CHAPTER

80

Engine Starting

(LEAP-1B ENGINES)

CHAPTER 80
ENGINE STARTING

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A = Added, R = Revised, D = Deleted, O = Overflow, C = Customer Originated Change

80-EFFECTIVE PAGES

CHAPTER 80
ENGINE STARTING

80-CONTENTS

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ENGINE STARTING - INTRODUCTION

General

The engine starting system uses pneumatic power to turn the engine's N2 rotor during a start or motor procedure. Pneumatic power comes from one of these sources:

- APU
- Pneumatic ground equipment
- Opposite engine.

These components control the engine start system:

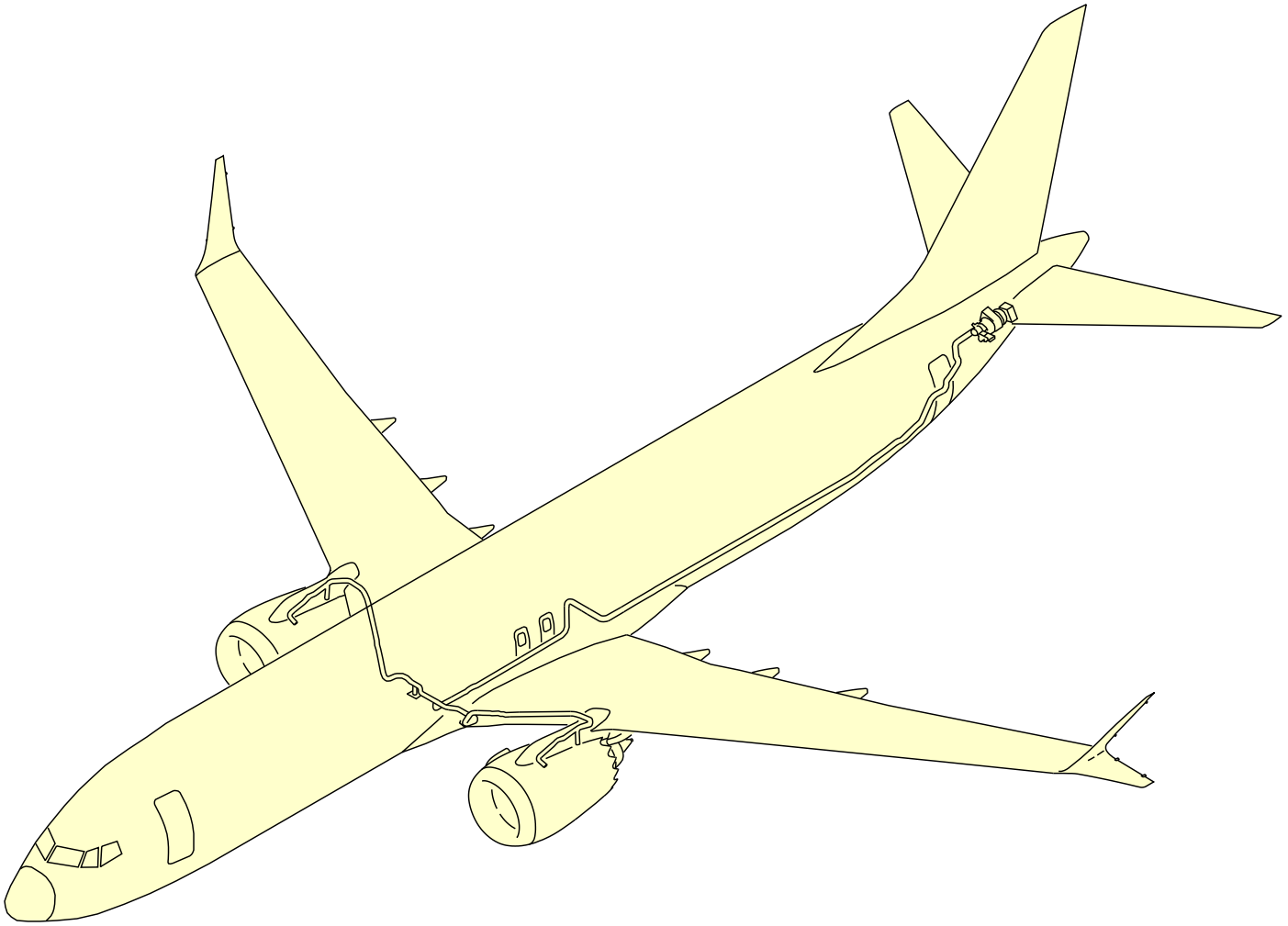
- Flight compartment switches
- Display processing computer (DPC)
- Electronic engine control (EEC).

The engine starting system operates on the ground and in flight.

Abbreviations & Acronyms

- AGB - engine accessory gearbox
- ALF - aft looking forward
- AMM - airplane maintenance manual
- CDU - control display unit
- DPC - display processing computer
- EEC - electronic engine control
- FMCS - flight management computer system
- MDS - max display system.

ENGINE STARTING - INTRODUCTION



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ENGINE STARTING - INTRODUCTION

ENGINE STARTING - GENERAL DESCRIPTION

General

The engine starting system uses these airplane and engine systems or components:

- Pneumatic power
- Electrical power
- Flight compartment switches
- Electronic Engine Controls
- Display Processing Computers (DPCs)
- Max Display System (MDS).

ENGINE START Switch

The starter is controlled by the EEC based on inputs received from the ENGINE START switch and sensed engine core speed. When the ENGINE START switch is moved to the GRD position, the EEC commands the Starter Air Valve (SAV) to open, supplying compressed air (from the opposite engine, APU, or a ground cart) to the air turbine starter, which rotates the accessory, transfer, and inlet gearboxes.

ENGINE START Switch Functions:

- GRD - Commands EEC to open the SAV to activate the air turbine starter, commands the selected igniter(s) on for ground starts, commands both igniters on for starter-assisted airstarts.
- OFF (Auto) - Turns off starter and commands both igniters to off.
- CONT - Commands selected igniter(s) (L, BOTH, or R) to on.
- FLT - Commands both igniters on for windmill inflight start and starter assist is not required.

Start Air Valve (SAV) and Starter

The SAV opens to supply pneumatic power to the starter when the ENGINE START switch is moved to the GRD position. The START VALVE OPEN alert shows on the engine display when the SAV is commanded open and its position indicates it is open. If the electrical control of the valve is not operational, the valve can be manually opened and closed on the ground.

The ENGINE START switch is spring loaded to the OFF (auto) position from the GRD position. A latching solenoid holds it in the GRD position until the EEC commands the solenoid to release via the engine starter cutout discrete command sent over ARINC 429 to the Display Processing Computers (DPC)s.

EEC

If the ENGINE START switch latching function fails to release the switch following a successful engine start, the EEC will set the appropriate maintenance fault. The ENGINE START switch must be moved back to the OFF position manually if the switch fails to release automatically. If the EEC detects that the ENGINE START switch has not been moved to the OFF position 30 seconds after the EEC command to unlatch, the EEC will command the SAV closed in order to minimize the possibility of damage to the starter from operating above cutout speed for extended periods of time.

DPCs

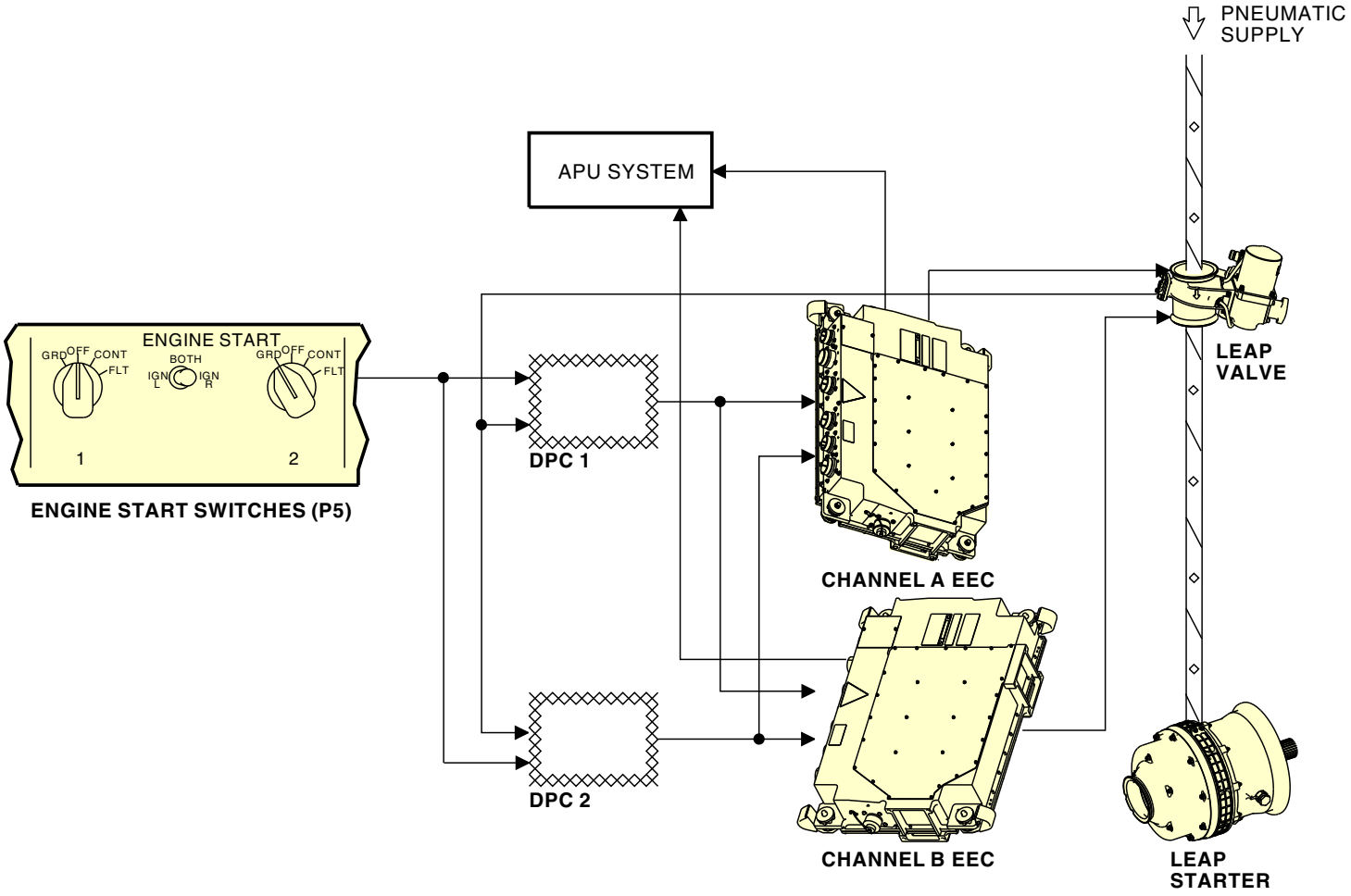
The Display Processing Computers receive the signals from the ENGINE START switch. The DPCs convert the signals and send it to the EECs via ARINC 429 data bus.

Bowed Rotor Starts

Bowed Rotor Start (BRS) logic has been implemented in the EEC to reduce the impact of the “bowing” effect on the rotor shafts that may occur due to residual thermal gradient buildup following engine shutdown. If shaft bowing is not alleviated, it can lead to high engine vibration levels, which could potentially damage turbo machinery and/or other components.

BRS logic alleviates the bowing effect by motoring the engine for a period of time prior to introducing fuel. The resulting rotation of the shafts is intended to distribute the residual thermal energy more evenly and thereby “straighten” the shaft.

ENGINE STARTING - GENERAL DESCRIPTION



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ENGINE STARTING - GENERAL DESCRIPTION

ENGINE STARTING - COMPONENT LOCATIONS - ENGINE

General

The engine starting system has these components on the left side of the engine:

- Pneumatic starter ducts
- Start valve
- Starter.

Access to these components is under the left fan cowl.

Pneumatic Starter Ducts

There are two pneumatic starter duct assemblies.

The upper starter duct assembly is installed on the strut. One end is connected the airplane pneumatic supply. The other end is connected to the lower pneumatic starter duct installed on the left side of the fan case.

The lower pneumatic starter duct is connected to the start valve and to the starter.

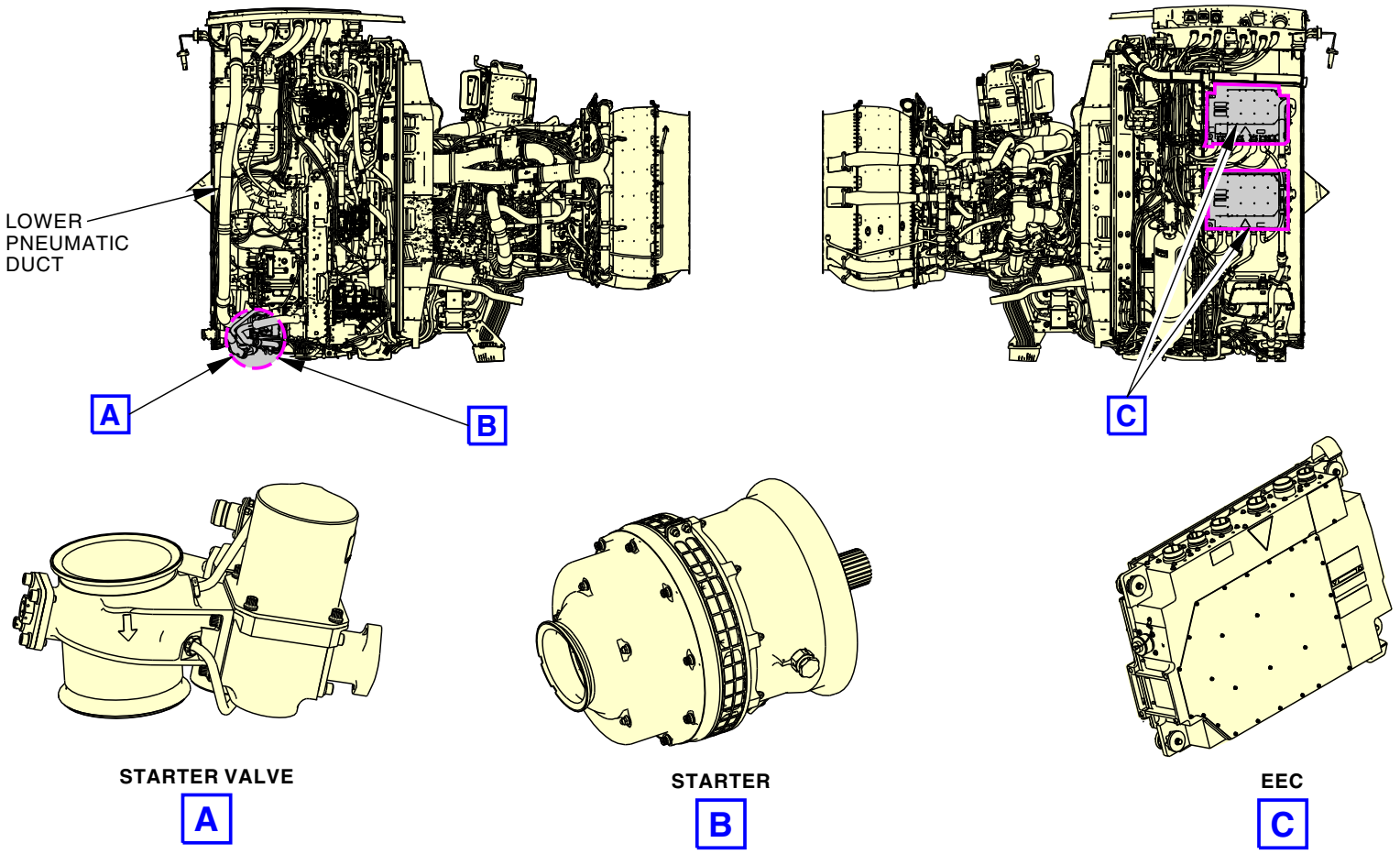
Start Valve

The start valve is installed on the forward end of the starter.

Starter

The starter is mounted on the forward face of the engine Accessory Gearbox (AGB) below the Integrated Drive Generator (IDG).

ENGINE STARTING - COMPONENT LOCATIONS - ENGINE



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ENGINE STARTING - COMPONENT LOCATIONS - ENGINE

ENGINE STARTING - COMPONENT LOCATIONS - FLIGHT COMPARTMENT AND EE COMPARTMENT

Flight Compartment

The ENGINE START switches and the ignition selector switch are on the P5 forward overhead panel.

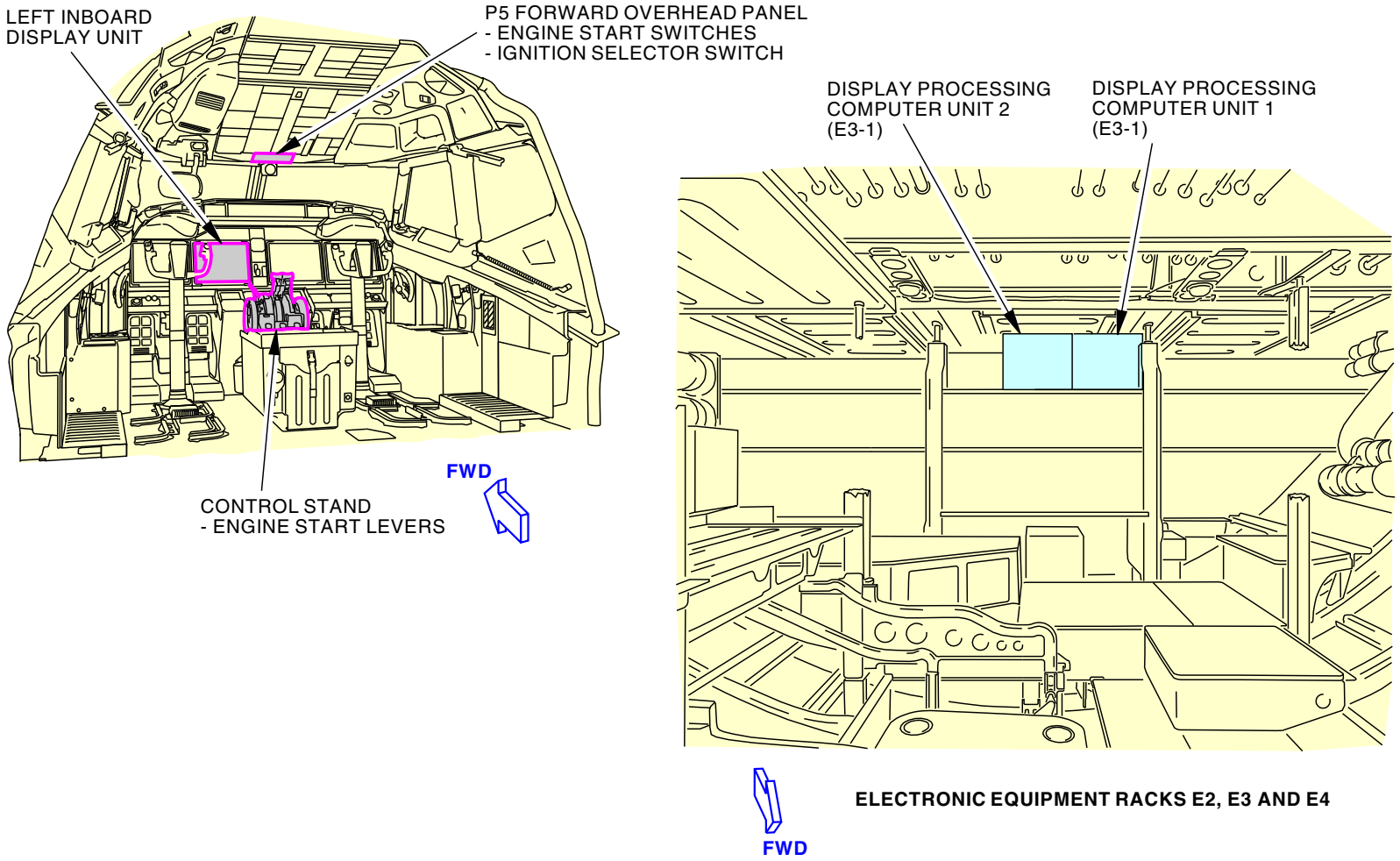
The MAX Display System (MDS) processes and formats the engine data through the Display Processing Computers (DPCs). The engine parameters usually show on the left inboard display unit of the MDS.

The engine start levers are on the control stand, aft of the thrust levers.

Electrical Equipment Compartment

The Display Processing Computer Units are on the E3 rack.

ENGINE STARTING - COMPONENT LOCATIONS - FLIGHT COMPARTMENT AND EE COMPARTMENT



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ENGINE STARTING - COMPONENT LOCATIONS - FLIGHT COMPARTMENT AND EE COMPARTMENT

ENGINE STARTING - START VALVE

Purpose

The start valve supplies pneumatic power to the starter. The valve opens for these engine operations:

- Ground start
- In flight starts that require starter assist
- Motoring.

Physical Description

The start valve is a butterfly shutoff valve. It is electrically controlled and pneumatically operated. The valve is spring-loaded closed.

The primary components are the valve body assembly and actuator assembly.

The valve body assembly has these components:

- Butterfly valve
- Valve shaft
- Shaft bearings
- External position indicator.

The actuator assembly has these components:

- Torsion spring
- Pneumatic actuator
- Electromagnetic control valve
- Strain gauge pressure sensor
- Manual override provision.

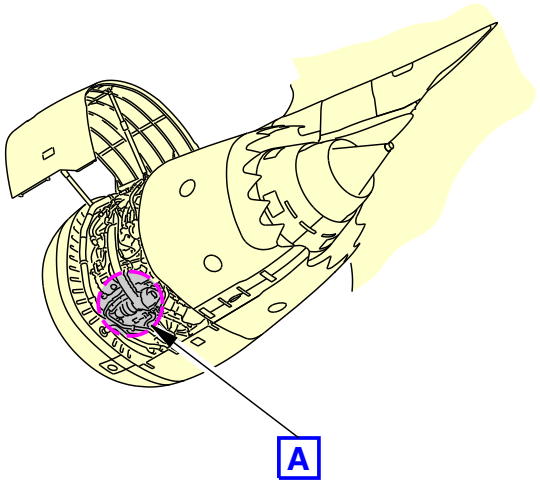
Functional Description

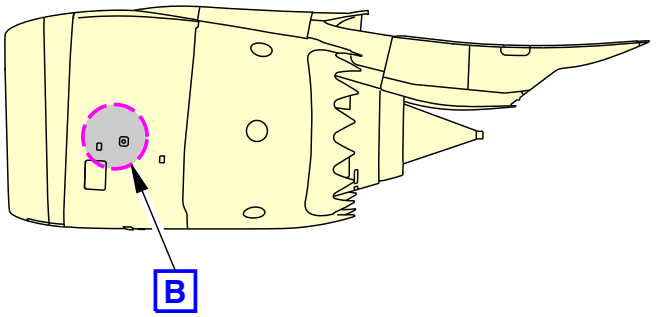
The electromagnetic valve is energized when the engine start switch is moved to the GRD position. This allows air pressure to the pneumatic actuator. The pneumatic actuator force is greater than the torsion spring force and the start valve opens.

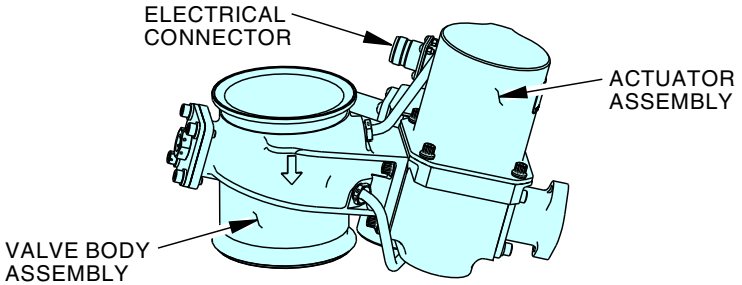
The DPCs use the strain gauge pressure sensor to supply indication in the flight compartment.

The start valve can be manually operated with a ⅜ in. (9.5 mm) square drive tool in the manual override access hole in the left fan cowl. A placard is near the hole. A visual indicator on the valve body shows valve position.

ENGINE STARTING - START VALVE







START VALVE

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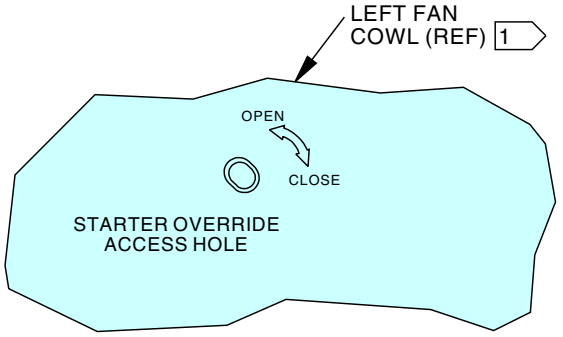

MANUAL OVERRIDE STENCIL

B

NOTE:

1 STENCIL ITEMS NOT TO SCALE

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ENGINE STARTING - START VALVE

ENGINE STARTING - STARTER

General

The starter turns the engine for engine starting or motoring procedures. The starter changes air pressure into mechanical energy.

Physical Description

The starter has a single-stage, axial-flow, turbine air motor. The starter uses reduction gears and a sprag clutch to turn the output shaft to the engine accessory gearbox (AGB).

The starter has one port for oil drain and fill. This port also has a magnetic chip detector.

A coupling attaches the starter to the Accessory Gearbox (AGB). A V-band clamp attaches the starter air inlet to the starter air valve.

Functional Description

Pneumatic power goes through an open starter air valve to turn the turbine air motor in the starter. The turbine turns the reduction gears and engages the clutch. The clutch transmits torque to the output shaft of the starter. The reduction gears engage the clutch as long as pneumatic power turns the turbine.

The starter output shaft turns the AGB. The AGB turns the engine N2 rotor through shafts and other gears.

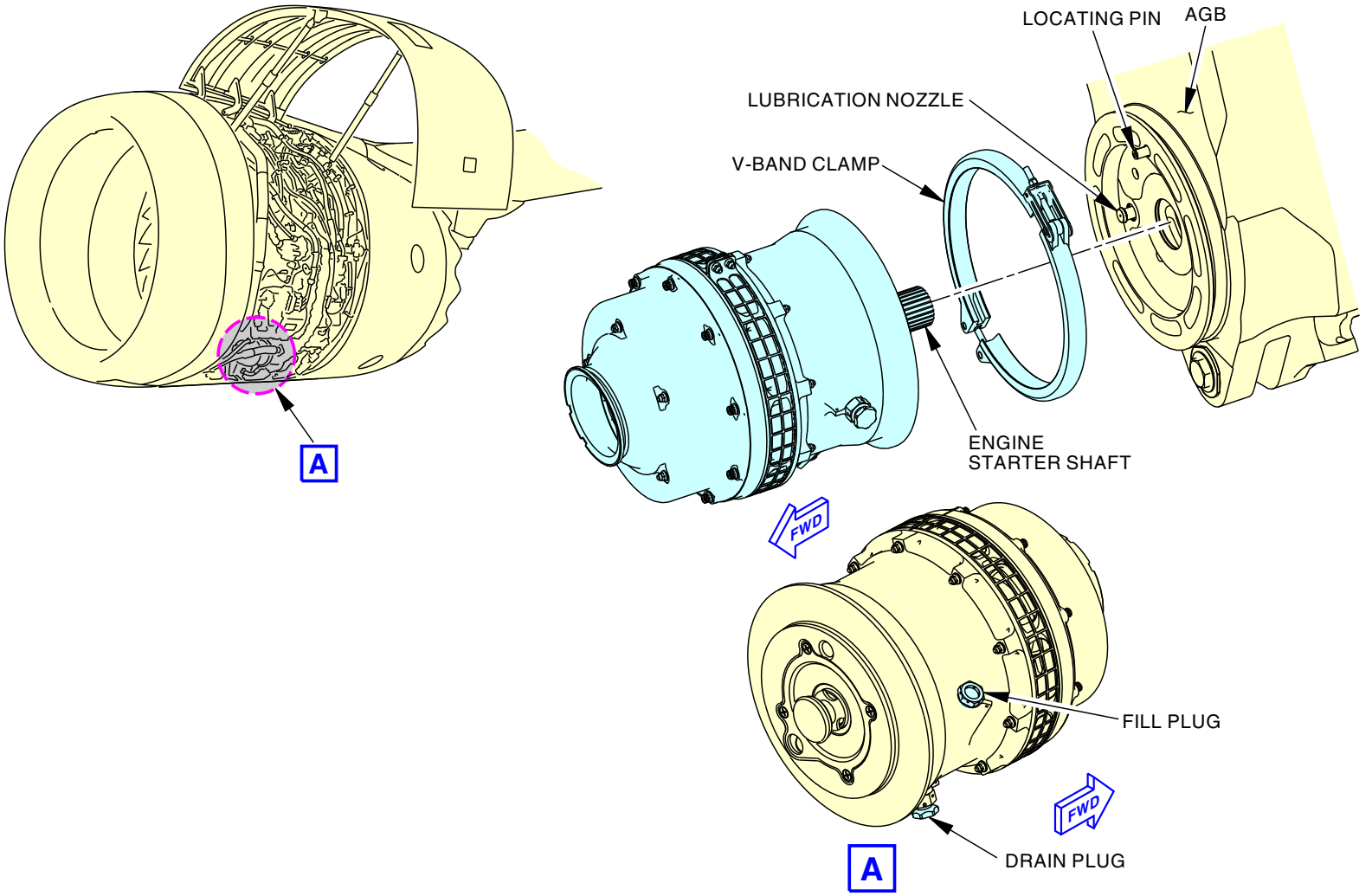
At approximately 63% N2, the start valve closes and removes pneumatic power from the starter. The turbine and reduction gears slow and the clutch disengages. The starter output shaft then turns with the gearbox and engine. The turbine and reduction gears continue to slow until they stop.

The starter receives a continuous flow of oil from the AGB when the engine turns. The oil cools and lubricates these starter components:

- Clutch
- Gears
- Bearings.

Oil returns to the AGB. A small quantity of oil stays in the starter. There is a drain plug that also serves as a magnetic plug at the bottom of the starter.

ENGINE STARTING - STARTER



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ENGINE STARTING - STARTER

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ENGINE STARTING - FUNCTIONAL DESCRIPTION

General

The engine starting is controlled by the EEC based on inputs received from the engine Start Switch and sensed engine core speed.

Starting Control

When the ENGINE START switch is moved to the GRD position, the EEC commands the SAV to open, supplying compressed air (from the opposite engine, APU, or a ground cart) to the air turbine starter, which rotates the accessory, transfer, and inlet gearboxes. Electrical power for engine starting control comes from the battery bus.

Indication

The DPCs use input data to show engine parameters and start valve position on the MAX Display System (MDS).

These are the two modes of operation for the amber START VALVE OPEN message:

- Steady
- Flash (crew alert).

The START VALVE OPEN message is steady when the start valve is open and the ENGINE START switch is in the ground position.

The START VALVE OPEN message flashes when the start valve is open while the EEC is commanding it closed.

The Display Processing Computers (DPCs) also flash the START VALVE OPEN alert when the ‘Start Valve Open’ discrete is TRUE and the engine has been above the starter cutout speed for 5 seconds.

Start Switch

The following occur when the engine start switch is moved to the GRD position when electrical and pneumatic power are available:

- The DPCs receive the start signal from the ENGINE START switch and convert it to ARINC 429 data.
- EEC receives the ARINC 429 engine start signal from the DPCs and commands the SAV to open.
- APU electronic control unit receives a signal to schedule the APU inlet guide vanes for the engine start.
- Electromagnetic control valve energizes and the valve opens.
- Starter clutch engages and the engine N2 rotor turns
- A latching solenoid holds the start switch in the GRD position until the EEC commands the solenoid to release via the engine Starter Cutout discrete command sent over ARINC 429 to the DPCs.

Fuel and Ignition

The engine start lever is moved to the IDLE position to add fuel and ignition during the start.

Starter Cutout

The EEC commands the solenoid to release via the engine Starter Cutout discrete command sent over ARINC 429 to the DPCs. The EEC will also command the SAV to close if engine core speed exceeds the starter cutout threshold. The following occur during starter cutout:

- The DPCs remove the electrical ground for the ENGINE START switch solenoid.
- The ENGINE START switch goes to the OFF position
- The electromagnetic control valve in the SAV de-energizes and the valve closes.

Engine Wet Start

The EEC stops the engine start if the EGT does not increase within 10 seconds after the engine start lever is moved to the IDLE position. The EEC stops fuel flow and turns off ignition. The engine starter will continue to motor the engine until the ENGINE START switch is moved to OFF.

ENGINE STARTING - FUNCTIONAL DESCRIPTION

Engine Hot Start

If the EEC detects a hot start condition or a start stall (hung start) condition during a ground start, the numeric EGT display box will thicken and turn on and off. If the EGT starting limit is exceeded, the EEC stops the fuel flow and ignition. The numeric EGT display will continue to flash until the engine start lever is moved to the CUTOFF position. This feature operates on the ground only.

In-Flight Start

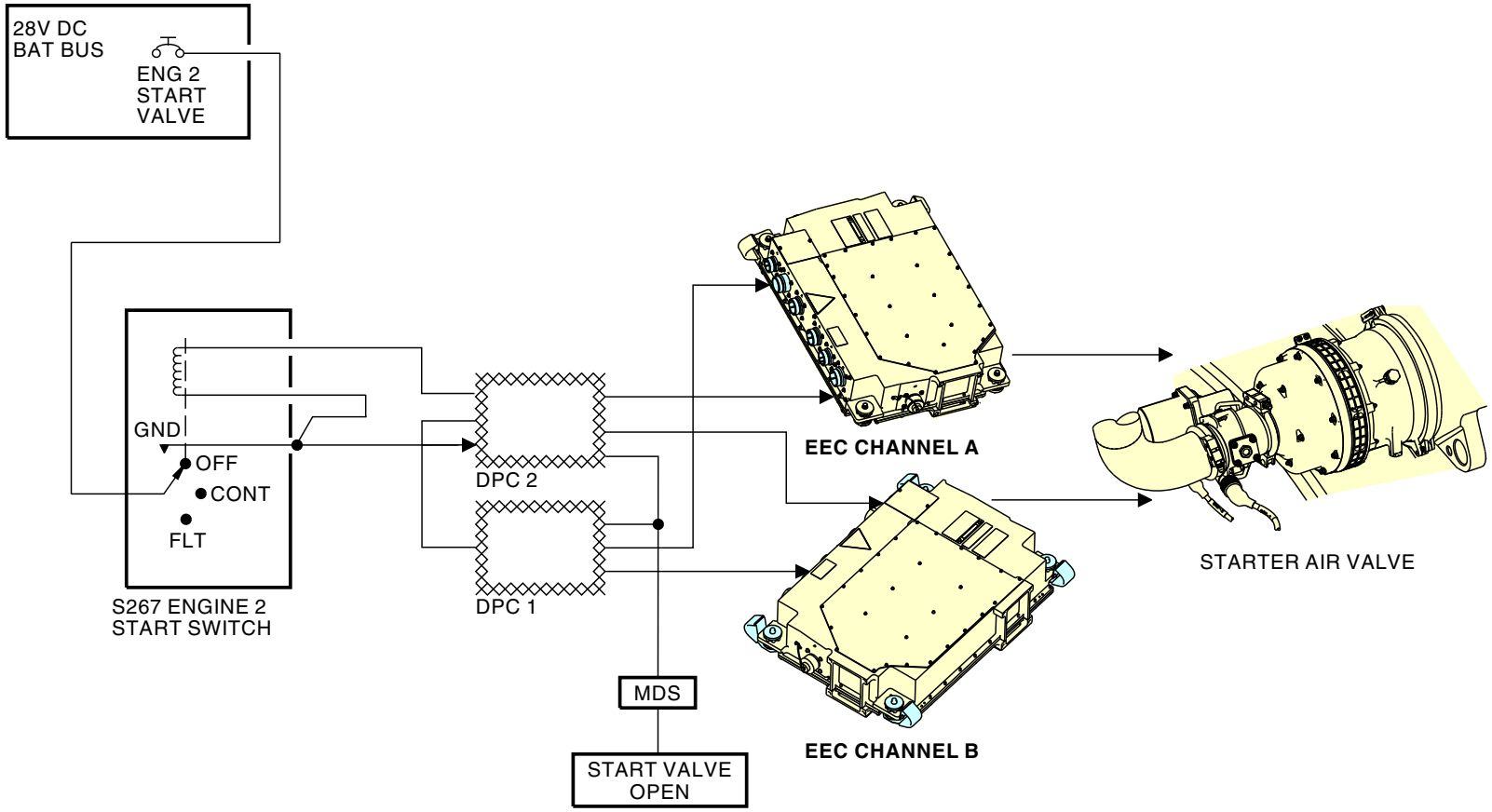
The EEC supports in-flight starting of the engine within a defined airspeed/altitude envelope. Depending upon the indicated position of the flight deck ENGINE START Switch, the EEC logic will attempt to perform either a Starter Assisted Air Start (SAAS) or a windmill start.

The EEC will initiate a SAAS sequence when ENGINE START switch is moved to the GRD position, the engine Start Lever is moved to the IDLE position, and the EEC primary air/ground signal indicates “in-air”. the following occur during SAAS attempt:

- During in-flight starts, the EEC will energize both igniters and exciters as soon as the engine Start Lever is moved to the IDLE position.
- The EEC will command the FMV to switch on fuel at the Starter Assisted In-Flight start fuel-On N2 speed of approximately 20%. However, if core speed does not reach this fuel-ON speed within 5 seconds, the EEC will not command fuel on.
- Once the engine Start Lever is moved to IDLE, the EEC will attempt to start the engine. The start attempt shall only be terminated if either the engine successfully reaches idle or the flight crew moves the engine Start Lever to the CUTOFF position.

A magenta X-BLD indication appears on the engine display above the N2 to indicate when the airspeed is less than the minimum required for a windmill start.

ENGINE STARTING - FUNCTIONAL DESCRIPTION



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ENGINE STARTING - FUNCTIONAL DESCRIPTION

ENGINE STARTING - OPERATION

General

The controls for engine start are in these areas:

- Forward overhead panel
- MDS display
- Control stand.

Pneumatic power must be available to start the engine on the ground.

The following engine parameters are monitored during engine start:

- N2
- Oil pressure
- N1
- Fuel flow
- EGT.

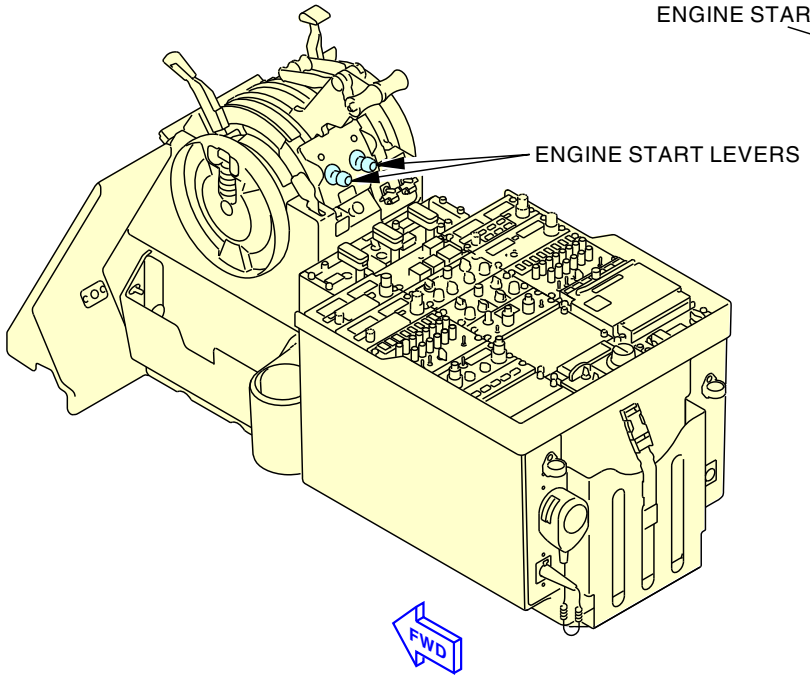
EGT, fuel flow, engine oil pressure, oil temperature, and vibration information are not available until the ENGINE START switch is moved to GRD and the engine start lever to IDLE. The N1, N2, and engine oil quantity sensor signals are input directly to the MDS. The N1, N2, and engine oil quantity indications are active when the EECs are not powered.

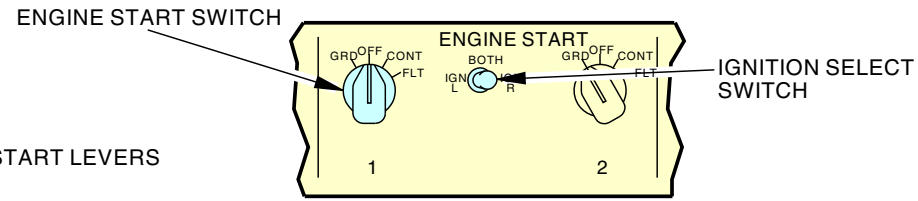
Engine Start

This is a summary of the engine start procedure:

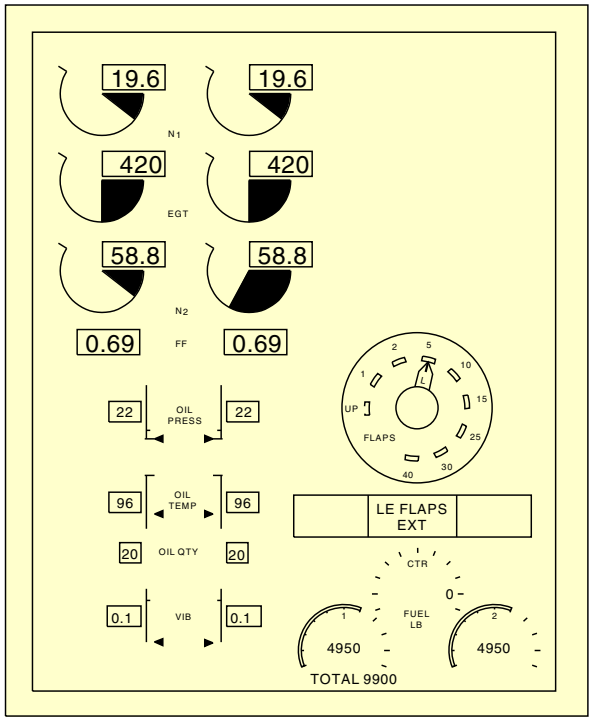
- Follow safety procedures and airplane and engine limitations
- Set the air conditioning PACK switches to OFF.
- Put the engine start switch to the GRD position. This will also power up the EEC and all engine indications will appear.
- Look for the START VALVE OPEN alert on the engine display indication.
- Monitor N2 to verify engine acceleration. A white MOTORING indication will appear across the middle of the N2 indication at 18% during extended motoring to accommodate bowed rotor starts. Bowed Rotor Motoring (BRM) is active for all ground starts. N2 speed is controlled to approximately 23% during BRM. The dwell time spent at the BRM speed is a function of the residual T3 temperature, how long the engine has been shut down, and the sensed core vibration levels during the motoring. Once that dwell time is reached, the rest of the start sequence continues.
- Make sure that the oil pressure increases.
- Speak with the ground personnel to make sure N1 begins to turn counterclockwise
- Once MOTORING is no longer displayed over the N2 indication, move the start lever from CUTOFF to IDLE position when N2 reaches 25% or achieves maximum motoring speed (minimum of 20% N2).
- Make sure that the fuel flow indication shows a positive reading and that the EGT rises within 10 seconds.
- Monitor EGT and N2 increase until starter cutout at 63% N2.
- Make sure that engine start switch goes back to the OFF [AUTO] position at 63% N2 and the START VALVE OPEN alert is no longer displayed.
- Monitor all engine parameters as engine speed increases to idle.

ENGINE STARTING - OPERATION





ENGINE START PANEL (P5)



ENGINE INDICATION DISPLAY

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ENGINE STARTING - OPERATION