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Introduction

A GTCP-36-100E constant-speed gas turbine auxiliary power unit (APU) is installed in a fire-resistant compartment in the aft equipment bay of the airplane.

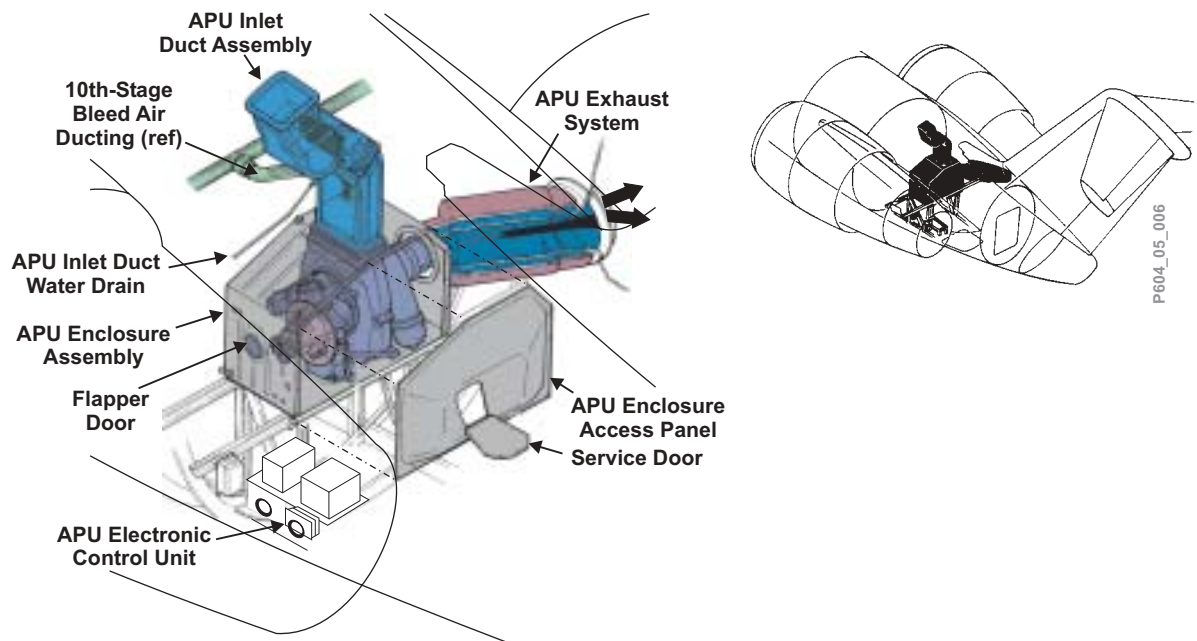
The APU drives a generator providing AC electrical power during ground operations, and serves as a backup AC power source in flight. The APU also provides pressurized bleed air to the 10th-stage manifold for air conditioning and engine starting.

The maximum operating altitude of the APU is 20,000 feet MSL. In-flight APU starting is guaranteed below 15,000 feet and has been demonstrated up to 20,000 feet, from 141 to 290 KIAS. In-flight APU bleed air extraction for air conditioning is not permitted above 14,500 feet.

APU Enclosure

The APU enclosure is a stainless-steel, fireproof box with dedicated fire detection and fire extinguishing capabilities. The enclosure is located in the forward section of the aft equipment bay, and is equipped with a service door for APU oil servicing. A spring-loaded flapper door on the left side of the enclosure provides cooling airflow while the APU is operating. When the APU is shut down, the flapper door is spring-loaded closed.

APU fire detection and fire extinguishing systems are covered in Chapter 9 Fire Protection.



Auxiliary Power Unit (APU)

Figure 5-1

Power Section and Accessory Gearbox

Description

The APU power section consists of a gas turbine engine with integrated oil, ignition, and start systems. The power section drives a gearbox that reduces the rotational speed of the APU to a speed appropriate for operation of gearbox-mounted accessories.

The APU powerplant consists of the following major components:

- Single-stage centrifugal compressor
- Single-stage turbine
- Accessory gearbox with integral oil reservoir
- Annular reverse flow combustor
- Exhaust duct

Components and Operation

Power Section

Engine power is developed through compression of ambient air by a centrifugal compressor. The compressed air, when mixed with fuel and ignited in the annular reverse-flow combustor, drives a turbine. The rotating shaft of the turbine rotor drives the compressor and the drive shaft of the accessory gearbox.

Gearbox

The APU gearbox assembly provides power transfer from the starter motor to the accessories and power section during APU starting as well as to all gearbox-mounted accessories during on-speed rotation. The accessories include:

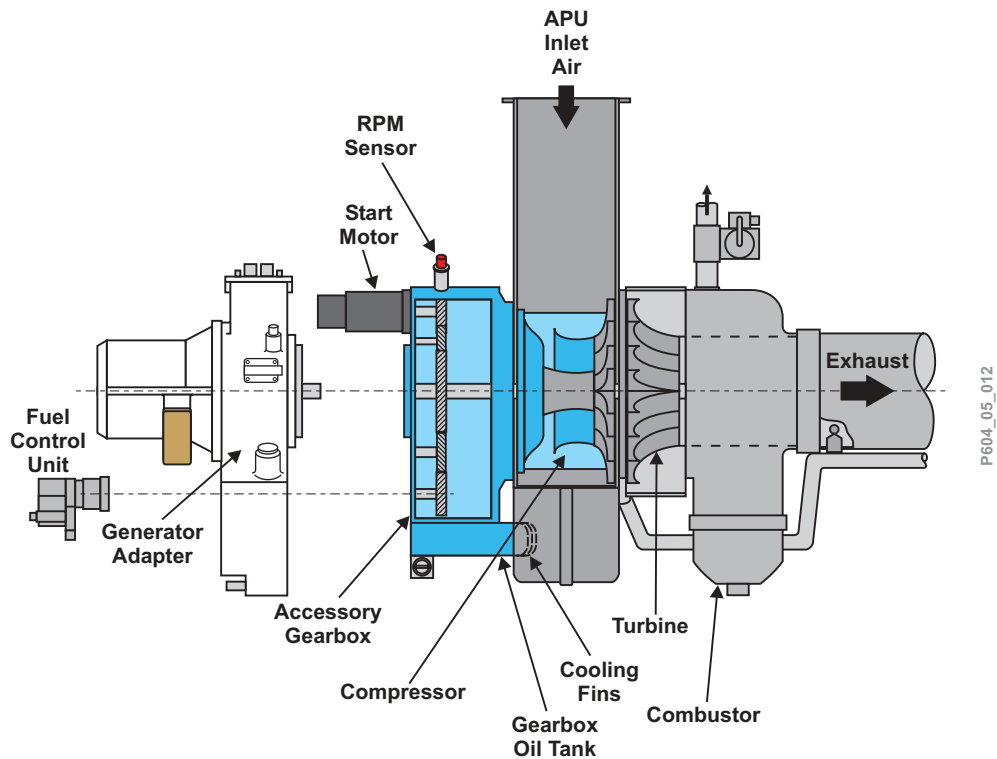
- Start Motor
- Generator adapter
- Speed sensor
- Lubrication module
- Fuel Control Unit

Lubrication System

The APU gearbox also serves as an oil reservoir and wet-sump lubrication system. A filler cap with integrated dipstick is incorporated for gearbox oil servicing. Gearbox oil cooling is achieved by airflow over cooling fins integral to the lower casing of the accessory gearbox.

NOTE

Wait a minimum of 30 minutes after APU shutdown to allow the gearbox wet sump oil level to stabilize. Otherwise, quantity indications may be inaccurate, and the reservoir may be overfilled.



APU Schematic (Power Section and Accessory Gearbox)

Figure 5-2

Generator Adapter

Description

The generator adapter transfers APU rotational power from the gearbox to the APU generator. It has a dedicated pressurized lubrication system.

Components and Operation

Lubrication System

The generator adapter lubrication system is independent from the accessory gearbox lubrication system, and has a separate filler cap with integrated dipstick for servicing.

The oil within the generator adapter lubrication system is cooled by a fuel/oil heat exchanger. The cooling fuel supply to the heat exchanger is from the normal APU fuel feed from the right main tank. If the normal fuel feed is not available, generator adapter oil will not be cooled, and APU operating time will be limited.

NOTE

Wait a minimum of 30 minutes after APU shutdown to allow the generator adapter oil level to stabilize. Otherwise, quantity indication may be inaccurate, and the adapter may be overfilled.

CAUTION

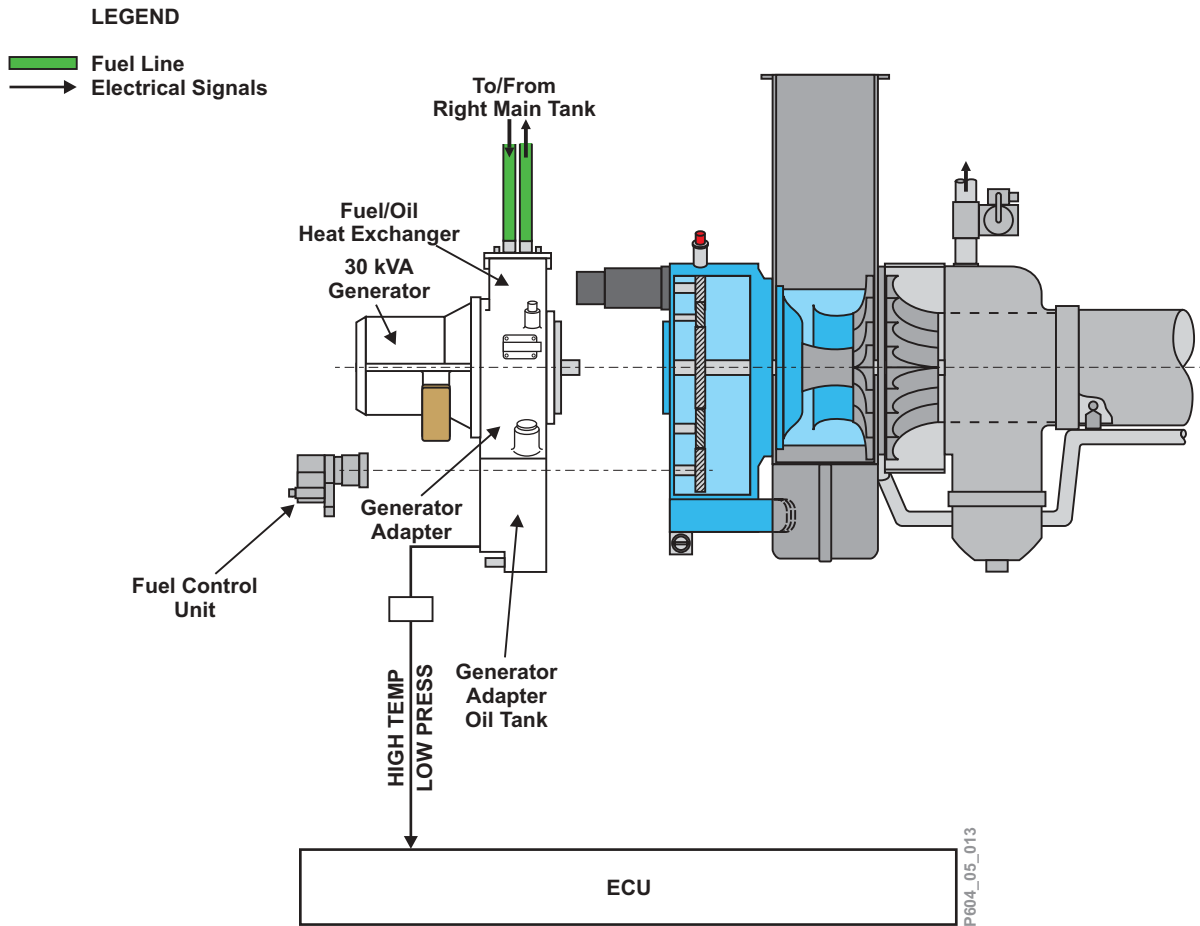
Generator adapter oil pressure is high immediately after shutdown. To avoid injury, bleed excess pressure from the generator adapter by pushing the pressure-relief valve cap for at least 5 seconds prior to opening the APU generator/adapter oil filler cap.

Electrical Generator

The APU generator adapter drives a 30 kVA, 400-Hz, three-cycle AC generator used as a backup electrical power supply for the aircraft. The APU generator is identical to the engine-driven generators, and is primarily used during ground operations. If the APU generator is being used to supply electrical power in flight, bleed air extraction from the APU is not permitted (see Chapter 7 Electrical for additional information).

NOTE

Use of APU generator in flight is not permitted unless both main generators have failed or are off-line.



APU Schematic (Generator Adapter)

Figure 5-3

Air Intake and Exhaust

Description

The APU air intake is located on the upper left portion of the aft fuselage, near the base of the vertical stabilizer. The opening of the intake is flush with the fuselage.

APU exhaust gases are expelled through an exhaust duct which exits on the right side of the aft fuselage, below the right engine pylon.

Components and Operation

Air Intake

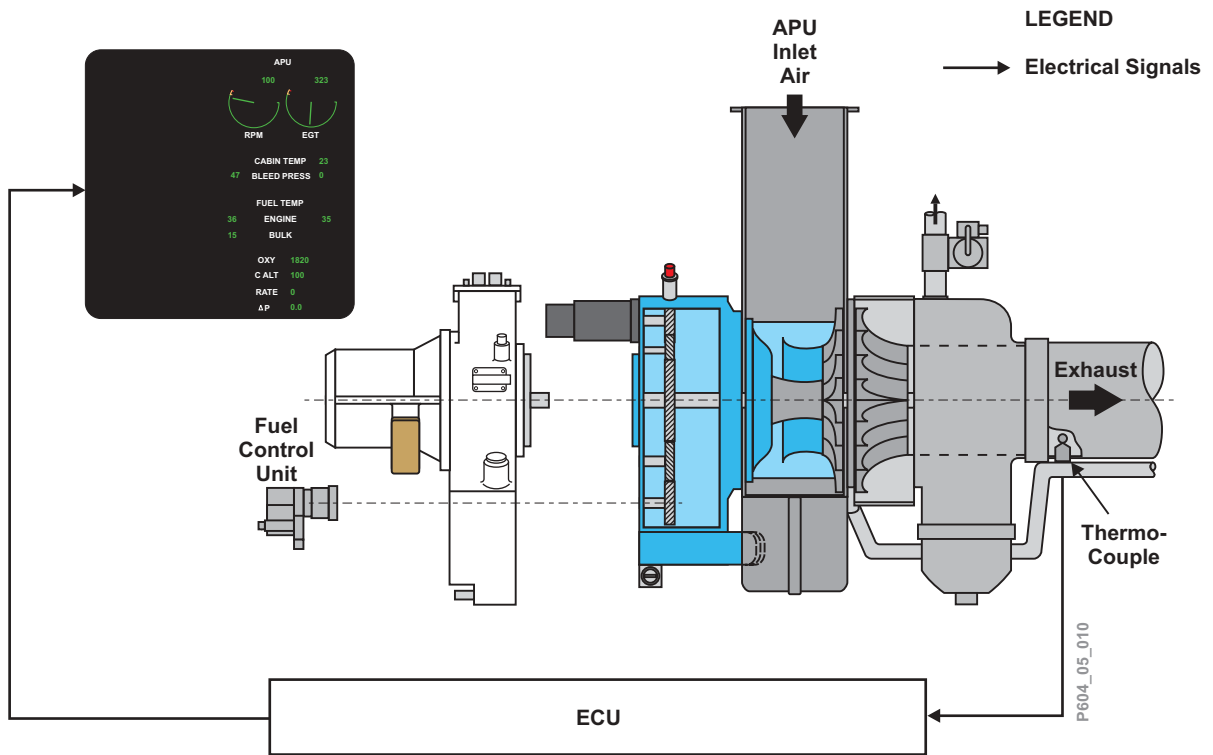
The air intake is an s-shaped duct with an inlet screen and a water trap (with associated drain line). The intake is attached to the top of the APU enclosure.

Exhaust

The APU exhaust gases are discharged overboard through an exhaust duct located below the right engine. The exhaust duct is equipped with a muffler assembly which also acts as an ejector, drawing cooling air through the APU enclosure by means of a spring-loaded flapper door installed on the opposite side of the APU enclosure.

EGT Indications

APU exhaust gas temperature is indicated on the EICAS status page using an indicating arc that expands and contracts as APU operating limits change.



APU Schematic (Air Intake and Exhaust)

Figure 5-4

APU Fuel Distribution System

Description

The APU fuel system provides fuel for start, acceleration, and governed speed control of the APU. During start, the fuel system provides the correct amount of fuel to support combustion and for smooth acceleration of the engine to full power. Once full power is reached, fuel flow is modulated as necessary to meet the demands of varying pneumatic and electrical loads, while maintaining a constant speed.

The APU is protected from overtemperature by the electronic control unit.

The normal fuel supply to the APU is from the right main tank. A backup fuel supply from the left engine motive flow system is provided in case negative-G conditions are encountered.

The APU fuel feed system incorporates an APU fuel pump, an APU fuel shutoff valve, a negative-G shutoff valve, one-way check valves, and a fuel control unit.

Components and Operation

APU Fuel Pump

The APU fuel pump is powered by the DC Battery Bus, and draws fuel from the right main tank. The pump provides fuel to the APU fuel control unit through the feed line and the APU fuel shutoff valve.

Selection of the APU PWR FUEL switch/light activates the APU fuel pump and opens the APU fuel shutoff valve and negative-G shutoff valve. Insufficient pump output pressure is indicated by illumination of the PUMP FAIL indicator in the PWR FUEL switch/light and the APU PUMP caution EICAS message.

A portion of the fuel from the APU fuel pump reaches the APU fuel control unit for combustion, while the remainder is directed through the fuel/oil heat exchanger to provide cooling of the APU generator adapter oil. Fuel that has passed through the heat exchanger is returned to the right main tank.

APU Fuel Shutoff Valve

The APU fuel shutoff valve opens when the PWR FUEL switch/light is pressed in, and closes when it is pressed out. If the valve does not match the switch position within 5 seconds, the APU SOV caution EICAS message is displayed.

When the APU FIRE PUSH switch/light is pressed in, the APU fuel shutoff valve (and the APU negative-G shutoff valve) will close. Successful closing of the valves is indicated by illumination of the green SOV CLOSED switch/light indicator, and the APU SOV CLOSED advisory EICAS message. If the APU fuel shutoff valve fails to

close after APU FIRE PUSH switch/light selection, the APU SOV caution EICAS message will be displayed.

APU Negative-G Shutoff Valve

The APU negative-G shutoff valve opens when the PWR FUEL switch/light is pressed in, and closes when it is pressed out. The APU negative-G shutoff valve allows fuel from the left engine feed line (by motive flow or electric boost pump operation) to automatically supply the APU fuel control unit during negative-G conditions or in the case of APU fuel pump failure. Positive pressure is required for fuel to pass through the differential pressure check valve. A one-way check valve prevents this fuel from entering the fuel-oil heat exchanger.

APU FIRE PUSH switch/light operation commands the APU negative-G shutoff valve closed (as described in the previous section). If the valve fails to close, the APU NEG G SOV caution EICAS message is displayed. In this condition, the left engine's motive flow will continue to supply fuel to the APU. It may be necessary to shut down the left engine in order to shut off the fuel supply to the APU if the APU FIRE PUSH switch/light was selected due to an APU fire condition.

NOTE

The APU may be only operated for a short time using the alternate fuel source through the APU negative-G shutoff valve because of the danger of generator adapter oil overheating. Refer to your Minimum Equipment List for operating time limits.

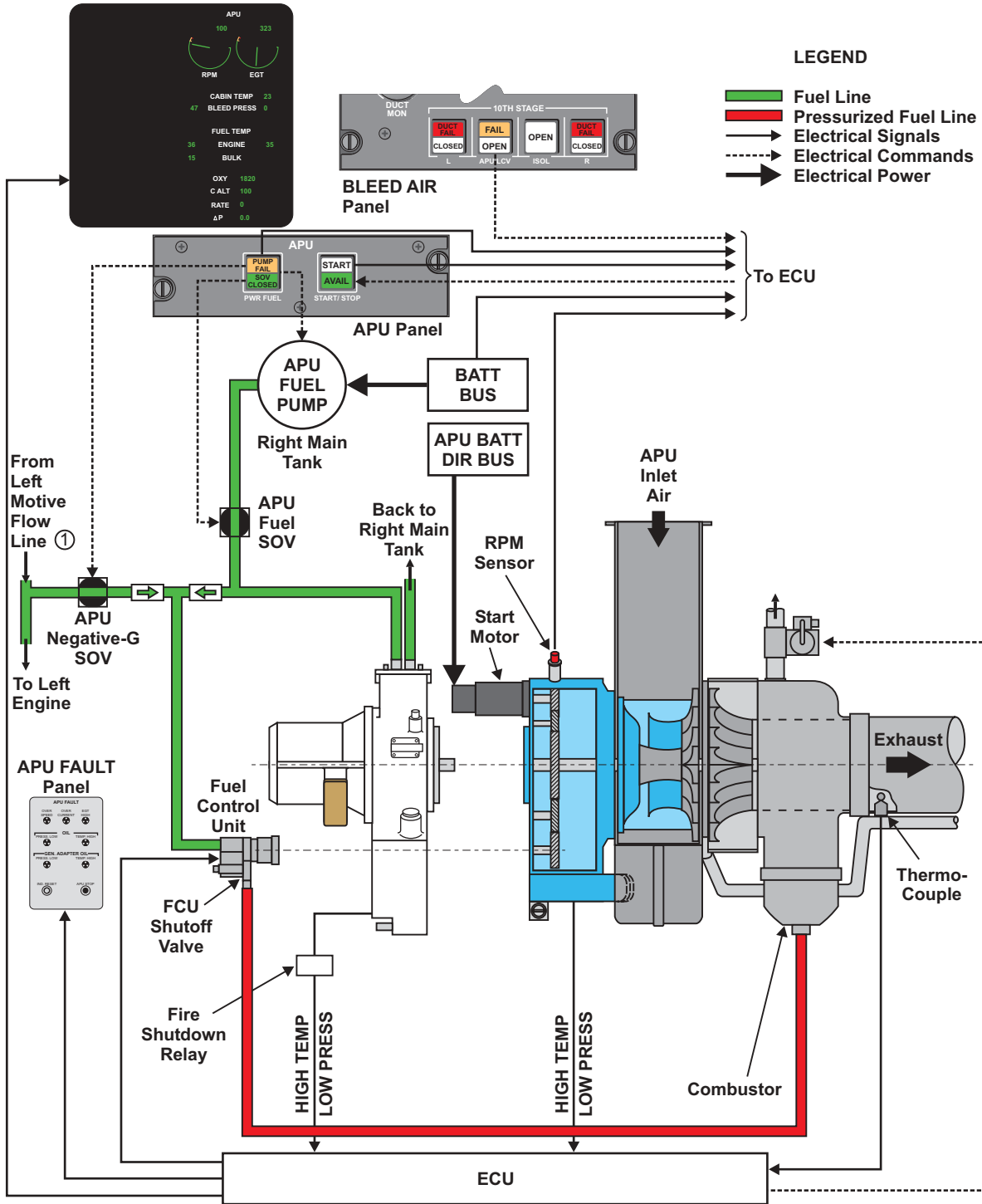
APU Fuel Control Unit (FCU)

The APU fuel control unit is driven by the accessory gearbox and meters fuel to the combustor under command of the electronic control unit (ECU). The APU fuel control unit is equipped with an internal fuel shutoff solenoid, located between the fuel control unit and the combustor fuel nozzles, which opens and closes when commanded by the ECU. In addition to controlling fuel shutoff, the ECU regulates fuel flow to ensure proper operating speed and temperatures throughout the operating envelope of the APU.

During normal or automatic APU shutdown, an overspeed signal is generated to close the fuel control unit shutoff solenoid. Closing the solenoid shutoff valve interrupts the supply of fuel, causing the APU to shut down.

AUXILIARY POWER UNIT

PILOT TRAINING GUIDE



APU Schematic (Fuel Distribution, Start and Ignition)

Figure 5-5

Start and Ignition

Description

The starting and ignition systems operate automatically during the APU start sequence.

Components and Operation

APU Battery

The 24-volt, 43-ampere-hour APU battery is located below the APU enclosure in the aft equipment bay. The APU battery provides the cranking power required to turn the APU starter. In the event of APU battery rundown, external DC power may be connected to the aircraft to supply the APU Battery Direct Bus, allowing APU start.

Electronic Control Unit (ECU)

The ECU monitors APU sensors and switches, and sets the appropriate fuel and temperature schedules. In addition, the ECU relays APU operating data to the flight crew through the data concentrator units (to EICAS) and to the APU fault indication panel located on the left aft fuselage (next to the ground air adapter).

The ECU senses changes in shaft or bleed load and adjusts the fuel supply to maintain a constant rpm at 100%. If EGT operating limits are exceeded, the ECU will reduce the bleed load by cycling the load control valve closed.

The ECU is powered by the Battery Bus when the APU PWR FUEL switch/light is pressed in.

APU Starter

The APU starter motor is DC powered by the APU Battery Direct Bus. It transfers cranking power to the APU drive shaft through the accessory gearbox. The white START indicator in the top half of the START/STOP switch/light illuminates whenever the starter motor is engaged.

The APU Battery must have at least 22 volts for starter motor operation.

Ignition System

The ignition system ignites the fuel/air mixture during start.

The ignition system is energized after the START/STOP switch/light is pressed and APU rpm reaches 10%. Ignition is de-energized when rpm reaches 95%.

Operating Sequences

Start Sequence

With the Battery Master switch ON, pushing the PWR FUEL switch/light opens the APU fuel shutoff valve and negative-G shutoff valve, turns on the APU fuel pump, arms the START/STOP switch/light, and displays the APU gauges on the EICAS.

Pressing in the START/STOP switch/light powers and signals the ECU to initiate the start sequence. The start is automatically controlled.

- 10% - Ignition activated
- 60% - Starter cutout
- 95% - Ignition deactivated
- 95% + 4 secs (approx.) - APU AVAIL (green) on
- 100% + 15 secs (approx.) - APU GEN OFF (amber) message on EICAS

When the APU has stabilized and is ready for use, a green AVAIL light illuminates. The APU GEN OFF (amber) message indicates that the APU is stabilized, operational, and the APU generator has not been selected.

NOTE

If time permits, allow APU rpm to stabilize at 100% for two minutes before applying bleed air load.

Shutdown Sequence

The normal shutdown sequence is as follows:

- press out the START/STOP switch/light
- wait until RPM and EGT gauges wind down through the 6 o'clock position
- press out the PWR FUEL switch

Pressing out the START/STOP switch/light causes the internal FCU fuel shutoff valve to close and the APU to shut down. When the PWR FUEL switch is pressed out, ECU power is removed, the APU fuel shutoff valve and negative-G shutoff valve are closed, and the APU fuel pump turns off. The gauges will remain in view for approximately 60 seconds with RPM and EGT indications reading zero.

NOTE

If the PWR FUEL switch is not deselected at the end of the APU shutdown sequence, the internal runtime clock of the APU continues to register as if the APU was still operating.

Protective Shutdowns

Automatic protective shutdowns occur for the following preprogrammed conditions:

CONDITION	EICAS INDICATION
FIRE	Master warning, fire bell, APU fire light, APU FIRE warning message
OVERSPEED	Master warning, triple attenson, APU OVERSPEED warning message
OVERTEMP	Master warning, triple attenson, APU OVERTEMP warning message
LOW OIL PRESSURE	Master warning, single attenson, APU OIL PRESS caution message
HIGH OIL TEMPERATURE	Master caution, single attenson, APU OIL TEMP caution message
OVERCURRENT	Nil
GENERATOR ADAPTER LOW OIL PRESSURE	Master caution, single attenson, APU OIL PRESS caution message
GENERATOR ADAPTER HIGH OIL TEMPERATURE	Master caution, single attenson, APU OIL TEMP caution message

Protective Shutdowns Table

Table 5-1

All protective shutdowns generate EICAS messages except for the Overcurrent condition.

The cause of the shutdown is also annunciated on the APU FAULT indication panel (except for APU FIRE) by magnetic trip indicators or LEDs. Starting with aircraft 5492 and subsequent, the fault panel has LED fault indicators (see Figure 5-9).

The panel also includes an IND RESET button to clear all trip indicators and an APU STOP button for emergency shutdown of the APU from outside the airplane. If the APU STOP button is used, the OVERSPEED magnetic indicator will show a fault condition.

Pneumatic Supply

Description

APU compressor bleed air is used to pressurize the left side of the 10th-stage bleed air manifold to provide pneumatics for engine starting and air conditioning. Reverse airflow protection is provided by a one-way check valve and the interlock control logic of the 10th-stage bleed air switch/lights (for additional information on the 10th-stage bleed air manifold, see Chapter 19 Pneumatic System).

Components and Operation

The APU pneumatic control system consists of two components, the load control valve (LCV) and the surge control valve (SCV).

Bleed Air Supply

The APU delivers its pneumatic output to the 10th-stage manifold through the load control valve. When the load control valve is opened, a portion of the compressor discharge air is routed to the left side of the 10th-stage bleed air manifold. This diverts pneumatic energy from the turbine and some of the cooling air from the combustion system. As with shaft loads, the rpm drops, and the ECU commands an increase in fuel flow to recover full governed speed. The loss of pneumatic energy is replaced with thermal energy (fuel), and EGT increases.

Two variables influence EGT under bleed load conditions:

- Aircraft demand for bleed air (air conditioning packs or engine starting)
- Ambient air temperature and air density

If the EGT reaches its limit, the ECU will reduce the bleed air load by cycling the LCV toward the closed position.

Load Control Valve (LCV)

The APU LCV is controlled from the flight deck by selecting the APU LCV OPEN switch/light on the BLEED AIR control panel. It controls APU bleed air supply to the left side of the 10th-stage manifold. The ECU ensures that priority is given to electrical loads by cycling the LCV closed (reducing bleed load) when the exhaust gas temperature approaches operating limits.

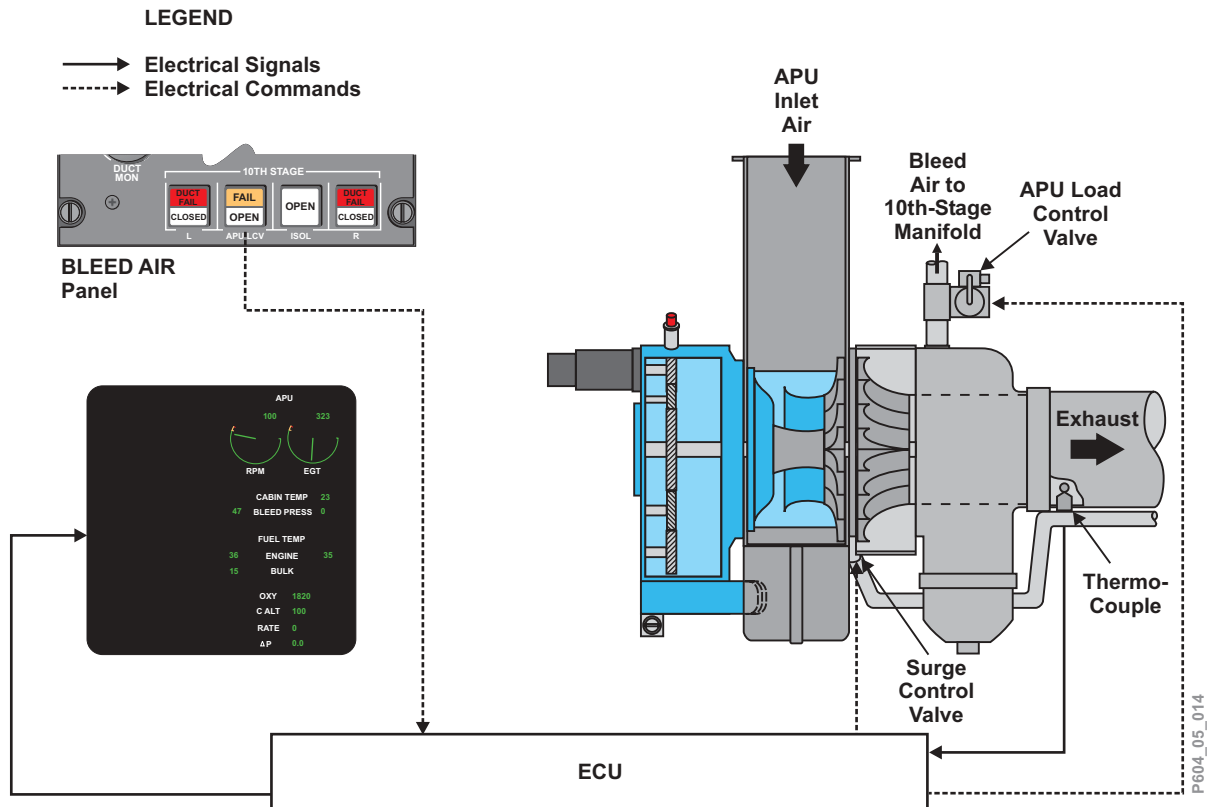
Load control valve operation is indicated by illumination of the OPEN indicator in the APU LCV switch/light. When the ECU cycles the LCV for EGT limit protection, the OPEN indicator will extinguish. If the APU LCV has failed open with the 10th stage switch/light interlock protection activated, the APU LCV FAIL caution EICAS message is displayed.

Surge Control Valve (SCV)

To prevent compressor surge, unused bleed air is vented through the SCV into the APU exhaust muffler whenever the LCV is commanded closed. Surge control valve operation is automatically controlled by the electronic control unit.

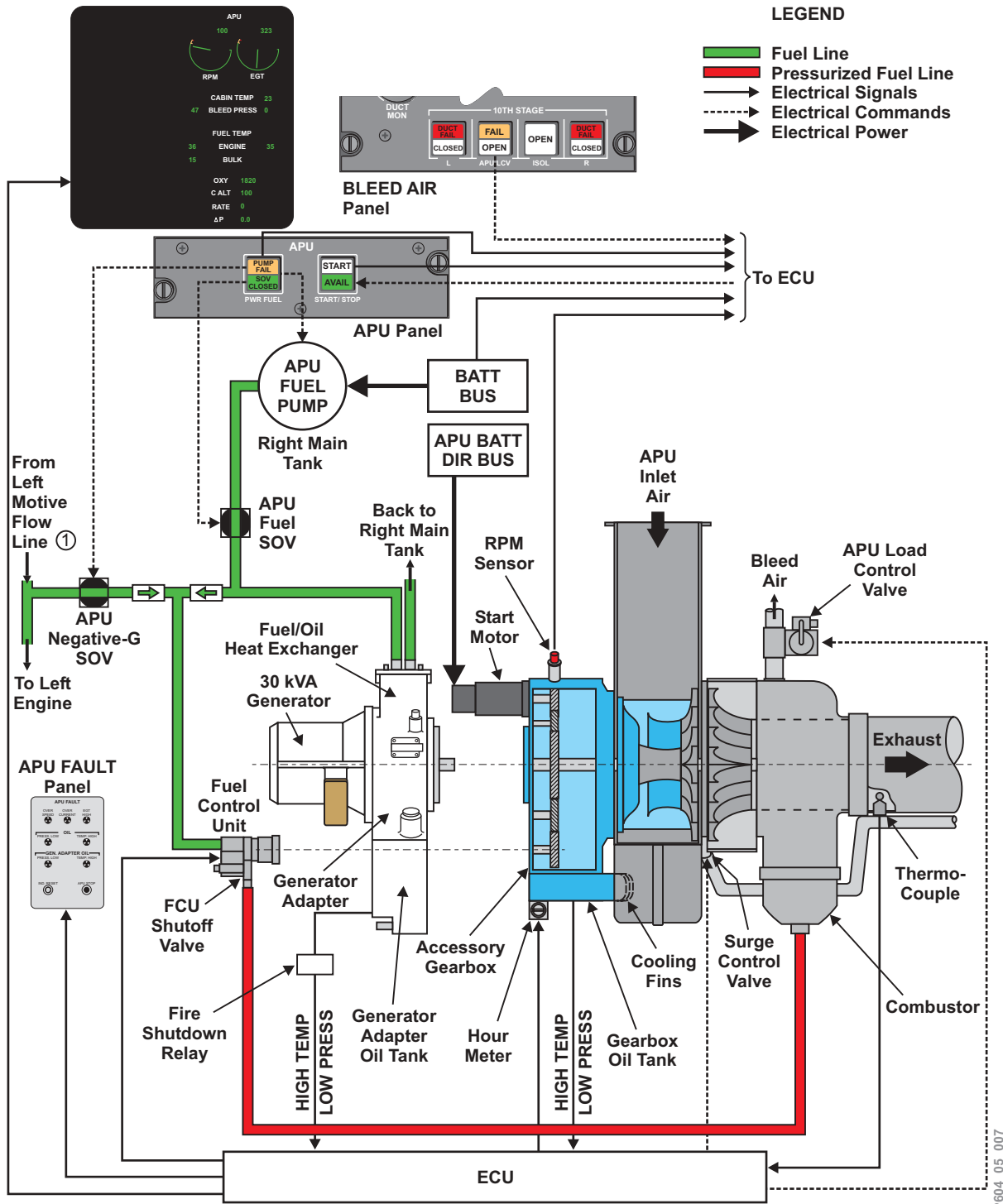
Bleed Air Indication

Left and right 10th-stage bleed air indications are displayed on the EICAS status page below the APU gauges.



APU Schematic (Pneumatic Supply)

Figure 5-6



APU System Schematic
Figure 5-7

Controls and Indicators

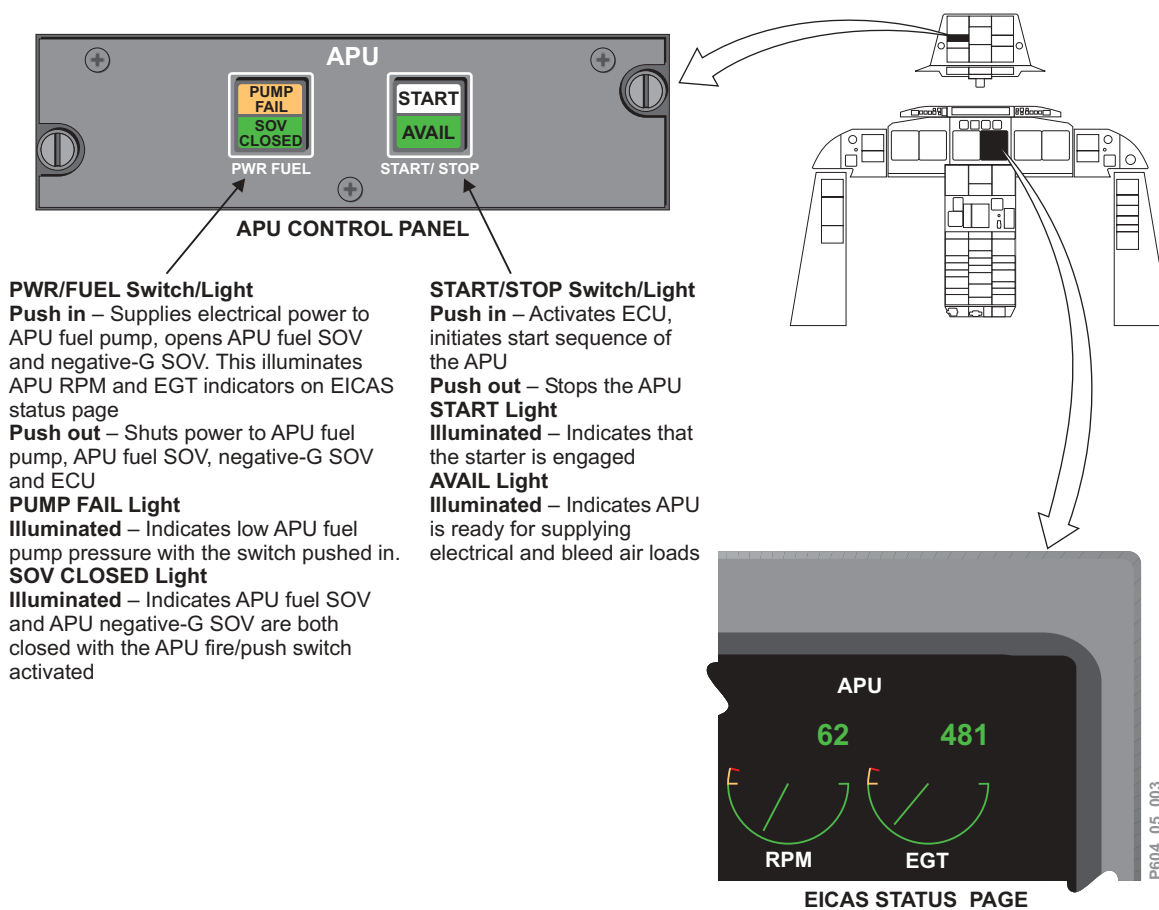
The APU control panel and the EICAS status page provide the APU controls and indicators.

The APU control panel has two switch/lights:

- PWR FUEL supplies power to APU fuel pump
- START/STOP to activate the ECU and to start and stop the APU

APU monitoring is provided by two gauges (RPM and EGT) on the EICAS status page. These indicators are activated when the PWR FUEL switch/light is pressed in and are removed from the display 60 seconds after selecting the PWR FUEL switch/light off.

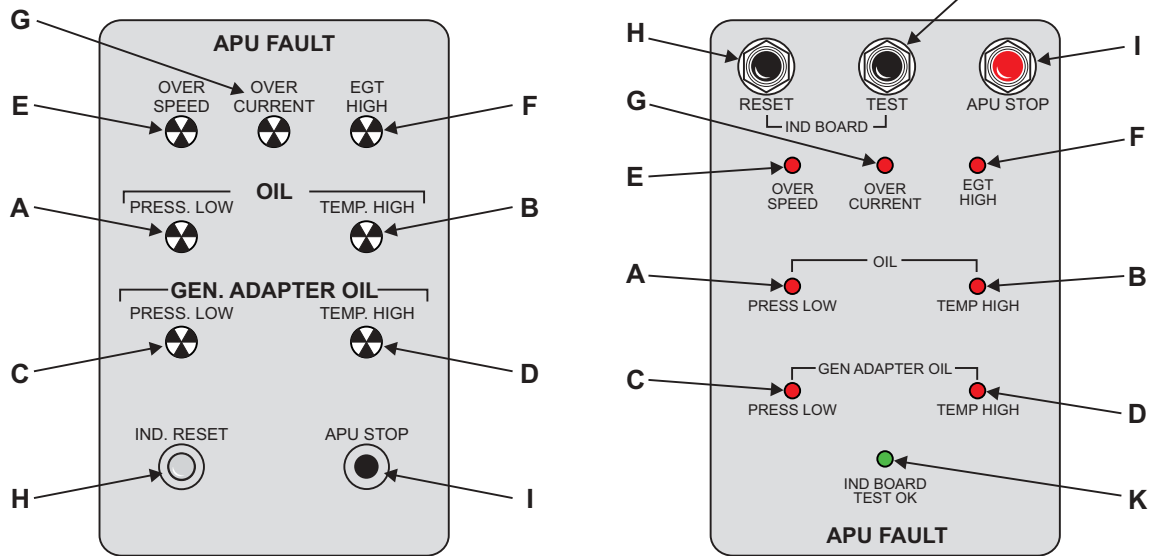
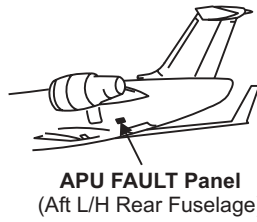
The APU fault panel supplements the EICAS for APU fault indications.



APU Control Panel and EICAS Indications

Figure 5-8

AUXILIARY POWER UNIT



EFFECTIVITY: 5452 – 5990 and Sub

A	APU OIL PRESS LOW Indicates APU low oil pressure. APU shuts down automatically, followed by EICAS message of APU OIL PRESS (amber).	F	APU EGT HIGH Indicates APU exhaust gas temperature exceeded limits. APU shuts down automatically, followed by EICAS message of APU OVERTEMP (red) and voice message calling out "APU".
B	APU OIL TEMP HIGH Indicates APU high oil temperature. APU shuts down automatically, followed by EICAS message of APU OIL TEMP (amber).	G	OVER CURRENT Indicates overcurrent at one or more of the circuits downstream of the ECU-APU shuts down automatically (no EICAS message).
C	GEN ADAPTOR OIL PRESS LOW Indicates generator adapter low oil pressure. APU shuts down automatically, followed by EICAS message of APU OIL PRESS (amber).	H	IND RESET Pushbutton When pressed, fault flags are reset by rotating them out of view or extinguishing red LED. If condition has not been corrected flags stay in view.
D	GEN ADAPTOR OIL TEMP HIGH Indicates generator adapter high oil temperature. APU shuts down automatically, followed by EICAS message of APU OIL TEMP (amber).	I	APU STOP Pushbutton When pressed, stops APU at any time.
E	APU OVER SPEED Indicates APU overspeed. APU shuts down automatically, followed by EICAS message of APU OVERSPEED (red) and voice message calling out "APU".	J	TEST Switch Allows testing the circuitry and the LEDs.
		K	TEST Led Illuminates green if test is OK.

P604_05_005

APU Fault Indication Panel

Figure 5-9



Description	Symbol	Condition
APU Generator Load Readout	7 KVA	Generator is loaded
	36 KVA	Generator is overloaded
	0 KVA	Generator is not on-line
	-- KVA	Invalid data
APU Generator Voltage Readout	113 V	Voltage between 100 and 125 VAC
	94 V	Voltage less than 100 VAC or more than 125 VAC
	--- V	Invalid data
APU Generator Frequency Readout	401 HZ	Frequency between 375 and 425 Hz
	429 HZ	Frequency less than 375 Hz or more than 425 Hz
	--- HZ	Invalid data
APU Generator Output Flow Lines (Upper)		Generator line contactor at generator position
		Generator line contactor at tie position
APU RPM Readout		Green: 0 to 104% Amber: 105 to 109% Red: 110%
APU EGT Readout		Green: 0 to 680°C Amber: 680 to 974°C Red: 974°C Running RPM from start to less than 60%
		Green: 0 to 680°C Amber: 680 to 731°C Red: 731°C Running RPM more than 60%

P604_05_009

EICAS Synoptic and Status Page Color Coding

Figure 5-10

EICAS Messages

MESSAGE	MEANING	AURAL WARNING (IF ANY)
APU FIRE	Fire detected in the APU enclosure.	FIRE BELL
APU OVERSPEED	APU has shut down due to an overspeed condition.	"APU"
APU OVERTEMP	APU has shut down due to an overtemperature condition.	"APU"
APU LCV FAIL	APU load control valve has failed in the open position with APU LCV interlock activated.	
APU SOV	APU fuel shutoff valve is open with the APU FIRE PUSH switch activated, or the fuel shutoff valve position does not match the APU PWR FUEL switch position, within 5 seconds.	
APU NEG-G SOV	APU negative-G shutoff valve is open with the APU FIRE PUSH switch activated, or the negative-G shutoff valve position does not match the APU PWR FUEL switch position, within 5 seconds.	
APU OIL PRESS	APU oil pressure or APU adapter oil pressure is low and the APU will shut down.	
APU OIL TEMP	APU oil temperature or APU adapter oil temperature exceeds limits and the APU will shut down.	
APU PUMP	APU fuel pump has failed.	
APU SOV CLOSED	APU fuel shutoff and negative-G shutoff valves have closed after actuation of the APU FIRE PUSH switch/light.	

EICAS Messages

Table 5-2