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.

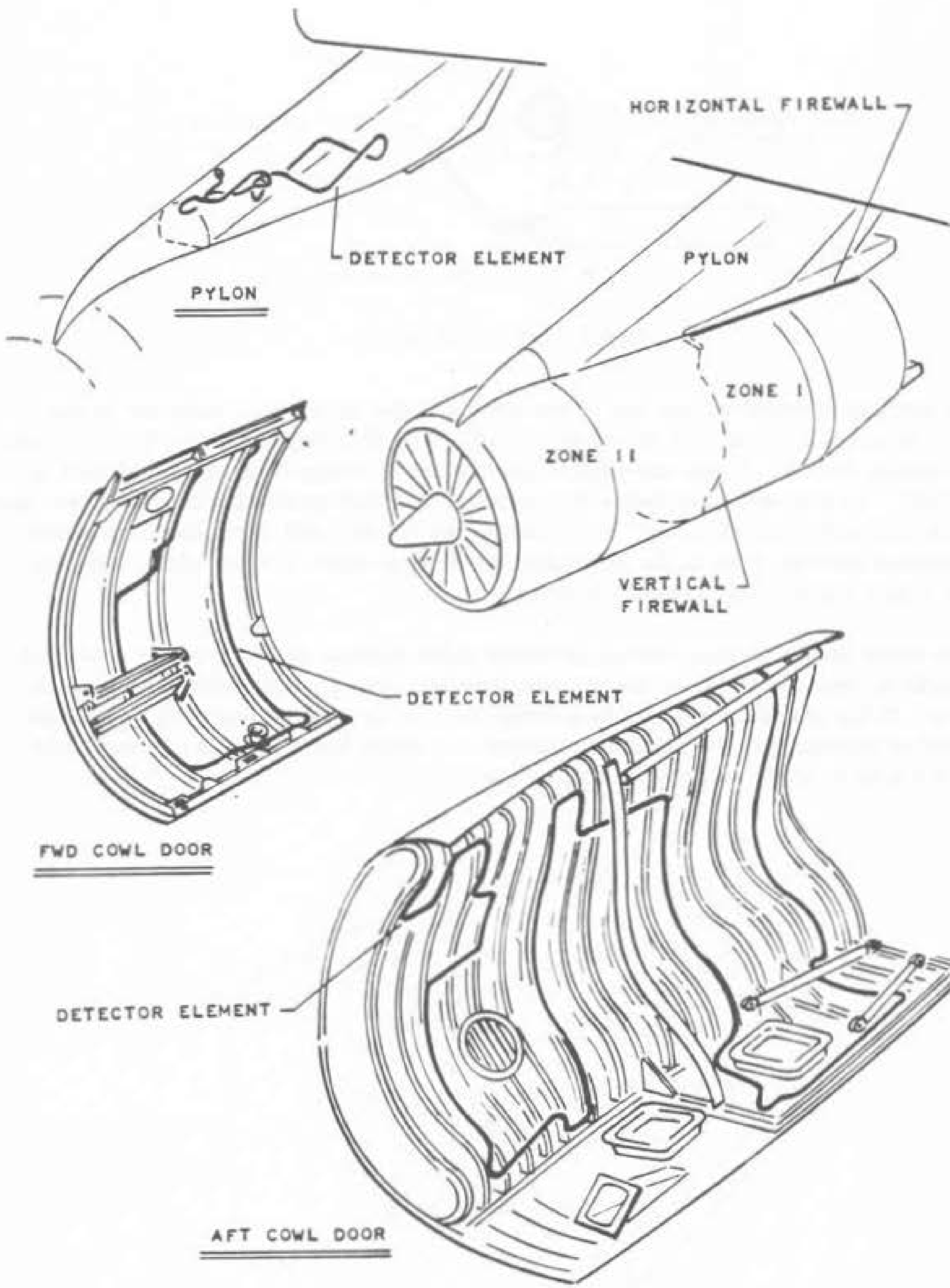
The engine, nacelle, and pylon of each power plant assembly are protected by a fire and overheat warning system. The system is composed of a continuous-loop, wire-like element routed through the areas where a fire or overheat condition could occur. The wire is a temperature-sensing element which is connected 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.

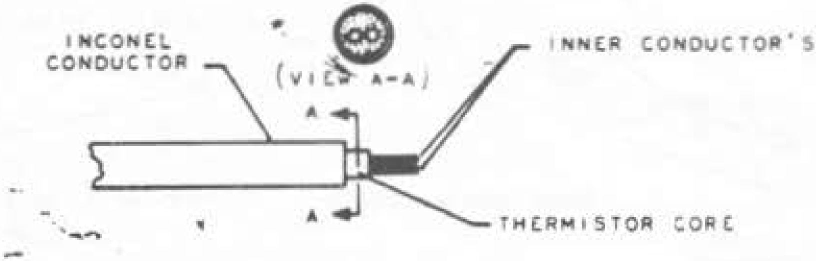
Each power plant has three sections which are constantly monitored. They are Zone No. 1, which is aft of the vertical firewall; Zone No. 2, which is forward of the firewall; and the engine plyon. The pylon is separated from the other areas by a horizontal firewall. These firewalls prevent combustibles 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

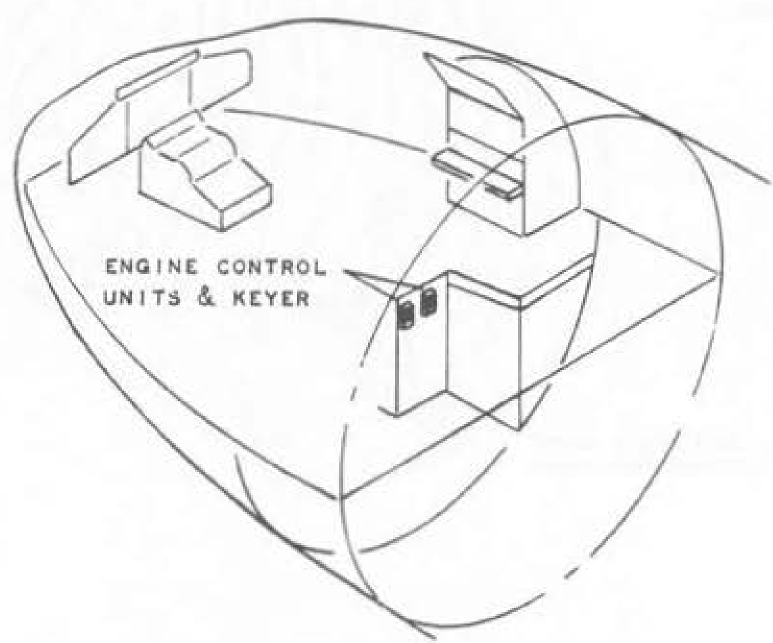

HORIZONTAL FIREWALL
DETECTOR ELEMENT
PYLON
PYLON
ZONE I
ZONE II
VERTICAL FIREWALL
DETECTOR ELEMENT
FWD COWL DOOR
DETECTOR ELEMENT
AFT COWL DOOR

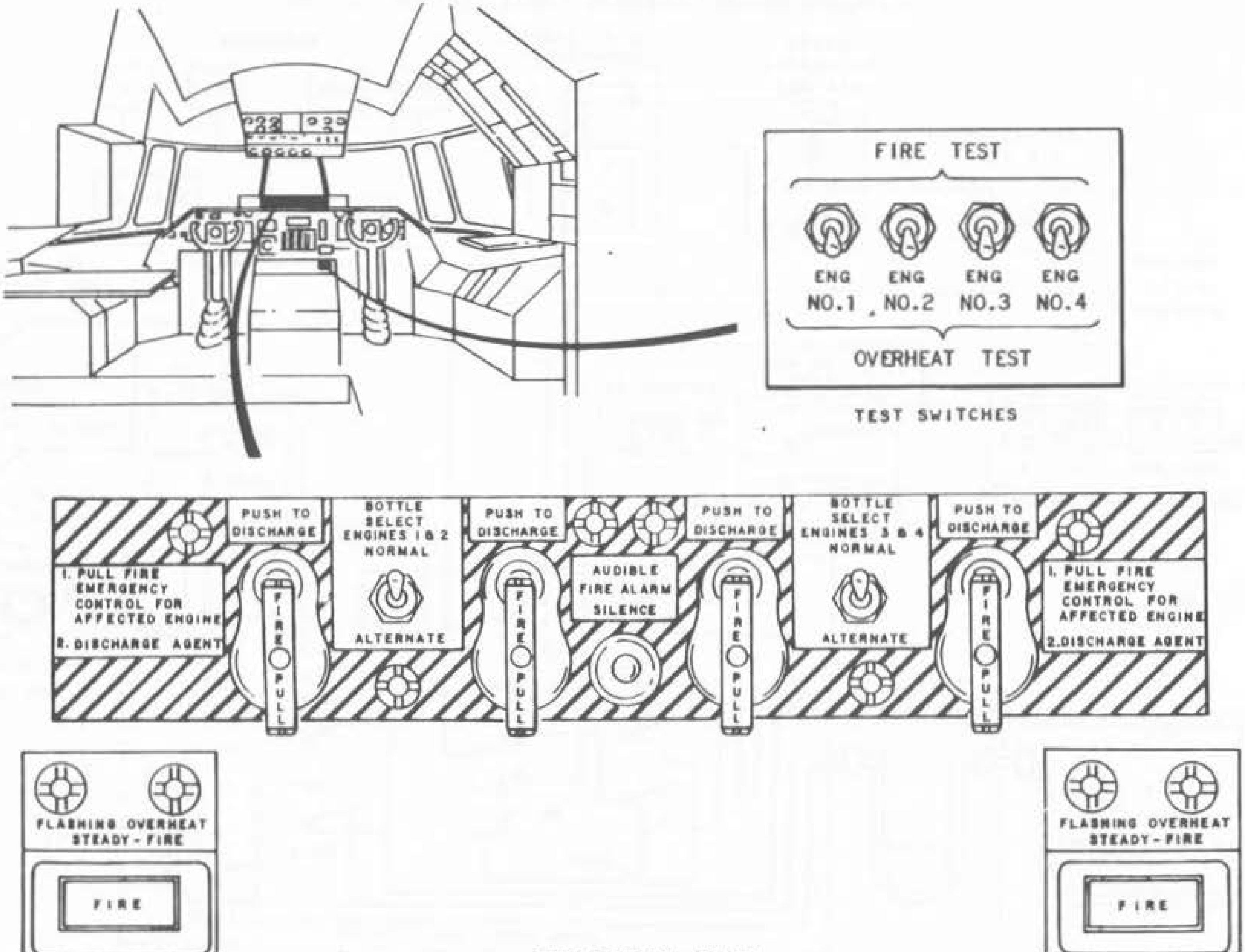


CROSS SECTION OF WIRE

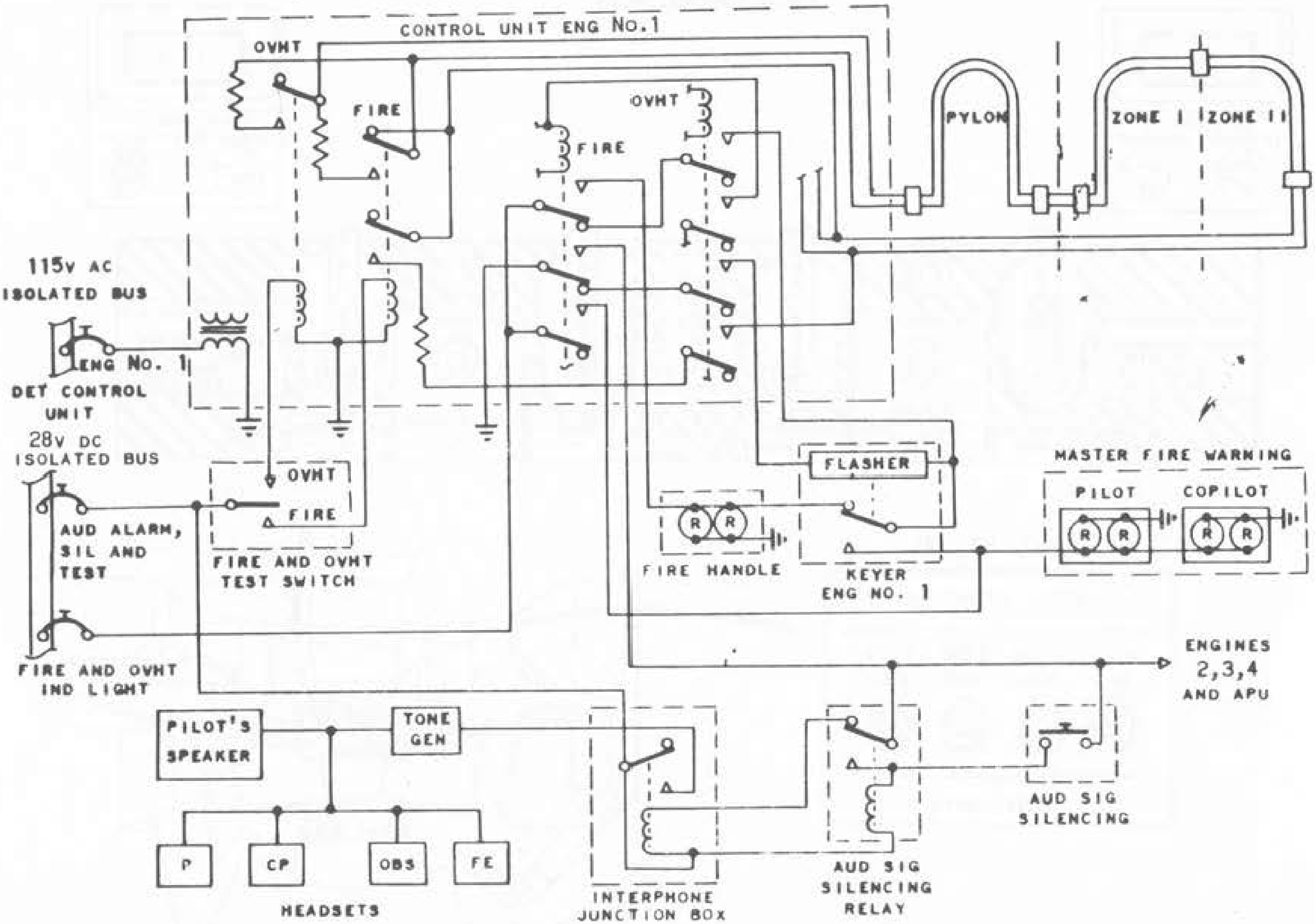
the sensing element as one leg of the bridge. The bridge null detector is the first stage of a transistor flip-flop circuit. The flip-flop circuit is the automatic switching device. When one-half of the circuit is conducting, the other half is cut off. As element resistance decreases to the null-producing 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.





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, "OVERHEAT 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.

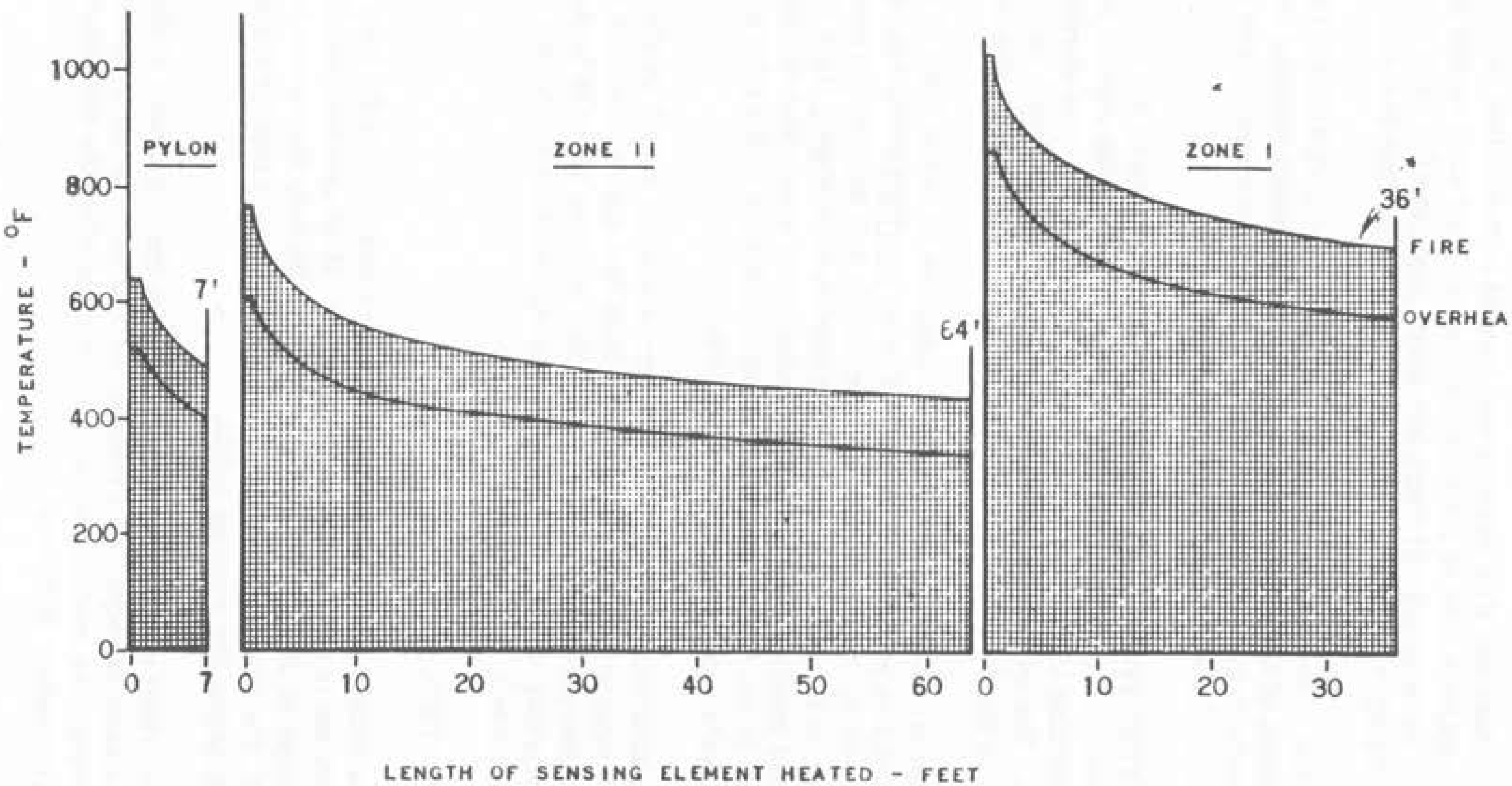
In the nacelle and pylon wire loop, the resistance of the loop under normal conditions is approximately 2629 ohms. If an overheat condition (207°C±16°) develops in the pylon, the resistance of the loop decreases to 1061 ohms. At this point, the overheat warning relay in the control box for the affected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

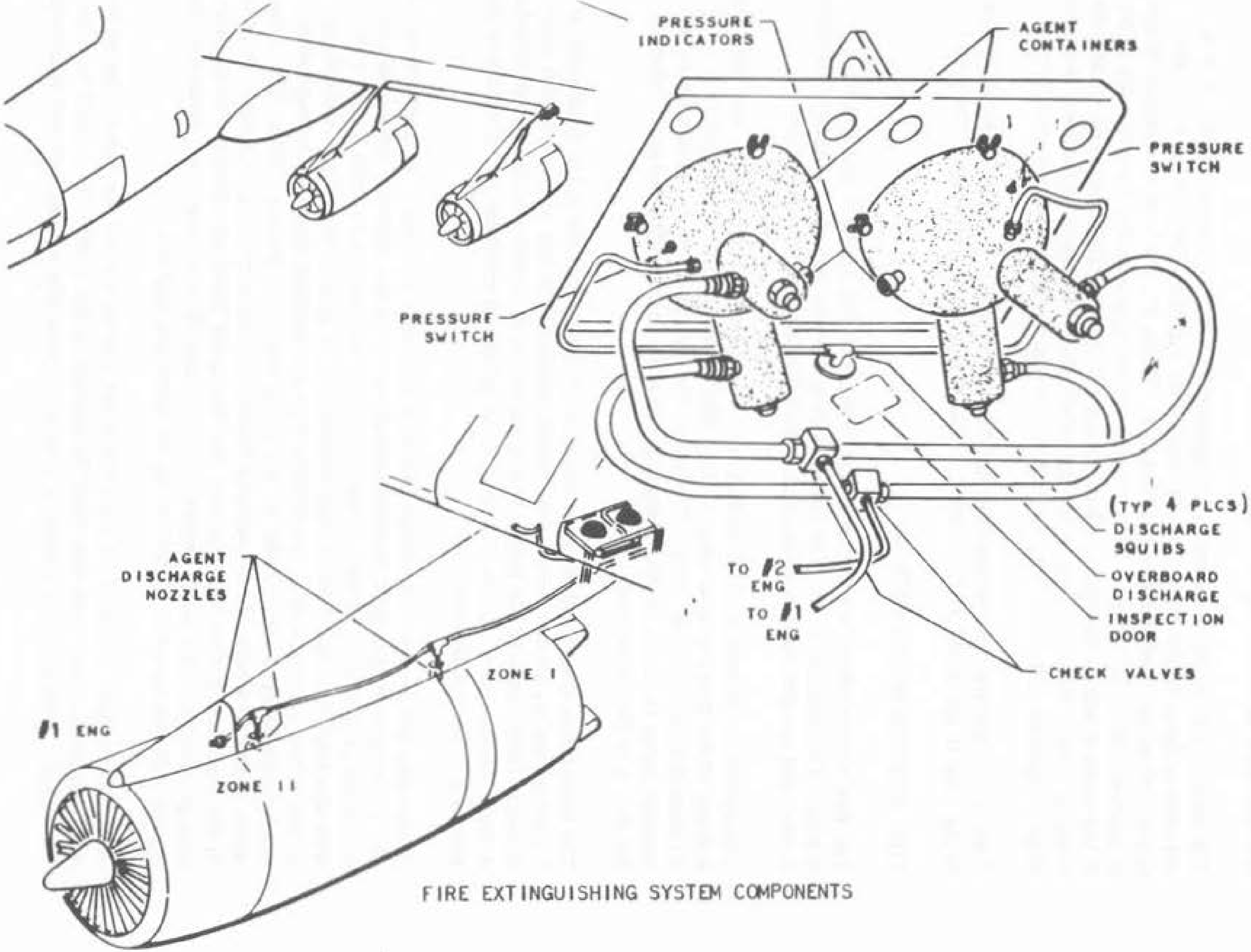
The fire extinguishing system provides protection for Zones 1 and 2 of each engine. Components of the fire extinguishing system include the agent containers, directional control valves, plumbing, and indicating and control units.

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.

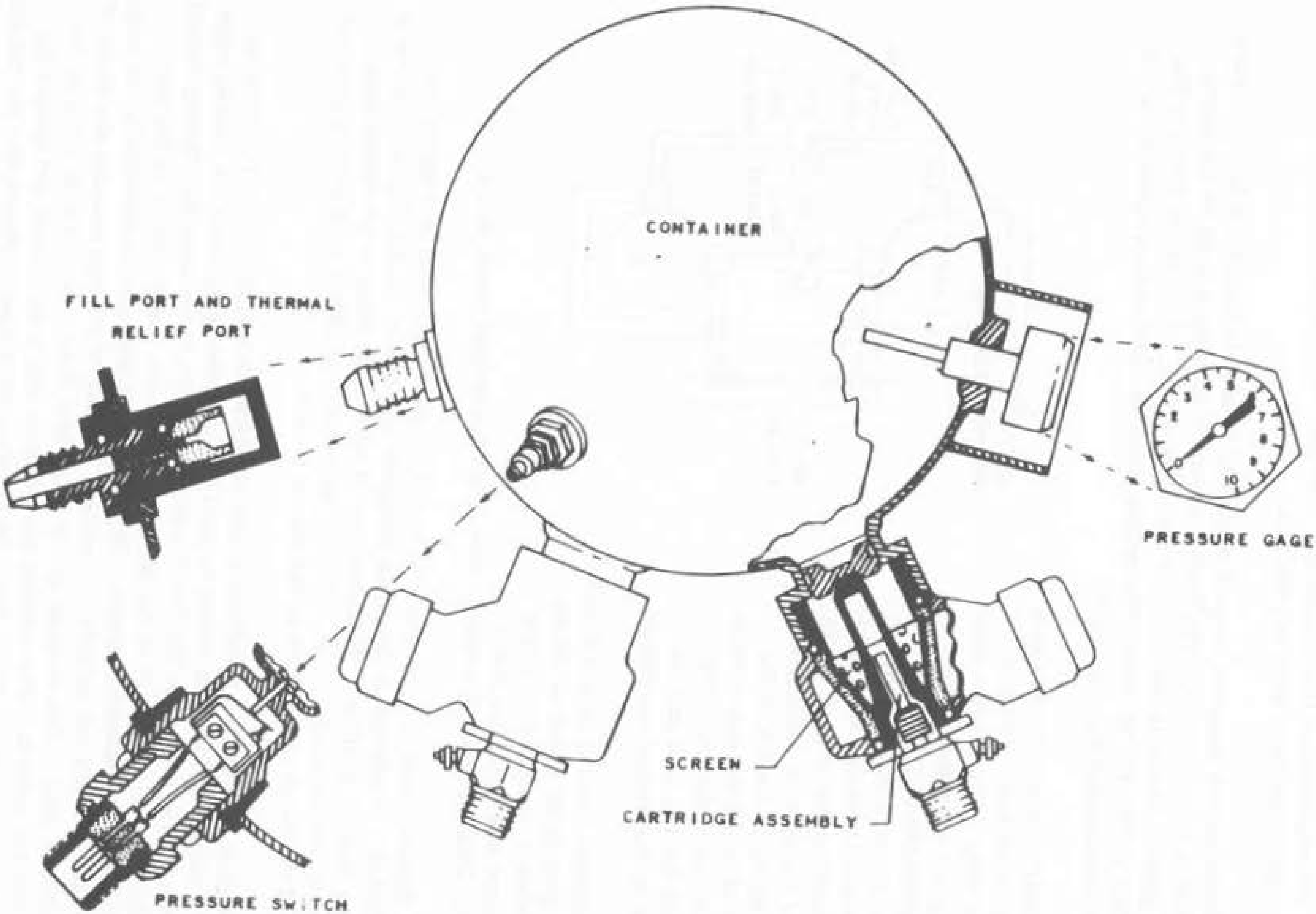
The containers are mounted in the outboard pylons aft of the pylon bulkheads in the pylon box structure. Four horizontal, slotted lugs are welded to each container. Each container is bolted to a rack which is attached to the pylon structure. A large access panel on the left side of the pylons is provided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

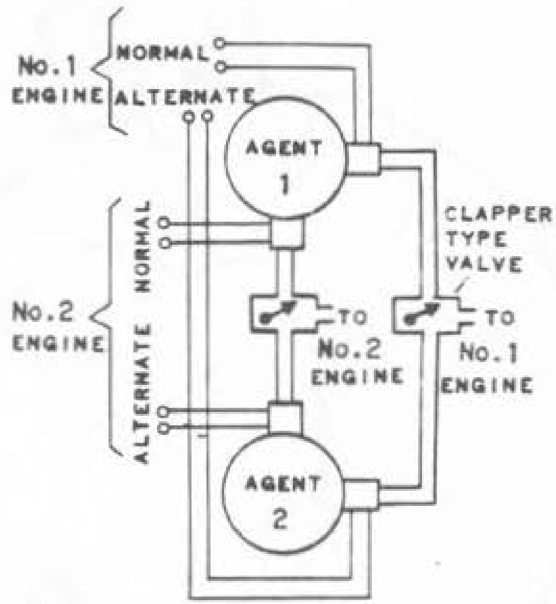


ENGINE FIRE EXTINGUISHING CONTAINER

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.

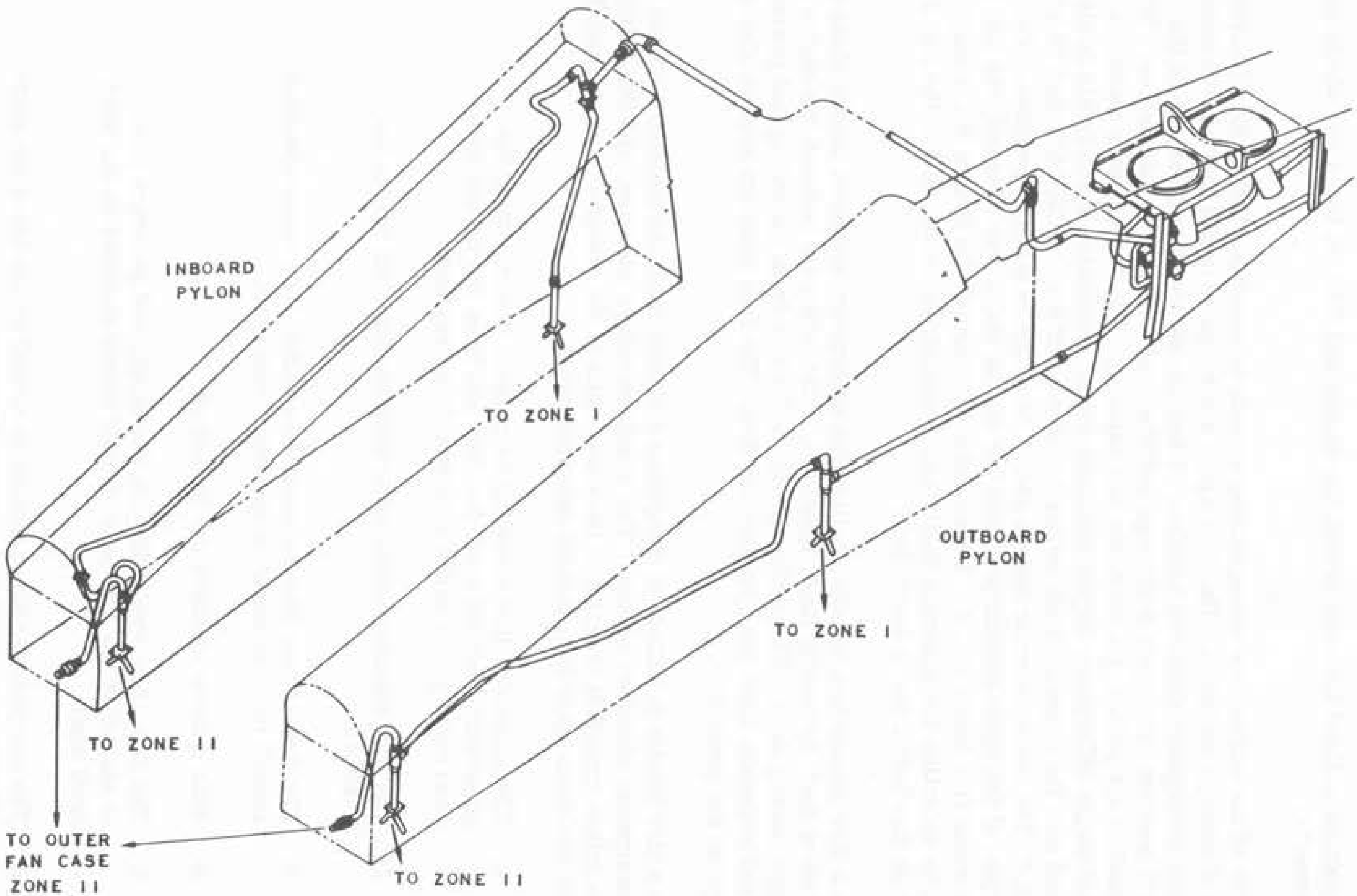
The filler port also serves as a safety outlet and contains a fusible plug. The fusible-alloy-type plug is designed to relieve at a pressure of 775 PSI or a temperature of 93.3°C-107.2°. A 1/4-inch tube is connected to the safety outlet of each bottle and is routed to a red indicator disk which is flush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

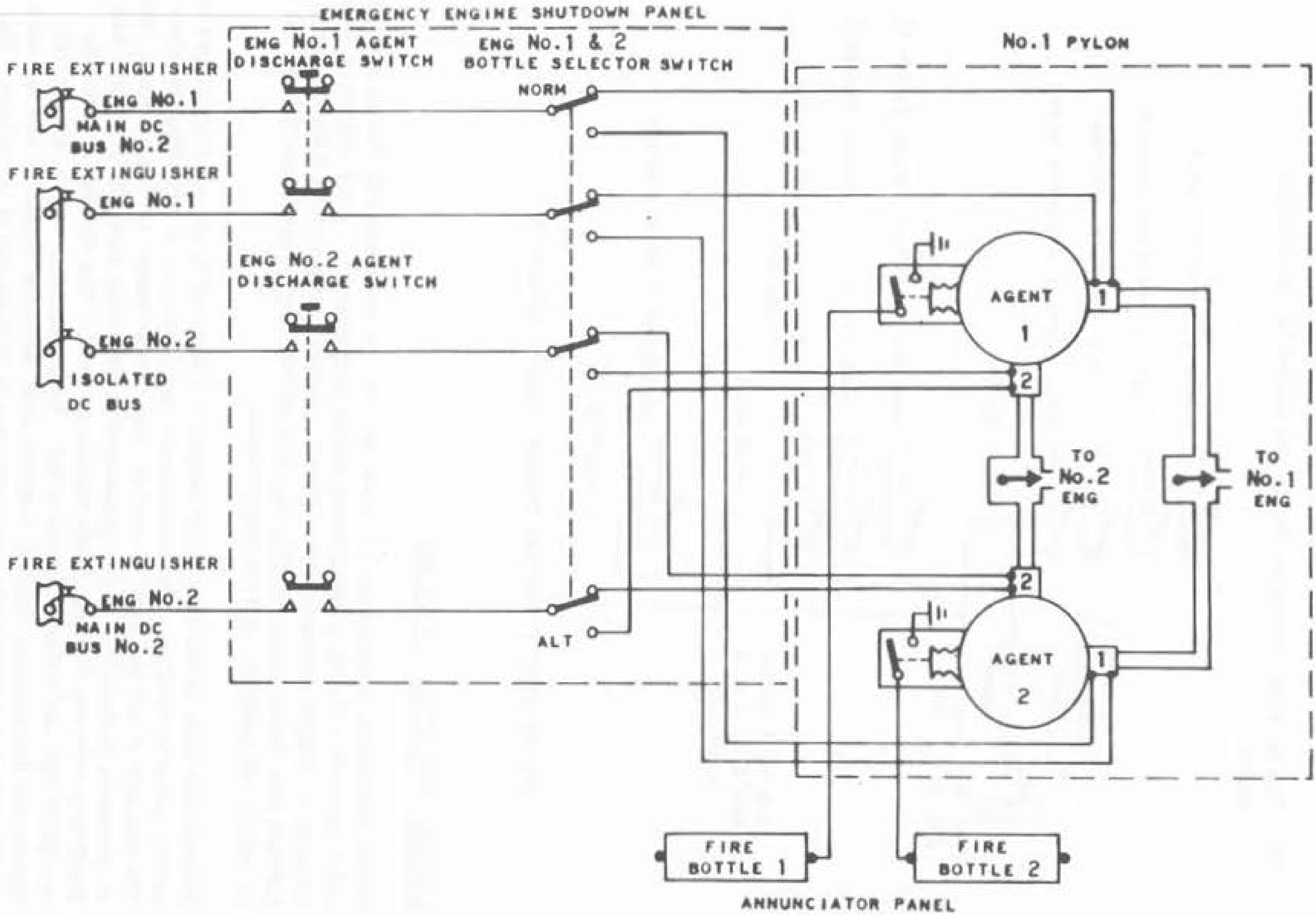
2. The fuel control shutoff valve actuator shuts off fuel to the control.

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.

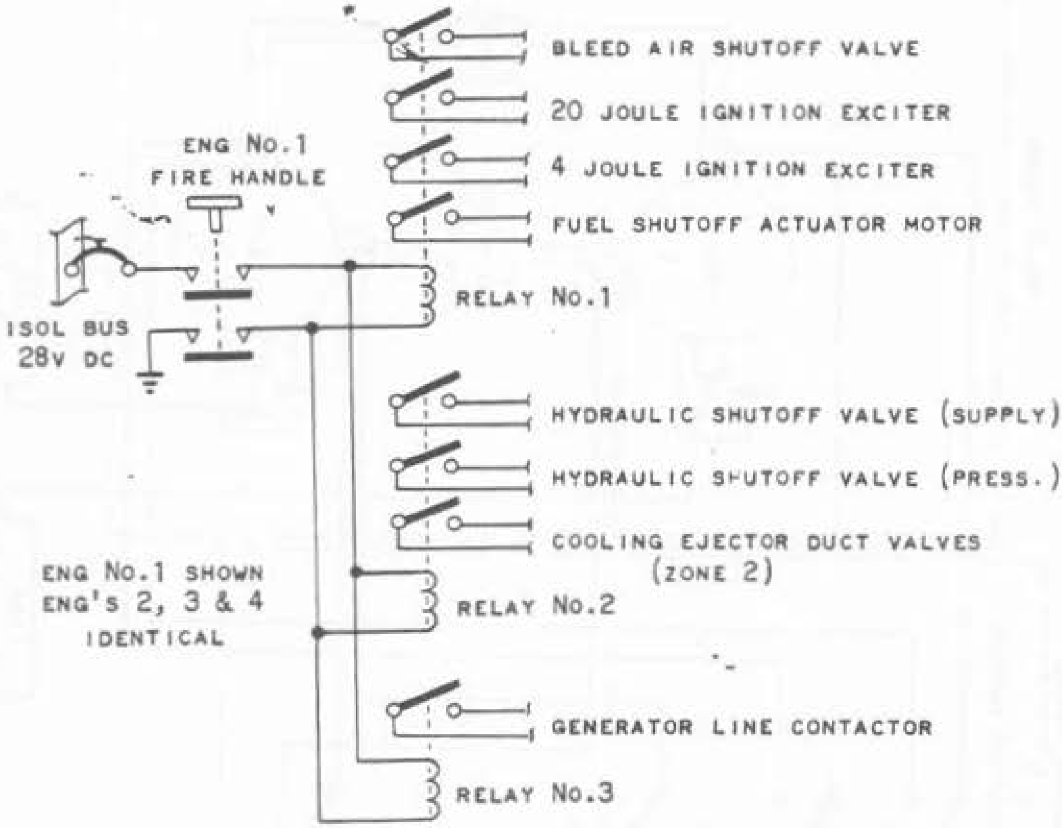
5. The flow of hydraulic fluid in the supply and pressure lines is shutoff by the hydraulic shutoff valves mounted on the wing front spar.

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.

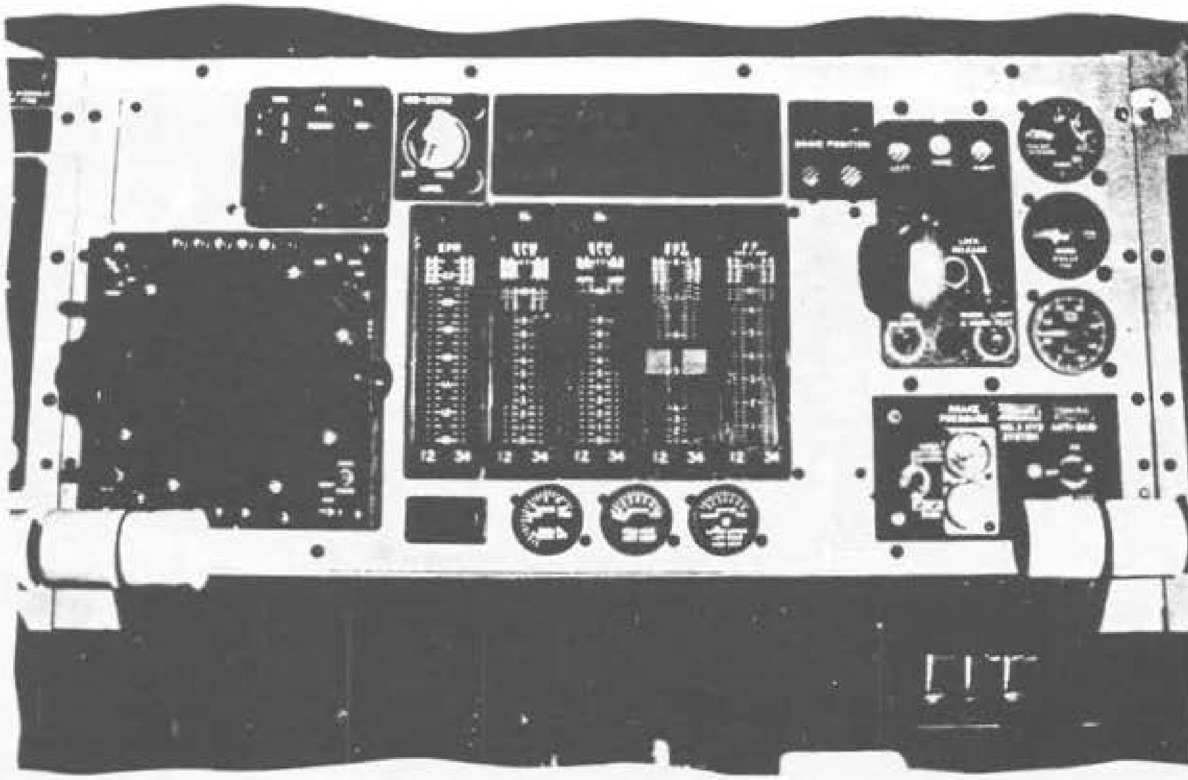


ENGINE FIRE ISOLATION SYSTEM CIRCUIT SCHEMATIC

ENGINE INDICATING SYSTEMS.

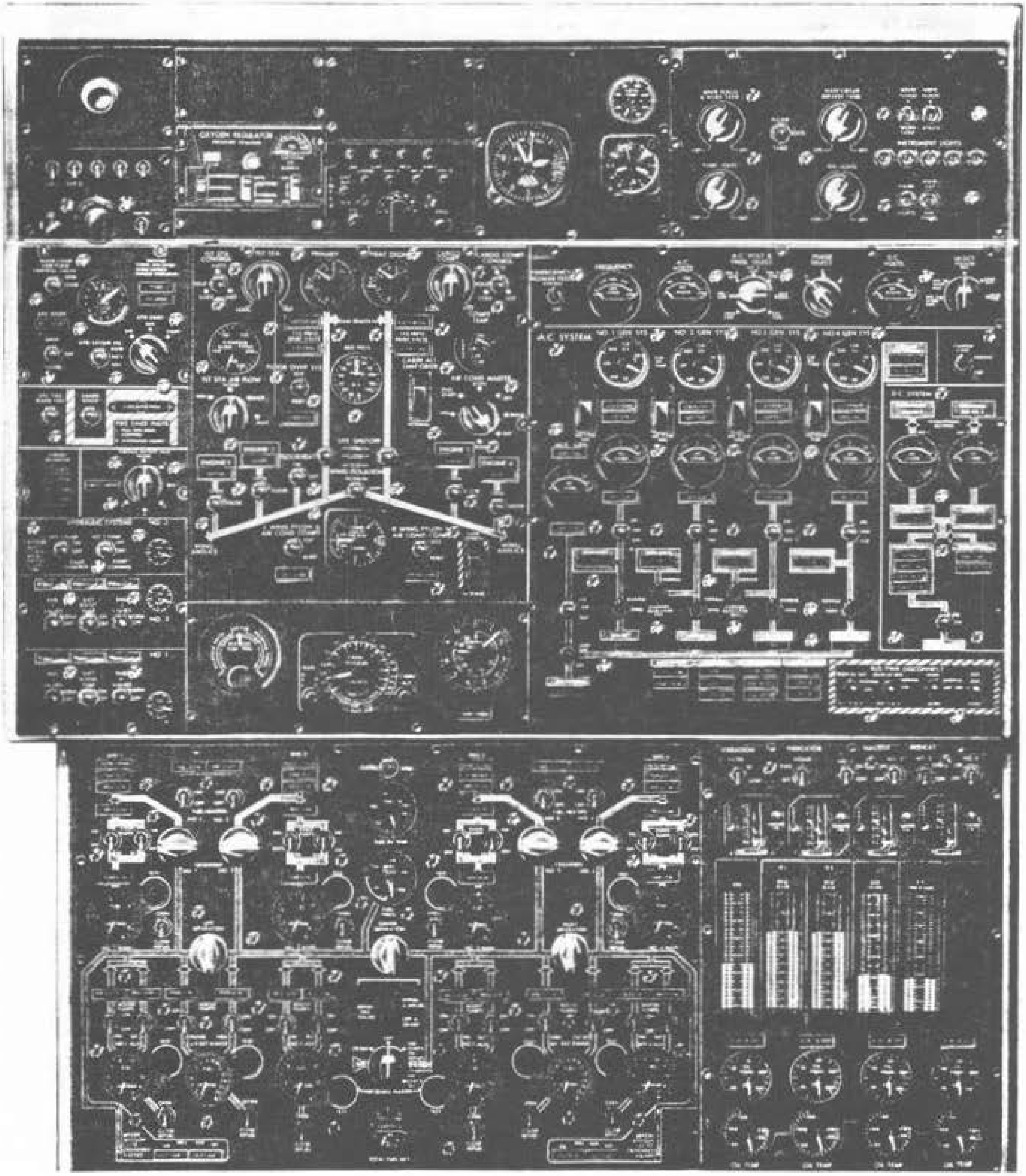
Engine indicating systems are installed in order to ensure safety during operation and to provide a means of monitoring engine performance. Each engine is monitored as to Engine Pressure Ratio (EPR), compressor speed N1 RPM (percent), Exhaust Gas Temperature (EGT), fuelflow (PPH), engine vibration (MILS),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

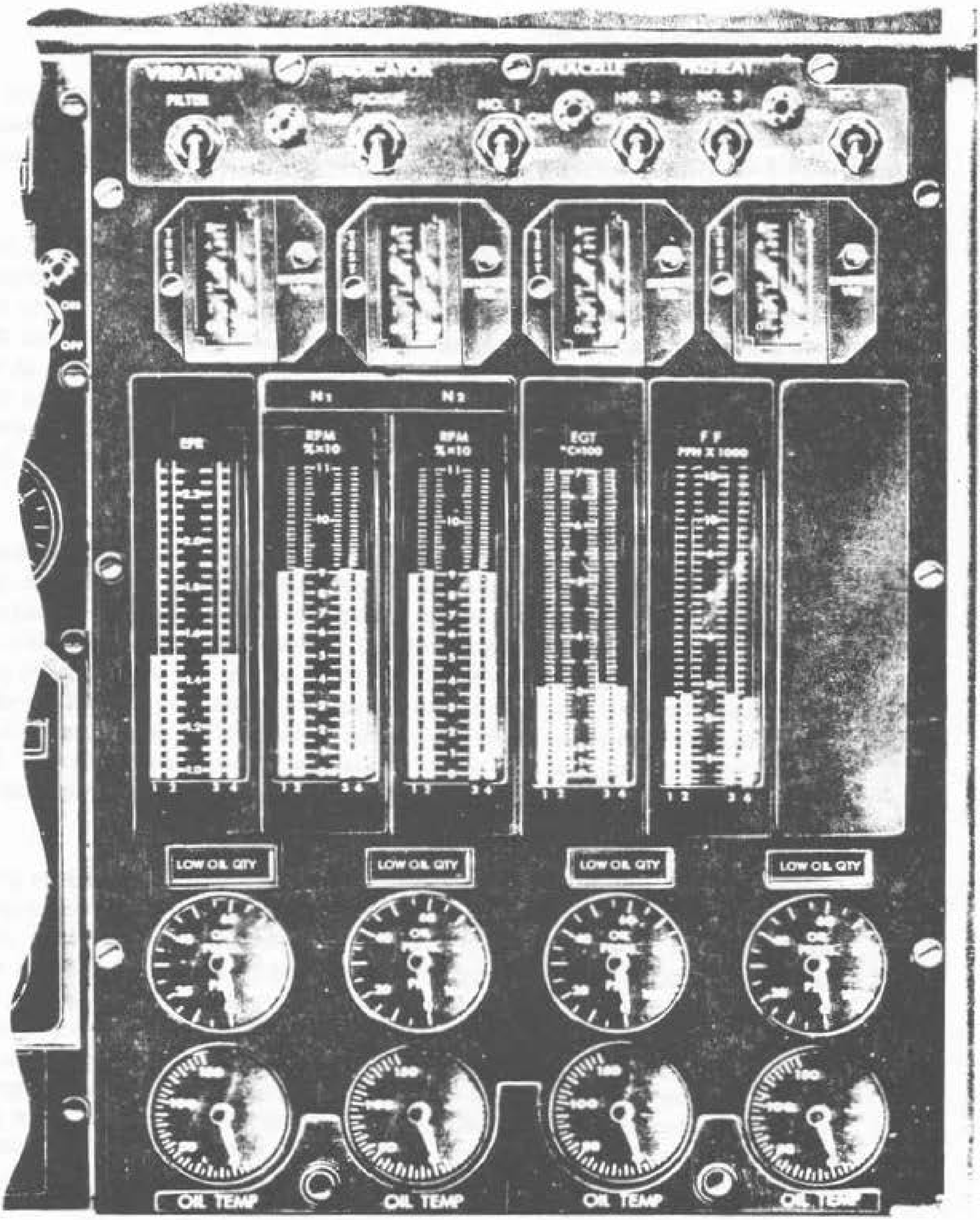


MAIN ENGINE INSTRUMENT PANEL

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.

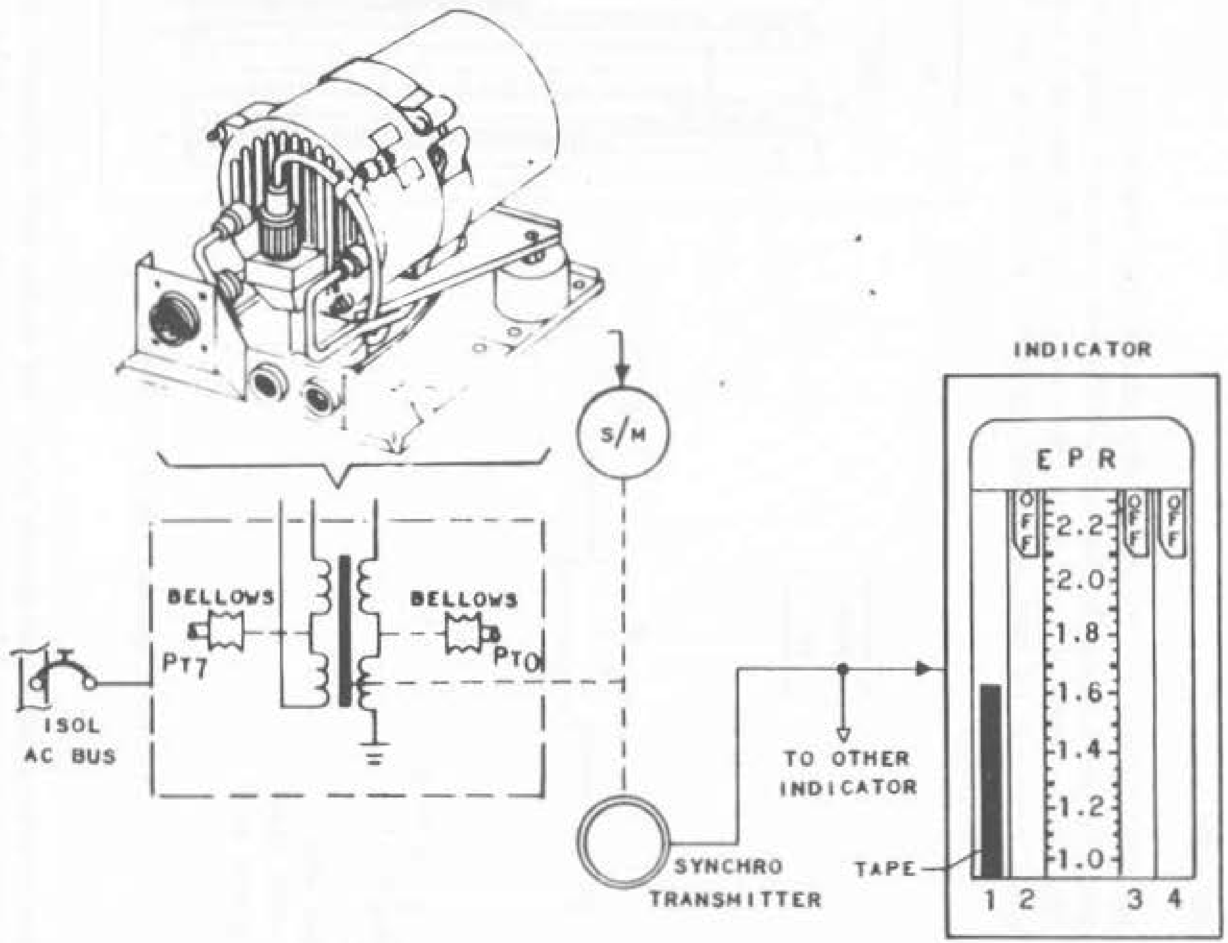
The EPR indicator is the first VSI (left to right) on the pilot's and flight engineer's instrument panel. The VSI monitors all four engines and is labeled 1, 2, 3, and 4 from left to right. The vertical scale is marked in 0.05 increments with a range from 1.0 to 2.3.

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.

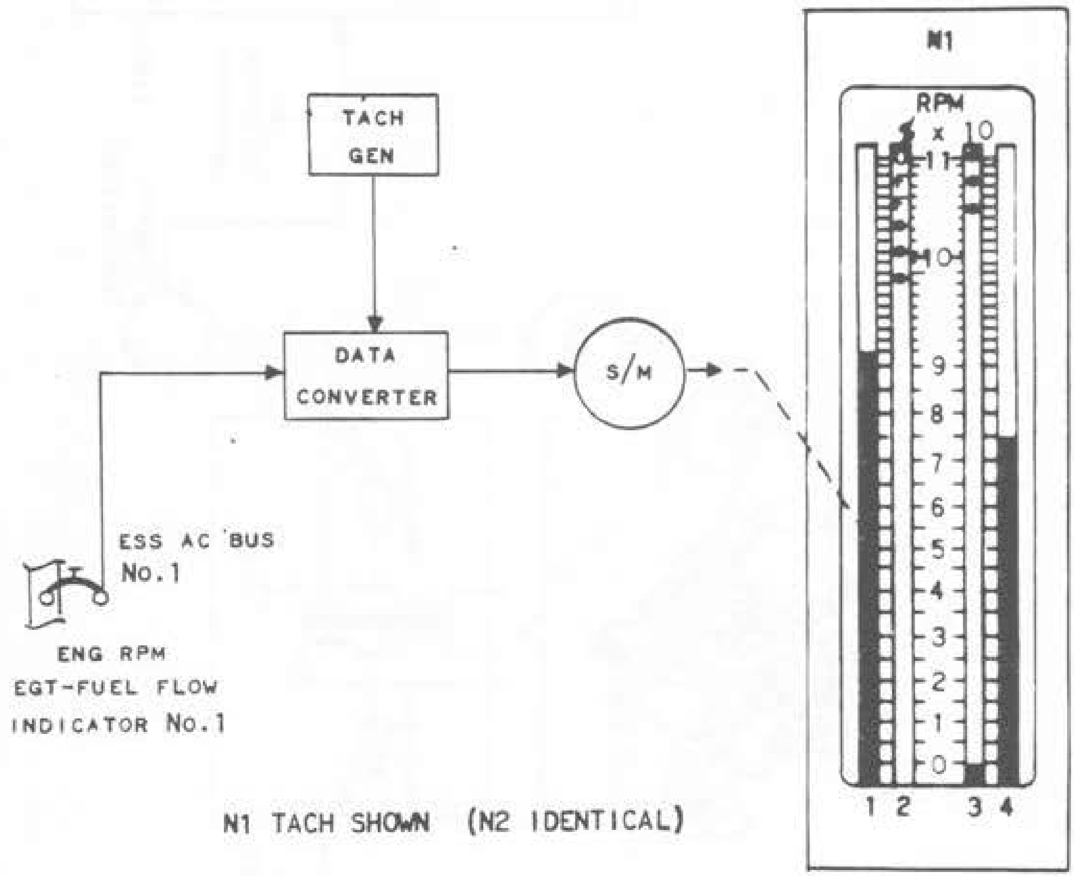
The transmitter senses Pt 0 and Pt 7 pressures through a bellows pickup assembly and converts the mechanical movement of the bellows into an electrical signal. The signal is sent directly to the VSI, where it is amplified and used to drive the servo motor connected to the tape.


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

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

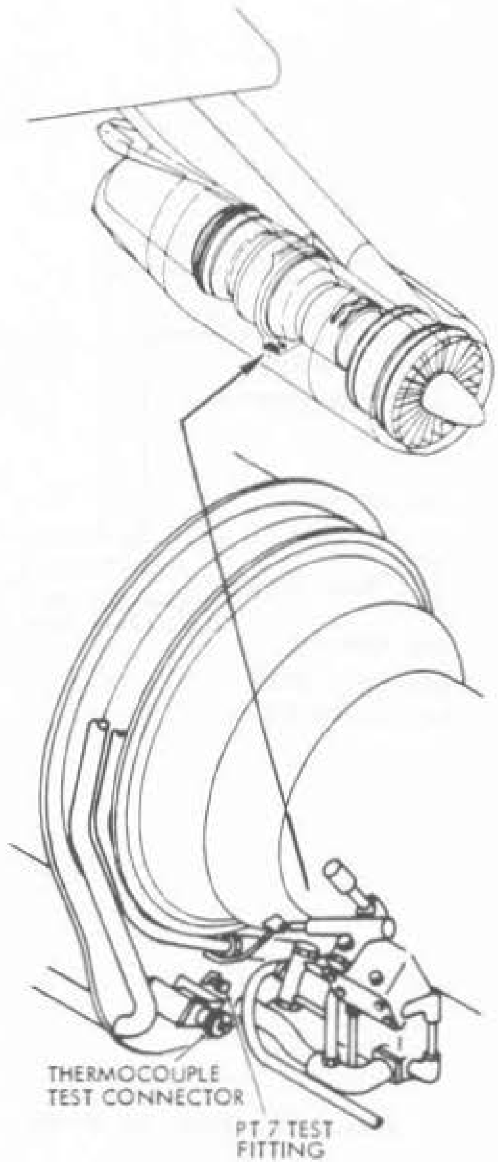


N1 TACH SHOWN (N2 IDENTICAL)

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.



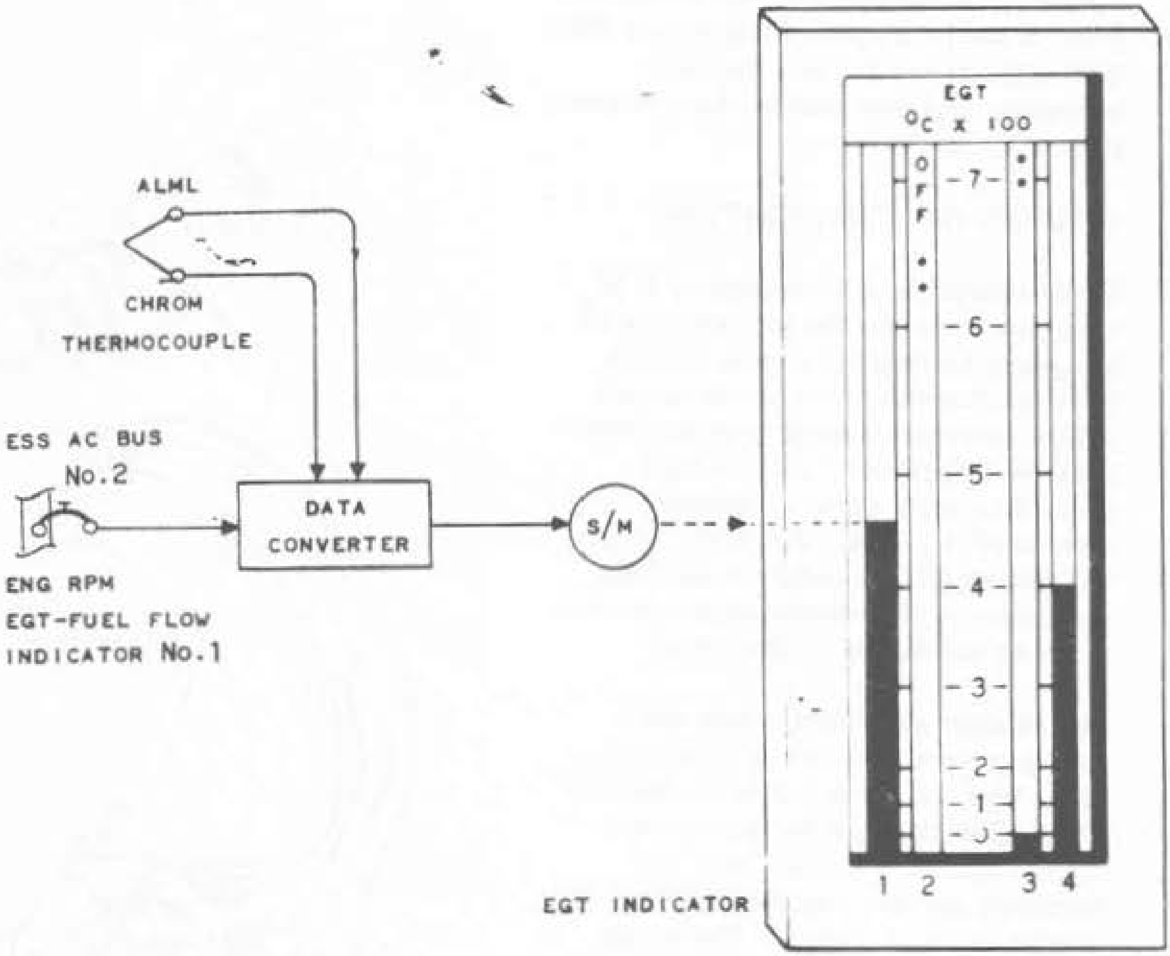
THERMOCOUPLE AND
PT7 TEST CONNECTIONS

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 (°C x 100).

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.

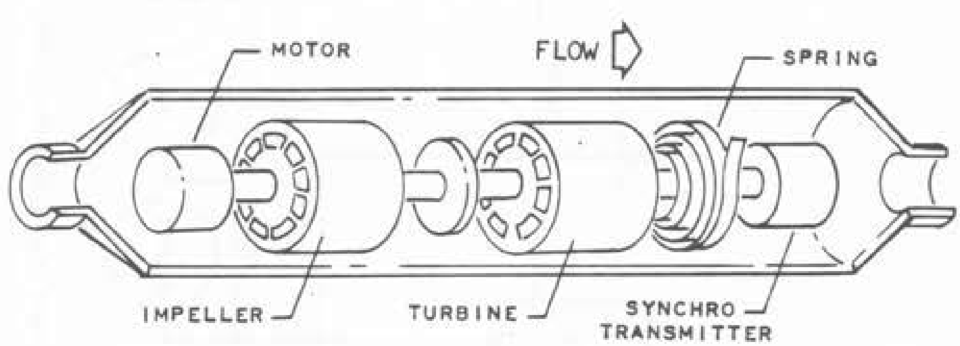
FUELFLOW.

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.

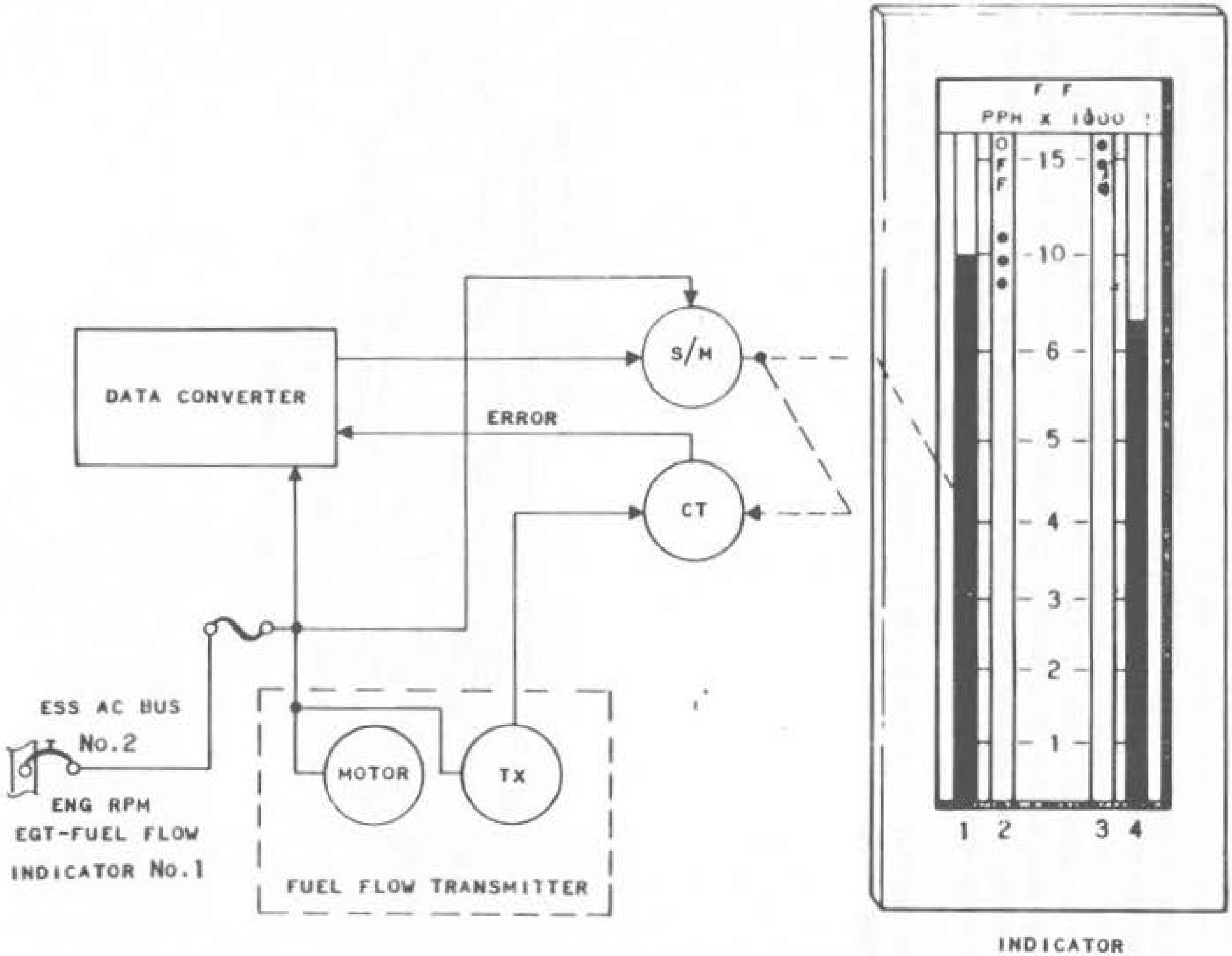
The fuelflow transmitter and indicator monitors fuel which is leaving the fuel control and going to the fuel nozzles. The indicator is the last VSI in the row of engine instruments, one on the pilot's panel and the other on the flight engineer's panel. Both are single indicator, four scale-type vertical 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.

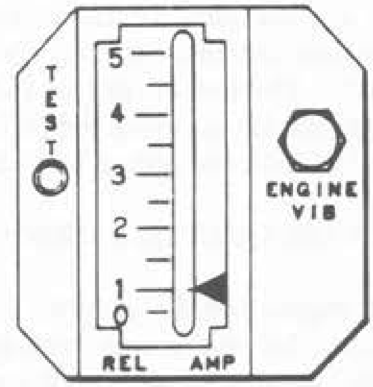


FUEL FLOW METER



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.

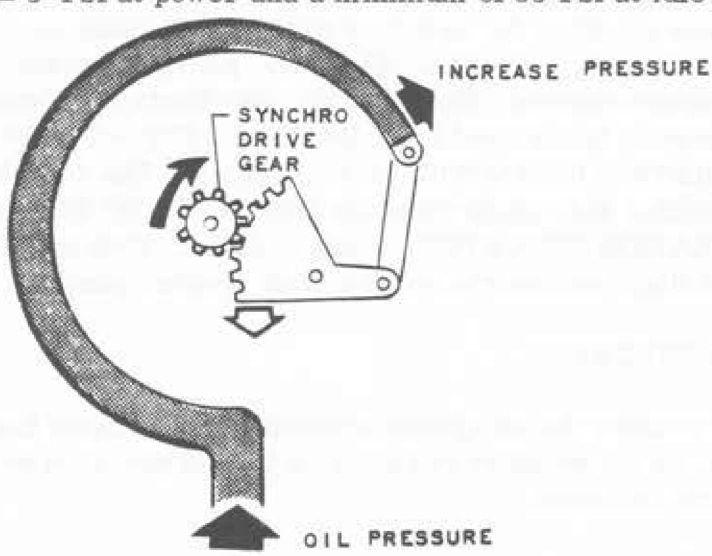
The engine low-oil quantity indicating system consists of an oil tank float-type switch, located inside each engine oil tank, and one low oil quantity indicator light, located on the flight engineer's instrument panel. When the oil level reaches one gallon of usable oil remaining, the float switch completes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

OIL PRESSURE INDICATION.

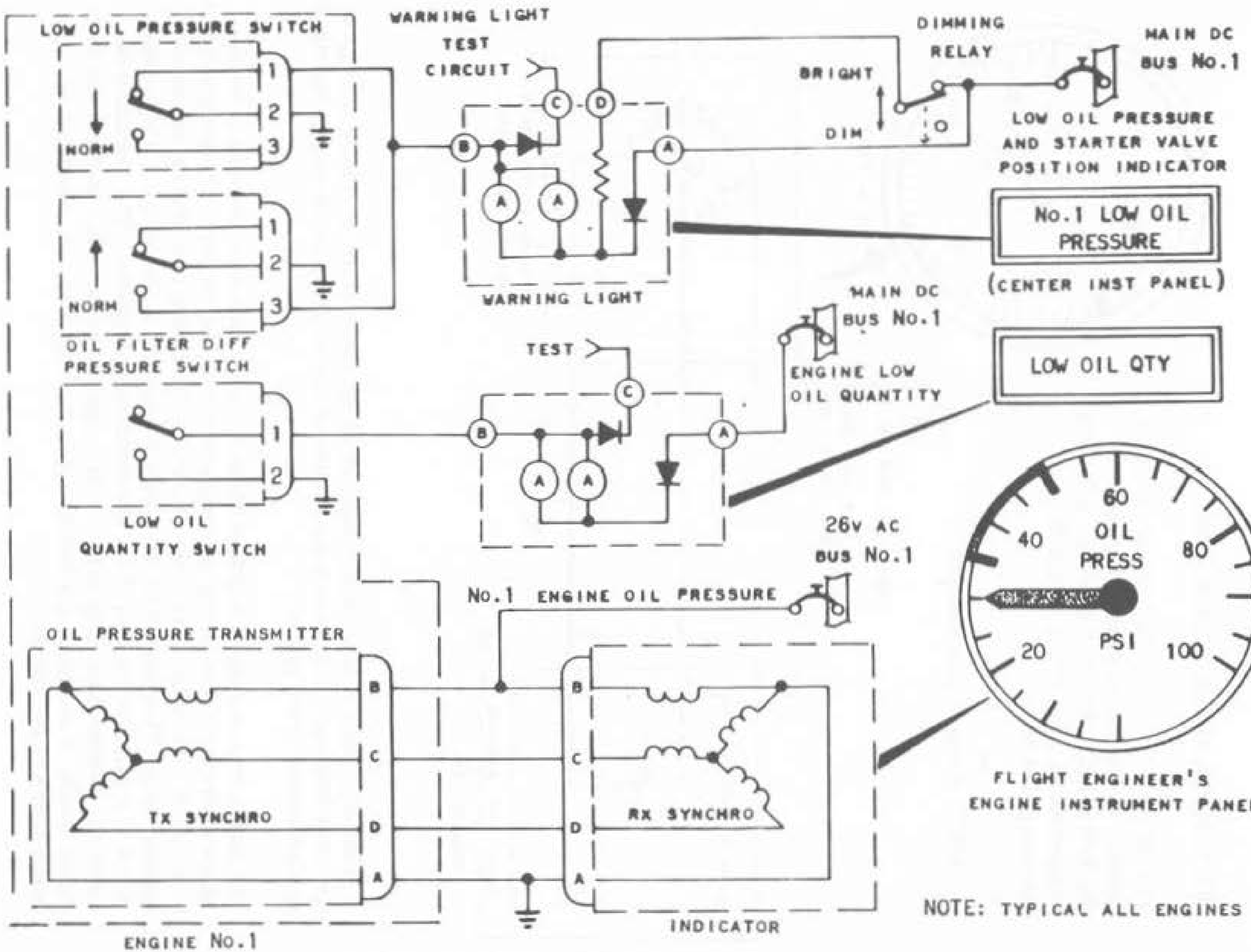
The oil pressure indicating system consists of a pressure transmitter and a pressure indicator. The system is identical for all engines on the aircraft. The transmitter is located just above the oil filter housing assembly and monitors oil pressure in the pressure passage on the downstream side of the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



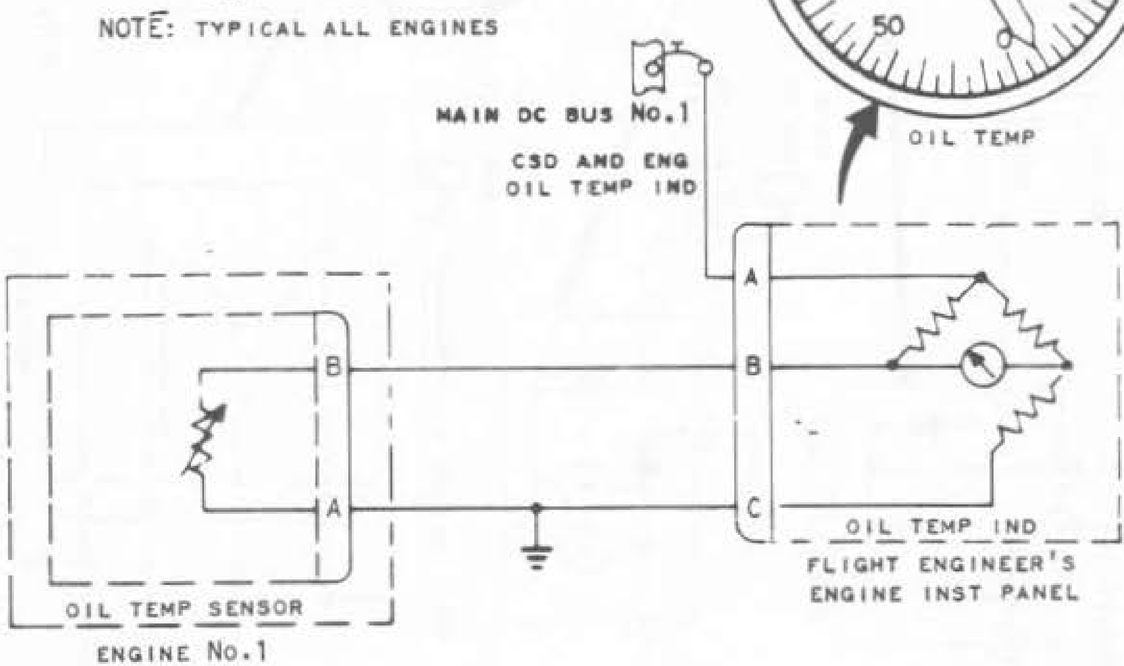
BOURDON TUBE OPERATION



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.

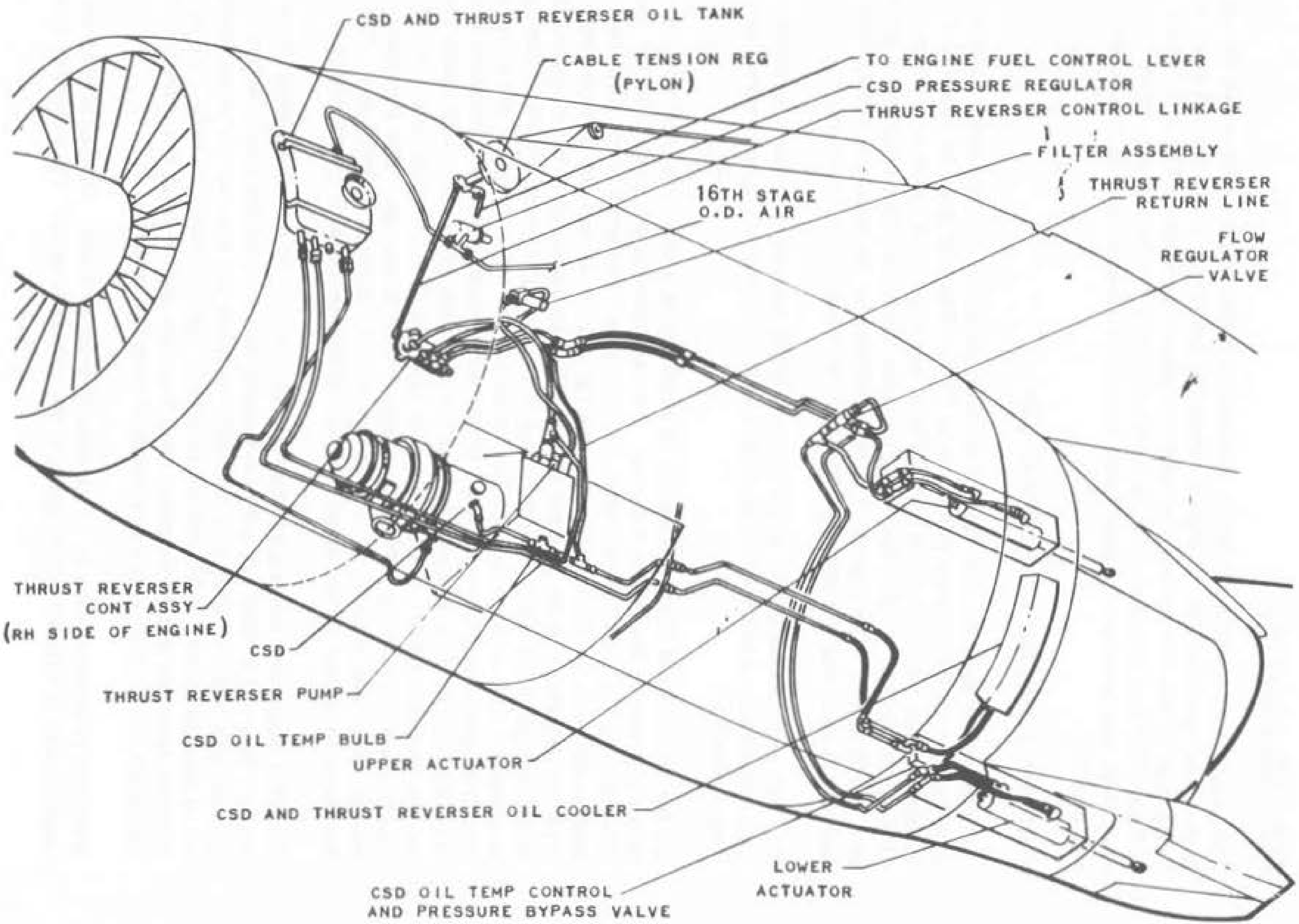
The purpose of the CSD is to drive a 40-KVA generator at a constant speed of 6000 revolutions per minute (RPM), ± 60 RPM. The CSD must be capable of maintaining an output speed of 6000 RPM at any time input speed is between 4100 RPM and 8500 RPM. This RPM ensures a constant frequency of the generator 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.

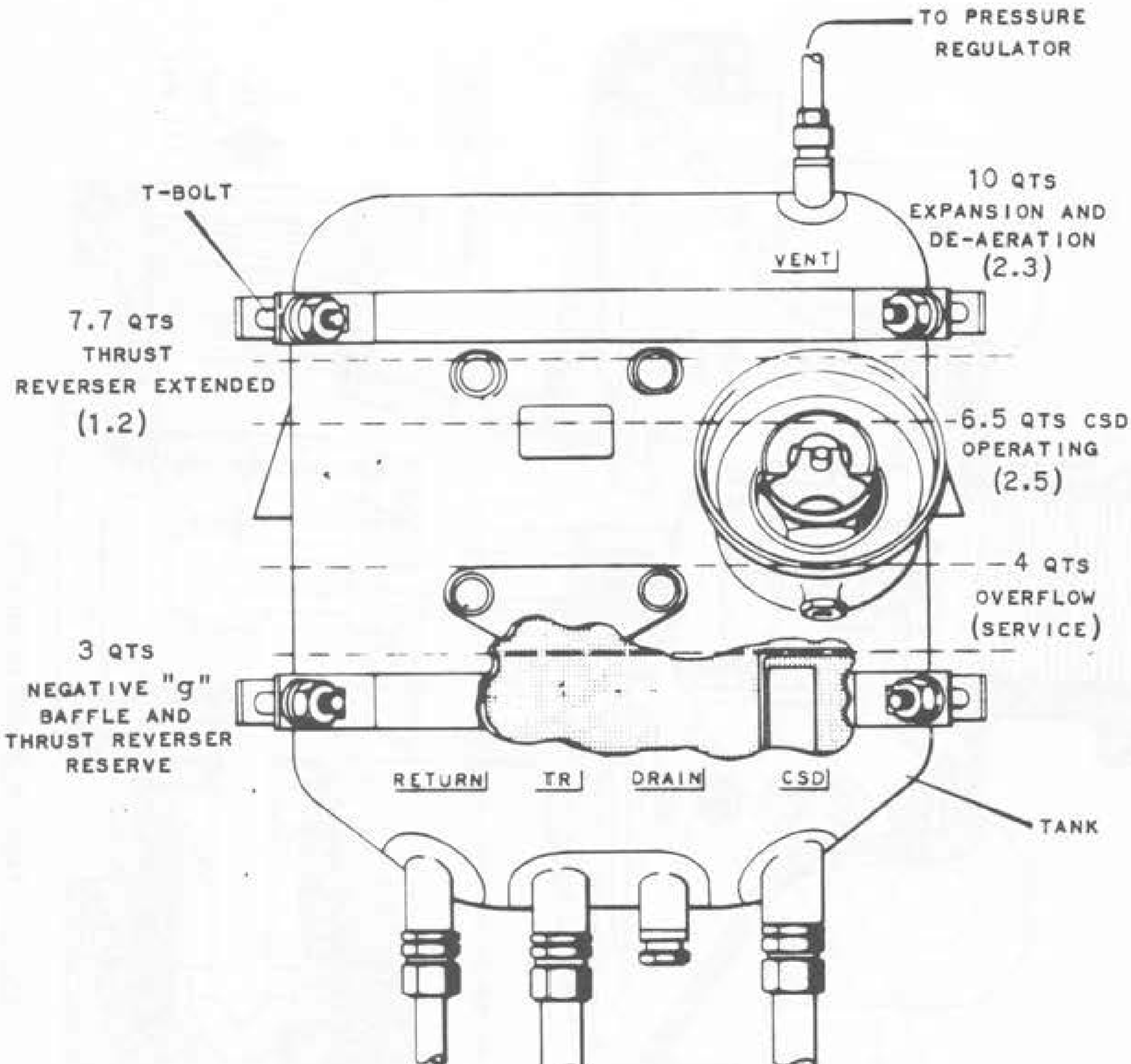
Oil for the CSD and Thrust Reverser is contained in a stainless steel tank located on the left side of the engine fan case. Two separate supply lines from the tank allow flow to the individual systems. A standpipe, connected to the CSD line, allows oilflow to the CSD during negative "g" conditions and 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



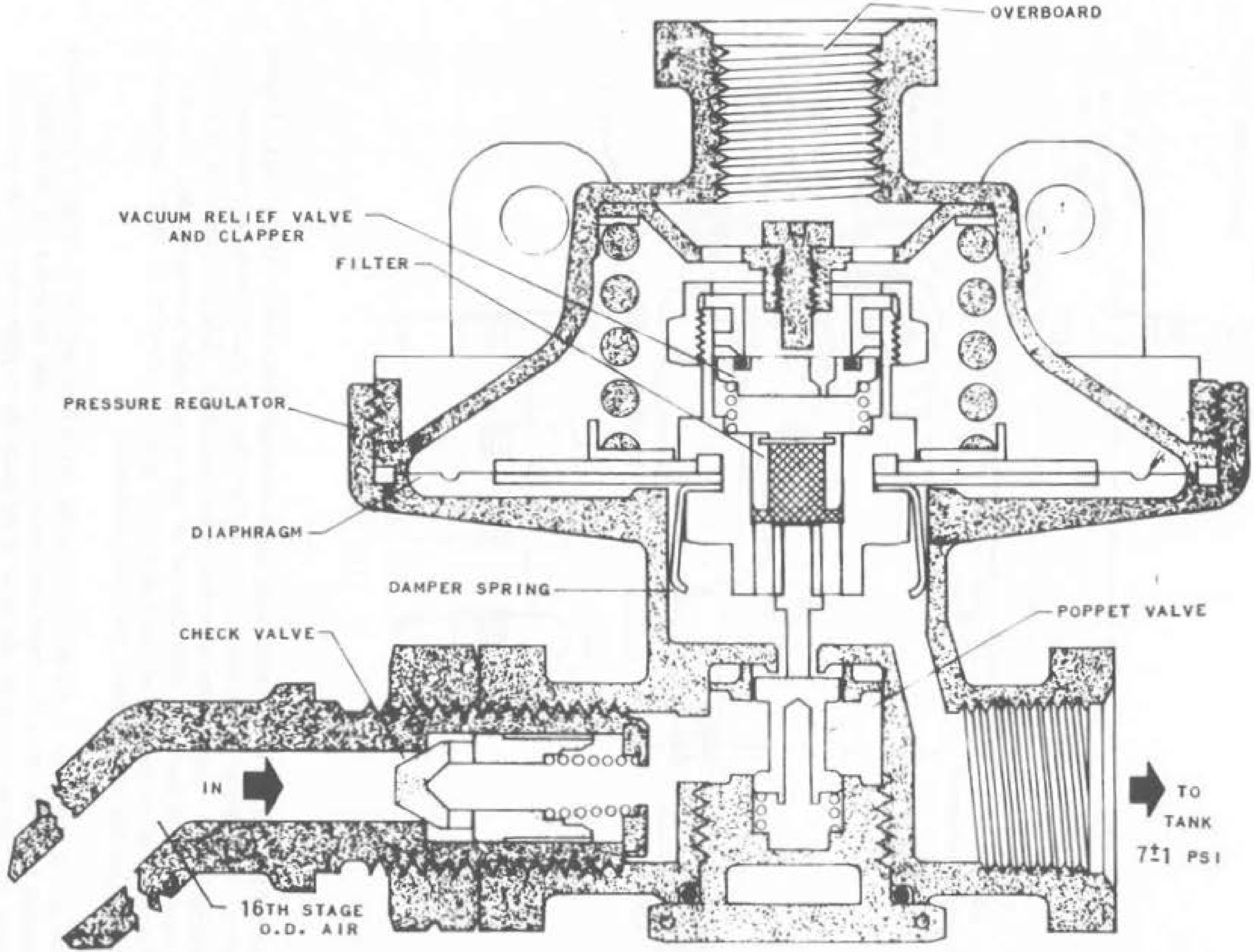
THRUST REVERSER AND CSD COMPONENTS LOCATION



CSD OIL TANK

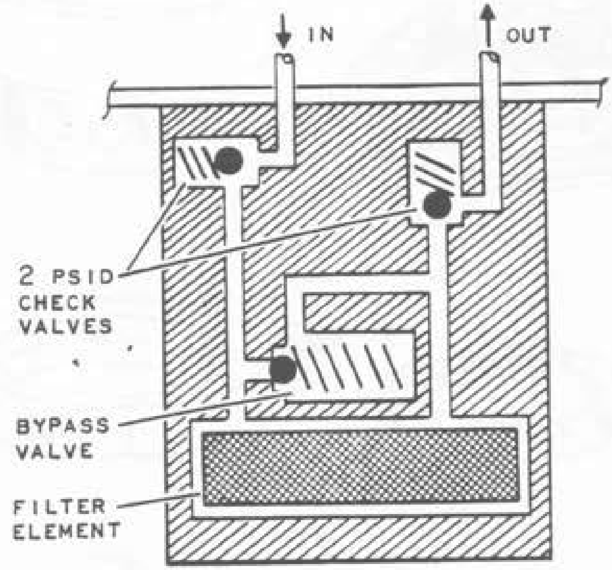
assembly consists of a replaceable filter element, two check valves, and a bypass valve. The check valves are located in the inlet and outlet ports and remain spring-loaded closed when the drive is not operating. The bypass valve is positioned between the filter inlet and outlet and is normally spring-loaded 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.



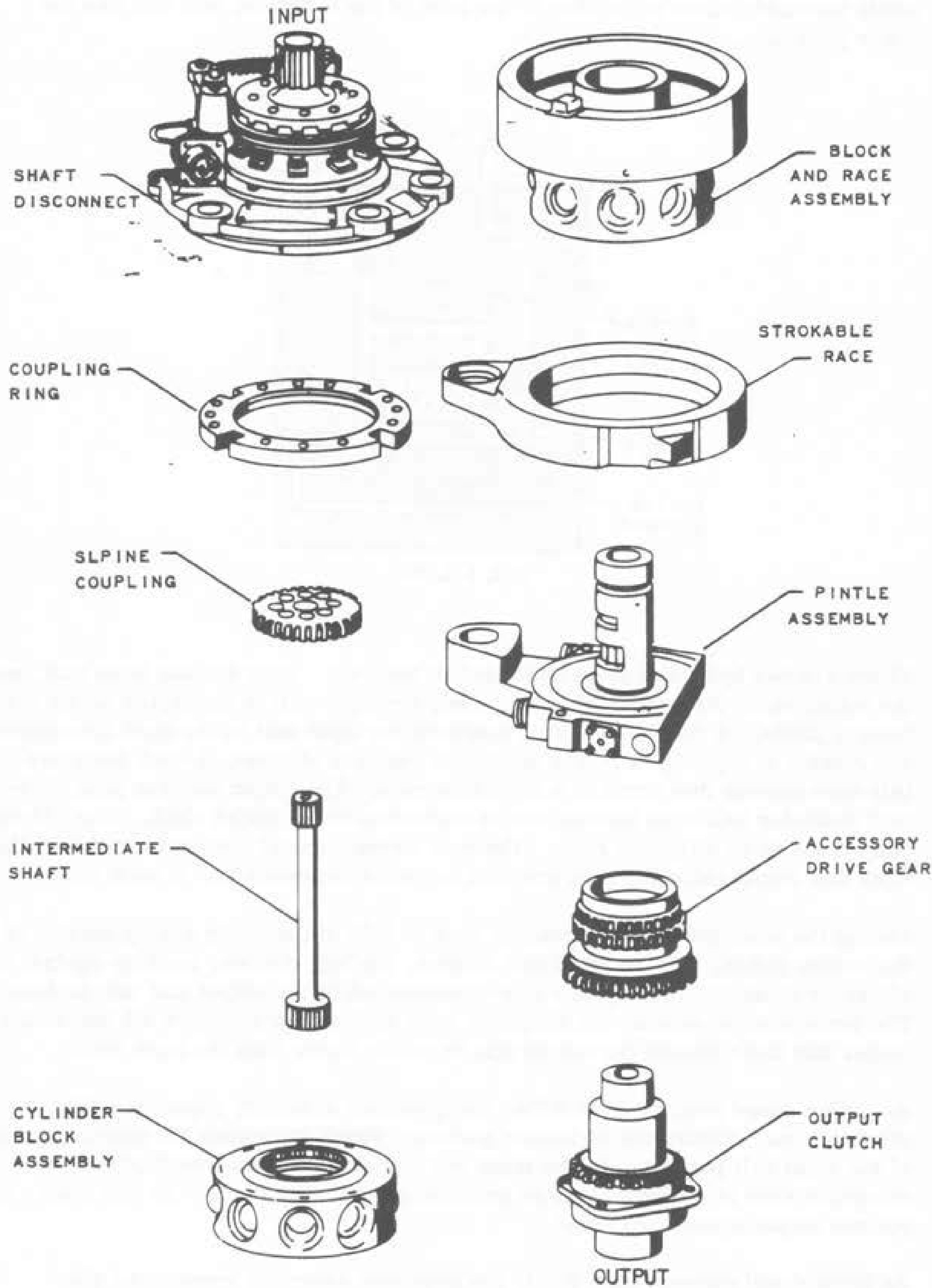
OIL FILTER

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.

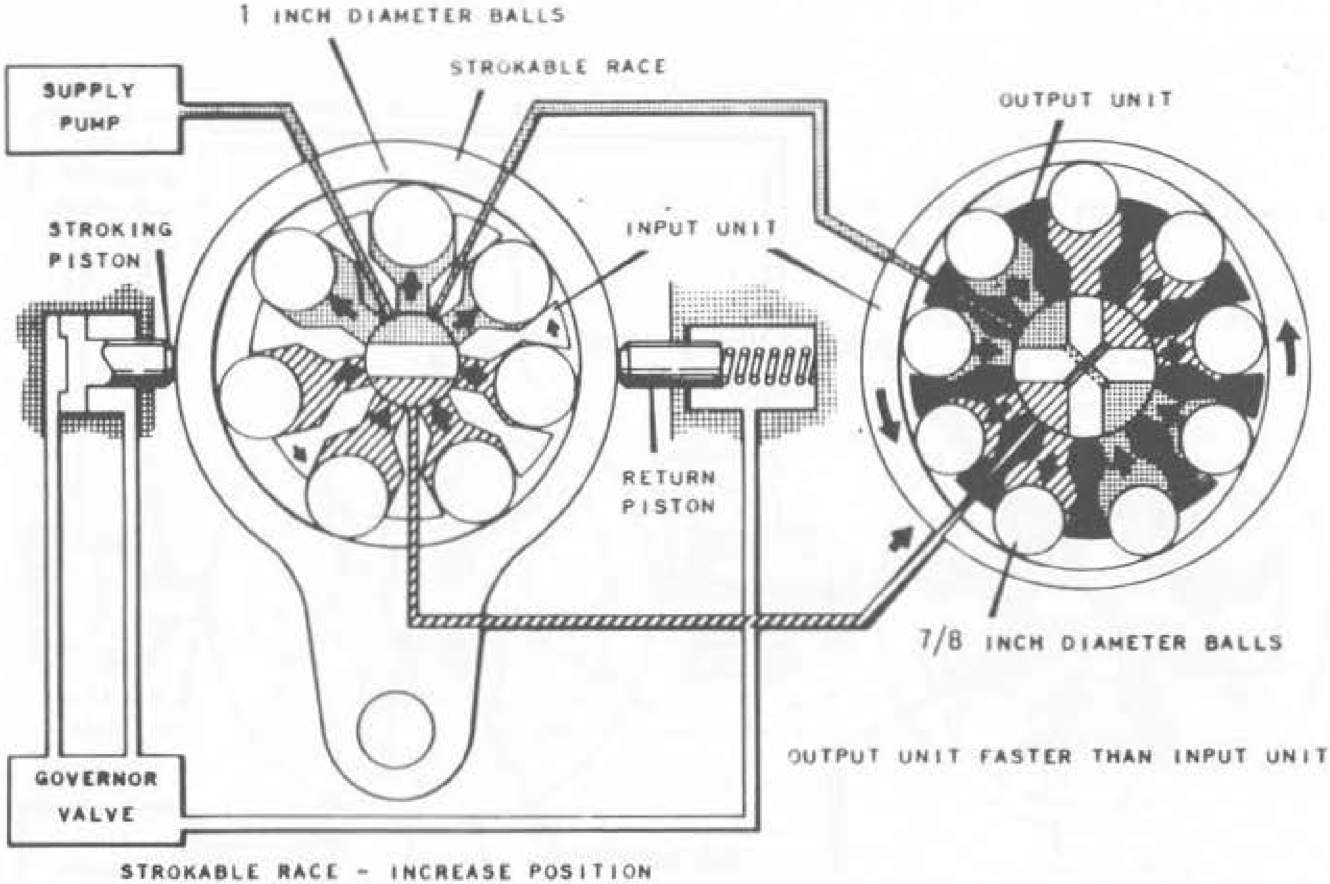
During the start cycle, the strokable race is held offcenter by spring tension of the return piston. As the input unit rotates, the ball pistons, working against the offcenter strokable race, pump high-pressure oil to the output unit ball pistons. The force exerted against the elliptical race by the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

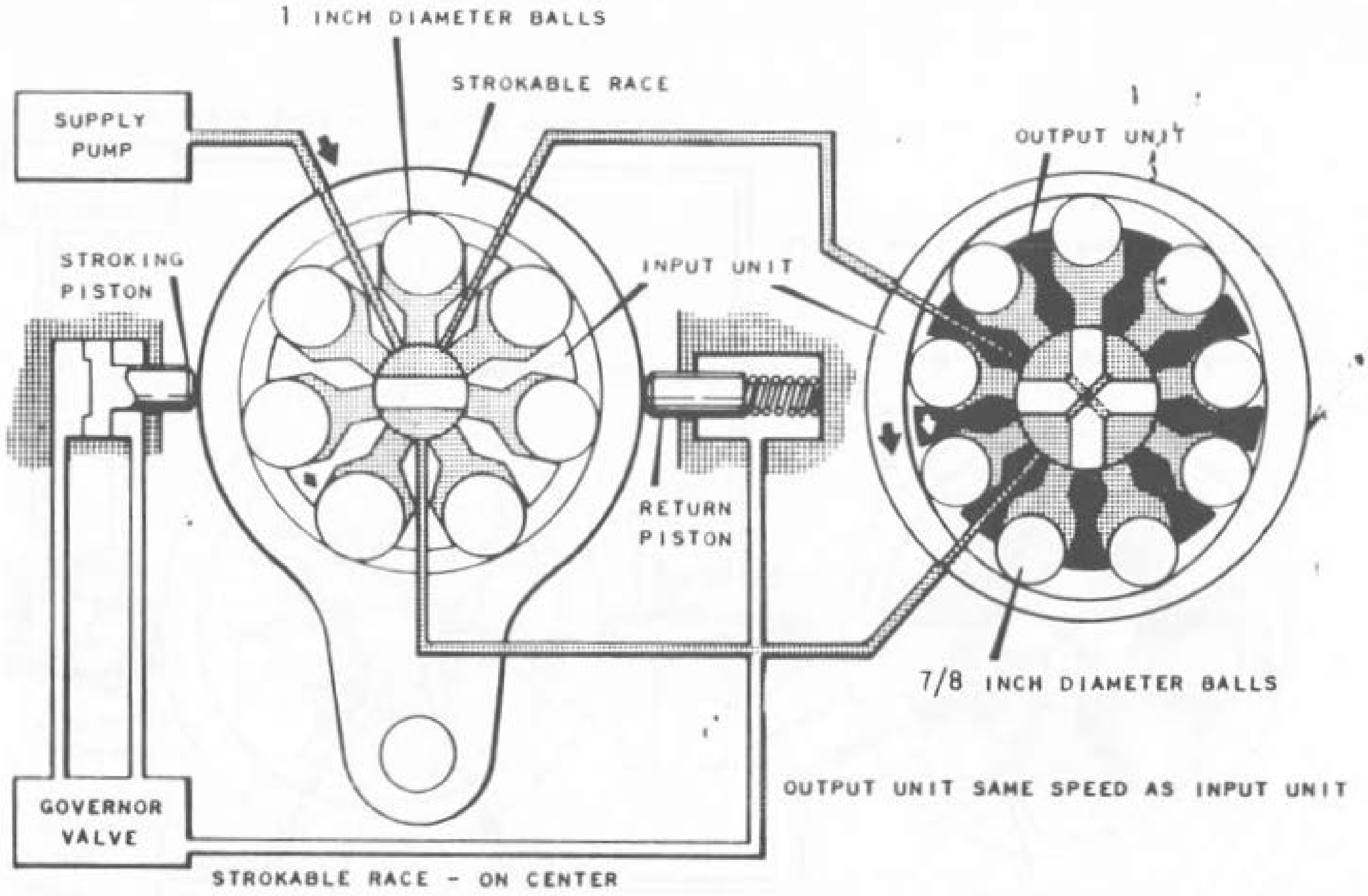
As input speed exceeds 6000 RPM, the governor assembly repositions the



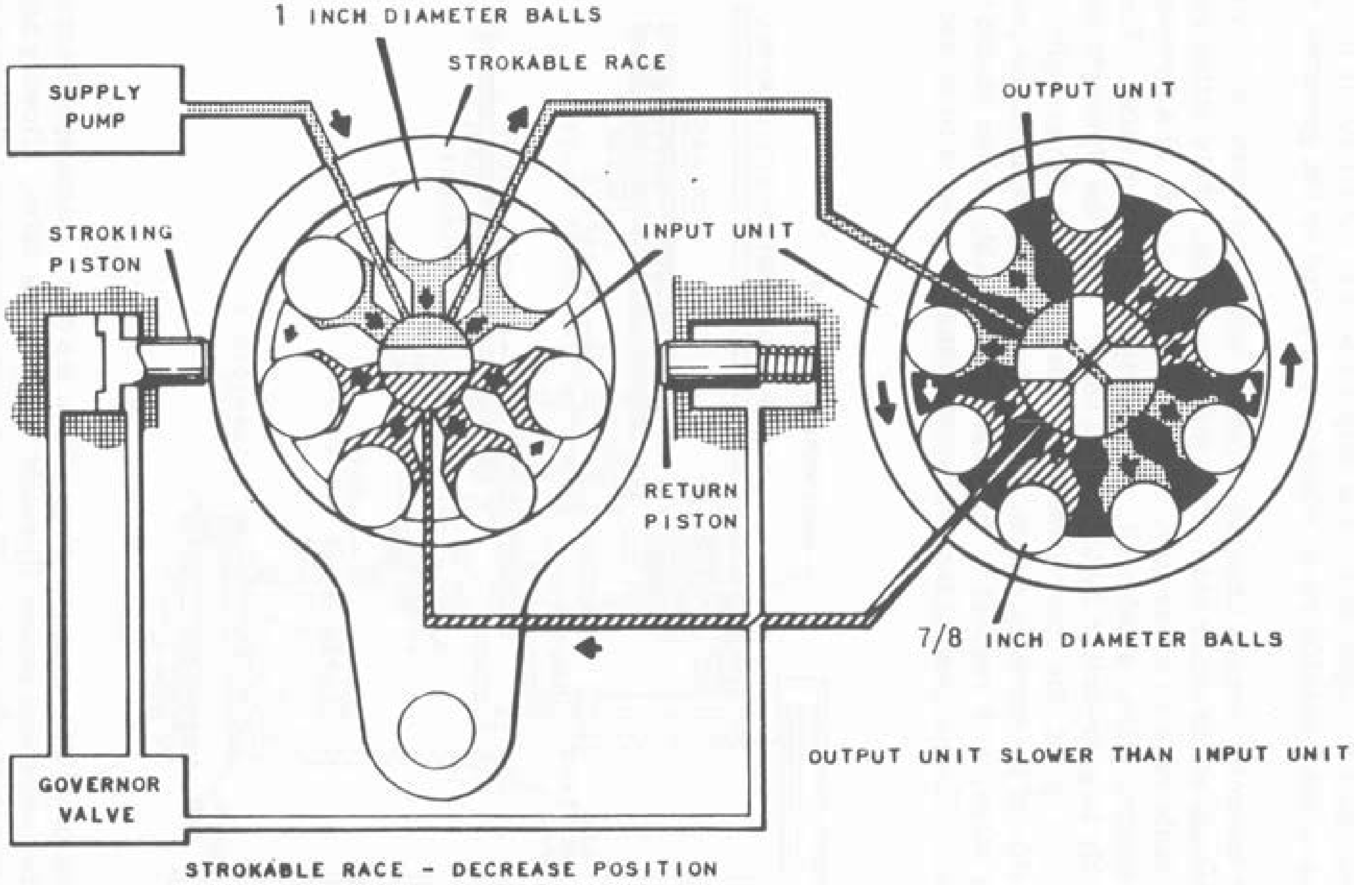
CSD MAJOR COMPONENTS



CDS OPERATION - STEP UP RATIO



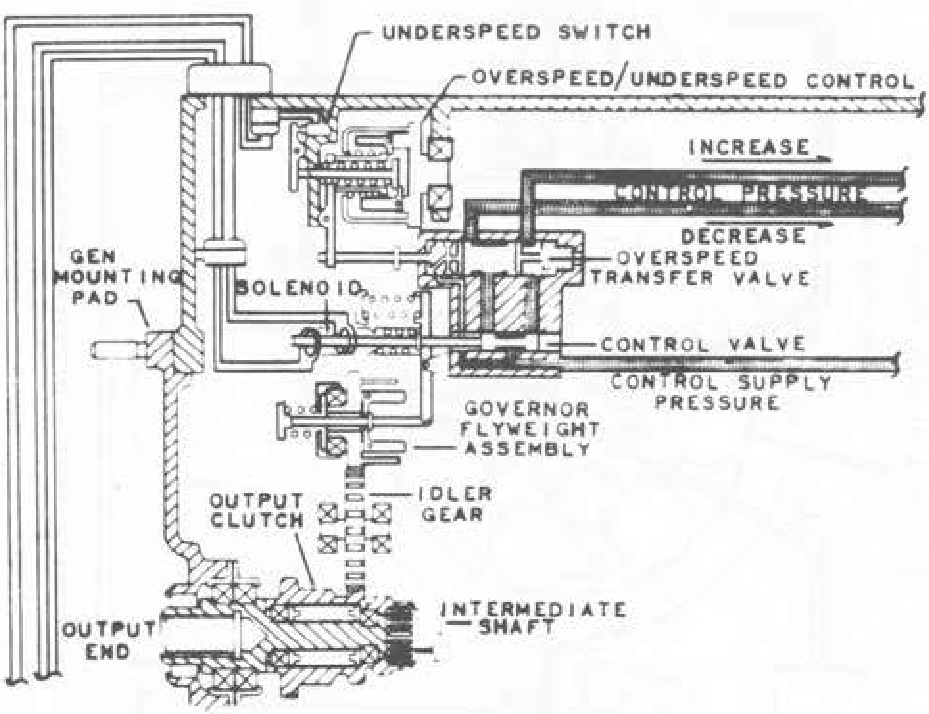
CDS OPERATION - THROUGH RATIO



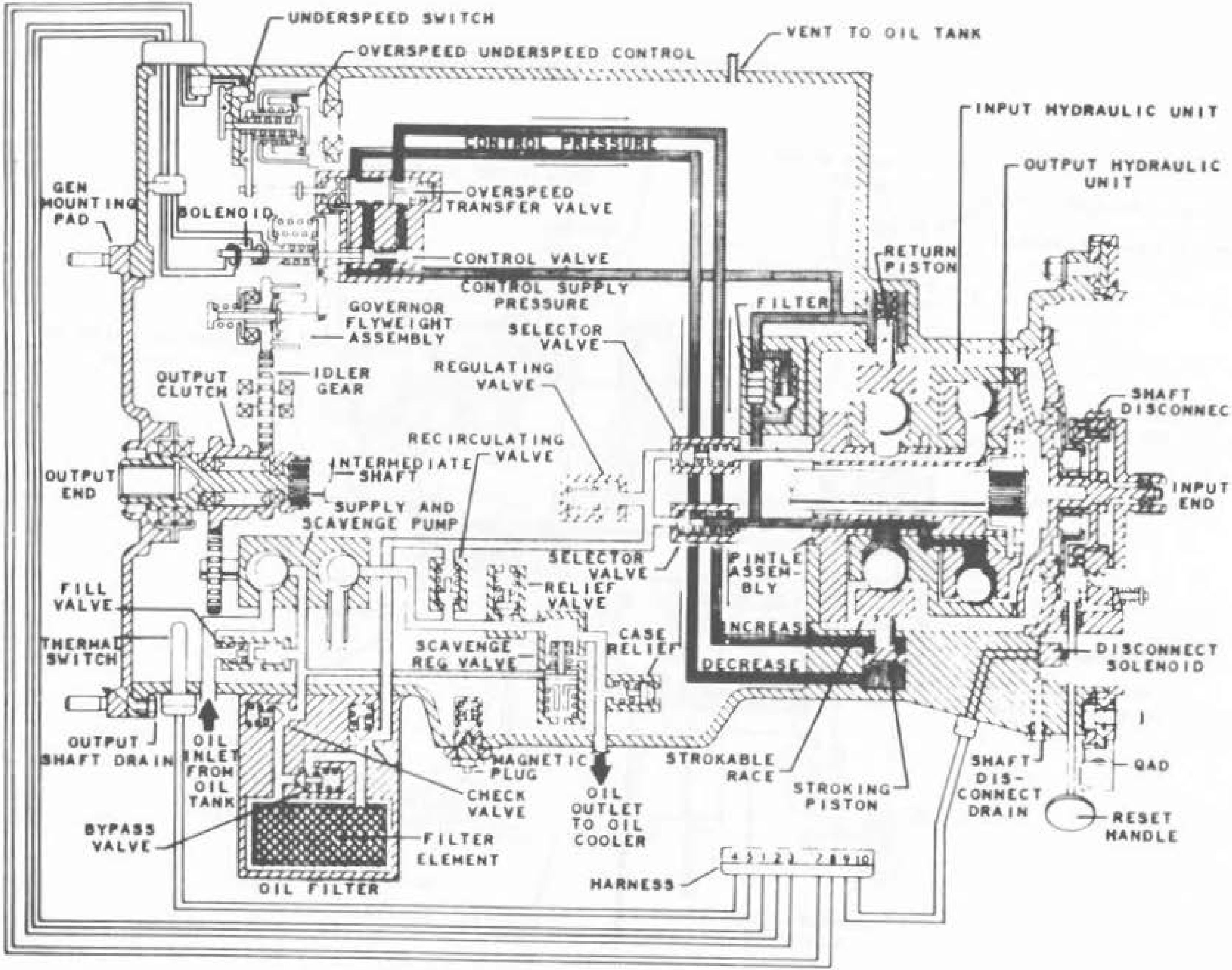
CDS OPERATION - STEP DOWN RATIO

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.

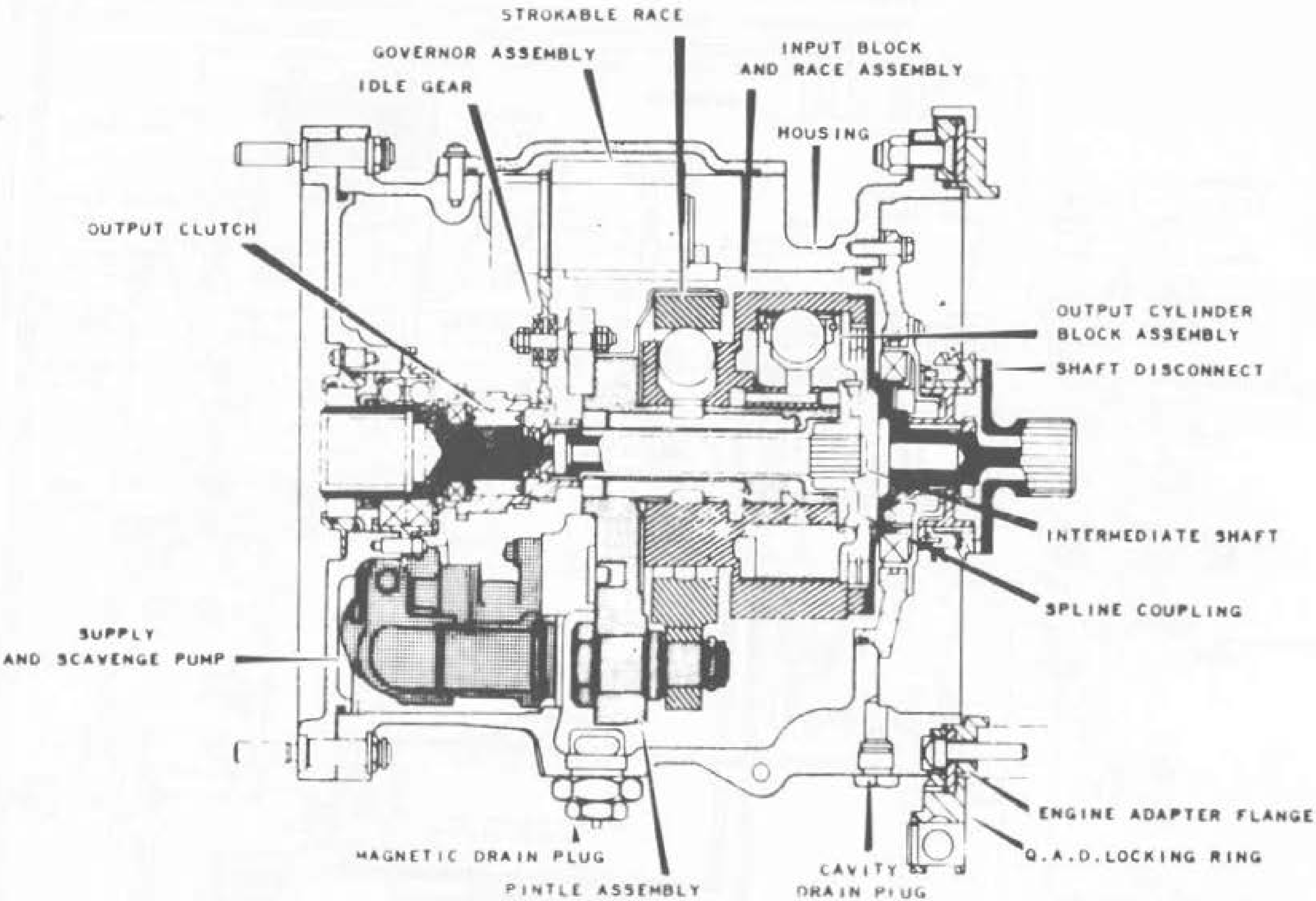
The governor assembly senses changes in output speed and corrects it by directing high-pressure oil to either side of the stroking piston. This action repositions the strokable race as necessary. The governor consists of a flyweight assembly, a control valve, a solenoid, and overspeed transfer valve. 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.



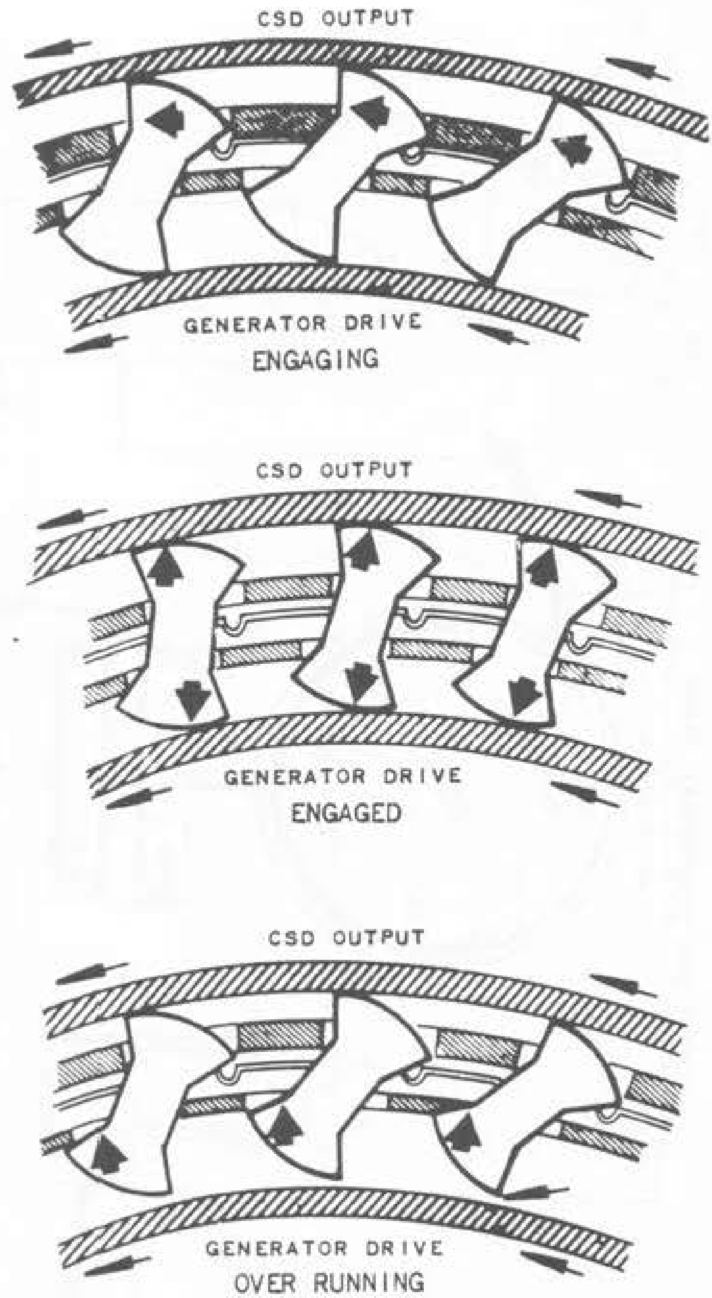
CONSTANT SPEED DRIVE OIL SYSTEM SCHEMATIC



CONSTANT SPEED DRIVE CROSS-SECTION

A load controller, used in conjunction with each drive, is located inside the StarLifter 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.

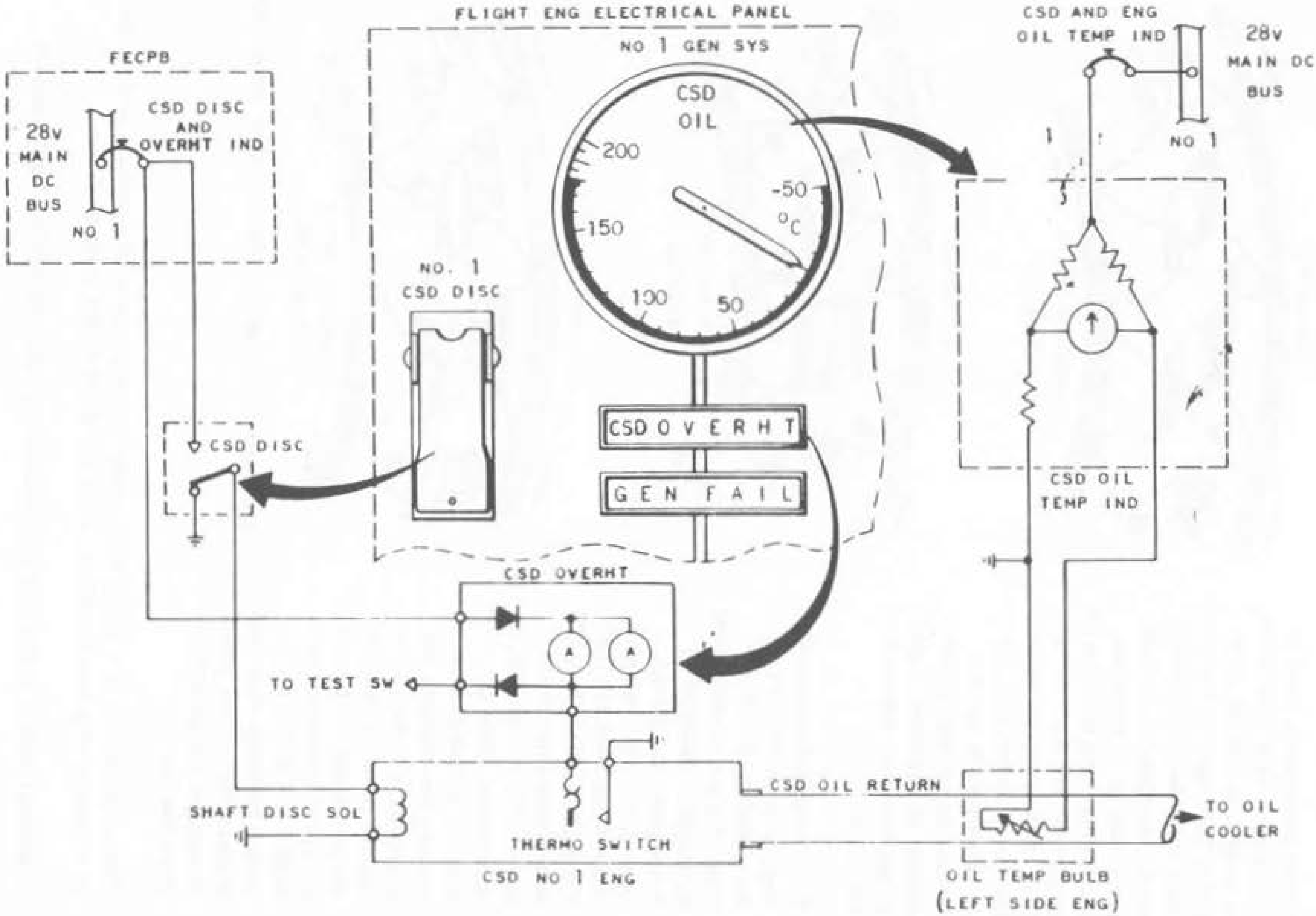
The overspeed-underspeed control is gear-driven by the output shaft. It consists of a set of overspeed flyweights, underspeed flyweights, and switch assembly. The overspeed control has been previously discussed. When the CSD output speed increases above 5700 ± 120 RPM, the underspeed flyweight actuates 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.

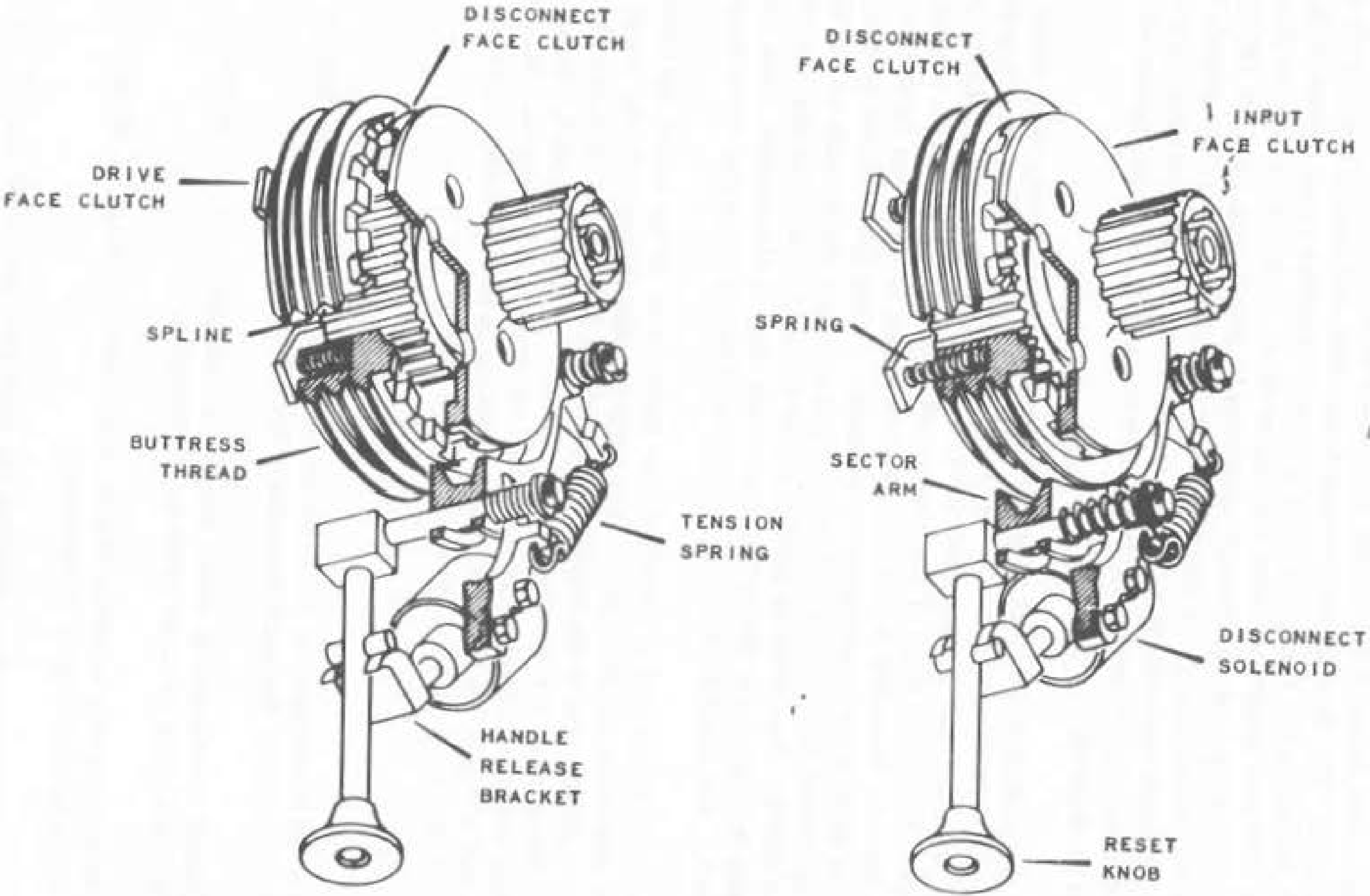
CAUTION

Do not disengage the drive under static conditions because damage may occur to the shaft disconnect during engine start.

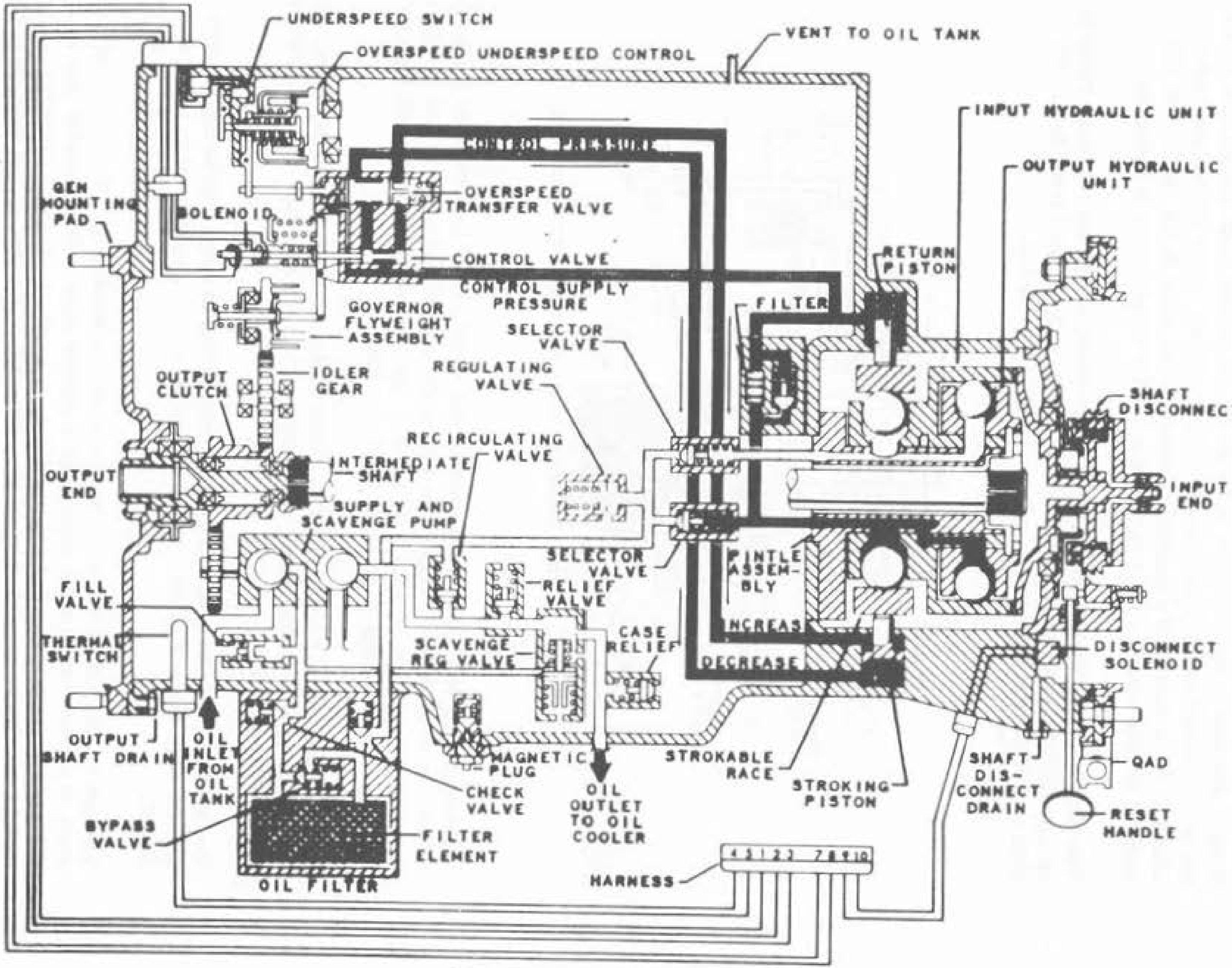
Should a malfunction occur during system operation, corrective action should be taken prior to re-engaging.

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



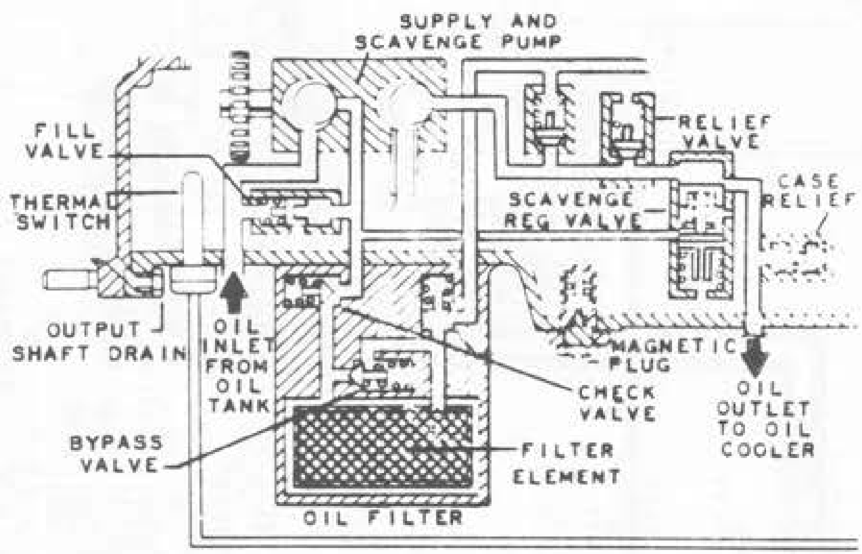
CONSTANT SPEED DRIVE OIL SYSTEM SCHEMATIC



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.

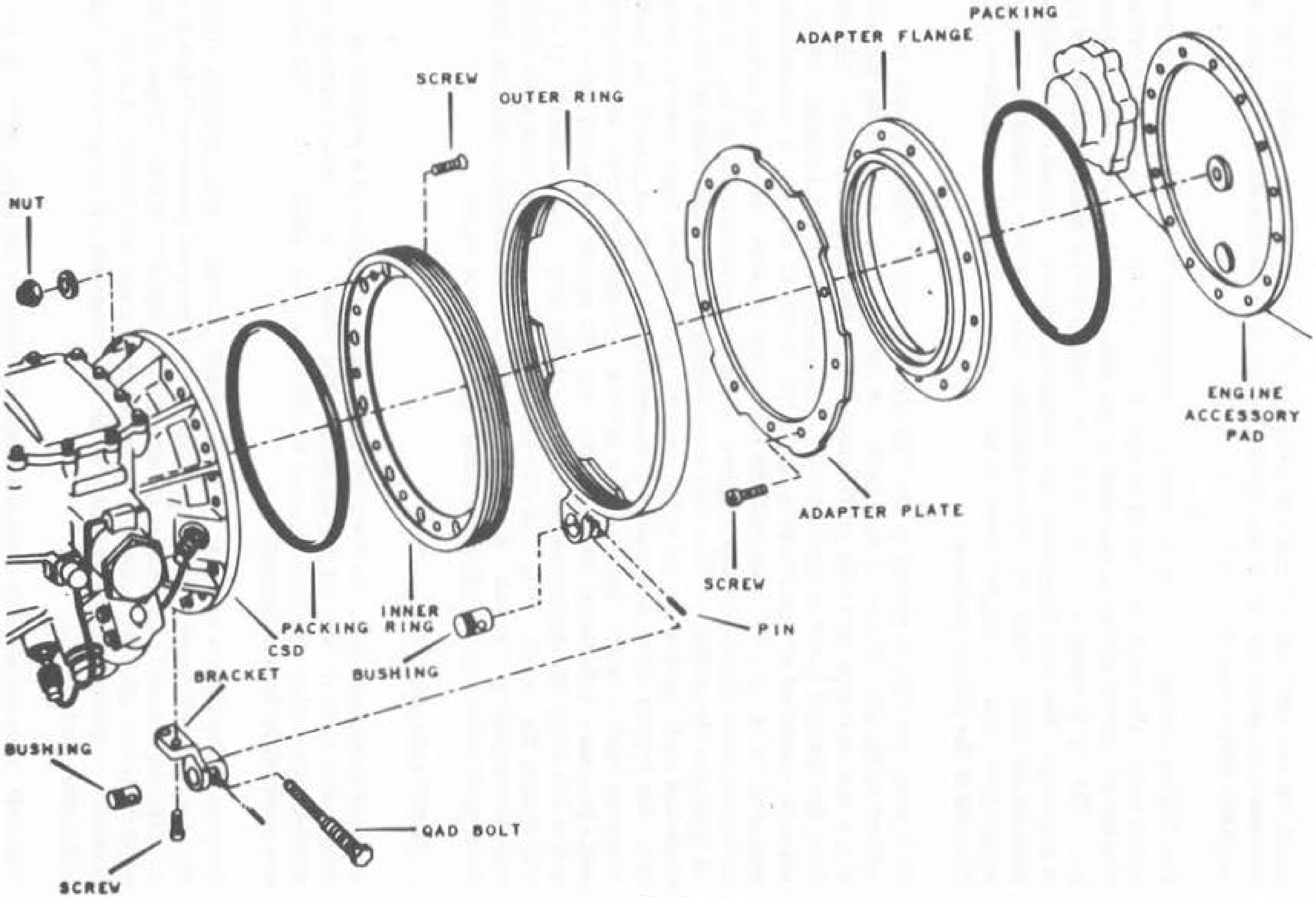


A recirculating valve is located between the outlet line of the scavenge pump and outlet line of the filter. This valve allows the scavenge pump to act as a supply pump when supply pump pressure is lost. The recirculating valve will function only when the scavenge regulating valve is closed.

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.

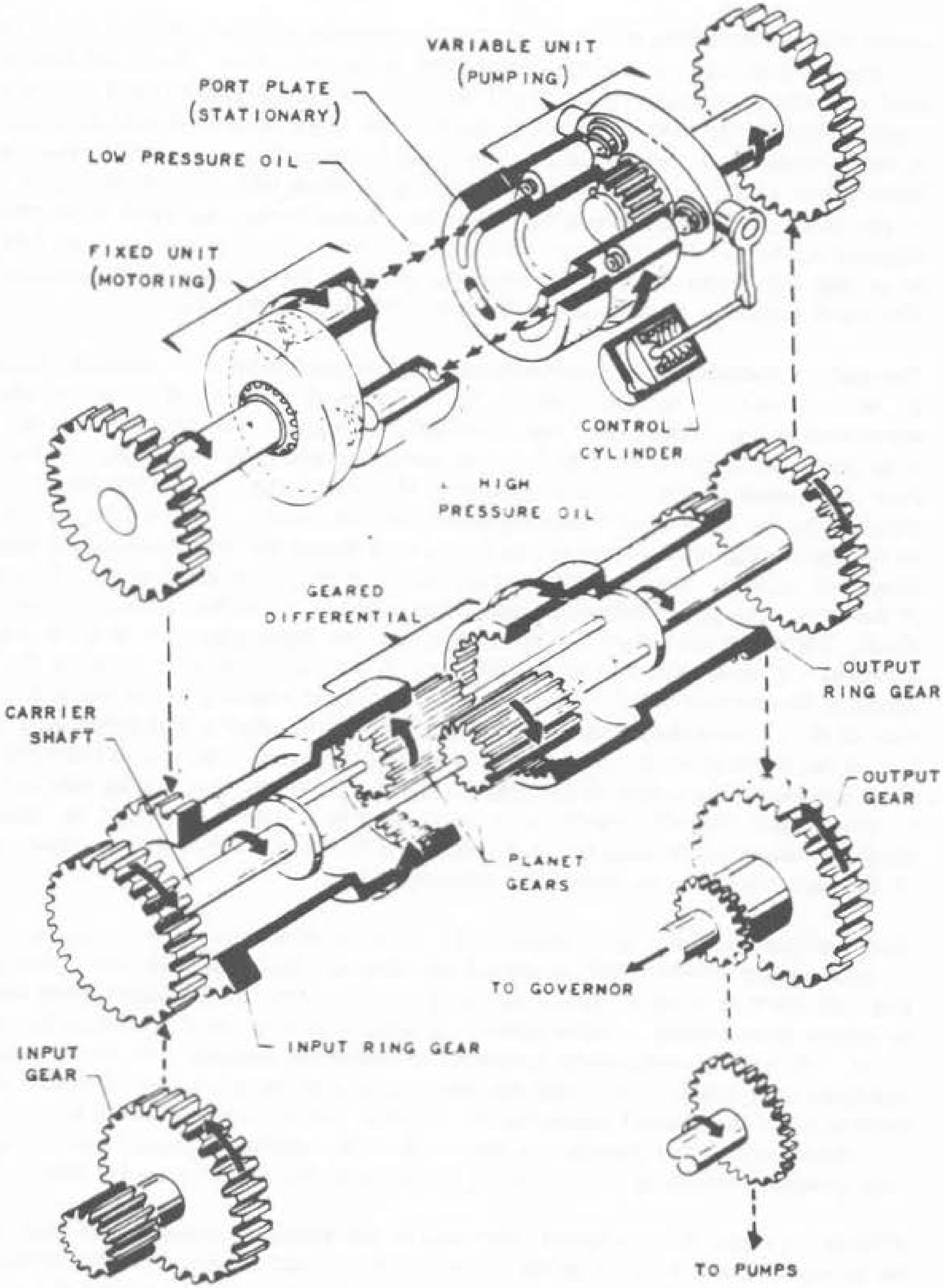
Oil leaving the CSD is ported to the CSD air-oil cooler. The oil cooler is located on the aft left side of the engine, on the outer periphery of the fan duct. It is a radiator-type unit with oil flowing through the core, and the cooling air from the fan duct flows around the core. A temperature and pressure 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

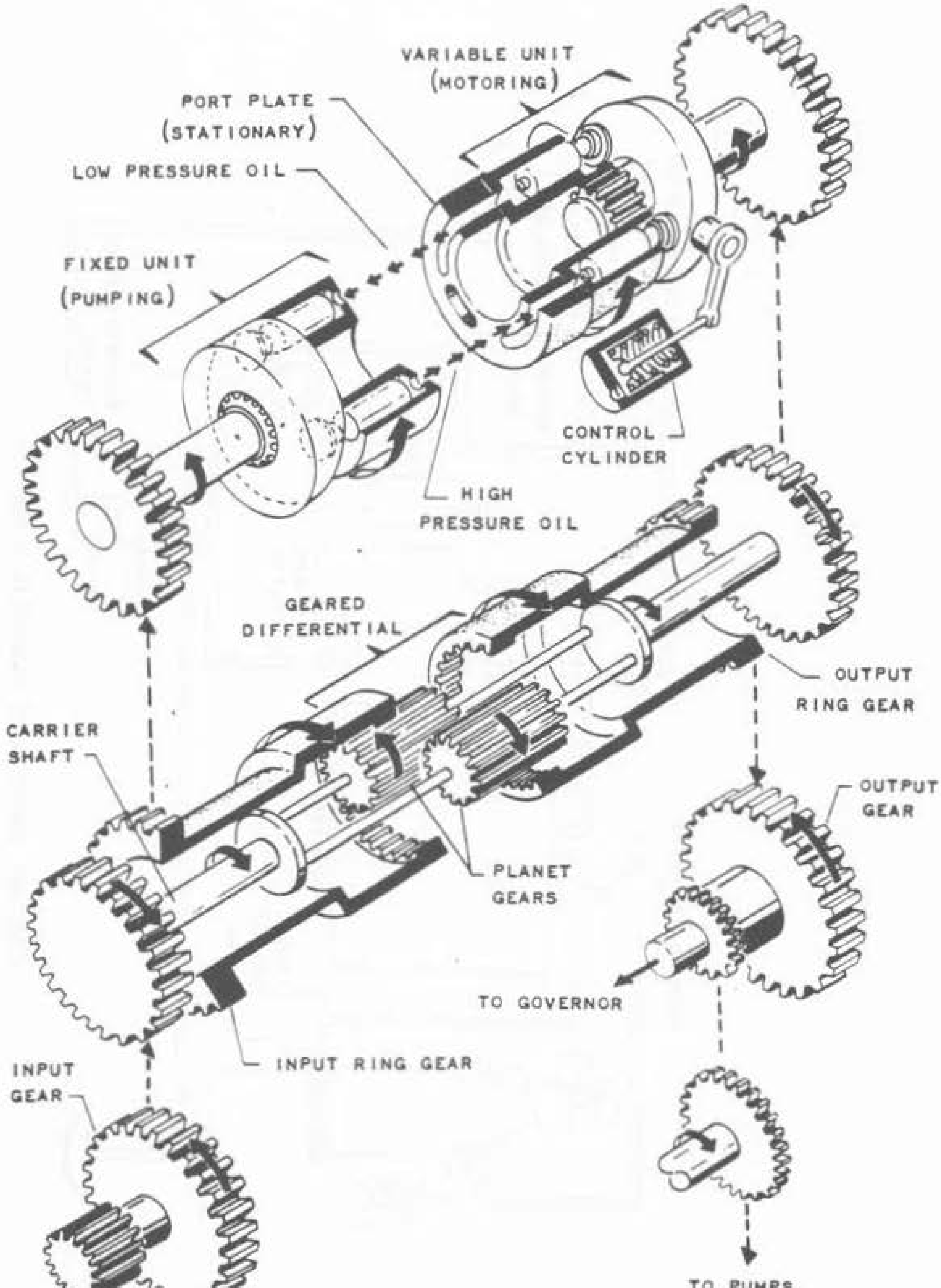


OVERDRIVE PHASE (STEP UP) CONSTANT SPEED DRIVE event of a transmission malfunction, an electrically actuated device, which is incorporated decouples the input shaft from the input spline. When the disconnect solenoid is actuated by the flight engineer, a spring-loaded pawl moves into contact with the 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.

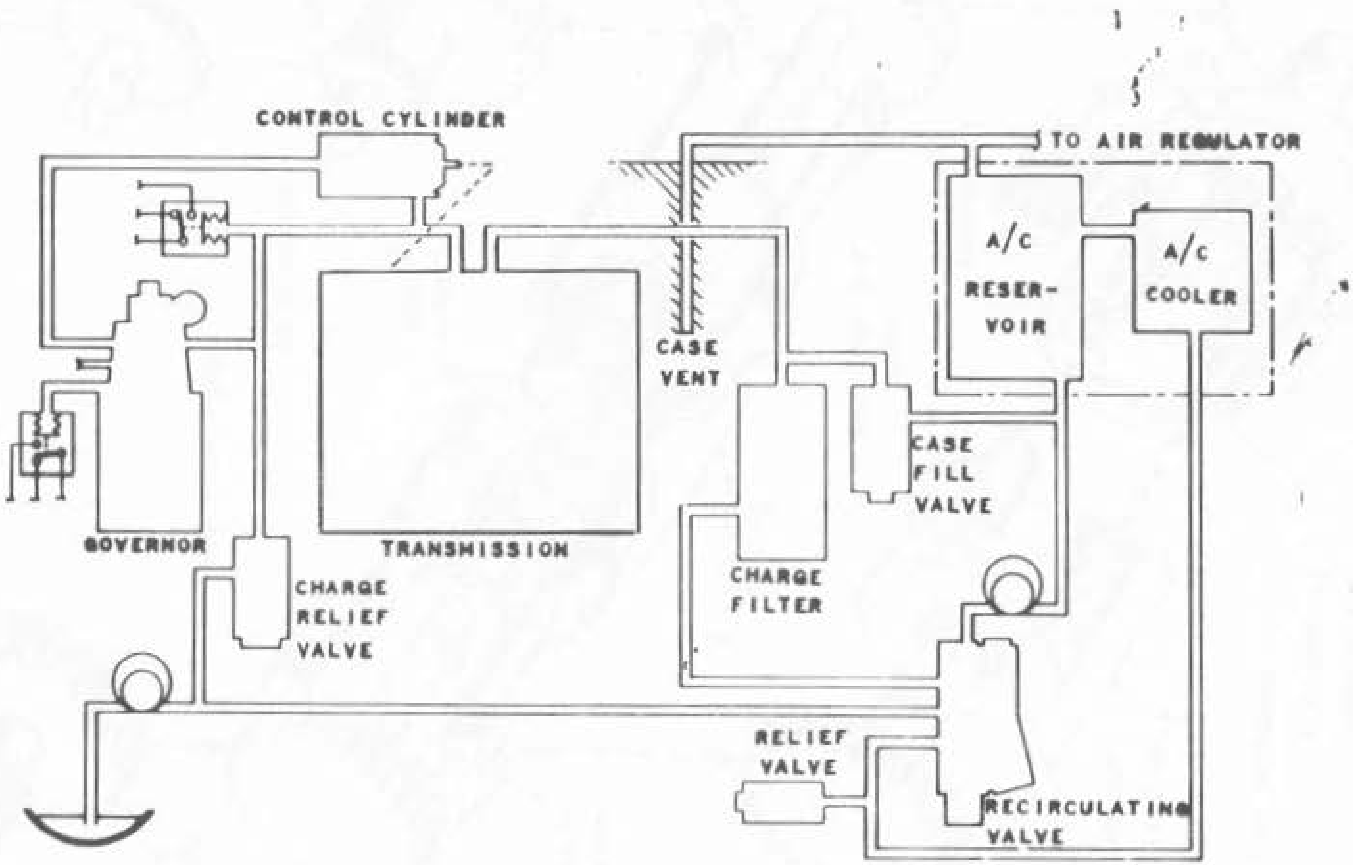
The basic transmission is composed of a differential assembly, variable hydraulic unit, and a fixed hydraulic unit. The differential consists of a carrier shaft, two planet gears, input gear, and an output ring gear. The ratio between the ring gears and carrier shaft is 2:1. At any speed and load condition, 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.

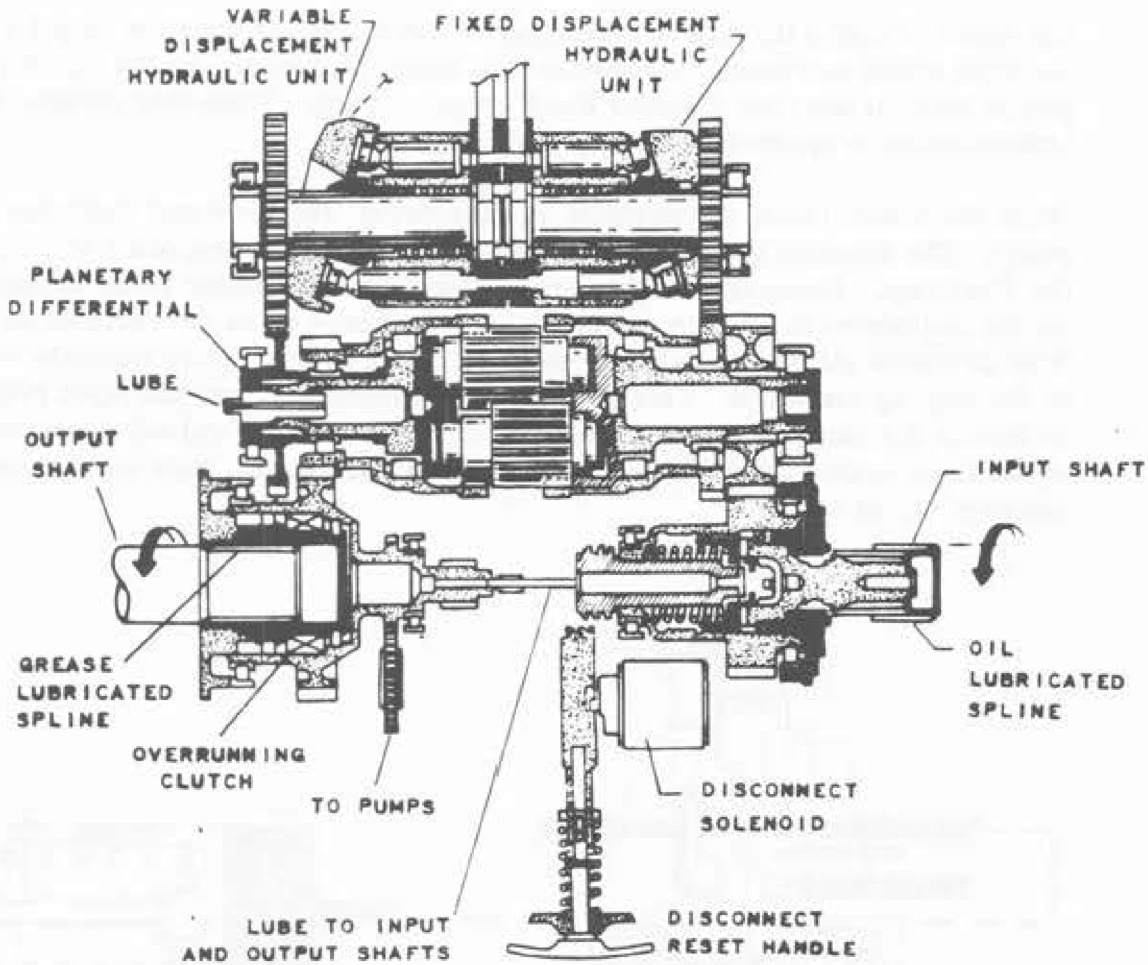
With an increase of input speed, the need to add speed decreases. As this occurs, the governor ports less oil to the control cylinder and repositions the variable unit until the face of the variable wobbler is approximately perpendicular to the pistons; no oil is pumped or received by the variable unit. 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

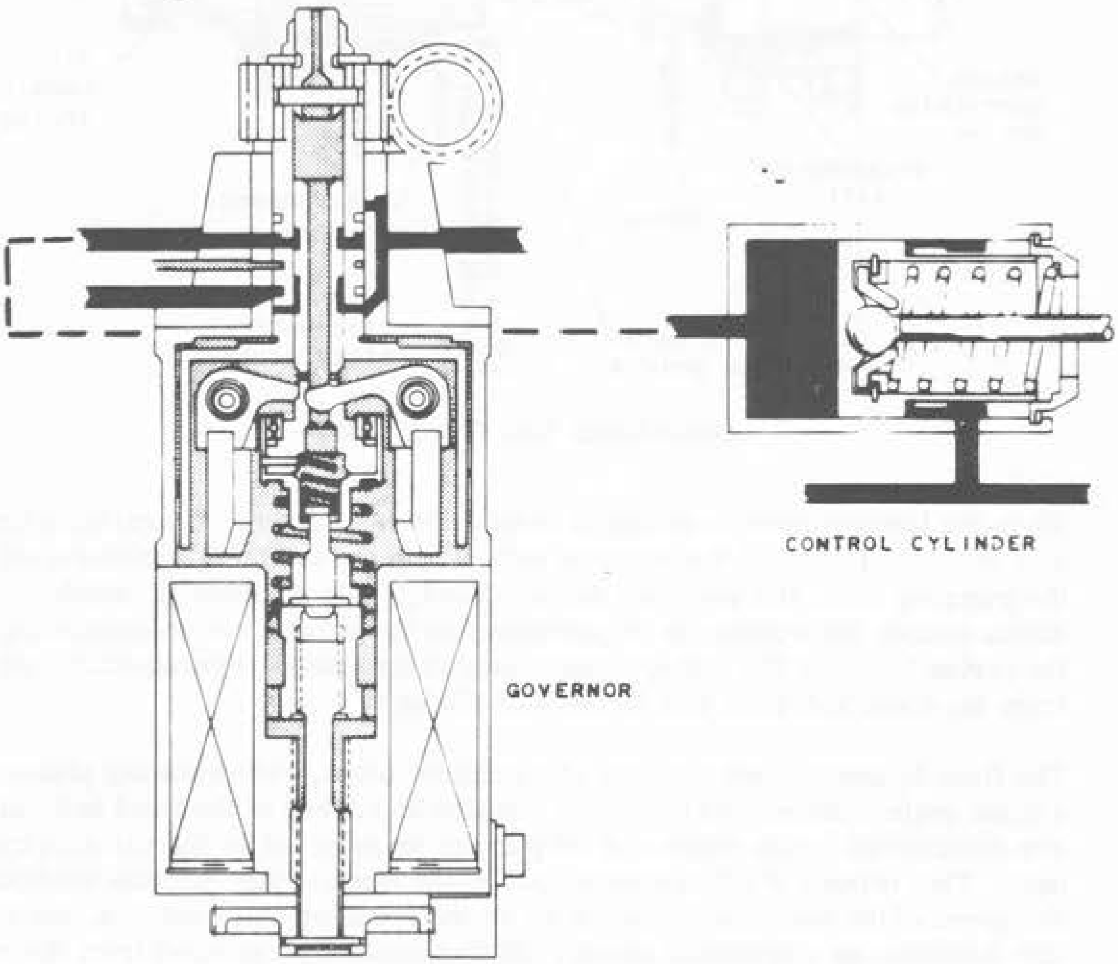


SUNDSTRAND CSD TRANSMISSION

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.



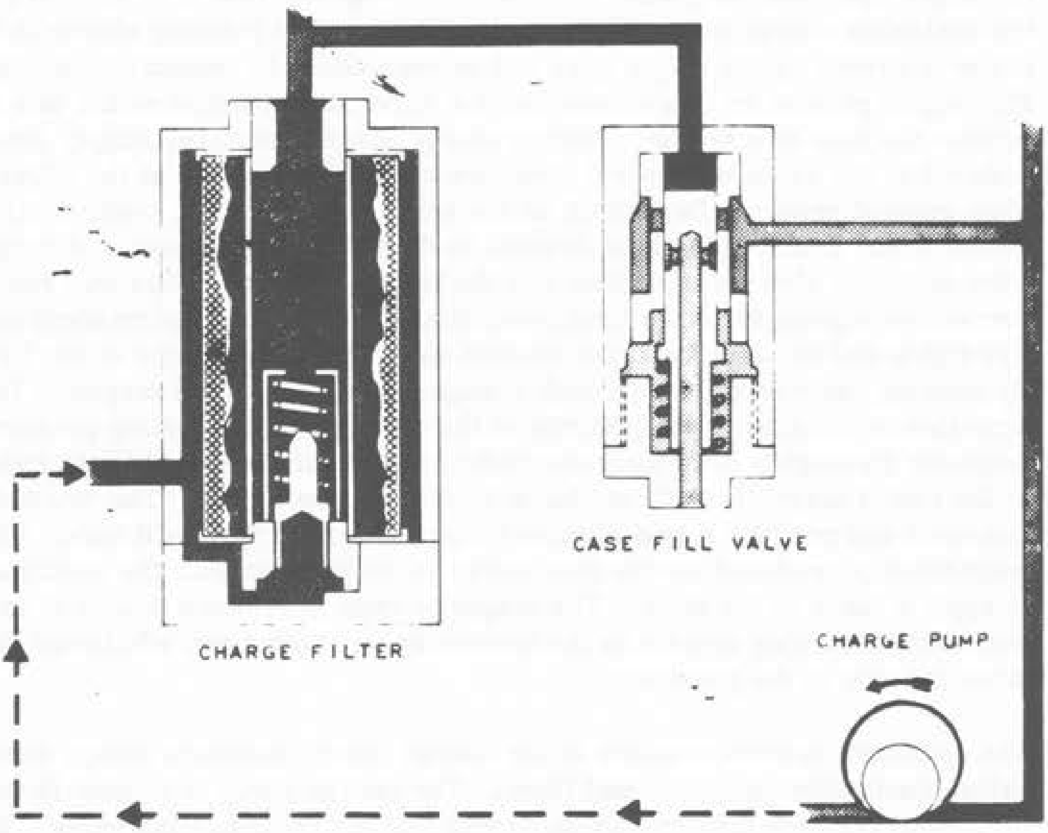
SUNDSTRAND CSD GOVERNOR AND CONTROL CYLINDER

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.

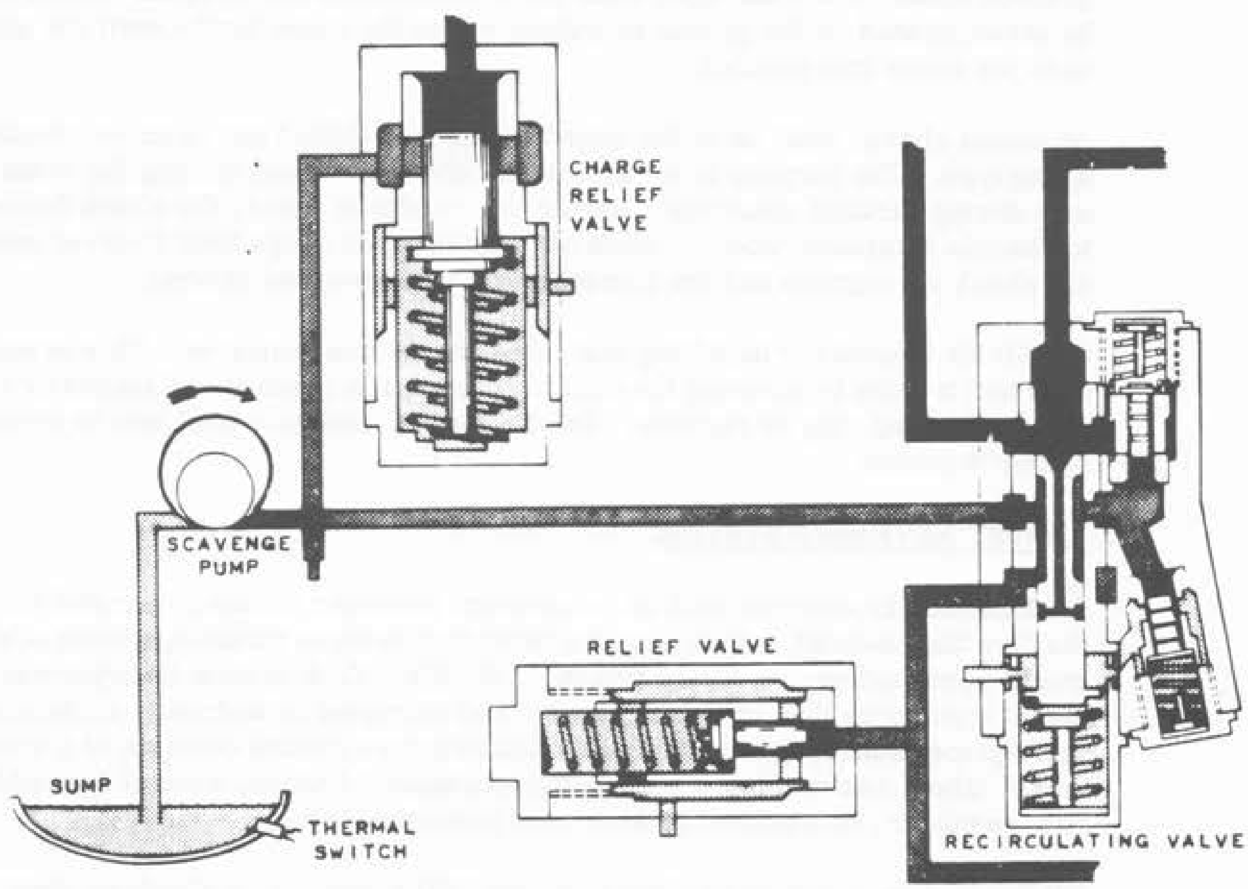
The filter assembly consists of a 20-micron stainless steel mesh filtering element. Its purpose is to remove contamination from the oil before it is ported to the hydraulic units. A bypass valve is incorporated to prevent damage from oil starvation should the element become clogged.

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.

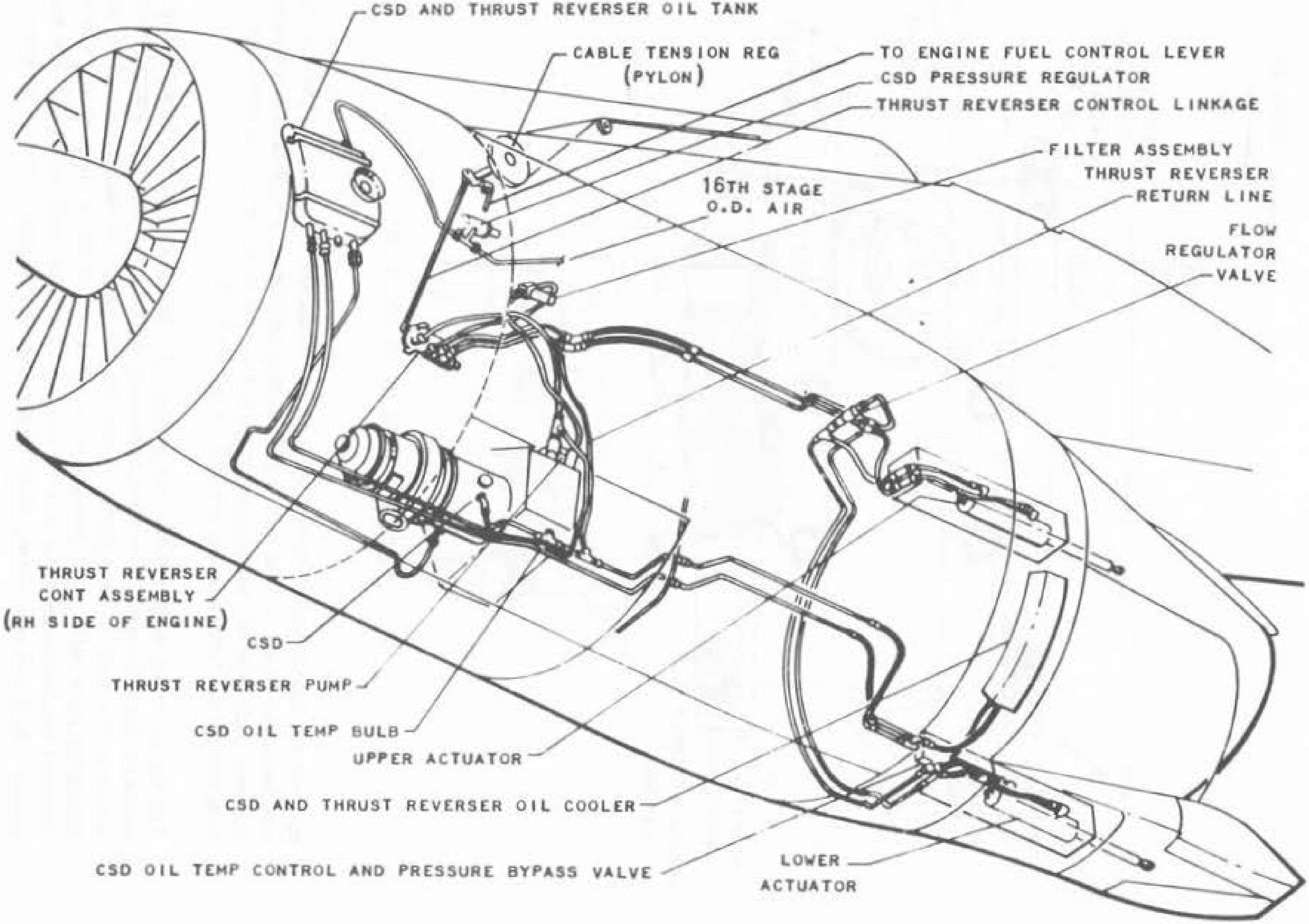
An output clutch, built on to the output shaft, is installed and is an overrunning sprag type. The purpose is to prevent the alternator from driving the transmission during parallel operation. Should this condition occur, the clutch freewheels to absorbe alternator speed. When alternator speed drops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

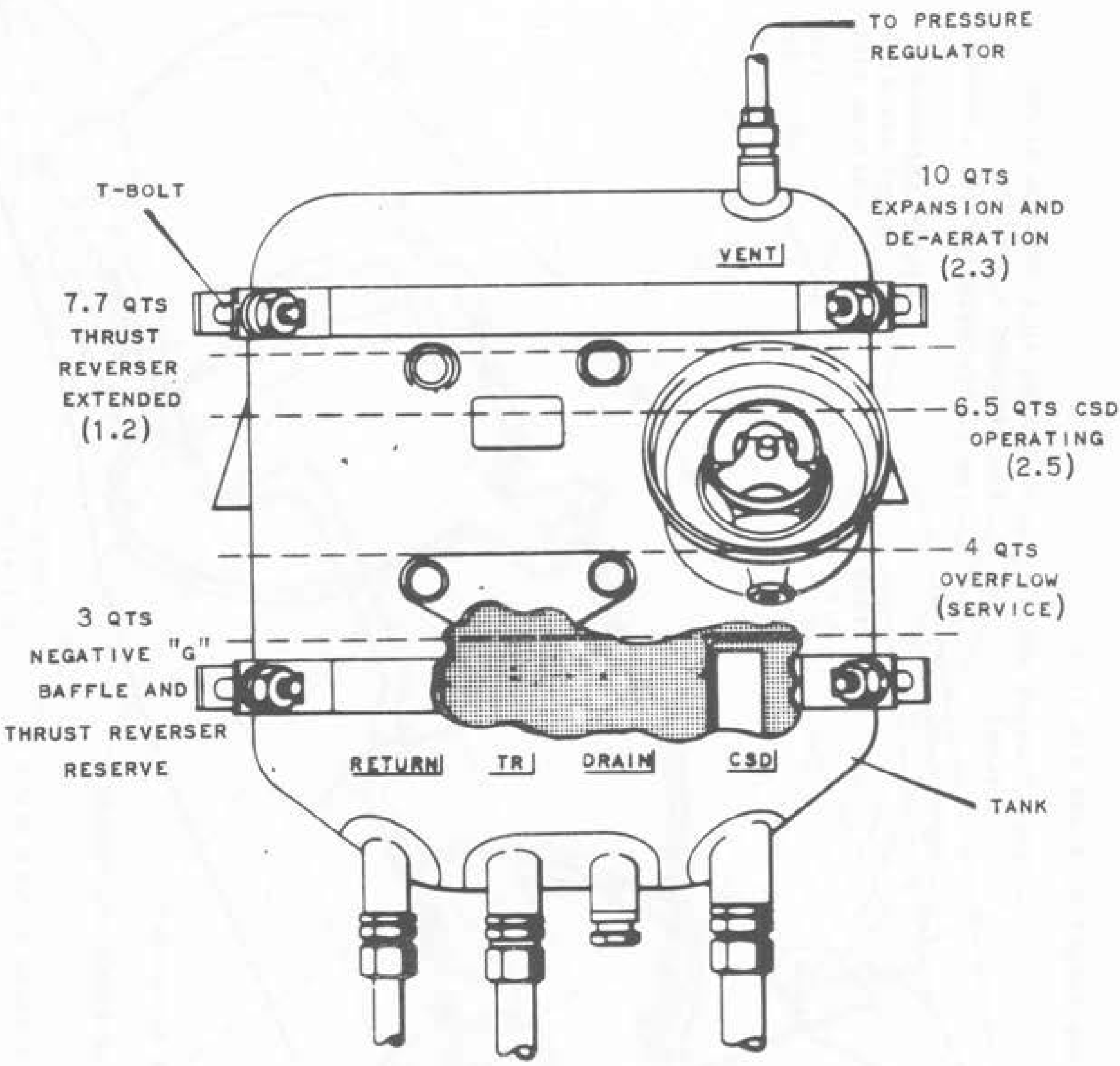
THRUST REVERSER SYSTEM.

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,



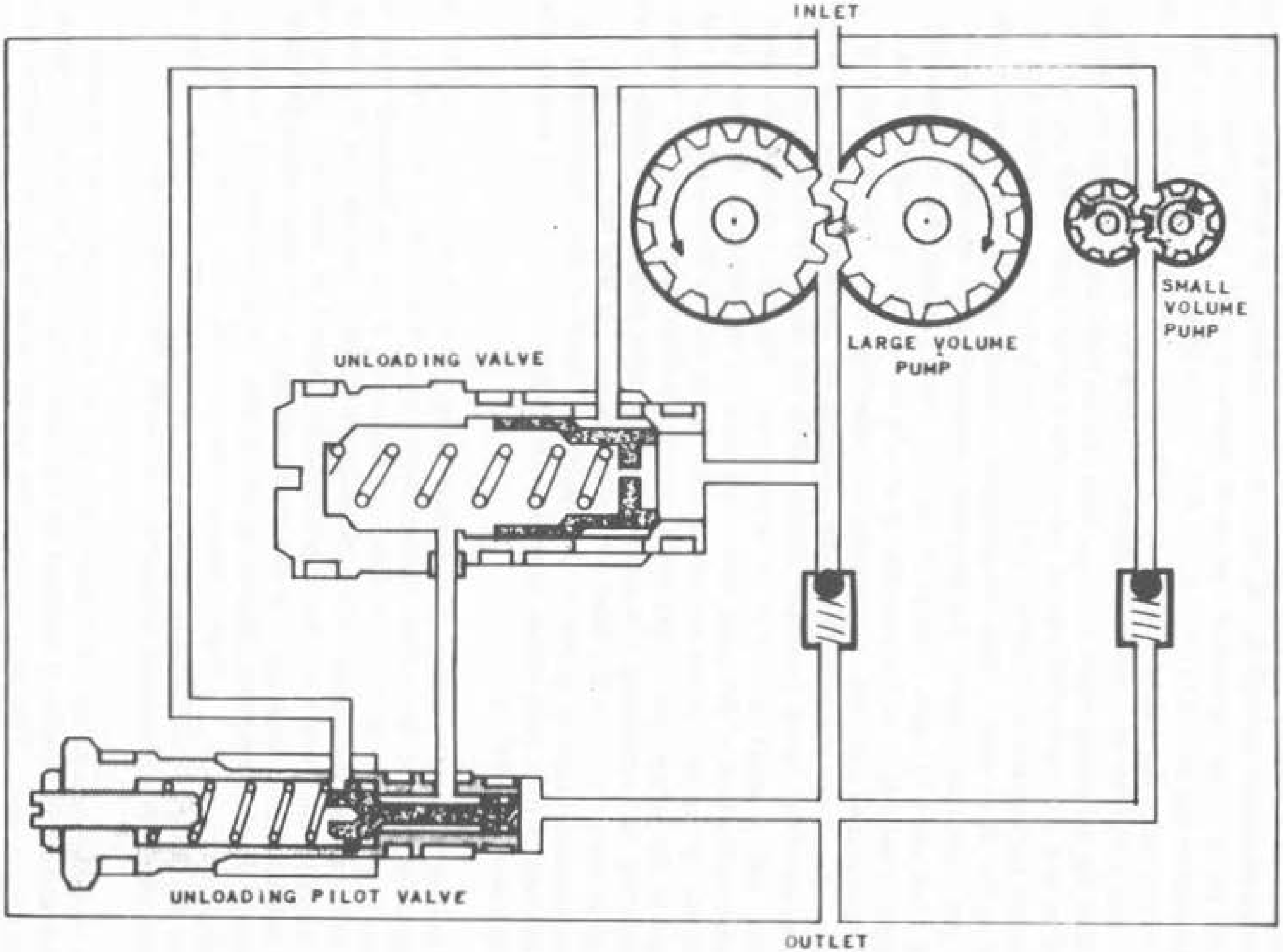
THRUST REVERSER AND CSD COMPONENTS LOCATION



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

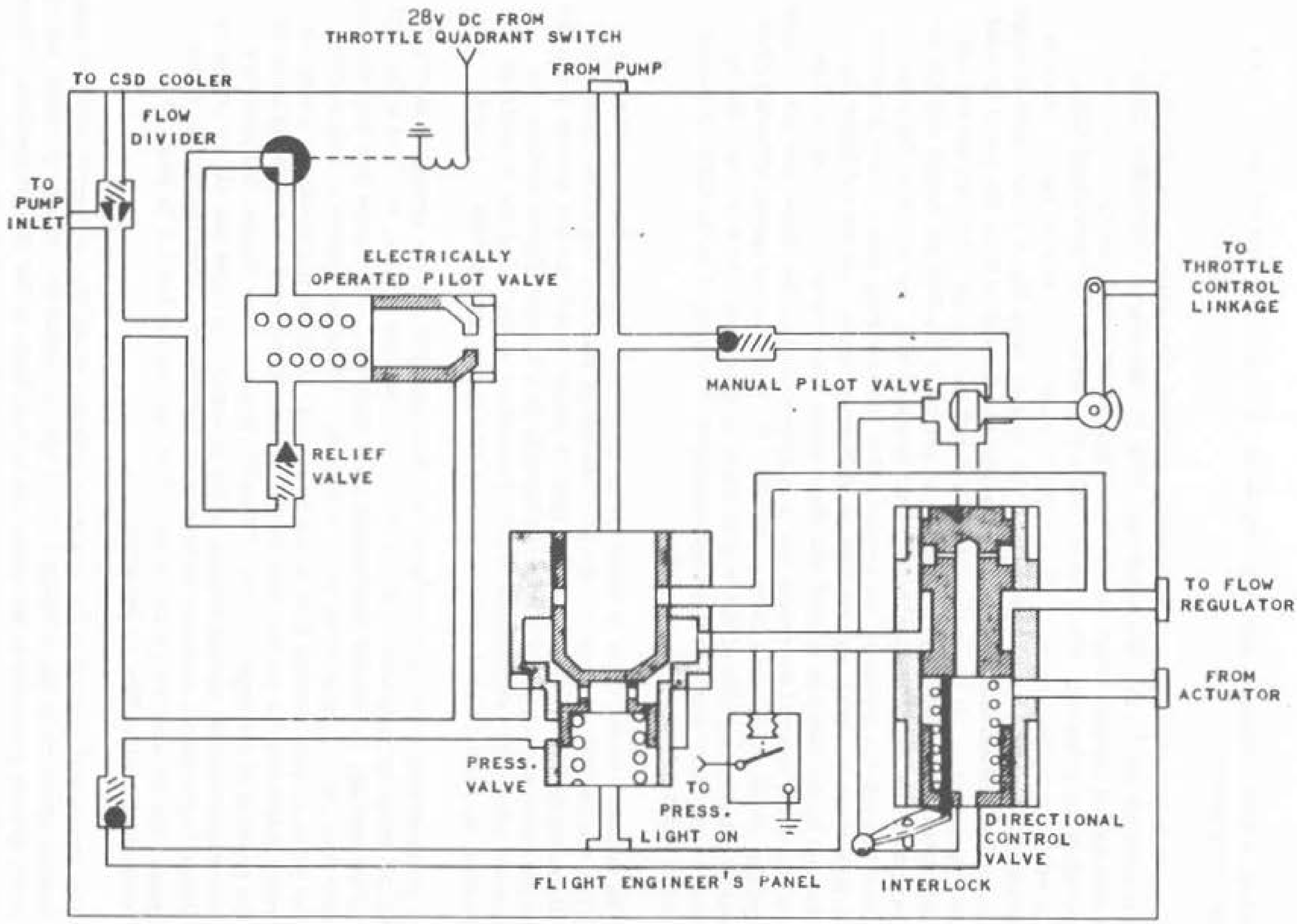


THRUST REVERSER PUMP SCHEMATIC

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℃. 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.

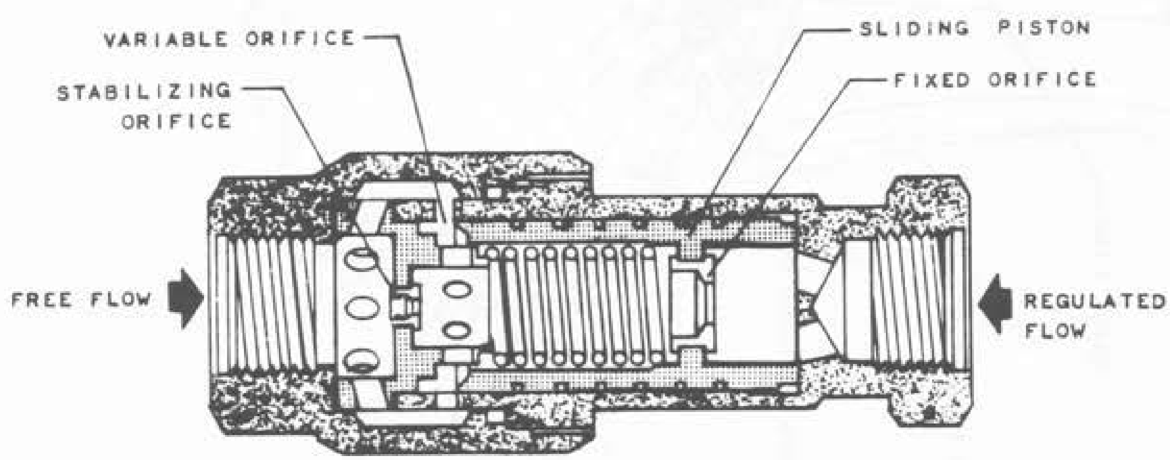
The manual control valve is operated by mechanical linkage from the throttle. When the throttle is moved to the reverse thrust position, the valve opens and allows oil to flow to the directional control valve, which directs system pressure to the reverser actuators. With the throttle in a forward thrust 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.

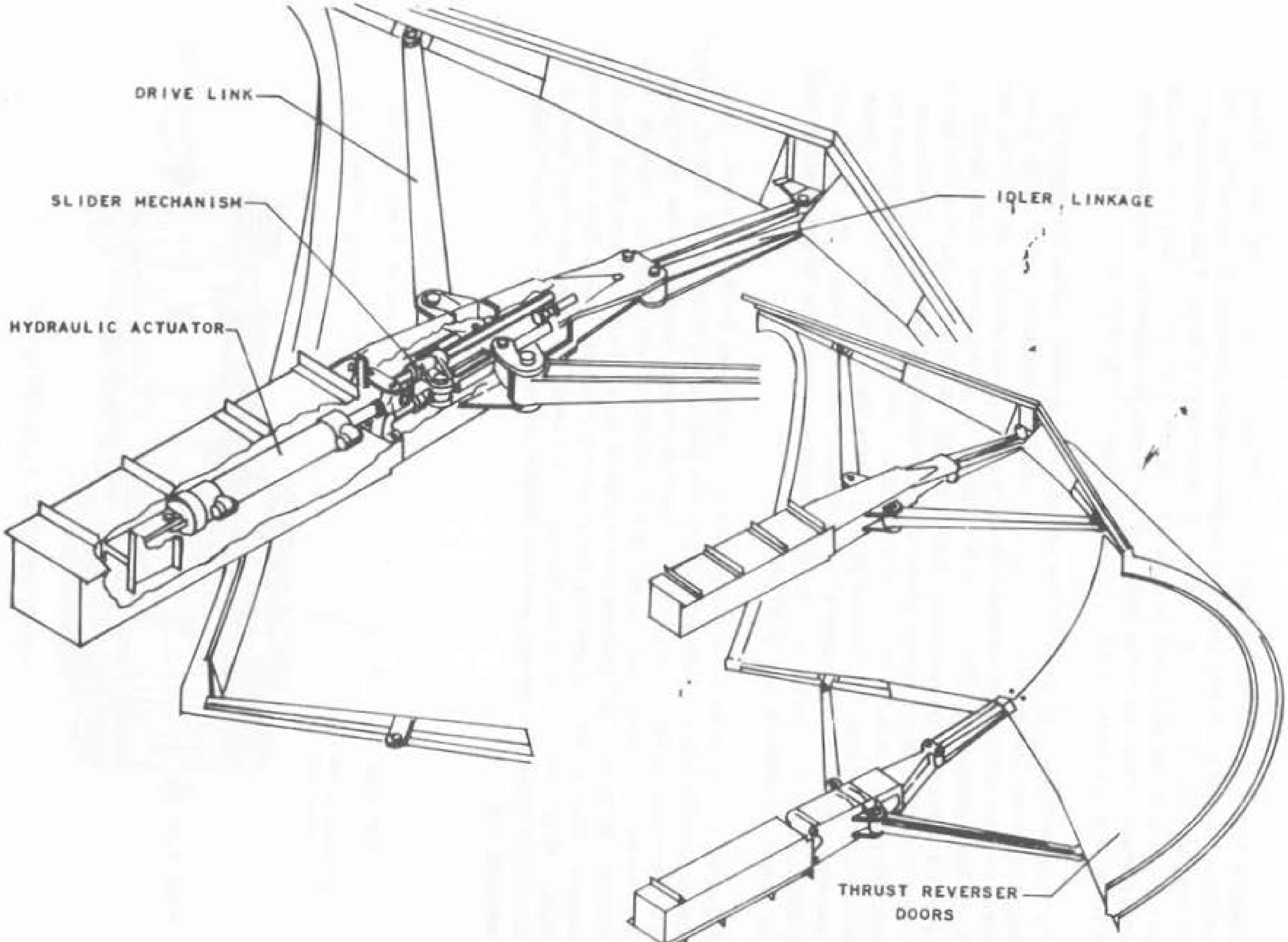
The directional control valve is a two-position, spool type assembly which directs system pressure to the actuators. It is spring-loaded to a stowed position, which ports system pressure to the actuators to hold them in the stowed position. When the throttle is in a reverse thrust setting, the manual 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.

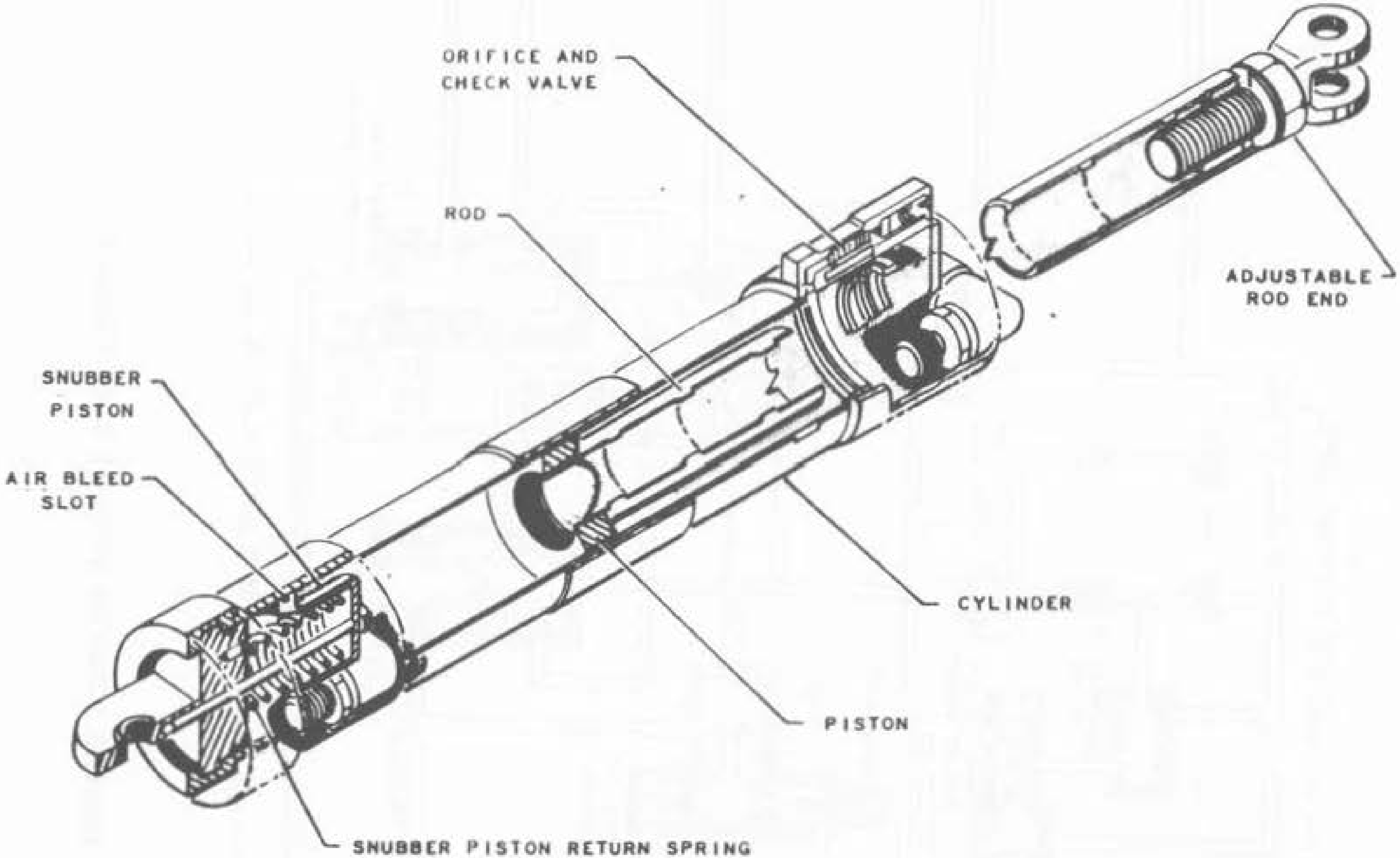
All of the oil returning from the system passes through the flow divider. This action ensures that a maximum of 2 gallons per minute flows to the CSD oil cooler and the rest back to the pump inlet. The flow divider consists of one inlet port and two outlets. Inside the divider is a fixed orifice and 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.



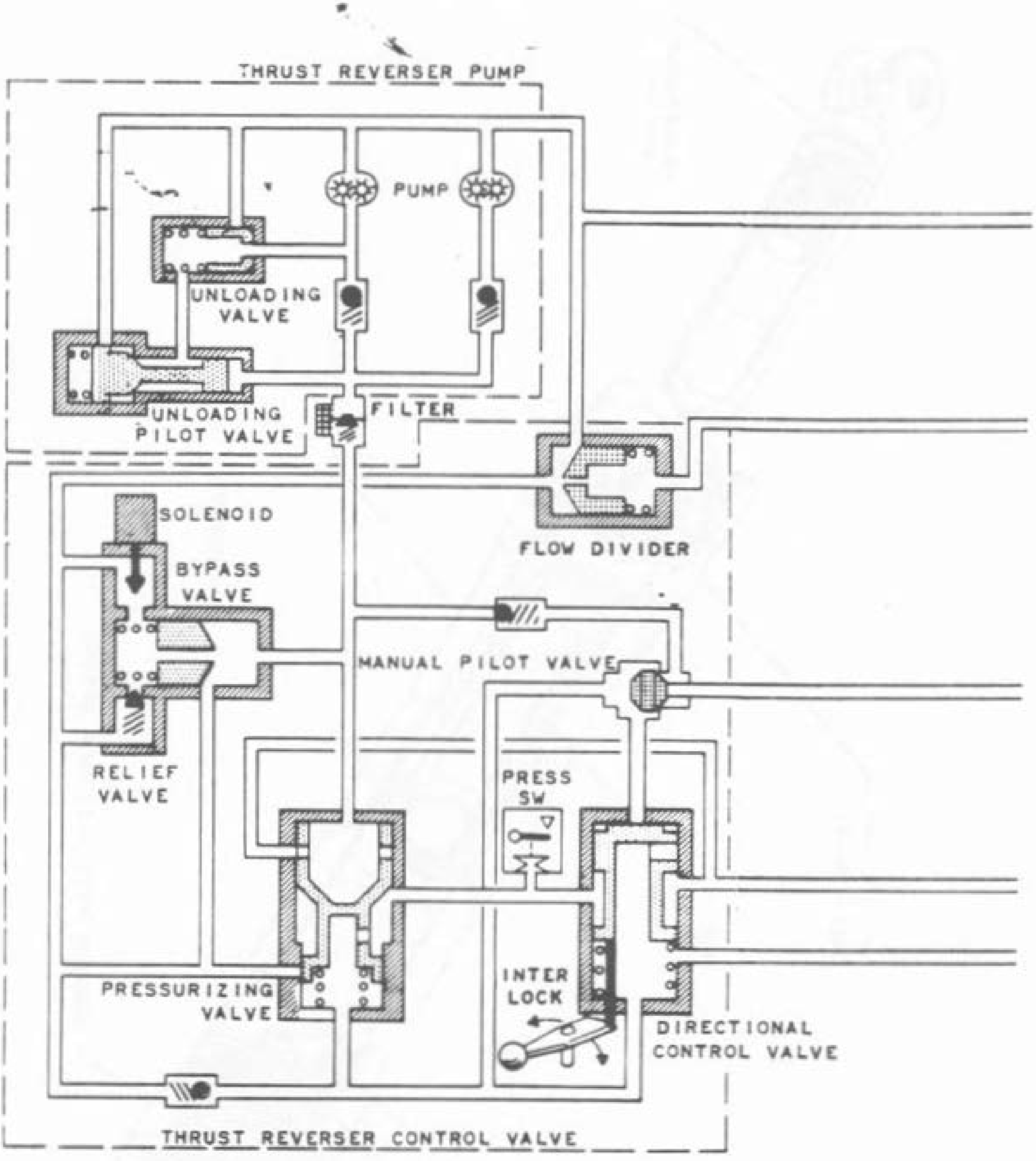
THRUST REVERSER FLOW REGULATOR



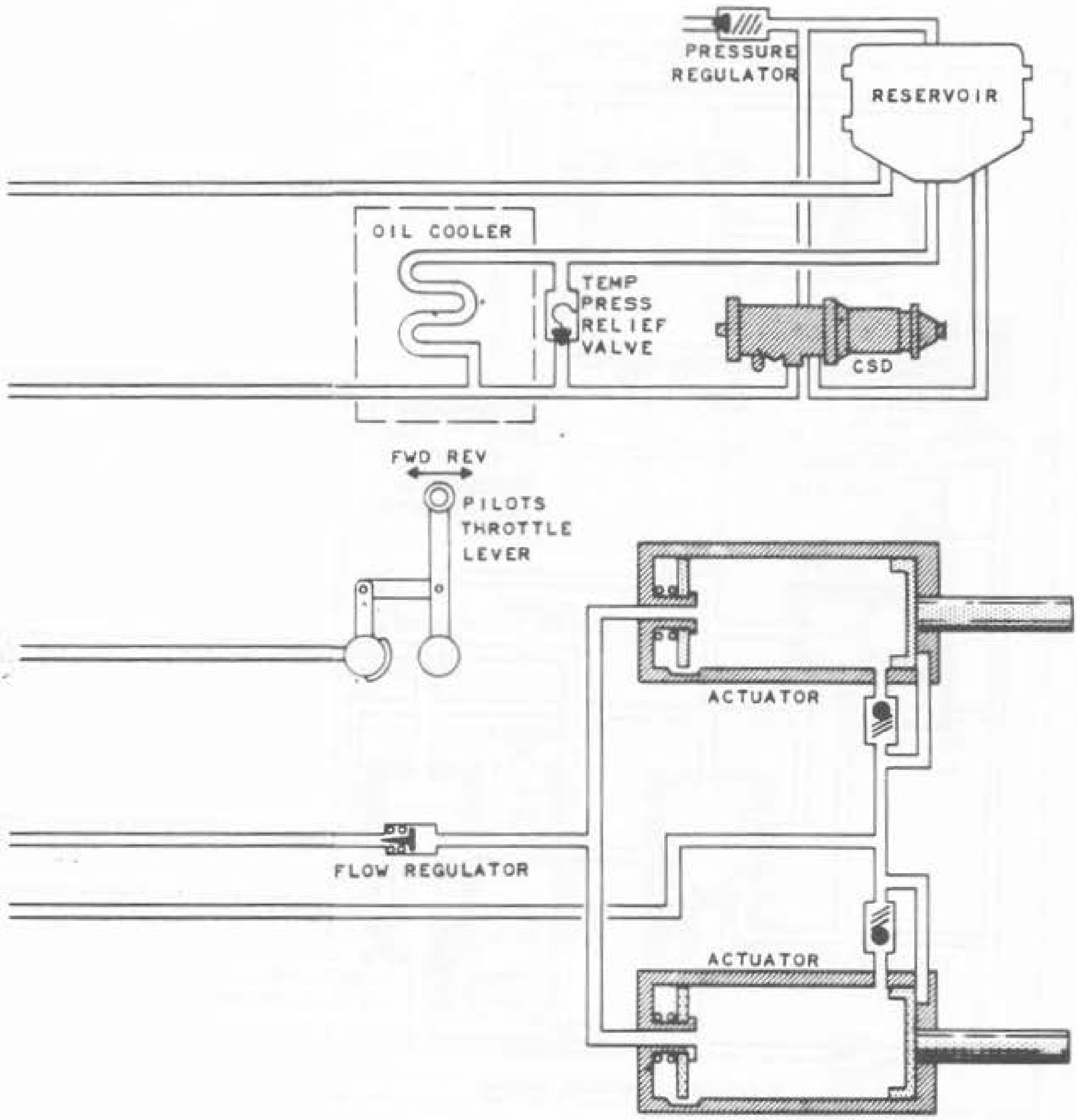
THRUST REVERSER DOORS AND ACTUATORS



THRUST REVERSER ACTUATOR



THRUST REVERSER ACTUATION SYSTEM (DOORS STOWED)


PRESSURE
REGULATOR
RESERVOIR
OIL COOLER
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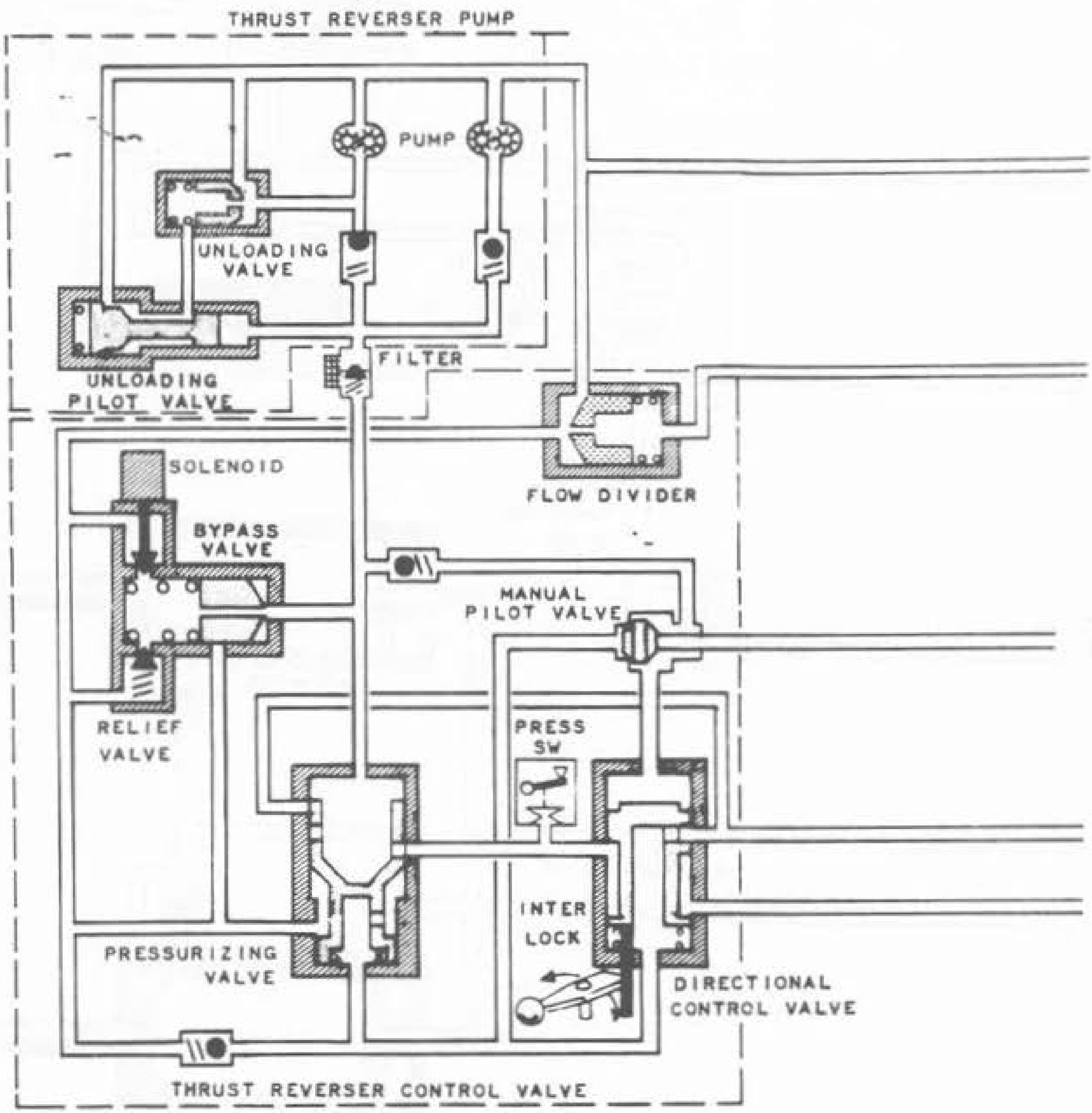
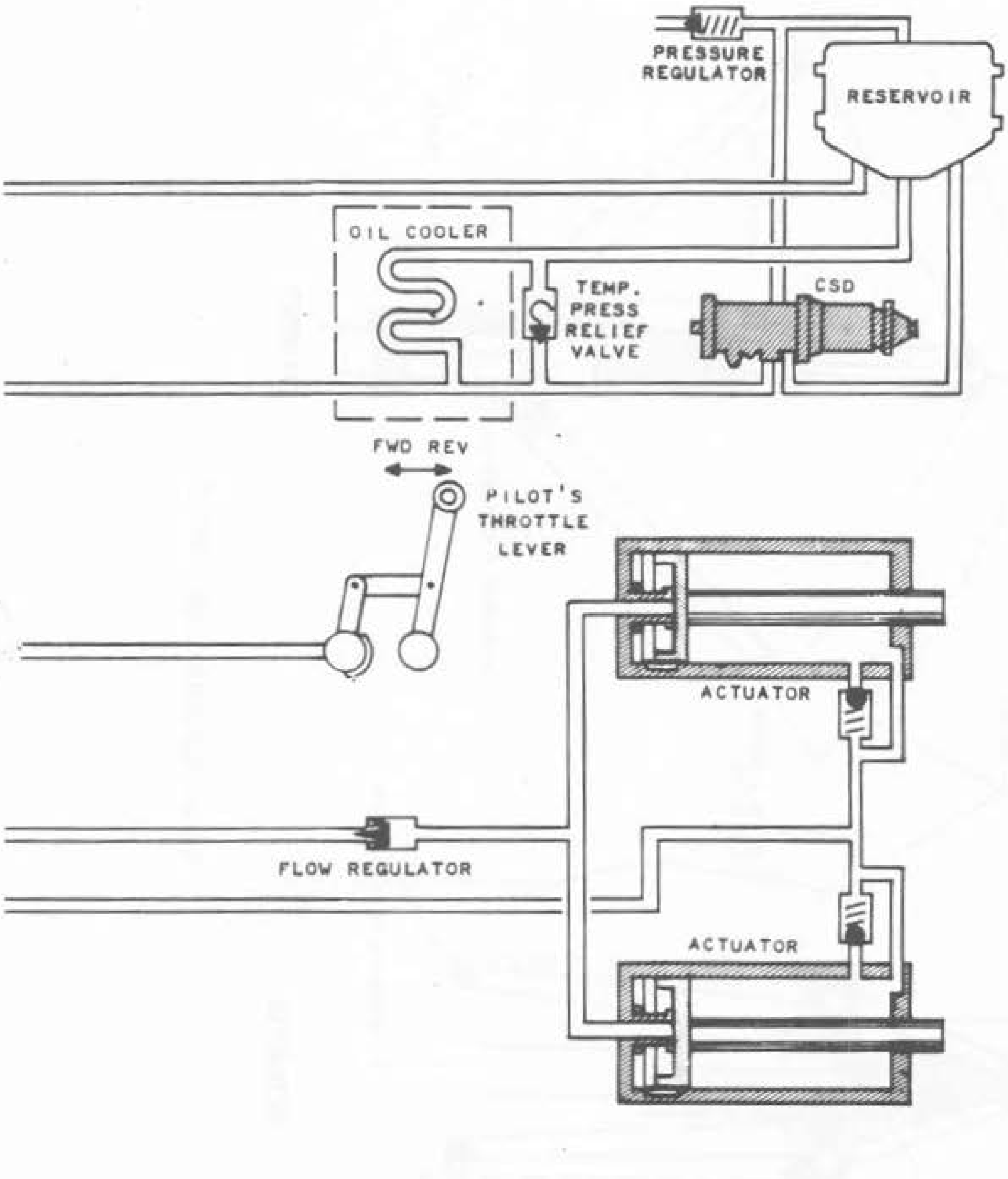
FLOW REGULATOR
ACTUATOR



THRUST REVERSER ACTUATION SYSTEM (DOORS EXTENDED)


PRESSURE
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FLOW REGULATOR
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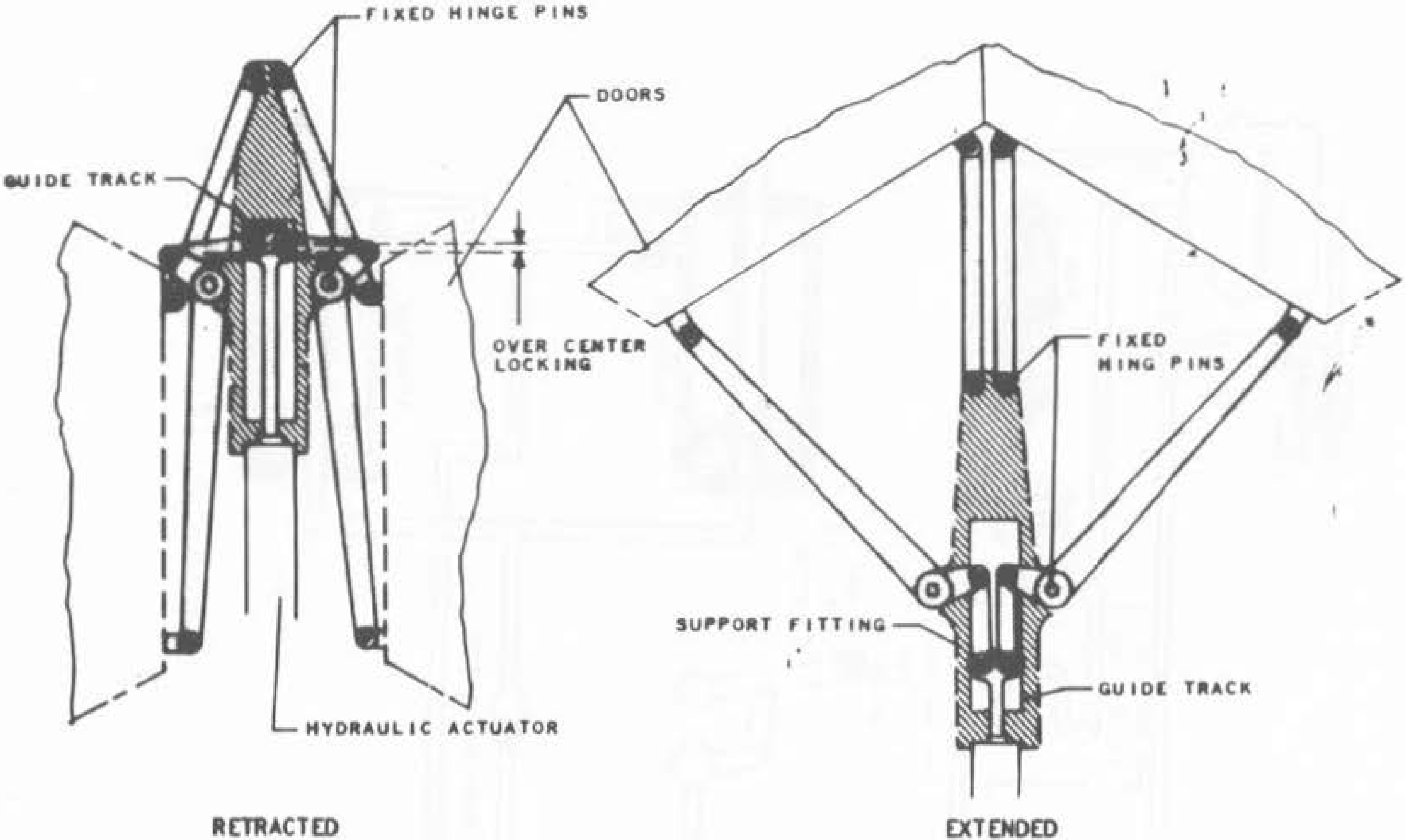


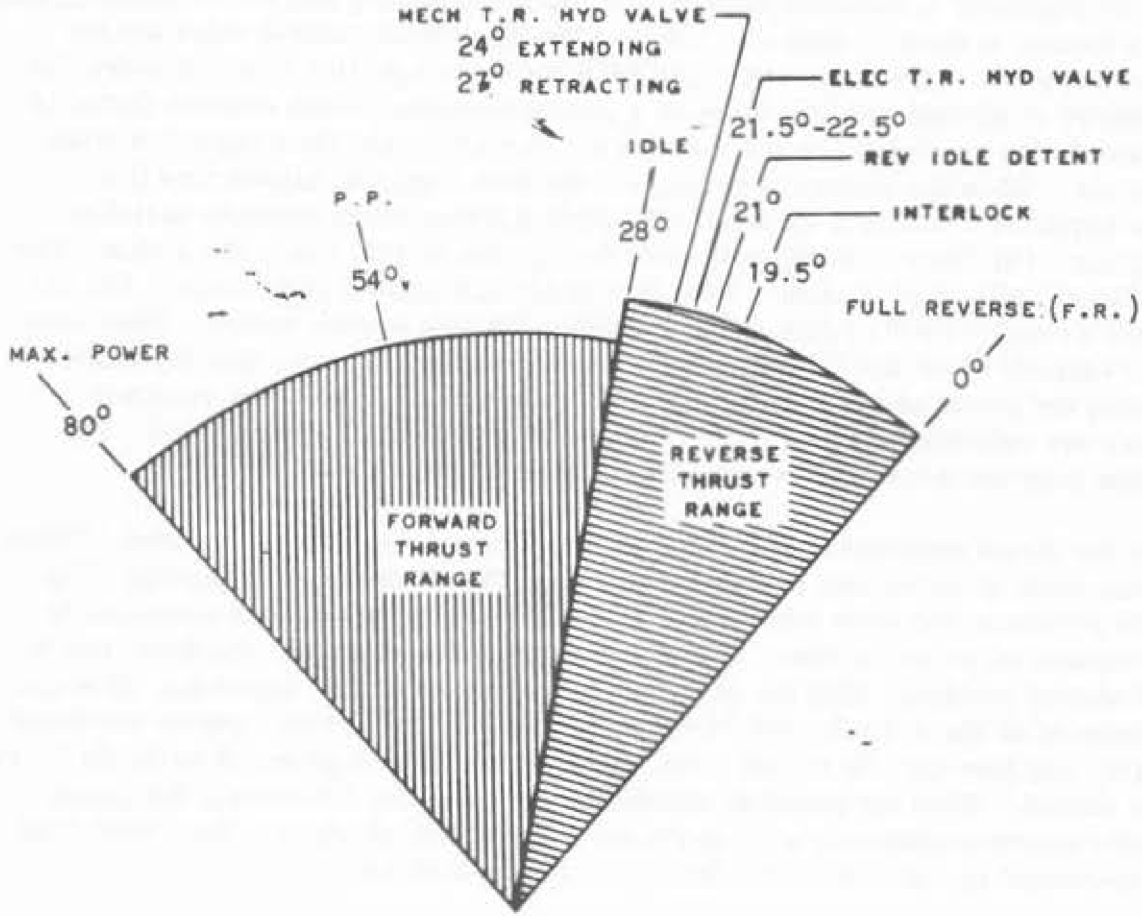
THRUST REVERSER DOOR LINKAGE

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.

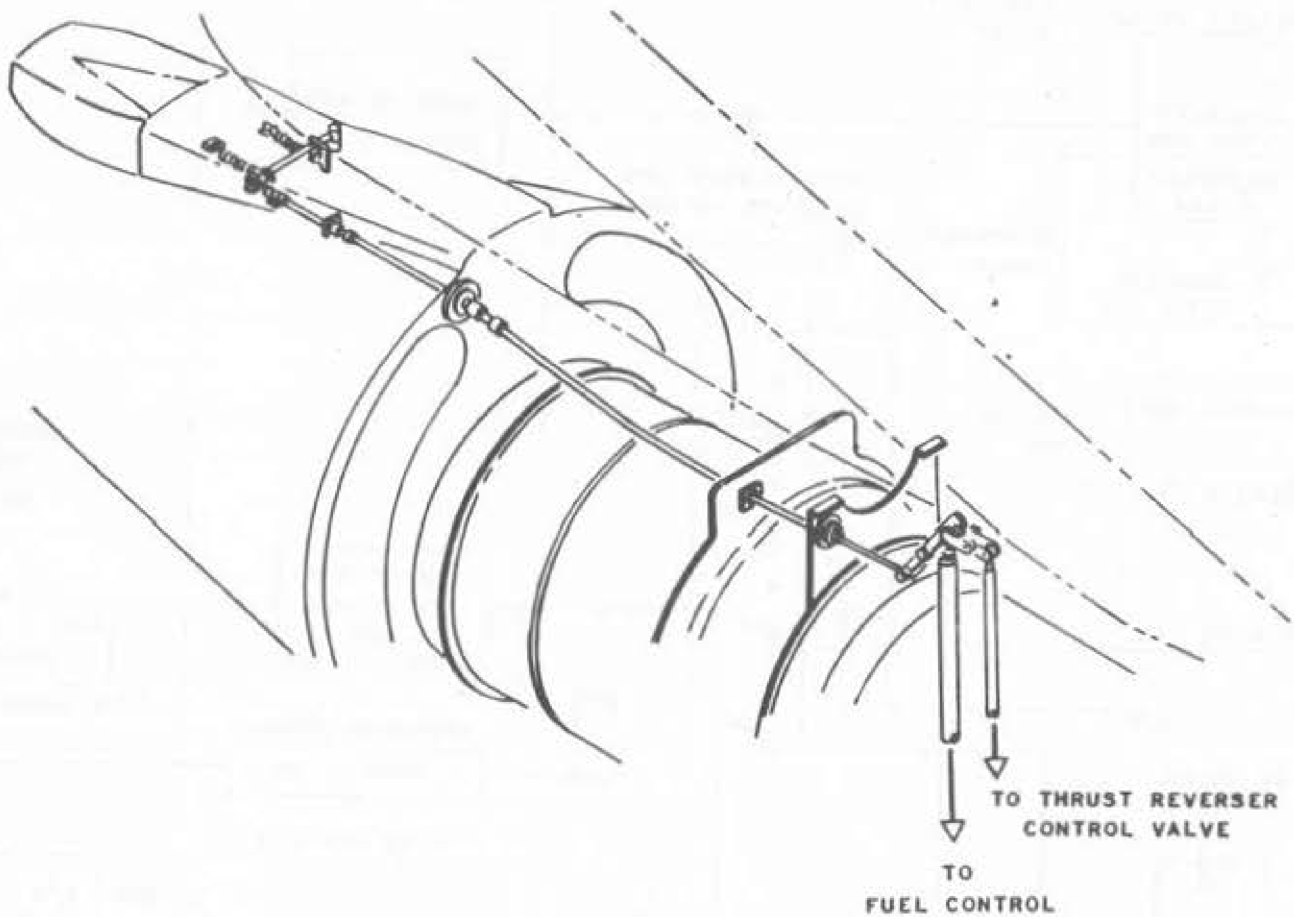
Target-type thrust reverser doors were selected, mainly for the weight savings as compared to other thrust reverser configurations. Simplicity of design also contributes to the reliability of the system. The material selected for their manufacture consists of an inner surface of stainless steel and an 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

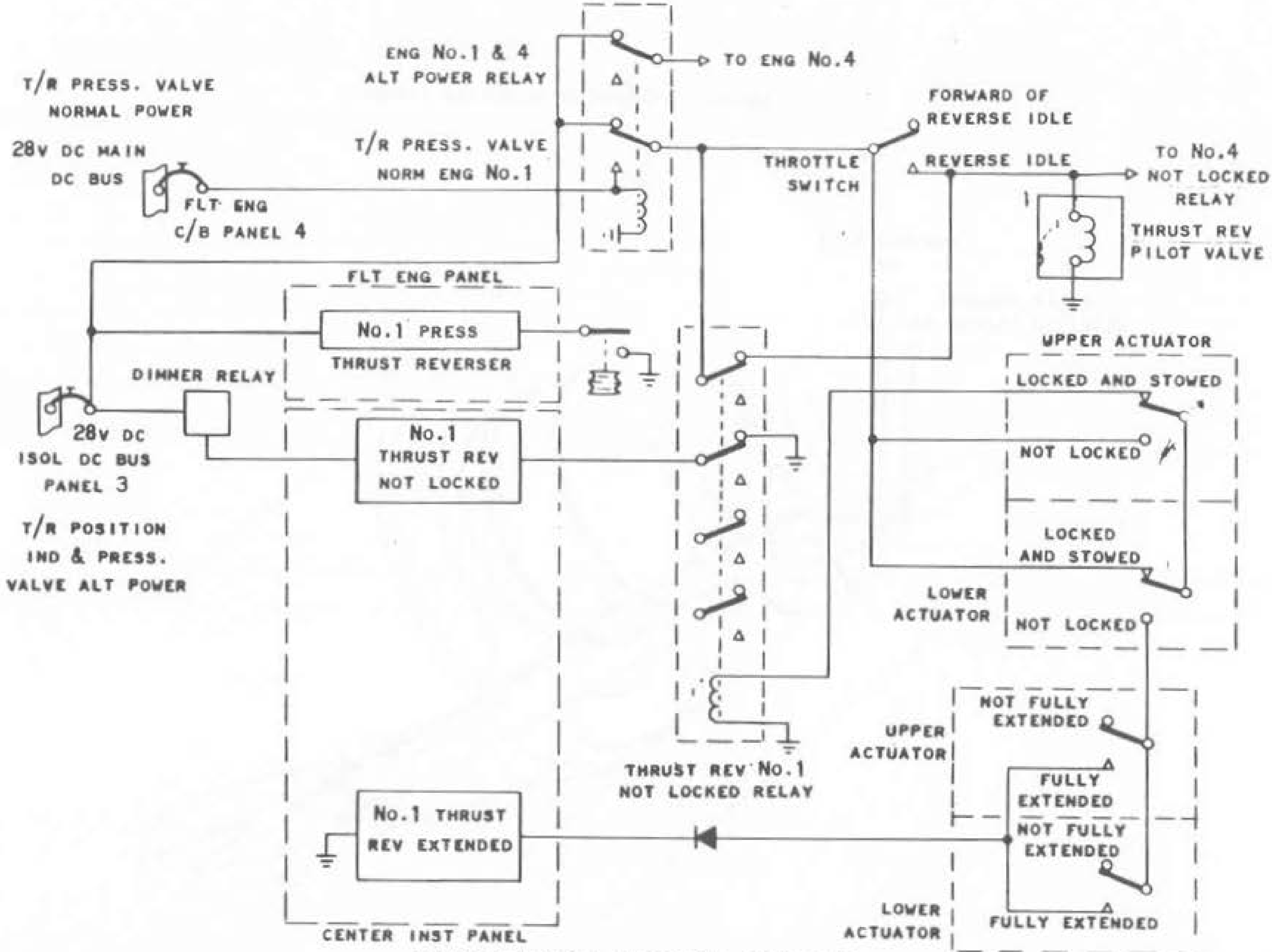


THROTTLE QUADRANT SCHEMATIC

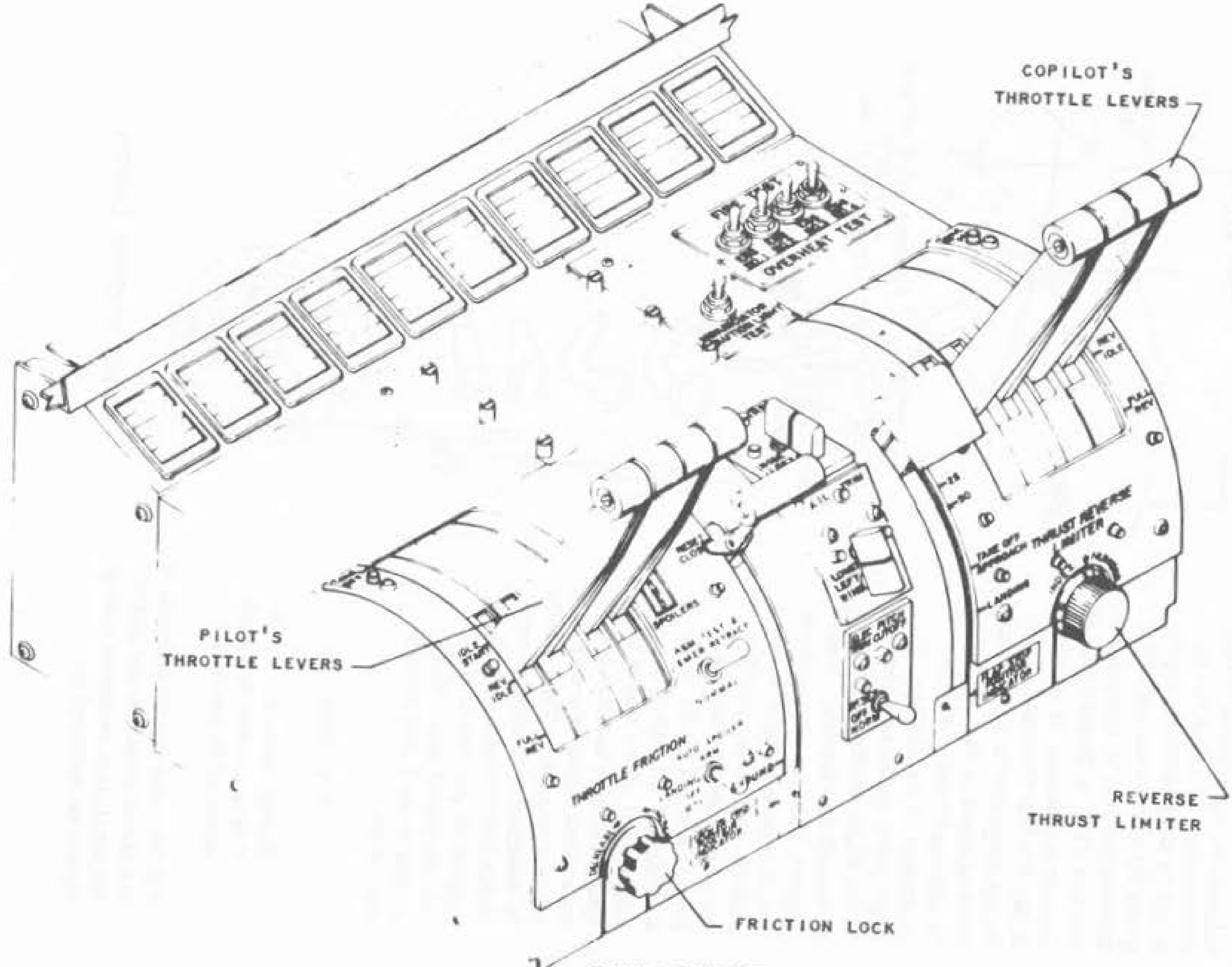
on the throttle quadrant energizes the solenoid valve in the control assembly to the closed position. This pressurizes the thrust reverser hydraulic system. Pressure causes the directional control valve to shift to the extend position and closes contacts of a pressure switch at approximately 1000 PSI. 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



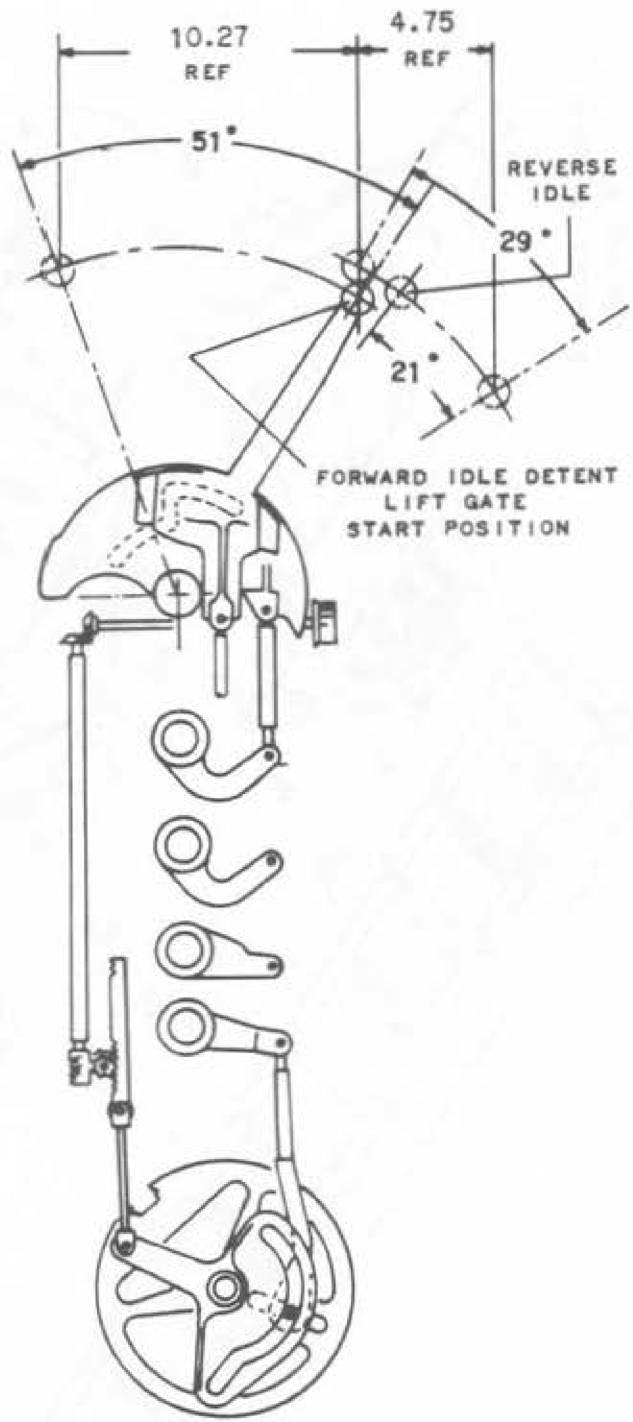
CENTER CONSOLE

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.

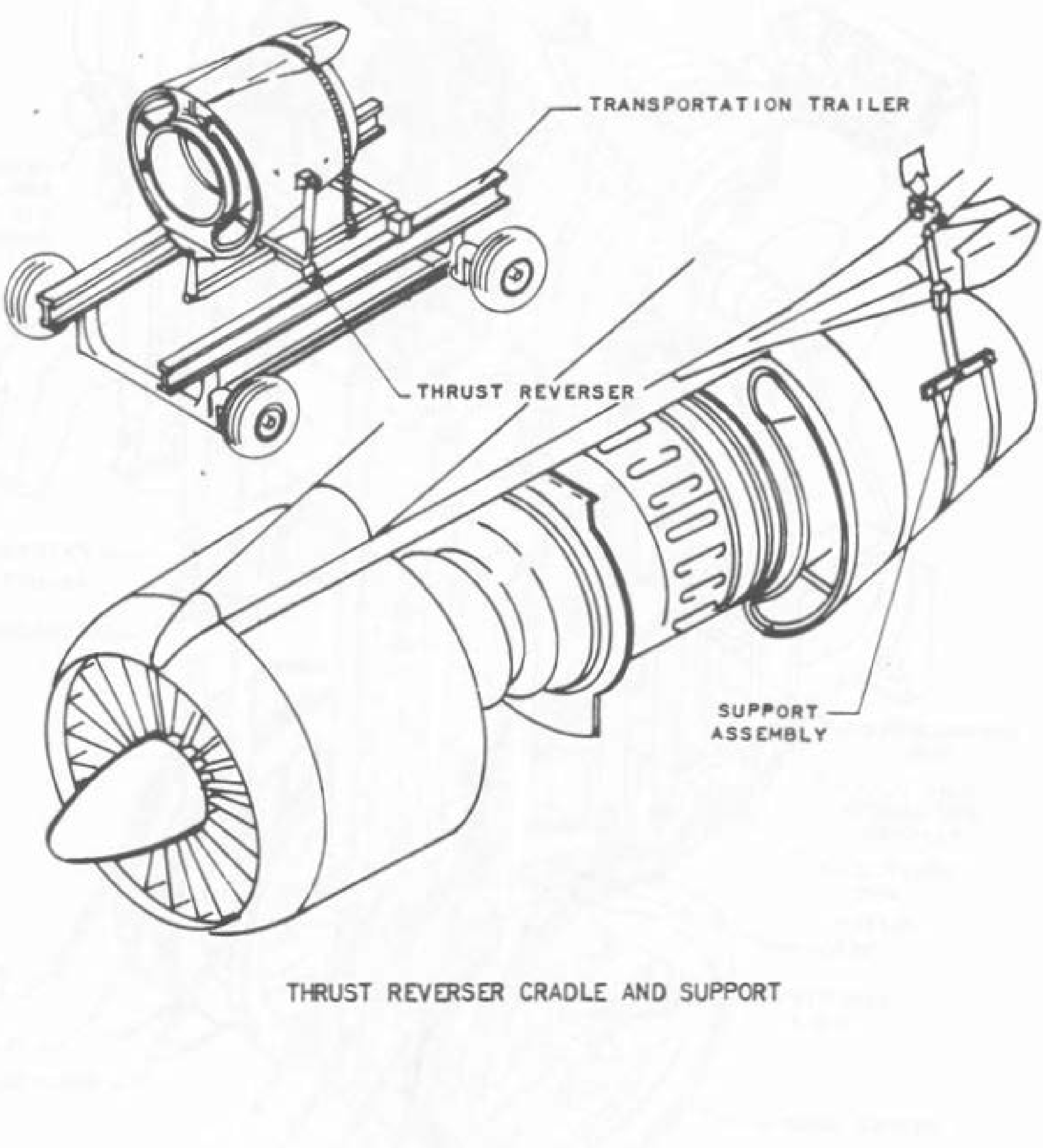
CAUTION

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

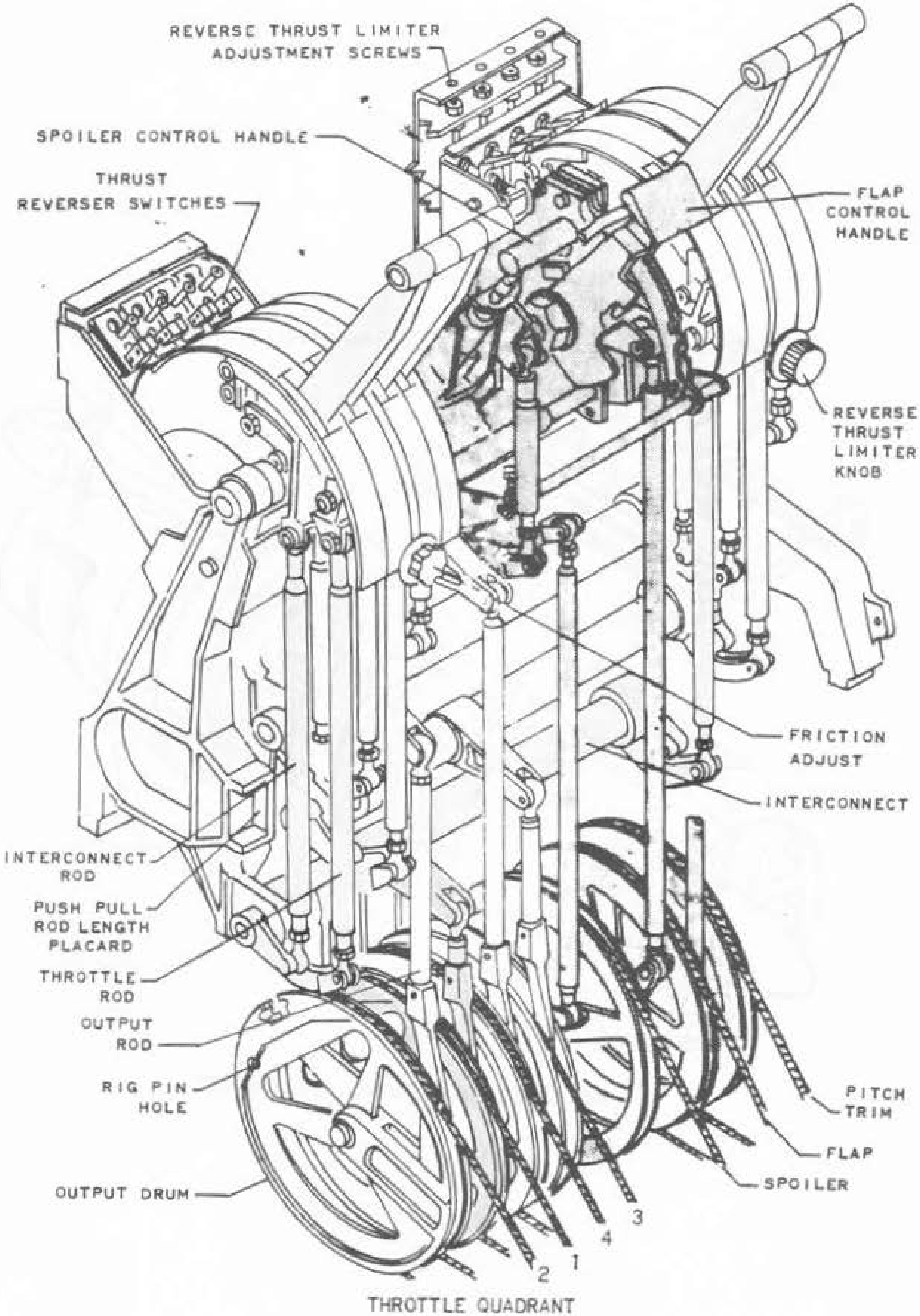
For removal and installation of the thrust reverser assembly, the applicable technical manual should be referred to.



THRUST REVERSER LIMITER



THRUST REVERSER CRADLE AND SUPPORT



THROTTLE QUADRANT