2A-80-10: Engine Starting System

1. General:

A. Description:

The engine is equipped with an air turbine starter mounted on the accessory gearbox. The starter is powered by pressurized pneumatic air provided by the Auxiliary Power Unit (APU), the other operating engine or by an external air cart. Airflow to the turbine starter is controlled by the Starter Air Valve (SAV). When the SAV opens, pneumatic air is directed onto the turbine blades of the starter causing the starter to turn. Gears within the starter transmit starter rotation to the drive shaft of the accessory gearbox. Rotation of the gearbox turns the High Pressure (HP) engine rotor assembly, inducing airflow through the engine and consequently causing rotation of the Low Pressure (LP) rotor. When the engine reaches sufficient speed, the Electronic Engine Control (EEC) energizes the engine ignitors and provides fuel flow to the nozzles in the engine combustion chamber to start the engine. After combustion has been initiated, the engine HP and LP rotors accelerate and rotation of the turbine starter is no longer required. The SAV closes, blocking air to the starter, and the starter is disengaged through the action of an internal clutch in the starter gear assembly that actuates when engine HP rotor speed exceeds starter turbine speed. An overview of the engine starting system is shown in Figure 1.

NOTE:

The power levers on the center pedestal must be in the idle position during engine starting. The engine will accelerate to the power setting commanded by the power levers at the completion of the starting process. An amber Crew Alerting System (CAS) caution message reading “L-R Throttle Configuration” will be displayed to alert the crew if a power lever is forward of the idle position during engine start.

2. Description Of Subsystems, Units And Components:

A. Starter Air Valve (SAV):

The Starter Air Valve (SAV) is located on the rear section of the engine at the juncture of lines connecting engine bleed valves to the aircraft pneumatic system. The valve is directly connected to the aircraft bleed air manifold in order to receive pressurized air from the APU, the other engine when operating or from an external air source. The primary element of the SAV is a butterfly valve controlled by a solenoid. The valve is normally held in the closed position by an integral spring and the pressure of air within the aircraft pneumatic supply manifold directed against the valve. When the SAV is commanded open by the EEC during engine start, the electrical open signal is provided to the valve solenoid that subsequently opens an internal chamber on the SAV to admit pneumatic manifold air to the open side of the valve. Pneumatic pressure overcomes the loading of the integral spring and moves the butterfly valve open, admitting pressurized air into a duct running forward on the engine to the starter turbine. The rate

of valve opening is controlled to prevent a rapid spin-up of the starter.

When the engine has reached sufficient rpm and the starter turbine is no longer required, the EEC signals the solenoid on the SAV to close the air passage holding the valve open and spring pressure closes the SAV.

If an electrical failure of the SAV solenoid prevents normal engine starting, a procedure is provided for manually opening the SAV to power the starter turbine in order to dispatch the aircraft. See Section 09-03-40 for instructions regarding the procedure.

CAUTION

MANUAL OPERATION OF THE SAV PLACES A CREW MEMBER IN CLOSE PROXIMITY TO VERY HIGH TEMPERATURES AND EXTREMELY LOUD NOISE LEVELS. THE PROCEDURE REQUIRES A HEADSET OR OTHER MEANS OF COMMUNICATION WITH THE COCKPIT IN ORDER TO MONITOR ENGINE RPM DURING START FOR CUES IN TIMING THE OPERATION OF THE SAV. THE PROCEDURE SHOULD BE THOROUGHLY REVIEWED PRIOR TO PREFORMING THE OPERATION.

If a failure during an engine start prevents the SAV from closing at the normal starter cutout HP rpm, the flight crew must shut off the bleed air supply to the SAV to prevent damage to the starter air turbine. The abnormal condition is indicated by the continued display of the L SVO or R SVO (left or right start valve open) text icon on the Engine Start 1/6 window after the engine has reached idle rpm. See the procedure in Section 05-09-30: Start Valve Failure to Close After Engine Start.

B. Air Turbine Starter:

The air turbine starter is mounted on the engine accessory gearbox at the forward section of the engine. Pneumatic pressurized air from the SAV is routed to the starter through a dedicated duct. When the SAV opens to drive the starter, air is directed against the blades of the turbine, rotating the starter. Air from the starter is exhausted through an outlet on the bottom of the engine cowling. The starter turns an attached gear assembly that is connected to the drive shaft of the accessory gear box, rotating the engine HP rotor. A sprag clutch is incorporated in the starter gearing in order to disengage the starter when engine rpm exceeds starter drive speed. At starter disengagement, the EEC closes the SAV and the starter turbine spins down through the frictional forces of the gear assembly.

3. Starter Operation:

A. Normal Engine Starting:

In normal engine starts, the EEC controls the operation of the SAV and initiates ignition and fuel flow in the engine combustion chamber according to a schedule related to HP rpm. The EEC will close the SAV and shutoff ignition at approximately forty-seven percent (47%) HP rpm. If an anomaly occurs during the start, the EEC will discontinue the starting process and the FADEC will signal the condition to the Modular Avionics Units (MAUs), prompting the display of an amber “L-R Autostart Abort” CAS caution

message. See Section 03-03-30: Normal Engine Ground Start.

B. Alternate Engine Starting:

If operational circumstances require that the flight crew assume direct control over the engine starting procedure, an alternate starting procedure is provided. The procedure is appropriate when tailwinds over ten (10) knots exist or when other circumstances dictate that the engine should achieve maximum starter rpm prior to the initiation of combustion. During an alternate engine start it is the responsibility of the flight crew to monitor engine parameters since the EEC will not automatically interrupt the starting process. The alternate engine starting process is found in Section 03-08-10: Alternate Engine Ground Start.

C. Automatic Air Starting:

As part of the supervisory functions of the engine FADEC, the EEC will automatically attempt to restart an engine that flames out or fails during flight, provided that the failure is not associated with a recognized abnormal condition (for instance, an engine fire). The EEC restart attempt involves unloading the engine by opening the engine handling bleed valves and supplying continuous ignition to the combustion chamber. If the restart attempt is not successful, the FADEC will prompt the display of the amber “L-R Autostart Abort” CAS caution message. Flight crew procedures for automatic air starting are found in Section 05-08-20: Airstart - Automatic.

D. Assisted Air Starting:

If during an automatic airstart the EEC determines that engine rotor speed is too low to accomplish a successful restart, the FADEC will prompt the MAUs to display a CAS blue “Assisted Airstart” advisory message. The message notifies the flight crew that the engine starter must be engaged in order to restart the engine. Since the starter requires a pneumatic air source in order to function, consideration must be given to the bleed air requirements to maintain cabin pressurization if the APU or the operating engine is used as pneumatic source for starter operation. The procedure, found in Section 05-08-30: Airstart - Starter Assist, requires a descent to twenty-five thousand (25,000) feet or below. See the graph in Figure 3.

E. Windmilling Airstart:

If the engine starter is not used to increase rotor speed in attempting to restart an engine, an alternate method employing an increase in airspeed at an altitude below twenty-five thousand (25,000) feet is available. See Figure 3. The procedure uses additional airflow through the engine to increase engine rotor speed to support a restart. The procedure is detailed in Section 05-08-40: Airstart - Windmilling.

F. Engine Cranking:

The engine starter may be used to rotate the engine LP and HP sections without starting the engine. The MASTER CRANK switch on the cockpit ENGINE START panel enables EEC operation of the SAV but inhibits EEC operation of ignition and fuel flow to the combustion chamber. Cranking the engine may be necessary to reduce engine temperature prior to start, to

expel accumulated fuel from a previous unsuccessful start, or for maintenance troubleshooting procedures.

NOTE:

Starter engagement for cranking purposes must be counted as an engine start cycle under the starter duty cycle limitations.

4. Controls And Indications:

A. Controls:

(See Figure 2.)

Engine starting controls are located on the cockpit overhead panel and on the cockpit center console. The ENGINE START panel on the cockpit overhead contains the pushbutton switches that enable engine starting. The MASTER START switch, used in normal ground starting, enables the EEC to control the engine starting sequence, scheduling SAV operation, ignition application and fuel flow to the combustion chamber. If the alternate starting procedure is used, the MASTER CRANK switch is depressed to allow the EEC to control only SAV operation with the application of ignition and fuel flow remaining the responsibility of the flight crew using the continuous ignition switches (L-R CONT IGN) and the FUEL CONTROL switches on the center pedestal.

NOTE:

If both the MASTER CRANK and MASTER START switches are selected on, a blue advisory CAS message of “Start Switch Configuration” will be displayed to prompt the flight crew to select one or the other of the switches.

The L ENG and R ENG START switches on the ENGINE START overhead panel provide the command to the EEC to open the SAV powering the engine starter.

All switches on the ENGINE START panel have internal ON legends that illuminate blue when selected.

B. Indications:

The engine start sequence is monitored on the Engine Start 1/6 window display. The window contains:

- Digital indications of bleed air pressure available to power the starter
- Bar graph displays of engine Turbine Gas Temperature (TGT) and HP rotor rpm
- Digital displays of engine oil pressure
- Digital readings of hydraulic system pressures
- Abbreviated text icons for operation of the starter air valve (SVO -start valve open) and ignition (IGN)
- Text annunciations of low fuel pressure
- A text annunciation of “Single Rudder” when only one hydraulic system is operating

A complete description of the Engine Start 1/6 window display is contained in Section 2B-07-00.

C. Circuit Breakers (CBs):

The following CBs power the engine starting system:

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L/R START A	POP	F-8	L ESS DC Bus
L/R START B	CPOP	F-8	R ESS DC Bus

D. Crew Alerting System (CAS) Messages:

The following CAS messages are associated with the Engine Starting system:

Area Monitored:	CAS Message:	Message Color:
EEC	L-R Autostart Abort	Amber
EEC	L-R SAV Maintenance	Amber
EEC	L-R Throttle Configuration	Amber
EEC	Assisted Airstart	Blue
EEC	Start Switch Configuration	Blue

5. Limitations:

A. Flight Manual Limitations:

(1) Starter Duty Cycle:

The starter duty cycle is three (3) start cycles with a maximum of three (3) minutes per start cycle. Delay fifteen (15) seconds between start cycles. After three (3) start cycles, delay use of the starter for at least fifteen (15) minutes.

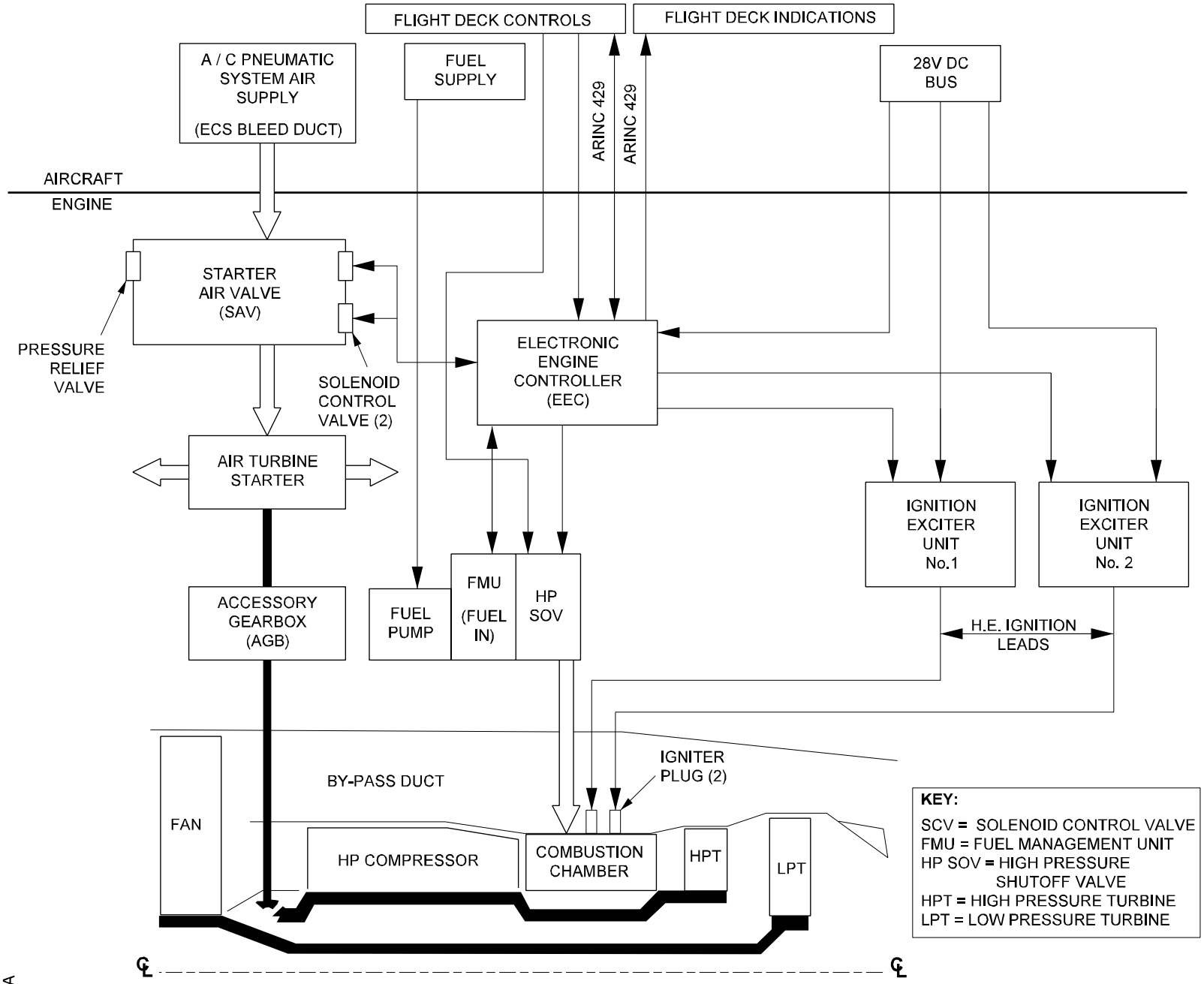
(2) Starter Re-engagement:

The starter may be reengaged at HP RPM speeds up to starter cutout of 42% HP RPM.

(3) Airstart Envelope:

See Figure 3: Airstart Envelope.

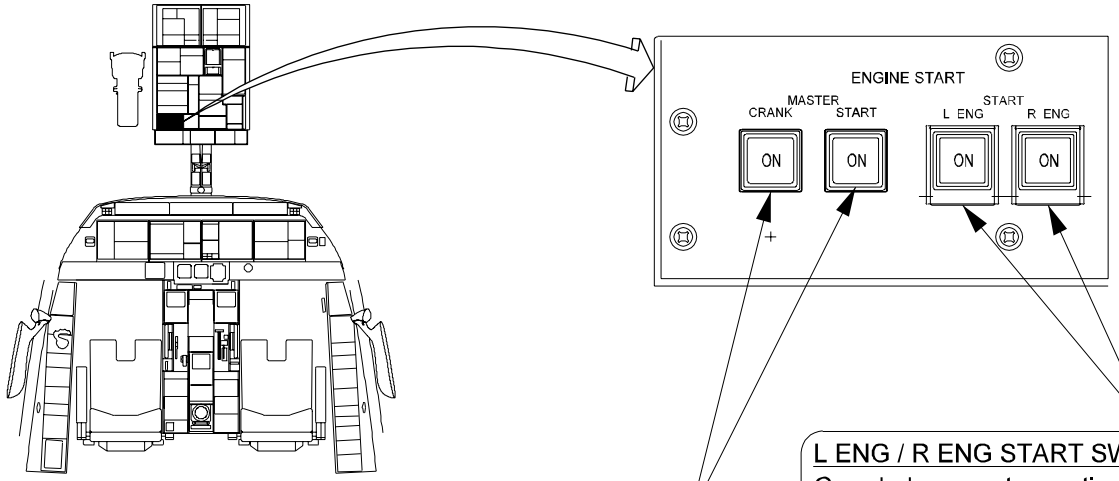
THIS PAGE IS INTENTIONALLY LEFT BLANK.



1602A

36018F00

Engine Starting System
Simplified Block Diagram
Figure 1



MASTER CRANK / START SWITCHES

Alternate action switches. Normal position is off.

When MASTER CRANK switch is selected ON, alternate engine starting mode and wet / dry crank mode are enabled.

When MASTER START switch is selected ON, normal start mode is enabled.

After selection of either switch to ON:

- Respective ON legend illuminates blue.
- If APU is running, APU load control valve opens.
- If right ECS pack is operating, ECS pack is shut down.

When selected OFF:

- ON legend exitnguishes.
- Associated mode is disabled.
- If right ECS pack was operating when either switch was selected ON, ECS pack operation resumes.

L ENG / R ENG START SWITCHES

Guarded momentary action switches. Normal position is off.

With selection of either ENG START switch to ON and MASTER CRANK switch ON, a crank sequence for selected engine is initiated.

With selection of either ENG START switch to ON and MASTER START switch ON, a start sequence for selected engine is initiated.

In either above case, the following also occurs when either ENG START switch is elected ON:

- Respective ON legend illuminates blue.
- If left ECS pack is operating, ECS pack is shut down.
- Starter Air Valve (SAV) opens to supply air to starter. SVO icon is displayed on Engine Instruments page on Display Unit.

Crank sequences are terminated manually. Start sequences can be terminated:

- Automatically under normal conditions by the EEC at approximately 42% HP RPM.
- Automatically under abnormal conditions at any time by the EEC.
- Manually by selection of the ENG START switch to OFF.

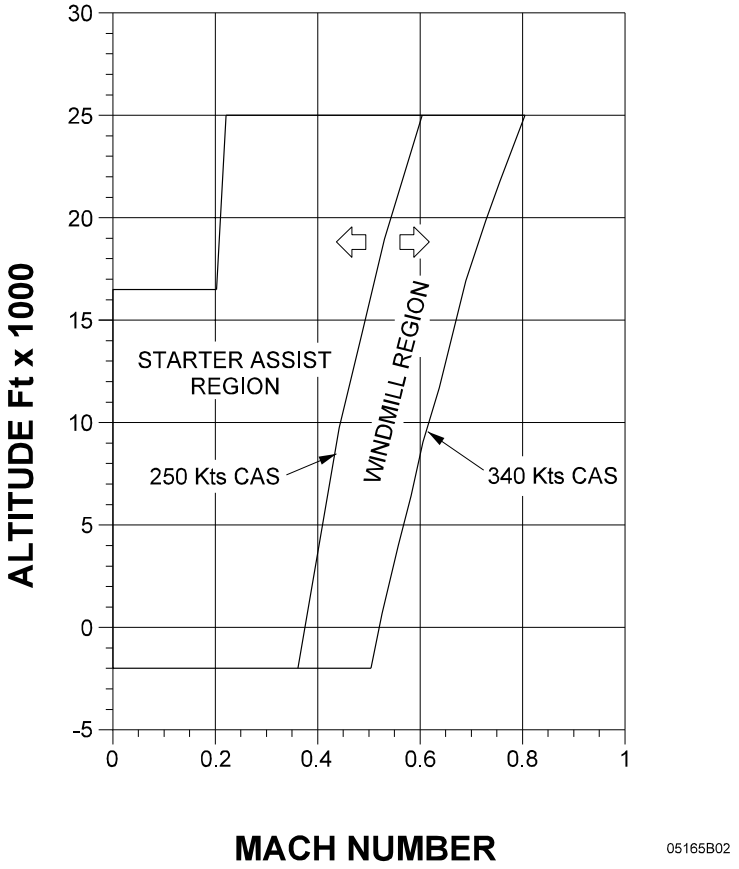
When the crank or start sequence is terminated:

- ON legend extinguishes.
- SAV closes. SVO icon extinguishes.
- If left ECS pack was operating when either ENG START switch was selected ON, ECS pack operation resumes.

36019F00

Engine Starting System
Controls and Indications
Figure 2

START ENVELOPE



Airstart Envelope
Figure 3

THIS PAGE IS INTENTIONALLY LEFT BLANK.