CHAPTER 9

A. GENERAL DESCRIPTION (ATA 77-00)

1. The engine indicating systems described in this chapter include the engine pressure ratio (EPR) indicating system, a tachometer system to measure the speed of the low pressure compressor (N1) and high pressure compressor (N2), and an exhaust gas temperature (EGT) indicating system. Fuel flow indicating system, oil pressure system, oil temperature system and oil quantity indicating system are included in there respective systems.

2. Each system provides a reading of engine operating conditions on indicators located in the control cabin. This information enables the monitoring of engine output and maintaining a selected flight performance.

B. ENGINE PRESSURE RATION INDICATING SYSTEM

1. General

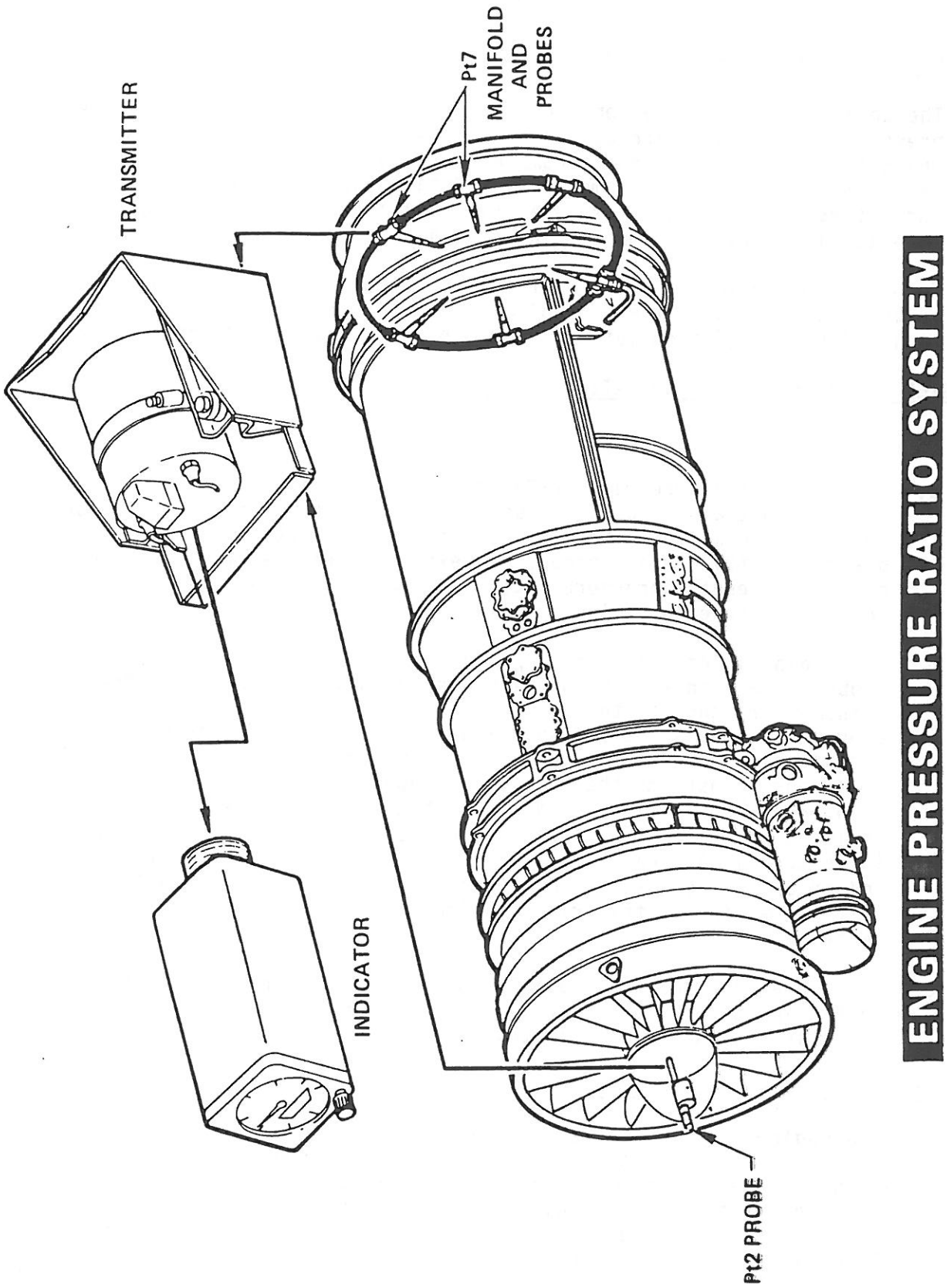
a. The engine pressure ratio (EPR) indicating system shows the engine power output and is used for setting engine thrust and for monitoring engine performance. The EPR indicating system consists of one inlet pressure (Pt2) sensing probe, six exhaust pressure (Pt7) sensing probes, an engine pressure ratio transmitter and a pressure ratio indicator for each engine.

b. The engine inlet and exhaust pressure, sensed by the pressure sensing probes, are transmitted to the pressure ratio transmitter. The transmitter converts the exhaust and inlet pressures into a ratio, provides output signals proportional to the EPR and transmits the signals to the EPR indicator located in the flight compartment. The indicator transforms the electrical input signals into the indicator pointer shaft rotation and digital three-wheel counter to show the engine pressure ratio. A test receptacle, used to attach a master indicator, is included in the circuit to provide a means of adjusting and checking the system. On airplanes incorporating EPR-activated takeoff warning system, refer to Chapter 31, Instruments, for a description.

c. On airplanes incorporating a Performance Data Computer System (PDCS), an EPR indicator incorporating a second servo loop and a driven bug is installed on the pilot's instrument panel.

2. Inlet Pressure Sensing Probe

a. The engine inlet pressure (Pt2) is sensed by a probe similar to a pitot tube. This probe is mounted through the center of the nose dome with the open end of the tube facing the inlet air stream. The vent hole in the probe functions as the probe ice detector by decreasing engine inlet pressure (increasing EPR) when icing occurs. The probe is anti-iced by the engine anti-ice system.


TRANSMITTER
Pt7 MANIFOLD AND PROBES
INDICATOR
Pt2 PROBE
ENGINE PRESSURE RATIO SYSTEM

3. Exhaust Pressure Sensing Probe

   a. Each engine has six exhaust (discharge, Pt7) pressure sensing probes projected into the stream of turbine exhaust gases. The probes are connected to a common manifold for obtaining an average pressure of the exhaust gases. Exterior connection to the manifold is made at a single point through the fan discharge outer duct at approximately the 7 o'clock position.

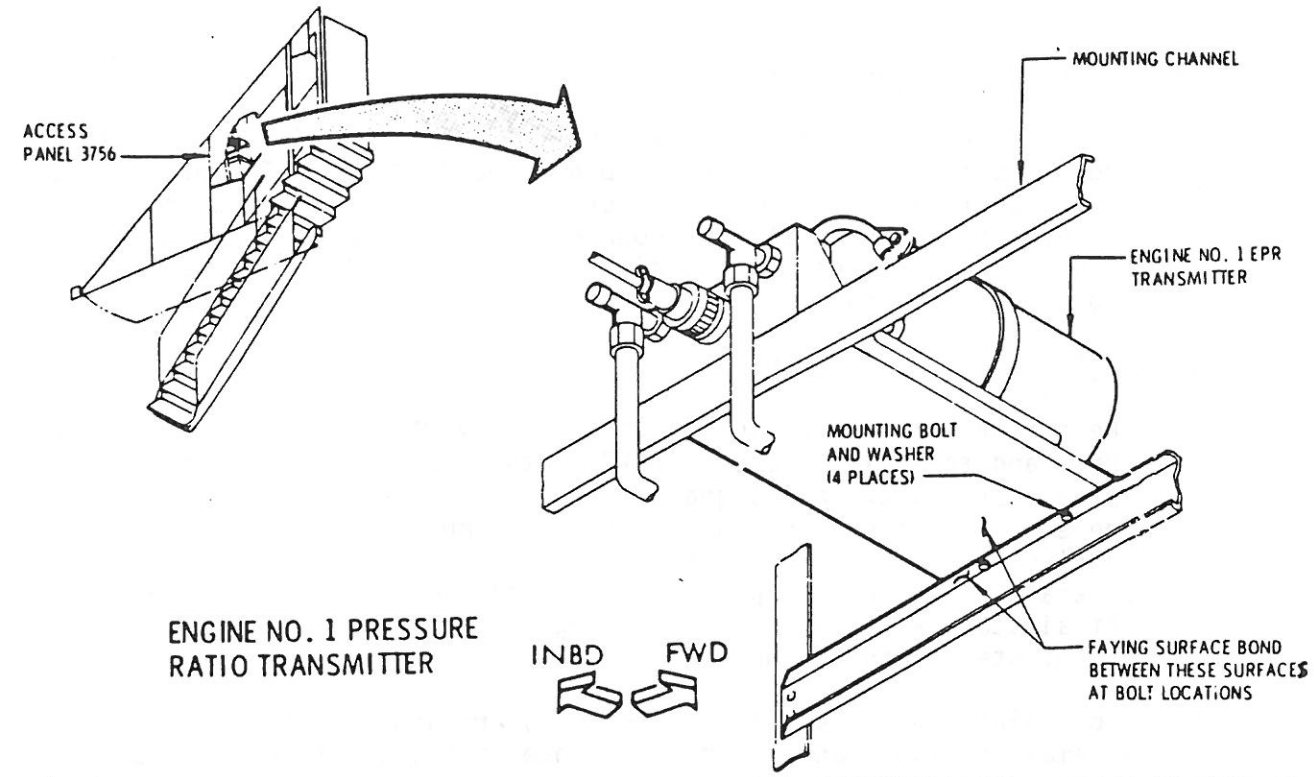
4. Engine Pressure Ratio Transmitter

   a. The engine pressure ratio transmitter converts the exhaust pressure (Pt7) and the inlet pressure (Pt2) into a ratio, and generates three-phase electrical signals corresponding to pressure changes in the engine. It consists of two bellows (multicell diaphragms), a sensing mechanism, an amplifier, a motor-gear train, and a synchronous generator. The engine pressure ratio transmitters are located in the aft airstair equipment area; for engines No. 2 and No. 3 to the right of the stairs and for No. 1 to the left of the stairs.

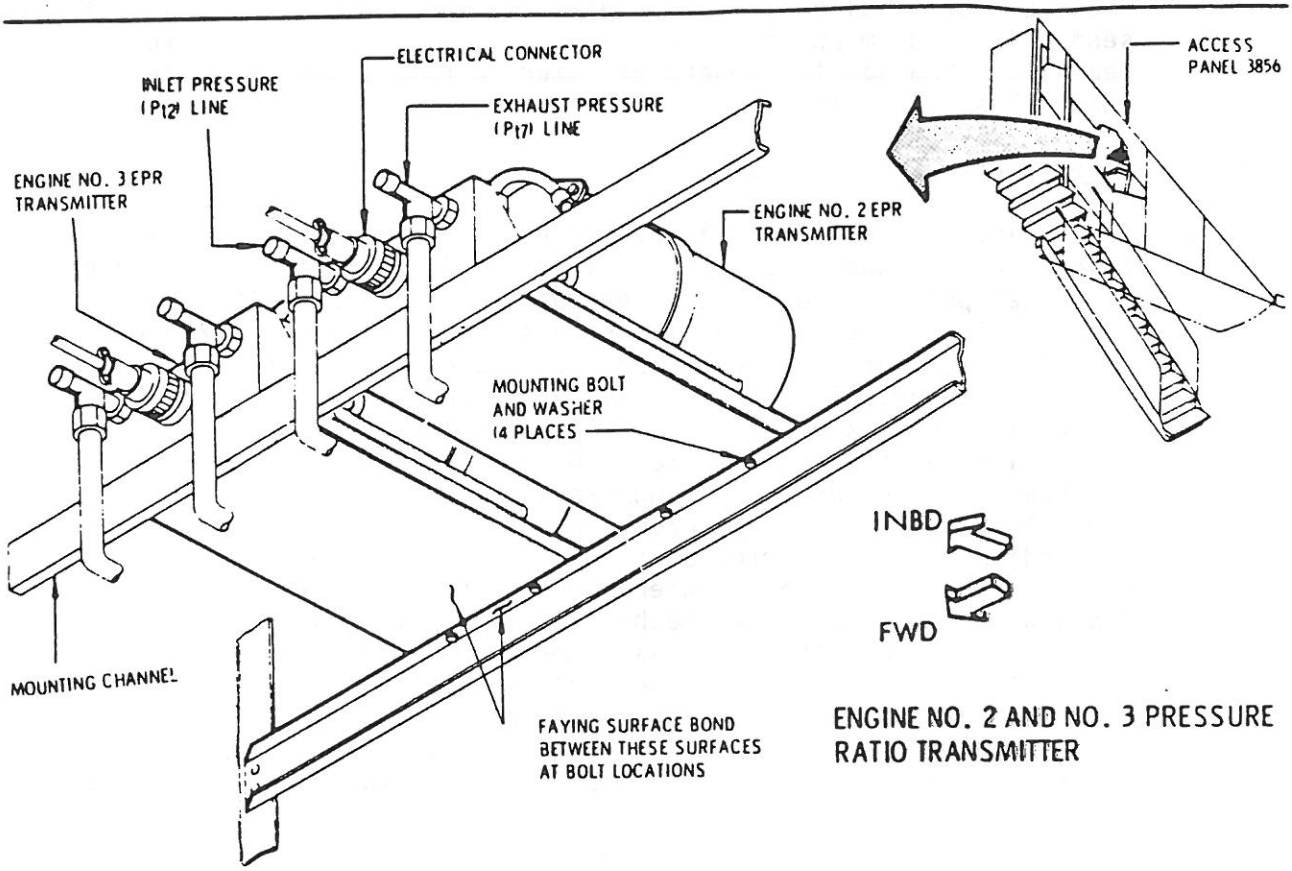
   b. The engine exhaust and inlet pressures are applied to the bellows assembly of the transmitter. A change in either of these pressures cause differential bellows movement. The bellows movement affects the sensing mechanism which, with the aid of the amplifier and the motor gear train, causes the generator rotor to rotate and generate three-phase electrical signals.

5. Engine Pressure Ratio Indicator

   a. The engine pressure ratio indicator provides pointer and digital readout of the engine exhaust pressure ratio (PT7/Pt2) and on some airplanes pointer and digital readout of the Command EPR input signal. The indicator consists of a synchro receiver, servomotor, gear trains, coarse indicator pointer and numerical counter, command index and numerical counter, command set knob, graduated dial face, integral lights, and case. The indicator is not hermetically sealed. The dial face is graduated from 1.0 to 2.6 EPR. Each counter consists of three rotating drums with numerals, readable from 0.50 to 2.00 EPR. Downward rotation of drums indicates pressure ratio increase. The indicator incorporates a failure warning flag which drops in front of coarse counter numerals when power is not received, when voltage is too low, or when sustained mechanical malfunction of indicator occurs. The indicator displays Command EPR over the range of 1.0 to 2.6 EPR by means of moving index against a fixed scale and a three wheel numerical counter. Increasing EPR will be clockwise rotation of the index and downward rotation of the counter wheels and is set by clockwise rotation of the set knob located on the lower right front face.

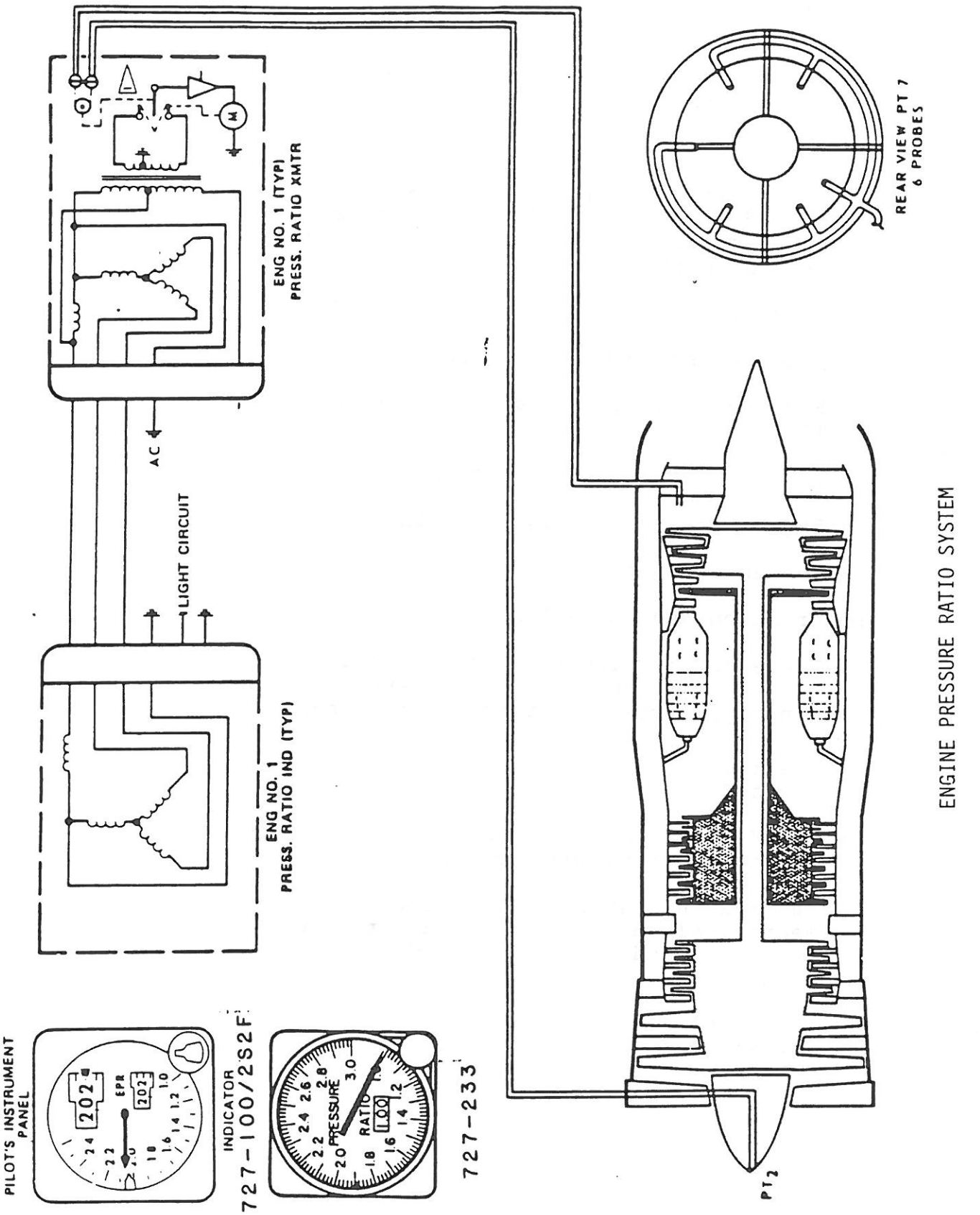


ENGINE NO. 1 PRESSURE RATIO TRANSMITTER



ENGINE NO. 2 AND NO. 3 PRESSURE RATIO TRANSMITTER

ENGINE PRESSURE RATIO TRANSMITTER INSTALLATION



ENGINE PRESSURE RATIO SYSTEM

ENGINE PRESSURE RATIO SYSTEM

Purpose:

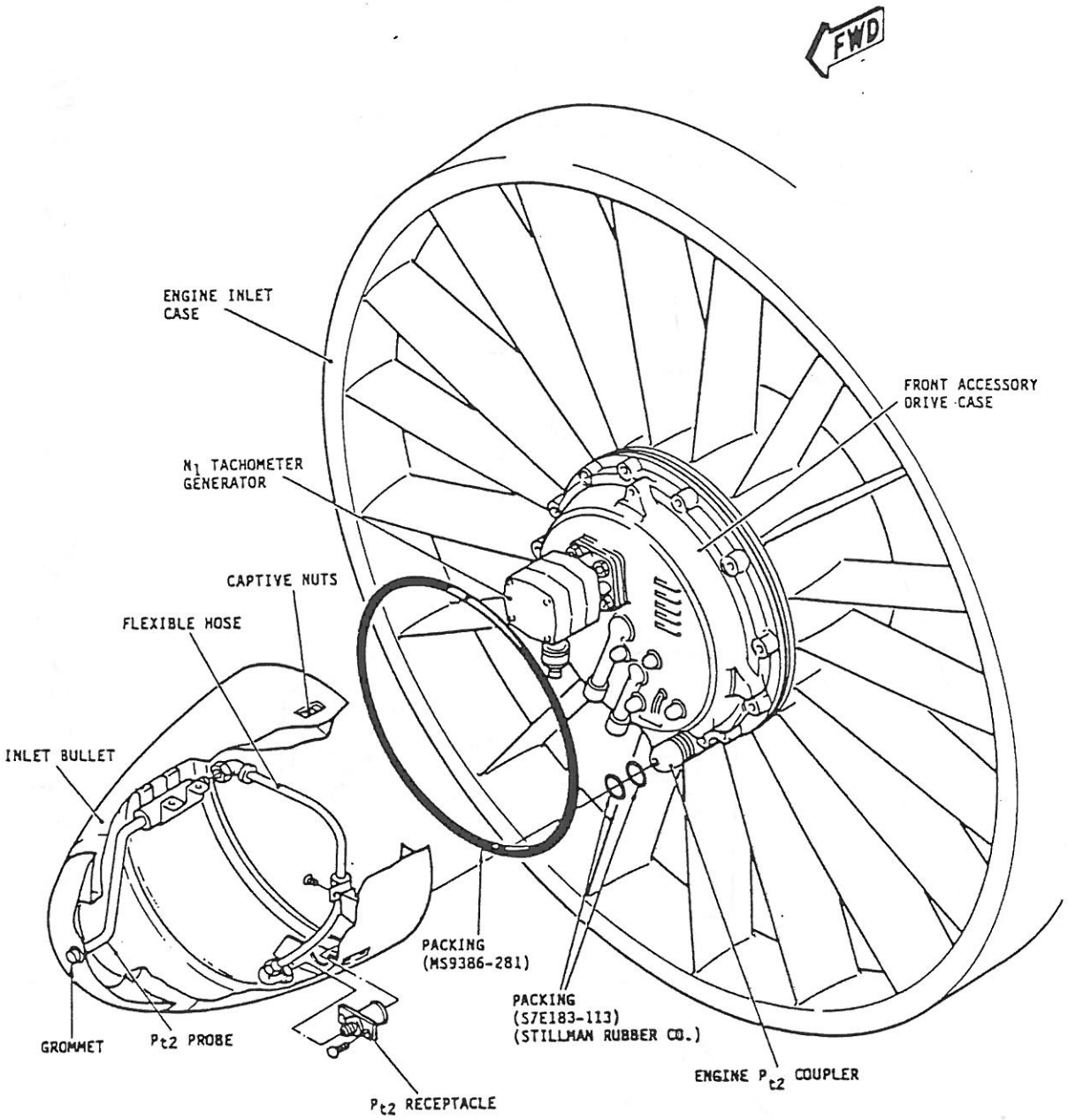
- The engine pressure ratio (EPR) system provides a visual display of the ratio between engine inlet pressure and turbine exhaust discharge pressure.

Components:

- Inlet pressure sensing probe (Pt2)
- Eight averaging exhaust pressure probes (Pt7)
- Engine pressure ratio transmitter
- Engine pressure ratio indicator
- Condensation trap

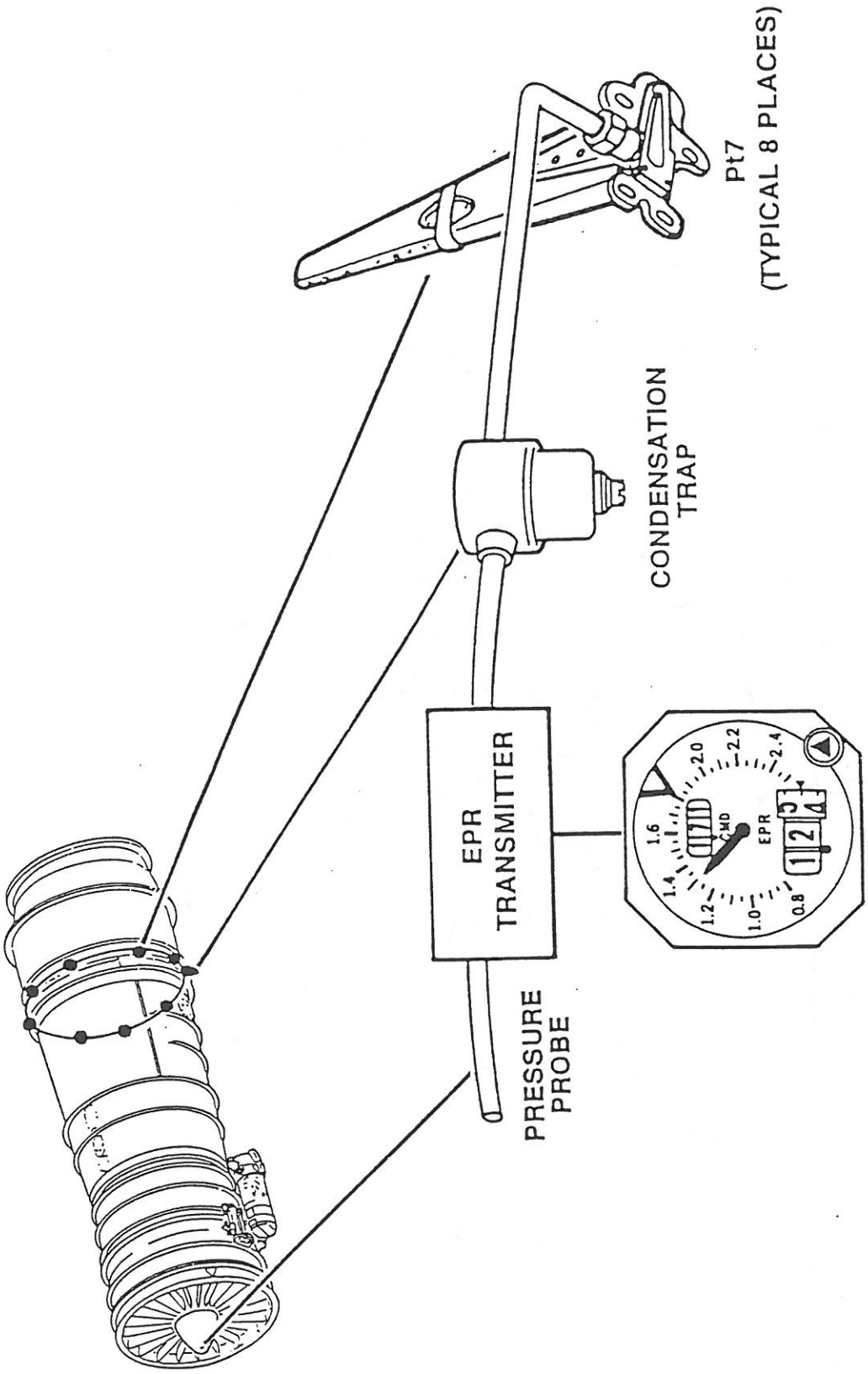
Description and Operation:

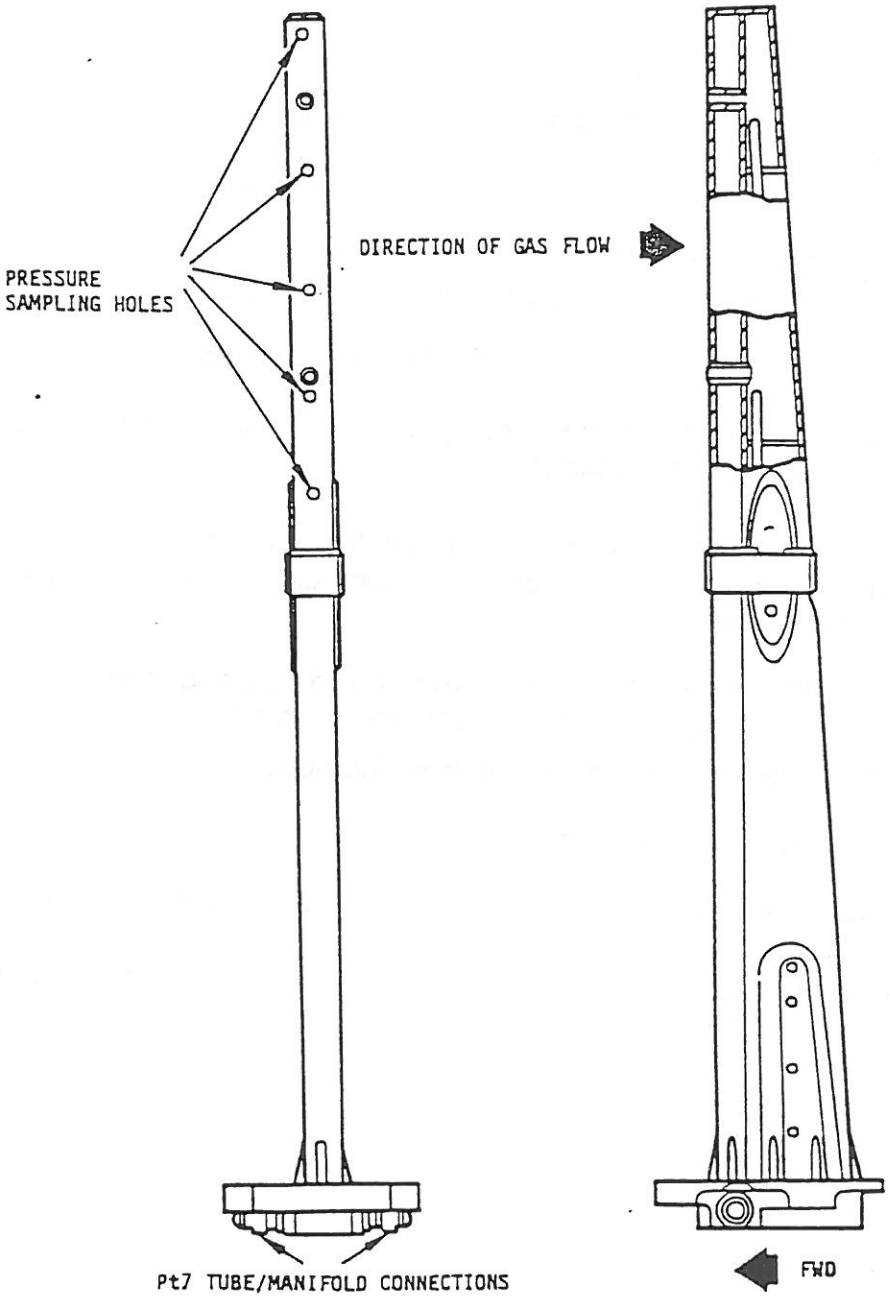
- The eight turbine exhaust probes are externally mounted to the exhaust case and sense primary exhaust total pressure.
- The inlet pressure sensing probe is mounted in the inlet bullet
- The EPR transmitter is mounted in the aft accessory compartment of the aircraft.
- The EPR indicator is an electrical/ mechanical unit which displays the EPR (Pt7/Pt2) and has digital and analog displays.
- Line replaceable unit
  - Cleanable
  - Pressure check for leaks



EPR P_{t2} Inlet Pressure Sensing Probe – Installation

ENGINE PRESSURE RATIO SYSTEM





EPR P_{t7} Turbine Exhaust Pressure Probes

Pressure Check Probes (Air Pressure Check)

(1) Pressure check P_{t7} manifold and pressure probe connections as follows:

(a) Disconnect tube to P_{t7} pressure manifold on turbine exhaust outer rear duct.

(b) Connect adapter PWA 45513 to P_{t7} manifold outlet and attach source of dry filtered compressed air, with regulator PWA 21875, to adapter.

(c) Pressurize P_{t7} system 35 to 45 psig (241.3 to 310.3 kPa).

(d) Using soap and water solution, check each connection in manifold and at probes for leakage. No leakage permitted.

NOTE: If leaks exist, check nut torque. P_{t7} manifold nuts should be 65 to 70 inch-pounds (7.35 to 7.9 Nm). Manifold to probe connections should be 90 to 100 inch-pounds (10.17 to 11.30 Nm).

NOTE: On engines with condensation trap installed, vent in plug at bottom of condensation trap should remain open and unobstructed

(e) Relieve air pressure and remove regulator and adapter.

(f) Connect tube to P_{t7} pressure manifold.

(g) Remove tools, equipment, loose hardware and debris from maintenance area.

NOTE: Air will escape through probe sensing holes during pressure test. Maintain air pressure while checking for leaks.

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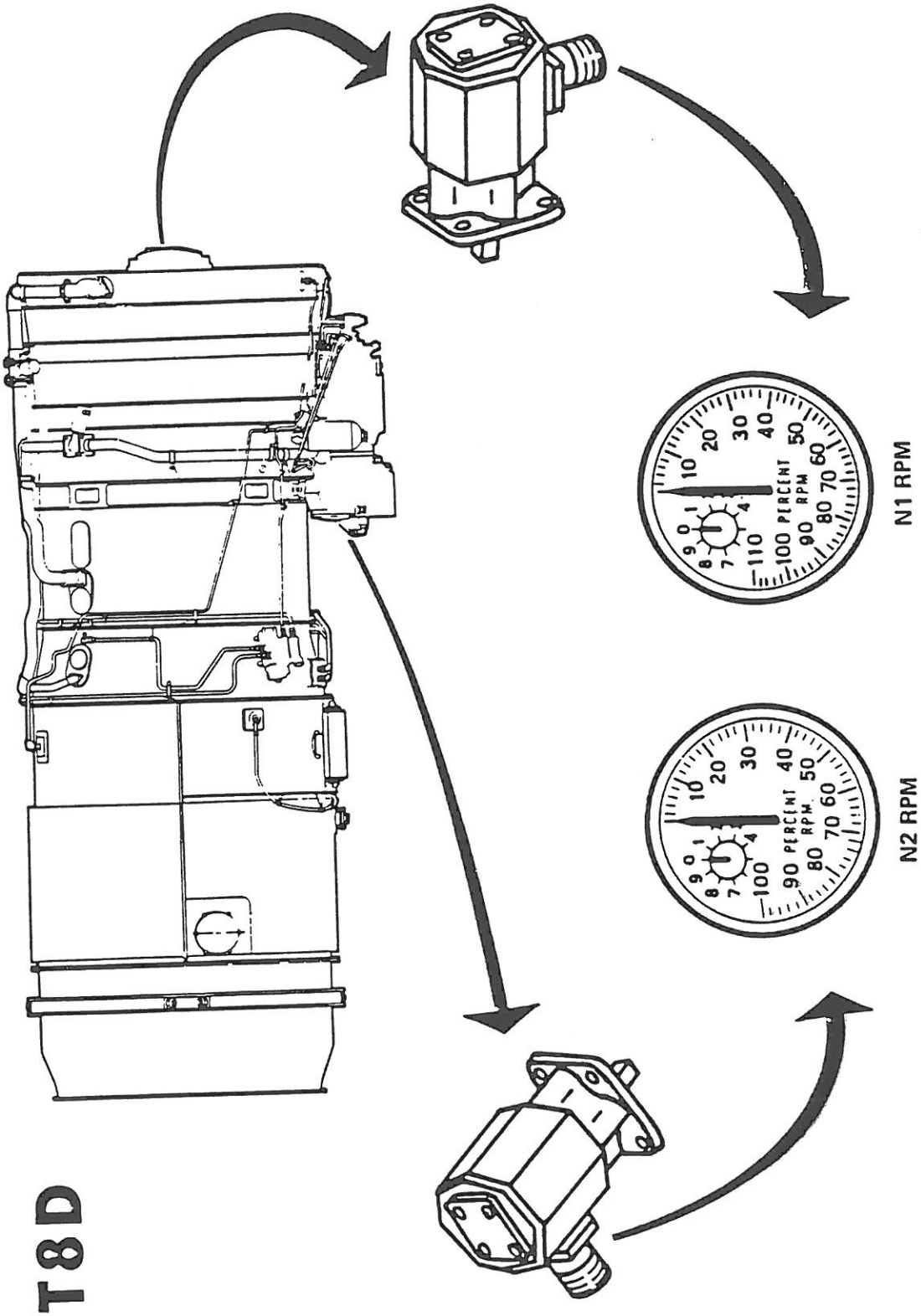
ENGINE RPM INDICATING SYSTEMS



b. On airplanes incorporating a Performance Data Computer System (PDCS), the EPR indicator incorporates an index marker (bug) which may be set to a command EPR position by an input signal from the PDCS.

CAUTION: WHEN THE PDCS MODE IS DISCONNECTED, OPERATE THE EPR INDICATORS IN MANUAL MODE ONLY. FAILURE TO DO SO WILL RESULT IN ACCELERATED CLUTCH WEAR TRAIN DAMAGE.

6. Operation

a. The system operates on ac power.

b. The engine exhaust and inlet pressures are sensed by the pressure sensing probes. These pressures act on the bellows assembly of the pressure ratio transmitter, causing differential bellows movement whenever either of the pressure change. The relative bellows movement effects the sensing mechanism of the transmitter which, with the aid of the amplifier and motor-gear train, cause the generator rotor to rotate and generate three-phase electrical signals. The generated electrical signals are transmitted to the pressure ratio indicator over a three-wire system. The indicator converts the electrical signals into the pointer shaft rotation or indicator movement corresponding to the pressure change in the engine.

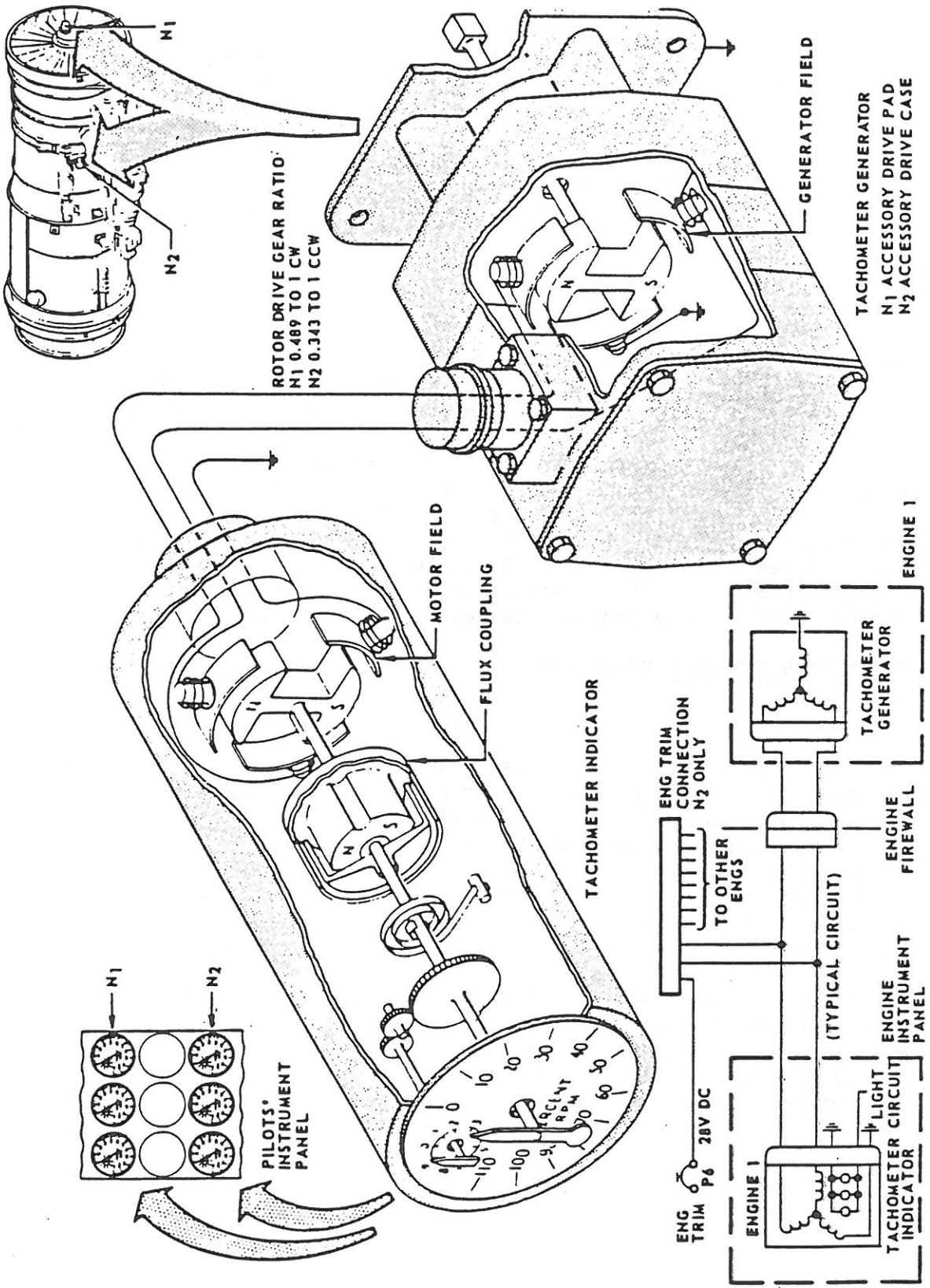
C. ENGINE TACHOMETER SYSTEM DESCRIPTION

1. General

a. The engine tachometer system measures the rotary speed of an engine low pressure or high pressure rotor and provides visual speed indication to the pilots for monitoring engine performance. The engine tachometer system consists of two generator units (N1 and N2) on each engine and corresponding tachometer indicators on the engine instrument panel. The N1 tachometer indicator shows the speed of rotation of the low pressure compressor. The N2 tachometer indicator shows the speed of rotation of the high pressure compressor.

b. The tachometer generators, driven by the compressor rotors through reduction gearing, generate alternating electrical signals. The electrical signals, received from the generators, energize corresponding indicators, which in turn show their respective compressor speeds in percent.

ENGINE TACHOMETER INDICATING SYSTEM



2. Engine Tachometer Generator

a. The tachometer generator is a mechanism which transforms the rotational input energy into equivalent electrical energy. It consists of a three-phase stator winding, end shields, and a permanent magnet rotor assembly, all contained in a sealed case. The tachometer generator is used to sense a compressor rotor speed and generate corresponding alternating electrical signals for the tachometer indicator operation. The N1 tachometer generator is located on the front accessory drive, and the N2 tachometer generator is on the aft right side of the accessory drive gearbox.

b. Each tachometer generator is driven by its respective compressor rotor through a reduction gearing. The generator drive shaft turns the rotor assembly inside the stator coils, thus generating alternating electrical signals. The frequency of the generator output signals is a function of the engine compressor rpm.

3. Engine Tachometer Indicator

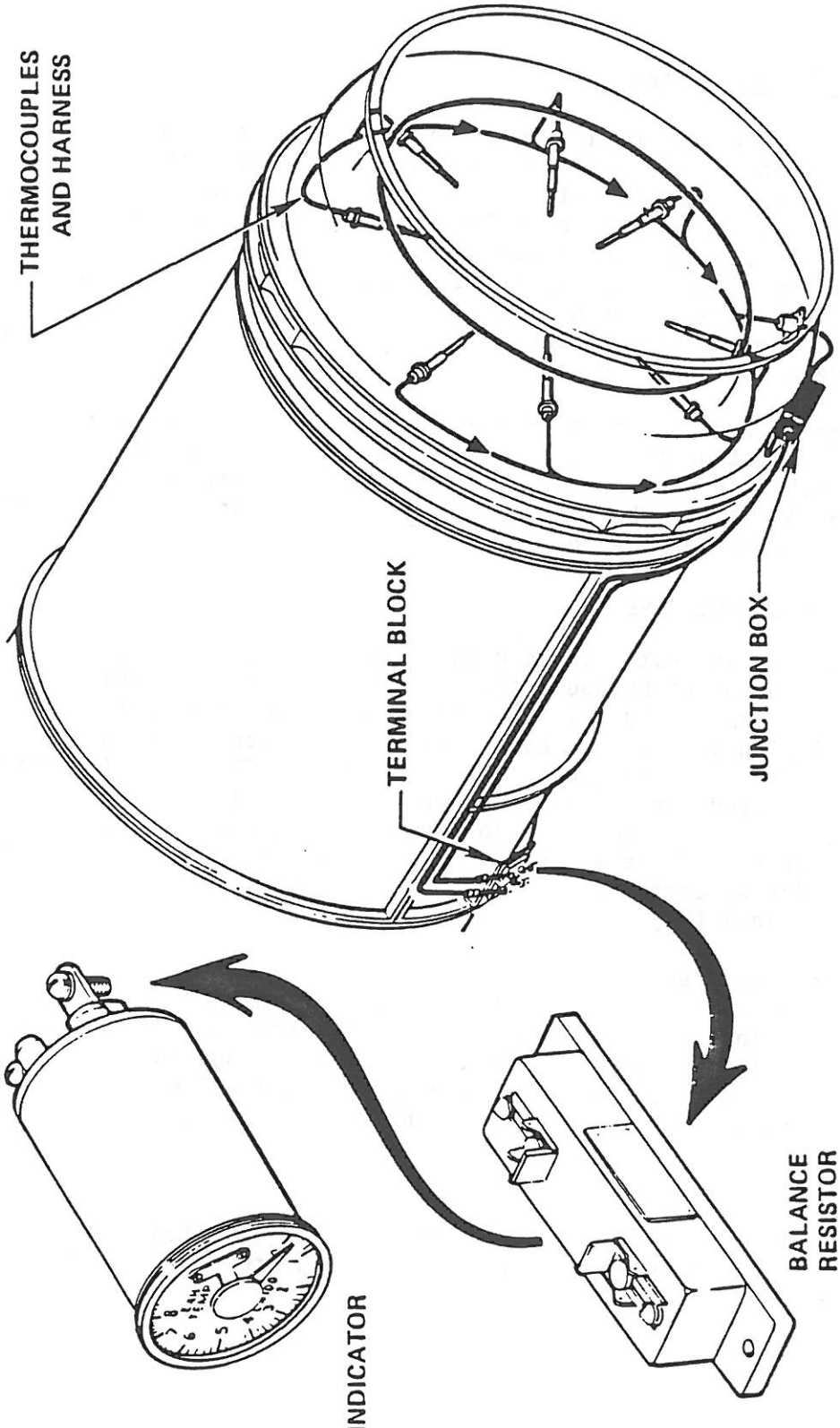
a. The tachometer indicator shows compressor rotor speeds. It consists of a three-phase synchronous motor, a rotating drag assembly, a calibrated clock spring, all hermetically sealed in a case, and a round dial with a subdial. Each engine tachometer indicator shows its respective engine rotor speed as a percentage. The round indicator dial is graduated for readings between zero and 110 percent rpm, while the small subdial is graduated in ten divisions for each 10 percent change in speed. There are six tachometer indicators, three for N1 and three for N2 compressor rotors, mounted in two rows on engine instrument panel (P2).

b. The alternating electrical signals from the respective tachometer generator are fed into a tachometer indicator which cause the drive shaft of the indicator synchronous motor to rotate. The synchronous motor drives the magnetic drag assembly or flux coupling which, in turn, restrained by a clock type spring, moves the indicator pointers to a dial position corresponding to the compressor rotor speed.

4. Operation

a. The engine tachometer system operates on self generated electrical power. The airplanes electrical power is required only for the integral lighting of the tachometer indicators.

EGT INDICATING SYSTEM



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b. Each tachometer generator (N1 and N2) is driven by its respective compressor rotor through reduction gearing. The generator drive shaft turns the rotor assembly inside the stator coils, thus generating alternating electrical signals. These signals are transmitted to the corresponding tachometer indicator synchronous motor by a two wire system, while the third phase if completed to ground. The alternating electrical signals cause the drive shaft of the indicator synchronous motor to rotate. This rotation, through a flux coupling, tends to rotate the indicator pointer which is restrained by a spring. The speed of the synchronous motor determines the degree to which the indicator pointer is rotated, and corresponds to the related compressor rotor speed. The round indicator dial is graduated for readings between zero and 110 percent compressor rpm. The small subdial is graduated in ten divisions for each 10 percent change in speed.

D. EXHAUST GAS TEMPERATURE INDICATING SYSTEM WITHOUT BOOST CIRCUIT

1. General

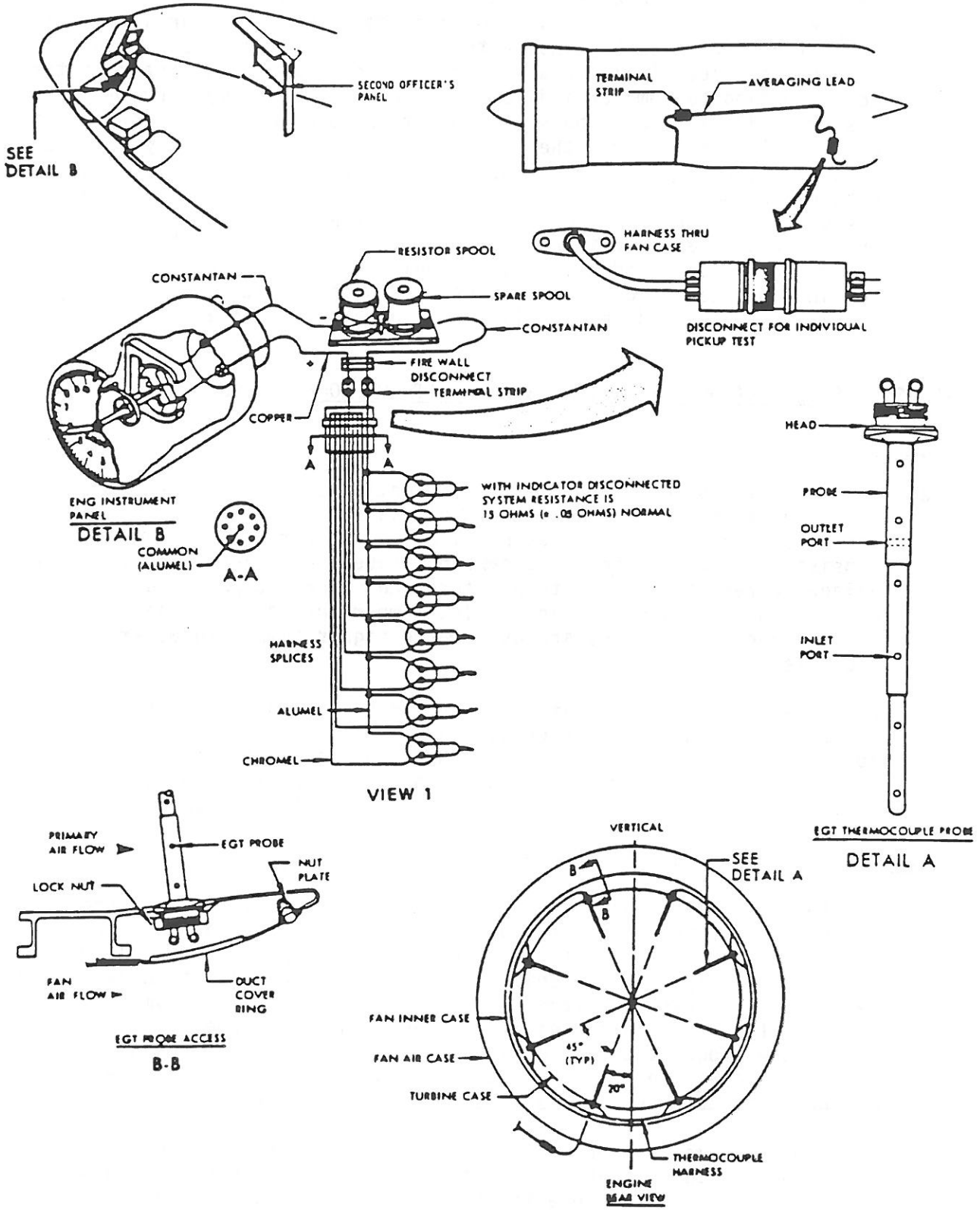
a. The exhaust gas temperature (EGT) indicating system measures the engine exhaust gas temperature and displays the temperature value on indicators in the control cabin. The system, for each engine, consists of eight temperature sensing probes, a harness and lead, one balancing resistor, and a temperature indicator. Copper and constantan wires are used in the low temperature zone of the engine; chromel and alumel wires are used where higher temperatures are encountered.

b. Engine exhaust gas temperature is sensed by the thermocouple elements. The heat of the exhaust gases causes the thermocouple to generate dc electrical signals which actuate the meter movement of the exhaust gas temperature indicator. The balancing resistor is included in the circuit to provide a means of adjusting the system.

2. Exhaust Gas Temperature Thermocouple Probe

a. The thermocouple probe is a temperature sensing device that senses the temperature of the engine exhaust gases. It consists of two stud terminals, a head, and a thermocouple measuring junction and leads enclosed in a cylindrical shield. The thermocouple junction leads and terminals are made of chromel and alumel material. The alumel terminal (-) has a larger diameter hole than the chromel terminal (+). Each probe is provided with the five gas inlet ports and two gas exhaust ports. The correct orientation of the probe with respect to an engine is obtained with an index slot in the probe.

b. Eight probes are mounted on the turbine exhaust section fan discharge inner duct of each engine and project into the engine exhaust gas path. The probes are connected in parallel to obtain the average value of the exhaust gas temperatures sensed by the eight probes.



EXHAUST GAS TEMPERATURE INDICATING SYSTEM

3. Exhaust Gas Temperature Thermocouple Balancing (N101FE thru N105FE thru N136FE and N218FE thru N223FE

The exhaust gas temperature thermocouple balancing resistor permits adjustments of circuit resistance. The resistor consists of a spool of No. 24 constantan wire with a resistance of 8.0 (+) 10 percent, (-0 percent) ohms before adjustment. Since adjustment of the resistance is made by cutting off lengths of the wire, a spare resistance spool is included for each engine system. The thermocouple resistors are connected into the constantan lead of the circuit. The resistors are located on the second officer's panel support channel directly below the table.

4. Exhaust Gas Temperature Thermocouple Balancing Resistor (N106FE thru N113FE

a. The exhaust gas temperature thermocouple balancing resistor permits adjustment of circuit resistance. The resistor consists of a spool of No. 24 constantan wire, coarse adjustment terminals and vernier adjustment terminals. Since primary adjustment of the resistance is made by cutting off lengths of the wire, a spare resistance spool is included for each engine system.

b. The thermocouple resistors are on the second officer's panel support channel directly below the table and are connected to the constantan lead of the circuit.

5. Exhaust Gas Temperature Indicator

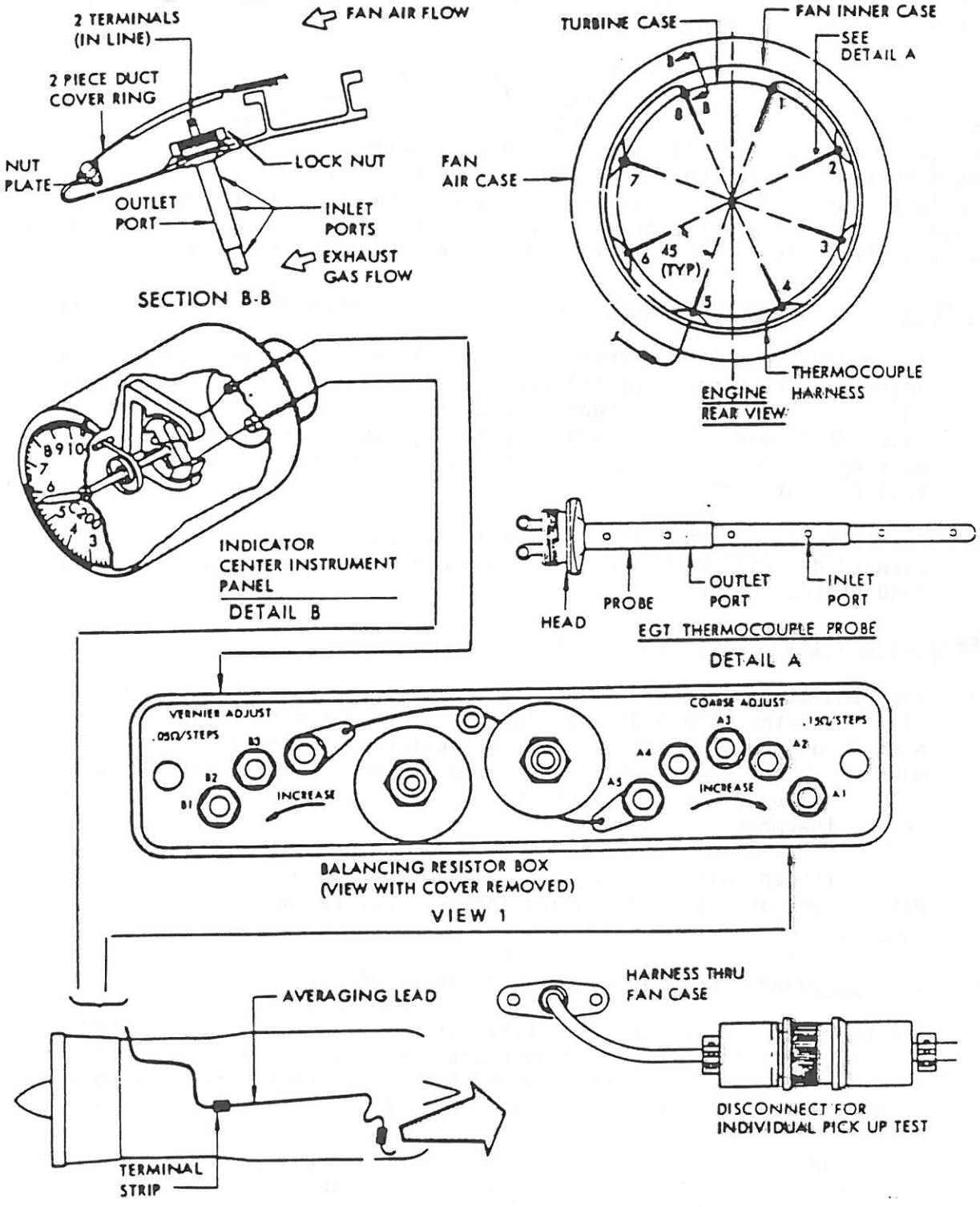
a. The exhaust gas temperature indicator is a specially built, sensitive millivoltmeter with a dial graduated in degrees centigrade, in a hermetically sealed case. Three indicators, one for each engine, are mounted on the engine instrument panel. Two terminals, marked plus (+) and minus (-) on the back of the indicator connect the meter unit to the thermocouple circuit.

b. The instrument dial indicates a temperature range from 0° to 850°C, with normal and dangerous operating temperatures marked in a color code.

6. Exhaust Gas Temperature Thermocouple Harness and Lead

a. The thermocouple harness is a flexible electrical conduit mounted on the circumference of the engine exhaust fan discharge inner duct. A two wire thermocouple lead from the harness is routed forward to an electrical terminal strip on the fan discharge diffuser outer duct.

b. The harness is connected to the lead with a nine pin electrical plug, located on the engine exhaust section fan discharge outer duct at approximately 7 o'clock position.



EXHAUST GAS TEMPERATURE INDICATING SYSTEM

7. Operation

a. Each engine exhaust gas indicating system consists of eight thermocouple probes connected in parallel to an indicator and operated on self-generated power. The airplane power is used only for integral lighting of the indicators.

b. The difference in the temperatures at the probes, the hot junction of the thermocouple, and the indicator, the cold junction of the thermocouple, cause electrical signals to be generated in the thermocouple circuit. These electrical signals are proportional to the temperature difference between the two junctions and are measured by the indicator. Since the generated signals correspond only to the temperature difference, the control cabin ambient temperature must be added to this measured temperature difference to obtain the actual temperature of the exhaust gases; the indicator does this addition automatically. The control cabin temperature, where the indicator is located, is reasonably constant; however, small temperature changes in the indicator are compensated with a bimetal (thermostatic) spring, connected to the indicator control mechanism. The indicated exhaust gas temperature is therefore an accurate indication irrespective of prevailing ambient temperatures.

c. The thermocouple probes are connected in parallel to obtain the average temperature of the exhaust gases. Another advantage of the parallel connection is that if a probe burns out or is damaged, thermocouple circuit is not disrupted.

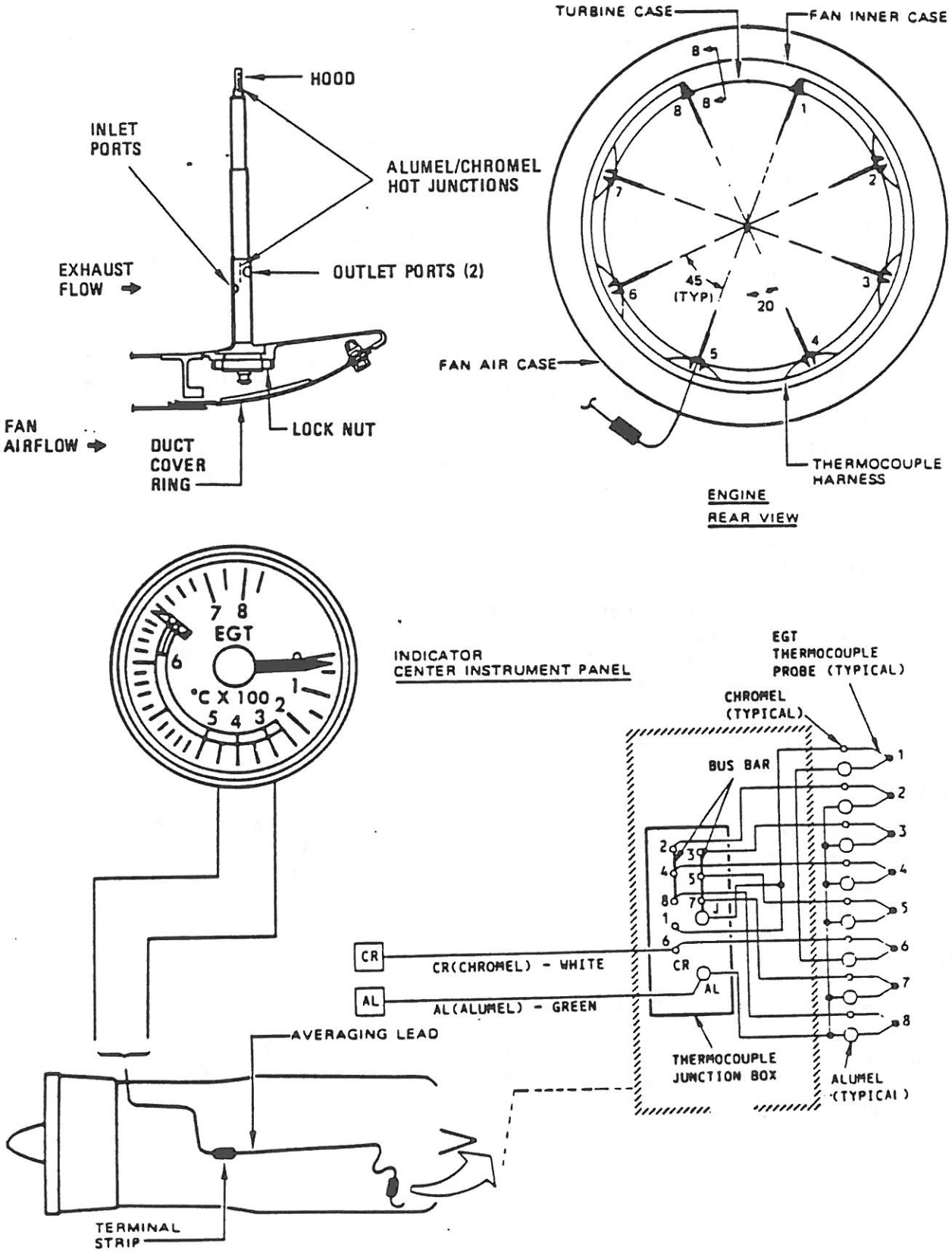
E. EXHAUST GAS TEMPERATURE SYSTEM WITH BOOST CIRCUIT (N201FE thru N217FE)

1. General

The operating limits of the engine, monitoring of the mechanical integrity of the turbines and engine condition during operation are performed by measurement of the engine exhaust gas temperature which is displayed in the control cabin.

2. Components

The exhaust gas temperature (EGT) system consists of eight thermocouples arranged radially in the engine exhaust, thermocouple junction box located on left side of turbine case and an indicator on the P2 center instrument panel. The indicator receives 115v ac power from P6-3 circuit breaker panel. Chromel and alumel wires are used between the thermocouples and indicator.



EXHAUST GAS TEMPERATURE INDICATING SYSTEM

3. Thermocouple Probe

   a. The thermocouple consists of two paralleled junctions of chromel and alumel wires. One is enclosed in a tube which has an inlet hole facing the gas stream to provide a ram temperature rise. Two exit holes clear the probe. The second junction is on the probe tip, hooded, but exposed to the exhaust free stream. The probe has two stud terminals, the alumel (-) terminal has a larger diameter than the chromel (+) terminal. The correct orientation of the probe with respect to gas stream is obtained with an index slot in the probe base.

   b. The eight thermocouples are connected in two groups, six and two, paralleled probes to obtain a biased average gas temperature. This network causes the indicator to read slightly false - highs to assure instrument interchangeability for the cooler running engines, especially when intermixed with same-thrust-rated engines.

4. Thermocouple Junction Box

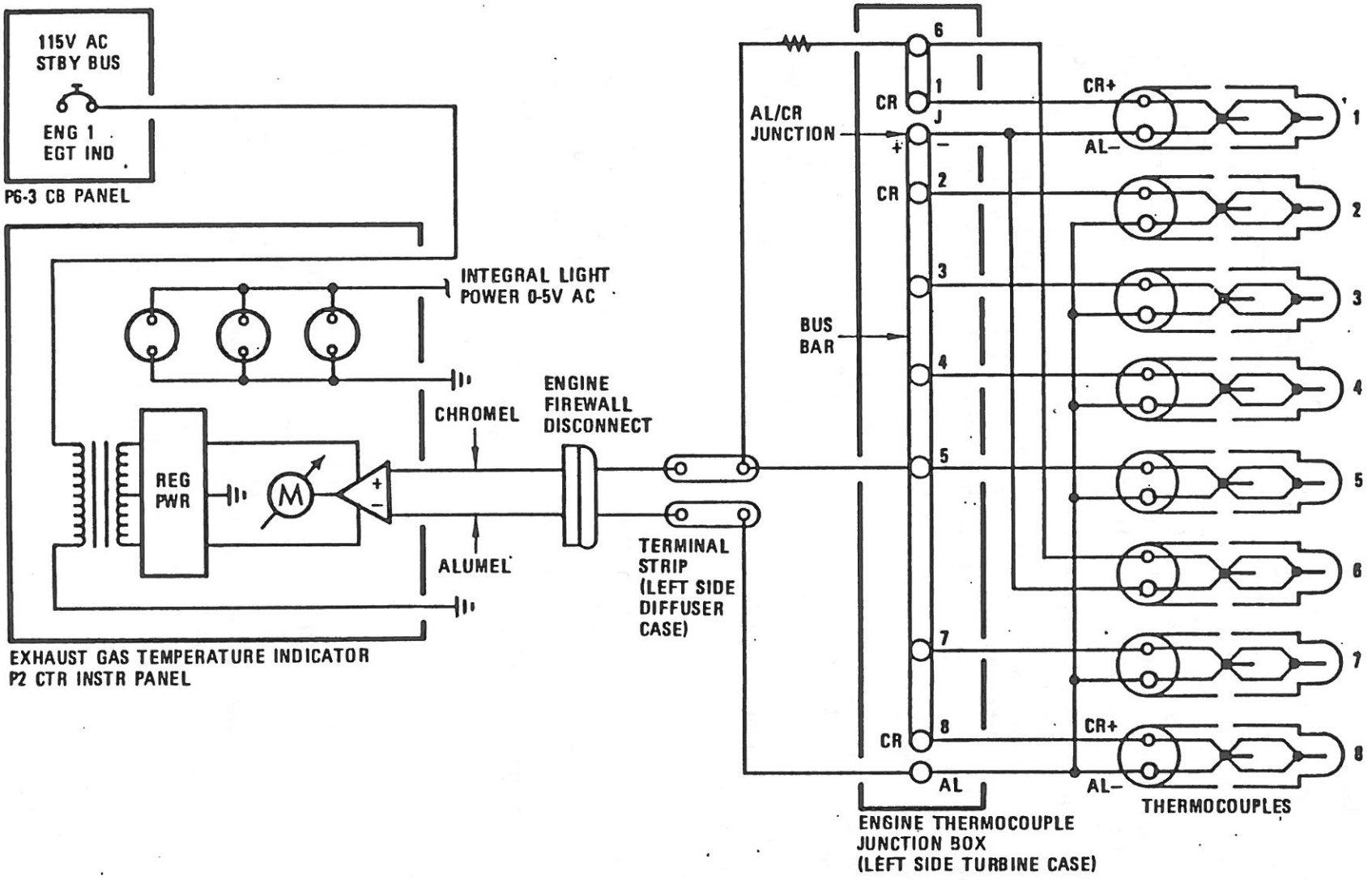
   The junction box is used to check the thermocouple quality and to check the temperature at each thermocouple for the engine "spread" check. Removal of the bus bars provides electrical access to each probe. From the junction box, the chromel and alumel wires are routed along the left side of the engine diffuser case to a terminal block where PW wiring joins Boeing wiring.

5. Exhaust Gas Temperature Indicator

   The indicator is a served instrument with a dial graduated from 0 to 850°C. The normal and dangerous operating temperatures are marked in a color code. The range between 500° and 600°C is expanded to give a more accurate indication. The indicator has integral lighting. Standby ac bus must be powered by placing the battery switch ON and the essential power selector switch to the, detented, STANDBY position for an engine run with no normally supplied and/or selected 115v ac power.

6. Operation

   The difference in temperature, between the hot junction at the thermocouple probes and the cold junction at the indicator causes a voltage difference in the thermocouple circuit. This electrical signal, with voltage proportional to temperature, is applied to the amplifier. The amplifier received regulated power supply from transformer within the indicator. Output of the amplifier is applied to a torquer which in turn drives the indicator pointer. With power interrupted, pointer goes to the 0 position. The indicator incorporates a cabin ambient temperature compensator for the cold junction to provide exhaust gas temperature indication irrespective of prevailing control cabin temperature.



EXHAUST GAS TEMP. SYSTEM W/ BOOST CIRCUIT

7. Exhaust Thermocouple Installation

a. General

The exhaust gas thermocouples are located within the primary exhaust flow and transmit electrical signals to a flight deck indicator.

b. Installation

The eight thermocouples are mounted in the inner wall of the primary exhaust duct.

An index guide assures the proper positioning of the probe and a lock nut holds the probe in position.

A 2 segment duct cover ring covers the terminal end of the probe and creates a passage for the interconnecting wiring.

c. Accessibility

Access to the thermocouples on a built up engine is through the tail pipe and thrust reverser. On those engines with the noise reduction kits installed, the exhaust mixer must be removed to access the thermocouples.

Deactivation of the thrust reverser is required prior to entering the exhaust pipe.

EGT SYSTEM

Purpose:

- The exhaust gas temperature (EGT) system provides a visual display of the gaspath temperature at turbine exhaust.

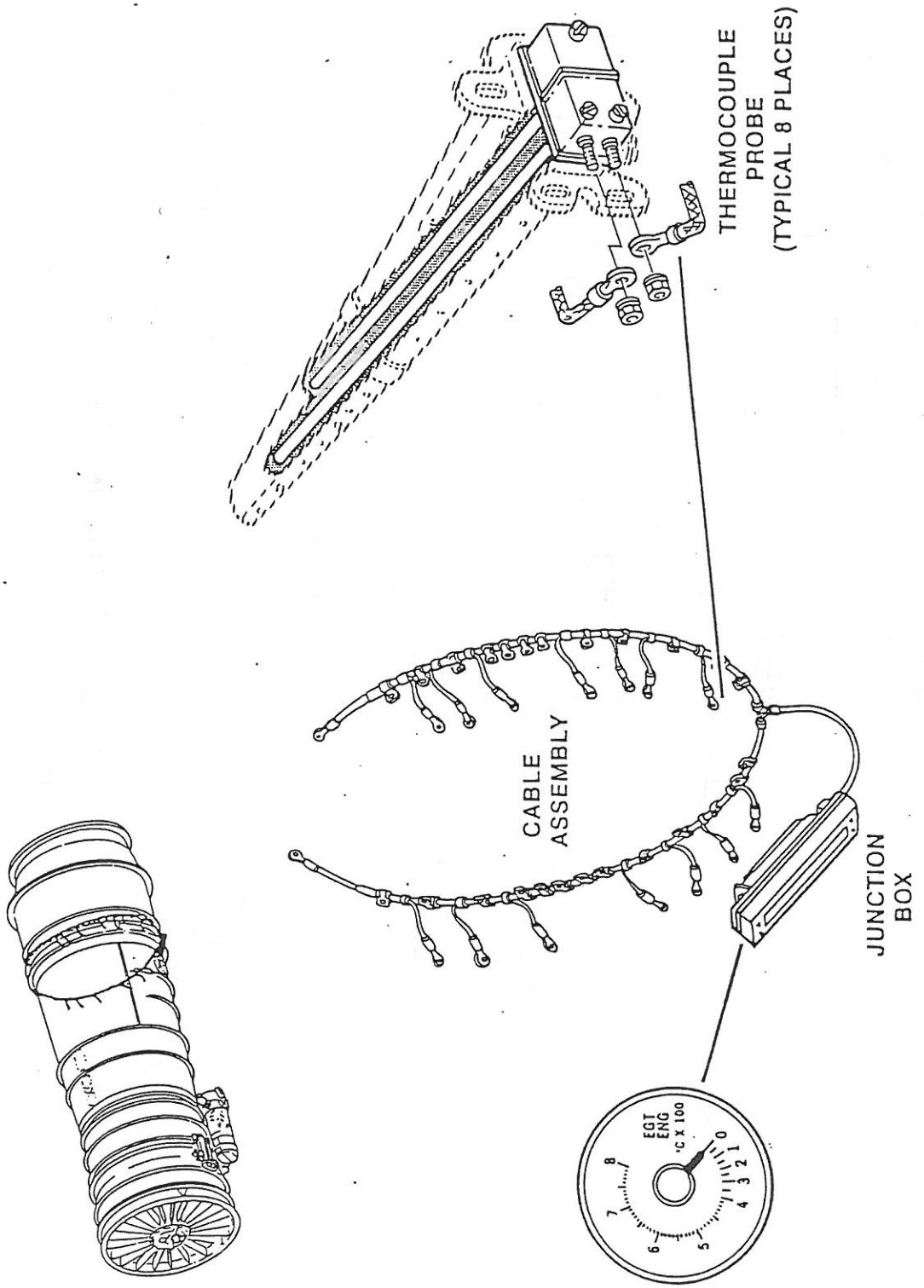
Components:

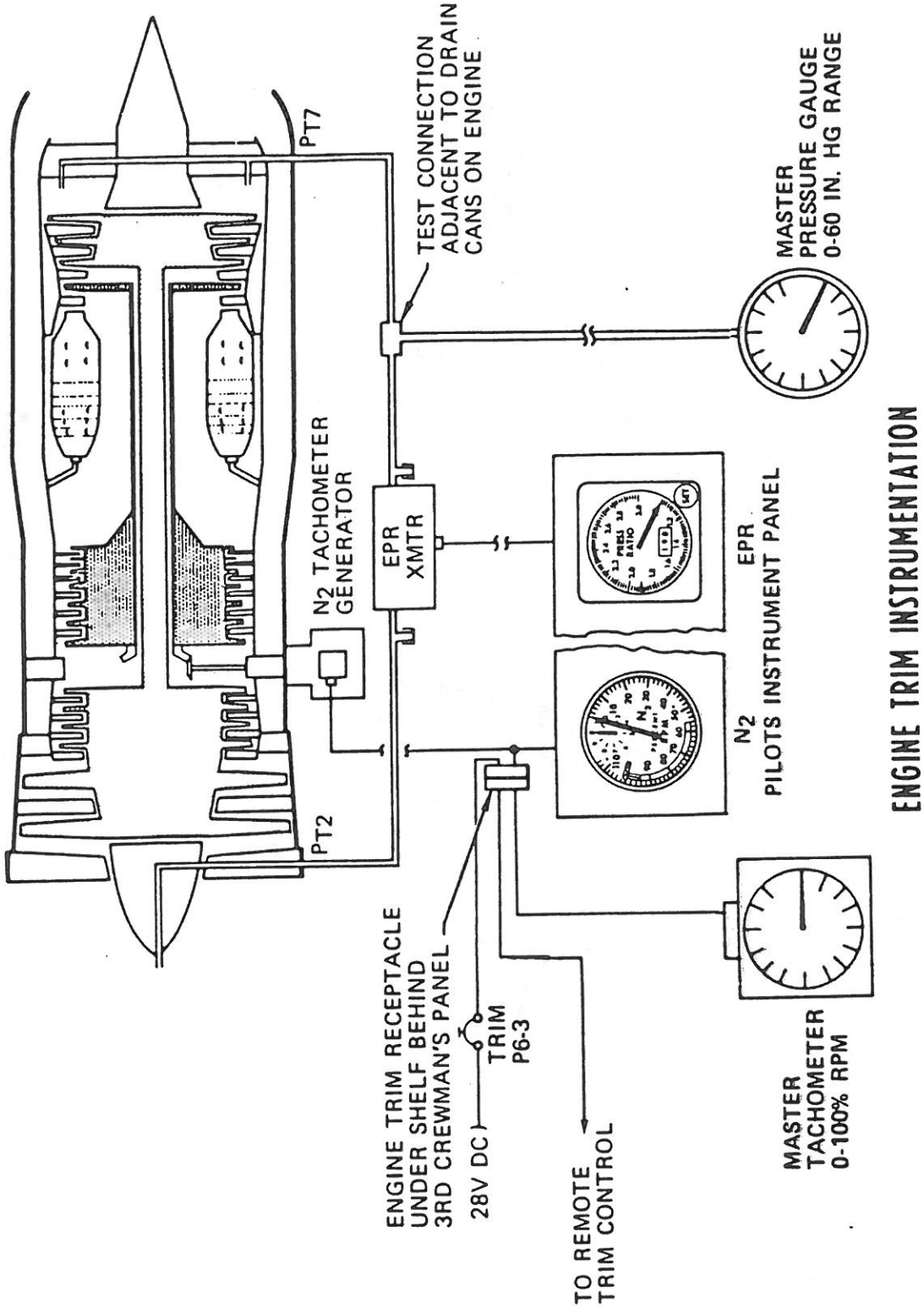
- 8 dual junction thermocouple probes
- Thermocouple cable junction box
- Averaging cable assembly
- EGT indicator

Description and Operation:

- The thermocouple probes are of chromel–alumel, dual–junction, stud connection type and are mounted in the average pressure probes on the turbine exhaust case and extend into the primary gaspath.
- The averaging cable assembly consists of the electrical harness connecting each of the thermocouple circuits to a common junction box.
- The thermocouple cable junction box consists of two terminal blocks and a cover. The junction box is mounted on the exhaust case at the 7:00 position.
- The EGT indicator converts the heat generated temperature signal from the thermocouple probes to a visual display of the exhaust gas temperature in degrees C times 100 (EGT).

EGT INDICATING SYSTEM




PT7
TEST CONNECTION
ADJACENT TO DRAIN
CANS ON ENGINE
MASTER
PRESSURE GAUGE
0-60 IN. HG RANGE
N2 TACHOMETER
GENERATOR
EPR
XMTR
EPR
PILOTS INSTRUMENT PANEL
N2
PT2
ENGINE TRIM RECEPTACLE
UNDER SHELF BEHIND
3RD CREWMAN'S PANEL
28V DC
TRIM
P6-3
TO REMOTE
TRIM CONTROL
MASTER
TACHOMETER
0-100% RPM
ENGINE TRIM INSTRUMENTATION