

## GENERAL ENGINE DATA

### Objectives:

At the completion of this section a student should be able to:

- ....given a list identify the safety precautions associated with the CFM56-3/3B/3C engine (1.A.x).
- ....given a specific model and a list identify the dimensions and weights of the CFM56-3/3B/3C engine (1.A.x).
- ....given a specific model and a list identify the ratings and applications of the CFM56-3/3B/3C engine (1.A.x).
- ....given a list recall the engine transportation requirements for a CFM56-3/3B/3C engine (1.A.x).
- ....given a list recall the types of on-condition monitoring used with the CFM56-3/3B/3C engine (1.A.x).
- ....given a list recall the maintenance strategy of the CFM56-3/3B/3C engine (1.A.x).
- ....given a list select the purpose of on-condition monitoring for the CFM56-3/3B/3C engine (1.B.x).
- ....given a list select the purpose of the maintenance strategy of the CFM56-3/3B/3C engine (1.B.x).

**GROUND SAFETY PRECAUTIONS****Overview (1.A.a)**

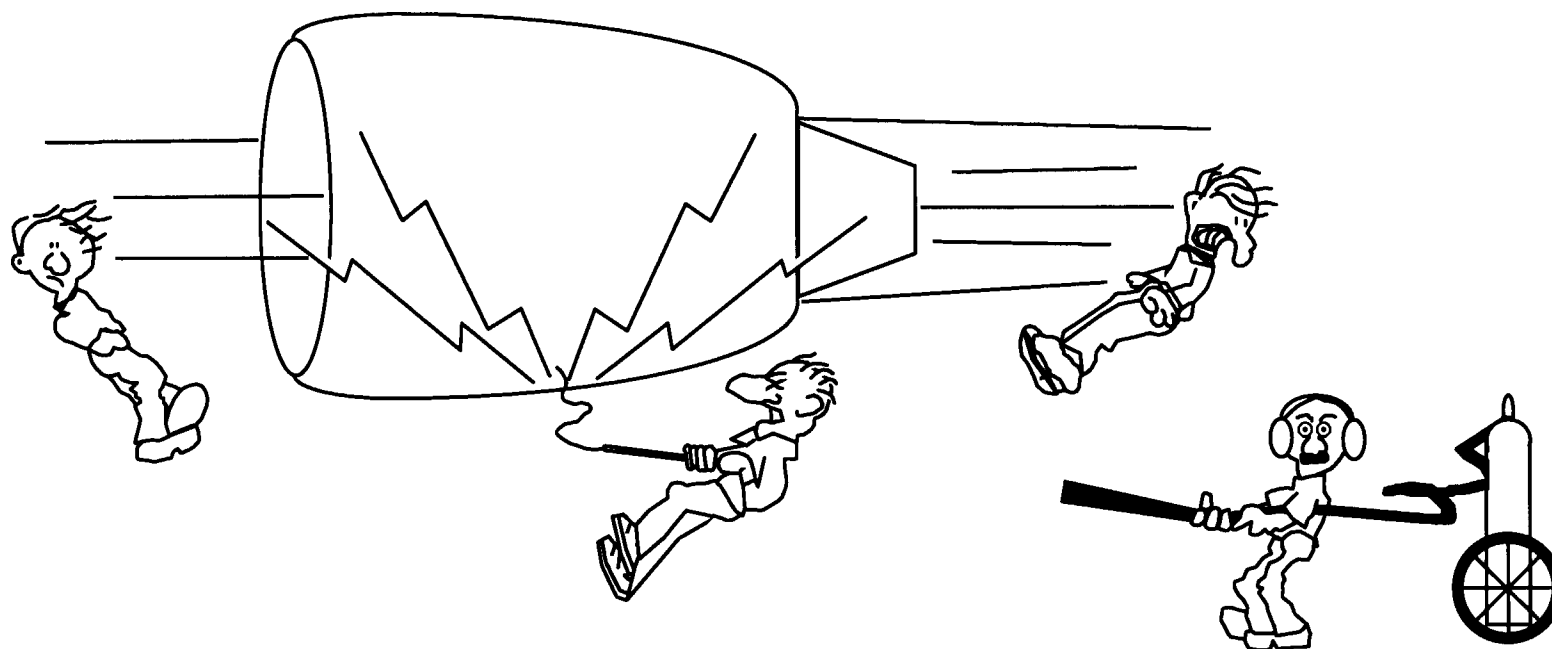
The operation of jet power plants is dangerous. While the engine operates, these dangerous conditions can occur:

- There is a very strong suction at the front of the engine that can pull persons and unwanted materials into the air inlet.
- Very hot, high speed gases go rearward from the turbine exhaust nozzle.
- The fan exhaust at high thrust has very high speed.
- When the Thrust Reverser (T/R) is extended, the fan exhaust goes forward while the turbine exhaust goes rearward.
- When exposed to engine noise for extended periods of time hearing loss can occur.
- High voltage output from the ignition system can be fatal if not properly handled.

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## THE HAZARDS OF AIRCRAFT MAINTENANCE

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## GROUND SAFETY PRECAUTIONS

### Inlet and Exhaust Safety Precautions (1.A.a)

Persons positioned near the power plant during power plant operation must be aware of the following inlet/exhaust hazard areas:

When the engine operates, it makes a low air pressure area in the inlet. This low pressure area causes a large quantity of air to move from the forward side of the inlet cowl and go into the engine. The air which is near the inlet moves at a much higher velocity than air which is farther from the inlet. The quantity of the engine suction does not increase slowly and continuously when you go near the inlet. The suction is small until you get near the inlet, where the suction increases suddenly. The engine suction can pull small objects into the engine easier than it can pull large objects.

Aft of the inlet cowl lip the hazard area extends completely around the outer diameter and to the forward end of the power plant.

When the engine operates, a large quantity of exhaust comes from the aft end of the engine. The exhaust is hot and moves at high speed. The exhaust temperature near the engine is sufficient to melt bituminous (asphalt) pavement. engine operation on concrete pavement is therefore recommended.

When an engine is started, fuel that has collected in the turbine exhaust sleeve can ignite. Long flames are blown out of the exhaust nozzle. For this reason all flammable materials must be kept clear of the exhaust nozzle.

There are contamination and bad gases which were pulled into the engine by suction. There are also gases from the fuel that has burned or fuel which has not burned. These gases in the exhaust are dangerous to you. Tests have shown that the amount of carbon monoxide in the exhaust is small, but there are other gases in the exhaust that smell bad and can cause injury or irritation to your eyes and lungs. These gases will usually cause a watering or burning sensation to your eyes. Less noticeable, but more important, is the respiratory irritation. When working near running aircraft you must stay away from small spaces where these gases can collect.

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## GROUND SAFETY PRECAUTIONS

### Inlet and Exhaust Safety Precautions

Before you operate the engine, do these steps:

- Make sure there are no tools, unwanted materials or objects in the air inlet.
- Make sure the area 40 feet to each side and forward of the power plant is clean.
- Make sure the ground which is forward of the engine is strong and solid.
- Make sure the suction of the engine will not pull the unwanted material on the ground into the engine.
- Make sure that persons with loose objects (such as hats, eyeglasses, loose clothing or rags) do not go into this area.
- When the engine is operated, use an engine inlet guard. This will prevent persons from being pulled into the inlet because of air suction from the engine.

It is recommended that ground persons stay outside of the inlet hazard area for at least 30 seconds after the fuel cutoff signal (start lever placed in CUTOFF position) from the flight compartment.

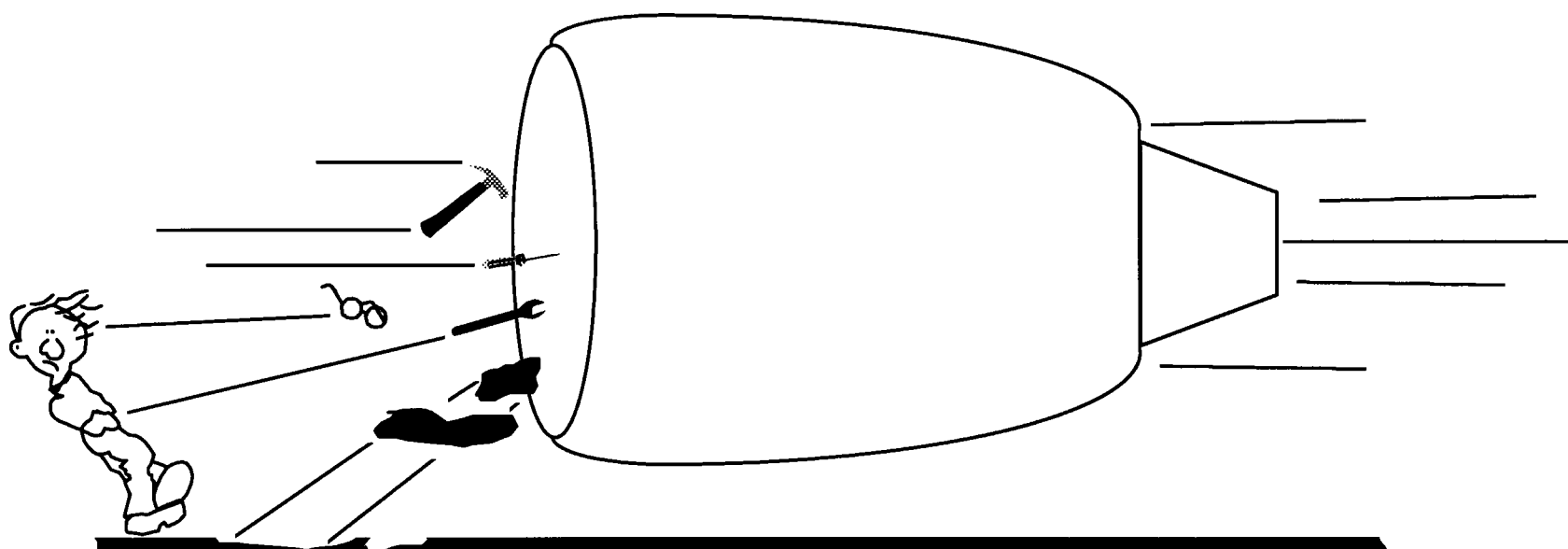
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## PROTECT AGAINST INLET HAZARDS

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## GROUND SAFETY PRECAUTIONS

### Inlet and Exhaust Safety Precautions

At idle power (forward thrust), the inlet hazard area starts four feet aft of the inlet cowl lip and extends to a distance of approximately 9 feet forward. The exhaust hazard area extends aft to a distance of approximately 100 feet from the tail of the B737 aircraft.

- If the surface wind is more than 25 knots, increase the distance of the inlet hazard area by 20%.
- If the ramp surfaces are wet or frozen, make the ramp clean to prevent injury to persons.
- After the engine is shut down, let the engine spool down before the engine is approached.

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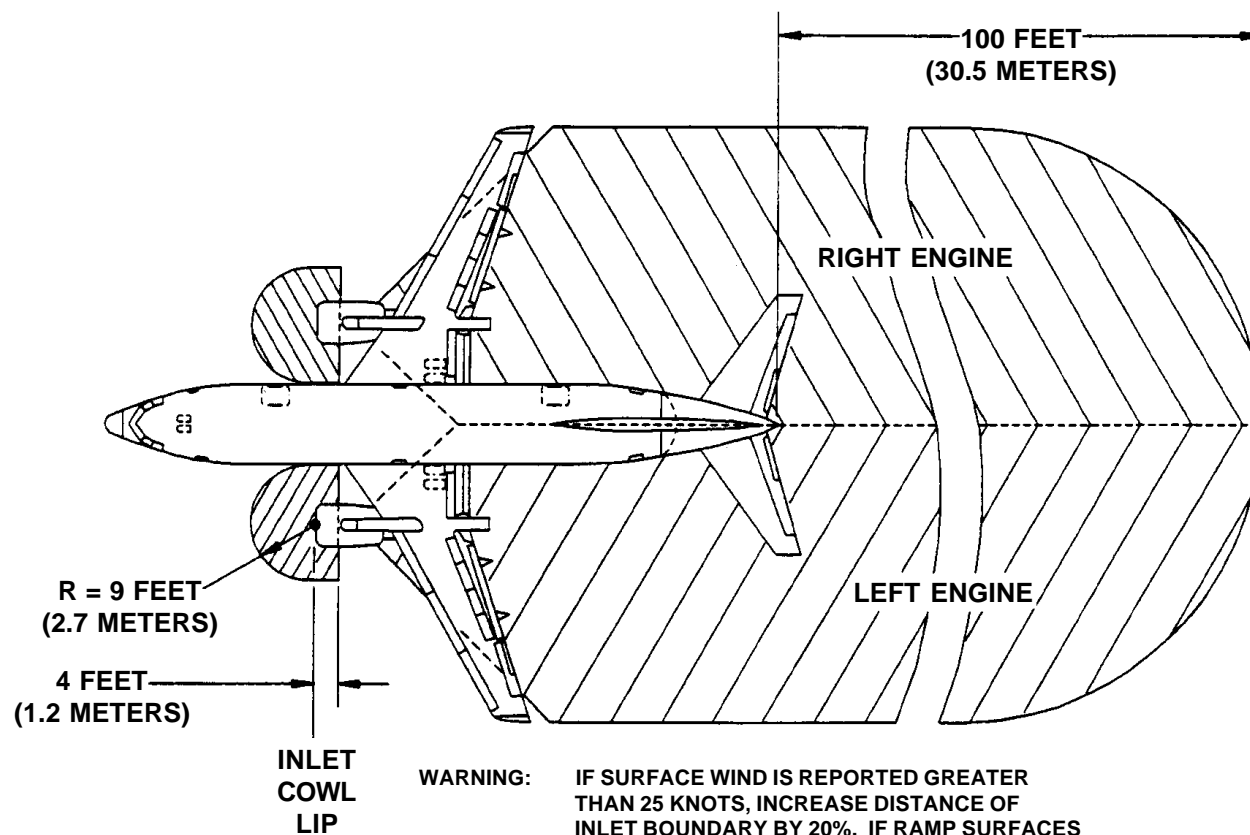
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**WARNING:** IF SURFACE WIND IS REPORTED GREATER THAN 25 KNOTS, INCREASE DISTANCE OF INLET BOUNDARY BY 20%. IF RAMP SURFACES ARE SLIPPERY, ADDITIONAL PRECAUTIONS SUCH AS CLEANING THE RAMP WILL BE NECESSARY TO PROVIDE PERSONNEL SAFETY.

GROUND PERSONNEL MUST STAND CLEAR OF THESE HAZARD ZONES AND MAINTAIN COMMUNICATION WITH FLIGHT COMPARTMENT PERSONNEL DURING ENGINE RUNNING.

## ENGINE INLET AND EXHAUST HAZARD AREAS - IDLE POWER (FORWARD THRUST)

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**GROUND SAFETY PRECAUTIONS****Inlet and Exhaust Safety Precautions**

At breakaway power (forward thrust), the inlet hazard area starts five feet aft of the inlet cowl lip and extends to a distance of approximately 13 feet forward. The exhaust hazard area extends aft to a distance of approximately 510 feet from the tail of the B737 aircraft.

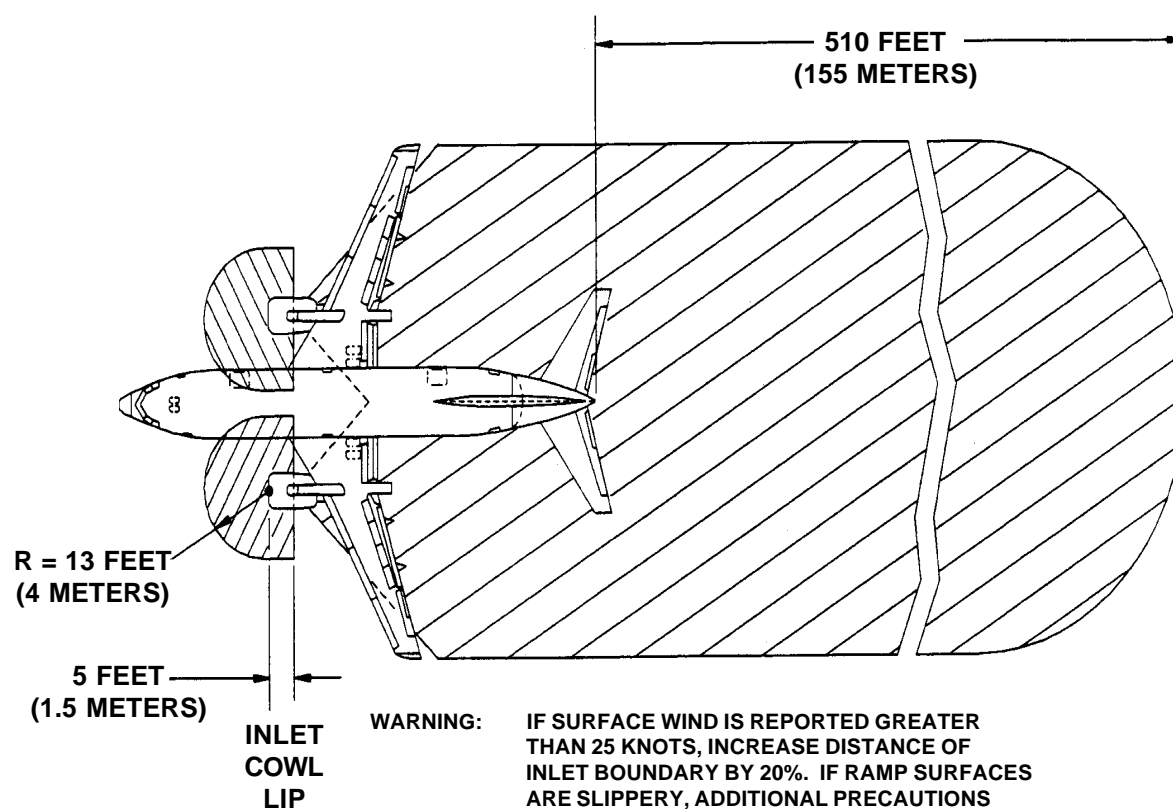
- If the surface wind is more than 25 knots, increase the distance of the inlet hazard area by 20%.
- If the ramp surfaces are wet or frozen, make the ramp clean to prevent injury to persons.
- After the engine is shut down, let the engine spool down before the engine is approached.

At high power, the fan and turbine exhaust can blow loose dirt, stones, sand and other unwanted materials at a distance of 300 feet. Park at an area where injury to persons or damage to equipment or other airplanes can be prevented. When available use a blast fence to deflect the thrust if the engines are operated without sufficient space to decrease the fan and turbine exhaust thrust to zero.

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**WARNING:** IF SURFACE WIND IS REPORTED GREATER THAN 25 KNOTS, INCREASE DISTANCE OF INLET BOUNDARY BY 20%. IF RAMP SURFACES ARE SLIPPERY, ADDITIONAL PRECAUTIONS SUCH AS CLEANING THE RAMP WILL BE NECESSARY TO PROVIDE PERSONNEL SAFETY.

GROUND PERSONNEL MUST STAND CLEAR OF THESE HAZARD ZONES AND MAINTAIN COMMUNICATION WITH FLIGHT COMPARTMENT PERSONNEL DURING ENGINE RUNNING.

## ENGINE INLET AND EXHAUST HAZARD AREAS - BREAKAWAY POWER (FORWARD THRUST)

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**GROUND SAFETY PRECAUTIONS****Inlet and Exhaust Safety Precautions**

At takeoff power (forward thrust), the inlet hazard area starts five feet aft of the inlet cowl lip and extends to a distance of approximately 13 feet forward. The exhaust hazard area extends aft to a distance of approximately 1900 feet from the tail of the B737 aircraft.

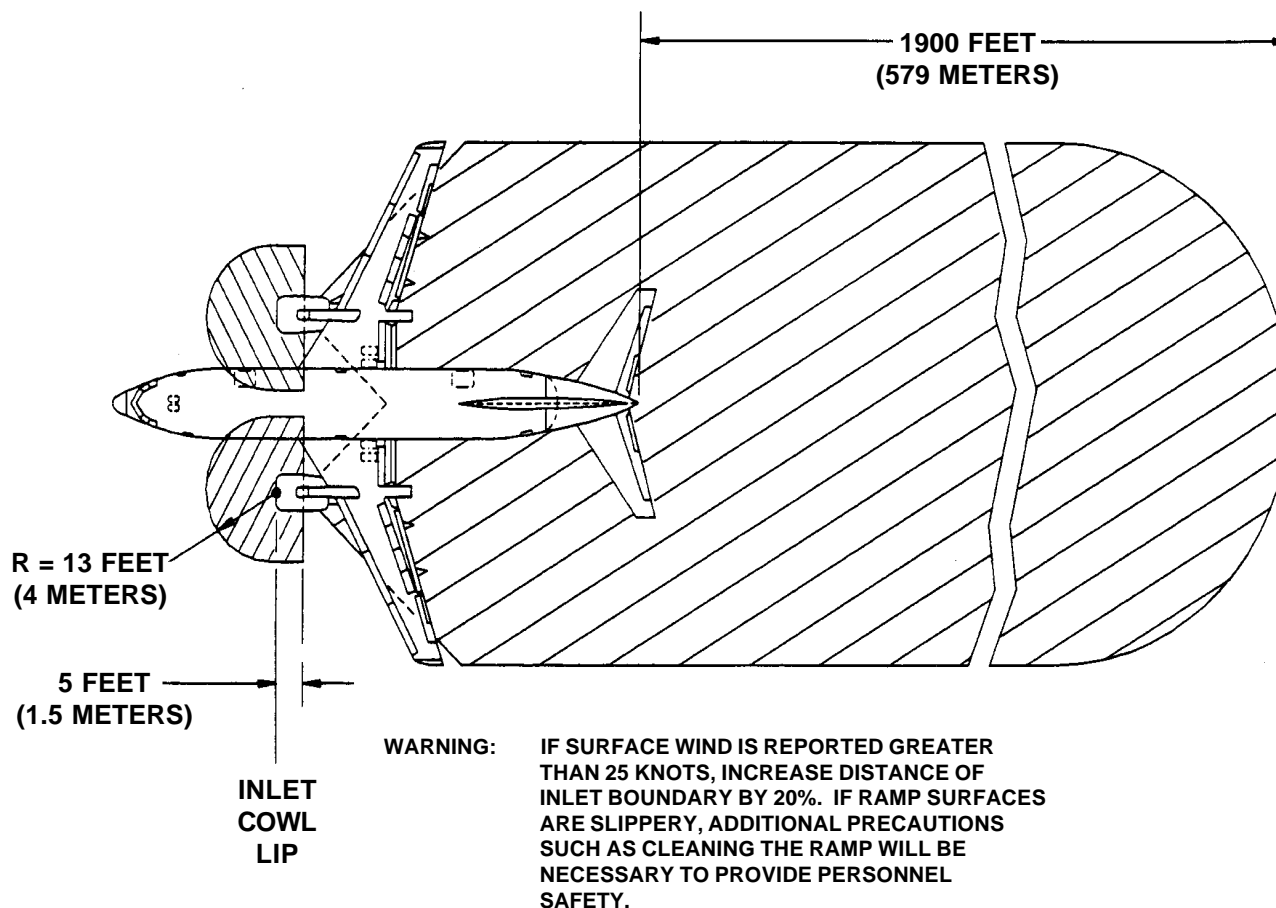
- If the surface wind is more than 25 knots, increase the distance of the inlet hazard area by 20%.
- If the ramp surfaces are wet or frozen, make the ramp clean to prevent injury to persons.
- After the engine is shut down, let the engine spool down before the engine is approached.

At high power, the fan and turbine exhaust can blow loose dirt, stones, sand and other unwanted materials at a distance of 300 feet. Park at an area where injury to persons or damage to equipment or other airplanes can be prevented. When available use a blast fence to deflect the thrust if the engines are operated without sufficient space to decrease the fan and turbine exhaust thrust to zero.

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## ENGINE INLET AND EXHAUST HAZARD AREAS - TAKEOFF (T/O) POWER

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**GROUND SAFETY PRECAUTIONS****Inlet and Exhaust Safety Precautions**

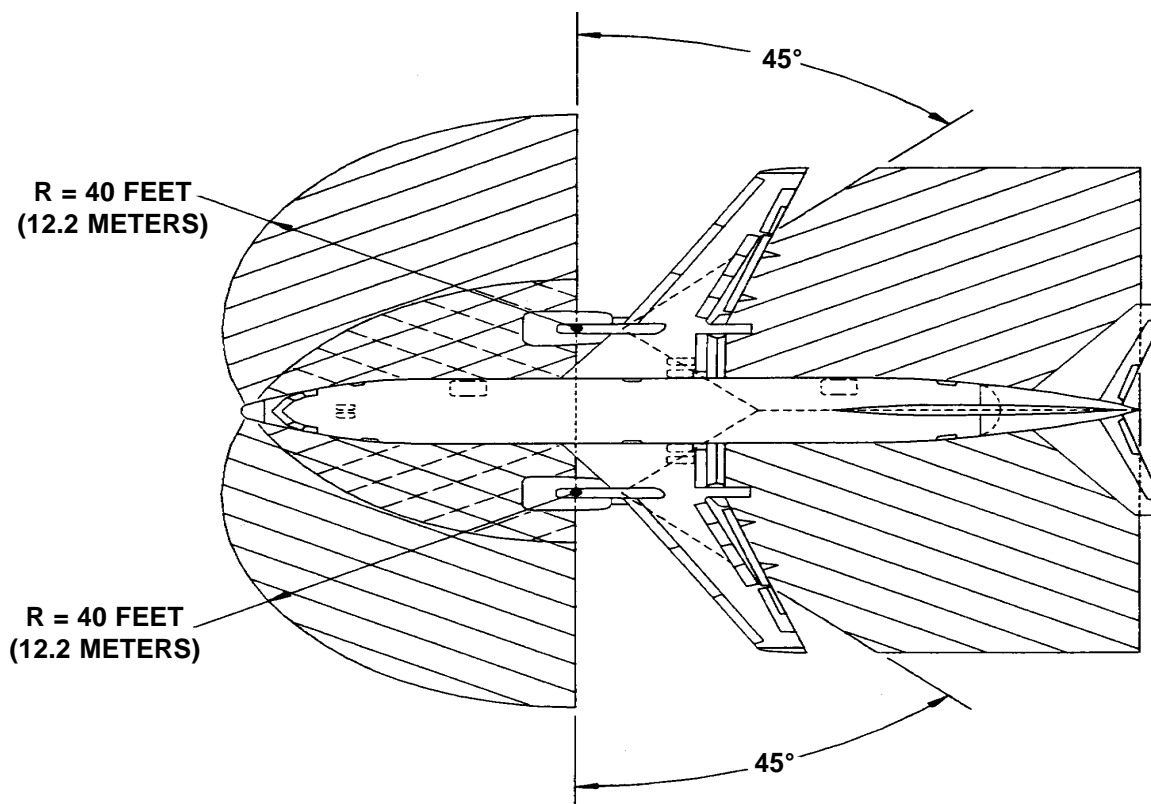
At idle power (reverse thrust), the inlet hazard area starts four feet aft of the inlet cowl lip and extends to a distance of approximately 9 feet forward. The secondary exhaust hazard area extends to a distance of approximately 40 feet forward of the exhaust nozzle while the primary exhaust hazard area extends aft to the tail of the B737 aircraft.

- If the surface wind is more than 25 knots, increase the distance of the inlet hazard area by 20%.
- If the ramp surfaces are wet or frozen, make the ramp clean to prevent injury to persons.
- After the engine is shut down, let the engine spool down before the engine is approached.

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**WARNING:** GROUND PERSONNEL MUST STAND CLEAR OF THESE HAZARD ZONES AND MAINTAIN COMMUNICATION WITH FLIGHT COMPARTMENT PERSONNEL DURING ENGINE RUNNING.

## ENGINE INLET AND EXHAUST HAZARD AREAS - IDLE POWER (REVERSE THRUST)

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**GROUND SAFETY PRECAUTIONS****Inlet and Exhaust Safety Precautions**

At breakaway power (reverse thrust), the inlet hazard area starts five feet aft of the inlet cowl lip and extends to a distance of approximately 13 feet forward. The secondary exhaust hazard area extends to a distance of approximately 130 feet forward of the exhaust nozzle while the primary exhaust hazard extends aft 175 feet from the tail of the B737 aircraft.

- If the surface wind is more than 25 knots, increase the distance of the inlet hazard area by 20%.
- If the ramp surfaces are wet or frozen, make the ramp clean to prevent injury to persons.
- After the engine is shut down, let the engine spool down before the engine is approached.

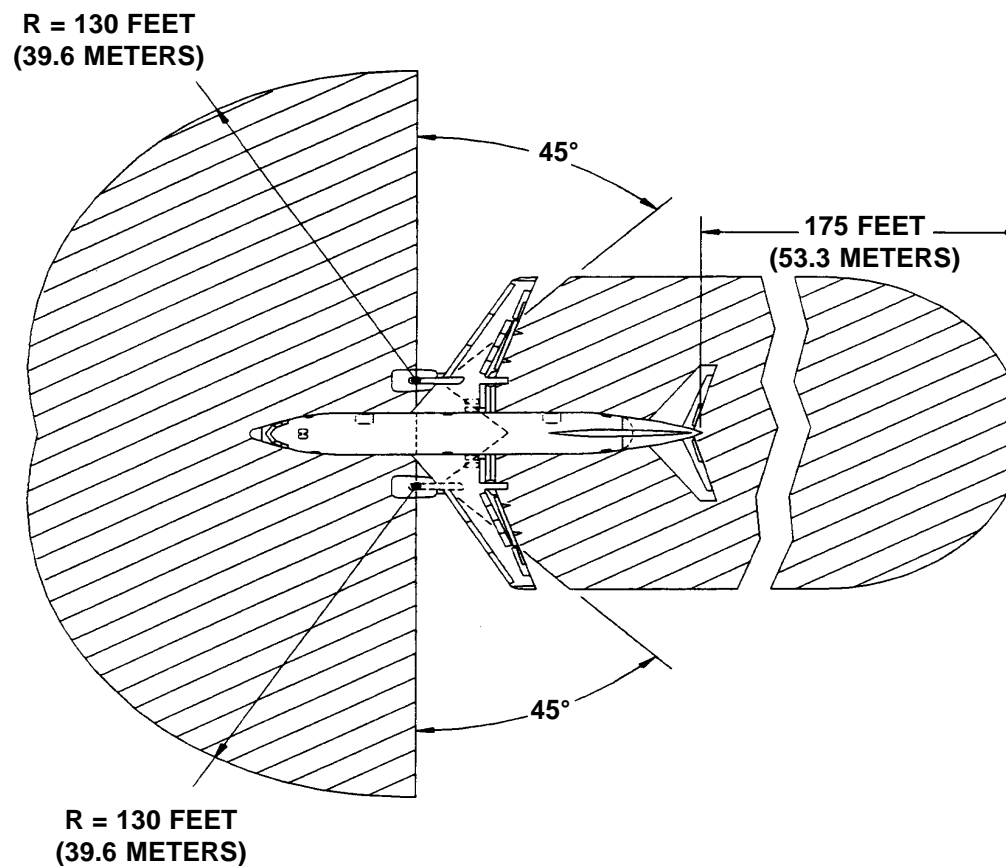
At high power, the fan and turbine exhaust can blow loose dirt, stones, sand and other unwanted materials at a distance of 300 feet. Park at an area where injury to persons or damage to equipment or other airplanes can be prevented. When available use a blast fence to deflect the thrust if the engines are operated without sufficient space to decrease the fan and turbine exhaust thrust to zero.

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**WARNING: GROUND PERSONNEL MUST STAND CLEAR OF THESE HAZARD ZONES AND MAINTAIN COMMUNICATION WITH FLIGHT COMPARTMENT PERSONNEL DURING ENGINE RUNNING.**

## ENGINE INLET AND EXHAUST HAZARD AREAS - BREAKAWAY POWER (REVERSE THRUST)

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## GROUND SAFETY PRECAUTIONS

### Entry Corridor Safety Precautions (1.A.a)

During the engine runs for maintenance which position you near the engine (such as during an idle leak check), enter and exit the engine fan case area in the entry/exit corridor.

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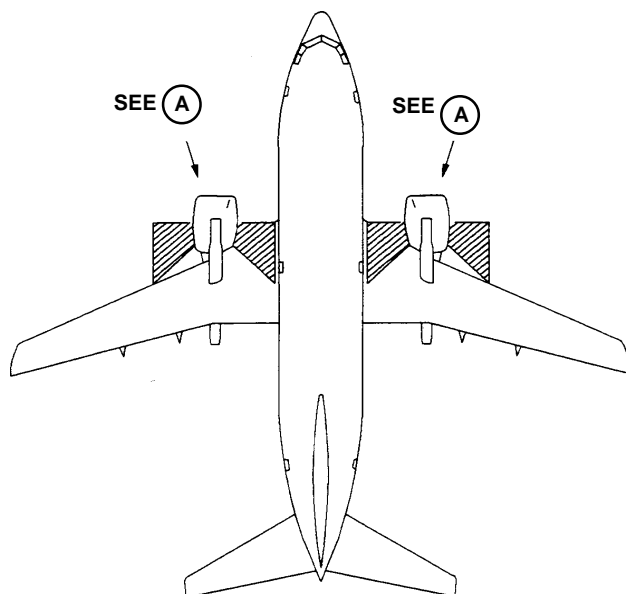
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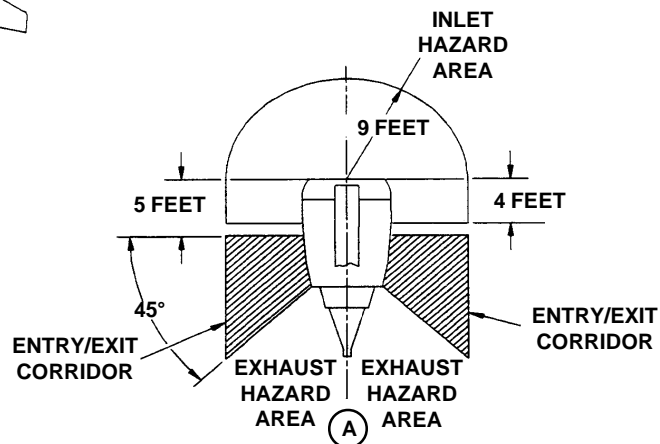
**WARNING: ENTRY/EXIT CORRIDOR MUST BE USED ONLY UNDER FOLLOWING CONDITIONS:**

1. ENGINE OPERATION MUST NOT EXCEED LOW IDLE REVOLUTIONS PER MINUTE (RPM) WHILE PERSONNEL ARE IN ENTRY/EXIT CORRIDOR.
2. POSITIVE COMMUNICATION BETWEEN PERSONNEL IN FLIGHT COMPARTMENT AND PERSONNEL USING ENTRY/EXIT CORRIDOR IS MANDATORY.
3. INLET AND EXHAUST HAZARD AREAS MUST BE STRICTLY OBSERVED BY PERSONNEL IN ENTRY/EXIT CORRIDOR.
4. USE OF SAFETY LANYARD IS RECOMMENDED (SEE SHEET 2 AND 3).

IF SURFACE WIND IS REPORTED GREATER THAN 25 KNOTS, INCREASE DISTANCE OF INLET BOUNDARY BY 20%. IF RAMP SURFACES ARE SLIPPERY, ADDITIONAL PRECAUTIONS SUCH AS CLEANING THE RAMP WILL BE NECESSARY TO PROVIDE PERSONNEL SAFETY.



 ENTRY/EXIT CORRIDOR



### ENTRY/EXIT CORRIDOR (LOW IDLE)

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## GROUND SAFETY PRECAUTIONS

### Entry Corridor Safety Precautions

The safety lanyard, inlet barrier or the inlet guard are recommended for your safety.

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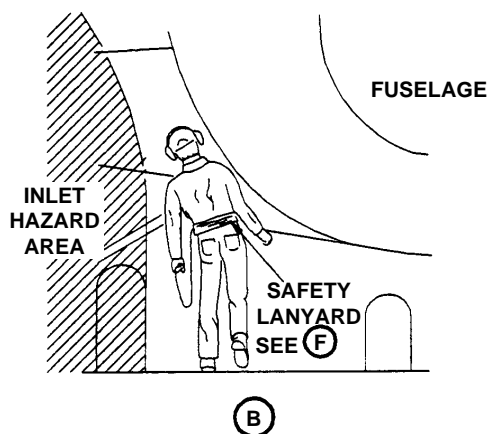
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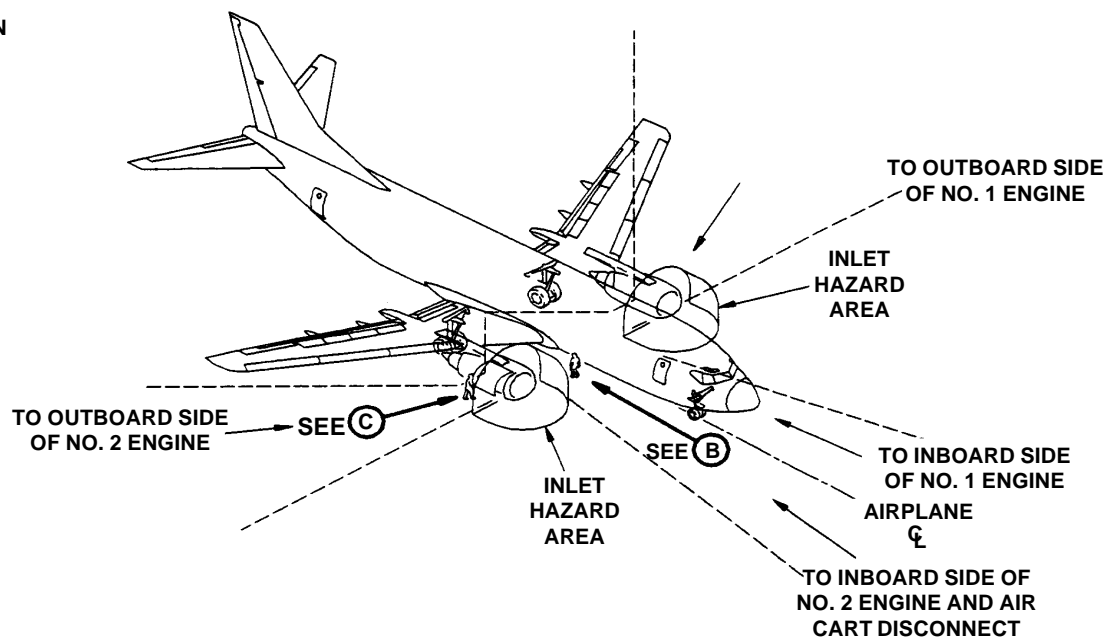
**NOTE:** PRIOR TO ENGINE OPERATION, THE PLUG-IN PERSONNEL INLET BARRIER OR ENGINE RUN-UP INLET GUARD MAY BE POSITIONED AT THE ENGINE INLET AS AN ADDED PRECAUTION

1. TO APPROACH OUTBOARD SIDE OF ENGINE, ENTER FAN CASE AREA FROM AFT END OF FAN COWL PANEL.



2. TO APPROACH INBOARD SIDE OF ENGINE, START WELL FORWARD OF INLET HAZARD ZONE. WALK AFT WITH SHOULDER NEXT TO FUSELAGE, CROSS OVER TOWARD ENGINE AT A POINT JUST FORWARD OF LANDING GEAR, AND ENTER FAN CASE AREA FROM AFT END OF FAN COWL PANEL.

**NOTE:** USE OF SAFETY LANYARD IS RECOMMENDED



## HOW TO APPROACH/EXIT FAN CASE AREA DURING ENGINE MAINTENANCE RUN

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## GROUND SAFETY PRECAUTIONS

### Cooldown Safety Precautions (1.A.a)

After engine operation, make sure the turbine exhaust sleeve and plug have become sufficiently cool before maintenance is done in these areas.

The other parts of the engine can be worked on with no danger of burns.

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## GENERAL ENGINE DATA

### Noise Safety Precautions (1.A.a)

The engines make sufficient noise to cause damage to your ears.

- You can temporarily cause your ears to become less sensitive to sound, if you listen to loud engine noise
- You can become permanently deaf if you listen to the engine noise for a long time
- Noise can affect the ear mechanism and cause unsteadiness or an inability to walk or stand without reeling

When you are near an operating engine, always use ear protection to decrease the quantity of sound energy which reaches your ears.

Note: The use of both cup-type ear protection and ear plugs is recommended.

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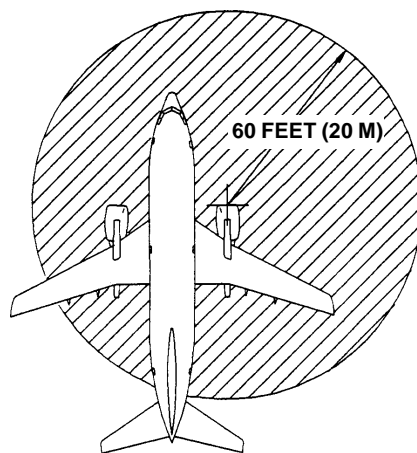
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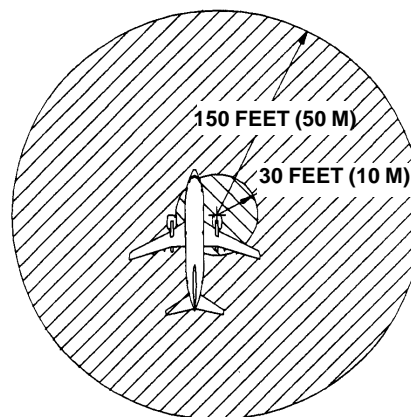
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**IDLE POWER**



**T/O POWER**

-  **WARNING:** EAR PROTECTION REQUIRED WITHIN THIS AREA.
-  **WARNING:** PROLONGED EXPOSURE WITHIN THIS AREA OF MORE THAN SIX MINUTES, EVEN WITH EAR PROTECTION, CAN CAUSE EAR DAMAGE

## ENGINE NOISE HAZARD AREAS

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## GROUND SAFETY PRECAUTIONS

### Ignition Safety Precautions (1.A.a)

The engine ignition system is an electrical system with high energy. You must be careful to prevent electrical shock. Injury or death can occur to you. Do not do maintenance on the ignition system when you operate the engine.

Open the circuit breakers for the ignition system to deactivate the ignition system. Manually ground the exciter terminal to discharge the current.

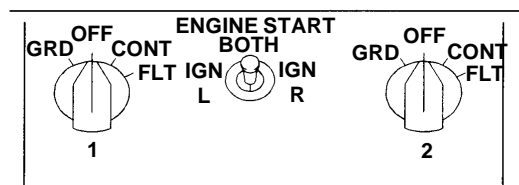
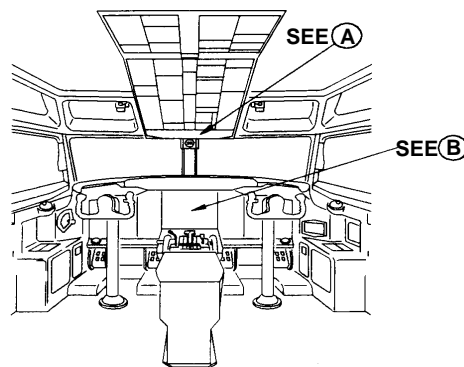
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PILOTS' OVERHEAD PANEL

(A)



PILOTS' CENTER INSTRUMENT PANEL

(B)

## ENGINE START AND IGNITION MODULE LOCATION

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## DIMENSIONS AND WEIGHTS

### Dimensional Data (1.A.a)

	<u>inch</u>	<u>mm</u>
*Engine Overall Length	98.16	2,722
Fan Inlet Case Forward Flange Diameter	63.39	1,610
Fan Frame Rear Outer Flange Diameter	40.63	1,032
Fan Major Module Length	33.81	859
Core Engine Major Module Length	51.60	1,310
TRF Outer Flange Diameter	40.63	1,032
LPT Major Module Length	76.17	1,935

\*Indicates from tip of spinner cone to rear end of cage assembly.

### Weight Data (1.A.a)

	<u>lb</u>	<u>kg</u>
Basic Engine Weight		
Dry	4,240	1,923
Serviced	4,297	1,949
Drained	4,252	1,929
With QEC Installed on Engine	5,340	2,420
Fan Major Module	1,536	697
Core Engine Major Module	1,400	635
LPT Major Module	812	369

Note: All of the above engine values are approximate and may vary slightly.

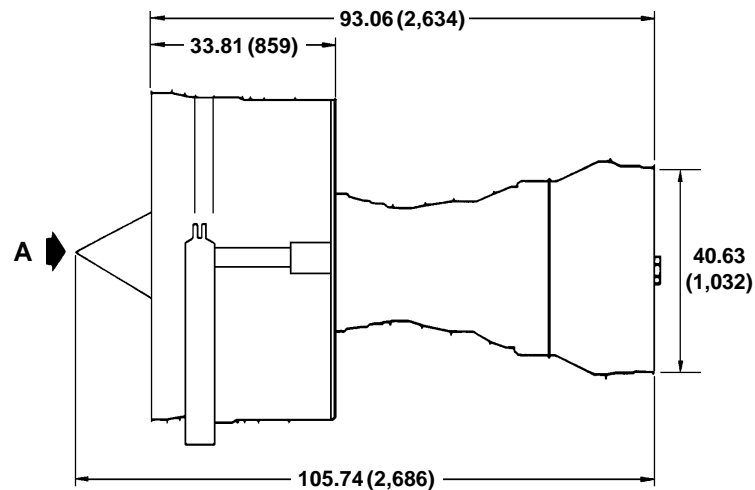
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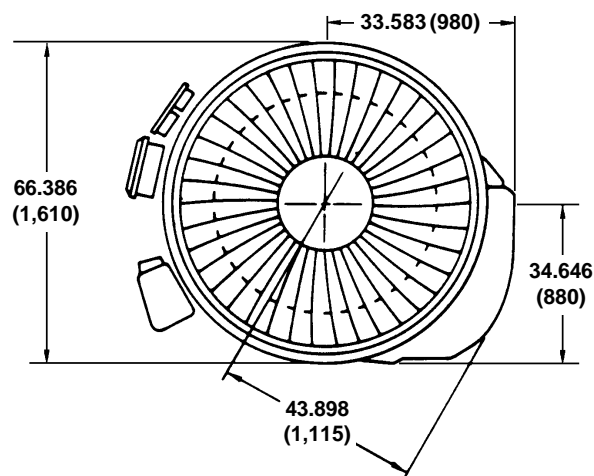
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VIEW A



Note: Dimensions are in inches with millimeters in parentheses

## CFM56-3 ENGINE OVERALL DIMENSIONS

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## RATINGS AND APPLICATIONS

### Thrust Ratings (1.A.a)

The CFM56-3 is available in these various power plant thrust ratings:

CFM56-3-B1 - 18,500 and 20,100 lbs.

CFM56-3-B2 - 20,100, 22,000 and 22,100 lbs

CFM56-3C - 18,500, 20,100, 22,100 and 23,500 lbs.

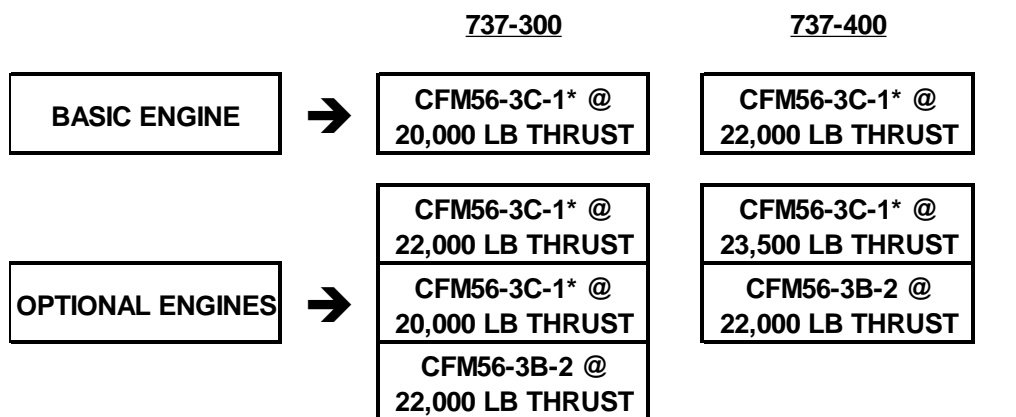
### Aircraft Applications (1.A.a)

The CFM56-3 was designed specifically for the Boeing Series 737 airframe. The CFM56-3 is available in these Commercial Boeing Series 737 airframe configurations.

CFM56-3-B1 - B737-300 and 737-500.

CFM56-3-B2 - B737-300 and 737-400.

CFM56-3C - B737-300, 737-400 and 737-500.



\* May use higher thrust at SL/temperature > 86 degree F or high altitude airport

## CFM56-3 THRUST AND AIRFRAME CONFIGURATION CHART

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## RATINGS AND APPLICATIONS

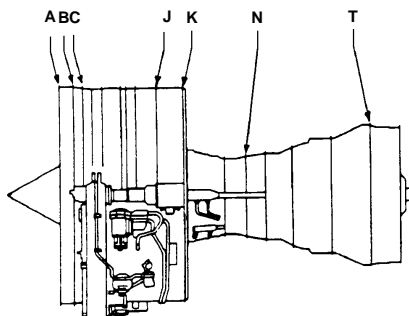
### Data Plate (1.A.a)


To locate the specific engine model and thrust rating you must first locate the engine data plate. The engine data plate is located at 3:30 o'clock/ALF on the fan inlet case between flanges "B" and "C".

The engine plate provides the following information:

- Engine Model Number
- Engine Serial Number
- Thrust Ratings
- Production Number
- FAA/DGAC Type Certificate





			
TURBO-REACTEUR CFM 56		TURBO FAN	
No C. T. DGAC		FAA TC No	
		FAA	
		PRODUCTION C N°	
No D'ORDRE			SERIAL N°
REGIME DECOLLAGE (daN)		RATING T.O. THRUST (LB)	
REGIME MAXI CINTINU (daN)		RATING MAX CONT. THRUST (LB)	
INSP. CONTR.		MANUFACTURED BY FABRIQUE PAR	

## ENGINE DATA PLATE

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## TRANSPORTATION REQUIREMENTS

### Requirements (1.A.a)

The compact physical dimensions of the CFM56-3 make for convenient shipment of the engine without disassembly.

Shipping a CFM56-3 engine by trailer over the road requires certain precautions that must be taken to ensure that the engine is properly protected from internal damage while in transit. The trailer must be equipped with an air-ride suspension system for one engine transportation. When shipping two or more engines, both the tractor and trailer must be equipped with an air-ride suspension system.

The CFM56-3 engine assembly can be shipped in some narrow or wide body aircraft (Engine Axis Must Be Parallel To Aircraft Axis). When transporting in low cargo compartments it will be necessary to separate the engine

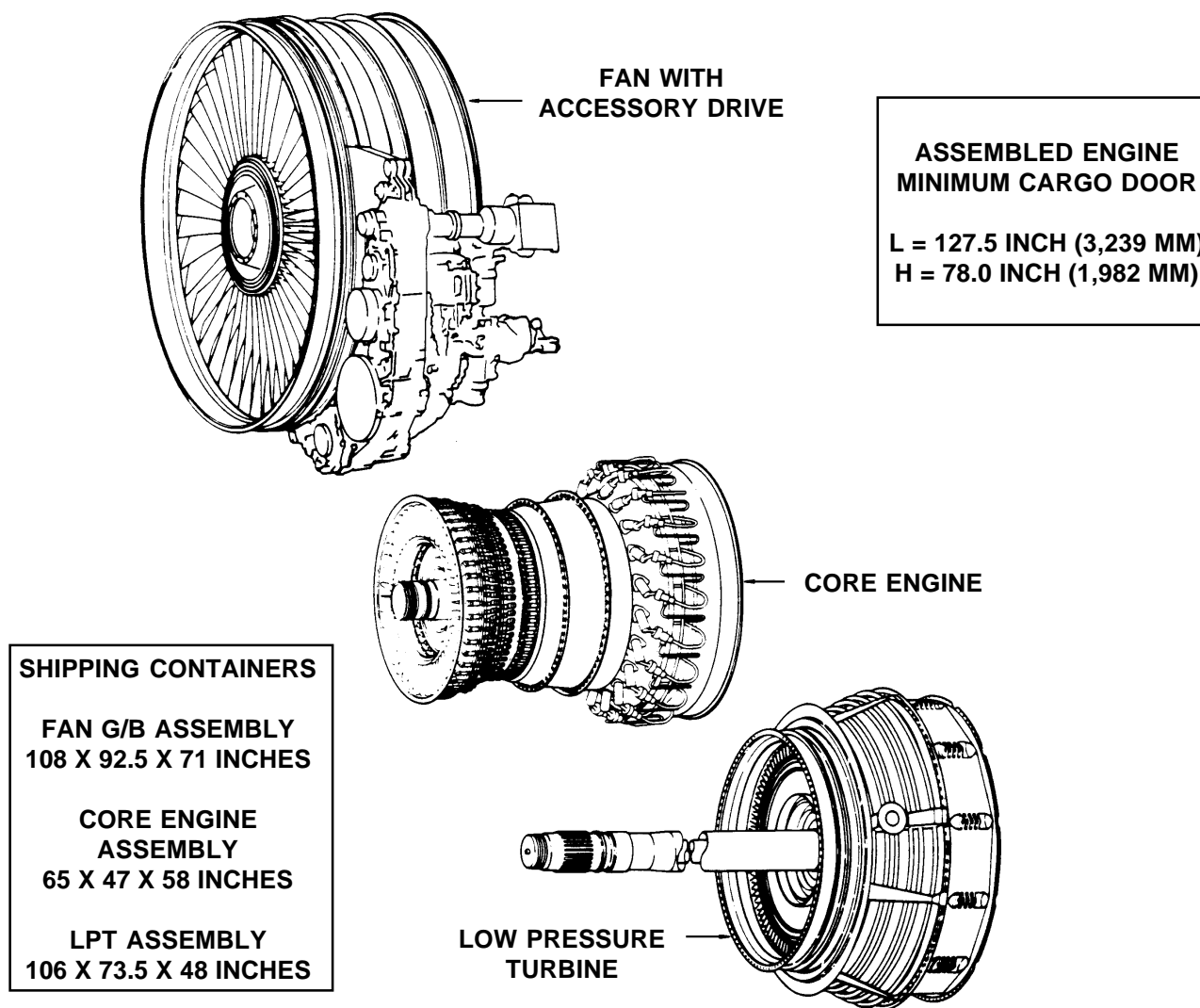
When the CFM56-3 engine is reassembled on-site, it is "NOT NECESSARY" for a test cell run before reinstalling engine on the aircraft.

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## CFM56 TRANSPORTABILITY

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**ON-CONDITION MONITORING****Description (1.A.a)**

The engine design includes all the features necessary for in-flight and ground fault detection and isolation.

The condition monitoring program incorporates the maximum utilization of existing, proven techniques and the development of new and improved diagnostic methods.

The CFM56-3 on-condition monitoring system consists of:

- Gas path health monitoring
- Borescope inspection capability
- Gamma Ray inspection capability
- SOAP (Spectral Oil Analysis Program)
- Lube particle analysis
- Vibration monitoring system

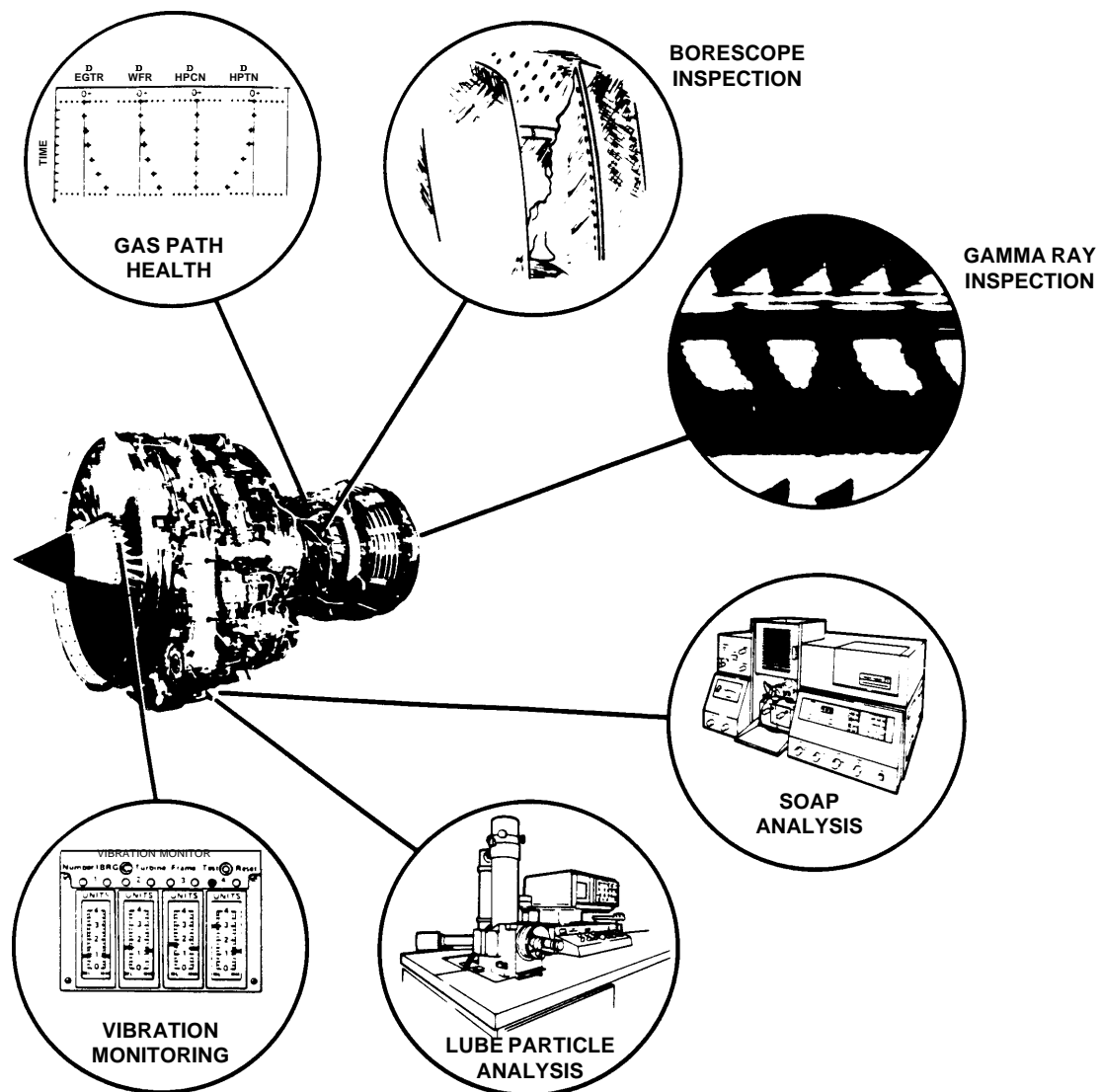
**Purpose (1.B.a)**

The on-condition maintenance concept utilized on the CFM56-3 eliminates periodic removal of the engine for specified inspections and overhauls and thereby reduces the frequency of shop visits.

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## CFM56 CONDITION MONITORING

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## MAINTENANCE STRATEGY

### Identification (1.A.a)

The CFM56-3 engine can be separated into three major modules, seventeen individual modules, of which ten are replaceable under the Modular Maintenance Concept.

Improved subassembly designs within the modules reduced a number of parts. These improvements over previous engine designs support the CFM56-3 modular maintenance system.

The three major modules that can be separated from the assembly to perform specific maintenance operations are the:

- Fan major module
- Core major module
- LPT major module

This engine concept gives the maintenance personnel the option to work on any of the three modules with a minimum amount of disassembly of the other major modules. This modular design provides the customer a cost savings for maintenance procedures.

### Purpose (1.B.a)

The CFM56-3 engine design is to minimize maintenance costs and out of service time so that each maintenance

action requires as few man hours and total elapsed time as possible. With an advanced modular engine design and excellent accessibility of components, this concept provides the capability for an extensive on-wing maintenance program.

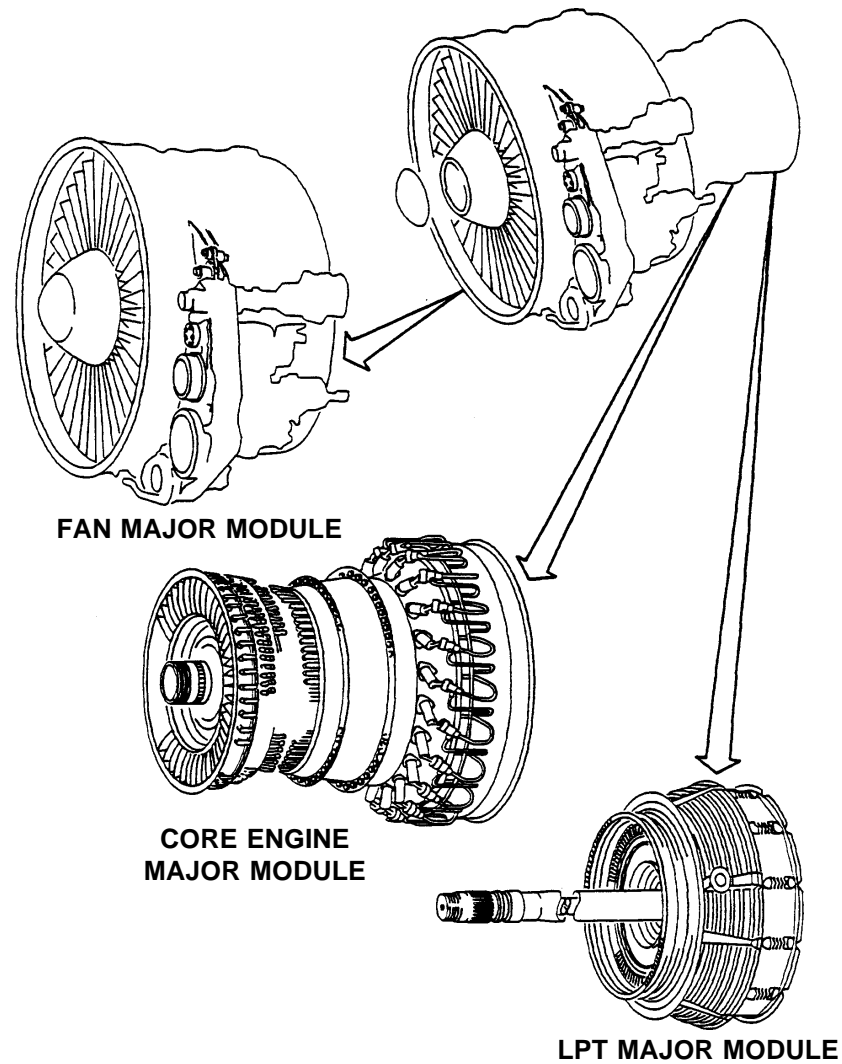
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## ENGINE MODULES

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## BASIC ENGINE DESIGN

### Objectives:

At the completion of this section a student should be able to:

....identify the general construction features of the CFM56-3/3B/3C engine (1.A.x).

## GENERAL ENGINE CONSTRUCTION

### Engine Features (1.A.a)

The CFM56-3 is a high bypass, dual rotor, axial flow advanced technology turbofan engine that features:

- A four stage integrated fan and Low Pressure Compressor (LPC) booster driven by a four stage Low Pressure Turbine (LPT)
- A nine stage High Pressure Compressor (HPC) driven by a single stage High Pressure Turbine (HPT)
- Compressor airflows controlled by Variable Bleed Valves (VBV) located aft of the booster and Variable Stator Vanes (VSV) within the HPC front stages
- An annular combustion chamber increases the HPC delivery air velocity to drive both turbines
- An accessory drive system extracting energy from the high pressure rotor to drive the engine mounted accessories

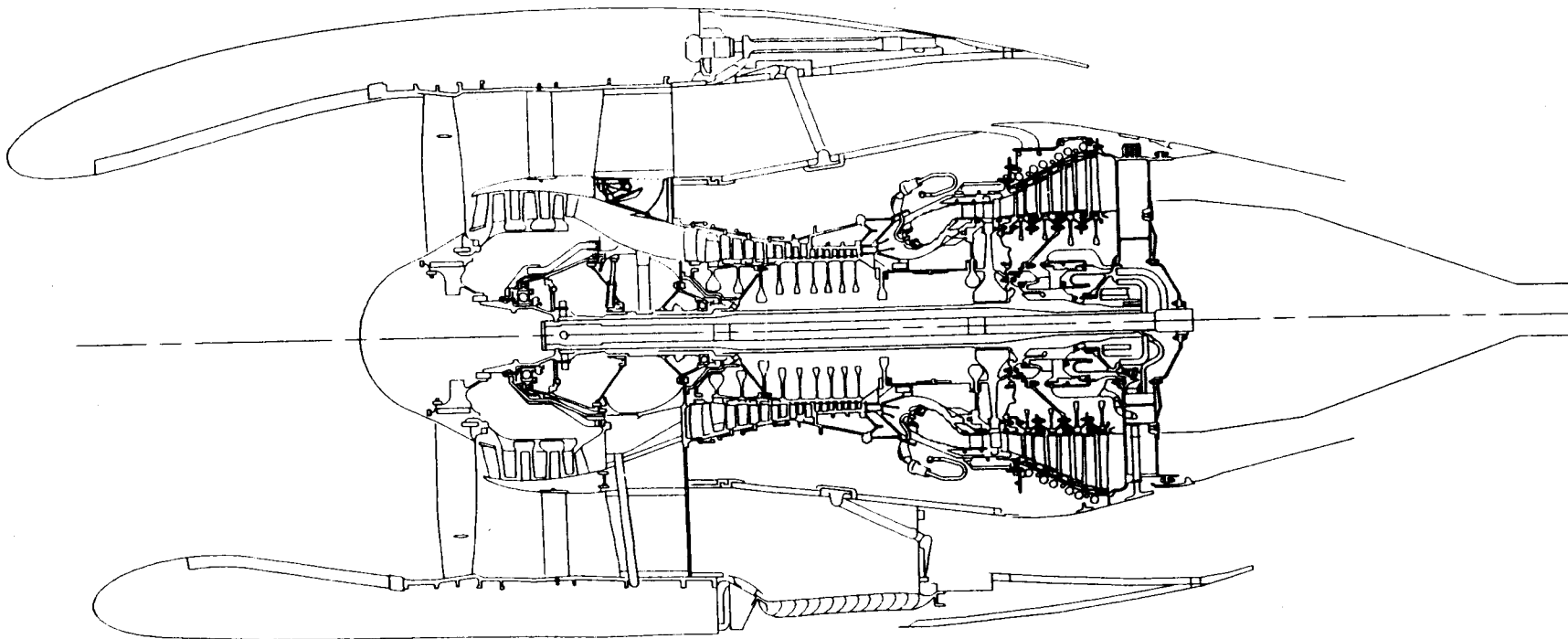
A pylon mounted thrust reverser provides the capability of reducing aircraft speed on the ground. The thrust reverser is designed, manufactured, and supported by The Boeing Company.

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## CFM56 TURBOFANS

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## GENERAL ENGINE CONSTRUCTION

### Frames and Bearings (1.A.a)

The solid structure design is acquired by a short length, a fan frame, and a turbine frame.

- The fan frame is in the front located between the fan case and core module and is a component of the fan major module.
- Turbine frame is in the rear located after the LPT case and is a component of the LPT major module.

The rotors are supported by five main bearings that are mounted in two engine sumps of the lubricating system.

- In the forward sump of the fan frame, the No. 1 ball bearing supports thrust and radial loads while the No. 2 roller bearing supports the radial loads of the fan and booster assembly.
- The HPC front shaft thrust and radial loads are supported by the No. 3 ball bearing contained within the Inlet Gearbox (IGB) assembly.
- In the aft sump area of the LPT, the No. 4 roller bearing supports the radial load of the HPT rear shaft on the LPT shaft.
- The No. 5 roller bearing mounted within the turbine frame supports the radial load of the LPT shaft aft end.

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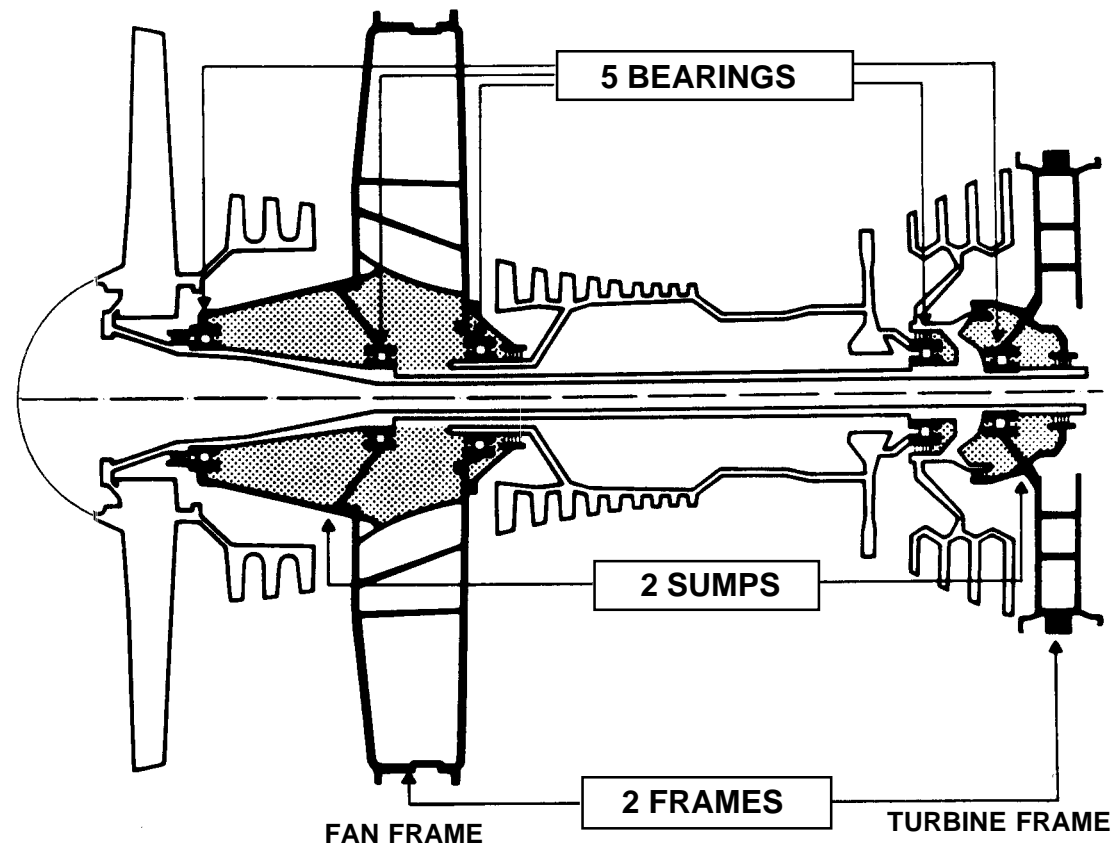
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## ENGINE CONSTRUCTION

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## GENERAL ENGINE CONSTRUCTION

### Engine Breakdown (1.A.a)

The dual rotor design of the CFM56-3 engine consists of:

The Low Pressure System:

- A single stage fan, connected to a three stage booster rotor assembly
- A single stage fan Outlet Guide Vane (OGV) assembly in the secondary airflow
- Four stage booster stator assembly in the primary airflow
- Twelve fully controlled VBV, located in the fan frame between booster and HPC for engine air cycle matching throughout the operating range
- Four stage LPT to drive fan and booster

The High Pressure System:

- Nine stage HPC rotor
- One variable Inlet Guide Vane (IGV) assembly
- Three VSV assemblies
- Five HPC stator assemblies

- One OGV assembly (HPC stator stage 9)
- Short machined ring construction annular combustor with 20 fuel nozzles
- A single stage HPT nozzle and rotor assembly to drive the HPC

The Accessory Drive System:

- IGB
- Radial drive shaft
- Transfer Gearbox (TGB)
- Horizontal drive shaft
- Accessory Gearbox (AGB)

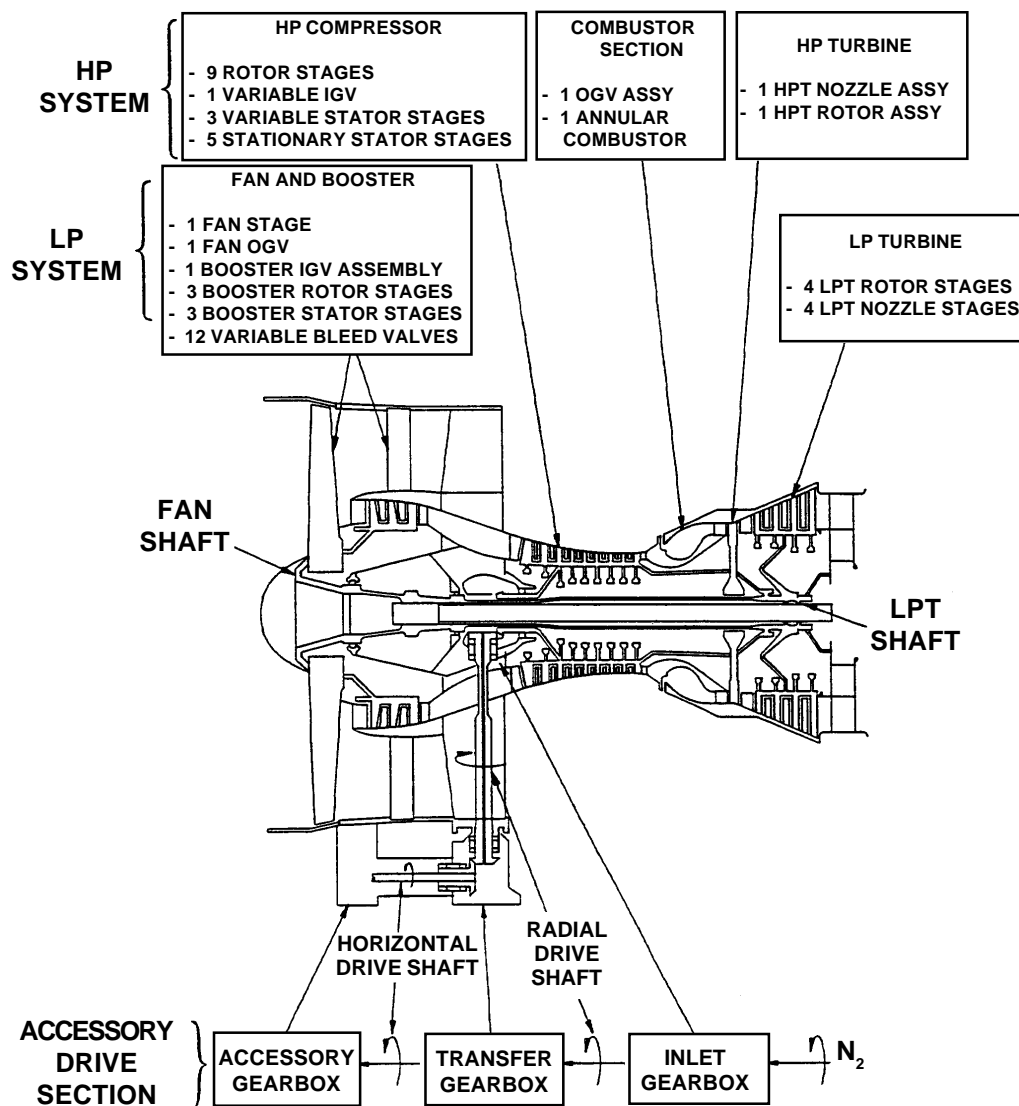
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## CFM56 ENGINE CONSTRUCTION

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**GENERAL ENGINE CONSTRUCTION****Flange Identification (1.A.a)**

The external flanges of the engine have been assigned letter designations. The letter designations will be used for flange identification wherever it is necessary to be explicit about flange location, such as positioning of brackets, clamps, bolts, etc. Some documents like assembly instructions or service bulletins may use a different locating system.

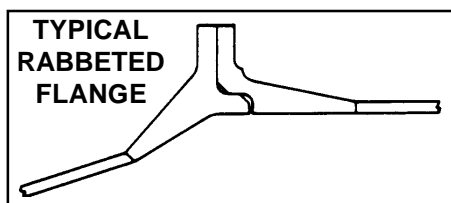
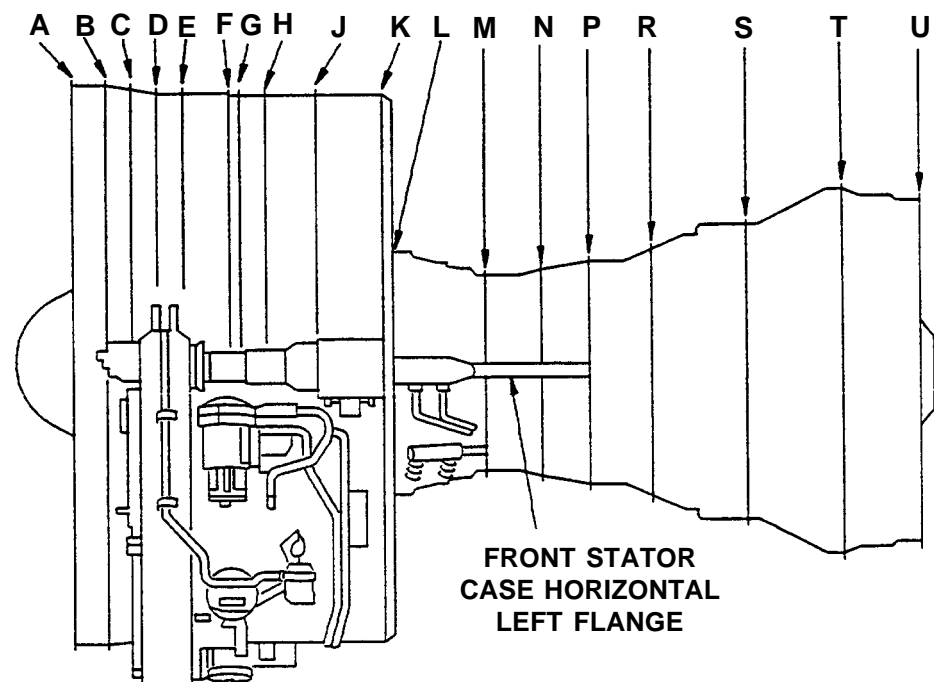
To reduce air leakage between mating flanges and to ensure proper alignment during assembly, all flange mating points are of a rabbet fit construction. However, the horizontal flanges are a butt type flange.

Horizontal flanges are identified as:

- Front stator case horizontal left flange
  
- Front stator case horizontal right flange

The engine stator cases are a matched set and should not be disassociated with other engine stator cases.





## ENGINE FLANGES

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## GENERAL ENGINE CONSTRUCTION

### Sump Philosophy (1.A.a)

The following are key features of the CFM56 sump philosophy

- The oil system is of "dry sump" design.
- It consists of an external oil tank and lubrication unit.
- Lubrication oil for the bearings is scavenged at a rate equal to or greater than the supply oil.
- Scavenge oil is filtered and cooled prior to return to the oil tank.
- Main engine bearing sumps are sealed by labyrinth type seals and airflow across the seals.
- A pressurization and cooling chamber is created around the bearing sump by the use of two sets of seals; oil and air.
- Pressurization between the oil and air seals is supplied by booster discharge air.
- The bearing sump area is vented through a rotating air/oil separator to the center vent tube creating a low pressure chamber.
- Pressurization air, seeking the path of least resistance, flows across the oil seals thus preventing oil flow past the oil seals.
- Any oil that might cross the oil seals is collected in the air seal housing and forced by the pressurization air out through cavity drain piping.
- Cavity drain fluid is carried overboard by an external drain system.

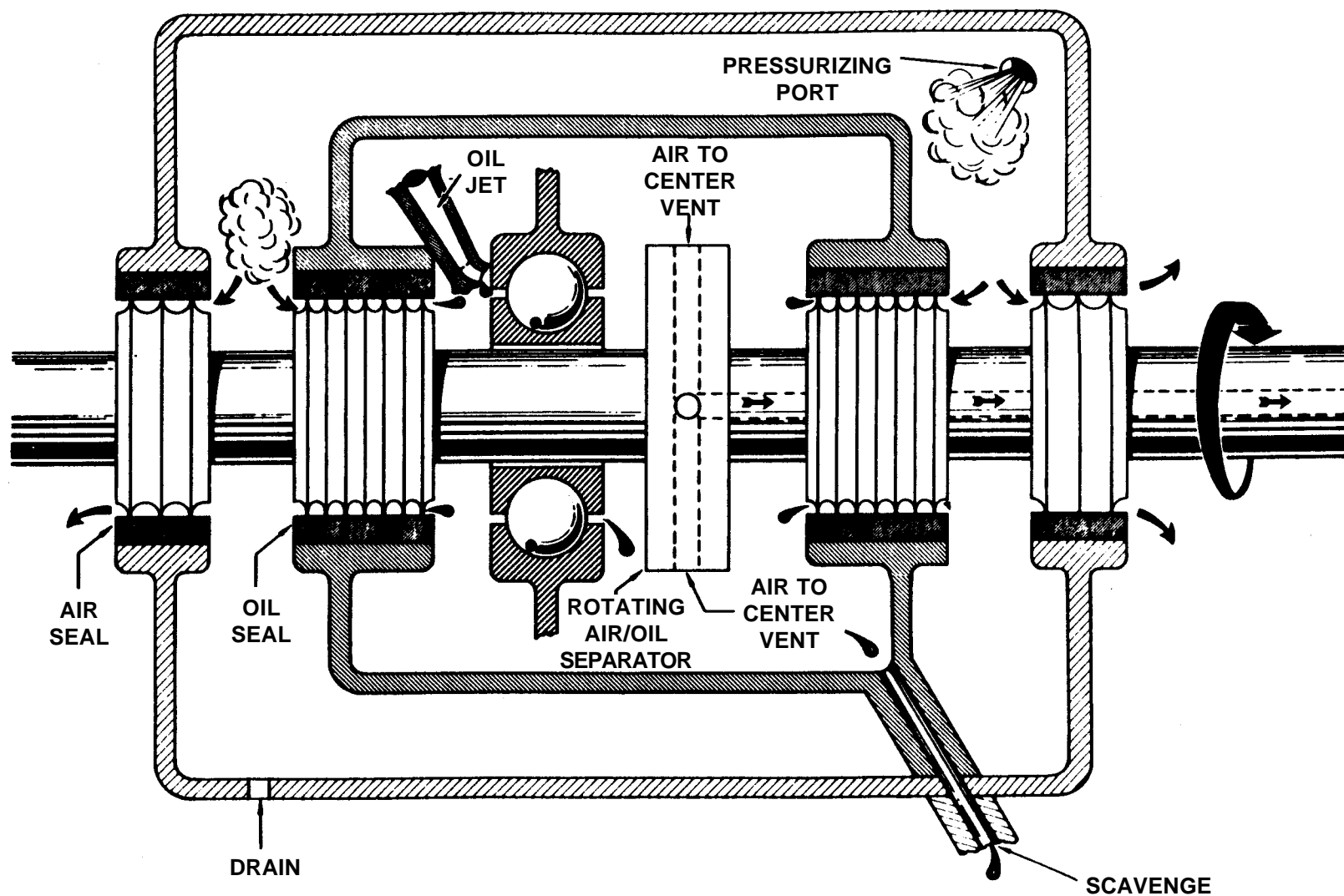
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### SUMP PHILOSOPHY

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## GENERAL ENGINE CONSTRUCTION

### Aerodynamic Stations (1.A.a)

The airflow path design of the CFM56-3 high bypass engine consists of two flow paths; primary and secondary, through which the engine discharges jet velocities.

- The **Primary Airflow** passes through the inner portion of the fan blades (stage 1 rotor) and continuing through the booster. The flow path then continues entering the core engine and the LPT exiting through the nacelle discharge duct.
- The **Secondary Airflow** passes through the outer portion of the fan blades (stage 1 rotor), OGV's and exits through the nacelle discharge duct.

Flow path aerodynamic stations have been established to facilitate design and development of the engine thermodynamic cycle as well as performance assessment and monitoring.

The following are the most commonly used parameters on the CFM56-3 engine:

- $T_{12}$  for fan speed scheduling.
- $T_{2.0}$  for core speed scheduling.
- $T_{2.5}$  for VSV/VBV and fuel limiting schedules.
- $T_{4.95}$  for flight deck indication (EGT).

$Ps_{12}$  for fan and core altitude corrected speed schedules.

$Ps_3$  for fuel limiting schedule (CDP).

CBP for fuel limiting schedule.

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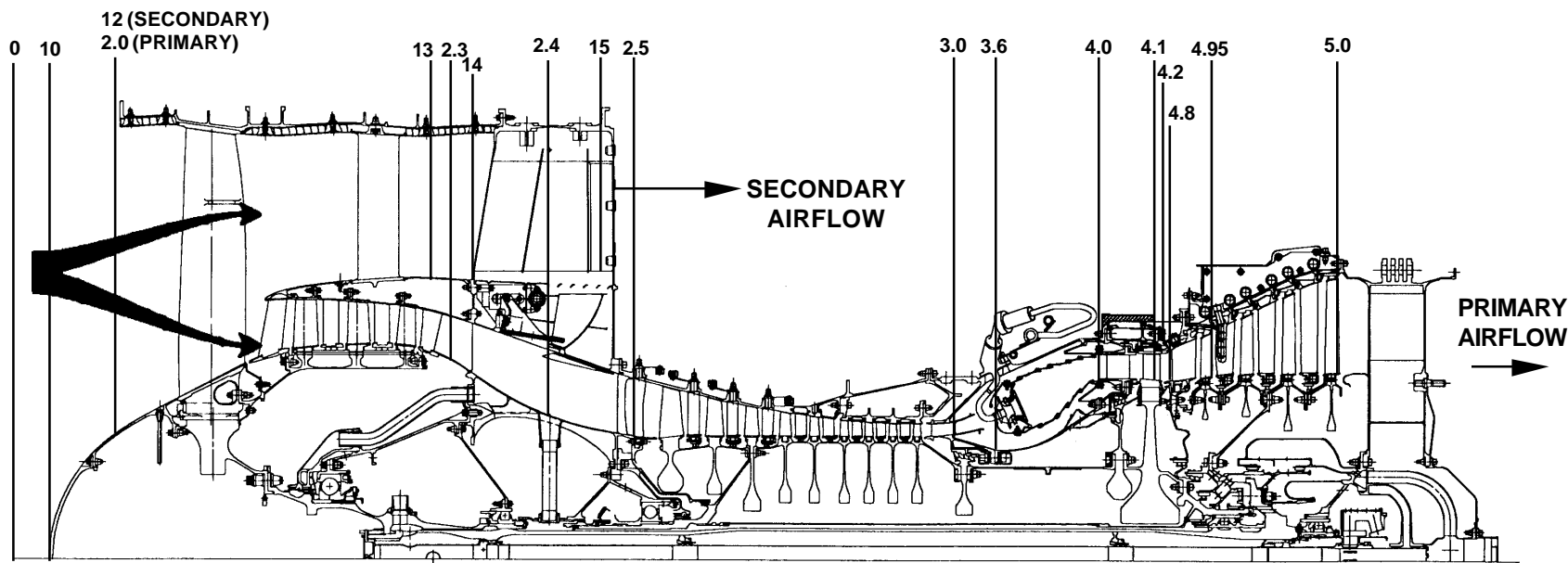
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SECONDARY AIRFLOW    0    AMBIENT  
                               10    ENGINE ENTRANCE  
                               12    SECONDARY AIRFLOW INLET  
                               13    FAN OGV DISCHARGE  
                               14    FAN FRAME INLET  
                               15    FAN FRAME DISCHARGE

PRIMARY AIRFLOW    2.0    PRIMARY AIRFLOW INLET  
                               2.3    BOOSTER DISCHARGE AIR  
                               2.4    VBV AIR EXIT  
                               2.5    HPC INLET  
                               3.0    HPC DISCHARGE  
                               3.6    COMBUSTOR INLET  
                               4.0    COMBUSTOR DISCHARGE  
                               4.1    HPT INLET  
                               4.2    HPT DISCHARGE  
                               4.8    LPT INLET  
                               4.95    STAGE 2 LPT INLET  
                               5.0    LPT DISCHARGE



## AERODYNAMIC STATIONS

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## AIRFLOW COOLING, PRESSURIZING, AND VENTING

### Objectives:

At the completion of this section a student should be able to:

- ....identify the airflow paths for cooling, pressurizing and venting of the CFM56-3/3B/3C engine (1.A.x).
- ....state the purpose of the airflow paths for cooling, pressurizing and venting of the CFM56-3/3B/3C engine (1.B.x).

## OVERVIEW

### Definitions

Main Propulsion Airstream - The total airflow through the fan.

Secondary Airflow - The airflow passing through the bypass duct (Fan Discharge).

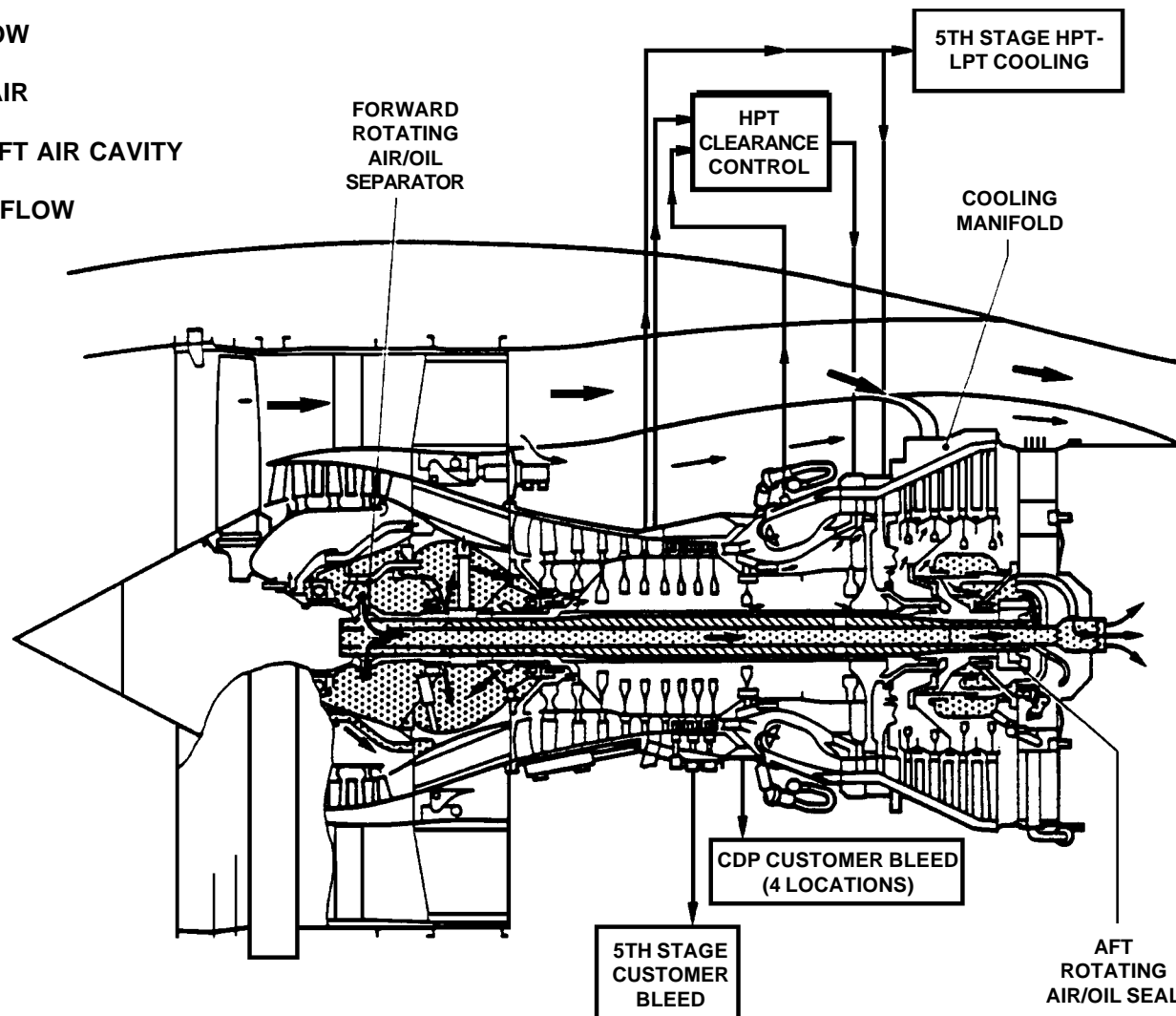
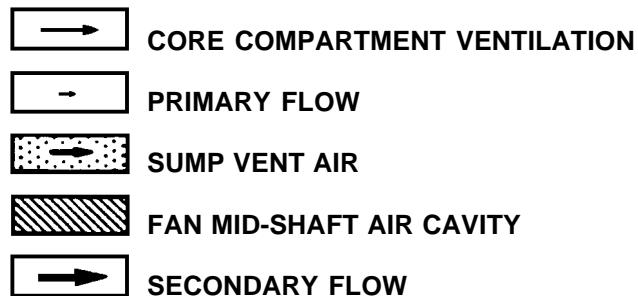
Primary Airflow - The airflow passing through the core (Core Discharge).

Pressurizing and Cooling Airflow - Those systems using the main propulsive airstream as a supply and/or vent.

### Purpose (1.B.a)

This system of parasitic leakage is necessary to provide engine reliability and efficiency while it is being subjected to high temperature operating conditions.





AIR SYSTEM SCHEMATIC

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## AFT SUMP PRESSURIZING

### Identification (1.A.a)

The source of air is booster discharge pressure received through the four tubes that carry air radially inward from between struts in fan frame to HPC rotor forward stub shaft. Air flows toward aft sump between the LPT shaft and the compressor rotor air duct to the sump.

### Purpose (1.B.a)

Pressurizes aft sump to prevent oil loss.

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**SEE COLOR AIRFLOW CHART**

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**SUMP AND GEARBOX VENTING****Identification (1.A.a)**

Vent air from the oil tank is routed to the forward sump via an external line which passes through strut No. 4 of the fan frame. Combined vent air from the AGB and TGB flows through the radial drive shaft housing to join the forward sump vent.

The rotating air/oil separator on the fan shaft allows vent air into the center vent tube for venting rearward to the primary exhaust.

**Purpose (1.B.a)**

To allow air to escape at a rate which will maintain adequate head pressure levels for positive action of lube and scavenge pumps while preventing sump pressure levels that would upset the pressure differential across the oil seals.

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**SEE COLOR AIRFLOW CHART**

**CORE ROTOR CAVITY ("BORE") COOLING****Identification (1.A.a)**

Booster discharge air flows to the No. 3 bearing air/oil seal through holes in the HPC forward shaft. Rearward through the HPC/HPT to the aft shaft of the HPT through holes in the HPT aft shaft to the LPT rotor aft cavity. Exits to the primary air stream by flowing underneath the stage 4 LPT blade dovetails and by passing through a gap between stage 4 LPT disk and the turbine frame.

**Purpose (1.B.a)**

The core rotor cavity ("bore") cooling airflow does the following:

- Cooling of HPC rotor aft cavity
- Cooling of HPT forward shaft cavity
- Cooling of HPT hub
- Cooling of LPT rotor aft cavity
- Cooling of 4th stage LPT rotor blade dovetails

**SEE COLOR AIRFLOW CHART**

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## HPT BLADE COOLING PATHWAYS

### Identification (1.A.a)

Refer to hot section airflow diagram on page 21 of this section.

### Purpose (1.B.a)

Provide internal cooling for HPT rotor blades.

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**SEE COLOR AIRFLOW CHART**

## HPT NOZZLE COOLING PATHWAYS

### Identification (1.A.a)

Refer to hot section airflow diagram on page 21 of this section.

### Purpose (1.B.a)

Cools the HPT nozzle.

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**SEE COLOR AIRFLOW CHART**

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## HPT SHROUD ACTIVE CLEARANCE CONTROL

### Identification (1.A.a)

Refer to hot section airflow diagram on page 21 of this section.

### Purpose (1.B.a)

Cools or heats the HPT rotor shroud.

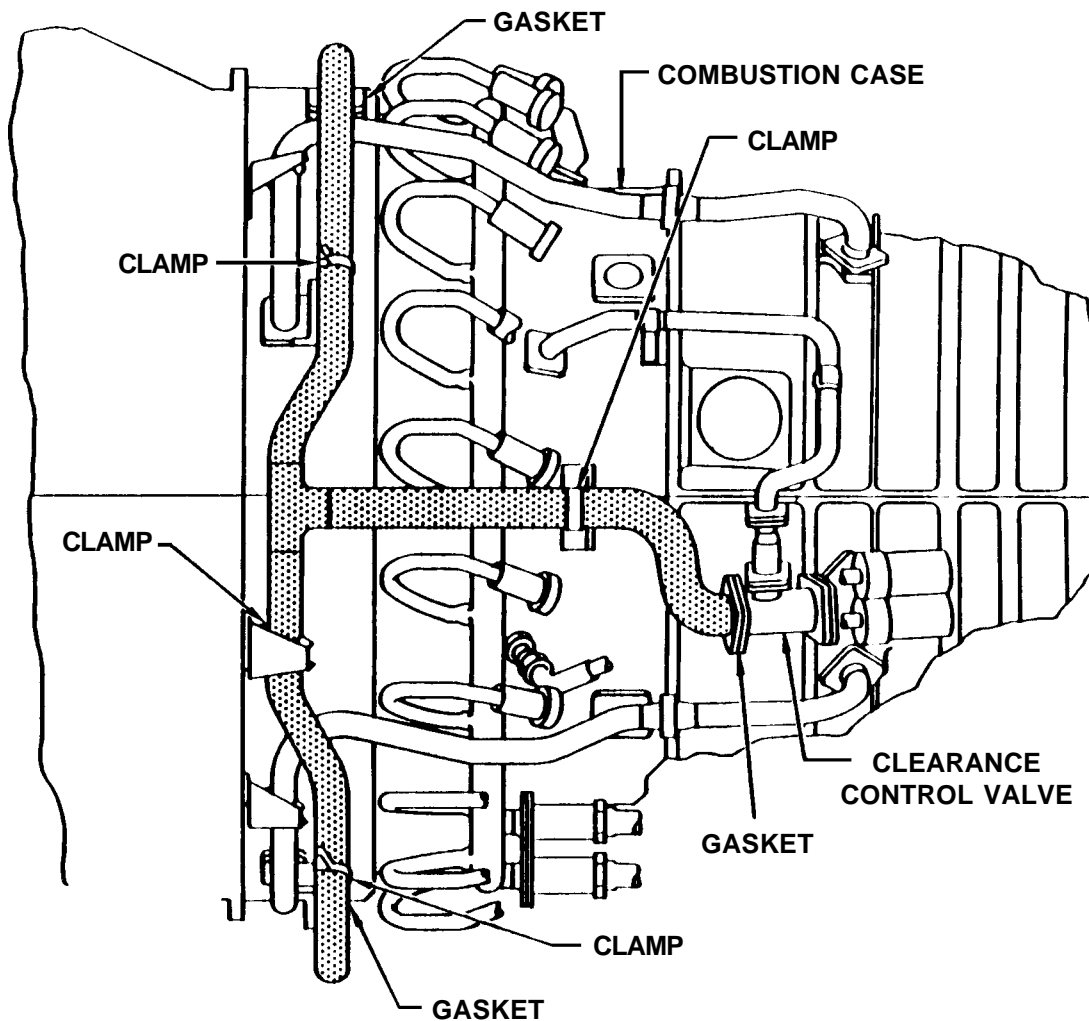
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## HIGH PRESSURE TURBINE SHROUD CLEARANCE CONTROL AIR SUPPLY

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## LPT FIRST STAGE NOZZLE COOLING FLOW PATH

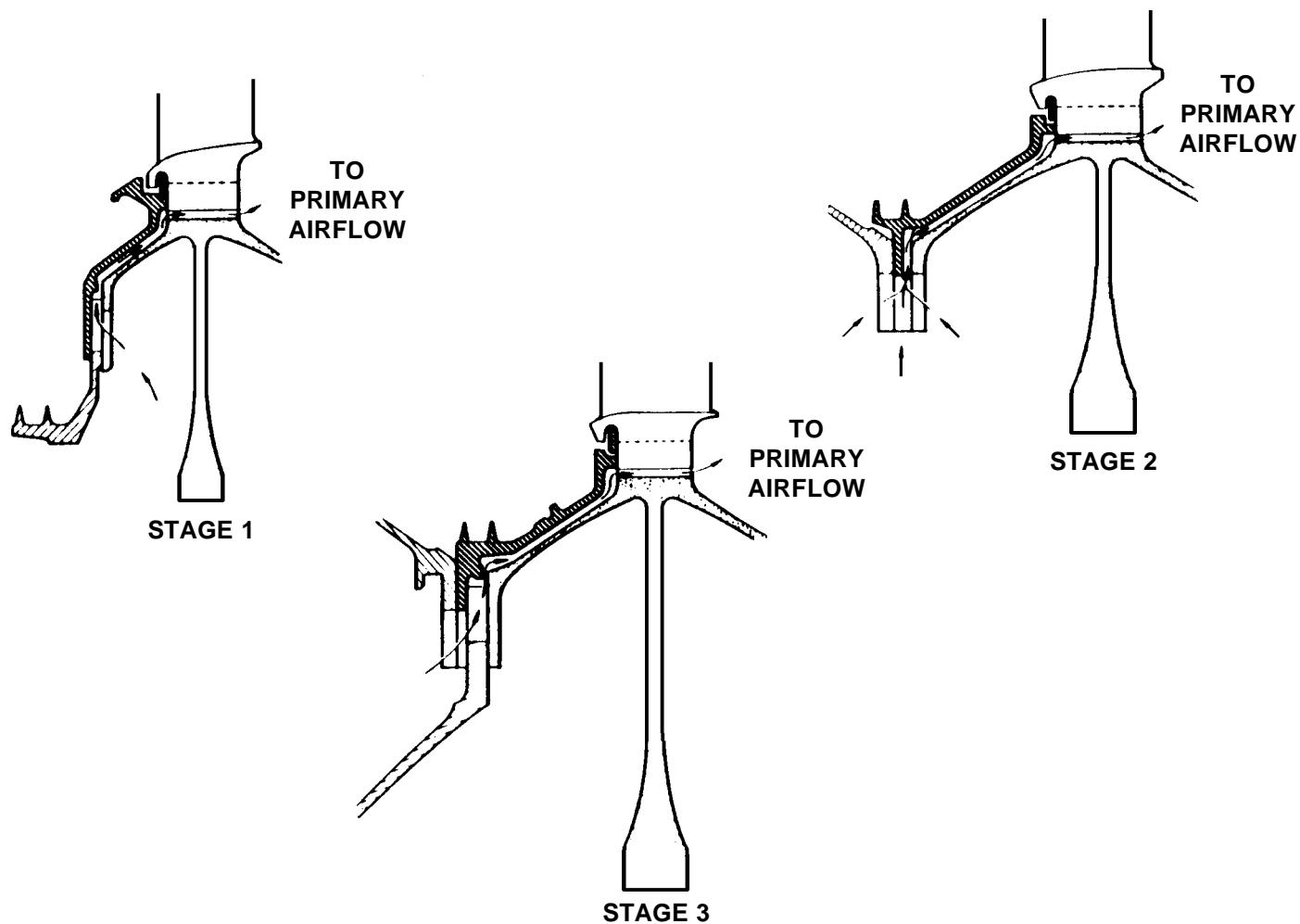
### Identification (1.A.a)

Refer to hot section airflow diagram on page 21 of this section.

### Purpose (1.B.a)

The LPT 1st stage nozzle cooling flow does the following:

- Cools LPT first stage turbine nozzle.
- Cools the aft face of the HPT rotor and the cavity between the HPT and LPT rotors.
- Ventilates and cools the LPT rotor forward cavity.
- Cools LPT rotor rims, dovetails and blade roots of stage 1, 2 and 3.



## LOW PRESSURE TURBINE BLADE COOLING AIRFLOW

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## LPT CASING COOLING FLOW PATH

### **Identification (1.A.a)**

Using discharge secondary air two air scoops on the thrust reverser pick up and direct fan discharge to distributors mounted on LPT case. Distributors provide air to six impingement tubes encircling the turbine case.

### **Purpose (1.B.a)**

Provides impingement cooling on the outer surface of the LPT casing to thermally stabilize the radial dimension and seal clearances (performance). Minimizes radial operating clearances (see CFM56-3 color air flow chart).

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**SEE COLOR AIRFLOW CHART**

## HOT SECTION AIRFLOW PATHWAYS

### Overview

The facing illustration shows three types of airflow within the hot section.

- Turbine Clearance Control (TCC).

Note: For the Turbine Clearance Control (TCC) description refer to air systems section.

- Compressor Discharge Pressure (CDP).
- Stage 5 air extraction.

### Identification (1.A.a)

Air for combustion enters primary and secondary swirl nozzles on the forward end of the combustor.

Cooling air for the combustor enters holes in the inner and outer liners and flows aft along the inner surfaces to provide a film cooling effect. The HPT nozzles are cooled by CDP air that flows past the liners of the combustor. Air entering through the inner platform of the nozzle cools the forward cavity and air entering through the outer platform cools the aft cavity. The cooling air exits through film cooling holes in the nozzle walls. CDP air which flows past the outside diameter of the HPT nozzles cools the HPT shrouds. This air exits to the primary air stream through holes in the shroud.

The inner support for the combustor/HPT nozzle provides air passages and swirl inducer to deliver CDP air through holes in the front seal of the HPT rotor. The air flows to the base of the HPT blades and exits through holes in the blades.

Four external tubes carry the 5th stage air rearward and input it into the cavity surrounding the stage 1 LPT nozzle support. After passing through the nozzles, the air flows out the inner end and enters the chamber behind the HPT disk and the chamber inside the stage 1 and 2 LPT rotor disks. The air will join the primary airstream when it flows underneath the dovetails of the stage 1, 2 and 3 blades.

### Purpose (1.B.a)

CDP is used for combustion and cooling of the combustor, HPT rotor, HPT blades, HPT nozzles and HPT shrouds.

Stage 5 air extraction from the forward manifold of the compressor stator case is used to cool the stage 1 LPT nozzle, HPT disk and LPT stage 1 and 2 disks.

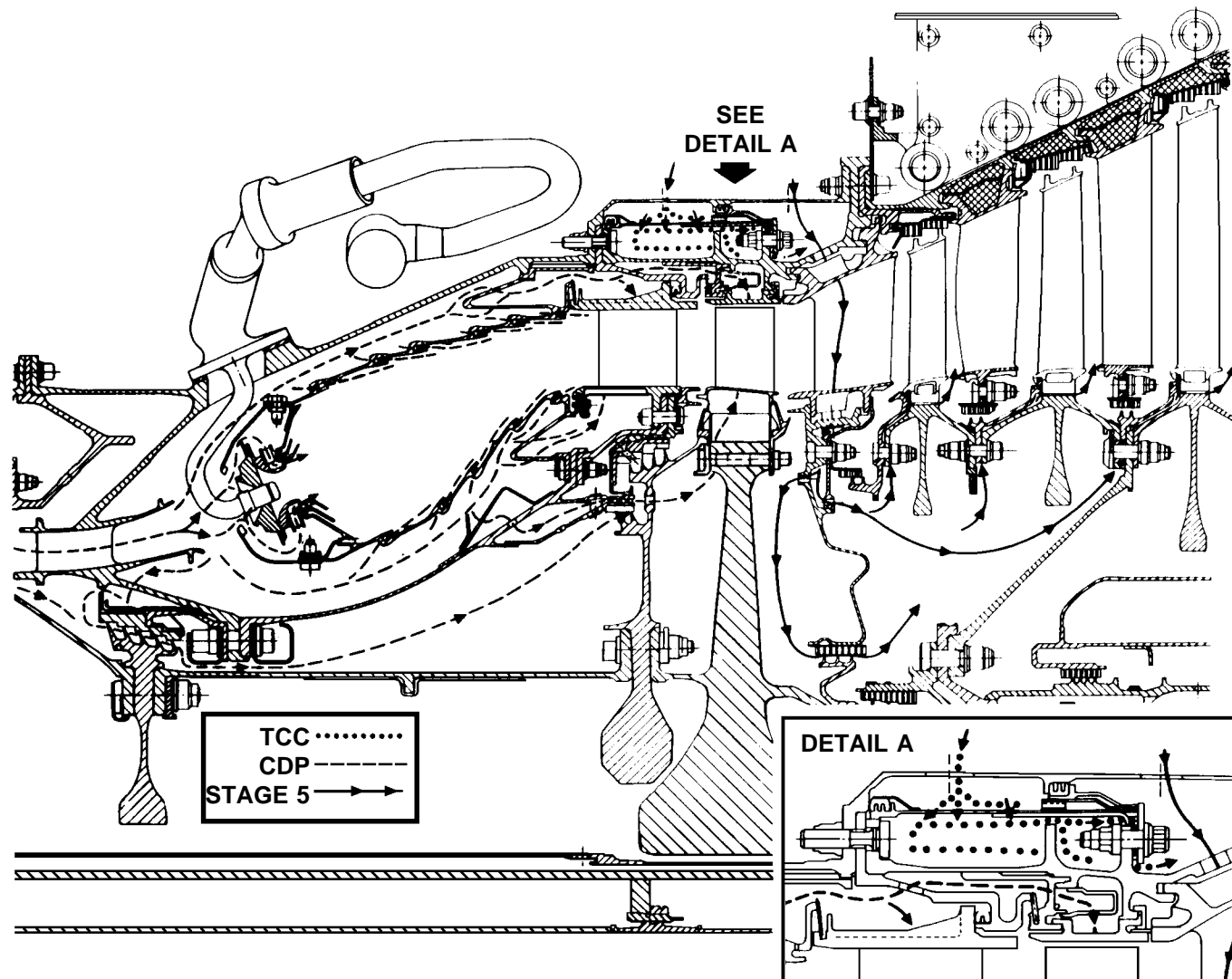
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## HOT SECTION AIRFLOW CIRCUITS

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## FAN MAJOR MODULE

### Objectives:

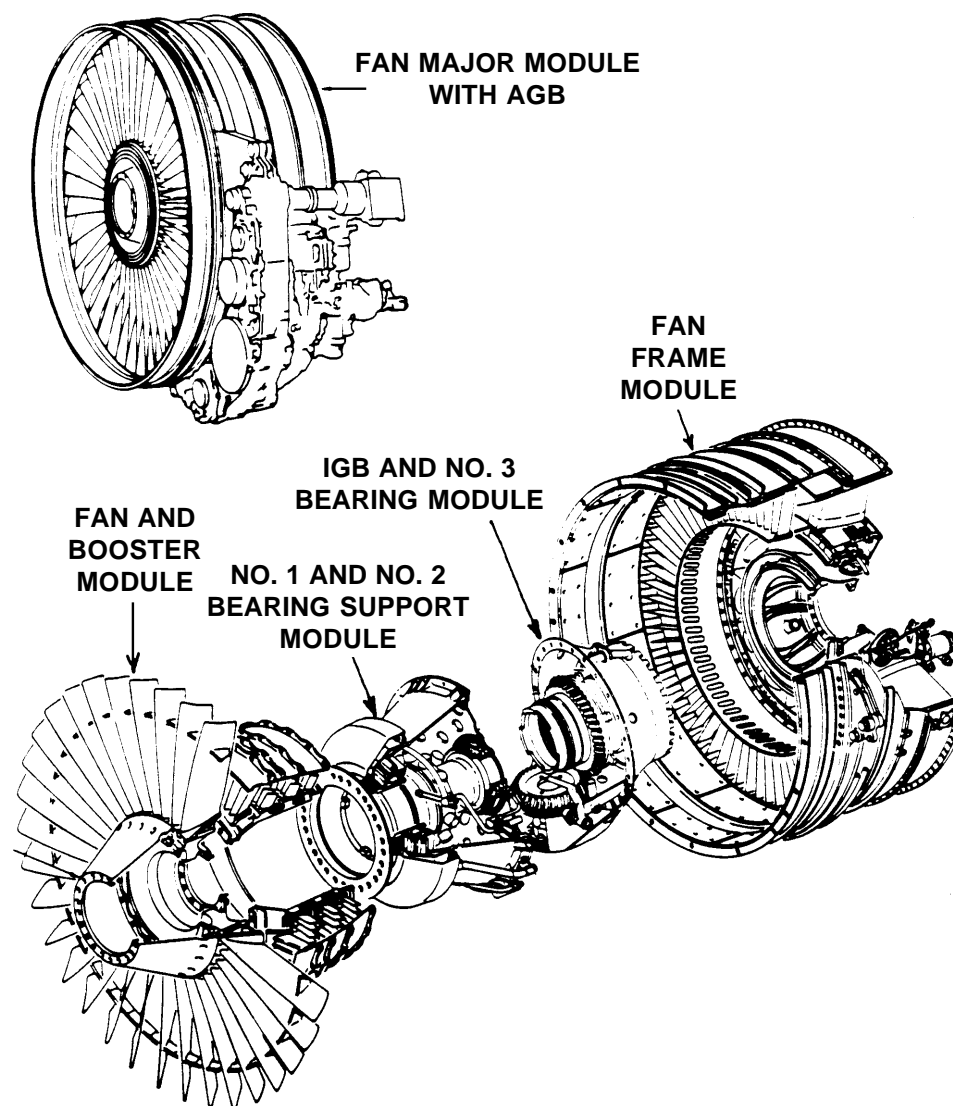
At the completion of this section a student should be able to:

- ....identify the major assemblies of the CFM56-3/3B/3C Fan Major Module (1.A.x).
- ....state the purpose of the major assemblies of the CFM56-3/3B/3C Fan Major Module (1.B.x).
- ....locate the major assemblies of the CFM56-3/3B/3C Fan Major Module (2.A.x).
- ....recall the interfaces of the major assemblies of the CFM56-3/3B/3C Fan Major Module (2.B.x).

**INTRODUCTION****Overview (1.A.a)**

The fan major module consists of the fan rotor, the fan OGV, the booster rotor and stator, the No. 1 and No. 2 bearing support, the IGB and No. 3 bearing support, the fan casing and the fan frame. These combined components form four individual modules:

- Fan and booster module
- No. 1 and No. 2 bearing support module
- IGB and No. 3 bearing module
- Fan frame module



## FAN MODULES

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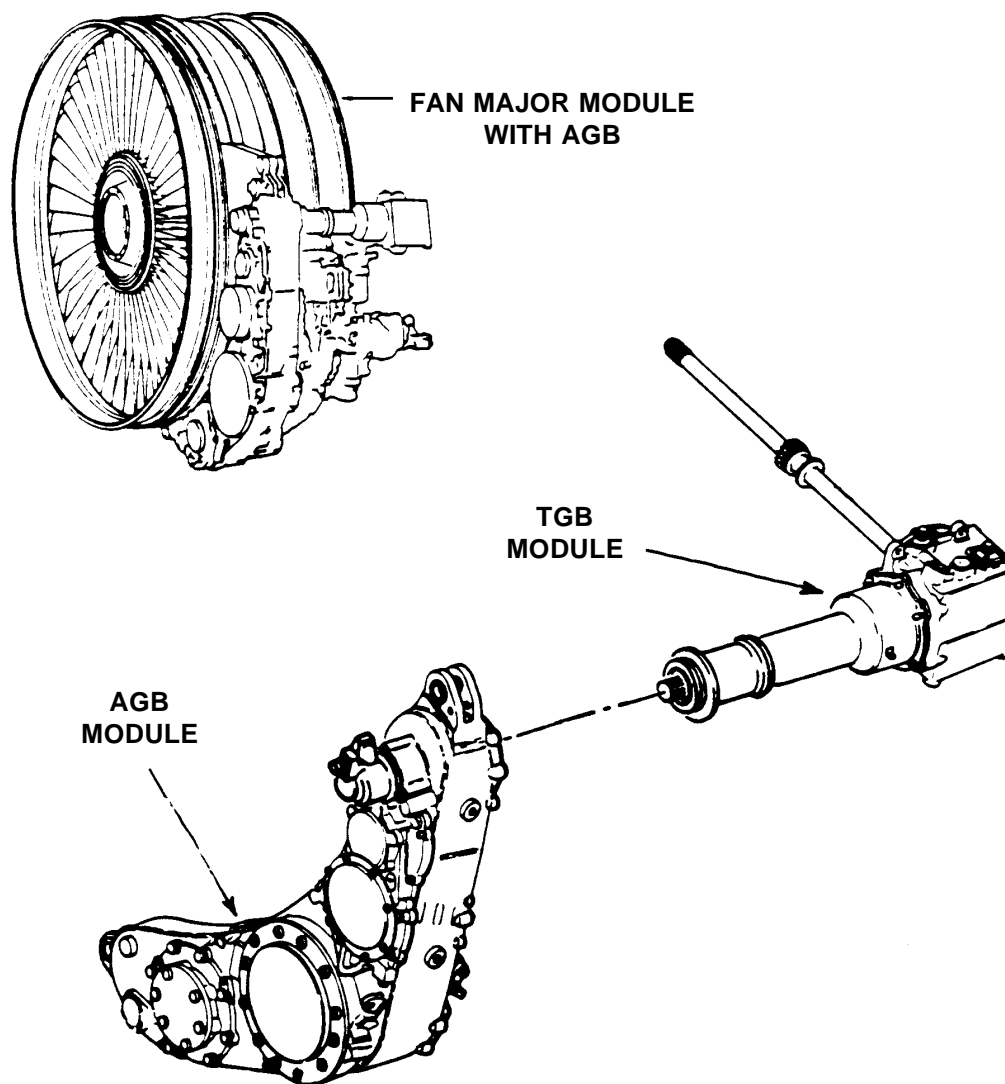
## INTRODUCTION

### Overview (1.A.a)

The accessory and transfer drive consists of the radial driveshaft, the TGB, the horizontal driveshaft and the AGB. These combined components form two individual modules:

- Accessory drive module
  - TGB module
  - AGB module





## ACCESSORY DRIVE MODULES

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## FAN AND LOW PRESSURE BOOSTER ASSEMBLY

### Identification (1.A.b)

The fan and booster module is a single stage fan rotor (38 blades) and a three stage axial flow compressor. A compression stage consists of a compressor rotor stage and is followed by a compressor stator stage. The fan and booster module consists of the following principle parts:

- Spinner front cone
- Spinner rear cone
- Fan disk
- Fan blades (38)
- Low pressure booster vane assembly
- Low pressure booster rotor assembly

### Purpose (1.B.b)

The fan and booster module is driven by the LPT and provides two separate air streams. The primary (or inner) air stream flows through the fan and booster section where the air is compressed for introduction into the HPC. The secondary (or outer) air stream is mechanically compressed by the fan as it enters the engine and is ducted to the outside of the core engine. This secondary air stream adds to the propulsive force

generated by the core engine. The results of the secondary air flow produces approximately 78% of the total engine thrust.

Each rotor stage increases the speed of the air volume moving the mass through each stator vane stage and compressing the air.

### Interface (2.B.b)

The fan and low pressure booster module is bolted to the rear outer flange of the fan disk.

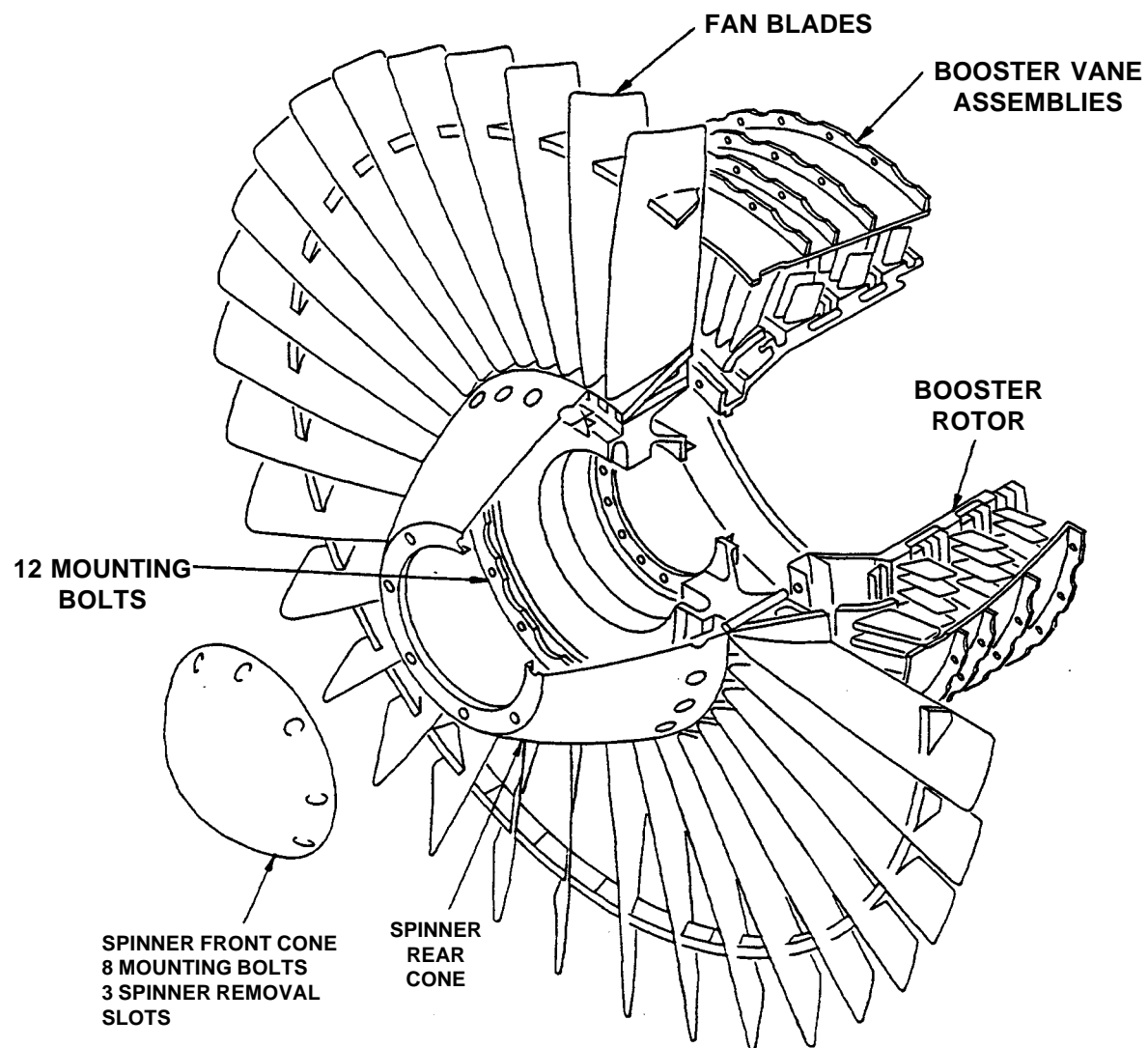
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**FAN AND BOOSTER ASSEMBLY**

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## NO. 1 AND NO. 2 BEARING SUPPORT ASSEMBLY

### Identification (1.A.b)

The "No. 1 and No. 2 bearing support assembly" module consists of the following parts and assemblies:

- Fan shaft
- No. 1 bearing assembly
- No. 1 bearing support assembly
- No. 2 bearing assembly
- No. 2 bearing support
- Oil supply tubes assembly
- External tubing

### Purpose (1.B.b)

The No. 1 and No. 2 bearing support is the foundation for the forward sump.

The No. 1 and No. 2 bearing support assembly maintains the principle method to support the fan and booster rotor assembly. The assembly also functions as the engine forward sump so that it will provide for proper operation of the systems (lubrication, pressurization, scavenge and venting) and coupling of the LPT shaft with the fan shaft.

### Interface (2.B.b)

The No. 1 and No. 2 bearing support assembly is positioned by a rabbeted fit and is mounted to the fan frame. The fan shaft attaches to the fan disk at the front flange and a coupling nut arrangement attaches the LPT shaft at the mid-length inner flange to the fan shaft. Splines of the fan shaft maintain rotational interface.

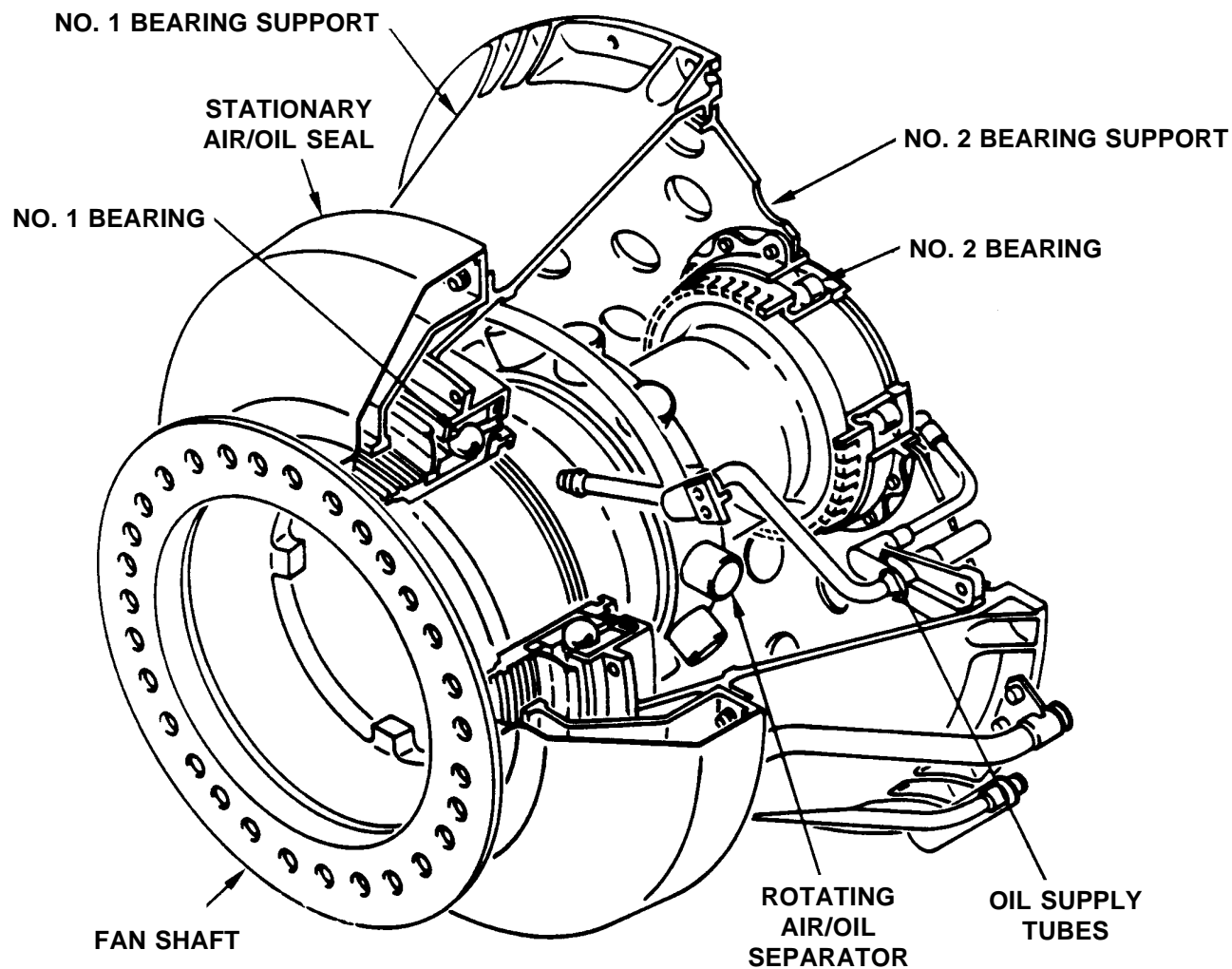
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**NO. 1 AND NO. 2 BEARING SUPPORT ASSEMBLY**

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**INLET GEARBOX AND NO. 3 BEARING SUPPORT****Identification (1.A.b)**

The IGB contains:

- A horizontal bevel gear
- A radial bevel gear
- The core engine thrust (No. 3 ball) bearing

**Purpose (1.B.b)**

The inlet gearbox and No. 3 bearing support serves as the mechanical coupling between the HPC and the TGB. Also, it provides support for the forward end of the core engine.

**Interface (2.B.b)**

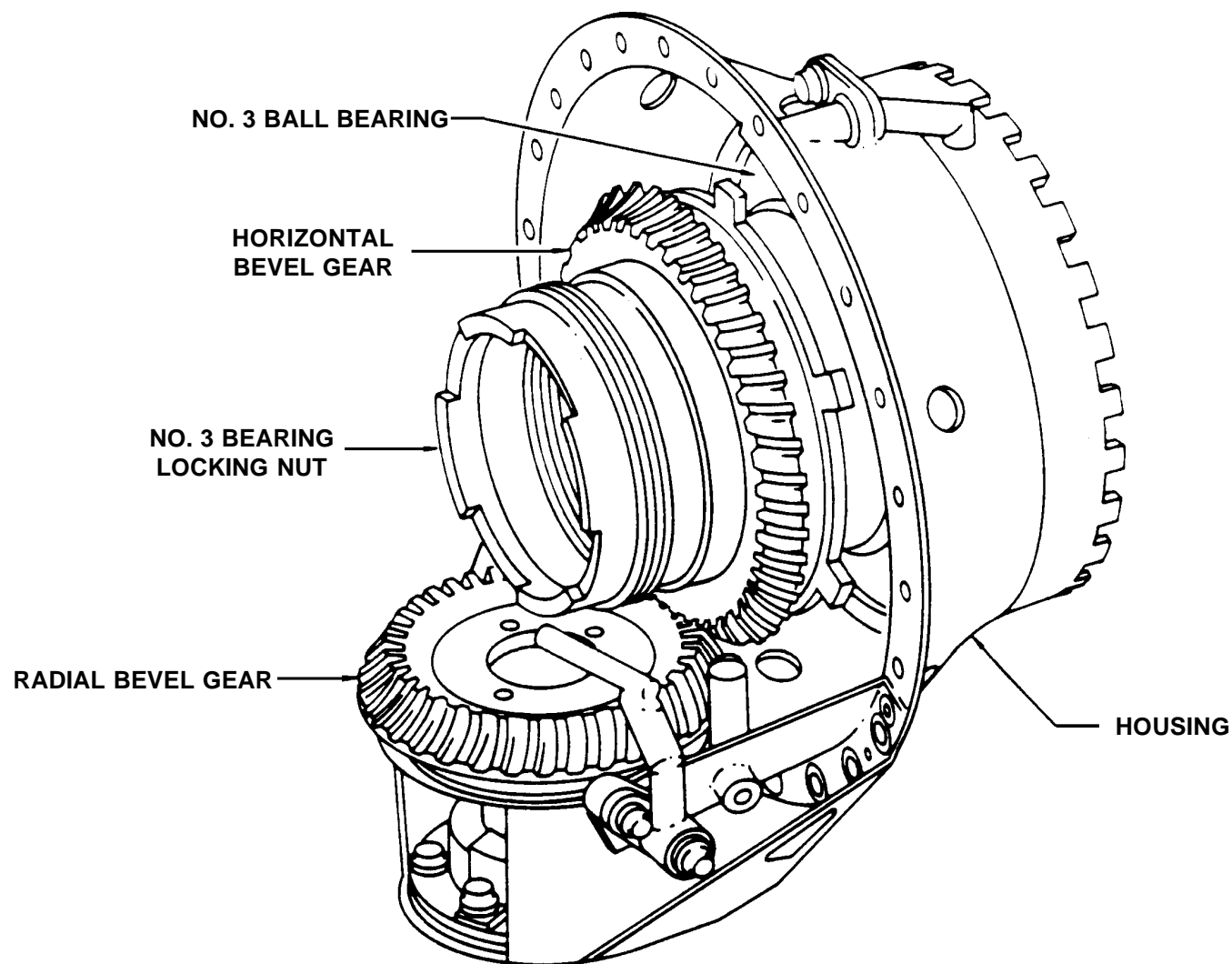
The inlet gearbox and No. 3 bearing support is bolted to the forward side of the fan frame aft flange.

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INLET GEARBOX

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## FAN FRAME ASSEMBLY

### Identification (1.A.b)

The primary airflow to the HPC is ducted in between the center hub outer contour and the mid-box structure inner contour. It houses the VBV system and has provisions for attachment of the engine to the airframe through engine mounts. The secondary airflow is ducted in between the mid-box structure outer contour and the fan case/fan frame inner contour.

The fan frame module consists of the following major parts:

- Fan frame
- Fan inlet case assembly
- Fan OGV assembly
- Tube bundles

### Purpose (1.B.b)

The fan frame is the major structure at the front of the engine. Its main functions are:

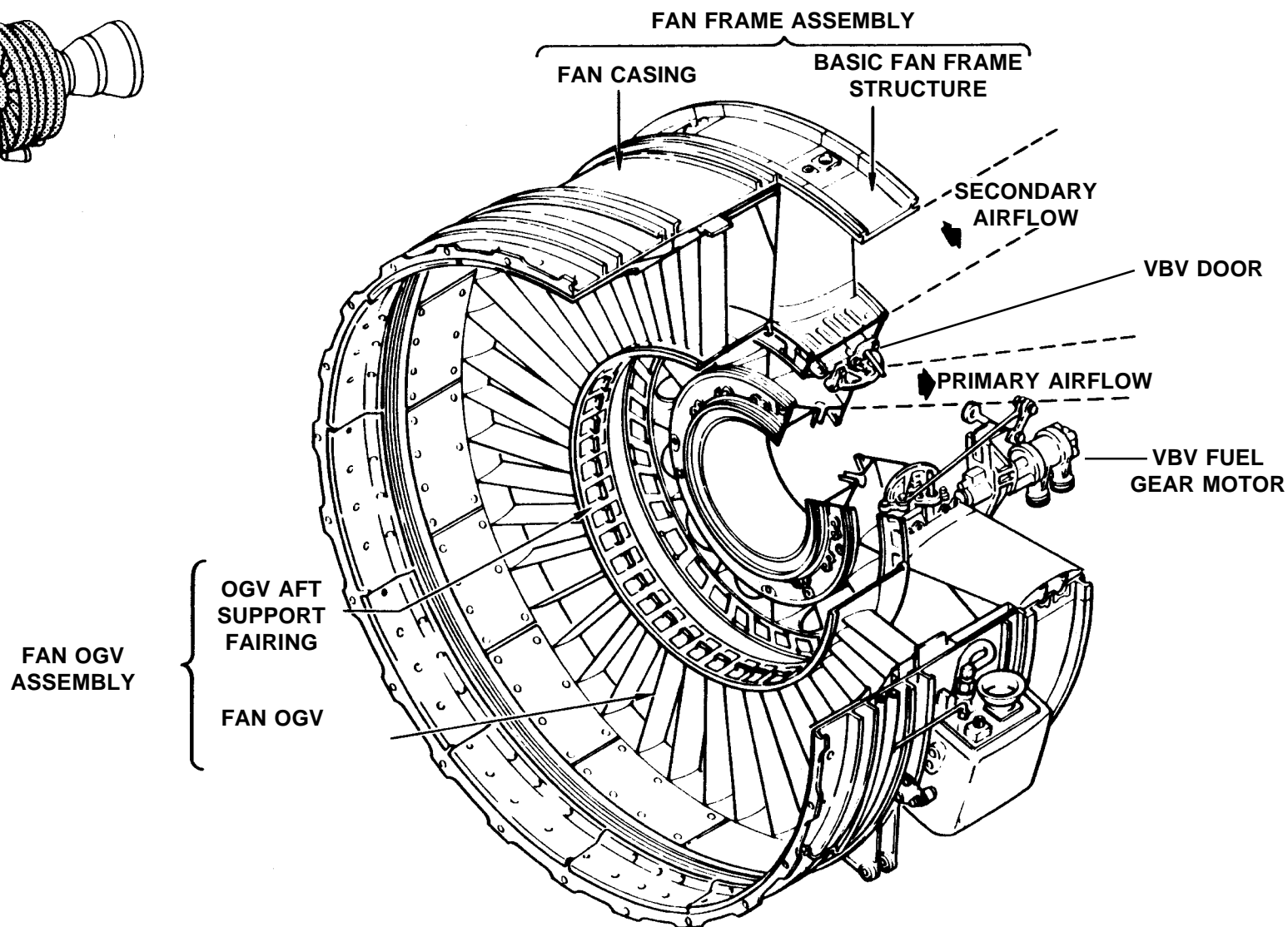
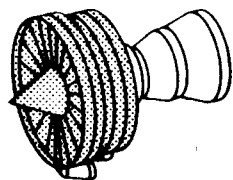
- To support the LPC rotor, through the No. 1 and No. 2 bearing support assembly
- To support the front of the HPC rotor, through the No. 3 bearing support

- To provide ducting for both the primary and the secondary airflows
- To provide attachment for the forward engine mounts, the front handling trunnions and lifting points

### Interface (2.B.b)

The fan frame center hub accommodates the No. 1 and No. 2 bearing support at the front and the IGB/bearing No. 3 assembly at the back. The mid-box structure supports the booster stator assembly at the front and the HPC stator at the back. Center hub, mid-box structure and outer case are linked by struts. The outer structure has provisions for handling points and for installation of equipments.





FAN FRAME MODULE

## FAN FRAME STRUT CONFIGURATION

### Identification (1.A.b)

In the primary air flow path, all twelve struts have a narrow aerodynamic cross section to reduce surface drag to a minimum. In the secondary flowpath, the number of struts has been reduced to eight. The 3, 6, 9, and 12 o'clock struts have a wider cross section. The remaining struts have the same narrow cross section as in the primary airflow struts.

All strut positions are numbered 1 through 12 ALF, (No. 1 strut is in the 12 o'clock position). All 12 struts are hollow and some contain lines, sensors, or shafts.

Within strut No. 4 is the forward sump vent line to balance all internal sump pressures. Also, within the primary airflow path at the mid-box structure, is the No. 1 bearing vibration electrical sensor cable connecting to the accelerometer at the 9 o'clock position on the outside of the No. 1 bearing support.

Strut No. 5 contains a housing for the N1 speed sensor. The housing is bolted to the outer diameter of the fan frame and extends to the center hub.

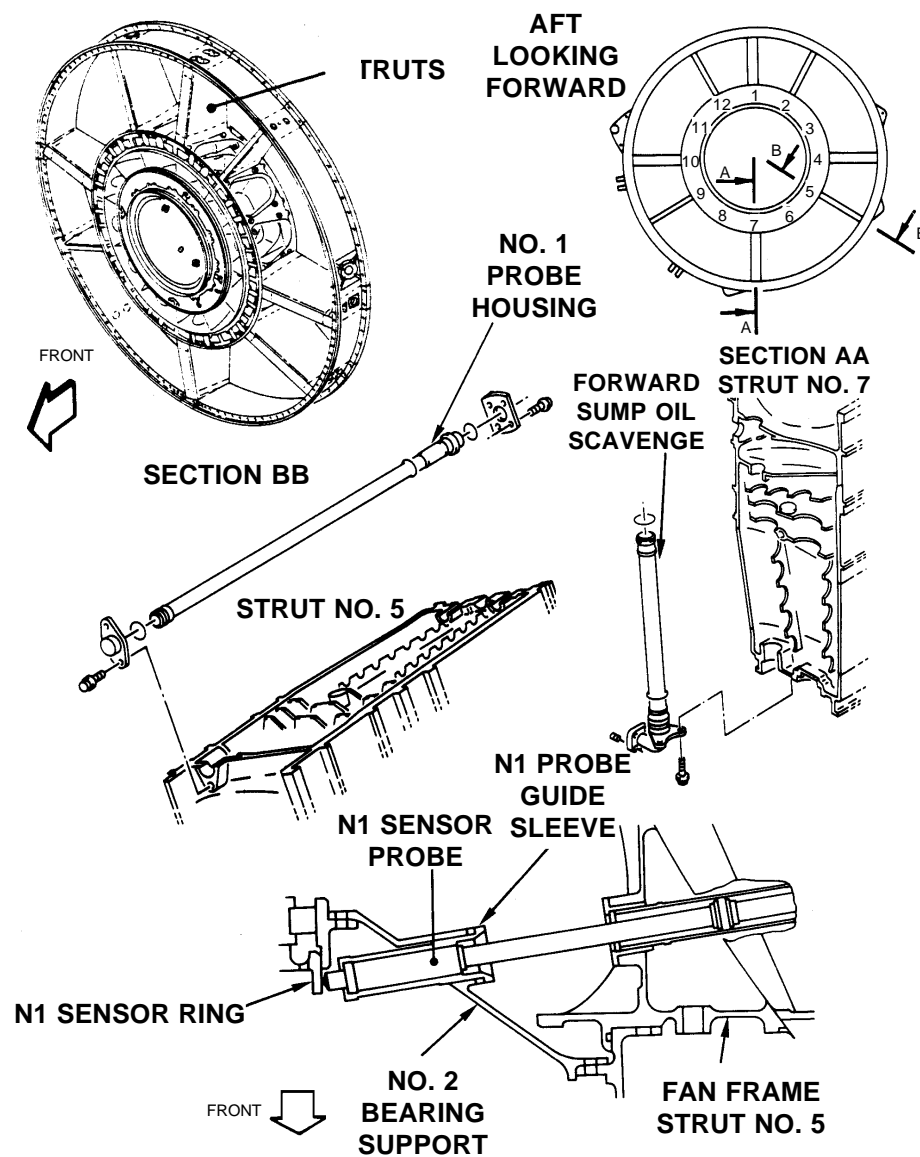
Strut No. 7 contains the forward sump oil scavenge line. It extends from a compartment provided in the center hub to the outer diameter of the fan frame where it is bolted.

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## FAN FRAME STRUTS NO. 5 AND NO. 7

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## FFAN FRAME STRUT CONFIGURATION

### Identification

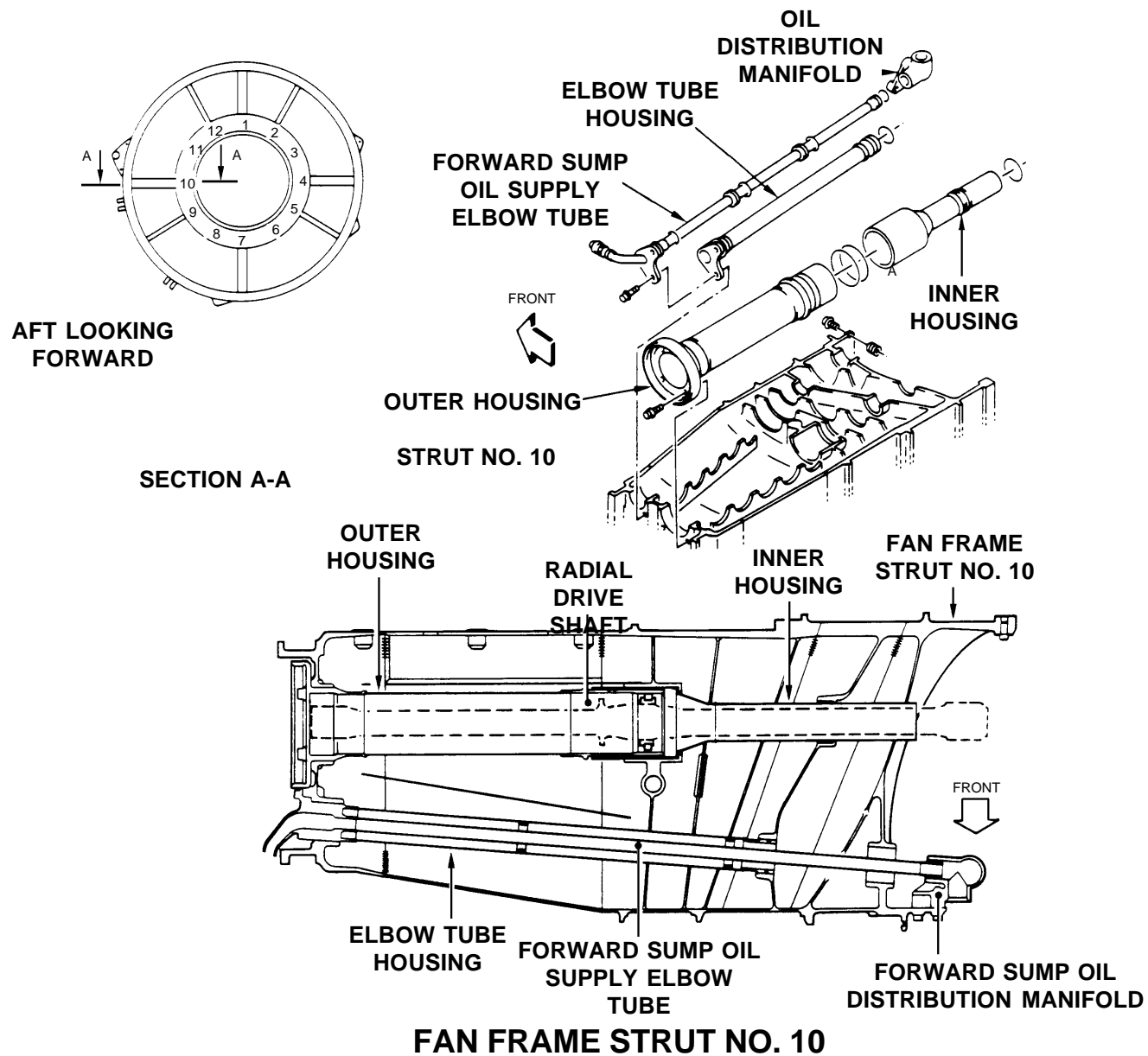
Strut No. 9 contains the cavity drain for the forward sump air/oil seals to the overboard drain system.

Strut No. 10 contains both the forward sump oil supply line and the TGB radial drive shaft housing. The oil supply line provides lubrication to the bearings.

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**TUBE BUNDLE CONFIGURATION****Identification (1.A.b)**

Three junction box structures are mounted to the midbox structure of the fan frame.

**Purpose (1.B.b)**

These junction boxes are designed to isolate tube connections from the core engine compartment.

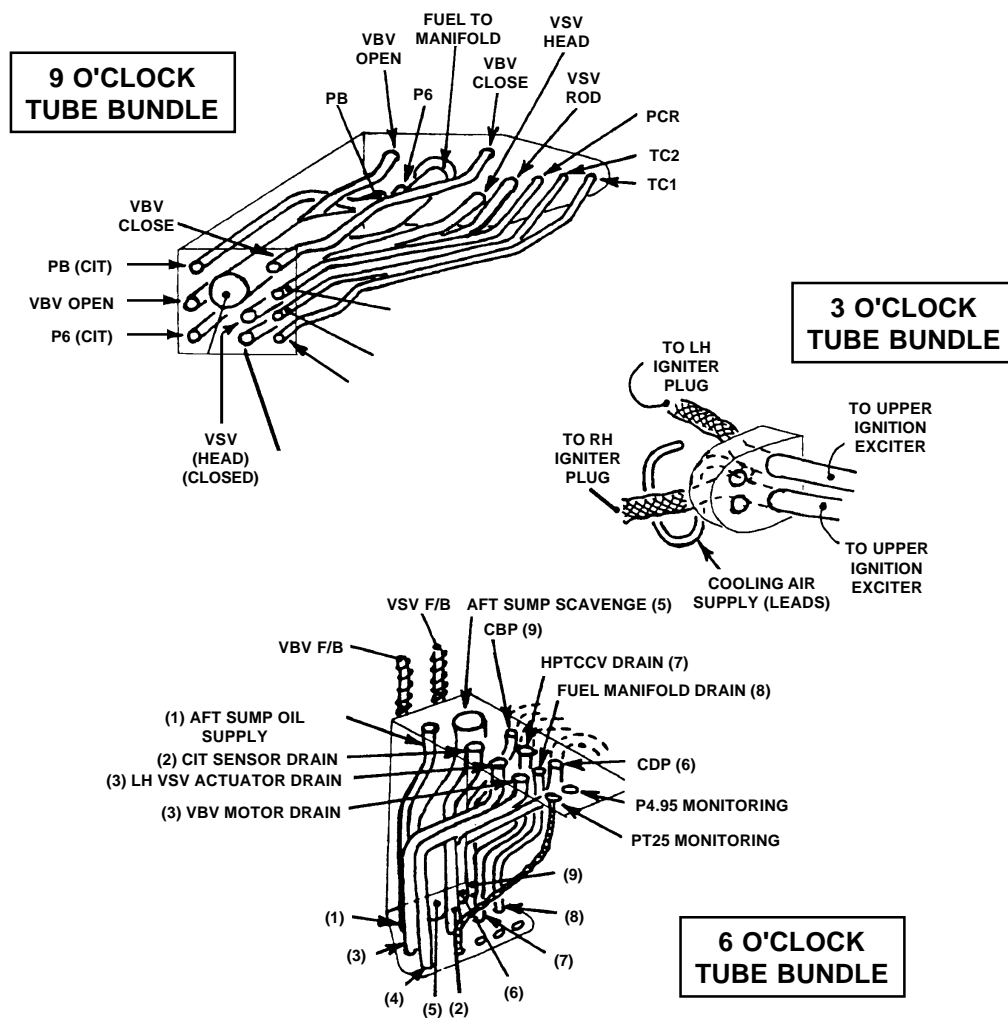
**Location (2.A.b)**

The tube bundles are located at the 3, 6 and 9 o'clock positions/ALF.

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## TUBE BUNDLES

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## ACCESSORY DRIVE SECTION

### Identification (1.A.b)

The Accessory Drive Section contains:

- The Accessory Gearbox.
- The Transfer Gearbox.

### Purpose (1.B.b)

The main functions of the accessory drive section are:

- To provide power to the gearbox mounted accessories
- To adapt rotational speed to the requirements of each individual equipment
- To convey torque from the starter to the HP rotor during engine start
- To provide for handcranking of the HP rotor during borescope inspection or maintenance tasks

### Location (2.A.b)

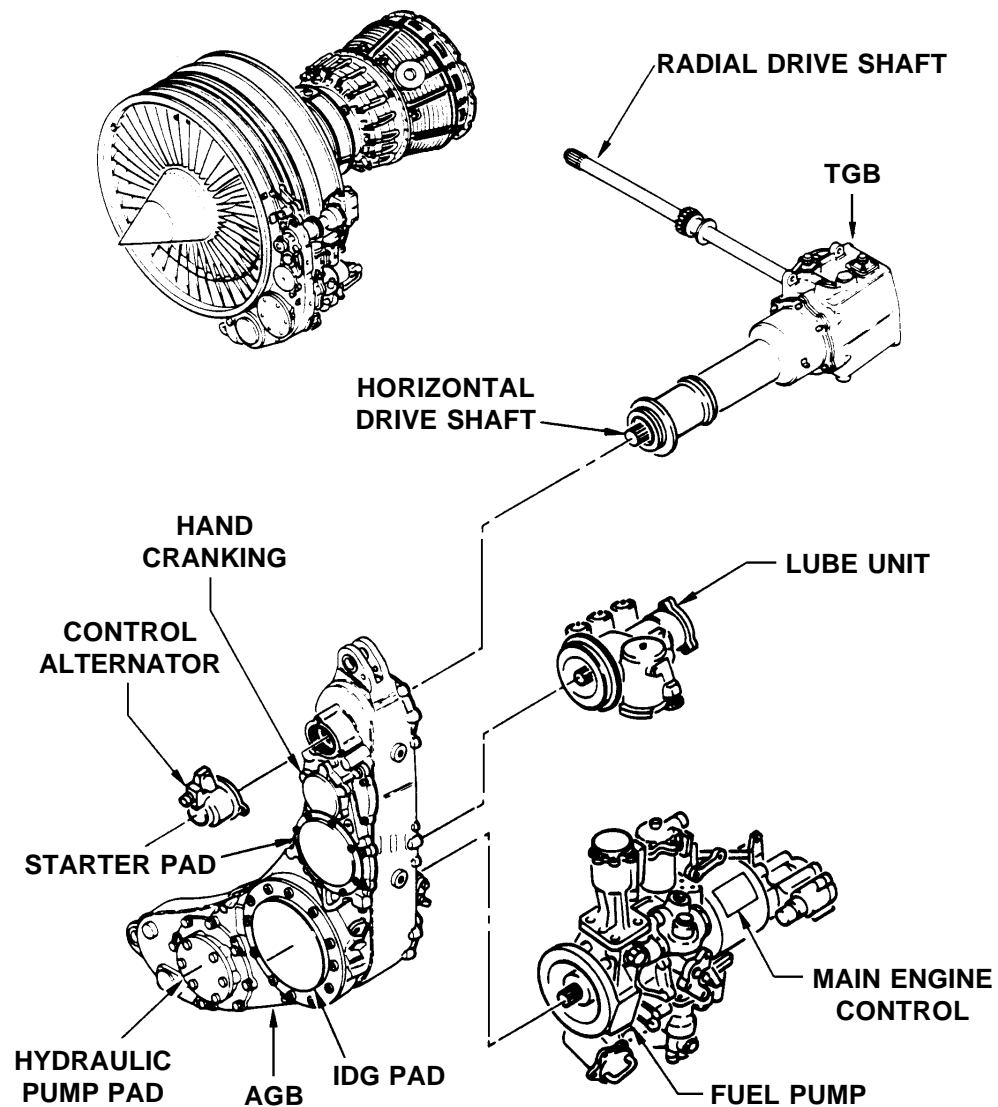
The AGB and TGB are located at approximately the 7:30 to 9 o'clock positions.

### Interface (2.B.b)

The AGB is mounted to the fan frame and the TGB to the fan case. Drive power is extracted from the HPC rotor

through the IGB. A radial drive shaft (RDS) conveys this drive power (torque) to the TGB installed on the left-hand side of the fan frame. The TGB then redirects torque to a housing drive shaft (HDS). The HDS links the TGB with the AGB attached to the fan inlet case. The AGB mounting pads accommodate all accessories.





### ACCESSORY DRIVE SECTION

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## CORE MAJOR MODULE

### Objectives:

At the completion of this section a student should be able to:

- ....identify the major assemblies of the CFM56-3/3B/3C Core Major Module (1.A.x).
- ....state the purpose of the major assemblies of the CFM56-3/3B/3C Core Major Module (1.B.x).
- ....locate the major assemblies of the CFM56-3/3B/3C Core Major Module (2.A.x).
- ....recall the interfaces of the major assemblies of the CFM56-3/3B/3C Core Major Module (2.B.x).

**INTRODUCTION****Overview (1.A.b)**

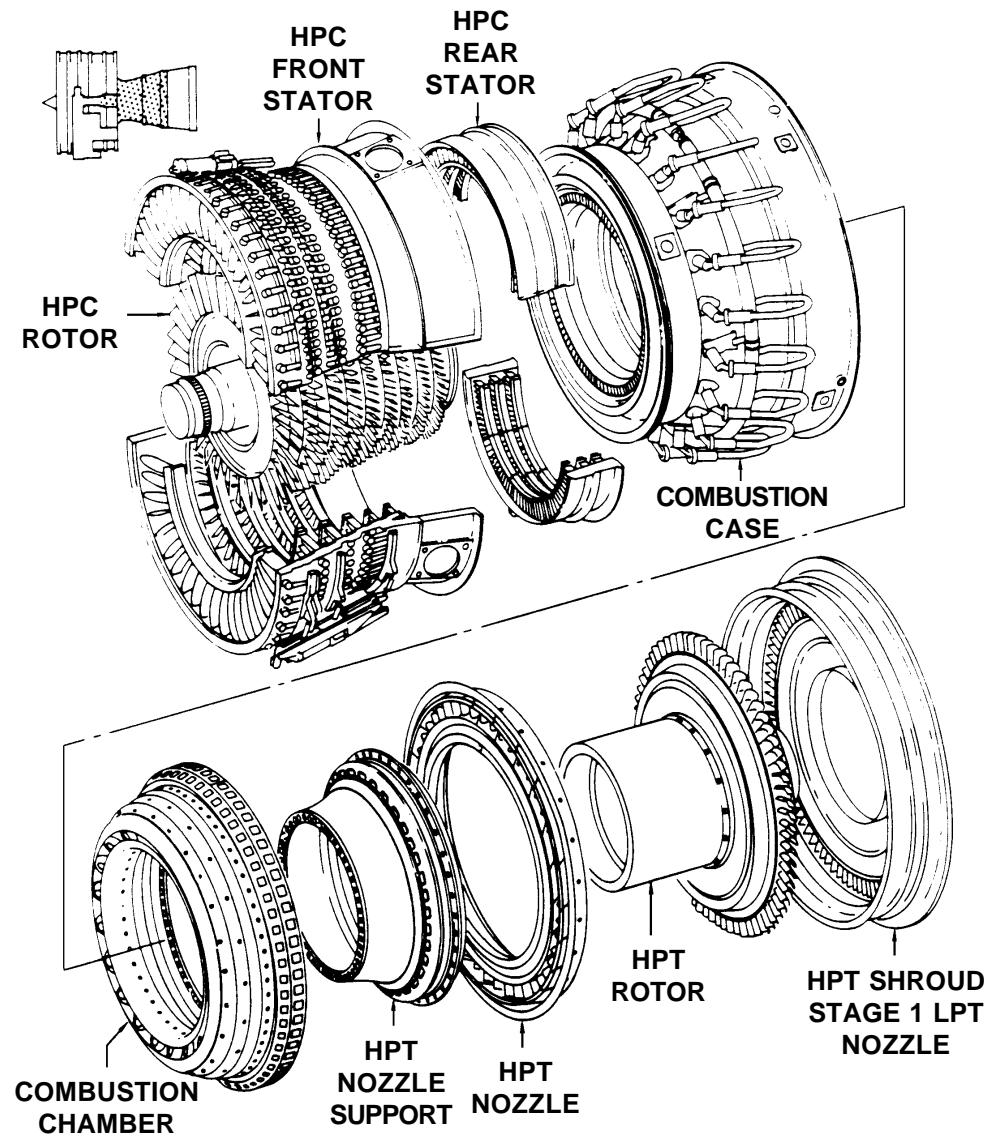
The core major module consists of the rotor and stator assemblies, the combustion casing and chamber, the HPT nozzle and rotor assemblies and the HPT shroud and stage 1 LPT nozzle assembly. These combined components form eight individual modules:

- HPC rotor module
- HPC forward stator module
- HPC rear stator module
- Combustion casing module
- Combustion chamber module
- HPT nozzle module
- HPT rotor module
- HPT shroud and stage 1 LPT nozzle module

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## CORE ENGINE COMPONENTS

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## HIGH PRESSURE COMPRESSOR

### Purpose (1.B.b)

The compressor section provides compressor air for combustion and bleed air from stages 5 and 9 for engine and aircraft use.

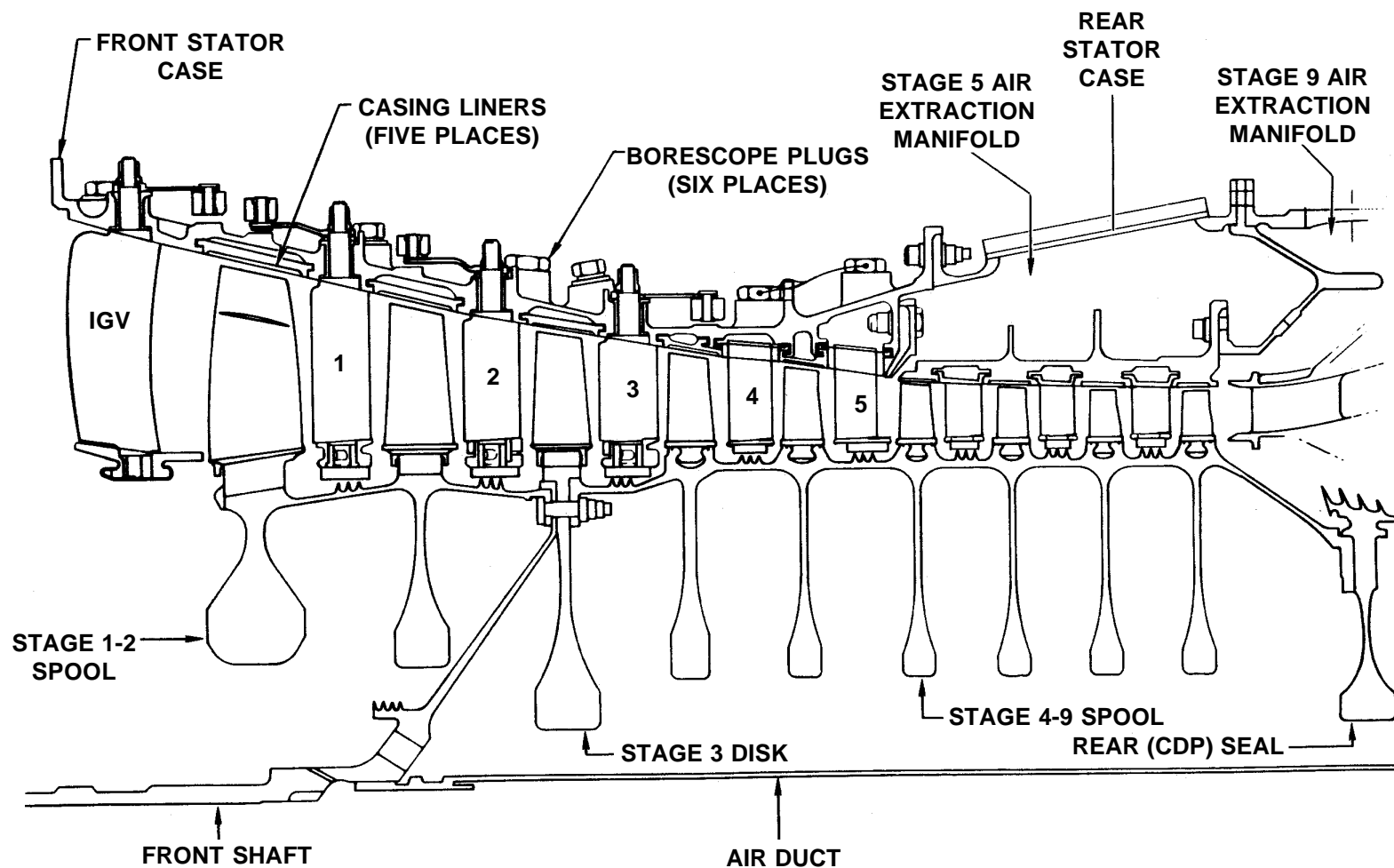
Fifth stage air is extracted through bleed manifold segments just aft of the stage 5 stator and is directed into forward and aft air extraction manifolds. The forward manifold provides air for turbine clearance control and stage 1 LPT nozzle cooling. The aft manifold provides a bleed source for aircraft use. Ninth stage air is extracted through a gap between the rear stator case and combustion case (just aft of stage 9 rotor). Stage 9 manifold provides the aircraft with the high pressure source of bleed air.

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## HIGH PRESSURE COMPRESSOR SECTION

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**HIGH PRESSURE COMPRESSOR ROTOR****Identification (1.A.b)**

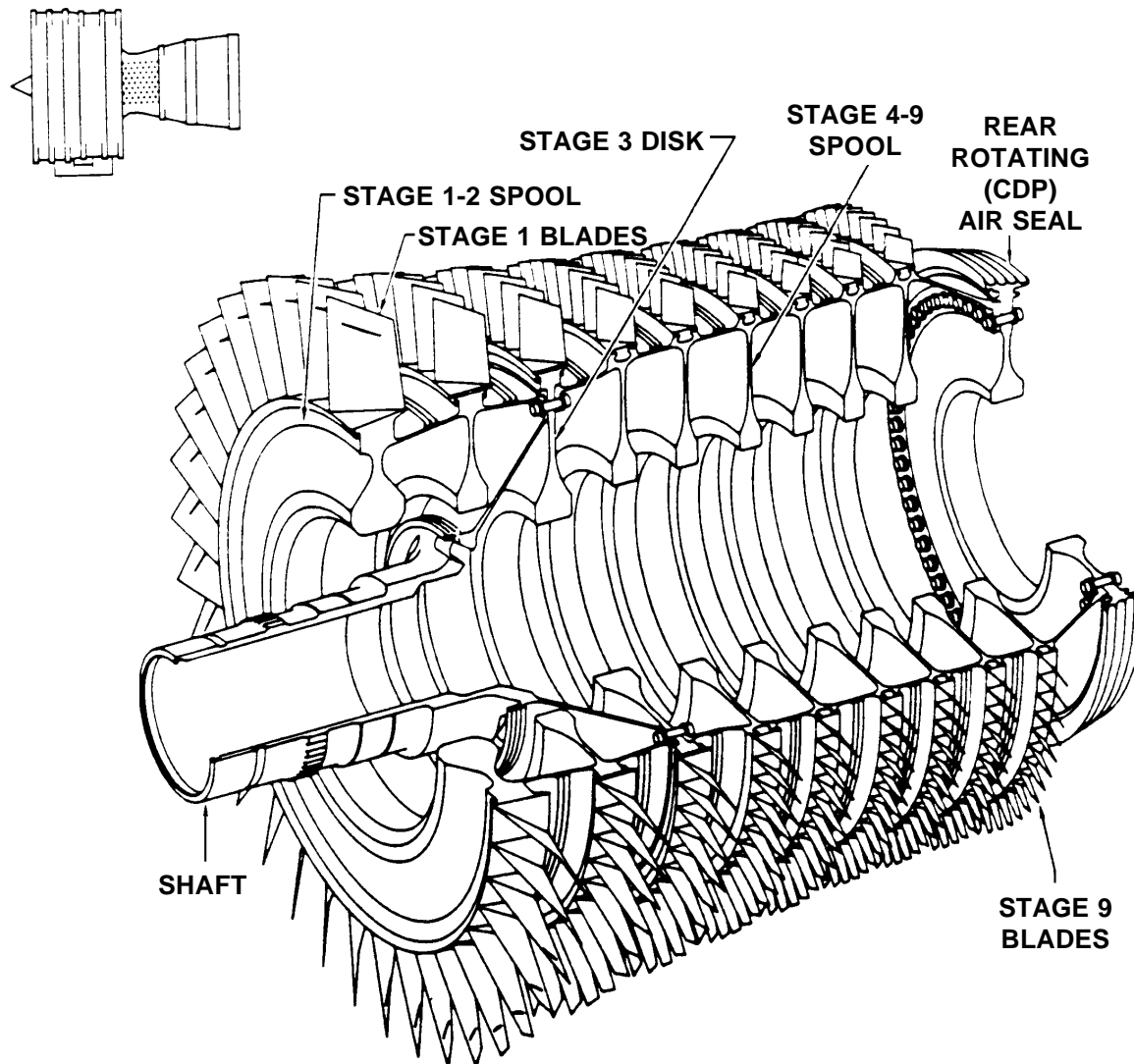
The HPC rotor is a nine stage, high speed, unitized spool-disk structure. The rotor consists of five major parts:

- the front shaft.
- the 1st and 2nd stage spool.
- the 3rd stage disk.
- the 4th through 9th stage spool.
- the compressor rear seal.

**Interface (2.B.b)**

The front shaft, disk and spools are joined at a single bolted joint to form a smooth, rigid unit.





**HIGH PRESSURE COMPRESSOR ROTOR**

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## HPC FRONT STATOR

### Identification (1.A.b)

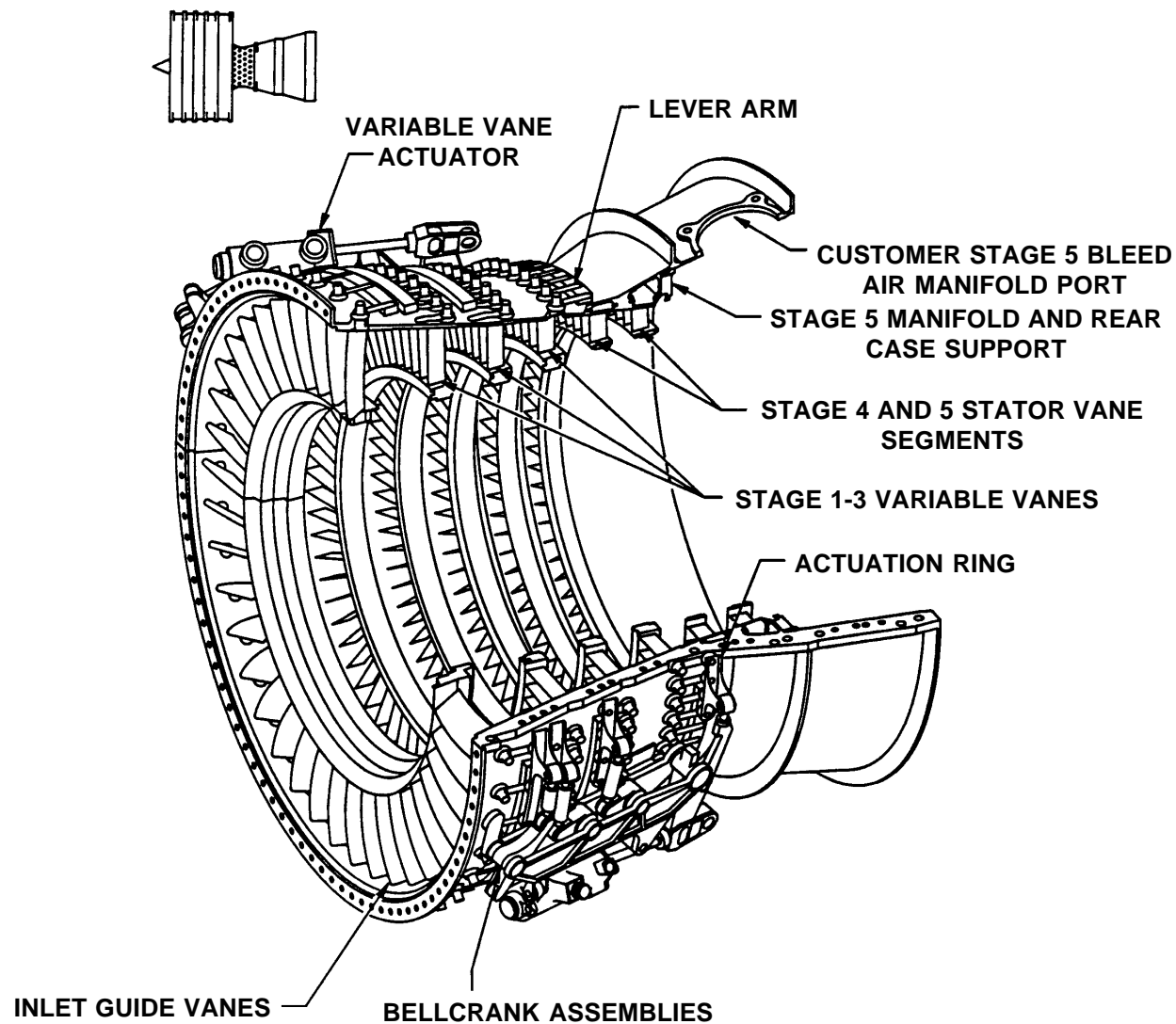
The HPC front stator, consists of:

- front casing halves.
- extension casing halves.
- IGV's
- first five stages of stator vanes.

The IGV's and the 1st through 3rd stage vanes are variable, the 4th and 5th stage vanes are fixed.

### Location (2.A.b)

Actuation of the variable vanes is accomplished with hydraulically actuated bellcrank assemblies mounted on the front compressor stator at the 1:30 and 7:30 o'clock positions.



## HIGH PRESSURE COMPRESSOR FRONT STATOR ASSEMBLY

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## HPC REAR STATOR

### Identification (1.A.b)

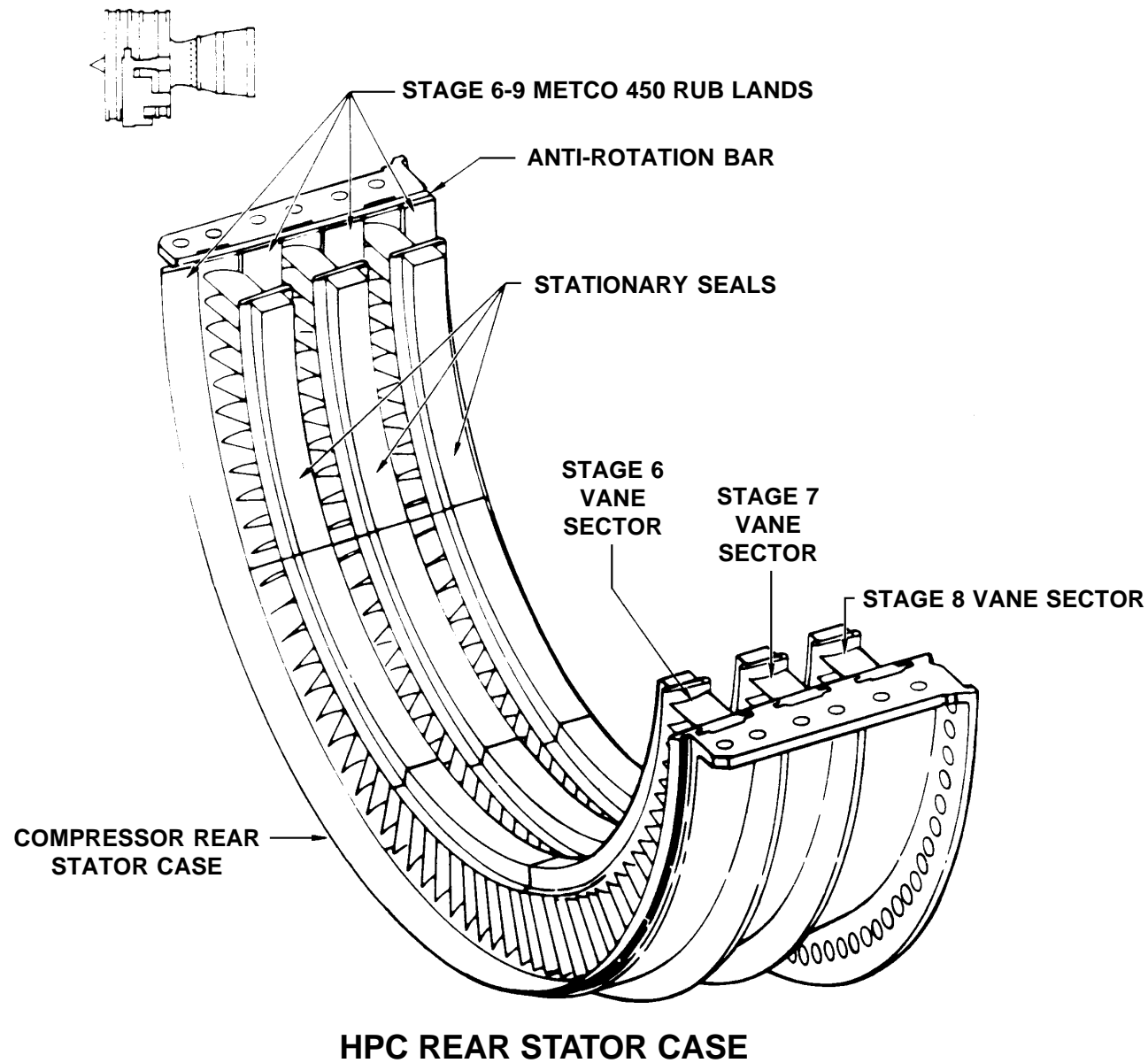
The HPC rear stator consists of: rear casing halves, liners, three stages of fixed vanes, and vane shrouds.

### Location (2.A.b)

The rear stator is located inside the front stator extension case.

### Interface (2.B.b)

It is cantilever-mounted to the rear stator support. The rear stator support outer flange is mounted between the compressor front stator extension and the combustion case.



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## COMBUSTION CASE

### Identification (1.A.b)

The combustion case is a fabricated structural weldment it incorporates compressor OGV's and a diffuser for the reduction of combustion chamber sensitivity to the compressor air velocity profile. It includes six borescope ports: four for inspection of the combustion chamber and two for inspection of the HPT nozzle.

### Purpose (1.B.b)

It provides structural interface, transmits engine axial loads, and provides a gas flow path between the compressor and the LPT.

### Location (2.A.b)

The combustion case is located between the HPC and the LPT.

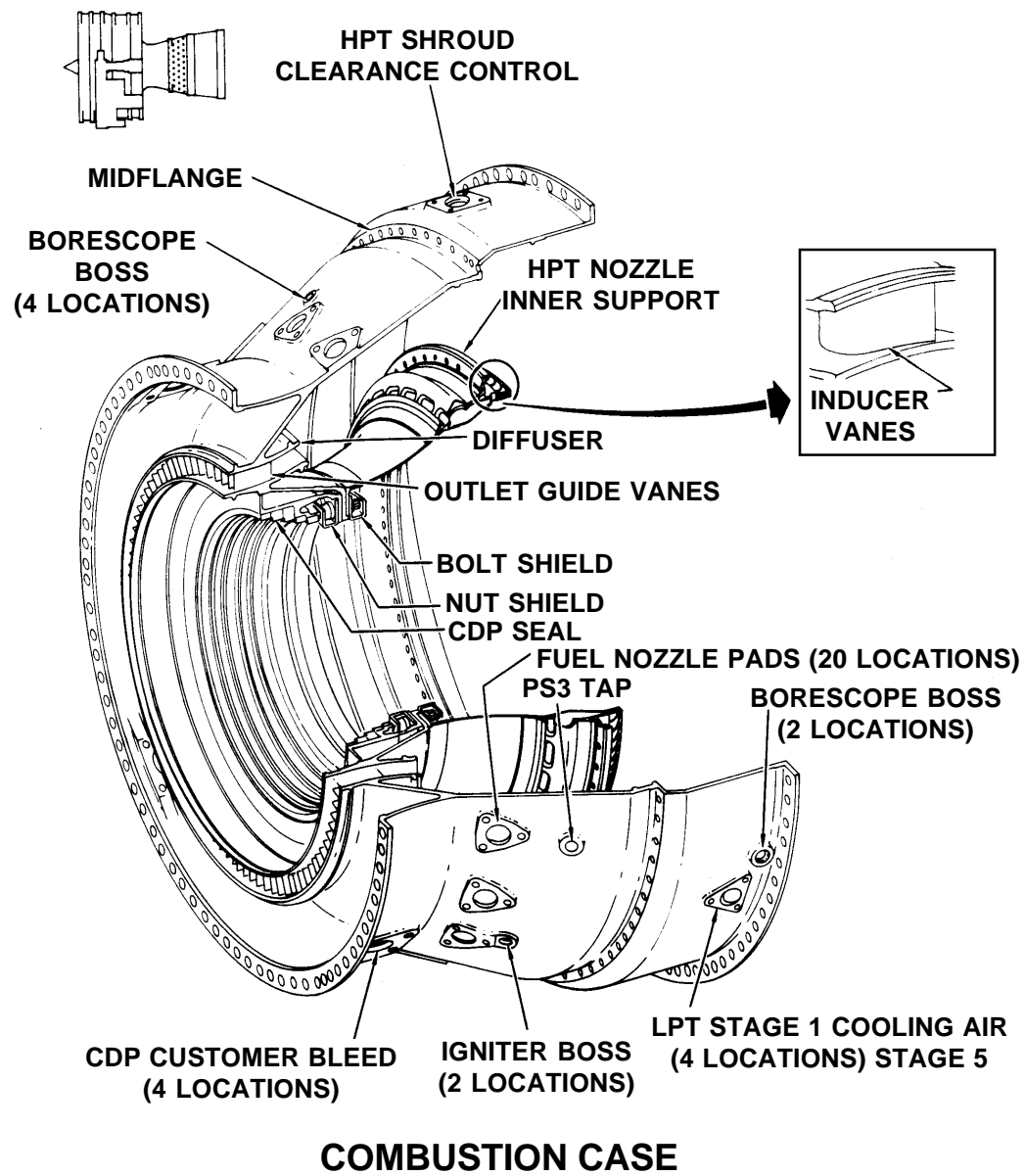
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## COMBUSTION CHAMBER

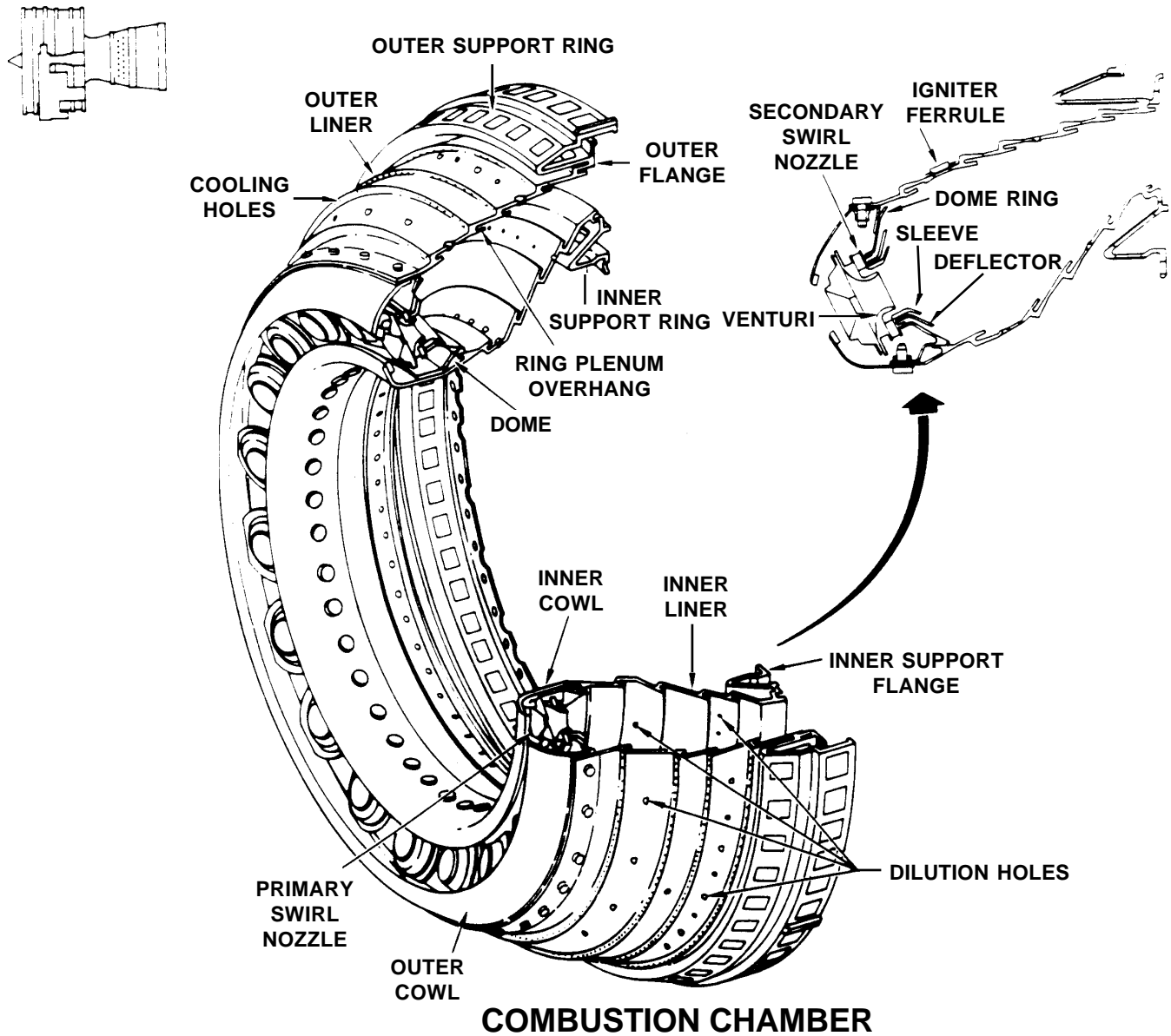
### Identification (1.A.b)

The combustion chamber consists of outer and inner cowls, 20 primary and 20 secondary swirl nozzles, dome, and outer and inner liners.

### Location (2.A.b)

The combustion chamber is contained within the combustion case.





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## HIGH PRESSURE TURBINE NOZZLE

### Identification (1.A.b)

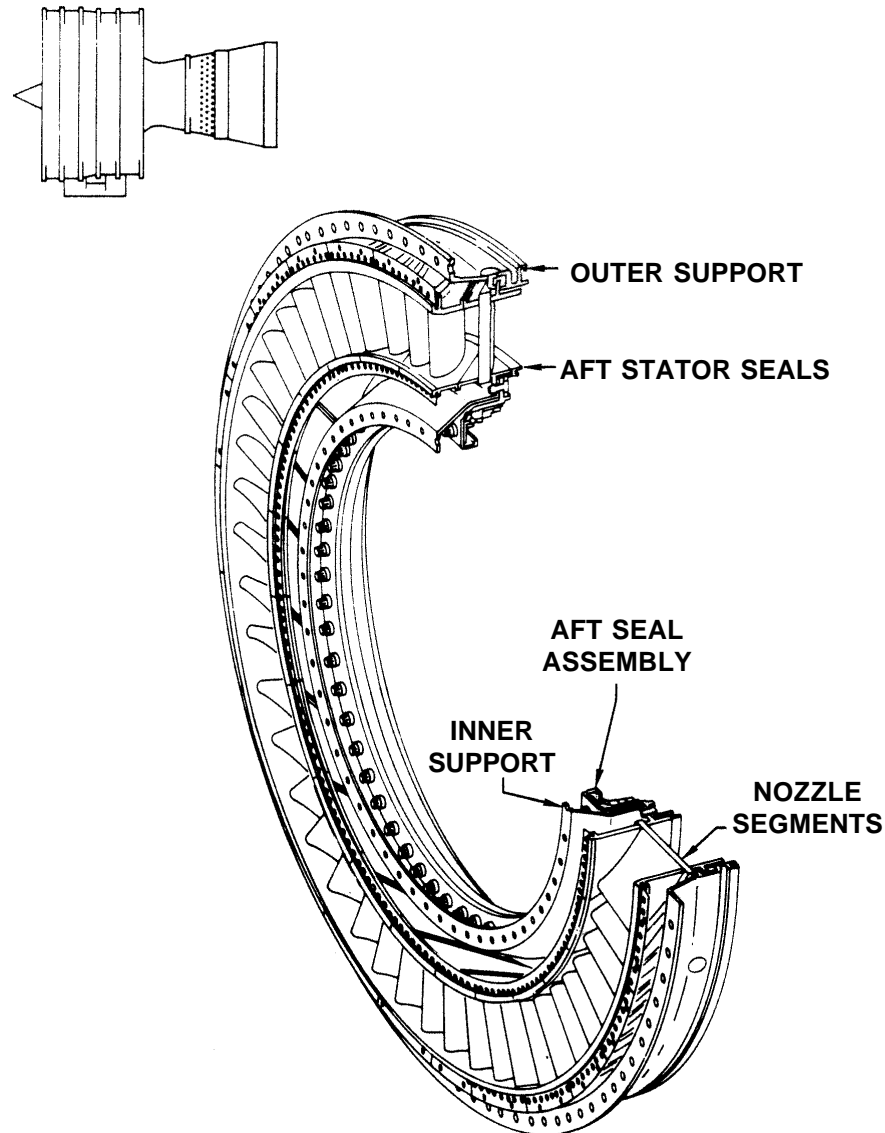
The major parts of the nozzle are 23 nozzle segments, outer support, and inner support.

### Purpose (1.B.b)

The high pressure turbine (HPT) nozzle is a single-stage air cooled assembly that directs the gas flow from the combustion chamber onto the blades of the HPT rotor at the optimum angle.

### Interface (2.B.b)

The high pressure turbine (HPT) nozzle mounts in the combustion case. The aft support and seal assembly and the aft stator seals, while not integral components of the HPT nozzle module are included since they attach to the HPT stator parts.



**HIGH PRESSURE TURBINE STATOR**

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## HIGH PRESSURE TURBINE ROTOR

### **Identification (1.A.b)**

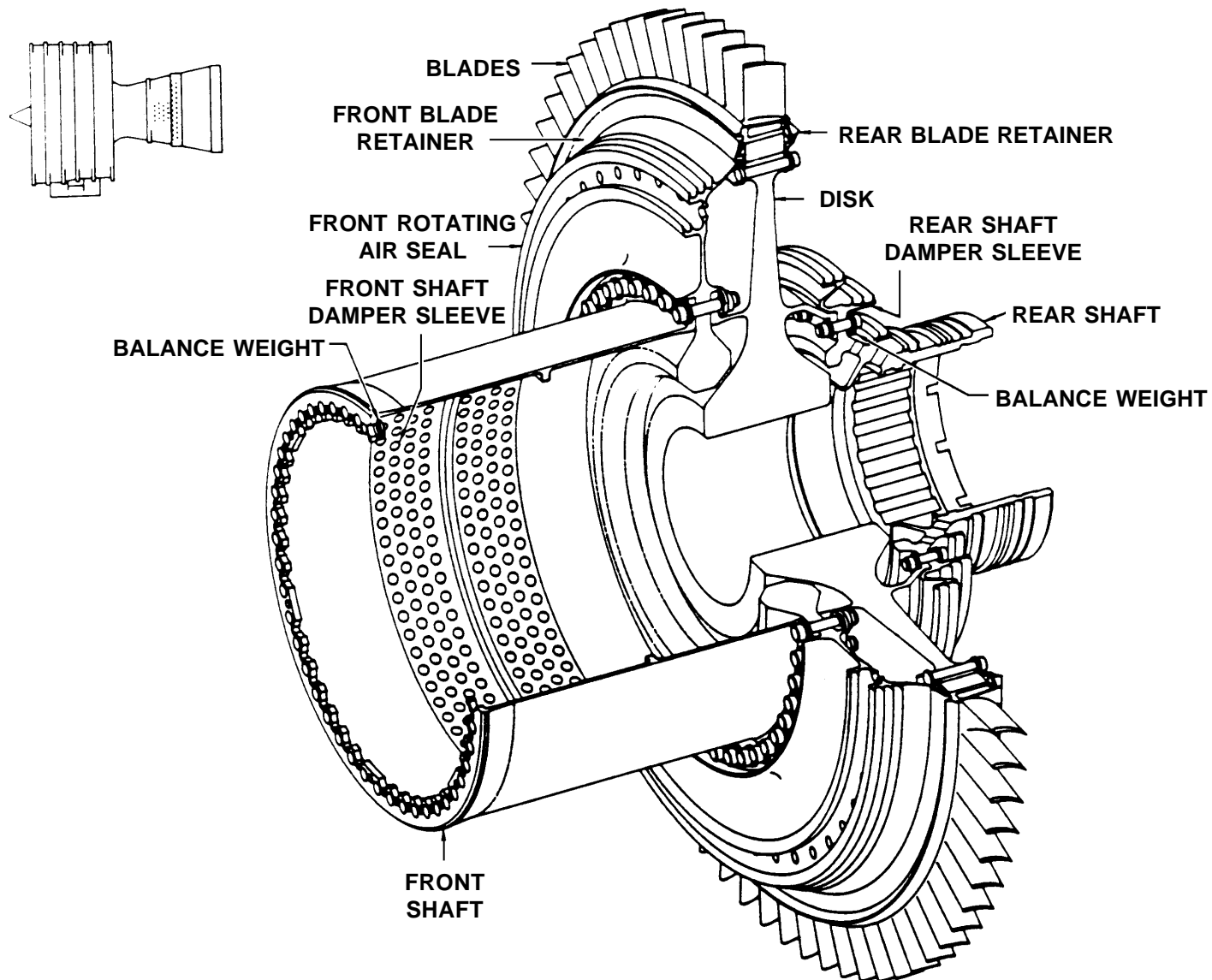
The rotor consists of the front shaft, the front rotating air seal, the bladed disk, and the rear shaft. The rotor is internally cooled by low pressure compressor (booster) discharge air. It has interference rabbeted flanges for rigidity and stability. The four main structural parts are made of high strength nickel alloys.

### **Purpose (1.B.b)**

The high pressure turbine (HPT) rotor is a single-stage, air-cooled, high efficiency turbine. The HPT rotor drives the high pressure compressor rotor.

### **Interface (2.B.b)**

The high pressure turbine (HPT) rotor is directly connected to the compressor rotor by a bolted flange to form what is essentially a single core rotor.



**HIGH PRESSURE TURBINE ROTOR**

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## HIGH PRESSURE TURBINE SHROUD AND STAGE 1 LPT NOZZLE

### Identification (1.A.b)

The high pressure turbine shroud and stage 1 low pressure turbine nozzle assembly consists of:

- the shroud/nozzle support assembly.
- HPT shrouds.
- 28 LPT stage 1 nozzle segments.
- inner air seal.
- stationary air seal.

### Purpose (1.B.b)

It forms the interface between the core section and the LPT module of the engine. The shroud support/nozzle assembly has a thermal response (turbine clearance control) matched to the rotor to provide good tip clearance control and structural stability. The stage 1 LPT nozzles direct the core engine exhaust gas onto the stage 1 LPT blades.

### Location (2.A.b)

The high pressure turbine (HPT) shroud and stage 1 low pressure turbine (LPT) nozzle assembly is located inside the aft end of the combustion case.

### Interface (2.B.b)

The forward flange of the assembly is bolted to the inner surfaces of the combustion case. The aft flange is bolted between the combustion case aft flange and the LPT stator forward flange.

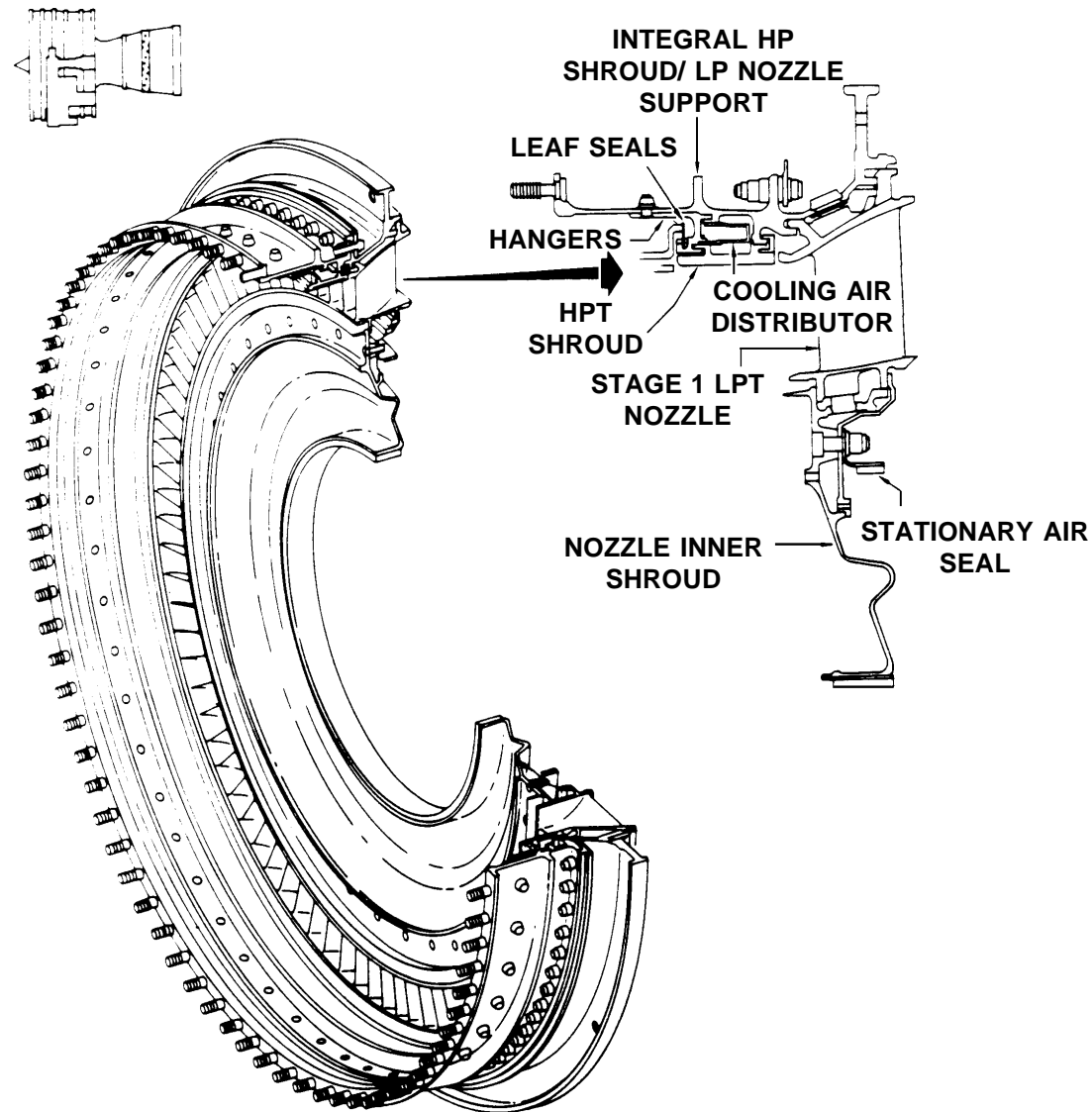
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**HPT SHROUD AND STAGE 1 LPT NOZZLE ASSEMBLY**

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## LOW PRESSURE TURBINE MAJOR MODULE

### Objectives:

At the completion of this section a student should be able to:

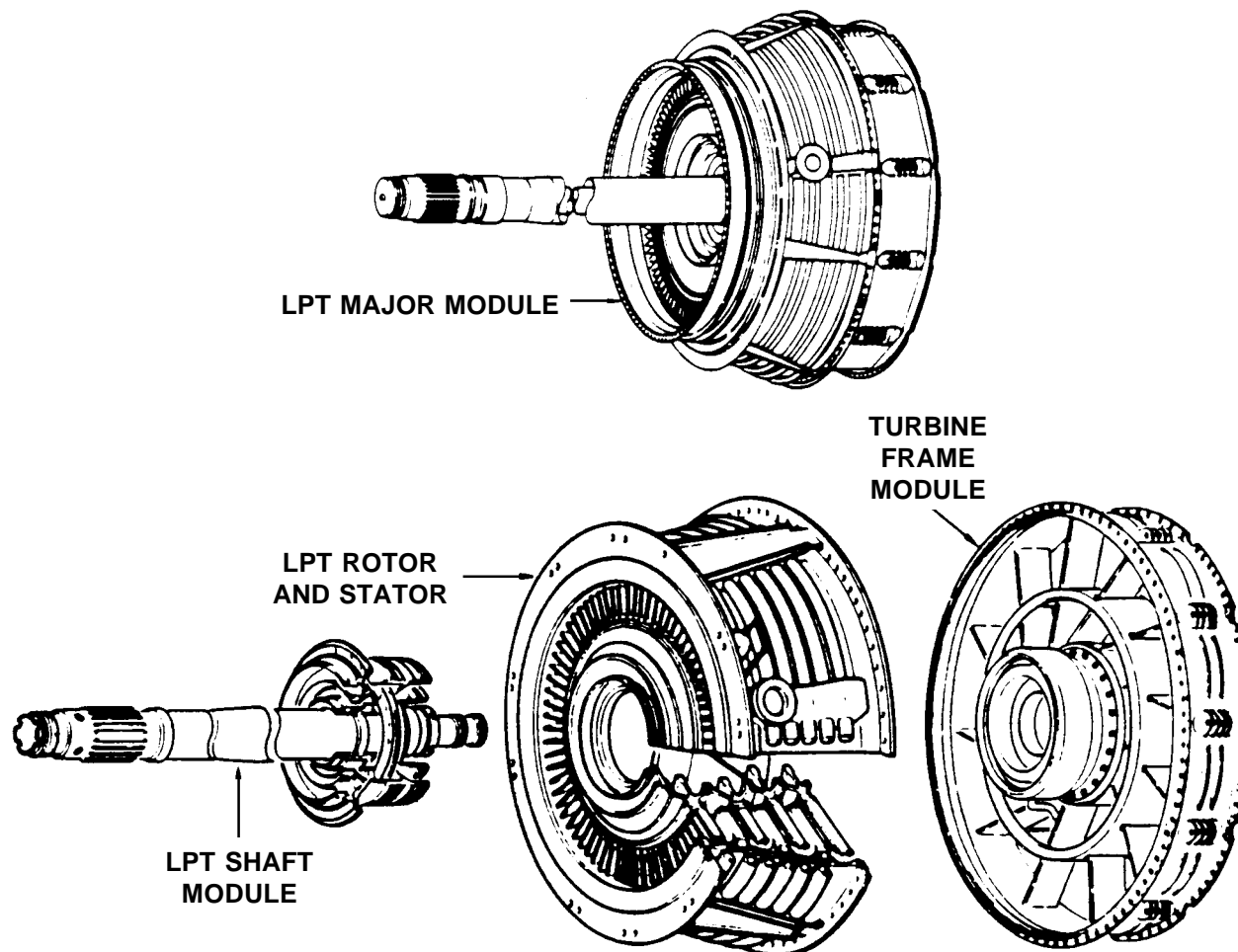
- ....identify the major assemblies of the CFM56-3/3B/3C Low Pressure Turbine Major Module (1.A.x).
- ....locate the major assemblies of the CFM56-3/3B/3C Low Pressure Turbine Module (1.A.x).
- ....state the purpose of the major assemblies of the CFM56-3/3B/3C Low Pressure Turbine Module (1.B.x).
- ....recall the interfaces of the major assemblies of the CFM56-3/3B/3C Low Pressure Turbine Module (1.B.x).

## INTRODUCTION

### Overview (1.A.b)

The LPT major module consists of the turbine shaft, the bearing No. 4 and No. 5 assemblies, LPT rotor and stator assemblies, the turbine frame and No. 5 bearing support. These combined components form three individual modules:

- LPT shaft module
- LPT rotor and stator module
- Turbine frame module



## LOW PRESSURE TURBINE MAJOR MODULE

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## LPT STATOR ASSEMBLY & LPT CASE

### Identification (1.A.b)

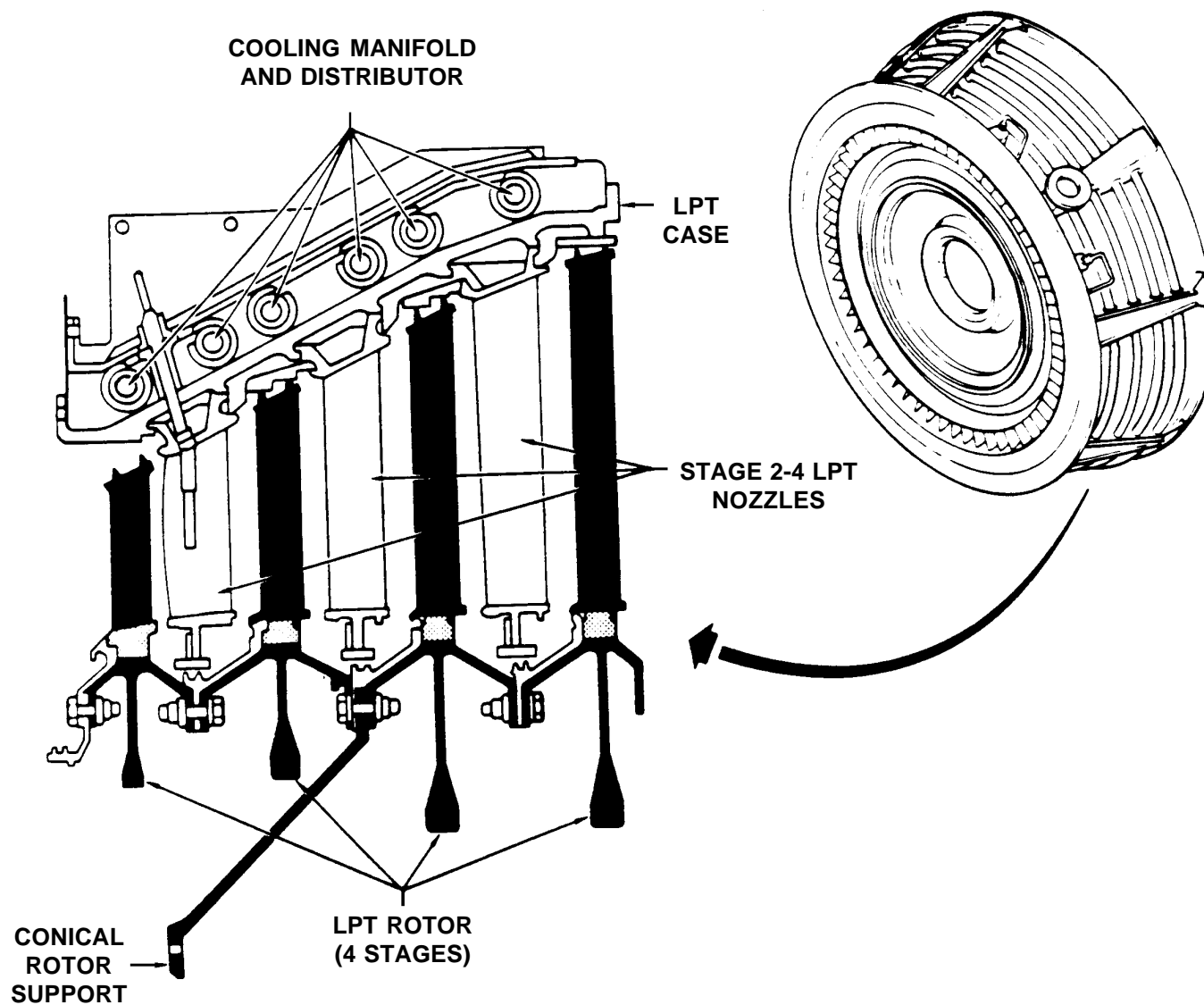
This assembly consists of the LPT case, LPT shroud support ring, outer stationary air seal segments, thermal shields and thermal insulation blanket segments. Each nozzle stage is identical in design.

The LPT case is a one-piece casing provided with circular recesses in its inner diameter to accommodate nozzle and stationary air seal assemblies. The case also features:

- Nine bosses for installation of the T<sub>4.95</sub> thermocouples
- Three bosses for installation of borescope plugs through LPT nozzle stages 2, 3 and 4 (approximately 5 o'clock position/ALF)
- One locating pin, protruding forward on the front flange (approximately 12 o'clock ALF)

### Interface (2.B.b)

Assembly starts from the front and is accomplished together with rotor assembly. It is bolted with the combustor case and the HPT shroud/LPT stage 1 nozzle support at the front, and is attached to the turbine frame at the back.



## LOW PRESSURE TURBINE

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## LOW PRESSURE TURBINE SHAFT ASSEMBLY

### Identification (1.A.b)

The LPT shaft assembly consists of the following major parts:

- LPT shaft.
- LPT stub shaft.
- Center vent tube.
- Center vent tube rear extension duct.
- No. 4 roller bearing.
- No. 5 roller bearing.

The aft end is supported by the No. 5 roller bearing and the LPT shaft houses the center vent tube of the forward and aft engine oil sumps.

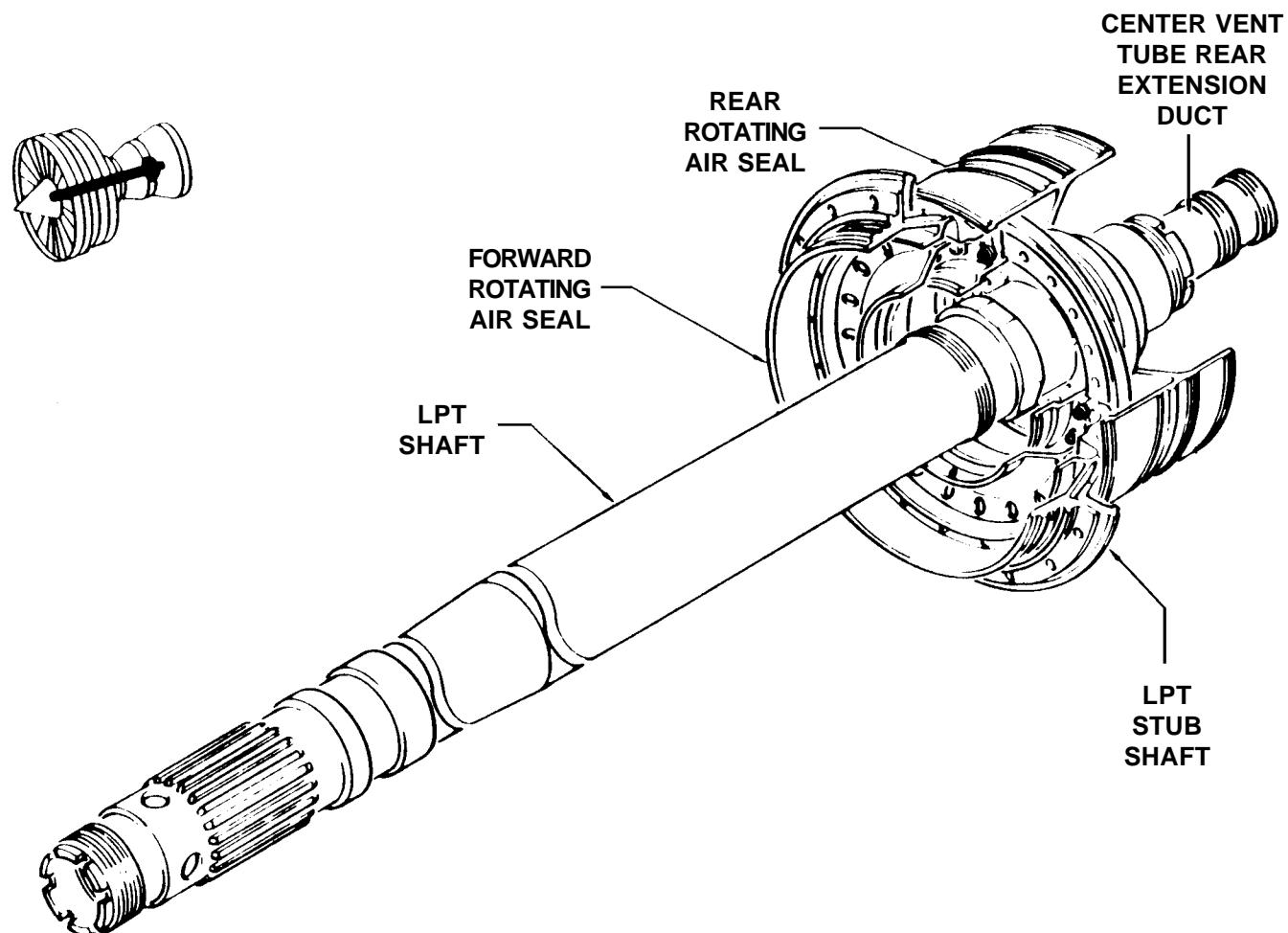
### Purpose (1.B.b)

The LPT shaft has two functions:

- coupling the fan booster rotor with the LPT rotor.
- providing rear support of the HPC through the No. 4 roller bearing.

### Interface (2.B.b)

The LPT shaft assembly connects the fan shaft with the LPT rotor assembly at the stub shaft and conical support.



## LOW PRESSURE TURBINE SHAFT ASSEMBLY

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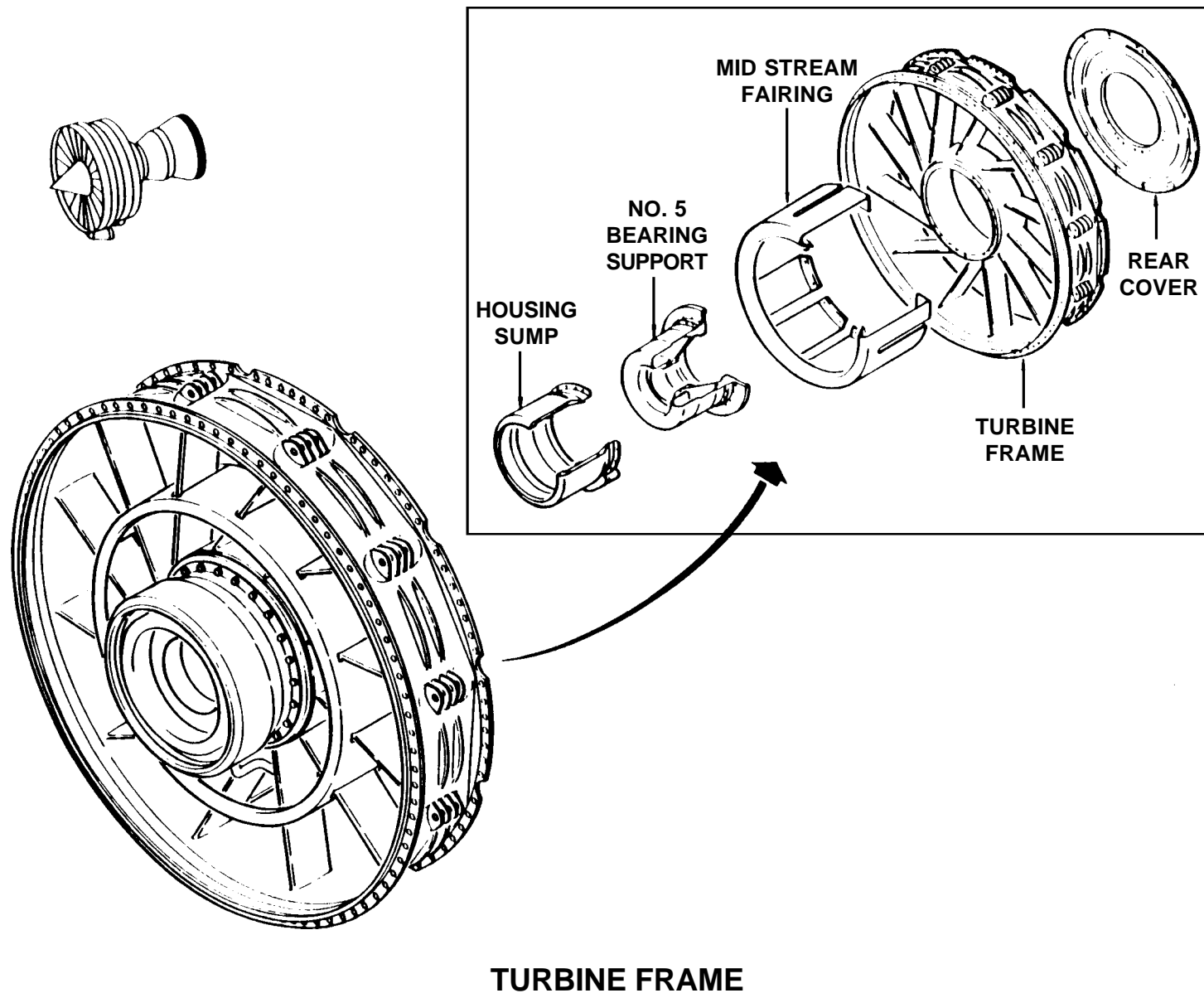
**TURBINE FRAME ASSEMBLY****Identification (1.A.b)**

The turbine frame assembly consists of a central hub and a polygonal shape outer casing. The two configurations are connected by slanted struts. This design minimizes thermal stresses. These twelve hollow struts support a midstream fairing, the exhaust plug and the rear outer flange supports the primary exhaust nozzle. The hub inner front flange carries the No. 5 bearing support.

**Purpose (1.B.b)**

The turbine rear frame is the second of the main structural components. It serves as a support for the LPT rotor rear section. Also, it provides for rear engine mounting on the airframe.





**TURBINE FRAME**

## TURBINE FRAME ASSEMBLY

### Interface (2.B.b)

Strut No. 5 provides the scavenge pathway for oil leaving the aft sump.

Strut No. 6 provides the supply pathway for oil going to the aft sump.

Strut No. 7 provides the pathway for aft sump oil seal leakage to an overboard drain mast.

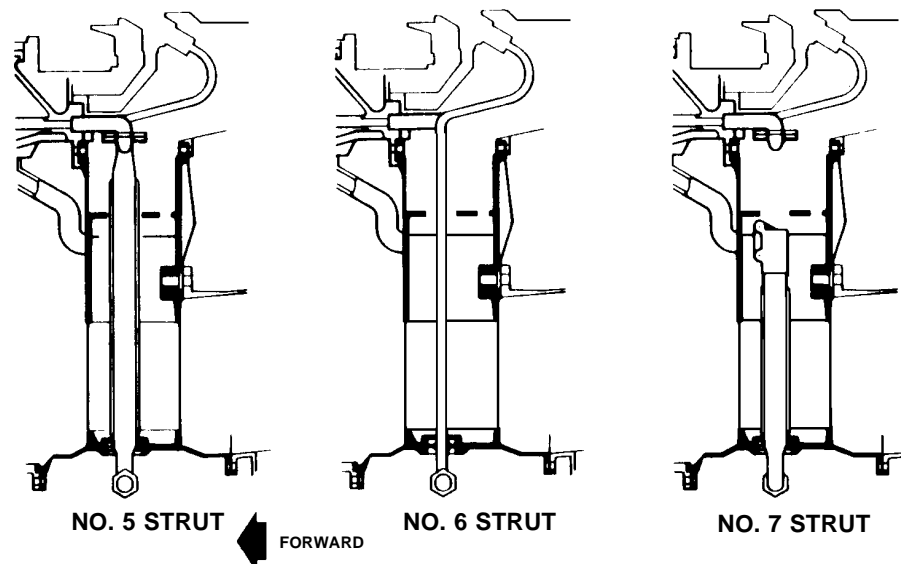
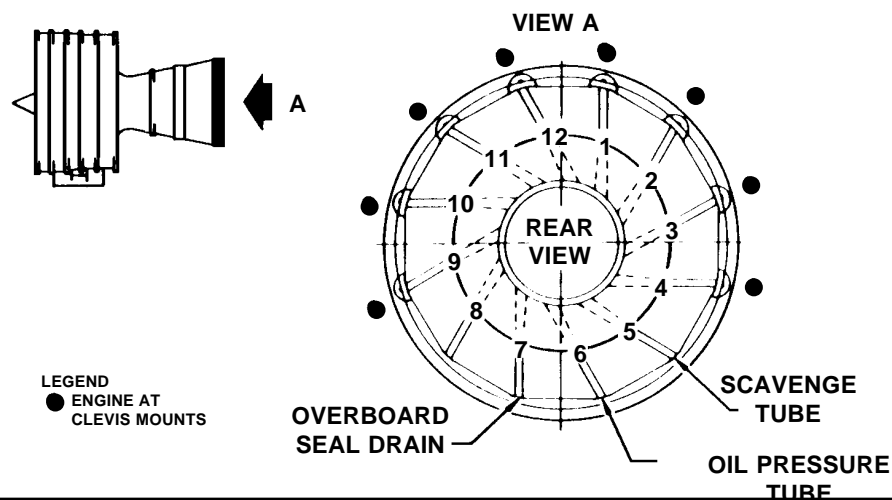
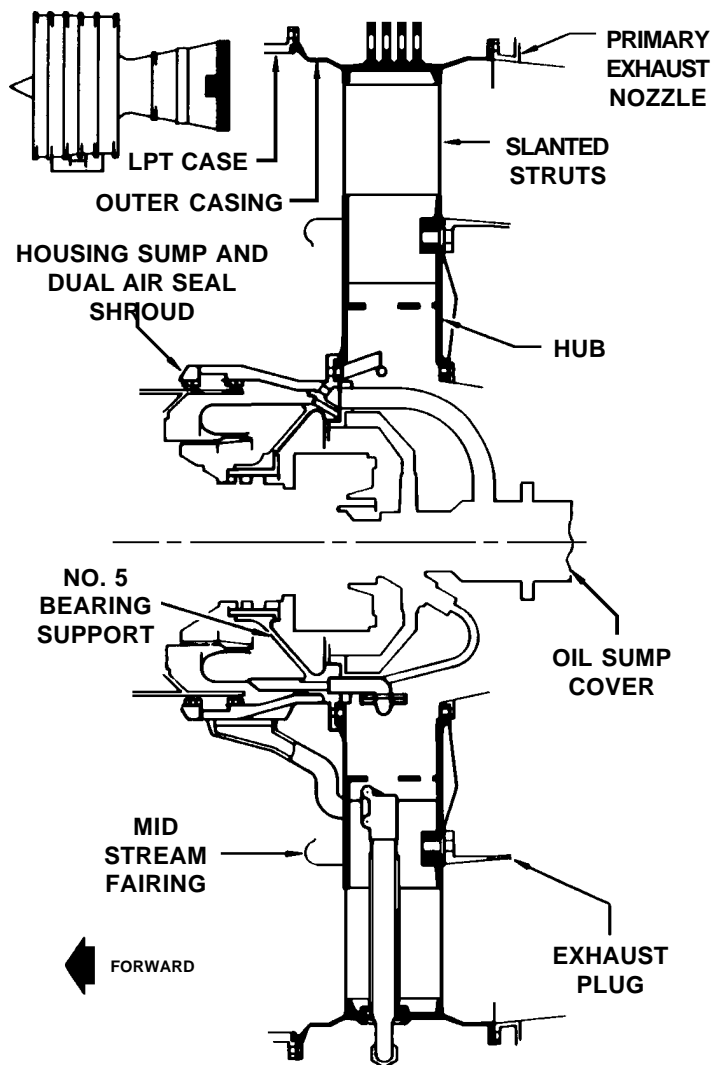
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## TURBINE FRAME

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## POWER MANAGEMENT AND ENGINE SYSTEMS INTRODUCTION

### Objectives:

At the completion of this section a student should be able to:

- ....identify the engine systems by ATA number of the CFM56-3/3B/3C engine family (1.A.x).
- ....identify the basic functions of power management and operational control of the CFM56-3/3B/3C engine (1.A.x).
- ....state the purpose of the engine systems of the CFM56-3/3B/3C engine (1.B.x).

## ENGINE SYSTEMS INTRODUCTION

### **Identification (1.A.a)**

The CFM56-3 engine systems covered in this book are identified by the following ATA sections:

Fuel System - 73-00-00

Ignition System - 74-00-00

Air System - 75-00-00

Indicating System - 77-00-00

Oil System - 79-00-00

### **Purpose (1.B.a)**

In the fuel system, fuel is delivered to the main fuel pump via the airframe tank boost pump. The fuel delivery system contains the main fuel pump, its filter, the servo fuel heater, main fuel/oil heat exchanger, Main Engine Control (MEC), fuel manifold and fuel nozzles.

The ignition system is to produce an electrical spark to ignite the fuel/air mixture in the engine combustion chamber during the starting cycle and to provide continuous ignition during T/O, landing and operation in adverse weather conditions.

In addition to sump pressurization and internal engine cooling (see section 1) the air system provides engine operational flexibility by means of compressor control. This is accomplished by controlling airflow to and through the HPC and by monitoring bleed demands.

The indicating system is to verify proper and safe engine operation throughout the flight envelope. The engine is equipped with various sensors that monitor engine performance. Some parameters are used directly by the aircraft crew, and others later by the maintenance personnel for engine performance trend monitoring purposes.

The oil system is used for lubrication and cooling of the engine bearings and gears in the Transfer Gearbox (TGB) and Accessory Gearbox (AGB).

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GRAPHIC TO BE DETERMINED

## POWER MANAGEMENT AND OPERATIONAL CONTROL

### Identification (1.A.a)

Power Management of the CFM56-3 engine consists of both hydromechanical (MEC) and electrical (PMC) components.

Hydromechanical units include the MEC, Fan Inlet Temperature sensor ( $T_{2.0}$ ), High Pressure Compressor (HPC) Inlet Air Temperature sensor ( $T_{2.5}$ ), hydraulic motor for the Variable Bleed Valves (VBV), Turbine Clearance Control Valve (TCCV) and Variable Stator Vane (VSV) actuators.

The MEC is mounted on the main fuel pump and provides Actual Core Speed ( $N_2$ ) governing in response to power lever input, and fuel limiting as modified by engine operational variables. The control automatically adjusts the VSV system through external actuators and the VBV system through a gear motor. The MEC also provides signals to operate the High Pressure Turbine Clearance Control (HPTCC) system.

The MEC acceleration fuel schedule is compensated for aircraft bleeds. Thus engine acceleration time is essentially the same with bleed on or off.

The electrical units include the Power Management Control (PMC), control alternator, fan speed sensor, Fan

Inlet Total Air Temperature ( $T_{12}$ ) sensor and Fan Inlet Static Air Pressure sensor ( $Ps_{12}$ ) [part of the PMC].

Operational control of the engine is achieved by use of the power lever, fuel shutoff lever and a PMC.

The PMC operates from power delivered by the control alternator and functions to set actual Fan Speed ( $N_1$ ) by trimming the MEC within narrow authority limits. With PMC on, automatic calculation of Takeoff (T/O)  $N_1$  is accomplished from sensed fan inlet temperature and static pressure signals. The power level signal is used to select a percentage of T/O thrust; this percentage is used to establish a demanded fan speed achieved by control of fuel flow through the MEC. With PMC off, the MEC provides  $N_2$  governing.

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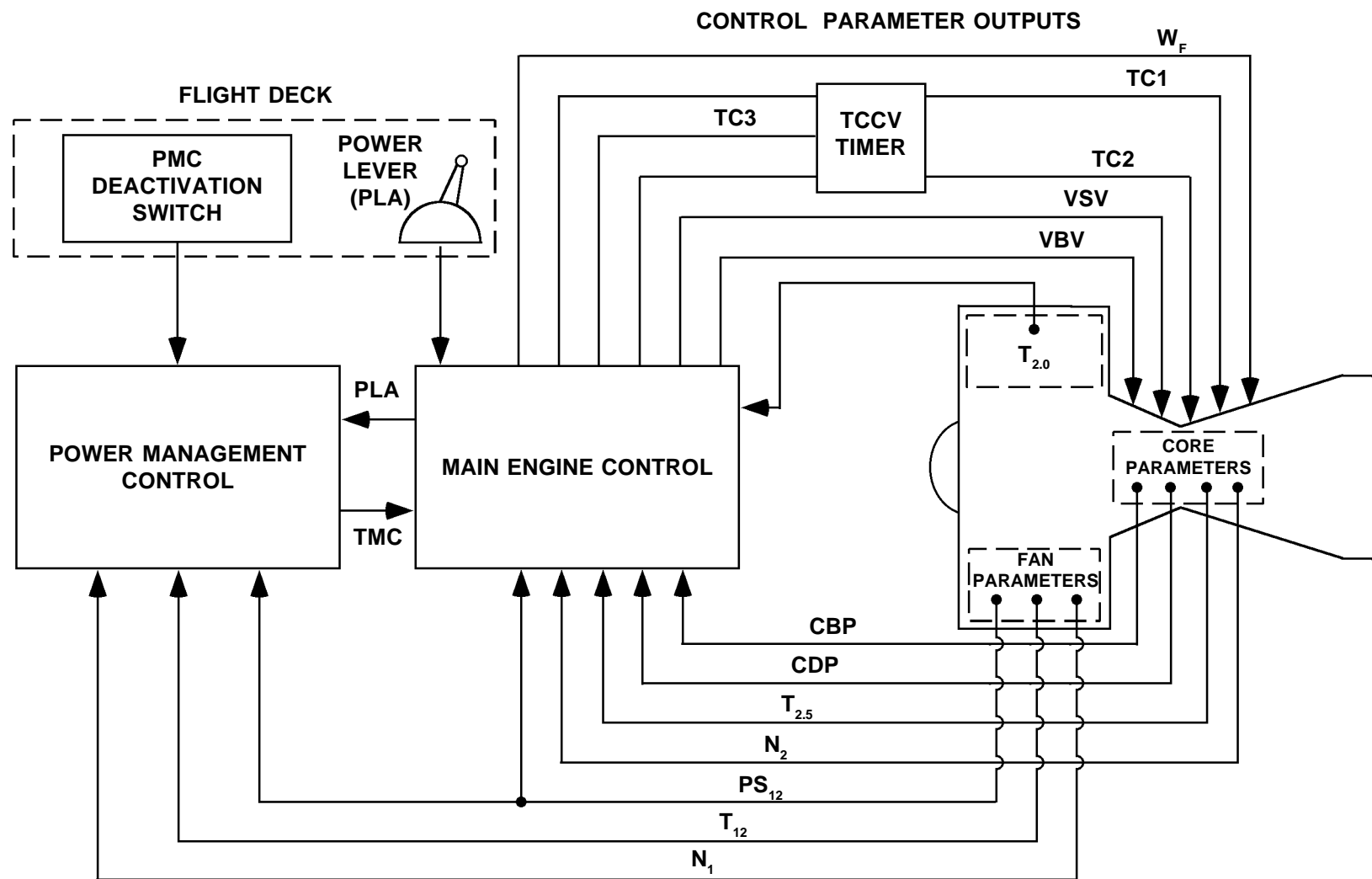
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CONTROL SYSTEM SCHEMATIC

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## FUEL AND CONTROL SYSTEM

### Objectives:

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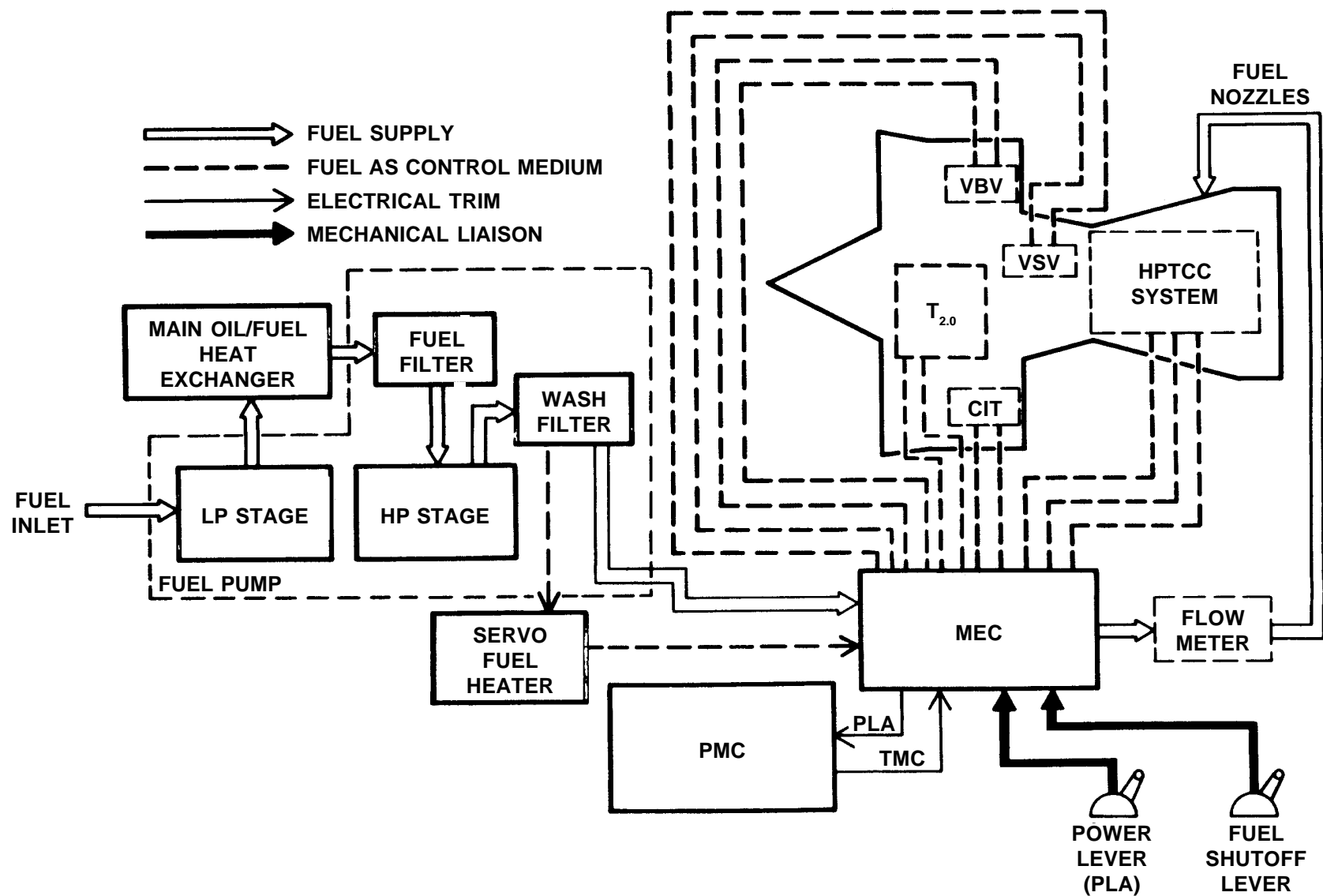
- ....identify the components comprising the fuel system for the CFM56-3/3B/3C engine (1.A.x).
- ....state the purpose of the fuel system for the CFM56-3/3B/3C engine (1.B.x).
- ....state the purpose of the components comprising the fuel system for the CFM56-3/3B/3C engine (1.B.x).
- ....describe the flow sequence of the fuel system for the CFM56-3/3B/3C engine (1.D.x).
- ....locate the components comprising the fuel system for the CFM56-3/3B/3C engine (2.A.x).
- ....identify the aircraft interfaces associated with the fuel system of the CFM56-3/3B/3C engine (2.B.x).
- ....describe the component operation of the fuel system for the CFM56-3/3B/3C engine (2.C.x).
- ....describe the particular component functions of the fuel system for the CFM56-3/3B/3C engine (3.D.x).

## FUEL DELIVERY SYSTEM

### Purpose (1.A.b)

The fuel delivery system performs several functions by providing:

- The energy required for the engine thermodynamic process.
- Supply hydraulic power to the systems controlling the VBV, VSV and HPTCC.
- The hydromechanical amplification necessary to the MEC.
- Cooling of the lubrication oil.



FUEL AND COMPRESSOR CONTROL SYSTEM SCHEMATIC DIAGRAM

## FUEL DELIVERY SYSTEM

### Flow Sequence (1.D.b)

Fuel from the aircraft fuel supply system enters the engine at the fuel pump inlet.

The fuel is pressurized through the Low Pressure (LP) stage of the fuel pump and flows through the main oil/fuel heat exchanger and the fuel filter.

The fuel then flows through the High Pressure (HP) stage of the pump, through the wash filter, and enters the MEC.

Since the fuel pump has a higher fuel flow capacity than the fuel and control system requires, the fuel flow is divided in the MEC into metered flow and bypass flow.

Bypass fuel is ported back to the outlet of the fuel pump LP stage.

Metered fuel from the MEC flows through the pressurizing valve, the flowmeter, the fuel manifold, and fuel nozzles into the combustion chamber.

Some of the fuel is extracted through the pump wash filter, heated by the servo fuel heater, and supplied to the MEC to provide clean, ice-free fuel for the following MEC servo operations:

- The MEC establishes a fuel flow ( $P_6$ ) to the Compressor Inlet Temperature (CIT) sensor with a return  $P_b$  to the control. The differential fuel pressure ( $P_6 - P_b$ ) is proportional to  $T_{2.5}$ .
- The MEC establishes schedules for VSV and VBV positioning.
- The MEC establishes a schedule for the TCCV as a function of  $N_2$  speed. This then regulates the airflow of 5th and 9th stage compressor bleed air to the High Pressure Turbine (HPT) shroud support. Under certain T/O conditions (above 13,800  $N_2$ ) the MEC will alter this schedule through the use of a TCCV timer.
- The MEC establishes a fuel flow ( $P_7$ ) to the  $T_{2.0}$  sensor with a return ( $P_b$ ) to the control. The differential fuel pressure ( $P_7 - P_b$ ) is proportional to  $T_{2.0}$ .

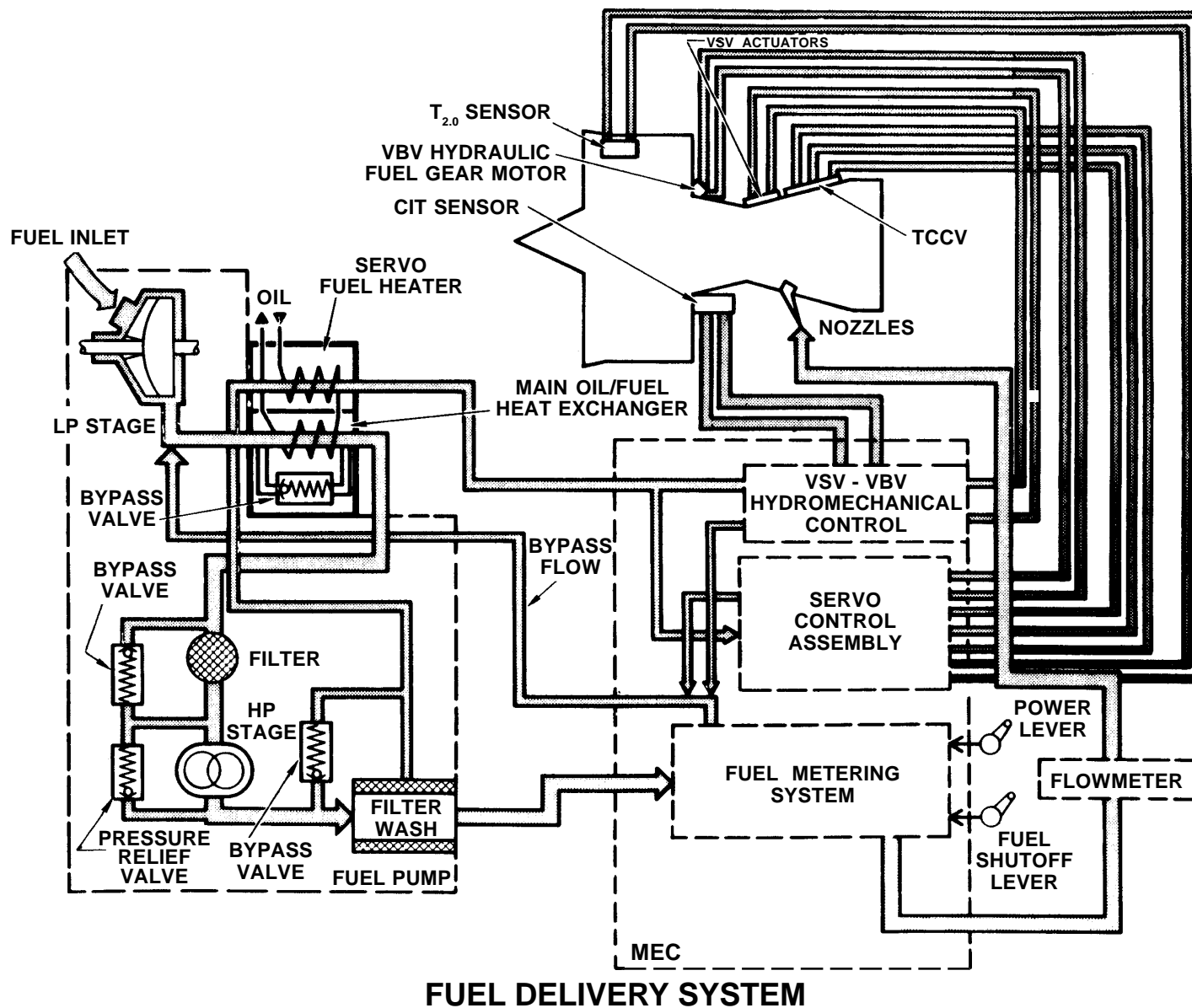
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## FUEL DELIVERY SYSTEM

### Identification (1.A.b)

The fuel delivery System consists of:

- Fuel pump and integral filter
- Servo fuel heater
- MEC
- Fuel manifold
- Fuel nozzles.



**GRAPHIC TBD**

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## FUEL PUMP

### Identification (1.A.b)

The fuel pump contains a LP stage (centrifugal boost stage), a integral fuel filter, a HP stage (gear stage) and a wash filter.

### Purpose (1.B.b)

The fuel pump pressurizes and circulates the fuel required for combustion and fuel-operated servo systems throughout the operational envelope of the engine.

### Location (2.A.b)

The fuel pump is mounted on the aft side of the AGB at the 8 o'clock position.

### Interface (2.B.b)

The pump housing provides mounting surfaces for the MEC and the main oil/fuel heat exchanger.

### Operation (2.C.b)

The fuel pump is driven by the AGB through an arrangement of three splined shafts. Fuel enters the pump inlet at aircraft boost pressure. The low pressure stage prevents cavitation by increasing the aircraft boost pressure. The high pressure stage provides adequate fuel pressure to the fuel delivery system. Fuel is filtered and heated before delivery to the MEC.

### Functional Description (3.D.b)

Of the three splined shafts the main drive shaft turns the HP stage gear pump, the LP stage shaft rotates the LP impeller pump, and the control drive shaft rotates the internal MEC speed governor and tachometer flyweights.

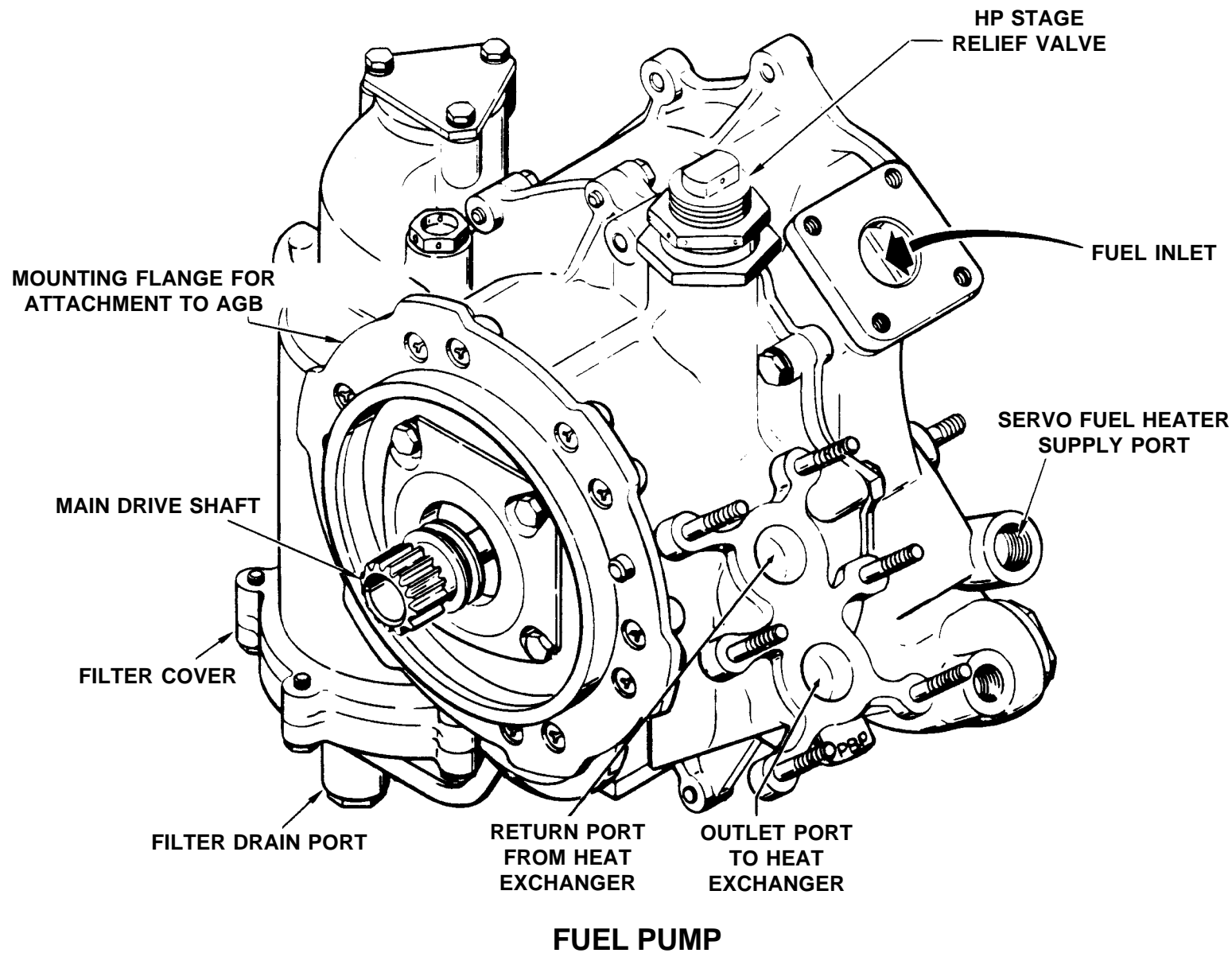
The LP stage raises the fuel pressure and sends the LP stage output flow through the external main oil/fuel heat exchanger and through the fuel filter.

A filter bypass valve relieves LP stage output around the filter if it becomes clogged.

The filtered fuel, through internal passages in the pump housing, enters the HP stage. A pressure relief valve relieves a portion of the HP stage discharge flow back to the HP stage inlet if HP stage discharge pressure exceeds a predetermined maximum.

The HP stage discharges through the wash filter to the MEC fuel metering system. The excess fuel is bypass fuel flow recirculating back to the outlet of the LP stage.

The fuel flow extracted through the wash filter is heated by the servo fuel heater and then supplies the MEC servos.



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## FUEL FILTER

### **Identification (1.A.b)**

The replaceable filter element is a paper or metal corrugated design which has a nominal filtering capability of 20 microns.

### **Purpose (1.B.b)**

To filter particle contaminants suspended with the fuel and , protects the HP stage and the MEC from particles within the fuel.

### **Location (2.A.b)**

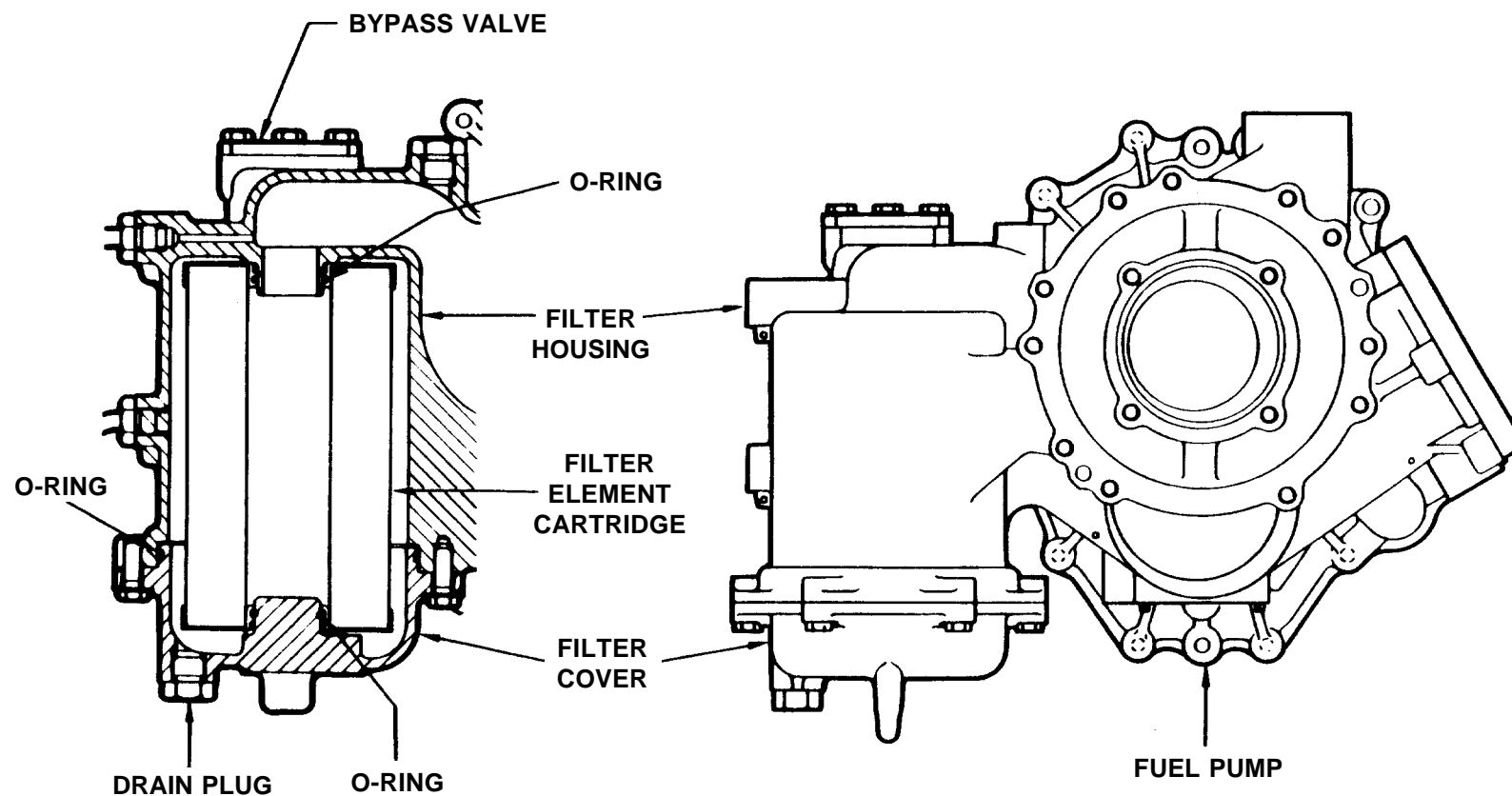
The replaceable filter element is contained in the integral fuel filter housing, located between the main oil/fuel heat exchanger and the fuel pump HP stage.

### **Operation (2.C.b)**

The fuel circulates from the outside to the inside of the filter cartridge.

### **Functional Description (3.D.b)**

In case of a clogged filter, a bypass valve relieves fuel to the HP stage.



## FUEL PUMP - FUEL FILTER

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**SERVO FUEL HEATER****Identification (1.A.b)**

The servo fuel heater consists of a housing with a heat exchanger core inside and a cover.

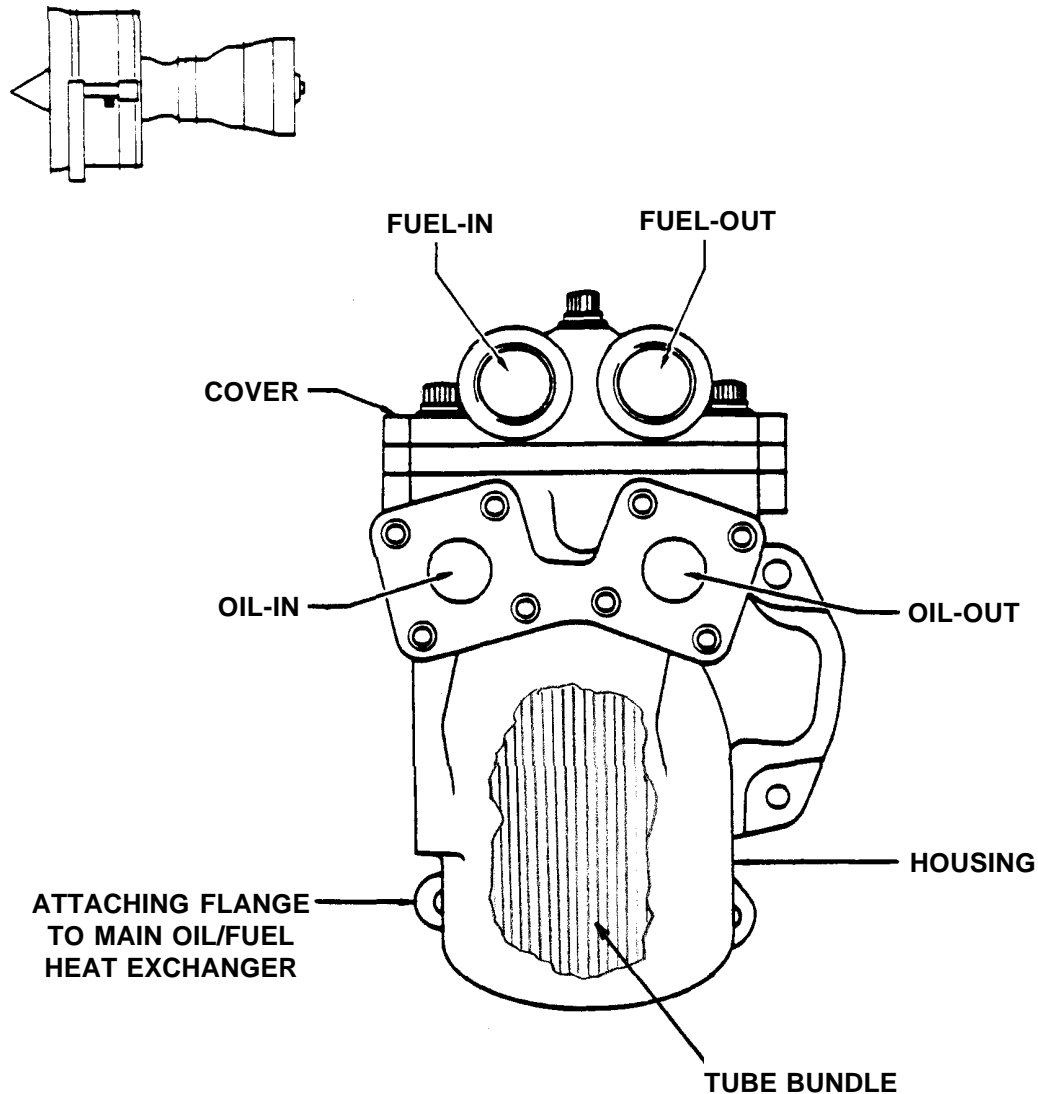
The core assembly is removable. It consists of a number of aluminum alloy dimple U-shaped tubes, inserted through a series of drilled baffle plates. The tubes are mechanically bonded to a tube plate which is profiled to the housing and end cover flanges. The core/housing assembly is designed to direct oil in four radial flow passes over the fuel-filled "U" tubes.

**Purpose (1.B.b)**

The servo fuel heater raises the temperature of the fuel to eliminate ice in the fuel before entering the control servos, inside the MEC.

**Location (2.A.b)**

The servo fuel heater is mounted on the aft side of the main oil/fuel heat exchanger.



### SERVO FUEL HEATER

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## SERVO FUEL HEATER

### Operation (2.C.b)

The servo fuel heater is a heat exchanger using the engine scavenge oil as its heat source. The hot scavenge oil first goes through the servo fuel heater and then to the main oil/fuel heat exchanger. Within the servo fuel heater, fuel from the fuel pump wash filter is heated by the scavenge oil and then goes to the MEC servos. Inside the main oil/fuel heat exchanger, fuel from the fuel pump LP stage cools the scavenge oil. Then the fuel goes to the inlet of the fuel filter and the cooled oil returns to the tank.

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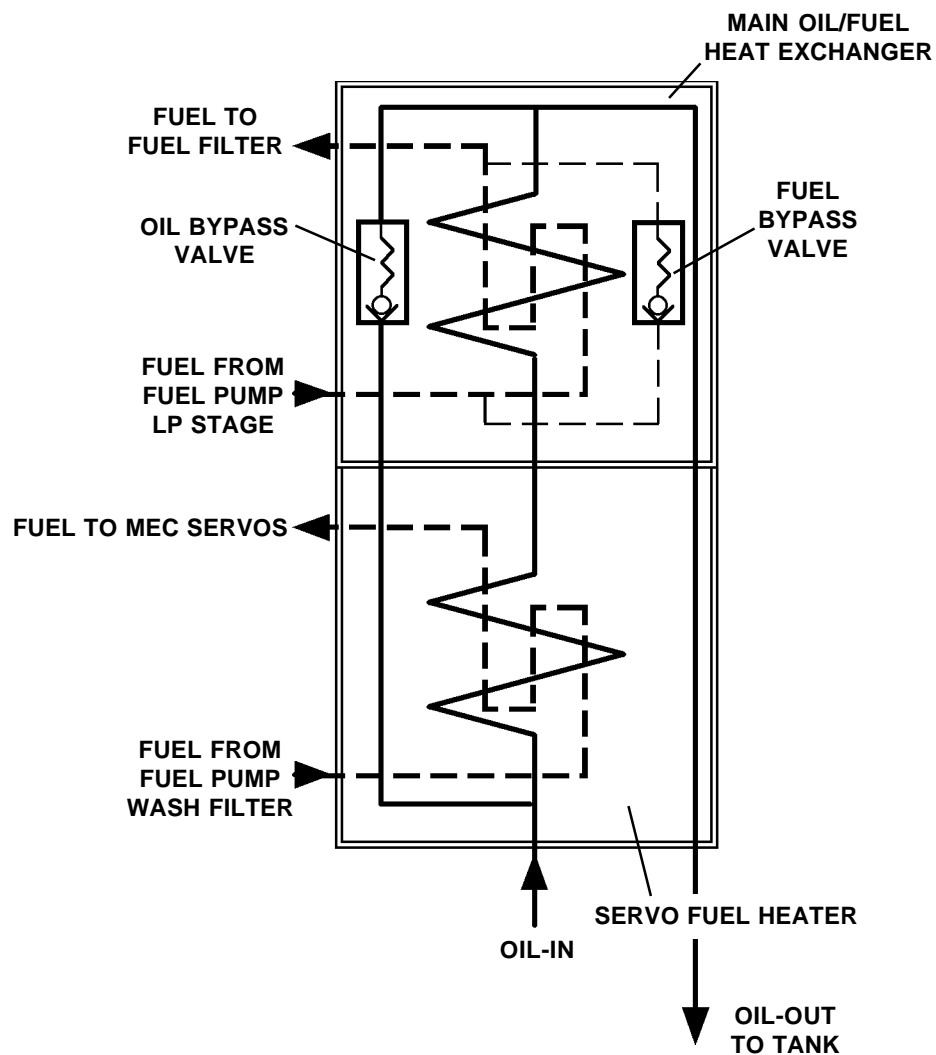
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## SERVO FUEL HEATER AND MAIN OIL/FUEL HEAT EXCHANGER OPERATION

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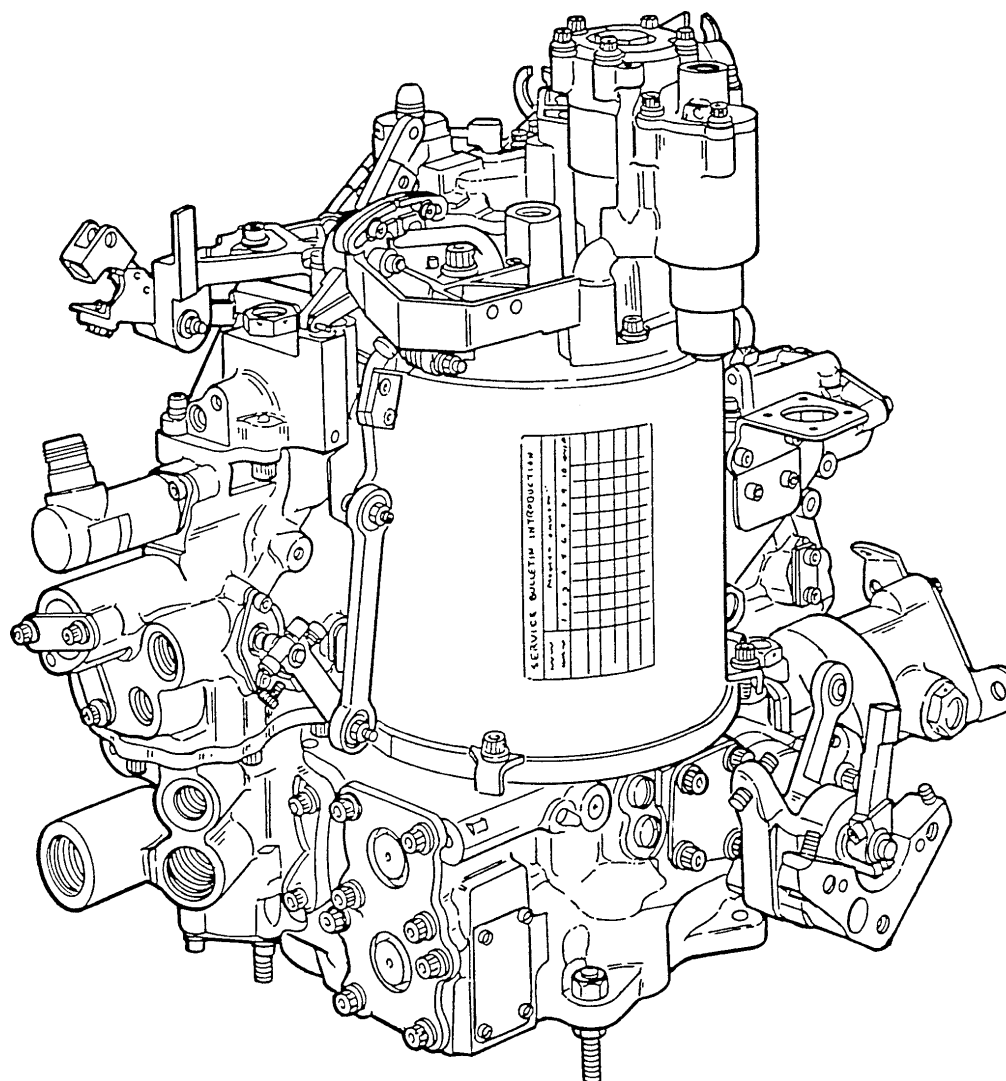
## MAIN ENGINE CONTROL (MEC)

### Purpose (1.B.b)

The MEC is a hydromechanical device that is basically a speed governor with refinements to provide automatic speed adjustments. This corrects for a broad variation in engine operational environments and provides additional control functions to optimize engine performance.

### Location (2.A.b)

The MEC is mounted to the fuel pump at approximately the 8 o'clock position on the aft end of the AGB.



**CFM56-3 MAIN ENGINE CONTROL (MEC)**

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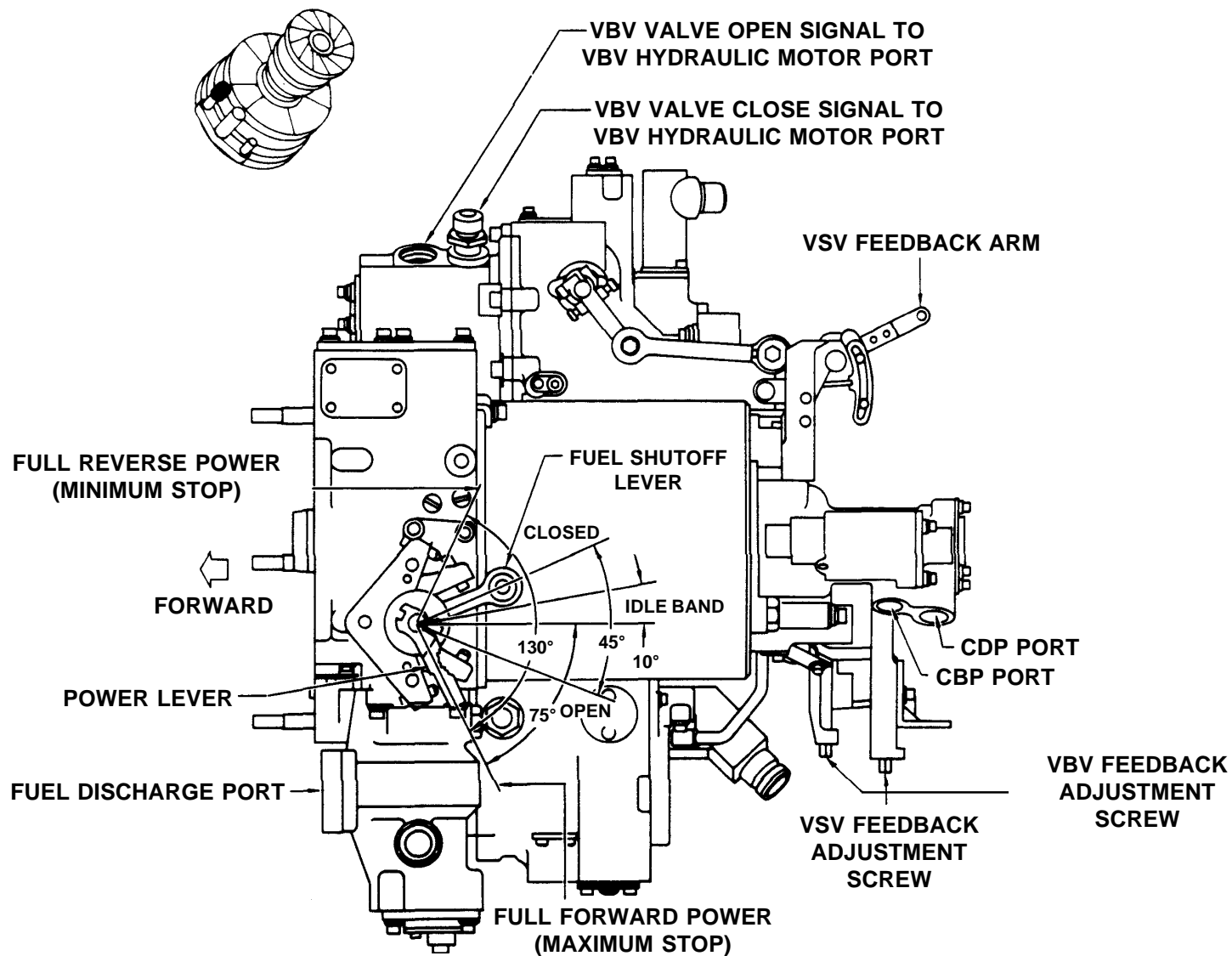
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**MAIN ENGINE CONTROL (MEC)****Operation (2.C.b)**

The main engine control is hydromechanical and operates using fuel operated servo valves.

**Functional Description (3.D.b)**

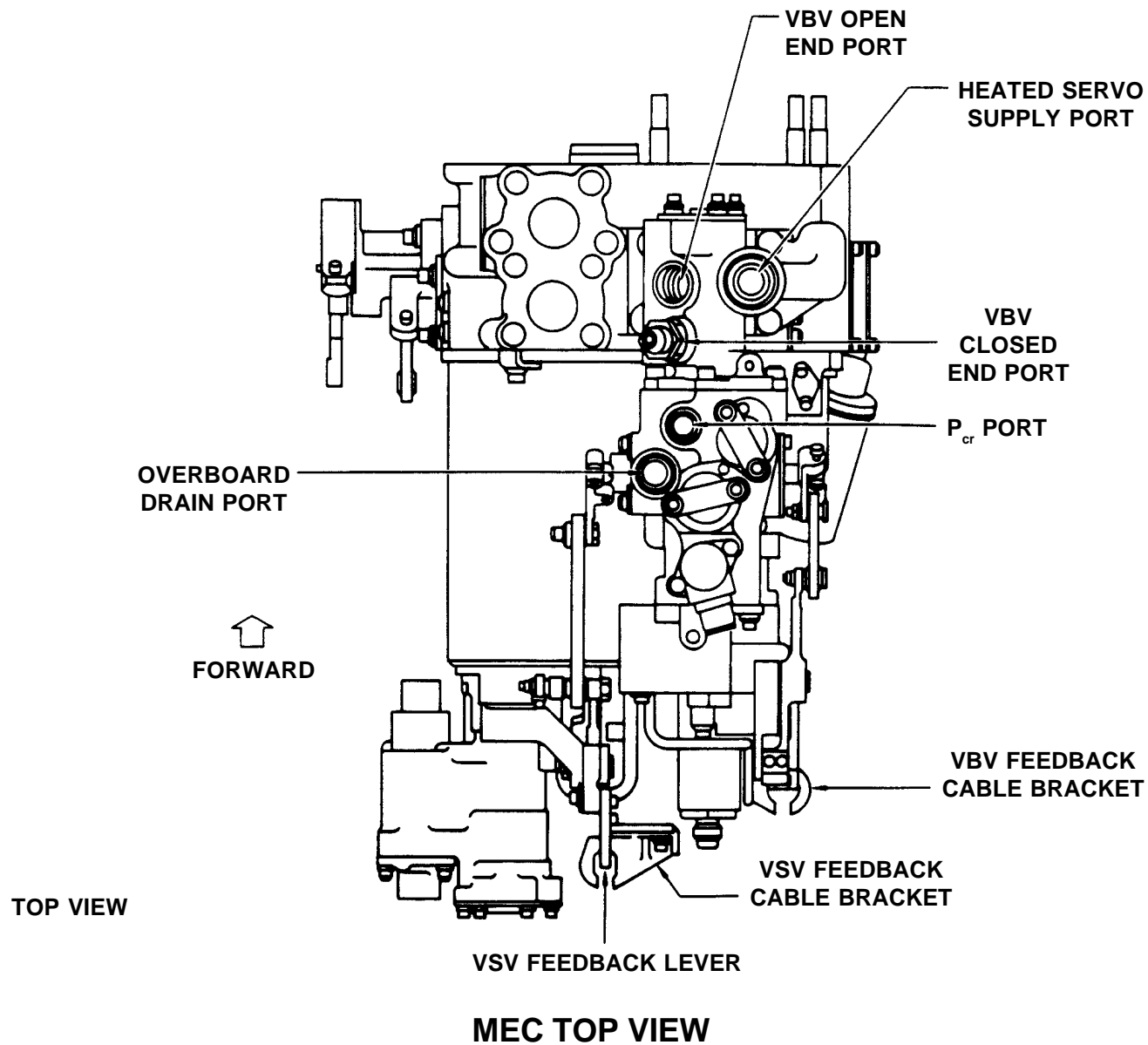
Engine speed control is effected by controlling fuel flow to maintain the flight deck speed setting and establishes the maximum safe fuel limit under any operating condition. The conditions (parameters) vary, and the limits vary accordingly to definite acceleration and deceleration schedules. In order for the control to determine the schedules, certain parameters such as CDP, CBP, CIT, T2.0 and N<sub>2</sub> must be sensed. The control not only senses these parameters, but also amplifies and computes them and establishes acceleration and deceleration limits for fuel flow. The computed limits are compared with actual fuel flow and are imposed when the limits are approached.



MEC LEFT SIDE VIEW

**MAIN ENGINE CONTROL (MEC)****Functional Description (3.D.b)**

A pressurizing valve maintains system pressure at low flow conditions to ensure adequate fuel pressure for MEC servo operation and accurate fuel metering. The schedule for VSV position is directed by fuel pump HP fuel ( $P_f$ ) to the VSV actuators to position the vanes as the schedule changes. The signal which determines the position of the VSV actuators is the result of the control computing  $N_2$  and CIT specifically for this purpose. The schedule for VBV position is directed by  $P_f$  to the VBV hydraulic motor to position the valves as a function of the VSV schedule. A bias to the normal VBV schedule occurs whenever the Thrust Reverser (T/R) is deployed or there is a rapid actuation of VSV toward the closed position.



## MAIN ENGINE CONTROL (MEC)

### Functional Description (3.D.b)

Scheduling the positions of the turbine clearance air valves is created by the output of signal pressures ( $TC_1$  and  $TC_2$ ), which are a function of  $N_2$ .

Because of a concentric shaft design, positive fuel shutoff operation is independent of power lever position. The MEC defines and regulates its own operating pressures and returns any excess fuel supplied by the fuel pump to the downstream side of the pump LP element.

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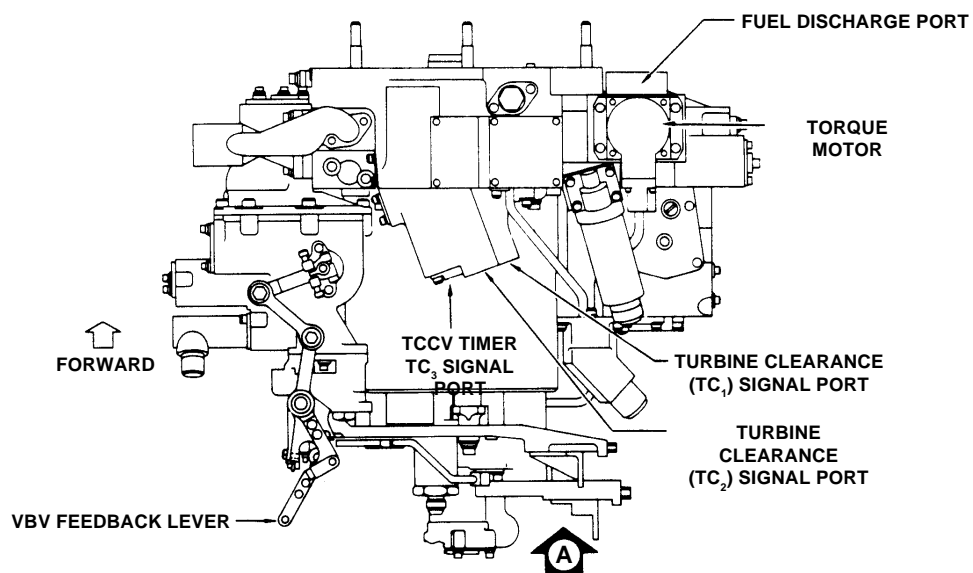
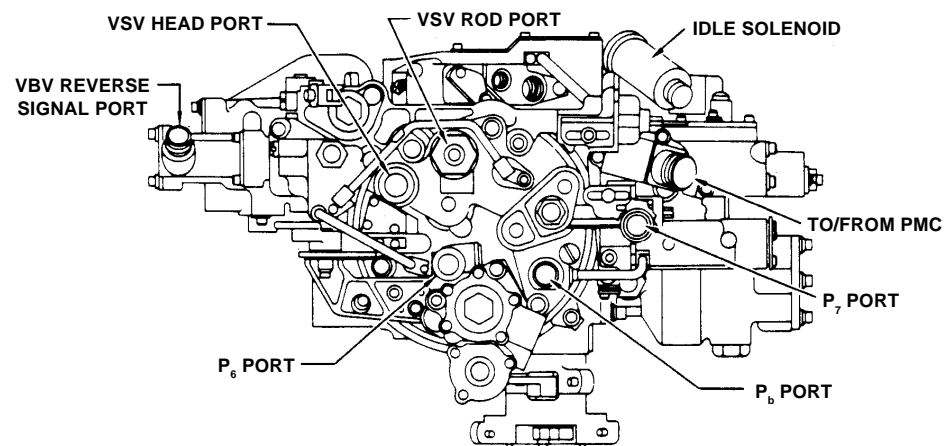
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VIEW A



MEC RIGHT VIEW

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## MAIN ENGINE CONTROL (MEC)

### Functional Description (3.D.b)

#### Low Idle Adjustment - $N_2$ Ground Idle Speed

- Adjusts the level of the ground idle flat in the MEC. This determines the  $N_2$  which will occur if the flight idle solenoid is energized (28 VDC) and the power lever is placed in the proper position.
- Since ground idle speed is biased by CIT, a proper adjustment cannot be made until the ambient temperature ( $T_{12}$ ) is determined. Once the proper temperature is established, a reference to the appropriate schedule data chart is required.
- This adjustment does not affect any other field adjustment.

#### High Idle Adjustment - $N_2$ Flight Idle Speed

- Adjusts the level of the flight idle flat in the MEC. This determines the  $N_2$  speed which will occur if the flight idle solenoid is not energized and the power lever is placed in the proper position.
- Since the flight idle speed is biased by CIT, a proper adjustment cannot be made until the ambient temperature is determined. Once the proper
- temperature is established, a reference to the appropriate schedule data chart is required.

- A properly adjusted flight idle speed will produce a power setting that will permit acceptably quick acceleration to go-around power.
- This adjustment does not affect any other field adjustment.

#### Power Trim

- Physically adjusts the  $N_2$  which will occur with a given PLA to the MEC at power lever positions above idle.
- Since the power lever directly controls only  $N_2$ , variations in engines will cause slight differences in  $N_1$  occurring at given power lever positions with the PMC switched OFF.
- With the PMC switched ON,  $N_2$  will be modified by the PMC to help maintain  $N_1$  for a given PLA, temperature and ambient pressure.

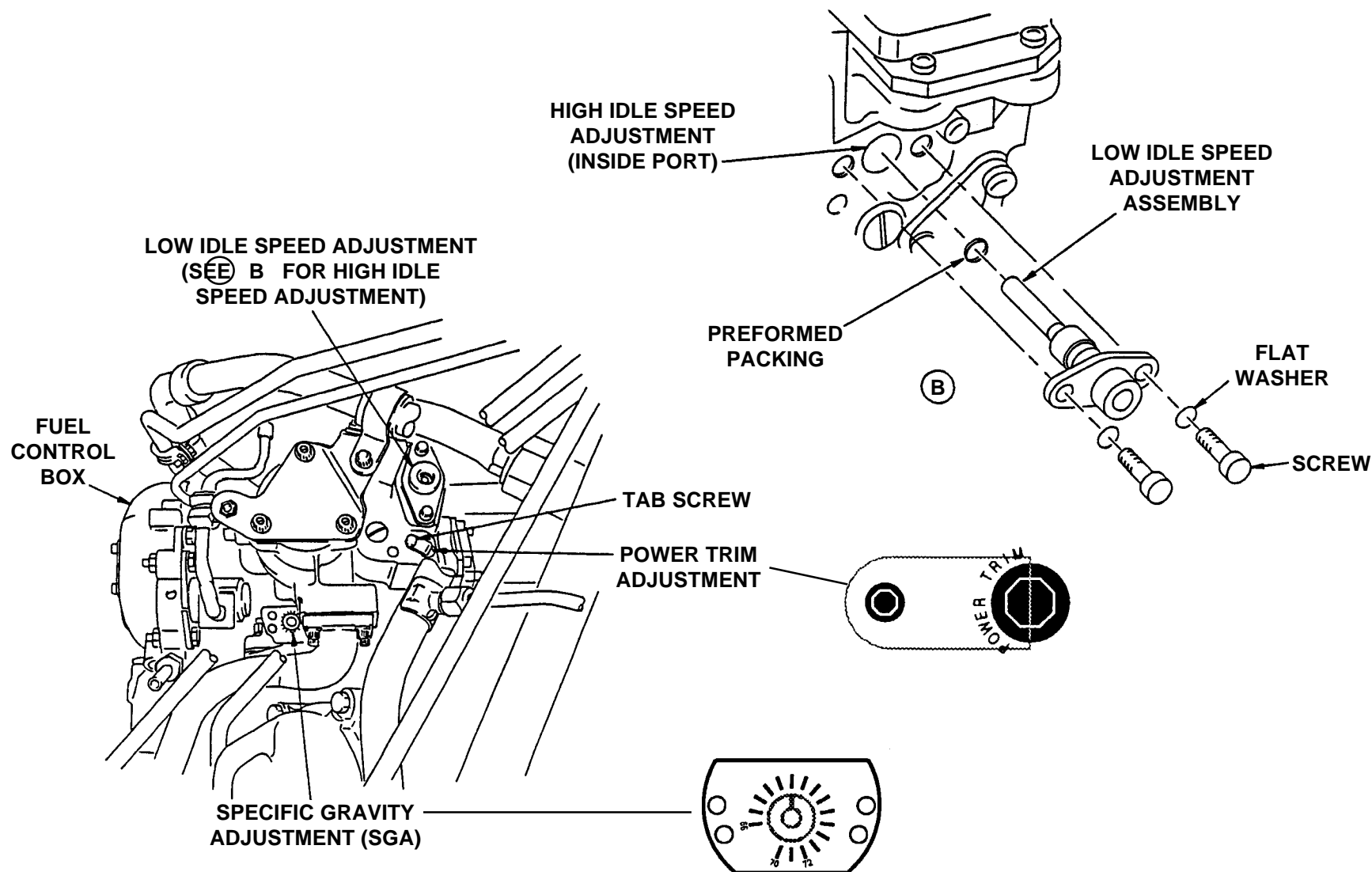
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MEC - BOTTOM VIEW

## MEC ADJUSTMENTS

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## MAIN ENGINE CONTROL (MEC)

### Functional Description

#### Power Trim

- The engine is trimmed to a correct  $N_2$  with the PMC OFF. Since core speed is corrected for temperature and pressure, a reference to the appropriate schedule of information is required.
- This adjustment does not affect any other field adjustment.

#### Specific Gravity Adjustment

- Used to obtain similar engine transient responses with different types of fuel.
- Physically adjusts the pressure drop across the metering valve in the MEC. This changes the volume flow which will occur during transient operation (starts, rapid accels and rapid decels). This compensates for variations in heat energy per unit volume (BTU's) which will occur with variations in fuel type.
- Adjustments should be set to the specific gravity (heat energy content) of the fuel being used.
- This adjustment does not affect any other field adjustment.

Ground/Flight Idle (MEC)= 1 full turn equals approximately 5%  $N_2$  CW (+) CCW (-)

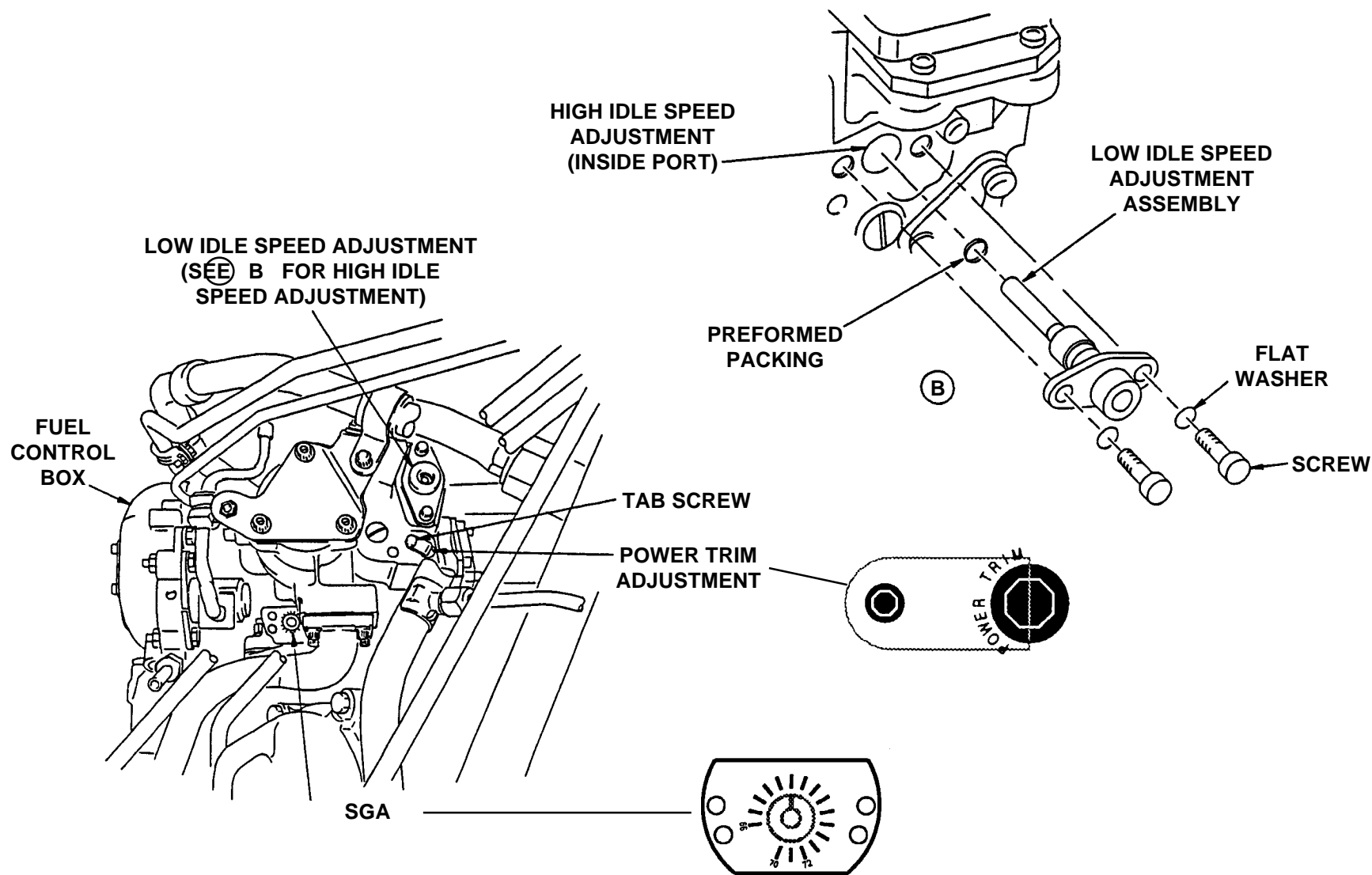
Specific Gravity (MEC) = Set to match specific gravity for type of fuel used:

0.82 = JET A, A1, JP-1, JP-5, JP-8

0.77 = JET B, JP-4

Power Trim (MEC) = 1 full turn equals approximately 1.2%  $N_2$  CW (+) CCW(-)

PLA Gain (PMC) = If PLA gain indicates between 7.43 and 7.57 VDC, no corrective action required. If indication is outside limits, adjust indication between 7.48 and 7.52 VDC



MEC - BOTTOM VIEW

## MEC ADJUSTMENTS

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## SPEED GOVERNING SYSTEM

### Purpose (1.B.b)

The speed governing system senses physical core speed ( $N_2$ ) and PLA and adjusts the fuel flow ( $W_f$ ) as necessary to maintain the desired speed setting established by power lever position (speed demand  $N_2^*$ ).

### Operation (2.C.b)

The PLA speed demand is biased by Fan Inlet Temperature ( $T_{2.0}$ ) and Fan Inlet Pressure ( $Ps_{12}$ ), in a manner to change  $N_2$  as necessary to produce the proper fan speed (thrust).

### Functional Description (3.D.b)

The power lever (PLA) controlled from the flight deck, is applied to the speed sensing governor. The speed governor monitors actual speed through engine driven flyweights. The centrifugal force of the flyweights, which is a function of engine  $N_2$  core speed, is applied to the speed governor spring; a counteracting force is applied by the power lever. The position of the governor pilot valve is determined by comparing engine speed with the desired speed setting established by the power lever. A buffer piston provides stabilization pressures to the governor pilot valve to prevent hunting which will cause the fuel flow to oscillate. The positioning of the governor (speed) pilot valve by the resultant difference of the power command (power lever) and actual speed (flyweights) determines the pilot valve governor servo

command ( as limited by the pilot valve) to the governor servo piston to increase or decrease the fuel flow to the combustion chamber and thus control speed.

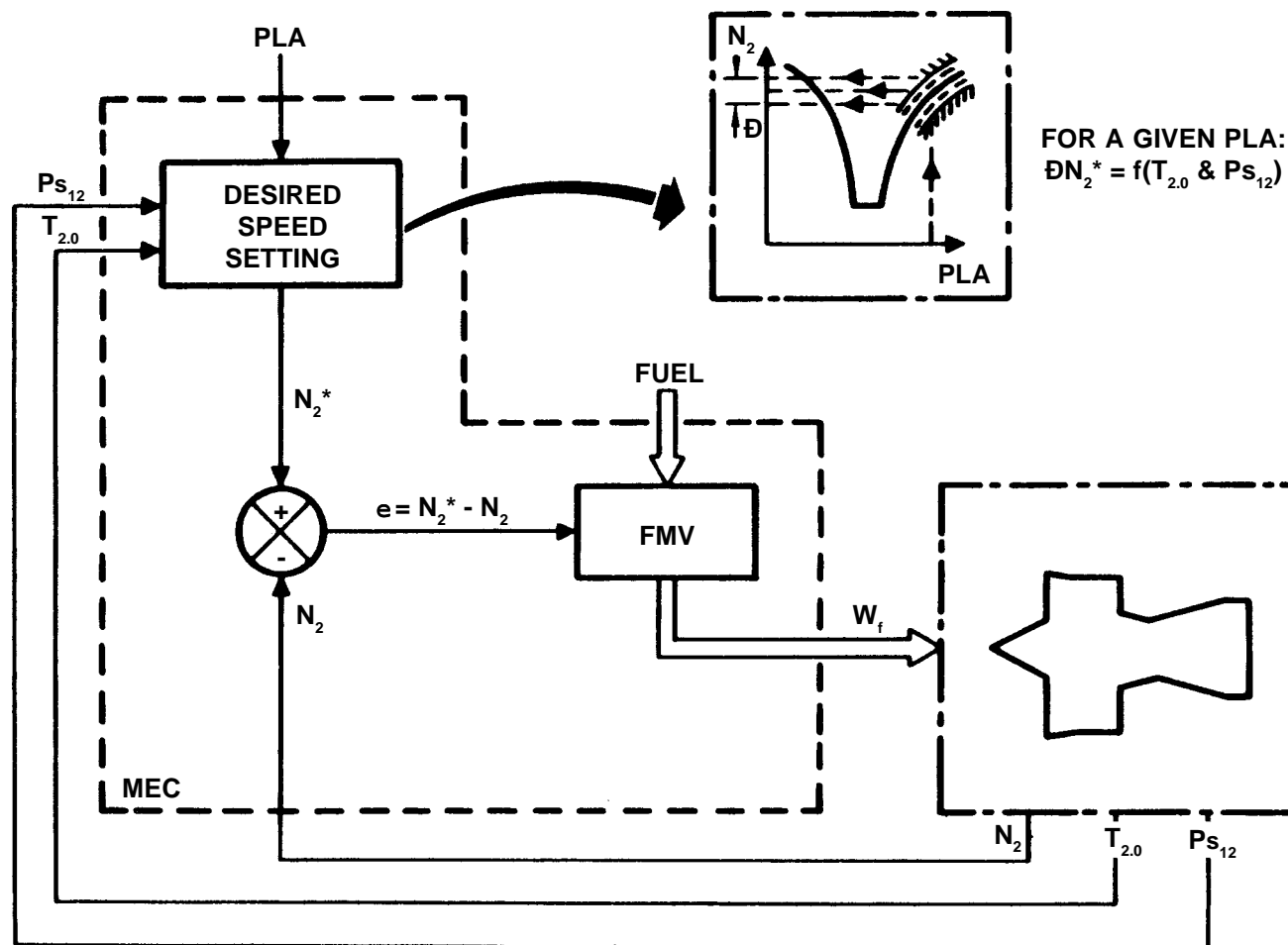
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## SPEED GOVERNING SYSTEM

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## FUEL RATE LIMITING SYSTEM

### Purpose (1.B.b)

Apart from the operating limits governed by the mechanical integrity of its components, the engine is subject to two other limits:

1. Lower or minimum limit imposed by the risks of lean flameout.
2. Upper or maximum limit imposed by the risk of rich flameout compressor flow instability (stall) and overheating.

During transient operation, the speed governing system could change the metered fuel flow beyond the safe limits described above.

The purpose of the fuel limiting system is to define and impose correct engine fuel flow limits during rapid transients including accels, decels and starts.

### Operation (2.C.b)

The fuel limiting system schedules acceleration and deceleration fuel flow to the engine as a function of  $N_2$ ,  $T_{2.5}$ ,  $Ps_3$  and CBP.

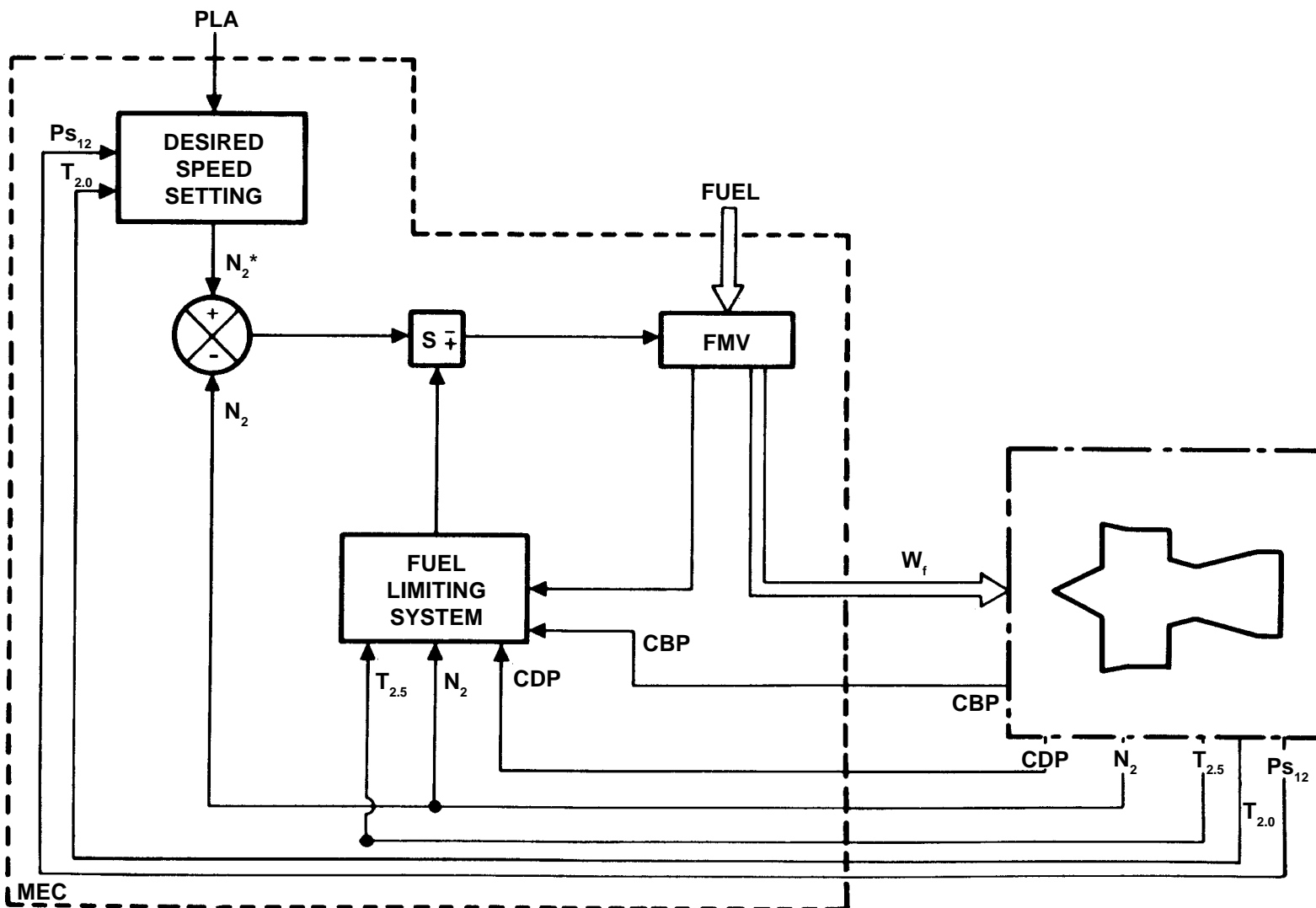
### Functional Description (3.D.b)

Three engine parameters establish the fuel rate:

- CDP or  $Ps_3.0$  (modified for bleed, CDP) - KP3.
- Compressor Inlet Temperature ( $T_{2.5}$ ).
- $N_2$  core engine speed.

These 3 parameters are used to position the 3 D cam and CDP cam, and through connecting linkages establish fuel flow limits. The contours of the 2 cams are designed to represent the fuel flow limits. The computing (summing/adding) levers mix the output of the two cams and compare the result to the actual fuel flow. The resultant comparison linkage then controls the servo supply pressure to (and the drain from) the governor pilot valve. By stopping the supply or blocking the drain, the governor action of positioning the fuel metering valve is limited as a function of the output of this cam and linkage.





## FUEL LIMITING SYSTEM

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## FUEL RATE LIMITING SYSTEM

### Functional Description (3.D.b)

The maximum fuel flow rate allowed during acceleration is determined by two cams:

- The "3D cam", rotated according to  $N_2$  received from the tachometer flyweights and driven linearly according to  $T_{2.5}$ . The cam position represents the required ratio for the fuel flow rate  $(W_{f2})/Ps_3$ , which varies for each  $N_2$  and  $T_{2.5}$  value.
- The "CDP cam", rotated according to  $Ps_3$  and the ratio  $Ps_3/CBP$ .

A lever, in contact with the 3D and CDP cams, combines both position data in order to define the  $W_{f2}$  limit allowed during acceleration.  $W_{f2}$  is compared to the actual engine fuel flow rate ( $W_{f1}$ ). The signal resulting from  $W_{f2} - W_{f1}$  limits fuel flow rate automatically during acceleration, for every point within the flight envelope.

The deceleration fuel flow rate changes are 55 percent of the acceleration fuel flow rate changes. This is done by the limit pilot valve control of PC and PB fuel pressures to the governor pilot valve for deceleration versus acceleration. The deceleration fuel flow schedule established at a rate which would prevent the engine from incurring a flameout due to too much reduction in fuel flow relative to the air supplied by the high pressure compressor.

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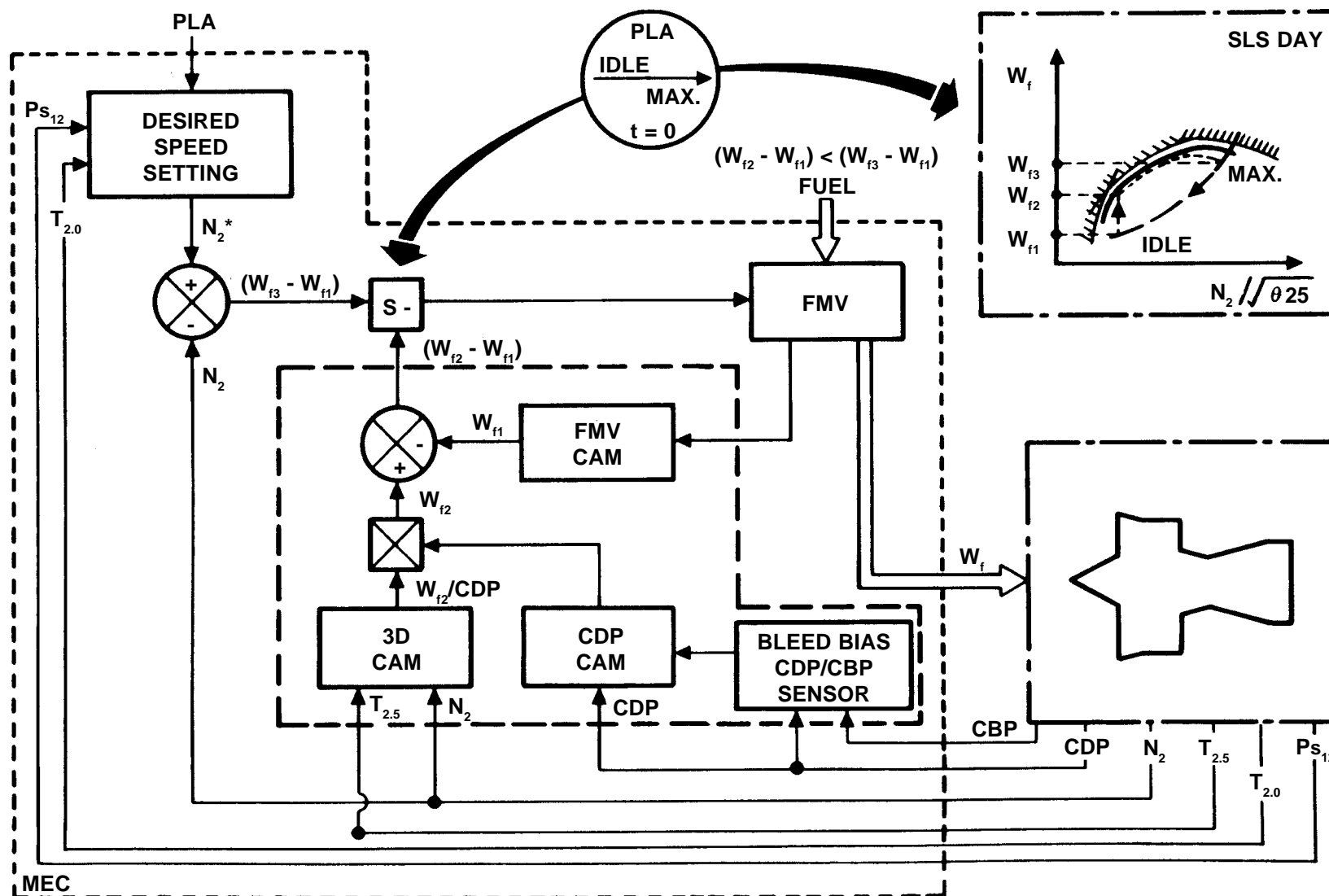
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FUEL LIMITING SYSTEM: ACCELERATION EXAMPLE

## IDLE CONTROL SYSTEM

### **Purpose (1.B.b)**

The engine idle control system is an automatic system which uses the aircraft's ground sensing relay to maintain engine high idle in flight and low idle when the airplane is on the ground.

Low idle speed for ground use will provide a constant thrust level regardless of inlet temperature and is scheduled to produce adequate taxi thrust while minimizing noise, fuel consumption and braking effort. In flight low idle speed is scheduled to minimize fuel consumption.

High Idle speed is optimized to provide rapid recovery of T/O thrust if required.

### **Operation (2.C.b)**

Only one throttle position is used regardless of which idling speed is selected. Both idling speeds are automatically adjusted as a function of  $T_{2.0}$  and  $P_{s_{12}}$ .

### **Functional Description (3.D.b)**

When the PLA is at idle, the speed governing system receives an idle-corrected speed signal corresponding to low or high idle. The system is designed to switch to the high idle schedule from the low idle schedule when a 28 VDC signal is removed from the solenoid mounted on the MEC.

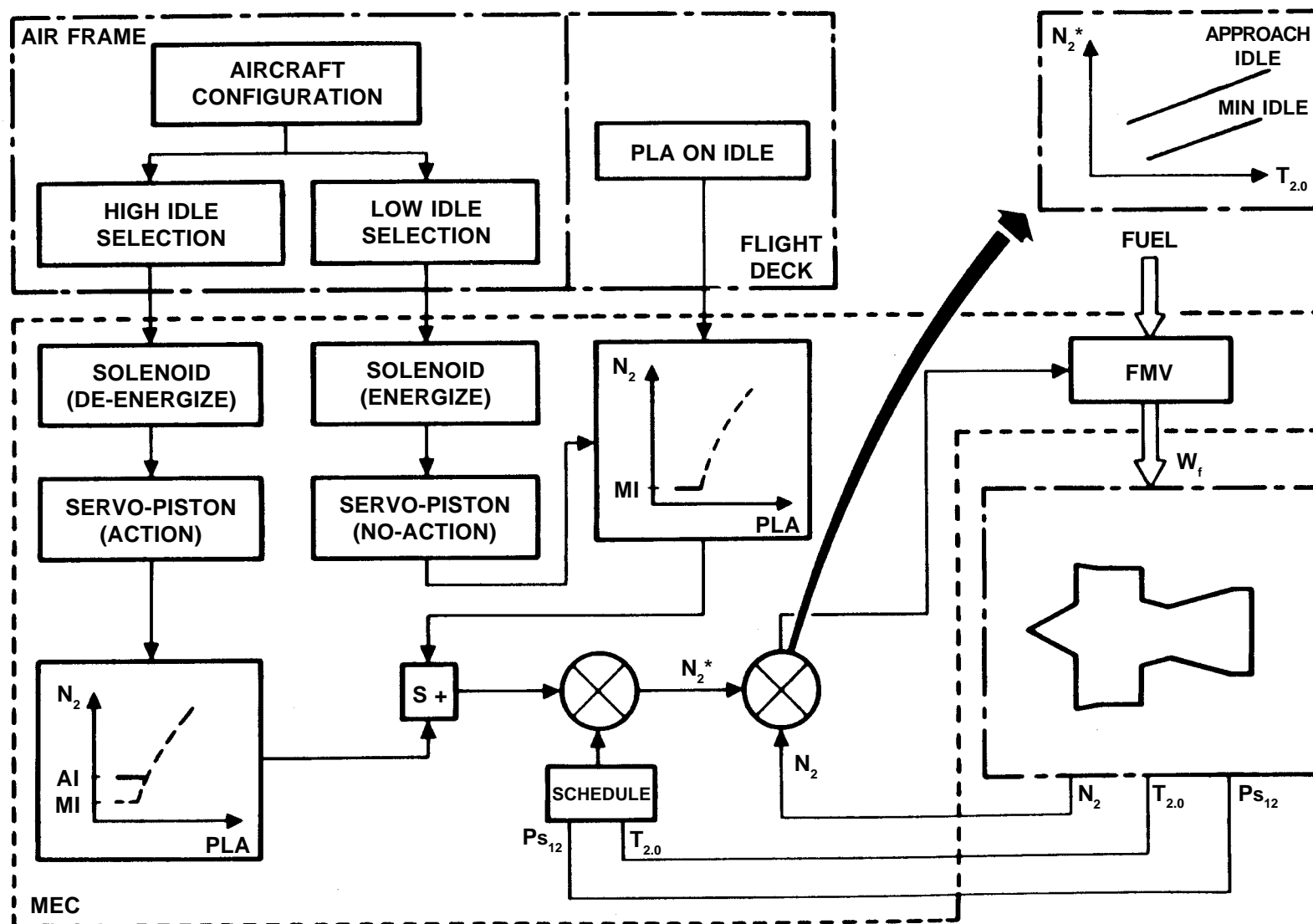
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# IDLE SYSTEM

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## FUEL MANIFOLD ASSEMBLY

### Identification (1.A.b)

The fuel manifold is composed of two halves with a three-piece drain manifold.

Each manifold half incorporates 10 fuel nozzle connections. The complete fuel manifold supplies fuel to 20 fuel nozzles.

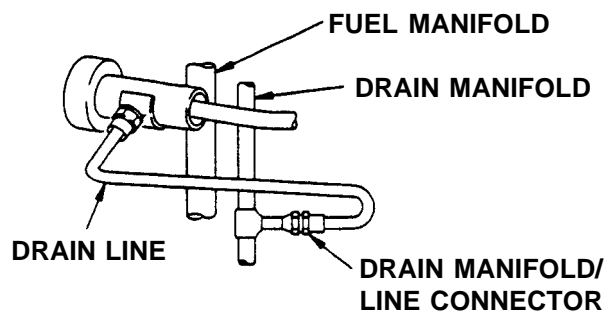
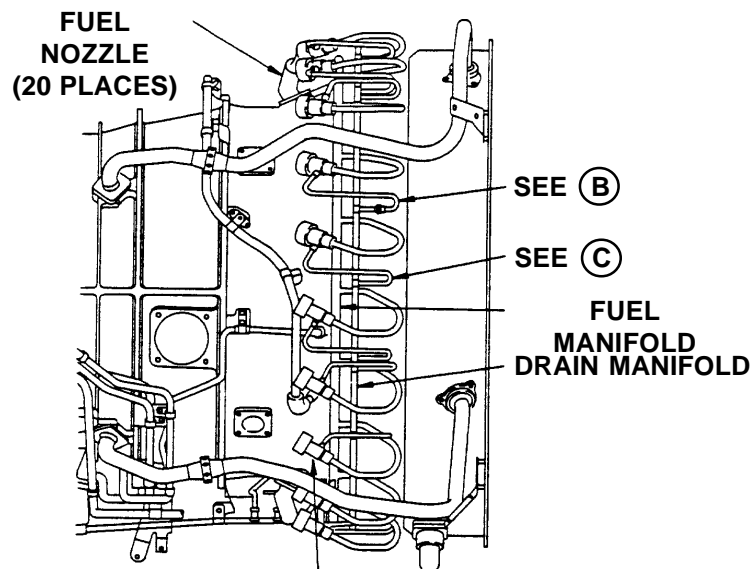
The drain manifold has 15 integral and 5 removable drain tubes and is connected to each fuel nozzle. The 5 removable drain tubes are to facilitate borescoping.

### Purpose (1.B.b)

To distribute fuel from the MEC to the fuel nozzles, and provide drainage in the event of a leak.

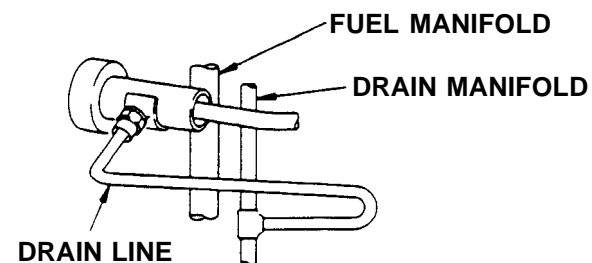
### Location (2.A.b)

The fuel manifold is connected to a Y-shaped supply tube at approximately the 5 and 6 o'clock positions. Each connection of the Y has an individual drain tube that is secured to the fuel manifold by bolts.



AT NOZZLE POSITIONS  
3, 6, 8, 11 AND 18

(B)



AT NOZZLE POSITIONS  
1, 2, 4, 5, 7, 9, 10, 12, 13,  
14, 15, 16, 17, 19 AND 20

(C)

## FUEL MANIFOLD ASSEMBLY

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**FUEL NOZZLES****Identification (1.A.b)**

Each of the 20 fuel nozzles contains a primary and a secondary flow path, a flow divider, a check valve, fuel strainers and a dual orifice spray tip.

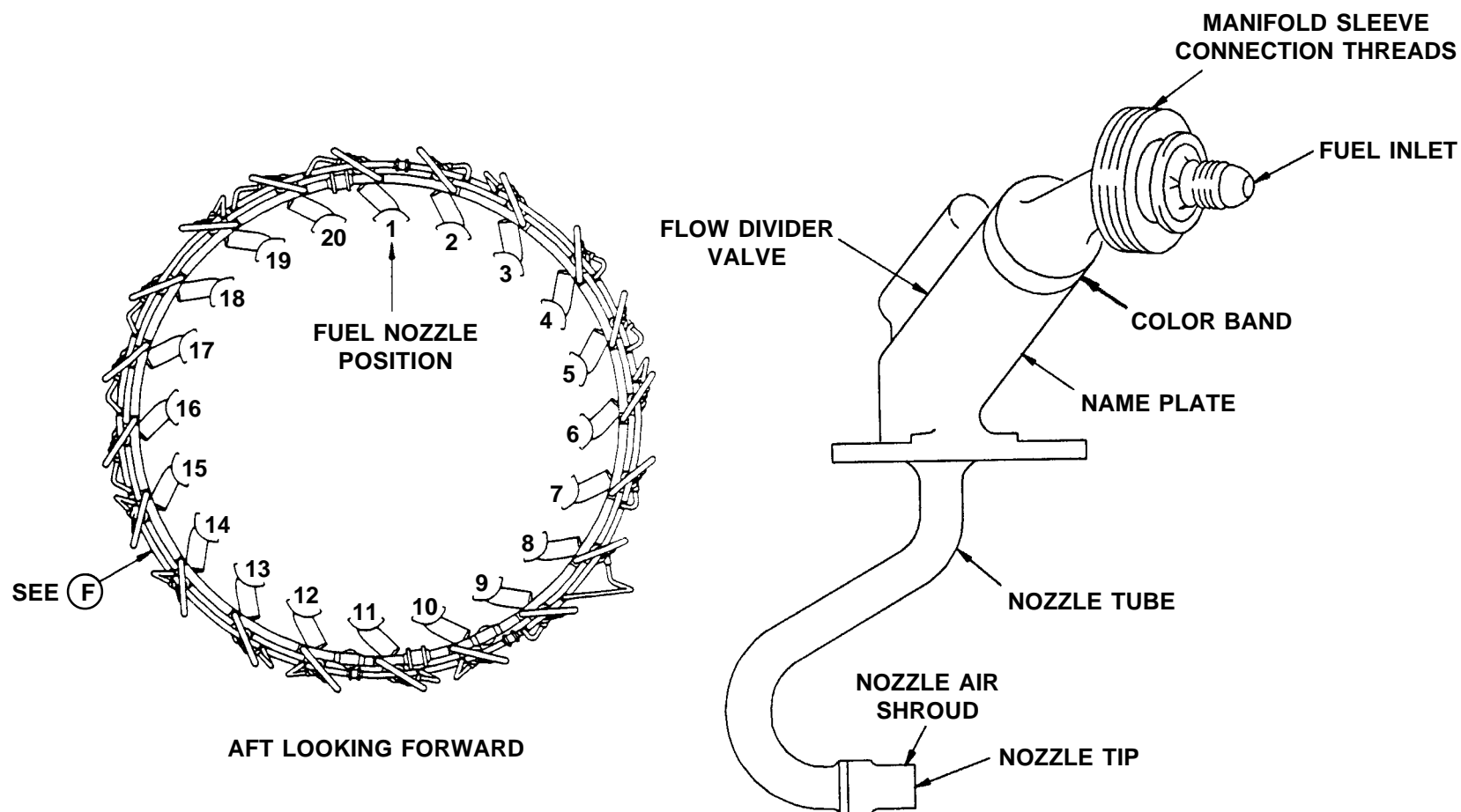
**Purpose (1.B.b)**

The fuel nozzles are designed to spray a fine mist of fuel into the combustion chamber and are installed into the combustion case at 20 locations. Each nozzle is connected to a fuel manifold and drain manifold.

**Location (2.A.b)**

The twenty fuel nozzles are numerically identified clockwise (CW) beginning just right of the 12 o'clock position (aft looking forward).





## FUEL NOZZLES

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**FUEL NOZZLES****Operation (2.C.b)**

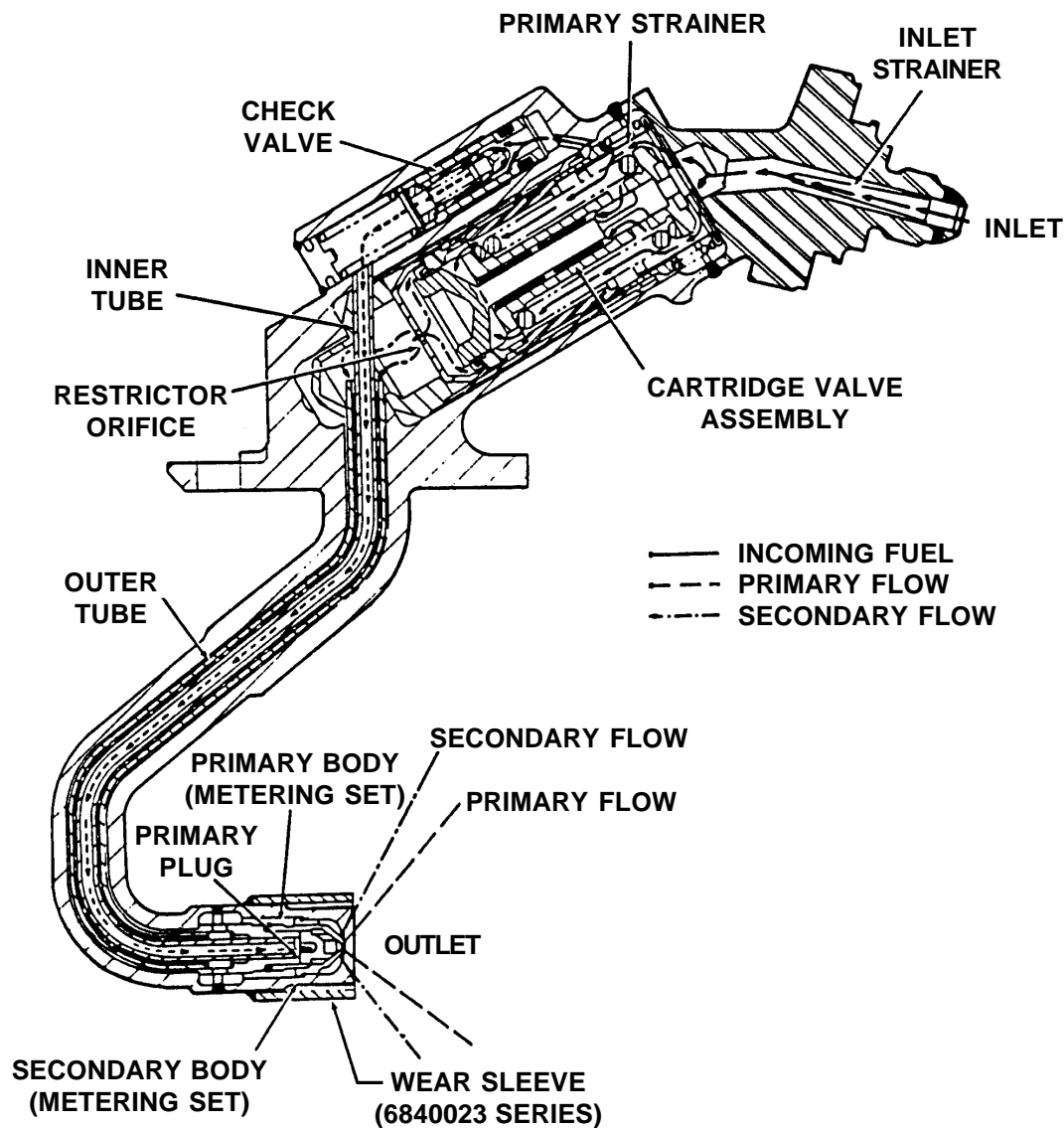
During engine starting and at altitude low power conditions when fuel flow is equally low, the flow divider valve will close the secondary flow path thus assuring the development of system pressures high enough to produce an adequate spray pattern even at low fuel flows.

The check valve in the primary flow path closes at shutdown and helps to maintain fuel manifold prime.

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## FUEL NOZZLE

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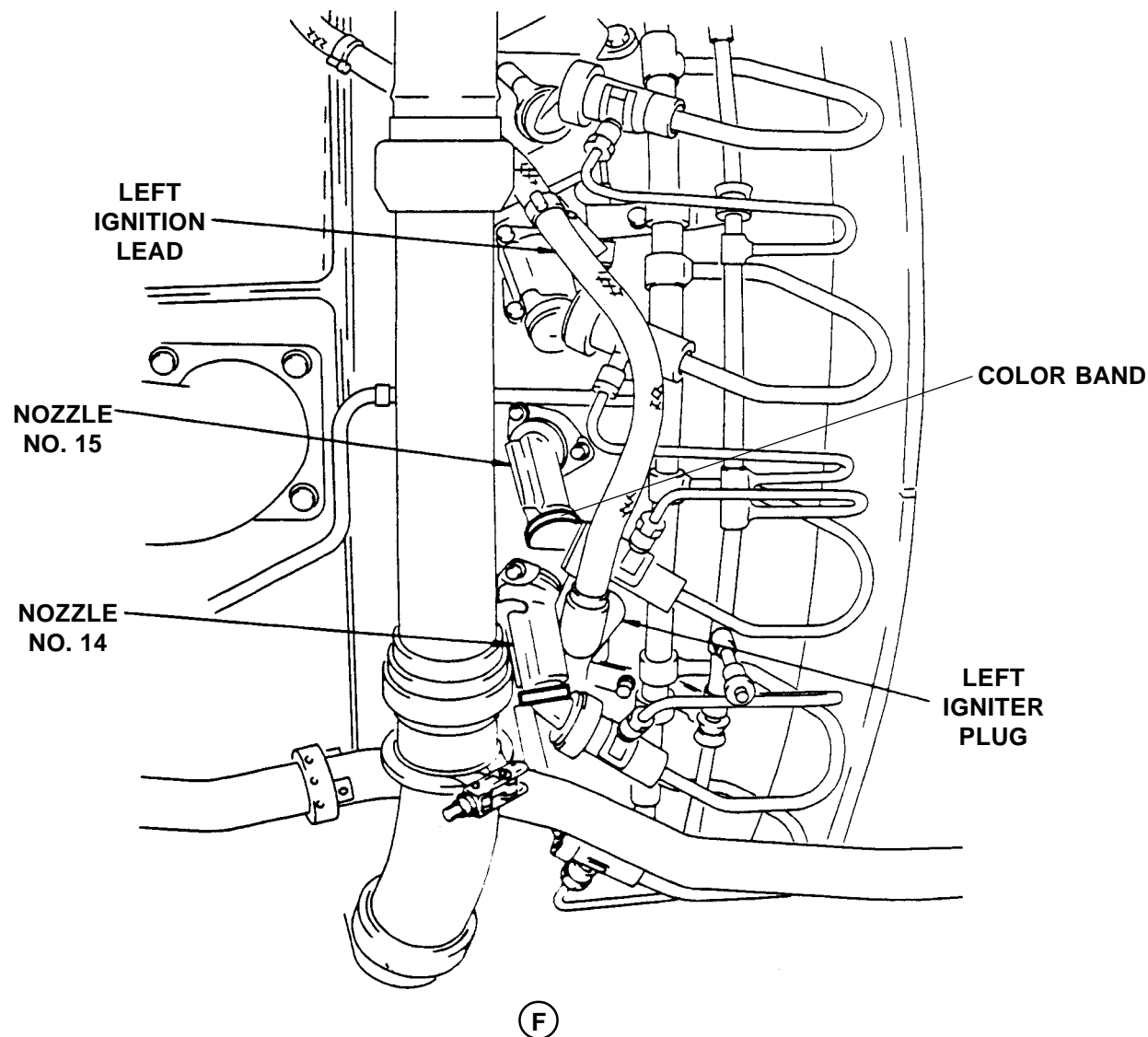
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**FUEL NOZZLES****Functional Description (3.D.b)**

Introduced by service bulletins to improve upon start flameout margin, two or four nozzles were equipped with a richer primary fuel flow. These nozzles are placed on either side of the ignition system igniters at nozzle positions 7 and 8 (four-nozzle configurations) and 14 and 15 (two-nozzle and four-nozzle configurations). In addition to their part numbers, the nozzles are identified by a color band around the nozzle body.

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## FUEL NOZZLE INSTALLATION

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**COMPRESSOR INLET TEMPERATURE (CIT)****Identification (1.A.b)**

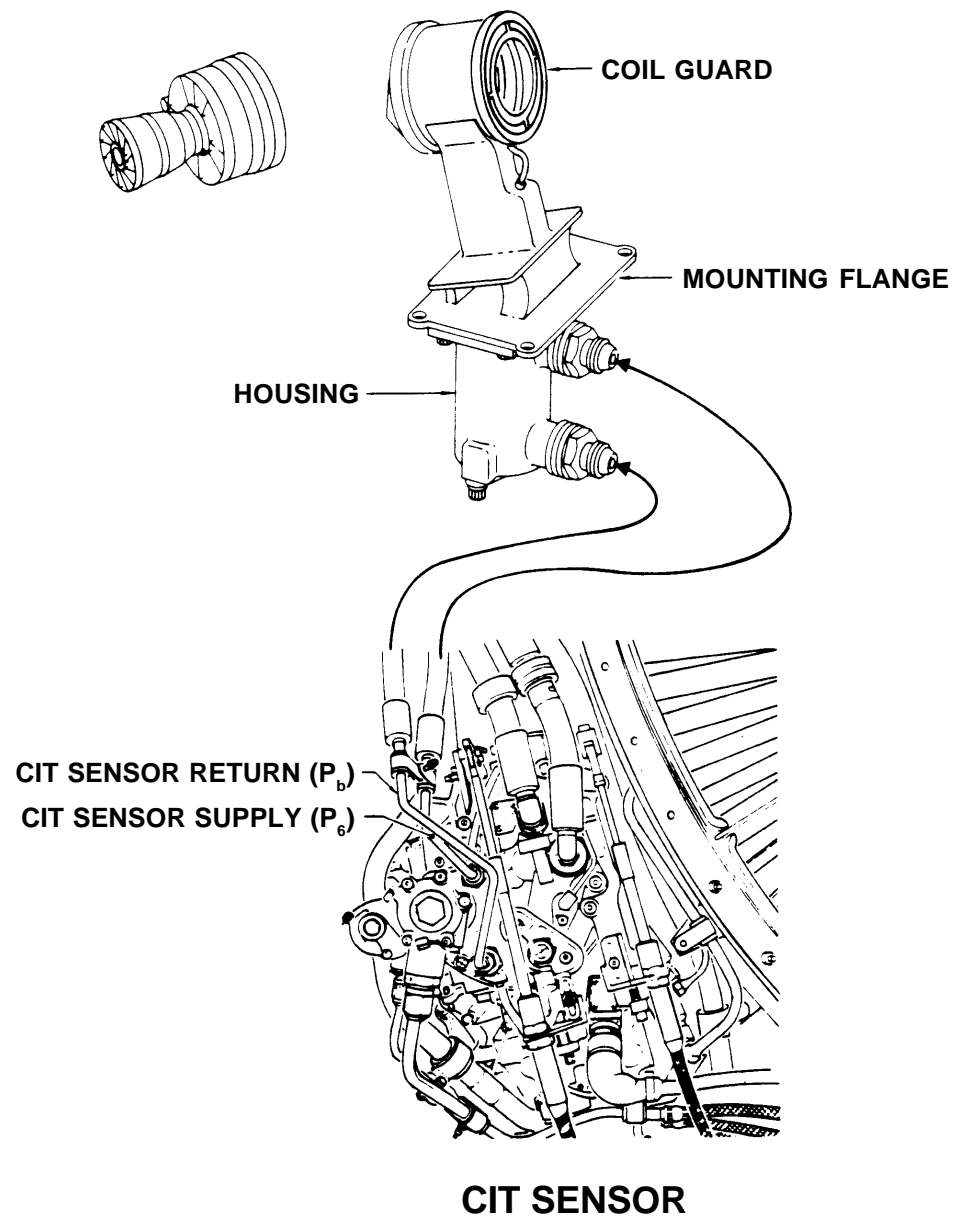
The CIT sensor consists of a guarded, constant volume, gas-filled coil and a metering valve.

**Purpose (1.B.b)**

The CIT sensor is a temperature sensor and temperature compensator unit for the MEC to establish parameters in controlling VSV position, VBV position and acceleration/ deceleration fuel flow schedules.

**Location (2.A.b)**

The sensor is mounted into a port between the 5 and 6 o'clock struts on the fan frame with the coil projected into the HPC inlet airstream, just forward of the IGV's.



**COMPRESSOR INLET TEMPERATURE (CIT)****Operation (2.C.b)**

The CIT responds to the sensed primary inlet engine air temperature and provides a hydraulic signal pressure (using fuel as a medium), which is a function of CIT, to the MEC.

**Functional Description (3.D.b)**

The temperature sensing coil has a constant volume; therefore, the gas pressure inside the coil is proportional to the temperature. The coil is connected to the sensing bellows so that any change in gas pressure within the coil changes the force on the feedback bellows and spring. The feedback bellows' force is a result of the fuel pressure inside the bellows which is controlled by the metering valve.

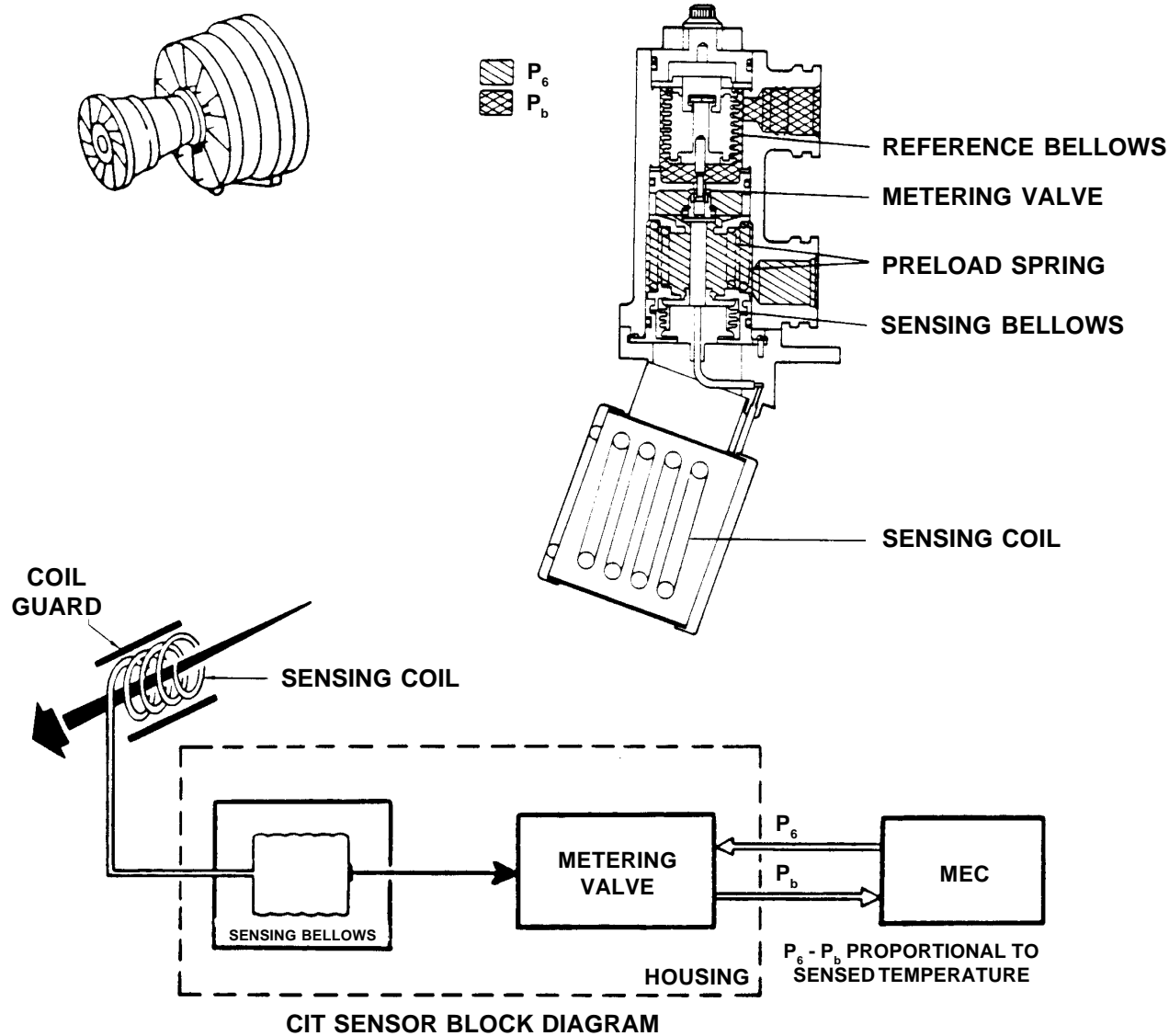
When CIT changes, the gas pressure inside the sensing bellows varies, thereby opening or closing the metering valve. The metering valve changes the fuel pressure which alters the force on the feedback bellows, thus balancing the sensing bellows force. The differential fuel pressure, therefore, is proportional to the temperature at the sensing coil. This fuel pressure is then used by the MEC as a scheduling parameter.

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CIT SENSOR (T<sub>2.5</sub>)

## COMPRESSOR INLET TEMPERATURE (CIT)

### Functional Description

This pressure actuates a servo system that positions the MEC's 3D cam axially. A decrease in temperature (cold shift), will decrease the pressure signal to the MEC. The affect is to reduce speed and position the 3D cam so that the VSV's will track on the open side of the schedule. An abnormal CIT (cold shift) input could cause a compressor stall. A complete (cold shift) failure of the CIT sensor would cause a large drop in hydraulic signal pressure and would drive the VSV schedule to its fail-safe setting (59°F).

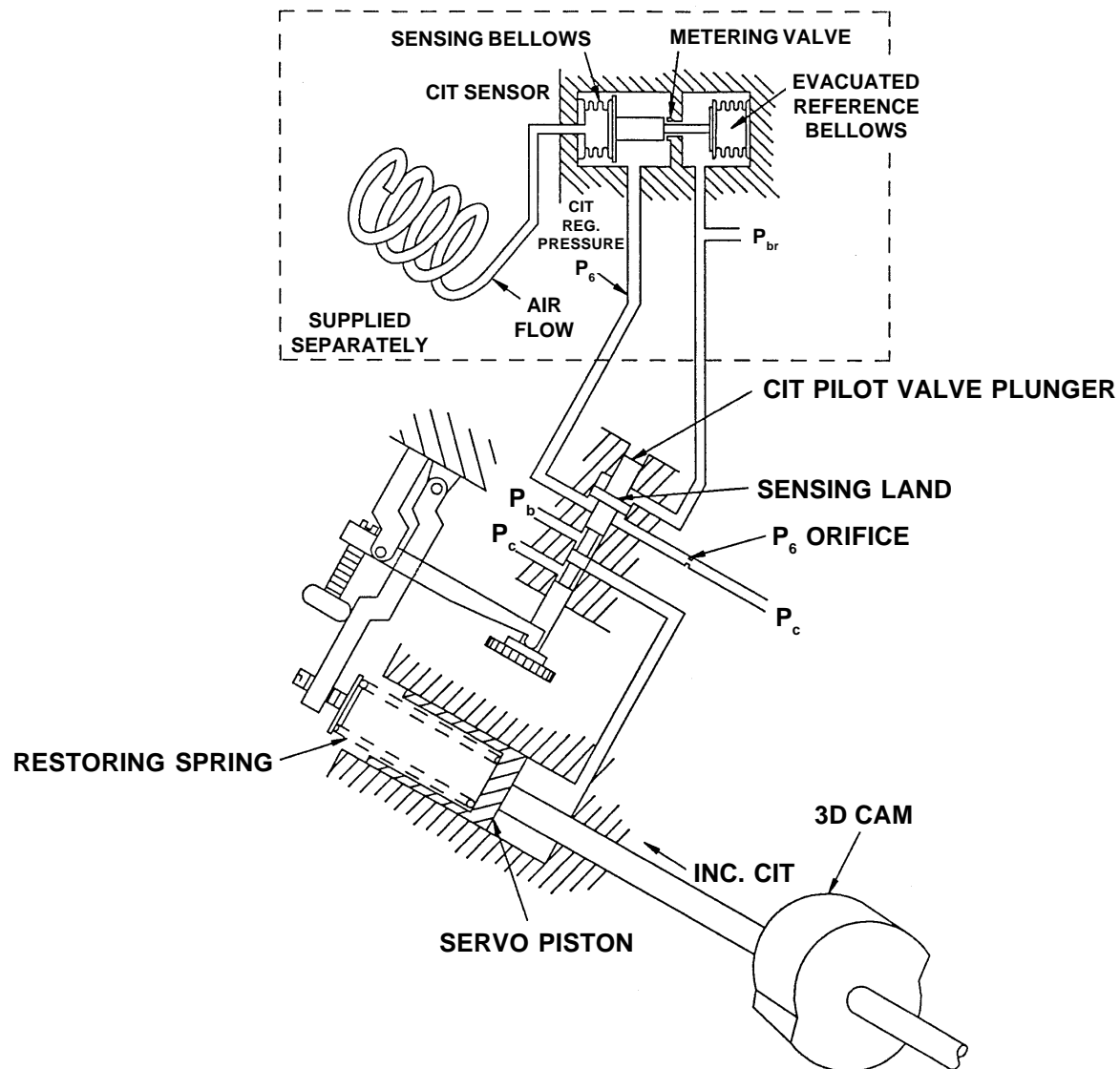
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**CIT SYSTEM**

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**COMPRESSOR DISCHARGE PRESSURE (CDP)****Purpose (1.B.b)**

The CDP sensor and associated computer linkage system establish a fuel flow schedule.

**Location (2.A.b)**

CDP, or  $P_3$ , is piped to the MEC from a port located at approximately 9 o'clock just aft of the fuel nozzles on the combustion case.

**Operation (2.C.b)**

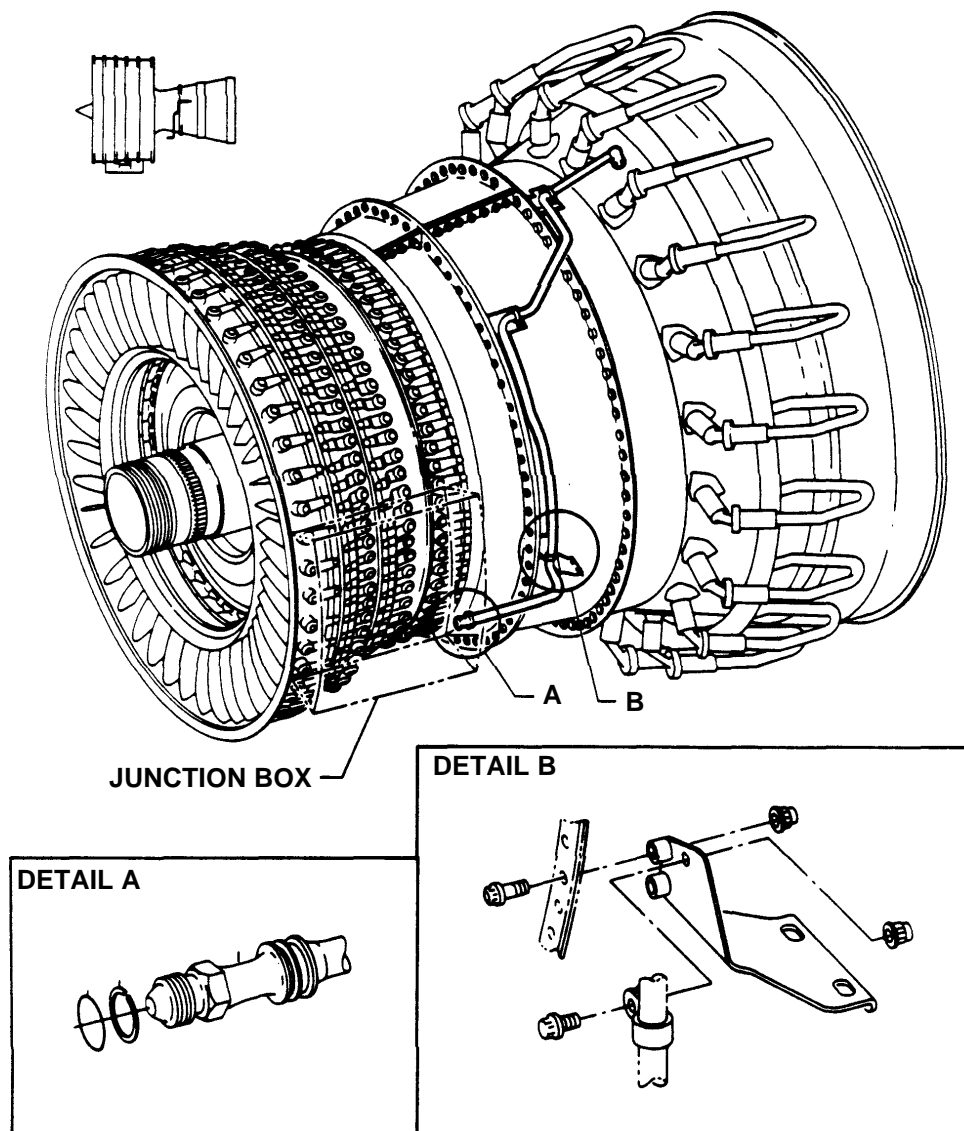
The CDP sensor, in the MEC, converts the pneumatic ( $P_3$ ) pressure to a hydraulic pressure and through the CDP servo system rotates the Main Engine Control's CDP cam. As CDP increases, the fuel flow schedule is increased.

The CDP input is biased by a CBP measurement to provide automatic resetting of the acceleration schedule to maintain rapid acceleration times when airplane bleed demands are large and provide adequate stall margins when bleed demands are lower. The CBP signal imposes a bias on the CDP sensor which changes CDP cam positioning to allow for a higher acceleration rate when airplane bleed rates are higher.

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**CDP SENSING LINE**

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**BLEED BIAS SENSOR****Identification (1.A.b)**

The system consists of a bleed bias sensor and connecting tubing to the MEC. The sensor is a dual venturi device which senses CBP.

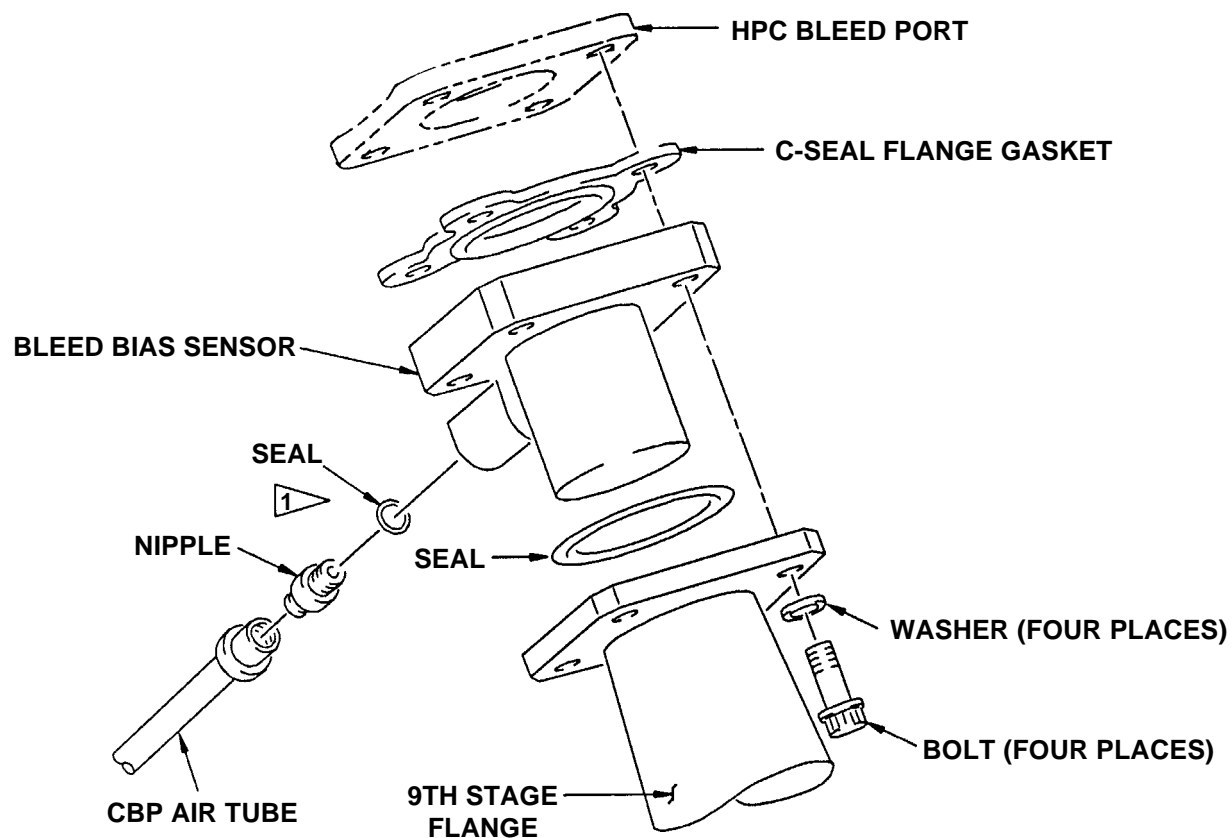
**Purpose (1.B.b)**

The bleed bias sensor system provides automatic resetting of the acceleration schedule to maintain rapid acceleration rates when bleed demands are high, and enables adequate stall margins to be observed when bleed demands are low.

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## BLEED BIAS SENSOR INSTALLATION

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## BLEED BIAS SENSOR

### Location (2.A.b)

The sensor is located in the 9th stage ducting and is mounted between the 9th stage ducting flange and the 9th stage HPC bleed port at the 4 o'clock position.

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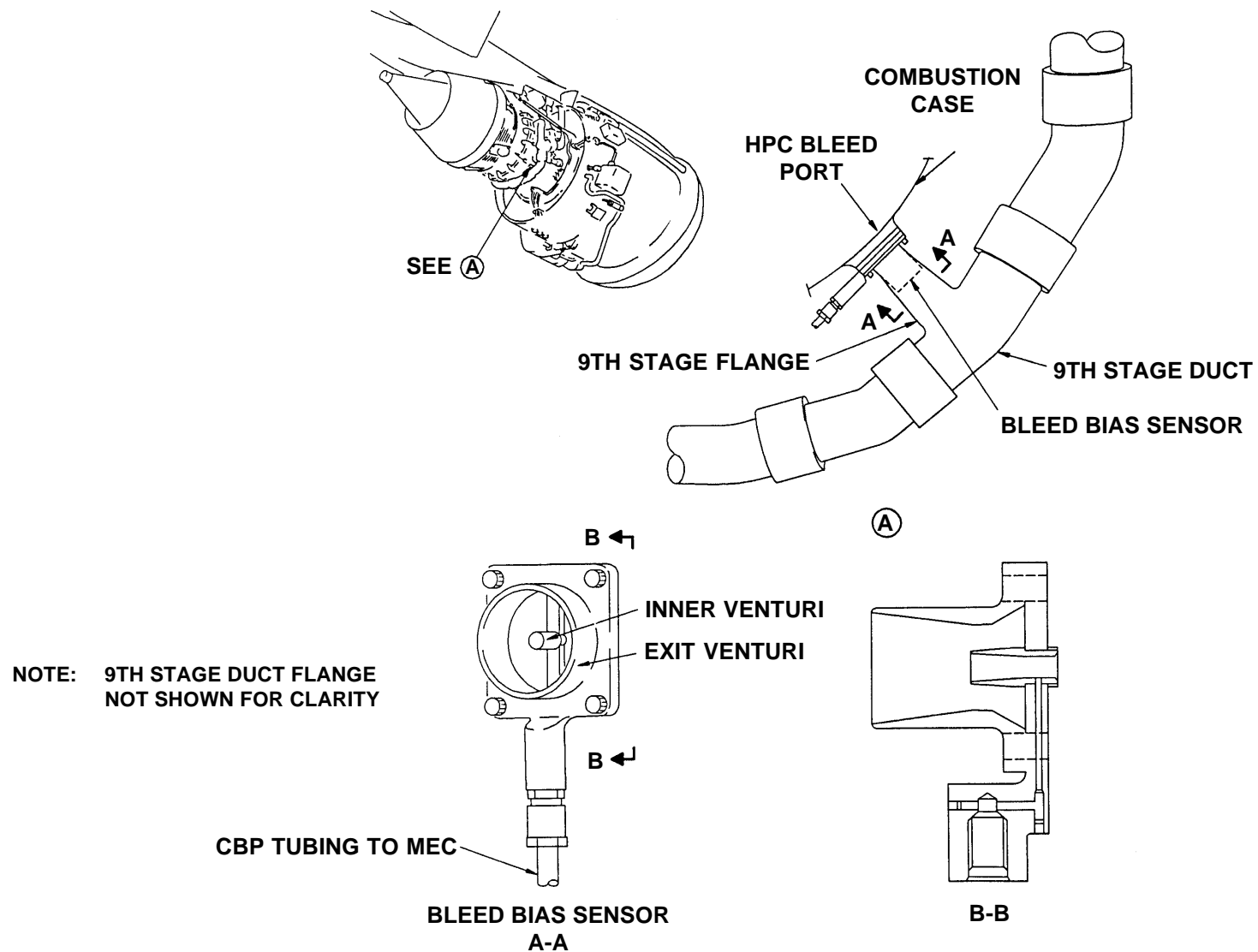
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## BLEED BIAS SENSOR SYSTEM COMPONENT LOCATION

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## BLEED BIAS SENSOR

### Operation (2.C.b)

The pressure measurement (CBP) from the venturi, which is a function of the bleed rate, is transmitted by tubing to the MEC CBP sensor and imposes a bias on the CDP sensor which changes the CDP cam positioning to allow for a higher acceleration rate and adequate stall margins depending on bleed demands.

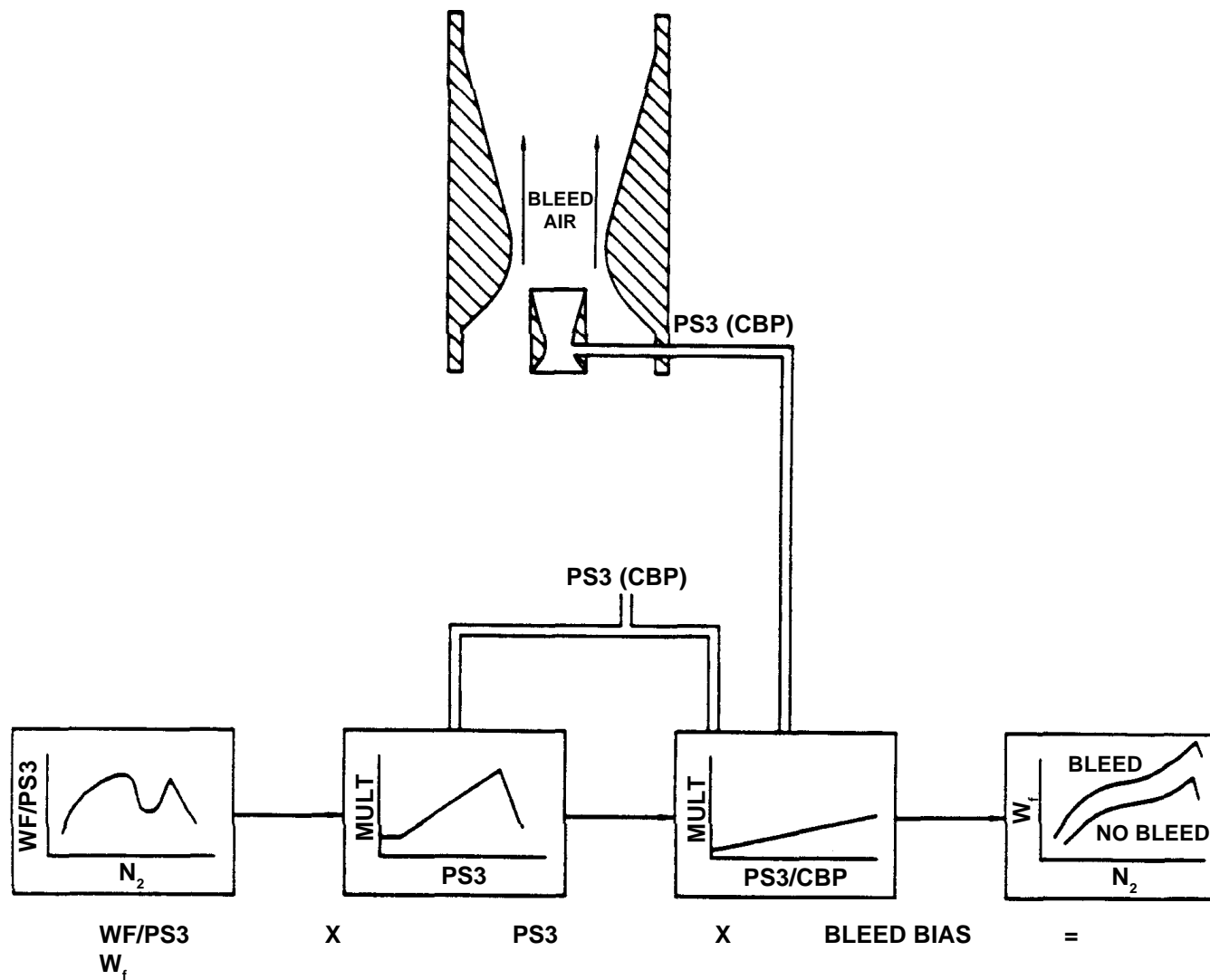
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**BLEED BIAS FUNCTION DIAGRAM**

**N<sub>2</sub> SPEED SENSOR (FLIGHT DECK)****Identification (1.A.b)**

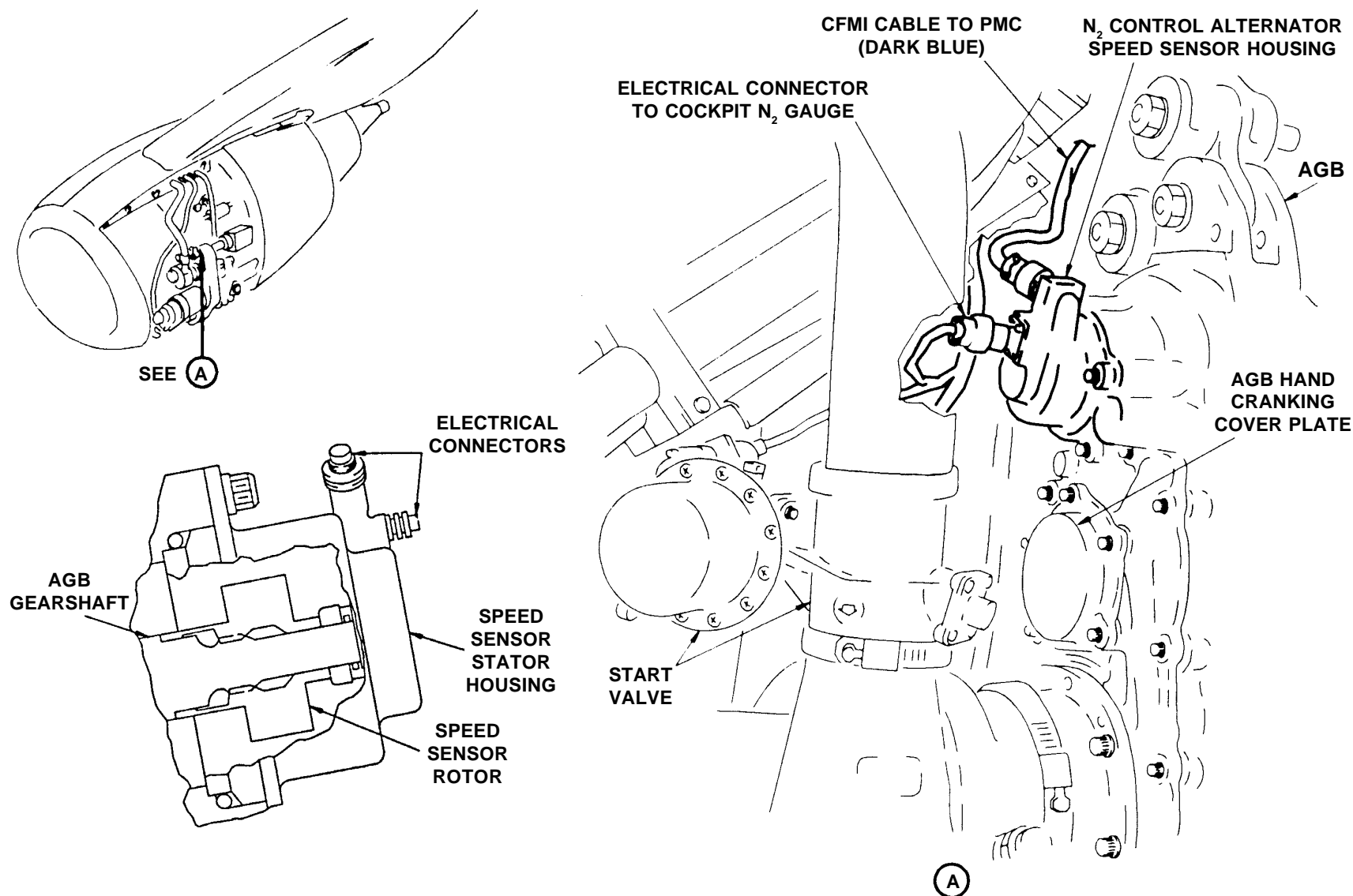
The sensor consists of a rotor, a stator and case with two-insert electrical connectors located on and driven by the AGB shaft.

**Purpose (1.B.b)**

The N<sub>2</sub> speed sensor is an Alternating Current (AC) generator, whose frequency is directly proportional to rotor speed, that provides signals to the N<sub>2</sub> tachometer indicator and electrical power for the PMC.

**Location (2.A.b)**

The N<sub>2</sub> speed sensor is mounted on a bolt pad to the top forward face of the AGB at the 8 o'clock position.



## N<sub>2</sub> CONTROL ALTERNATOR SPEED SENSOR INSTALLATION

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## N<sub>2</sub> SPEED SENSOR (FLIGHT DECK)

### Interface (2.B.b)

The sensor is spline-mounted to the gearbox shaft by a self-locking nut. The stator and case are completely separable and mount directly to the gearbox housing.

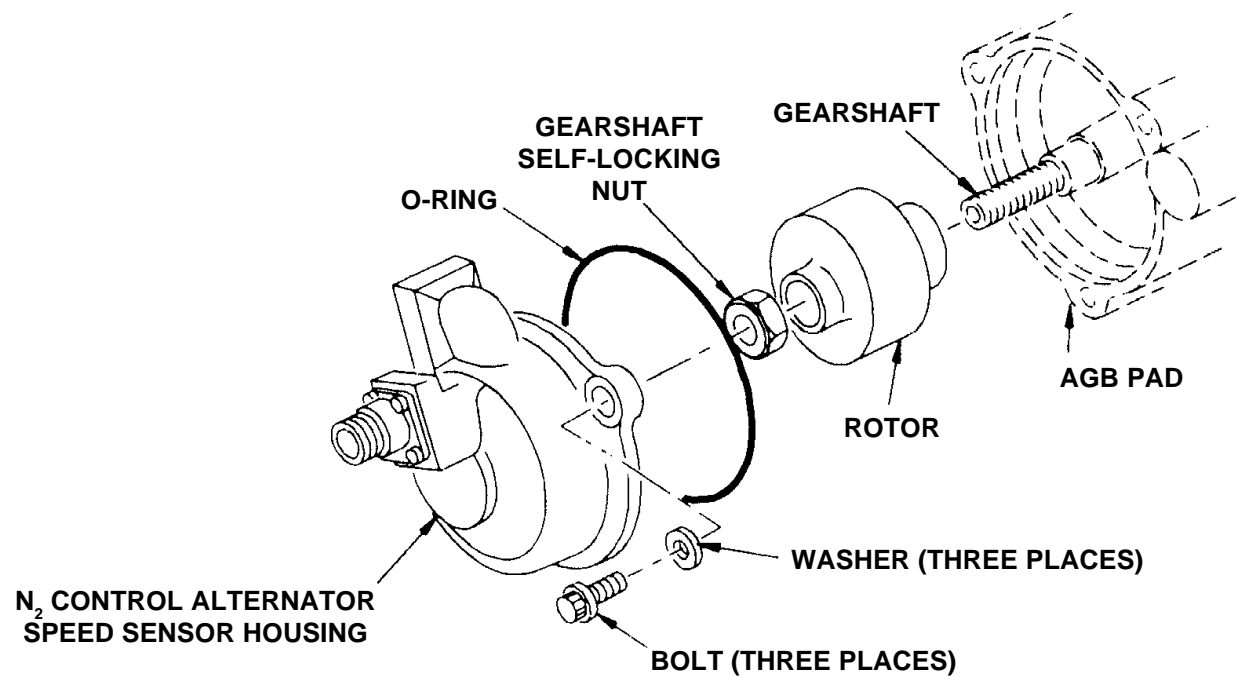
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## N<sub>2</sub> CONTROL ALTERNATOR SPEED SENSOR

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**N<sub>2</sub> SPEED SENSOR (MEC)****Identification (1.A.b)**

Flyweights in the MEC are driven by a shaft and gear coupling through the fuel pump and the engine accessory drive system.

**Purpose (1.B.b)**

N<sub>2</sub> core engine speed sensing for the governor and tachometer systems of the MEC.

**Operation (2.C.b)**

The flyweights provide a control input that is a function of N<sub>2</sub>.

**Functional Description (3.D.b)**

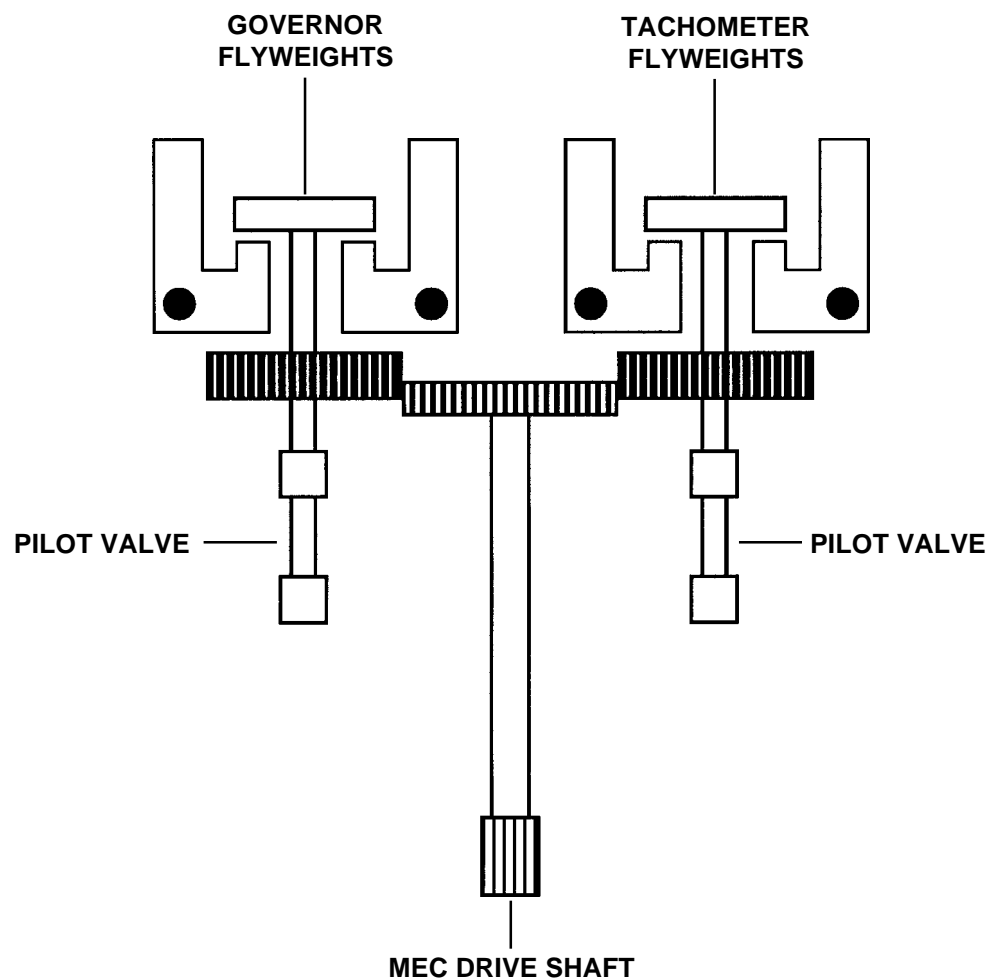
The MEC governor system utilizes this signal input as feedback to null the power demand input as described in speed governing. The tachometer system utilizes this signal input to command the positioning of the turbine clearance valves (TC<sub>1</sub>, TC<sub>2</sub>, and TC<sub>3</sub> on engines with HPTCC timer) and the rotational positioning of the 3D cam. As N<sub>2</sub> increases, the 3D cam initiates the opening of the VSV's and establishes the fuel flow acceleration schedule for the engine.

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### MEC FLYWEIGHTS

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## N<sub>1</sub> SPEED SENSOR

### Identification (1.A.b)

The sensor consists of a rigid metal tube with a mounting flange and two-connector receptacle. Within the tube is an elastomer damper and a magnetic head sensor with two protruding pole pieces. When the N<sub>1</sub> speed sensor is installed on the engine, only the two-connector receptacle and the body are visible.

### Purpose (1.B.b)

The N<sub>1</sub> speed sensor is a pulse counter that senses N<sub>1</sub> rotor speed and provides signals to the N<sub>1</sub> tachometer indicator and PMC.

### Location (2.A.b)

The N<sub>1</sub> speed sensor is mounted in strut No. 5 of the fan frame at the 4 o'clock position and is secured to the fan frame with two bolts.

### Operation (2.C.b)

Actual N<sub>1</sub> fan speed is measured by speed sensor elements which provide an AC voltage whose frequency is proportional to the fan speed.

### Functional Description (3.D.b)

The sensor incorporates dual sensing elements with one element providing N<sub>1</sub> signal for the PMC and the other element providing signal to the N<sub>1</sub> tachometer indicator. A magnetic ring mounted on the fan shaft is provided

with teeth. The passage of each tooth generates an alternating voltage in the sensor element proportional to actual N<sub>1</sub> speed.

Note: The sensor ring has one tooth thicker than the 29 others to generate a signal of greater amplitude used as phase reference for trim balance.

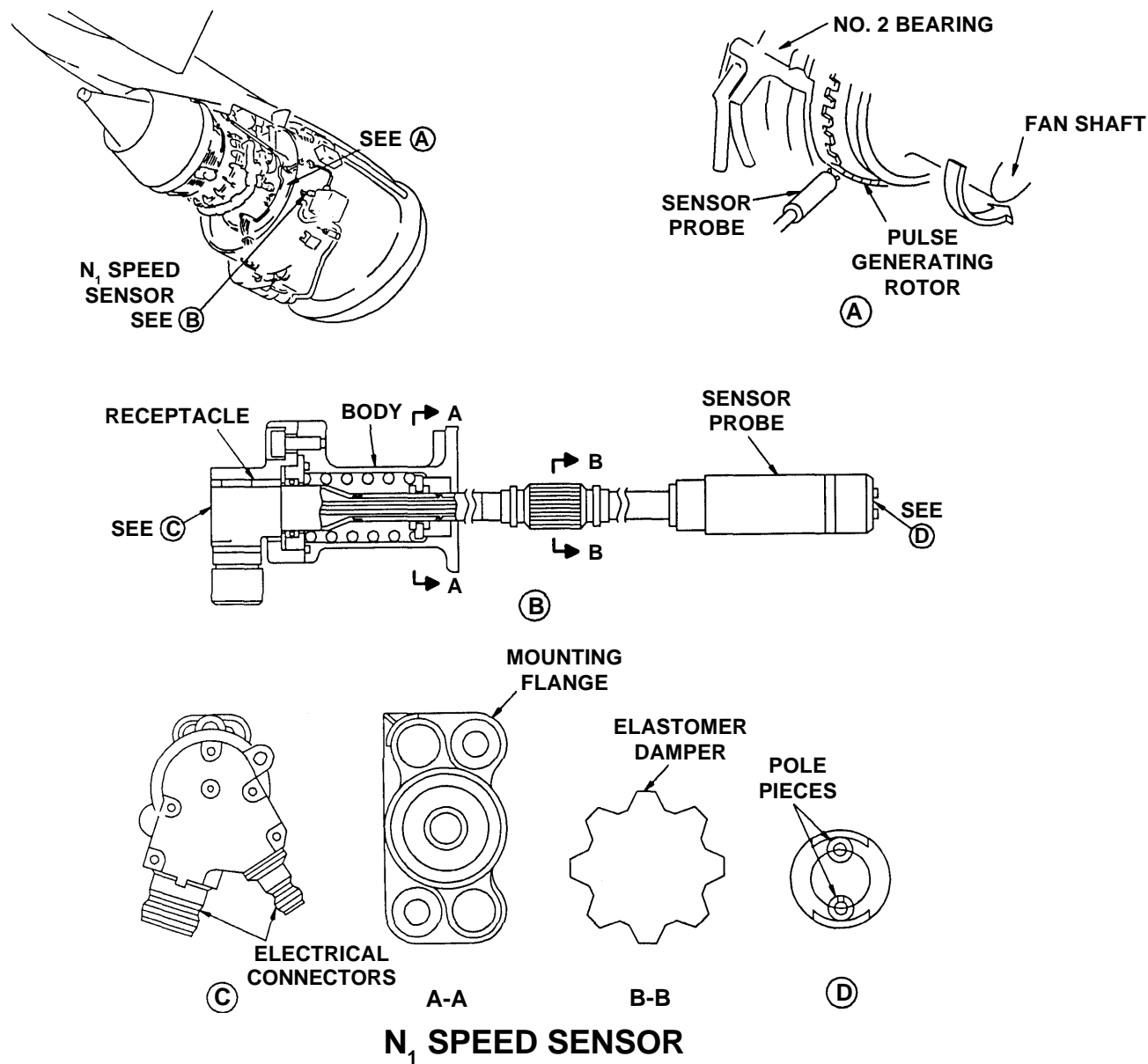
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**Ps<sub>12</sub> PRESSURE SENSING****Identification (1.A.a)**

Four static ports are connected to a 1/4 inch line that goes to the top of the PMC, and to the MEC.

**Purpose (1.B.a)**

Ps<sub>12</sub> pressure sensing measures the engine inlet pressure for core and fan corrected speed requirements.

**Location (2.A.a)**

The sensors are mounted on the forward section of the fan casing at the 2:30, 5, 8 and 11 o'clock positions.

**Operation (2.C.a)**

The Ps<sub>12</sub> pressure is supplied to a sensor located internally in the PMC. The sensor is a strain gage resistance bridge type with an amplifier network.

The same pneumatic pressure is applied to the MEC.

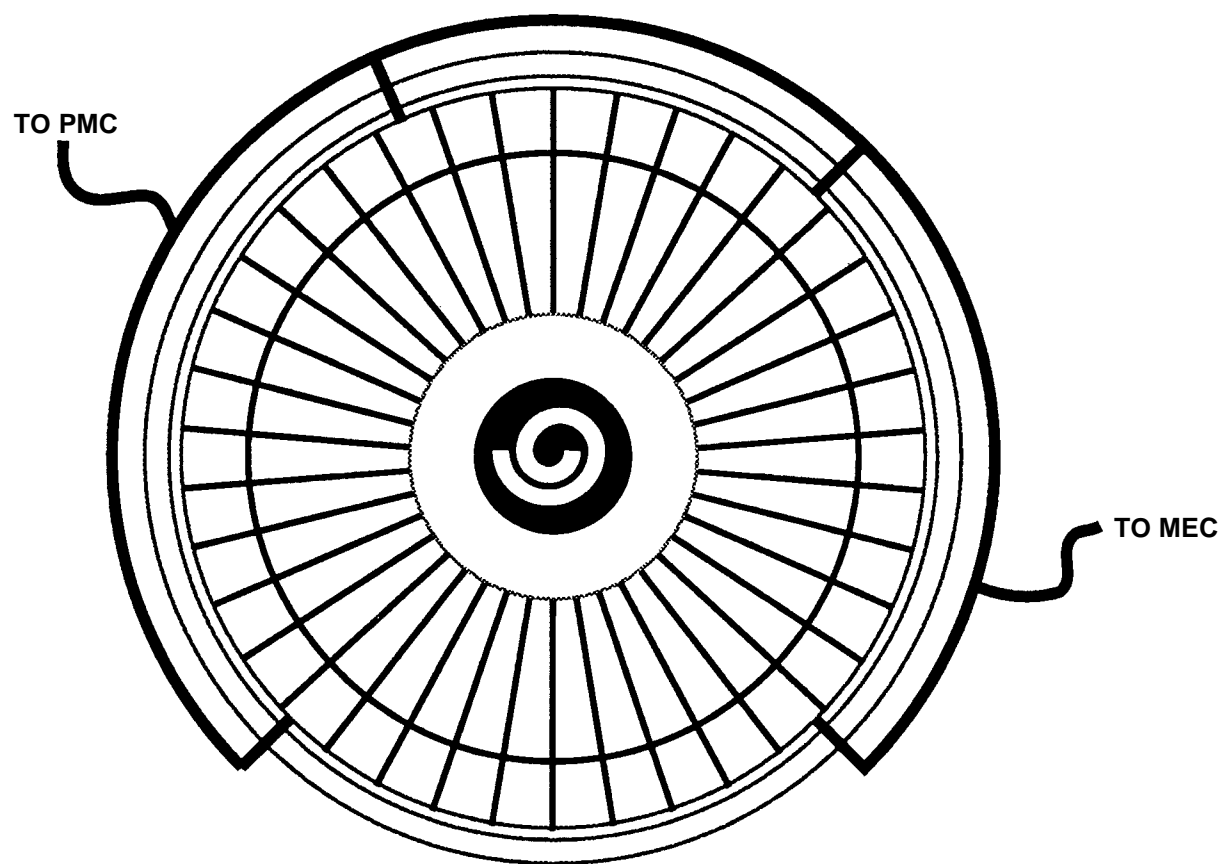
**Functional Description (3.D.a)**

The PMC internal sensor accepts an air pressure input (pounds per square inch absolute [psia]) and converts it to a proportional Direct Current (DC) voltage. A 0-50 MVDC differential output is generated as fan inlet air pressure of 1-20 psia is applied.

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**Ps<sub>12</sub> PRESSURE SENSING SYSTEM**

## T<sub>12</sub> TEMPERATURE SENSOR

### Identification (1.A.b)

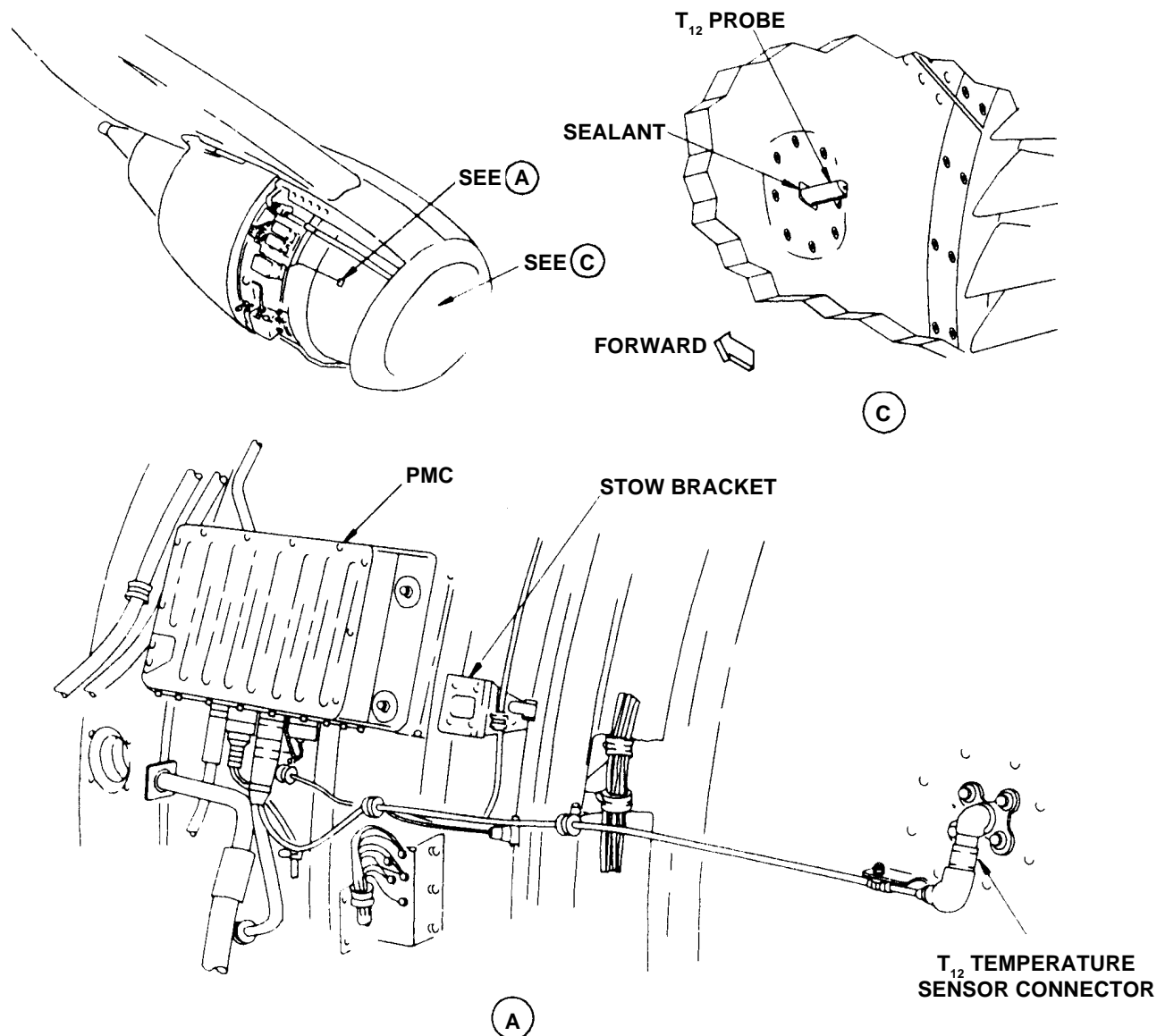
The T<sub>12</sub> temperature sensor consists of two components, a sensing element and a housing.

### Purpose (1.B.b)

To measure the engine inlet air temperature and provide a proportional electrical signal to the PMC.

### Location (2.A.b)

Mounted on the inlet cowl at the 3 o'clock position.  
When the inlet cowl is separated from the engine, the sensor is stowed in a bracket on the engine fan case.



## T<sub>12</sub> TEMPERATURE SENSOR INSTALLATION

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**T<sub>12</sub> TEMPERATURE SENSOR****Operation (2.C.b)**

The sensing element is a thermo resistance device. The PMC provides the sensing element a constant current and measures the voltage, thus the voltage is a function of the temperature.

**Functional Description (3.D.b)**

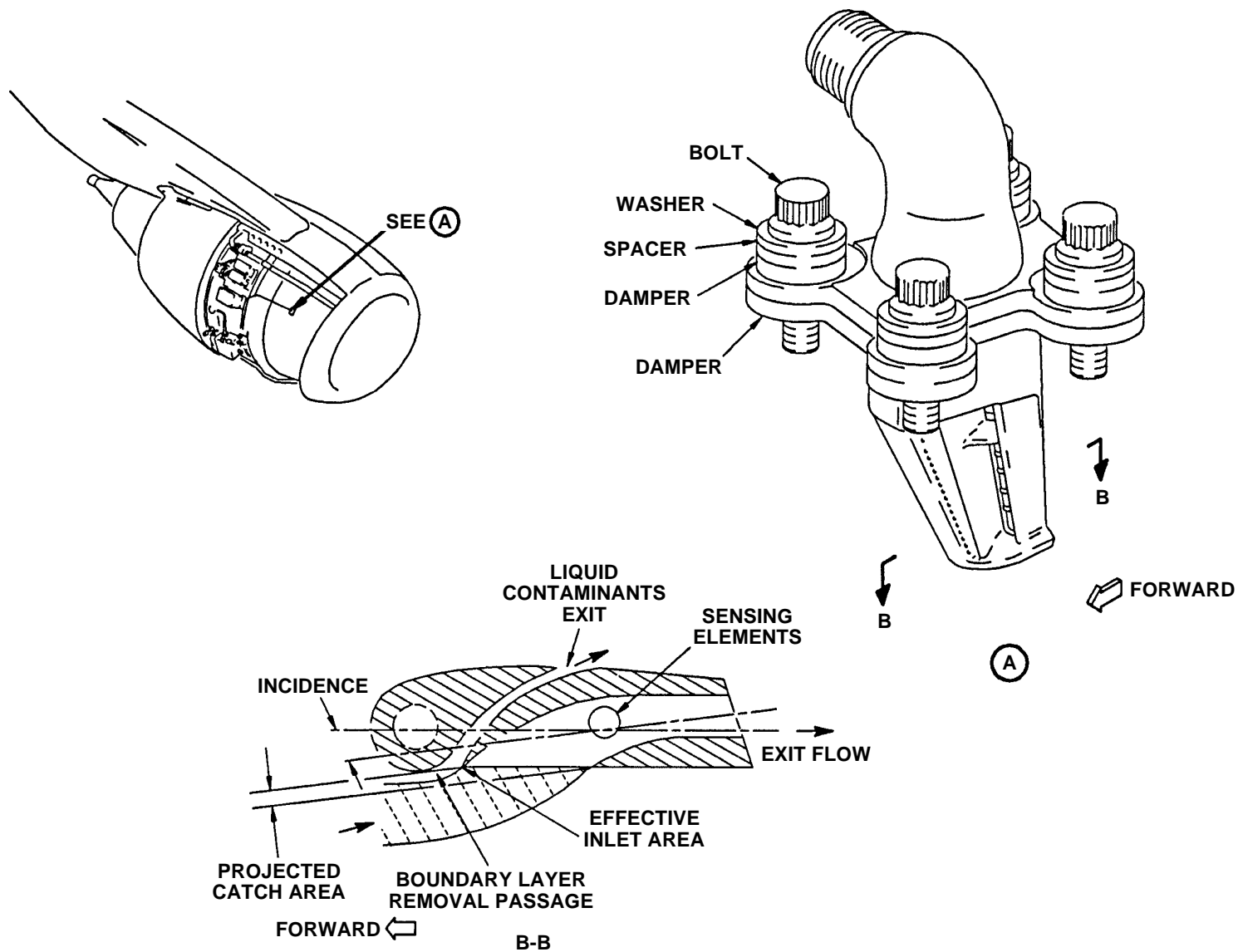
The sensing element consists of reference grade platinum wire bifilar wound on a cylindrical mandrel. The housing for the temperature sensing element is designed to protect the element and keep vibration to a minimum. The sensing element is located in a slot in the housing and forms a bypass for airflow. Air flowing past the housing changes direction to enter the slot. This prevents foreign objects from entering the slot and damaging the element. It also uses boundary layer control to ensure that the sensed temperature is the free stream temperature rather than that of the boundary layer. The housing is designed to minimize turbulence in the gas stream and is also designed to operate over a limited range of angle of attack.

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**T<sub>12</sub> TEMPERATURE SENSOR LOCATION**

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**T<sub>2.0</sub> FAN INLET TEMPERATURE (FIT) SENSOR****Identification (1.A.b)**

The helium-filled sensing element is permanently attached by a capillary tube to the housing containing the bellows and a variable orifice metering valve. Attaching fuel lines transmit fuel flow from the MEC through the housed metering valve and back to the MEC.

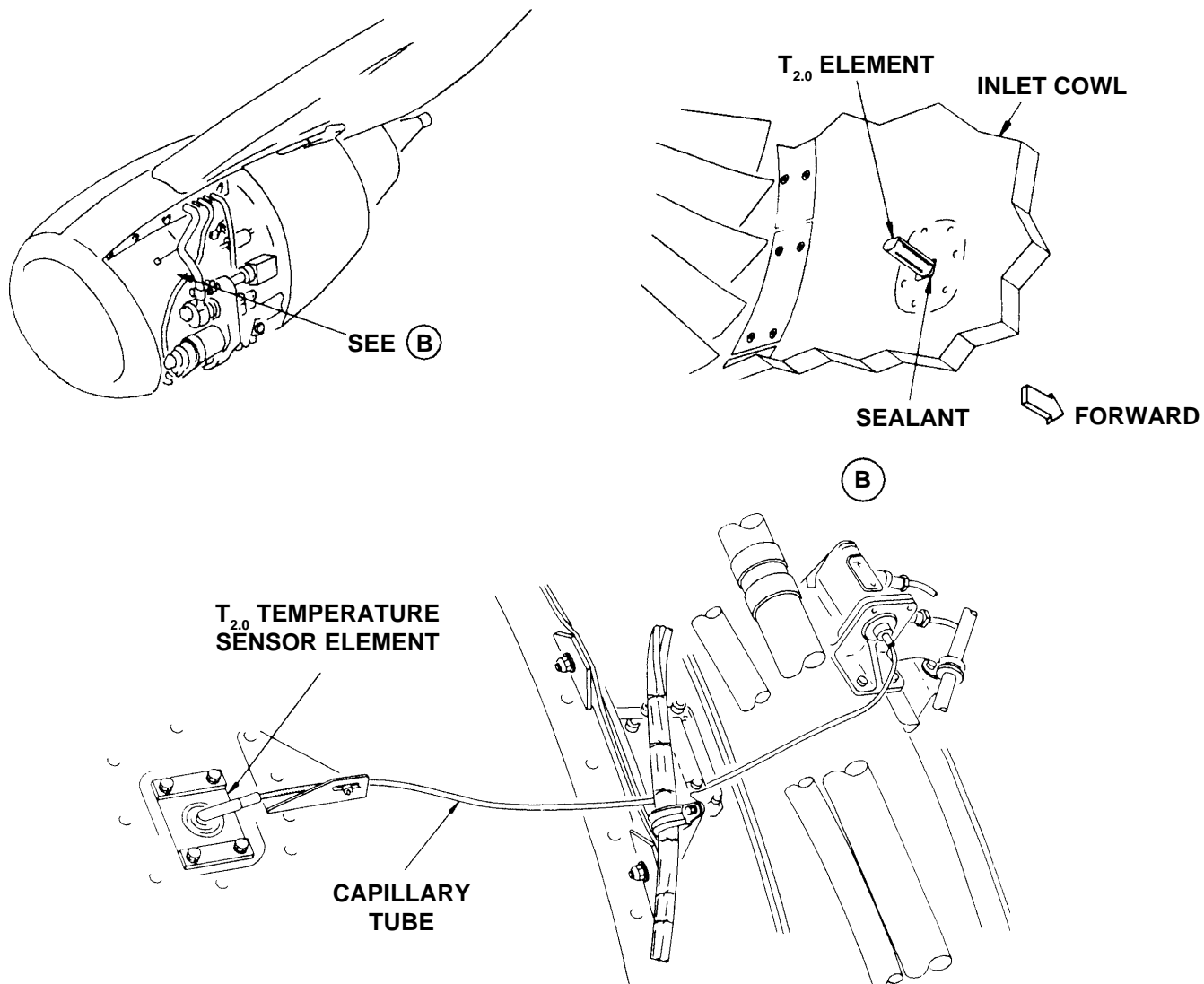
**Purpose (1.B.b)**

To provide a hydraulic signal (fuel pressure) to the MEC proportional to the fan inlet temperature.

**Location (2.A.b)**

The sensing element is located in the fan inlet duct at approximately the 11 o'clock position and is inserted in the fan inlet airstream. The bellows/valve housing is mounted on the fan case directly aft of the sensing element.

When the fan inlet duct is separated from the engine, the sensing element is stowed on a bracket on the engine fan case.



**T<sub>2.0</sub> FAN INLET TEMPERATURE (FIT) SENSOR**

## T<sub>2.0</sub> FAN INLET TEMPERATURE (FIT) SENSOR

### Functional Description

Helium trapped in the sensing element cylinder, capillary tube and housed bellows will vary in pressure with changes in inlet temperature. The change in bellows force will change the FMV position with back pressure in the fuel inlet line ( $P_7$ ) being developed proportionally to the inlet temperature. The differential pressure between  $P_7$  and  $P_b$  increases with increases in inlet temperature.

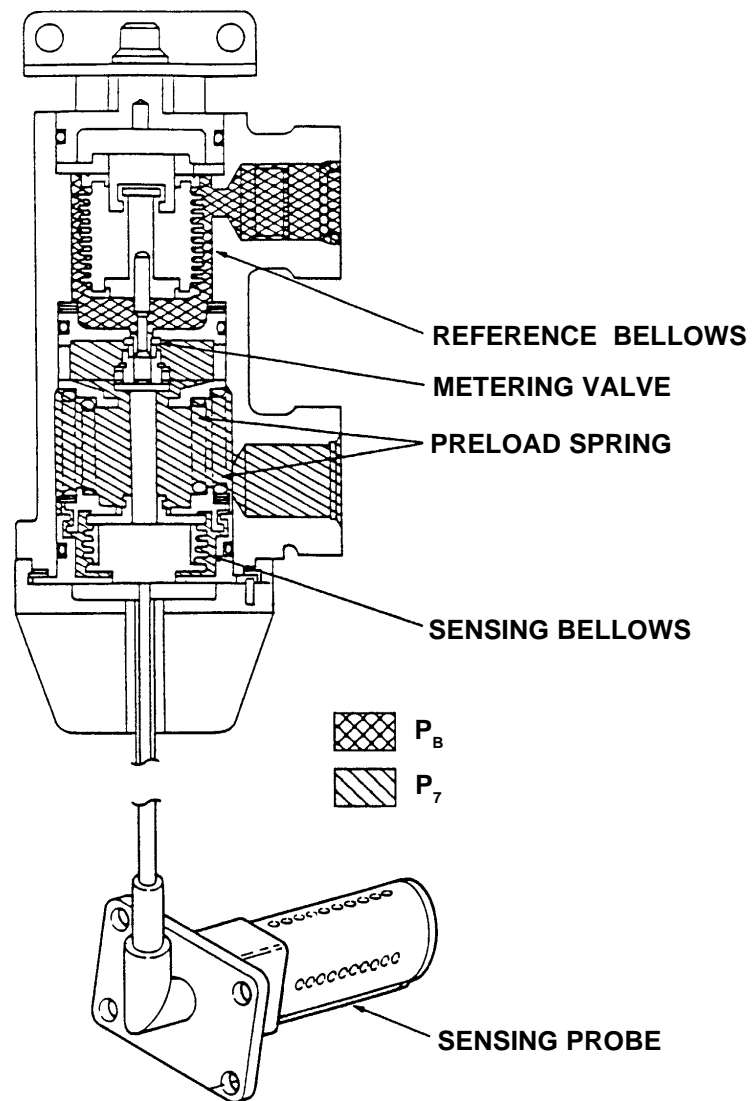
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**T<sub>2.0</sub> FAN INLET TEMPERATURE (FIT) SENSOR**

**POWER LEVER ANGLE (PLA)****Purpose (1.B.b)**

The PLA provides the PMC with an electrical signal proportional to the position of the throttle-controlled power lever on the MEC.

**Location (2.A.b)**

It is mounted within the MEC with electrical connections to the PMC.

**Interface (2.B.b)**

The power lever connecting the aircraft thrust lever cables to the control has stops established during the control assembly adjustments to define power lever position limits and fuel shut-off position.

**Operation (2.C.b)**

PLA information is transmitted to the PMC from the MEC via a Rotary Variable Differential Transducer (RVDT) located inside the MEC.

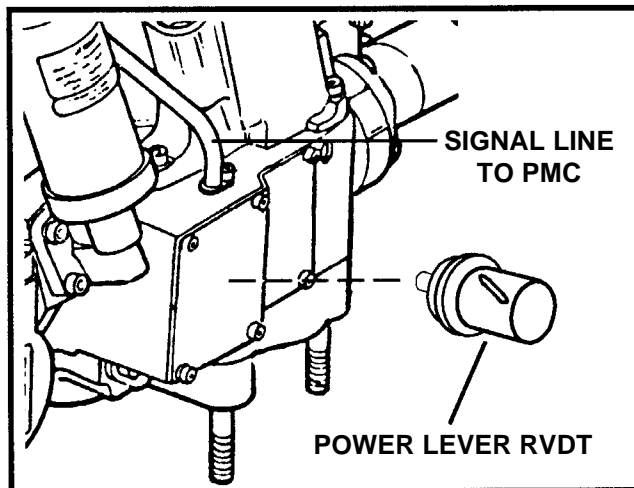
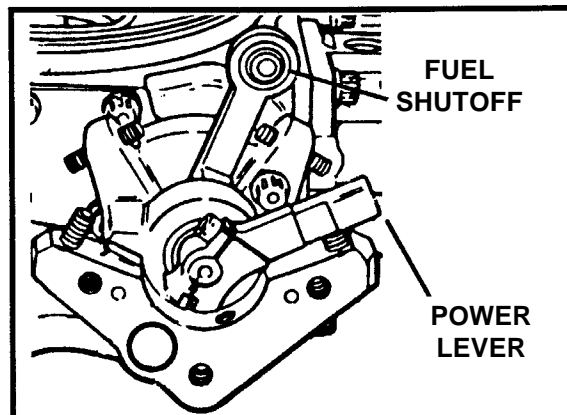
**Functional Description (3.D.b)**

The PMC produces an excitation voltage to the PLA RVDT which is the PLA transducer. As PLA is rotated, the RVDT provides an electrical relationship between forward and reverse, PLA thrust demand.

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### POWER LEVER ANGLE (PLA)

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## POWER MANAGEMENT CONTROL (PMC)

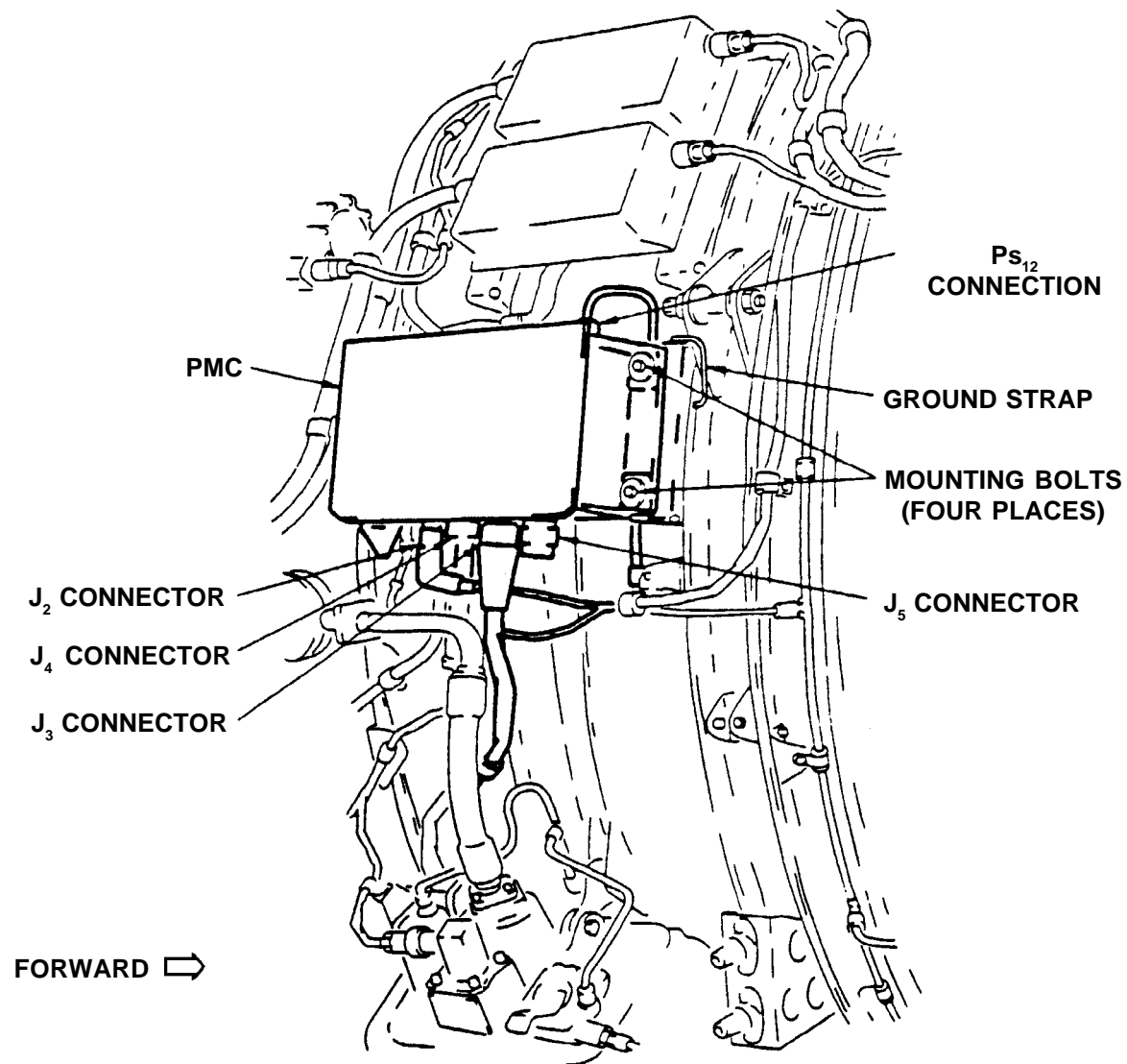
### **Purpose (1.B.b)**

Provide an electronic adjustment of the MEC to obtain optimum power settings for takeoff, climb, and cruise flight conditions without constant adjustment of the thrust lever by the flight crew.

### **Location (2.A.b)**

The PMC, mounted on outer surface of the fan inlet case at approximately the 3 o'clock position.





### PMC INSTALLATION

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**POWER MANAGEMENT CONTROL (PMC)****Operation (2.C.b)**

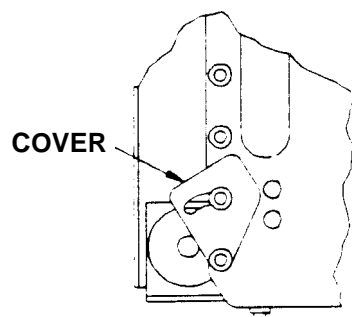
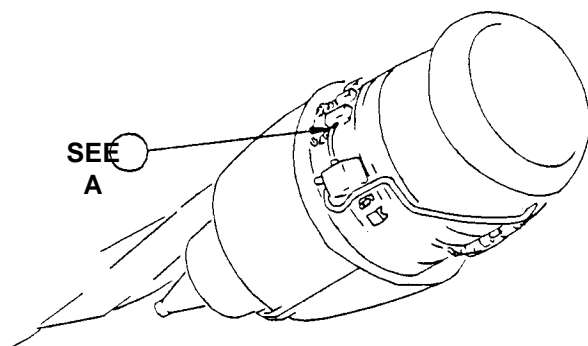
The PMC is an analog electronic supervisory control system with limited authority. Primarily, it integrates inputs of  $N_1$ , fan inlet temperature and pressure, and PLA, and provides signals to the MEC to modify  $N_1$  for better control of thrust settings.

The PMC receives information and transmits commands through connectors  $Ps_{12}$ ,  $J_2$ ,  $J_3$ ,  $J_4$  and  $J_5$

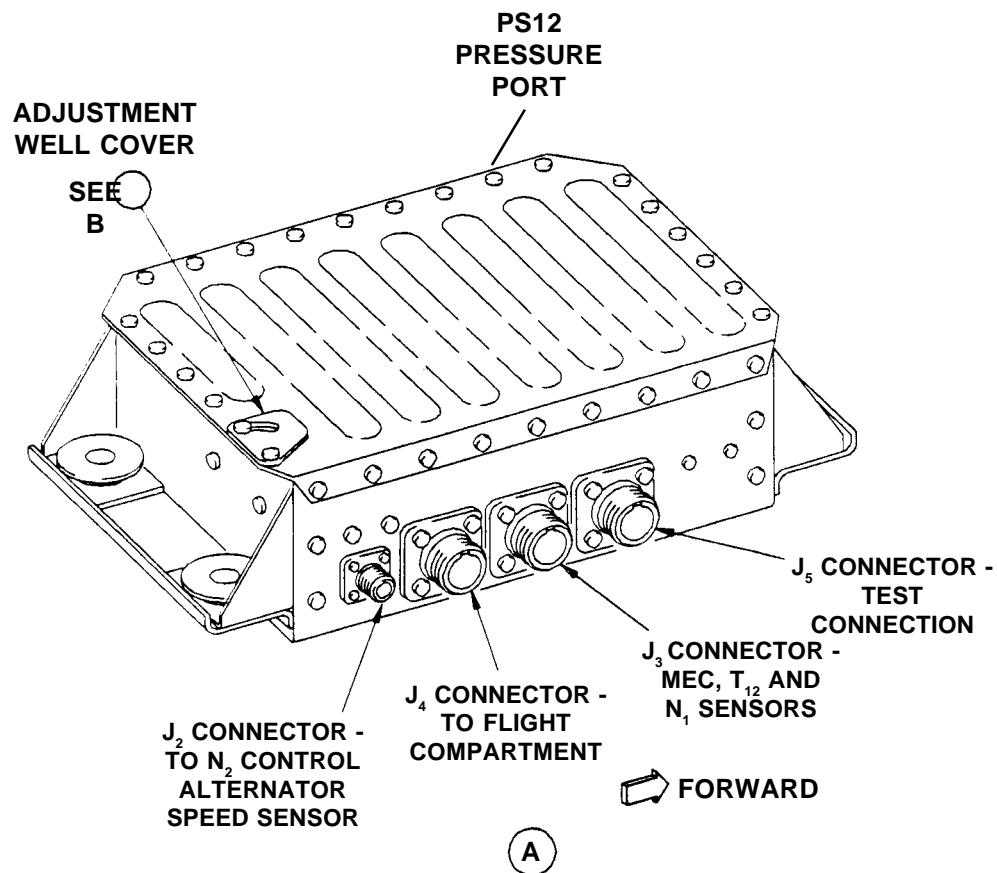
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(B)



## PMC CONNECTORS AND ADJUSTMENT WELL LOCATION

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## POWER MANAGEMENT CONTROL (PMC)

### Functional Description (3.D.b)

The PMC has a number of sections, each serving a specific function. The operation of these functions is as follows:

- Power for the PMC connector J2 is supplied by the  $N_2$  control alternator speed sensor mounted on the accessory gearbox. AC voltage is supplied to the PMC through an external variable reactor which serves as a coarse DC regulator. A solid-state fine regulator then supplies the constant DC reference voltage for all internal computations.
- To determine throttle scheduling the basic flat rated  $N_1$  speed demand signal is computed as a scheduled function of sensed power lever angle (PLA). The PMC provides excitation to and signal modulation of a rotor position transducer (RVDT) inside the MEC.
- For altitude compensation of the corrected  $N_1$  fan speed is set by the power lever position is adjusted as a function of sensed  $Ps_{12}$  pressure to give the required altitude bias. The PMC has a self-contained pressure transducer which is supplied from the  $Ps_{12}$  manifold from the fan inlet.
- For speed correction the physical  $N_1$  fan speed is sensed by the  $N_1$  speed sensor and combined with

inputs of  $T_{12}$  to provide a signal proportional to corrected  $N_1$  fan speed. This corrected fan speed is compared to the computed demand speed and results in an adjustment to the torque motor current to null the error. Input signals for fan speed ( $N_1$  actual),  $T_{12}$ , and  $N_1$  demand (PLA) and an output signal for the torque motor (TMC) are transmitted through connection J3.

- To provide temperature limiting when  $T_{12}$  temperatures are beyond the flat-rated point, the demand corrected speed is reduced to give a calculated maximum gas temperature. The computed demand speed obtained from the thrust schedule, and altitude bias ( $Ps_{12}$ ), is compared to a computed  $T_{12}$  function and to the minimum demand speed selected for use in the torque motor amplifier.
- To deactivate the PMC manually a switch control through connector J4 can be used to override the torque motor current signal to the MEC torque motor. An amber light in the flight deck will illuminate when the PMC is in the PMC OFF mode.

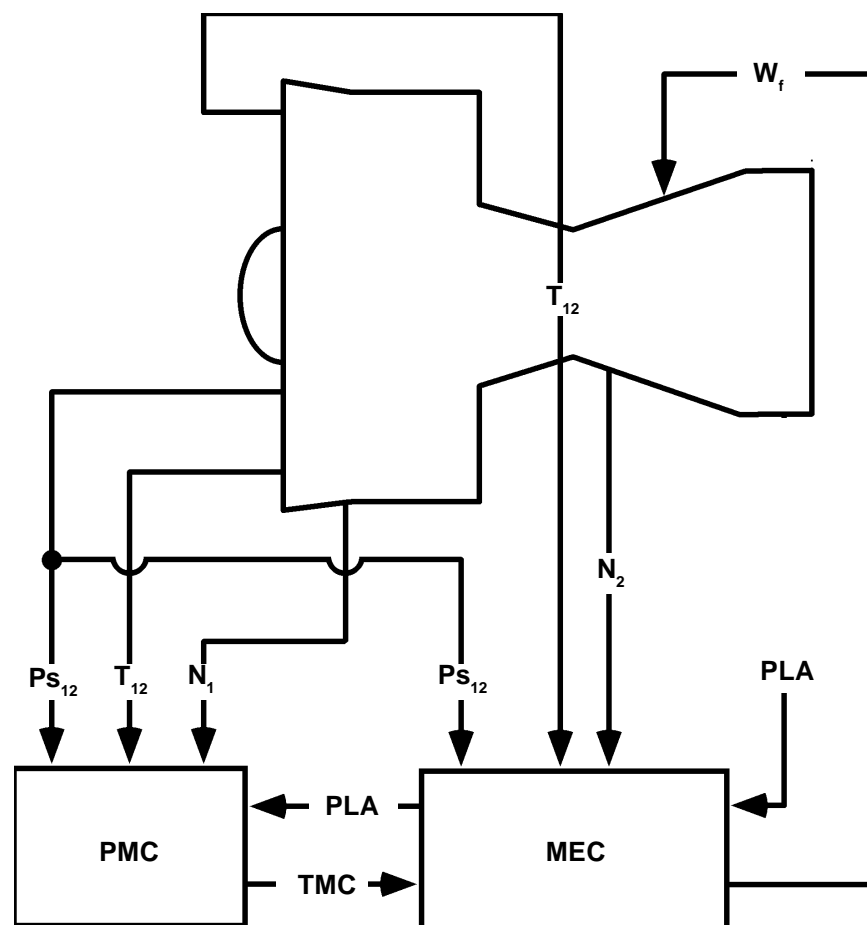
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### PMC - CONTROL MODE

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## POWER MANAGEMENT CONTROL (PMC)

### Functional Description

- A contact closure is provided at the J4 connector that automatically closes if a failure occurs in the PMC or in a sensor used by the PMC. When the PMC deactivates itself the appropriate INOP warning light will illuminate. This closure will remain until the fault is cleared and a manual disable is reset.

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## CFMI WIRING HARNESS

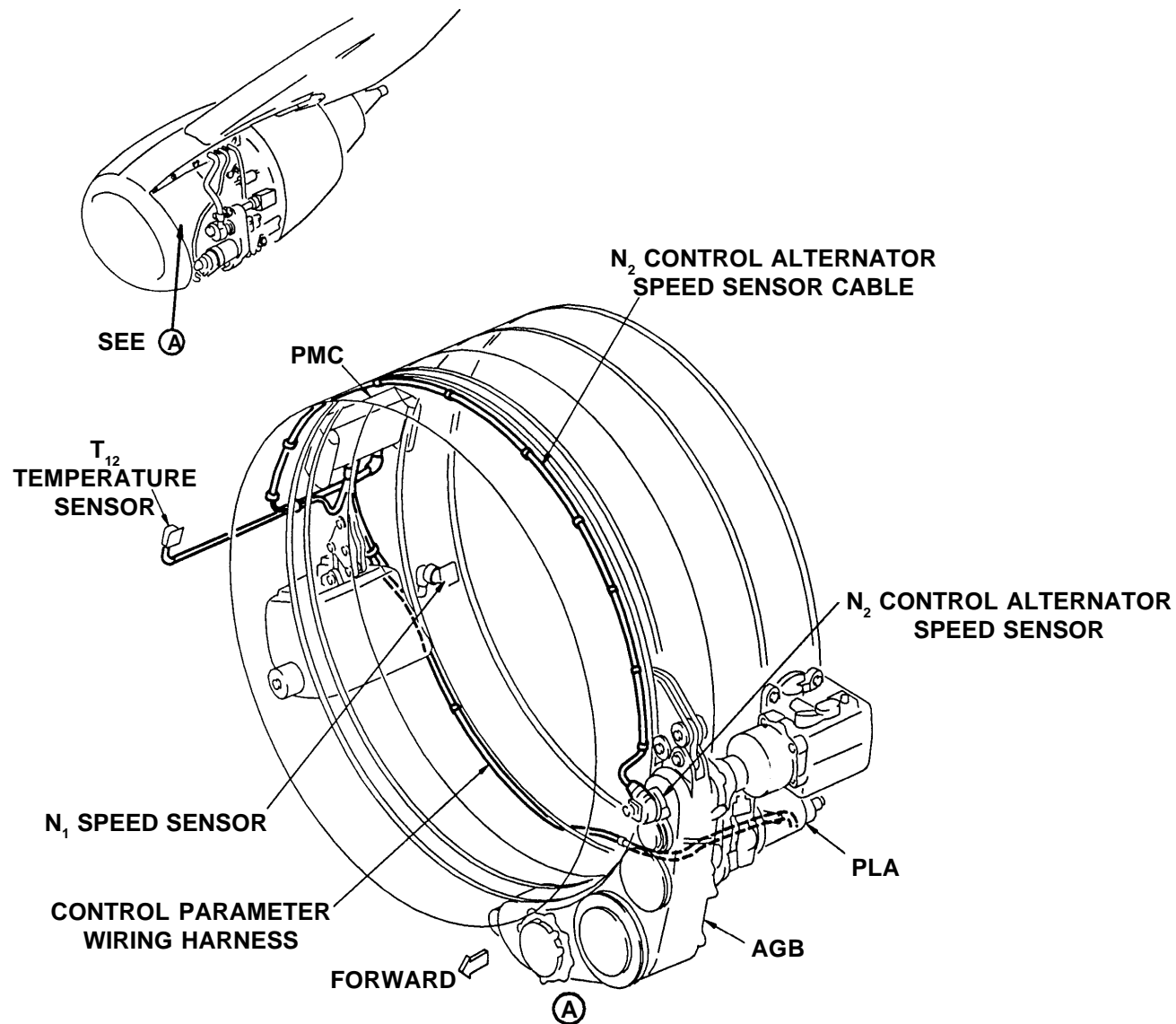
### Identification (1.A.b)

The CFMI wiring harness is made up of two cable assemblies: the control parameter wiring harness and the  $N_2$  control alternator speed sensor cable.

### Purpose (1.B.b)

These cables provide power from the  $N_2$  control alternator speed sensor to the PMC, provide signal information from the  $N_1$  speed sensor, PLA,  $T_{12}$  temperature information to the PMC and PMC signals to the MEC torque motor PLA.





## CFMI WIRING HARNESS INSTALLATION

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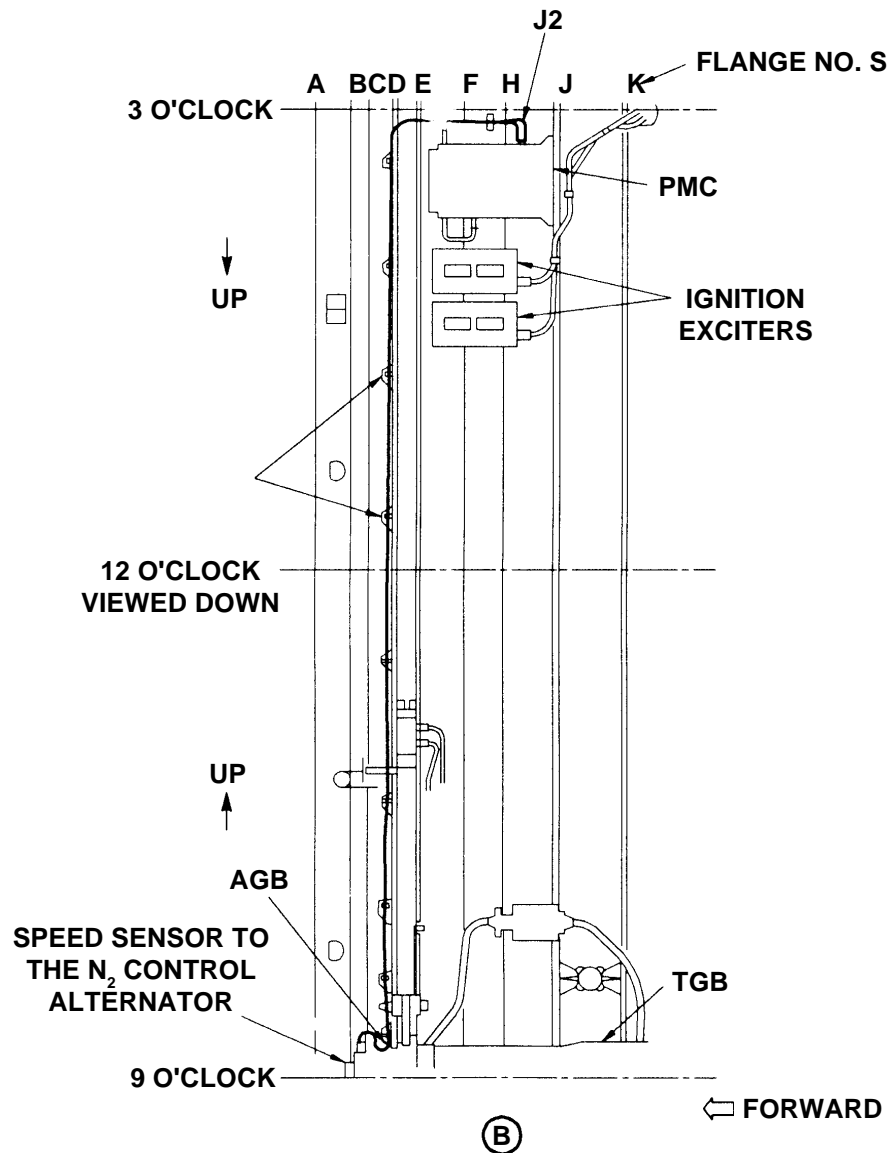
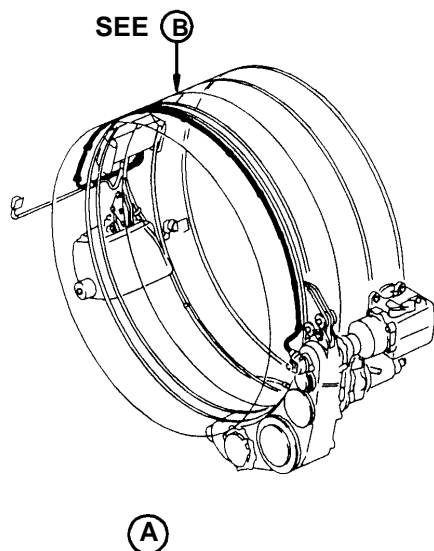
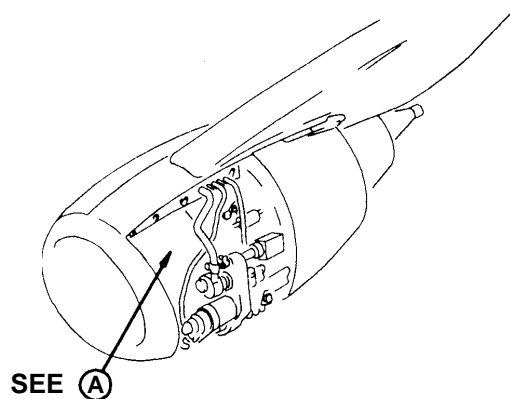
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## SPEED SENSOR CABLE INSTALLATION FOR THE N<sub>2</sub> CONTROL ALTERNATOR

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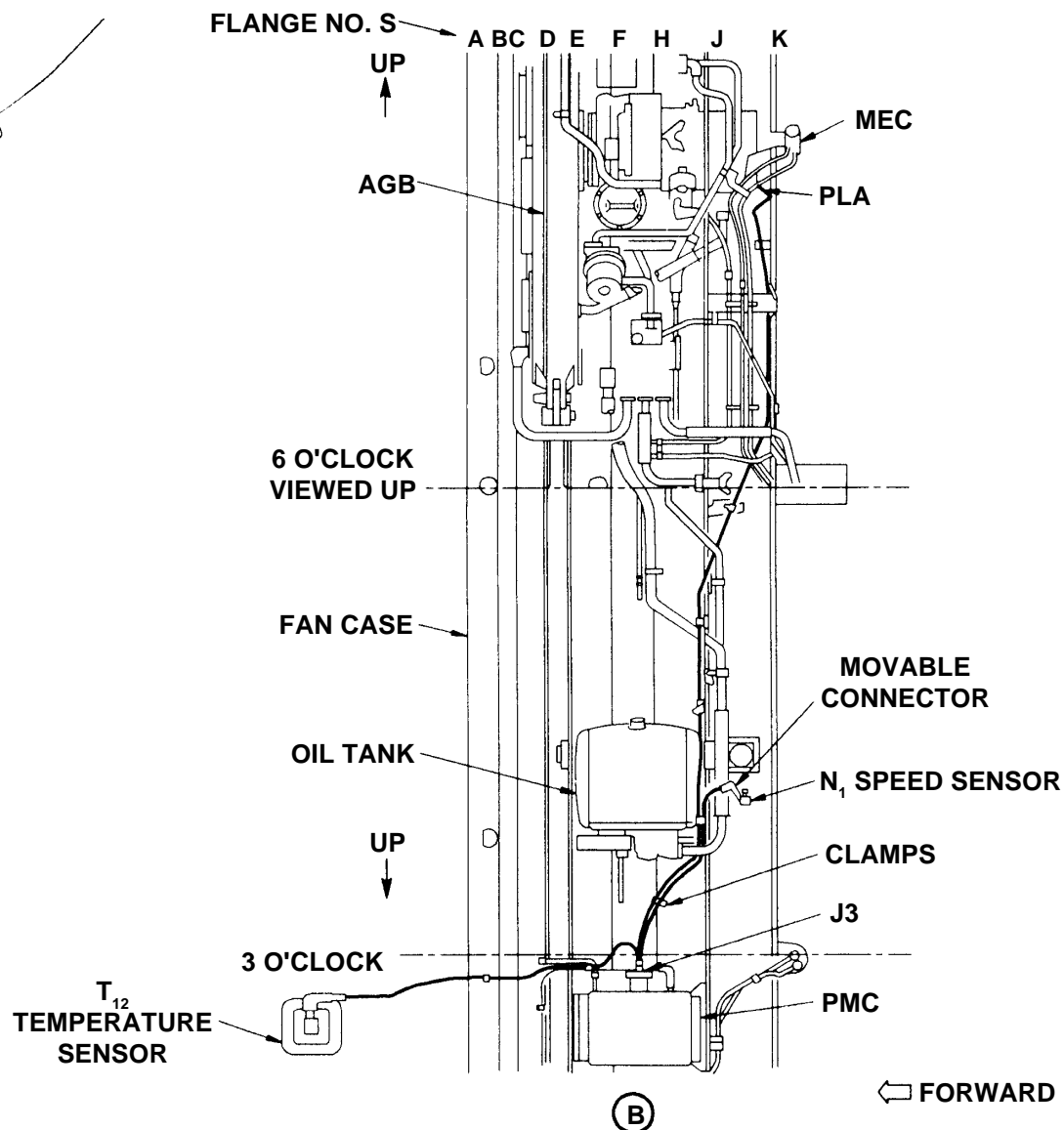
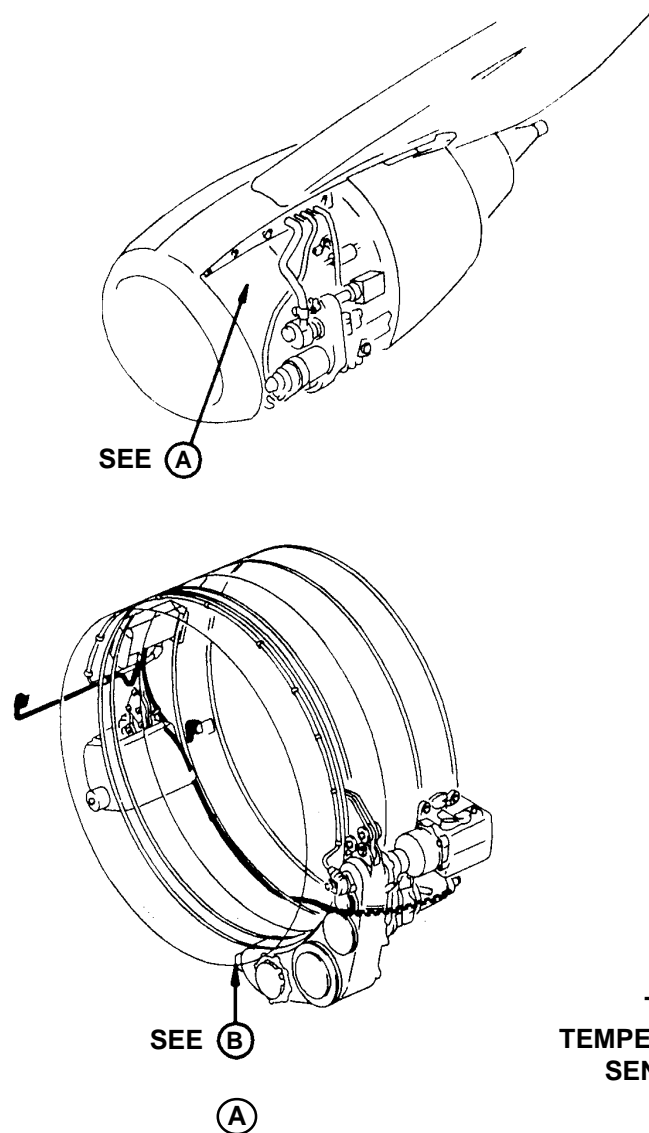
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## WIRING HARNESS INSTALLATION FOR THE CONTROL PARAMETER COMPONENTS

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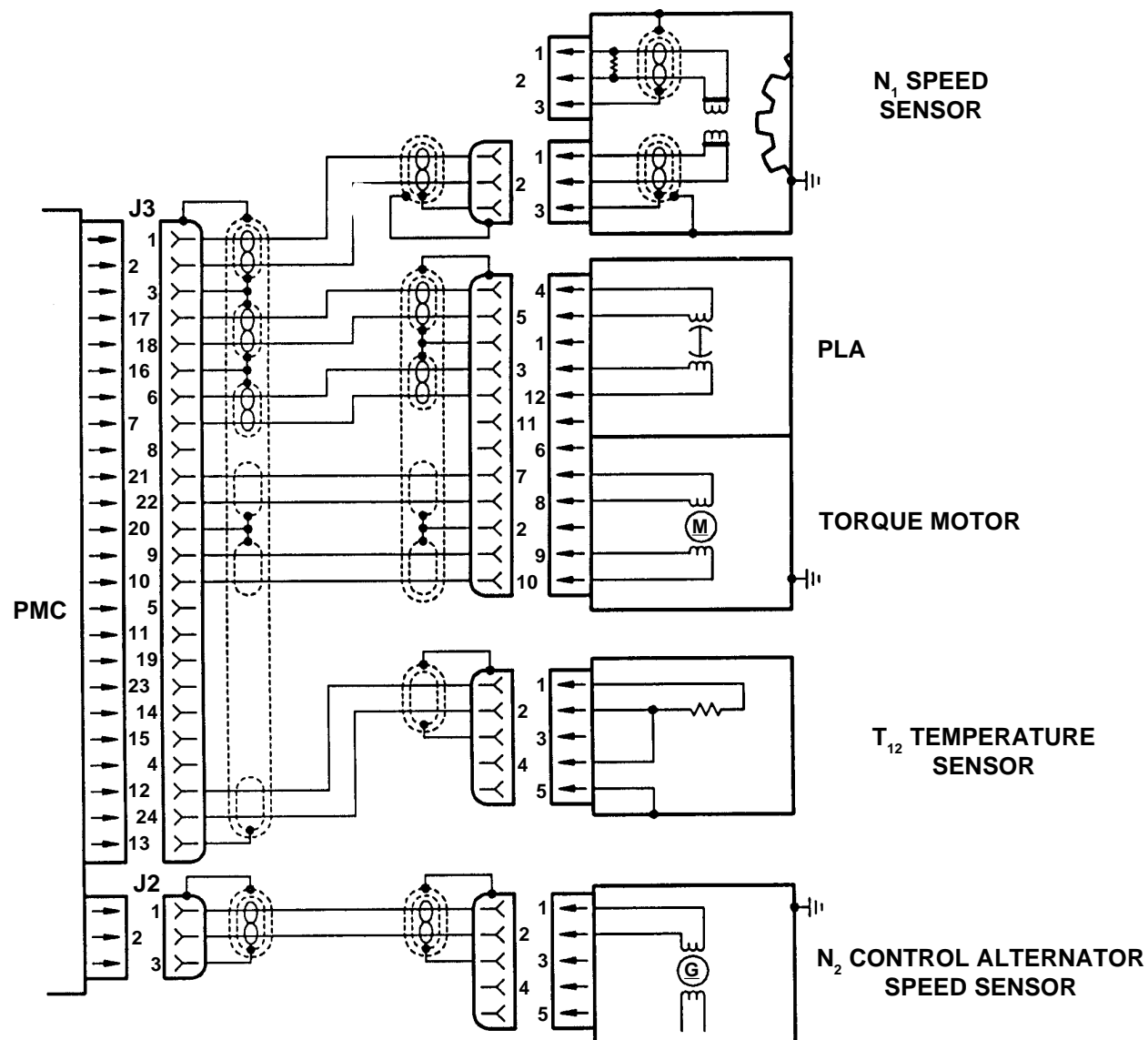
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CFMI WIRING HARNESS SCHEMATIC DIAGRAM

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## IGNITION SYSTEM

### Objectives:

At the completion of this section a student should be able to:

- ....identify the components comprising the ignition system of the CFM56-3/3B/3C engine (1.A.x).
- ....state the purpose of the ignition system of the CFM56-3/3B/3C engine (1.B.x).
- ....state the purpose of the components comprising the ignition system of the CFM56-3/3B/3C engine (1.B.x).
- ....locate the components comprising the ignition system of the CFM56-3/3B/3C engine (2.A.x).
- ....identify the aircraft interfaces associated with the ignition system of the CFM56-3/3B/3C engine (2.B.x).
- ....describe the component operation of the ignition system of the CFM56-3/3B/3C engine (2.C.x).
- ....describe the particular component functions of the ignition system of the CFM56-3/3B/3C engine (3.D.x).

**IGNITION SYSTEM****Identification (1.A.a)**

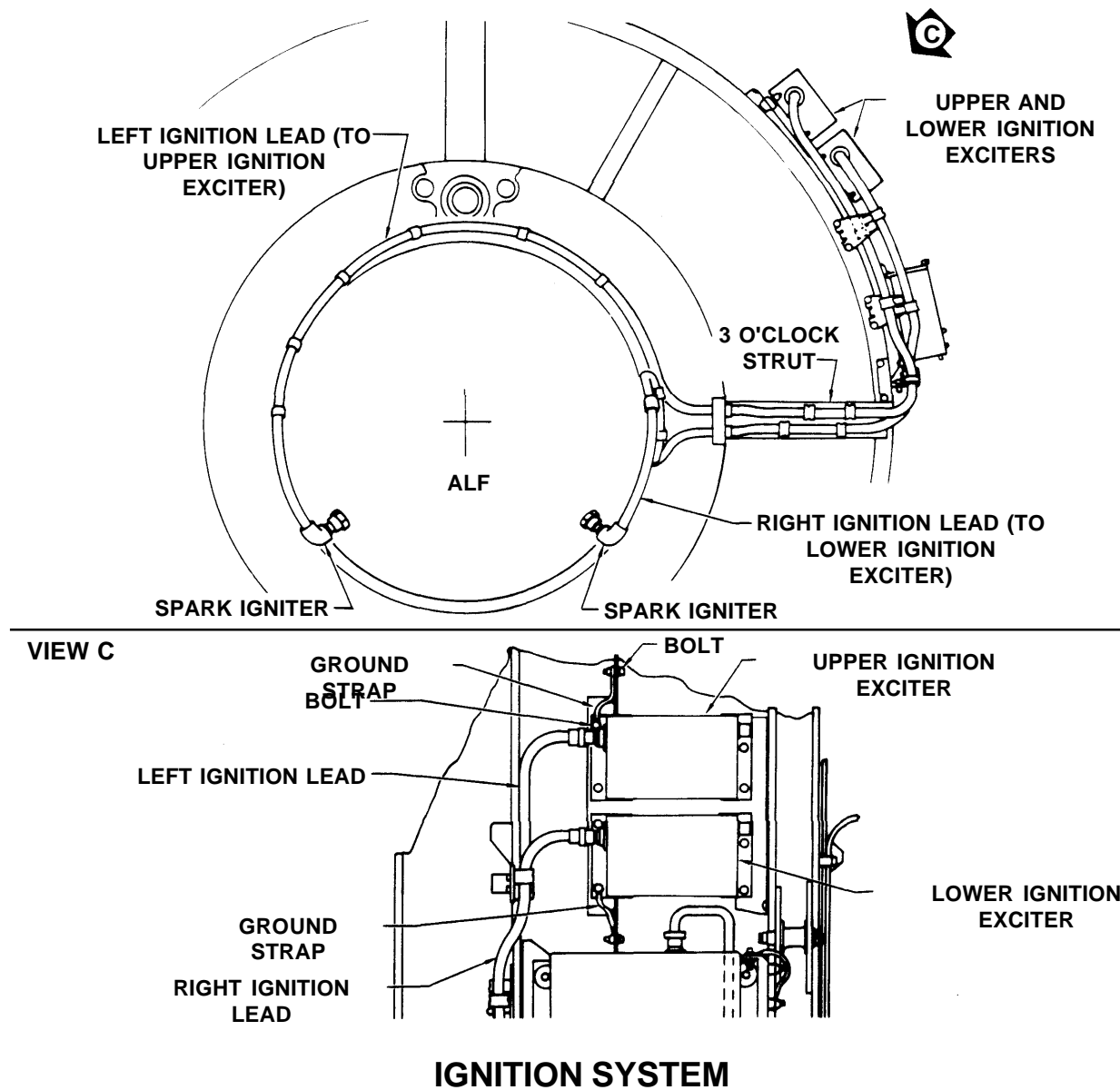
The ignition system consists of an engine start switch, engine igniter selector switch, two high energy ignition exciters or two low energy ignition exciters, two igniter plugs and two coaxial shielded ignition leads.

**Purpose (1.B.a)**

The purpose of the system is to produce an electrical spark to ignite the fuel/air mixture in the engine combustion chamber during the starting cycle and to provide continuous ignition during T/O, landing and operation in adverse weather conditions.

**Operation (2.C.a)**

The left, right or both igniter plugs may be selected during the starting cycle or for continuous ignition operation.



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## IGNITION POWER SUPPLY

### Identification (1.A.a)

The ignition power supply consists of two independent ignition exciters. Each exciter has an input and output connector. Two types of exciters are available. Both types are unidirectional.

### Purpose (1.B.a)

The exciters provide starting and continuous duty ignition on demand.

### Location (2.A.a)

The two independent ignition exciters are mounted on the inlet fan case with resilient shock mounts at the 2 o'clock position.

### Operation (2.C.a)

Each exciter is capable of independent operation and alternate use of ignition circuits is recommended. Selection is made by an engine igniter selector switch in the flight deck.

The ignition exciters operate on 108-122 volts AC, 380-400 Hz input. The power is transformed, rectified and discharged in the form of capacitor discharge pulses through the ignition leads to the igniter plugs.

### Functional Description (3.D.a)

The high energy output is 15-20 kv, with a spark rate of

two sparks per second. Energy delivered is two joules per spark. The low energy exciter output is 14-18 kv, with a spark rate of one spark per second. Energy delivered is 1.5 joule per spark.

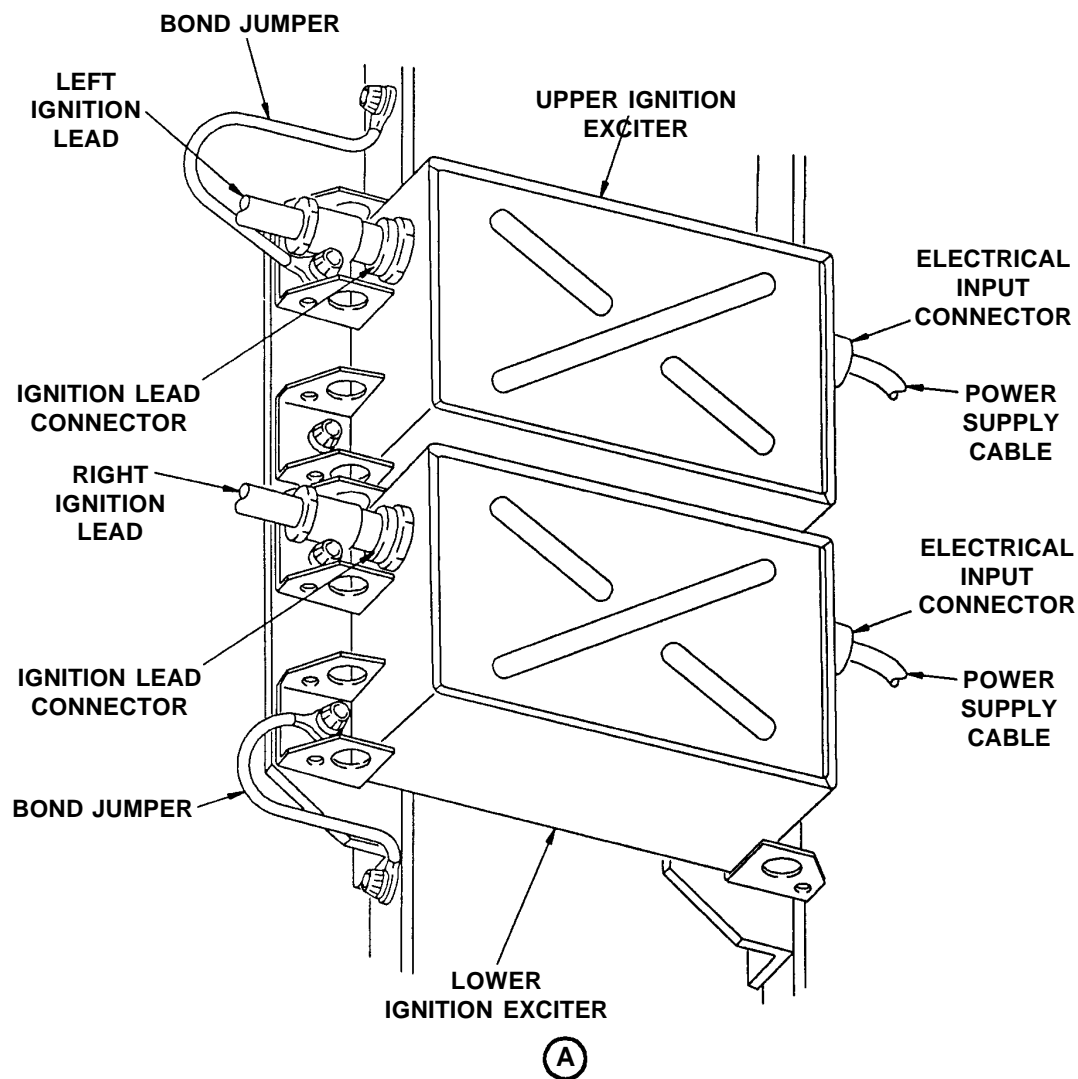
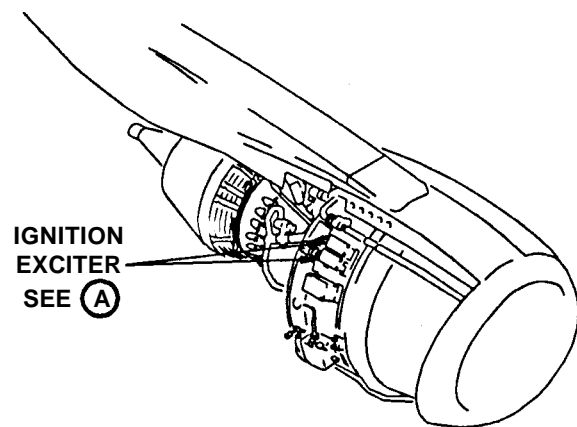
## EFFECTIVITY

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## IGNITION POWER SUPPLY

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**HIGH TENSION DISTRIBUTION****Identification (1.A.b)**

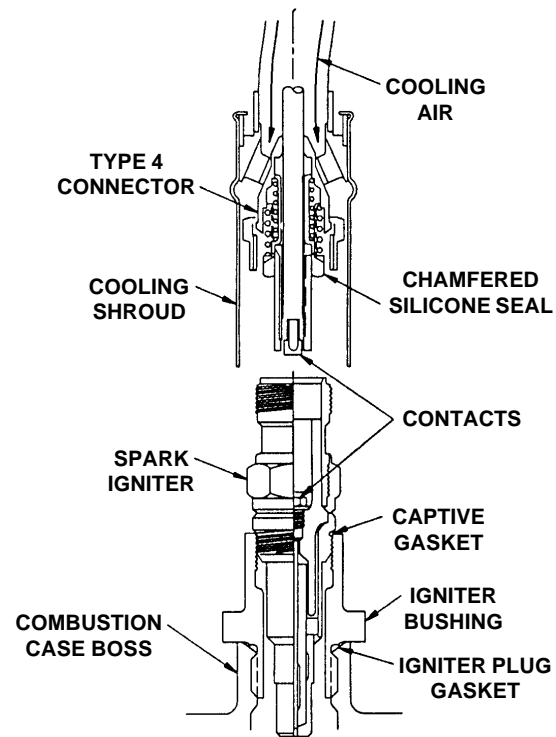
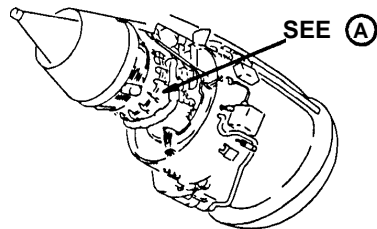
A distribution system consists of ignition leads and spark igniters. The type 4 distribution system has button-type contacts, spring-loaded elastomeric chamfered silicone seals and a two-piece cooling shroud which is retained by a clamp at the spark igniter end of the ignition lead.

**Purpose (1.B.b)**

The high tension distribution system conducts the high voltage electrical energy developed in the ignition exciters to the spark igniter.

**Location (2.A.b)**

A type 4 spark igniter is threaded into an igniter bushing at the spark igniter boss at 4 and 8 o'clock on the combustion case.



## TYPE 4 IGNITION LEADS

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## IGNITION LEADS

### Functional Description (3.D.b)

Type 4 ignition leads are constructed of silicone insulated wire. It has a sealed flexible conduit having a copper inner braid and a nickel outer braid. The leads connect the spark igniter to the output connectors of the ignition exciters. The aft ends of the leads, from the 3 o'clock strut support bracket to the spark igniter, are cooled by booster discharge air passing through the lead conduit.

EFFECTIVITY

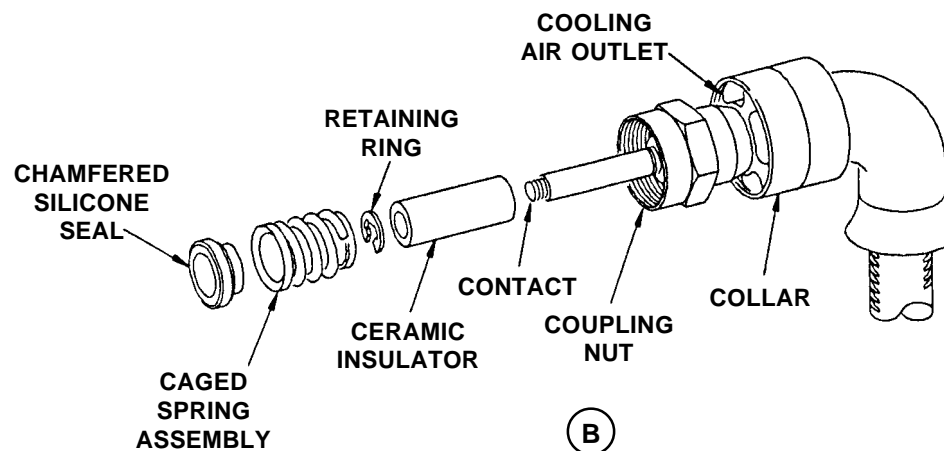
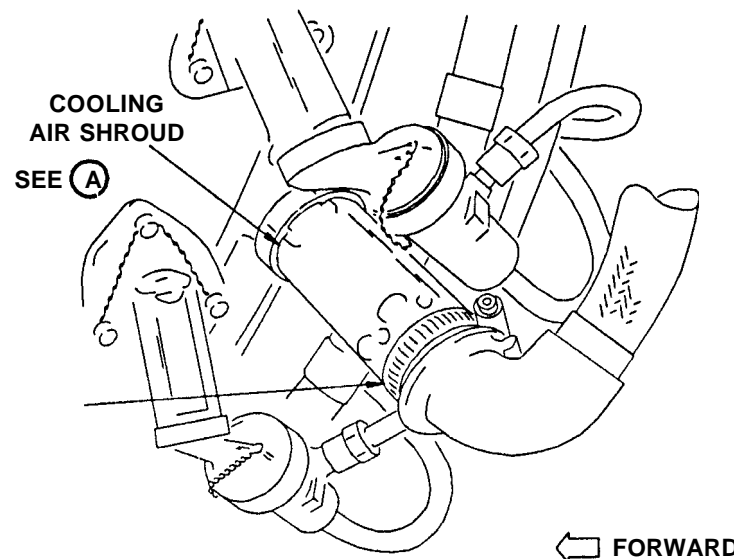
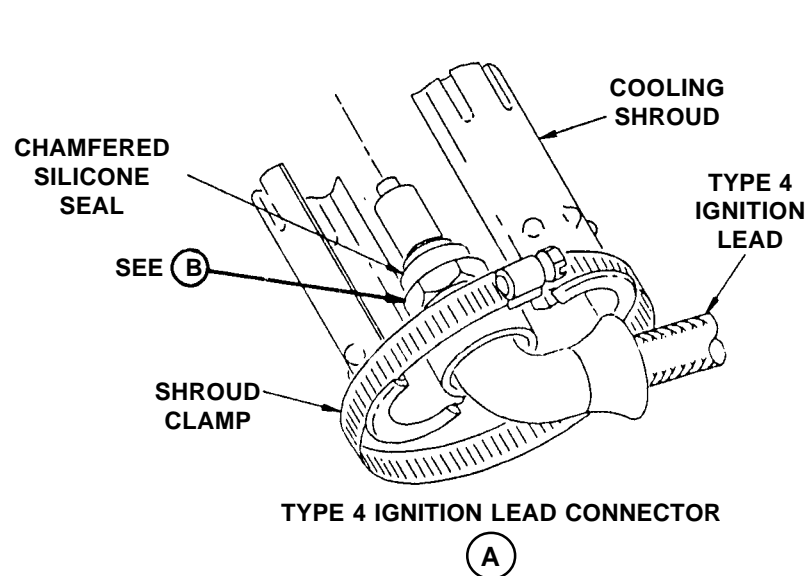
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## IGNITION LEAD INSTALLATION

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**IGNITER PLUG****Identification (1.A.b)**

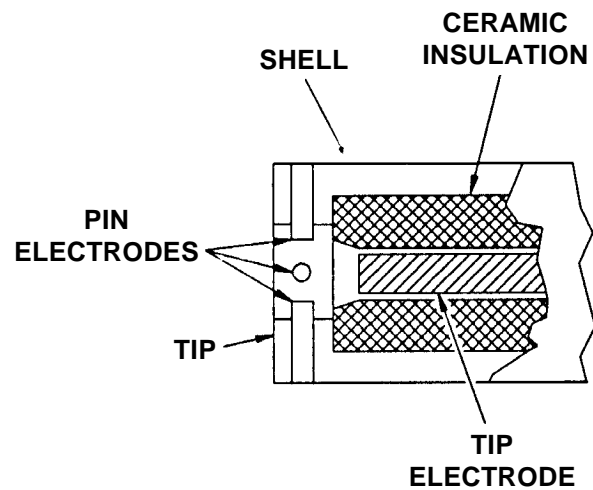
The spark igniter consists of a body, washer electrode or pin electrode, tip electrode, connector pin or contacts and ceramic insulation. The tips of the spark igniters extend through ferrules in the outer liner into the combustion chamber. The depth of the spark igniter into the combustion chamber is controlled on the new type 4 (S/B 72-458).

**Purpose (1.B.b)**

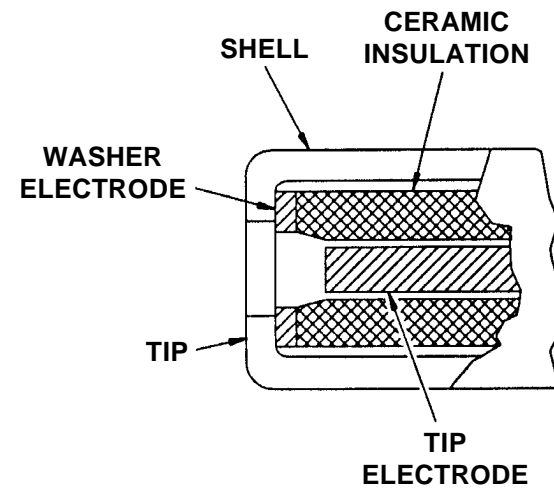
Produces prompt ignition of the fuel/air mixture.

**Location (2.A.b)**

There are two igniter plugs in bosses at the 4 and 8 o'clock positions on the combustion case.



PIN-TYPE ELECTRODE



WASHER-TYPE ELECTRODE

## ELECTRODES

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**IGNITER PLUG****Operation (2.C.b)**

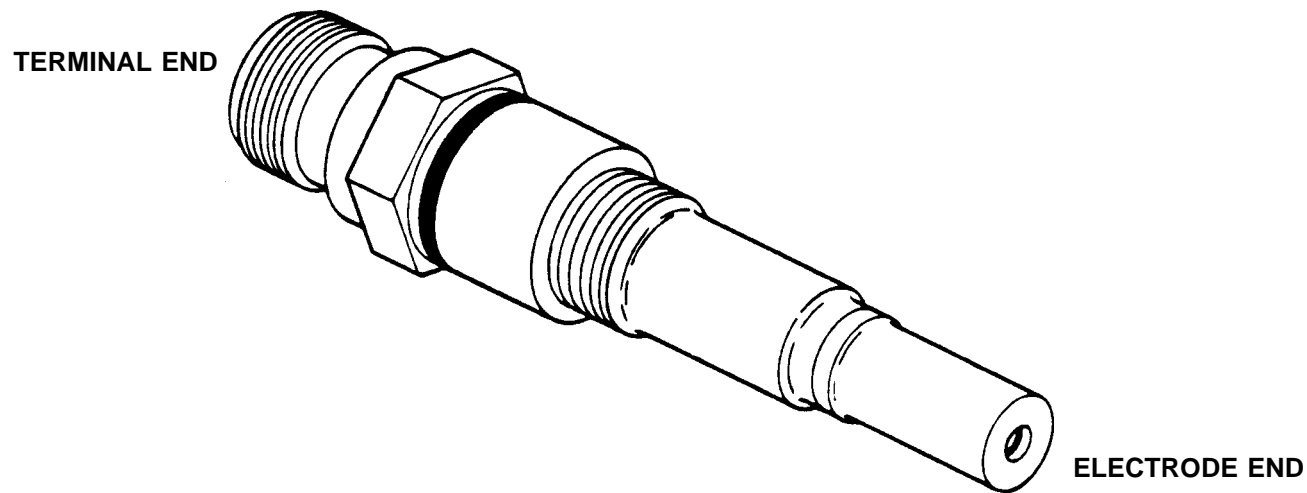
The igniter plug operates in conjunction with a capacitor discharge-type ignition exciter that produces an electrical potential which is applied across the gap between the plug center electrode and shell. As the potential increases, air at the gap ionizes. When ionization occurs, the high energy electrical discharge of the exciter appears as a brilliant spark across the gap. The spark produces prompt ignition of the fuel/air mixture and produces sufficient heat to burn clean a fouled plug. Ignition is assured under the most adverse conditions.

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**TYPE 4 IGNITER PLUG**

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## AIR SYSTEMS

### Objectives:

At the completion of this section a student should be able to:

- ....identify the components comprising the air system of the CFM56-3/3B/3C engine (1.A.x).
- ....state the purpose of the air system of the CFM56-3/3B/3C engine (1.B.x).
- ....state the purpose of the components comprising the air system of the CFM56-3/3B/3C engine (1.B.x).
- ....locate the components comprising the air system of the CFM56-3/3B/3C engine (2.A.x).
- ....identify the aircraft interfaces associated with the air system of the CFM56-3/3B/3C engine (2.B.x).
- ....describe the component operation of the air system of the CFM56-3/3B/3C engine (2.C.x).
- ....describe the particular component functions of the air system of the CFM56-3/3B/3C engine (3.D.x).

## HPTCC VALVE WITHOUT HPTCC TIMER

### Identification (1.A.b)

The HPTCC system consists of a hydraulic-actuated valve (HPTCCV) and connecting tubing to the MEC.

### Purpose (1.B.b)

To obtain maximum steady-state HPT performance and to minimize EGT transient overshoot during Takeoff.

### Location (2.A.b)

The High Pressure Turbine Clearance Control Valve (HPTCCV) is located on the right side of the engine just below the horizontal split-line of the HPC case.

### Operation (2.C.b)

The system uses HPC bleed air from the 5th and 9th stages. Air selection is determined as a function of  $N_2$  RPM Which results in fuel pressure signals sent from the MEC to actuate the valve. The selected bleed air is ducted from the valve to a manifold surrounding the HPT shroud. The temperature of the air controls the thermal expansion of the shroud support structure to optimize the shrouds' relative clearance to the HPT blade tips.

The combination of valve positions in the MEC and the clearance control valve can result in any of the following three (open or closed) combinations of airflow to the HPT shroud area:

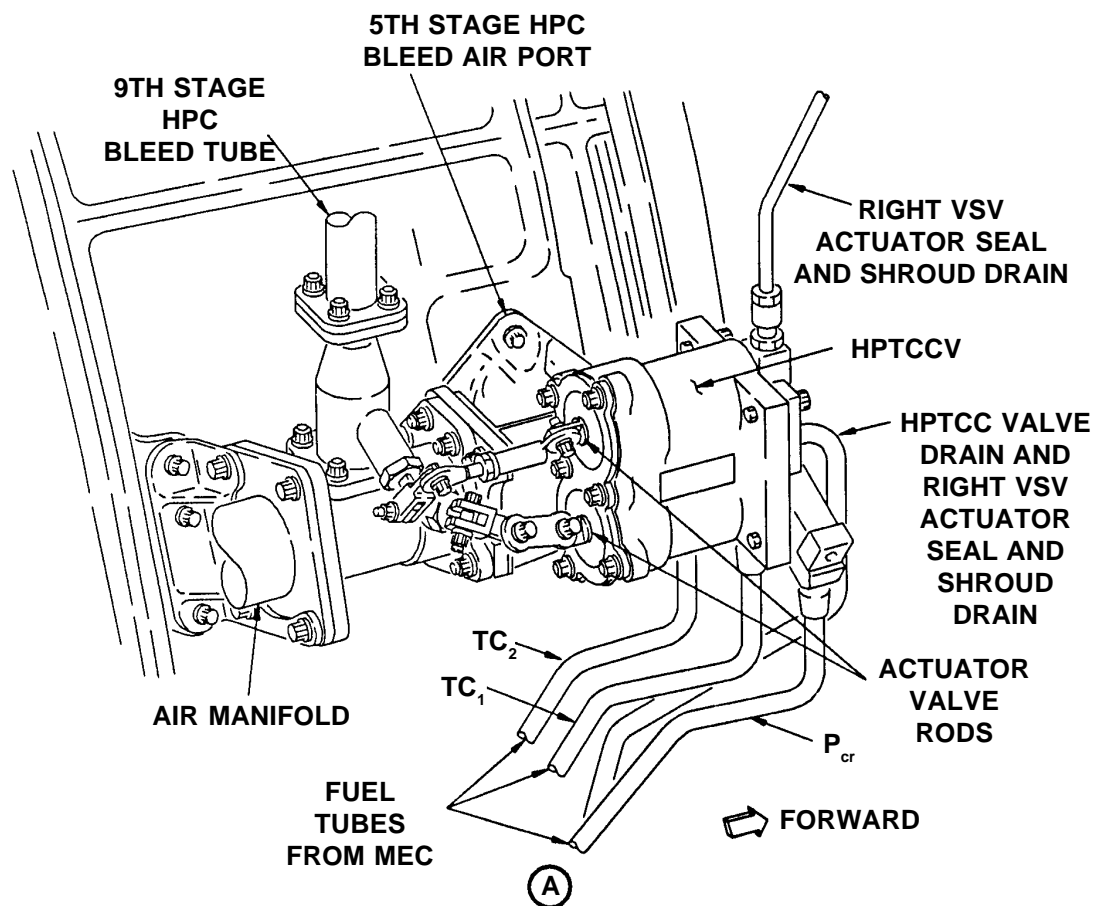
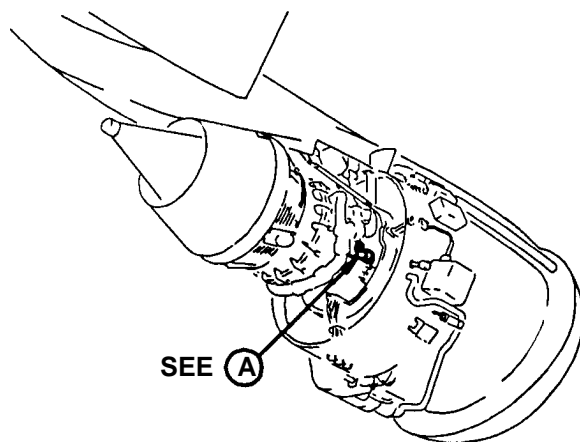
- 5th stage airflow only.

- 5th and 9th stage airflow mixture.

- 9th stage airflow only.

5th stage air is extracted from the forward 5th stage manifold of the HPC stator case at the point where the HPTCCV mounts. 9th stage air is extracted from the combustion case through a port adjacent to one of the fuel nozzle ports and routed forward through an external tube to the HPTCCV.





## HPTCCV INSTALLATION

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## HPTCC VALVE WITHOUT HPTCC TIMER

### Functional Description (3.D.b)

Actuation of the TCC valve is controlled by the following fuel pressure signals:

- $TC_1$ , and  $TC_2$  originate from turbine clearance valves within the MEC. These valves are positioned by the TCCV scheduling cam as directed by the tach servo valve, which is a function of  $N_2$ . At selected speeds,  $TC_1$  and  $TC_2$  will provide outputs of either Bypass Pressure ( $P_b$ ) or Case Pressure ( $P_c$ ).  $TC_1$  and  $TC_2$  are supplied at all times during engine operation to control the 5th and 9th stage valve positions in the TCCV.
- $P_{cr}$  is supplied to the TCCV from the MEC.  $P_{cr}$  pressure, along with spring pressure, opposes  $TC_1$  and  $TC_2$  fuel pressure signals from the MEC to control the 5th stage and 9th stage bleed air valves.
- The pressure relationship of the three control pressures is  $P_b < P_{cr} < P_c$ .

After engine start and with the engine at low idle power setting, the airflow to the HPT shroud is from the HPC 9th stage bleed.  $TC_1$  and  $TC_2$  both carry  $P_b$  pressure and are opposed by  $P_{cr}$  and spring pressure to maintain the 5th stage valve closed and the 9th stage valve open.

Air from the HPTCCV flows through a manifold and

enters two ports near the aft flange of the combustion case. The air circulates around an impingement manifold, moves through the manifold and impinges on the support for the HPT shrouds. This air acts on the shroud support to control the expansion rate of the support and therefore controls the clearance between the HPT blades and HPT shroud. The air then flows through passageways towards the aft end of the support and joins 5th stage cooling air entering the 1st stage Low Pressure Turbine Nozzle (LPTN).

When the engine is shut down, the two position hydraulic actuator valve rods are retracted, closing the 5th and opening the 9th stage air valves.

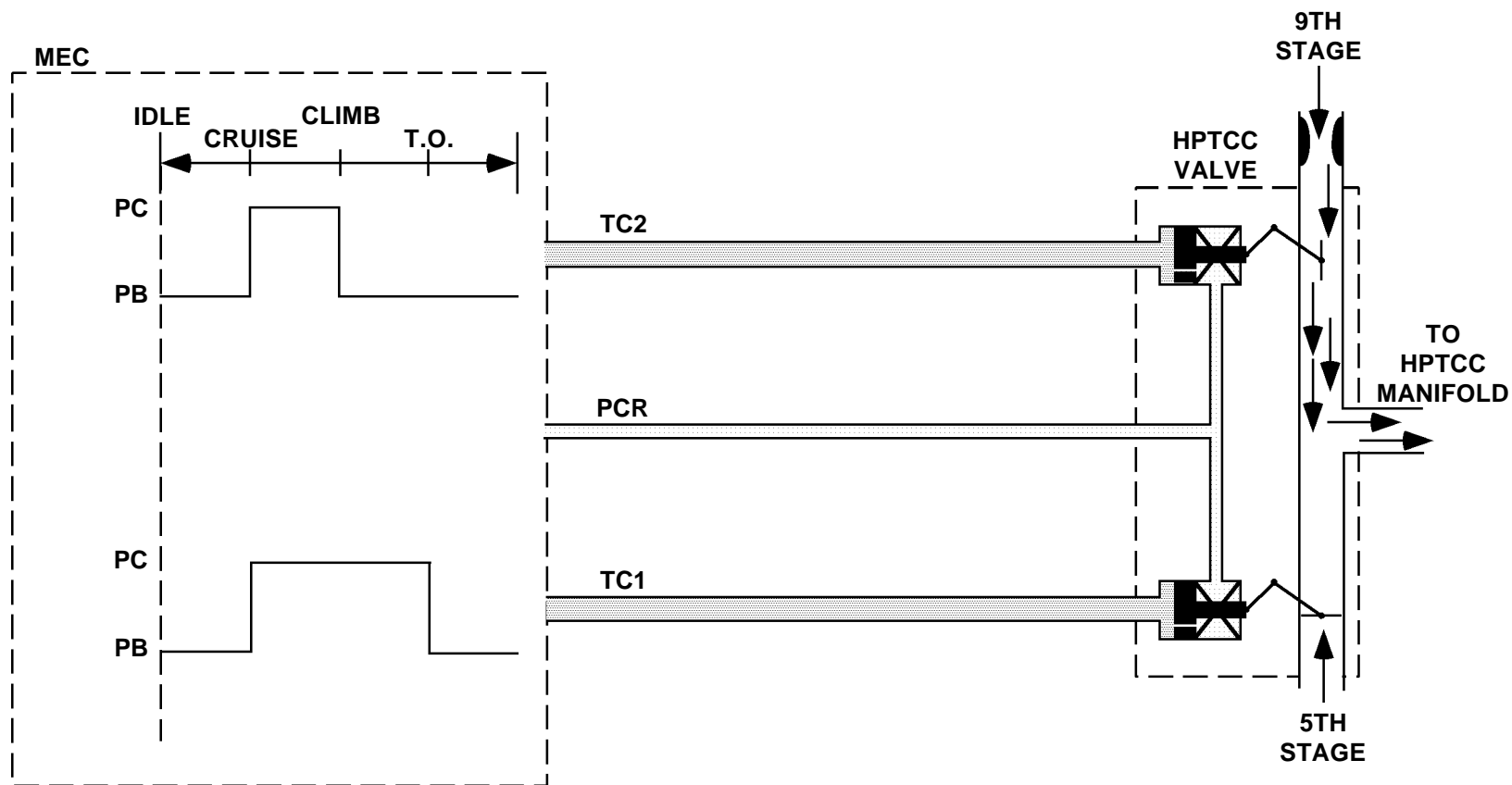
### EFFECTIVITY

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# HPTCCV OPERATION SHEET 1

## EFFECTIVITY

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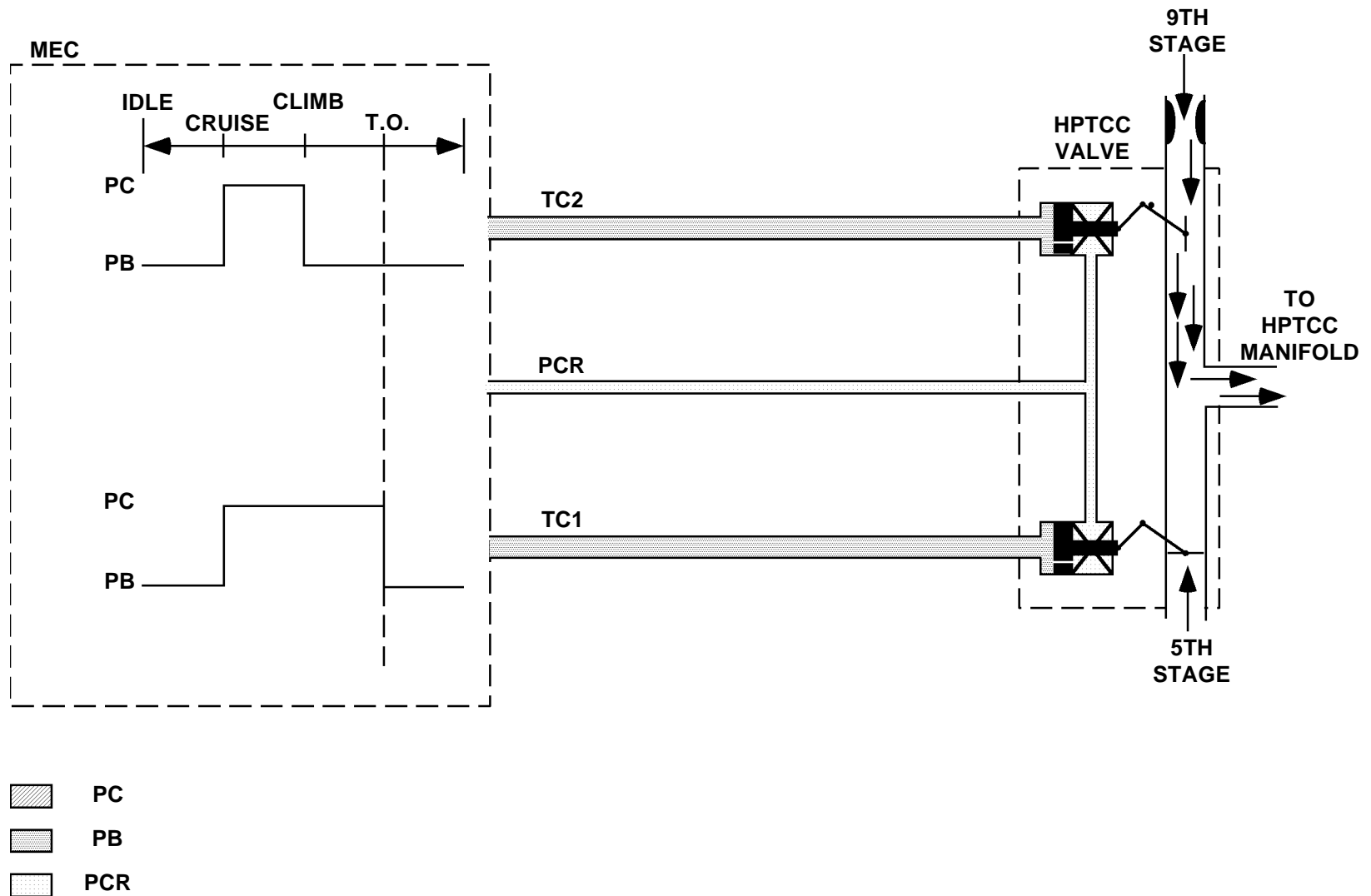
**HPTCC VALVE WITHOUT HPTCC TIMER****Functional Description**

As the engine reaches takeoff power, the scheduled bleed air to the HPT shroud is from the 9th stage of the HPC.  $TC_1$  and  $TC_2$  both carry  $P_b$  pressure and are opposed by  $P_{cr}$  and spring pressure to maintain the 5th stage valve closed and the 9th stage valve open.

**EFFECTIVITY****ALL**

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## HPTCCV OPERATION SHEET 2

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**HPTCC VALVE WITHOUT HPTCC TIMER****Functional Description**

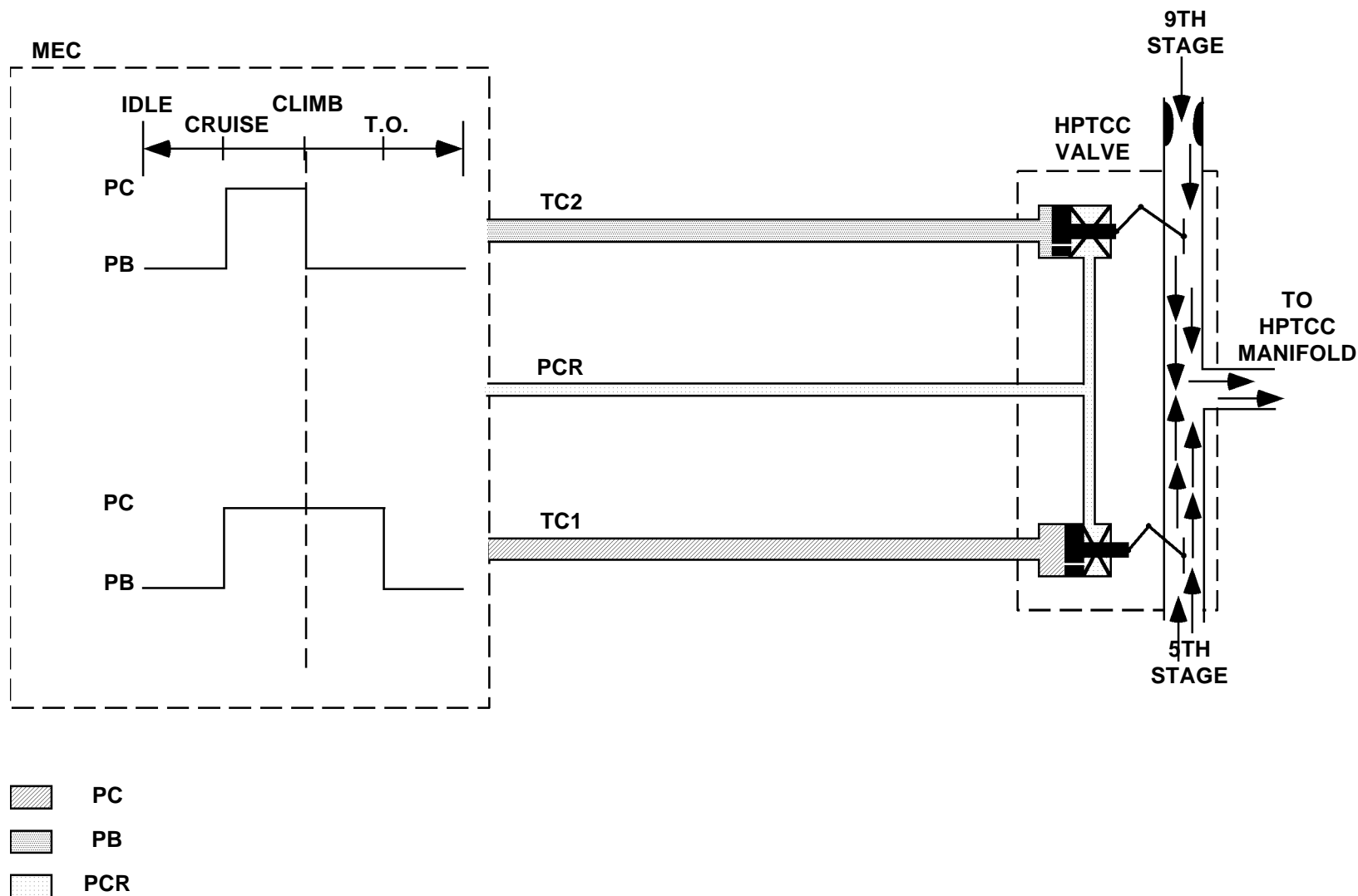
When the throttle is positioned for climb the scheduled bleed air to the HPT shroud is from both 5th and 9th stage of the HPC.  $TC_1$  will carry  $P_c$  pressure to open the 5th stage valve while  $TC_2$  will maintain  $P_b$  pressure to keep the 9th stage valve open. Both  $TC_1$  and  $TC_2$  are opposed by  $P_{cr}$  and spring pressure.

A restrictor, located at the 9th stage air extraction line inlet to the TCC valve, reduces the air pressure being extracted. This prevents 9th stage air introduction into the 5th stage of the compressor when both valves are open during climb power. This simple system eliminates the possibility of a stall condition due to inflow bleed.

**EFFECTIVITY****ALL**

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### HPTCCV OPERATION SHEET 3

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## HPTCC VALVE WITHOUT HPTCC TIMER

### Functional Description

When the throttle is positioned for cruise the scheduled bleed air to the HPT shroud is from the 5th stage of the HPC only.  $TC_1$  will carry  $P_c$  pressure to open the 5th stage valve and  $TC_2$  will carry  $P_c$  pressure to close the 9th stage valve. Both  $TC_1$  and  $TC_2$  are opposed by  $P_{cr}$  and spring pressure.

EFFECTIVITY

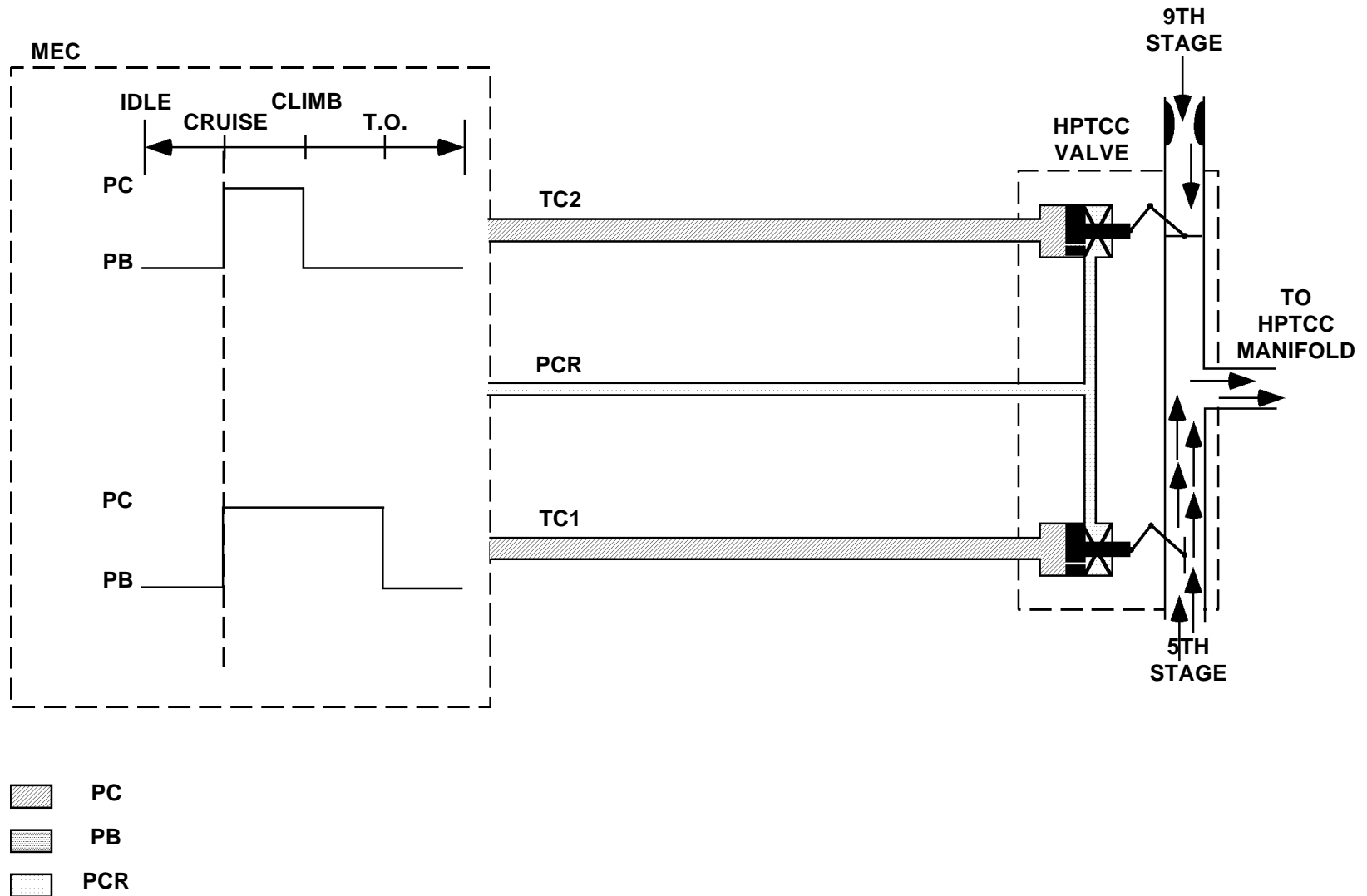
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## HPTCCV OPERATION SHEET 4

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## HPTCC VALVE WITH HPTCC TIMER

### Identification (1.A.b)

The HPTCC system consists of a hydraulically-actuated timer, timer lockout solenoid valve, HPTCCV and connecting tubing to the MEC.

### Purpose (1.B.b)

To obtain maximum steady-state HPT performance and to minimize EGT transient overshoot during Takeoff.

### Location (2.A.b)

The High Pressure Turbine Clearance Control Valve (HPTCCV) is located on the right side of the engine just below the horizontal split-line of the HPC case.

### Operation (2.C.b)

During "hot day" T/O operation, the timer modifies operation of the valve by sequencing a transient air schedule over a specified time period to maintain a more nearly constant HPT blade tip clearance during the period of HPT rotor/stator thermal stabilization. This maintains turbine efficiency, and thereby decreases transient EGT overshoot.

The system uses HPC bleed air from the 5th and 9th stages. Air selection is determined as a function of  $N_2$  RPM. Which results in fuel pressure signals sent from the MEC to actuate the valve. The selected bleed air is ducted from the valve to a manifold surrounding the HPT

shroud. The temperature of the air controls the thermal expansion of the shroud support structure to optimize the shrouds' relative clearance to the HPT blade tips.

The combination of valve positions in the MEC, the TCC timer and the TCCV can result in any of the following three (open and closed) combinations of airflow to the HPT shroud area:

- 5th stage airflow only.
- 5th and 9th stage airflow mixture.
- 9th stage airflow only.

5th stage air is extracted from the forward 5th stage manifold of the HPC stator case at the point where the HPTCCV mounts. 9th stage air is extracted from the combustion case through a port adjacent to one of the fuel nozzle ports and routed forward through an external tube to the HPTCCV.

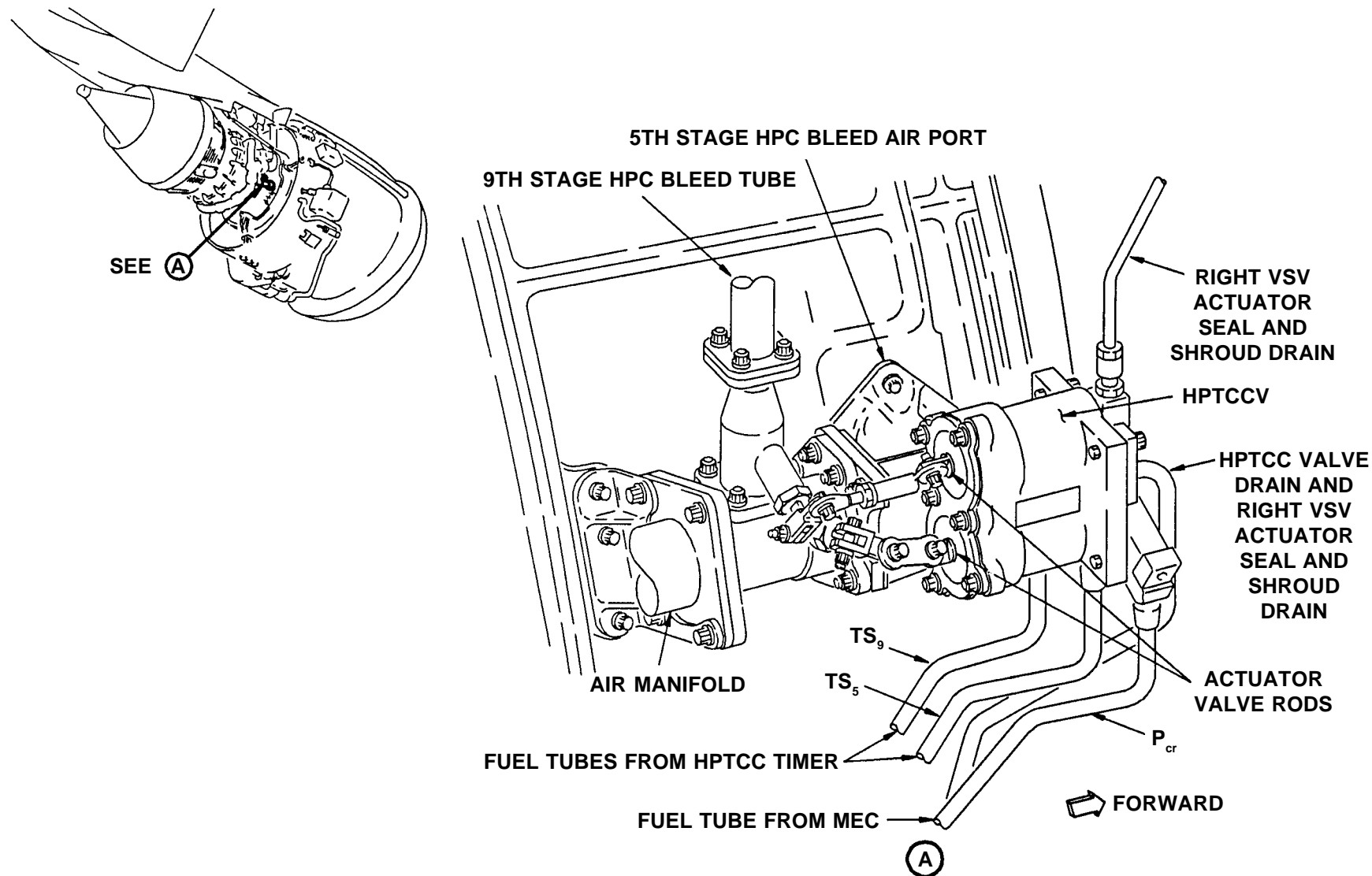
### EFFECTIVITY

737-300,-400/CFM56-3B-2, -3C-1 with Timer

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## HPTCCV INSTALLATION

**HPTCC VALVE TIMER****Identification (1.A.b)**

The HPTCC timer consists of a latching valve and return spring, a timer piston and return spring, and two maximum selector valves.

**Purpose (1.B.b)**

The HPTCC timer is a self-locking, hydraulically-actuated sequencing unit which controls operation of the HPTCCV during the first 182 seconds of the CFM56-3B-2 and the CFM56-3C-1 engine operation above 95%  $N_2$  (13,800 RPM)

**Location (2.A.b)**

The HPTCC timer is located on the left fan case at the 10 o'clock position.

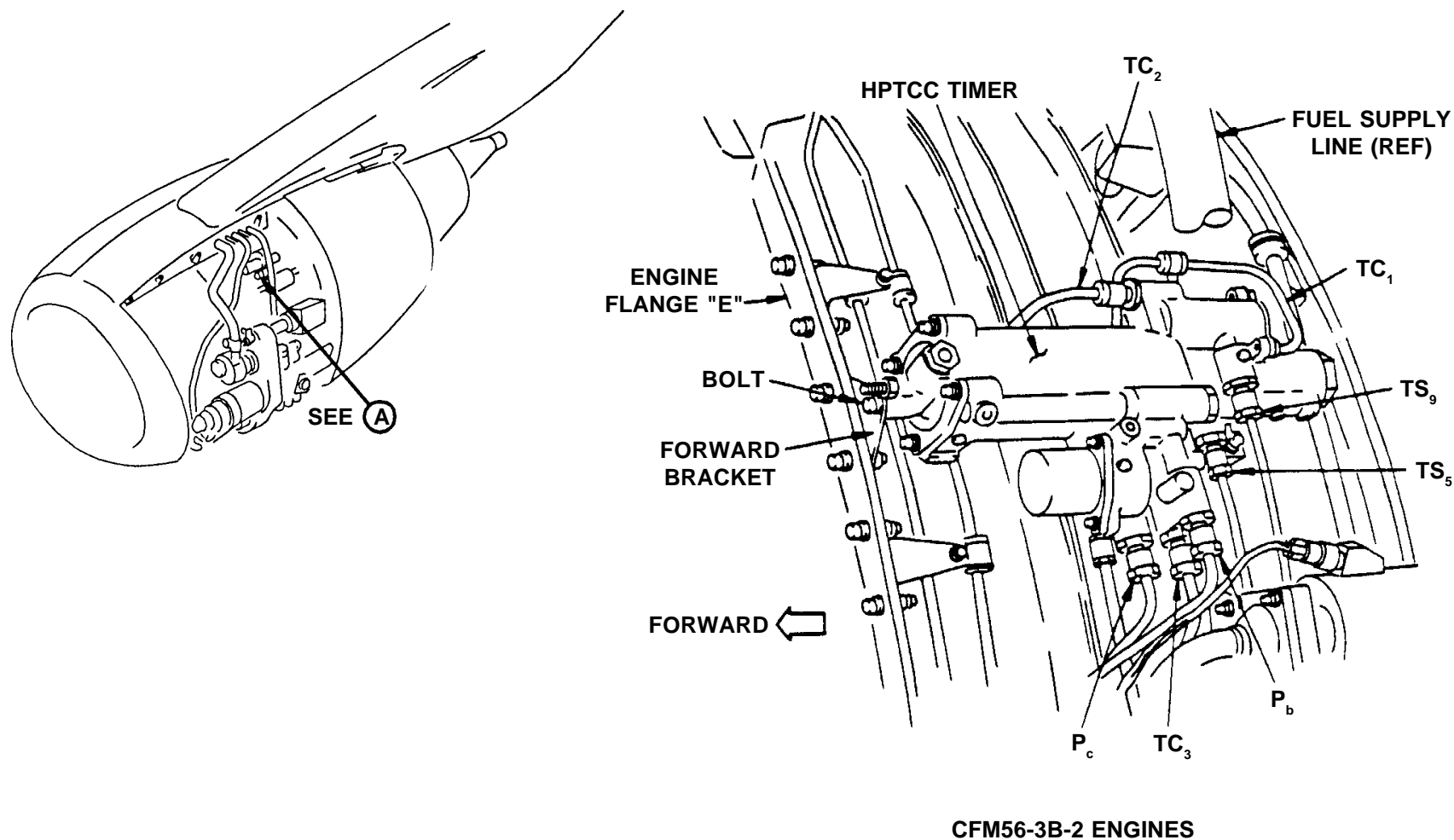
**Operation (2.C.b)**

The latching (or lockout) valve permits the timer to actuate only once per engine cycle (i.e., from engine start to shutdown). The timer piston provides sequencing actuation for the 5th and 9th stage bleed air valves in the HPTCCV. The two maximum selector valves permit the HPTCCV to be controlled by either normal MEC fuel pressure signals or by timer sequencing.

**EFFECTIVITY****737-300,-400/CFM56-3B-2, -3C-1 with Timer**

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CFM56-3B-2 ENGINES

(A)

## HPTCC TIMER INSTALLATION

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737-300,-400/CFM56-3B-2, -3C-1 with Timer

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**HPTCC VALVE TIMER LOCKOUT SOLENOID****Purpose (1.B.b)**

The HPTCC timer solenoid is an electronically-controlled valve which prevents the timer from being actuated after lift-off.

**Location (2.A.b)**

The HPTCC timer lockout solenoid valve is located just above the timer on the fan case at the 11 o'clock position.

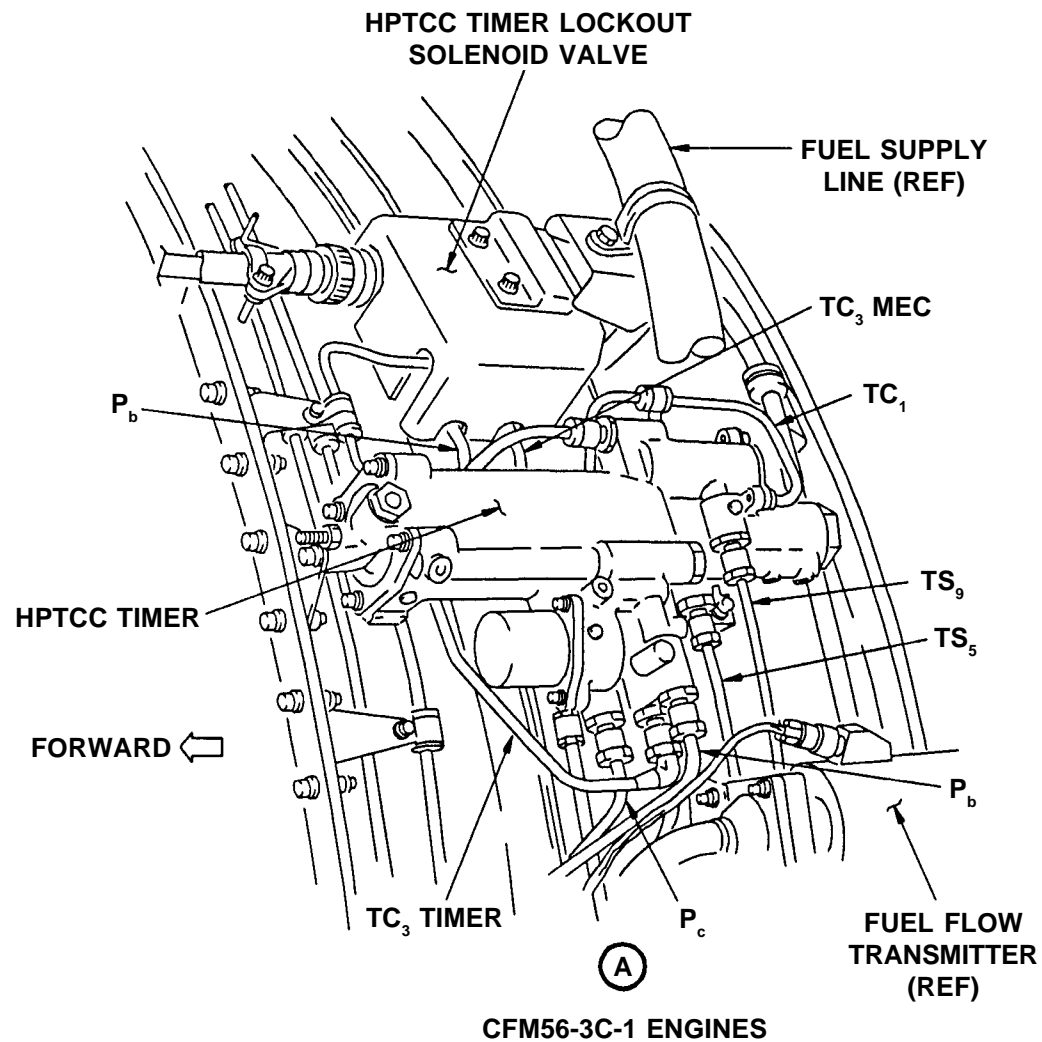
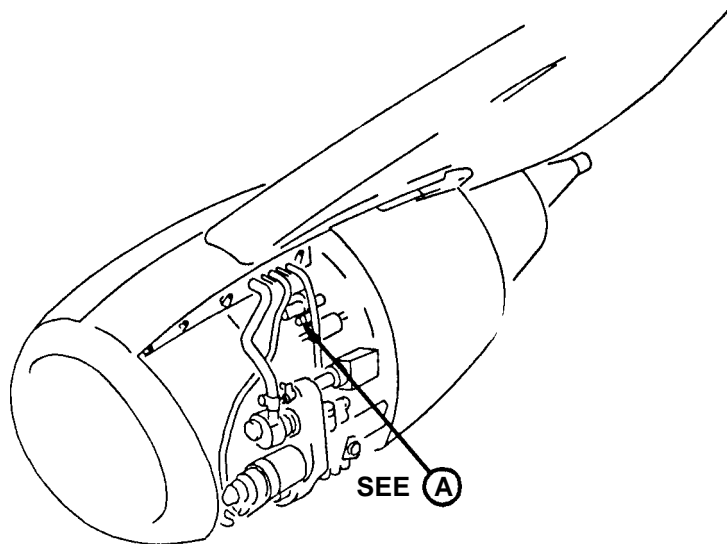
**Operation (2.C.b)**

An air sensing relay permits a 28 VDC power supply to energize the solenoid when an airborne condition is sensed.

**EFFECTIVITY****737-300,-400/CFM56-3B-2, -3C-1 with Timer**

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## HPTCC TIMER INSTALLATION

## HPTCC VALVE WITH HPTCC TIMER

### Functional Description (3.D.b)

Actuation of the TCC timer and valve is controlled by the following fuel pressure signals:

- $TC_1$ ,  $TC_2$  and  $TC_3$  originate from turbine clearance valves within the MEC. These valves are positioned by the TCCV scheduling cam as directed by the tach servo valve, which is a function of  $N_2$ . At selected speeds,  $TC_1$  and  $TC_2$  will provide outputs of either Bypass Pressure ( $P_b$ ) or Case Pressure ( $P_c$ ).  $TC_1$  and  $TC_2$  are supplied to the timer at all times during engine operation to control the 5th and 9th stage valve positions in the TCCV.  $TC_3$  is supplied to the timer lockout solenoid valve at all times during engine operation. If an airborne condition is not sensed,  $TC_3$  passes through the solenoid valve and acts as a trigger signal when  $N_2$  reaches 95% to initiate the timer sequence.
- $P_c$  is supplied to the timer from the MEC at all times during engine operation.  $P_c$  pressure holds the timer latching valve in the latched position allowing the timer to operate only once per start to shutdown cycle of the engine. This valve prevents the timer from responding to  $TC_3$  trigger signals after the initial accel to high power, and it assures that the timer will operate through its full cycle even if  $TC_3$  turns off during the timer sequence. The latching valve (in its latched position) also ports  $P_c$  pressure

to the timer piston to initiate the timer sequence.

- $P_b$  is supplied to the timer and timer solenoid valve from the fuel boost pump discharge pressure port at all times during engine operation.
- $Ts_5$  provides output of either  $P_c$  or  $P_b$  fuel pressure from the TCC timer to the TCCV to control actuation of the 5th stage bleed air valve. When the timer is disarmed,  $Ts_5$  ports  $TC_1$  fuel pressure to the TCCV.
- $Ts_9$  provides output of either  $P_c$  or  $P_b$  fuel pressure from the TCC timer to the TCCV to control actuation of the 9th stage bleed air valve. When the timer is disarmed,  $Ts_9$  ports  $TC_2$  fuel pressure to the TCCV.
- $P_{cr}$  is supplied to the TCCV from the MEC.  $P_{cr}$  pressure, along with spring pressure, opposes  $Ts_5$  and  $Ts_9$  fuel pressure signals from the timer to control the 5th stage and 9th stage bleed air valves.
- Pressure relationship of the three control pressures is  $P_b < P_{cr} < P_c$ .

#### Conditions:

- Timer "off".
- Aircraft on ground.
- Engine at low power.
- Timer not triggered.
- $TC_3$  still at  $P_b$  pressure

### EFFECTIVITY

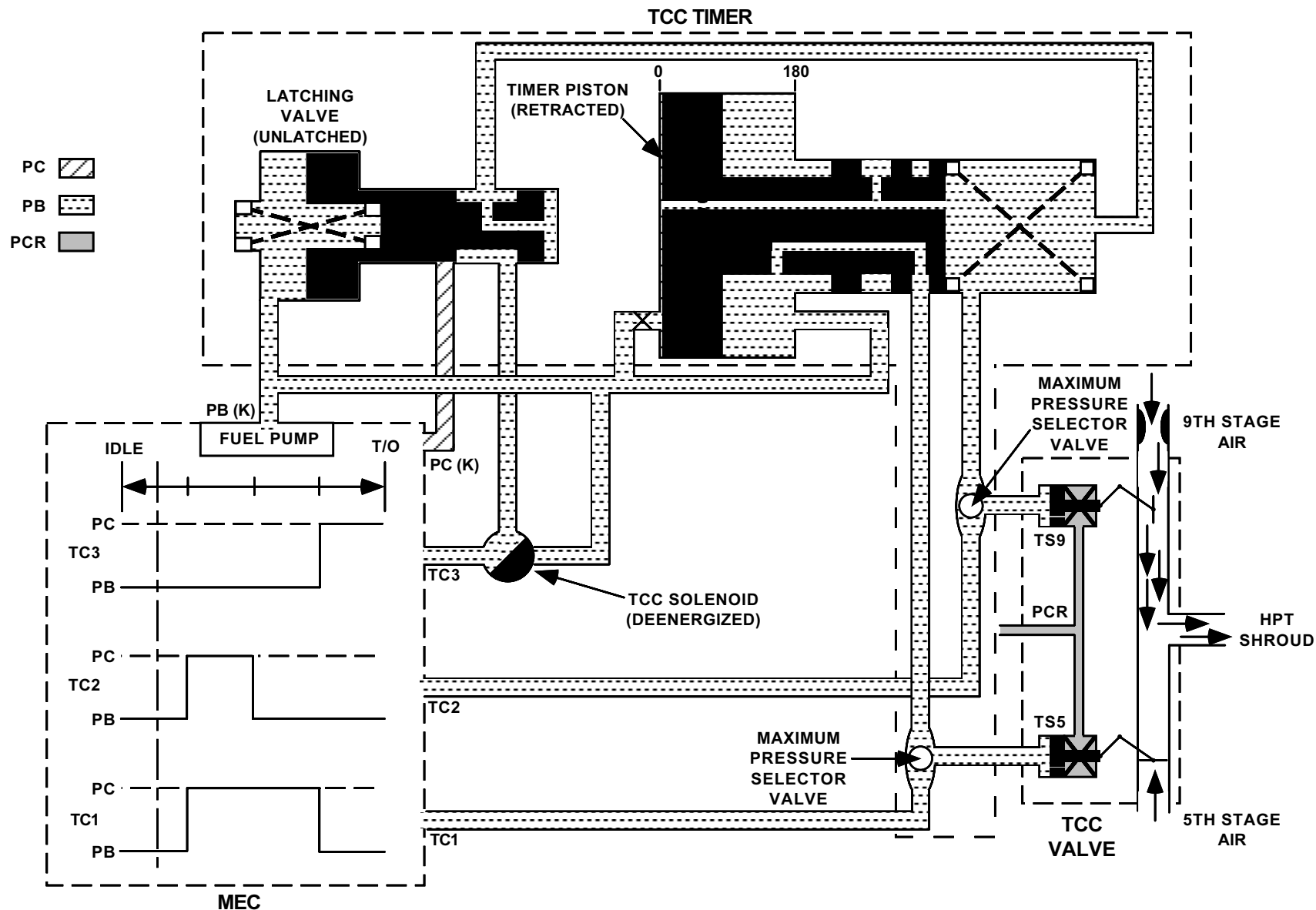
737-300,-400/CFM56-3B-2, -3C-1 with Timer

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**TCC TIMER OPERATION - SHEET 1**

## HPTCC VALVE WITH HPTCC TIMER

### Functional Description

Timer sequencing is accomplished by the action of  $P_c$  pressure pushing the timer piston (against the return spring) through its travel in 182 seconds for CFM56-3B-2 and 3C-1 engines.

As the timer piston moves through its stroke, various ports in the cylinder wall are covered or uncovered which send  $P_b$  or  $P_c$  pressure to the maximum selector valves to override the normal  $TC_1$  and  $TC_2$  outputs and to position the TCCV in the desired air source mode as a function of time.

After the timer sequence elapses, the timer becomes disarmed, and control of the TCCV returns to the normal  $TC_1$  and  $TC_2$  signals. In order to rearm the timer, the engine must be shut down for approximately three minutes to allow fuel to drain.

#### Conditions:

- Timer "off".
- 0 seconds.
- Engine above trigger point.
- Latching valve, timer piston and 9th stage air valve about to operate.
- $TC_3$  now  $P_c$  pressure

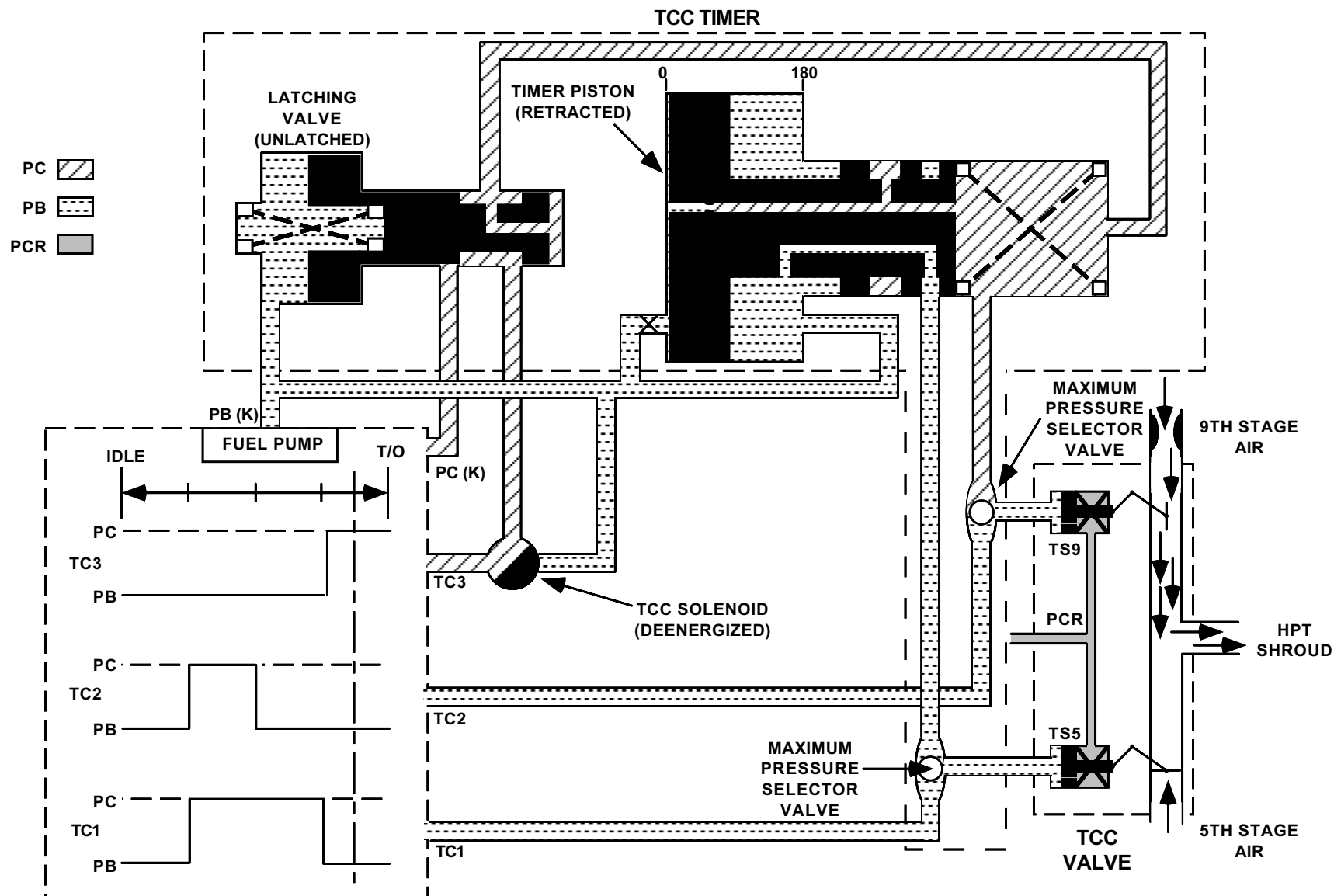
#### EFFECTIVITY

**737-300,-400/CFM56-3B-2, -3C-1 with Timer**

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TCC TIMER OPERATION - SHEET 2

**HPTCC VALVE WITH HPTCC TIMER****Functional Description**

As the engine accelerates to T/O power and core engine speed reaches 95%  $N_2$  (13,800 RPM), the MEC actuates the TCC timer.

The timer then overrides the normal MEC control signals to begin a 182 second sequence of 8 seconds of no air (5th and 9th stage bleed air TCCV's not actuated).

Conditions:

- Cycle initiated.
- No air mode.
- 0-7 seconds.
- Higher  $P_c$  pressure has closed 9th stage air valve, whereas normally it would be open at this RPM.

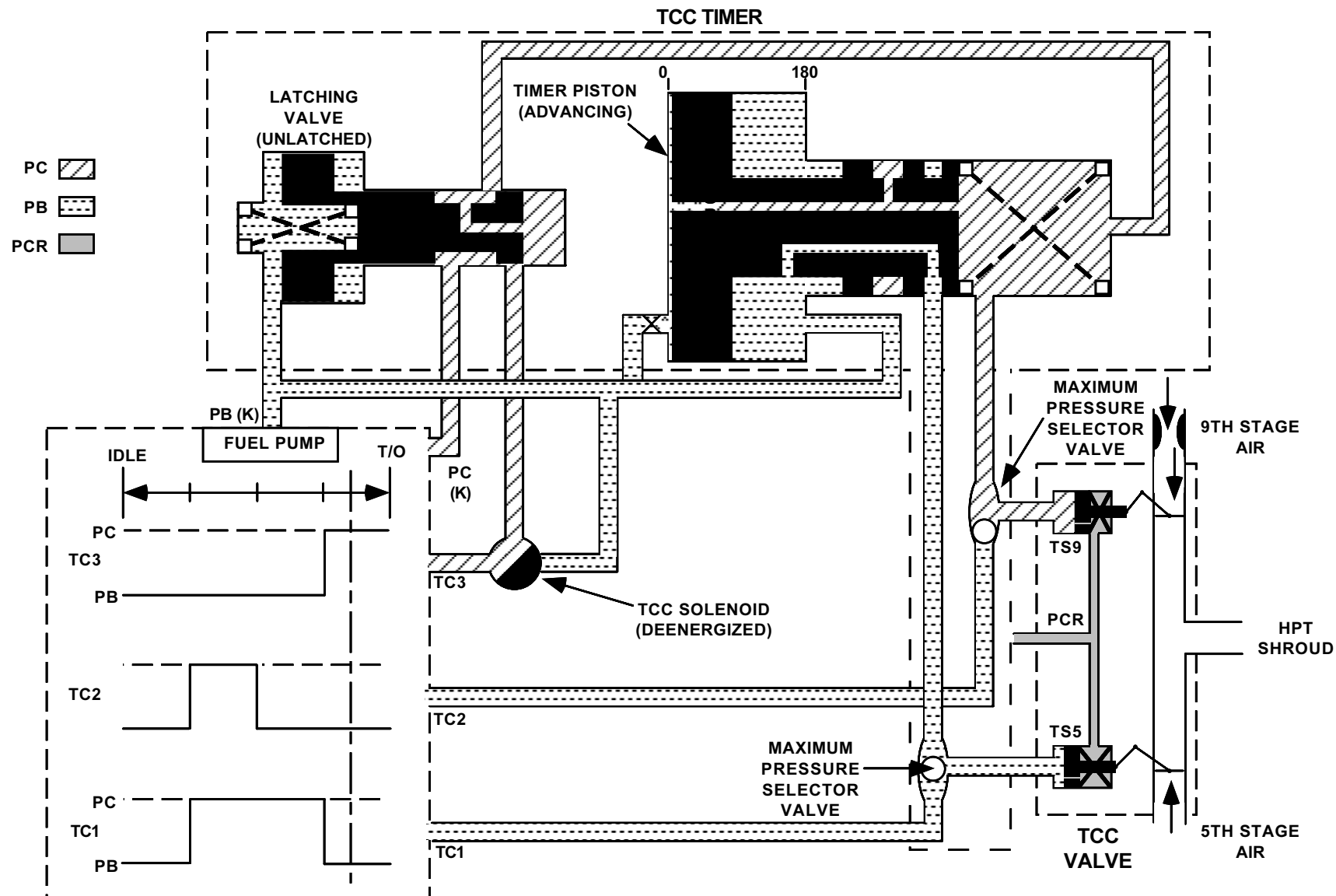
**EFFECTIVITY**

**737-300,-400/CFM56-3B-2, -3C-1 with Timer**

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TCC TIMER OPERATION - SHEET 3

## HPTCC VALVE WITH HPTCC TIMER

### Functional Description

Conditions:

- 5th stage air.
- 7-152 seconds.

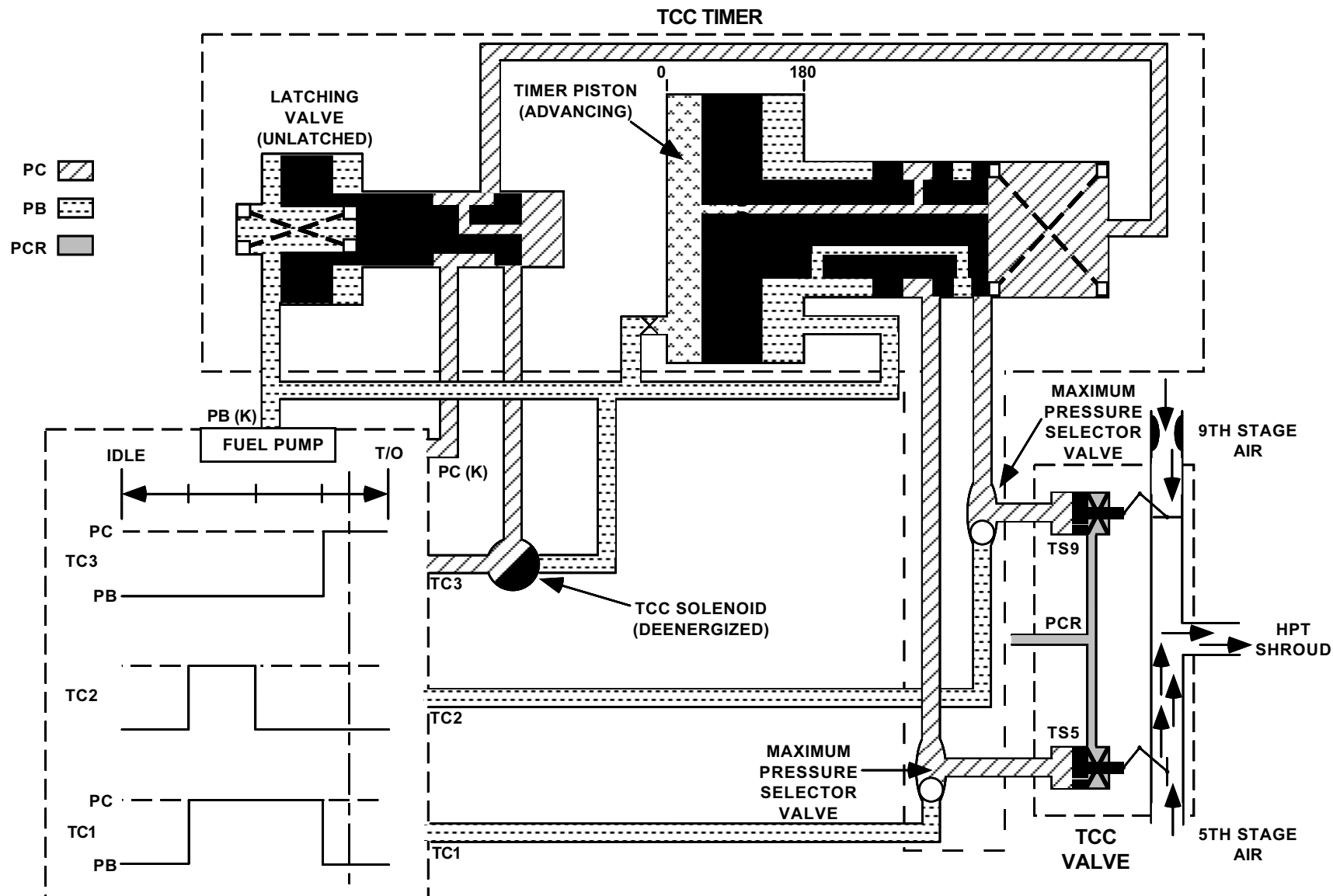
### EFFECTIVITY

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**TCC TIMER OPERATION - SHEET 4**

## HPTCC VALVE WITH HPTCC TIMER

### Functional Description

Conditions:

- Mixed air mode.
- 152 to 180 seconds.

### EFFECTIVITY

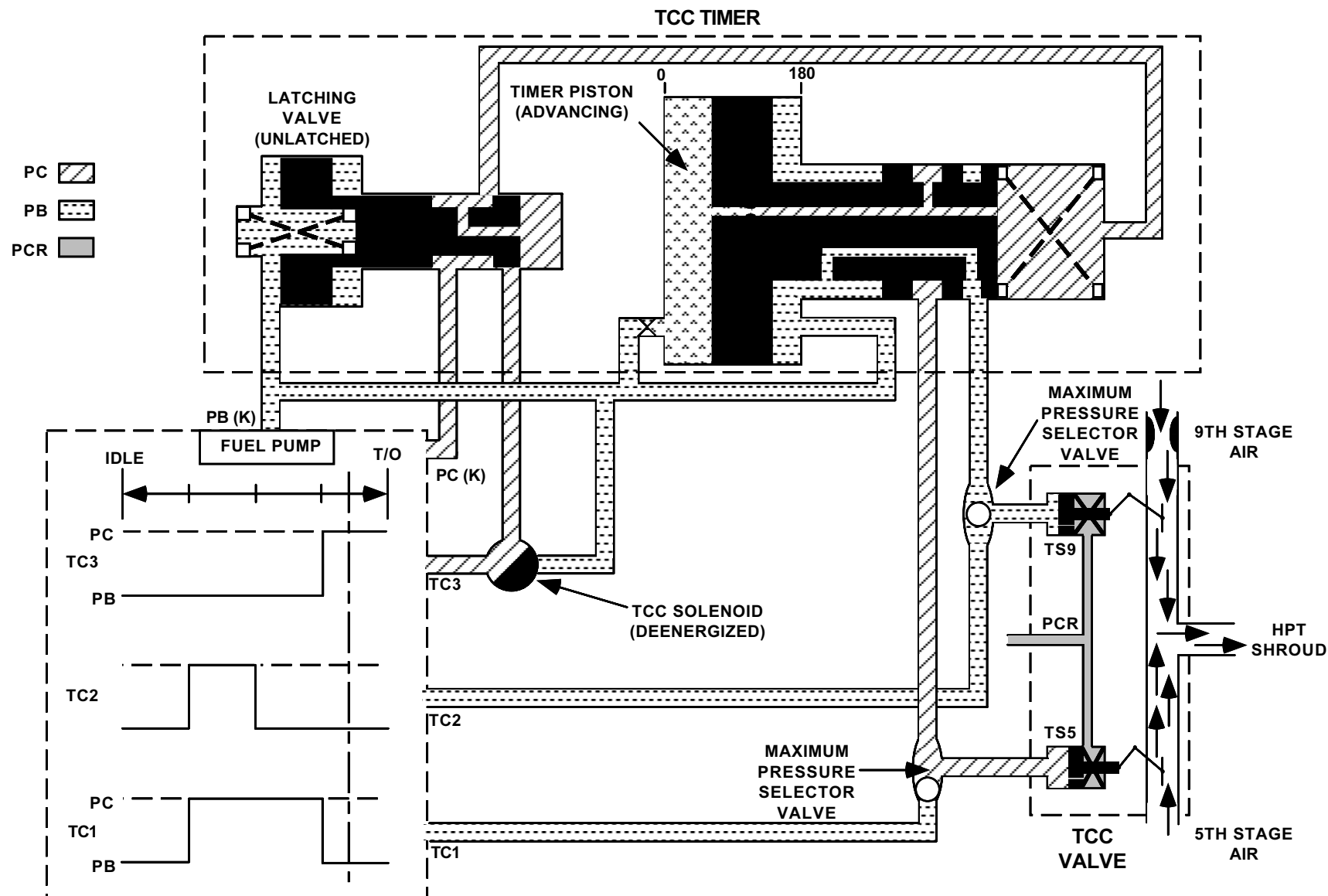
737-300,-400/CFM56-3B-2, -3C-1 with Timer

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**TCC TIMER OPERATION - SHEET 5**

## HPTCC VALVE WITH HPTCC TIMER

### Functional Description

Conditions:

- 9th stage air mode.
- At 180 seconds.
- Engine at low power.
- Timer cycle now complete.

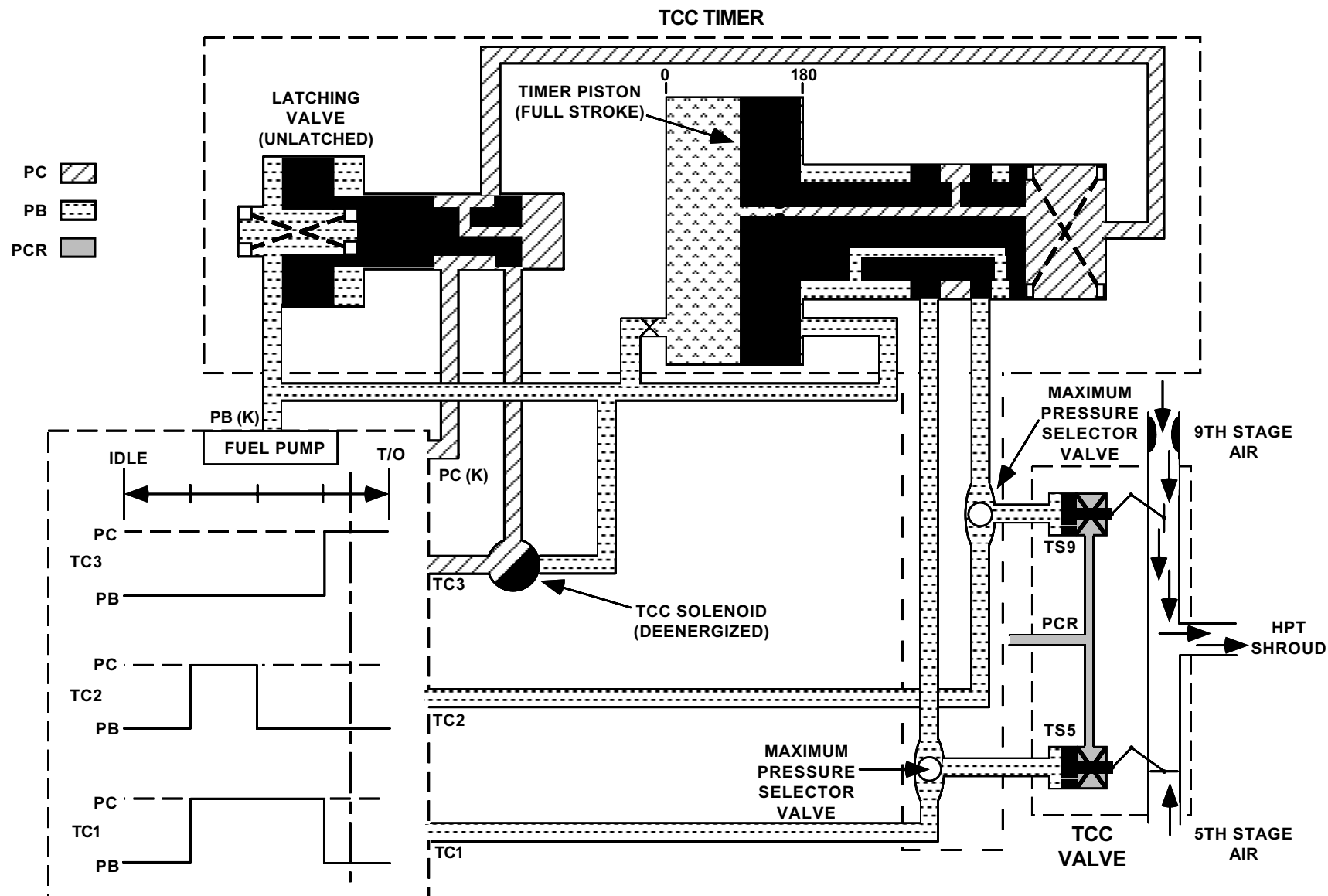
### EFFECTIVITY

737-300,-400/CFM56-3B-2, -3C-1 with Timer

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**TCC TIMER OPERATION - SHEET 6**

## HPTCC VALVE WITH HPTCC TIMER

### Functional Description

The HPTCC timer lockout solenoid valve will become energized after lift-off and prevent actuation of the timer if the timer was not actuated during T/O roll. The 182 second cooling sequence will not be affected by the solenoid after it is initiated during T/O roll.

An orifice, located in the 9th stage air extraction line between the valve and the compressor casing extraction manifold, reduces the 9th stage air pressure being extracted to prevent 9th stage air introduction into the 5th stage of the compressor when both valves are open (during power climb).

When the engine is shut down, the two position hydraulic actuator valve rods are retracted, closing the 5th and opening the 9th stage air valves.

After 182 seconds, the timer returns control of the valve to the normal MEC control signals until the next engine shutdown. The timer resets when the engine is shut down.

#### Conditions:

- Aircraft airborne.
- TCC solenoid energized, shutting off fuel to latching valve.
- Latching valve remains latched by constant  $P_c$  pressure until next engine shutdown, but cannot

- again latch until the aircraft is on ground and TCC de-energized..
- TCC system can only operate as per TC<sub>1</sub> and TC<sub>2</sub> schedule once airborne and timer timed out.

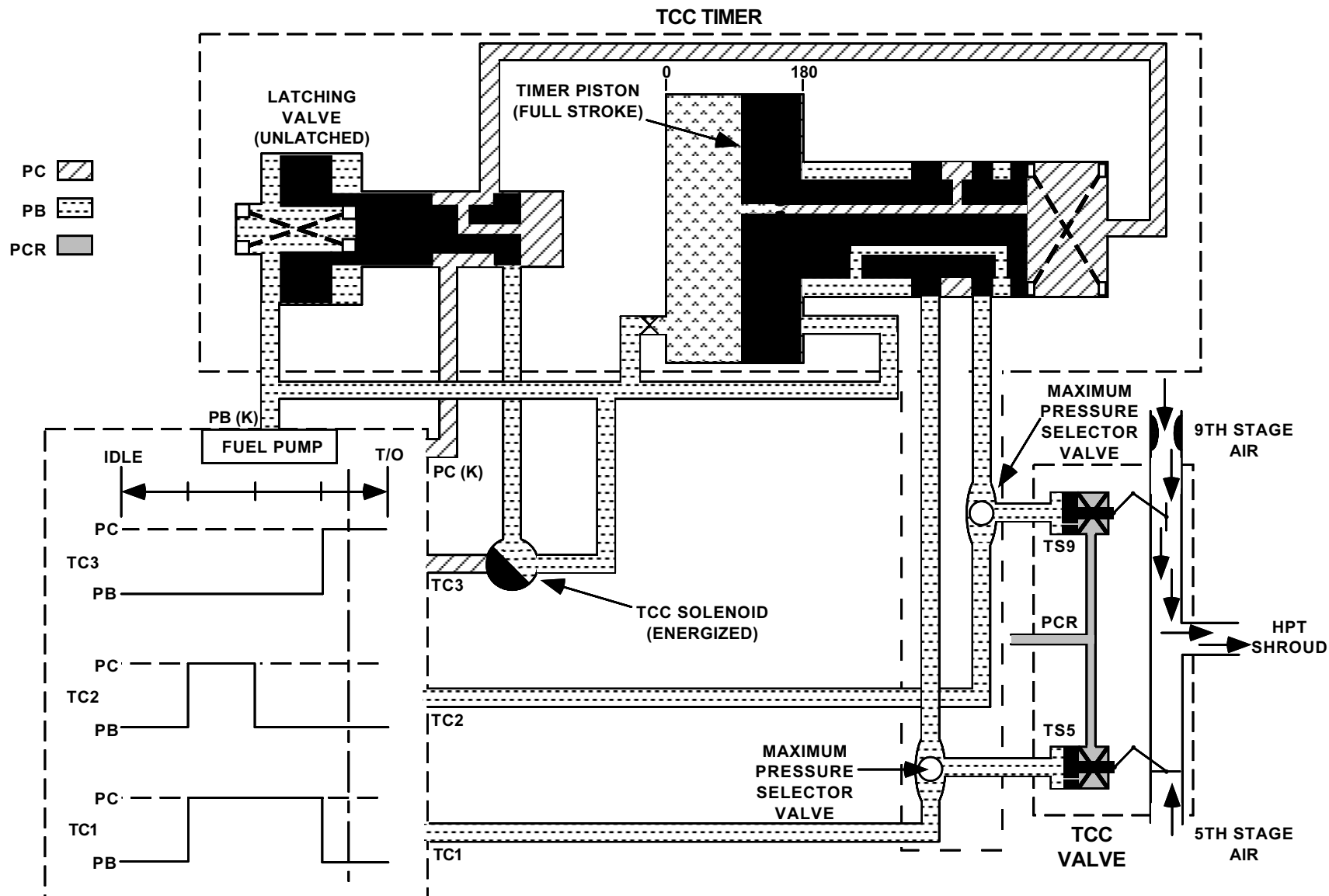
### EFFECTIVITY

**737-300,-400/CFM56-3B-2, -3C-1 with Timer**

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**TCC TIMER OPERATION - SHEET 7**

**VARIABLE STATOR VANE SYSTEM****Identification (1.A.b)**

The system consists of two VSV hydraulic actuators, two bellcrank assemblies and linkage, and a flexible feedback cable.

**Purpose (1.B.b)**

The Variable Stator Vane (VSV) actuation system controls primary airflow through the HPC.

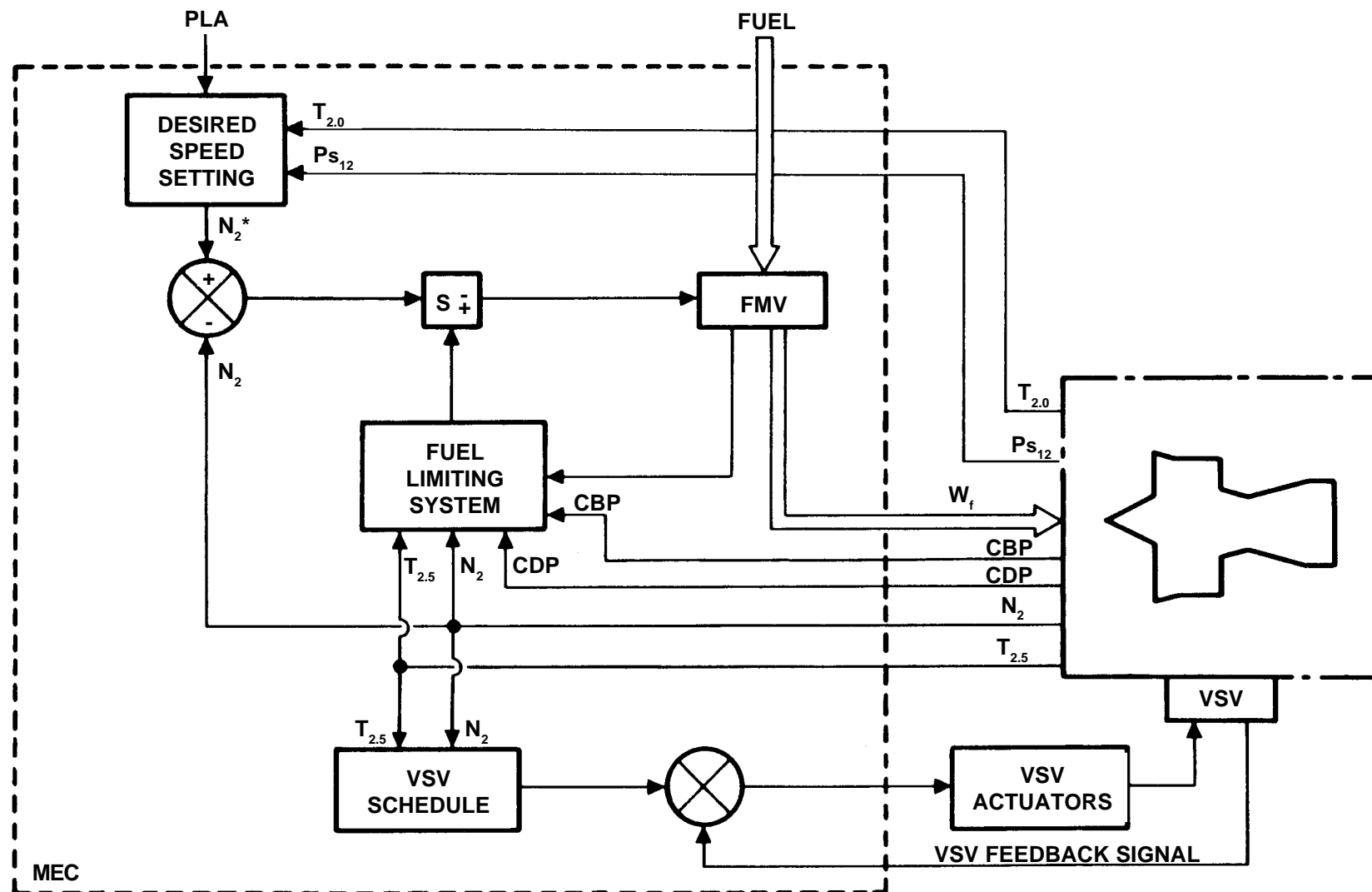
**Operation (2.C.b)**

The VSV actuation system maintains satisfactory compressor performance over a wide range of operating conditions. The system varies the angle of the IGV's and the three stages of variable vanes to aerodynamically match the LP stages of compression with the HP stages. This variation of vane position changes the effective angle at which air flows across the rotor blades. The angle determines the compression characteristics (direction and velocity) for any particular stage of compression. By varying the variable vane position in accordance with a predetermined schedule as a function of those conditions affecting compressor performance (CIT and  $N_2$ ), the critical LP stages are automatically realigned or rematched to maintain satisfactory airflow and compressor performance during all engine operating conditions within the requirements of the system.

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VSV SYSTEM

**VSV ACTUATOR****Identification (1.A.b)**

Each VSV actuator is connected through a clevis link and the stage 3 bellcrank to a master rod which unites the bellcranks to mechanically position the actuation rings which control VSV angular positions.

**Location (2.A.b)**

Two VSV actuators are mounted on the HPC forward stator case at the 1:30 and 7:30 o'clock positions.

**Operation (2.C.b)**

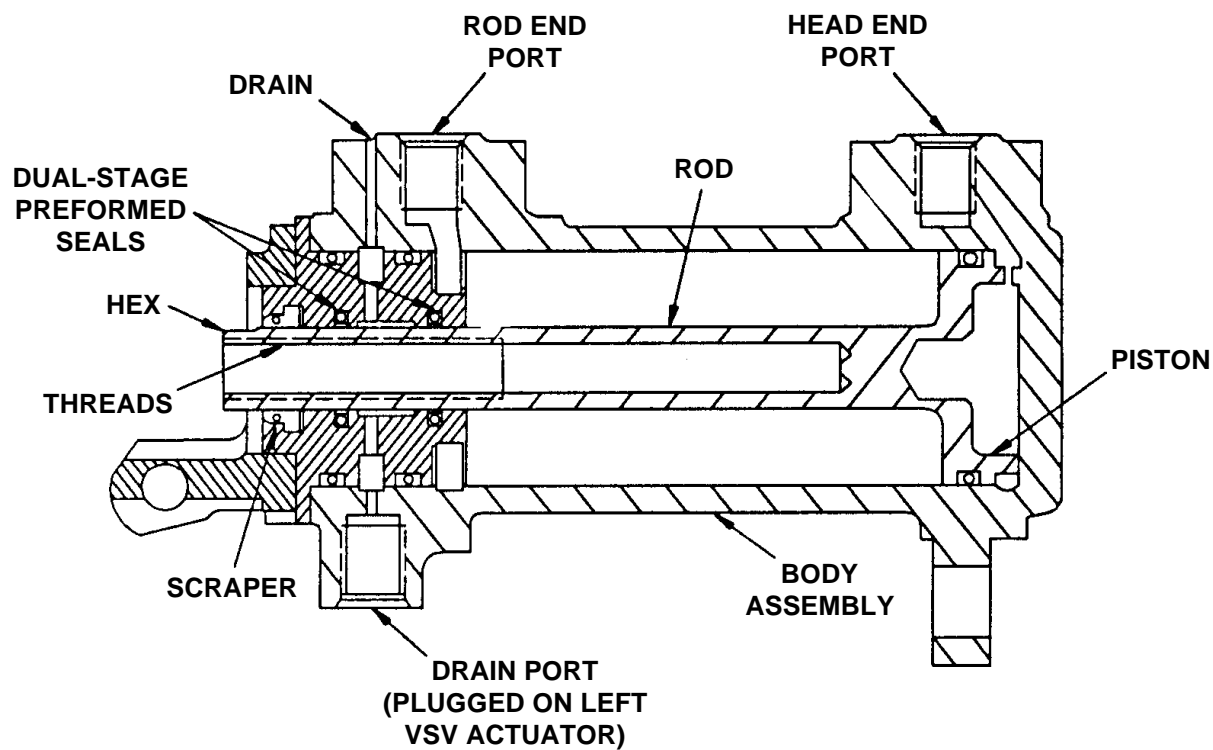
The VSV actuators are single-ended, uncushioned hydraulic cylinders, which are driven in either direction by HP fuel ( $P_f$ ). The actuator rod end is sealed against fuel leakage by dual-stage preformed seals. Fuel, which could leak past the preformed seals, is drained overboard through the starter air discharge duct fitting. The piston incorporates a capped preformed packing to prevent leakage across the piston and controls stroke by internal stops. The piston rod is ensured of dirt-free operation by means of a wiper which cleans the rod as it retracts past the dual-stage seals. The rod end is threaded and fitted with an adjustable extension that includes a clevis for connection to the VSV bellcrank assembly.

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**VSV ACTUATOR CROSS SECTION**

## VSV BELLCRANK ASSEMBLY

### Identification (1.A.b)

Each VSV bellcrank assembly consists of four bellcranks (Inlet Guide Vane (IGV), stage 1, stage 2 and stage 3) which are mechanically driven by the VSV actuator through connections to the master rod. Adjustable links, consisting of a tie rod and bearing, connect each bellcrank to the actuation rings.

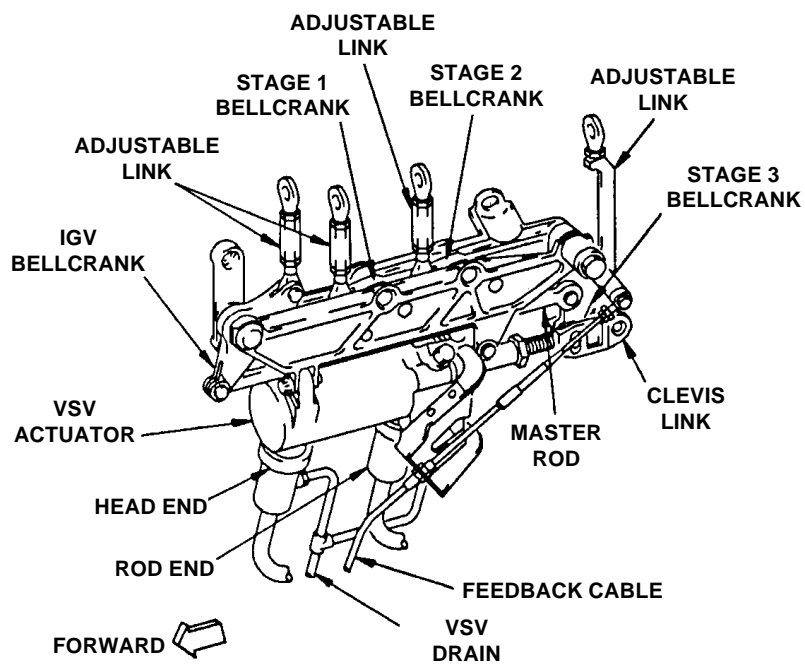
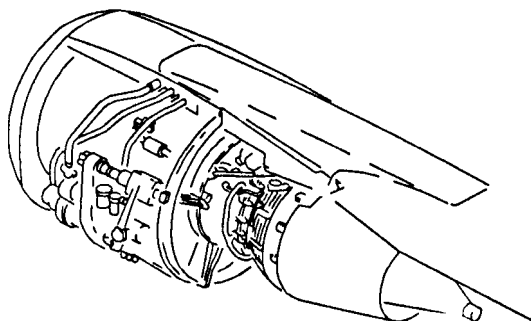
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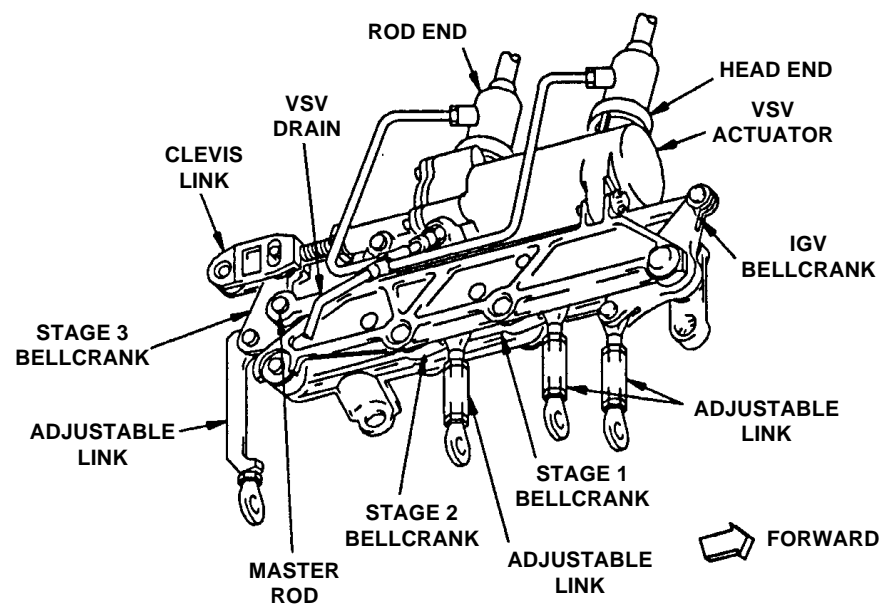
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LEFT VSV ACTUATOR



RIGHT VSV ACTUATOR

## VSV ACTUATION SYSTEM COMPONENTS

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**VSV ACTUATION HALF RING****Identification (1.A.b)**

The actuation rings, are connected by actuation ring connectors at the horizontal split-line of the compressor casing.

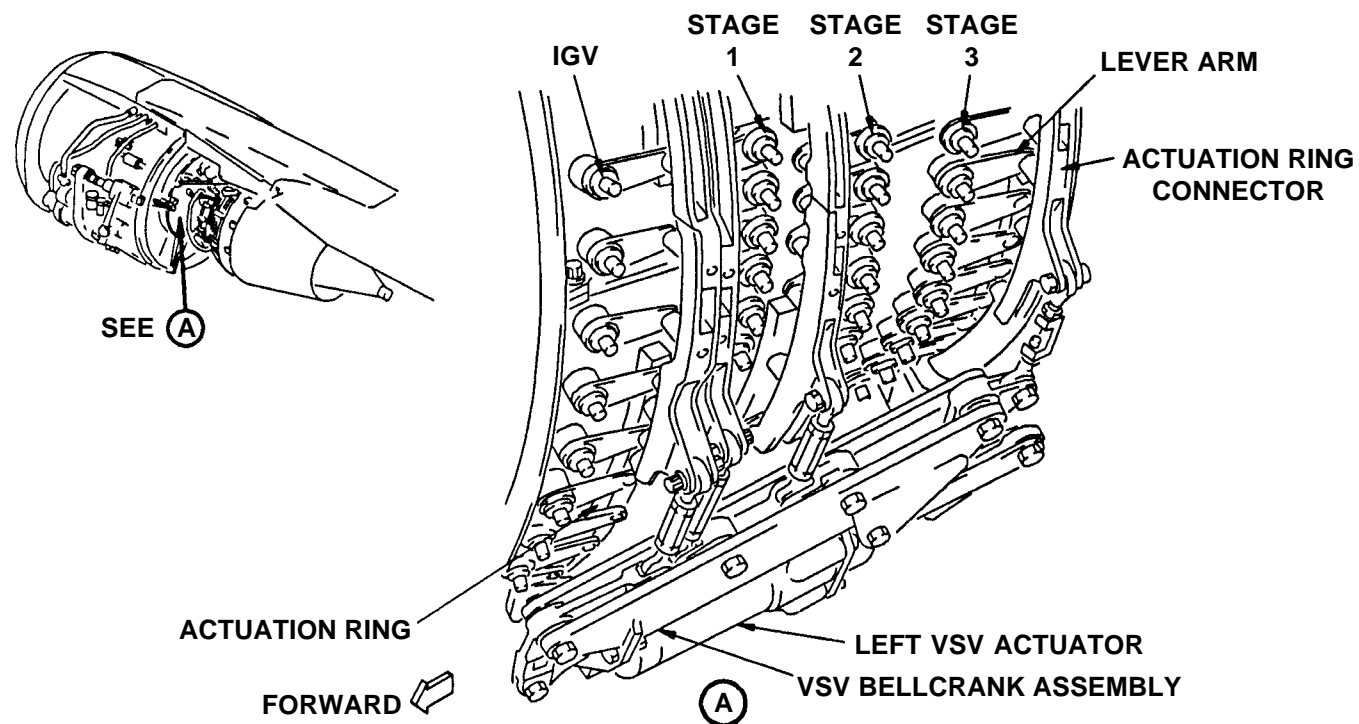
**Operation (2.C.b)**

The actuation rings rotate circumferentially about the horizontal axis of the compressor. Movement of the rings is transmitted to the individual vanes through vane actuating lever arms.

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## VSV BELLCRANK ASSEMBLY AND ACTUATION HALF RINGS

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**VSV FEEDBACK CABLE****Identification (1.A.b)**

The VSV feedback cable is connected to the MEC lever on the aft side.

**Purpose (1.B.b)**

VSV feedback cable movement transmits the position of the VSV's to the MEC.

**Location (2.A.b)**

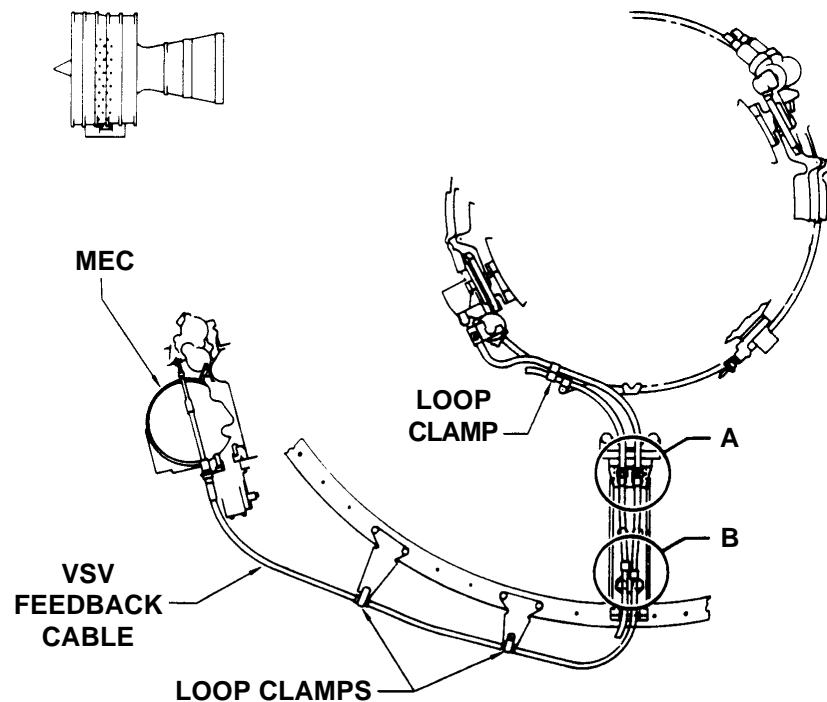
It is routed up through the rear portion of the 6 o'clock fan frame strut area. It connects to the bellcrank of the VSV actuator located at the 8 o'clock position on the compressor case.

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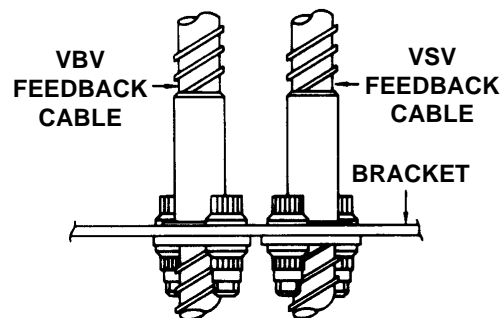
**EFFECTIVITY****ALL**

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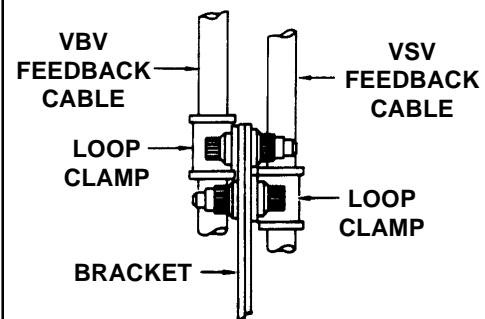
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DETAIL A



DETAIL B



### ROUTING OF FEEDBACK CABLE (VSV)

## VSV SYSTEM

### Operation (2.C.b)

The VSV's are positioned by two VSV actuators which are operated by fuel pressure from the MEC.

### Functional Description (3.D.b)

In the MEC are a VSV scheduling 3D cam, which is positioned by  $N_2$  and CIT signals, a VSV feedback mechanism which transmits actual vane position to the control, and a VSV pilot valve, which is positioned as a result of the comparison of the scheduling cam position and the feedback signal.

Changes in  $N_2$  rotate the 3D scheduling cam, while changes in CIT axially translate the cam. Movement of the cam repositions the pilot valve. The pilot valve ports HP fuel (main fuel pump discharge pressure) to either the head end or rod end port of the VSV actuators, and vents the other end to bypass pressure. The feedback mechanism in the control repositions the pilot valve to stabilize the actuator signal when the vanes reach the scheduled position.

HP fuel supplied to the head end port of the VSV actuator causes the piston rod to move aft (extended position), which in turn drives the master rod to position the IGV and stage 3 bellcrank upward (or downward on the right VSV actuator) and the stage 1 and stage 2 bellcranks downward (or upward on the right VSV

actuator). Movement of the bellcranks is transmitted to the actuation rings and thus to the individual vanes causing the vanes to close.

HP fuel supplied to the rod end port causes the piston rod to move forward (retracted position), which in turn drives the master rod to position the IGV and stage 3 bellcranks downward (or upward on the right VSV actuator) and the stage 1 and stage 2 bellcranks upward (or downward on the right VSV actuator). Movement of the bellcranks is transmitted to the actuation rings and thus to the individual vanes causing the vanes to open.

## EFFECTIVITY

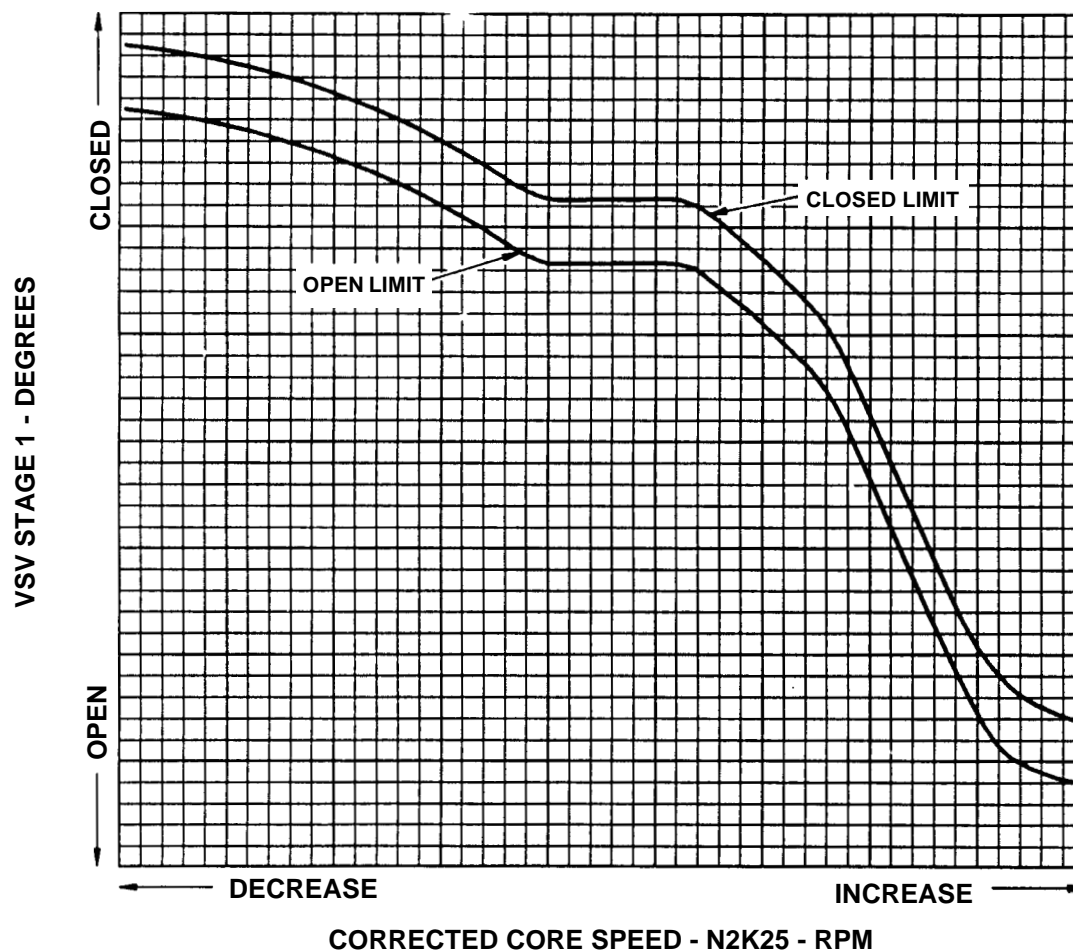
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NOTE: THIS CURVE IS INTENDED ONLY TO PROVIDE A GENERAL VISUAL PRESENTATION OF VSV OPERATION AS A FUNCTION OF ENGINE SPEED. USE MAINTENANCE MANUAL TABLE FOR SPECIFIC LIMITS.

### VSV STEADY-STATE TRACKING SCHEDULE (TYPICAL)

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## VARIABLE BLEED VALVE SYSTEM

### Identification (1.A.b)

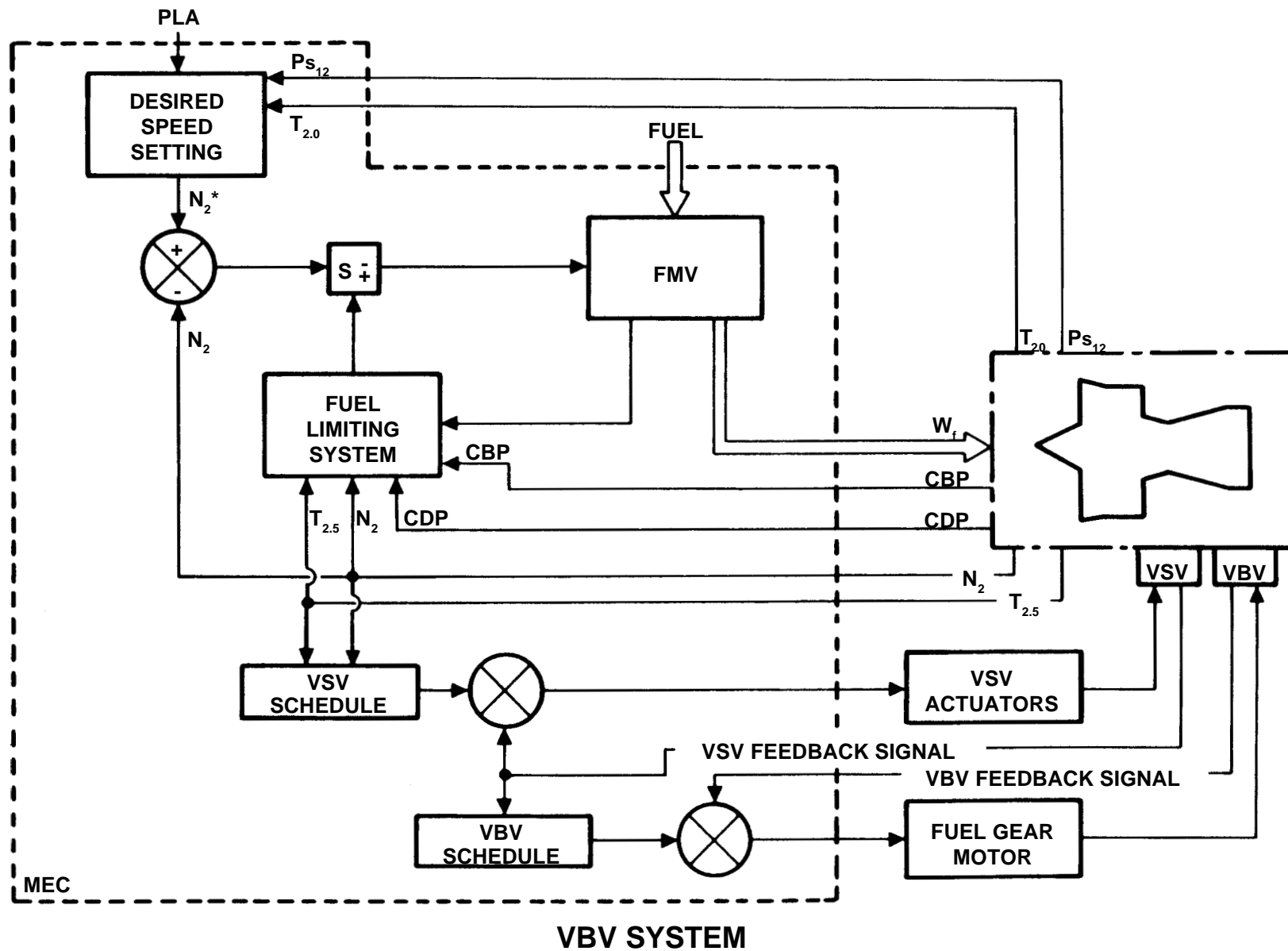
The VBV system includes the following:

- A power unit consisting of a fuel-powered hydraulic gear motor supplied by fuel from the HP pump as scheduled by an external signal.
- A bleed valve stop mechanism
- A bleed valve and master ballscrew actuator unit consisting of a speed reduction gearbox and a ballscrew actuator linked to a bleed valve door
- Eleven bleed valve and ballscrew actuator units. Each unit has a speed reduction gearbox and a ballscrew actuator linked to a bleed valve door.
- A bleed valve main flexible shaft installed between the bleed valve and master ballscrew actuator and the fuel gear motor
- Eleven bleed valve flexible shafts installed between the bleed valve and ballscrew actuators and the flexible shaft relays.
- A flexible feedback cable to transmit to the MEC the position of the bleed valve system.

### Purpose (1.B.b)

The VBV system performs four primary functions:

- Positions the bleed valves in response to a differential fuel pressure through the fuel gear motor.
- Mechanically synchronizes the bleed valves throughout the stroke.
- Limits the bleed valve position at the end of each stroke.
- Provides feedback of the bleed valve position.



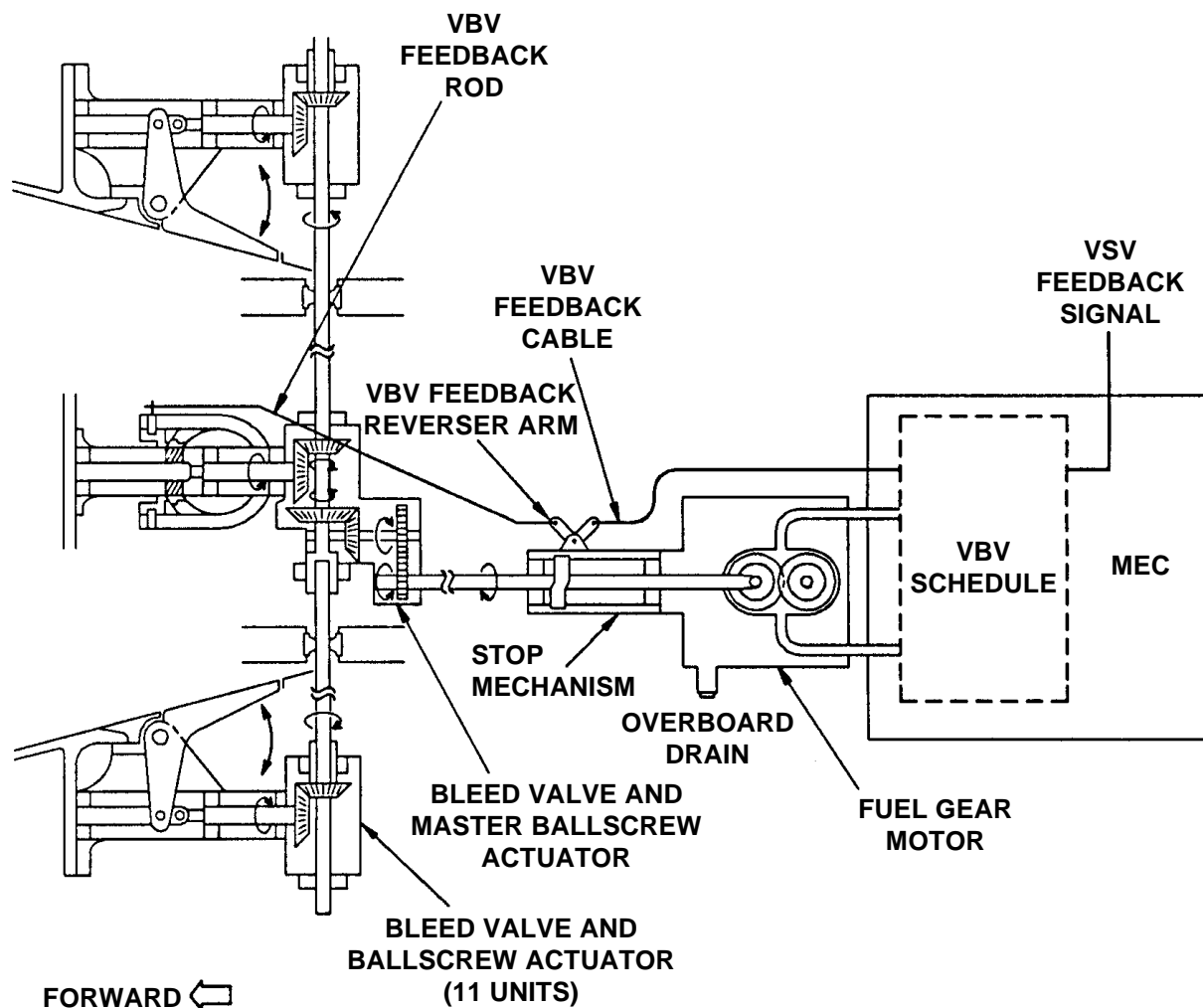
**VARIABLE BLEED VALVE SYSTEM****Operation (2.C.b)**

When the bleed valves are open, a portion of the primary airflow from the booster (Low Pressure Compressor (LPC)) is permitted to go through the midbox and into the secondary (fan) airflow. The bleed valves open during low and transient operations to increase the booster mass flow and to improve booster and HPC matching.

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## VBV SYSTEM

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## VARIABLE BLEED VALVE SYSTEM

### Functional Description (3.D.b)

A hydromechanical computer, integral within the MEC, determines the bleed schedule as a function of the angular setting of the variable compressor stator at steady-state operation and during acceleration. The bleed valve schedule is biased to open more toward the open side of the schedule during rapid decelerations or T/R operation.

The VBV actuation system provides an angular output through the fuel gear motor, master ballscrew actuator and 11 ballscrew actuators. The system is interconnected by 11 flexible shafts. There are 11 ferrules installed in the fan frame struts to provide support for the flexible shafts. The system is designed to open, close or modulate the 12 VBV's to an intermediate position in response to an input command signal. The VBV's remain fully synchronized throughout their complete stroke by the continuous mechanical flexible shaft arrangement. The MEC supplies HP fuel to hydraulically operate the VBV actuation system. The master ballscrew actuator and the corresponding bleed valve are connected to the MEC by a push-pull feedback cable. The feedback cable provides VBV position bias to the MEC.

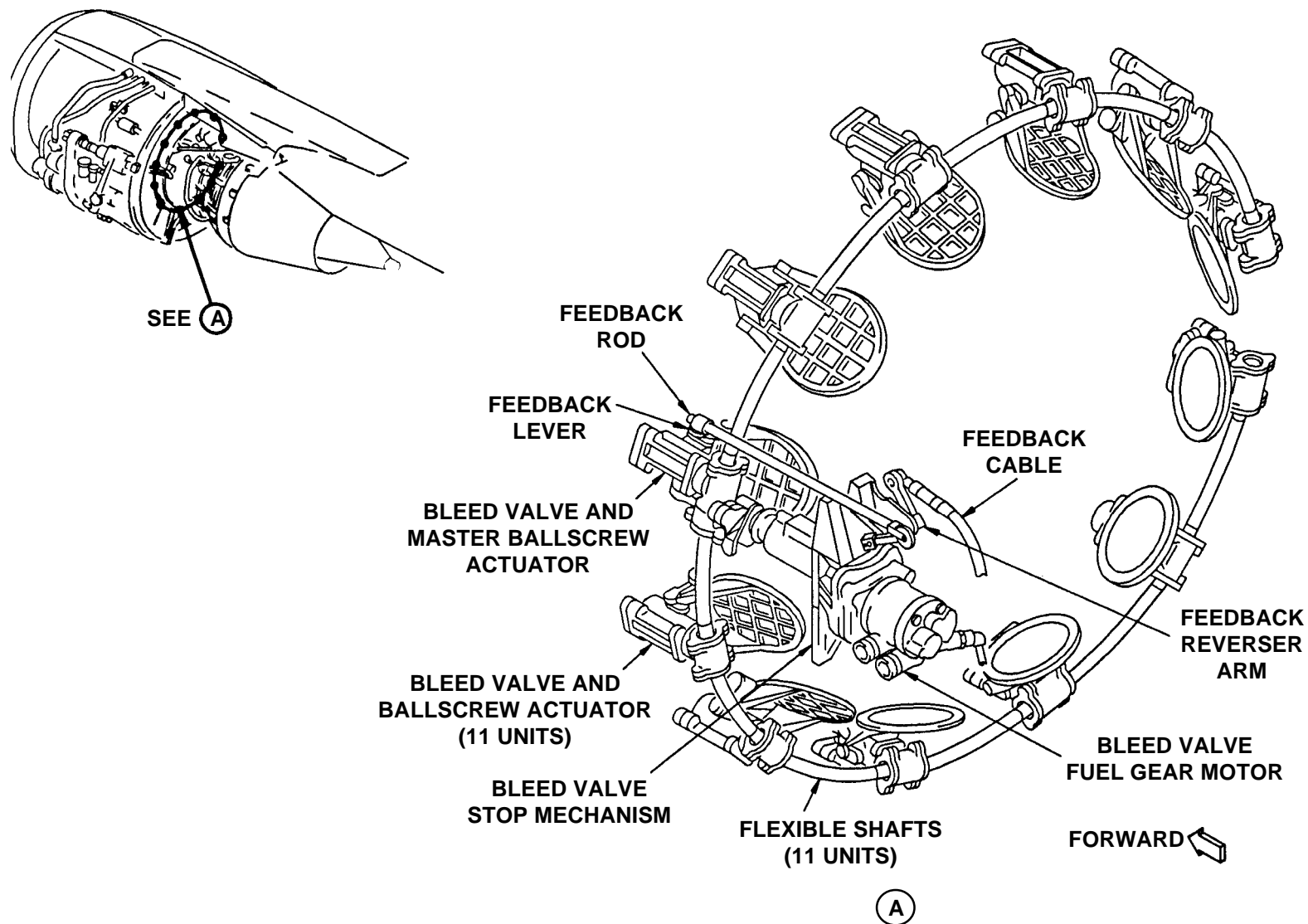
### EFFECTIVITY

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## VARIABLE BLEED VALVE SYSTEM

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**VBV FUEL GEAR MOTOR****Identification (1.A.b)**

The bleed valve fuel gear motor consists of a positive displacement gear motor and end-of-stroke stop mechanism. It consists of two spur gears guided during rotation by needle bearings.

Sealing at the drive gear shaft is provided by carbon seals. A secondary lip seal is mounted on the output shaft for further sealing.

**Purpose (1.B.b)**

The fuel gear motor, which is driven by  $P_r$  pressure controls the position of the bleed valves.

**Location (2.A.b)**

The fuel gear motor is mounted to the aft end of the VBV stop mechanism.

**Operation (2.C.b)**

The motor converts pressurized fuel into rotary shaft power which is driven through the bleed valve stop mechanism to the gear reduction stage of the bleed valve and master ballscrew actuator.

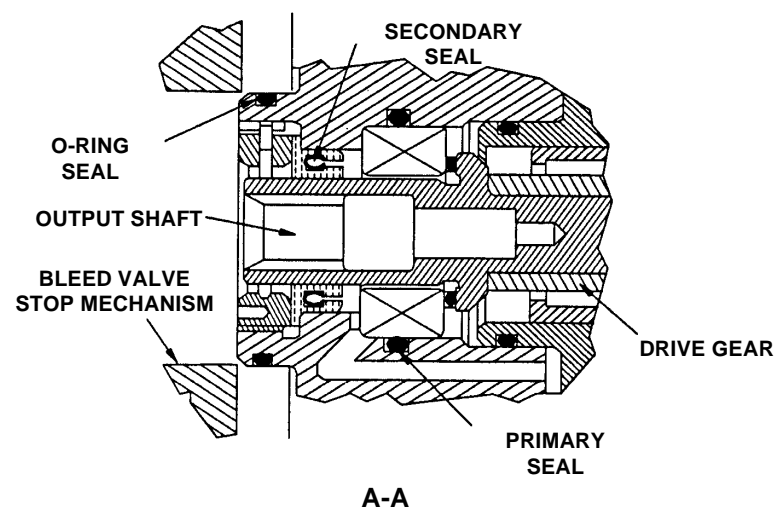
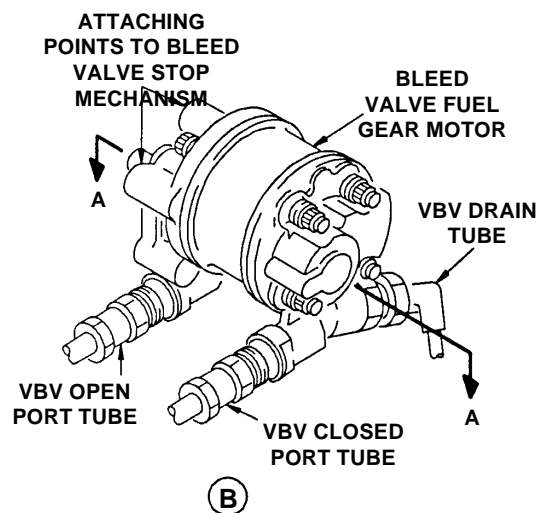
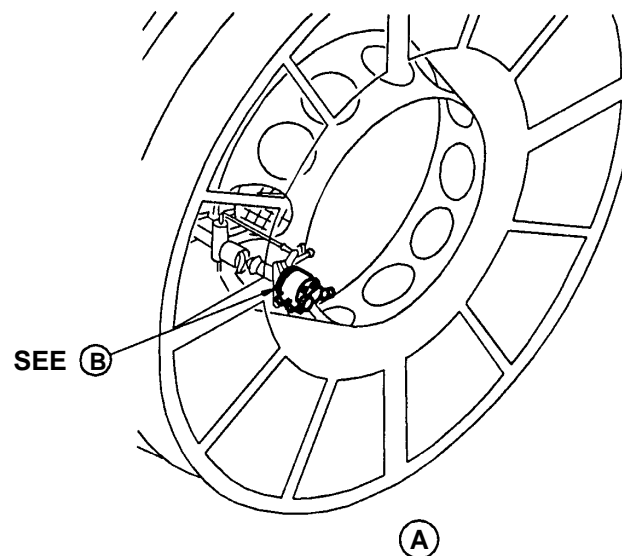
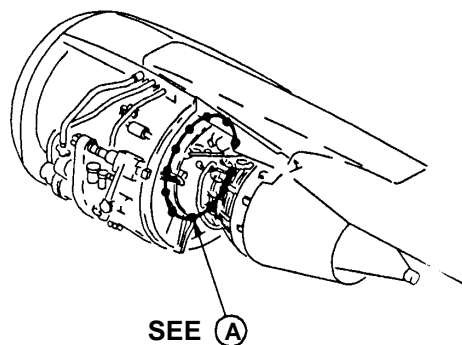
Fuel, which could leak past the different sealing provisions, is drained overboard through the starter air discharge duct fitting.

**EFFECTIVITY****ALL**

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## VARIABLE BLEED VALVE FUEL GEAR MOTOR

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## STOP MECHANISM

### Identification (1.A.b)

The stop mechanism consists of a housing, a hollow screw, the main VBV flexible shaft, and a follower nut.

### Purpose (1.B.b)

The function of the bleed valve stop mechanism is to limit the number of revolutions of the bleed valve fuel gear motor to the number of revolutions required for a complete cycle (opening-closing) of the VBV doors. This limiting function supplies the reference position for installing and adjusting the VBV actuators.

### Location (2.A.b)

The bleed valve stop mechanism is installed inside the fan frame midbox structure between the bleed valve fuel gear motor and the bleed valve and master ballscrew actuator at the 9:30 o'clock position.

### Functional Description (3.D.b)

The hollow screw is driven by the bleed valve fuel gear motor. This hollow screw shaft holds the main VBV flexible shaft which connects the bleed valve fuel gear motor to the master ballscrew actuator. The follower nut translates along the screw and stops the rotation of the bleed valve fuel gear motor when it reaches the ends of the screw threads.

The VBV feedback reverser arm is mounted on the bleed

valve stop mechanism housing. The feedback reverser arm links the feedback rod from the master ballscrew actuator to the feedback cable, which is routed to the MEC. Through this linkage, the MEC constantly monitors the angular position of the VBV doors.

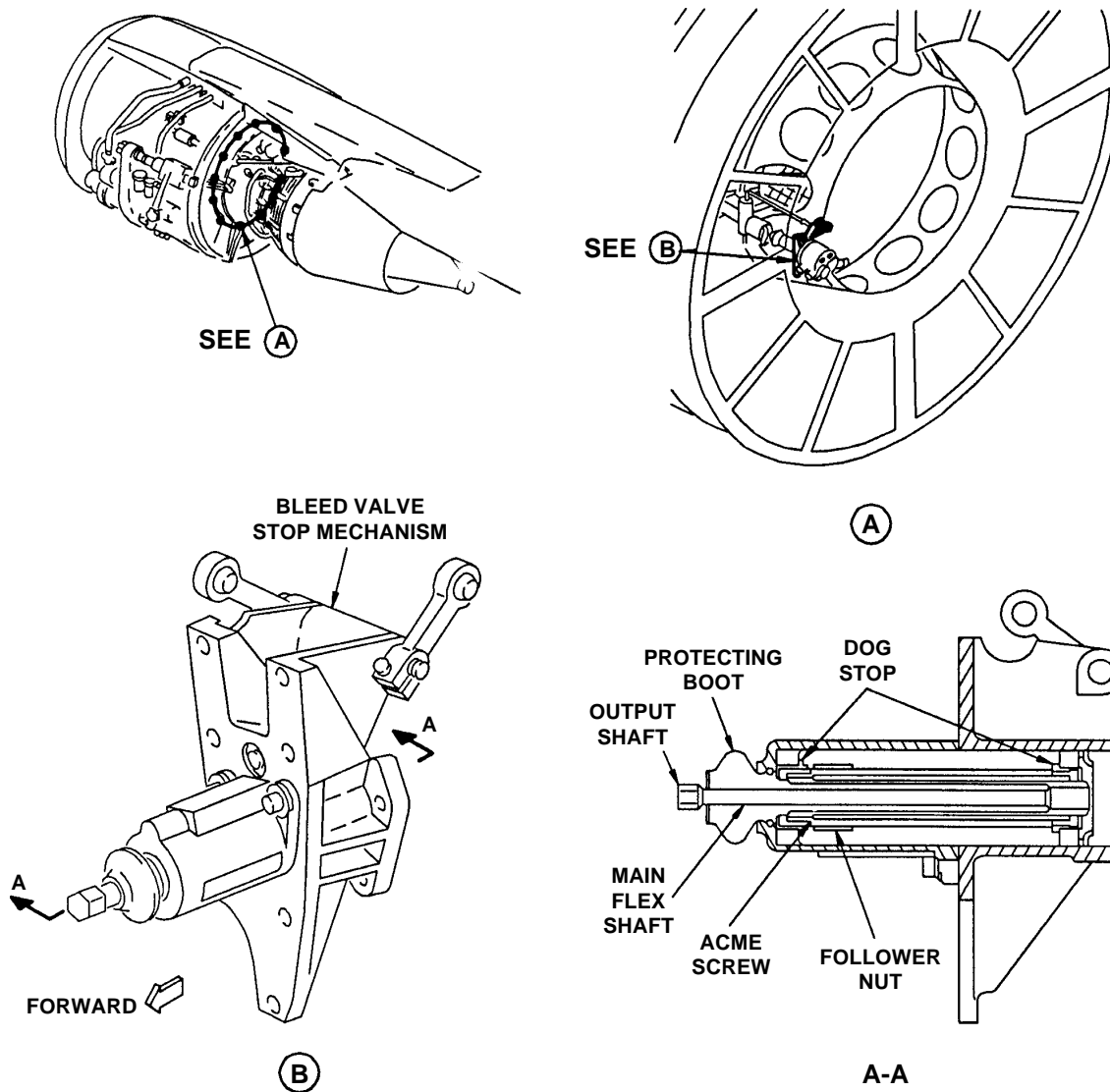
## EFFECTIVITY

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## VARIABLE BLEED VALVE STOP MECHANISM

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**STOP MECHANISM****Functional Description**

With S/B 72-580 CFMI introduced a modification to the VBV stop mechanism.

The VBV kicker system modifies the VBV tracking schedule to further open the VBV doors (40° versus 25°) during transient operation. This positioning of the VBV doors in association with other changes provides an improvement to hail and rain bypass from the primary.

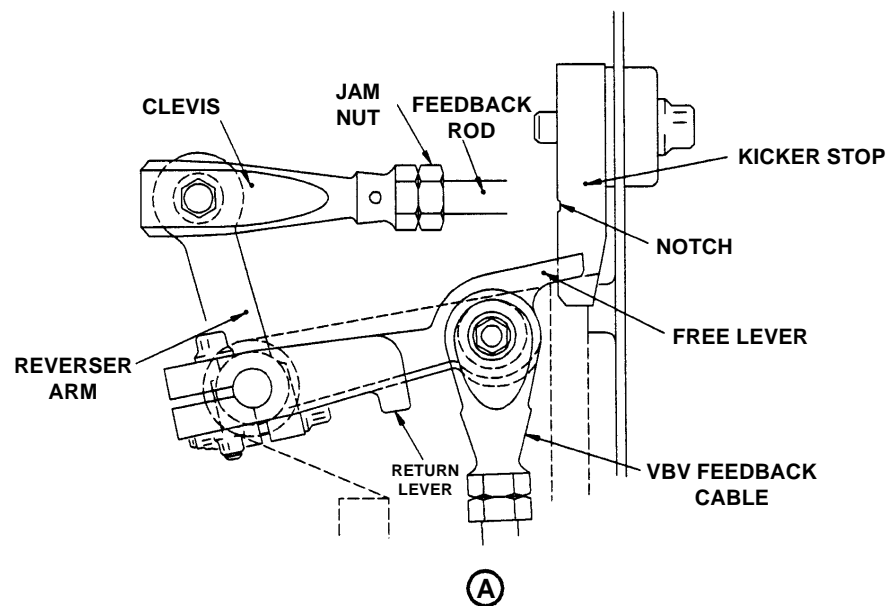
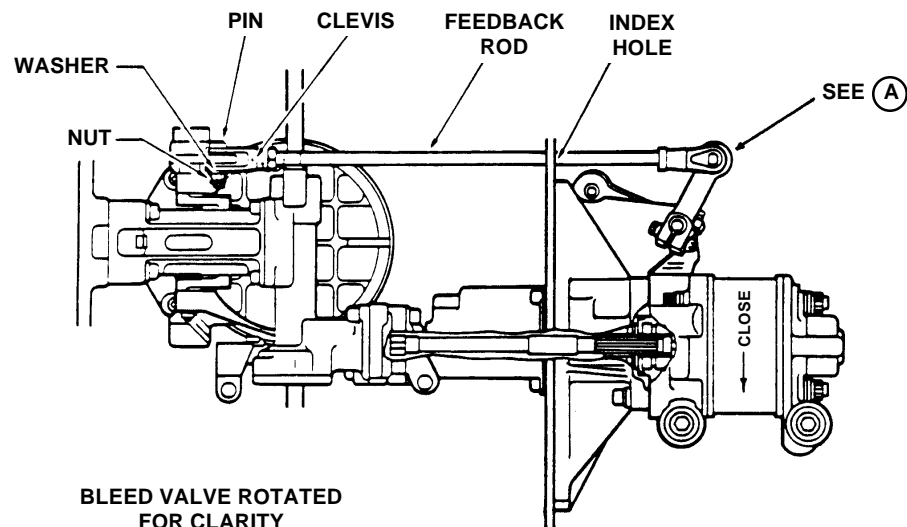
The kicker system consists of a:

- free lever
- return lever
- kicker stop

**EFFECTIVITY****737/Engines with S/B 72-580**

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### VBV KICKER SYSTEM

## MASTER BLEED VALVE AND BALLSCREW ACTUATOR

### **Identification (1.A.b)**

It consists of a speed reduction gearbox and a ballscrew actuator linked to a hinged door. Speed reduction is consecutively carried out through one pair of spur gears and then by two pairs of bevel gears. The last set of bevel gears drives the ballscrew.

The ball bearing type screw and nut assembly consists of a screw, nut, ball return tube, a clamp attached to two screws and washers, and 68 balls.

### **Purpose (1.B.b)**

The bleed valve and master ballscrew actuator transfers the driving input from the bleed valve fuel gear motor to the ballscrew actuator system.

### **Location (2.A.b)**

The master bleed valve and ballscrew actuator is located at the 11 o'clock position between the center hub and the midbox structure of the fan frame.

### **Functional Description (3.D.b)**

The ballscrew translating nut is held during rotation by two pins which slide within two slots in the actuator body. The travel of the nut is transmitted to the door by two links. The feedback rod is attached to the feedback lever on the bleed valve door. This permits the MEC to

constantly monitor the position of the bleed valve door. The output motion of the first pair of bevel gears is transferred to the other bleed valve and ballscrew actuators by the flexible shafts. The flexible shafts are driven by the two ends of the output gear of this pair of bevel gears.

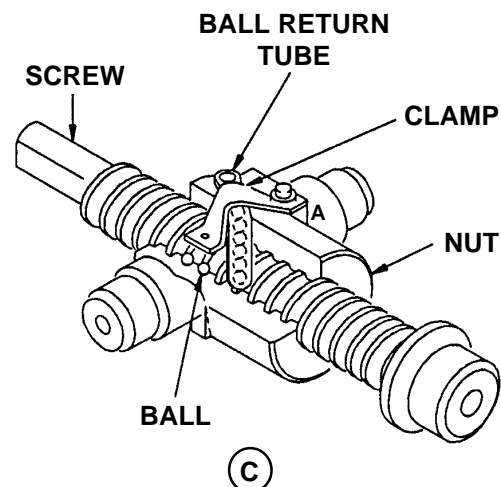
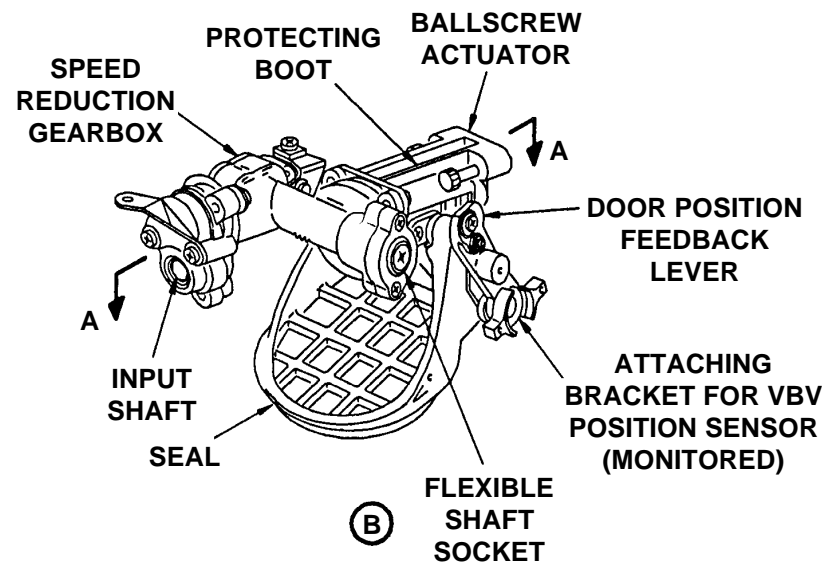
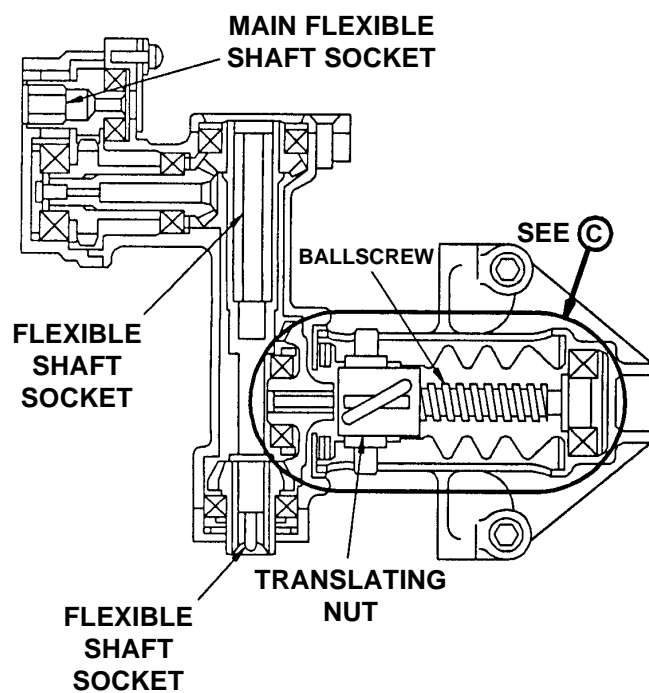
## EFFECTIVITY

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## VARIABLE BLEED VALVE AND MASTER BALLSCREW ACTUATOR

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## BLEED VALVE AND BALLSCREW ACTUATOR

### **Identification (1.A.b)**

Each bleed valve and ballscrew actuator consists of a bevel gear speed reduction gearbox and a ballscrew unit linked to a hinged door.

### **Purpose (1.B.b)**

The bleed valve and ballscrew actuator transfers the driving input from the master bleed valve and ballscrew actuator to the next ballscrew actuator.

### **Location (2.A.b)**

There are 11 bleed valve and ballscrew actuators connected on either side of the master ballscrew actuator.

### **Functional Description (3.D.b)**

The translating nut is held during rotation by two pins which slide within two slots in the actuator body. The travel of this unit is transmitted to the door by two links. The driving gear of the speed reducer is used as a drive shaft to the other ballscrew actuators. A flexible shaft fits into a hex head drive in each end of the gear.

The ball bearing type screw and nut assembly consists of a screw, nut, ball return tube, a clamp attached by two screws and washers, and 68 balls.

EFFECTIVITY

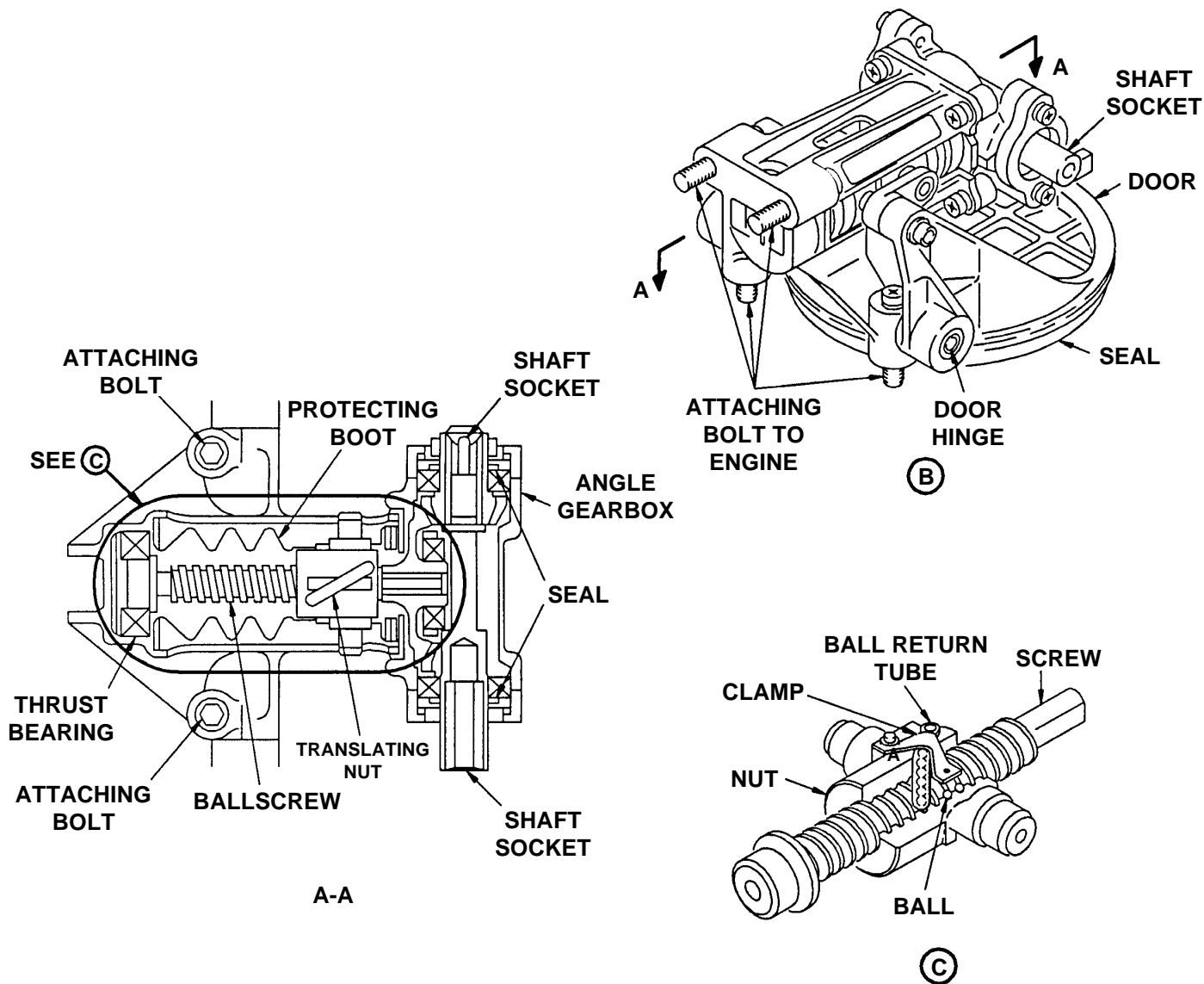
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## VARIABLE BLEED VALVE AND BALLSCREW ACTUATOR

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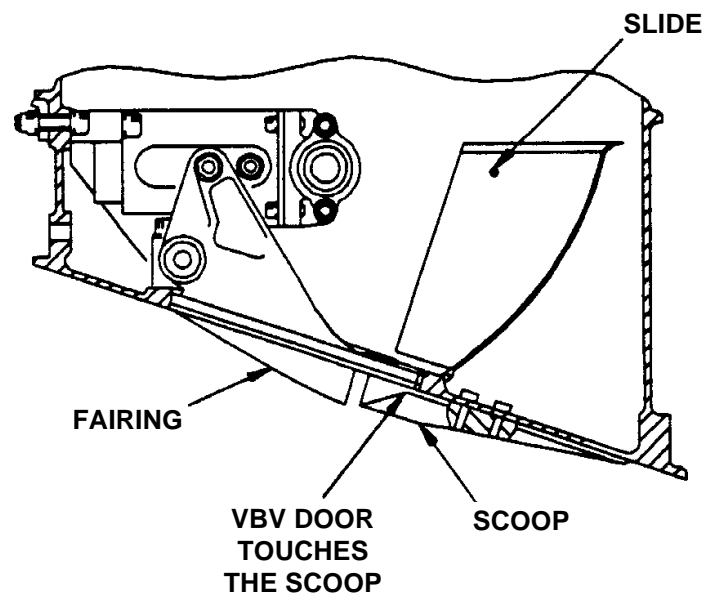
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**BLEED VALVE AND BALLSCREW ACTUATOR****Functional Description**

Introduced in January of 1991, the 11 VBV doors were modified with a series of scoops, slides and fairings. These items were added to direct ingested water, hail and sleet from the core flow path (primary) to the fan stream (secondary).

This VBV modification works in conjunction with an elliptical spinner, cutback splitter fairing and a new VBV schedule to provide an  $N_1$  flight idle speed of 32% versus 45% when operating in hail and rain conditions.



## VARIABLE BLEED VALVE AND MASTER BALLSCREW ACTUATOR

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**VBV MAIN FLEXIBLE SHAFT****Identification (1.A.b)**

The main flexible shaft is an unshielded power core which has a hexagon fitting on one end and a splined end fitting on the other. A spring is attached to the splined end. The spring holds the shaft in position during operation and also permits easy removal of the shaft.

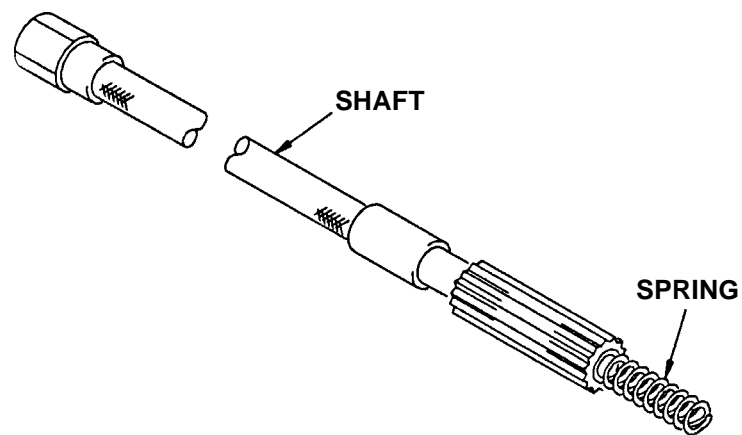
**Purpose (1.B.b)**

The main flexible shaft transfers power from the fuel gear motor through the stop mechanism to the master bleed valve and ballscrew actuator.

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### MAIN FLEXIBLE SHAFT

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## VBV FLEXIBLE SHAFT

### **Identification (1.A.b)**

Each of the 11 shafts is an unshielded power core which has a hexagon fitting on one end and an eight-point fitting on the other end. A spring is attached to the hexagon end. The spring holds the shaft assembly in position during operation and also permits easy removal of the shaft assembly. The ferrules that are installed in the struts of the engine fan frame are designed to support the flexible shaft assemblies during operation.

### **Purpose (1.B.b)**

The flexible shaft transmits through its interconnection, rotational power to each of the 11 bleed valve and ballscrew actuators.

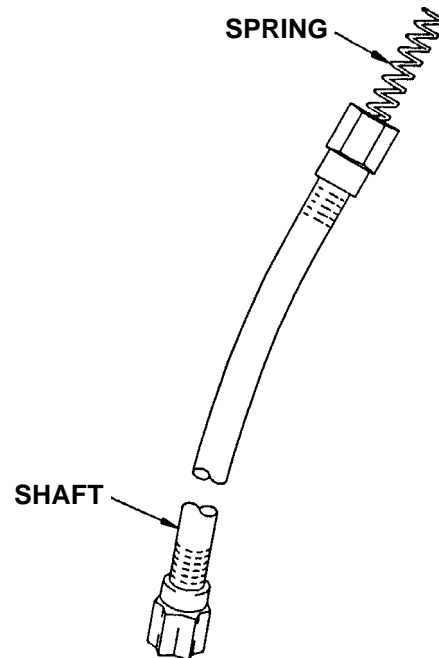
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## FLEXIBLE SHAFT

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## VBV FEEDBACK CABLE

### Identification (1.A.b)

The VBV feedback cable is a flexible cable which connects the MEC VBV feedback system lever to the VBV actuation system at the master valve.

### Purpose (1.B.b)

VBV feedback cable movement transmits the position of the VBV's to the MEC.

### Location (2.A.b)

It's location starts at the connection to the stop mechanism bellcrank at 9 o'clock and is mounted down through the 6 o'clock tube bundle over to the MEC VSV lever arm at about the 8 o'clock position..

### Operation (2.C.b)

As the VBV hydraulic motor and drive system operate, the position signal is compared in the MEC through a comparative linkage system to the position command established in the MEC through linkage with the VSV feedback system. The VBV control valve discontinues operation of the hydraulic motor when the VBV feedback signal nulls the command input.

### Functional Description (3.D.b)

The VBV feedback system differs from the VSV feedback system in that the feedback and command error measurement linkage system has a provision for

repositioning the feedback linkage null position as directed by the VBV reset piston. This provides for actuation of the VBV's by other commands. Two commands to the VBV reset piston may do this: a command by the VBV reset valve when a rapid deceleration change in VSV positioning is sensed by the VBV reset valve, or a command from the reverser signal valve when the reverser is actuated.

Like the VSV feedback, it is important to accurately adjust (rig) the VBV feedback cable to the MEC to assure proper feedback inputs to the MEC. Also, like the VSV feedback system, the VBV feedback cable is maintained in tension during engine operation by a hydraulic load cylinder in the control that is coupled to the VBV feedback linkage. This tension load must be simulated during adjustment rigging of the feedback cable to the MEC.

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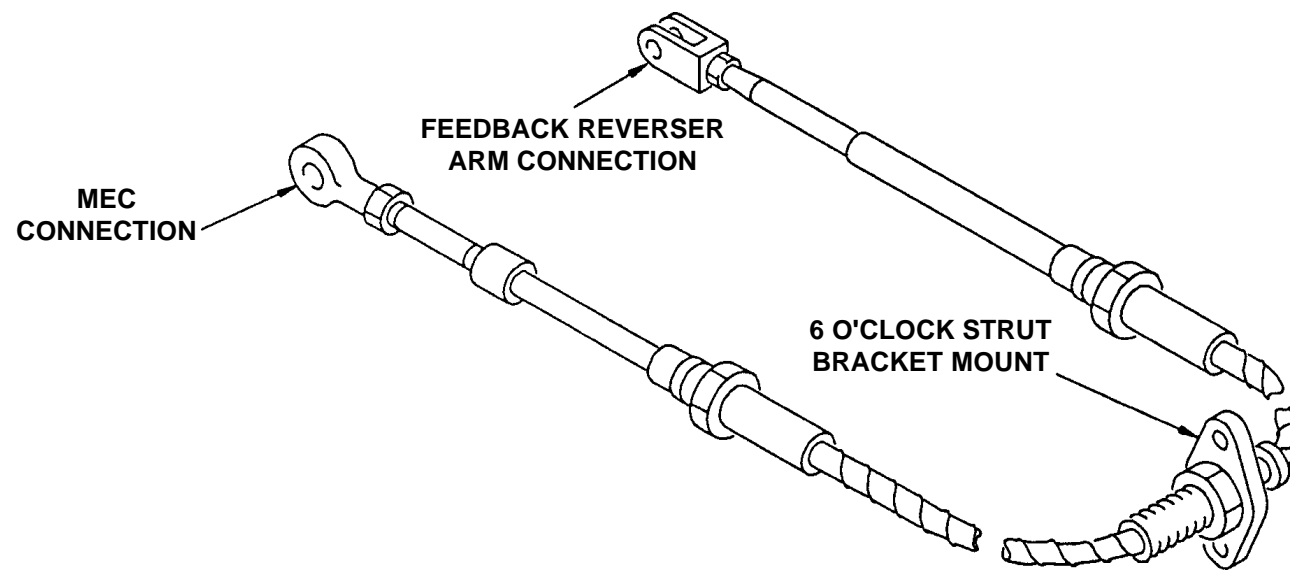
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### VBV FEEDBACK CABLE

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## VBV SYSTEM OPERATION

### Operation (2.C.b)

The fuel gear motor is hydraulically activated by pressurized fuel. The MEC determines the direction and speed of motor rotation. The gear motor drives the rotary shaft which drives the gear reduction stage of the master ballscrew actuator through the stop mechanism. The flexible shafts transmit power from the rotary shaft to the remaining ballscrew actuators.

### Functional Description (3.D.b)

The flexible shafts are supported by ferrules at their midpoints. The ballscrew actuators reduce shaft speed with bevel-cut gears and convert rotary motion to linear output.

The actuator output is from a trunnion mount provided on the translating ball nut. The mount is connected to the bleed valve by a tandem linkage to provide a rotational movement on the bleed valve pivotal axis. The direction of the bleed valve rotation is controlled by fuel gear motor.

The fuel gear motor, actuated by the VBV control valve in the MEC, drives the system to the command (open, closed or modulated) position with the required power. The VBV feedback mechanism relays the bleed valve position to the MEC as the system approaches the

commanded position. The VBV control valve is moved towards the null position (or minimum opening needed to neutralize the bleed valve loads) as the bleed valve approaches the end of its stroke. This reduces motor speed and allows the motor to engage the end-of-stroke stops at low impact force.

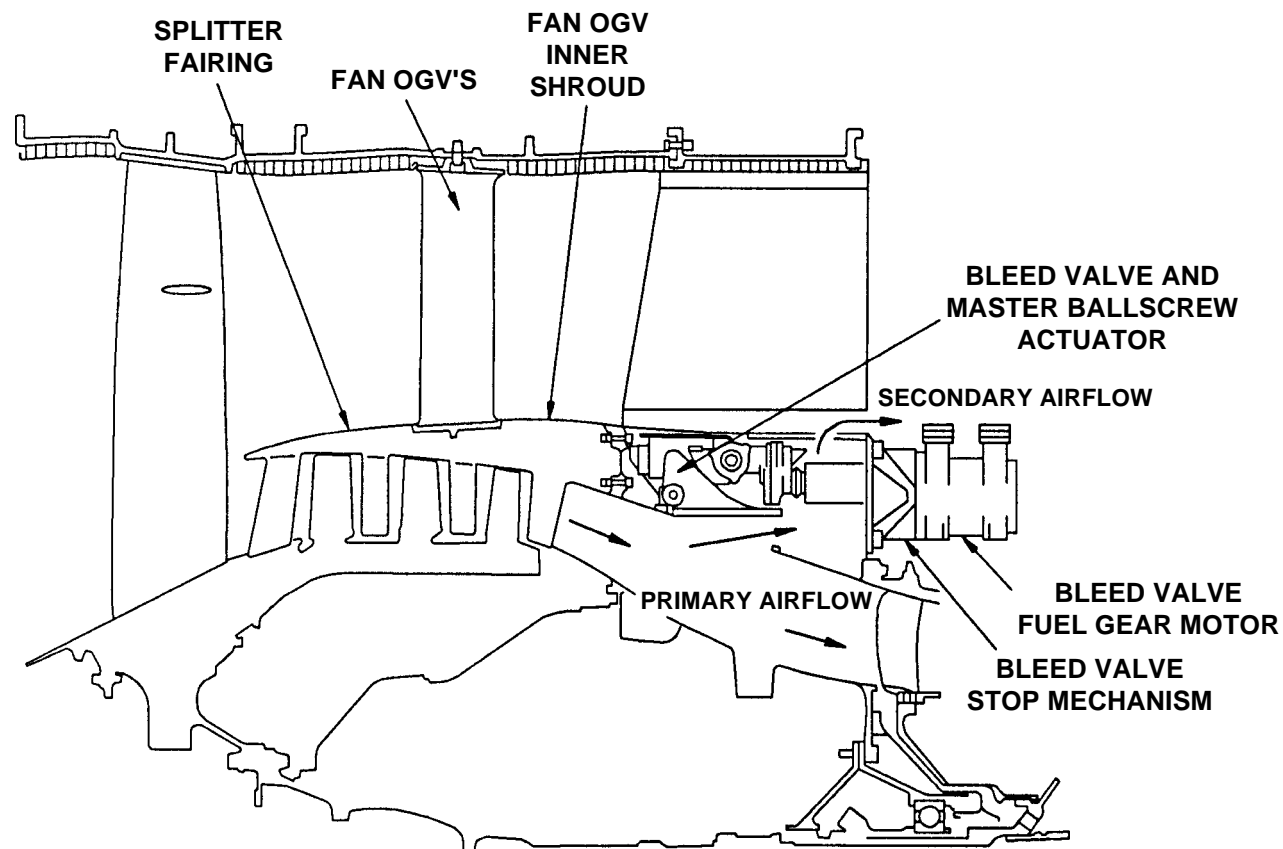
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**VBV SYSTEM AIRFLOW DIAGRAM**

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## VBV SYSTEM OPERATION

### Functional Description

The tracking schedule identifies the position required of the VBV's in percent of angle at a specified corrected core engine speed.

The VBV kicker system is designed to improve CFM56-3 operations in inclement weather (hail and rain) conditions. The purpose of the kicker is to modify the VBV schedule in order to fully open (40°) the VBV doors during transient operation and decel.

Efficient operation requires the bleed valves to be fully closed at or above 12,250 RPM corrected core speed. As the engine decelerates the VBV feedback rod will start to move with the scheduled operation of the VBV master bleed valve door. At the same time fuel pressure within the MEC will pull the feedback cable downward maintaining the free lever against the return lever.

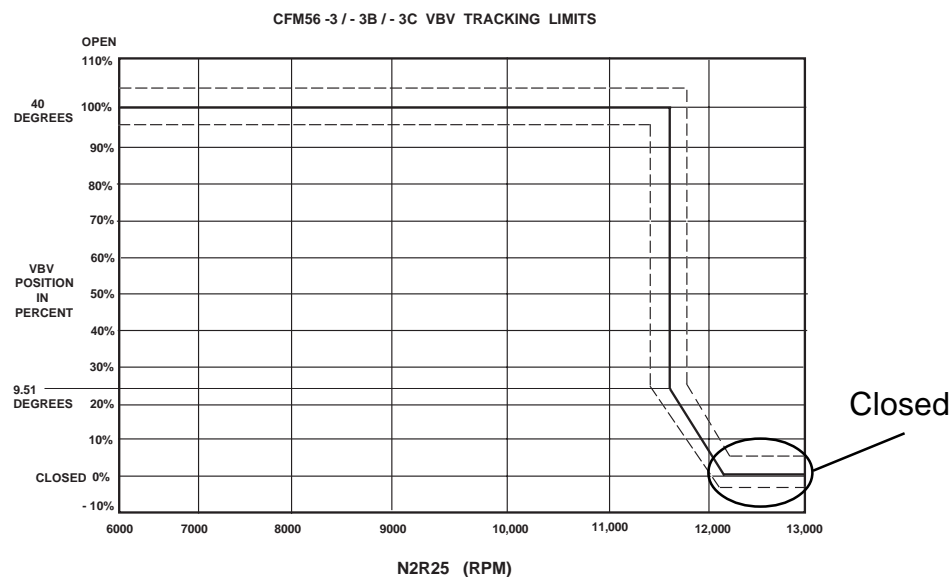
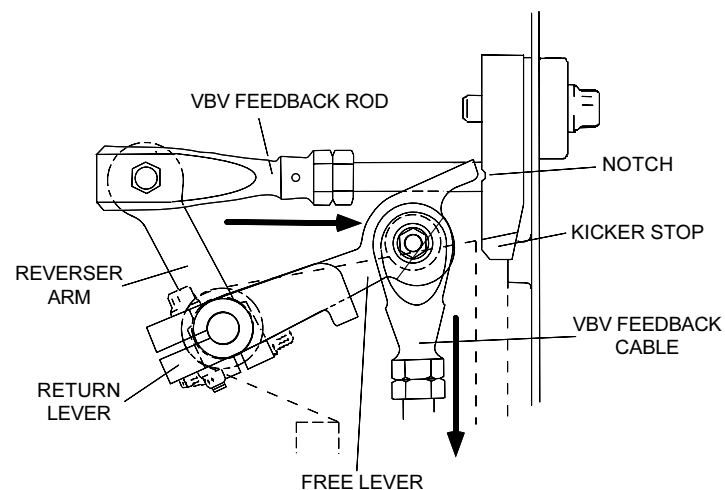
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## VBV TRACKING SCHEDULE

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## VBV SYSTEM OPERATION

### Functional Description

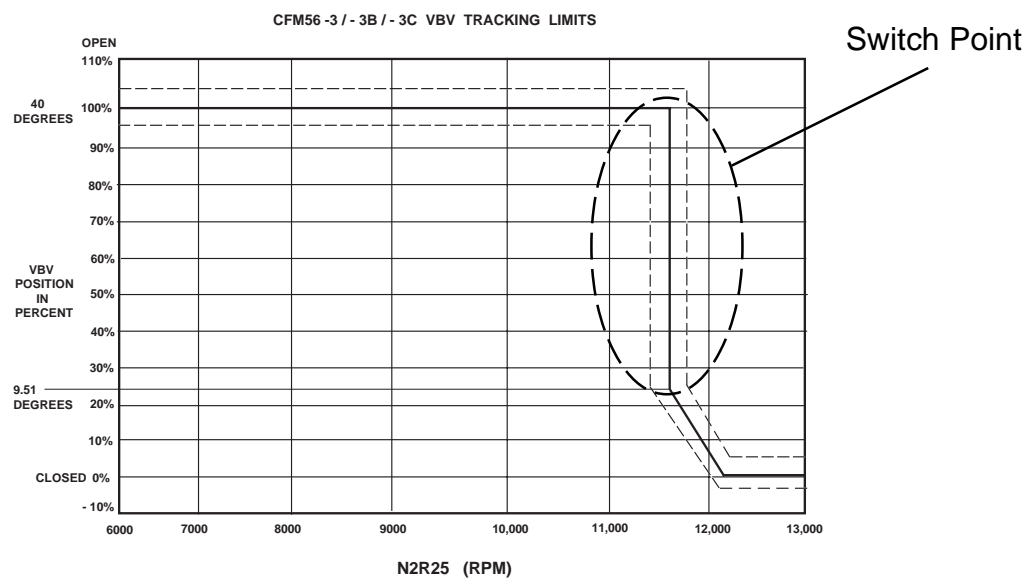
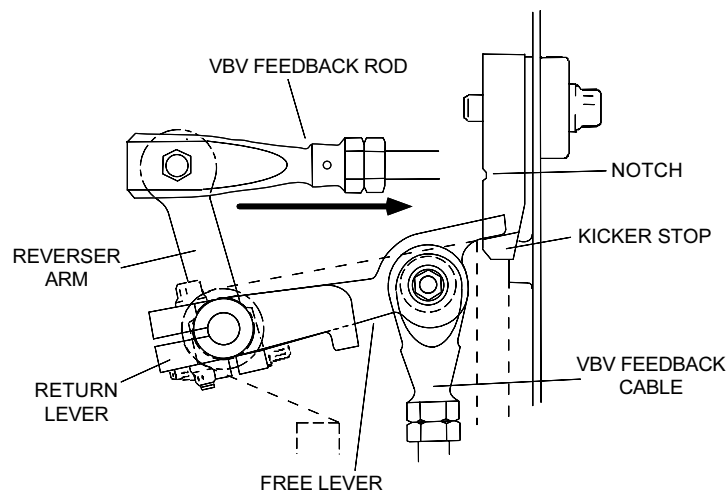
As the engine decelerates the free lever stops movement of the feedback cable at 10° VBV opening by contacting the kicker stop. When the free lever contacts the kicker stop on the fan frame, feedback cable movement is halted. This is known as the deceleration switch point.

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## KICKER DECELERATION SCHEDULE

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## VBV SYSTEM OPERATION

### Functional Description

Based on this false feedback indication the MEC will continue to drive the VBV doors to a 40° full open position.

At the lower speeds more booster air must be bled over into the fan discharge to maintain an optimum flow through the core engine.

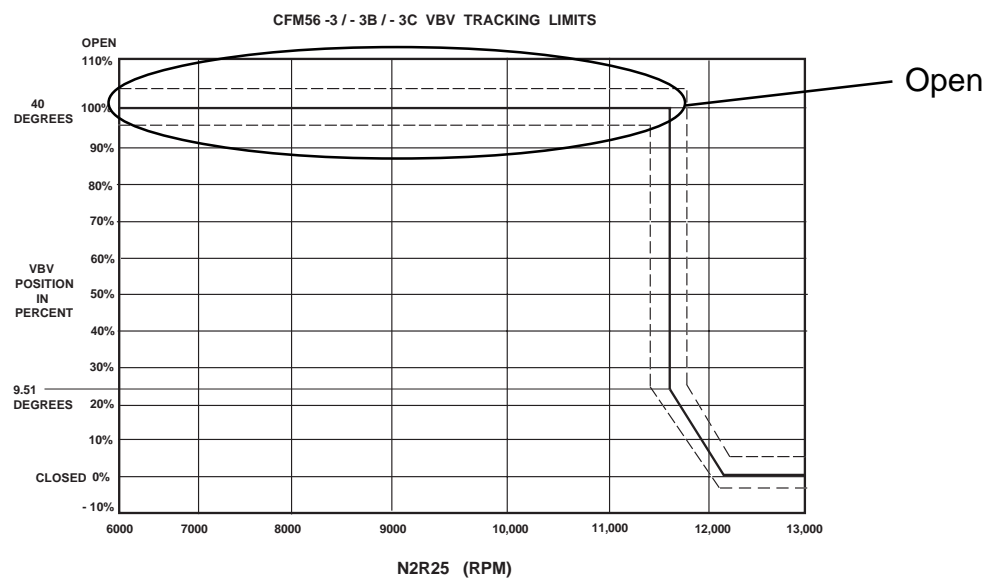
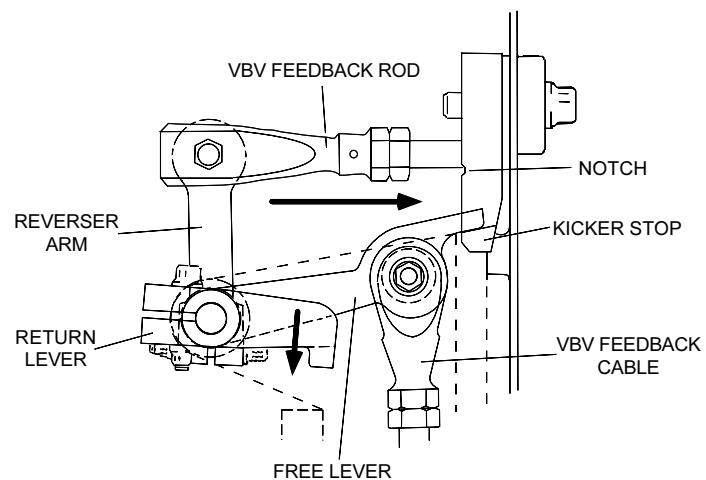
When the engine is accelerated the return lever will contact the free lever at the acceleration switch point and provide feedback to the MEC by the feedback cable.

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## KICKER ACCELERATION SCHEDULE

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**5TH STAGE START BLEED VALVE****Identification (1.A.b)**

The 5th stage start bleed valve consists of a bleed valve, an air diffuser, an optional deflector baffle, and connecting tubing to the start valve.

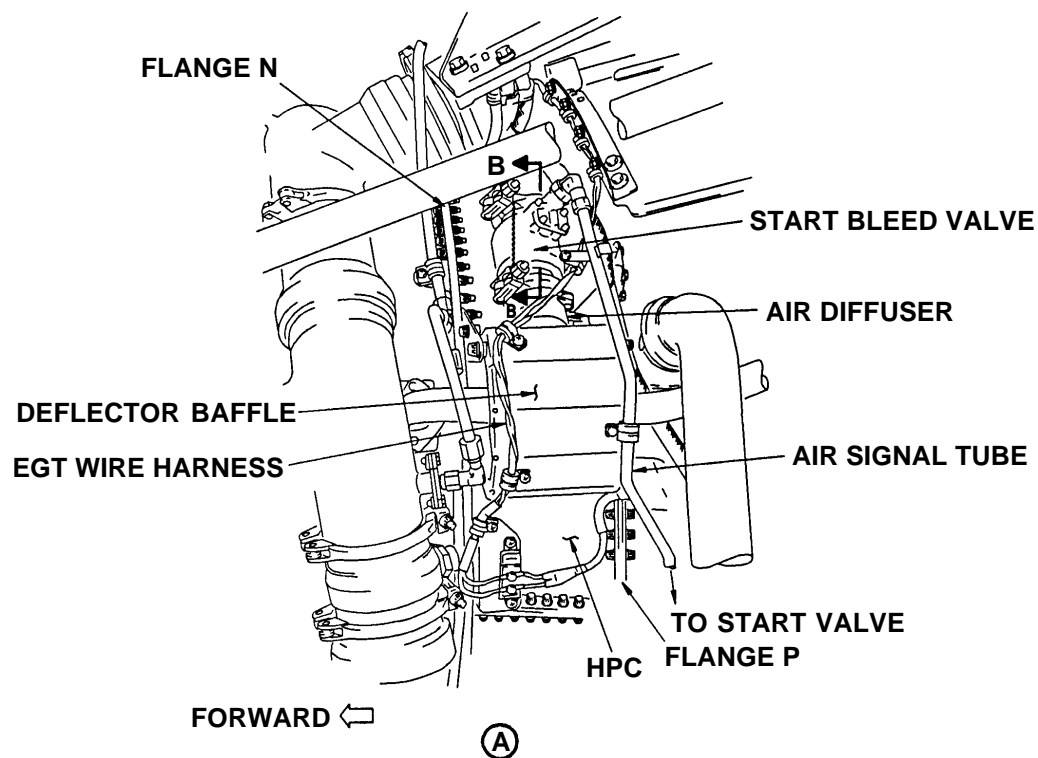
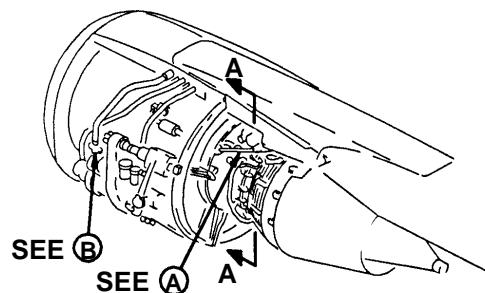
**Purpose (1.B.b)**

The 5th stage start bleed system uses starter air pressure from the start valve to signal the bleed valve to open and unload 4% of the compressor 5th stage pressure. This reduced pressure in the HPC section during start will increase engine stall margin at low starting speeds. The start bleed system has no significant adverse effects on start time and EGT.

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## 5TH STAGE START BLEED SYSTEM COMPONENTS

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## 5TH STAGE START BLEED VALVE

### Location (2.A.b)

The 5th stage start bleed valve is located on the left side of the HPC case at the 11 o'clock position.

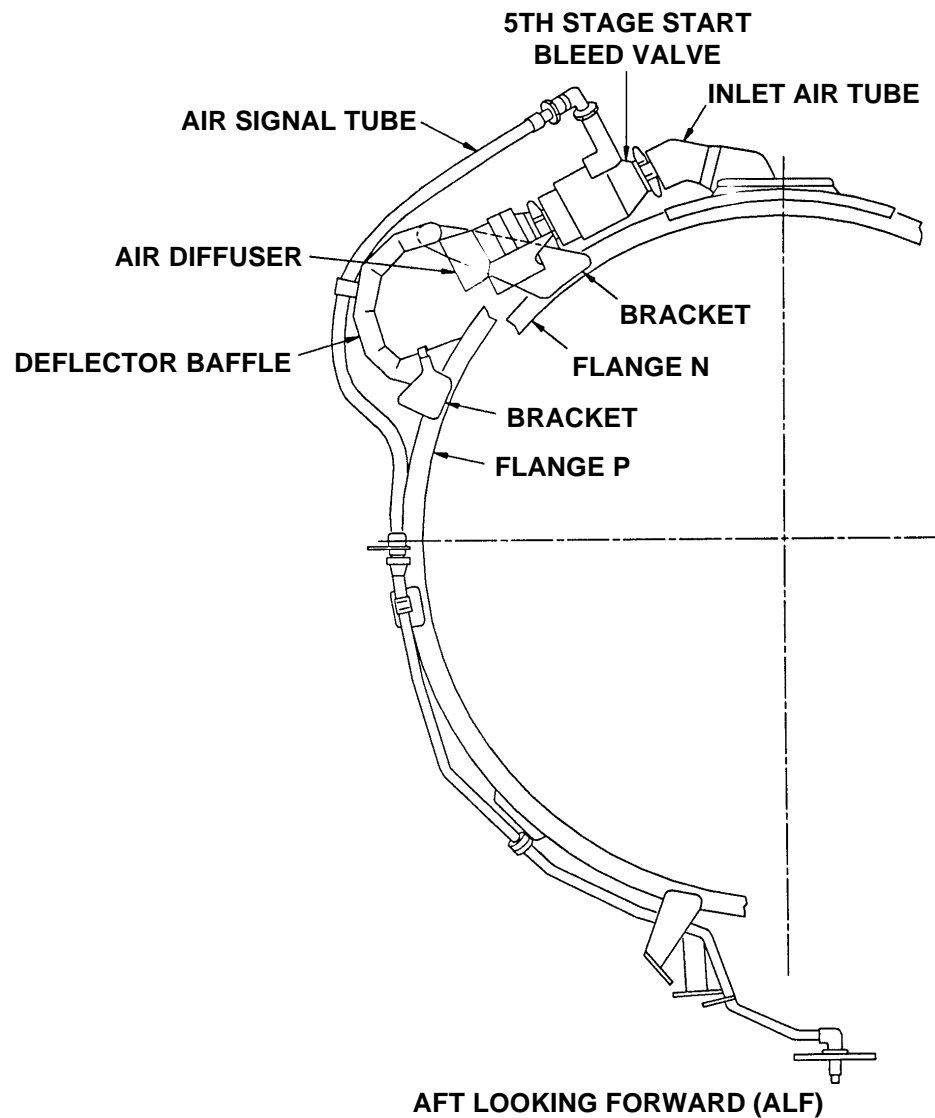
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## 5TH STAGE START BLEED VALVE LOCATION AND INSTALLATION

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## 5TH STAGE START BLEED VALVE

### Operation (2.C.b)

It is a pneumatically operated, normally closed valve which is opened when starter air pressure is applied to the signal port. The air diffuser is attached to the exit port of the bleed valve to reduce the velocity of the exiting bleed air.

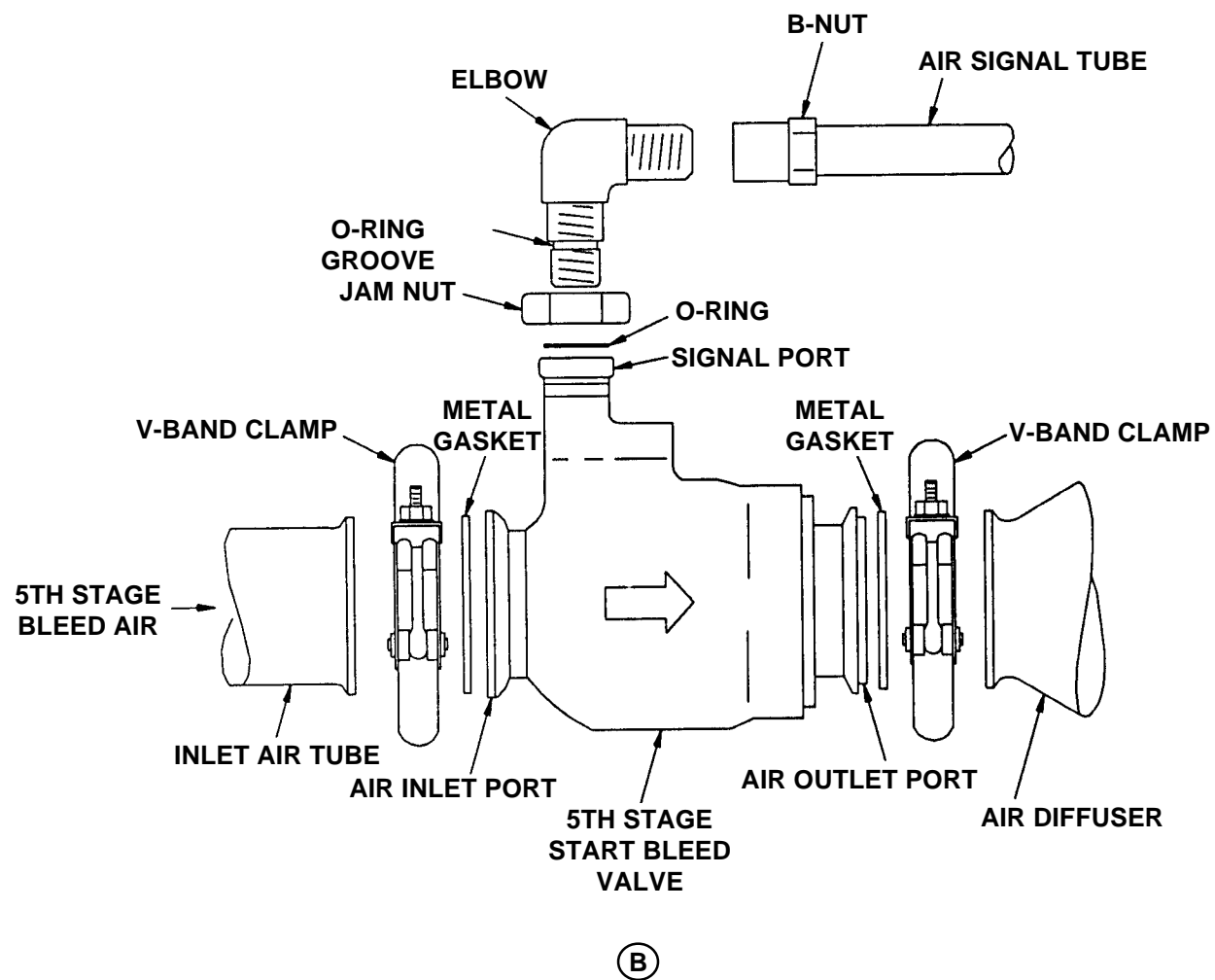
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## 5TH STAGE START BLEED VALVE

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## 5TH STAGE START BLEED VALVE

### Functional Description (3.D.b)

During engine start, air pressure is ducted to the start valve and the starter is engaged (start valve open). After start valve opening, air pressure is applied to a pressure sensing port just downstream of the valve which directs air to the signal port on the start bleed valve, causing it to open. This allows engine core airflow to exit the HPC for improved stability. Bleed air passes through the valve, then the diffuser, and is deflected against an optional baffle where it mixes with engine compartment air. The air discharges overboard through the gap between the aft end of the fan duct cowl and the exhaust sleeve.

When the starter is disengaged, the start valve closes, cutting off the air signal to the bleed valve. Spring pressure aided by a 5th stage pressure boost traveling through a small orifice to the spring side of the piston sleeve closes the bleed valve and holds it shut during normal engine operation. This pressure boost assist will hold the valve shut in the case of a spring (or valve) failure.

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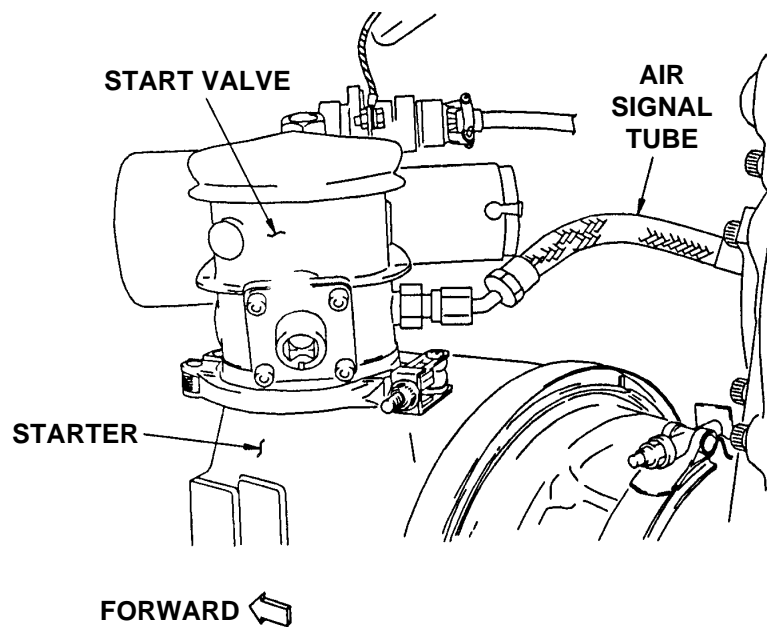
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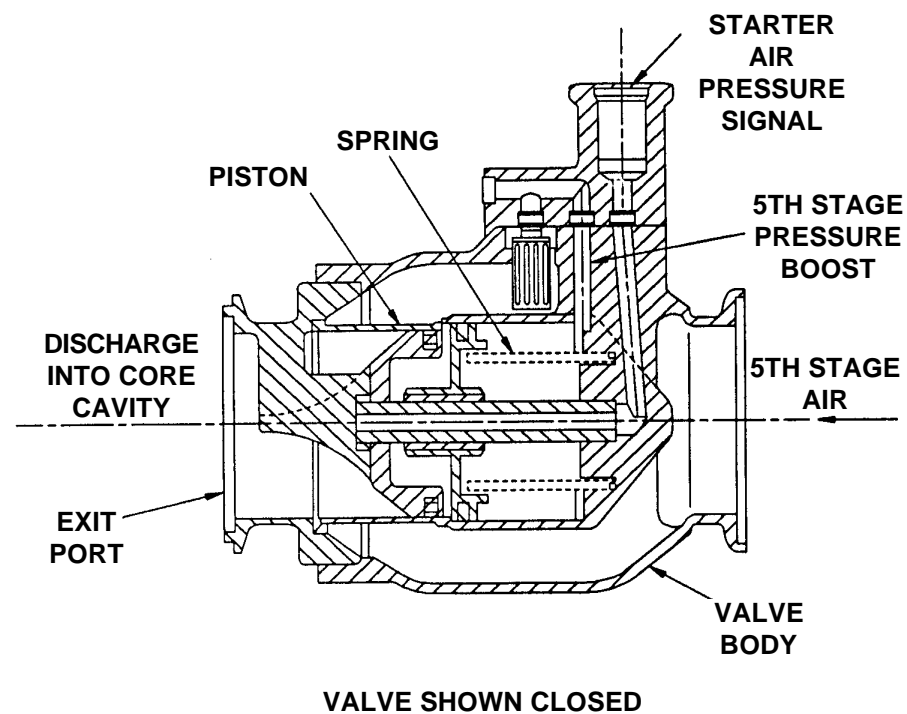
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## 5TH STAGE START BLEED VALVE

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## ENGINE INDICATING SYSTEM

### Objectives:

At the completion of this section a student should be able to:

- ....identify the components comprising the indicating system of the CFM56-3/3B/3C engine (1.A.x).
- ....state the purpose of the indicating system of the CFM56-3/3B/3C engine (1.B.x).
- ....state the purpose of the components comprising the indicating system of the CFM56-3/3B/3C engine (1.B.x).
- ....locate the components comprising the indicating system of the CFM56-3/3B/3C engine (2.A.x).
- ....identify the aircraft interfaces associated with the indicating system of the CFM56-3/3B/3C engine (2.B.x).
- ....describe the component operation of the indicating system of the CFM56-3/3B/3C engine (2.C.x).
- ....describe the particular component functions of the indicating system of the CFM56-3/3B/3C engine (3.D.x).

**ENGINE INDICATING SYSTEM****Identification (1.A.a)**

It consists of the engine tachometer system, which measures rotational speed of the low speed rotor ( $N_1$ ) and high speed rotor ( $N_2$ ), the engine EGT indicating system and Airborne Vibration Monitoring (AVM) system.

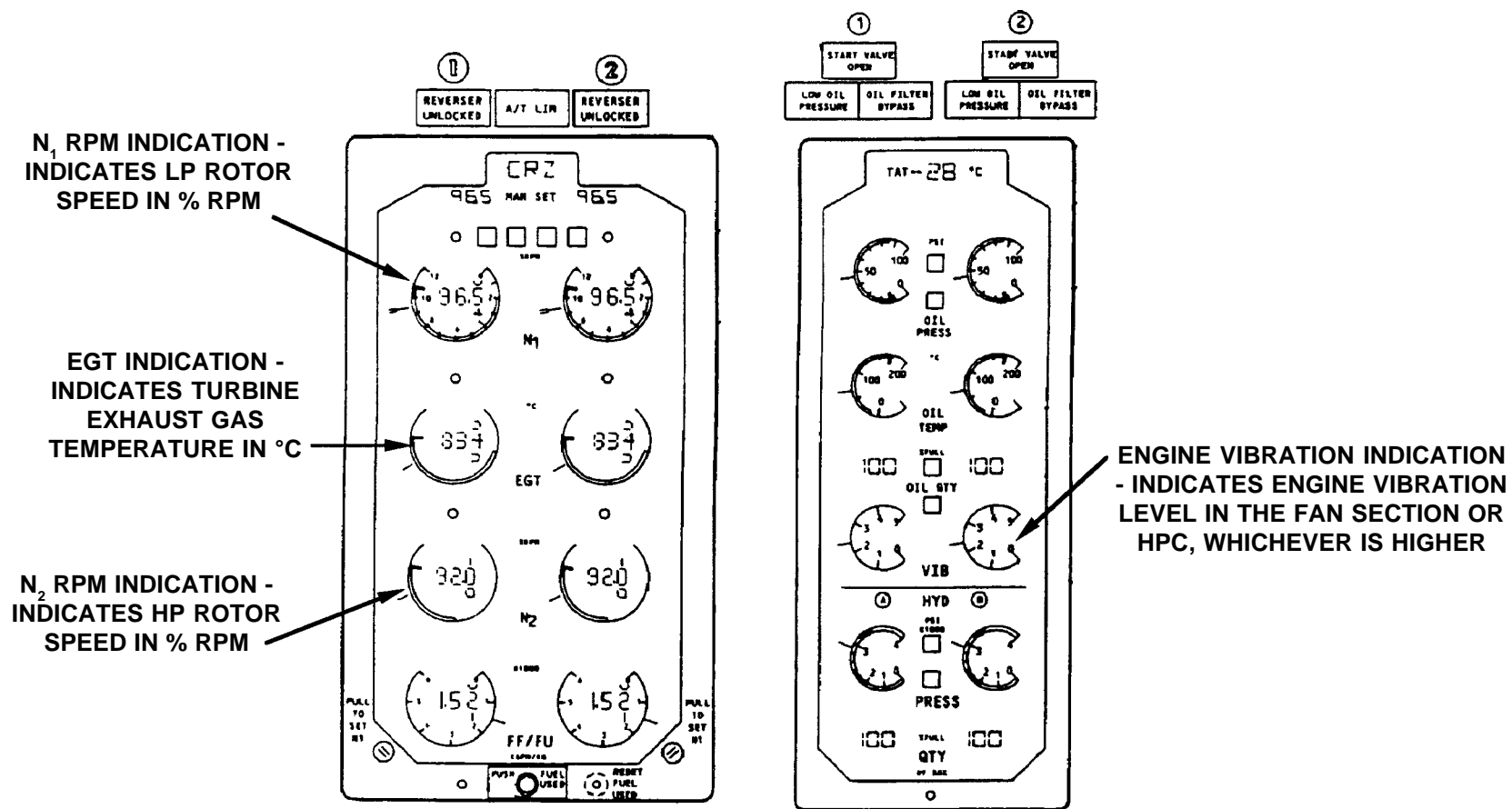
**Purpose (1.B.a)**

The indicating system (77-00-00) is to verify proper and safe engine operation throughout the flight envelope.

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## ENGINE INDICATING SYSTEM

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## N<sub>1</sub> SPEED SENSOR

### Identification (1.A.b)

The sensor consists of a rigid metal tube with a mounting flange and two-connector receptacle. Within the tube is an elastomer damper and a magnetic head sensor with two protruding pole pieces.

### Purpose (1.B.b)

The N<sub>1</sub> speed sensor is a pulse counter that senses N<sub>1</sub> rotor speed and provides signals to the N<sub>1</sub> tachometer indicator and PMC.

### Location (2.A.b)

The N<sub>1</sub> speed sensor is mounted in strut No. 5 of the fan frame at the 4 o'clock position and is secured to the fan frame with two bolts. When the N<sub>1</sub> speed sensor is installed on the engine, only the two-connector receptacle and the body are visible.

### Operation (2.C.b)

Actual N<sub>1</sub> fan speed is measured by speed sensor elements which provide an AC voltage whose frequency is proportional to the fan speed.

### Functional Description (3.D.b)

The sensor incorporates dual sensing elements with one element providing N<sub>1</sub> signal for the PMC and the other element providing signal to the N<sub>1</sub> tachometer indicator. A magnetic ring mounted on the fan shaft is provided

with teeth. The passage of each tooth generates an alternating voltage in the sensor element proportional to actual N<sub>1</sub> speed.

Note: The sensor ring has one tooth thicker than the 29 others to generate a signal of greater amplitude used as phase reference for trim balance.

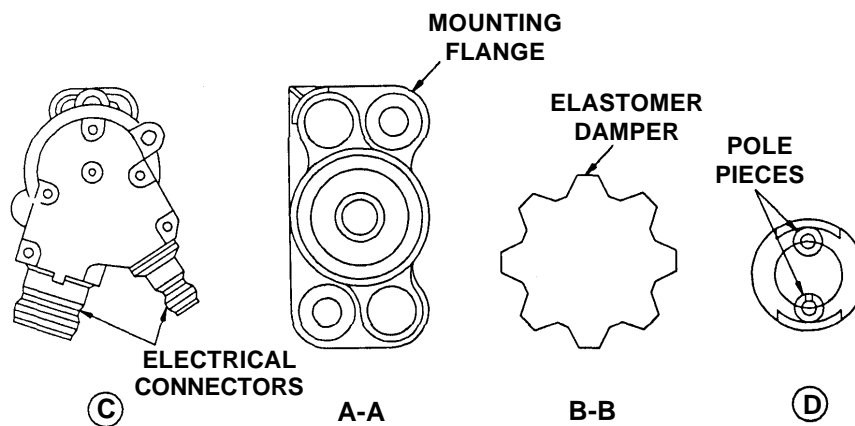
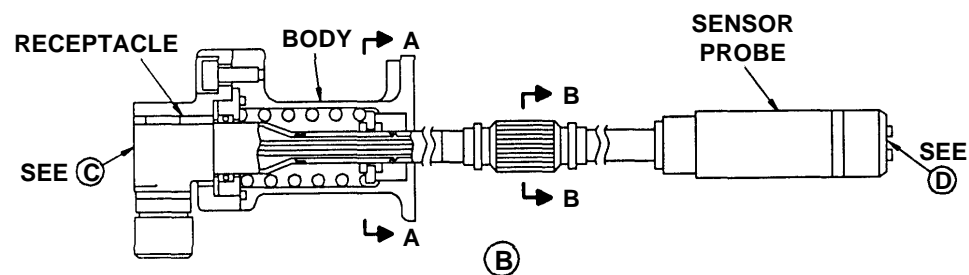
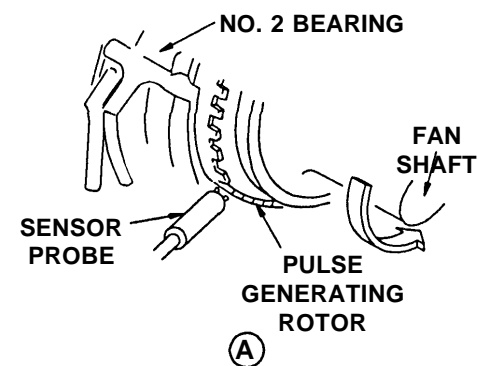
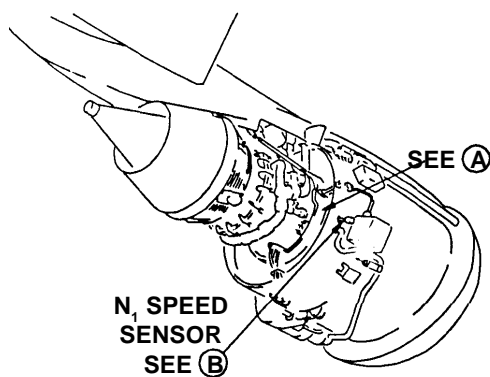
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## N<sub>1</sub> SPEED SENSOR

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## EGT INDICATING SYSTEM

### Identification (1.A.b)

EGT is measured by nine thermocouple probes. The signals transmitted by these probes are routed through rigid thermocouple harnesses and one of three extension leads which make up the EGT thermocouple harness assembly.

There are two identical and interchangeable left-hand thermocouple harness segments which consist of:

- A flange-mounted secondary junction box with a receptacle connector for connection with the main junction box extension lead.
- Three rigid metal tubes, each of them provided with a flange-mounted chromel-alumel thermocouple probe, that are permanently mounted to the secondary junction box.

The right-hand thermocouple harness segment consists of:

- A flange-mounted secondary junction box with a receptacle connector for connection with right-hand harness segment extension lead.
- Three rigid metal tubes, each of them provided with a flange-mounted chromel-alumel thermocouple probe, that are permanently mounted to the secondary junction box.

The main junction box and leads assembly consists of:

- A main junction box with two receptacle connectors for connecting with the right-hand harness segment extension lead and the forward extension lead.
- Two main junction box extension leads which are rigid metal tubes, each permanently affixed to the main junction box on one end with a mobile connector on the other end for connection to the left-hand secondary junction boxes.

The right-hand harness segment extension lead is a rigid metal tube fitted with a mobile connector at each end. One for connection with the right-hand secondary junction box and the other for connection with the main junction box.

The forward extension lead is a rigid metal tube with a mobile connector at one end for connection with the main junction box and either a terminal block or a receptacle connector on the other end for airplane interface. The lead provides ease of access for engine removal and EGT system testing.

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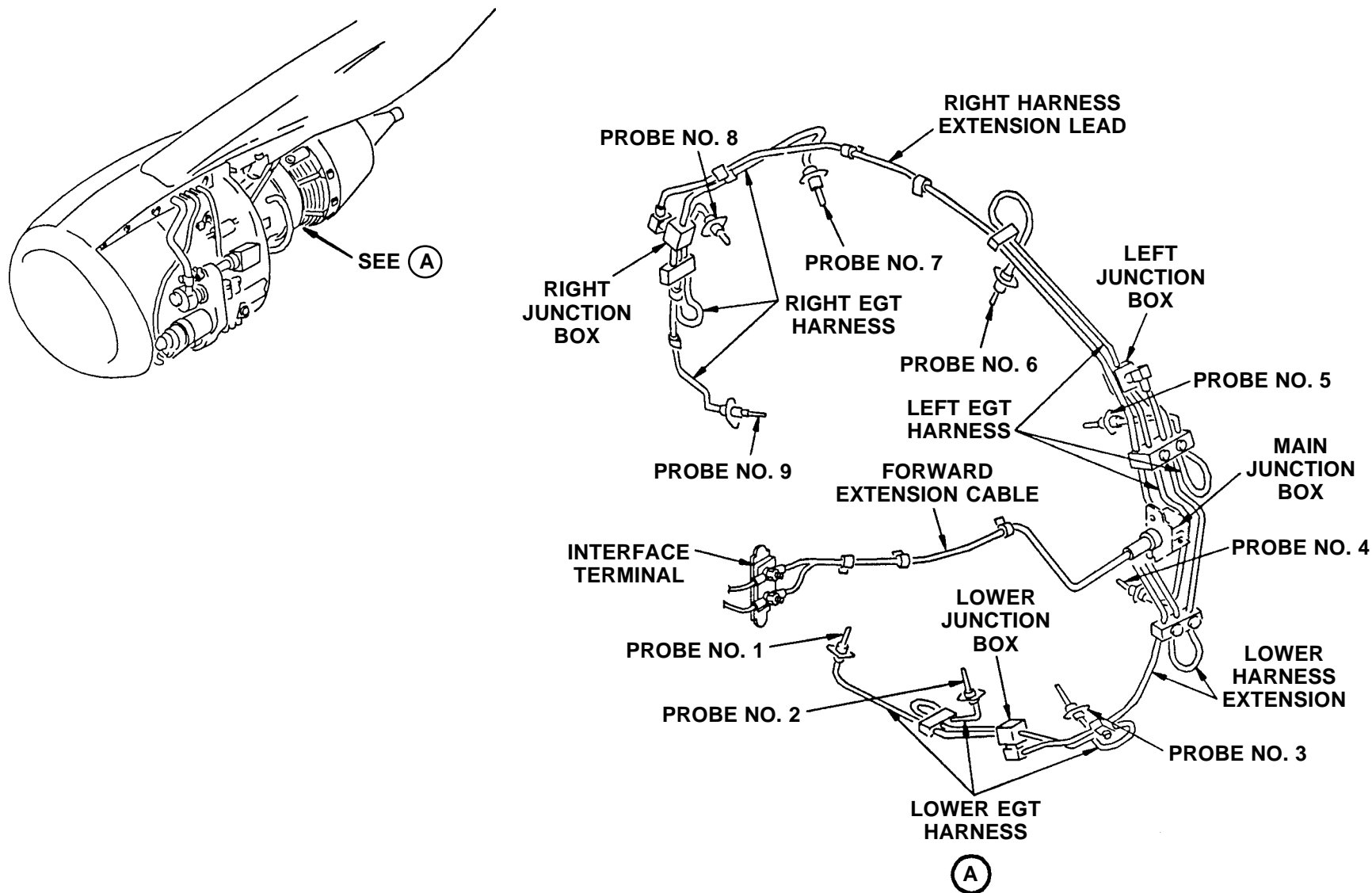
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## EGT THERMOCOUPLE HARNESS AND NINE PROBES

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**EGT INDICATING SYSTEM****Purpose (1.B.b)**

The Exhaust Gas Temperature (EGT) indicating system provides a visual indication in the flight compartment of an averaged exhaust gas temperature as it passes through the LPT of each engine.

**Location (2.A.b)**

The thermocouple probes are installed in the stage 2 LPTN assembly.

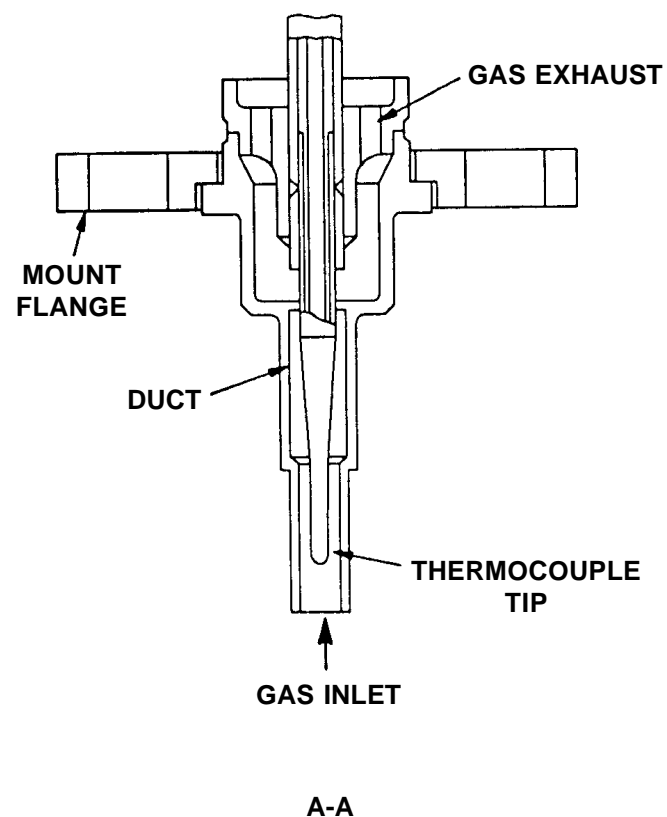
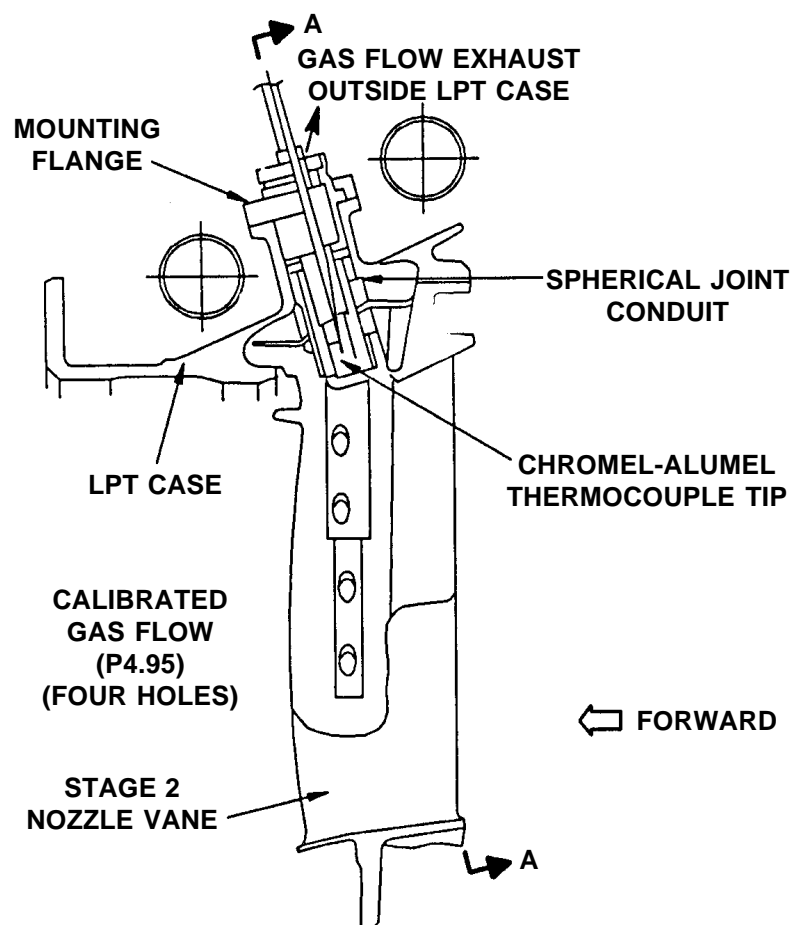
**Operation (2.C.b)**

The thermocouple probes create a voltage that is proportional to the temperature around the chromel-alumel hot-junction. Parallel chromel-alumel leads connect the probes to the junction boxes. The junction boxes transfer an average of the voltages for delivery to the flight deck indicator.

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## EGT THERMOCOUPLE

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## AIRCRAFT VIBRATION SENSING SYSTEM

### Identification (1.A.b)

The system consists of two accelerometers (vibration sensors), a vibration indicator for each engine, and a signal conditioner.

### Purpose (1.B.b)

Abnormal engine vibration, sudden or progressive, is a positive indication of an engine malfunction. Abnormal vibration can be caused by compressor or turbine blade damage, rotor imbalances, or other problems. Early warning of engine malfunction permits corrective action before extensive damage results.

The aircraft vibration sensing system continuously shows engine vibration levels.

### Operation (2.C.b)

With engine operating, the engine accelerometers generate signals proportional to engine motion in a radial direction. These signals are received by the signal conditioner, where they are amplified to signal levels suitable for flight deck indicator operation. The strongest signal is then sent to the flight deck vibration indicator for each engine.

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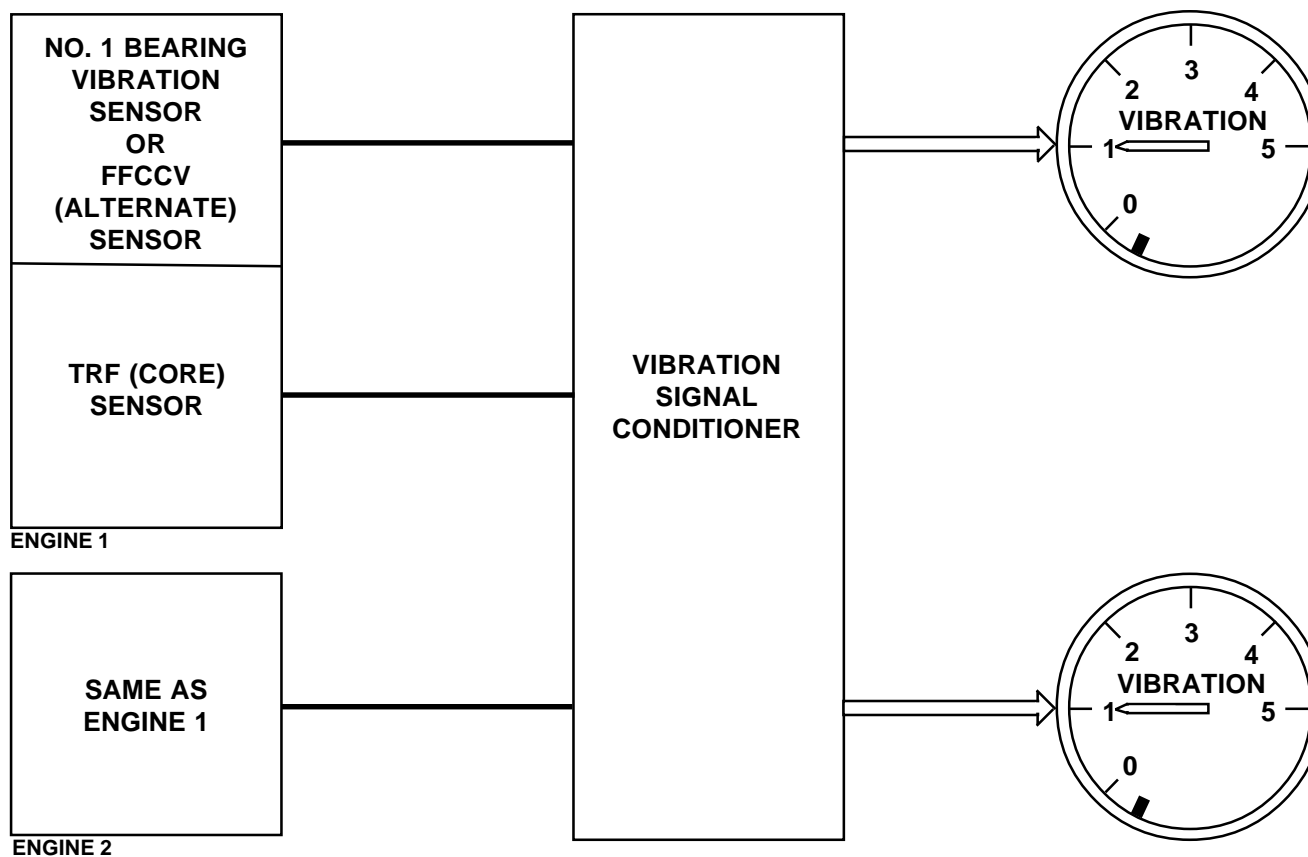
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## AIRCRAFT VIBRATION SENSING SYSTEM

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## NO. 1 BEARING VIBRATION SENSOR

### Identification (1.A.b)

The No. 1 bearing (NOB) vibration (fan) sensor has a charge sensitivity of 100 pc/g.

### Purpose (1.B.b)

This sensor senses both low (no. 1 bearing) and high (no. 3 bearing) speed rotor vibration levels.

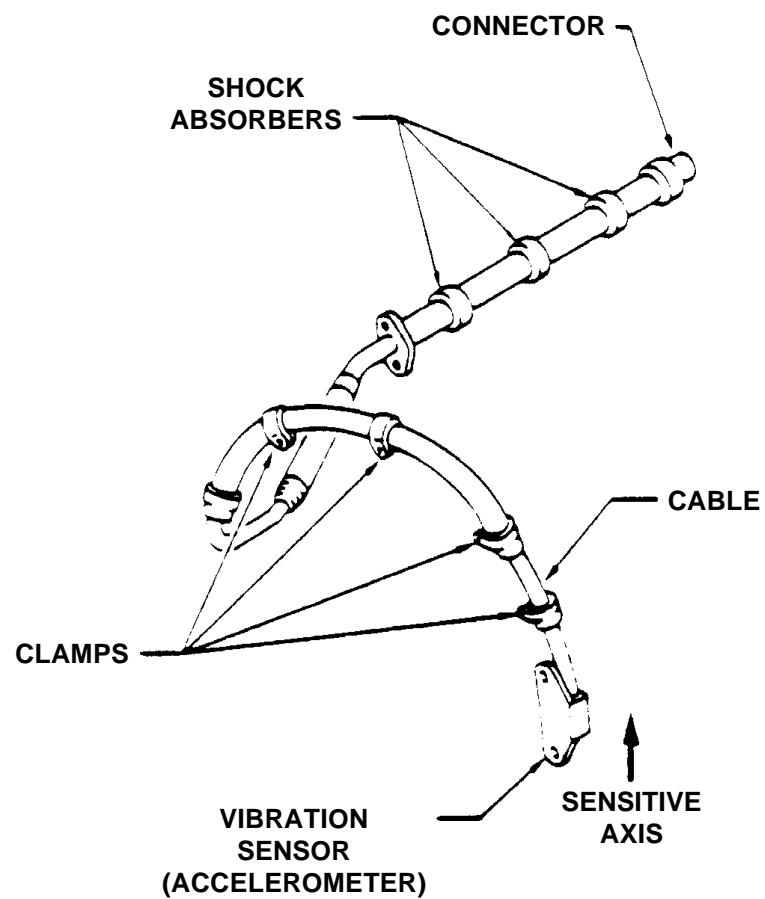
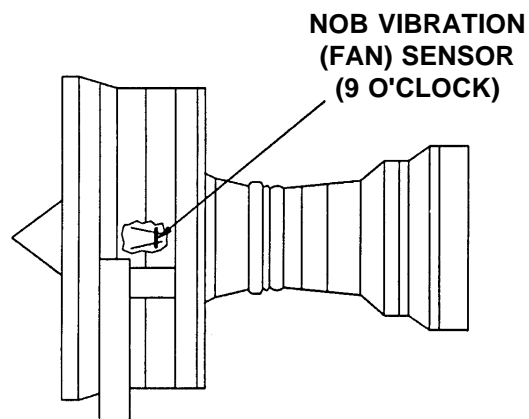
### Location (2.A.b)

The No. 1 bearing (NOB) vibration (fan) sensor is mounted on the No. 1 bearing housing at the 9 o'clock position. The lead connector is on the fan frame midbox structure aft frame at the 3 o'clock position.

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## NO. 1 BEARING VIBRATION SENSOR

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**FFCCV SENSOR (ALTERANATE SENSOR)****Identification (1.A.b)**

The FFCCV or Fan Frame Compressor Case Vertical sensor has a charge sensitivity of 100 pc/g.

**Purpose (1.B.b)**

This sensor is an alternate to the No.1 bearing sensor and senses both low (no. 1 bearing) and high (no. 3 bearing) speed rotor vibration levels.

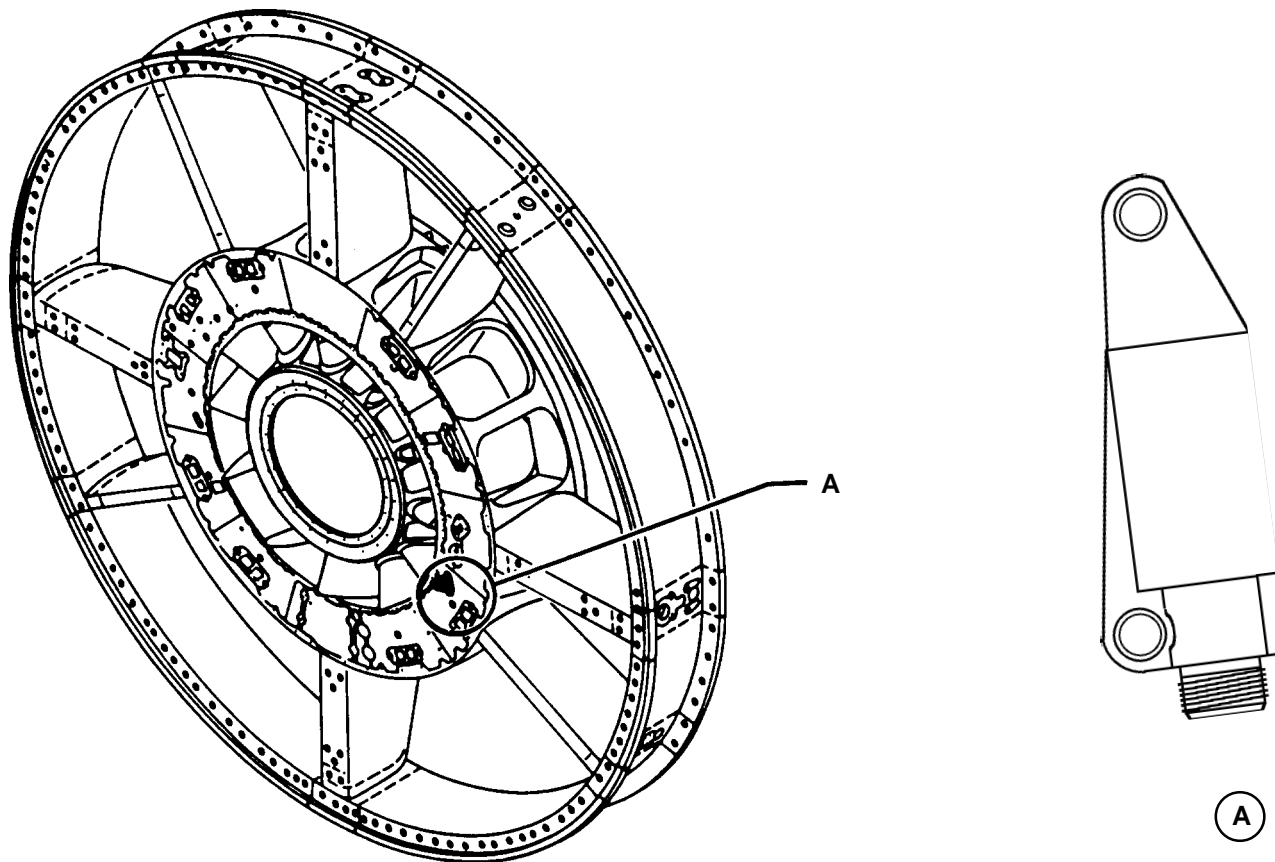
**Location (2.A.b)**

The FFCCV or Fan Frame Compressor Case Vertical sensor is mounted just below the No. 1 bearing sensor lead connection on the fan frame midbox structure at the 3 o'clock position.

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## FAN FRAME COMPRESSOR CASE VERTICAL (ALTERNATE) SENSOR

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**CORE VIBRATION SENSOR****Identification (1.A.b)**

The core vibration sensor has a charge sensitivity of 50 pc/g. Older CFM56-3 engine systems may have a core vibration sensor with a charge sensitivity of 20 pc/g.

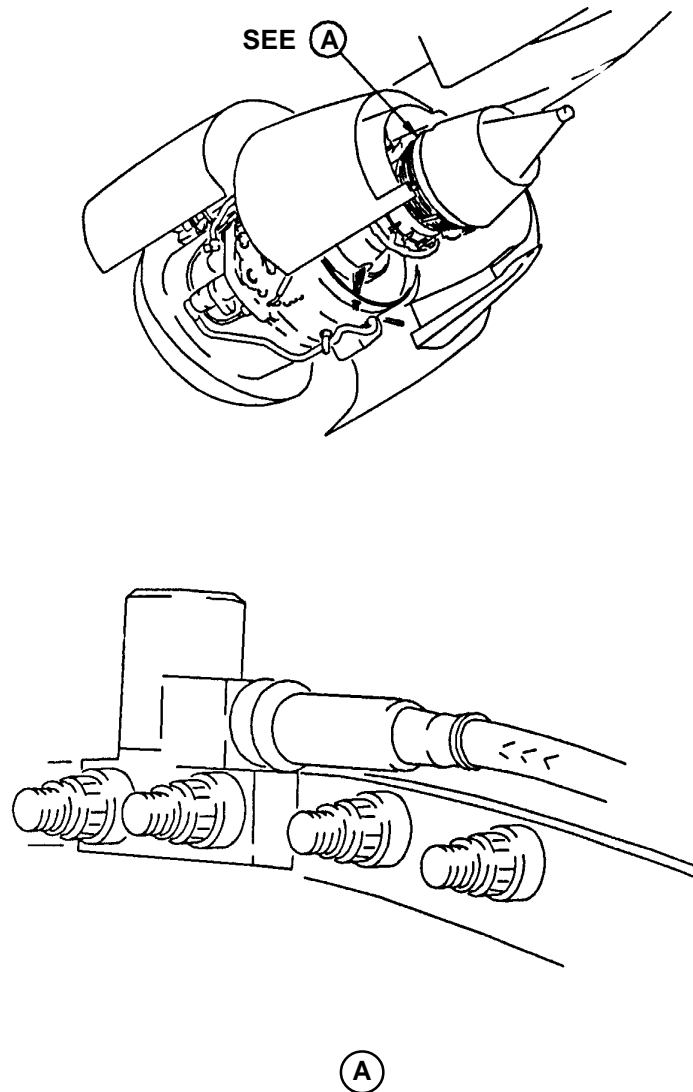
Check appropriate part numbers to verify sensitivity.

**Purpose (1.B.b)**

This sensor senses both low (no. 5 bearing) and high (no. 4 bearing) speed rotor vibration levels.

**Location (2.A.b)**

The core vibration sensor is mounted on the forward flange of the turbine frame at about the 12 o'clock position. The lead connector is mounted with a bracket to the forward high pressure compressor case flange "N" at the 5 o'clock position.



# CORE VIBRATION SENSOR

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## OIL SYSTEM

### Objectives:

At the completion of this section a student should be able to:

- ....identify the components comprising the oil system of the CFM56-3/3B/3C engine (1.A.x).
- ....state the purpose of the oil system of the CFM56-3/3B/3C engine (1.B.x).
- ....state the purpose of the components comprising the oil system of the CFM56-3/3B/3C engine (1.B.x).
- ....describe the flow sequence of the oil system for the CFM56-3/3B/3C engine (1.D.x).
- ....locate the components comprising the oil system of the CFM56-3/3B/3C engine (2.A.x).
- ....identify the aircraft interfaces associated with the oil system of the CFM56-3/3B/3C engine (2.B.x).
- ....describe the component operation of the oil system of the CFM56-3/3B/3C engine (2.C.x).
- ....describe routine servicing of the oil system of the CFM56-3/3B/3C engine (2.D.x).
- ....describe the particular component functions of the oil system of the CFM56-3/3B/3C engine (3.D.x).

## INTRODUCTION

### Purpose (1.B.b)

The engine oil system is a self-contained, center-vented, recirculating type system. Each engine has an independent oil system comprised of oil storage, distribution, and indicating to provide lubrication and cooling for the engine main bearings, radial drive shaft bearings, and gears and bearings in the TGB and AGB.

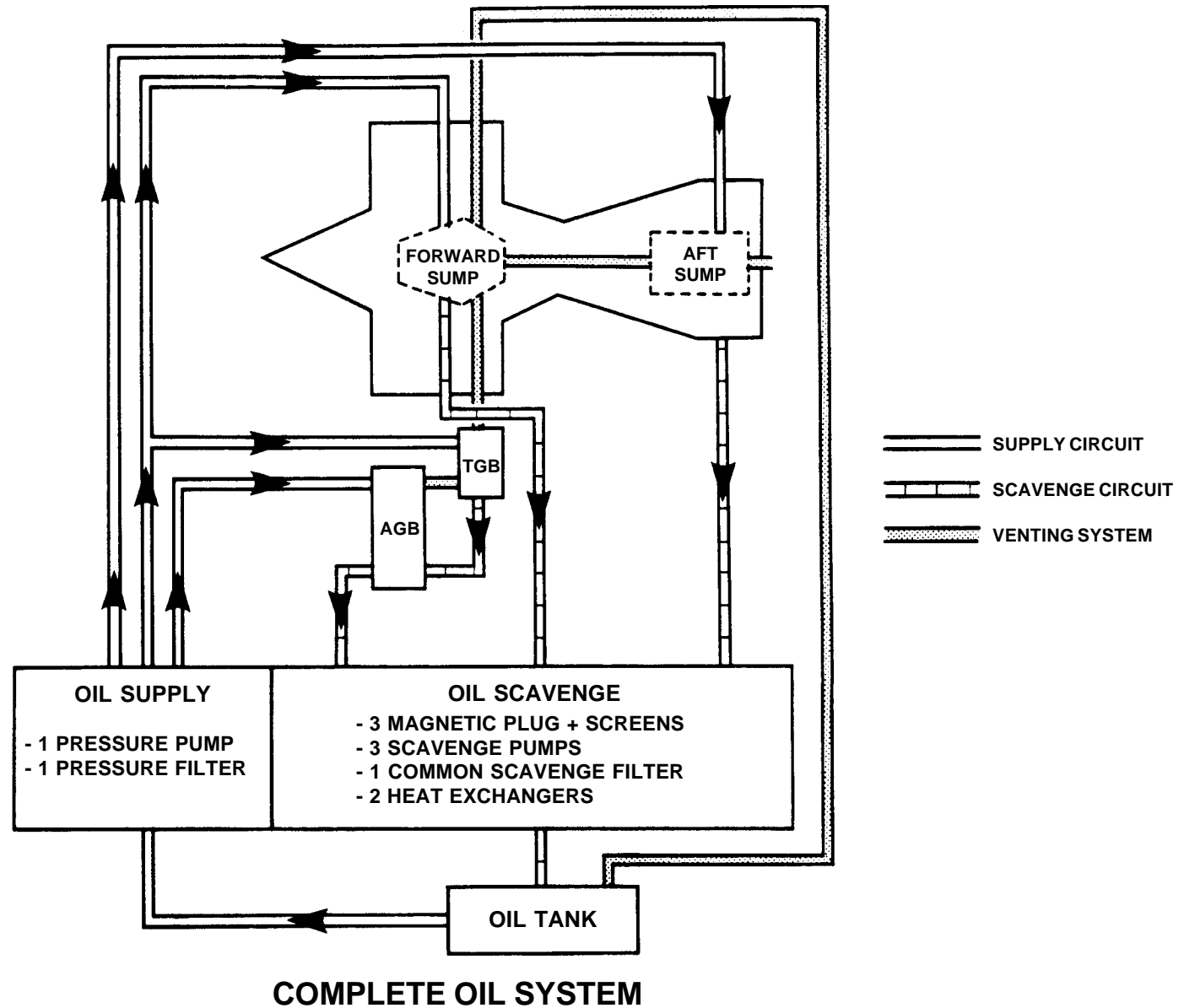
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## INTRODUCTION

### Flow Sequence (1.D.b)

The oil tank provides storage of oil for continuous distribution by the supply system. Oil flows from the tank to the supply pump in the lubrication unit on the AGB.

The four positive displacement oil pumps are on a single shaft driven by the AGB. The supply pump incorporates a pressure relief valve that diverts the oil flow to a scavenge pump in the event of abnormal operating conditions. The pressure relief valve opens when the pressure downstream of the supply pump exceeds 305 psi (2,100 kPa).

During normal operating conditions, the oil flows through the oil supply filter prior to distribution. When the supply filter becomes clogged, the flow will divert through the bypass valve. The bypass valve starts to open when the pressure drop reaches 17.4-20.3 psi (120-140 kPa) across the oil supply filter.

The clogging indicator pops up before a filter bypass condition. When the pressure drop across the supply filter reaches 11.6-14.5 psi (80-100 kPa), the magnets are forced apart - the indicator pops up, becoming visible in the glass inspection bowl. A bimetal spring prevents actuation at low operating temperatures.

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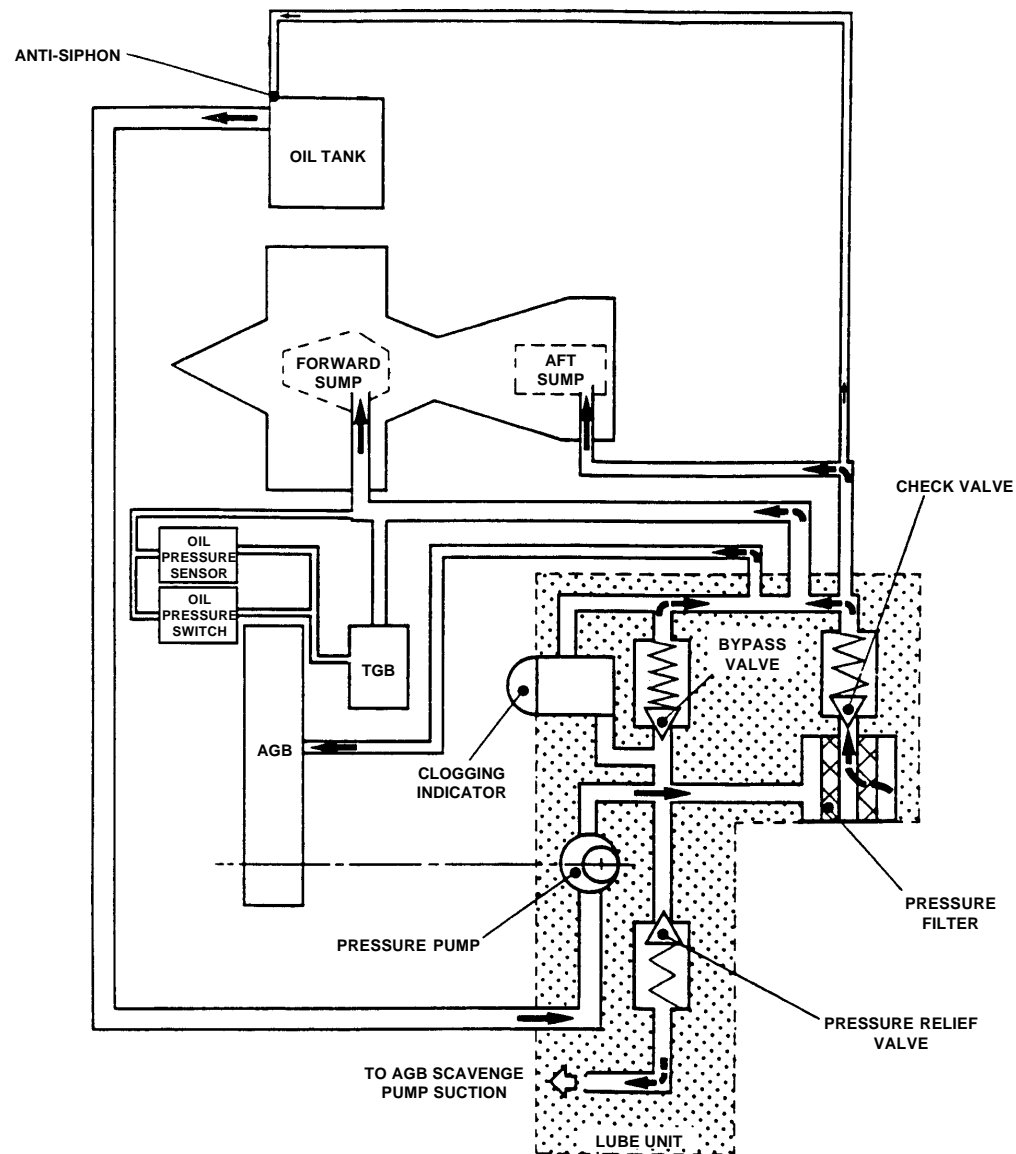
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**OIL SUPPLY SYSTEM SCHEMATIC**

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## INTRODUCTION

### Flow Sequence

After distribution, oil is returned to the lubrication unit from three sumps. The forward sump services the No. 1, No. 2 and No. 3 main bearings. The aft sump services the No. 4 and No. 5 main bearings. The gearbox sump for the AGB also collects oil through an external tube from the TGB.

The lubrication unit contains a scavenge pump for each sump. The oil is drawn through one of three Magnetic Chip Detectors (MCD's). Oil upon leaving the MCD's returns through the common scavenge filter assembly. When the filter becomes clogged, the flow will divert through the bypass valve. Before a filter bypass condition occurs, a flight deck indication of scavenge filter clogging will light at 25-27 psi (172.2-186 kPa). When the pressure drop across the scavenge filter reaches 28-34 psi (193-234 kPa), the filter clogging indicator pops up becoming visible in the glass bowl. A bimetal spring prevents clogging indicator actuation at low operating temperatures. The bypass valve starts to open when the pressure drop reaches 36.3-39.2 psi (250-270 kPa) across the scavenge filter. Before returning to the engine oil tank, the oil is cooled in the main oil/fuel heat exchanger. Fuel enters the cylindrical core through the fuel inlet in the housing. It flows the length of the core through half the core tubes. The fuel flows around a baffle in the core access cover and

returns through the remaining core tubes.

Oil passes through the servo fuel heater and enters the main oil/fuel heat exchanger perpendicular to the fuel flow. The oil circulates around the fuel tubes in the core, transferring heat to the fuel by convection and conduction. The cooled oil exists back through the servo fuel heater and is returned to the oil tank.

A drain is provided at the forward and aft bearing compartment for possible oil leaking past the stationary air/oil seal. The forward seal drain exits through the 8 o'clock fan frame strut. The aft seal drain exits through the 6 o'clock turbine frame strut.

The bearing sumps and gearboxes are interconnected to collect oil vapors before air/oil separation and venting. The oil tank vent and the TGB/AGB sump are connected to the forward sump. Vapors from the forward and aft sumps pass through rotating air/oil separators into the main shaft center vent tube to be vented out the exhaust. The separated oil is returned to the sumps.

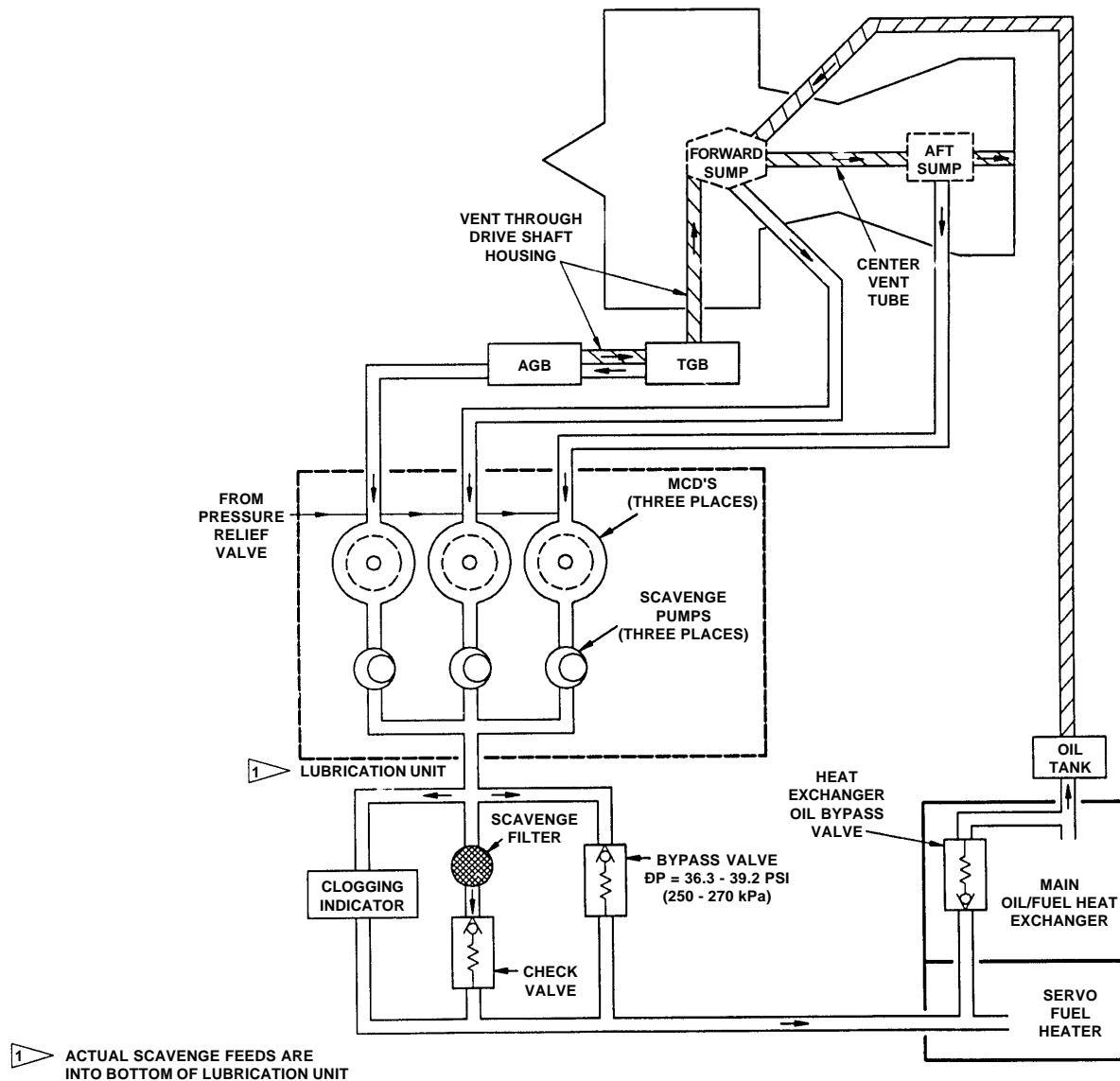
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**OIL SCAVENGE AND VENT SYSTEM SCHEMATIC**

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## OIL TANK

### Identification (1.A.b)

The oil tank is a fabricated light alloy weldment envelope with a sealed cast light alloy cover. It has an external flame-resistant coating and five inner bulkheads to reduce sloshing and strengthen the tank. A sight glass is provided on the outboard side of the tank to check oil level and a magnetic drain plug is located at the bottom of the tank.

Total volume (usable oil plus residual oil plus air) of the oil tank is 5.3 U.S. gallons (20 liters). It has an oil capacity (usable oil plus residual oil) of 4.8 U.S. gallons (18 liters). Engine No. 1 oil tank has 2% less capacity and engine No. 2 oil tank has 3% more capacity due to wing inclination angle.

Several operational components are incorporated into the tank cover:

- The filler cap with scupper, scupper drain and screen.
- Lube supply port, suction tube and screen.
- Lube scavenge port, located next to the lube supply port.
- Air vent outlet to the forward sump.

- Anti-siphon device and tube.
- Air/oil separator and tube.
- Oil quantity transmitter mounting boss.

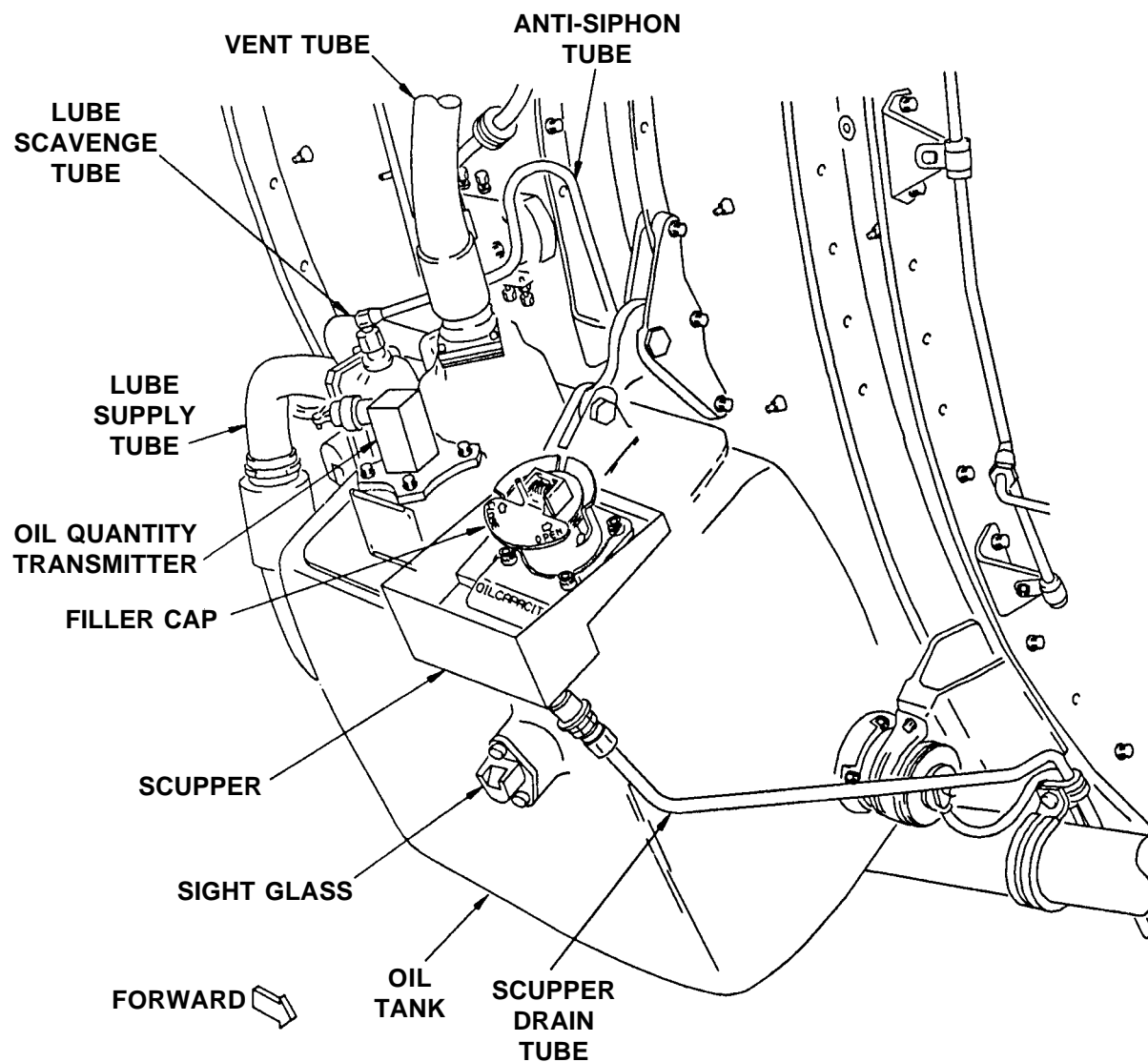
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## OIL TANK COMPONENT IDENTIFICATION

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## OIL TANK

### Purpose (1.B.b)

The engine oil tank is part of oil storage and provides a continuous supply of oil for distribution.

### Location (2.A.b)

It is located on the lower right side of the fan case.

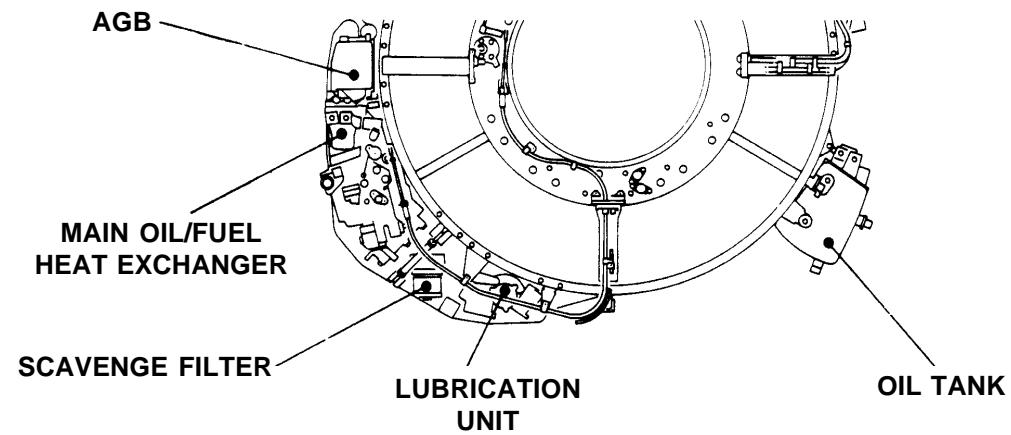
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### OIL TANK LOCATION

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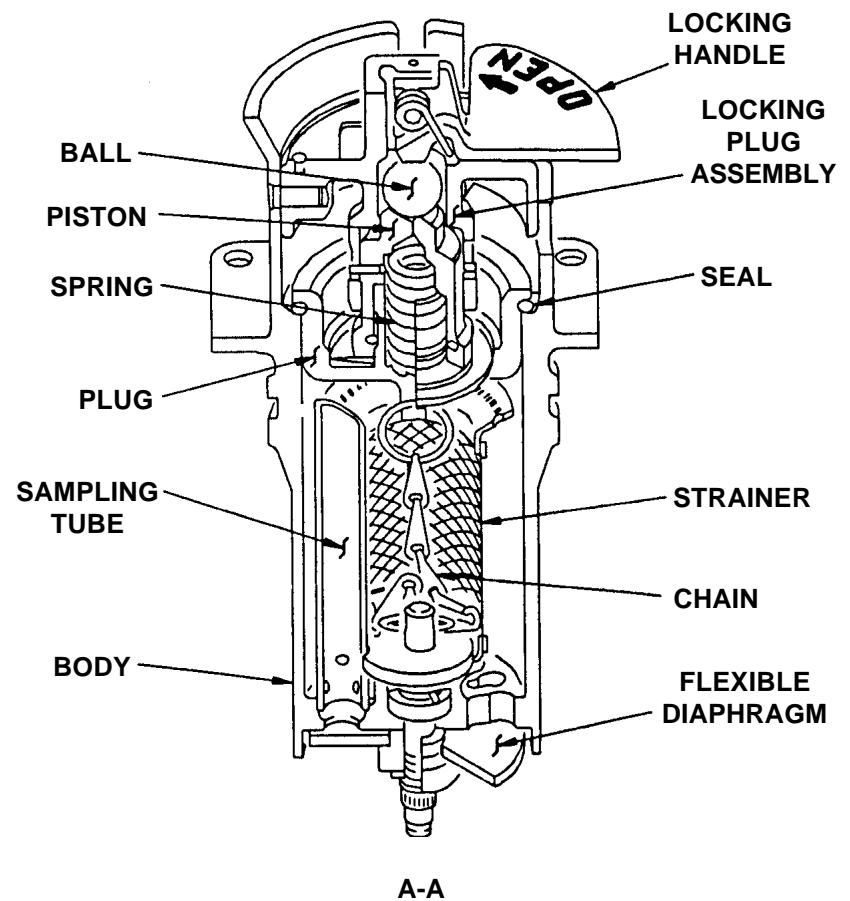
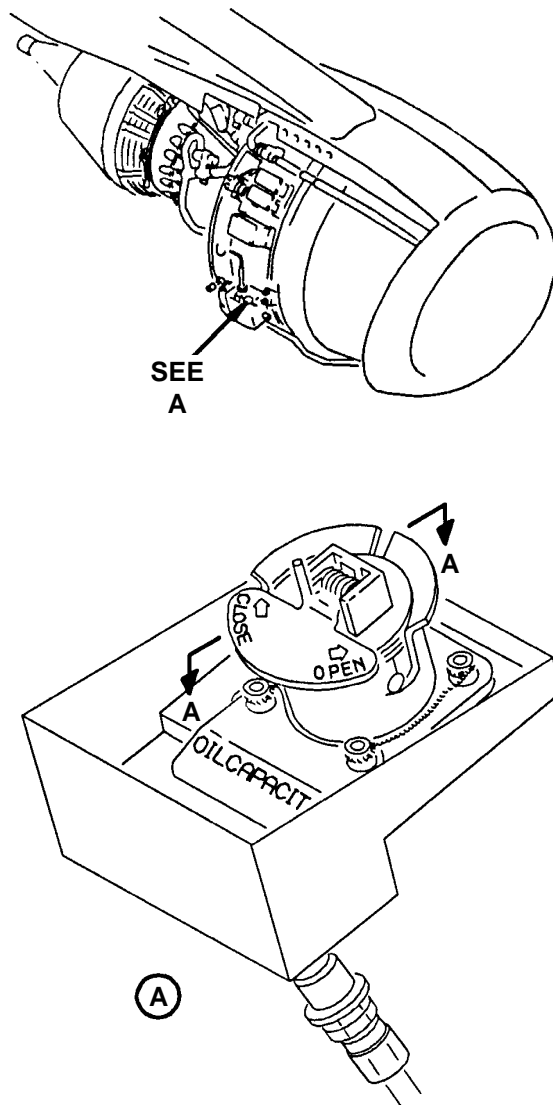
## OIL TANK FILLER CAP

### Identification (1.A.b)

The oil tank filler cap consists of a locking assembly fastened to the filler cap body by chain, a sampling tube, a strainer and a check valve incorporated in the filler cap body.

- The locking plug assembly consists of a piston, spring, washers, ball and plug. With the locking handle lowered, the ball compresses the spring which exerts a force on the seal against the body.
- The check valve consists of a diaphragm which seals the lower filler cap body using oil tank pressure. The check valve ensures that no oil leakage occurs while the oil tank is pressurized, even if the locking plug is incorrectly installed.





## OIL TANK FILLER CAP

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## OIL TANK AIR/OIL SEPARATOR

### **Purpose (1.B.b)**

The air/oil separator reduces the amount of air trapped within the returning oil flow to the oil tank.

### **Operation (2.C.b)**

Oil is drawn from the bottom of the oil tank through a suction tube attached to the tank cover. Returning oil discharges tangentially into the air/oil separator where the air is spun out through the air vent to the forward oil sump.

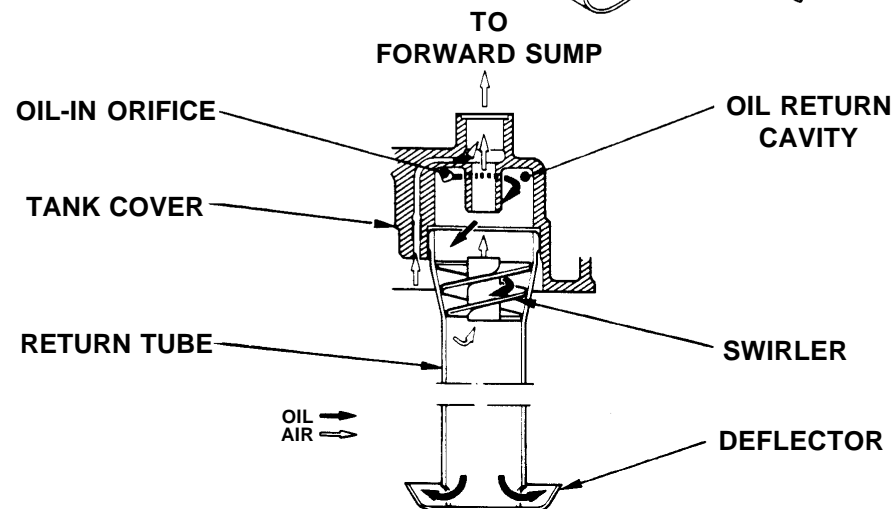
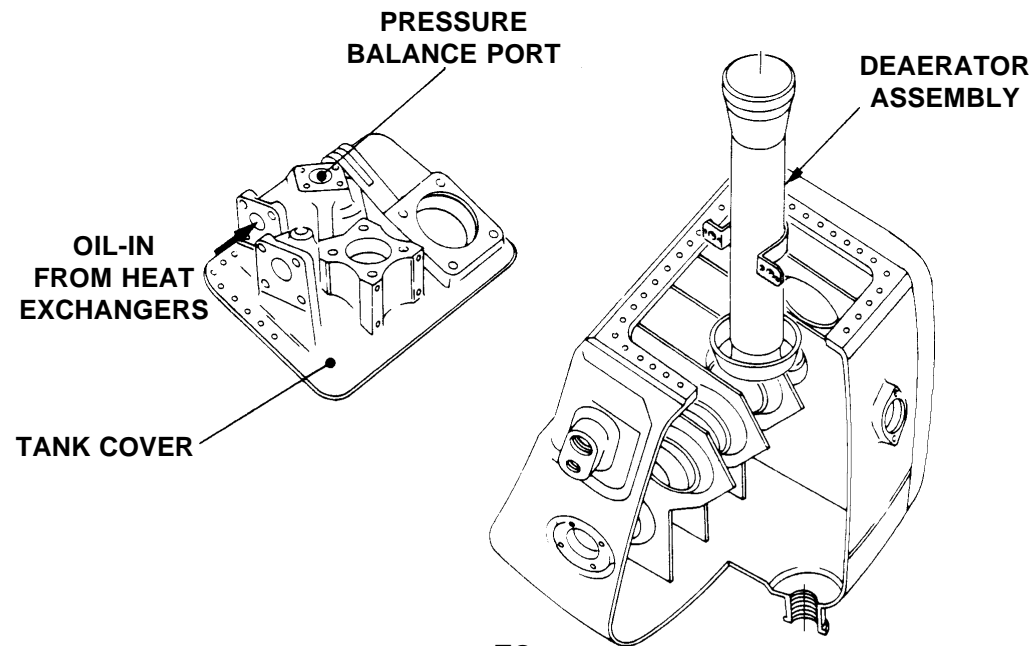
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### OIL TANK AIR/OIL SEPARATOR

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**OIL TANK ANTI-SIPHON****Purpose (1.B.b)**

The anti-siphon device prevents the oil from being siphoned through the oil supply when the engine is not operating.

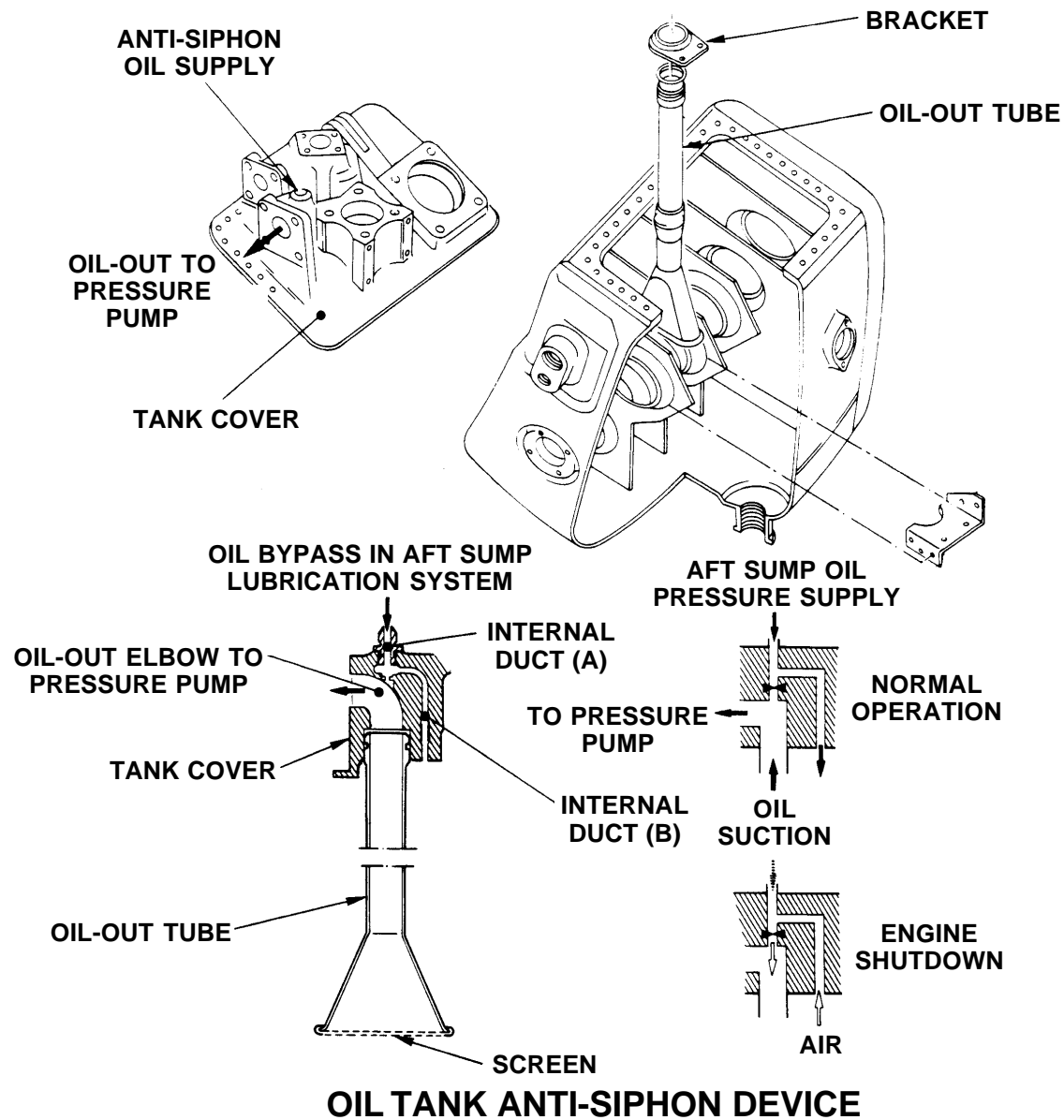
**Operation (2.C.b)**

After engine shutdown, the oil pressure downstream of the supply pump falls below the oil tank internal pressure. This enables the lubrication unit to be unprimed by air in the oil tank. The oil is forced back into the oil tank through the anti-siphon tube.

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## OIL DISTRIBUTION

### Identification (1.A.b)

The oil distribution system consists of the following components:

- Lubrication unit
- MCD's (part of Lubrication Unit)
- Supply filter (part of Lubrication Unit)
- Scavenge filter
- Monitoring indicators
- Main fuel/oil heat exchangers

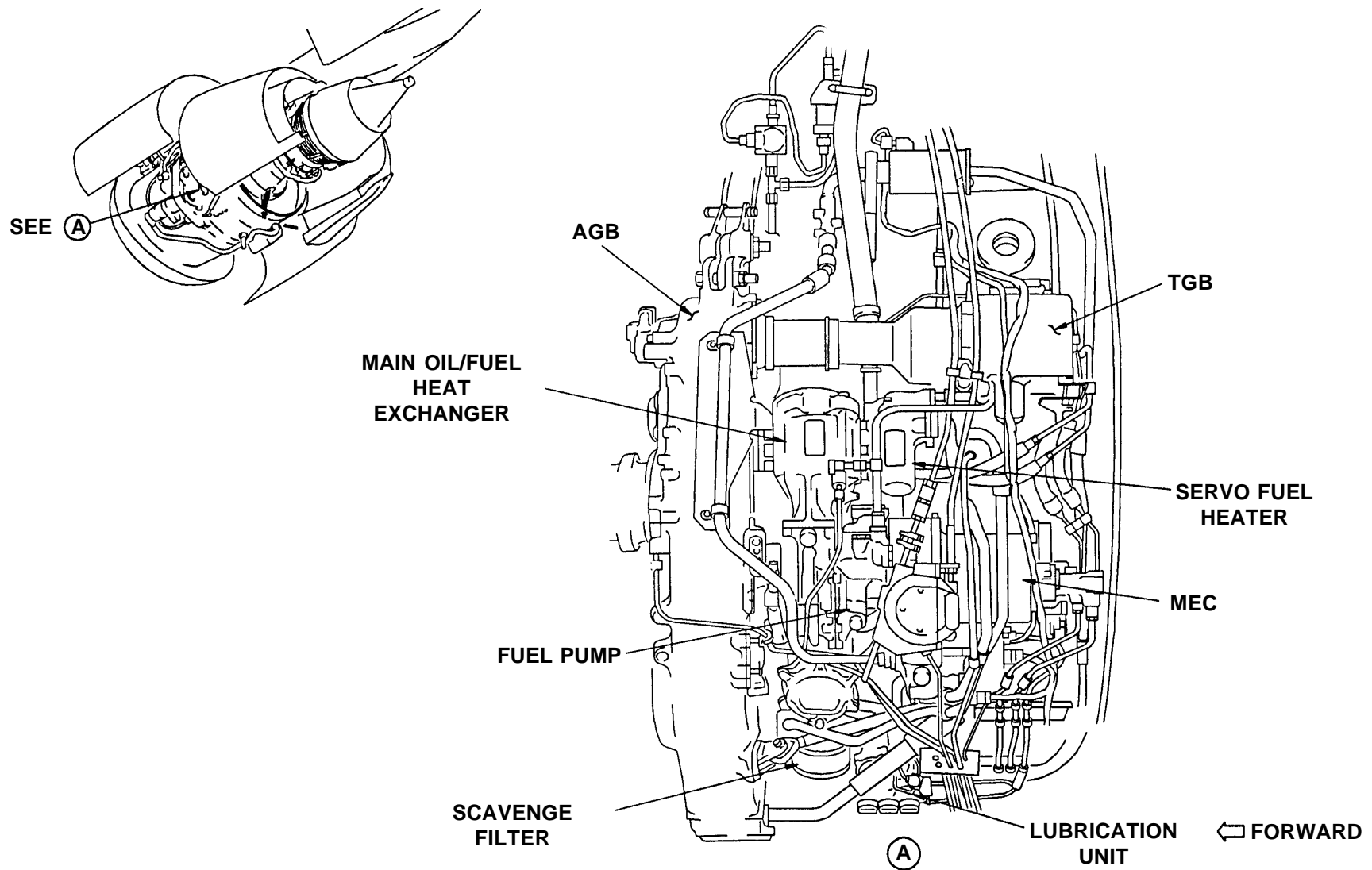
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## OIL DISTRIBUTION SYSTEM COMPONENT LOCATION

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## LUBRICATION UNIT

### Identification (1.A.b)

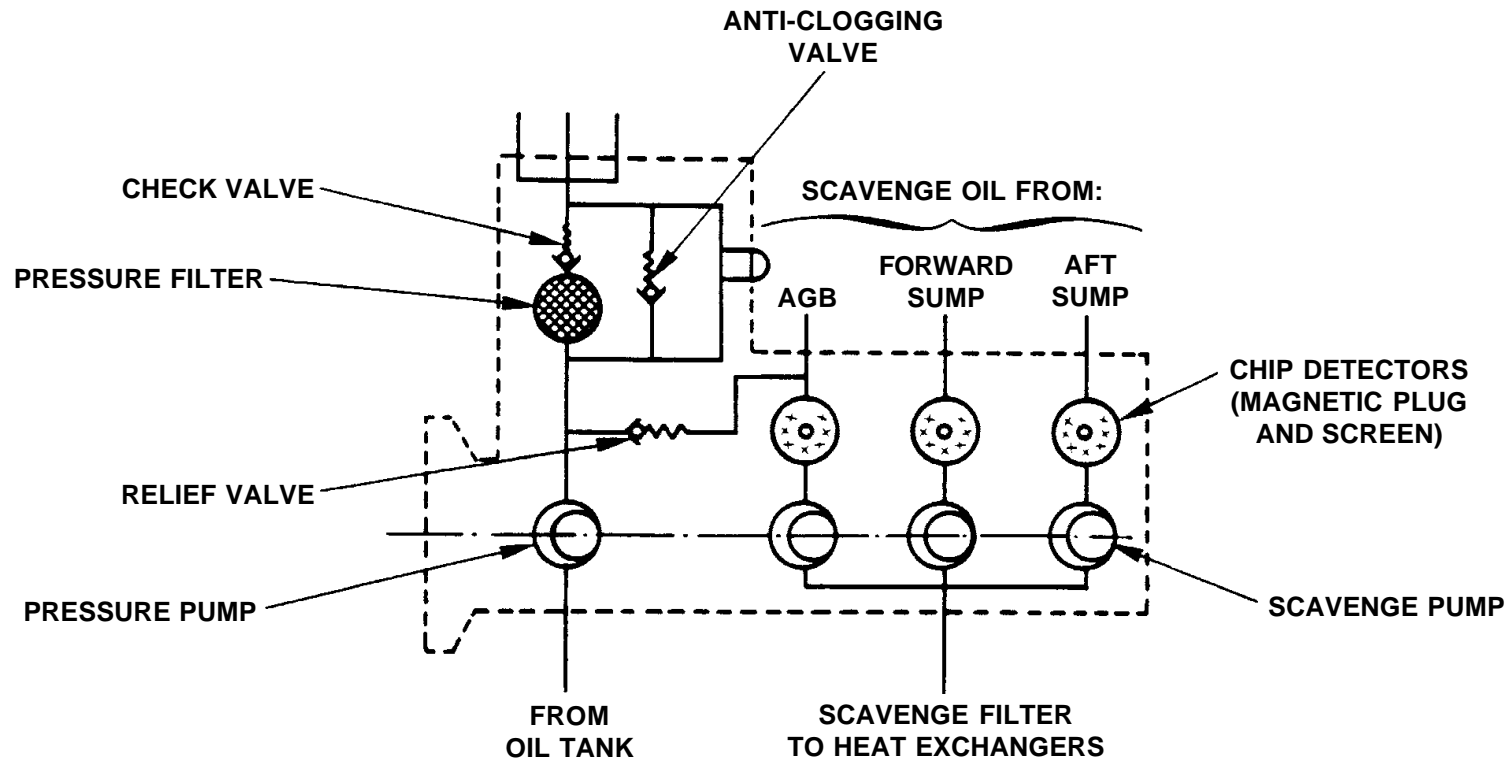
The lubrication unit contains the following:

- Four positive displacement pumps (three scavenge pumps and the supply pump)
- Oil supply filter, check valve and bypass valve with clogging indicator
- Pressure relief valve located on the oil supply pump discharge side of the unit
- Three Magnetic Chip Detectors (MCD's)

### Location (2.A.b)

The lubrication unit is located on the AGB near the bottom of the fan case on the left side.





## OIL SYSTEM COMPONENTS - LUBRICATION UNIT

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## MAGNETIC CHIP DETECTORS

### Identification (1.A.b)

Three MCD's are used on the lubrication unit, one on the inlet of each scavenge pump. Each has a removable magnetic plug and a scavenge screen.

### Purpose (1.B.b)

There purpose is to trap ferrous/nonferrous particulates before entering the lubrication unit.

### Location (2.A.b)

The MCD's are located at the inlet to the scavenge pumps.

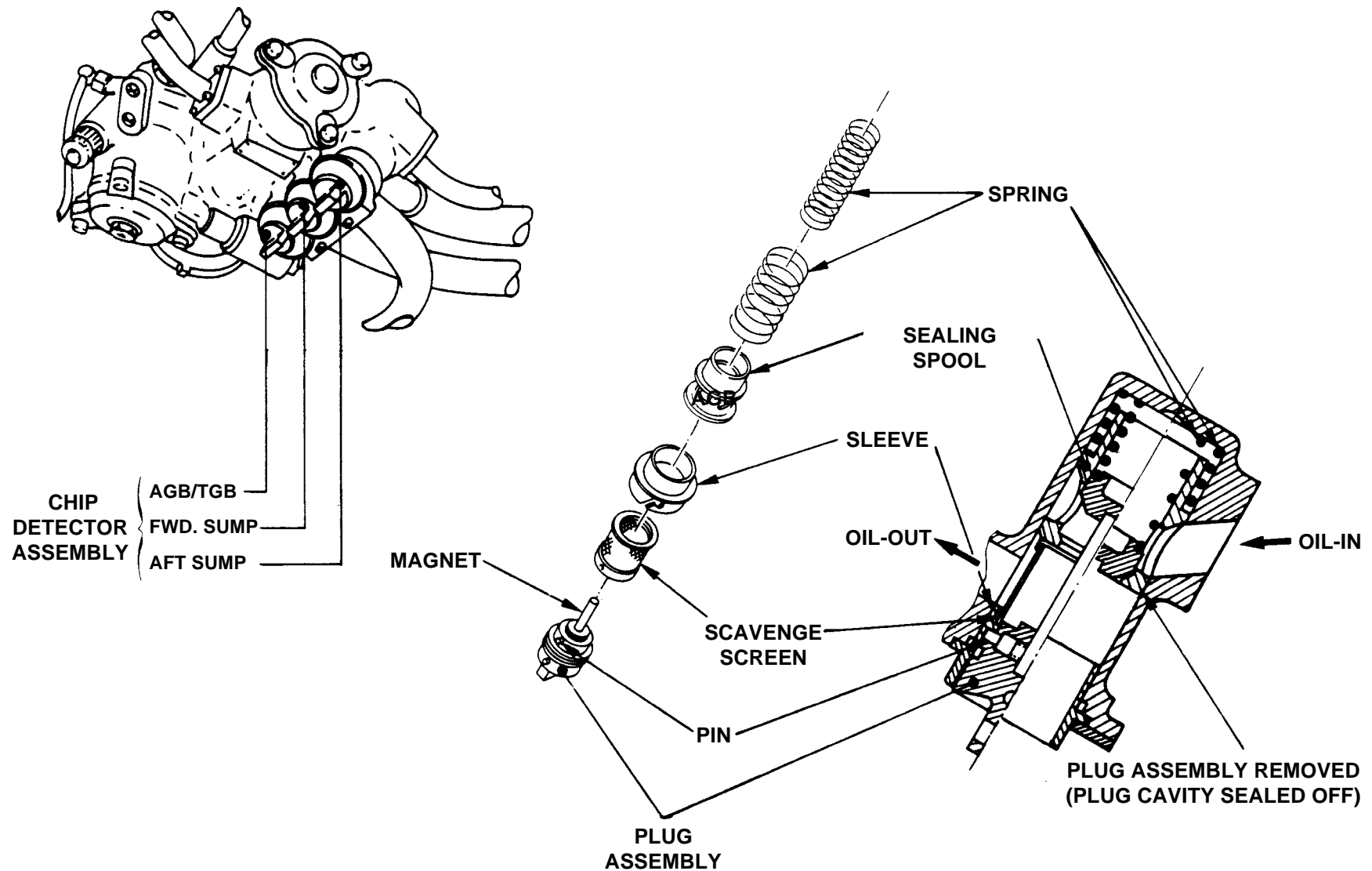
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## MAGNETIC CHIP DETECTOR ASSEMBLY

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## OIL SUPPLY FILTER

### Identification (1.A.b)

The filter is a 44 micron cleanable element. The assembly contains a pressure relief valve and a bypass valve with visual clogging indicator.

### Purpose (1.B.b)

To screen particle contamination contained within the oil supplied from the oil tank.

### Location (2.A.b)

The oil supply filter is housed in the lubrication unit.

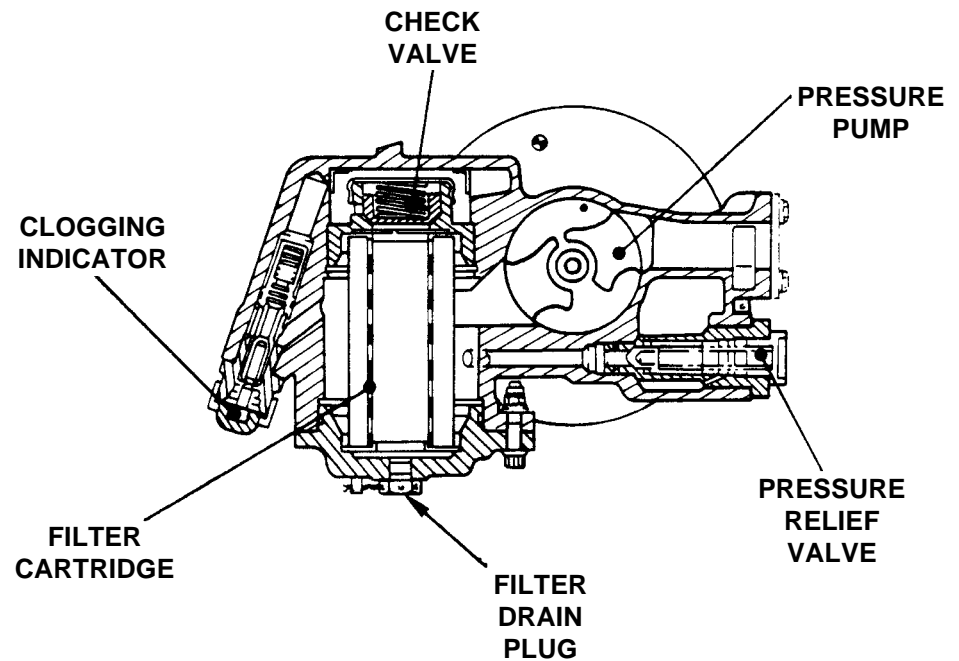
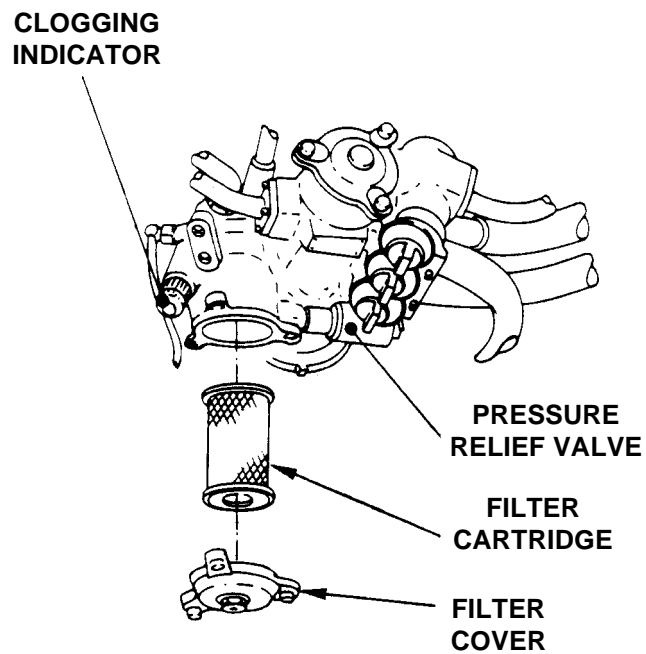
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## LUBRICATION UNIT - OIL PRESSURE FILTER ASSEMBLY

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## OIL SCAVENGE FILTER

### **Identification (1.A.b)**

The scavenge filter assembly consists of a replaceable filter cartridge, a bypass valve with visual clogging indicator and a non-return valve.

### **Purpose (1.B.b)**

To screen particle contamination contained within the oil scavenged from the engine sumps.

### **Location (2.A.b)**

The scavenge oil filter is installed in series between the scavenge pump outlet and the main oil/fuel heat exchanger. The assembly is located just above the lubrication unit.

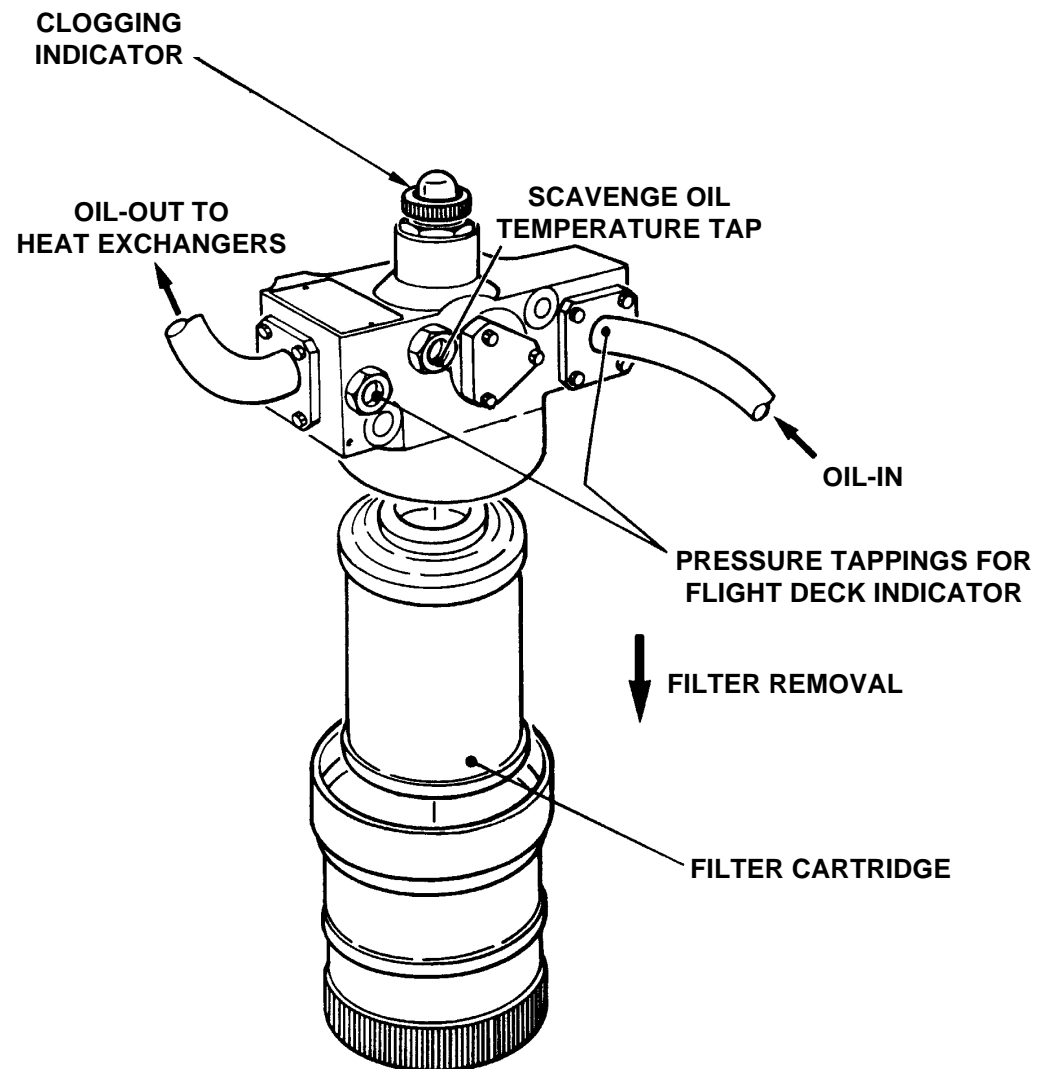
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## OIL SYSTEM COMPONENTS - COMMON SCAVENGE FILTER ASSEMBLY

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**MAIN OIL/FUEL HEAT EXCHANGER****Identification (1.A.b)**

The main oil/fuel heat exchanger is of a tubular type construction and consists of the housing, removable core and core access cover.

Both fuel and oil portions of the oil/fuel heat exchanger contain bypass valves. This permits fuel and/or oil to bypass the core in the event of a blockage. A drain port is also provided to check for possible fuel leaks from the core ends into the core housing.

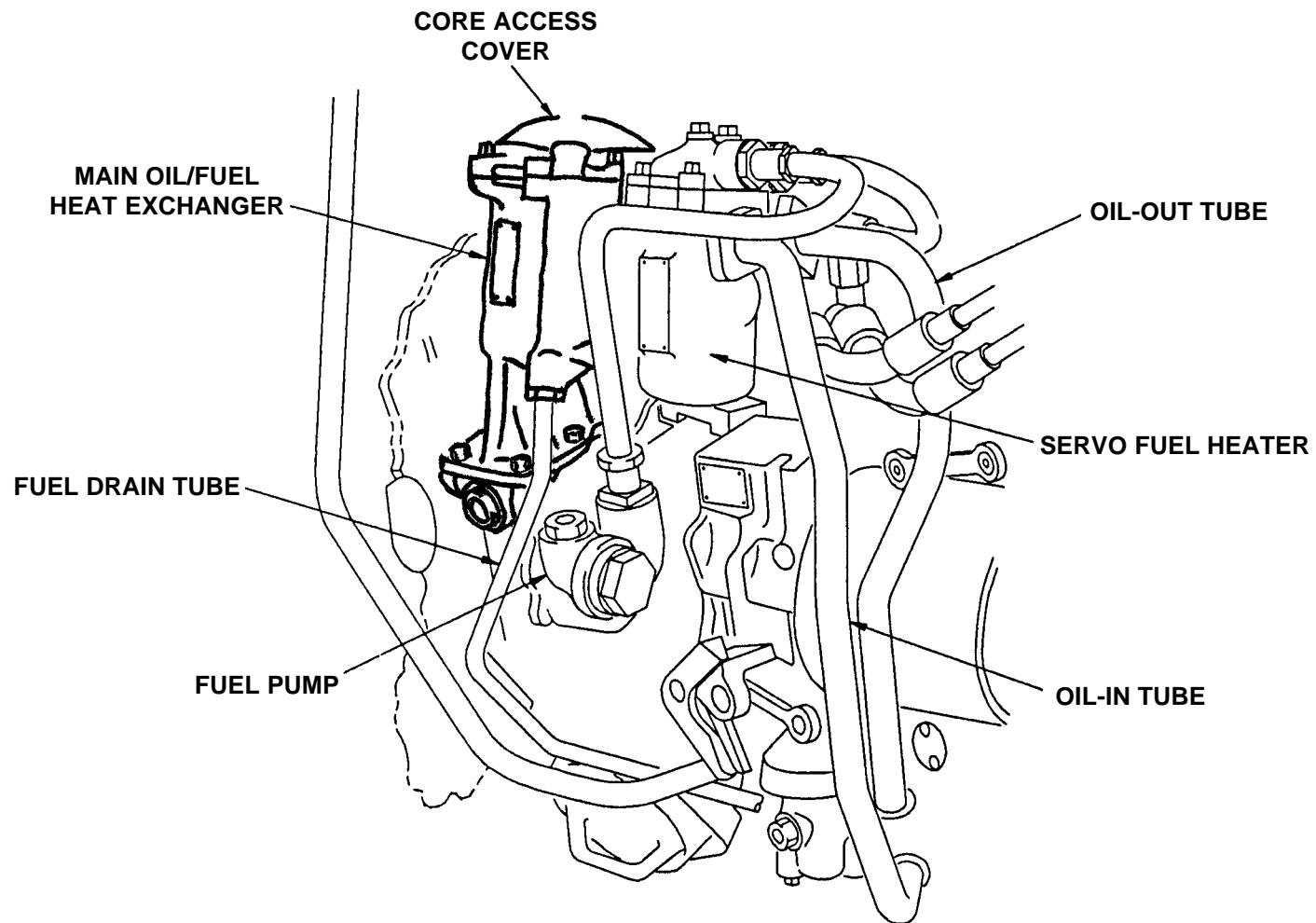
**Purpose (1.B.b)**

The main oil/fuel heat exchanger is designed to reduce the temperature of the scavenge oil prior to returning to the oil tank.

**Location (2.A.b)**

The main oil/fuel heat exchanger is located at the 9 o'clock position on the fan case and is attached to the fuel pump and the servo fuel heater.





## MAIN OIL/FUEL HEAT EXCHANGER

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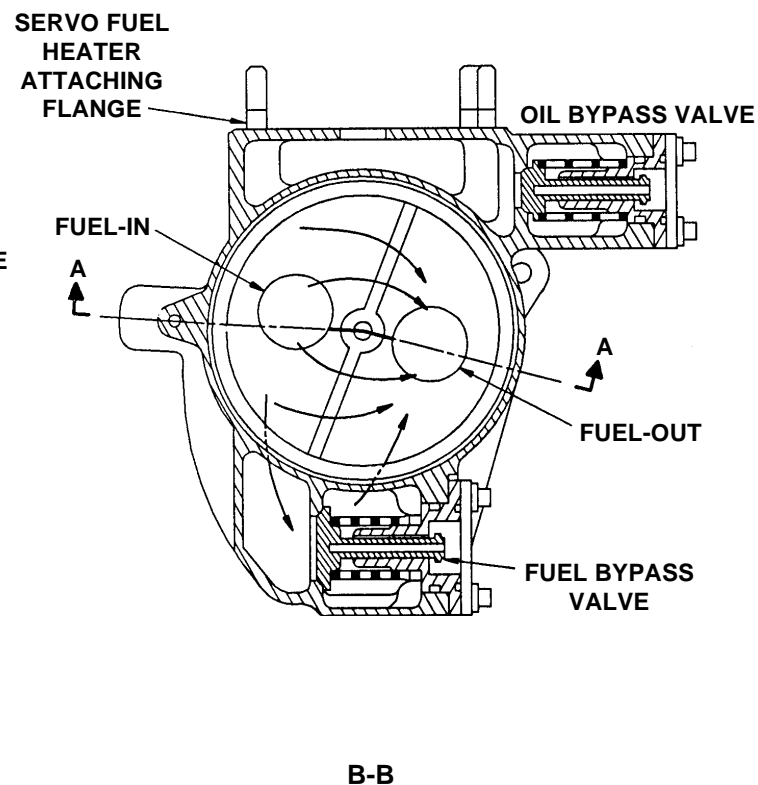
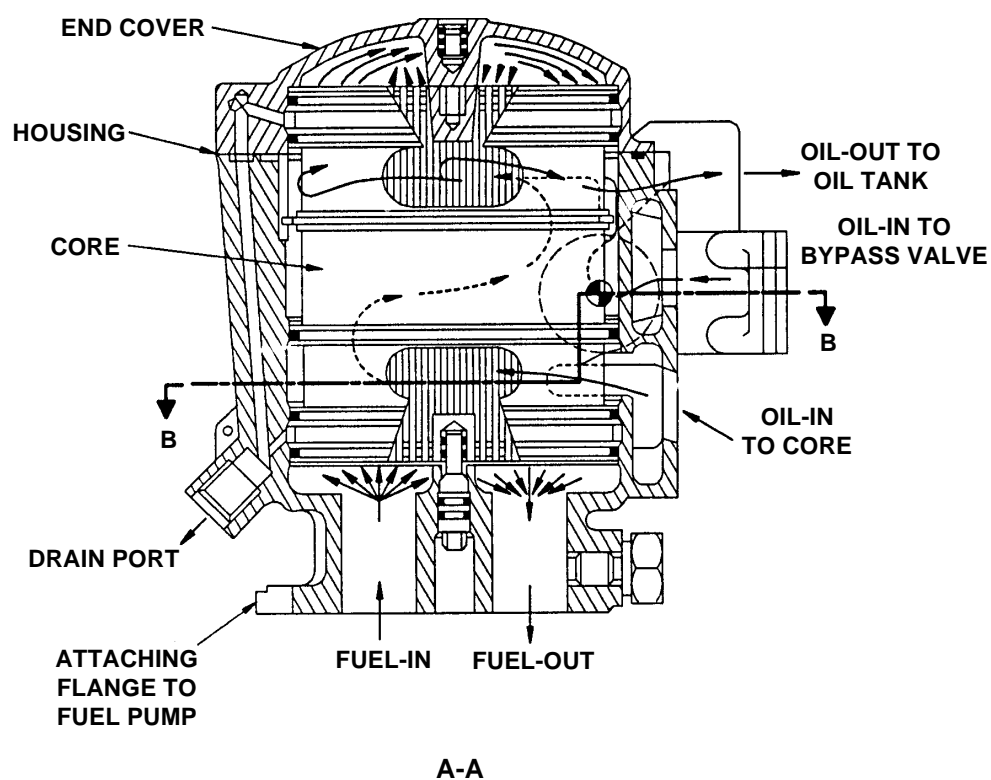
**MAIN OIL/FUEL HEAT EXCHANGER****Operation (2.C.b)**

Oil received from the servo fuel heater passes externally over the core tubes of the main oil/fuel heat exchanger. Heat from the oil is transferred through the process of convection to the fuel passing through the tubes from the low pressure stage of the fuel pump. The cooled oil is then sent back to storage in the engine oil tank. The heated fuel returns to the fuel pump and is processed through the main fuel filter. In the event of a blockage the fuel bypass will open at approximately 26 psid, and the oil bypass at approximately 130 psid.

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## MAIN OIL/FUEL HEAT EXCHANGER

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**OIL SYSTEM MONITORING****Identification (1.A.b)**

To properly monitor the oil system, the following indications are available:

- Oil pressure: Reads differential pressure between forward sump supply and TGB vent pressure.
- Oil temperature: Reads scavenge oil temperature at the scavenge filter.
- Oil quantity: Reads quantity (flight deck) from oil tank transmitter. System also provides for a tank visual indication.
- Filter clogging (scavenge): Senses scavenge filter differential pressure.
- Low oil pressure: Senses differential pressure between forward sump supply and TGB vent pressure.

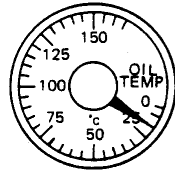
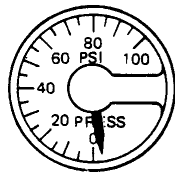
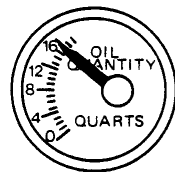
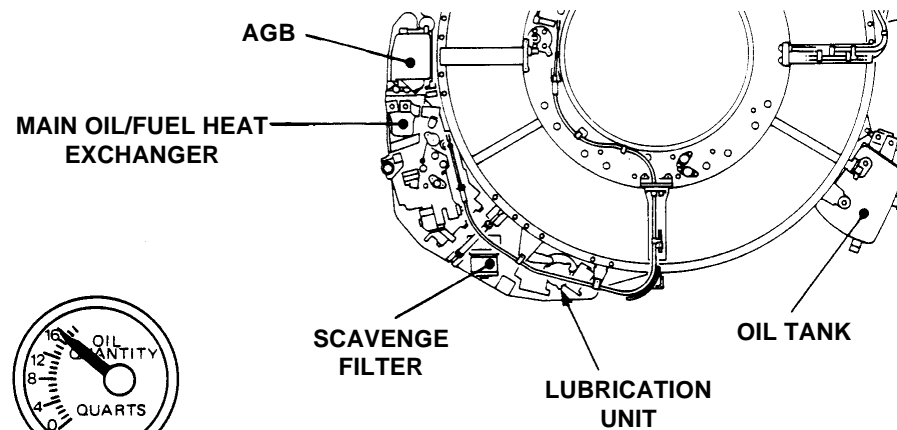
**Purpose (1.B.b)**

Indicating systems provide measurements of oil quantity, oil pressure and oil temperature. Warning lights also provide a low oil pressure warning and oil filter bypass warning. The condition of the engine oil system and the performance of associated engine components are determined by visual indication of these systems in the flight compartment.

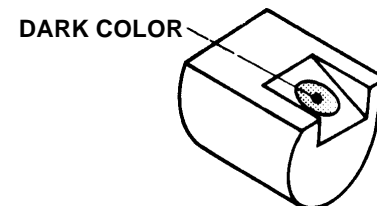
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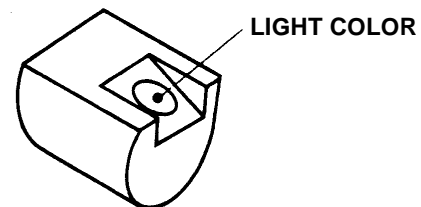
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**VISUAL OIL LEVEL**



NO SERVICING REQUIRED



ADD OIL

**OIL SYSTEM MONITORING**

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## VISUAL CLOGGING INDICATORS

### **Purpose (1.B.b)**

The visual clogging indicators provide a visual indication of impending filter bypass.

### **Location (2.A.b)**

The oil supply filter and the oil scavenge filter are both equipped with visual clogging indicators.

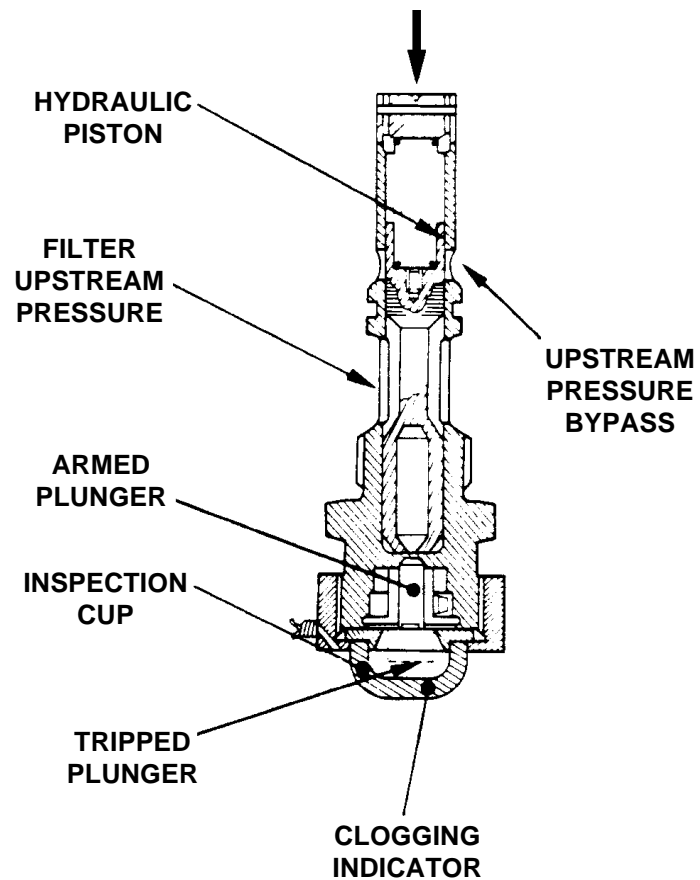
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NORMAL  
(RESET)



CLOGGED FILTER  
(POPPED OUT)

## CLOGGING INDICATORS CROSS SECTION

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## OIL SYSTEM SERVICING

### Description (2.D.b)

This section contains information for filling of oil, changing of oil, and flushing the engines oil system.

When servicing the oil system apply the general guidelines shown below.

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### OIL SERVICING GUIDELINES

**FLUSH THE OIL SYSTEM IF FUMES INDICATE A MIXTURE OF FUEL AND OIL OR SYSTEM IS CONTAMINATED**

**OIL CAN BE CHANGED THROUGH SERVICING**

**DO NOT MIX TYPE 1 AND TYPE 2 OILS**

**DRAIN AND FLUSH SYSTEM IF CHANGING FROM TYPE 1 TO TYPE 2 OIL**

**DO NOT SERVICE WITH UNAPPROVED BRANDS**

**WAIT AT LEAST 5 BUT NO MORE THAN 30 MINUTES BEFORE SERVICING**

**OIL SYSTEM SERVICING****Description**

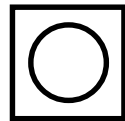
After open the oil tank access door do a check of the oil quantity sight gage. The sight gage for the oil tank shows a bright view when the oil level falls below the gage. It shows a black view when the oil level is higher than the gage. The indication of a black view shows that a sufficient quantity of oil is in the tank for airplane dispatch. A sufficient quantity is more than 2.5 U.S. gallons (9.5 liters), or more than 60% full, as shown on the pilots' center instrument panel.

If the indication of a bright view is showing through the sight gage then the oil tank requires servicing. The sight gage does not give an indication that the oil tank is full or empty.

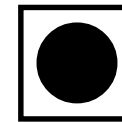
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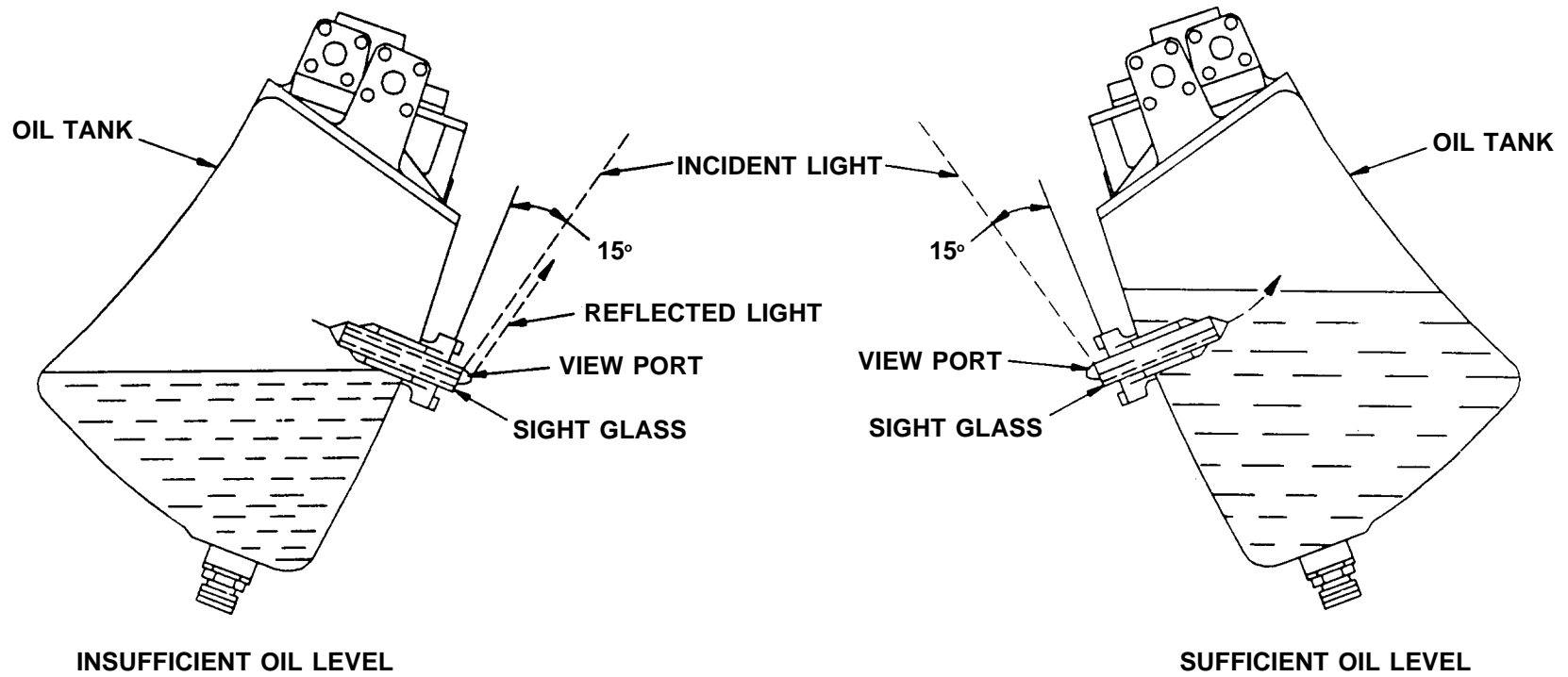
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BRIGHT IMAGE



BLACK IMAGE



### OIL SIGHT GLASS LEVEL INDICATION

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## OIL SYSTEM SERVICING

### Description

Filling of the oil tank can be accomplished by one of two procedures:

- gravity fill method
- remote fill method.

When you gravity fill the oil tank add oil to the fill port and stop just before the oil level reaches the overflow port.

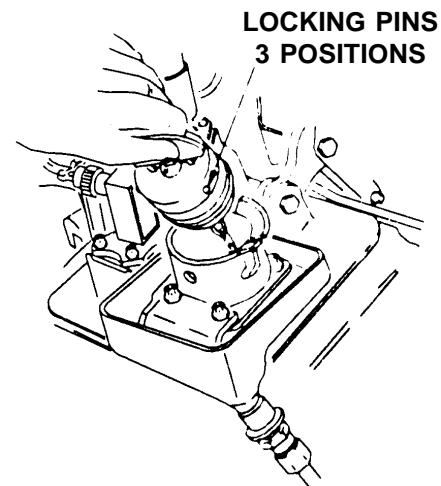
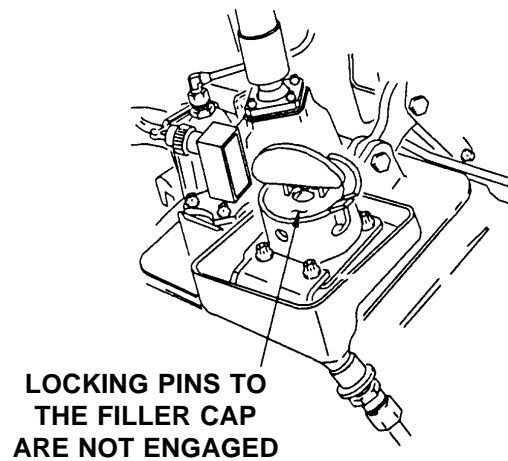
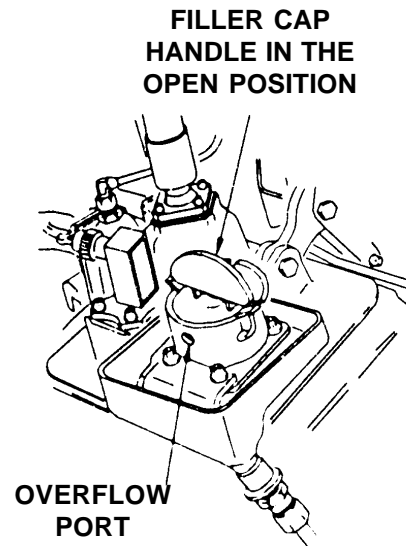
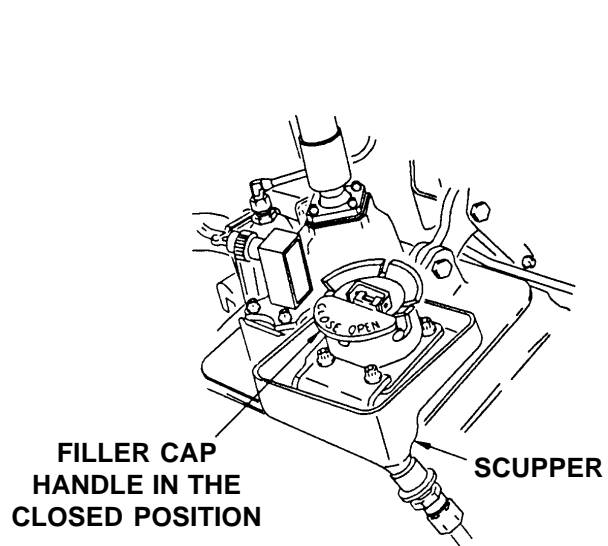
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## OIL TANK SERVICING (GRAVITY FILL METHOD)

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## OIL SYSTEM SERVICING

### Description

When servicing the oil system by the remote fill method use a clear plastic hose attached to the overflow coupling. This will give you a visual indication that the tank is full. Once oil is visible out the overflow hose stop servicing. Wait until the oil stops flowing from the overflow drain line before disconnecting. If the overflow drain line is removed before flow stops over servicing of the oil tank can occur. Always check couplings after completion of servicing to insure that no leakage is present. A lightly wet surface, not sufficient to make one drop, is permitted.

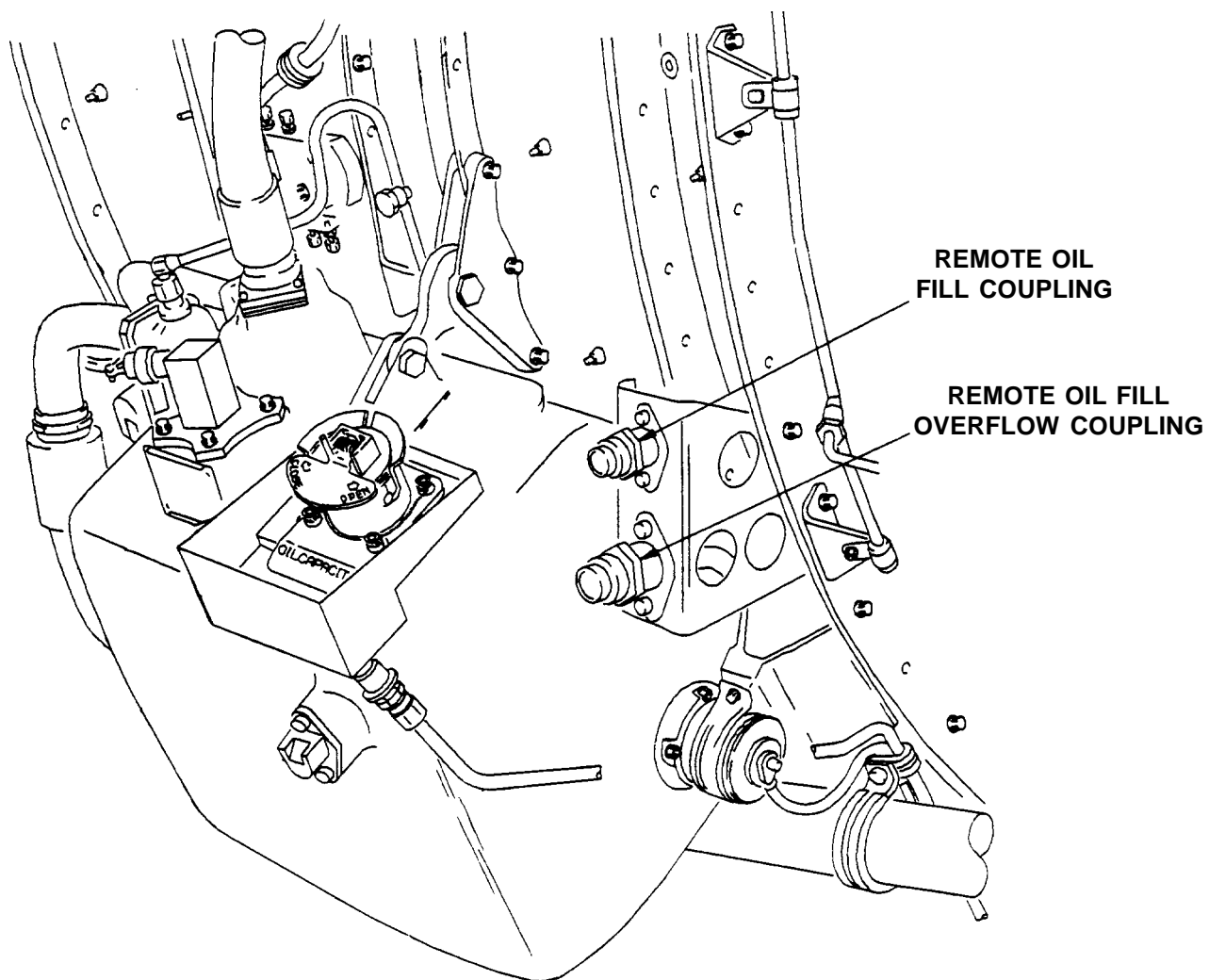
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## OIL TANK SERVICING (REMOTE FILL METHOD)

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## CHANGING ENGINE OIL

### Description (2.D.b)

When the changing of oil is required both gravity and pressure methods can be used. Also a drain adapter 856A2506 may be required to drain the oil tank. After the oil is drained service the system with new oil.

If a change from one brand of approved oil to another brand of approved oil is required, draining is not necessary and this may be accomplished through normal servicing. However, do not mix brands of oil on a regular basis as this can lead to contamination due to chemical incapacibilities between oils.

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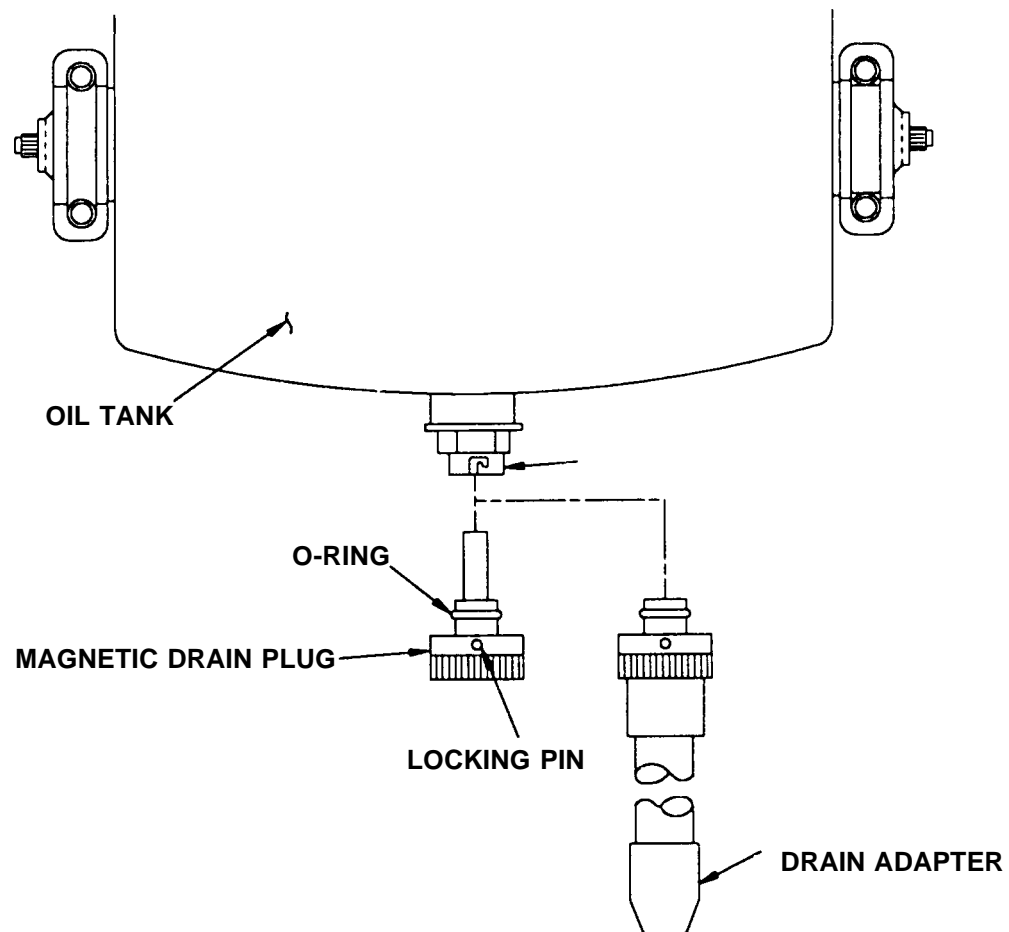
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## CHANGING OIL - DRAIN PLUG AND ADAPTER

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## CHANGING ENGINE OIL

### Description

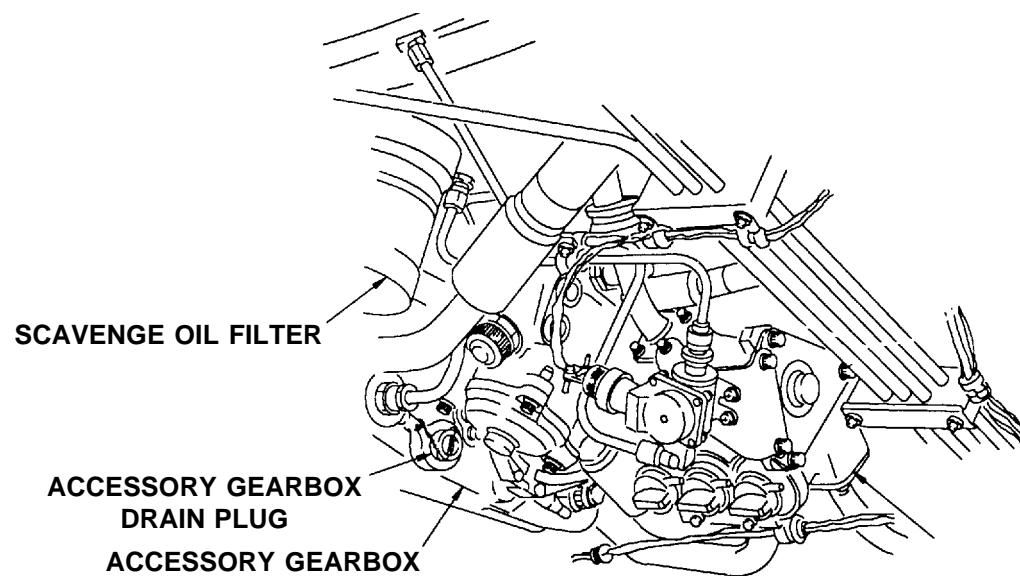
After changing the oil, drain the accessory gearbox.  
Then operate the engine and do a check for leaks in accordance with Test #3 Leak Check - Idle Power as indicated in the maintenance manual.

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## CHANGING OIL - AGB DRAIN

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## FLUSHING THE OIL SYSTEM

### Description (2.D.b)

If contamination is suspected of entering the oil system then a system flush can be performed.

When flushing the oil system keep the old O-rings, they can be used while flushing the system. In addition half the oil tank capacity is a sufficient quantity of oil to flush the system.

A summary of the procedure is given below.

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### OIL SYSTEM FLUSH SUMMARY

- STEP 1: CHANGE THE OIL.
- STEP 2: RUN ENGINE AT IDLE FOR TEN MINUTES.
- STEP 3: CHANGE THE OIL.
- STEP 4: INSPECT THE MCD'S.
- STEP 5: REPLACE THE SUPPLY AND SCAVENGE FILTERS.
- STEP 6: RUN AT IDLE FOR TEN MINUTES.
- STEP 7: SERVICE THE OIL SYSTEM.
- STEP 8: INSPECT THE SUPPLY AND SCAVENGE FILTER ELEMENTS.
- STEP 9: RUN ENGINE AT IDLE FOR TEN MINUTES.
- STEP 10: CHECK OIL FOR FUEL.
- STEP 11: REMOVE, CLEAN, AND INSPECT MCD'S.
- STEP 12: CHECK SUPPLY AND SCAVENGE FILTER ELEMENTS.
- STEP 13: SERVICE OIL SYSTEM.

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## POWER PLANT ADJUSTMENT AND TEST

### Objectives:

At the completion of this section a student should be able to:

....state the purpose of the power plant adjustments and tests of the CFM56-3/3B/3C engine (3.B.x).

....describe the power plant adjustments and tests of the CFM56-3/3B/3C engine (3.E.x).

**POWER PLANT - ADJUSTMENT/TEST****Purpose (3.B.a)**

Provide information to conduct the necessary tests to make sure that the engine operates correctly after replacement of a line component.

The tests go from those with no engine run to those with a MEC trim or a vibration survey check.

The tests have numbers for positive identification:

<u>Test No.</u>	<u>Title of the Test</u>
1.	Pneumatic Leak Test
2.	Engine Motoring
3.	Leak Check - Idle Power
4.	Idle Speed Check
5.	Power Assurance Check
6.	MEC Trim
7.	Vibration Survey
8.	Accel/Decel Check
9.	Replacement Engine Test (Pretested)
10.	Replacement Engine Test (Untested)
11.	T <sub>2</sub> /Compressor Inlet Temperature (CIT) Sensor Test

The chart below shows the line replaceable components and the applicable test required after replacement.

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POWER PLANT TEST REFERENCE TABLE (EXAMPLE)	
COMPONENT REPAIRED OR REPLACED	NECESSARY TEST
<b><u>Basic Engine Components</u></b>	
Fan Rotor Blades	7
Fuel Pump Drive Seal	6
N2 Rotor Rotation Drive Pad Seal	3
<b><u>Engine Fuel System Components</u></b>	
Fuel Pump Fuel Filter Cartridge	6
Servo Fuel Heater	3
Fuel Nozzle	3
Main Engine Control (MEC)	6
CIT Sensor	3
CBP Sensor/Filter	3
<b><u>Ignition System Components</u></b>	
Ignition exciter	System Test (74-00-00/501)
Ignition Lead	System Test (74-00-00/501)
Igniter Plug	System Test (74-00-00/501)
<b><u>Bleed and Air Control Systems Components</u></b>	
Variable Stator Vane (VSV) Actuator	3, 8
VSV Feedback Cable	8
Bleed Valve Fuel Gear Motor	3
VBV Feedback Cable	8

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**TEST NO. 1 - PNEUMATIC LEAK TEST****Purpose (3.B.a)**

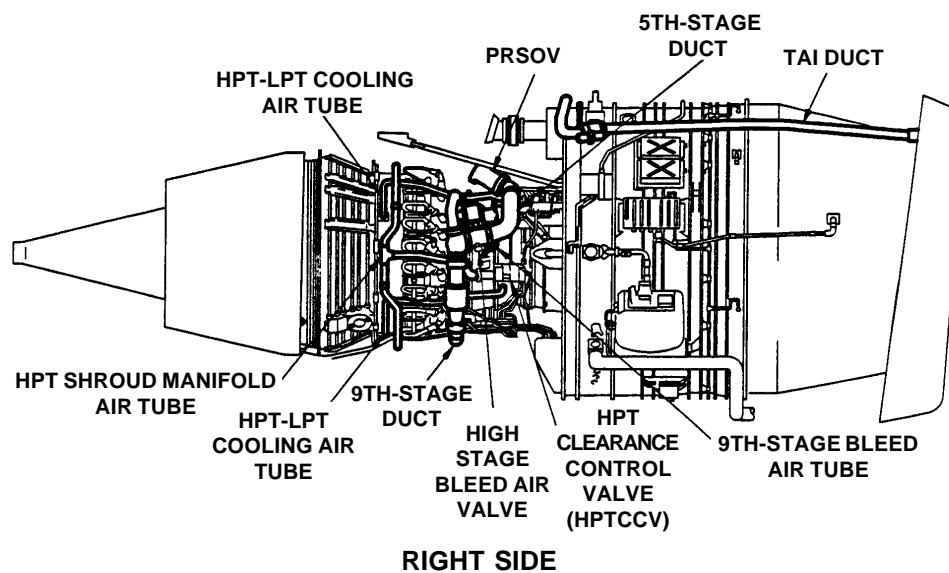
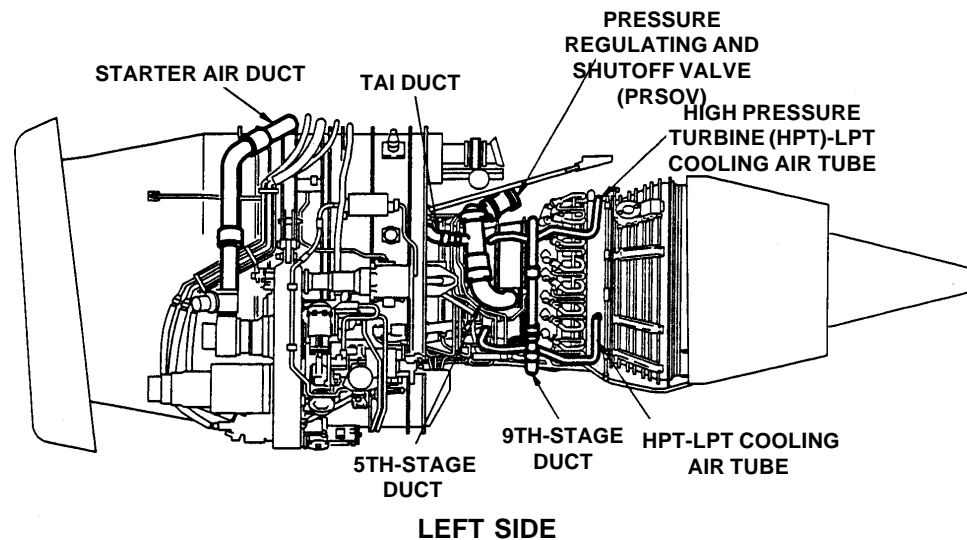
Referencing 36-11-05/501, Engine Bleed Air Distribution System this procedure will have maintenance personnel examining these pneumatic ducts for a leak:

- Starter duct (up to the start valve).
- 5th and 9th stage ducts (up to the bleed air check valve and the high stage valve).
- Anti-ice duct on the inlet cowl (up to the Thermal Anti-ice (TAI) valve).

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## ENGINE PNEUMATIC DUCTING

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**TEST NO. 2 - ENGINE MOTORING****Purpose (3.B.a)**

The engine motoring procedure can be used for any operation requiring engine rotation by starter only.

**Maintenance Tasks (3.E.a)**

Motoring can be performed in dry mode (no fuel introduced into the combustor) or wet mode (fuel introduced into the combustor) as desired.

Dry motoring will determine that the engine rotates freely, that instruments function properly, and that the starter meets requirements for a successful start. Dry motoring can also be used to check the lube system after maintenance, cool the engine down for borescope inspection, or to clear residual fuel that may have accumulated in the combustion chamber or low section of the turbine casing.

Wet motoring is only used to depreserve the fuel system after storage.

Following starter limitations as outlined in the Boeing 737 maintenance manual do the dry or wet motor procedure, as it is necessary for the required test (reference 71-00-00/201).

Examine the applicable component or system when you motor the engine.

- Make sure that the component or system operates correctly.
- Make sure that there is no leakage.

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REASONS FOR DRY MOTORING	REASONS FOR WET MOTORING
<p>DETERMINE FREE ROTATION OF ENGINE.</p> <p>PROPER FUNCTION OF INSTRUMENTATION.</p> <p>PROPER STARTER FUNCTION.</p> <p>CHECK LUBE SYSTEM AFTER MAINTENANCE.</p> <p>COOL ENGINE FOR BORESCOPE INSPECTION.</p> <p>CLEAR RESIDUAL FUEL FORM COMBUSTION CHAMBER.</p>	<p>DEPRESERVATION OF THE FUEL SYSTEM.</p>

## ENGINE MOTORING

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## TEST NO. 3 - LEAK CHECK - IDLE POWER

### **Purpose (3.B.a)**

The idle leak checks test for the following correct engine operation:

- The connections do not have a leak.
- The operational noise is correct.
- All of the engine-related instruments have the correct indications.

### **Maintenance Tasks (3.E.a)**

Do a visual leak check, if you disconnected the engine tubes during the maintenance procedure (and you did not do a static pressure check).

The following pages show the key areas to check.

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## TEST NO. 3 - LEAK CHECK - IDLE POWER

### Maintenance Tasks

Check for evidence of fuel leakage from fuel manifold and fuel drain manifold on engine core.

Check for evidence of internal fuel leaks, indicated as fuel dripping from fuel drain lines (refer to 71-71-00 I/C for allowable leakage and corrective action).

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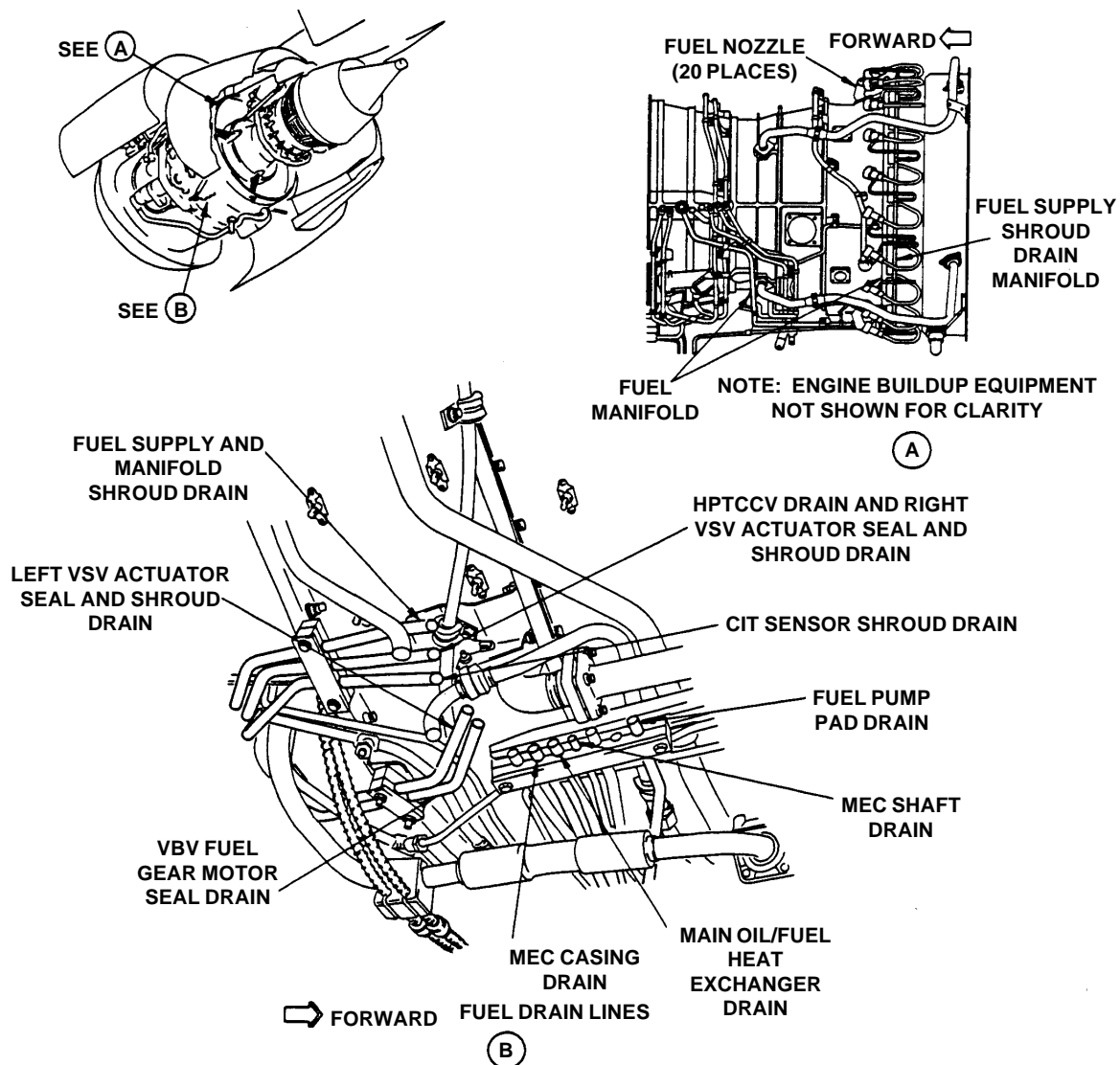
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## ENGINE FUEL SYSTEM LEAK CHECK

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## TEST NO. 3 - LEAK CHECK - IDLE POWER

### Maintenance Tasks

Examine the following oil system plumbing for damage and/or leaks:

- Main oil/fuel heat exchanger (1).
- Servo fuel heater (2).
- "Oil in" tube (3) from scavenge oil filter (13) to servo fuel heater (2).
- "Oil out" tube (4) from servo fuel heater (2) to oil tank (14).

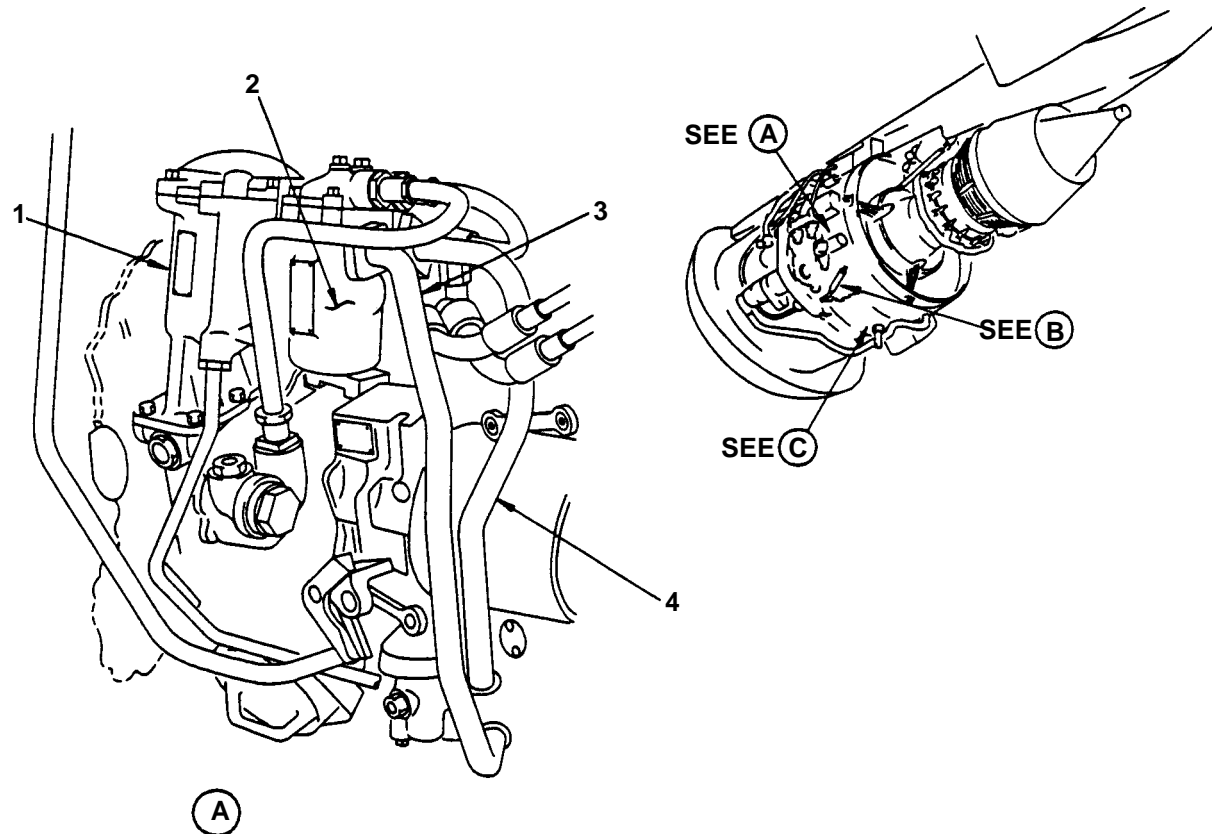
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## ENGINE OIL SYSTEM PLUMBING AND LEAK CHECK

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### TEST NO. 3 - LEAK CHECK - IDLE POWER

#### Maintenance Tasks

Examine the following oil system plumbing for damage and/or leaks:

- Scavenge oil filter (13).
- Oil supply filter (9).
- Magnetic chip detectors (8).
- Lubrication unit (7).
- Forward sump oil supply tube (5) from lubrication unit (7) to forward sump and TGB.
- Aft sump oil supply tube (6) from lubrication unit (7) to aft sump via 6 o'clock strut.
- AGB oil supply tube (11) from lubrication unit (7) to AGB.
- Scavenge oil filter inlet tube (10) from lubrication unit (7) to scavenge oil filter (13).
- TGB scavenge tube (12) from TGB to AGB.
- Oil tank (14).
- Oil tank magnetic drain plug (15).
- Aft sump scavenge tube (19) from aft sump to lubrication unit (7) via 6 o'clock strut.
- Forward sump scavenge tube (18) from forward sump to lubrication unit (7).
- AGB scavenge tube (17) from AGB to lubrication unit (7).
- Lube supply tube (16) from oil tank (14) to lubrication unit (7).

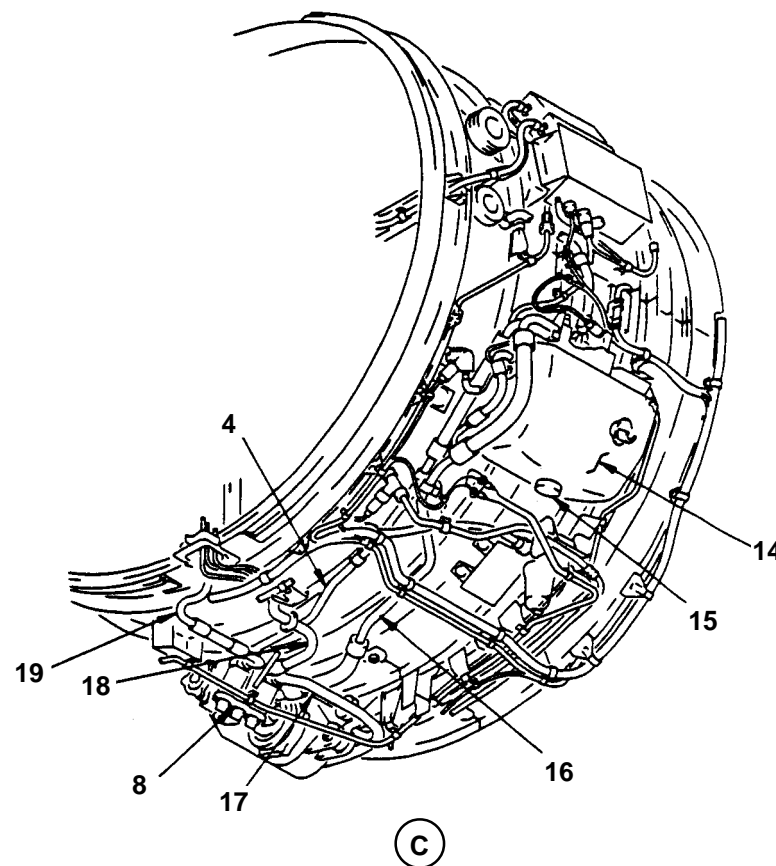
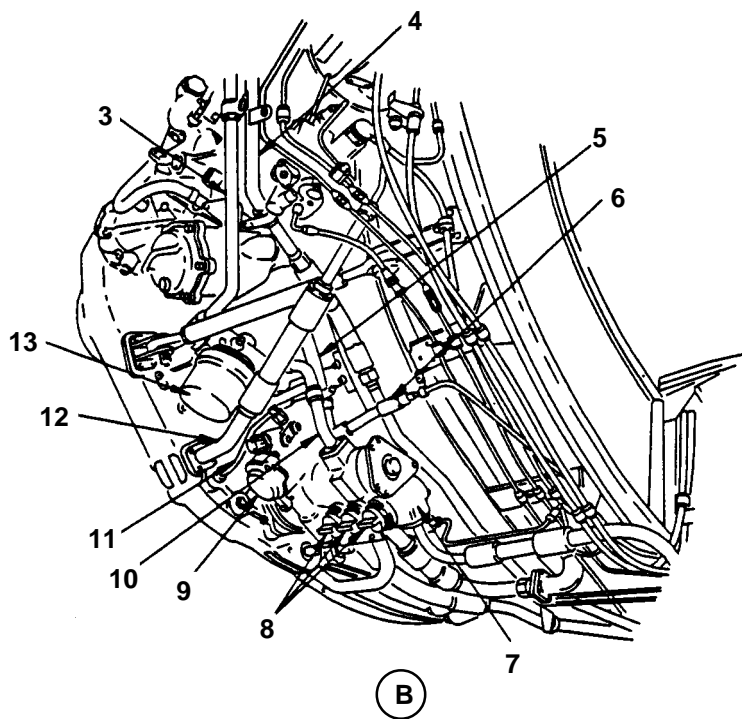
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## ENGINE OIL SYSTEM PLUMBING AND LEAK CHECK

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## TEST NO. 3 - LEAK CHECK - IDLE POWER

### Maintenance Tasks

Check CIT sensor shroud drain tube for evidence of fuel leakage. If found, replace CIT sensor (73-21-02).

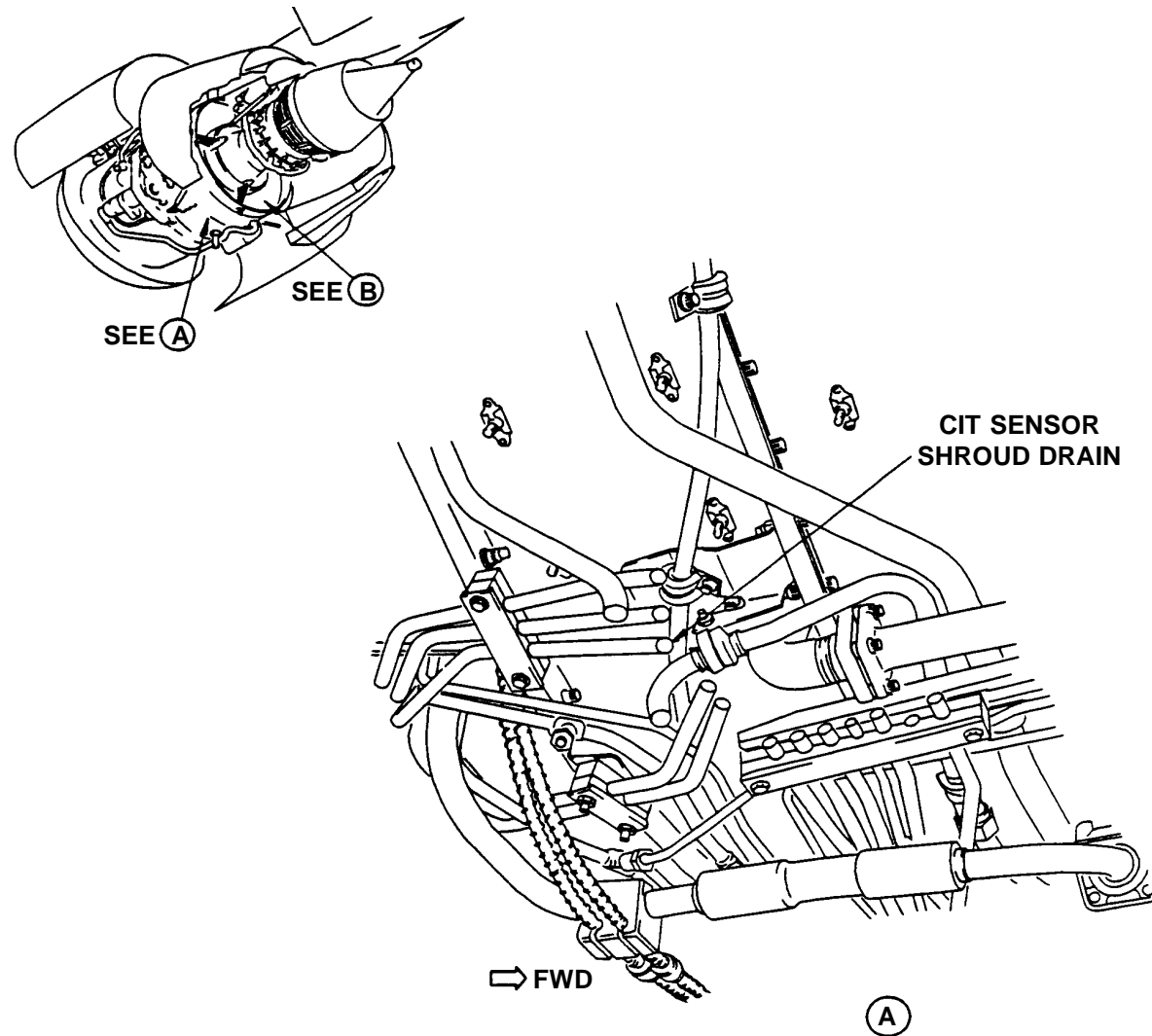
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## CIT SENSOR TUBING CHECK

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## TEST NO. 3 - LEAK CHECK - IDLE POWER

### Maintenance Tasks

Visually examine accessible CIT sensor tubing on fan case and engine core for the following:

- Evidence of fuel leaks.
- Cracks.
- Dents.
- Collapsed sections.
- Wear through.
- Kinks.
- Loose Fittings.

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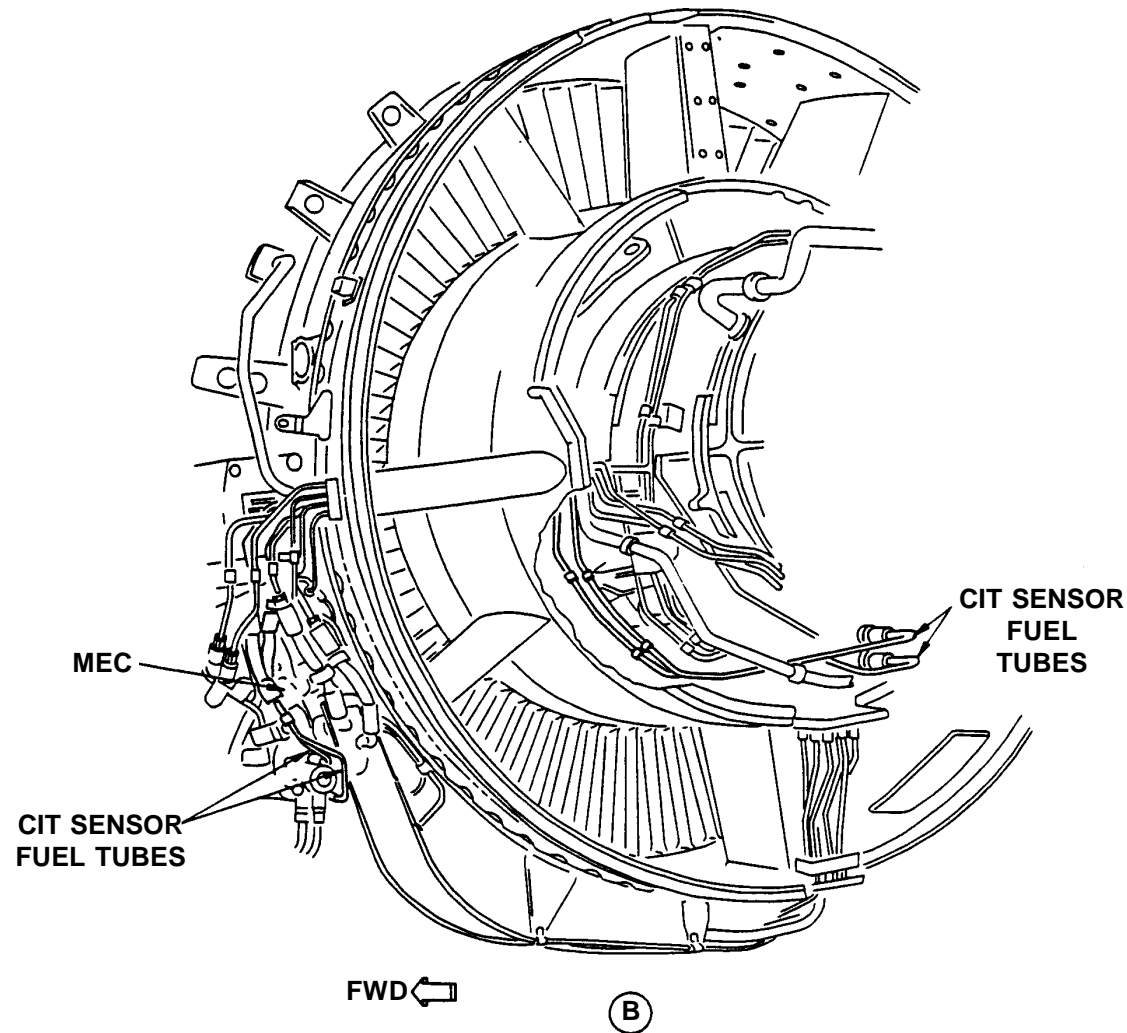
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## CIT SENSOR TUBING CHECK

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**TEST NO. 3 - LEAK CHECK - IDLE POWER****Maintenance Tasks**

Examine T<sub>2.0</sub> sensor element for damage or obstruction.

Examine the following:

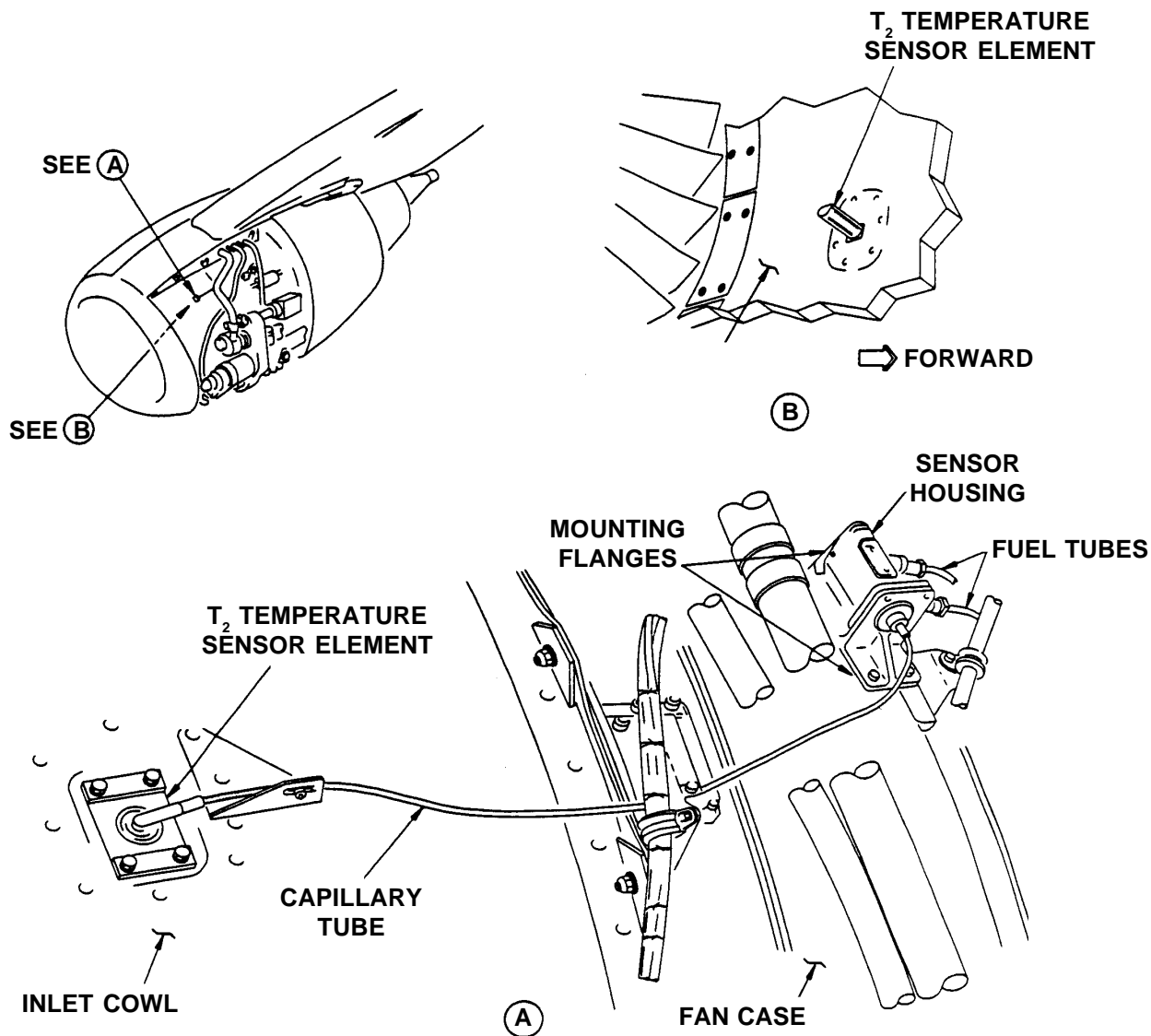
- Sensor housing for cracks, nicks, dents, and scratches.
- Mounting flanges for cracks, bending, and distortion.
- Capillary tube for kinks or breakage.
- Fuel tubes for leaks.

Refer to 73-21-09 I/C for serviceable limits and corrective action.

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## T<sub>2</sub> TEMPERATURE SENSOR CHECK

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## TEST NO. 4 - IDLE SPEED CHECK

### **Purpose (3.B.a)**

The idle speed check makes sure that the %N<sub>2</sub> RPM is within the limits at both low and high idle.

### **Maintenance Tasks (3.E.a)**

If it is necessary, adjustments to the low or high idle are made with the engine static on the MEC.

To get access to the adjustment for the high idle, you must remove the adjustment for the low idle.

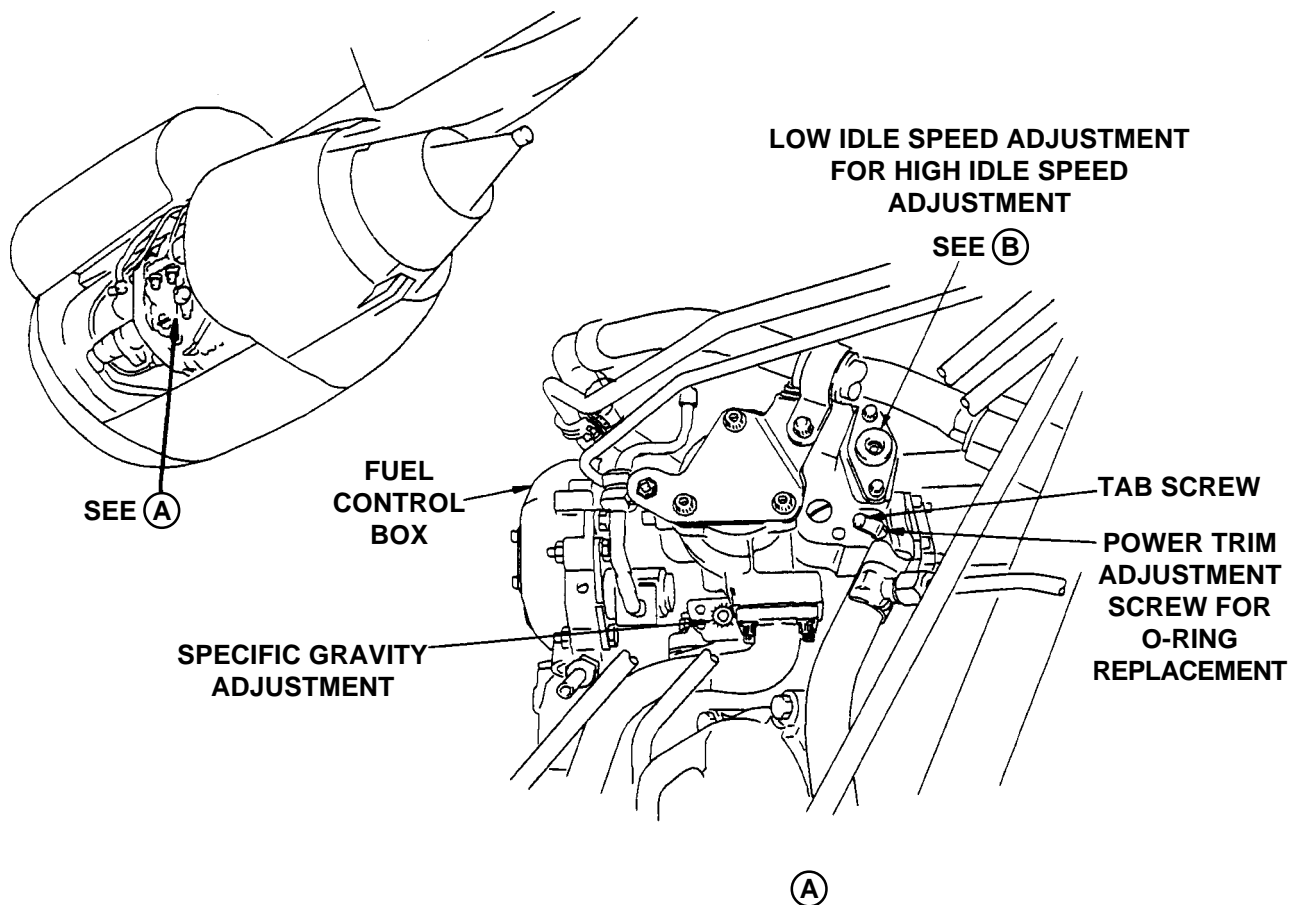
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## SPECIFIC GRAVITY, LOW IDLE AND HIGH IDLE, AND POWER TRIM ADJUSTMENTS

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## TEST NO. 4 - IDLE SPEED CHECK

### Maintenance Tasks

The following is a summary of the low idle speed check.

- Record the ambient air temperature (outside air temperature [OAT]) and barometric pressure.
- Start the engine (reference 71-00-00/201).
- Make sure that all of the bleed air and electrical loads are off.
- Let the engine operation become stable at the low idle.
- Make sure that the %N<sub>2</sub> RPM stays in the limits for the OAT and barometric pressure.

Specific MEC part numbers require that no adjustments be made to low idle at temperatures of 40°F (4°C) or below or 16°F (-9°C) or below. A low idle adjustment below these temperatures can cause an incorrect low idle speed schedule. The idle RPM is controlled by a governor in the MEC that is not adjustable (not by the engine low idle speed schedule). Do a check of the low idle speed, when it is possible, at a higher OAT than these temperatures (reference 71-00-00 adjust/test for more specific information).

If the %N<sub>2</sub> RPM stays in the limits, continue to the high idle check.

If the %N<sub>2</sub> RPM does not stay in the limits, adjust the low idle.

### EFFECTIVITY

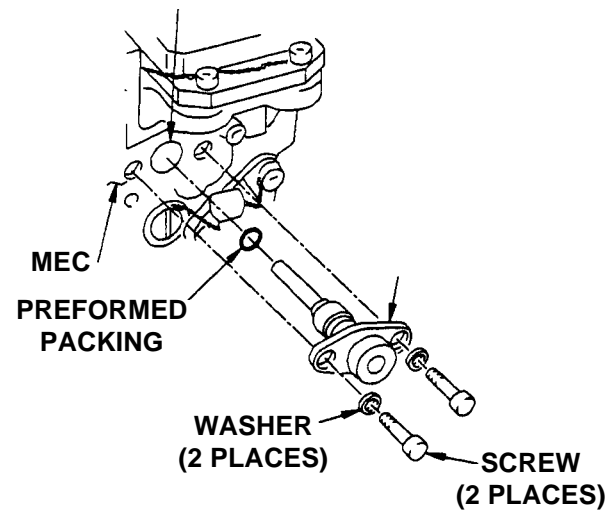
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**HIGH IDLE SPEED  
ADJUSTMENT (INSIDE PORT)**



(B)

**LOW IDLE AND HIGH IDLE ADJUSTMENTS**

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## TEST NO. 4 - IDLE SPEED CHECK

### Maintenance Tasks

The following is a summary of the high idle speed check.

- With the engine at the low idle (no airbleeds or electrical loads), open the IDLE CONT circuit breaker (flight idle solenoid) on the circuit breaker panel, P6.
- Make sure that the %N<sub>2</sub> RPM increases approximately 10% and becomes stable at the target %N<sub>2</sub> RPM.
- If the %N<sub>2</sub> RPM is not in the limits, adjust the high idle.

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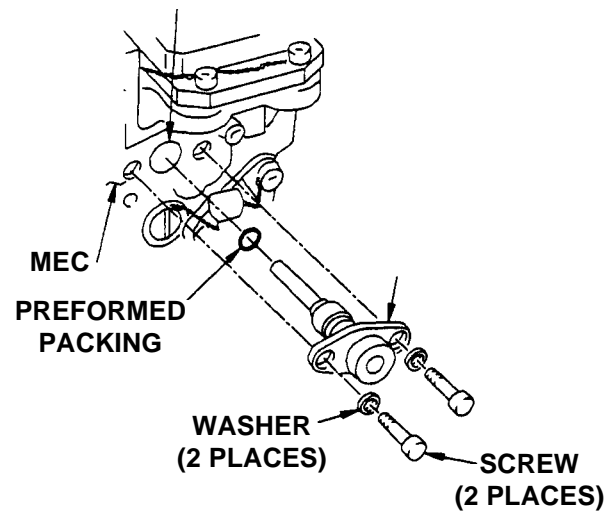
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**HIGH IDLE SPEED  
ADJUSTMENT (INSIDE PORT)**



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**LOW IDLE AND HIGH IDLE ADJUSTMENTS**

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## TEST NO. 5 - POWER ASSURANCE CHECK

### **Purpose (3.B.a)**

The power assurance check is a good test for the performance analysis of the engine. The check should not be used by itself for the acceptance or rejection of an engine.

This procedure may be used as a functional test to determine the general condition of an engine and as a diagnostic for troubleshooting. This test gives an indication of the engine ability to produce the necessary T/O power within the EGT and  $N_2$  limits during a full rated T/O on a hot day (corner point) environment.

### **Maintenance Tasks (3.E.a)**

When you do this test as specified after maintenance, you must include a T/O power check to make sure the engine and system are serviceable.

If you do Test No. 8 (Accel/Decel Check) after this test, it is not necessary to do the T/O power check.

The corrected fan speed used for the maximum thrust rating is indicated in the chart below.

See the MPA tables in the Boeing 737 maintenance manual for the corrected fan speeds of 80%  $N_1$ , 85%  $N_1$ , 90%  $N_1$ . The 90%  $N_1$  table where  $N_1$  is above the corner point (30°C OAT) has been reduced to hold constant

EGT and  $N_1$  below CFM56-3-B1 T/O power.

You can use one of the three MPA fan speeds, however do not exceed the engine operational limits, make sure to use the correct thrust rating, and think of the operating thrust and the environment for the MPA fan speed you use.

Use the power assurance check examples given in the maintenance manual to assist in calculating the EGT and  $N_2$  margins.

There may be adjustments to the EGT and  $N_2$  margins for engines equipped with a HPTCC timer, as well as altitude and thrust level.

The power assurance check includes a T/O power check.

If you wish to do a T/O power check only, use the maintenance manual procedure for the T/O power check.

It is recommended that you do Test No. 6 (MEC Trim) before you do the MPA and/or T/O power check for these reasons:

- The MEC has not been trimmed.
- Faulty engine trim is suspected.

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MAXIMUM THRUST POUNDS	SEA LEVEL MAXIMUM CORRECTED *FAN SPEED (%N <sub>1</sub> K)
18,500	88.3
20,000	90.4
22,000	93.7
23,500	95.3

\* From Boeing data, T/O power level, aircraft auto, PMC ON, standard day

## MAXIMUM THRUST RATINGS

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**TEST NO. 5 - POWER ASSURANCE CHECK****Maintenance Tasks**

The following is a summary of the steps required to do a power assurance test. Refer to the Boeing 737 maintenance manual for more specific information.

- Record the ambient air temperature (outside air temperature [OAT]) and barometric pressure.
- Find and make a record of these values for the current OAT on the MPA table you use.
  - The %N<sub>1</sub> target
  - The maximum EGT
  - The maximum N<sub>2</sub>
- Crosswinds may have an effect on the engine operation and cause the data to be less accurate. If it is possible, park the airplane such that it is pointed into the wind.
- On engines with the HPTCC timer, make sure you deactivate the HPTCC timer (reference 75-24-02/201). If you do not do this procedure, you can get unsatisfactory HPT blade clearances.

You must do this procedure before each high power test (N<sub>2</sub> RPM more than 94%) or series of engine tests (including both idle and high power tests). The

timer sets itself at each engine shutdown if it was activated in the previous test.

- Start the engine and let it become stable for five minutes at low idle. (reference 71-00-00/201).
- Make sure that all the bleed air and electrical loads are off.
- Make sure the engine indications are in the correct ranges.
- Make sure the applicable PMC switch is in the ON position, and the PMC INOP light is off.

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## TEST NO. 5 - POWER ASSURANCE CHECK

### MPA TEST TABLE - 90%N<sub>1</sub> CORRECTED FAN SPEED

[\*] Above 86°F (30°C), N<sub>1</sub> is decreased to keep EGT constant.

OAT		%N <sub>1</sub>	Maximum EGT - °C				Maximum %N <sub>2</sub>		
			Target	Thrust Rating - Pounds			Engine Model		
°F	(°C)	±0.5%	18.5K	20K	22K	23.5K	-3-B1	-3B-2	-3C-1
28	(-2)	87.5	812	788	748	745	95.9	95.3	94.6
30	(-1)	87.6	816	792	751	748	96.1	95.5	94.8
32	(0)	87.8	819	796	755	752	96.2	95.6	94.9
34	(1)	87.9	823	799	758	755	96.4	95.8	95.1
36	(2)	88.1	827	803	761	759	96.6	96.0	95.3
37	(3)	88.2	830	806	765	762	96.7	96.1	95.5
39	(4)	88.4	834	810	768	765	96.9	96.3	95.6
41	(5)	88.5	838	813	772	769	97.0	96.4	95.8
43	(6)	88.7	841	817	775	772	97.2	96.6	95.9
45	(7)	88.9	845	820	779	776	97.3	96.7	96.0
46	(8)	89.0	848	824	782	779	97.5	96.9	96.2
48	(9)	89.1	852	828	785	782	97.7	97.0	96.3
50	(10)	89.3	856	831	789	786	97.8	97.2	96.5
52	(11)	89.5	859	835	792	789	98.0	97.4	96.7
54	(12)	89.6	863	838	796	793	98.1	97.5	96.8
55	(13)	89.7	867	842	799	796	98.3	97.7	97.0
57	(14)	89.9	870	845	802	799	98.4	97.8	97.1
59	(15)	90.0	874	849	806	803	98.6	98.0	97.3
61	(16)	90.1	877	852	809	806	98.7	98.1	97.4
63	(17)	90.3	881	856	813	810	98.9	98.3	97.6
64	(18)	90.4	885	859	816	813	99.0	98.4	97.7
66	(19)	90.6	888	863	819	816	99.2	98.6	97.9
68	(20)	90.7	892	867	823	820	99.3	98.7	98.0
70	(21)	90.9	896	870	826	823	99.5	98.9	98.2
72	(22)	91.0	899	874	830	827	99.7	99.0	98.3
73	(23)	91.2	903	877	833	830	99.8	99.2	98.5
75	(24)	91.3	906	881	836	833	100.0	99.3	98.6
77	(25)	91.5	910	884	840	837	100.1	99.5	98.8
79	(26)	91.6	914	888	843	840	100.3	99.6	98.9
81	(27)	91.7	917	891	847	844	100.4	99.8	99.1
82	(28)	91.9	921	895	850	847	100.6	99.9	99.2
84	(29)	92.0	924	898	853	850	100.7	100.1	99.4
86	(30)	92.2	928	902	857	854	100.9	100.2	99.5
88	(31)	92.1	928	902	857	854	100.9	100.2	99.5
90	(32)	91.9	928	902	857	854	100.9	100.2	99.5
91	(33)	91.8	928	902	857	854	100.9	100.2	99.5
93	(34)	91.7	928	902	857	854	100.9	100.2	99.6
95	(35)	91.5	928	902	857	854	100.9	100.2	99.6

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## TEST NO. 5 - POWER ASSURANCE CHECK

### Maintenance Tasks

- Move the forward thrust lever to the applicable power position ( $N_1$  target) as found in the maintenance manual charts. The tolerance is  $\pm 0.5\%N_1$ .
- Let the engine become stable without throttle adjustments for a minimum of four minutes.
- Make a record of the  $N_1$ ,  $N_2$  and EGT.
- Slowly move the forward thrust lever to the idle position.

If the  $N_1$  record is different from the  $N_1$  target by more than  $\pm 0.5\%N_1$  tolerance, the test point should be done again.

Find if there is a positive or negative difference between the  $N_1$  target and  $N_1$  record.

- If the  $N_1$  target is more than the  $N_1$  record, there is a positive (+) difference.
- If the  $N_1$  target is less than the  $N_1$  record, there is a negative (-) difference.

Adjust the EGT and  $N_2$  records using the difference

between the  $N_1$  target and the  $N_1$  record that you found.

For each  $0.1\%N_1$  positive difference ( $N_1$  target more than  $N_1$  record)

- Add  $1.0^\circ\text{C}$  to the EGT record to get EGT adjustment.
- Add  $0.045\%$  to the  $N_2$  record to get  $N_2$  adjustment.

For each  $0.1\%N_1$  negative difference ( $N_1$  target less than  $N_1$  record)

- Subtract  $1.0^\circ\text{C}$  from the EGT record to get EGT adjustment.
- Subtract  $0.045\%$  from the  $N_2$  record to get  $N_2$  adjustment.

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TEMPERATURE	N <sub>1</sub> TARGET	N <sub>1</sub> RECORDED	DIFFERENCE	EGT CORRECTION	N <sub>2</sub> CORRECTION
61° F (16° C)	90.1	89.8	+.3	1.0° C * 3 = +3.0° C	0.045% * 3 = +.135
82° F (28° C)	91.9	92.0	-.1	1.0° C * 1 = -1.0° C	0.045% * 1 = -.045

## EGT AND N2 ADJUSTMENTS

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## TEST NO. 5 - POWER ASSURANCE CHECK

### Maintenance Tasks

To find the  $N_2$  and EGT margins do the following:

- $N_2$  margin =  $N_2$  maximum -  $N_2$  adjustment
- EGT margin = EGT maximum - EGT adjustment

Adjust the EGT and  $N_2$  margins for these effects:

- On engines equipped with a HPTCC Timer operated at 22,000 pounds thrust or less, increase the EGT margin by 17°C.
- On engines with ratings of 20,000 pounds thrust or less that operate at an altitude of 4000 feet or above, decrease the EGT margin by 44°C.
- If an engine is operated with a rerated thrust use the table to find the adjustment for  $N_2$ .

If the EGT or  $N_2$  margins are more than the maximum limits:

- shutdown the engine and troubleshoot for cause.
- Do a check of the  $N_2$  (ref. 77-12-00/501) and/or the EGT (ref. 77-21-00/501) indication system.
- Do a borescope inspection of the engine (reference 71-00-00/601).

- Correct the problems you find, and repeat the MPA test.

If the initial MPA test was done under cold engine conditions, a second test would be a more satisfactory indication of the engine condition.

Many conditions have an effect on the accuracy of the MPA test, thus the MPA test should not be used by itself for the acceptance or rejection of an engine.

If the power assurance check is specified as necessary for after maintenance, do the T/O power check.

- If no more tests or corrections are necessary, shutdown the engine and return the aircraft to normal configuration.

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Thrust Rating	CFM56-3-B1	CFM56-3-B2	CFM56-3C-1
20,000		+0.6%	+0.6%
18,500	+0.7%		+1.3%

## ADJUSTMENT FOR N<sub>2</sub>

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## TEST NO. 5 - POWER ASSURANCE CHECK

### Maintenance Tasks

The following is a summary of the steps required to do to do the T/O power check. Refer to the Boeing 737 maintenance manual for more specific information.

- If not already done, record the ambient air temperature (outside air temperature [OAT]) and barometric pressure.
- On engines with the HPTCC timer, make sure you deactivate the HPTCC timer (reference 75-24-02/201). If you do not do this procedure, you can get unsatisfactory HPT blade clearances.

You must do this procedure before each high power test ( $N_2$  RPM more than 94%) or series of engine tests (including both idle and high power tests). The timer sets itself at each engine shutdown if it was activated in the previous test.

- Start the engine and let it become stable for five minutes at low idle. (reference 71-00-00/201).
- Make sure that all the bleed air and electrical loads are off.
- Make sure the engine indications are in the correct ranges.

- Move the forward thrust lever to the static T/O  $N_1$ .
- Make sure the engine accelerates smoothly.
- Let the engine become stable and make sure the engine instrumentation indications are in the operation ranges.
- Move the forward thrust lever to the idle position.
- Make sure the engine decelerates smoothly and is stable at idle.
- If no more tests or corrections are necessary, shutdown the engine.

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**GRAPHIC TO BE DETERMINED**

## TEST NO. 6 - MEC TRIM

### Purpose (3.B.a)

This test gives the checks that you must do after a MEC replacement.

### Maintenance Tasks (3.E.a)

Do this test for the conditions that follow:

- If you think that you have incorrect engine trim
- The Power Plant Test Reference Table tells you to do this test after a component replacement.

This test gives the instructions for the specific gravity adjustment and the trim adjustment for part power.

It also includes the following checks:

- The travel check and the static rig check for the VSV and VBV feedback cable.
- The gain check of the PLA transducer.
- The travel test for the engine control system.
- The idle leak check.
- The idle speed check.
- The power assurance check (optional).
- The accel/decel check.

In the maintenance manual information for the specific gravity adjustment is in a different paragraph from the trim adjustment. This will help in tests where only the specific gravity adjustment is necessary.

Engine trim changes with the relative wind direction and velocity. Therefore, do not adjust it when the wind direction and velocity are more than limits stated in the Boeing 737 maintenance manual (reference 71-00-00/201).

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**A MEC TRIM CHECK INCLUDES THE FOLLOWING**

TRAVEL CHECK FOR VSV AND VBV FEEDBACK SYSTEMS

STATIC RIG CHECK FOR VSV AND VBV SYSTEMS

PLA GAIN CHECK

TRAVEL TEST FOR ENGINE CONTROL SYSTEM

IDLE LEAK CHECK (TEST NO. 3)

IDLE SPEED CHECK (TEST NO. 4)

POWER ASSURANCE CHECK (TEST NO. 5) - OPTIONAL

ACCEL/DECEL CHECK (TEST NO. 8)

**MEC TRIM CHECK**

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**TEST NO. 6 - MEC TRIM****Maintenance Tasks**

The following is a summary of the steps required to prepare for the MEC trim. Refer to the Boeing 737 maintenance manual for more specific information

- Make sure that the autothrottle PLA synchro is correct. Adjust it if it is necessary (reference 22-31-111/501).
- Make sure that the specific gravity position is correct.

Note: Use the specific gravity adjustment only to make the correct adjustment for the type of fuel. Do not adjust it to change or correct the engine performance for a different problem. Incorrect adjustment can cause unsatisfactory engine performance.

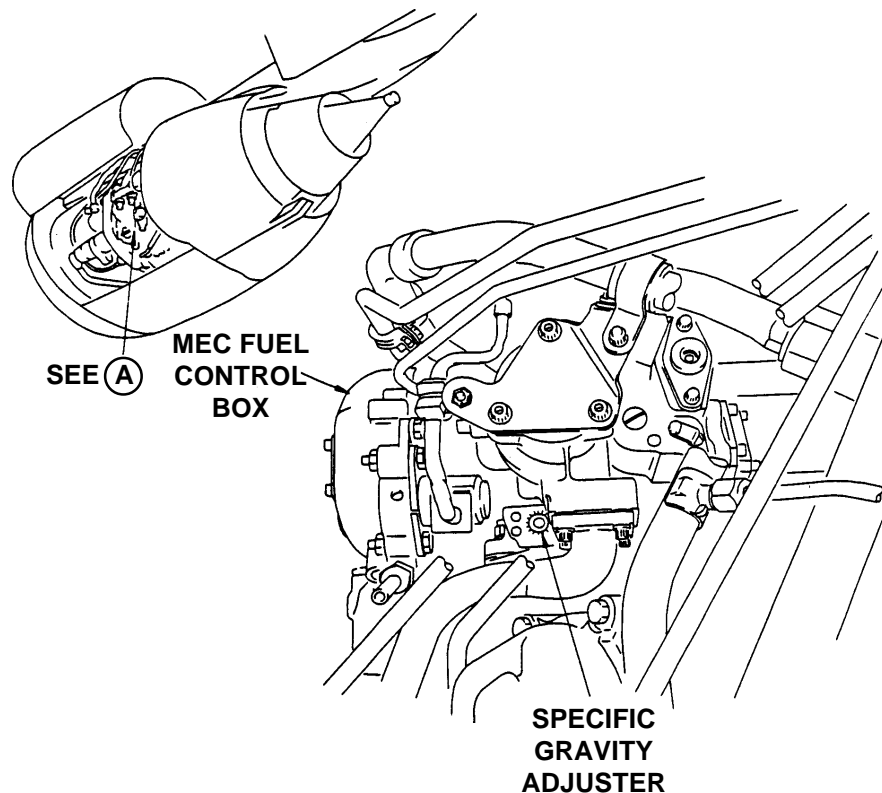
If you change to a different fuel type, you must change the specific gravity position on the MEC. On a flight leg with more than one type of fuel, no specific gravity adjustment of the MEC is necessary.

Make sure that the specific gravity position for the type of fuel agrees with the table.

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MAIN ENGINE CONTROL (MEC) - BOTTOM VIEW

(A)

FUEL	SPECIFIC GRAVITY SETTING
JET A, JET A1, JP-1, JP-5, JP-8	0.82
JET B, JP-4	0.77

**CAUTION:** SPECIFIC GRAVITY ADJUSTMENT IS ONLY TO ESTABLISH PROPER SETTING FOR TYPE OF FUEL BEING USED. DO NOT ADJUST SPECIFIC GRAVITY AS AN ATTEMPT TO CHANGE OR CORRECT ENGINE PERFORMANCE FOR ANY OTHER REASON.

## MEC SPECIFIC GRAVITY SETTING CHECK

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## TEST NO. 6 - MEC TRIM

### Maintenance Tasks

Viewing bottom of MEC, check setting of specific gravity adjuster, and compare to specification for fuel type.

- If required, adjust the specific gravity setting.
  - On engines with the HPTCC timer, make sure you deactivate the HPTCC timer (reference 75-24-02/201). If you do not do this procedure, you can get unsatisfactory HPT blade clearances.
- You must do this procedure before each high power test (N<sub>2</sub> RPM more than 94%) or series of engine tests (including both idle and high power tests). The timer sets itself at each engine shutdown if it was activated in the previous test.
- Do the travel check for the VSV feedback cable and the static rig check (reference 75-31-02/501).
  - Do the travel check for the VBV feedback cable and the static rig check (reference 75-32-05/501).
  - Make sure that the specific gravity position is correct. Adjust it if it is necessary.
  - Do the gain check of the PLA transducer (reference 73-21-00/501).

- Do the travel test for the engine control system (reference 76-11-00/501).
- Do the idle leak check (reference Test No. 3).
- Do the idle speed check (reference Test No. 4).

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**TEST NO. 6 - MEC TRIM****Maintenance Tasks**

The following is a summary of the steps required to do a Part power trim check:

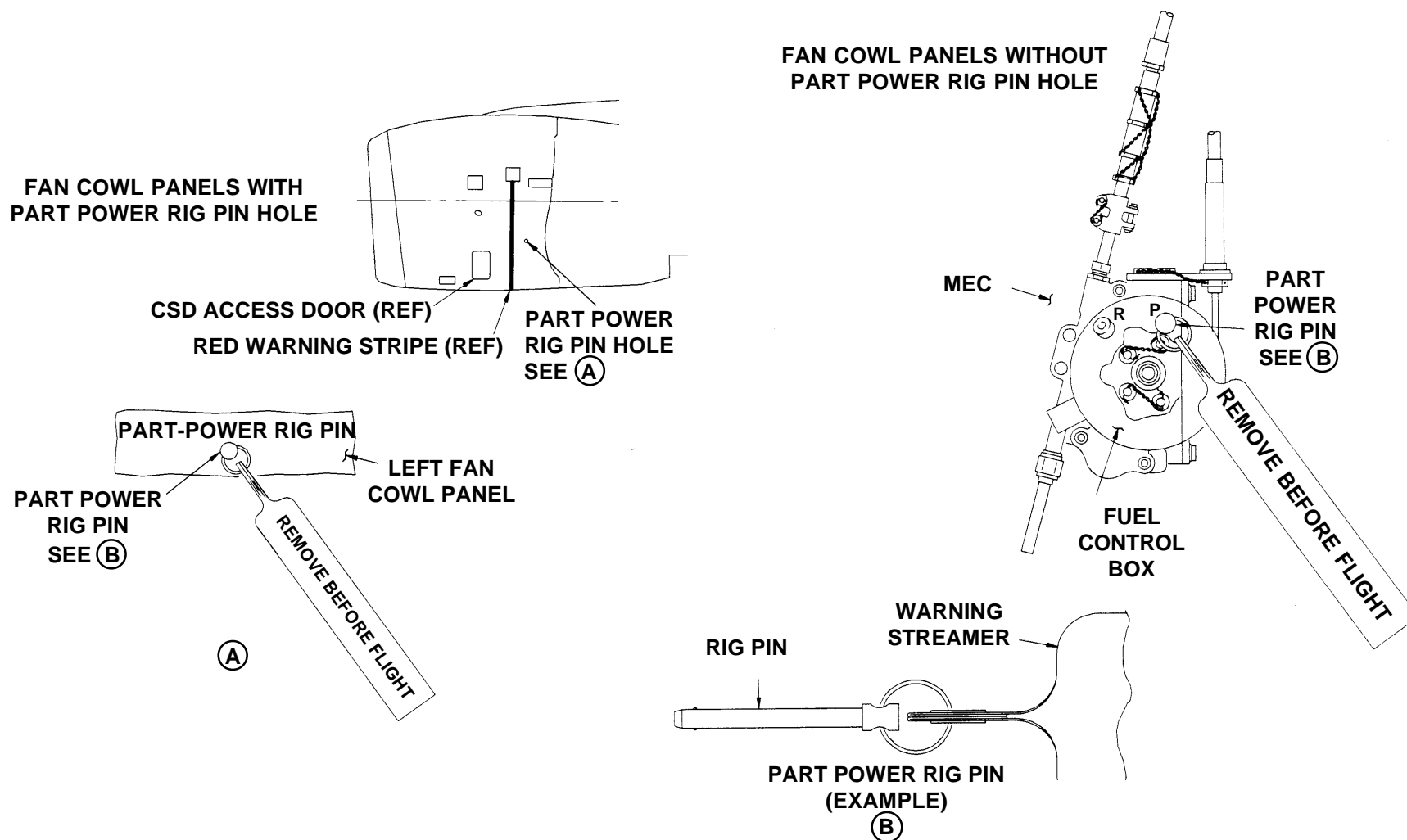
- Put the part power rig pin (C76001-2) through the part power rig pin hole. The rig pin hole aligns with the hole marked "P" at the fuel control box this position relates to 92.5° PLA. There are two possible installation methods ( cowl closed or cowl open).
- Record the ambient air temperature (outside air temperature [OAT]) and barometric pressure.
- Start the engine and let it become stable for five minutes at low idle. (reference 71-00-00/201).
- Make sure that all the bleed air and electrical loads are off.
- Make sure the engine indications are in the correct ranges.
- Make sure the applicable PMC switch is in the ON position, and the PMC INOP light is off.
- Move the forward thrust lever against the part power stop (92.5° PLA).

- Let the engine become stable for a minimum of one minute.
- Make sure that the %N<sub>2</sub> RPM is in the limits for the current OAT and barometric pressure.

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## PART POWER RIG PIN INSTALLATION

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## TEST NO. 6 - MEC TRIM

### Maintenance Tasks

- Look at the PART POWER (P-P) PMC OFF ( $\%N_2$ ) trim data listed in the maintenance manual (reference 71-00-01/201).

Note: There are numerous trim table configurations. The Boeing 737 maintenance manual may or may not contain all of these configurations. To avoid looking up incorrect data insure that the effectivity block of the trim table matches the configuration of the engine you are testing

- Make sure that the MEC power trim is  $\pm 0.5\%$   $\%N_2$  of the  $\%N_2$  trim target.

If it is necessary, do an engine shutdown and adjust the MEC power trim.

Note: Adjust the MEC power trim to  $\pm 0.5\%$   $\%N_2$  of the  $\%N_2$  trim target. One full turn is approximately equal to a 1.2% change in the  $N_2$  RPM, clockwise to increase RPM, counterclockwise to decrease RPM.

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OAT °F (°C)	POWER SETTING	BAROMETER (INCHES OF MERCURY)									
		31.0	30.5	30.0	29.5	29.0	28.5	28.0	27.5	27.0	26.5
<b>60</b> (16)	LOW IDLE (%N2)	60.8	60.8	60.8	60.9	61.0	61.1	61.2	61.3	61.4	61.5
	HIGH IDLE (%N2)	69.9	69.9	69.9	70.0	70.2	70.3	70.5	70.6	70.7	70.8
	<b>P-P PMC OFF (%N2)</b>	88.9	89.1	<b>89.3</b>	89.5	89.7	89.9	90.1	90.3	90.4	90.6
	P-P PMC ON (%N1)	71.9	72.1	72.4	72.7	73.0	73.2	73.5	73.8	74.1	74.3
	STATIC T.O. PMC ON/OFF (%N1)	90.5	90.9	91.3	91.7	92.1	92.4	92.8	93.3	93.7	94.3
	ACCEL CHECK TARGET (%N1)	88.6	89.1	89.5	90.0	90.4	90.8	91.2	91.6	92.1	92.6
62 (17)	LOW IDLE (%N2)	60.9	60.9	60.9	61.0	61.1	61.2	61.3	61.4	61.5	61.6
	HIGH IDLE (%N2)	70.0	70.0	70.0	70.1	70.3	70.5	70.6	70.8	70.9	71.0
	P-P PMC OFF (%N2)	89.1	89.3	89.5	89.7	89.9	90.1	90.3	90.4	90.6	90.8
	P-P PMC ON (%N1)	72.0	72.3	72.6	72.8	73.1	73.4	73.7	73.9	74.2	74.5
	STATIC T.O. PMC ON/OFF (%N1)	90.6	91.1	91.5	91.9	92.3	92.6	93.0	93.4	93.9	94.5
	ACCEL CHECK TARGET (%N1)	88.8	89.3	89.7	90.1	90.6	91.0	91.4	91.8	92.2	92.8
64 (18)	LOW IDLE (%N2)	61.0	61.0	61.0	61.1	61.2	61.3	61.4	61.6	61.7	61.8
	HIGH IDLE (%N2)	70.2	70.2	70.2	70.3	70.4	70.6	70.8	70.9	71.0	71.1
	P-P PMC OFF (%N2)	89.2	89.5	89.7	89.9	90.1	90.3	90.5	90.6	90.9	90.9
	P-P PMC ON (%N1)	72.2	72.4	72.7	73.0	73.3	73.5	73.8	74.1	74.3	74.6

### PART POWER TRIM CHART - PMC OFF

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## TEST NO. 6 - MEC TRIM

### Maintenance Tasks

- With the engine stable at the %N<sub>2</sub> RPM target, push the PMC switch to the ON position. Make sure that the PMC INOP light goes out.
- Let the engine become stable for a minimum of two minutes.
- Make sure that the %N<sub>2</sub> RPM is in the limits for the current OAT and barometric pressure.
- Look at the PART POWER (P-P) PMC ON (%N<sub>1</sub>) trim data listed in the maintenance manual (reference 71-00-01/201).

Note: If the %N<sub>1</sub> RPM is not in the limits, start the troubleshooting (reference 71-00-42/101) for a possible PMC malfunction.

- Do the power assurance check (reference Test No. 5) (performance of this check is optional).
- Do the accel/decel check (reference Test No. 8).

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OAT °F (°C)	POWER SETTING	BAROMETER (INCHES OF MERCURY)									
		31.0	30.5	30.0	29.5	29.0	28.5	28.0	27.5	27.0	26.5
60 (16)	LOW IDLE (%N2)	60.8	60.8	60.8	60.9	61.0	61.1	61.2	61.3	61.4	61.5
	HIGH IDLE (%N2)	69.9	69.9	69.9	70.0	70.2	70.3	70.5	70.6	70.7	70.8
	P-P PMC OFF (%N2)	88.9	89.1	89.3	89.5	89.7	89.9	90.1	90.3	90.4	90.6
	<b>P-P PMC ON (%N1)</b>	71.9	72.1	<b>72.4</b>	72.7	73.0	73.2	73.5	73.8	74.1	74.3
	STATIC T.O. PMC ON/OFF (%N1)	90.5	90.9	91.3	91.7	92.1	92.4	92.8	93.3	93.7	94.3
	ACCEL CHECK TARGET (%N1)	88.6	89.1	89.5	90.0	90.4	90.8	91.2	91.6	92.1	92.6
62 (17)	LOW IDLE (%N2)	60.9	60.9	60.9	61.0	61.1	61.2	61.3	61.4	61.5	61.6
	HIGH IDLE (%N2)	70.0	70.0	70.0	70.1	70.3	70.5	70.6	70.8	70.9	71.0
	P-P PMC OFF (%N2)	89.1	89.3	89.5	89.7	89.9	90.1	90.3	90.4	90.6	90.8
	P-P PMC ON (%N1)	72.0	72.3	72.6	72.8	73.1	73.4	73.7	73.9	74.2	74.5
	STATIC T.O. PMC ON/OFF (%N1)	90.6	91.1	91.5	91.9	92.3	92.6	93.0	93.4	93.9	94.5
	ACCEL CHECK TARGET (%N1)	88.8	89.3	89.7	90.1	90.6	91.0	91.4	91.8	92.2	92.8
64 (18)	LOW IDLE (%N2)	61.0	61.0	61.0	61.1	61.2	61.3	61.4	61.6	61.7	61.8
	HIGH IDLE (%N2)	70.2	70.2	70.2	70.3	70.4	70.6	70.8	70.9	71.0	71.1
	P-P PMC OFF (%N2)	89.2	89.5	89.7	89.9	90.1	90.3	90.5	90.6	90.9	90.9
	P-P PMC ON (%N1)	72.2	72.4	72.7	73.0	73.3	73.5	73.8	74.1	74.3	74.6

### PART POWER TRIM CHART - PMC ON

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## TEST NO. 7 - VIBRATION SURVEY

### **Purpose (3.B.a)**

This test gives the necessary data to make sure that the engine vibration stays within permitted levels.

### **Maintenance Tasks (3.E.a)**

This test is applied after a component replacement as it is specified in the Power Plant Test Reference Table.

Use the vibration survey with the troubleshooting.

If the vibration levels are above the permitted levels, install the test equipment to isolate the source of the vibration.

Note: If the test equipment is not available, maximum engine vibration levels can be determined by interrogating the AVM history data.

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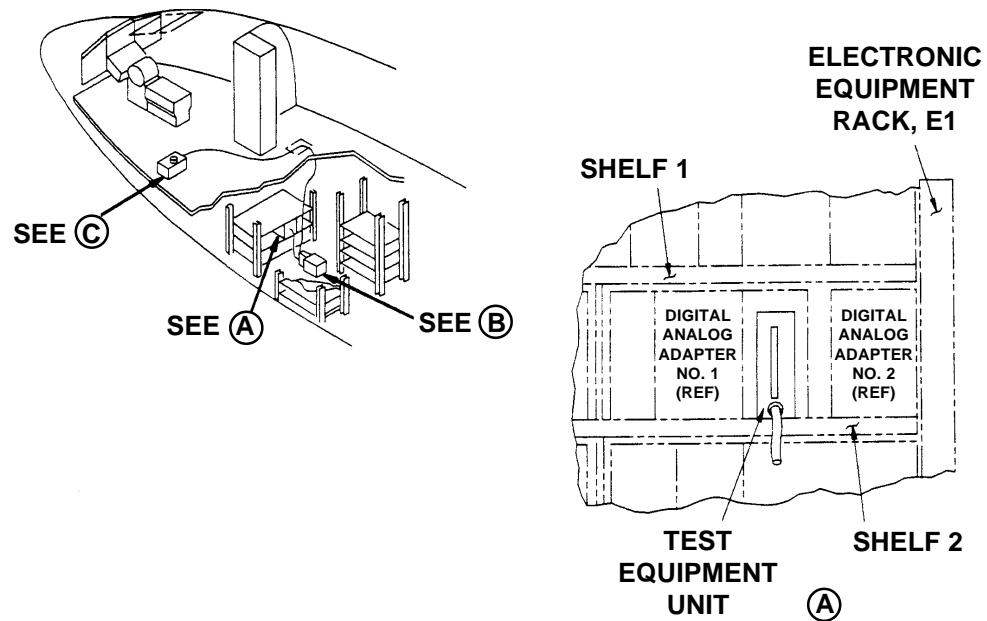
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## ENGINE VIBRATION ISOLATION TEST EQUIPMENT

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## TEST NO. 7 - VIBRATION SURVEY

### Maintenance Tasks

The following is a summary of the steps required to do a vibration survey. Refer to the Boeing 737 maintenance manual for more specific information.

- On engines with the HPTCC timer, make sure you deactivate the HPTCC timer (reference 75-24-02/201). If you do not do this procedure, you can get unsatisfactory HPT blade clearances.

You must do this procedure before each high power test ( $N_2$  RPM more than 94%) or series of engine tests (including both idle and high power tests). The timer sets itself at each engine shutdown if it was activated in the previous test.

Note: Operate the CFM56-3-B1 engines at CFM56-3B-2 power positions in this procedure only. The continuous operation of the CFM56-3-B1 engines at the CFM56-3B-2 T/O power positions will cause engine performance deterioration.

- Record the ambient air temperature (outside air temperature [OAT]) and barometric pressure.
- Find and make a record of the T/O power position for the current OAT and barometric pressure.
- Using the appropriate table lookup the STATIC T/O

PMC ON/OFF trim data (reference 71-00-01/201).

- If it is available, install the test equipment for the engine vibration isolation.
- Start the engine and let it become stable for two minutes at low idle. (reference 71-00-00/201).
- Make sure that all the bleed air and electrical loads are off.
- Make sure the engine indications are in the correct ranges.
- Move the forward thrust lever (within 20 to 30 seconds) to the  $80 \pm 2 \% N_1$  RPM.
- Let the engine become stable for a minimum of seven minutes (this allows thermal stabilization of the engine and ensures accurate vibration readings).
- Move the forward thrust lever (within 20 to 30 seconds) to the idle position.
- Let the engine become stable at the low idle for a minimum of 30 seconds.

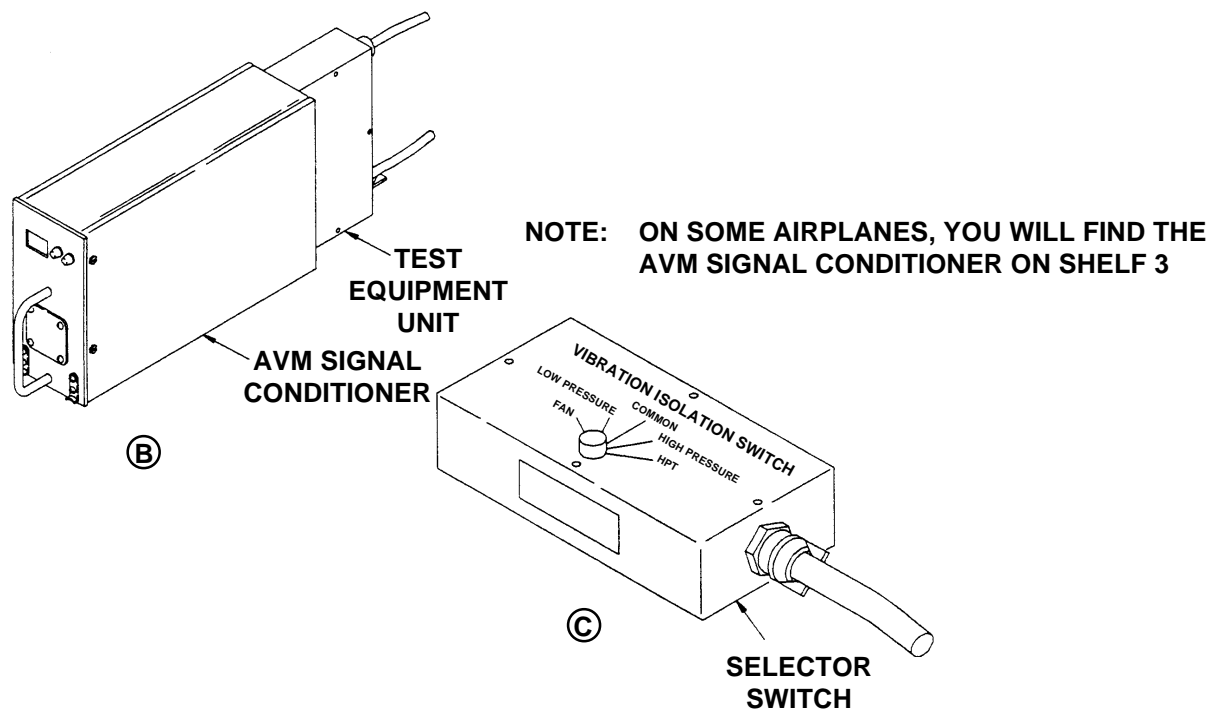
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## ENGINE VIBRATION ISOLATION TEST EQUIPMENT

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## TEST NO. 7 - VIBRATION SURVEY

### Maintenance Tasks

- Slowly move the forward thrust lever (at a constant rate, that takes approximately two minutes to accelerate) from the stable idle to the static T/O power position in your records.

Note: The rate of the acceleration/deceleration must be sufficiently slow (approximately two minutes) for you to find a vibration maximum.

- Monitoring the applicable engine VIBRATION indicator make a record of the  $N_1$  and  $N_2\%$  RPM, where vibration maximums occur.
- Let the engine become stable at the static T/O power position for 30 seconds.
- Slowly move the forward thrust lever (at a constant rate, that takes approximately two minutes to decelerate) from the stable static T/O power position to the low idle.
- Again monitoring the applicable engine VIBRATION indicator make a record of the  $N_1$  and  $N_2\%$  RPM, where vibration peaks occur.
- Let the engine become stable at the low idle.

- Increase the engine speed to the % RPM where you found the highest engine vibration.
- Let the engine become stable for two minutes at each point (if more than one).
- Make a record of all of the high vibration points that you found during the engine acceleration.

On Aircraft systems using AVM S360N021-100/-201 a mean vibration reading of less than 2.5 units is acceptable. For all other AVM systems a mean vibration reading of less than 3.0 units is acceptable.

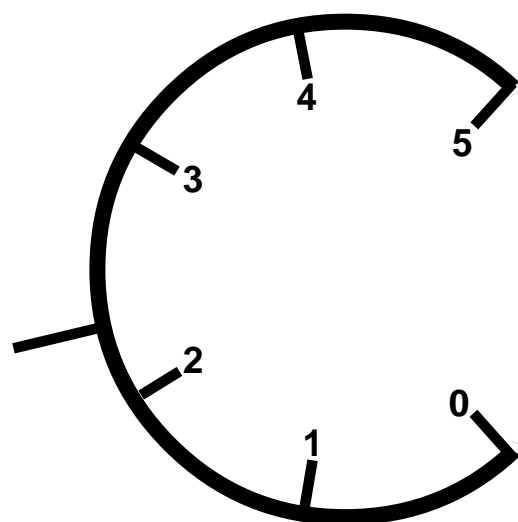
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# VIBRATION INDICATOR

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## TEST NO. 7 - VIBRATION SURVEY

### Maintenance Tasks

To determine the source of the vibration do the following:

- Turn the selector switch on the isolation test equipment to find the source of the vibration indications above the limits.
- You can also examine the history data in the AVM signal conditioner. You will find the AVM signal conditioner in the EE bay area (reference 77-31-00/201).

Do the test again for all of the high vibration points that you found (if there are more than one) during the engine acceleration.

Do a dynamic fan rotor trim balance (reference 72-31-00/501), if you find that one of the following conditions is the source of the high vibration:

- The high vibration is in the  $N_1$  rotor only (FAN and/or LPT).
- The high vibration is in the  $N_1$  rotor (FAN and/or LPT) and the  $N_2$  rotor (HPC and HPT).
- If you find the high vibrations only in the  $N_2$  rotor (HPC and/or HPT) and they are more than 3.0 units, then replace the engine (reference 71-00-02/401).

- If no more tests or corrections are necessary, shutdown the engine and return the aircraft to normal configuration.
- If you installed it, remove the test equipment for the engine vibration isolation.

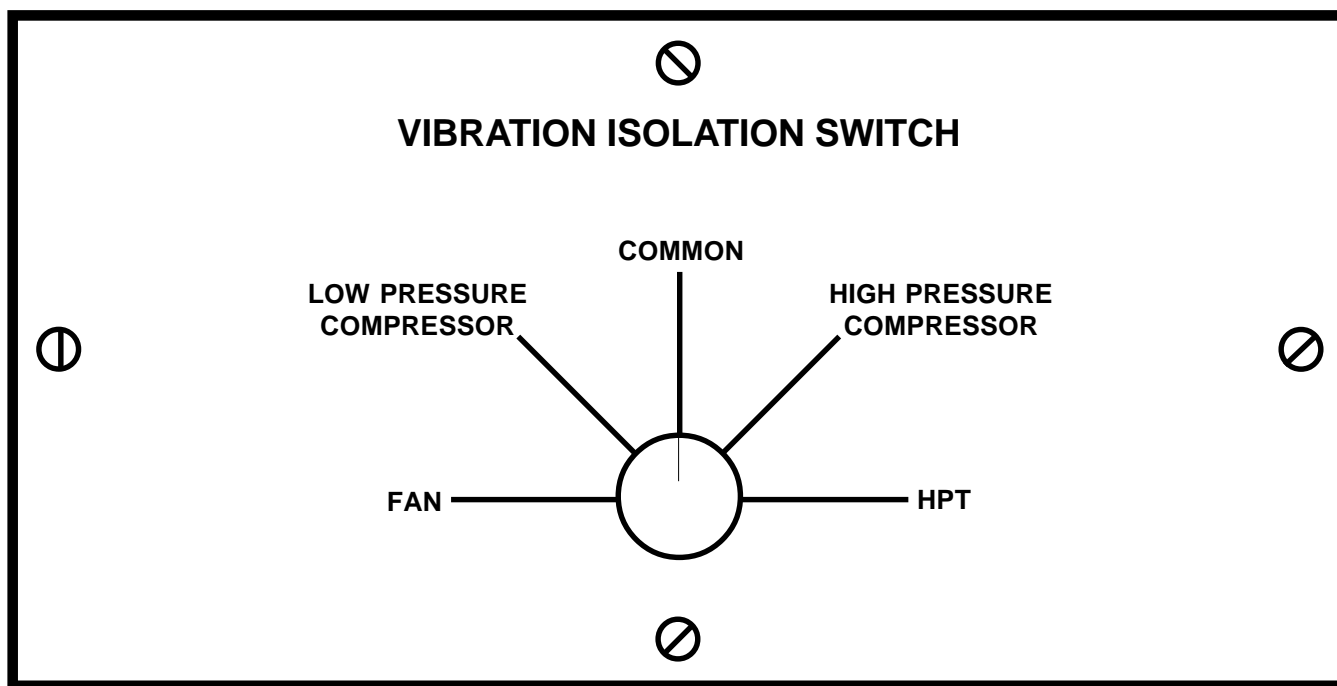
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## VIBRATION ISOLATION

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## TEST NO. 8 - ACCEL/DECEL CHECK

### **Purpose (3.B.a)**

This procedure makes sure of a smooth accel/decel operation with no stalls or flameouts.

### **Maintenance Tasks (3.E.a)**

You will do the check first with the PMC on, and then with the PMC off.

The following is a summary of the steps required to do an accel/decel check. Refer to the Boeing 737 maintenance manual for more specific information.

- On engines with the HPTCC timer, make sure you deactivate the HPTCC timer (reference 75-24-02/201). If you do not do this procedure, you can get unsatisfactory HPT blade clearances.

You must do this procedure before each high power test ( $N_2$  RPM more than 94%) or series of engine tests (including both idle and high power tests). The timer sets itself at each engine shutdown if it was activated in the previous test.

- Record the ambient air temperature (outside air temperature [OAT]) and barometric pressure.

Using the current OAT, barometric pressure, and the appropriate trim table from the Boeing 737 maintenance manual, find and make a record of the following:

- STATIC T/O PMC ON/OFF  $N_1$
- ACCEL CHECK TARGET  $N_1$

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OAT °F (°C)	POWER SETTING	BAROMETER (INCHES OF MERCURY)									
		31.0	30.5	30.0	29.5	29.0	28.5	28.0	27.5	27.0	26.5
<b>60</b> (16)	LOW IDLE (%N2)	60.8	60.8	60.8	60.9	61.0	61.1	61.2	61.3	61.4	61.5
	HIGH IDLE (%N2)	69.9	69.9	69.9	70.0	70.2	70.3	70.5	70.6	70.7	70.8
	P-P PMC OFF (%N2)	88.9	89.1	89.3	89.5	89.7	89.9	90.1	90.3	90.4	90.6
	P-P PMC ON (%N1)	71.9	72.1	72.4	72.7	73.0	73.2	73.5	73.8	74.1	74.3
	<b>STATIC T.O. PMC ON/OFF (%N1)</b>	90.5	90.9	<b>91.3</b>	91.7	92.1	92.4	92.8	93.3	93.7	94.3
	<b>ACCEL CHECK TARGET (%N1)</b>	88.6	89.1	<b>89.5</b>	90.0	90.4	90.8	91.2	91.6	92.1	92.6
62 (17)	LOW IDLE (%N2)	60.9	60.9	60.9	61.0	61.1	61.2	61.3	61.4	61.5	61.6
	HIGH IDLE (%N2)	70.0	70.0	70.0	70.1	70.3	70.5	70.6	70.8	70.9	71.0
	P-P PMC OFF (%N2)	89.1	89.3	89.5	89.7	89.9	90.1	90.3	90.4	90.6	90.8
	P-P PMC ON (%N1)	72.0	72.3	72.6	72.8	73.1	73.4	73.7	73.9	74.2	74.5
	STATIC T.O. PMC ON/OFF (%N1)	90.6	91.1	91.5	91.9	92.3	92.6	93.0	93.4	93.9	94.5
	ACCEL CHECK TARGET (%N1)	88.8	89.3	89.7	90.1	90.6	91.0	91.4	91.8	92.2	92.8
64 (18)	LOW IDLE (%N2)	61.0	61.0	61.0	61.1	61.2	61.3	61.4	61.6	61.7	61.8
	HIGH IDLE (%N2)	70.2	70.2	70.2	70.3	70.4	70.6	70.8	70.9	71.0	71.1
	P-P PMC OFF (%N2)	89.2	89.5	89.7	89.9	90.1	90.3	90.5	90.6	90.9	90.9
	P-P PMC ON (%N1)	72.2	72.4	72.7	73.0	73.3	73.5	73.8	74.1	74.3	74.6

## PART POWER TRIM CHART - STATIC T/O AND ACCEL CHECK TARGET (%N1)

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## TEST NO. 8 - ACCEL/DECEL CHECK

### Maintenance Tasks

- Start the engine and let it become stable for two minutes at low idle. (reference 71-00-00/201).
- Make sure that all the bleed air and electrical loads are off.
- Open the applicable IDLE CONT circuit breaker on the P6 panel and check that  $N_2\%$  is within limits for high idle.
- Make sure the engine indications are in the correct ranges.
- Make sure the applicable PMC switch is in the ON position, and the PMC INOP light is off.
- Manually set the  $N_1$  reference/target bug on the applicable  $N_1$  indicator to the accel check target  $N_1$ .
- Move the forward thrust lever to the static T/O  $N_1$ .
- Let the engine become stable for a minimum of 15 seconds.
- Make sure the engine indications are in the correct ranges.
- Move the forward thrust lever to the idle position.
- Let the engine become stable for a minimum of 15 seconds.
- Quickly move the forward thrust lever (in one second or less) from idle to the full throttle position measuring and making a record of the time it takes the engine RPM to accelerate to the accel check target  $N_1$ .
- Quickly move the forward thrust lever (within one to two seconds) to the idle position making sure that the engine decelerates smoothly and becomes stable at idle.
- No flameout or compressor surge (stall) should occur.

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**TEST NO. 8 - ACCEL/DECEL CHECK****Maintenance Tasks**

Make sure that the acceleration time from your records is not more than 7.4 seconds.

If the engine uses more than 7.4 seconds in the acceleration, do the steps that follow:

- Do the accel/decel check again.
- Make sure that you let the engine become stable at the accel check start  $N_1$  before the fast acceleration.
- If the acceleration time is more than 7.4 seconds, start troubleshooting (reference 71-00-42/101).

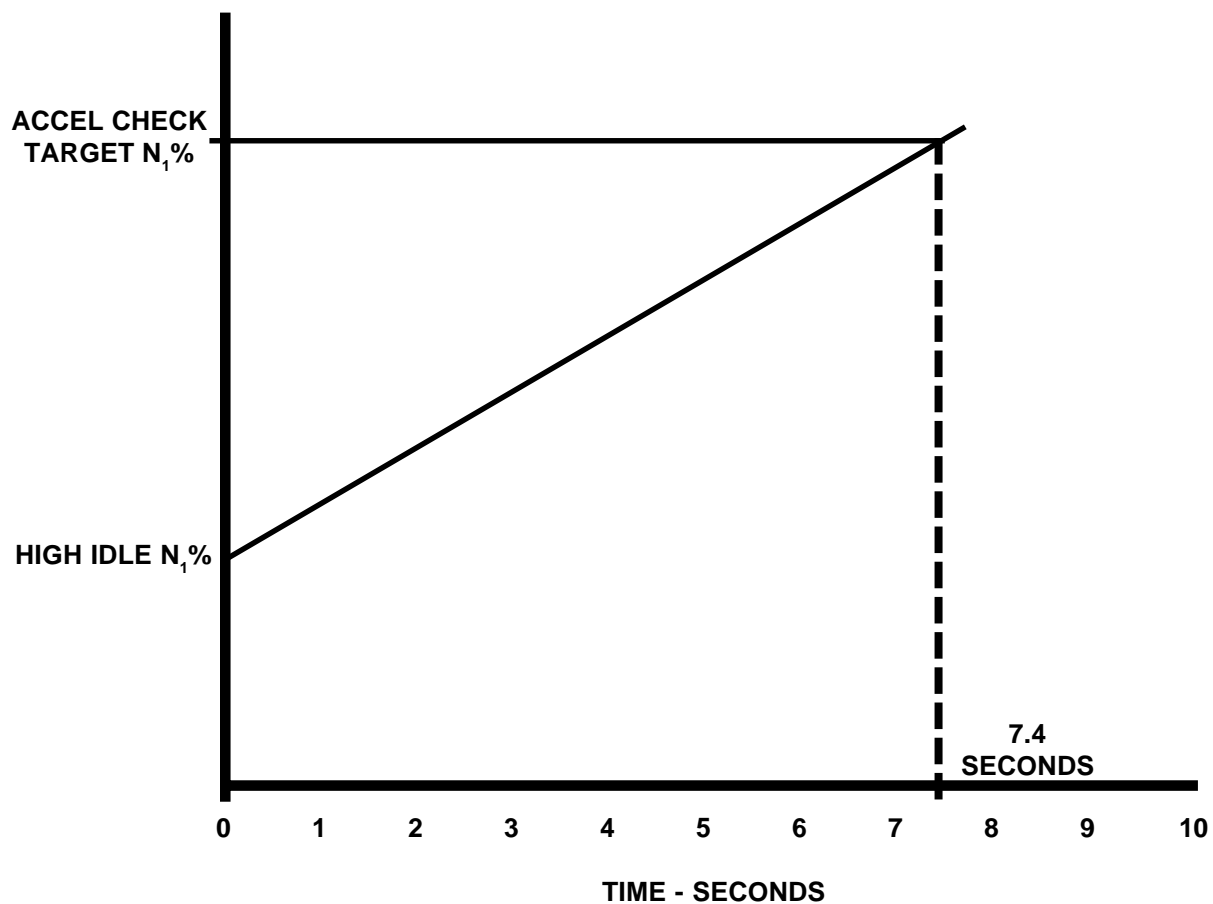
If no troubleshooting is necessary repeat the accel/decel check with the applicable PMC switch (located on the pilots' aft overhead panel, P5) in the off position.

- If no more tests or corrections are necessary, shutdown the engine and return the aircraft to normal configuration.

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### ACCEL/DECEL CHECK

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## TEST NO. 9/10 - REPLACEMENT ENGINE TESTS

### **Purpose and Interface (3.B.a)**

This test provides necessary data after a new installation of a replacement engine.

### **Maintenance Tasks (3.E.a)**

Test No. 9 Replacement Engine Test (Pretested) is performed if the replacement engine has completed one of the tests that follow:

- The test occurred in an approved test cell with the vibration isolators on the engine mount.
- The engine operated satisfactorily with the vibration isolators on the engine mount before the installation.

If you do not have a replacement (pretested) engine, then you must do the procedures in Test No. 10 Replacement Engine Test (Untested).

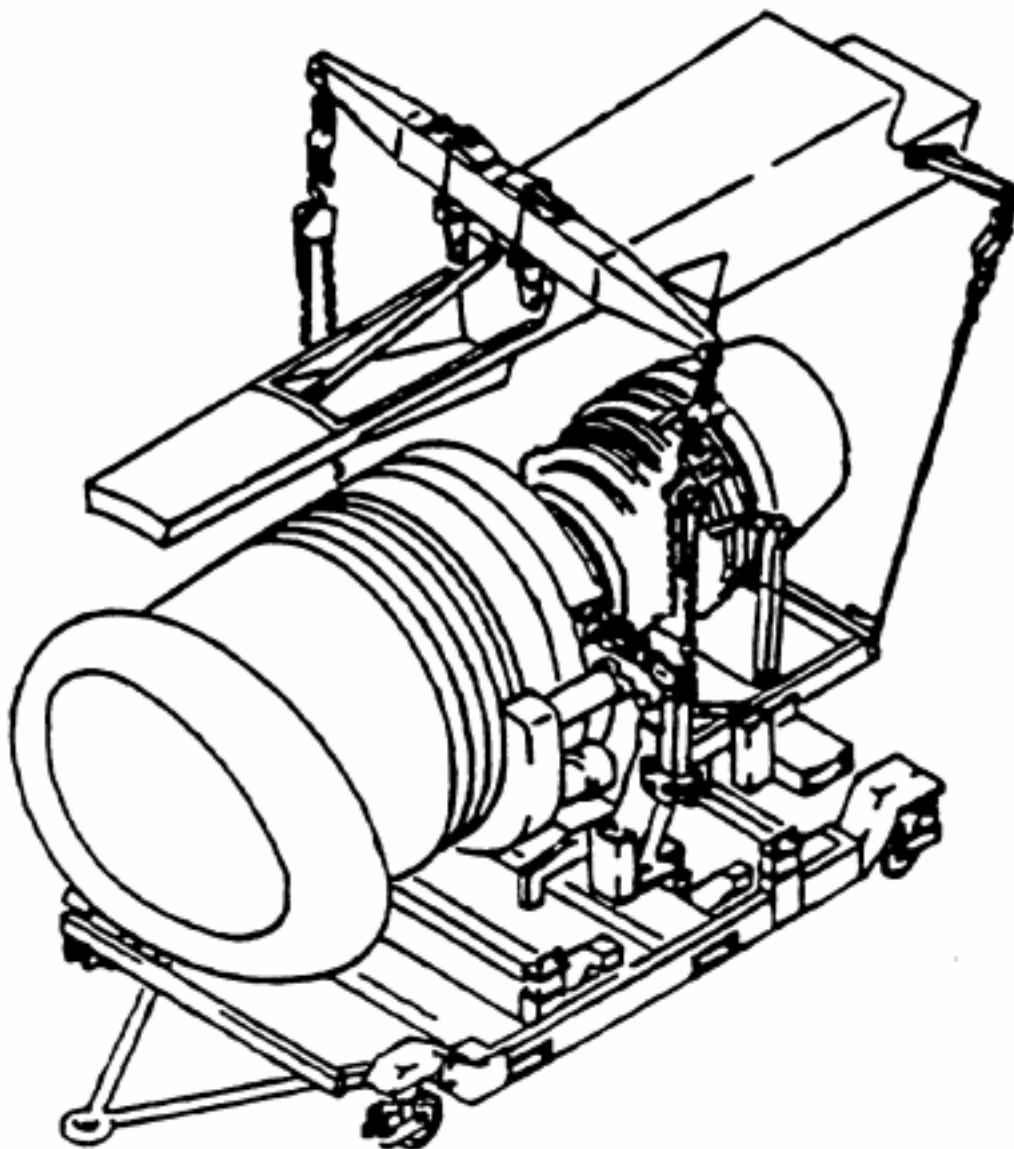
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## ENGINE REPLACEMENT

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## TEST NO. 11 - $T_2$ /CIT SENSOR TEST

### **Purpose (3.B.a)**

This test provides data for troubleshooting of the  $T_2$  or  $T_{2.5}$  (CIT) sensors for incorrect operation.

### **Maintenance Tasks (3.E.a)**

For the test, you use the ambient air temperature, operate the engine at low idle and read the pressure differentials across the  $T_2$  and CIT sensors.

The condition of the sensors is found when you compare the measured pressure differentials to the usual pressure differentials for the air temperature.

The following is a summary of the steps required to perform a test of the  $T_2$  or  $T_{2.5}$  (CIT) sensors. Refer to the Boeing 737 maintenance manual for more specific information.

- Install the FIT/CIT sensor tester 856A1357.
- Get and write down the ambient air temperature in the shade of the airplane.
- Start and operate the engine at low idle (reference 71-00-00/201).
- Read the gages on the sensor tester and make a record.

- Stop the engine (reference 71-00-00/201).
- Using the  $T_2/T_{2.5}$  (CIT) sensor limit data from the chart find the correct sensor limits for the outside air temperature. Compare the gage values with the correct limits and determine the condition of the sensors.
- If the  $T_{2.5}$  (CIT) sensor is out of the limits, replace the  $T_{2.5}$  (CIT) sensor (reference 73-21-02/401).
- If the  $T_2$  sensor is out of the limits, replace the  $T_2$  sensor (reference 73-21-09/401).
- If the sensors are in the limits, continue with this procedure.
- Remove the FIT/CIT sensor tester 856A1357.
- Do Test No. 3 - idle leak check (ref. 71-00-00/501).

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AMBIENT AIR TEMPERATURE °F (°C)	T <sub>2</sub> P7-PB PSID	CIT P6-PB PSID	AMBIENT AIR TEMPERATURE °F (°C)	T <sub>2</sub> P7-PB PSID	CIT P6-PB PSID
-40 (-40)	48-68	29-49	42 (06)	90-110	59-79
-38 (-39)	50-70	30-50	44 (07)	91-111	60-80
-36 (-38)	51-71	31-51	46 (08)	92-112	60-80
-34 (-37)	52-72	32-52	48 (09)	93-113	61-81
-32 (-36)	53-73	32-52	50 (10)	94-114	62-82
-30 (-34)	54-74	33-53	52 (11)	95-115	62-82
-28 (-33)	55-75	34-54	54 (12)	96-116	63-83
-26 (-32)	56-76	34-54	56 (13)	97-117	64-84
-24 (-31)	57-77	35-55	58 (14)	98-118	65-85
-22 (-30)	58-78	35-55	60 (16)	99-119	65-85
-20 (-29)	59-79	36-56	62 (17)	100-120	66-86
-18 (-28)	60-80	37-57	64 (18)	101-121	67-87
-16 (-27)	61-81	38-58	66 (19)	102-122	67-87
-14 (-26)	62-82	39-59	68 (20)	102-123	68-88
-12 (-24)	63-83	39-59	70 (21)	104-124	69-89
-10 (-23)	64-84	40-60	72 (22)	105-125	70-90
-08 (-22)	65-85	41-61	74 (23)	106-126	70-90
-06 (-21)	66-86	41-61	76 (24)	107-127	71-91
-04 (-20)	67-87	42-62	78 (26)	108-128	72-92
-02 (-19)	68-88	43-63	80 (27)	109-129	73-93
0 (-18)	69-89	43-63	82 (28)	110-130	73-93
02 (-17)	70-90	44-64	84 (29)	111-131	74-94
04 (-16)	71-91	45-65	86 (30)	112-132	74-94
06 (-14)	72-92	46-66	88 (31)	113-133	75-95
08 (-13)	73-93	47-67	90 (32)	114-134	76-96
10 (-12)	74-94	47-67	92 (33)	115-135	77-97
12 (-11)	75-95	48-68	94 (34)	116-136	78-98
14 (-10)	76-96	48-68	96 (36)	117-137	79-99
16 (-09)	77-97	49-69	98 (37)	118-138	79-99
18 (-08)	78-98	50-70	100 (38)	119-139	80-100
20 (-07)	79-99	51-71	102 (39)	120-140	81-101
22 (-06)	80-100	51-71	104 (40)	121-141	82-102
24 (-04)	81-101	52-72	106 (41)	122-142	82-102
26 (-03)	82-102	53-73	108 (42)	123-143	83-103
28 (-02)	83-103	54-74	110 (43)	124-144	84-104
30 (-01)	84-104	54-74	112 (44)	125-145	85-105
32 (0)	85-105	55-75	114 (46)	126-146	85-105
34 (01)	86-106	56-76	116 (47)	127-147	86-106
36 (02)	87-107	57-77	118 (48)	128-148	87-107
38 (03)	88-108	57-77	120 (49)	129-149	87-107
40 (04)	89-109	58-78			

**TEST NO. 11 - T<sub>2</sub>/T<sub>2.5</sub> (CIT) SENSOR TEST LIMITS**
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## BASIC TROUBLESHOOTING

### Objectives:

At the completion of this section a student should be able to:

- ....state the purpose of troubleshooting the CFM56-3/3B/3C engine (3.B.x).
- ....recall the basic systematic process used when troubleshooting a CFM563/3B/3C engine (3.F.x).
- ....recall analyzing hints used when troubleshooting a CFM563/3B/3C engine (3.F.x).
- ....identify selected operational problems associated with the CFM56-3/3B/3C engine (3.F.x).

## INTRODUCTION

### **Purpose (3.B.a)**

Troubleshooting is the systematic process of identifying a faulty element in an otherwise functional system and determining the actions necessary to restore the system to an operational condition.

### **Troubleshooting (3.F.a)**

Troubleshooting begins with recognition and documentation of the problem. Precise documentation is essential to isolation of the fault with a minimum expenditure of time and effort.

The Boeing 737 maintenance manual provides information for troubleshooting procedures that are in the form of flow charts. These flow charts contain troubleshooting steps and corrective actions in a recommended sequence based on probability of component failure and ease of performing checks required.

In addition to following the maintenance manual charts troubleshooting procedures should be based on the following assumptions:

- Double failures do not exist.
- The faulty system was fully operational prior to the fault indication with all equipment properly installed.
- All relevant circuit breakers were checked.

- All applicable airplane/engine operating procedures were accomplished.
- The airplane is on the ground, it has been shut down in accordance with normal operating procedures and all power is off.
- Fault was accurately described.

All warnings, cautions and operating limitations associated with power plant maintenance and operation must be observed during troubleshooting.

Generally, electrical wiring is considered to be satisfactory. The location of the wiring, its environment, exposure to possible damage and experienced failure rate will be factors in determining the need for electrical circuit checks.

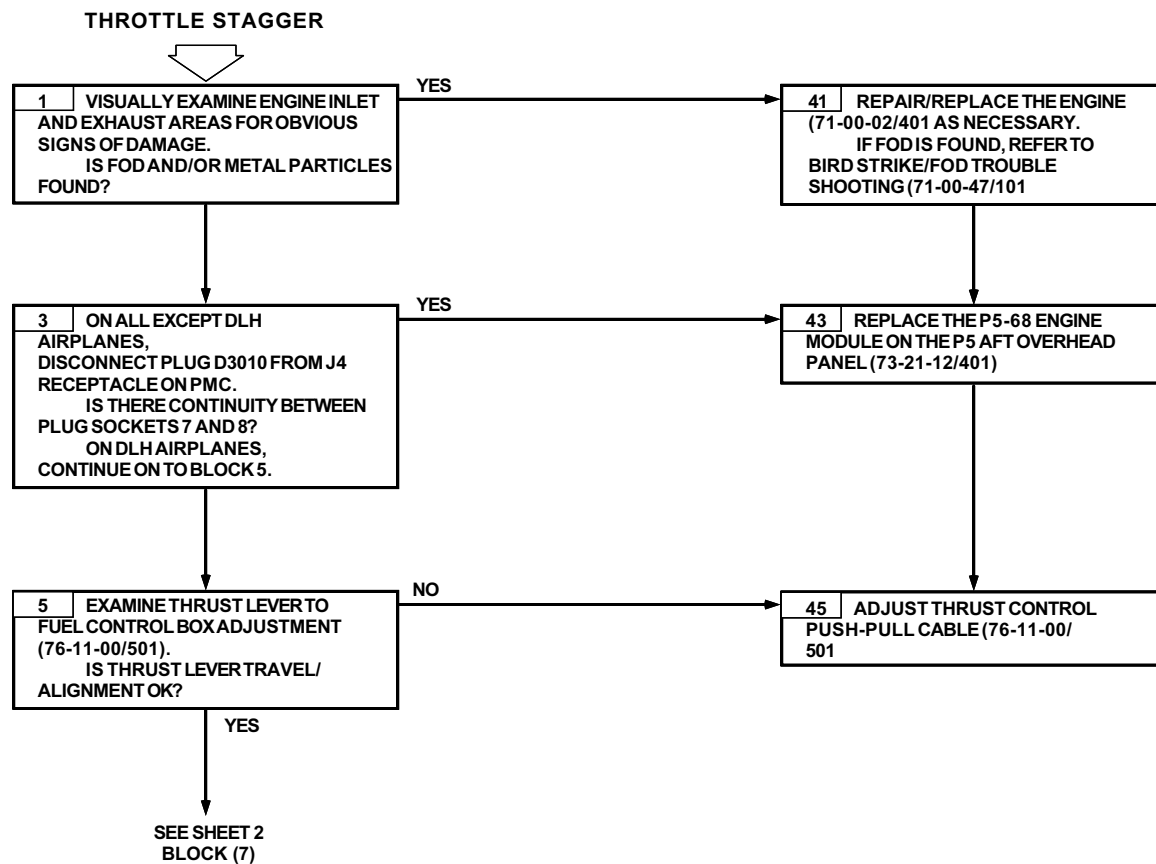
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## MAINTENANCE MANUAL FAULT CHART

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## TROUBLESHOOTING FAULT CHARTS

### Troubleshooting (3.F.a)

In the Boeing 737 Maintenance manual, powerplant troubleshooting is separated into several major sections (see chart below).

Each section contains a listing of trouble symptoms associated with the section. Each listed symptom includes a reference to the troubleshooting chart and block within the chart to begin troubleshooting for the particular problem.

Troubleshooting charts are provided for major symptoms and each chart is given a figure number. Component location illustrations and schematic diagrams are also provided where essential to support troubleshooting.

Prerequisites are provided to assure that the system is in the required mode, including the power required and identification of the circuit breakers which need to be closed ("in"), to perform the procedure. Time consuming operations such as engine operation are noted.

Visual check (71-00-58) and engine check (71-00-59) sections provide details for checks that appear repeatedly within troubleshooting charts or that have a degree of complexity requiring a detailed procedure or specific illustrations to accomplish. Visual checks are those checks which may be accomplished by visual

observation only (opening of fan cowls or fan duct cowl and thrust reverser halves for access may be required). Engine checks are more complex and may require test equipment, engine operation, and/or removal of components to accomplish.

Troubleshooting tips may be included in the section introduction to describe typical problems to the mechanic or technician, and to alert of specific pitfalls that may be encountered.

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## BOEING 737-300/400/500 MAINTENANCE MANUAL TROUBLESHOOTING SECTIONS

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**TROUBLESHOOTING HINTS****Troubleshooting (3.F.a)**

EGT is the primary indicator for monitoring engine health. A gradual deterioration of EGT is considered normal and can be expected on all turbine engines.

An EGT shift of 10 to 15°C can be expected due to compressor or turbine damage, after FOD or DOD ingestion, turbine stator leakage, shroud to turbine tip damage, or blockage of the turbine cooling system. These problems should be reported to maintenance for monitoring or corrective action.

Large EGT shifts of 25 to 30°C or more are indicative of greater compressor or turbine damage. Some examples would be HPT damage caused by liberated pieces of the combustion chamber or bearing failure, etc.

Instrumentation failures are always a possibility and other parameters should be checked prior to major decision making. Generally, EGT shifts or trends downward are an indication of a faulty instrument or instrumentation system.

A trending of  $N_2\%$  is a good indication of VSV positioning. Since VSV's are initially set on the ground, and  $N_2\%$  gages are not error free and are sometimes hard to read,  $\Delta N_2\%$  is not used for absolute reading of

VSV position.

If the VSV's are too far closed, then  $N_2\%$  will tend to shift upward. This is caused by the fact that the  $N_2\%$  must increase to produce the same  $N_1\%$ . Often this is first detected on a hot day/full power takeoff and  $N_1\%$  cannot be obtained because either the  $N_2\%$  reaches its limit or the throttle stop is encountered.

If the VSV's are too far open, then  $N_2\%$  will tend to shift downward. These type of shift could be attributed to a CIT sensor failure.

If a trending of the  $\Delta N_2\%$  shows an erratic scatter then the possibility of a sticking feedback cable could exist.

Fuel flow ( $W_f$ ) trending by itself is not a good parameter to use for troubleshooting, but may be helpful when used in conjunction with EGT and  $N_2\%$ .

Verify the problem first and use the on-board computers, flight recorders, maintenance manuals, etc. to help track down the problem.

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*****
***      Aircraft Data Engine Performance Trending      ***
***      (ADEPT)                                         ***
***                                                     ***
***      Version 10.1 PC12/93                           ***
***      Copyright 1993 by GE Aircraft Engines          ***
***      All Rights Reserved                             ***
*****

REPORT ID:      CRDATA      GE ENGINE CONDITION MONITORING PROGRAM
                  CRUISE PERFORMANCE DATA - MOST RECI
                  -----C

AIRCRAFT  AIRCRAFT  ENG  SERIAL  ENGINE  INSTALL  N1  THRUST
ID         TYPE     POS  NUMBER  TYPE     DATE    MOD  RATING
FGLZB     A340-200  1   740183  CFM56-5C2  920101   3   -999
                  2   740135  CFM56-5C2  920101   1   -999
                  3   740136  CFM56-5C2  920101   3   -999
                  4   740140  CFM56-5C2  920101   2   -999
-----
                  FLIGHT DATA
DATE/      TAT  ALT  MACH  ENG  A/C  ISO  OIL  FUEL
GMT        -31.8 33000 .788 1234 123  LRC  N1  PRES  FLOW
41692=1    -31.8 33000 .788 1111 0    79.42 46. 2826.
1706=2          .788 1111 0    79.41 51. 2844.
=3          .788 1111 0    79.42 43. 2824.
=4          .788 1111 0    79.42 44. 2879.
42092=1    -32.0 39020 .812 1111 0    87.77 -55. 3025.
141=2          .812 1111 0    87.77 -55. 3115.
=3          .812 1111 0    87.77 -55. 3020.
=4          .812 1111 0    87.78 -55. 3097.

```

## EXAMPLE - CRUISE TREND DATA REPORT

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## **N<sub>1</sub> MISMATCH DURING IDLE DESCENT**

### **Troubleshooting (3.F.a)**

Not all conditions are faults. CFMI has received a number of reports from CFM56-3 operators experiencing engine-to-engine N<sub>1</sub> differences of up to 15% during descent with the throttles on the idle stop. The greatest difference occurs at the top of descent at high altitudes and airspeeds. The amount of mismatch gradually becomes less as altitude and airspeed decrease. The N<sub>1</sub> mismatch usually disappears by the time the aircraft descends to 10,000 feet.

This N<sub>1</sub> mismatch during idle descent is caused by a lower operating line on some engines; i. e. the engine is more efficient, so less fuel flow (W<sub>f</sub>) is required to maintain minimum idle N<sub>1</sub> and N<sub>2</sub> speeds. On these engines at high altitudes and airspeeds, the scheduled deceleration fuel flow (W<sub>f</sub>) is sufficient to maintain N<sub>1</sub> and N<sub>2</sub> speeds higher than minimum idle. As the airplane descends and/or slows down, the engines require more fuel to operate (engines less efficient due to operating line moving up), so N<sub>1</sub> and N<sub>2</sub> decelerate towards idle.

The condition does not exist on all engine and (MEC) combinations, but may occur on one or more engines on a given airplane. The engine steady state operating line varies due to engine component efficiencies, and the deceleration fuel flow (W<sub>f</sub>) schedule varies somewhat because of dimensional tolerances within the MEC. A

combination of engine operating line on the low side of its tolerance band (more efficient engine) and a deceleration fuel flow (W<sub>f</sub>) schedule on the high side of its tolerance band can result in the "high" idle condition at high altitudes and airspeeds.

With an efficient HPC, the fuel control deceleration schedule may intersect the steady state operating line. At the intersection point, the decel schedule results in a fuel flow which is exactly that required for the engine to operate steady state at that rotor speed. In order to decelerate, the engine requires a further reduction in fuel flow, but this cannot be achieved because the fuel control will not schedule fuel flow below the decel limit. As the airplane descends and slows to a lower airspeed, the steady state operating line moves up (i.e., the engine requires higher fuel flow for a given steady state rotor speed). The intersection of the decel schedule and the operating line moves down to a lower rotor speed and eventually the engine spools down to idle. The engine parameter mismatch during idle descent is a consequence of a high efficiency engine.

The mismatch in N<sub>1</sub> during idle descent is a normal engine characteristic. The condition will gradually diminish with normal engine deterioration over time.

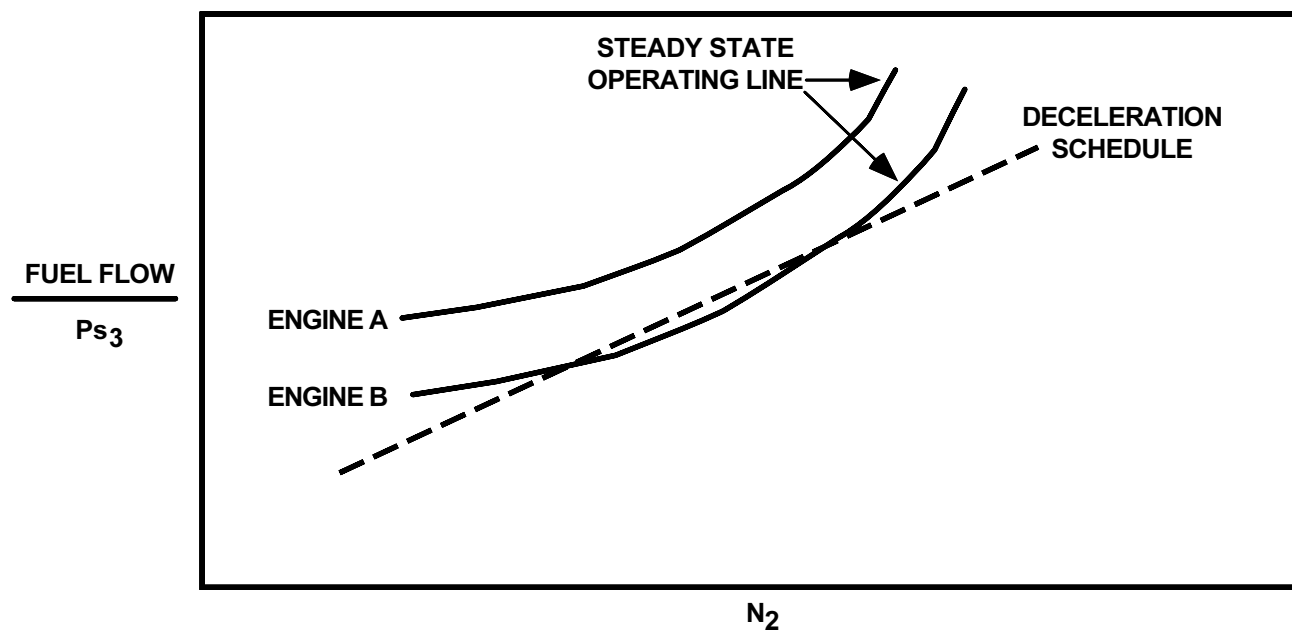
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### N1 MISMATCH DURING DESCENT

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**AIRCRAFT RUMBLE DURING IDLE DESCENT****Troubleshooting (3.F.a)**

Descent idle rumble can be characterized as a sudden onset of a perceived vibration while descending with a stabilized idle setting (no thrust lever movement) between 15,000 and 9,000 feet. The vibration has been reported over a very narrow engine speed range (typically 68-74%  $N_2$  or 30-35%  $N_1$ ) and is most pronounced in the cockpit floor but it has also been heard by flight crews on occasion. The onset of the vibration is not reflected on the Aircraft Vibration Monitoring (AVM) indicator. In addition, the vibration is not necessarily repeatable flight-to-flight nor is it always reproducible on the ground.

Investigation into the cause of descent idle rumble indicates the phenomenon is the result of a low amplitude non-synchronous engine vibration which occurs at low high pressure rotor axial loads and is transmitted into the airframe. This condition occurs at descent idle thrust settings and is a normal engine characteristic which has no impact on engine or airframe structural integrity.

Although this phenomenon has been observed since the beginning of the 737-300 program, in the past, the engine RPM at which the rumble occurs were in a range where the engine did not operate for extended periods of time. Since the deletion of minimum idle in flight, the

aircraft descent profile is such that the conditions associated with descent idle rumble are present for a greater portion of the descent.

Operator experience and recent flight testing indicates the descent idle rumble can be reduced/eliminated by a slight increase in engine RPM.

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GRAPHIC TO BE DETERMINED

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## HOT START

### Troubleshooting (3.F.a)

A hot start is indicated by an abnormally rapid EGT rate of rise after lightoff. The EGT will exceed limits if the start is not discontinued in time. By monitoring fuel flow ( $W_f$ ) and EGT, a hot start can be anticipated and discontinued before limits are exceeded.

The chart below shows the relationship between the amount of temperature during a hot start and the amount of time the overtemperature exists. This relationship will determine the type of inspection or corrective action that must occur following a hot start.

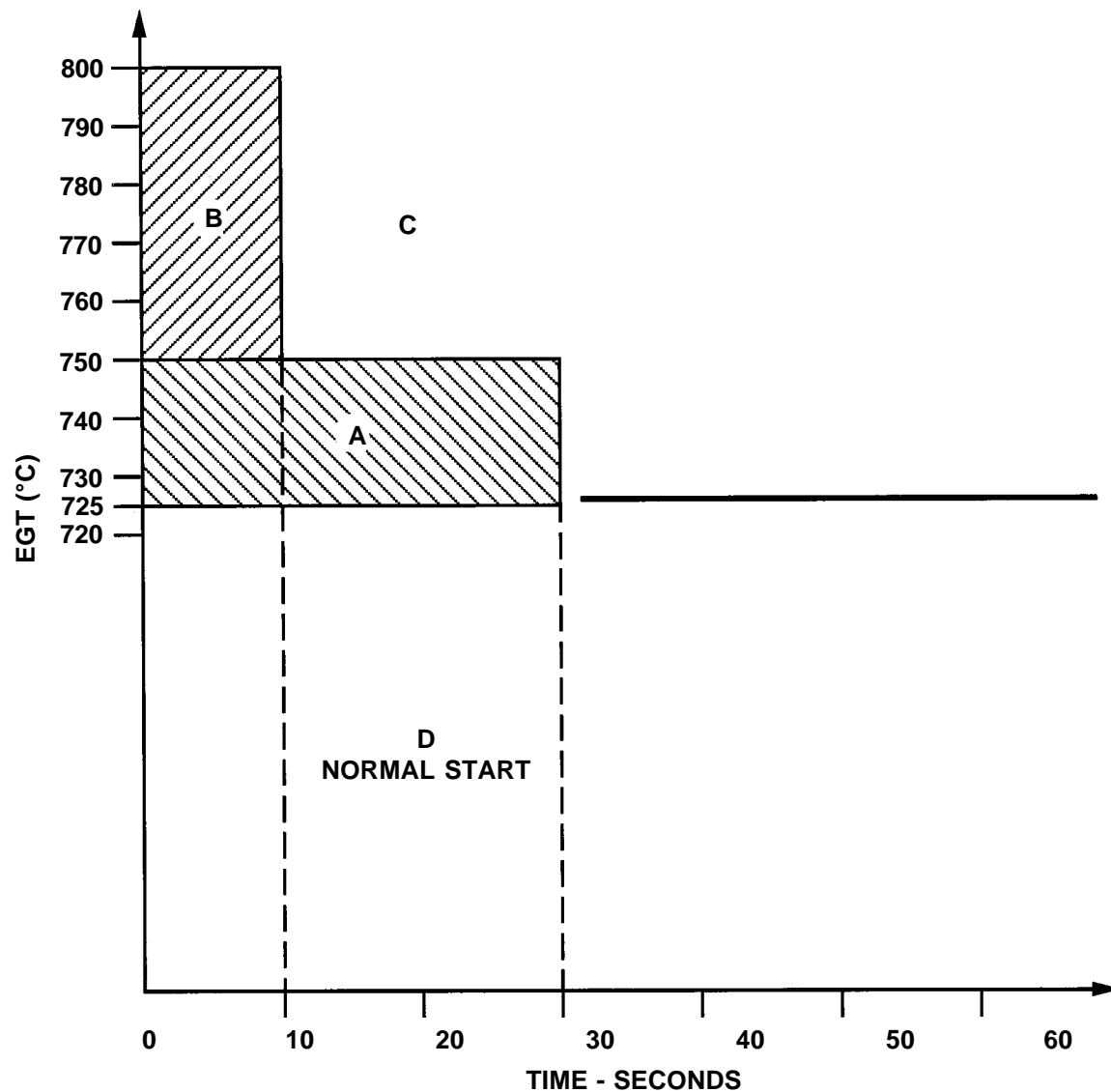
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EGT OVERTEMPERATURE CHART (STARTING)

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**SLOW/HUNG START****Troubleshooting (3.F.a)**

A slow/hung start occurs when following lightoff the engine displays and abnormally slow acceleration and RPM stabilization below idle. A hung start may be the result of fuel scheduling being too lean or too rich. A lean hung start is associated with low fuel flow ( $W_f$ ) and a proportionally low EGT. A rich condition can be recognized by a high fuel flow ( $W_f$ ), an EGT rise which may tend to develop into an overtemperature condition and possibly a rotating compressor stall.

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LEAN HUNG START	RICH HUNG START
LEAN FUEL SCHEDULE LOW EGT	RICH FUEL SCHEDULE HIGH EGT POSSIBLE OVERTEMPERATURE POSSIBLE STALL

## SLOW/HUNG START CONDITIONS

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## SLOW/DIFFERENTIAL ENGINE ACCELERATION FROM LOW IDLE

### Troubleshooting (3.F.a)

CFM56-3 series engines can exhibit differential acceleration times from low idle, which can affect T/O operation.

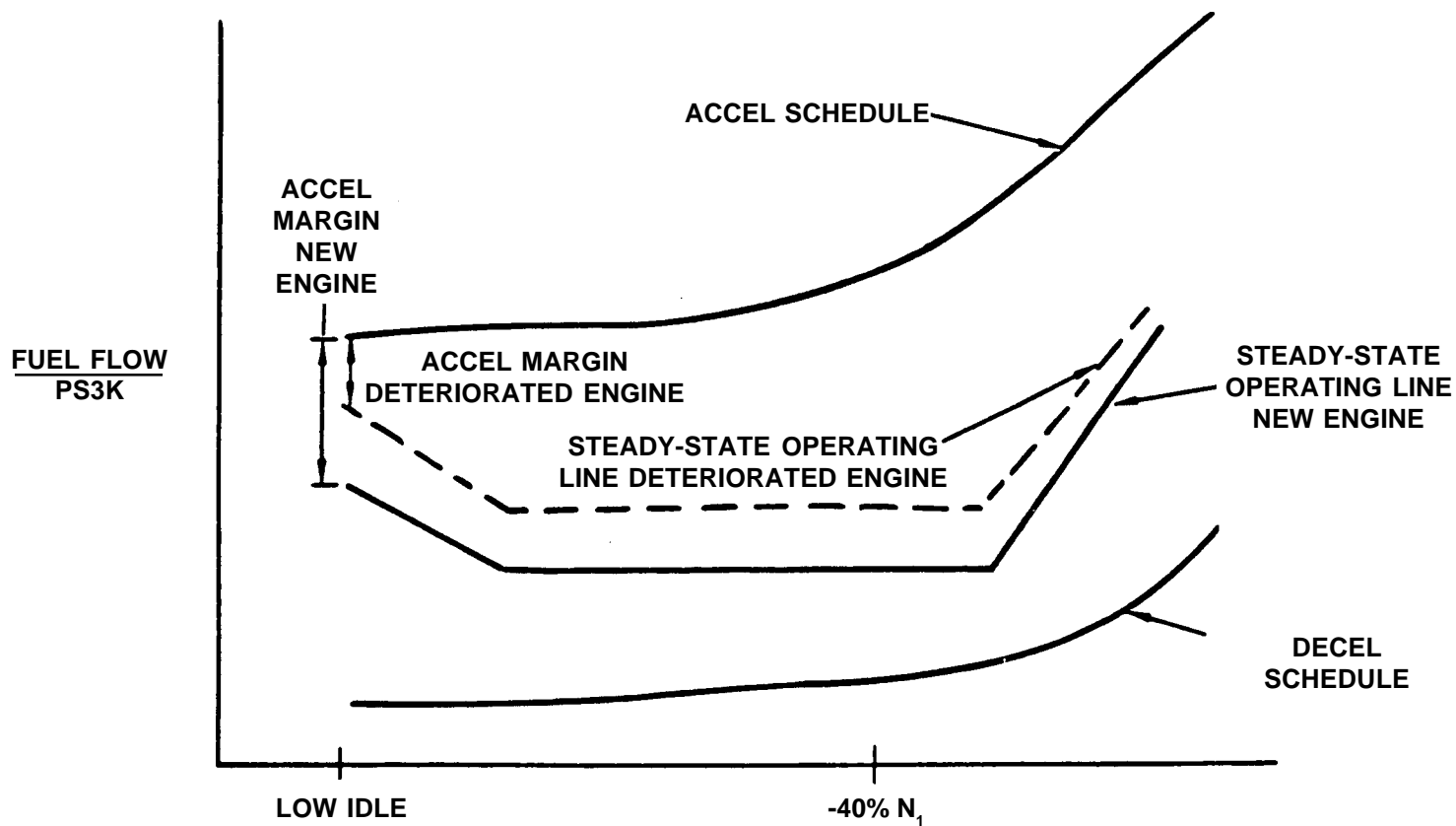
Investigations reveal that for both production and in-service engines, variation in acceleration time from low idle can be exhibited. Above 40%  $N_1$ , the engines accelerate with little variation. Tests of field engines have identified a phenomenon that can contribute to on-wing differential acceleration. The graph below depicts the relationship between the engine operating line and the MEC acceleration schedule. The operating line represents the fuel/air ratio required to maintain a steady-state speed, and is not scheduled. An engine's operating line is affected by engine health, engine thermal conditions, VSV tracking, pneumatic bleed, etc. It therefore differs from one engine to the next, and for a given engine can change as the engine accumulates time. Slow accelerating engines exhibit an upward migration of the low speed steady-state operating line toward the fixed acceleration schedule. This reduces the acceleration margin and causes these engines to accelerate more slowly from low idle.

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### ACCELERATION MARGIN REPRESENTATION

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## SLOW/DIFFERENTIAL ENGINE ACCELERATION FROM LOW IDLE

### Troubleshooting

Several procedures have been implemented by CFMI and Boeing to minimize and control differential acceleration from low idle. One of the changes recommended is the T/O thrust lever set procedure. Previously, the procedure called for positioning the throttles to the vertical position (60-70%  $N_1$ ) and allowing the engines to stabilize prior to performing the final thrust lever set to T/O power. While this procedure helps reduce differential acceleration/thrust during T/O, a thrust lever pause at a lower  $N_1$  minimizes the differential acceleration/thrust during the initial thrust lever set (from low idle to the pause speed). The revised procedure recommends pausing at 40%  $N_1$ , and provides a means to effectively control differential acceleration during the entire T/O thrust lever set. The graph below depicts this improvement.

Also, opening VSV's within limits can improve engine acceleration characteristics, particularly on engines which exhibit low speed operating line migration. A procedure for on-wing VSV dynamic rigging was introduced in April 1989. Special tooling is required to perform this procedure, which is available through CFMI (VSV Dynamic Rig Tool No. 856A1214 and 856A2001). Several operators have successfully used this procedure to improve acceleration times, in the start range as well as from low idle.

Adjusting low idle to the upper tolerance improves acceleration time as well. As with VSV dynamic rig, the impact on acceleration times is more pronounced for engines with low speed operating line migration. CFMI and Boeing have modified the MM tolerance for low idle to +3.0/-1.0%  $N_2$  (from +1.0/-1.0%  $N_2$ ) and high idle to +3.0/-0.7%  $N_2$  (from +0.7/-0.7%  $N_2$ ) to allow more flexibility in reducing on-wing engine-to-engine acceleration variation. This adjustment has also been successfully implemented in the fleet, and is particularly appealing since the adjustment is relatively simple and quick.

Specific gravity adjustments help to improve start and acceleration times. Engines that have the 5th stage start bleed valve system can adjust specific gravity from 0.82 to 0.78 as required. However, specific gravity adjustment should be accomplished after all other troubleshooting and corrective actions have been performed.

A fault isolation procedure addressing engine differential acceleration was introduced into the Boeing MM (71-00-42) in July 1989. As part of this troubleshooting procedure, adjustments to the low and high idle speed and VSV dynamic rigging may be performed on one or both engines to minimize differential acceleration.

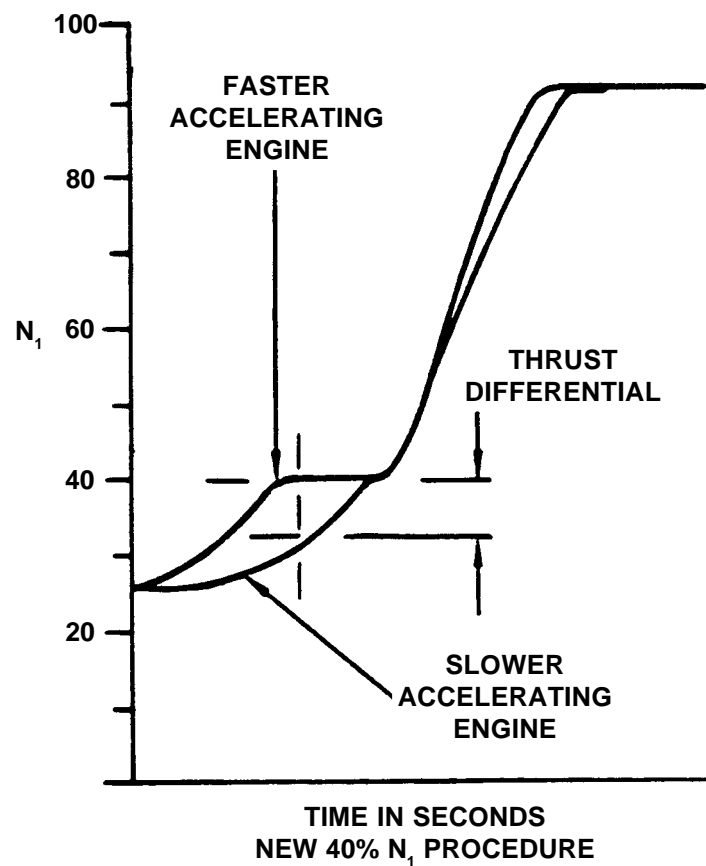
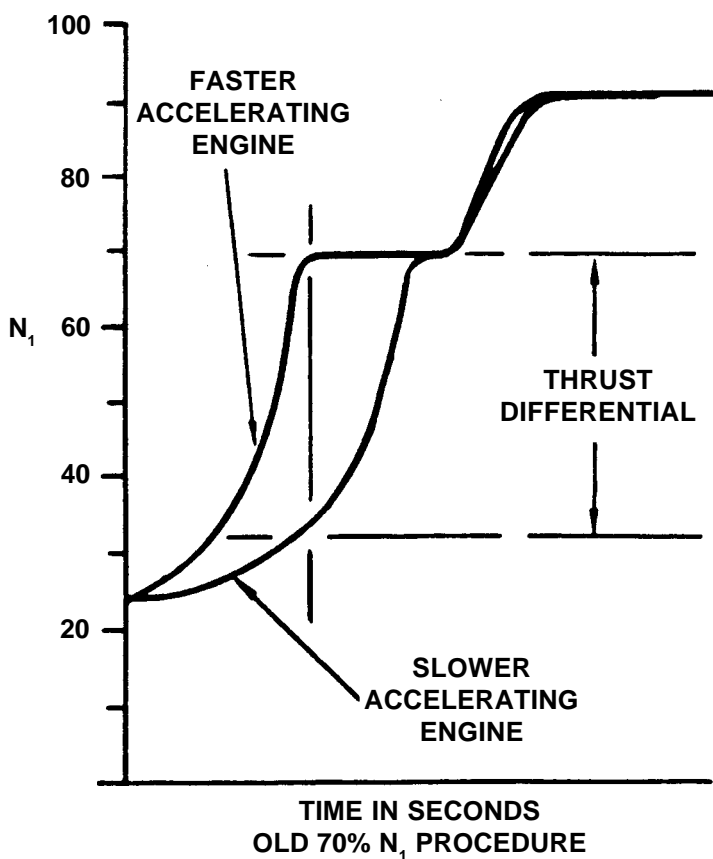
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CORRECTED CORE SPEED (N<sub>2</sub>K25)

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## **SLOW/DIFFERENTIAL ENGINE ACCELERATION FROM LOW IDLE**

### **Troubleshooting**

CFMI has identified excessive wear of the HPT nozzle W-seal as a strong contributor to low speed operating line migration. Internal parasitic leakages past this seal at low speeds causes the operating line to be higher. Increased seal loading at higher speeds reduces the parasitic leakages, therefore minimizing the impact on higher speed operating line. S/B 72-555 was issued October 10, 1990 to introduce a new T800 coated W-seal. The coating of the W-seal was developed to provide increased resistance to wear and cracking.

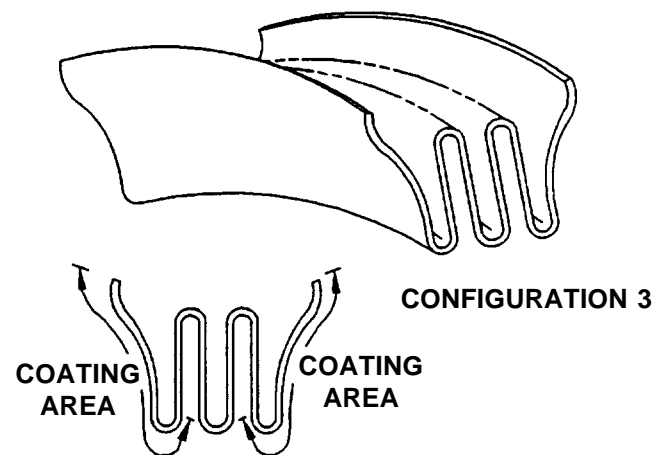
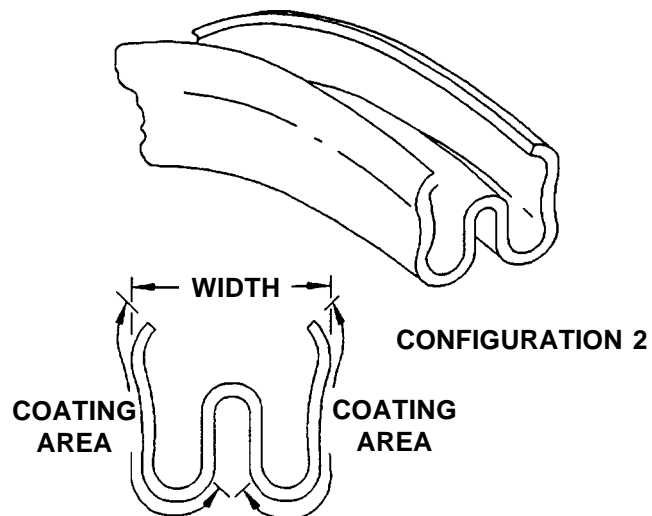
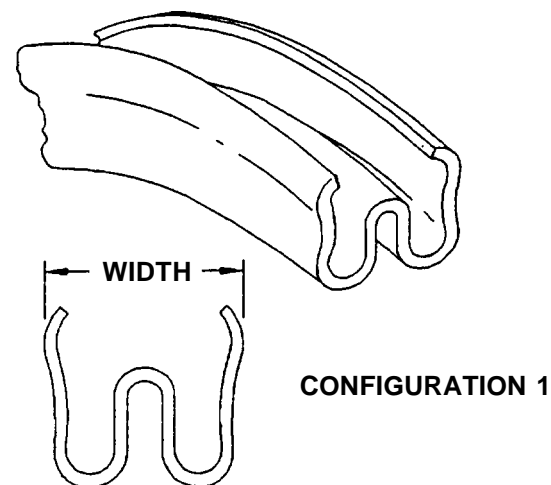
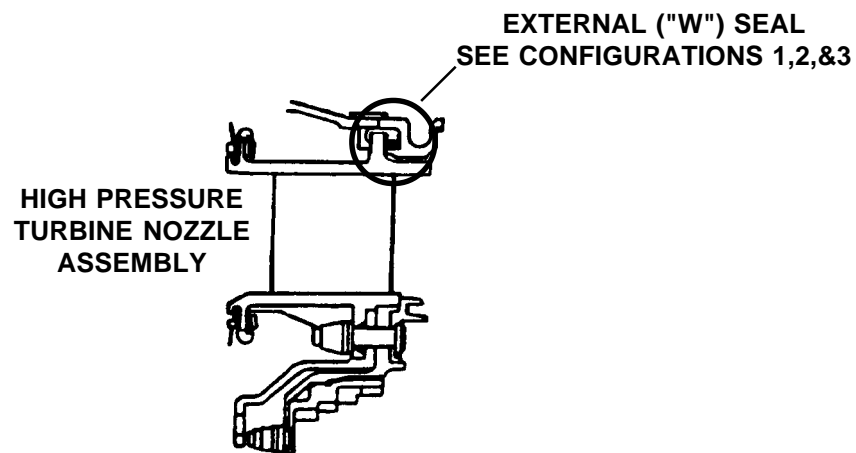
Finally, the CFM56-3 Workslope Planning Guide was updated to provide refurbishment recommendations for engines removed for slow acceleration.

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## HIGH PRESSURE TURBINE EXTERNAL ("W") SEAL

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## SLOW/DIFFERENTIAL ENGINE ACCELERATION FROM LOW IDLE

### Troubleshooting

A procedure has been developed to evaluate engine acceleration time during troubleshooting. It has been introduced into the Boeing MM (71-00-42). In general, the procedure is as follows:

- Stabilize the test engine at low idle for a minimum of three minutes.
- With no bleed or horsepower extraction, rapidly advance the thrust lever in one second or less from the idle stop to the vertical position.
- Record the time from the initial thrust lever movement to 40%  $N_1$ .
- Return thrust lever to idle.

Note: Setting the thrust lever to the vertical position (60 to 70%  $N_1$ ) provides a smooth acceleration through the 40%  $N_1$  test target.

Using this procedure, which provides a standard method of measuring engine acceleration time from low idle, two guidelines for engine acceleration are available for use at operator discretion. They are strictly guidelines to assist maintenance personnel during troubleshooting, and are not cause for engine removal.

The first guideline was introduced into the Boeing MM troubleshooting tree for differential acceleration in July 1990. The above procedure is carried out for both engines on the squawked airplane, and the acceleration times from low idle to 40%  $N_1$  compared. CFMI and Boeing consider a difference of four seconds or less to be an acceptable guideline for terminating troubleshooting activity.

Some operators have stated that an absolute time guideline from low idle to 40%  $N_1$  might be useful to their operations. For that reason, an acceleration time guideline is established for engines that are squawked as slow to accelerate from low idle. Based on engine test data and field experience, an acceleration time of 13 seconds is considered acceptable for terminating troubleshooting activity. Commercial Engine Service Memorandum 031 introduced the 13-second guideline.

It is important to emphasize that adherence to the T/O thrust lever set procedure, which includes a thrust lever pause at 40%  $N_1$ , will control the effects of differential acceleration. Operators are strongly encouraged to stress the benefits of this thrust lever pause to flight crews.

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GUIDELINES/LIMITS FOR ACCELERATION	TIME IN SECONDS
DIFFERENTIAL BETWEEN ENGINES	4.0 SECONDS
FROM LOW IDLE TO 40 % N1	13.0 SECONDS

## GUIDELINES FOR TROUBLESHOOTING SLOW/DIFFERENTIAL ACCELERATION

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**SLOW/DIFFERENTIAL ENGINE ACCELERATION  
FROM LOW IDLE****Troubleshooting**

A revised ground acceleration check (Test No. 8 Accel/Decel Check, 71-00-00) was implemented in November 1994 to correlate ground accel times to in-flight performance requirements. This check maintains a limit of 7.4-seconds from high idle to 95% Fn. If this limit cannot be met, troubleshooting must be initiated.

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GUIDELINES/LIMITS FOR ACCELERATION	TIME IN SECONDS
FROM HIGH IDLE TO 95% THRUST	7.4 SECONDS *

\*NOTE: THE 7.4 SECOND VALUE FOR HIGH IDLE TO 95% FN IS CONSIDERED A LIMIT AND NOT A GUIDELINE

## LIMITS FOR TROUBLESHOOTING SLOW/DIFFERENTIAL ACCELERATION

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## SLOW/DIFFERENTIAL ENGINE ACCELERATION FROM LOW IDLE

### Troubleshooting

Since upward migration of the engine operating line at low engine speeds has been identified as a strong contributor to increased acceleration time from low idle, evaluating the operating line of a given engine at low idle can provide a means of better understanding an engine's condition. CFMI has prepared a procedure for evaluating the engine operating line at low idle. It can be readily applied in the test cell, where all necessary parameters ( $N_2$ , fuel flow ( $W_f$ ), CDP and  $T_{2.5}$ ) are accurately instrumented. This procedure can be adapted for on-wing use, although the result will not be as accurate as in the instrumented test cell. The engine-mounted fuel flowmeter is not highly accurate in the low flow ranges, but is considered adequate for general operating line assessment. The operating line is measured in terms of (fuel flow ( $W_f$ )/CDP)k. A pressure gauge or transducer can be installed in the CDP line - a 50 Pounds Per Square Inch Absolute (psia) gauge/transducer is recommended for low idle assessment, but cannot be used for higher power operation.  $T_{2.5}$  can be estimated from OAT and  $N_1$ , as used in the VSV dynamic rig procedure. For low idle assessment,  $T_{2.5}$  is approximately 6°F (3.3°C) higher than ambient temperature.

In general, the low idle operating line for production engines is 18-20 units. As this level increases, approaching the acceleration schedule (nominally 25.5 units), acceleration time is expected to increase. Based on inbound engine tests, operating lines of 22.5 and higher at low idle are more likely to be squawked for acceleration problems.

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## SLOW/DIFFERENTIAL ENGINE ACCELERATION FROM LOW IDLE

### Troubleshooting

Some contributors to upward operating line migration are:

- Engine health
- VSV scheduling
- Pneumatic system leakages

A Borescope Inspection (BSI), and review of such tools as cruise trending (on-wing), engine history, and engine age can be helpful in understanding whether basic engine health may be a factor. However, some engines exhibit high operating lines at idle without high EGT's at T/O or cruise. Cruise trending is not an indicator of engine health at low speed and should be used only as a general engine health indicator.

VSV tracking has a very significant impact on the low speed operating line. With VSV's tracking toward the closed side of the tolerance band, the operating line will be higher; likewise, with VSV's tracking toward the open side of the tolerance band, the operating line will be lower. Several cases of high operating line due solely to VSV tracking at the closed tolerance have been experienced. In these cases, opening VSV's brought the operating line and acceleration time down. The VSV dynamic rig tooling

provides a means of accomplishing this on-wing.

Inspections of the pneumatic system/tubing can determine whether air leaks are a factor.

Knowing an engine's low idle operating line can be helpful in understanding the condition of an engine and in general troubleshooting. For example:

If an engine written up for slow acceleration has a very high operating line that is not the result of pneumatic system leakages, it may be more helpful to perform a VSV dynamic rig than an MEC change. The VSV dynamic rig will lower the engine operating line. A replacement MEC may track richer or leaner than the original MEC. It is therefore not possible to predict whether an MEC change will result in faster or slower engine acceleration.

If an engine is squawked for slow acceleration from low idle, yet has an operating line below approximately 22.0 units, it is possible that acceleration fuel scheduling may be too lean. This can be due to misadjusted Specific Gravity (SG), loose/leaking CDP line, MEC lean shift, etc.

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CONTRIBUTORS TO OPERATING LINE MIGRATION	RECOMMENDED MAINTENANCE PRACTICES
ENGINE HEALTH  VSV SCHEDULING  PNEUMATIC SYSTEM LEAKAGE	BOREScope, CRUISE TREND AND ENGINE HISTORY  STATIC RIG CHECK AND PERFORMANCE TREND  VISUAL INSPECTION OF PNEUMATIC SYSTEM

## OPERATING LINE ASSESSMENT

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## SLOW/DIFFERENTIAL ENGINE ACCELERATION FROM LOW IDLE

### Troubleshooting

The intent of this procedure provides a means of assessing engine operating line at low idle.

To begin the procedure install a 50 psia pressure gauge/transducer in the CDP line (near MEC). A 50 psia transducer or gauge is adequate for low idle operating line assessment ONLY. For speeds above low idle, a higher range gauge/transducer would be required. The procedure is as follows:

- Record OAT and Pamb.
- Start engine and stabilize at low idle with no horsepower extraction and bleeds off for five minutes.
- After stabilization, record  $N_1$ ,  $N_2$ , EGT, fuel flow ( $W_f$ ), and CDP.
- Shut engine down and perform calculation for  $(W_f/CDP)_k$ .



$$Q_{25} = \frac{T_{2.5} (^{\circ}\text{F}) + 459.67}{518.67}$$

WHERE  $T_{2.5} = \text{OAT} + \text{BOOSTER RISE}$   
(REFER TO CHARTS IN VSV DYNAMIC RIG PROCEDURE)

$$Q_{25} = \frac{T_{2.5} (^{\circ}\text{C}) + 273.15}{288.15}$$

AT LOW, IDLE  $T_{2.5} = \text{OAT} (^{\circ}\text{F}) + 6^{\circ}\text{F} = \text{OAT} (^{\circ}\text{C}) + 3.3^{\circ}\text{C}$

$$\frac{W_F / \text{CDPk}}{\text{CDP (psia)}} = \text{FF (PPH)} \times (Q_{25})^{-54}$$

## OPERATING LINE CALCULATION

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## SLOW/DIFFERENTIAL ENGINE ACCELERATION FROM LOW IDLE

### Troubleshooting

CFM56-3 engine acceleration from low idle is expected to vary from engine to engine. Upward migration of the steady-state low speed operating line has been isolated as a contributor to increasing the acceleration time for some engines as time is accumulated.

CFMI recommends several programs which have been developed to minimize and troubleshoot slow/differential acceleration. (see chart below)

A procedure for measuring and evaluating the low idle operating line is included to assist in understanding engine characteristics and refine troubleshooting techniques.

At shop level, the following are introduced:

- Coated HPT nozzle W-seal
- Workscope Planning Guide refurbishment recommendations for slow acceleration engines

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REVISED T/O THROTTLE SET  
VSV ON-WING DYNAMIC RIG  
IDLE SPEED ADJUSTMENT  
SPECIFIC GRAVITY ADJUSTMENT  
DIFFERENTIAL ACCELERATION TROUBLESHOOTING TREE  
ACCELERATION LIMIT AND GUIDELINES

## CFMI RECOMMENDATIONS FOR SLOW/DIFFERENTIAL ACCELERATION

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**FLAMEOUT****Troubleshooting (3.F.a)**

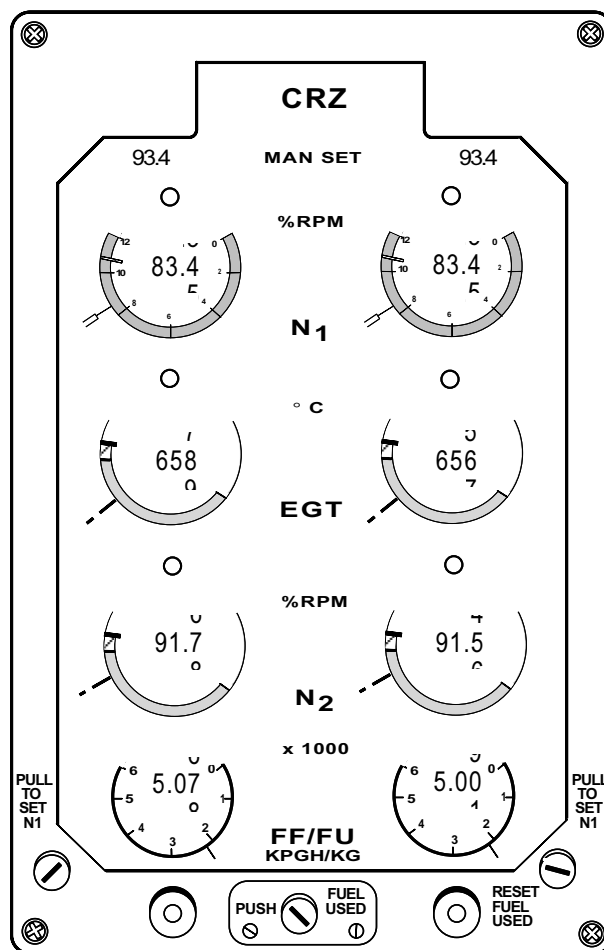
An engine flameout can be recognized by an immediate decrease in EGT,  $N_2$ , and fuel flow ( $W_f$ ), followed closely by a decrease in  $N_1$ .

Investigate the cause of the flameout. If engine indications prior to the flameout, and investigation following the flameout do not reveal an engine malfunction or failure, a restart may be made.

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## FLAMEOUT RECOGNITION

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## N<sub>1</sub> BLOOM

### Troubleshooting (3.F.a)

N<sub>1</sub> "bloom" past takeoff target N<sub>1</sub> is characteristic of a PMC OFF takeoff throttleset. When the PMC is off, the engine is controlled by the MEC, which schedules an N<sub>2</sub>K speed corresponding approximately to a known N<sub>1</sub>K at steady state. A throttle set for takeoff, however, results in a transient (dynamic) response in N<sub>2</sub> and N<sub>1</sub>. The MEC accelerates N<sub>2</sub> according to the acceleration fuel schedule until N<sub>2</sub>K reaches the desired scheduled value for takeoff - this N<sub>2</sub>K is then maintained by the MEC. The dynamic response in N<sub>1</sub>, due to the transient changes in clearances and component efficiencies, is a "bloom" past steady-state N<sub>1</sub> value by as much as 4-6% N<sub>1</sub>, prior to stabilizing at the steady-state value. This bloom is typically several minutes in duration.

Impacts of this condition include overboost of takeoff N<sub>1</sub> (thrust), and increased EGT during the N<sub>1</sub> bloom. The increase in EGT (10-12°C per 1% sustained bloom during the bloom only) results from efficiency and clearance transients and does not represent a permanent loss of EGT margin

Engine thrust deviations (from intent) and/or fluctuations can be caused by one or more fault possibilities. The initial factor in troubleshooting an N<sub>1</sub> bloom report is to first determine if the T/O was done with the PMC OFF. The PMC is designed to prevent this N<sub>1</sub> bloom. If the T/O

occurred with the PMC OFF, no further troubleshooting is necessary. If it is determined that the PMC was on, then some type of failure has caused a saturation of the PMC's trim limits. The T/O N<sub>1</sub> schedule is then the direct resultant of the N<sub>2</sub> (MEC) schedule.

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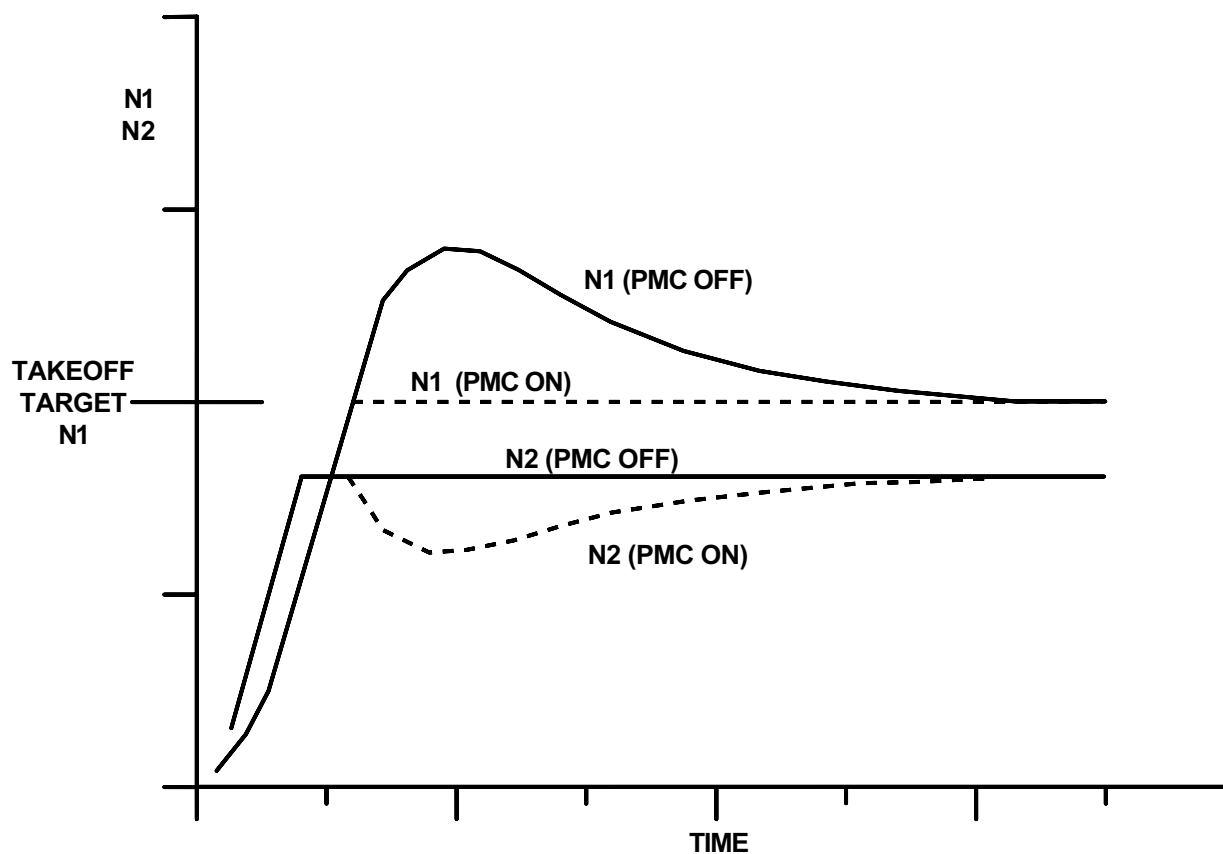
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Note 1: Airplane static.

Note 2: This plot represents general characteristics only.

Note 3: Time = 0 corresponds to PLA move to PMC off takeoff N2.



**N<sub>1</sub> BLOOM - PROPERLY RIGGED SYSTEM**

**N<sub>1</sub> BLOOM****Troubleshooting (3.F.a)**

Anything which causes the PMC OFF N<sub>1</sub> to be high at a given N<sub>2</sub> can cause N<sub>1</sub> bloom during takeoff. With the N<sub>1</sub> high at the MEC maintained N<sub>2</sub>, the PMC will require a greater N<sub>2</sub> down trim signal to the MEC, to the extent of possibly running out of downtrim authority/capability (saturation). The speeds in this situation may react similarly to those shown below, with the possibility of an N<sub>1</sub> bloom.

Variable geometry (VSVs & VBV) operating off schedule, causes such an N<sub>1</sub>/N<sub>2</sub> shift. In this particular scenario, either the VSVs are operating more open than design intent, and/or the VBV is operating further closed than design intent. Anything which can impact the way the variable geometry operates - hardware, rigging, CIT sensor, MEC - is inspected/checked in the troubleshooting tree.

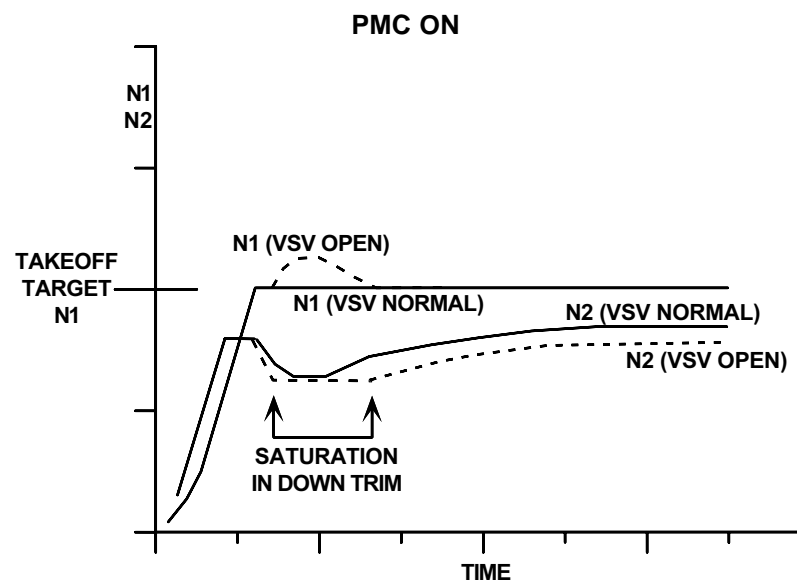
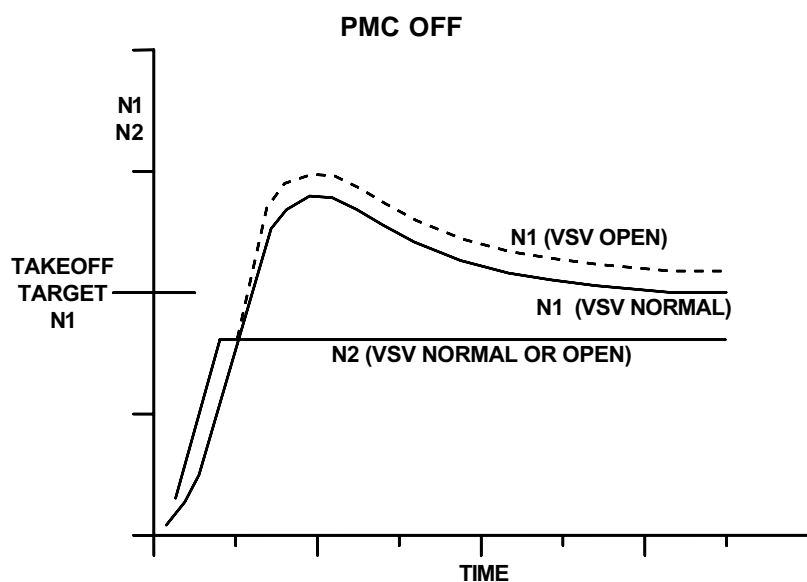
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- Note 1: Airplane static.  
 Note 2: This plot represents general characteristics only.  
 Note 3: Time = 0 corresponds to PLA move to PMC off takeoff N2.



## N<sub>1</sub> BLOOM - VSV'S TRACKING OPEN/OUT OF LIMITS

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**N<sub>1</sub> BLOOM****Troubleshooting (3.F.a)**

If the PMC is not operating, the resultant takeoff will behave as the characteristic PMC OFF takeoff, with N<sub>1</sub> bloom. The troubleshooting tree incorporates two inspections which could cause this scenario. First, the aircraft P5-68 cockpit panel is checked for possible failure which causes the PMC to be commanded off without illuminating the cockpit PMC inop light. Secondly, the N<sub>2</sub> alternator, which powers the PMC, is checked for swelling of the alternator stator grommet, which can intermittently interrupt power to the PMC, again without PMC inop light illumination.

Note: Modifications to both the P5-68 panel and the Control Alternator are available.

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## N<sub>1</sub> BLOOM

### Troubleshooting (3.F.a)

An engine which is improperly trimmed during the part power trim test can result in an N<sub>1</sub> bloom. In particular, if the PMC off N<sub>2</sub> is high out of limits, the engine system may saturate in downtrim and be unable to fully eliminate the total N<sub>1</sub> bloom. For this reason, a part power trim test is included in the troubleshooting tree.

The original trim authority incorporated into MECs and PMCs was +/- 3.25% N<sub>2</sub>. However, with this configuration, it was possible in some circumstances for a properly functioning system to become fully saturated in down trim during takeoff. Service bulletins 73-043 (PMC) and 73-048 (MEC) were introduced to increase the trim authority to +3.85%/-5.1% N<sub>2</sub>, providing ample downtrim margin to cover worst case stackups. In order to obtain the benefit of increased torque motor authority, both service bulletins must be incorporated.

The troubleshooting tree lists the MEC and PMC part numbers which incorporate the increased trim authority. If an engine is configured with old authority limits and is experiencing N<sub>1</sub> bloom, adjusting the PMC OFF N<sub>2</sub> during a part power trim run to the low side of the tolerance band will maximize the system's capability to successfully trim the N<sub>1</sub> bloom. This procedure is listed in the troubleshooting tree as well.

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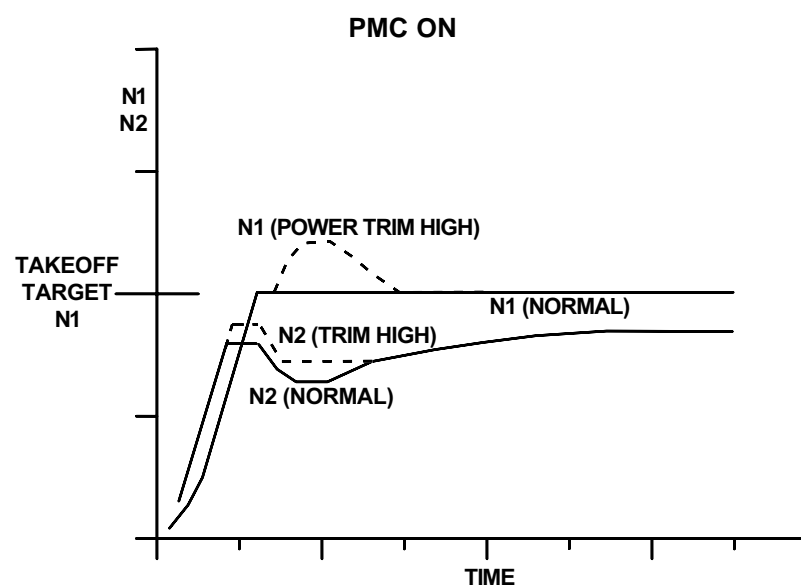
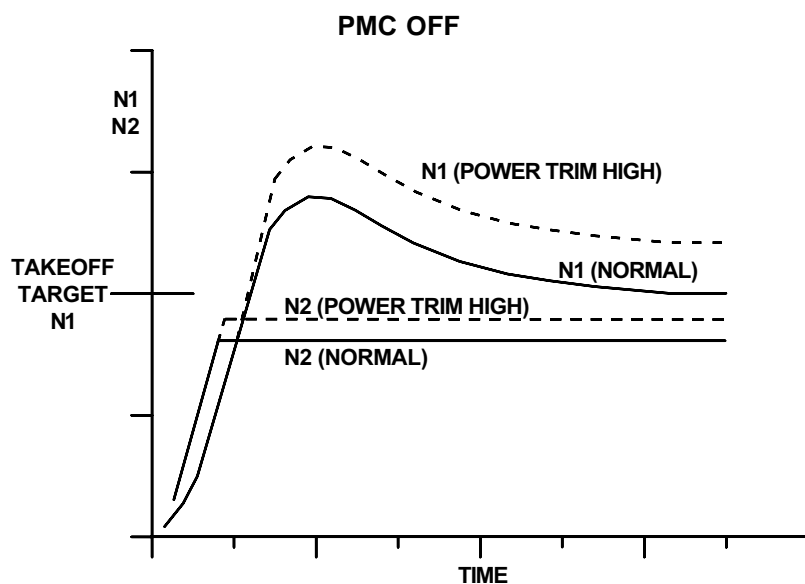
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- Note 1: Airplane static.  
 Note 2: This plot represents general characteristics only.  
 Note 3: Time = 0 corresponds to PLA move to PMC off takeoff N2.



## N<sub>1</sub> BLOOM - PART POWER TRIM ADJUSTED HIGH/OUT OF LIMITS

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**N<sub>1</sub> BLOOM****Troubleshooting (3.F.a)**

The MECs internal Rotary Variable Differential Transducer (RVDT) provides the PMC with a PLA signal for use in determining target N<sub>1</sub>K. If the RVDT fails to "open" the PMC will perceive a PLA of 70°, regardless of actual throttle position. The level of PMC trim authority is a function of PLA, and at 70° there is virtually no trim capability. Therefore, throttle sets are effectively PMC OFF, and N<sub>1</sub> bloom is likely to occur. While the PMC tester and maintenance manual procedures are provided for checking the RVDT, intermittent failures can occur especially when the RVDT is heated. An extra step has been added to the troubleshooting tree to run the engine at low idle for 5 minutes, then perform a 130° PLA gain check. With the RVDT heated, this check may be able to detect an intermittent RVDT open.

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**N<sub>1</sub> BLOOM****Troubleshooting (3.F.a)**

Internal failures of the MEC or PMC (or related component) may cause N<sub>1</sub> bloom. Hence the PMC is checked, and the MEC replaced at the conclusion of other troubleshooting.

All known causes/contributors to N<sub>1</sub> bloom are addressed in the troubleshooting fault tree. Since there are many potential causes of N<sub>1</sub> bloom on takeoff, the troubleshooting tree is extensive, yet considered necessary to effectively isolate the cause of a particular event. Thorough troubleshooting per the Maintenance Manual is expected to identify and correct the cause of N<sub>1</sub> bloom events.

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**THROTTLE STAGGER****Troubleshooting (3.F.a)**

Throttle stagger during manual operation with the PMC ON should not usually be more than one-half knob. During autothrottle operations, up to approximately one knob can occur, specially during cruise, when the thrust levers can operate in different directions.

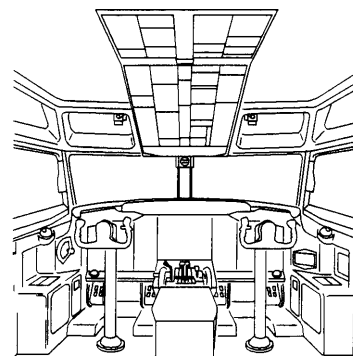
Throttle stagger with PMC OFF or inoperative can be more than one knob as the thrust is controlled to  $N_2\%$ , not  $N_1\%$ . Because of engine to engine speed ( $N_1\%$ ) - speed ( $N_2\%$ ) relationships, different PLA settings can occur for a given indicated  $N_1\%$ .

If the unsatisfactory engine is not known then it is recommended that troubleshooting on both engines be performed.

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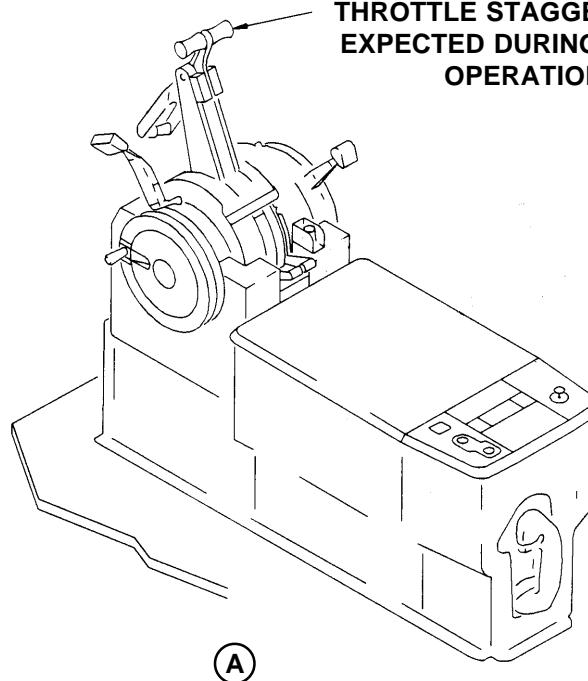
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SEE (A)

ONE-HALF TO ONE KNOB  
THROTTLE STAGGER CAN BE  
EXPECTED DURING NORMAL  
OPERATIONS



(A)

## THROTTLE STAGGER

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**UNABLE TO REACH T/O POWER****Troubleshooting (3.F.a)**

An upward shift of  $N_2$  means the HPC is turning faster than normal to produce the same  $N_1$  thrust. The problem shows up on a hot day full power T/O when  $N_1$  cannot be obtained because the  $N_2$ /EGT limit has been reached or the throttle lever has reached the limit stop.

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**ENGINE SURGE/STALL****Troubleshooting (3.F.a)**

Engine stalls are caused by an aerodynamic disruption of the normally smooth airflow through the compressor stages. A stall may be indicated by different abnormal engine noises, loud reports accompanied by flames from the engine inlet, fluctuating performance parameters, and sluggish or no throttle response.

Compressor stalls can result in fatigue fracturing of compressor blades and severe thermal deterioration of hot section parts. This may result in engine performance deterioration or engine failure following a severe stall, but more commonly, the full effects of a stall are deferred and consequently more difficult to correlate directly with a specific stall occurrence. The deferred effects are cumulative and repeated stalls will adversely affect engine durability, reliability, and operating cost.

The decision to continue operation of an engine that has encountered a severe compressor stall (or stalls) must be made under the consideration that possible additional stall occurrences and increased engine damage may occur.

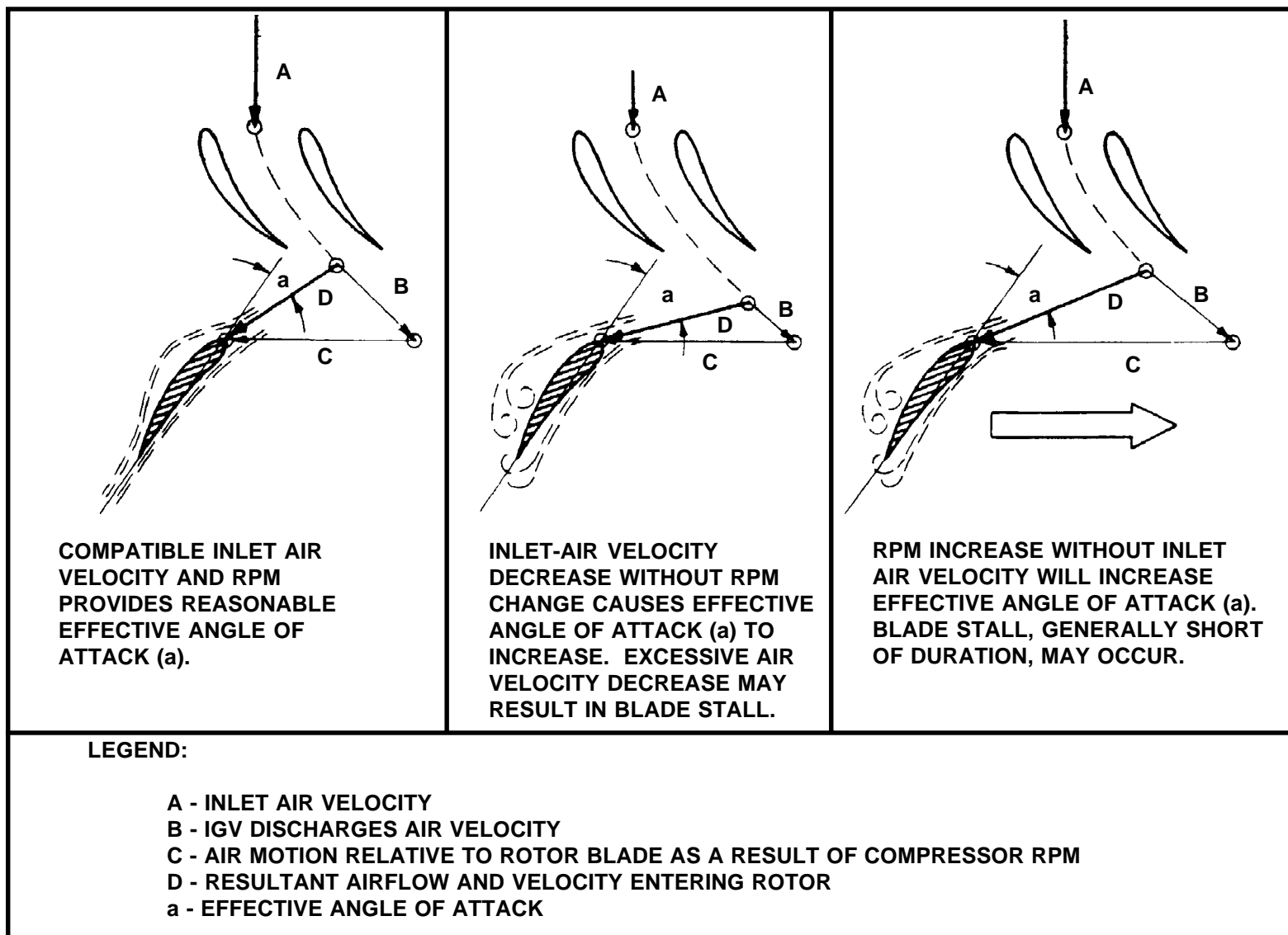
Never advance, or fail to retard, the thrust lever on an engine that is stalling. Engine destruction can result.

If the cause of the stall is known (tailwind, crosswind, or low airplane speed during reverse thrust) troubleshooting is not necessary after proper inspection of the engine.

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## EFFECTIVE ANGLE OF ATTACK VARIATIONS OF AXIAL FLOW COMPRESSOR BLADE

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## ENGINE SURGE/STALL

### Troubleshooting

There are three types of stalls:

- Fan
- Booster (low pressure compressor)
- Core (high pressure compressor)

Fan stalls usually occur during high thrust operation with excessive crosswinds or tailwinds. This type of stall is audible, but not evident on engine instrumentation. The sound of a fan stall is similar to that of an acetylene blowtorch. A quick reduction in thrust is the best way to clear this type of stall.

Booster stalls occur during decels at high altitude and low Mach number. Just like the Fan stall it is audible but not evident to the engine instruments. This type of stall is generally self-recovering but may lead to a Core stall.

Core stalls can be experienced over the entire flight envelope during both steady state and transient operation. This type of stall may or may not be audible, but will have an effect on EGT, N<sub>2</sub> and N<sub>1</sub> instrumentation.

If a core stall (surge) occurs do the following:

- Quickly (in one to two seconds) move the throttle

lever rearward to idle power to clear the stall.

- Make sure that EGT and N<sub>2</sub>% decreases to normal idle indications.
- Make sure the engine vibration levels are normal.

You must shut down the engine for these conditions:

- There is a high EGT, or
- A quick EGT increase occurs during slow throttle movement, or
- An increase over previous vibration levels occurs.

Slowly move the throttle lever forward to see if the stall recurs. If the stall does not recur and N<sub>2</sub> and EGT indications are normal, continue with engine operation.

If the core stall occurs again, or if the stall does not clear satisfactorily, operate the engine at low idle for three minutes and shut down the engine to investigate.

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**ENGINE SURGE/STALL****Troubleshooting**

There are two categories for engine stalls:

- High Thrust /Transient Stalls
- Off Idle and Start Stalls

High thrust/transient engine stalls are indicative of some sort of engine malfunction or exceedance of the operating envelope.

This disruption of the airflow to the fan, booster, or core airflow is generally due to FOD, VSV off schedule, excessive engine deterioration or Inlet distortion.

These types of stalls are very noticeable due to:

- Abnormal engine noise
- Exhaust or inlet flame
- Fluctuating N1, N2, EGT, and fuel flow
- Excessive vibration
- Abnormal throttle response

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## ENGINE SURGE/STALL

### Troubleshooting

Off Idle and start stalls are indicative of an engine malfunction, misscheduling or an aircraft system malfunction.

Causes can be attributed to the disruption of compressor airflow due to inflow bleed, eccentric rotor clearances, excessive deterioration, VSV off schedule or excessive fuel schedule.

The detection is more difficult due to the lack noise or flame. However an abnormal increase in EGT and a stagnation or rollback of rotor speeds will accompany this type of stall.

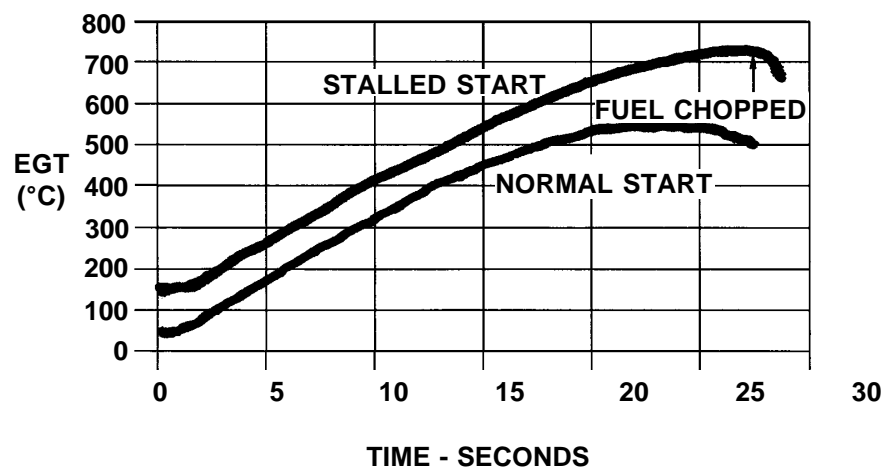
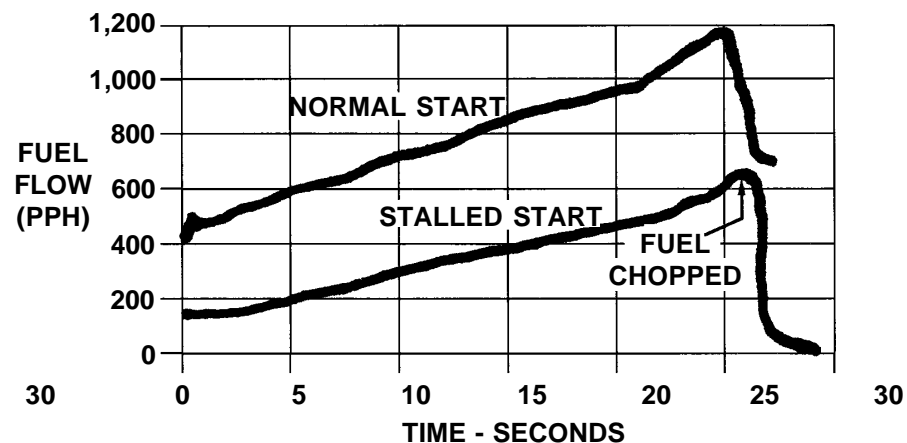
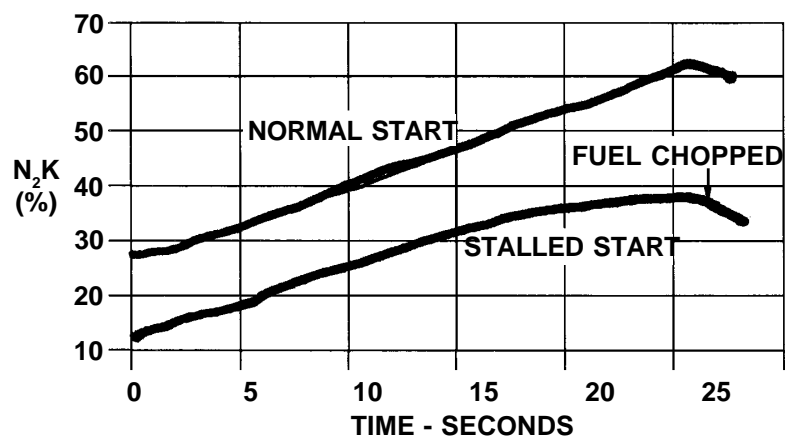
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## NORMAL VERSUS STALLED START CHARACTERISTICS

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## DIAGNOSTIC TOOLS FOR TROUBLESHOOTING

### Objectives:

At the completion of this section a student should be able to:

- ....state the purpose of performing diagnostic engine runs of the CFM56-3/3B/3C engine (3.B.x).
- ....describe the troubleshooting guidelines associated with a diagnostic engine run of the CFM56-3/3B/3C engine (3.D.x).
- ....identify the steps required to perform a diagnostic engine run of the CFM56-3/3B/3C engine (3.E.x).
- ....recall the normal and abnormal observations following a diagnostic run of the CFM56-3/3B/3C engine (3.F.x).
- ....practice analyzing the diagnostic run data of a CFM56-3/3B/3C engine.
- ....demonstrate analyzing the diagnostic run data of a CFM56-3/3B/3C engine.

## INTRODUCTION

### **Purpose (3.B.a)**

Because of the many engine sensors, component riggings, etc. that affect CFM56-3 operational characteristics, isolating the cause of a reported engine operational problem can sometimes be difficult. However, troubleshooting the cause can be simplified by first accomplishing one or two engine ground runs, and analyzing the collected data. The data can help determine which system may be at fault, or which systems appear to be functioning correctly. With this knowledge, the troubleshooting steps may be refined to investigate a more likely failure first, and eliminate (or postpone) certain steps in troubleshooting trees, saving time and unnecessary component replacements.

This section is intended to provide some basic guidelines for these engine run diagnostics. It is not intended to replace the maintenance manual troubleshooting trees, but rather to enhance them.

It is also not intended, nor recommended, that each and every pilot write-up be investigated with engine ground runs. The discretion of each airline should be used to determine when such action is appropriate.

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## GROUND RUNS

### Description (3.D.a)

Generally, three different engine ground runs are helpful in assessing engine characteristics. Each should be performed via proper maintenance manual procedures. It is recommended that data from both engines be collected for the runs, for two reasons: first, it allows a basis for comparing engines ( $N_1K/N_2K$  relationship, idle speeds for differential accel adjustments, etc.); secondly, it is particularly helpful when troubleshooting a condition where it is uncertain which engine may be at fault (i. e. throttle stagger). The three ground runs are:

- Low idle
- Part power trim check - rig pin installed, PMC ON and PMC OFF
- Max Power Assurance (MPA) check

For each of the checks, the following items should be recorded:

- Ambient temperature
- Ambient pressure
- Stabilization time
- $N_1$

- $N_2$
- EGT
- Fuel flow ( $W_f$ )
- PMC ON or off
- Targets from maintenance manual trim tables or MPA table

For the CFM56-3, there is a characteristic relationship between steady-state  $N_1K$  and  $N_2K$ . It is very important to understand that even on engines whose systems are operating properly, there is some expected variation in this  $N_1K/N_2K$  characteristic - for example, general engine deterioration results in a shift in  $N_1K/N_2K$  (lower  $N_2K$  for a given  $N_1K$ ). Additionally, control system tolerances from engine-to-engine can cause slight variations in  $N_1K/N_2K$  between engines. For this reason, absolute  $N_1K/N_2K$  relationship limits do not exist.

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**GROUND RUNS****Description (3.D.a)**

However, if the variable geometry (VSV/VBV) is not scheduling correctly, an engine's  $N_1K/N_2K$  relationship can shift more dramatically, which can result in numerous operational impacts, depending on the direction and level of shift (throttle stagger, unable to reach T/O,  $N_1$  bloom, slow acceleration, stalls, etc.). As stated previously, there are no absolute limits of  $N_1K/N_2K$ ; however, a significant shift in the  $N_1K/N_2K$  relationship can be determined by comparing the two engines at matched  $N_1$ 's or matched  $N_2$ 's. An assessment of the relative  $N_1K/N_2K$  relationship is most accurate at higher engine speeds, such as MPA or T/O. Since a substantial shift in  $N_1K/N_2K$  is indicative of a problem somewhere in the engine's variable geometry system (VSV/VBV rigging/hardware, CIT, MEC), a higher power ground run can help determine whether the VSV/VBV system may be a contributor to an operational problem.

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## GROUND RUNS

### Description (3.D.a)

The idle speed check is helpful in determining low speed engine health - particularly for squawks for slow acceleration or slow starts. A determination of available low idle speed adjustment (for slow/differential acceleration from low idle) can also be made by comparing the actual  $N_2$  with the maintenance manual limits (higher  $N_2$  improves acceleration time from low idle).

Because it is performed at a known throttle position, the part power trim check is extremely helpful in determining whether the MEC (PMC OFF data) and PMC (PMC ON data) systems are attaining the correct  $N_2$  (for the MEC) and  $N_1$  (for the PMC). The PMC and MEC use throttle position, temperature and pressure to determine target speed. During a ground run, ambient temperature and pressure are known, so with the known throttle position during a part power trim run (92.5°), each system can be independently checked. It is important that the rig pin be installed in the throttle box during this test - "ballpark" throttle positioning is not acceptable.

It is possible to compare the  $N_1K/N_2K$  of both engines during a part power trim check. However, it is important that the  $N_1$ 's be precisely matched, or the  $N_2$ 's be precisely matched. If this is not possible at the part power stop, perform the check during the MPA, where a

specific  $N_1$  is set on both engines.

The max power assurance check is helpful in two respects - first, it provides a means of assessing an engine's general EGT health (for write-ups of high T/O EGT); secondly, it allows obtaining data on both engines at a precise  $N_1$  target, so that a general comparison of  $N_1K/N_2K$  can be made. If there is a significant difference in this relationship between the two engines, it is indicative of a VSV/VBV system (hardware, rigging, MEC, CIT) problem on one of the engines.

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## GROUND RUNS

### Description (3.D.a)

The following pages provide the following:

- Procedures for performing each of the ground runs.
- Forms for collecting data from each of the ground runs.
- General observations about what may be learned from the collected data.

Because of the difficulty inherent at times in isolating the cause of a particular pilot write-up, this section provides a means of more refined and efficient troubleshooting. Ground run data is very helpful because it is concrete and specific - pilot reports on engine anomalies are often vague, making efficient troubleshooting extremely difficult.

The ground runs recommended in this document provide at least one of the following:

- Isolate which system may be at fault.
- Determine which systems appear to be functioning correctly, hence eliminating unnecessary engine inspections/component removals.

Again, these ground runs are not intended to replace the maintenance manual troubleshooting trees. The ground

runs allow an operator to use the troubleshooting trees more effectively, postponing troubleshooting steps that appear from the ground run data not to be contributing to the reported problem, or pinpointing the faulty system to troubleshoot.

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## IDLE SPEED CHECK

### Maintenance Tasks (3.E.a)

Perform idle speed check per the Boeing 737 maintenance manual.

Stabilize at low idle for five minutes.

Record the following after five minutes' stabilization (see chart below).

Shut engine down per maintenance manual, or proceed with other test point(s), if planned.

### Observations (3.F.a)

Engine  $N_2$  speed should be within maintenance manual limits. Determine allowable adjustment available if the  $N_2$  is out of limits, or if considering an adjustment for a slow/differential acceleration squawk.

Fuel flow ( $W_f$ ) in the 800 Pounds Per Hour (PPH) range or higher may be indicative (or support the possibility) of low speed engine deterioration, particularly if the engine has been written up for slow start/acceleration, has relatively high time, etc. (CESM 031 provides more details on low speed engine deterioration, and should be referenced for more details). If the engine is new, or recently overhauled, it is possible that another system fault is causing the higher fuel flow ( $W_f$ ) (pneumatic leaks, VSV's tracking closed, idle speed out of limits low,

etc.). Troubleshooting per the maintenance manual is still recommended.

It is inaccurate to check  $N_1K/N_2K$  relationship at idle speed - only at high engine speeds can this be accomplished. The  $N_1K/N_2K$  relationship is insensitive to swings in VSV/VBV scheduling at low engine speed.

The PMC has no authority at idle, and therefore troubleshooting for any problems identified at low idle should not involve the PMC system, but be isolated to the MEC system, engine hardware, or aircraft systems (per the MM troubleshooting trees).

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DATE:	_____	
TAIL NO:	_____	
AMBIENT TEMPERATURE:	_____	
AMBIENT PRESSURE:	_____	
STABILIZATION TIME:	_____	
	<u>ENGINE NO. 1</u>	<u>ENGINE NO. 2</u>
N <sub>1</sub> :	_____	_____
N <sub>2</sub> :	_____	_____
EGT:	_____	_____
FUEL FLOW (W <sub>f</sub> ):	_____	_____
N <sub>2</sub> TARGET (FROM TRIM TABLE):	_____	

## LOW IDLE SPEED CHECK RECORDING DATA SHEET

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## PART POWER TRIM CHECK

### Maintenance Tasks (3.E.a)

Using the part power rig pin, perform part power trim check per the maintenance manual (PMC OFF and PMC ON).

Stabilize for two minutes with PMC OFF, record data below, then stabilize for two minutes with PMC ON, and record the data below.

Record the following after two minutes' stabilization (see next page).

Per the maintenance manual, return the engine to idle.

Stabilize for five minutes, then shut engine down per maintenance manual, or proceed with other test point(s), if planned. Note that the rig pin will have to be removed if an MPA run follows this test point.

Use a duplicated chart for recording part power trim data after an adjustment is made (based on the results of the initial run).

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## PART POWER TRIM CHECK RECORDING DATA SHEET

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## PART POWER TRIM CHECK

### Observations (3.F.a)

The PMC OFF data offers information on how the MEC system is scheduling  $N_2$  based on throttle position, ambient temperature and pressure. The PMC OFF  $N_2$  value should be within the limits specified in the maintenance manual trim table. If it is not, adjust the part power trim screw per the maintenance manual. If the target is still not met, more detailed troubleshooting should follow: check  $Ps_{12}$  line (loose line causes low  $N_2$  speed),  $T_2$  sensor/lines (hot shift = high  $N_2$ , cold shift = low  $N_2$ ), throttle rigging, etc.

PMC OFF  $N_2$  that is out of limits may cause PMC ON  $N_1$  to be out of limits. Therefore, do not troubleshoot the PMC system because of not meeting PMC ON  $N_1$  limits until the MEC system (PMC OFF target  $N_2$ ) is operating correctly.

The VSV/VBV system scheduling will not affect whether the PMC OFF target  $N_2$  is met. Therefore, it is not necessary to check/inspect the VSV/VBV rigging or CIT sensor if the PMC OFF target is not met. These systems/components will, however, impact the resulting  $N_1$  speed at the target  $N_2$ .

The PMC ON data offers information on how the PMC system is scheduling  $N_1$  based on throttle position, ambient temperature and pressure. The PMC ON  $N_1$  value should be within the limits specified in the maintenance manual trim table. If it is not, first check the PMC OFF  $N_2$  - if it is out of limits, it can cause the PMC ON  $N_1$  to be out of limits -

correct the PMC OFF  $N_2$  problem first. If there is still a problem with PMC ON  $N_1$ , investigate the PMC system (PMC tester,  $T_{12}$ ,  $Ps_{12}$ , PLA gain/voltage, etc.), and the VSV/VBV systems.

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## PART POWER TRIM

### Observations

As a general guide, a difference of up to approximately 2%  $N_1$  between the two engines at perfectly matched  $N_2$ 's is within normal revenue service experience. If the difference is greater than 2%, it may be advisable to check the VSV/VBV rigging/hardware, and the CIT sensor. Some possible engine behavioral characteristics with VSV/VBV system scheduling improperly are as follows (depends on severity of system off-schedule):

- VSV running closed or VBВ running open:
  - Slow starts/acceleration
  - Throttle stagger, more pronounced PMC OFF (this engine throttle leading)
  - Unable to reach T/O target  $N_1$ , with high  $N_2$
  - Low/approach idle  $N_2$ 's OK
- VSV running open or VBВ running closed:
  - Compressor/booster stalls

- Throttle stagger, more pronounced PMC OFF (this engine throttle lagging)
- $N_1$  bloom/high EGT on T/O
- Low/approach idle  $N_2$ 's OK

Note: Checking the relationship of steady-state  $N_1K/N_2K$  can help isolate whether the VSV/VBV system/ components may need to be inspected. Never adjust VSV's to attain a specific  $N_1K/N_2K$  - this can cause serious operational problems, including stalls, LPT overtemperatures, throttle stagger, inability to reach T/O,  $N_1$  overshoot/bloom, etc.

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## MAX POWER ASSURANCE

### Maintenance Tasks (3.E.a)

Start engine per maintenance manual.

Perform MPA check per maintenance manual procedures.

Stabilize for four minutes and record the data (see next page).

Per the maintenance manual, return the engine to idle.

Stabilize for five minutes, then shut engine down per maintenance manual.

### Observations (3.F.a)

Check EGT limit per the maintenance manual to attain a general assessment of engine health.

To make an assessment of  $N_1K/N_2K$  relationship at MPA: with the  $N_1$ 's perfectly matched between the No. 1 and No. 2 engines (regardless of slight differences in throttle position), it is expected that there will be some difference in the observed  $N_2$ 's. As a general guide, a difference of less than 1%  $N_2$  between the two engines at perfectly matched  $N_1$ 's is within normal revenue service experience. If the difference is greater than 1%, it may be advisable to check the VSV/VBV rigging/hardware, and the CIT sensor. With the  $N_2$ 's perfectly matched

between the No. 1 and No. 2 engines, it is expected that there will be some difference in the observed  $N_1$ 's. As a general guide, a difference of up to approximately 2%  $N_1$  between the two engines at perfectly matched  $N_2$ 's is within normal revenue service experience. If the difference is greater than 2%, it may be advisable to check the VSV/VBV rigging/hardware, and the CIT sensor.

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DATE:		
TAIL NO:		
AMBIENT TEMPERATURE:		
AMBIENT PRESSURE:		
STABILIZATION TIME:		
	<u>ENGINE NO. 1</u>	<u>ENGINE NO. 2</u>
N <sub>1</sub> :		
N <sub>2</sub> :		
EGT:		
FUEL FLOW (W <sub>t</sub> ):		
PMC ON/OFF:		
MPA TARGET:		
MAXIMUM EGT (FROM TRIM TABLE):		
MAXIMUM N <sub>2</sub> (FROM TRIM TABLE):		

### MPA

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## MAX POWER ASSURANCE

### Observations

Some possible engine behavioral characteristics with VSV/VBV system scheduling improperly are as follows (depends on severity of system off-schedule):

VSV running closed or VBV running open.

- Slow starts/acceleration
- Throttle stagger, more pronounced PMC OFF (this engine throttle leading)
- Unable to reach T/O target  $N_1$ , with high  $N_2$
- Low/approach idle  $N_2$ 's OK

VSV running open or VBV running closed.

- Compressor/booster stalls
- Throttle stagger, more pronounced PMC OFF (this engine throttle lagging)
- $N_1$  bloom/high EGT on T/O
- Low/approach idle  $N_2$ 's OK

Checking the relationship of steady-state  $N_1K/N_2K$  can help isolate whether the VSV/VBV system/components may need to be inspected. Never adjust VSV's to attain a

specific  $N_1K/N_2K$  - this can cause serious operational problems, including stalls, LPT overtemperatures, throttle stagger, inability to reach T/O,  $N_1$  overshoot/bloom, etc.

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## POWER PLANT PRESERVATION AND DEPRESERVATION

### Objectives:

At the completion of this section a student should be able to:

- ....state the purpose of preserving a CFM56-3/3B/3C engine (3.B.x).
- ....state the purpose of an engine dry-out for a CFM56-3/3B/3C engine (3.B.x).
- ....state the purpose of depreserving a CFM56-3/3B/3C engine (3.B.x).
- ....describe the preservation guidelines of a CFM56-3/3B/3C engine (3.D.x).
- ....describe the dry-out guidelines of a CFM56-3/3B/3C engine (3.D.x).
- ....describe the depreservation guidelines of a CFM56-3/3B/3C engine (3.D.x).

## INTRODUCTION

### Overview

This section covers general information for power plant preservation, preservation renewal and depreservation.

- The instructions usually apply to power plants that are installed (on-wing).
- Where it is applicable, different instructions are given for engines that are not installed (off-wing).

The procedures are different for different lengths of no operation time, different types of preservation used and if the power plant is serviceable or not serviceable.

Preservation renewal, if permitted, gives the instructions for the renewal of the preservation period.

Note: For this procedure, the definition of an engine that is serviceable and an engine that is not serviceable is as follows: a serviceable power plant is one that can be started; a power plant that is not serviceable is one that cannot be started.



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## PRESERVATION

### Purpose (3.B.a)

Preservation instructions give the procedures recommended as the minimum steps necessary to prevent unwanted liquid and materials in the power plant, corrosion, and atmospheric conditions during times of storage and no operation, or landing after an IFSD.

### Description (3.D.a)

Do the applicable preservation procedure from the schedule that follows:

- Up to 10 days
- Up to 30 days
- Up to 90 days (serviceable power plant only)
- 30 to 365 days

Power plant preservation is a flexible program that can be done in a way which best agrees with the applicable weather and storage conditions.

More care is necessary for a program for power plants that are not operational in high humidity or large temperature changes or near a salt water area, than for the power plants that are in drier climates or less bad weather conditions.

You must make a schedule for the preservation programs

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for power plants that are not serviceable to do the preservation renewal procedures and monitor the schedule regularly to make sure the necessary procedures are done before the expiration of preservation time.

You must examine the preservation of the power plant as the weather conditions and conditions of power plant protection change and do the procedures necessary to keep the power plant in a serviceable condition.

Note: Engines cannot be preserved and put into storage without maintenance. A schedule must be (as disciplined as for a power plant in revenue service) made and then completed.

When desiccants are used, they must be changed regularly, applicable to environmental conditions, to keep the desiccant effective.

It is recommended that you pump the VBV's closed (reference 75-32-00/201) when the power plant is to be preserved and stored. This will prevent unwanted material in the core engine inlet through the VBV's.

If a power plant is preserved for more than the long-term preservation time (365 days), you must do the power plant operation procedure to make sure the power plant is serviceable before you put the power plant back into service or preserve the engine for a longer time.

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PRESERVATION DAYS	OPERABLE ENGINE	NON-OPERABLE ENGINE
UP TO 10 DAYS PRESERVATION	3 MINUTE LOW IDLE RUN ENGINE COVERS UNLIMITED RENEWAL	DRY-OUT PROCEDURE PERFORM WITHIN 24 HOURS OF IFSD NO RENEWAL
UP TO 30 DAYS PRESERVATION	20 MINUTE LOW IDLE RUN ENGINE COVERS RENEW 2 ADDITIONAL 30 DAYS	DRY-OUT PROCEDURE ENGINE COVERS NO RENEWAL; PERFORM 30 TO 365 DAY
UP TO 90 DAYS PRESERVATION	20 MINUTE RUN; PRESERVATIVE OILS ENGINE COVERS NO RENEWAL; PERFORM 30 TO 365 DAY	NO RENEWAL; PERFORM 30 TO 365 DAY
30 TO 365 DAYS PRESERVATION	TREAT OIL WITH ANTI-CORROSIVES TREAT FUEL SYSTEM WITH 10/10 OIL DRY-OUT PROCEDURE ENGINE COVERS DESSICANT WRAP ENGINE	EXTENSIVE PROCEDURE REQUIRED REFERENCE 71-00-03 FOR DETAILS NO RENEWAL MAKE ENGINE OPERABLE

## PRESERVATION REQUIREMENTS CHART

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**ENGINE DRY-OUT****Purpose (3.B.a)**

The engine dry-out procedure removes moisture from the oil system to prevent corrosion to the bearings and gears.

**Description (3.D.a)**

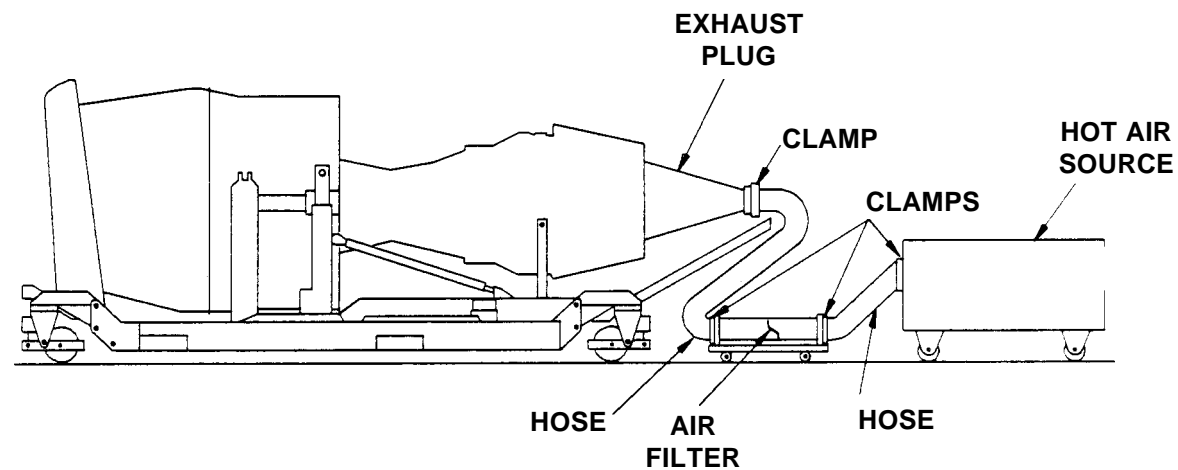
You must do the engine dry-out procedure when an engine has had an IFSD, and when an engine that is not serviceable will be preserved for a long time.

If an engine has been subjected to an IFSD and will not be operated within 24 hours, a dry-out procedure must be performed as soon as possible.

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NOTE: LAYOUT SHOWN FOR  
ENGINE OFF-WING;  
SIMILAR FOR ON-WING  
INSTALLATIONS

## DRY-OUT EQUIPMENT GENERAL LAYOUT

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**DEPRESERVATION****Purpose (3.B.a)**

Depreservation instructions consist of steps that put a power plant back to the usual operational condition.

**Description (3.D.a)**

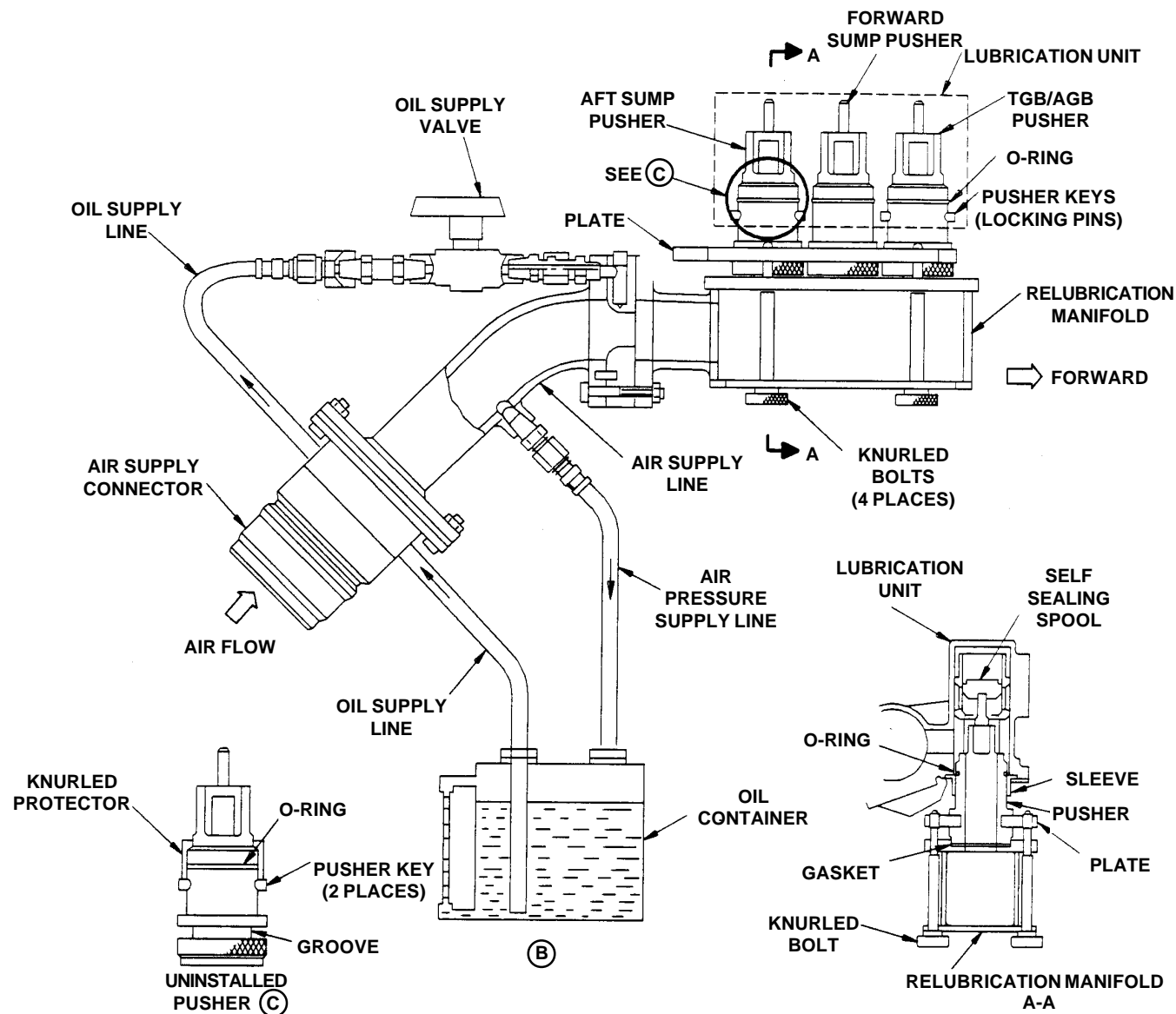
The following is a summary of guidelines for depreservation of a CFM56-3/3B/3C engine:

- Drain the oil and fuel systems of preservative fluids.
- Replenish the oil tank with new oil.
- Wet motor twice to purge fuel system of preservative fluids (dry motor after each wet motor).
- Replace oil and fuel filters.
- Perform engine test No. 3 (reference 71-00-00 A/T).  
Additionally, run engine for 10 minutes at low idle prior to shutdown.
- Check magnetic chip detectors.

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## ENGINE SUMPS RELUBRICATION MANIFOLD TOOL SET INSTALLATION

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## ENGINE GAS PATH CLEANING

### Objectives:

At the completion of this section a student should be able to:

- ....state the purpose of gas path cleaning a CFM56-3/3B/3C engine (3.B.x).
- ....describe the engine gas path cleaning process of a CFM56-3/3B/3C engine (3.E.x).

## INTRODUCTION

### Purpose (3.B.a)

Engine gas path cleaning restores engine efficiency by the removal of particle contaminants from the primary airflow path.

Experience has shown that an average 6°C EGT and 0.5% specific fuel consumption can be realized. This average delta provides the most significant benefit to high time engines.

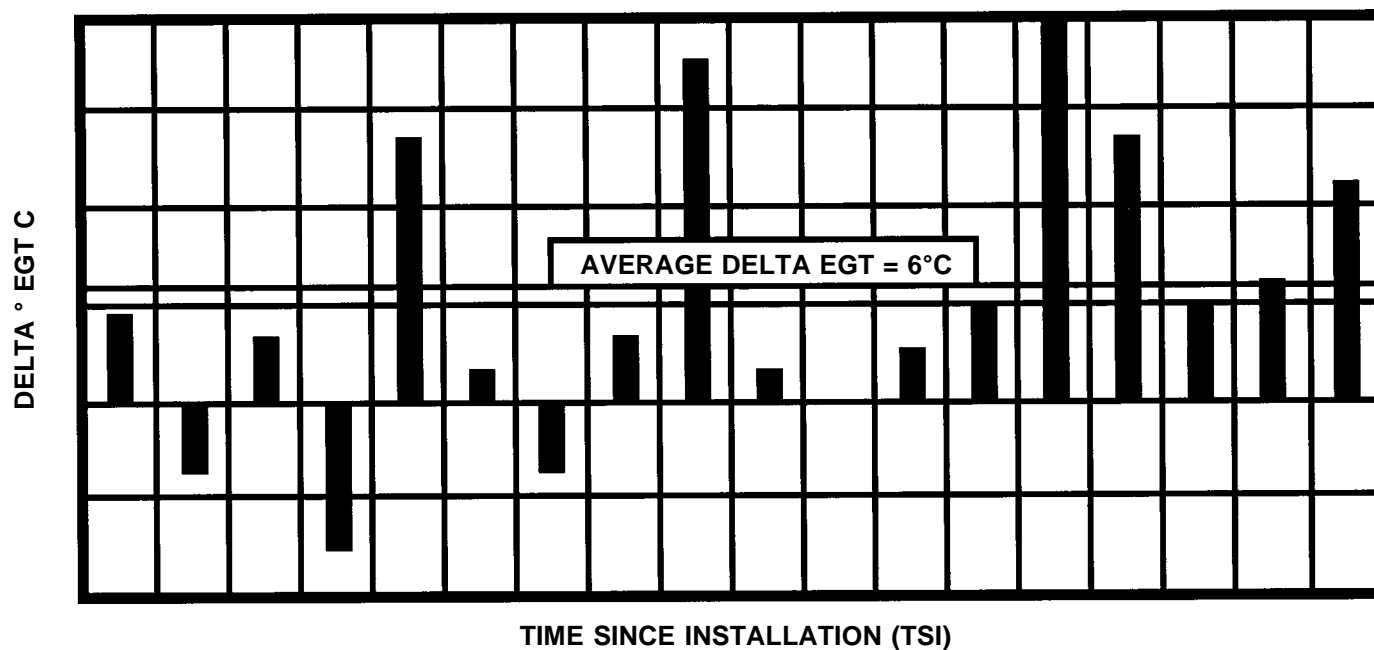
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### CFM56-3 WATER WASH BENEFIT EXPERIENCE (TEST CELL)

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## ENGINE WATER WASH

### Maintenance Tasks (3.E.a)

The following pages are a summarization of the CFM56-3 gas path cleaning procedure. To find more detailed information refer to the B737-300/400/500 Maintenance Manual.

Prepare the engine for the wash:

- Disconnect the CDP and CBP lines at the combustion case and put end caps on the lines.
- Make sure the left (right) start lever is in the CUTOFF position.
- Make sure the left (right) forward thrust lever is in the IDLE position.
- Make sure the left (right) reverse thrust lever is in the IDLE position.
- Make sure the left (right) ENG ANTI-ICE and BLEED switches are in the OFF position.

Detergent wash the engine:

- Adhere to the following warnings and cautions:
  - Use the rubber gloves when touching the solvent. Skin irritation can occur if you touch the solvent before it is mixed.

- The cleaner is flammable. Obey the precautions against fire. If you do not obey the precautions, injuries to persons can occur.
- Do not wash the engine if a fire extinguishing agent has been used. Damage to the engine can occur.
- Do not wash the engine if the EGT indication is more than 66°C. Engine damage can occur.
- Prepare the cleaning solution.
- Use the Power Plant Dry-motor procedure to motor the engine for one minute (reference 71-00-00/201).
- Disengage the starter and immediately apply the cleaning solution through the fan blades and into the LPC inlet.
- Apply the solution until the solution is gone or the N<sub>1</sub> rotor stops.
- Let the engine soak for five minutes.
- Do the water wash procedure.

Make sure the N<sub>1</sub> rotor turns freely when you wash the engine. If the N<sub>1</sub> rotor does not turn freely, damage to the engine could occur.

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## ENGINE WATER RINSE

### Maintenance Tasks (3.E.a)

Water rinse the engine:

- Adhere to the same cautions stated in the engine wash procedure.
- Use the Power Plant Dry-motor procedure to motor the engine for one minute (reference 71-00-00/201).
- While the engine turns, apply water through the fan blades and into the LPC inlet.
- Let the engine soak for five minutes.
- Motor the engine again for two minutes.
- While the engine turns, apply water through the fan blades and into the LPC inlet.
- Let the engine soak for five minutes.
- Motor the engine again for three minutes.
- For the first two minutes only, apply water through the fan blades and into the LPC inlet.
- Open the fan cowl panels.

Note: Obey the instructions in the procedure to open the T/R's. If you do not obey the instructions when you open the T/R's, injuries to persons and damage to equipment can occur.

Open the left (right) T/R's. Let the engine drain for five minutes.

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## ENGINE POST-RINSE

### Maintenance Tasks (3.E.a)

Prepare the engine:

- Connect the CDP and CBP lines.
- Add one quart (one liter) of Aeroshell fluid 12 oil, if available, to the oil tank.

Operate the engine:

- Operate the engine after no more than 30 minutes from the last wash cycle to remove all the water from the oil system.
- Operate the engine at low idle for five minutes.
- Make sure engine and APU bleed switches are in the OFF position.
- Put the applicable ENG ANTI-ICE switch in the ON position.
- Make sure there is an increase in the EGT of approximately 15°C
- Put the ENG ANTI-ICE switch in the OFF position.
- Move the forward thrust lever until the engine is in high idle. Put the applicable ENG ANTI-ICE switch in the ON position.

- Make sure there is an increase in the EGT of approximately 15°C.
- Put the ENG ANTI-ICE switch in the OFF position.
- Make the engine idle stable at the low idle position and operate the engine for five minutes.

Shut down the engine.

Note: Make sure the COWL VALVE OPEN light comes on bright (this indication shows valve movement) and then dim (this indication shows the valve fully open).

Note: Operate the engine for 10 minutes if the corrosion inhibiting oil was not added to the oil tank.

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