switch has a mechanical control provided for checking continuity of the overspeed circuit when the APU is static. With electrical power ON, door OPEN, and the APU control switch "OFF," actuating the manual overspeed test should illuminate the green light mounted on the panel between the oil cooler and oil tank.

APU CONTROL SWITCH. The control switch is a three-position switch located on the APU control panel. The positions are "OFF," "RUN," and "START." The switch is spring-loaded from the "START" to the "RUN" position. To have a complete circuit to the control switch, both fire handles must be in normal. The touchdown relays must be in the ground position and both the intake and exhaust doors must be open. Those components are in series from the bus to the control switch; therefore, any one of them can prevent APU operation.

The "OFF" position of the switch completes two circuits. The normal door close circuit and the overspeed manual test circuit. When the APU control switch is in "START" or "RUN" position, the door control switch cannot close the doors even if the oil pressure sequencing switch is faulty. This arrangement prevents closing the doors when the APU is operating. The oil pressure sequencing switch serves the same purpose. The manual overspeed test circuit is completed to the 110 percent side of the 110 percent switch. When the overspeed switch is manually operated, a circuit is completed back through the APU control switch and returned to the GREEN indicator light on the APU. Manual overspeed test is a preflight item necessary to ascertain that an actual APU results in automatic shutdown of the APU. Overspeed of the compressor and turbine rotors can result in destruction of the APU. Aircraft damage, fire, or possible personnel injuries could result from destruction of the APU.

The "START" position indicates the automatic starting circuit. The switch must be held momentarily until holding relay No. 1 is energized. Placing the switch to start completes circuits to the fuel shutoff relay (opens the valve) through the below 110 percent switch and below 35 percent switch to energize the selected start valve, acceleration limiter solenoid, and illuminates the start light. From the below 110 percent switch, through the deenergized contacts of holding relay No. 2, a circuit energizes holding relay No. 1. After holding relay No. 1 energizes, another circuit is completed through the high oil temperature relay and holding relay No. 1 so that the control switch can be released to the "RUN" position.

The "RUN" position keeps a complete circuit to the APU fuel shutoff relay and the control circuit.

35 PERCENT SWITCH. When the APU exceeds 35 percent, the circuit to the start selector valves, acceleration limiter solenoid, and start light is deenergized.

OIL PRESSURE SEQUENCING SWITCH. When the APU oil pressure reaches 3.5 PSIG, a circuit is completed from holding relay No. 1 through the oil pressure sequencing switch, to energize the fuel solenoid, and through the below 95 percent switch, to energize the ignition unit. Fuelflow to the nozzle and ignition cannot occur without oil pressure.

95 PERCENT SWITCH. The below 95 percent switch has two functions: It completes the ignition circuit and an A-C generator underfrequency circuit to prevent loading the A-C generator until the APU is on speed.

When the switch is positioned to about 95 percent, the ignition unit is deenergized, and the A-C generator can supply power to the aircraft. The bleed air load switch is then armed, the on speed light illuminated, the hourmeter and start counter energized, and holding relay No. 2 energized to complete a circuit to energize the acceleration limiter solenoid. Now, the APU can be loaded (bleed air and electrical) and it will operate under automatic control.

HIGH OIL TEMPERATURE SWITCH. If the APU oil temperature exceeds 118 to 124°C (245 to 255°F), the oil temperature switch energizes the high oil temperature relay. This action deenergizes the holding circuit for holding relay No. 1 which deenergizes the fuel solenoid. Fuelflow cuts off and the APU stops.

HOLDING RELAY NO. 1. Holding relay No. 1 keeps the fuel solenoid energized after the oil pressure sequencing switch closes (3.5 PSIG oil pressure) and completes the holding circuit for its own armature.

BELOW 110 PERCENT SWITCH. The below 110 percent switch is in series with the holding circuit for holding relay No. 1. If the APU exceeds 110 percent, holding relay No. 1 deenergizes to automatically shutdown the APU.

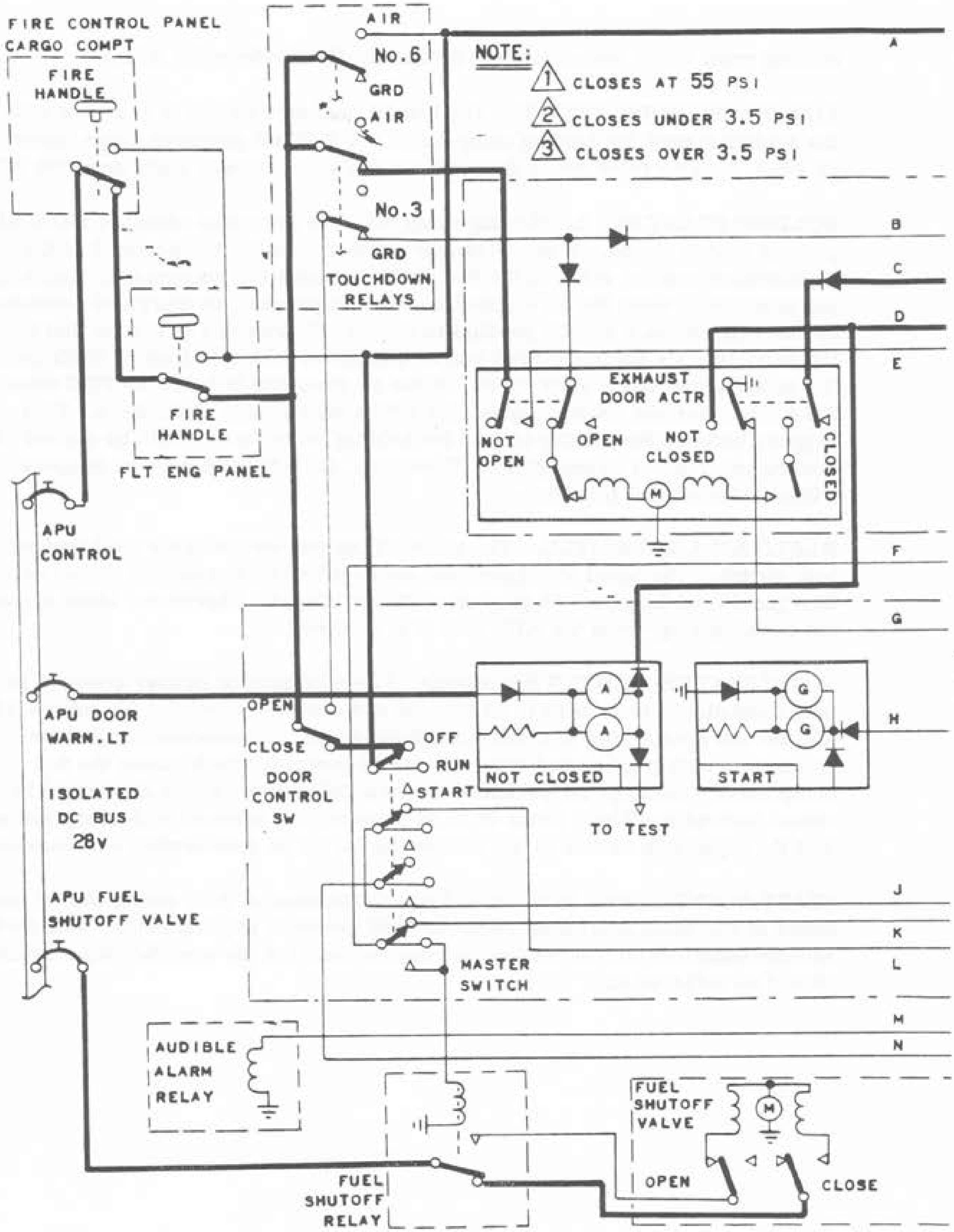
LOW OIL PRESSURE SWITCH. The low oil pressure switch is in series with the holding circuit for holding relay No. 1. If APU oil pressure drops below 55 PSIG, holding relay No. 1 deenergizes and automatically shuts down the APU.

HOLDING RELAY NO. 2. Holding relay No. 2 is energized when the above 95 percent switch closes. It energizes the acceleration limiter solenoid so the acceleration control valve on the fuel cluster senses full compressor discharge air pressure. When the APU speed is below 95 percent, deenergized contacts of this relay make a circuit parallel to the low oil pressure switch so that holding relay No. 1's holding circuit can be completed with less than 55 PSIG during the initial phase of the start cycle. If the oil pressure is below 55 PSIG when the APU 95 percent switch closes, the APU automatically shuts down. This happens because the holding circuit for holding relay No. 1 would be opened when holding relay No. 2 is energized. Therefore, the APU will not run on speed without adequate oil pressure.

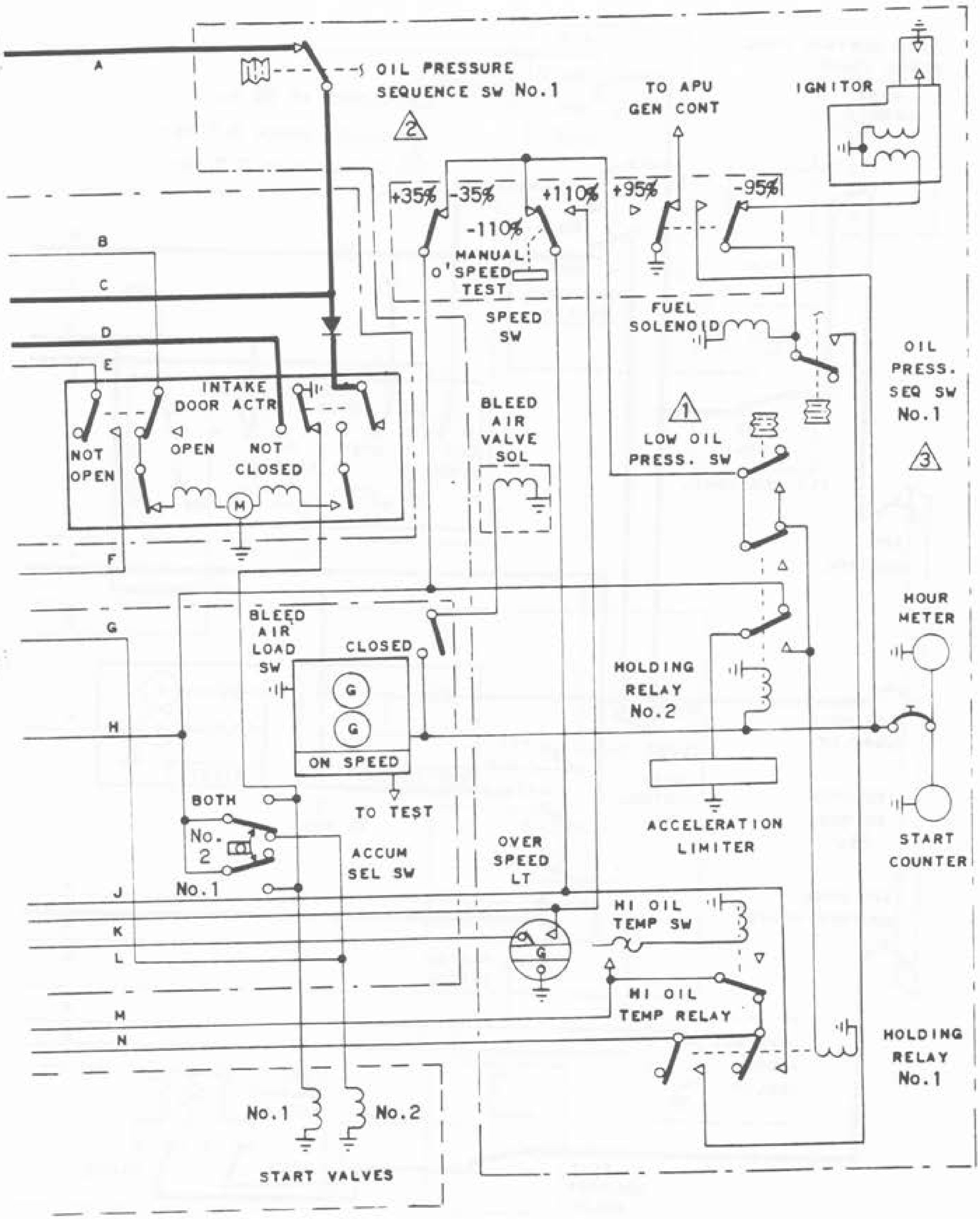
BLEED AIR LOAD SWITCH. The above 95 percent switch arms the bleed air load switch. The bleed air shutoff and load control valve solenoid cannot be energized until the above 95 percent switch is closed. Therefore, bleed air cannot be taken away from the APU until it is on speed.

ACCELERATION LIMITER SOLENOID. The acceleration limiter solenoid is energized closed from zero to 35 percent and above 95 percent. To get the APU started and accelerated to a self-sustaining speed, the acceleration limiter solenoid is energized closed from zero to 35 percent, which places the full compressor discharge air pressure on the acceleration control diaphragm to obtain desired fuelflow. From 35 to 95 percent, the solenoid is deenergized so that the adjustable orifice is the controlling factor on acceleration characteristics.

START COUNTER AND HOUR METER. The number of APU starts and/or total hours of operation determine inspection and overhaul requirements. Manufacturers recommendations and/or inspection requirements for the specific requirements should be referred to.



DC POWER "ON" DOOR CONTROL SWITCH "CLOSE" CONTROL SWITCH "OFF"


A
OIL PRESSURE
SEQUENCE SW No.1
2
TO APU
GEN CONT
IGNITOR
B
C
+35%
-35%
+110%
+95%
-95%
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No.1
3
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G
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LOAD
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HOUR
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RELAY
No.2
H
ON SPEED
TO TEST
BOTH
No.
2
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ACCUM
SEL SW
OVER
SPEED
LT
ACCELERATION
LIMITER
START
COUNTER
J
K
L
HI OIL
TEMP SW
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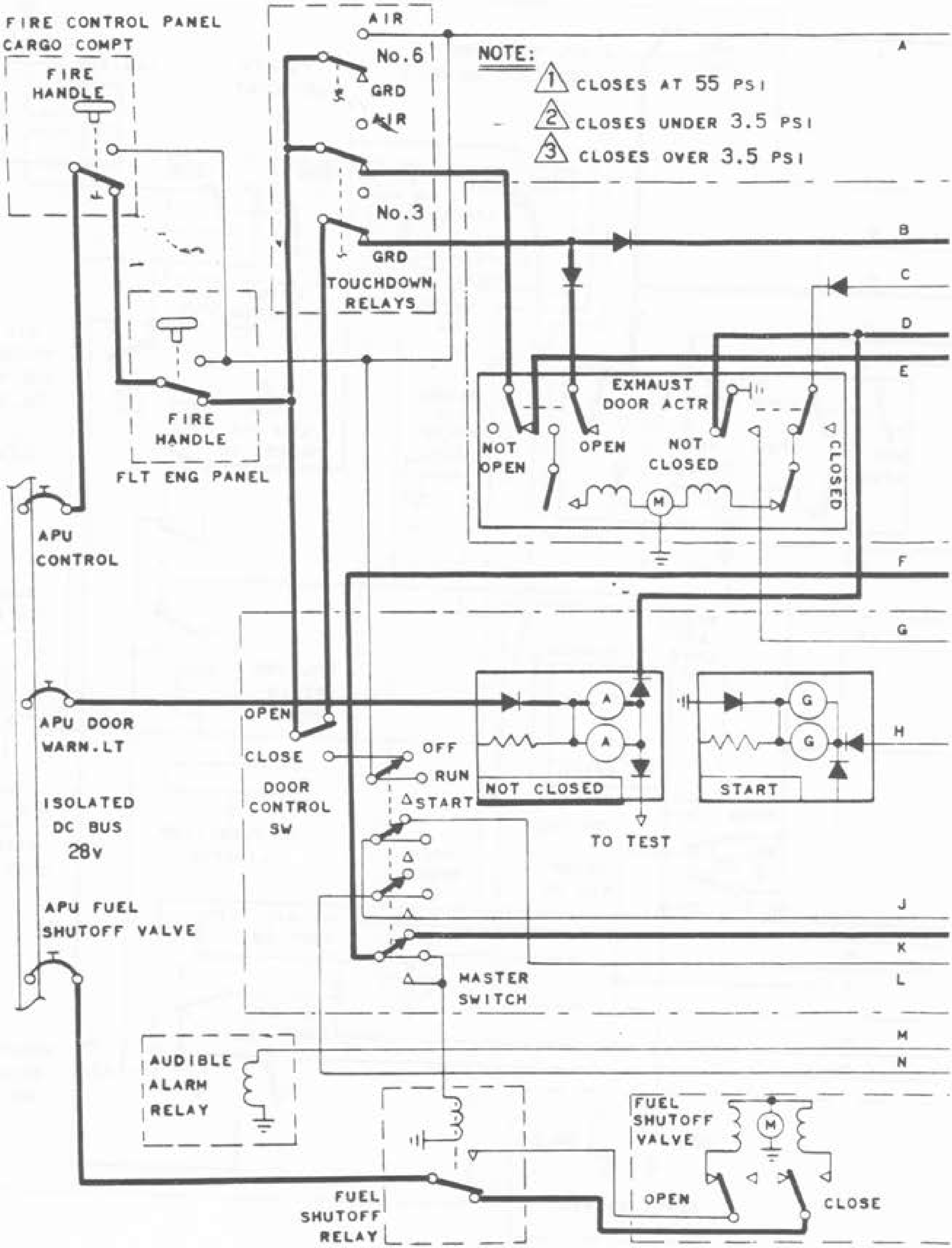
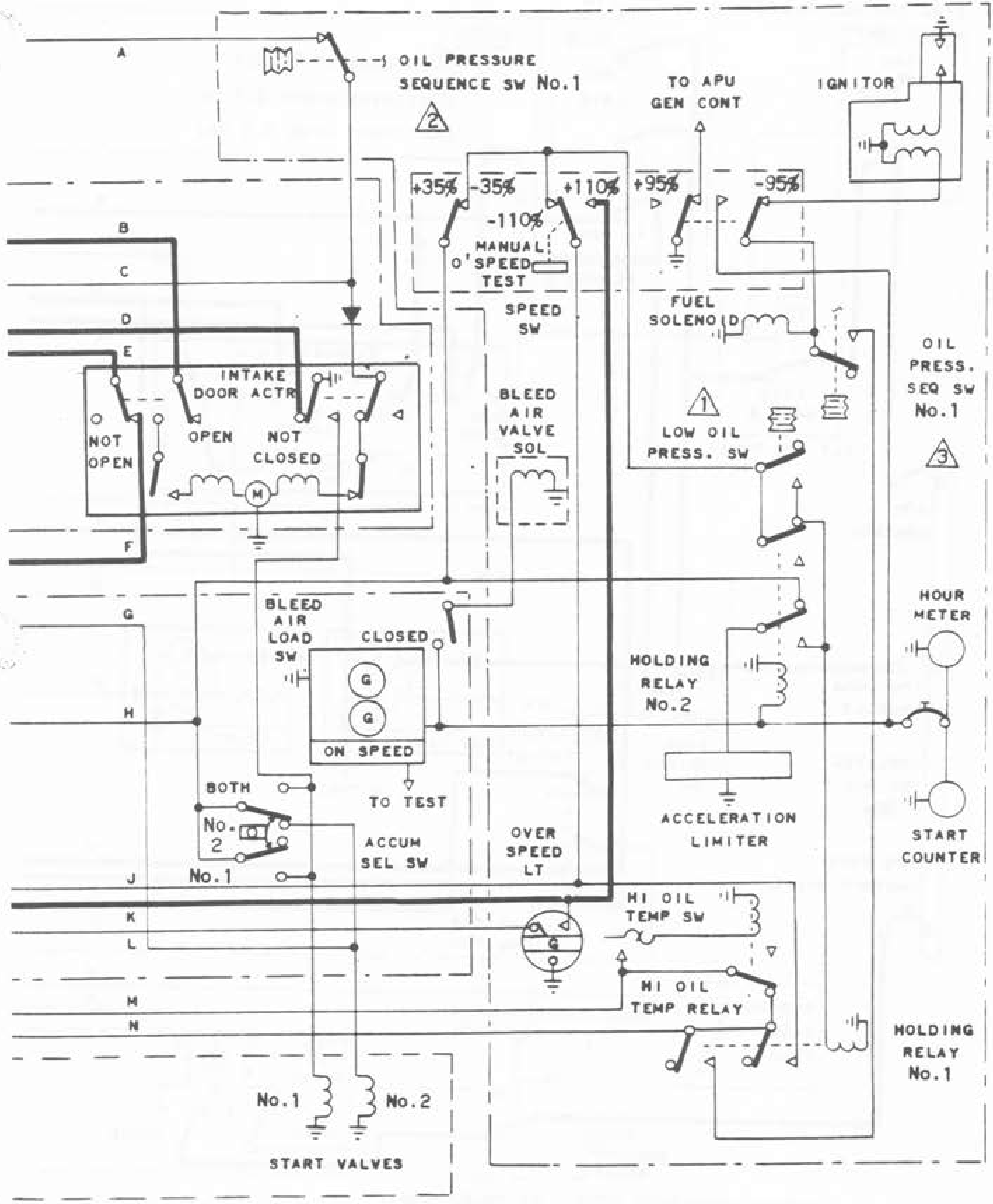
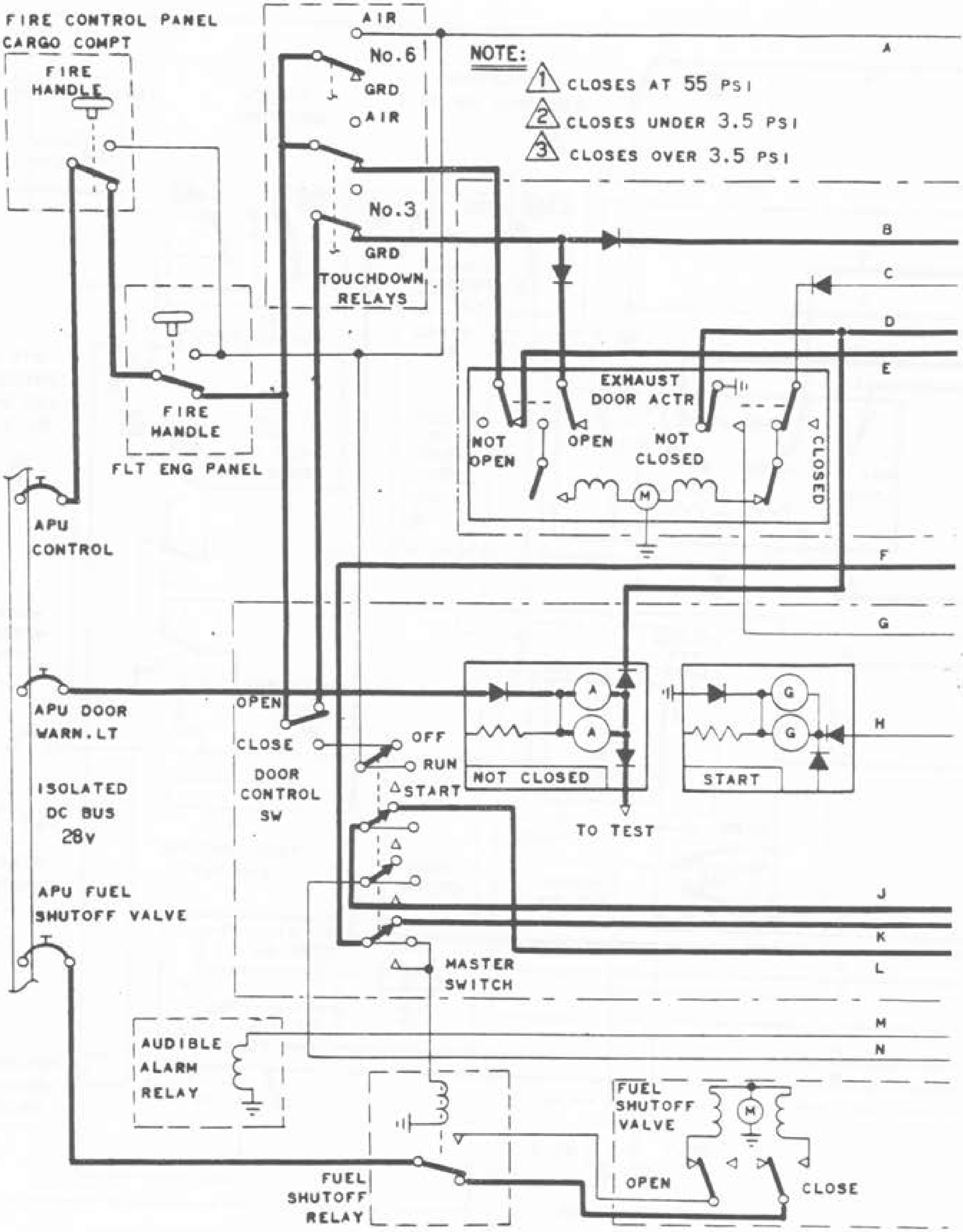
RELAY
No.1
No.1
No.2
START VALVES



DC POWER "ON" DOORS OPEN

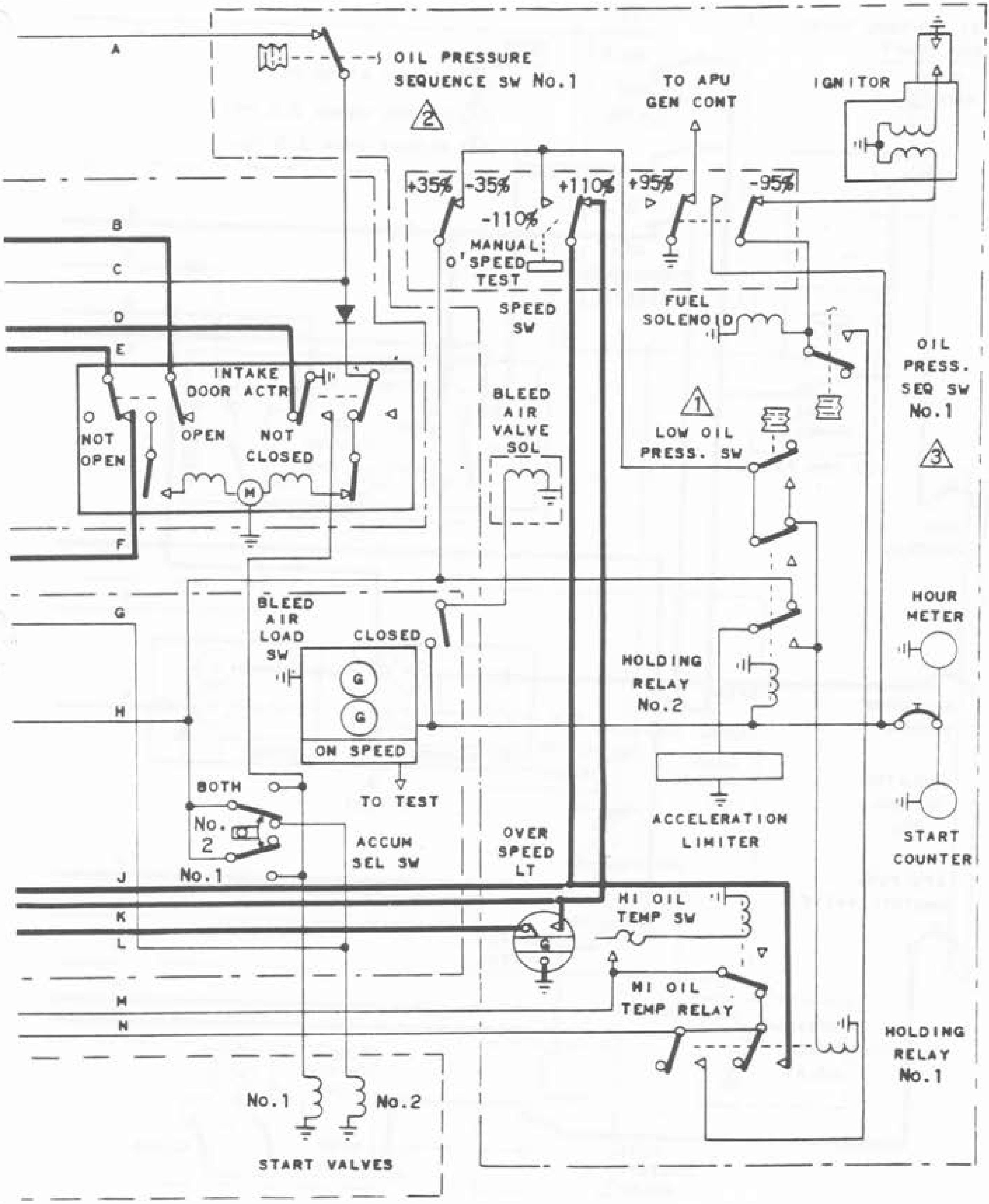
DOOR CONTROL SWITCH "OPEN" CONTROL SWITCH "OFF"


A
OIL PRESSURE SEQUENCE SW No.1
2
TO APU GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL O'SPEED TEST
B
C
D
E
SPEED SW
FUEL SOLENOID
OIL PRESS. SEQ SW No.1
INTAKE DOOR ACTR
NOT OPEN
OPEN
NOT CLOSED
BLEED AIR VALVE SOL
1
LOW OIL PRESS. SW
3
F
G
BLEED AIR LOAD SW
CLOSED
HOUR METER
HOLDING RELAY No.2
H
ON SPEED
TO TEST
BOTH
No. 2
No.1
ACCUM SEL SW
ACCELERATION LIMITER
START COUNTER
OVER SPEED LT
J
K
L
HI OIL TEMP SW
M
N
HI OIL TEMP RELAY
HOLDING RELAY No.1
No.1
No.2
START VALVES



MANUAL OVERSPEED TEST
DOOR CONTROL SWITCH "OPEN"

DC POWER "ON"
CONTROL SWITCH "OFF"



A
OIL PRESSURE
SEQUENCE SW No.1
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TO APU
GEN CONT
IGNITOR
B
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL
O'SPEED
TEST
C
SPEED
SW
FUEL
SOLENOID
D
E
INTAKE
DOOR ACTR
NOT
OPEN
OPEN
NOT
CLOSED
M
BLEED
AIR
VALVE
SOL
1
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PRESS. SW
OIL
PRESS.
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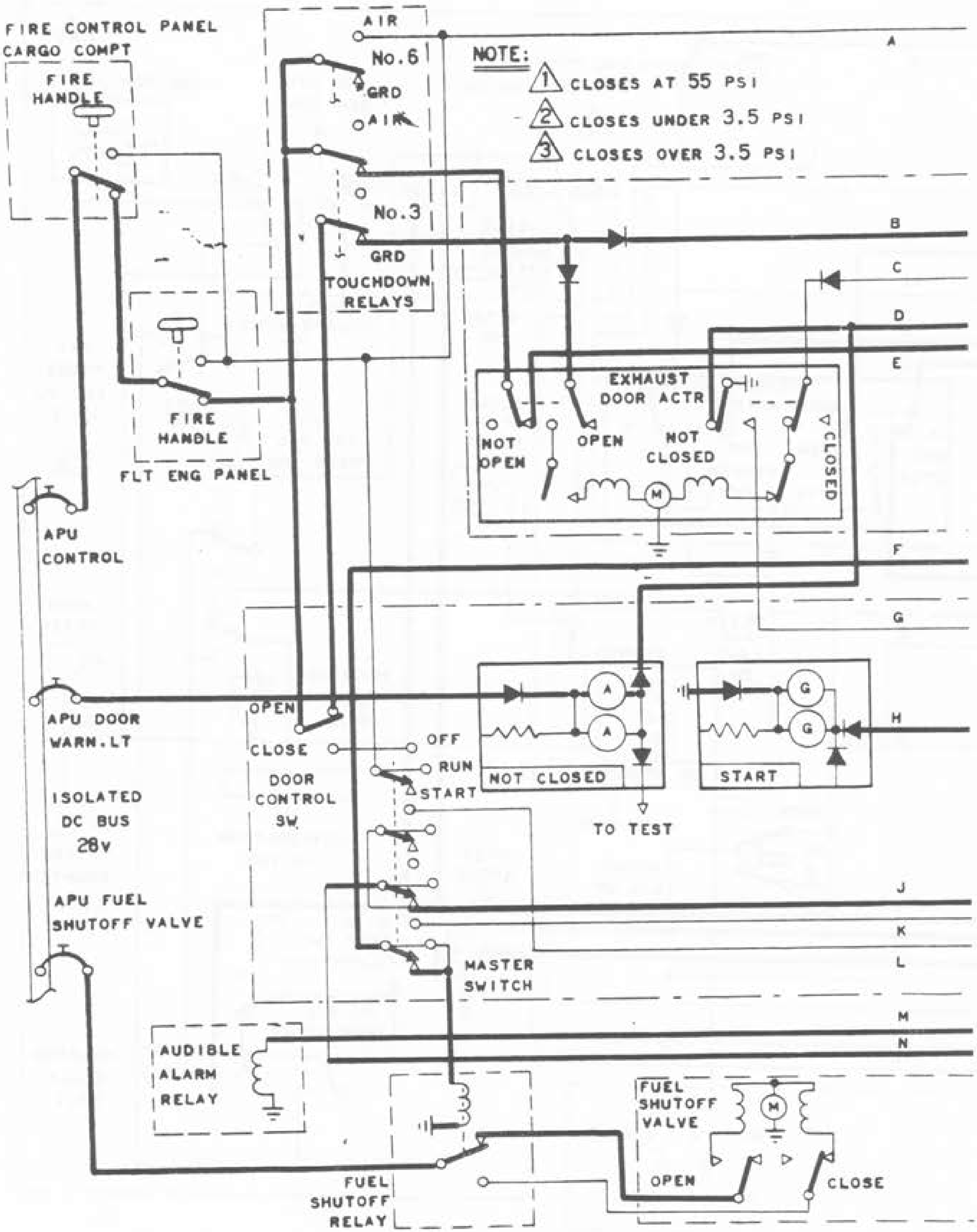
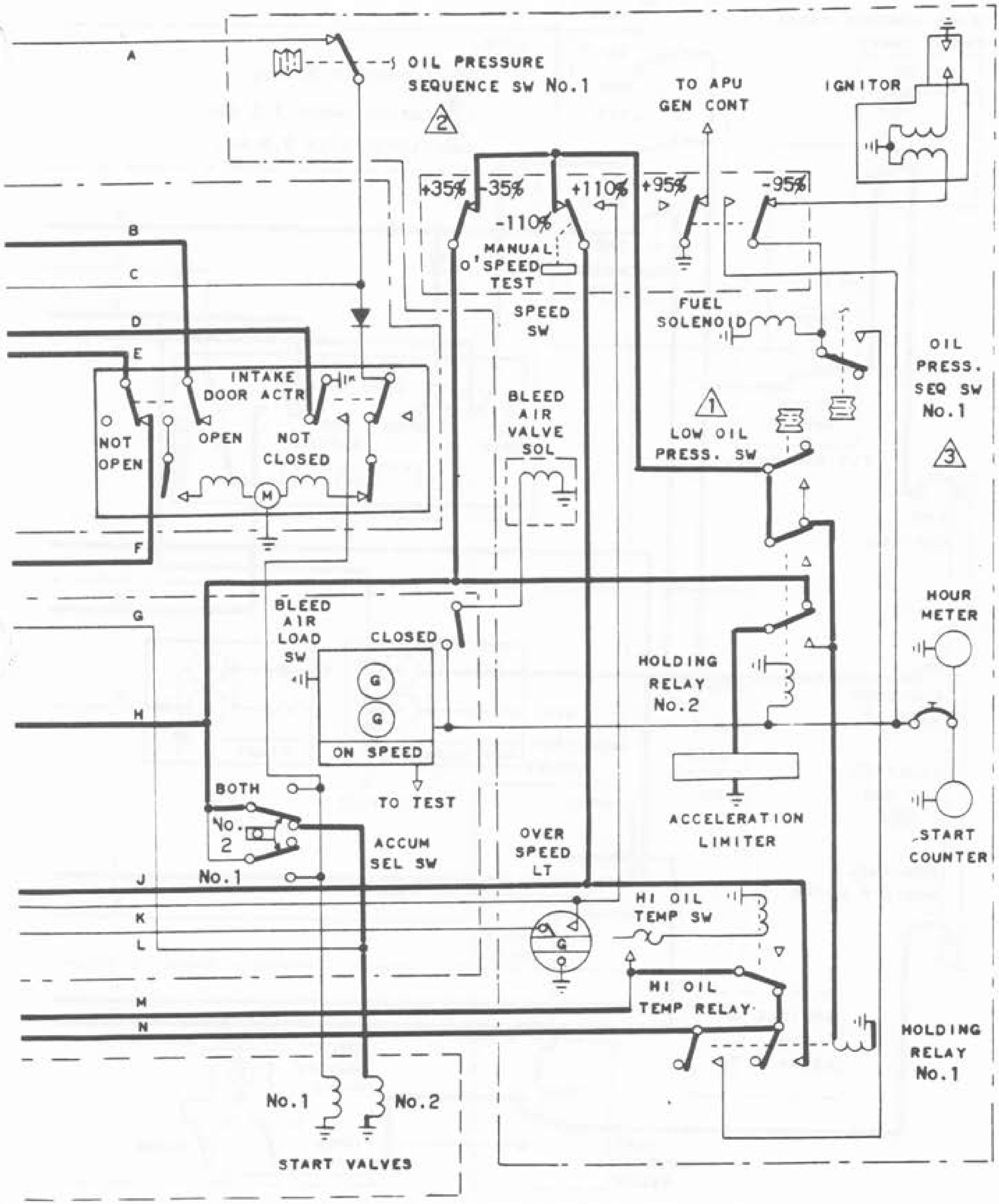
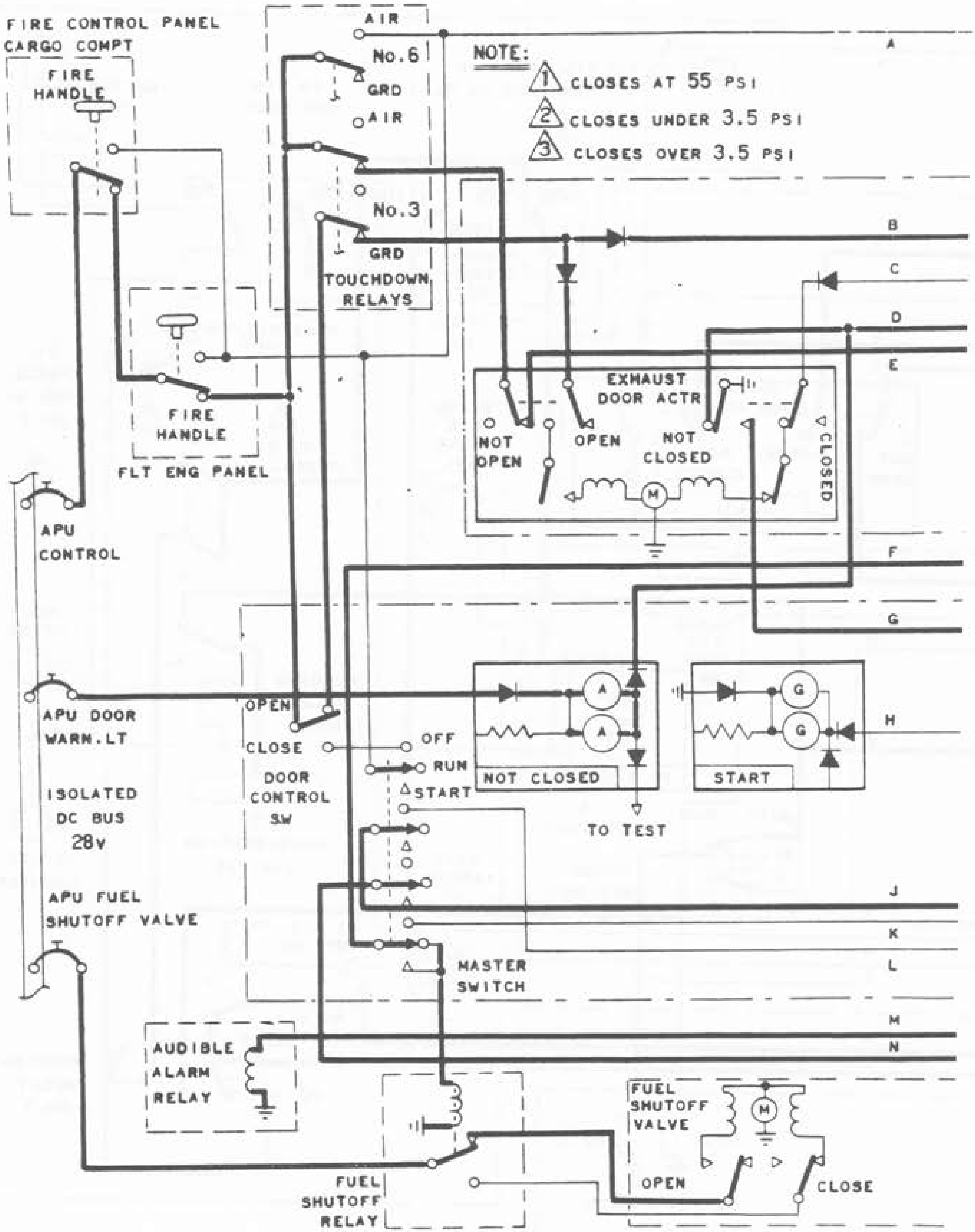
No.1
3
F
G
BLEED
AIR
LOAD
SW
CLOSED
G
G
ON SPEED
HOLDING
RELAY
No.2
HOUR
METER
H
TO TEST
BOTH
No.
2
No.1
ACCUM
SEL SW
OVER
SPEED
LT
ACCELERATION
LIMITER
START
COUNTER
J
K
L
HI OIL
TEMP SW
HI OIL
TEMP RELAY
M
N
HOLDING
RELAY
No.1
No.1
No.2
START VALVES

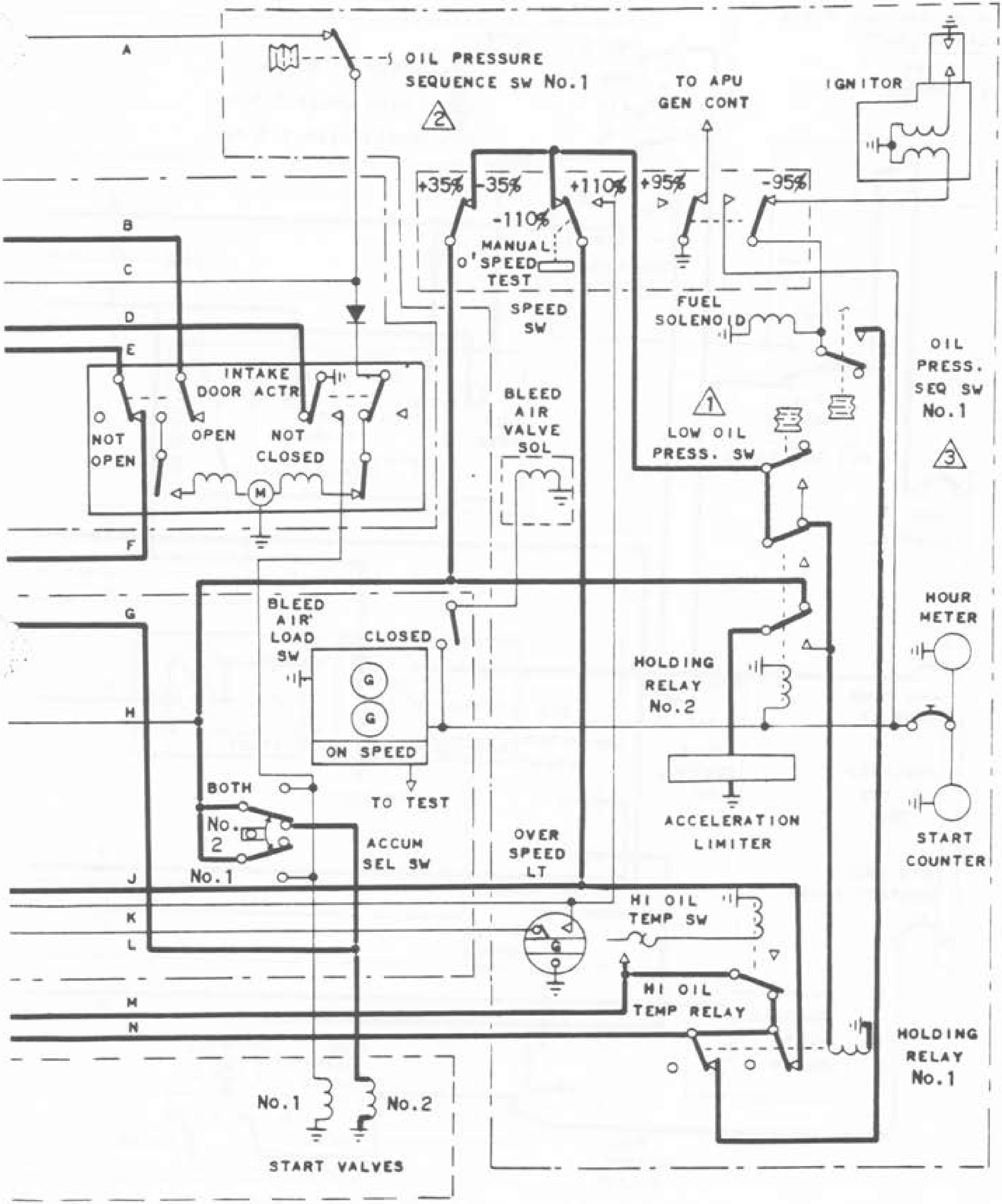


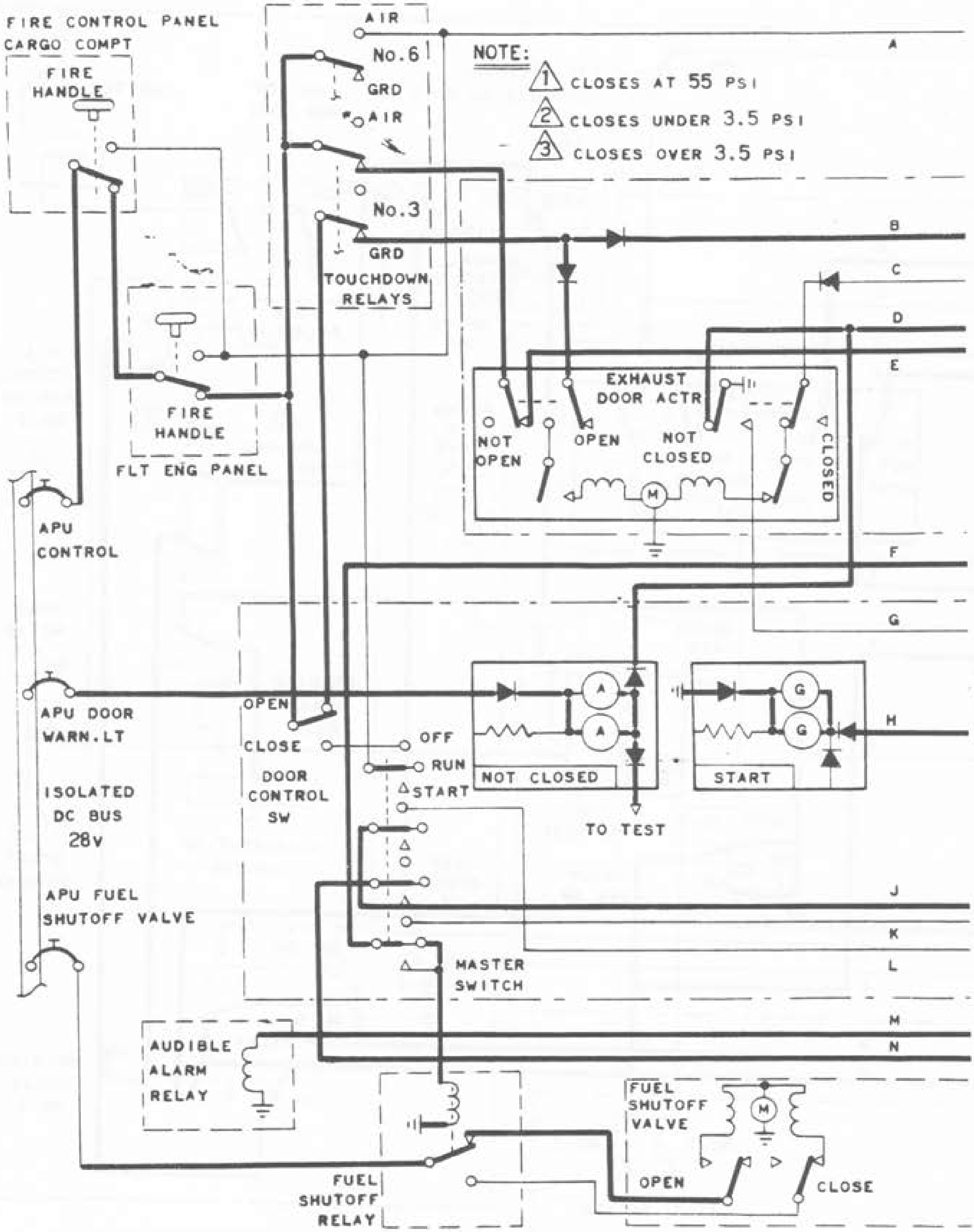
CONTROL SWITCH "START" INITIAL PHASE


A
OIL PRESSURE SEQUENCE SW No.1
2
TO APU GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL O'SPEED TEST
B
C
D
E
F
SPEED SW
FUEL SOLENOID
OIL PRESS. SEQ SW No.1
3
INTAKE DOOR ACTR
NOT OPEN
OPEN
NOT CLOSED
M
BLEED AIR VALVE SOL
1
LOW OIL PRESS. SW
G
BLEED AIR LOAD SW
CLOSED
G
G
ON SPEED
HOLDING RELAY No.2
HOUR METER
H
TO TEST
ACCELERATION LIMITER
START COUNTER
BOTH
No. 2
No.1
ACCUM SEL SW
OVER SPEED LT
J
K
L
HI OIL TEMP SW
G
M
N
HI OIL TEMP RELAY
HOLDING RELAY No.1
No.1
No.2
START VALVES

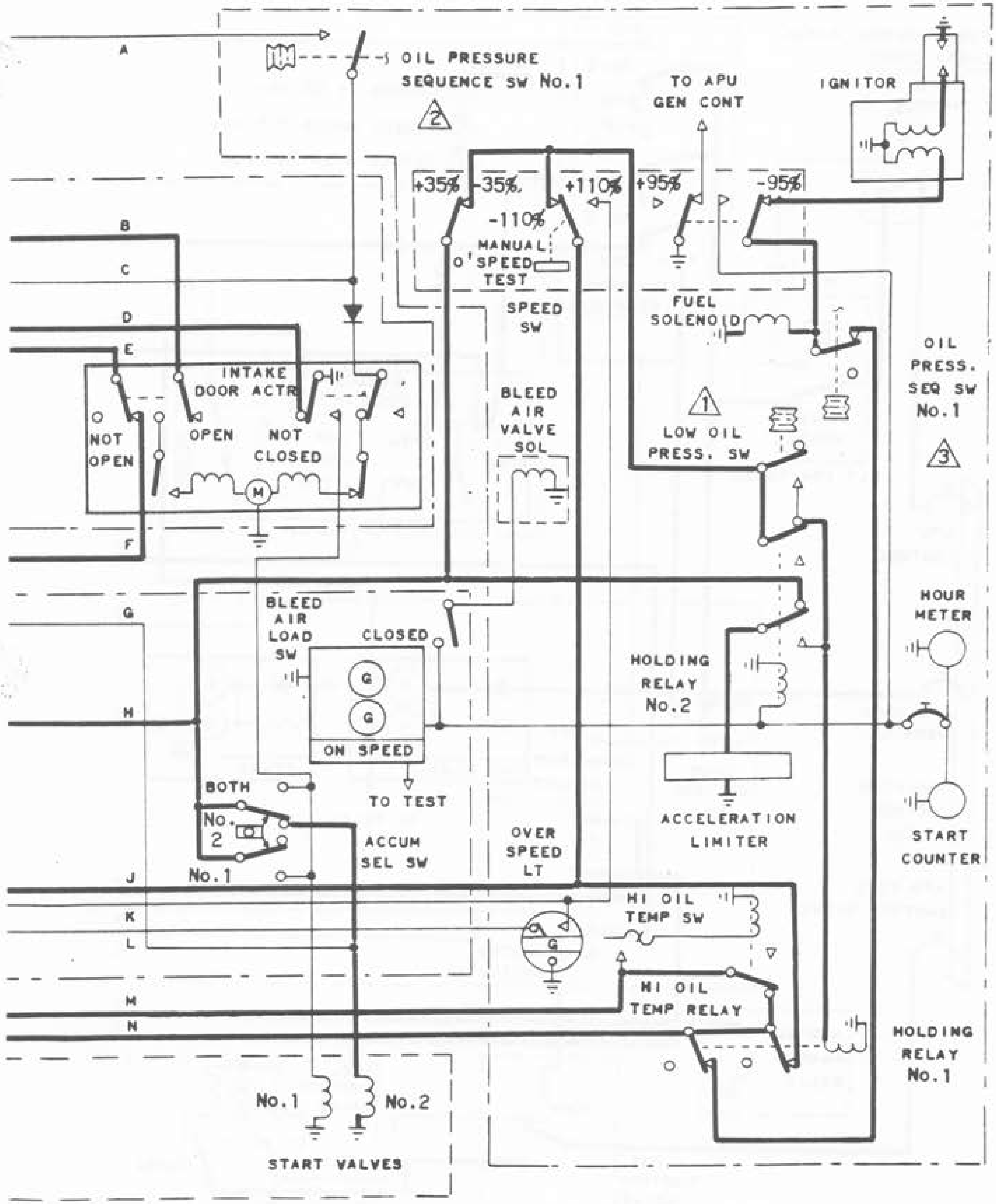


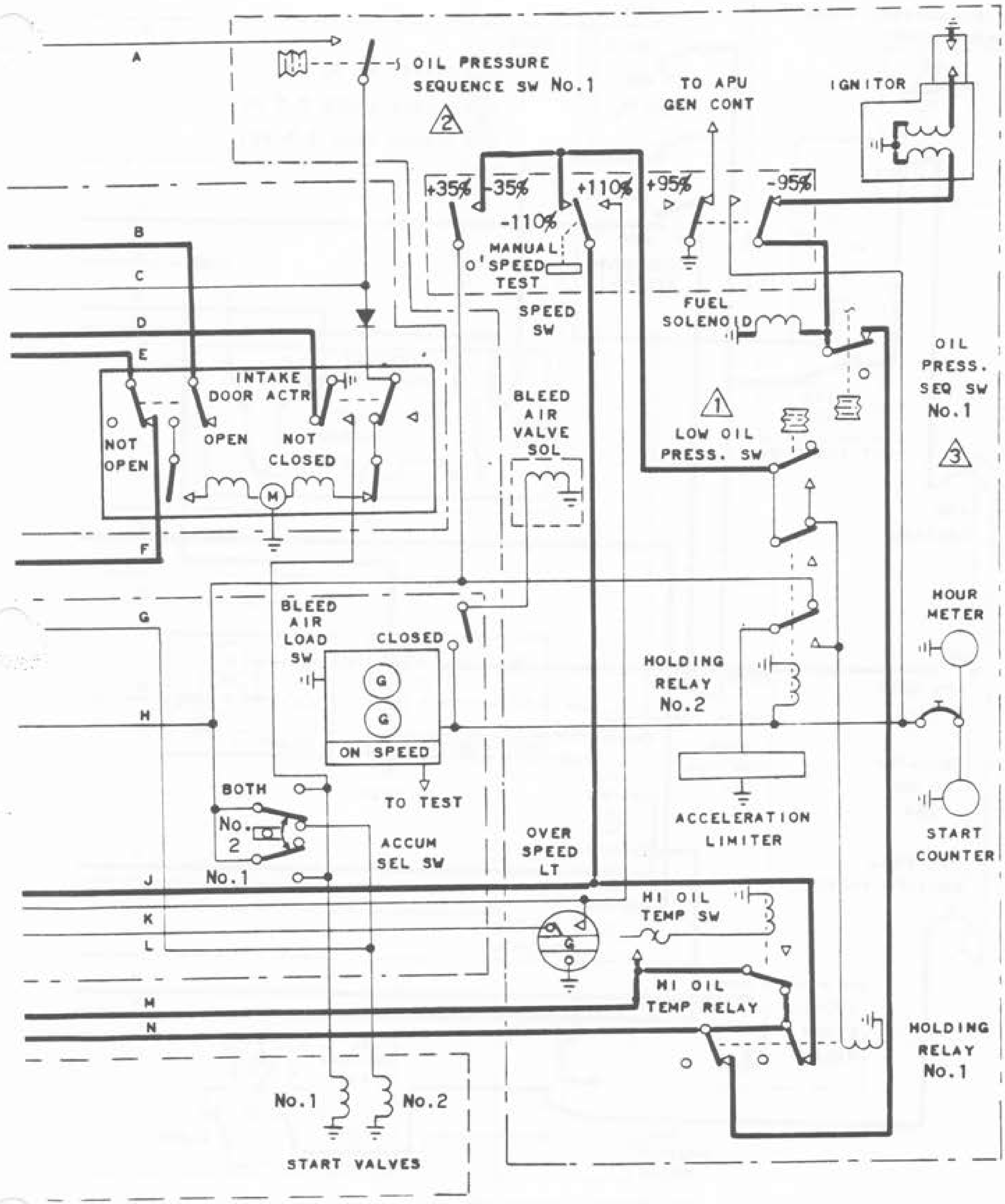
CONTROL SWITCH "RUN" 0-35%


A
OIL PRESSURE SEQUENCE SW No.1
2
TO APU GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL O'SPEED TEST
SPEED SW
FUEL SOLENOID
B
C
D
E
INTAKE DOOR ACTR
NOT OPEN
OPEN
NOT CLOSED
BLEED AIR VALVE SOL
1
LOW OIL PRESS. SW
OIL PRESS. SEQ SW No.1
3
F
G
BLEED AIR LOAD SW
CLOSED
ON SPEED
HOLDING RELAY No.2
HOUR METER
H
TO TEST
BOTH
No. 2
No.1
ACCUM SEL SW
OVER SPEED LT
ACCELERATION LIMITER
START COUNTER
J
K
L
HI OIL TEMP SW
HI OIL TEMP RELAY
M
N
HOLDING RELAY No.1
No.1
No.2
START VALVES



CONTROL SWITCH "RUN" 0-35% (FUEL AND IGNITION ENERGIZED)


A
OIL PRESSURE
SEQUENCE SW No.1
2
TO APU
GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL
O'SPEED
TEST
SPEED
SW
FUEL
SOLENOID
OIL
PRESS.
SEQ SW
No.1
3
B
C
D
E
INTAKE
DOOR ACTR
NOT
OPEN
OPEN
NOT
CLOSED
M
BLEED
AIR
VALVE
SOL
1
LOW OIL
PRESS. SW
F
G
BLEED
AIR
LOAD
SW
CLOSED
G
G
ON SPEED
HOLDING
RELAY
No.2
HOUR
METER
H
ACCELERATION
LIMITER
BOTH
No.
2
TO TEST
No.1
ACCUM
SEL SW
OVER
SPEED
LT
START
COUNTER
J
K
L
HI OIL
TEMP SW
G
HI OIL
TEMP RELAY
M
N
HOLDING
RELAY
No.1
No.1
No.2
START VALVES


A
OIL PRESSURE
SEQUENCE SW No.1
2
TO APU
GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL
O'SPEED
TEST
SPEED
SW
FUEL
SOLENOID
OIL
PRESS.
SEQ SW
No.1
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INTAKE
DOOR ACTR
NOT
OPEN
OPEN
NOT
CLOSED
M
BLEED
AIR
VALVE
SOL
1
LOW OIL
PRESS. SW
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G
BLEED
AIR
LOAD
SW
CLOSED
G
G
ON SPEED
HOLDING
RELAY
No.2
HOUR
METER
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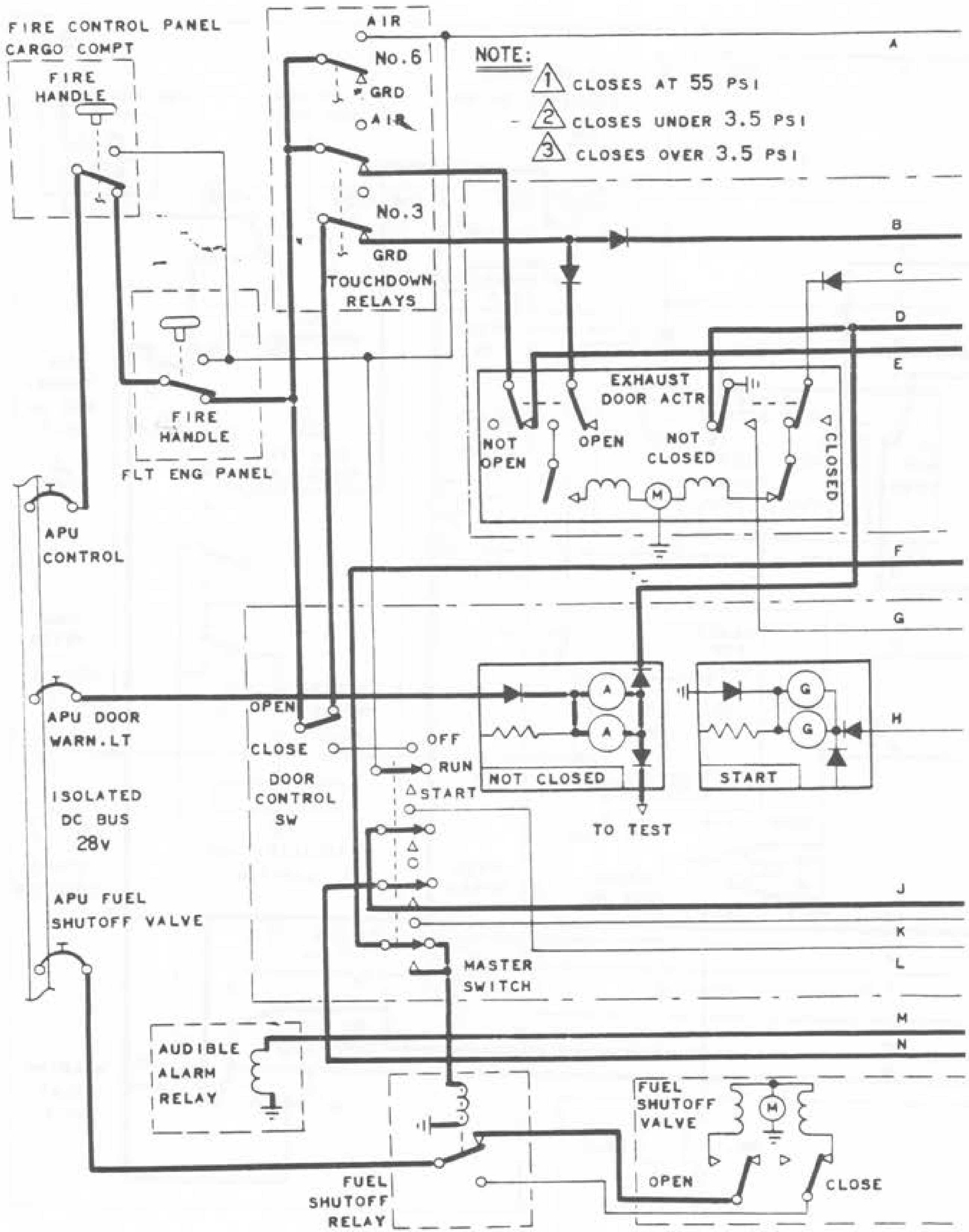
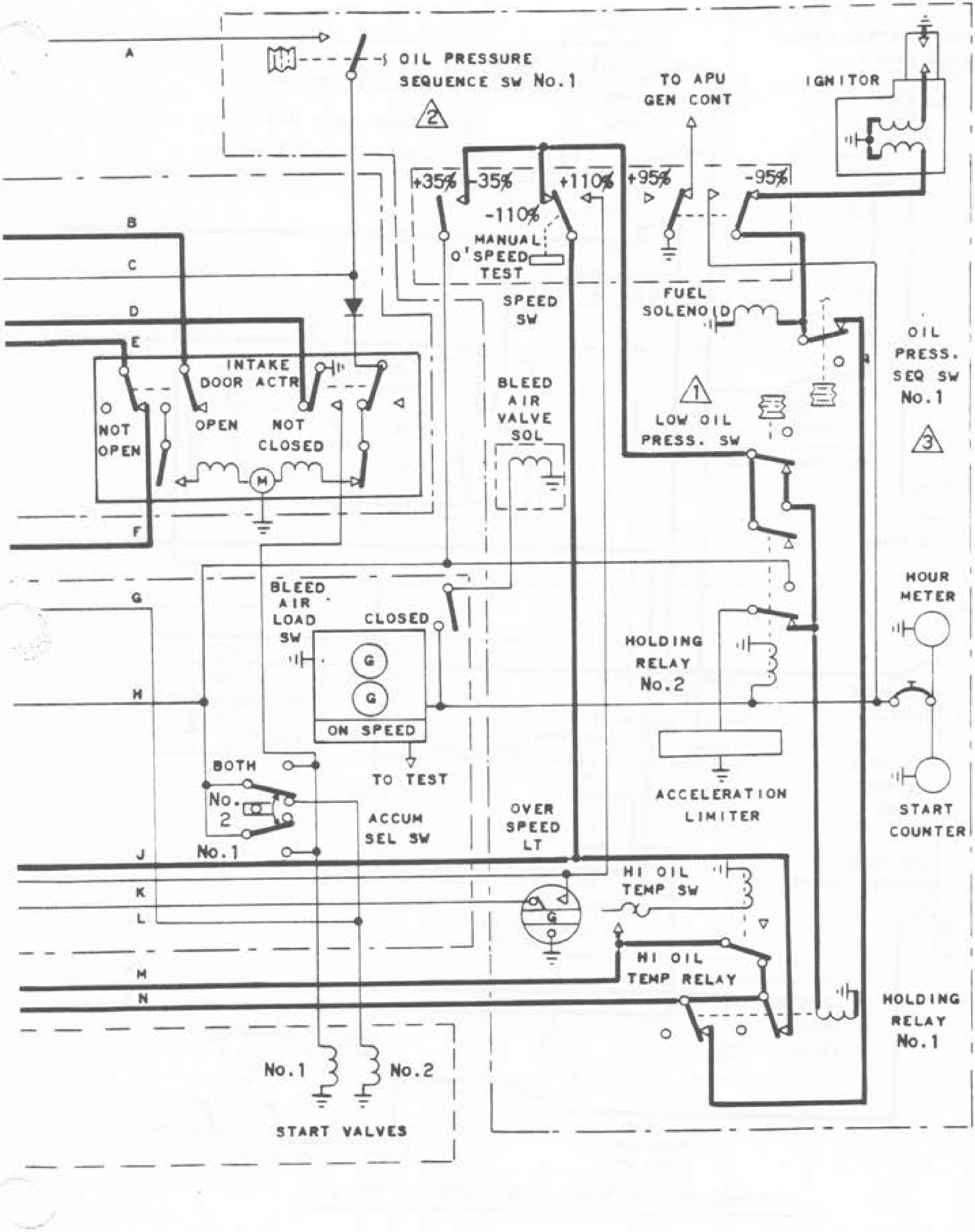
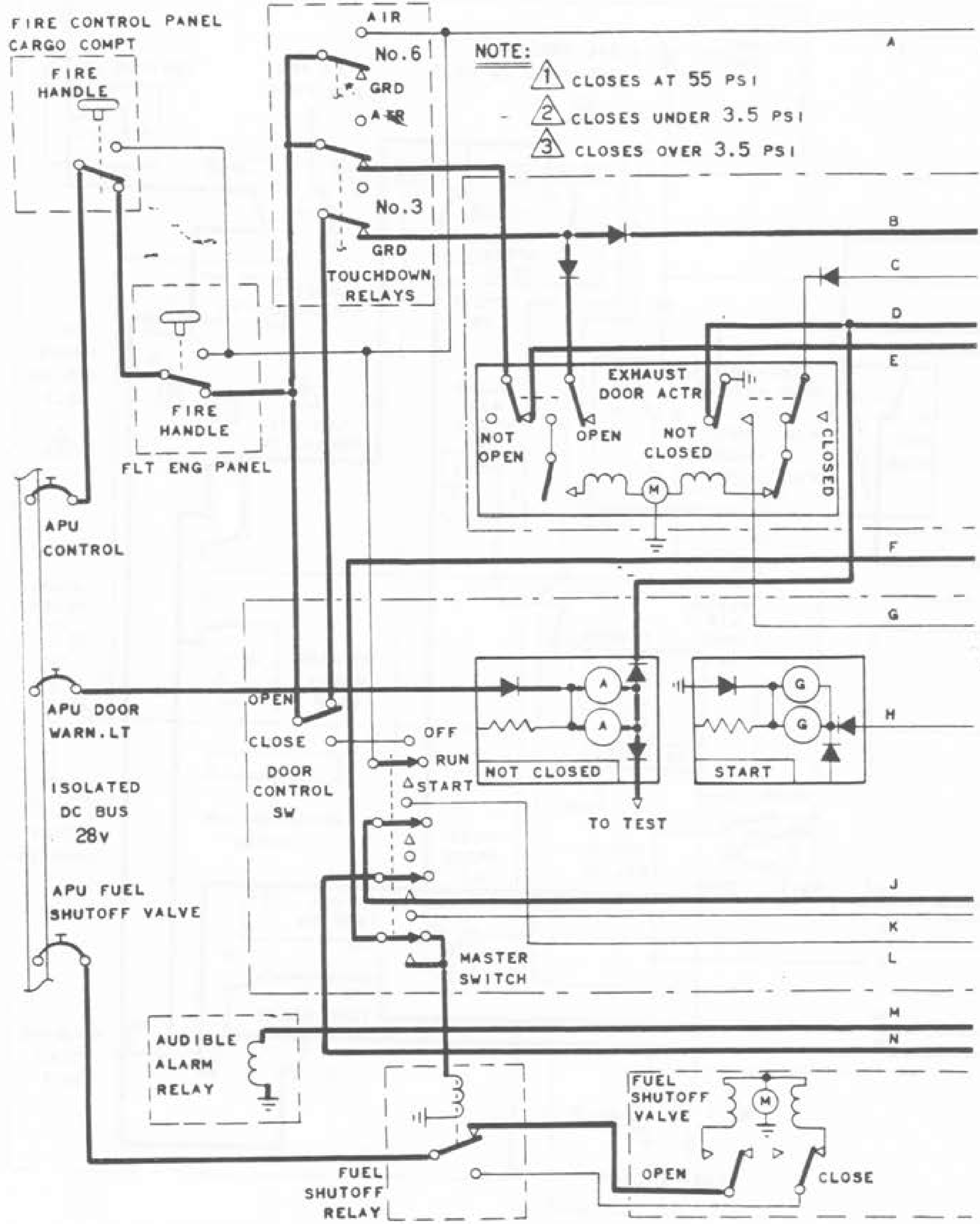
BOTH
No.
2
No.1
ACCUM
SEL SW
TO TEST
ACCELERATION
LIMITER
START
COUNTER
OVER
SPEED
LT
J
K
L
HI OIL
TEMP SW
HI OIL
TEMP RELAY
M
N
HOLDING
RELAY
No.1
No.1
No.2
START VALVES



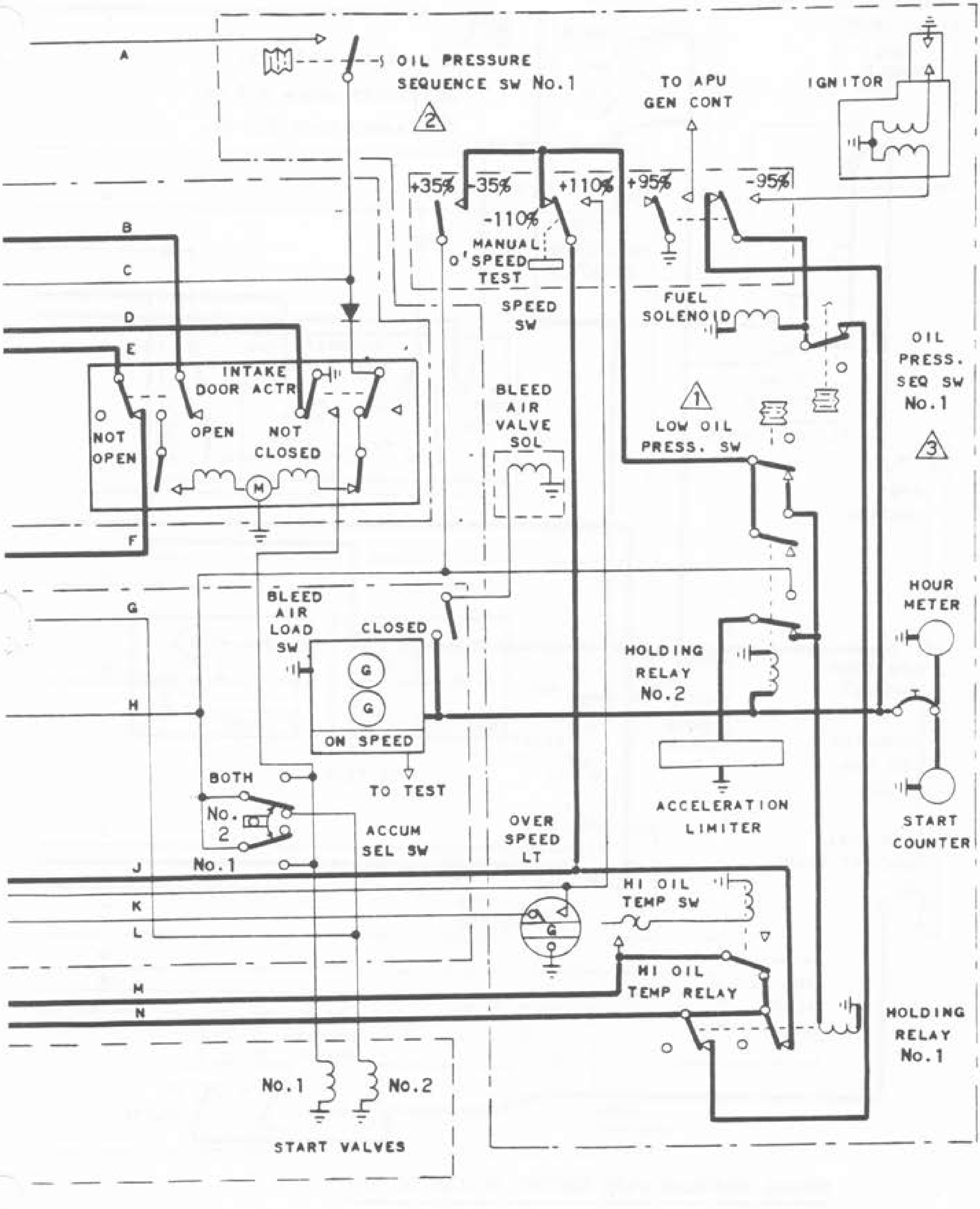
CONTROL SWITCH "RUN" ABOVE 35%
(OIL PRESSURE ABOVE 55 PSIG)

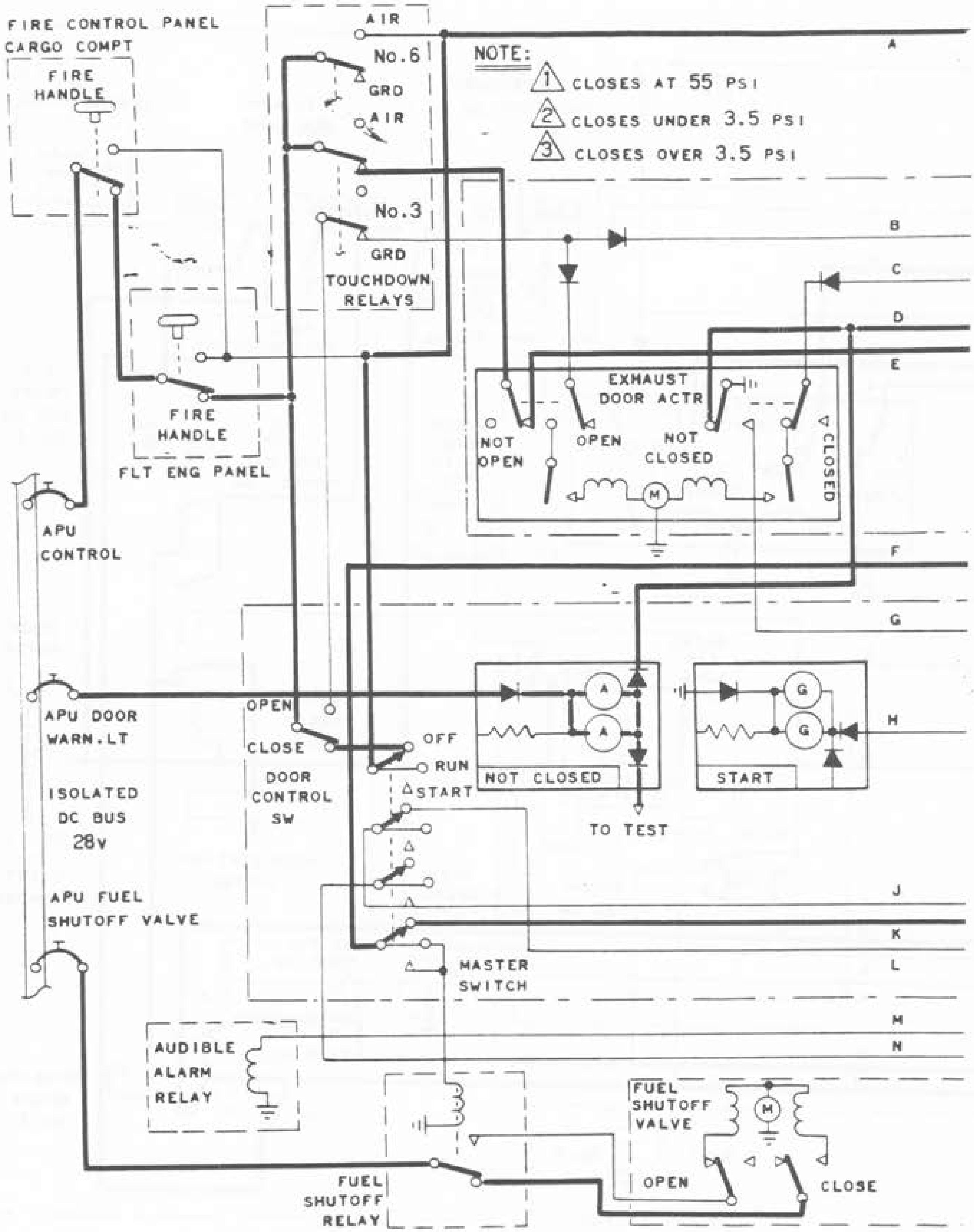


A
OIL PRESSURE
SEQUENCE SW No.1
2
TO APU
GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL
O'SPEED
TEST
B
C
D
E
SPEED
SW
FUEL
SOLENOID
INTAKE
DOOR ACTR
OPEN
NOT
CLOSED
NOT
OPEN
BLEED
AIR
VALVE
SOL
1
LOW OIL
PRESS. SW
OIL
PRESS.
SEQ SW
No.1
3
F
G
BLEED
AIR
LOAD
SW
CLOSED
HOLDING
RELAY
No.2
HOUR
METER
H
G
G
ON SPEED
TO TEST
ACCELERATION
LIMITER
BOTH
No.
2
No.1
ACCUM
SEL SW
OVER
SPEED
LT
START
COUNTER
J
K
L
HI OIL
TEMP SW
HI OIL
TEMP RELAY
M
N
HOLDING
RELAY
No.1
No.1
No.2
START VALVES

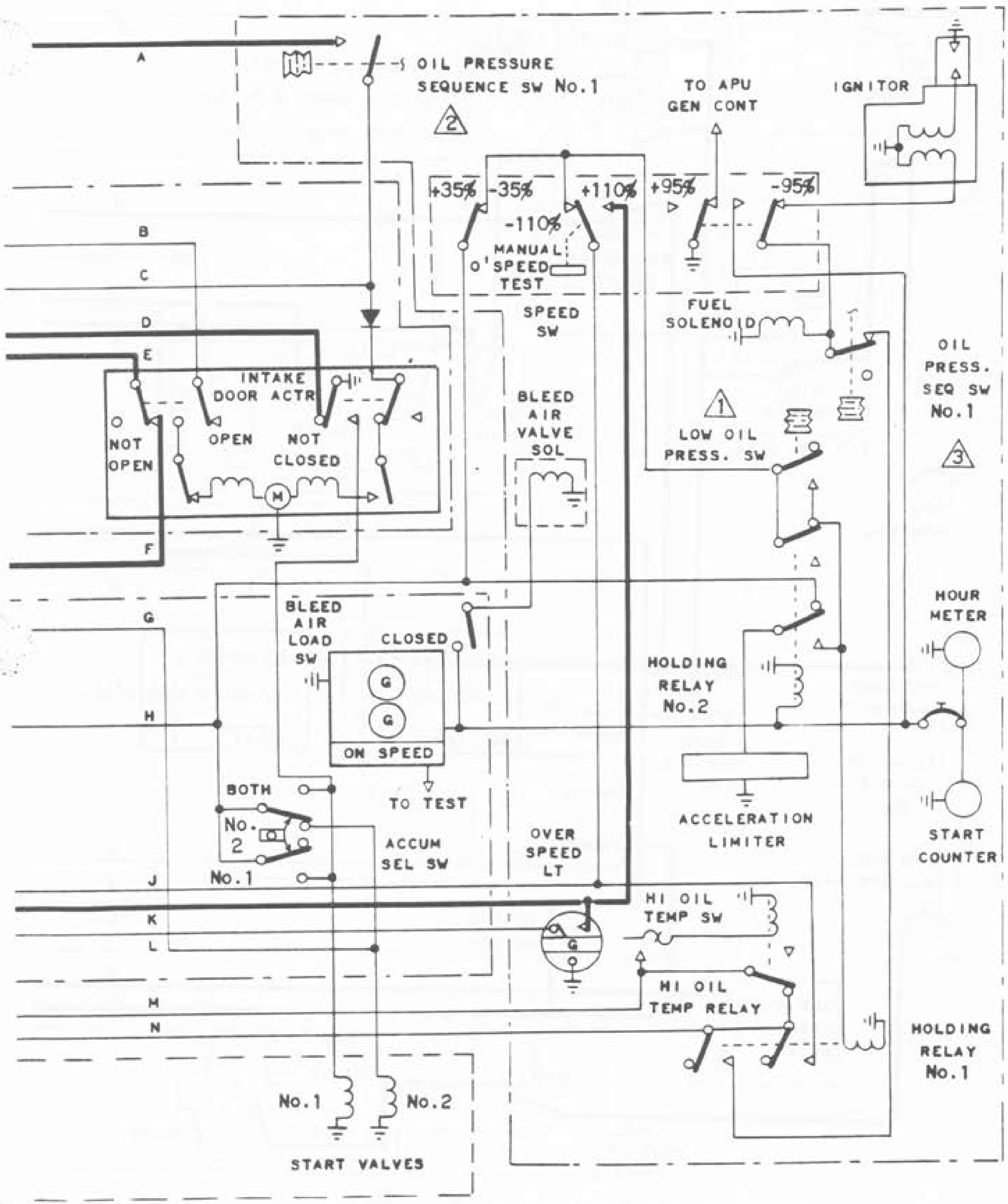


CONTROL SWITCH "RUN" ABOVE 95% "ON SPEED"


A
OIL PRESSURE SEQUENCE SW No.1
2
TO APU GEN CONT
IGNITOR
B
C
D
E
F
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL O'SPEED TEST
SPEED SW
FUEL SOLENOID
OIL PRESS. SEQ SW No.1
INTAKE DOOR ACTR
OPEN
NOT CLOSED
NOT OPEN
BLEED AIR VALVE SOL
1
LOW OIL PRESS. SW
3
G
H
BLEED AIR LOAD SW
CLOSED
ON SPEED
TO TEST
HOLDING RELAY No.2
HOUR METER
ACCELERATION LIMITER
START COUNTER
BOTH
No. 2
No.1
ACCUM SEL SW
OVER SPEED LT
J
K
L
M
N
HI OIL TEMP SW
HI OIL TEMP RELAY
HOLDING RELAY No.1
No.1
No.2
START VALVES



NORMAL SHUTDOWN WITH CONTROL SWITCH TO "OFF"


A
OIL PRESSURE SEQUENCE SW No.1
2
TO APU GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL O'SPEED TEST
SPEED SW
B
C
D
E
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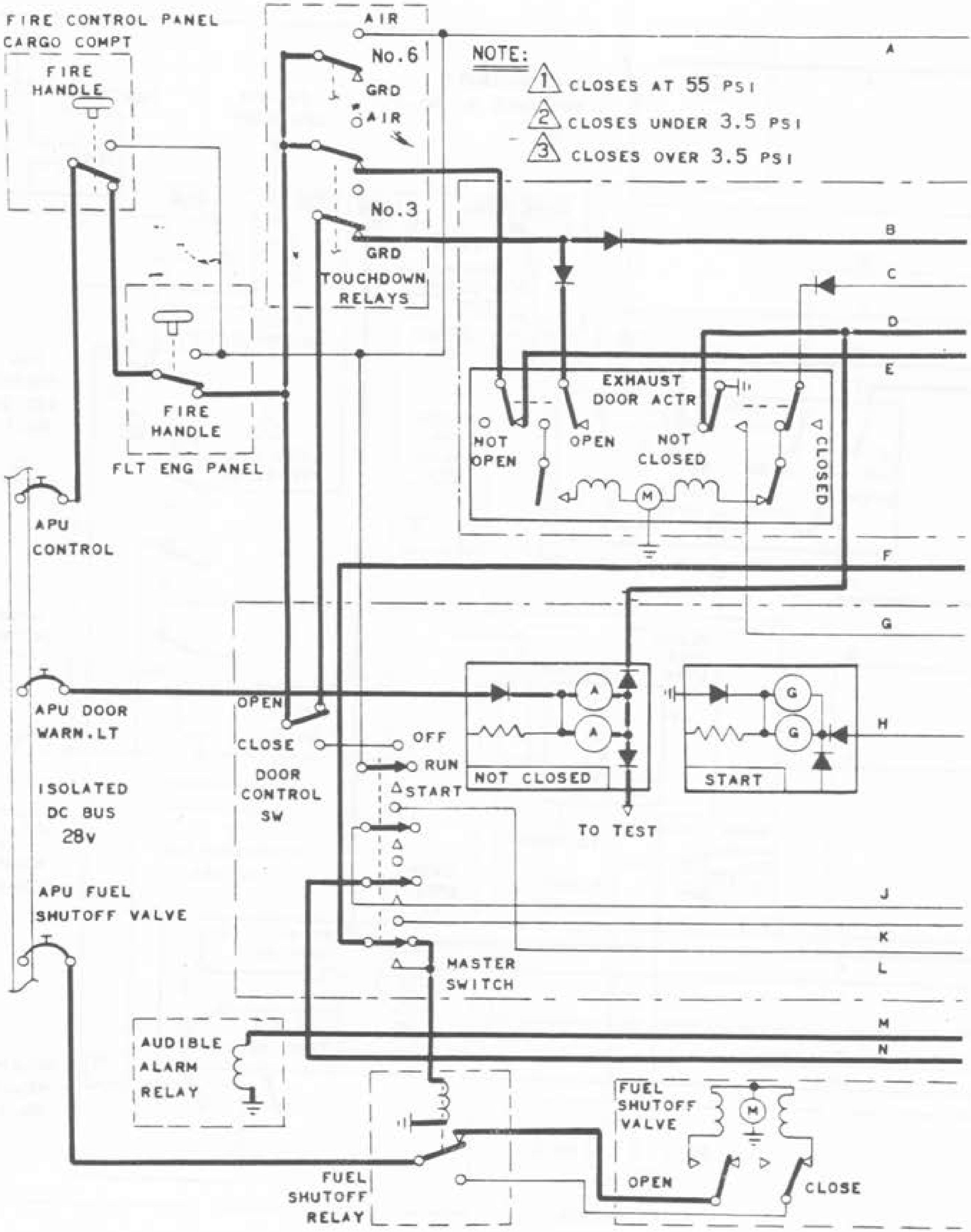
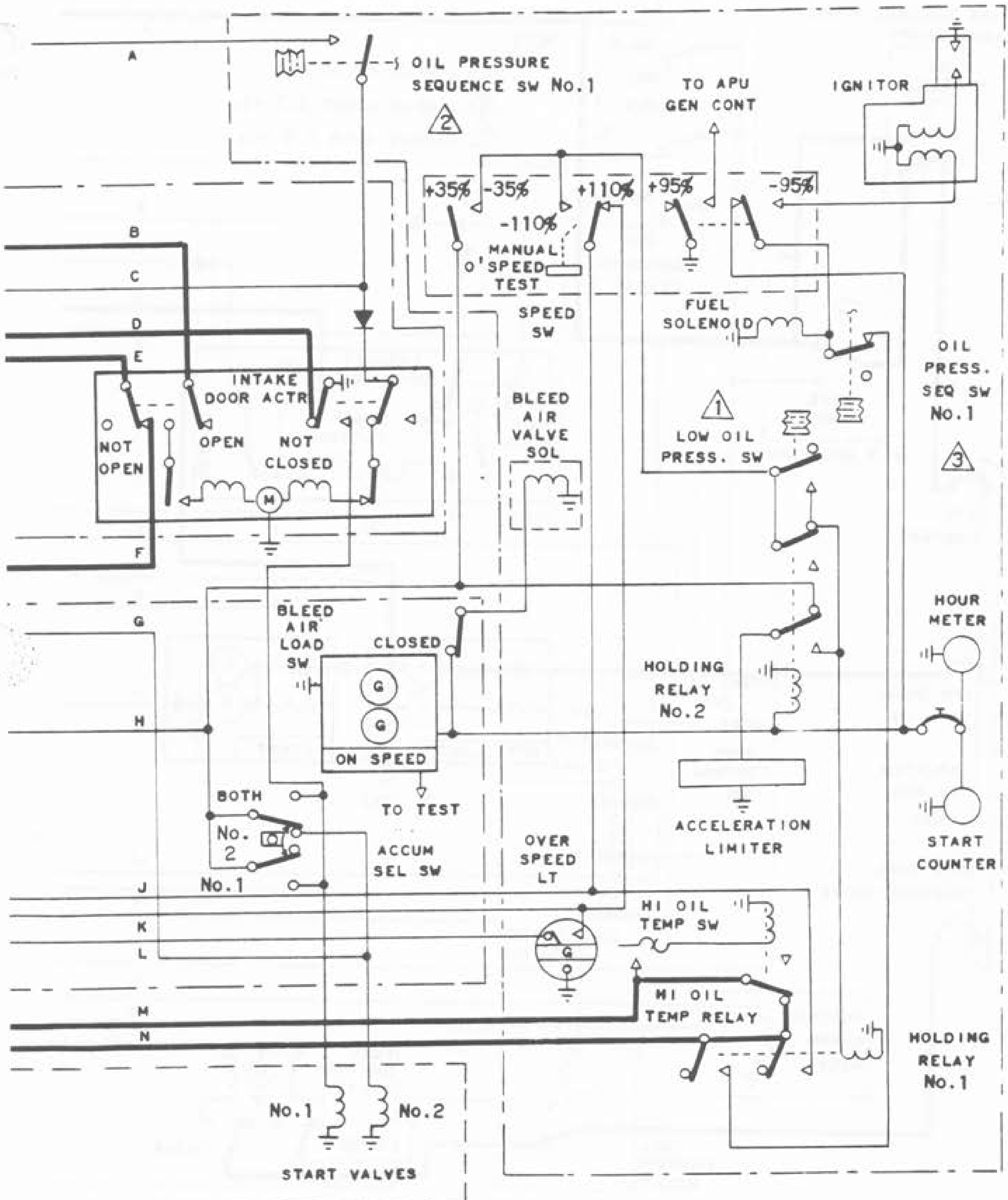
L
M
N
INTAKE DOOR ACTR
NOT OPEN
OPEN
NOT CLOSED
M
FUEL SOLENOID
OIL PRESS. SEQ SW No.1
3
1
LOW OIL PRESS. SW
BLEED AIR VALVE SOL
BLEED AIR LOAD SW
CLOSED
G
G
ON SPEED
TO TEST
HOLDING RELAY No.2
HOUR METER
ACCELERATION LIMITER
START COUNTER
BOTH
No. 2
No.1
ACCUM SEL SW
OVER SPEED LT
HI OIL TEMP SW
HI OIL TEMP RELAY
HOLDING RELAY No.1
No.1
No.2
START VALVES



CONTROL SWITCH "RUN" AUTOMATIC SHUTDOWN
(LOW OIL PRESSURE OR OVERSPEED)



A
OIL PRESSURE
SEQUENCE SW No.1
2
TO APU
GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL
O'SPEED
TEST
SPEED
SW
FUEL
SOLENOID
B
C
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E
INTAKE
DOOR ACTR
OPEN
NOT
CLOSED
NOT
OPEN
M
F
BLEED
AIR
VALVE
SOL
1
LOW OIL
PRESS. SW
OIL
PRESS.
SEQ SW
No.1
3
G
BLEED
AIR
LOAD
SW
CLOSED
G
G
ON SPEED
HOLDING
RELAY
No.2
HOUR
METER
H
ACCELERATION
LIMITER
START
COUNTER
BOTH
No.
2
No.1
TO TEST
ACCUM
SEL SW
OVER
SPEED
LT
J
K
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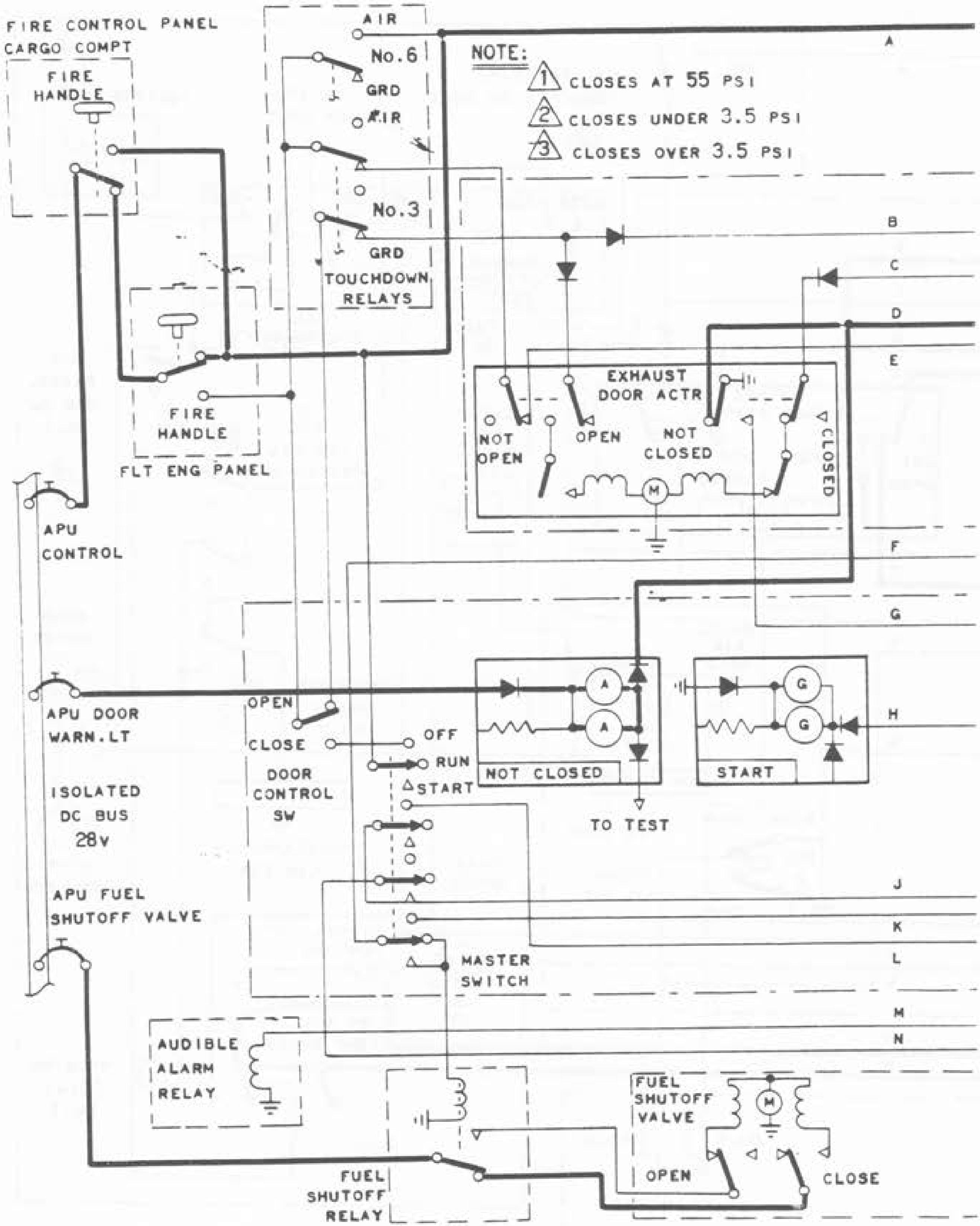
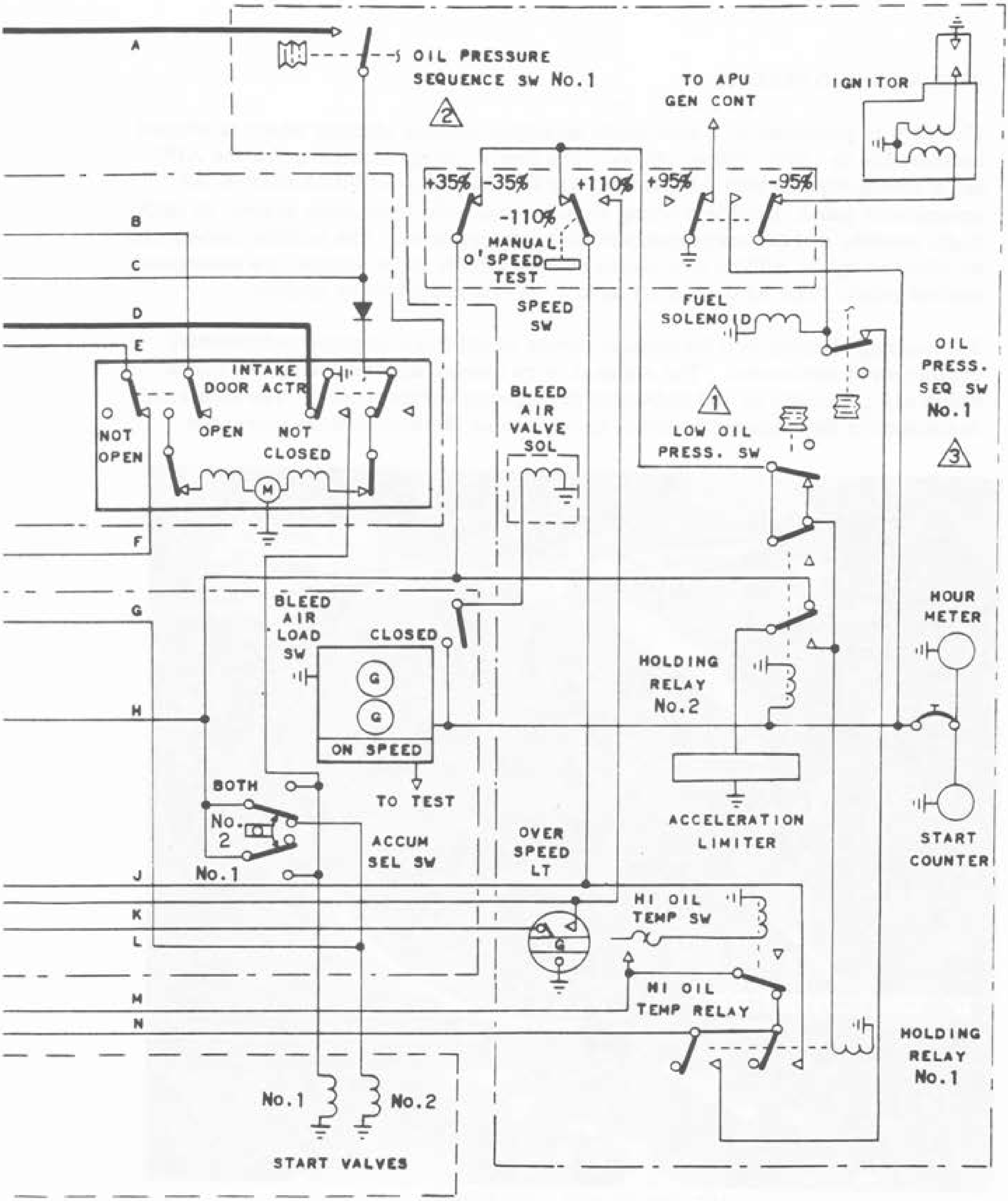
HI OIL
TEMP SW
G
HI OIL
TEMP RELAY
M
N
HOLDING
RELAY
No.1
No.1
No.2
START VALVES



APU CONTROL SWITCH "RUN" FIRE HANDLE SHUTDOWN

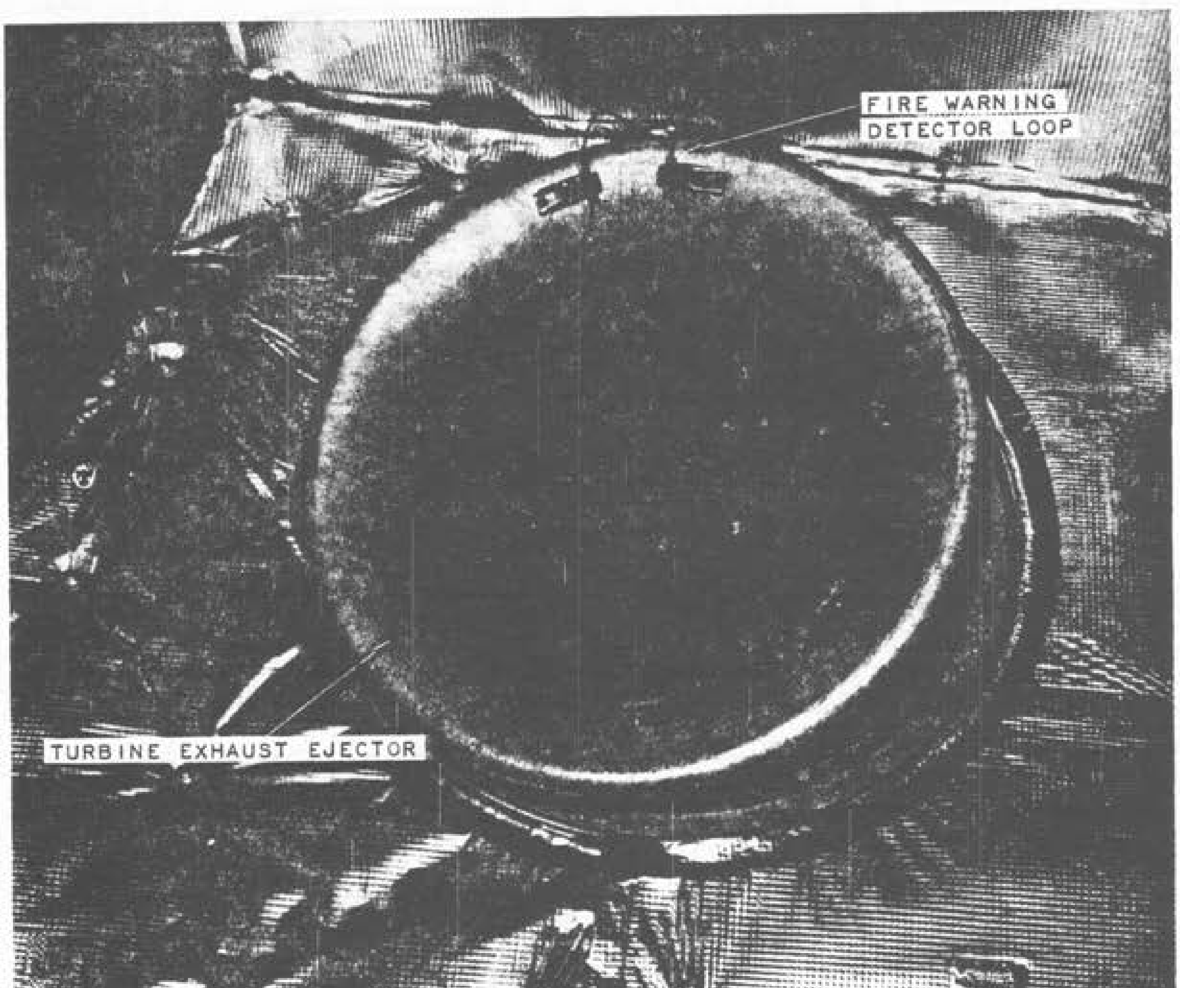


A
B
C
D
E
F
G
H
J
K
L
M
N
OIL PRESSURE SEQUENCE SW No.1
TO APU GEN CONT
IGNITOR
+35%
-35%
+110%
+95%
-95%
-110%
MANUAL O'SPEED TEST
SPEED SW
FUEL SOLENOID
OIL PRESS. SEQ SW No.1
INTAKE DOOR ACTR
NOT OPEN
OPEN
NOT CLOSED
BLEED AIR VALVE SOL
LOW OIL PRESS. SW
BLEED AIR LOAD SW
CLOSED
ON SPEED
TO TEST
HOUR METER
HOLDING RELAY No.2
ACCELERATION LIMITER
START COUNTER
BOTH
No. 2
No.1
ACCUM SEL SW
OVER SPEED LT
HI OIL TEMP SW
HI OIL TEMP RELAY
HOLDING RELAY No.1
No.1
No.2
START VALVES

FIRE WARNING SYSTEM.

The APU is protected by a continuous loop-type sensing element which is tripped between 196 to 235°C (385 to 455°F). The fire warning indications for the APU are a steady light in both APU emergency fire handles, APU fire light on the annunciator panel, audible warning signal through the interphone system at each flight station, and the cargo compartment warning horn. The audible system can be silenced by the audible fire alarm silence switch on the engine fire emergency control panel. The APU does not have an overheat protection system.

The sensing element is a thermistor device which has a negative temperature coefficient of resistance. The element is an inconel tube enclosing two wires which are separated by and imbedded in a special ceramic core. The electrical resistance of the ceramic material decreases as the temperature increases



AFT END OF APU COMPARTMENT

permitting a small current flow between the parallel wires. When the temperature reaches 196 to 235°C (385 to 455°F), the current flow between the two parallel wires triggers a relay in the control unit. This relay turns on the steady fire warning lights and activates the audible system.

Since the current flow in the sensing elements is not around the element loop but between the parallel wires, a break in the loop would not cause a malfunction or failure of the system. If more than one break existed, the portions of the element connected to the control unit would still detect a fire.

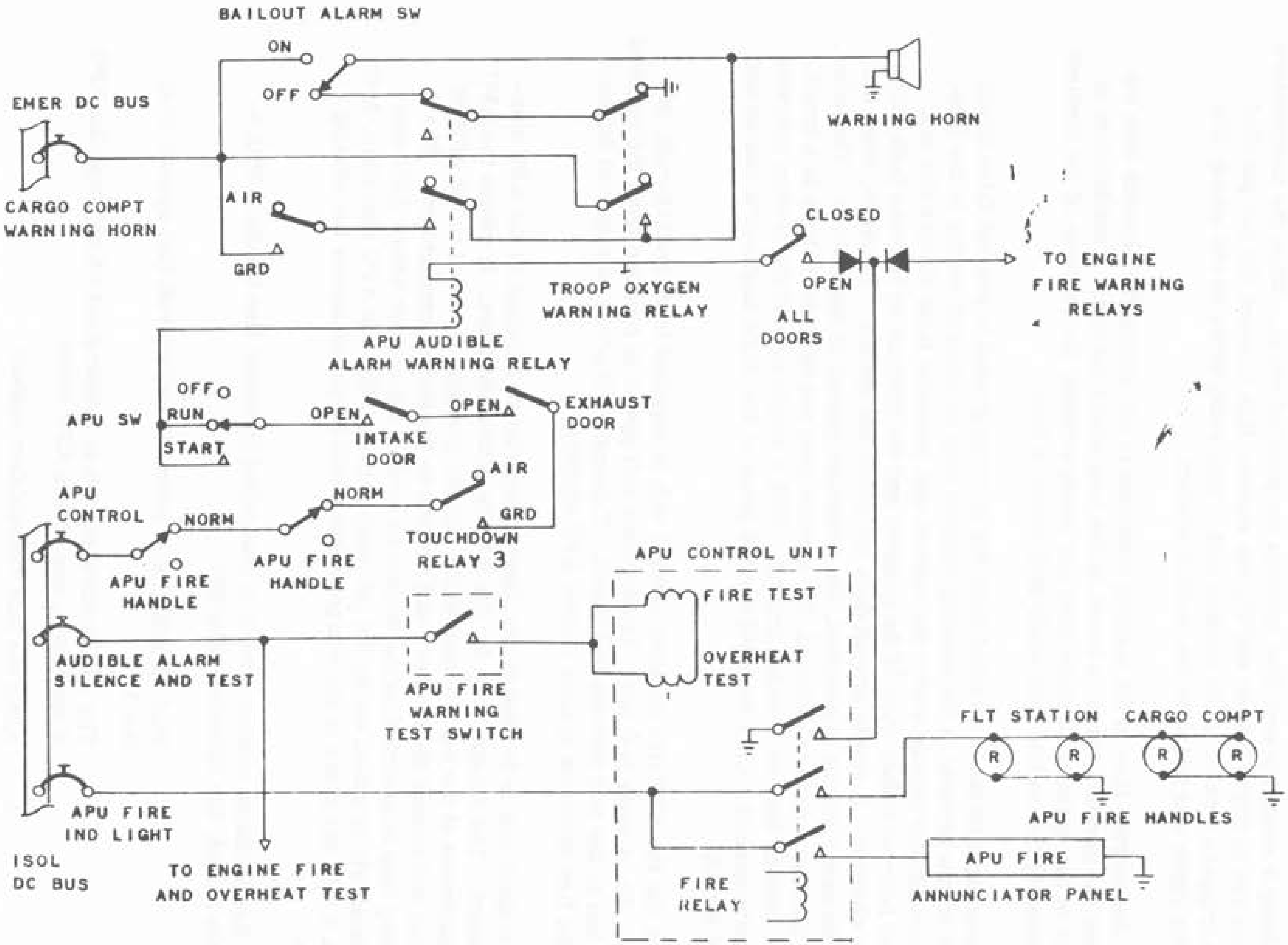
The sensing element is isolated from the aircraft ground to prevent false alarm due to single grounds in the sensing element loop or aircraft wiring to the loop. A discriminator circuit within the control unit prevents false alarms due to a ground between either wire of the element and the aircraft or between both wires of the element. A single ground does not affect the system. However, when the discriminator circuit is actuated, the detection system is inoperative. Therefore, when the test switch is actuated, the system does not operate if there is a break in the sensing loop or a double ground. With a single ground the system operates and tests normal. Only the APU control panel at the flight engineer's station has a test switch.

Power for the APU fire detector control unit is supplied from the 115-volt, 400 Hertz, No. 4 main A-C bus. Twenty-four volt power is supplied from the isolated D-C bus to the test circuits and lights. External A-C power is required for testing the fire detection system before APU starting.

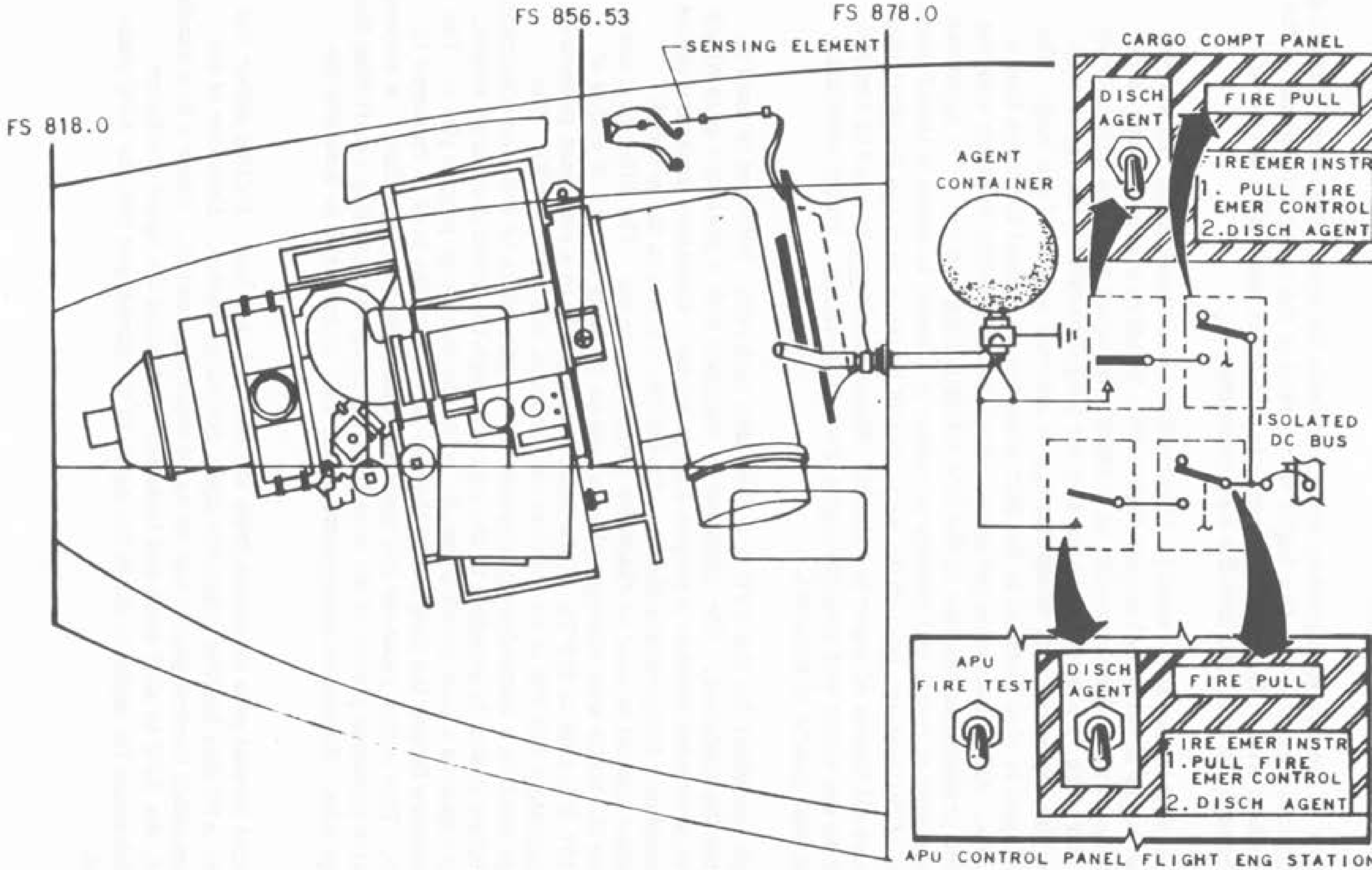
The control unit is located in the cargo compartment adjacent to the APU compartment. The sensing loop for the APU is relatively short. It enters the APU compartment at the top adjacent to the turbine plenum, it routed to the exhaust ejector and around the ejector, and returns to the cargo compartment. The sensing loop is mounted on the bellmouth area of the ejector where APU compartment air is pulled out by the jet pump action. With the APU operating, heat from a fire any place in the compartment would be pulled across the sensing loop.

The fire isolation system circuit is controlled by either fire handle. With a handle pulled, the following happens:

- o Fuel shutoff closes isolating the aircraft fuel system from the APU
- o The APU control circuit is deenergized which stops the APU if operating, and closes APU doors
- o Arms the fire extinguisher system



APU FIRE WARNING SCHEMATIC



APU FIRE EXTINGUISHING SCHEMATIC & COMPONENT LOCATIONS (6005 AND UP)

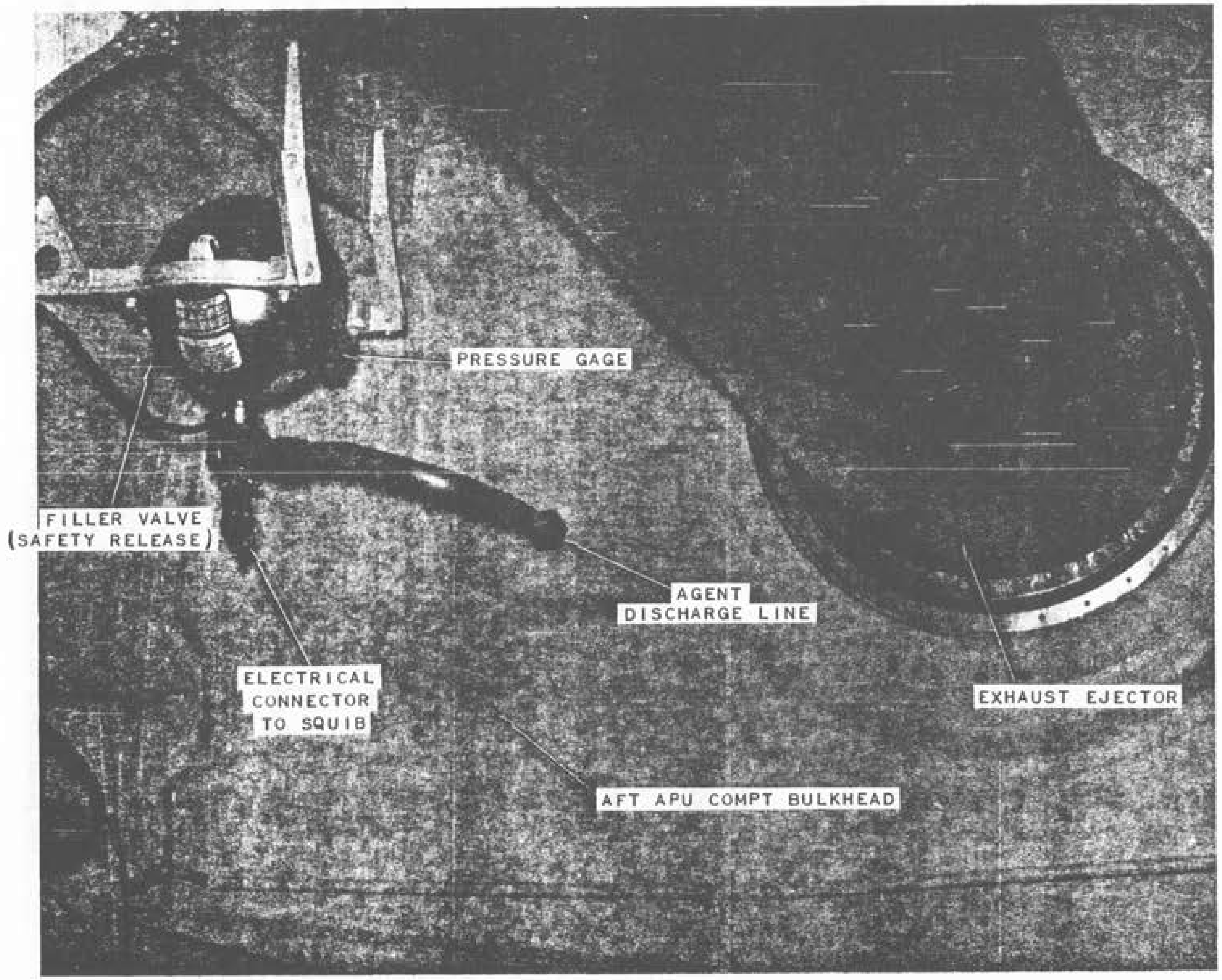
FIRE EXTINGUISHER SYSTEM.

Components of the fire extinguisher system include the agent container, plumbing and the control circuit. The fire bottle is mounted in the upper left corner of the left main wheel well. The plumbing consists of a short line with a nozzle projecting through the bulkhead into the APU compartment.

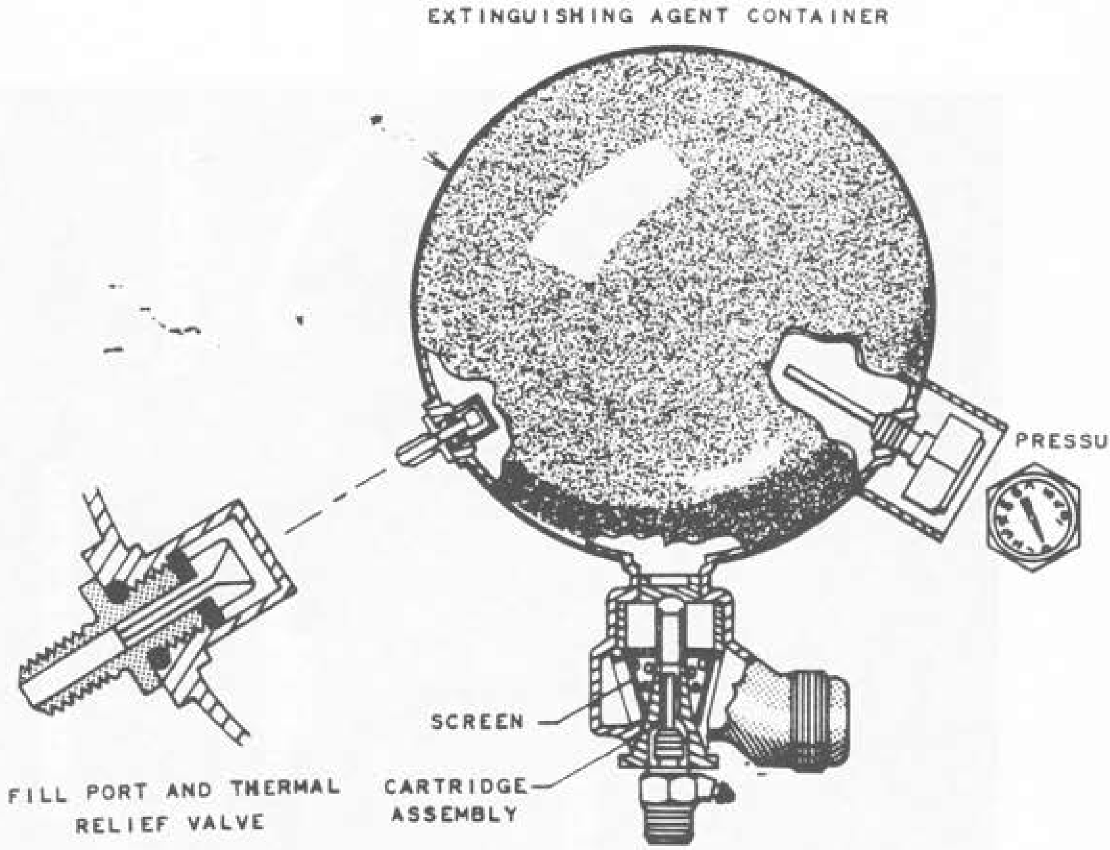
The fire extinguishing agent used is dibromodifluoromethane (DB). This agent can cause injury if personnel expose themselves to heavy concentrations of the vapor or the liquid. When expelled as a vapor, the agent removes oxygen from the air; therefore, a person could not live for long if breathing the vapor only. Breathing the vapor can also cause damage to internal organs of the body. The vapor or liquid is also harmful to the skin when left in contact for more than a few seconds. All maintenance personnel should be completely familiar with the prescribed precautions relative to the fire extinguishing system. The agent can cause corrosion of metal and damage to rubber if allowed to stand in liquid form. After use of the system, immediate steps should be taken to purge the plumbing and remove all traces of vapor and liquid. Water should not be used to remove the agent as the water will keep the agent from evaporating. Warm ventilating air is the best means of removal.

The single container for the APU is a 224 cubic inch unit. Nitrogen is used to pressurize the container. The container is equipped with a pressure gage which is used to determine whether a proper charge exists. Container pressure varies with atmospheric temperature changes; therefore, a chart in the aircraft maintenance manual is used to check for proper servicing. The filler port used to service the bottle with nitrogen also serves as a safety outlet. It yields at 93.3 to 107.2°C (200 to 225°F). This point corresponds to a container pressure of approximately 775 PSI at an ambient temperature of 21.1°C (70°F). The discharge squib is a cartridge-type pyrotechnic squib which is actuated electrically. When electric power is supplied to the squib through the agent discharge switch, the squib ruptures a post which normally holds the discharge plug in place. The agent pressure forces the plug out of the way as soon as the post is ruptured by the squib. This action releases the agent and allows unrestricted flow. A screen in the valve prevents pieces of the post from entering and possibly restricting the discharge tube. Sixteen to twenty-nine volts, DC, is required to detonate the squib.

The control circuit gets its power from the isolated D-C bus. Pulling either one of the two APU fire handles arms the agent discharge switch. Each one of the APU emergency control panels has an agent discharge switch. After a fire handle is pulled, the APU is shut down and isolated. Actuating the agent discharge switch detonates the squib to allow the agent to be discharged into the APU compartment.



FORWARD END - LEFT WHEEL WELL



APU FIRE EXTINGUISHER CONTAINER

APU STARTING AND OPERATION.

Starting and operating the APU are very similar whether the unit is installed in an aircraft or a test stand. In either case, consideration must be given for direction of the wind to prevent exhaust gases from being ingested into the compressor intake. Recirculating the hot gases through the APU compressor results in low performance and can cause excessive turbine exhaust gas temperatures.

Prior to APU operation, all the prescribed checks and precautions should be observed. A new installation requires additional steps to properly depreserve the APU oil and fuel systems. Specific procedures are found in the applicable maintenance handbook. A fire guard should be posted on the aircraft. The APU fire warning system is not operative unless external AC power is used. Personnel should never stand in line with the rotor assembly or the exhaust gases because of the possibility of serious injury.

Before the APU can be started, D-C power must be on, fire handles in normal, intake and exhaust doors open, and hydraulic starting pressure available (select for single or both as required). When the APU doors reach the fully opened position, a circuit is completed through the door switches to the APU control switch. When the APU control switch is placed in the "START" position, the start light illuminates, the start selector valve or valves are energized open, and the fuel shutoff valve is opened. The start light remains on until the RPM reaches 25 percent. Also, an underspeed signal is supplied to the APU generator underfrequency protection circuit which prevents generator operation at low RPM. When the RPM reaches 95 percent and above, the APU-driven generator can be loaded.

Momentarily after placing the APU control switch to "START," a holding circuit (HR1) is completed and the control switch is released to the "RUN" position. As the unit begins to rotate, the oil pump builds up pressure and actuates the oil pressure sequencing switch at approximately 3.5 PSIG. This action completes circuits to the fuel solenoid valve and the ignition unit.

After combustion, the combination of hot combustion gases and the starter accelerates the turbine. At this time the 35 percent (15,000 RPM) switch actuates which deenergizes the start selector valve or valves; the acceleration limiter solenoid and start light go out. The APU is now self sustaining and under its own power continues to accelerate. At approximately 95 percent (40,000 RPM), the 95 percent switch is actuated which deenergizes the ignition system and energizes the acceleration limiter solenoid. During this phase of operation, the fuel solenoid valve remains energized open by a holding circuit through an oil pressure switch and a deenergized relay contact (HR2). The oil pressure switch closes when the oil pressure reaches approximately 55 PSIG. At 95 percent, when HR2 is energized, the oil pressure switch is the holding circuit. This feature provides one of the safety circuits. If oil pressure drops below 55 PSIG, the holding circuit is deenergized which results in automatic shutdown of the APU.

When the 95 percent switch closes, it completes circuits to the ON SPEED light, bleed air load switch, hourmeter, and start counter. The start counter records the number of times the APU is started; the hourmeter records the total hours of operation on the APU. The APU is now ready to supply bleed air and/or electrical power.

After the unit is operating, it can be stopped by placing the APU control switch to the "OFF" position or, in an emergency, by pulling one of the fire handles.

The following six conditions result in automatic shutdown:

- o High Oil Temperature [excess of 124°C (255°F)]
- o Low Oil Pressure (below 55 PSIG)
- o Overspeed (110 percent; 45,000 to 46,000 RPM)

- o Intake or Exhaust Door Close Inadvertently
- o Touchdown Switches Open (aircraft takeoff)
- o Fuel or Electrical Power Interruption

If for any reason the APU RPM drops below 95 percent, the unit automatically is unloaded.

The intake and exhaust doors remain open during normal operation. Placing the door control switch to close cannot close the doors until the APU control switch is placed off and oil pressure has decreased below 3.5 PSIG. However, when the APU is shutdown by operation of a fire handle or touchdown relay, the doors automatically close when oil pressure drops below 3.5 PSIG at approximately 10 percent RPM.

In addition to the START and ON SPEED lights, there is the exhaust gas temperature indicator for monitoring the operation of the APU. The EGT should not exceed 709°C (1308°F) at any time. With the APU on speed and no load the EGT should stabilize at approximately 254°C (489°F). The maximum load EGT should not exceed 676°C (1249°F).

NOTE

a. The load control pneumatic thermostat should limit EGT to 676°C (1249°F).

b. The acceleration and temperature limiting thermostat should limit maximum EGT to 709°C (1308°F)

MOTORING THE APU.

Depreservation and troubleshooting problems require motoring the APU without ignition and/or fuel. Both fuel and ignition can be deactivated by removing the cannon plug from the oil pressure sequencing switch. To obtain fuelflow without ignition, the input 28-volt, DC power lead is disconnected from the ignition unit.

CAUTION

Insulate the connector to prevent arcing.

When the operation of the ignition unit is being checked, it is also desirable to deactivate the solenoid valve in a similar manner.

CAUTION

Be sure the operating limitations of the starting and ignition systems are not exceeded.

OPERATIONAL CHECKS.

After a unit is replaced in an aircraft, the following operational checks should be accomplished to ensure satisfactory performance. The applicable maintenance handbook provides detailed instructions for the initial operation of the unit, such as depreservation of the fuel and oil system, manual test of the centrifugal overspeed switch, and safety precautions.

The APU intake and exhaust doors opening and closing time should not exceed 10 seconds. The not closed light on the control panel should illuminate when the doors leave the closed position and stay illuminated until the doors are completely closed. This action should satisfy normal operation of the actuators without any mechanical difficulty and proper adjustment of the doors not closed microswitches. Also, with the doors closed, placing the APU control switch to "START" should not initiate a start of the APU.

The time a start is initiated until the APU reaches governed speed should not exceed 20 seconds. The APU should accelerate within the time limit without any overtemperature and/or compressor surges or stalls. This time period is basically a functional check of the APU fuel control system. Improper adjustments, control air lines loose, restricted fuel supply, and several other items could result in slow acceleration or overtemperature conditions and compressor stalls. Failure to pass this operational check is a definite indication of abnormal operation requiring corrective action.

To preform the minimum manifold bleed air pressure check, the pylon bleed valves must be closed, all pneumatic systems off, and the bleed load control switch on. This is a pressure check with no flow from the APU. The minimum pressure observed is affected by atmospheric conditions, temperature, and pressure of the air entering the APU compressor. A chart in the aircraft maintenance handbook shows a minimum pressure relative to air temperature, but the operator must calculate the correction for the atmospheric pressure.

EXAMPLE: MINIMUM BLEED AIR PRESSURE - - ATMOSPHERIC TEMPERATURE AND PRESSURE CORRECTIONS. For a day with 70°F air temperature, the maintenance manual chart indicates the minimum pressure should be 45 PSIG (no correction for atmospheric pressure).

1. The field elevation pressure (pressure altitude) must be determined first. It can be obtained from the control tower or weather station or it may be

calculated by using the aircraft's altimeters. To use the altimeters, the instrument should be positioned to indicate zero feet altitude. The reading in the altimeter setting window is atmospheric pressure for the location of the aircraft. To obtain the desired accuracy, both the pilot's and copilot's instruments should be used. (Two readings are taken from each card, and the average (mean) of the four readings is used.) One reading should be taken while altitude is decreased to zero and one should be taken while altitude is increasing to zero. (A slight tap on each instrument will improve accuracy.)

Assume the four readings are 28.58; 28.62; 28.64; and 28.60.

$$\frac{28.58 + 28.62 + 28.64 + 28.60}{4} = 28.61 \text{ inches Hg (average)}$$

2. The atmospheric pressure in inches of Hg must be converted to PSI for making the correction,

where

1 inch Hg = 0.491157 PSI.

28.61 x 0.491157 = 14.05 PSI

3. The maintenance manual indicates a minimum of 45 PSIG for a 70°F* day. This minimum bleed pressure would be for a 70°F day with atmospheric pressure at standard NASA day conditions. To correct for the existing field elevation, multiply the minimum bleed temperature correction (45 PSI) times the field pressure (14.05 inches Hg) and divided by the standard NASA day pressure (14.7 PSI), to obtain the minimum bleed at the existing temperature and pressure:

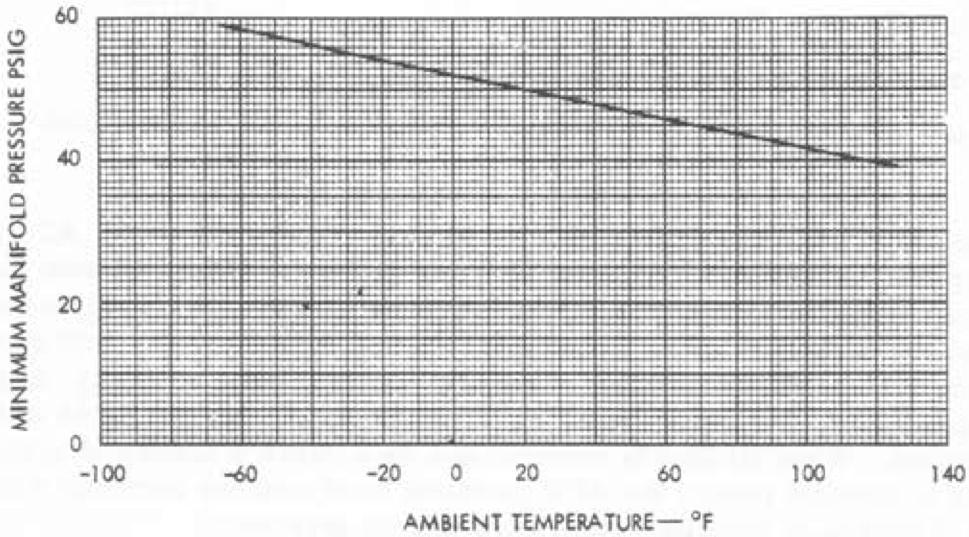
$$\frac{45 \times 14.05}{14.7} = 43 \text{ PSI.}$$

Therefore, 43 PSI represents the minimum bleed air pressure that the APU should deliver under existing atmospheric conditions.

Thus, if the manifold pressure in the aircraft's pneumatic system is maintained at 43 PSI or more, the APU is functioning normally. If the indicated pressure is below the minimum required, either the system has a leak or the APU compressor output is low. Low APU compressor output could be caused by several things: Air leakage or low governed speed would be most probable. If the APU had previous operating time on it, the compressor efficiency might have deteriorated.

* If the temperature is given in Centigrade units, convert to Fahrenheit by taking 9/5 of the Centigrade reading and add 32.

NOTE:
THE PRESSURE INDICATED ON THE CHART IS FOR NO FLOW AT SEA LEVEL CONDITIONS. TO OBTAIN THE MINIMUM MANIFOLD PRESSURE AT FIELD ALTITUDE, MULTIPLY THE PRESSURE FROM THE CHART BY THE FIELD AMBIENT PRESSURE AND DIVIDE THE PRODUCT BY 14.7 .



BLEED MANIFOLD PRESSURE Vs AMBIENT TEMPERATURE CHART

After the minimum bleed air pressure test is satisfied, several of the aircraft's pneumatic systems should be operated. With the pneumatic systems taking bleed air from the APU, it should continue to operate smoothly without any surging or indications of overtemperature.

WARNING

> The aircraft's wing overheat warning lights must be monitored. If the lights illuminate, immediately close the bleed air control switch.

When bleed airflow from the APU is closed, there should be no noticable change in APU operation except the exhaust gas temperature indication should be decreasing.

The APU should drive the auxiliary A-C generator and deliver normal voltage and frequency outputs which are without electrical load. To functionally check the APU-driven generator, the following procedure should be used:

Switch Positions

o	External Power	"AUX"
o	Auxiliary Generator Control	"ON"
o	A-C Voltmeter and Frequency Selector	"AUX. GEN."

With no electrical load, the voltage must be between 112 and 118 volts, AC with a frequency between 380 and 420 Hertz. Placing an electrical load on both the No. 3 hydraulic system pumps "ON" should produce no noticable change in the APU operation. If the preceding function is satisfied, a 100-percent load should be placed on the auxiliary generator. The APU should operate normally, and the auxiliary generator's frequency should remain between 380 and 420 Hertz without any fluctuations. When all load is removed and the aircraft's electrical system is retruned to external power, the APU operation must continue normally with no indication of voltage or frequency from the auxiliary generator.

The operator should not be able to close the APU's intake and exhaust doors inadvertently with the APU operating. To functionally check the electrical circuit, the door control switch must be placed in "CLOSE." The doors should not close. An additional test of the door control can be accomplished by turning the APU control switch to "OFF." The doors should remain open until the APU speed decreases to approximately 10 percent. At this speed, the oil pressure sequencing switch should complete the door close circuit which allows the door to close and to extinguish the door open light.

The APU control circuit normally prevents an electrical and bleed air load on the APU until its speed reaches 95 percent (ON SPEED). This circuit is functionally tested by performing a start with the respective switches on. The auxiliary generator should not come on the line and the bleed air load control and shutoff open until the ON SPEED light illuminates. If those events occur properly, the control circuit through the 95 percent switch is normal.

After the previous test, all loads should be removed from the APU and an emergency shutdown with the fire handle performed.

CAUTION

> Allow the APU to run several minutes with no load to assure stabilized temperatures in the hot section.

When the fire handle is pulled, the APU should shut down with the doors automatically closing when the speed decreases to approximately 10 percent.

The preceding operational checks satisfy normal operation of the APU after repair or replacement in the airframe. Functional testing after major repairs of the APU normally is performed in a test stand. The manufacturer's manuals should be referred to for test stand operation and operational checks required following major repairs.

APU ADJUSTMENTS.

Several adjustments on the APU systems are authorized and may be accomplished with the APU installed in the airframe. Most adjustments require some additional instrumentation of the APU; therefore, it is generally desired that the APU be removed from the aircraft and installed on a test stand. Several factors should be considered: time, whether the APU can be operated with overload conditions in the aircraft, how long the aircraft can be tied up, etc.

NOTE

> When an APU has been operating normally for some time and a trouble develops, do not make readjustments to restore normal indications without investigating and correcting the malfunction. For example, a control air pressure leak in the line between the compressor and the acceleration control valve could result in slow acceleration or failure to come "ON SPEED." An acceleration limiter adjustment could possibly restore normal operation, but this would be compounding the trouble if the leak were not corrected. When a sudden change takes place in a previously normal operating system, it is very improbable that a simple adjustment is the proper solution.

Throughout the life of the APU some deterioration in system operation may be compensated for with readjustments but this should not be confused with the malfunctioning of a system.

Considerable maintenance on components is authorized. If maintenance, parts replacement, or component replacements would affect system operation, then the necessary instrumentation to check for proper functioning and/or adjustments is necessary.

ACCELERATION CONTROL VALVE FUEL BYPASS VALVE ADJUSTMENTS.

This adjustment was previously referred to as the cracking fuel pressure for starting. The spring tension which opposes fuel pump output is adjustable to establish the fuel pressure required to overcome the spring tension and to open the valve to allow some fuel to bypass back to the pump inlet. A check and, if necessary, adjustments should be made anytime a fuel cluster is replaced or component parts, such as diaphragms, etc., are replaced, as follows:

- o The fuel line should be disconnected at the fuel nozzle, and a fuel pressure gage, zero to 60 PSI range with 0.50 range instruments, should be attached.
- o The pneumatic control air line from the acceleration control port on the fuel control unit should be disconnected.
- o The APU should be motored. The hydraulic starting system capacity is adequate to perform this function. (Fuel pressure must be between 33 and 35 PSIG.)
- o Fuel pressure is adjusted clockwise to increase pressure and counterclockwise to decrease pressure.
- o If more than two motoring cycles are required, the ignition unit should be deactivated.
- o The adjusting lock nut should be secured, the control air line should be connected to the fuel cluster, and the fuel line should be connected to the fuel nozzle.

FUEL GOVERNOR ADJUSTMENT. The fuel governor adjustment should be checked and adjusted if required, or anytime the fuel control unit is replaced. With a suitable tachometer generator and indicator, this check can be accomplished with the APU installed in the aircraft. If an APU test stand is available, it is equipped for this type of test and adjustment. The oil pump assembly has a tachometer generator drive pad. The APU is wired for the tachometer generator also. When major repairs are accomplished on an APU, the governor may require adjustment because of a change in the operating efficiency.

- o A suitable tachometer generator and indicator should be installed.
- o The adjustment screw should be loosened and turned three full turns counterclockwise to prevent possible overspeed.
- o The APU should be started and operated ON SPEED at no load. The no load speed should be a maximum of 43,000 RPM.
- o A clockwise movement increases governed speed, and a counter-

TACH RPM	TURBINE WHEEL RPM 10:043:1 RATIO	TACH RPM	TURBINE WHEEL RPM 10:043:1 RATIO
3750	37,661	4325	43,436
3800	38,163	4350	43,687
3850	38,666	4375	43,938
3900	39,168	4400	44,189
3950	39,670	4425	44,440
4000	40,172	4431	44,501
4050	40,674	4450	44,691
4100	41,176	4475	44,942
4125	41,427	4500	45,194
4150	41,678	4525	45,445
4175	41,930	4536	45,555
4182	42,000	4550	45,696
4200	42,181	4575	45,947
4212	42,301	4600	46,198
4225	42,432	4650	46,700
4234	42,522	4700	47,202
4250	42,683	4750	47,704
4254	42,723	4800	48,206
4275	42,934	4850	48,709
4300	43,185	4900	49,211
4316	43,346		

TURBINE SPEED CONVERSION CHART

clockwise movement decreases governed speed.

- Ratio of the turbine wheel to the tachometer drive is 10.043 to 1.

On a test stand, the RPM must not drop below 39,900 with a bleed air load resulting in a maximum of 675°C (1247°F) exhaust gas temperature. This requirement could be checked in the aircraft by placing a bleed air load on the APU until the exhaust gas temperature reaches 675°C (1247°F). This action is a functional check of the governors ability to increase fuelflow with the APU under bleed air load with a minimum droop in RPM. It is also an indication of turbine efficiency. Although a governor could be functioning normally, the RPM could droop too low because of any deterioration in the operating efficiency of the compressor or turbine section.

PNEUMATIC CONTROL THERMOSTATS.

Pneumatic thermostat adjustments should be functionally checked with the APU operated on a test stand. To accomplish this check, the bleed air load from the APU must be increased to reach the exhaust gas temperature operating range of the particular thermostat. On the test stand, a motor driven valve is connected downstream from the bleed air shutoff and control valve. This valve is used to control bleed airflow to atmosphere. It is possible to connect a valve to the APU with it installed in the aircraft, but is not recommended when a test trailer is available. Both thermostats are functionally checked in a similar manner and the method of adjusting both thermostats is identical.

To check the load control thermostat, the APU must be running ON SPEED and air bled to atmosphere until the exhaust gas temperature stops rising. The exhaust gas temperature indication should not exceed 675°C (1247°) (the desired setting of the thermostat). If the temperature exceeds 675°C (1247°F) the thermostat should be adjusted. When the temperature setting of the thermostat is reached, the bleed air shutoff and load control valve begins throttling or decreasing bleed airflow automatically.

To check the acceleration and overtemperature thermostat, the throttling action of the load control thermostat must be disabled by removing the line at the thermostat and capping it off. The bleed air load on the APU should be increased at a rate of about 100°C (212°F) and 30 seconds until the fuel pressure and RPM drop rapidly. The observed exhaust gas temperature at the time the fuel pressure and RPM drops is the cracking temperature of the thermostat which is to be 704 to 709°C (1300 to 1310°F). It should be recalled that this thermostat bleeds away control air pressure from the acceleration control valve which increases the fuel bypass. This action results in decreased fuelflow indicated by a drop in fuel pressure and RPM.

Replacement of shims will change the operating temperature of the thermostats.

INcrease shim thickness	- decrease operating temperature
DEcrease shim thickness	- increase operating temperature
0.001 inch shim thickness change	= approximately 17°C (30°F)
Load Control Thermostat	- 675°C (1250°F)
Acceleration & Overtemperature Thermostat	- 704 to 709°C (1300 to 1310°F)

NOTE

After a thermostat is adjusted and functionally checked, perform at least two repeat checks, and the operating temperature shall be ± 2°C (±5°F) of the initial indication. When a thermostat fails to repeat, replace it with a new item.

NOTE

A minimum spread of 22°C (72°F) is desired between the operating range of the two thermostats.

WARNING

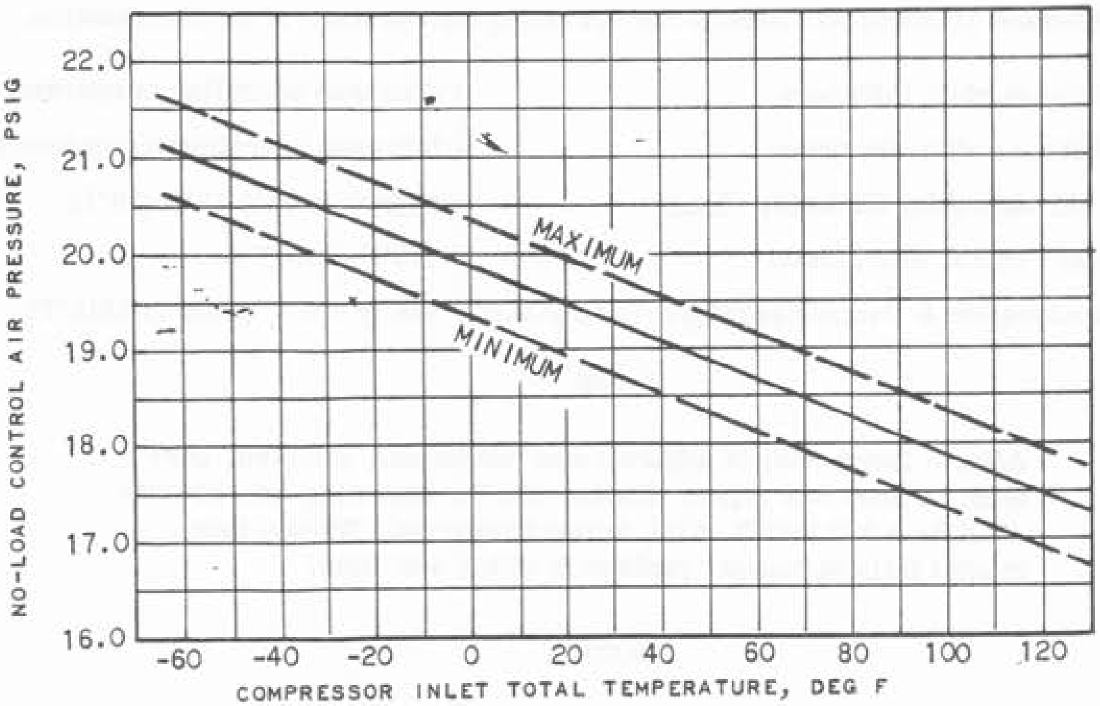
When functional checking the operation of thermostats, do not allow turbine discharge temperatures to exceed 738°C (1360°F). Maximum EGT for continuous operation is 709°C (1310°F).

ACCELERATION LIMITER SOLENOID ADJUSTABLE ORIFICE.

This check establishes the correct orifice adjustment to provide normal APU acceleration from 35 percent to 95 percent without overtemperature or compressor stall and within the prescribed time limit. Because compressor discharge air varies with atmospheric changes, a chart is provided which shows the maximum, desired, and minimum control pressure for any given compressor inlet air temperature.

A tee fitting is installed in the control air bleed line between the solenoid valve and the acceleration control valve. A zero to 50 PSI gage is connected to the tee fitting.

After the unit is running ON SPEED with no load for a minimum of one minute, the cannon plug should be disconnected from the solenoid valve. The control



TEMPERATURE CURVE FOR SETTING ADJUSTABLE ORIFICE ASSEMBLY

pressure should be within the limits of the chart; if not, the orifice screw should be adjusted.

Clockwise	-	Increase control pressure
Counterclockwise	-	Decrease control pressure

After adjustment, the APU should be shut down and the cannon plug connected back to the solenoid valve. The APU should now start and accelerate within the prescribed time limit without any abnormal indications.

It should be recalled that the acceleration limiter solenoid valve is spring-loaded open and energized closed. The APU control circuit energizes the valve closed from zero to 35 percent and at 95 percent and above. The adjustable orifice only affects fuel metering between 35 percent to 95 percent APU RPM. Therefore, with the APU operating ON SPEED, the solenoid valve must be deenergized to accomplish the adjustment.

When the control pressure is adjusted properly and the APU does not accelerate normally, something else is not functioning properly in the system. The control pressure should not be adjusted above or below the range called for on the chart to correct for some other manfunction in the system.

BLEED SHUTOFF AND LOAD CONTROL VALVE.

Two checks are performed on the valve, and one adjustment is authorized. When the bleed load switch is placed in the bleed "ON" position with the APU operating ON SPEED, the valve must open and fully load the unit within 9 to 10 seconds. When the bleed switch is turned off, the valve must close in approximately one-half second.

The rate control adjusting screw is located at the edge of the diaphragm cover.

Clockwise	-	Increase the rate of change
Counterclockwise	-	Decrease the rate of change

Should the valve be slow in closing, the problem could be mechanical or a restriction could be in the air passages. There is no adjustment for the closing rate.

When a problem arises with the rate of opening, all of the external air lines must be tight.

The valve is designed to throttle the bleed airflow at 675°C (1247°F). When indications are that the bleed air supply to the aircraft system is being limited, the bleed shutoff and load control valve should be checked. Leaking air lines can produce throttling of the valve regardless of the turbine exhaust gas temperature.

OIL PRESSURE.

The regulated oil pressure must be set at from 80 to 100 PSIG when the APU is operating at governed speed.

Much more can be accomplished with an APU operated in a test trailer because it is equipped to perform complete analysis, functional testing, and adjustments of the APU systems. Functional operation of the electrical control circuits and their related components, which are part of the basic APU, are also included.

The manufacturer's instruction manual must be referred to for detailed procedures and information relative to major maintenance, repair of components, inspection requirements, functional test and adjustments.

NOTE

The above are all subject to change.

INSPECTION AND MAINTENANCE.

Except for a few component replacements and replacement of the complete unit, the inspection and maintenance procedures for the APU are found in the field maintenance manual. Very little repair of the APU is anticipated with the unit installed in an aircraft; therefore, the aircraft maintenance manual only contains replacement procedures, system operation, and operation of the APU in the aircraft. The mechanic should be thoroughly familiar with both sources of information.

Overhaul requirements on the APU are not specifically laid down as such, as on an aircraft power plant. Criteria establishing overhaul depend primarily on the customer and his maintenance capability.

Preflight and/or post flight inspection are nothing more than a thorough visual inspection of the unit and servicing of the oil tank. Like any gas turbine engine, one of the most important items is to ensure that the intake and exhaust are free of foreign material.

On new or overhauled units, a special inspection is recommended after the first 20 hours of operation or the first 100 starts. A one-time inspection, specific requirements are the same as a periodic inspection including a performance check on the unit. The purpose of this inspection is to catch any impending failures of the unit, therefore, ensuring its reliability for continued use.

Periodic inspections of the unit are recommended after each 200 hours of unit operating time or each 1000 starts, whichever occurs first.

Details of the inspection procedure, specific cleaning procedures, inspection limits, etc. are listed in detail in the field maintenance manual.

The APU must be removed from the aircraft for the initial break in inspection and periodic inspections to be performed.

Thorough understanding of the APU systems and use of the troubleshooting charts provided in the maintenance manuals is the most reliable means of correcting problems in a minimum of time.

TROUBLE SHOOTING INFORMATION

TROUBLE	PROBABLE CAUSE	REMEDY
No response from starter when start switch is actuated.	External power supply defective.	Repair or replace leads or re-place power supply.
	Start switch failure.	Check for continuity between start switch poles with power supply off and start switch on. if no continuity, replace start switch.

TROUBLE SHOOTING INFORMATION

TROUBLE	PROBABLE CAUSE	REMEDY
No response from starter when start switch is actuated. (CONT)	Centrifugal switch assembly 110-percent switch open.	Repair or replace centrifugal switch assembly.
	Centrifugal switch assembly 35-percent switch open.	Repair or replace centrifugal switch assembly.
	Starter relay (external) defective.	Replace relay.
	Wiring defective.	Replace or repair wiring as necessary.
Starter rotates but does not crank unit.	Starter clutch or pawls improperly adjusted or defective.	Check clutch slippage torque. Repair or replace starter motor adapter assembly.
	Accessory drive gears stripped.	Replace complete unit.
	Torsion shaft or planetary drive shaft failure.	Check for positive coupling through engine by manually turning turbine wheel. Replace defective shaft.
Starter cranks unit but combustion does not occur. No (or low) fuel pressure.	Fuel supply low; or clogged filters.	Disconnect fuel inlet line. check for fuel flow. Check fuel supply. Check and replace fuel filters.
	Fuel control unit acceleration limiter valve improperly adjusted or defective.	Adjust limiter valve setting or replace fuel control unit diaphragm assembly.
	Fuel control unit governor stuck open.	Repair or replace fuel control unit.
	Fuel control unit relief valve stuck open.	Repair or replace fuel control unit.
	Fuel pump governor seal leakage, shaft seal leakage (fuel flow from drain line), or pump parts defective.	Replace fuel control unit shaft seal.
Starter cranks unit but combustion does not occur. Normal cracking pressure and no pressure drop at 10-percent speed.	Fuel atomizer screen clogged.	Clean screen or repair fuel atomizer assembly.
	Fuel solenoid valve defective.	Replace fuel solenoid valve.
	Oil supply low.	Check and replenish oil supply.
	Oil pump pressure relief valve stuck open.	Repair or replace oil pump relief valve.

TROUBLE	PROBABLE CAUSE	REMEDY
Starter cranks unit but combustion does not occur. Normal cracking pressure and no pressure drop at 10-percent speed. (CONT)	Oil pressure switch defective.	Check oil pump pressure while motoring unit. If normal, replace oil pressure switch.
Starter cranks unit but combustion does not occur. Fuel pressure normal, and drops momentarily at 10-percent speed.	Ignition unit defective.	Check ignition unit primary and secondary circuits for continuity with an ohmmeter. Replace ignition unit if open circuit is indicated.
	Igniter plug or ignition lead assembly defective.	Replace igniter plug or ignition lead assembly.
	Fuel atomizer flow divider valve stuck open or carbon on nozzle.	Repair or replace fuel atomizer assembly.
	Fuel filter clogged.	Replace fuel filter element.
	Oil pressure switch defective.	Replace oil pressure switch.
Unit starts, accelerates to governed speed or less, and shuts down.	Low fuel control unit governor setting.	Check RPM on tachometer at cutoff point. Reset fuel control unit governor setting.
	Centrifugal switch assembly overspeed switch setting low.	Repair or replace centrifugal switch assembly.
Unit does not reach governed speed, or rate of acceleration too slow.	Defective battery.	Replace battery.
	Control air leak.	Check control air lines and fittings. Check accelerator stabilizer solenoid and adjustable orifice assembly for proper adjustment. Adjust if necessary. If air lines and fittings are secure, repair or replace fuel control unit.
	Fuel pump acceleration limiter valve improperly adjusted or defective.	Adjust limiter valve setting or replace fuel control unit diaphragm assembly.
	Fuel control unit governor stuck open.	Repair or replace fuel control unit.
	Fuel control unit relief valve stuck open.	Repair or replace fuel control unit.
	Fuel pump governor seal leakage, shaft seal leakage, fuel flow from drain line, or pump parts defective.	Replace fuel control unit drive shaft seal, governor seal, or replace fuel control unit.

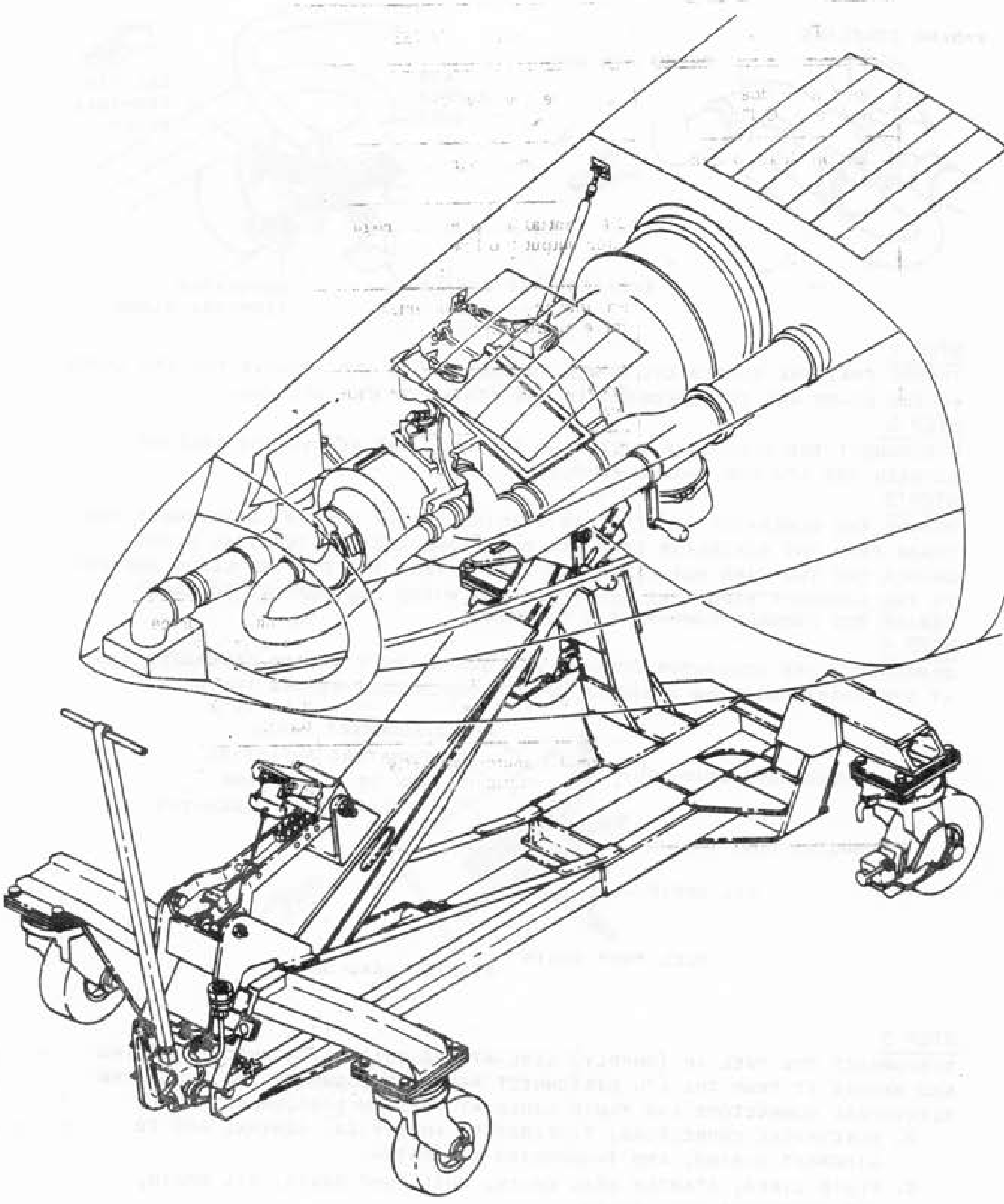
TROUBLE	PROBABLE CAUSE	REMEDY
Unit does not reach governed speed, or rate of acceleration too slow. (CONT)	Acceleration and overtemperature control thermostat defective.	Adjust or replace thermostat.
	Fuel pump governor setting low.	Check control air pressure normal, peak fuel pressure on acceleration normal. If idle fuel pressure low, reset governor.
	Fuel atomizer filter screen clogged.	Clean or replace filter screen.
	Fuel atomizer defective.	Check for irregular spray pattern and general appearance of nozzle. Repair or replace atomizer if abnormal.
	Air being bled from unit.	Check pneumatic shutoff butterfly valve for closed position. Repair or replace if partially open. Check for leakage from ducts and turbine plenum.
	Fuel filter clogged.	Replace fuel filter.
	Fuel supply restricted.	Check for adequate fuel supply.
Instability during start.	Fuel control unit acceleration limiter valve improperly adjusted or defective.	Adjust limiter valve setting or replace fuel control unit diaphragm assembly.
	Acceleration and overtemperature control thermostat defective.	Adjust or replace thermostat.
	Acceleration stabilizer orifice defective.	Adjust or replace acceleration stabilizer orifice assembly.
Excessive turbine temperature on start.	Acceleration control thermostat defective.	Adjust or replace acceleration control thermostat.
	Fuel control unit acceleration limiter valve improperly adjusted or defective.	Adjust acceleration limiter valve or replace fuel control unit diaphragm assembly.
	Fuel atomizer flow divider valve stuck open.	Repair or replace fuel atomizer.
Smoke emitted for short time after start.	Excessive oil in system or oil tank.	Drain oil to proper level.
	Oil pump check valve defective.	Repair or replace oil pump assembly.

TROUBLE	PROBABLE CAUSE	REMEDY
Smoke emitted for short time after start. (CONT)	Scavenge oil pump defective.	Repair or replace oil pump assembly.
	Fuel drain valve sticking closed.	Clean or replace valve.
Excessive oil smoke from unit or tank vent during operation.	Accessory housing vent plug loose.	Visually check. Tighten plug.
	Packing failure on oil jet nozzle and vent tubes.	Remove parts and replace packings.
	Output shaft seal leaking.	Replace seal.
	Fan shaft seal leaking.	Replace seal.
	Accessory housing oil pump shaft seal leaking.	Replace seal.
Excessive oil temperature.	Low oil supply.	Check for proper oil supply.
	Oil cooler cooling air tubes restricted.	Remove restriction or replace oil cooler.
Loss of oil pressure.	Oil pump relief valve sticking open.	Repair or replace oil pump relief valve.
	Low oil supply.	Check for proper oil supply.
	Oil line broken.	Replace broken oil line.
Fuel leaks from fuel and oil drain line.	Dirt under fuel control unit drive shaft seal retainer, or packing and seal failure.	Replace fuel control unit drive shaft seal.
	Fuel control unit drive shaft defective.	Replace fuel control unit drive shaft.
	Fuel control unit inner acceleration limiter valve diaphragm ruptured.	Replace fuel control unit diaphragm.
Excessive oil leakage from fuel and oil drain line when unit is shut down.	Oil pump relief valve defective.	Repair or replace oil pump relief valve.
Pneumatic shutoff butterfly valve fails to open.	Pneumatic shutoff butterfly valve control circuit switches, relays, or circuit breaker defective.	Check external circuit and replace defective part.
	Pneumatic shutoff butterfly valve solenoid defective.	Replace solenoid or repair shutoff valve.
	Differential air pressure regulator defective.	Check regulator outlet pressure. If abnormal, repair or replace regulator.

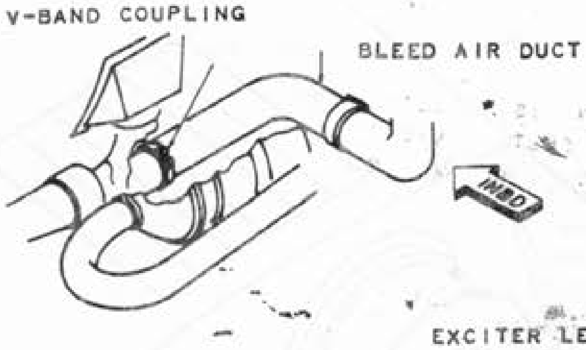
TROUBLE	PROBABLE CAUSE	REMEDY
Pneumatic shutoff butterfly valve fails to open. (CONT)	Control air line connection loose, or pneumatic shutoff butterfly valve inlet orifice restricted.	Check orifice or tighten connections.
	Actuator diaphragm leakage.	Disconnect regulator line to pneumatic butterfly shutoff valve. With shutoff valve de-energized, apply mouth pressure to inlet port. If air flow, replace diaphragm.
	Load control thermostat defective.	Adjust or replace load control thermostat.
	Centrifugal switch assembly 95-percent switch failure.	Repair or replace centrifugal switch assembly.
Pneumatic shutoff butterfly valve opening time too slow or too fast.	Rate control improperly set or valve defective.	Adjust rate control or repair pneumatic shutoff butterfly valve.
Unit speed drops more than 800 RPM (maximum) as load is applied.	Control air leakage.	If control air pressure is low at idle, and peak fuel pressure is low during start, check for loose control air connection and tighten.
	Fuel control unit acceleration limiter valve defective.	Repair or replace fuel control unit.
	Fuel supply to unit inadequate. Clogged filter screen in atomizer.	Check for fluctuating fuel pressure as load is applied. Check external fuel supply system for maintaining pressure. Clean or replace atomizer filter screen.
	Load control thermostat set high.	Adjust or replace load control thermostat.
	Acceleration control thermostat setting low	Adjust or replace thermostat.
	Mechanical overload.	If unit takes extended time to start, and idle fuel pressure is high, check unit for mechanical malfunction. Replace complete unit.
Hourmeter does not record.	Defective hourmeter circuit breaker.	Replace circuit breaker.

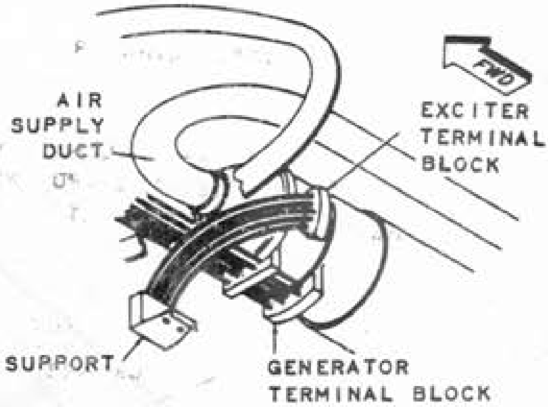
TROUBLE SHOOTING INFORMATION

TROUBLE	PROBABLE CAUSE	REMEDY
Hourmeter does not record. (CONT)	Defective hourmeter.	Replace hourmeter.
Low bleed air output.	Leaking control air line.	Check and tighten control air line.
	Differential air pressure regulator output too low.	Check regulator outlet pressure. If abnormal, repair regulator.
	Pneumatic shutoff butterfly valve malfunctioning.	Repair or replace pneumatic shutoff butterfly valve.
	Excessive drag of driven equipment.	Repair or replace driven equipment.
	Cracked turbine plenum.	Replace turbine plenum.
	Compressor leakage from turbine plenum gasket.	Replace gaskets, tighten bolts securely.
	Load control thermostat defective.	Adjust or replace load control thermostat.
Excessive turbine temperature on bleed load.	Load control thermostat defective.	Adjust or replace load control thermostat.
	Differential air pressure regulator output too high.	Repair or replace differential air pressure regulator.
	Pneumatic shutoff butterfly valve malfunctioning.	Adjust, repair, or replace pneumatic shutoff butterfly valve.



APU REMOVAL AND INSTALLATION





STEP 1

INSURE THAT THE ELECTRICAL POWER TO THE APU IS OFF. REMOVE THE APU LOWER ACCESS DOORS AND THE LONGERON IN THE CENTER OF THE OPENING.

STEP 2

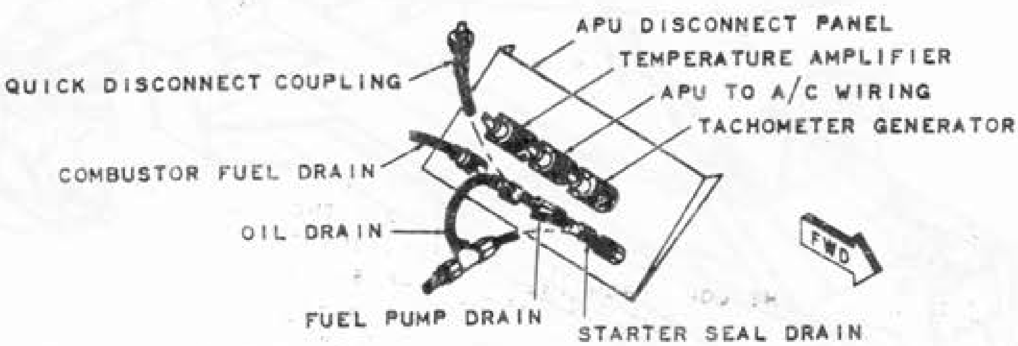
DISCONNECT THE BLEED AIR DUCT FROM THE APU, AND REMOVE THE SECTION BETWEEN THE APU AND V-BAND COUPLING.

STEP 3

REMOVE THE GENERATOR AND EXCITER TERMINAL BLOCK COVERS. DISCONNECT THE LEADS FROM THE GENERATOR TERMINAL BLOCK AND EXCITER TERMINAL BLOCK. UNLOCK THE TWO WING NUT FASTENERS THAT ATTACH THE EXCITER LEADS SUPPORT TO THE AIRCRAFT STRUCTURE AND ALLOW THE WIRES AND SUPPORT TO HANG BESIDE THE FORWARD COMPARTMENT BULKHEAD.

STEP 4

DISCONNECT THE GENERATOR COOLING AIR SUPPLY DUCT AT THE GENERATOR AND AT THE FIRST COUPLING UPSTREAM OF THE GENERATOR. REMOVE THE DUCT.



STEP 5

DISCONNECT THE FUEL IN (SUPPLY) LINE AT THE QUICK DISCONNECT COUPLING AND REMOVE IT FROM THE APU DISCONNECT PANEL. DISCONNECT THE FOLLOWING ELECTRICAL CONNECTORS AND FLUID LINES AT THE APU DISCONNECT PANEL.

A. ELECTRICAL CONNECTORS, TEMPERATURE AMPLIFIER, GENERAL APU TO AIRCRAFT WIRING, AND TACHOMETER GENERATOR.

B. FLUID LINES, STARTER SEAL DRAIN, FUEL PUMP DRAIN, OIL DRAIN, AND COMBUSTOR FUEL DRAIN.

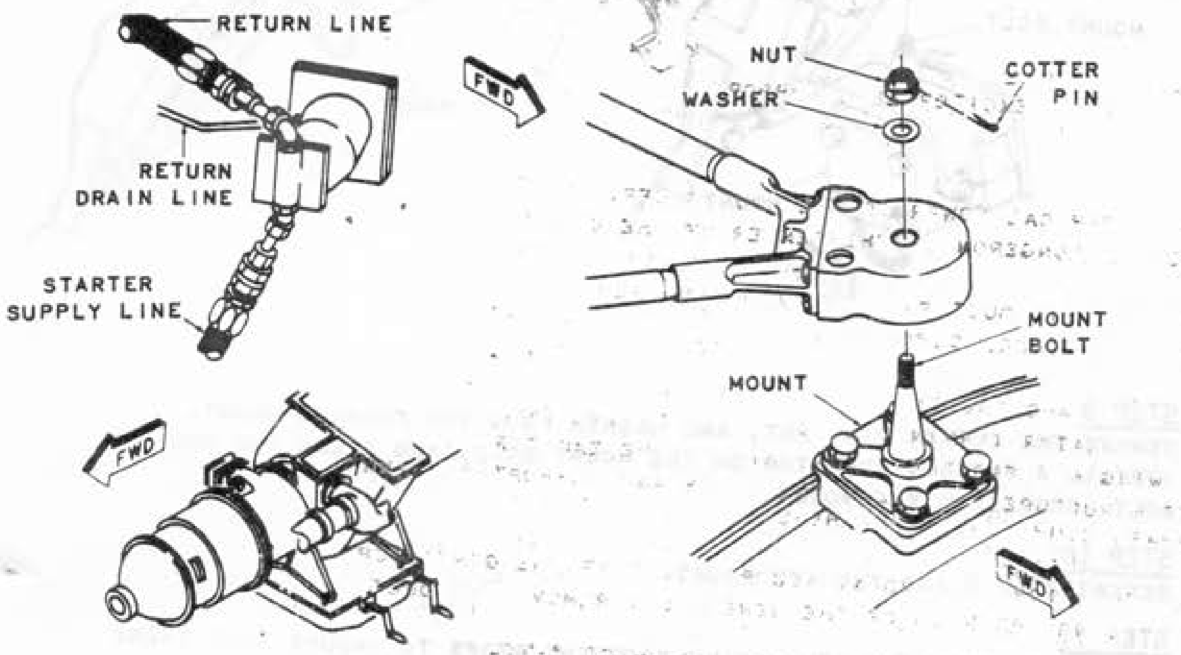
APU REMOVAL AND INSTALLATION

STEP 6

DISCONNECT THE HYDRAULIC STARTER SUPPLY LINE, RETURN LINE, AND RETURN DRAIN LINE AT THE APU STARTER.

NOTE:

HYDRAULIC FLUID WILL DRAIN FROM THE STARTER LINES, WHEN DISCONNECTED, UNTIL ALL THE FLUID IN THE LINES BETWEEN THE APU AND A SHUTOFF VALVE IN THE SUPPLY LINE AND A CHECK VALVE IN THE RETURN LINE, HAD DRAINED.

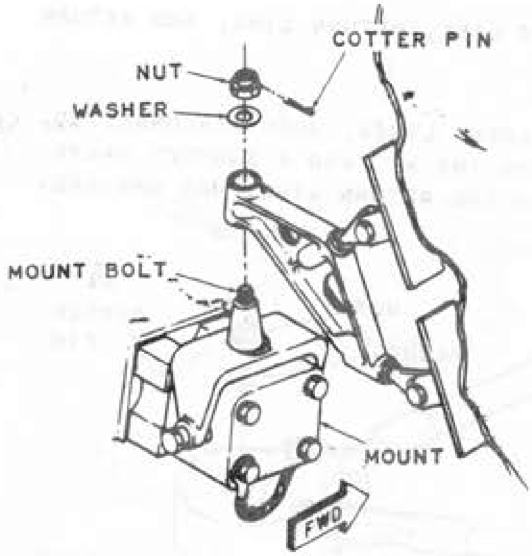


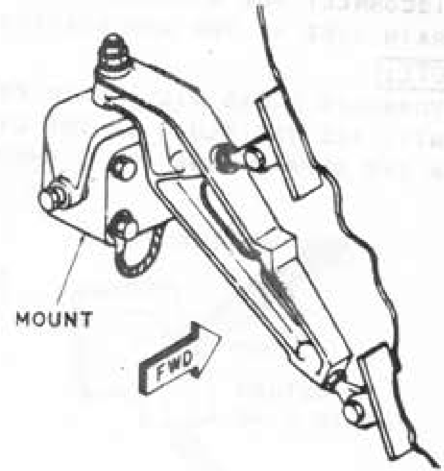
STEP 7

POSITION THE 3S30036 APU REMOVAL AND INSTALLATION TRAILER UNDER THE APU AND COUPLE THE ADAPTERS ON THE TRAILER TO THE TUBULAR FRAME UNDER THE APU. ADJUST THE TRAILER TO RELIEVE THE LOAD FROM THE APU MOUNTS.

STEP 8

REMOVE THE COTTER PIN, NUT, AND WASHER FROM THE TOP MOUNT. INSTALL A THREAD PROTECTOR ON THE MOUNT BOLT, AND BREAK THE MOUNT BOLT LOOSE FROM THE MOUNT. TIE THE MOUNT SUPPORT UP AND OUT OF THE WAY. LEAVE IT IN THIS POSITION FOR APU INSTALLATION.





STEP 9
REMOVE THE COTTER PIN, NUT, AND WASHER FROM THE FORWARD MOUNT. INSTALL A THREAD PROTECTOR ON THE MOUNT BOLT, AND BREAK THE MOUNT BOLT LOOSE FROM THE MOUNT.

STEP 10
REPEAT STEP 9 FOR THE AFT MOUNT.

STEP 11
CAREFULLY LOWER THE APU MAKING FREQUENT STOPS TO INSURE THAT THERE IS NO INTERFERENCE WITH STRUCTURE OR DUCTING.

STEP 12
CLOSE OFF ALL DUCTS AND TUBING BOTH ON THE APU AND THE AIRCRAFT.

INSTALLATION PROCEDURE

STEP 13
INSTALL THREAD PROTECTORS ON MOUNT BOLTS. APPLY SPECIFICATION MIL-T-5544 ANTISEIZE COMPOUND ON THE BOLTS.

STEP 14
REVERSE THE REMOVAL PROCEDURES. MAKE SURE THE DUCTS AND SEALS ALIGN PROPERLY. IT MAY BE NECESSARY TO ADJUST THE MOUNTS TO OBTAIN PROPER ALIGNMENT

APU REMOVAL AND INSTALLATION