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PNEUMATICS, GENERAL

Introduction

Bleed air for the pneumatic systems can be supplied by the engines or by an optional Auxiliary Power Unit (APU). The APU supplies the system with bleed air prior to engine start. The engines supply bleed air for pneumatics after engine start.

The following systems use pneumatics for operation:

- Air conditioning and pressurization
- Airframe deicing
- Airstair door seal pressurization
- Engine oil cooler ejectors.

APU bleed air, is used for air conditioning on the ground only.

General Description

Refer to Figure 1.

Bleed air operation from the left and right engines are similar. Compressed Bleed air is ducted from the Low Pressure (LP) compressor port or the High Pressure (HP) compressor port of each engine. Power lever position and the Electronic Control Unit (ECU) determine whether the HP port or the LP port will be used, when bleeds are selected ON.

The ECU has left and right digital channels and redundant left and right analog channels. The digital channels control the high and low pressure engine bleed ports, monitor protective sensors for temperature, pressure, differential pressure and duct leaks. The digital channels perform a Built–In–Test. The analog channels provide backup control for the digital channels. The analog channels control only LP engine bleed air. The use of HP bleed air and bleed air flow sharing is not permitted under analog control.

Bleed air for airframe deicing, is supplied through the HP or LP bleed air port and passes through the deice section of the precooler. This protects the components of the deice system from overheating. Each digital and analog channel generates a discrete signal to turn on the #1 or #2 BLEED HOT caution light if an overtemperature, overpressure or duct leak occurs. If the digital and analog channel on one side fails, the related BLEED HOT caution light will not turn on.

Refer to Figures 2 and 5.

Selection of the two Bleed Control switches on the AIR CONDITIONING control panel to BLEED 1 and 2, turns on the related engine bleed air system. Two PACKS switches, labelled OFF/MAN/AUTO, and a single rotary BLEED control selector are also on the AIR CONDITIONING control panel. Together they regulate the quantity of air flowing into the system. Selection of the bleed air (BL AIR) switchlight on the APU CONTROL panel turns on the APU bleed air.

If an overtemperature, overpressure or duct leak occurs, the ECU automatically shuts down the bleed air system. The bleed air from each engine flows through a precooler to lower the air temperature before it passes through the wing fuel zones for distribution. The venturis and differential pressure sensors are installed in each wing and APU duct to measure bleed air flow. This information is used by the ECU to control the bleed air flow from each engine or APU. The

ECU uses the NSOV in each nacelle to balance the bleed air output from each engine.

Bleed Air Switches on Air Conditioning Panel

Refer to Figure 2.

BLEED 1 AND 2 SWITCHES (two position)

Starts bleed airflow from the No. 1 and/or No. 2 engine to the air conditioning packs by enabling operation of the following:

- High pressure shutoff valve
- Nacelle shutoff valve
- P2.2 shutoff valve.

OFF – stops bleed airflow from the selected engine by closing the above mentioned valves.

BLEED CONTROL SELECTOR (three position, rotary action)

Refer to Figure 3.

MIN – allows Environmental Control System (ECS) controller to modulate the amount of bleed air from both engines at a minimum level. With the BLEED switches on, and NTOP or MTOP set, indicates BLEED (white) on the Engine Display (ED).

NORM, MAX – allows ECS controller to modulate the amount of bleed air from both engines at increased levels. With the BLEED switches on, and NTOP set, indicates BLEED (amber) on the ED. With the BLEED switches on, and MTOP set, rating display changes to, and indicates MCP. BLEED is not displayed.

PACKS CONTROL SWITCHES (three position)

- OFF – shuts related Air Cycle Machine (ACM) off
- MAN – selects analog channel of ECU to supply temperature control based on duct supply temperature
- AUTO – ECU digital channel in control – opens the pack Flow Control and Shut Off Valve – opens turbine Shut Off Valves – ACMs start operating and supply conditioned air to the cabin and flight compartment based on actual cabin temperature.

Detailed Description

ELECTRONIC CONTROL UNIT (ECU)

The ECU consists of a left digital channel with a left backup analog channel and a right digital channel with a right backup analog channel. The left digital/analog channel controls the left side and the right digital/analog channel controls the right side. The digital channels monitor the bleed protective sensors to maintain the correct temperature, pressure, flow rates and valve positions during normal operation. If one of the protective sensors exceed certain values, the ECU automatically shuts the system down. Analog channels provide the same protective functions as a backup.

The ECU responds to selections from BLEED 1 and 2 switches on the AIR CONDITIONING panel to configure the Bleed Air System for bleed source selection. The ECU and the Bleed Air System have redundant configurations to permit continued ECS operation with mechanical and electrical component malfunctions.

ECU OPERATION

Refer to Figure 4.

The left digital channel and left analog channel share control of the left Nacelle Shut Off Valve (NSOV). If the left digital channel loses power or fails, the left analog channel automatically takes control of the left NSOV. The right digital channel and right analog channel share control of the right NSOV and function in a similar manner.

Each analog channel functions as a backup controller for the digital channel. One or both analog channels take control of the NSOV only when one or both digital channels lose power or malfunction. If either PACKS switch on the AIR CONDITIONING control panel is selected to MAN (manual), the digital channel transfers control of the NSOV to the analog channel. This defaults the High Pressure Shut Off Valve (HPSOV) closed and selects the LP bleed air.

The right digital channel will modulate the right NSOV to keep the bleed air flow balanced. Only the digital channel can modulate the NSOV for varying bleed air demands. The analog channels are unable to do this and keep the NSOVs fully open or fully closed when in control. The protection circuits remain active but balanced bleed air (bleed sharing) from both engines is not possible. This is because the analog channels do not have sensors to monitor bleed air flow.

The left digital channel and right analog channel receive electrical power from the 28 Vdc L MAIN bus. The right digital channel and left analog channel, receive electrical power from the 28 Vdc R MAIN bus. This permits continued left and right channel control if one 28 Vdc bus loses power. If the left digital channel loses electrical power because the left bus fails, the left analog channel is still powered by the right bus.

BLEED AIR SYSTEM

The Bleed Air System (BAS), is part of the Environmental Control System (ECS) which supplies conditioned air to the flight and cabin compartments. Bleed air flows through ducts from each engine along the wing forward spar, through the dorsal fin then to the air conditioning packs. The APU also supplies bleed air to the ECS, on the ground when the engines are not providing bleed air.

At the start of a flight, the ECU selects one digital channel to control the shared components of the bleed air system. The digital channel in control is responsible for all functions applicable to the shared components.

BLEED FLOW SHARING

The ECU uses a differential pressure (flow) sensor to measure the bleed air flow through each NSOV. The ECU uses this bleed airflow information to balance the flow of bleed air from both engines to the ECS. Each digital channel in the ECU modulates its NSOV to maintain 50% total bleed air flow from its engine. Bleed sharing can occur only when both engines are in operation and both digital channels are functional. There is no analog channel function for bleed air sharing.

OPERATION

Bleed air flow to the ECS is controlled by the BLEED control switches and BLEED control selector on the AIR CONDITIONING control panel. The BLEED air flow control selector is a rotary knob with three positions MIN, NORM and MAX. Prior to engine start, the BLEED control switches are selected OFF and the BLEED control selector knob is set to MIN. After engine start, the bleed control switches are selected to BLEED 1 and 2 and the BLEED control selector knob is set to the NORM position. HP bleed air starts flowing for ECS operation.

Bleed air is supplied from the HP port or the LP port of each engine to the ECS. At low power settings, bleed air comes from the HP port, and at high power settings (takeoff climb and cruise) from the LP port. After the left and right engines have started and BLEED 1 and 2 switches have been selected on, the ECU opens its NSOVs.

The ECU uses data from the HP bleed air and the Air Data Units (ADUs) to select the bleed port. If HP bleed air is sufficient, the ECU opens the High Pressure Shutoff Valve (HPSOV). This lets bleed air from the HP port flow through the precooler to the ECS, deice system and oil cooler ejectors.

PRECOOLER OPERATION

At some engine power settings, the HP bleed air can be too hot for use by the ECS, deice system and oil cooler ejectors. Cooling air from the P2.2 engine bleed port is used in the precooler to lower the temperature of the HP air. The bleed air system uses the high stage precooler to reduce the HP bleed air temperature. The ECU opens the P2.2 shutoff Valve (SOV) to permit the flow of P2.2 bleed air through the high stage precooler then to overboard.

In the high stage precooler, the P2.2 bleed air absorbs heat from the HP bleed air. The HP bleed air that leaves the precooler, is cool enough to flow through the bleed air ducts in the wing.

If the initial HP bleed air temperature is correct, the ECU closes the P2.2 SOV disabling the high stage precooler operation. This allows HP bleed air to flow directly to the ECS, deice system and oil cooler ejectors with no temperature reduction. The high stage precoolers operate independently on each side of the aircraft.

At higher engine power settings, the ECU closes the HPSOV to select the LP bleed air. This allows LP bleed air to flow directly through to the ECS.

DE–ICING OPERATION

When the deice system is in operation, the ECU can select the HP or the LP port for bleed air. If during descent with low engine power setting, the HP bleed air pressure decreases below a certain value, the bleed stage pressure switch senses this and opens the HPSOV. This function is independent of the ECU. HP bleed air now flows through the high stage and de–ice precooler.

A signal from the de–ice system and a signal from the HPSOV tell the ECU that HP bleed air is selected for de–ice use. When engine power is increased, and HP increases above a certain value, the ECU closes the HPSOV and opens the LP port to provide bleed air flow. The ECU modulates the NSOV to adjust bleed air flow as necessary.

If BLEED 1 and BLEED 2 switches are selected OFF, bleed air to the ECS stops, but LP bleed air still flows to the de–icing systems and oil cooler ejector if the ejector SOV is open.

Protective Sensors

BLEED STAGE PRESSURE SWITCH

The bleed stage pressure switch, controls the High Pressure Shutoff Valve (HPSOV) independently of the ECU during de–ice operation. When the de–ice system is in operation, if HP bleed air drops below 77 psi (531 kPa), the bleed stage pressure switch opens the HPSOV to provide HP bleed. Signals from the de–ice system and the HPSOV inform the ECU that HP bleed air is now flowing. The ECU will now adjust bleed air flow as required.

HIGH PRESSURE SHUTOFF VALVE (HPSOV)

The HPSOV is a pneumatically operated butterfly valve which normally opens when HP bleed air decreases below 77 psi (531 kPa), and closes when bleed air increases above 82 psi (566 kPa). When the HPSOV is in the open position, HP bleed air flows through to the precooler to supply the ECS and/or the de−ice systems. The ECU uses HP information supplied by the Full Authority Digital Electronic Control (FADEC) to control the opening and closing of the HPSOV.

The ECU opens the HPSOV at low engine power settings. The HPSOV supplies information to the ECU of its position. The bleed stage pressure switch can open the HPSOV independently from the ECU to supply bleed air to the de−ice system.

PRECOOLER TEMPERATURE SWITCH

The precooler temperature switch monitors the temperature of the HP bleed air entering the precooler. If the HP bleed air entering the precooler is greater than 550 °F (288 °C), the switch signals the ECU to open the P2.2 shutoff valve. This allows cooling P2.2 air to pass through the precooler lowering the HP bleed air temperature.

OVERTEMPERATURE SWITCH/ SENSOR

The overtemperature switch is a protective switch that monitors nacelle HP and LP bleed air temperature. If the temperature of the bleed air entering the nacelle ducts is greater than 660 °F (349 °C), the overtemperature switch signals the ECU to close the Nacelle Shut Off Valve (NSOV) for the affected side. The ECU will then turn on the appropriate BLEED HOT caution light.

On aircraft with SB84−36−03 or ModSum 4Q113658 incorporated, the overtemperature switch is replaced with a sensor. This sensor is a Resistance Temperature Device (RTD). It gives resistance proportional to the temperature it senses. If the temperature of the bleed air entering the nacelle ducts is greater than 660 °F (349 °C), the over temperature sensor sends a signal to the ECU to close the NSOV for the affected side. The ECU will then turn on the appropriate BLEED HOT caution light.

NACELLE DUCT LEAK OVERTEMPERATURE SWITCH

The nacelle duct leak overtemperature switch is provided to detect a bleed air leak in the nacelle ducting. If the temperature in the nacelle ducting is greater than 360 °F (182 °C), the switch signals the ECU to close the appropriate NSOV. The ECU also sends a fault code to the Central Diagnostic System (CDS) identifying a duct leak.

OVERPRESSURE SWITCH

The overpressure switch is installed in the wing leading edge and is a protective switch that monitors nacelle bleed pressure. If the pressure in the nacelle ducting is greater than 100 psi (690 kPa), the overpressure switch will open. This sends a signal to the ECU to close the affected NSOV. The ECU also sends a signal to illuminate the No.1 or No. 2 BLEED HOT caution light.

AFT DUCT LEAK OVERTEMPERATURE SWITCHES

Two aft fuselage duct leak overtemperature switches are installed in the aft fuselage. The switches will detect if a bleed air leak occurs in the engine or APU bleed air ducting near the air conditioning pack inlet. If the temperature in the ducting is greater than 360 °F (182 °C), the switch signals the ECU to close the pack NSOV. The ECU also sends a fault code to the Central Diagnostic System (CDS) identifying a duct leak.

System Components

HIGH PRESSURE SHUT−OFF VALVE (HPSOV)

The HPSOV is a pneumatically operated butterfly valve which normally opens when HP bleed air decreases below 77 psi (531 kPa), and closes when bleed air increases above 82 psi (566 kPa). When the HPSOV is in the open position, HP bleed air flows through to the precooler to supply the ECS and/or the de−ice systems. The ECU uses HP information supplied by the Full Authority Digital Electronic Control (FADEC) to control the opening and closing of the HPSOV.

The ECU opens the HPSOV at low engine power settings. The HPSOV supplies information to the ECU of its position. The bleed stage pressure switch can open the HPSOV independently from the ECU to supply bleed air to the de−ice system.

PRECOOLER

The precooler is a single unit with a two−part air to air heat exchanger. It uses low temperature P2.2 bleed air to cool HP bleed air for the ECS or deicing. The main heat exchanger cools the HP bleed air before it is supplied to the ECS. The small heat exchanger cools either the HP or the low pressure (LP) bleed air before it is supplied to the de−ice system.

P2.2 SHUT−OFF VALVE

The P2.2 shutoff valve is a pneumatically operated butterfly valve that opens to supply cooling air through the precooler. The precooler temperature switch signals the valve open when the HP bleed air temperature is too high for the ECS. The shutoff valve supplies position information to the ECU and to FADEC.

EJECTOR SHUT−OFF VALVE

The oil cooler ejector shutoff valve controls the flow of engine bleed air for operation of the oil cooler ejector. This valve is controlled by FADEC. The oil cooler ejector provides cooling for the oil cooler when the airflow through the engine is insufficient (on the ground). Each engine must be operating to supply bleed air to its oil cooler ejector. Check valves in the wing ducts prevent the use of bleed air from the APU for the oil cooler ejectors.

NACELLE SHUT−OFF VALVE (NSOV)

The NSOV is a pneumatically operated butterfly valve. The valve opens when the BLEED 1 or BLEED 2 switch on the AIR CONDITIONING panel is selected to BLEED 1 or 2 position. The ECU uses the NSOV to control the flow of bleed air to the ECS. The ECU regulates the NSOV according to switch selections on the AIR CONDITIONING panel. The ECU also regulates the NSOV in each nacelle to supply 50% of the total flow demand for equal flow sharing between each engine. A switch on the NSOV, informs the ECU of the position of the valve.

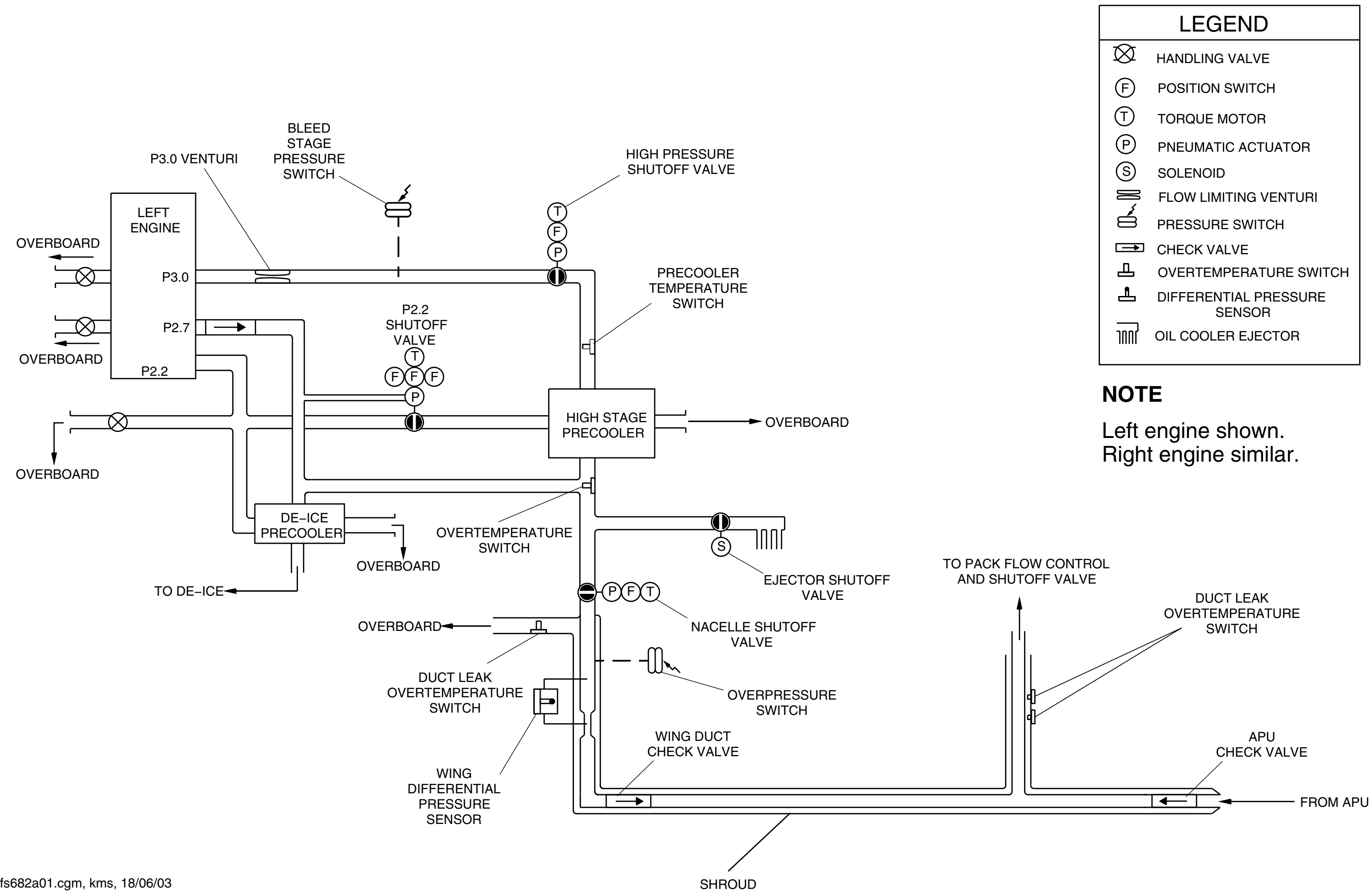
WING DIFFERENTIAL PRESSURE SENSOR

The wing differential pressure sensor is connected to bleed air ducting. The differential pressure sensor has two pressure ports. One port senses the pressure upstream of the wing venturi and the other port senses the pressure at the throat of the venturi. The differential pressure data is sent to the ECU. The ECU uses this data together with pressure and temperature data to regulate the bleed air flow through the nacelle SOV.

A similar differential pressure sensor is installed on the APU bleed air ducting in the aft fuselage. However the ECU uses this data together with pressure and temperature data to regulate the bleed air flow through the pack Flow Control and Shut−Off Valve (FCSOV).

WING DUCT CHECK VALVE

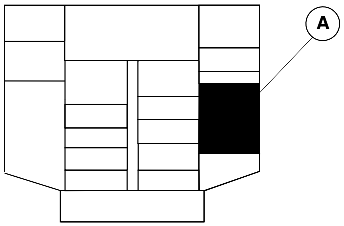
The wing duct check valve is a dual flapper, spring loaded check valve. The valve is installed in the bleed air ducting along the wing leading edge. It is held open by bleed air from the engine. The check valve closes during single engine operation to prevent bleed air from the operating engine flowing into the bleed air ducting of the opposite engine. The check valve also prevents reverse flow into both engine bleed air systems when the APU is supplying the bleed air. A similar check valve is installed in the APU bleed air ducting in the aft fuselage.



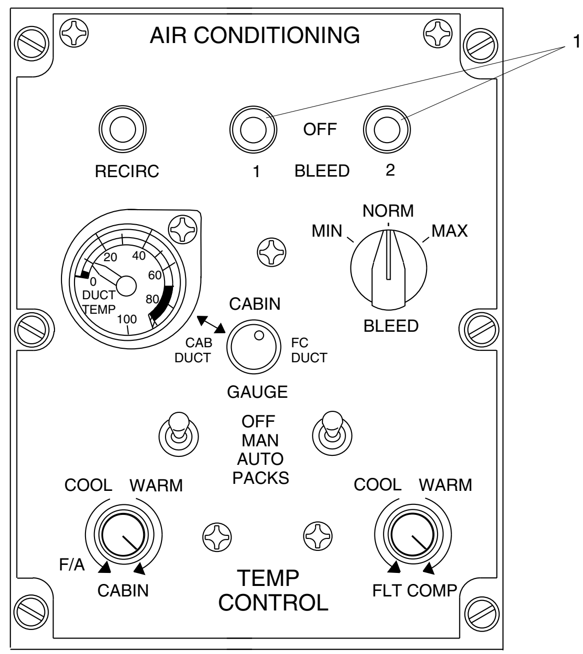
NOTE

Left engine shown.
Right engine similar.

Bleed Air System Schematic
Figure 1



OVERHEAD CONSOLE



A

LEGEND

1. Bleed Control Switches.

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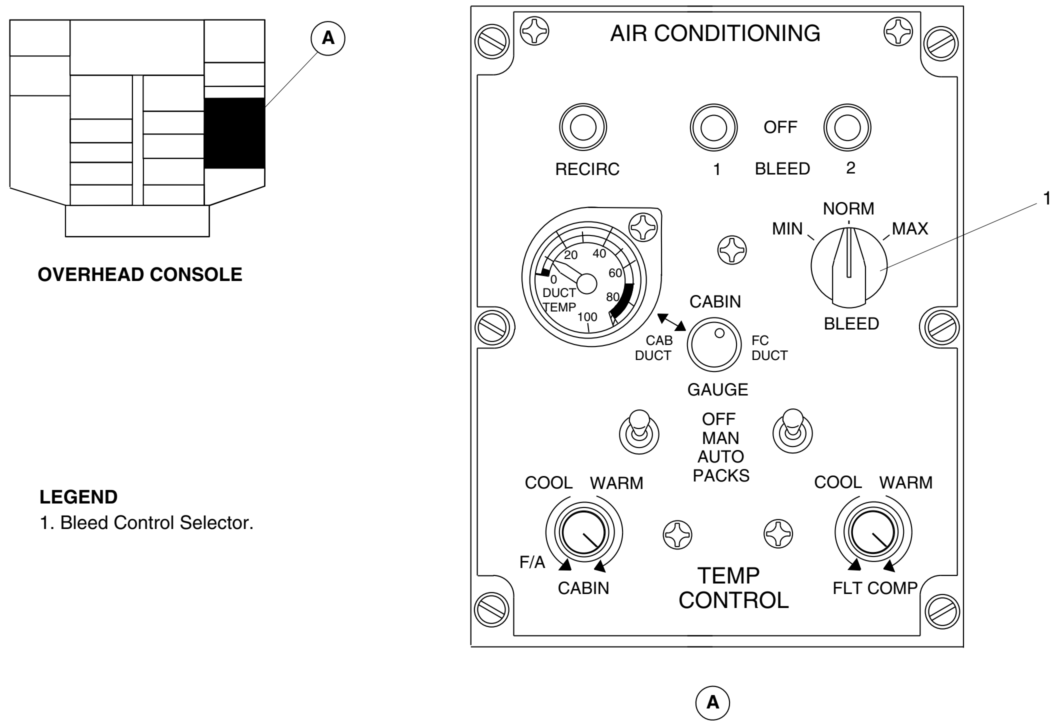
Bleed Air Select Switches
Figure 2



LEGEND
1. Bleed Control Selector.

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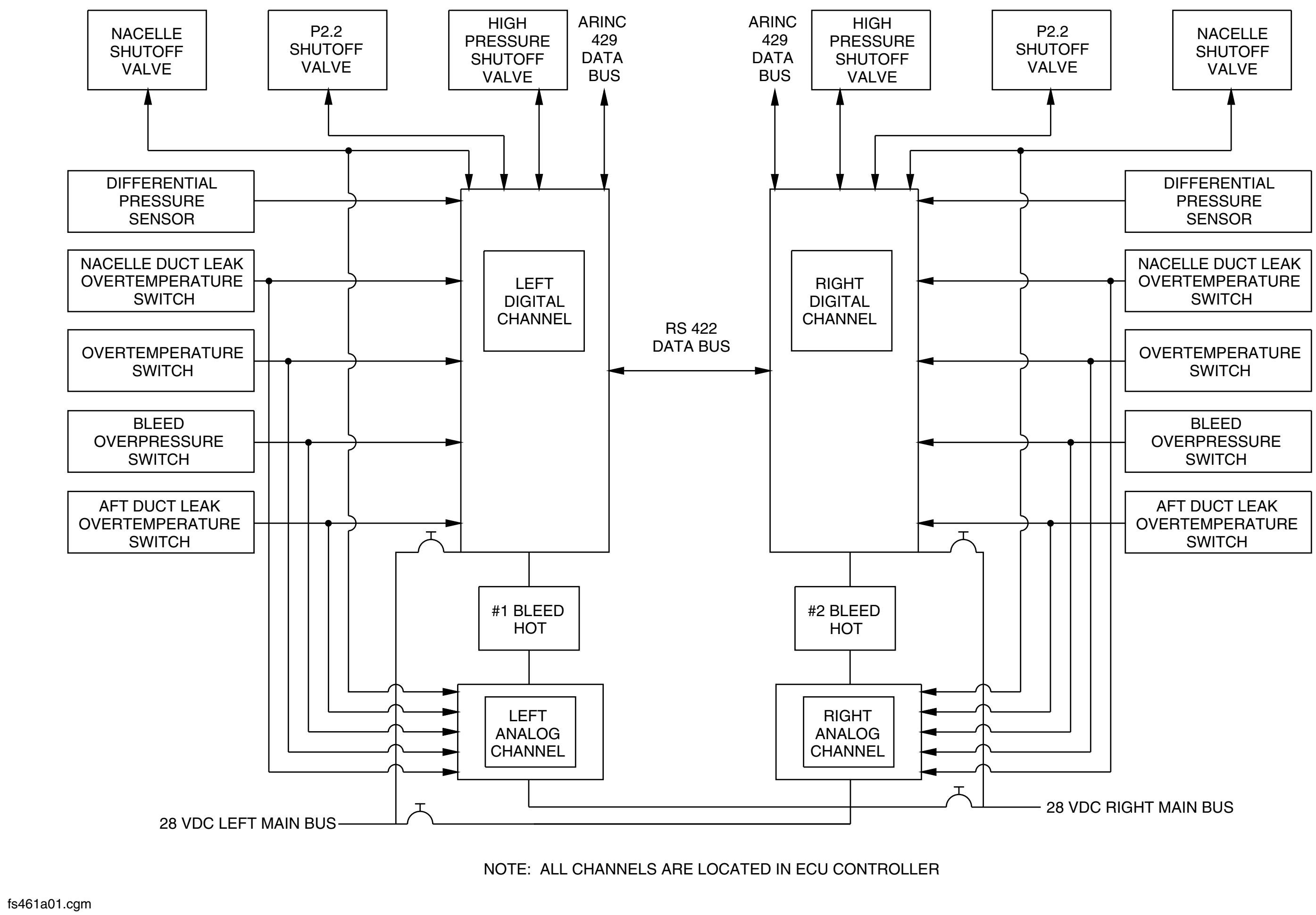
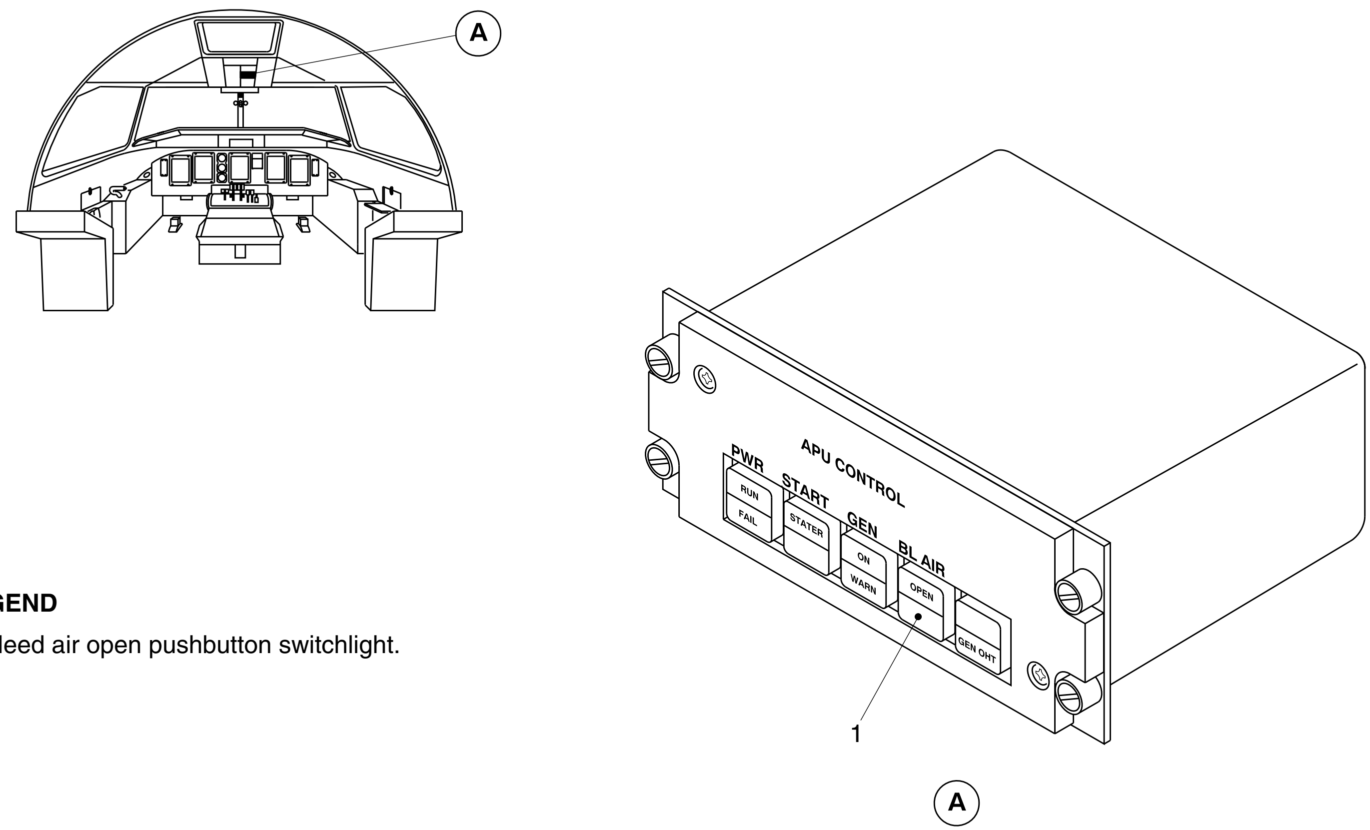
Bleed Air Selector Page 1
Figure 3



Bleed Air Selector Page 2
Figure 4



LEGEND

1. Bleed air open pushbutton switchlight.

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APU Control Panel
Figure 5

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BLEED AIR

Introduction

The bleed air system supplies compressed air to satisfy the requirements for:

- air conditioning
- airframe deicing
- door seal pressurization
- engine oil cooler ejectors
- cabin and flight compartment pressurization.

General Description

The bleed air system uses compressed air from either the engines or the Auxiliary Power Unit (APU) and conditions it to acceptable pressure, flow and temperature levels. The bleed air system then delivers the conditioned air to the air conditioning system, the deice system and the oil cooler ejectors. Crew selection of the switches on the AIR CONDITIONING control panel determine the bleed air source. The system is protected from overtemperature and overpressurization.

There is a bleed air system located within each engine nacelle. The left nacelle bleed air system is identical to the right nacelle system.

Detailed Description

Refer to Figures 1 and 2.

The bleed air system collects compressed air from the high pressure (HP P3.0 stage) or low pressure (LP P2.7 stage) bleed ports of each main engine. The use of either the HP port or the LP port depends on the engine power setting. The Auxiliary Power Unit (APU) also supplies compressed air to the bleed air system for ground operation. The bleed air system then distributes the compressed air to the Environmental Control System (ECS), the deice system (including the door seal pressurization system) and the oil cooler ejectors. The bleed air going to the ECS is also used for flight compartment and cabin pressurization.

Refer to Figures 3 , 4 , 5 and 6.

Selection of the BLEED 1 and/or BLEED 2 toggle switches on the flight compartment AIR CONDITIONING control panel turns on the related engine bleed air system. The Environmental Control System (ECS) Electronic Control Unit (ECU) selects which engine bleed port (P3.0 or P2.7) is used. The two PACKS switches, OFF/MAN/AUTO, are used to turn on the air conditioning packs in the automatic or manual control mode. The single rotary BLEED control selector is used to regulate the quantity of air conditioning. Selection of the bleed air (BL AIR) switchlight on the APU CONTROL panel turns on the APU bleed air.

The bleed air system in each nacelle has these components:

- precooler
- bleed stage pressure switch
- high pressure shut–off valve
- high pressure venturi

- low pressure check valve
- nacelle shutoff valve
- precooler temperature switch
- overtemperature switch
- oil cooler ejector shut–off valve.

The bleed air from the high pressure engine port flows through a precooler to lower the air temperature before it passes through the wing fuel zones. There is a flow limiting venturi in the high pressure line. This limits the amount of hot, high pressure air entering the bleed air system. The bleed air from the low pressure engine port is cooler than the high pressure air and does not flow through the precooler. However, the low pressure air does flow through the deice part of the precooler before it flows to the deice system. The airflows from the high and low pressure engine bleed ports join upstream of the nacelle shutoff valve. Shrouds are installed around the bleed air ducts to further reduce the surface temperature and to contain any duct leaks.

Downstream of the nacelle shutoff valve there is:

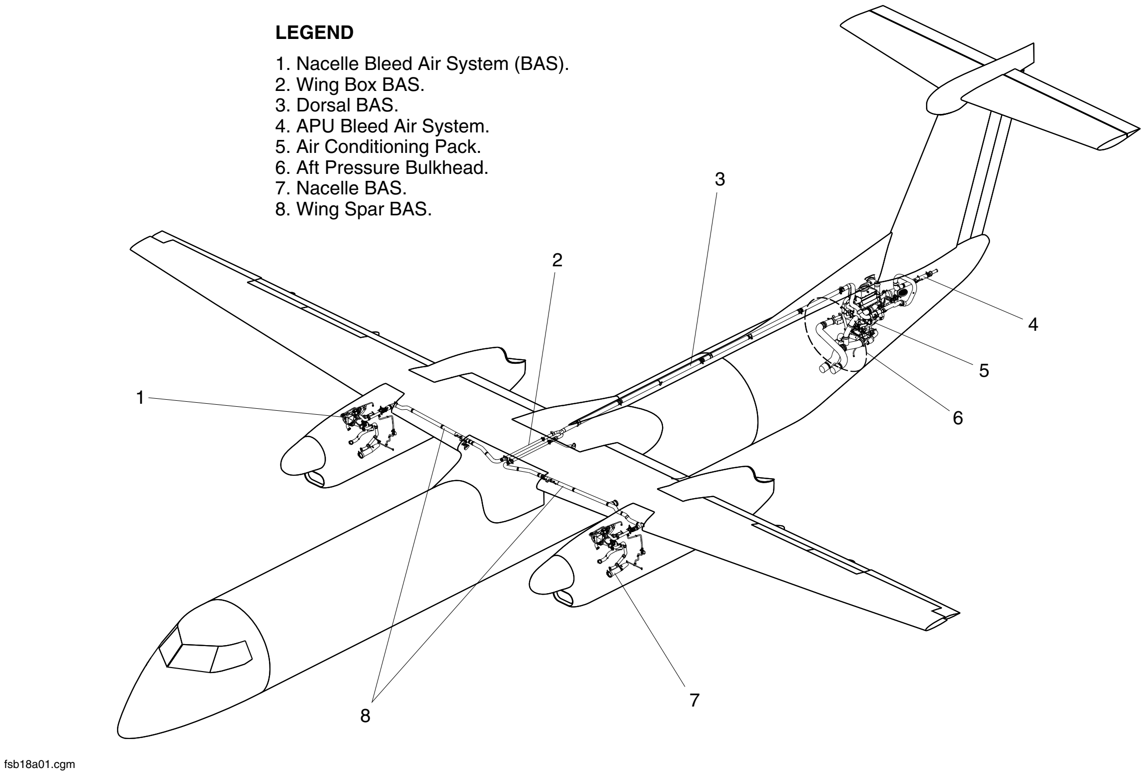
- a duct leak overtemperature switch
- an overpressure switch
- a flow sensing venturi
- a differential pressure sensor
- a wing duct check valve.

The two wing ducts join a central fuselage duct in the dorsal fin of the aircraft. This dorsal duct routes the bleed air to the air conditioning pack in the rear fuselage aft of the pressure bulkhead. A check valve in each wing duct prevents reverse airflow into the nacelle when the APU is supplying bleed air.

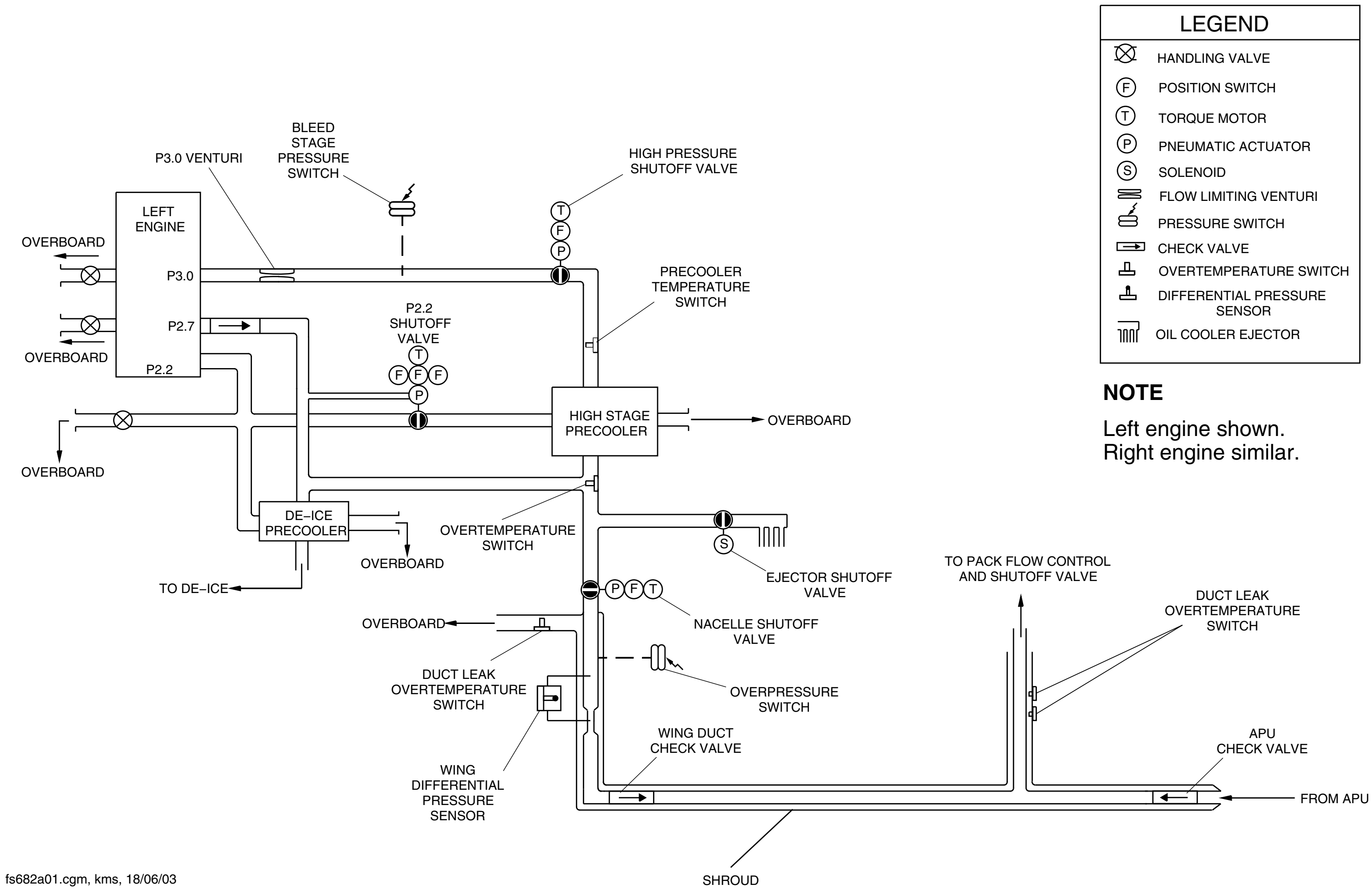
The venturis and differential pressure sensors are installed in each wing duct (and the APU duct) to measure bleed air flow. This information (together with absolute pressure and temperature information) is used to calculate the flow from each engine and from the APU. The ECU uses the nacelle shutoff valve in each nacelle to balance the bleed air output of each engine. Overtemperature, overpressure and duct leak switches are safety features which automatically shut down an individual bleed air system if an overtemperature, overpressure, or duct leak occurs.

The ECU has left and right digital channels and redundant left and right analog channels. The digital channels control the high and low pressure engine bleed ports as well as monitor the protective devices and perform a Built–In–Test. The analog channels provide backup control for the digital channels. The analog channels control only low pressure (P2.7) engine bleed air. The use of high pressure (P3.0) bleed air and bleed air flow sharing is not permitted under analog control.

Airframe deicing air is supplied through either the high pressure or low pressure bleed air port. The deicing air is passed through the precooler to protect the components of the deice system from overheating.



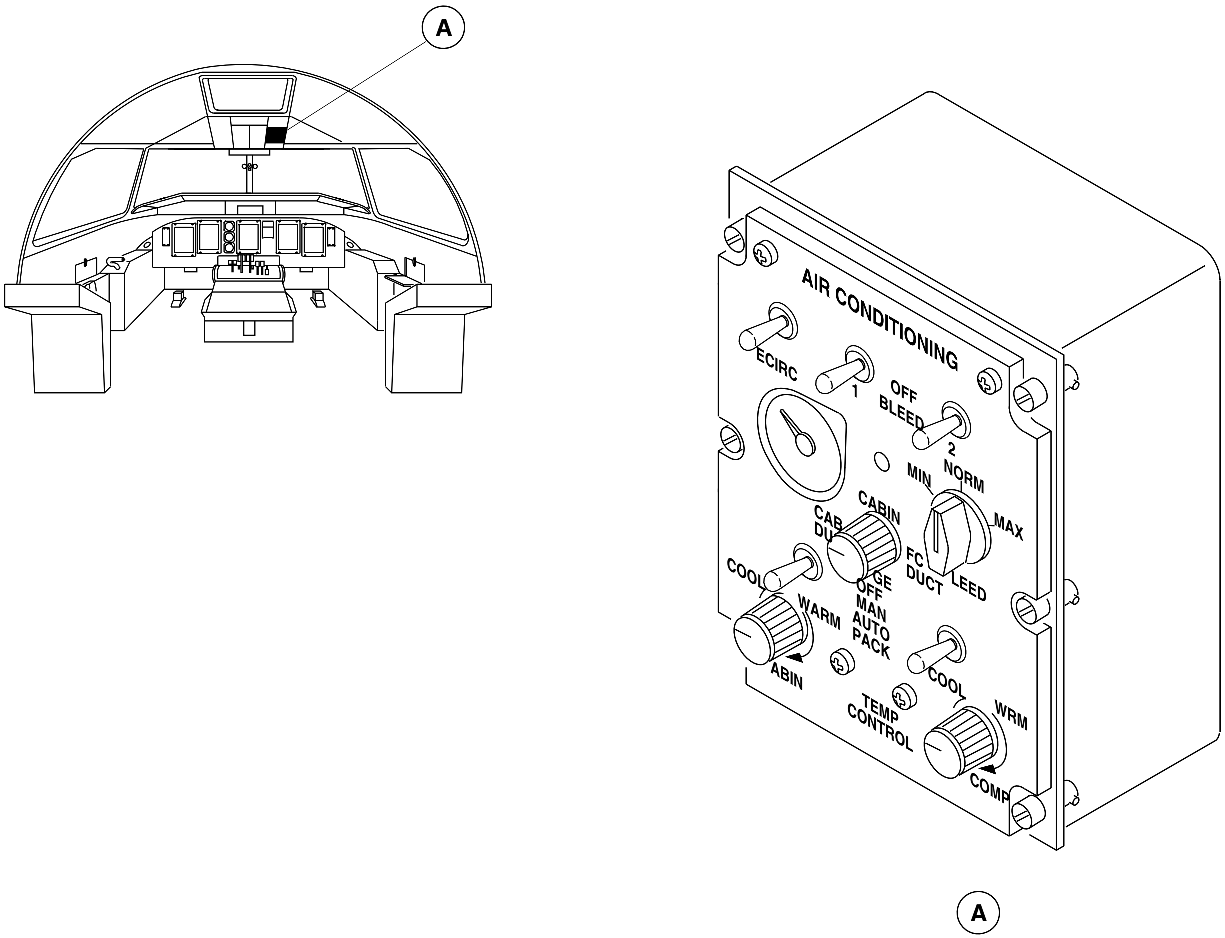
BLEED AIR SYSTEM
Figure 1



NOTE

Left engine shown.
Right engine similar.

BLEED AIR SYSTEM SYNOPTIC
Figure 2



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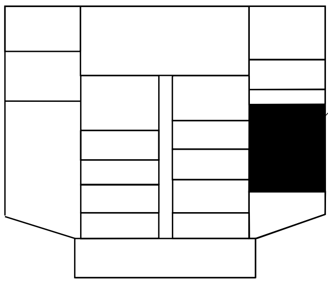
AIR CONDITIONING CONTROL PANEL LOCATOR
Figure 3



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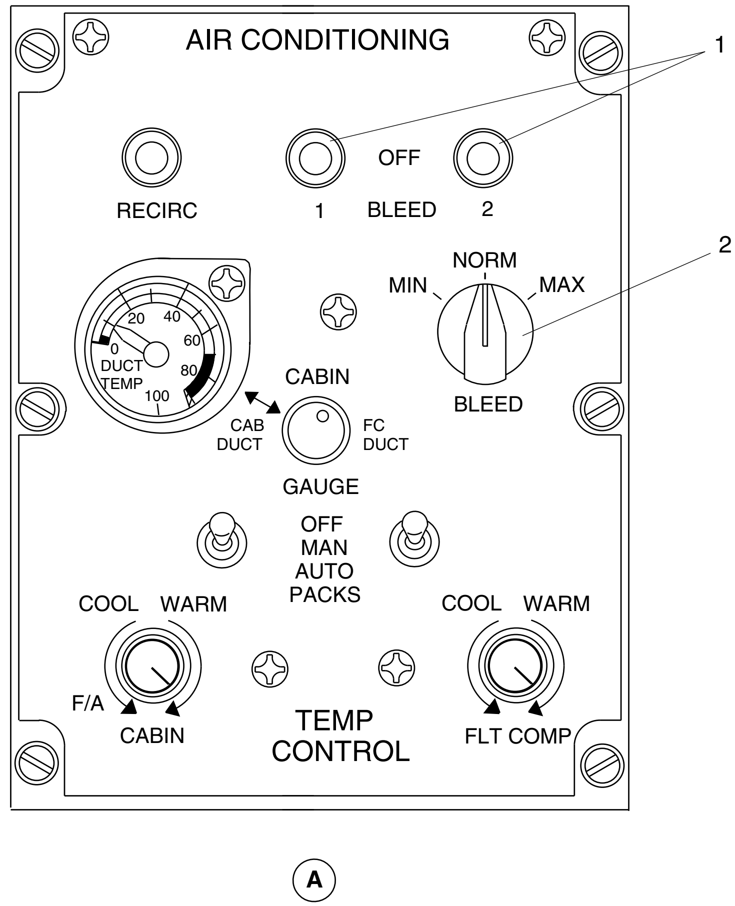
1. Bleed Control Switches.
2. Bleed Control Selector.



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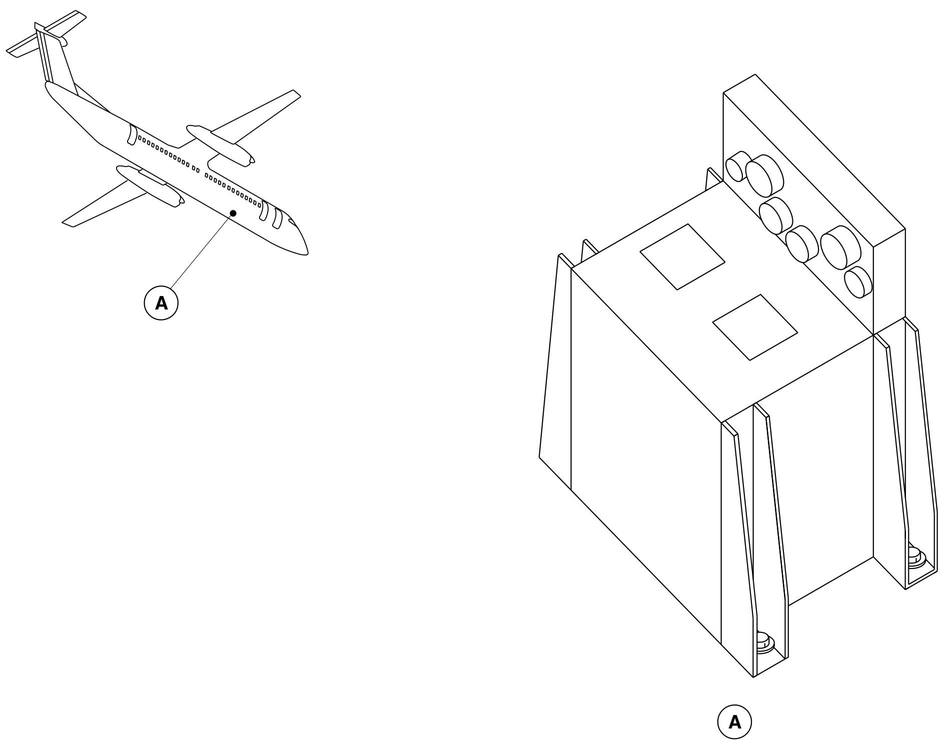
BLEED AIR, AIR CONDITIONING CONTROL PANEL DETAIL
Figure 4



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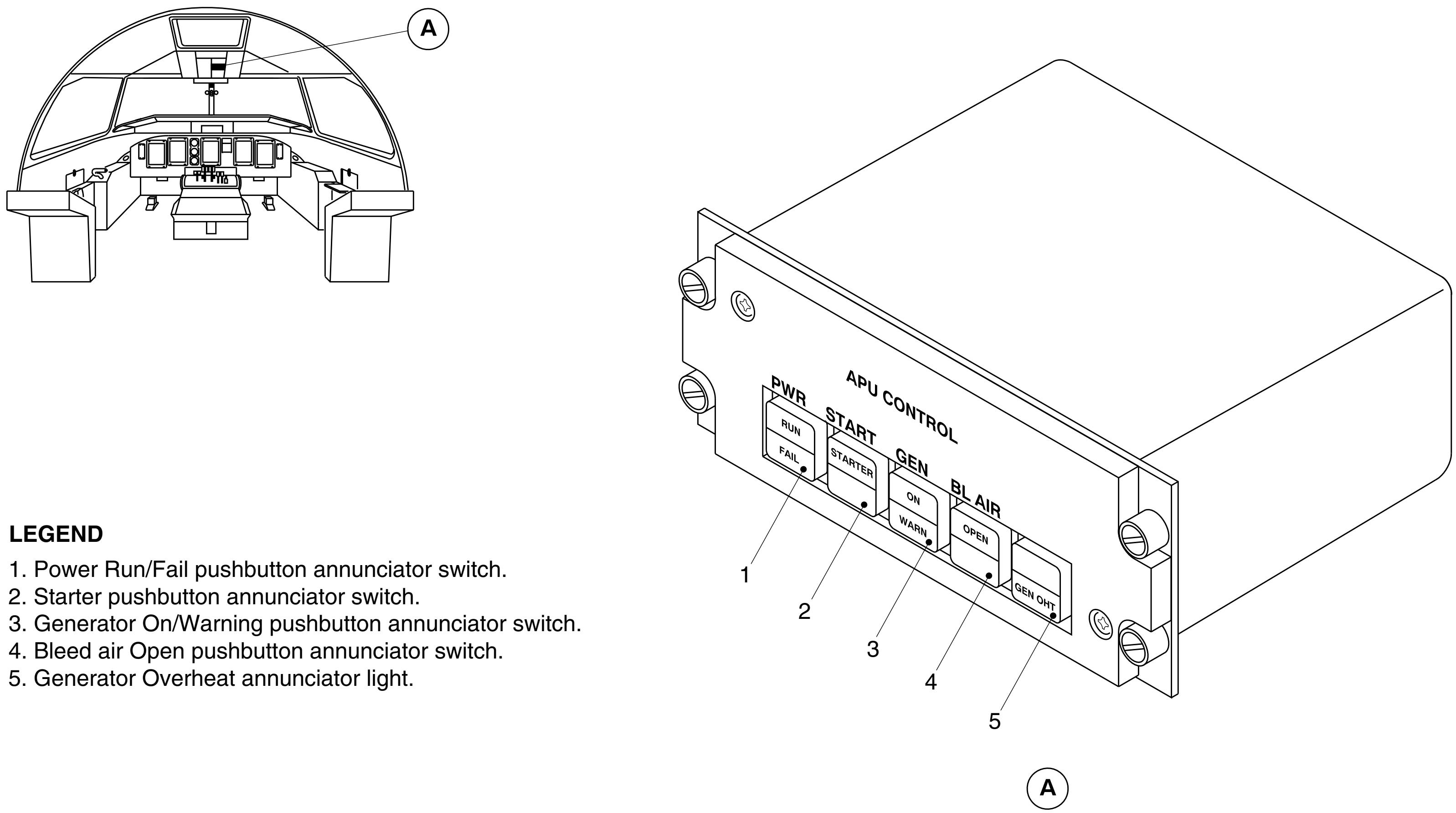
ELECTRONIC CONTROL UNIT (ECU)
Figure 5



LEGEND

1. Power Run/Fail pushbutton annunciator switch.
2. Starter pushbutton annunciator switch.
3. Generator On/Warning pushbutton annunciator switch.
4. Bleed air Open pushbutton annunciator switch.
5. Generator Overheat annunciator light.

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APU Control Panel and Bleed Air Switch
Figure 6

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BLEED AIR SYSTEM

Introduction

The bleed air system supplies compressed air to satisfy the requirements for:

- air conditioning
- airframe deicing
- door seal pressurization
- engine oil cooler ejectors
- cabin and flight compartment pressurization.

General Description

The Bleed Air System (BAS) is part of the Environmental Control System (ECS) which supplies conditioned air to the flight and cabin compartments of the aircraft.

The BAS has the components that follow:

- Bleed Stage Pressure Switch (36–11–06)
- High Pressure Shutoff Valve (36–11–09)
- Precooler Temperature Switch (36–11–11)
- Precooler (36–11–14)
- Overtemperature switch/sensor (36–11–16)
- Nacelle Shutoff Valve (36–11–19)
- Nacelle Duct Leak Overtemperature Switch (36–11–21)
- P2.2 Shutoff Valve (36–11–31)
- Overpressure Switch (36–11–36)
- Wing Differential Pressure Sensor (36–11–41)
- Wing Duct Check Valve (36–11–44)
- APU Differential Pressure Sensor (36–11–49)
- Aft Fuselage Duct Leak Overtemperature Switches (36–11–51)
- APU Check Valve (36–11–59)

The BAS has a series of air ducts which transfer bleed air from the engines or the Auxiliary Power Unit (APU) to the Environmental Control System (ECS).

Detailed Description

Refer to Figures 1 and 2.

The Bleed Air System (BAS) starts in the nacelles, where it collects compressed air from the engines. In the nacelles, the BAS has valves, heat exchangers, sensors and switches to select, monitor and condition the bleed air drawn from the left and right engines. As commanded by the Electronic Control Unit (ECU), the valves and heat exchangers condition the bleed air for correct temperature, pressure and flow rates. The bleed air is supplied to the ECS, the deice system (including the door seal pressurization system) and the oil cooler ejectors.

Bleed air flows from the two engines through the ducting on each wing forward spar to the wing center section. The wing bleed air ducts, one from each nacelle, join at the wing center section to combine the two engine bleed air flows into one air flow. Each wing bleed air duct has a pressure switch, a differential pressure sensor and a check valve to monitor and control the flow of engine bleed air. The ducts have shrouds and temperature sensors to contain and detect air leaks.

The next section of bleed air ducting transfers the combined engine bleed air flow from the wing center section through the dorsal fin of the fuselage to the tail. This section of air ducts also has a shroud to contain air leaks.

The last section of the BAS is in the aft fuselage. This section transfers the bleed air from the engines or from the Auxiliary Power Unit (APU) to the air conditioning pack. The ducts in this section also have shrouds and temperature switches to contain and detect duct leaks. A differential pressure sensor and a shutoff valve monitor and control bleed air flow from the APU.

The oil cooler ejector shutoff valve (one in each nacelle) controls the flow of engine bleed air for operation of the oil cooler ejector. This valve is controlled by FADEC (refer to SDS 79–21–00).

Operation

Refer to Figures 3 , 4 , 5 and 6.

The switch settings on the AIR CONDITIONING control panel and the APU CONTROL PANEL determine the selection of bleed air from the engines or the APU. Selection of the BLEED 1 and BLEED 2 switches on the AIR CONDITIONING control panel turns on the left and right engine bleed air systems respectively. The rotary BLEED MIN/NORM/MAX switch is used to control the amount of bleed air flow. Selection of the BL AIR switch on the APU CONTROL PANEL turns on the APU bleed air system.

Refer to Figure 7.

Selection of the BLEED 1 and BLEED 2 switches causes the ECU to open both nacelle shutoff valves. This allows bleed air to flow from the left and right engines. Selection of the OFF switch causes the ECU to close the High Pressure Shutoff Valve (HPSOV), P2.2 shutoff valve and the nacelle shutoff valve. This stops the flow of engine bleed air to the ECS. While bleed air to the ECS is stopped, low pressure (P2.7) bleed air from each engine can flow to the deice system and the oil cooler ejectors. Selection of the APU as a bleed air source by the ECU is done with the APU shutoff valve.

Each engine must be operating to supply bleed air to its oil cooler ejector and to the deice system. Check valves in the wing ducts prevent the use of bleed air from the APU for the deice system and oil cooler ejectors.

Bleed air can be supplied from either the high pressure (P3.0) port or the low pressure (P2.7) port on each engine. The ECU uses pressure data from the P3.0 bleed air and environmental data from the Air Data Units (ADUs) to determine which port supplies the bleed air. If the P3.0 bleed air has sufficient pressure, the ECU opens the High Pressure Shutoff Valve (HPSOV). This allows bleed air from the P3.0 port to supply the Environmental Control System (ECS). A flow–limiting venturi in the high pressure duct limits the maximum flow of high stage (P3.0) bleed air drawn from each engine. A check valve in each engine's P2.7 bleed duct prevents the back–flow of high pressure P3.0 bleed air into the P2.7 bleed port.

At some engine power settings, the P3.0 bleed air can be too hot (greater than 560 °F (293 °C)) for use by the ECS, deice system and oil cooler ejectors. The BAS uses the high stage precooler (a compact air–to–air heat exchanger in each nacelle) to reduce the P3.0 bleed air temperature. Cooling air from the P2.2 engine bleed port is used in the precooler to lower the temperature of the P3.0 air. The ECU opens the P2.2 shutoff valve to permit the flow of P2.2 bleed air through the high stage precooler. In the high stage precooler, the P2.2 bleed air absorbs heat from the P3.0 bleed air. The P3.0 bleed air that leaves the precooler is cool enough to flow through the bleed air ducts in the wing fuel zones.

If the initial high stage (P3.0) bleed air temperature is correct, the ECU closes the P2.2 shutoff valve. This disables the high stage precooler operation. This allows P3.0 bleed air to flow directly to the ECS, deice system and oil cooler ejectors with no temperature reduction. The high stage precoolers operate independently on each side of the aircraft.

At higher engine power settings, the ECU closes the HPSOV to select the low stage (P2.7) bleed air. With the HPSOV closed, the P2.7 bleed air pressure opens the P2.7 check valve. This allows P2.7 bleed air to flow directly through to the ECS.

A smaller deice precooler, attached to the high stage precooler, further reduces the temperature of the bleed air sent to the deice system. This precooler uses a continuous flow (no flow control valves) of P2.2 bleed air and operates during selection of either P3.0 or P2.7 bleed air. The flow of P2.2 bleed air through the deice precooler absorbs heat from the P3.0 or P2.7 bleed air. This reduces the temperature of the P3.0 or P2.7 bleed air to acceptable levels before it flows to the deice system.

When the deice system is in operation, and the P3.0 bleed air pressure decreases below 77 psi. (as detected by the bleed stage pressure switch), the HPSOV opens. This function is independent of the ECU. A discrete signal from the deice system and an open discrete signal from the HPSOV tell the ECU that P3.0 air is selected for deice use. The ECU adjusts bleed air flow as necessary.

The ECU uses a differential pressure (flow) sensor to measure the bleed air flow through each nacelle shutoff valve. The ECU uses this bleed airflow information to balance the flow of bleed air from both engines to the ECS. Each digital channel in the ECU modulates its nacelle shutoff valve to maintain 50% total bleed air flow from its engine. Bleed sharing can occur only when both engines are in operation and both digital channels are functional. There is no analog channel function for bleed air sharing (refer to ECU Operation).

ECU Operation

Refer to Figures 8 and 9.

The ECU is the interface between the pilot and crew control panels and the mechanical and electrical components of the ECS (which includes the Bleed Air System). The ECU uses sensors and switches to monitor temperature, pressure, flow rates and valve positions. The ECU responds to the pilot and crew commands to configure the Bleed Air System for bleed source selection. The ECU and the Bleed Air System have redundant configurations to permit continued ECS operation with mechanical and electrical component malfunctions.

The ECU is divided into a left digital channel with a left backup analog channel and a right digital channel with a right backup analog channel. The left digital channel and right analog channel receive electrical power from the 28 Vdc L MAIN bus. The right digital channel and left analog channel receive electrical power from the 28 Vdc R MAIN bus. This permits continued left and right channel control if one 28 Vdc bus loses power. For example, if the left digital channel loses electrical power because of bus failure, the left analog channel is still powered by the remaining bus.

Inside the ECU, the digital channels use an RS 422 digital data bus to communicate with each other. The ECU uses the ARINC 429 digital data bus to communicate to other aircraft systems. The ARINC 429 receivers of both digital channels are connected to the aircraft wiring. Only the ARINC 429 transmitter of the left digital channel is connected to the aircraft wiring.

The left and right digital channels share control of the nacelle shutoff valves. At the start of a flight, the ECU selects one digital channel to control the shared components of the bleed air system. The digital channel in control is responsible for all functions applicable to the shared components. Loss of the digital channel in control causes the other digital channel to take control of the shared components.

The left digital channel and left analog channel share control of the left nacelle shutoff valve. If the left digital channel loses power or fails, the left analog channel automatically takes control of this valve. The right digital channel and right analog channel share control of the right nacelle shutoff valve. If the right digital channel loses power or fails, the right analog channel automatically takes control of this valve.

If the pilot selects the manual mode, the left digital channel (responsible for the auto mode) transfers control of the left nacelle shutoff valve to the left analog channel. This description also applies to the right digital channel and right analog channel which control the right nacelle shutoff valve.

The analog channels function as backup controllers for the digital channels. One or both analog channels take control of the functions only when one or both digital channels lose power or malfunction. If the PACKS switch on the AIR CONDITIONING control panel is set to MAN (manual), the analog channels are in control of the ECS (including the BAS). The analog channels keep the nacelle shutoff valves fully open (50 mA drive current to the torque motors), but defaults the HPSOVs closed. This disables the high stage (P3.0) bleed air and selects the low stage (P2.7) bleed air. The protection circuits remain active but balanced bleed air (bleed sharing) from both engines is not possible. This is because the analog channels do not have inputs (differential pressure sensors) to sense bleed air flow.

The analog channels keep the nacelle shutoff valves fully open during these conditions:

- The BLEED 1 and/or BLEED 2 switches on the AIR CONDITIONING control panel turned on
- No overtemperature, overpressure or bleed leak indications are active.

The ECU (digital and analog channels) examines the state of all three switches: overtemperature switch (On aircraft with ModSum 4Q113658 or SB84–36–03 incorporated, the overtemperature switch is replaced with the overtemperature sensor), overpressure switch, and four duct leak switches. Each digital channel examines the state of the protective switches for the BAS on its side of the aircraft. A discrete signal from one or more switches activates a protective bleed shutoff (closes nacelle shutoff valve, HPSOV, and P2.2 shutoff valve). Built–In–Test (BIT) logic determines which switch caused the BAS shutdown.

The digital channel will keep its side latched off until the switch that tripped has reset and the BLEED 1 or BLEED 2 switch is set to off. The applicable analog channel supplies backup BAS protection if a digital channel loses power or fails. Bleed air (left or right) remains shut off until the pilot sets the BLEED 1 or BLEED 2 switch to OFF and then turns it on again.

Each digital and analog channel generates a discrete signal to turn on a BLEED HOT caution light which signals a failure of the BAS. If both the digital and analog channel on one side fail, the related BLEED HOT caution light will not turn on.

The ECU does high level operational checks of the ECS system as part of continuous BIT. For the ECS, the tests examine that the pack flow is within permitted limits and that the pack discharge temperature is reasonable. Failure of these high level tests causes the ECU to do low level tests to identify the failed component. The ECU also performs self tests on its digital and analog channels and the applicable interfaces.

The high pressure shutoff valves, nacelle shutoff valves and the APU shutoff valve each have a position switch to identify when the valve is closed. The P2.2 SOV has three electrically isolated position switches to identify an open or closed valve position. The digital channels use one of the three switches for its Built–In– Test (BIT). During its BIT, the ECU compares the commanded state (open or closed) of the valve to the actual state identified by the position switch. BIT logic can also examine the signals from the pressure and temperature sensors to determine if they function correctly.

When the ECU detects a BIT fault, it saves an applicable fault code in its non–volatile fault memory. A failure detected in a digital channel causes the ECU to transmit the fault code signal to the Central Diagnostic System (CDS).

During ground operation, the digital channels of the ECU respond to the INITIATE TEST and FAULT RESET input signals from the CDS as follows:

- The INITIATE TEST signal causes the ECU to report (transmit) BIT faults via the ARINC–429 digital data bus
- The FAULT RESET signal causes the ECU to erase all BIT faults saved in non–volatile memory which are transmitted via ARINC–429.

Bleed Stage Pressure Switch (36–11–06)

Refer to Figure 10.

The bleed stage pressure switch is installed in a bracket aft of the precooler. The switch controls the HPSOV independently of the ECU for deice operation. The switch contacts close when the high stage (P3.0) pressure is less than 77 psi (531 kPa). The switch contacts open when P3.0 pressure is greater than 82 psi (565 kPa). When the bleed stage switch is closed (P3.0 < 77 psi (531 kPa)) and the deice system is selected on, the HPSOV will open to supply P3.0 air to the deice system. A discrete signal from the deice system and an open discrete signal from the HPSOV identifies to the ECU that high stage (P3.0) bleed air is selected for deice use. The ECU adjusts bleed air flow as required.

High Pressure Shutoff Valve (36–11–09)

Refer to Figure 11.

The high pressure shutoff valve (HPSOV) is a pneumatically operated, torque motor actuated butterfly valve. The HPSOV is installed in line with the high pressure ducting between the engine (P3.0) bleed air port and the precooler. The high pressure ducting in the nacelle is enclosed in a composite shroud from the bleed port to the HPSOV. This reduces the possibility of ignition in the event of a fuel spillage. The valve has a wire mesh filter upstream of the torque motor to protect the servo from contamination.

The HPSOV opens when the torque motor is energized. When the HPSOV is in the open position, it allows P3.0 air to flow through to the precooler to supply the ECS and/or the deice systems. The ECU uses high pressure (P3.0) information supplied by FADEC to control the opening and closing of the HPSOV. The ECU opens the HPSOV at low engine power settings. The HPSOV has a closed position switch which informs the ECU of the status of the valve. The bleed stage pressure switch can open the HPSOV independently from the ECU to supply bleed air to the deice system.

Precooler Temperature Switch (36–11–11)

Refer to Figure 12.

The precooler temperature switch is installed in the ducting between the HPSOV and the precooler. The precooler switch monitors the temperature of the engine bleed air entering the precooler. If the bleed air entering the precooler is greater than 550°F (288 °C), the switch will open sending a signal to the ECU to open the P2.2 shutoff valve. This allows cooling P2.2 air to pass through the precooler.

Precooler (36–11–14)

Refer to Figures 13 and 14.

The precooler is installed near the top of the engine. It is a two–part plate and fin, cross flow, air to air heat exchanger which uses low temperature (P2.2) bleed air to cool high pressure bleed air. The main heat exchanger cools the temperature of the high pressure (P3.0) bleed air before it is supplied to the ECS. The small heat exchanger cools either the high pressure (P3.0) or the low pressure (P2.7) bleed air before it is supplied to the deice system.

Overtemperature Switch/Sensor (36–11–16)

Refer to Figure 15.

The overtemperature switch is installed in the precooler outlet duct. It is a protective switch that monitors nacelle bleed air temperature. If the temperature of the bleed air entering the nacelle ducts is greater than 660°F (349 °C), the overtemperature switch will open. This sends a signal to the ECU to close the nacelle shutoff valve for the affected side. The ECU will then turn on the appropriate BLEED HOT caution light.

On aircraft with ModSum 4Q113658 or SB84–36–03 incorporated, the overtemperature switch is replaced with a sensor. This sensor is a Resistance Temperature Device (RTD). It gives a resistance, which is proportional to the temperature it senses. If the temperature of the bleed air entering the nacelle ducts is greater than 660°F (349 °C), the overtemperature sensor sends a signal to the ECU to close the nacelle shutoff valve for the affected side. The ECU will then turn on the appropriate BLEED HOT caution light.

Nacelle Shutoff Valve (36–11–19)

Refer to Figure 16.

The nacelle shutoff valve is a pneumatically operated, torque motor actuated butterfly valve. The nacelle shutoff valve is installed in line with the precooler outlet duct and the wing ducting. The valve has a wire mesh filter upstream of the torque motor to protect the servo from contamination.

Selection of the BLEED 1 and/or BLEED 2 switches on the AIR CONDITIONING control panel opens the related nacelle shutoff valve. The ECU uses the nacelle shutoff valve to control the flow of bleed air to the ECS. The ECU regulates the nacelle shutoff valve according to the settings of the BLEED, PACKS and MIN/NORM/MAX switches on the AIR CONDITIONING control panel. The ECU also regulates the nacelle shutoff valve in each nacelle to supply 50% of the total flow demand. This ensures equal flow sharing between each main engine. The nacelle shutoff valve has a closed position switch which informs the ECU of the status of the valve.

<u>Nacelle Duct Leak Overtemperature Switch (36–11–21)</u>

Refer to Figures 17 and 18.

The nacelle duct leak overtemperature switch is installed on a bracket next to the nacelle shutoff valve. It detects a bleed air leak in the nacelle ducting. If the temperature in the nacelle ducting is greater than 360 °F (182.2 °C), the switch opens sending a signal to the ECU to close the appropriate nacelle SOV. The ECU also sends a fault code to the Central Diagnostic System (CDS) identifying a duct leak.

<u>P2.2 Shutoff Valve (36–11–31)</u>

Refer to Figure 19.

The P2.2 shutoff valve is a pneumatically operated, torque motor actuated butterfly valve. The valve has a wire mesh filter upstream of the torque motor to protect the servo from contamination. The P2.2 shutoff valve is installed in line with the P2.2 low pressure ducting and the P2.2 inlet at the bottom of the precooler. It opens to supply cooling air through the precooler. The precooler temperature switch (refer to 36–11–11) controls its operation. The valve has two closed position switches to supply valve position information to the ECU and to FADEC.

<u>Overpressure Switch (36–11–36)</u>

Refer to Figure 20.

The overpressure switch is installed on a bracket in the wing leading edge and is connected to the bleed air ducting with rigid tubing. It is a protective switch that monitors nacelle bleed pressure. If the pressure in the nacelle ducting is greater than 100 psi (690 kPa), the overpressure switch will open. This sends a signal to the ECU to close the affected nacelle shutoff valve. The ECU also sends a signal to turn on the appropriate BLEED HOT caution light.

<u>Wing Differential Pressure Sensor (36–11–41)</u>

Refer to Figure 21.

The wing differential pressure sensor is installed on a bracket in the wing leading edge and is connected to bleed air ducting with rigid tubing. The differential pressure sensor has two pressure ports. One port senses the pressure upstream of the wing venturi and the other port senses the pressure at the throat of the venturi. The differential pressure data is sent to the ECU. The ECU uses this data together with pressure and temperature data to regulate the bleed air flow through the nacelle shutoff valve.

Wing Duct Check Valve (36–11–44)

Refer to Figure 22.

The wing duct check valve is a dual flapper, spring loaded check valve. The valve is installed in the bleed air ducting along the wing leading edge. It is held open by bleed air from the engine. The check valve closes during single engine operation to prevent bleed air from the operating engine flowing into the bleed air ducting of the opposite engine. The check valve also prevents reverse flow into both engine bleed air systems when the APU is supplying the bleed air.

APU Differential Pressure Sensor (36–11–49)

Refer to Figure 23.

The APU differential pressure sensor is installed on a bracket on the APU bleed air ducting in the aft fuselage. It is connected to the bleed air ducting by rigid tubing. The differential pressure sensor has two pressure ports. One port senses the pressure upstream of the APU venturi and the other port senses the pressure at the throat of the venturi. The differential pressure data is sent to the ECU. The ECU uses this data together with pressure and temperature data to regulate the bleed air flow through the pack flow control and shutoff valve.

Aft Fuselage Duct Leak Overtemperature Switches (36–11–51)

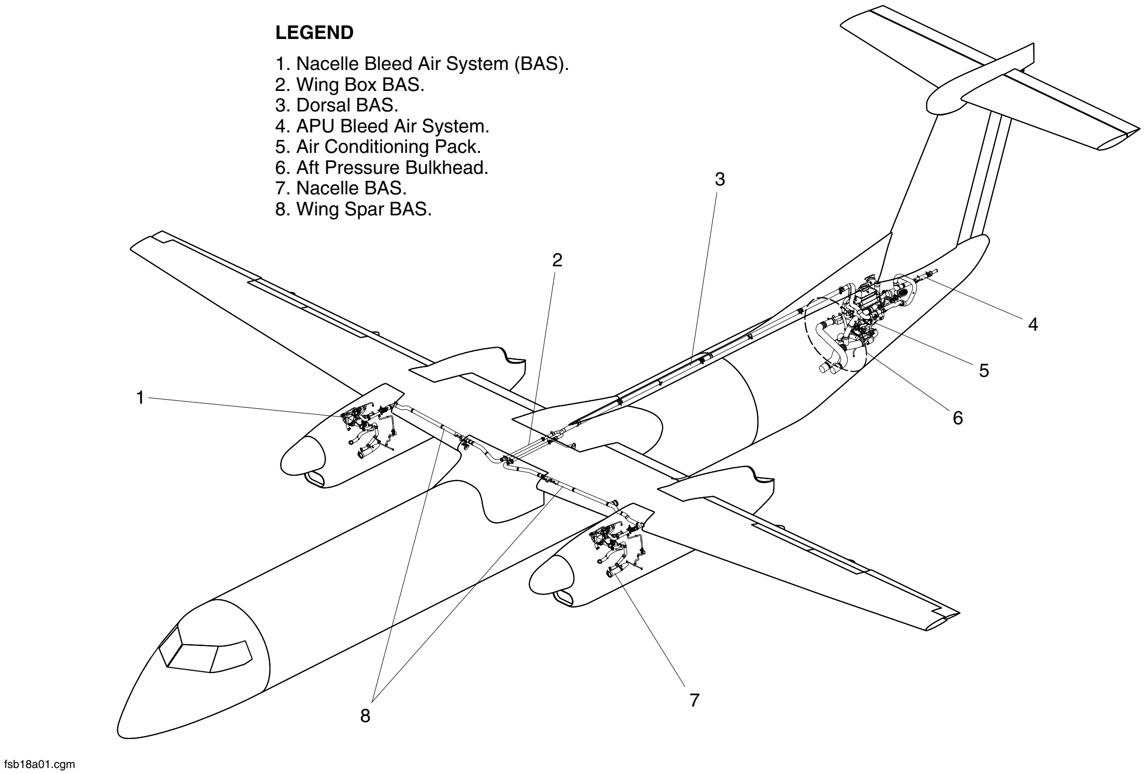
Refer to Figure 24.

Two aft fuselage duct leak overtemperature switches are installed on a bracket on the aft fuselage tee duct. They detect a bleed air leak in the engine or APU bleed air ducting near the air conditioning pack inlet. If the temperature in the ducting is greater than 360 °F (182.2 °C), the switch contacts will open. This sends a signal to the ECU to close the nacelle shutoff valve. The ECU also sends a fault code to the Central Diagnostic System (CDS) identifying a duct leak.

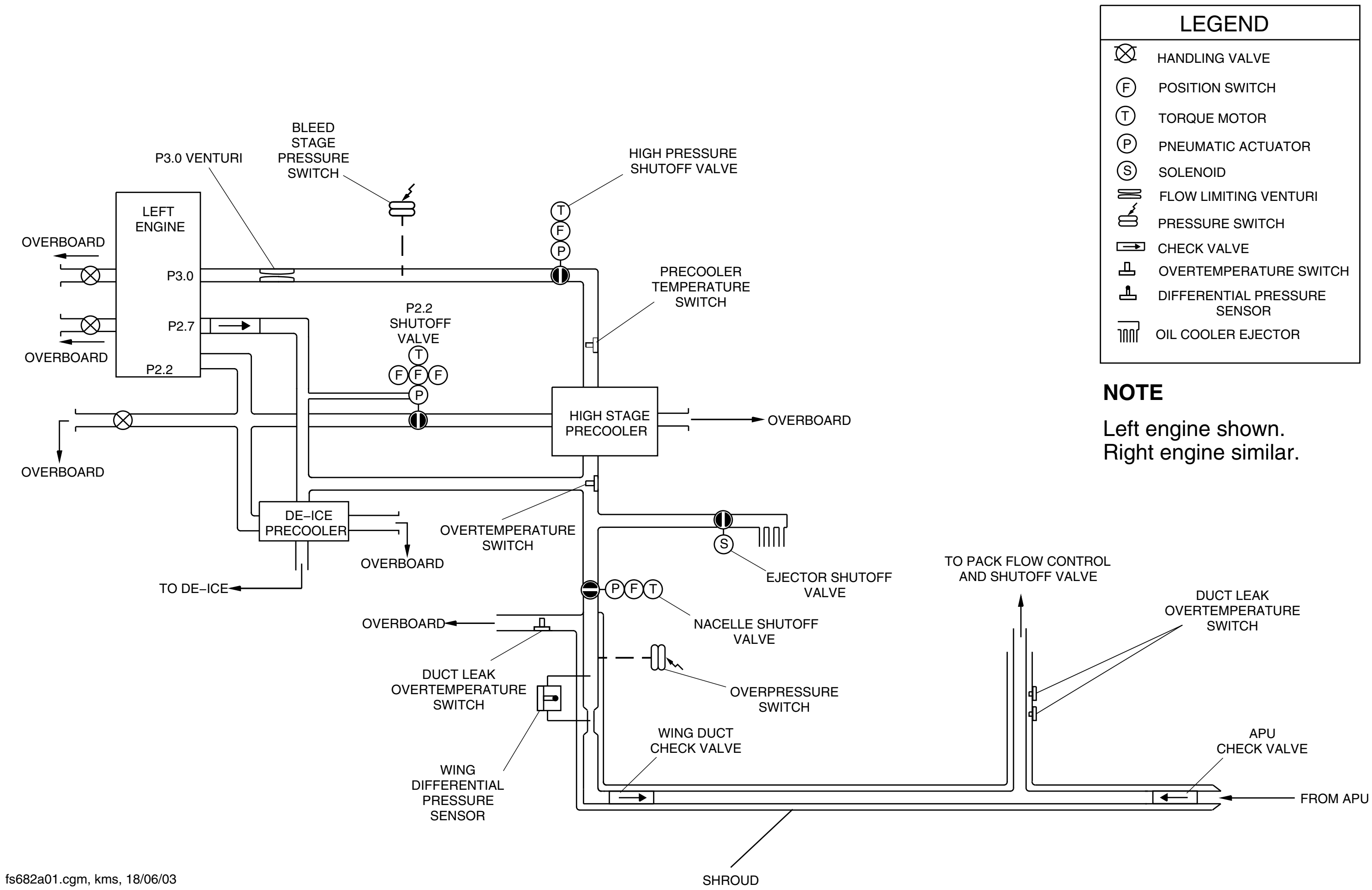
APU Check Valve (36–11–59)

Refer to Figure 25.

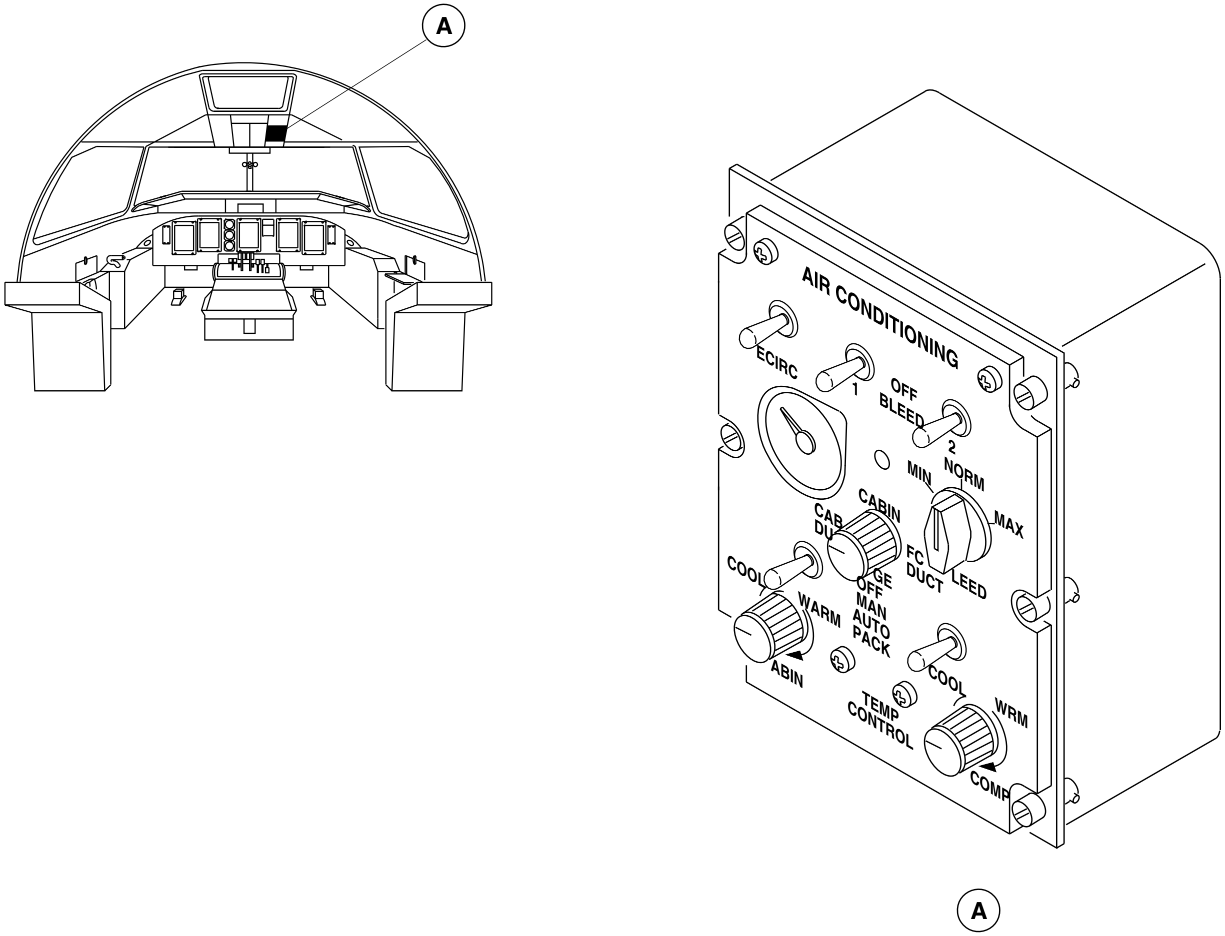
The APU check valve is a dual flapper, spring loaded check valve. The valve is installed in line with the APU bleed air ducting in the aft fuselage. It is held open by bleed air coming from the APU. It allows bleed air to flow to the air conditioning pack but prevents reverse flow to the APU from the engine bleed air system.



BLEED AIR SYSTEM PAGE 1
Figure 1



BLEED AIR SYSTEM PAGE 2
Figure 2



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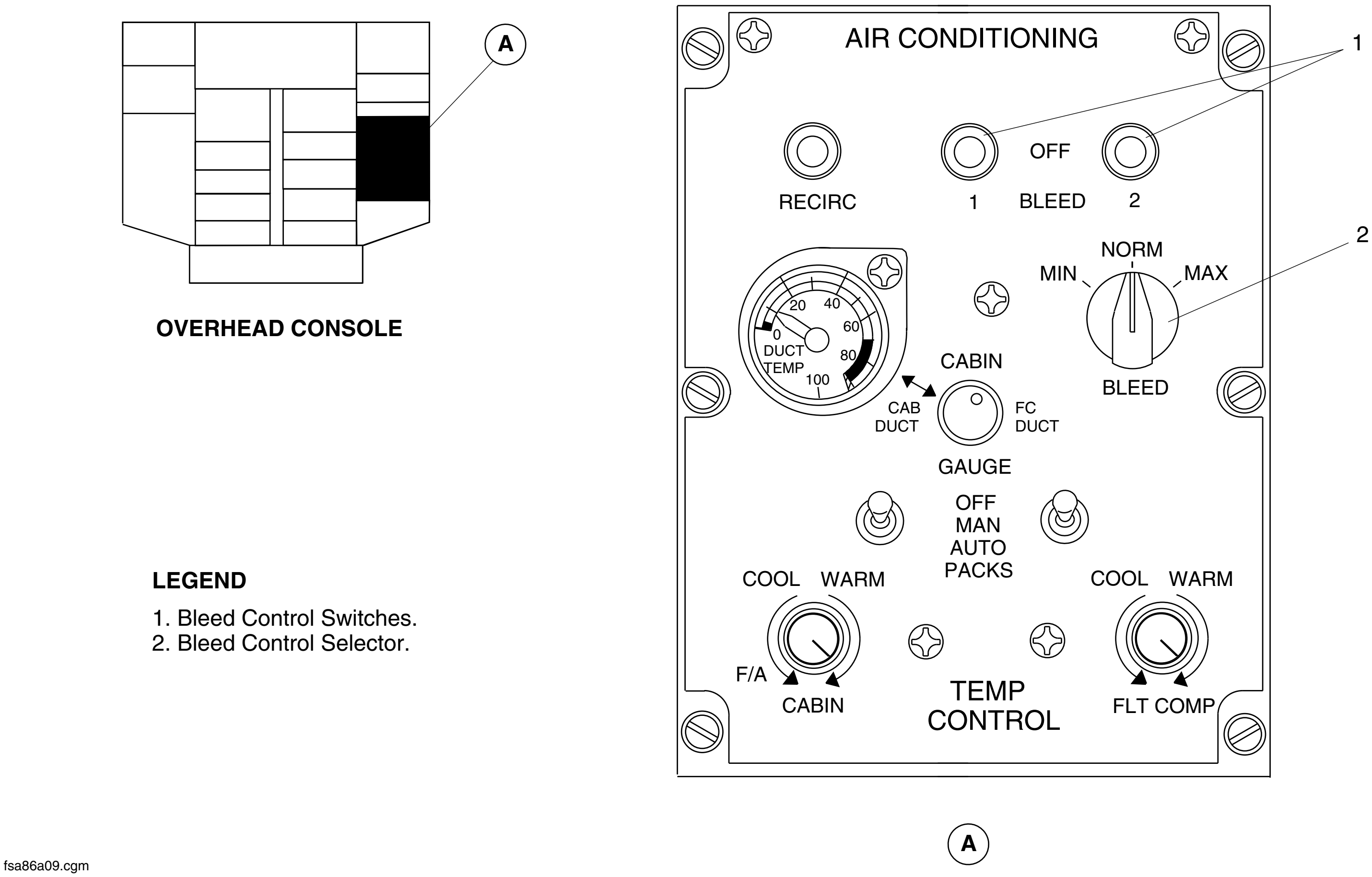
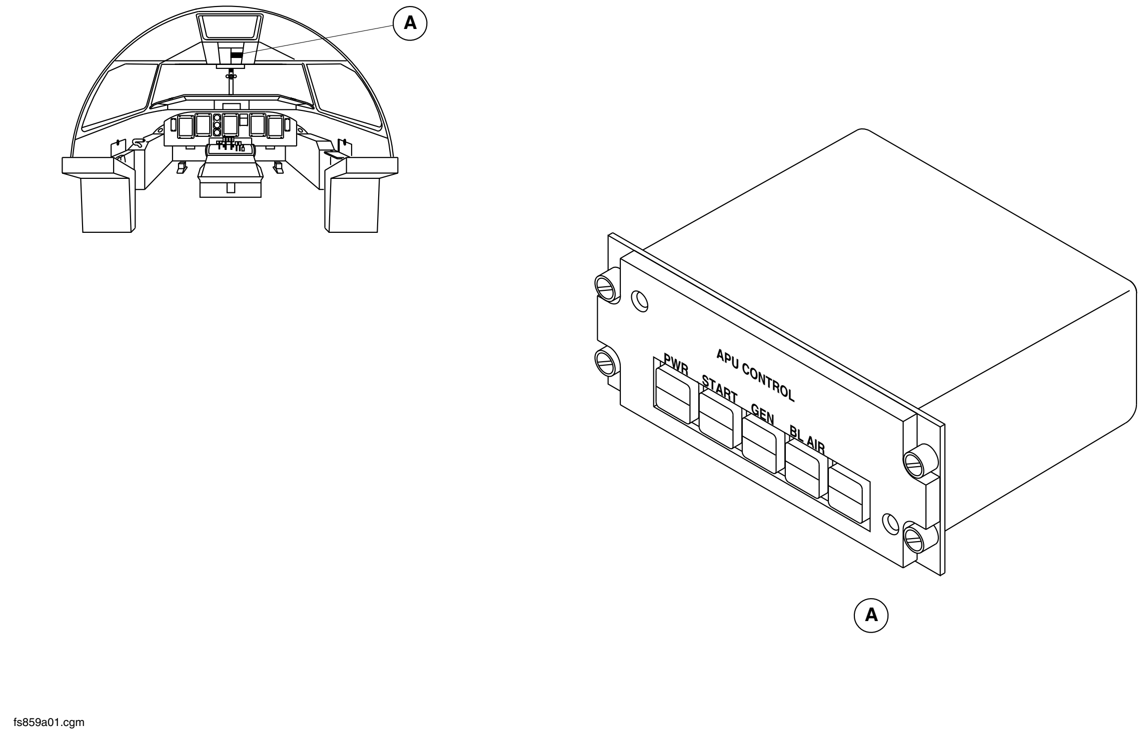
AIR CONDITIONING CONTROL PANEL LOCATOR
Figure 3



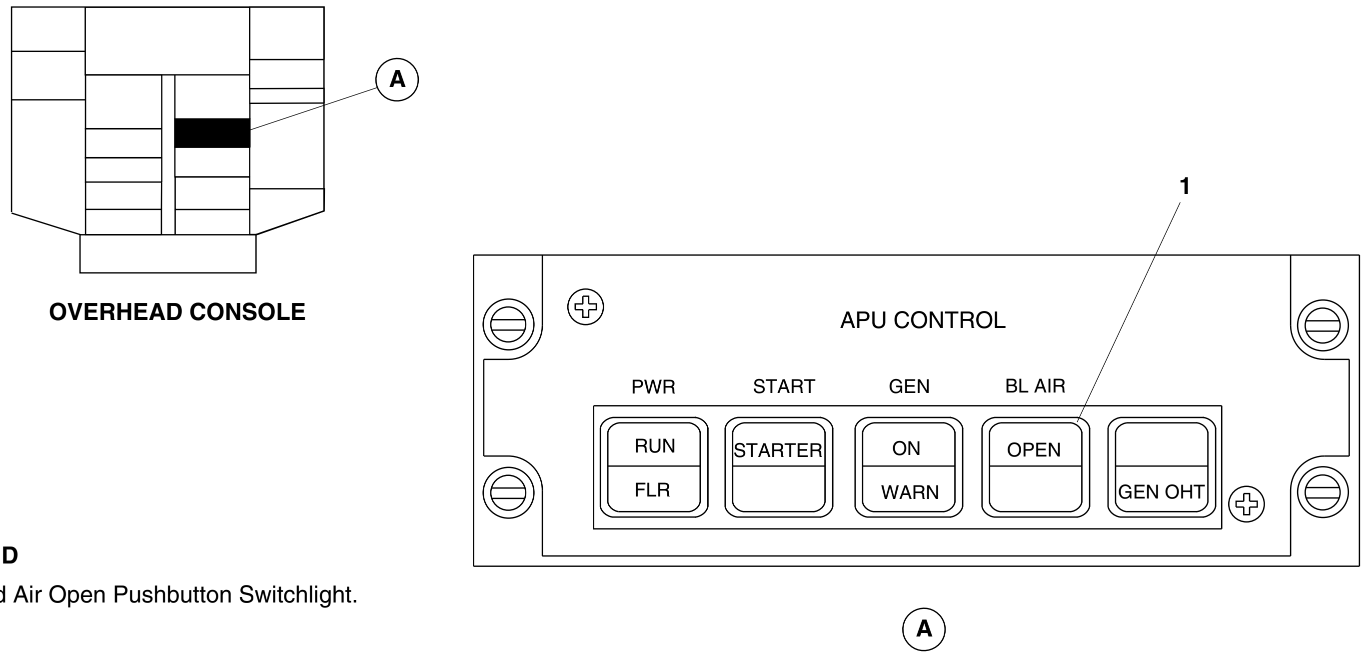
LEGEND

1. Bleed Control Switches.
2. Bleed Control Selector.

BLEED AIR SYSTEM, AIR CONDITIONING CONTROL PANEL DETAIL
Figure 4



APU CONTROL PANEL LOCATOR
Figure 5



LEGEND

1. Bleed Air Open Pushbutton Switchlight.

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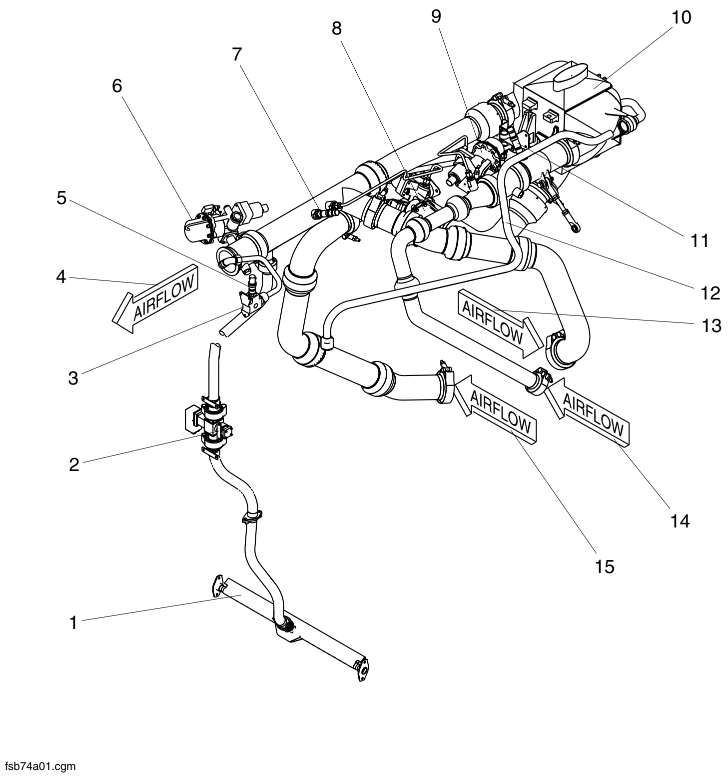
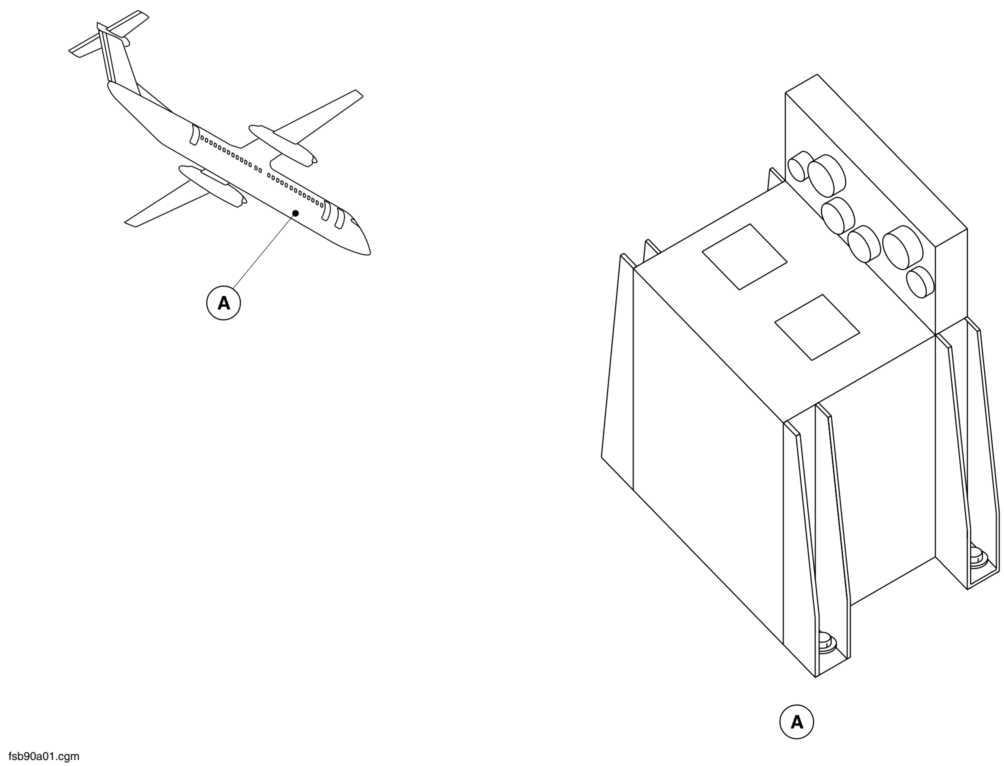
APU CONTROL PANEL DETAIL
Figure 6



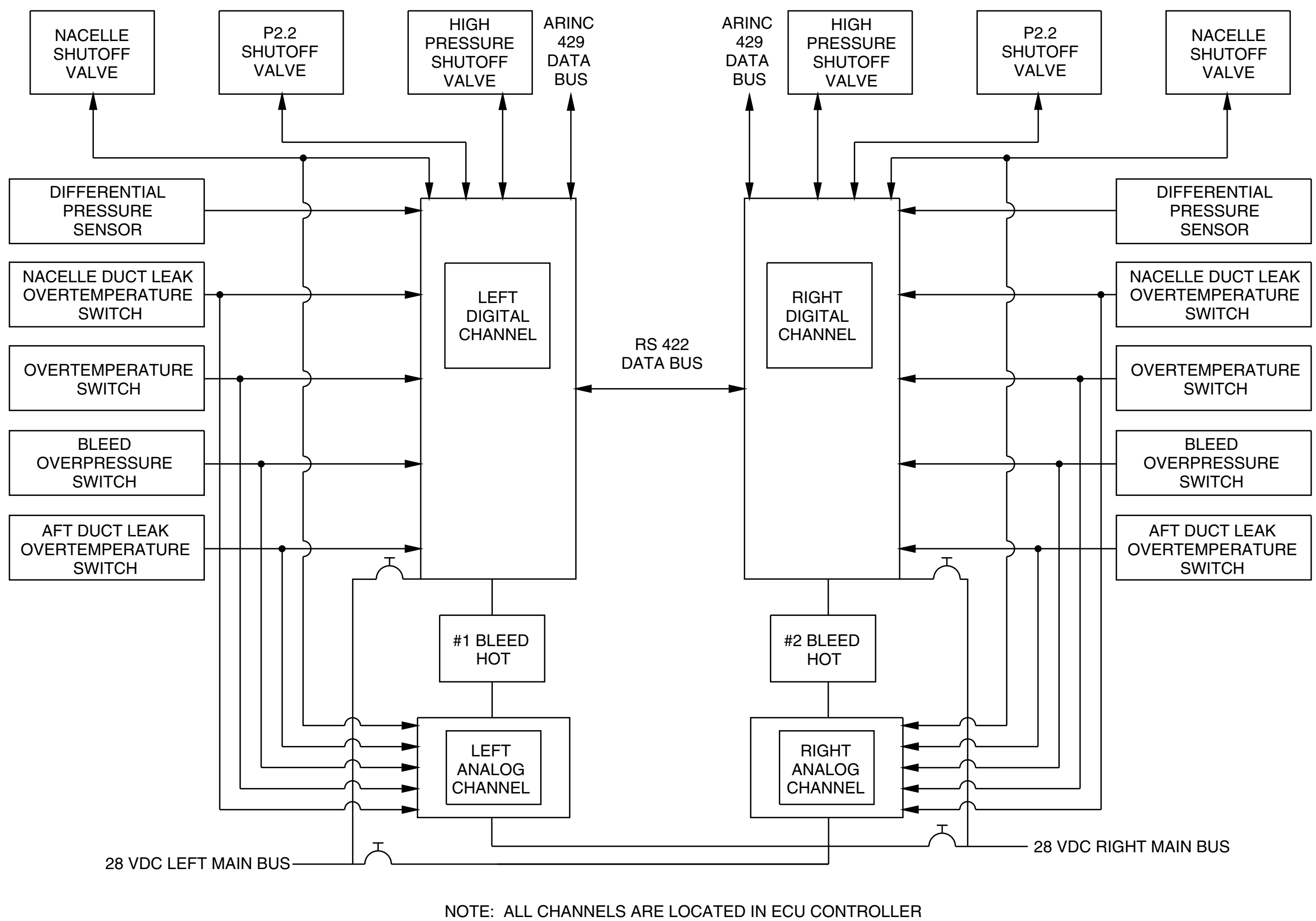
LEGEND

1. Oil Cooler Ejector.
2. Oil Cooler Ejector Shutoff Valve.
3. Leak Detection Housing.
4. Bleed Air Supply.
5. Duct Leak Overtemperature Switch.
6. Nacelle Shutoff Valve.
7. Overtemperature Switch.
8. P2.2 Shutoff Valve.
9. (P3.0) High Pressure Shutoff Valve (HPSOV).
10. Precooler.
11. Precooler Temperature Switch.
12. Deice Supply Line.
13. P 2.7 Air.
14. P 3.0 Air.
15. P 2.2 Air.

BLEED AIR SYSTEM / NACELLE
Figure 7



ECS ELECTRONIC CONTROL UNIT (ECU)
Figure 8



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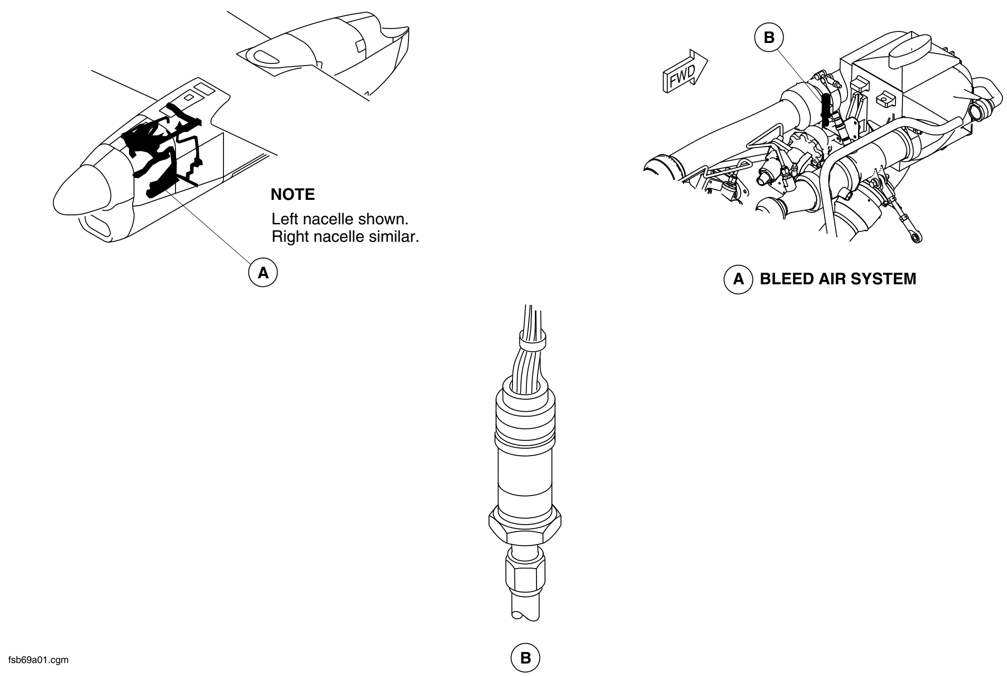
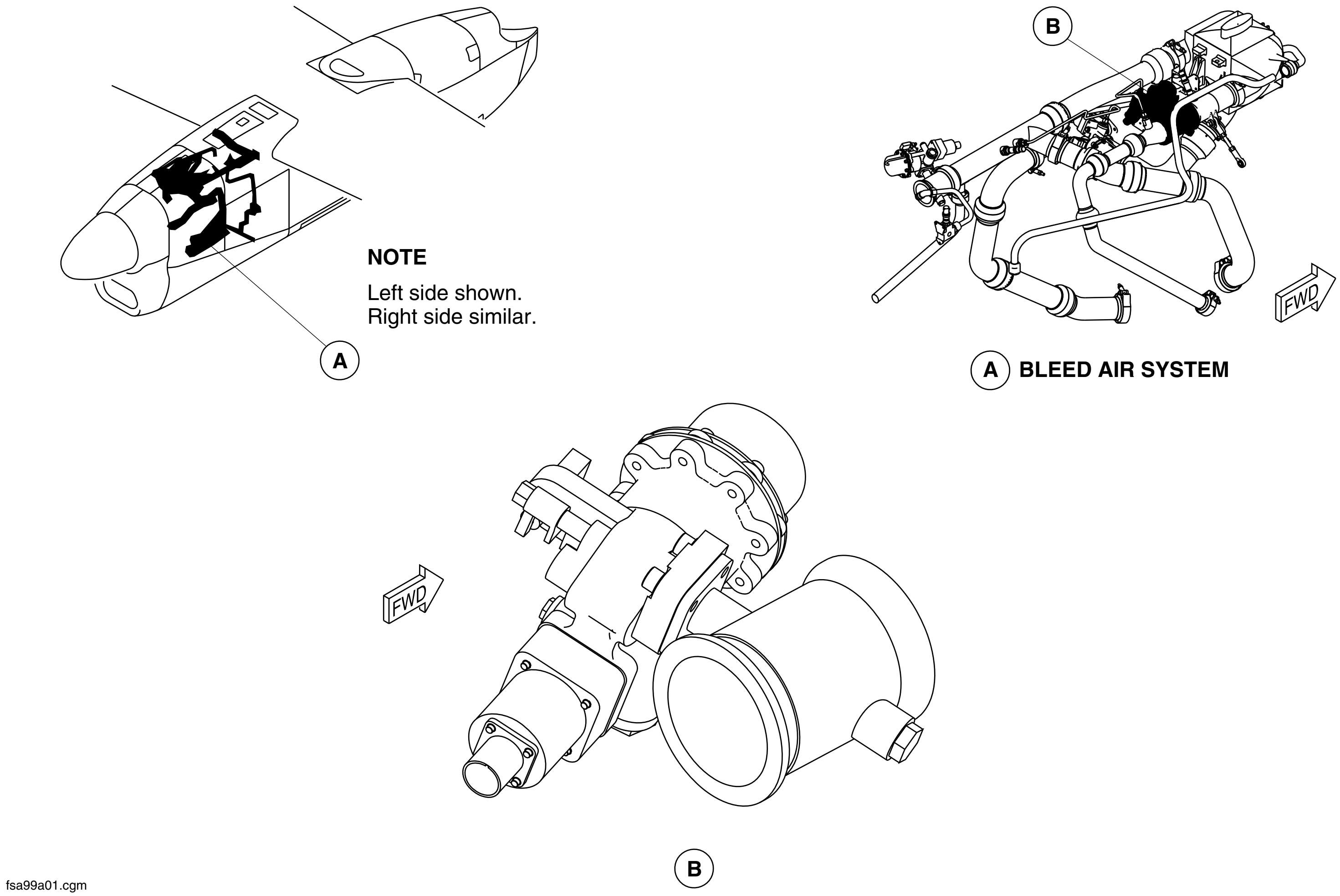
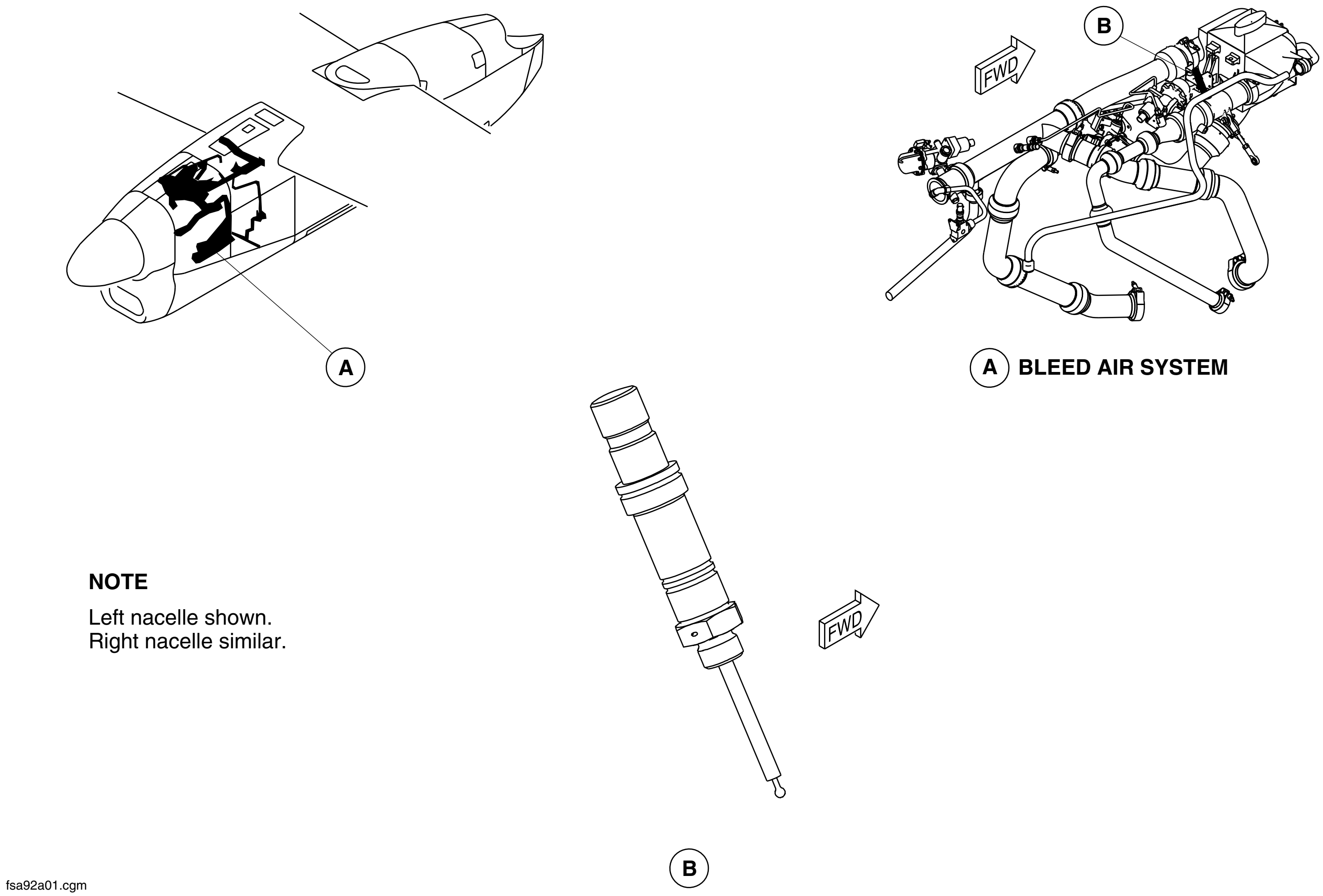
BLEED AIR CONTROL BLOCK DIAGRAM
Figure 9



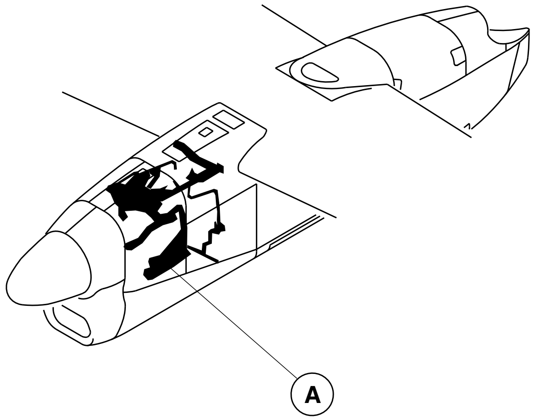
BLEED STAGE PRESSURE SWITCH
Figure 10

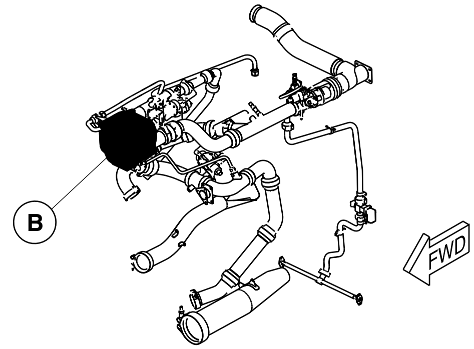


HIGH PRESSURE SHUT−OFF VALVE (HPSOV)
Figure 11



PRECOOLER TEMPERATURE SWITCH
Figure 12

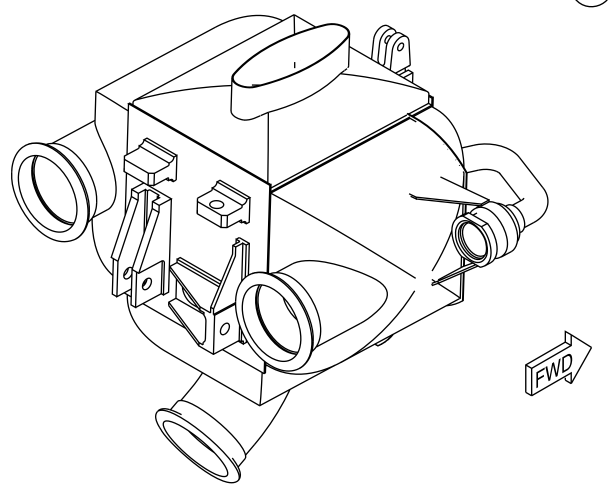




A **BLEED AIR SYSTEM**

NOTE

Left nacelle shown.
Right nacelle similar.



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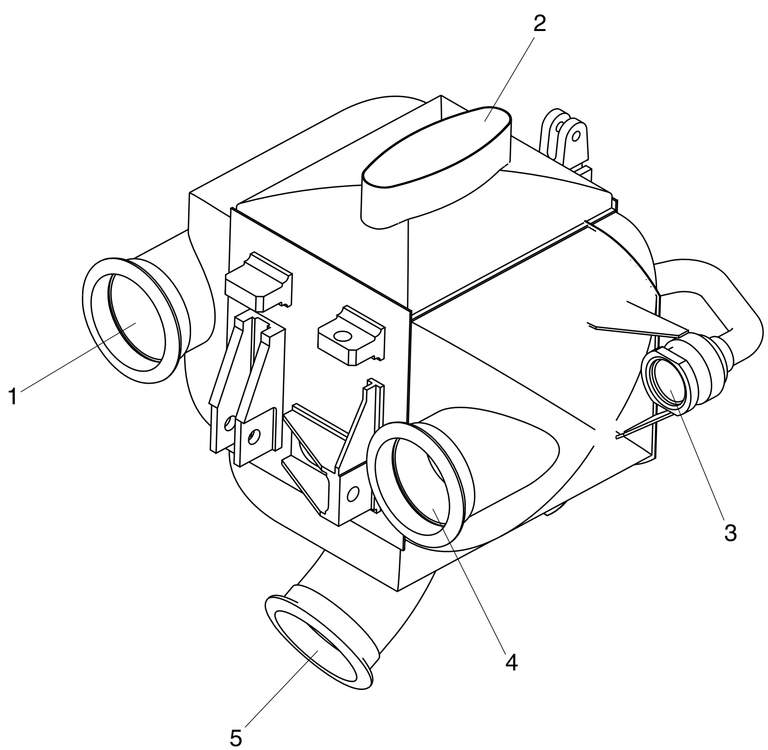
PRECOOLER LOCATOR
Figure 13



LEGEND

1. Bleed Air Supply Outlet.
2. Overboard Outlet.
3. De−ice Supply Outlet.
4. P3.0 High Pressure Inlet.
5. P2.2 Low Pressure Inlet.

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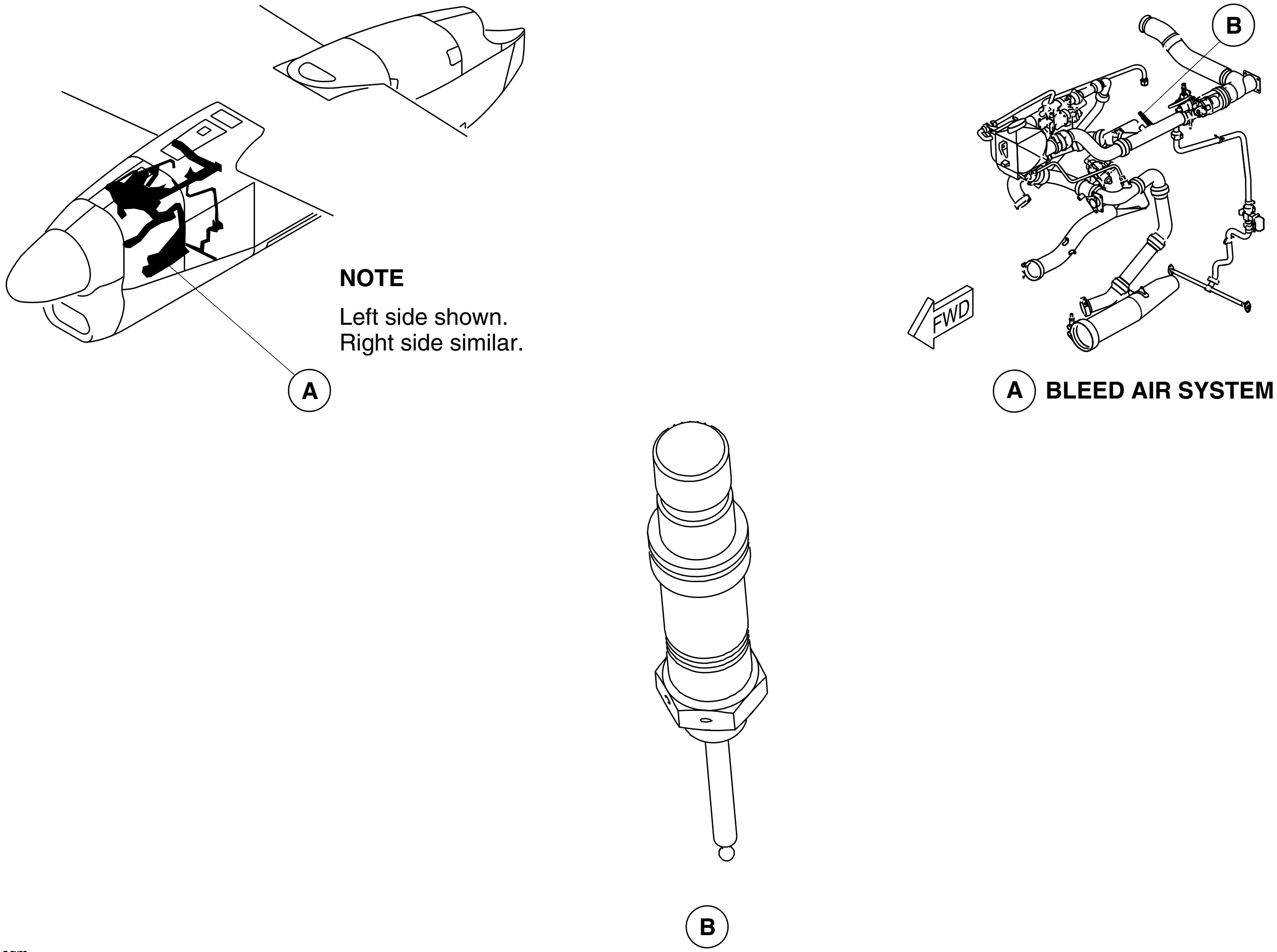
PRECOOLER DETAIL
Figure 14



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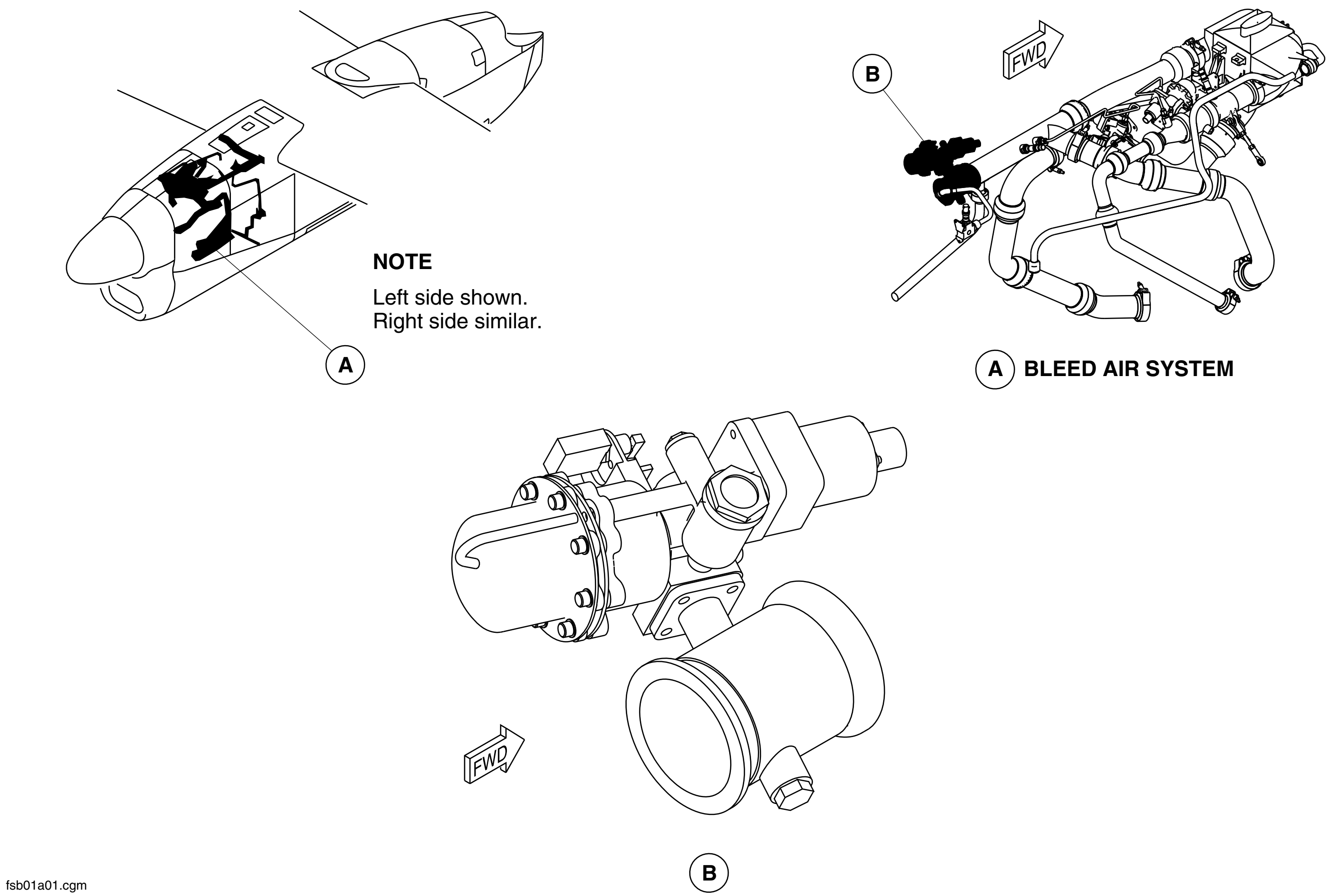
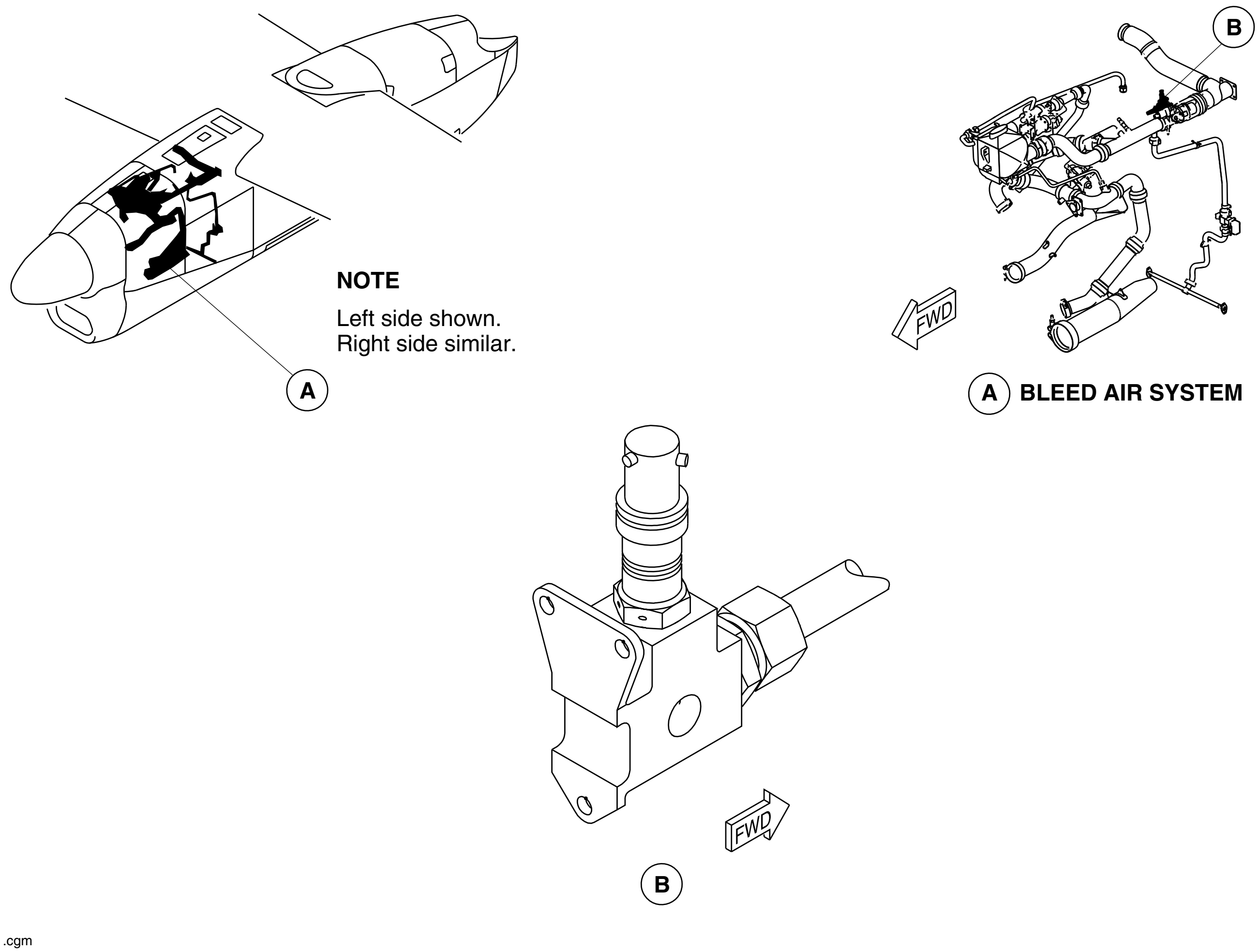
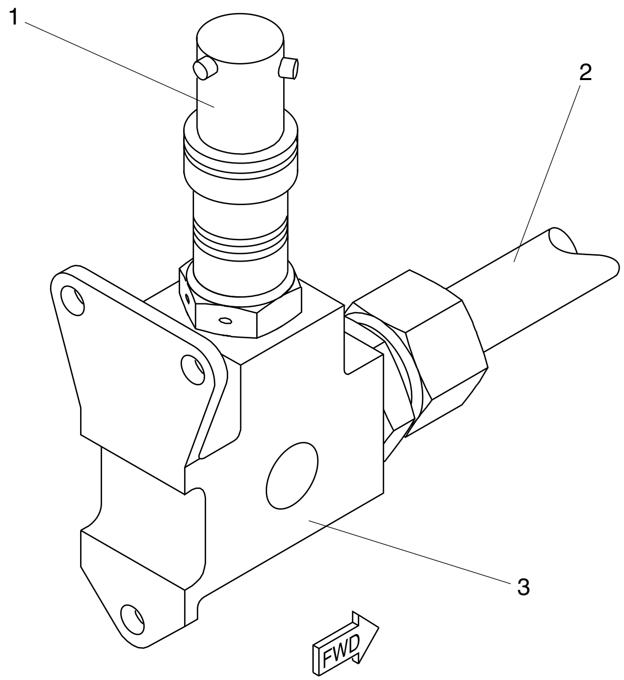
OVERTEMPERATURE SWITCH
Figure 15



NACELLE SHUT−OFF VALVE
Figure 16



NACELLE DUCT LEAK OVERTEMPERATURE SWITCH LOCATOR
Figure 17

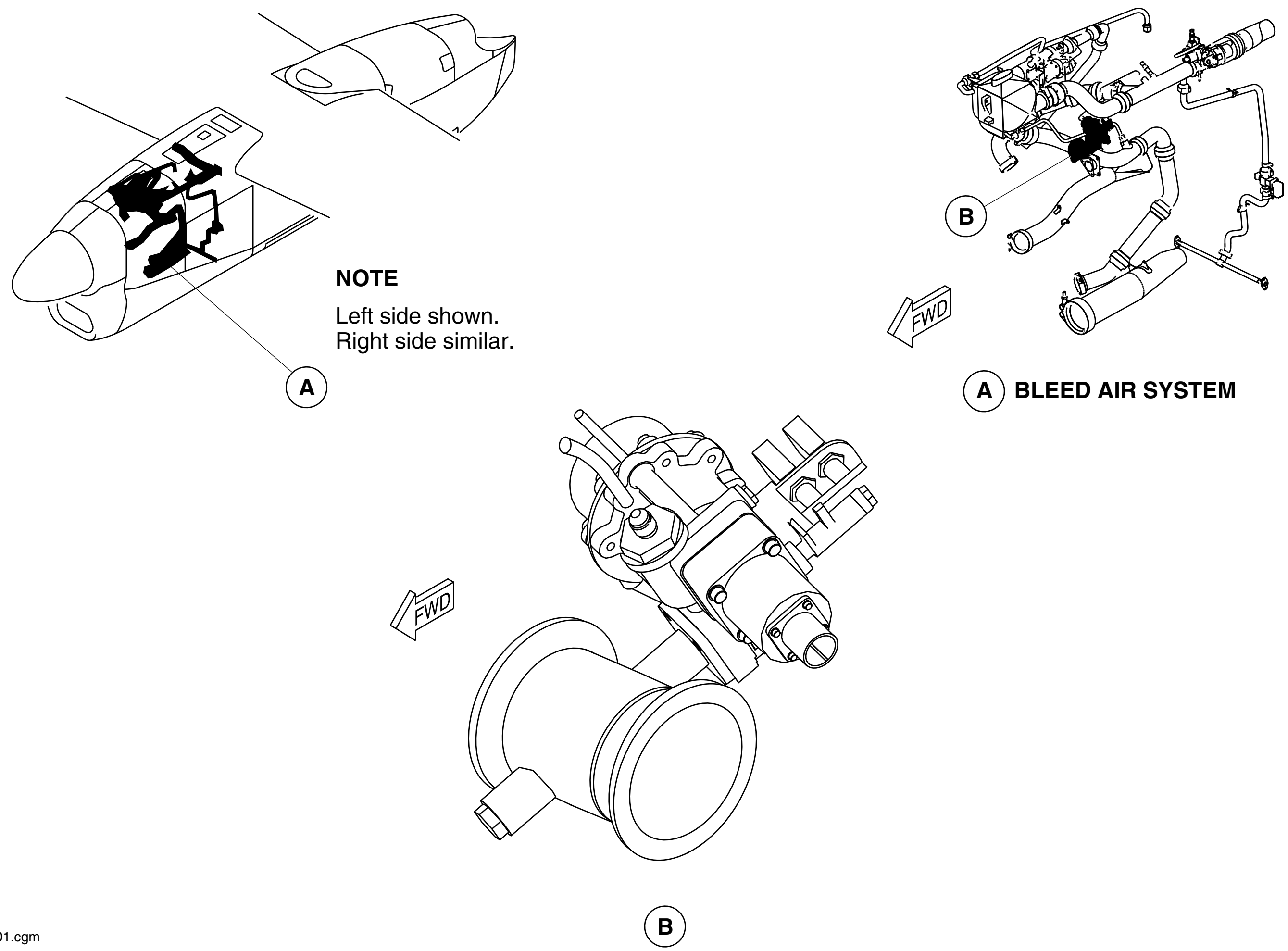


LEGEND

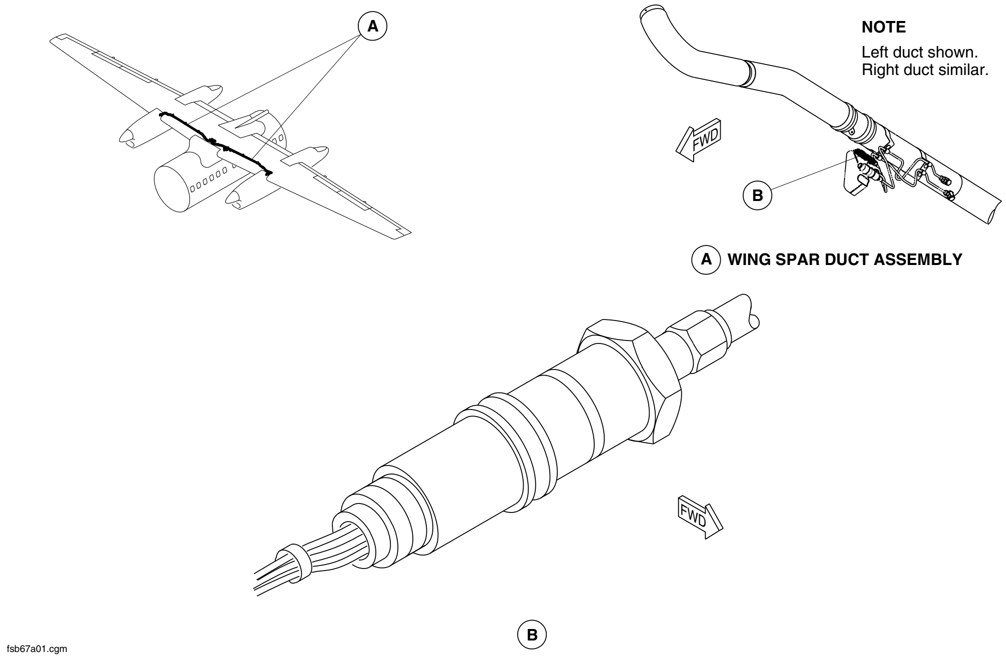
1. Duct Leak Overtemperature Switch.
2. Duct Leak Sensor Line.
3. Leak Detection Housing.

fsa90a01.cgm

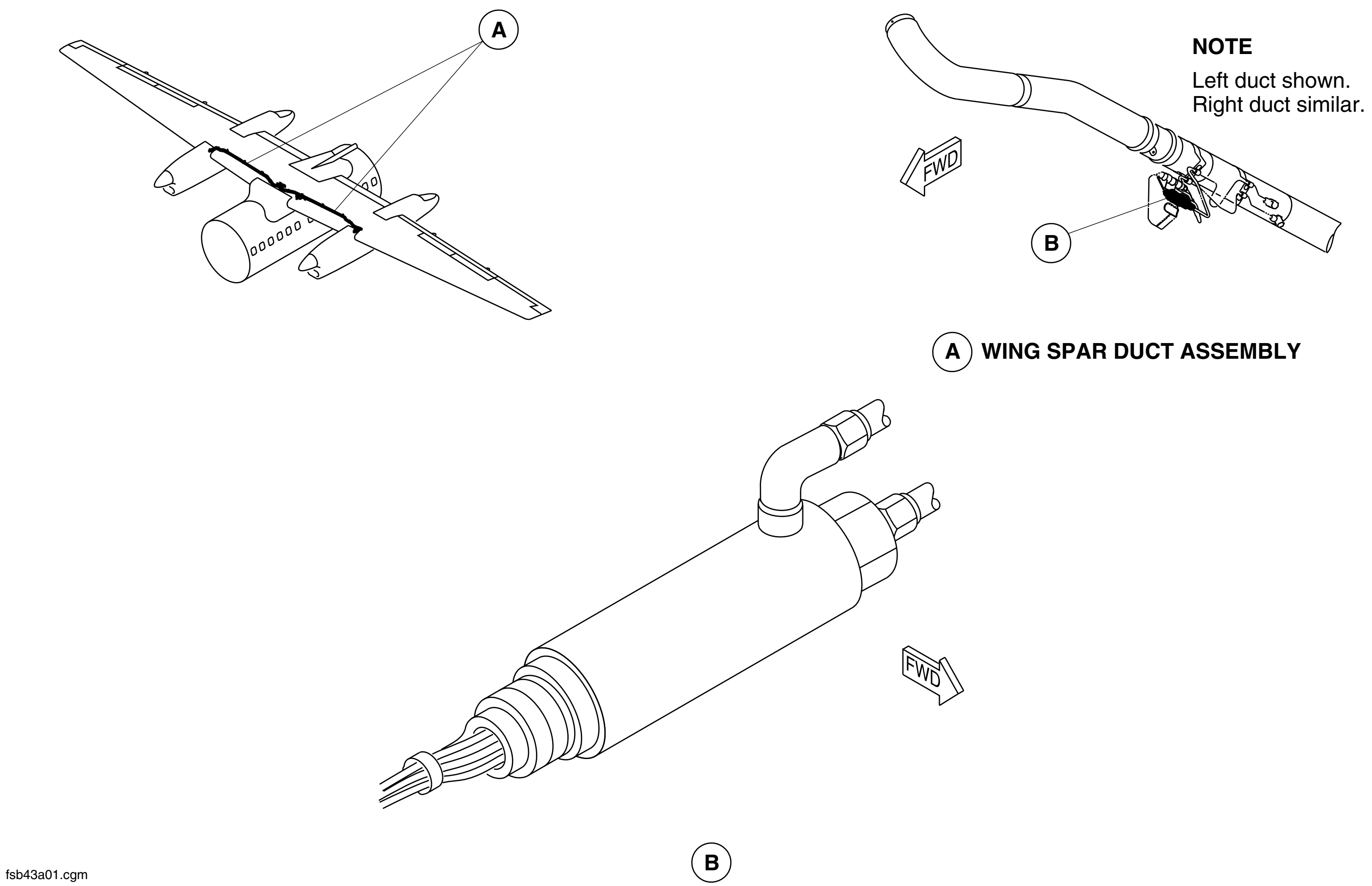
NACELLE DUCT LEAK OVERTEMPERATURE SWITCH DETAIL
Figure 18



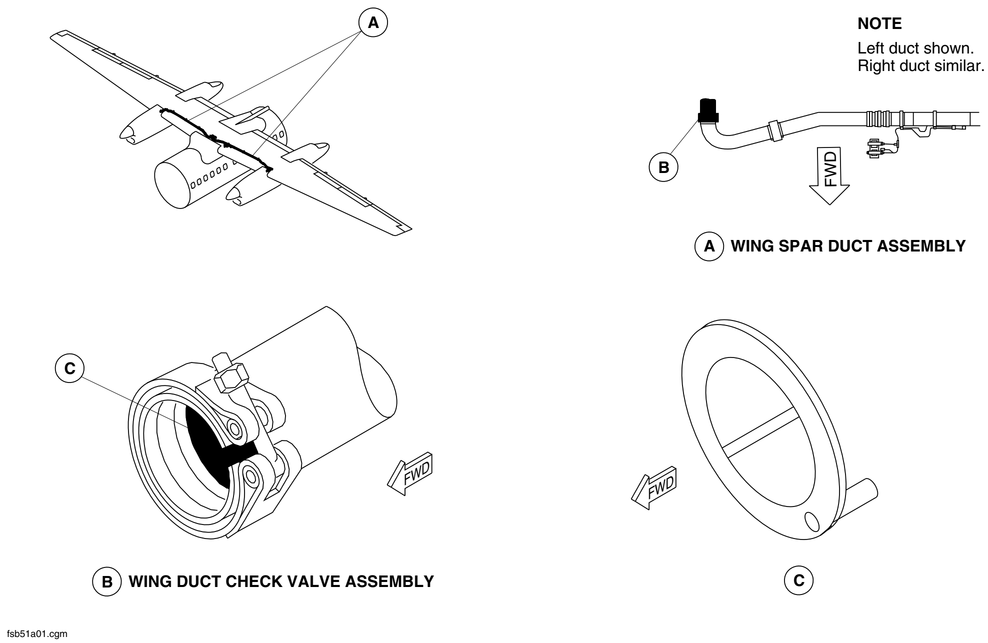
P2.2 SHUT–OFF VALVE
Figure 19



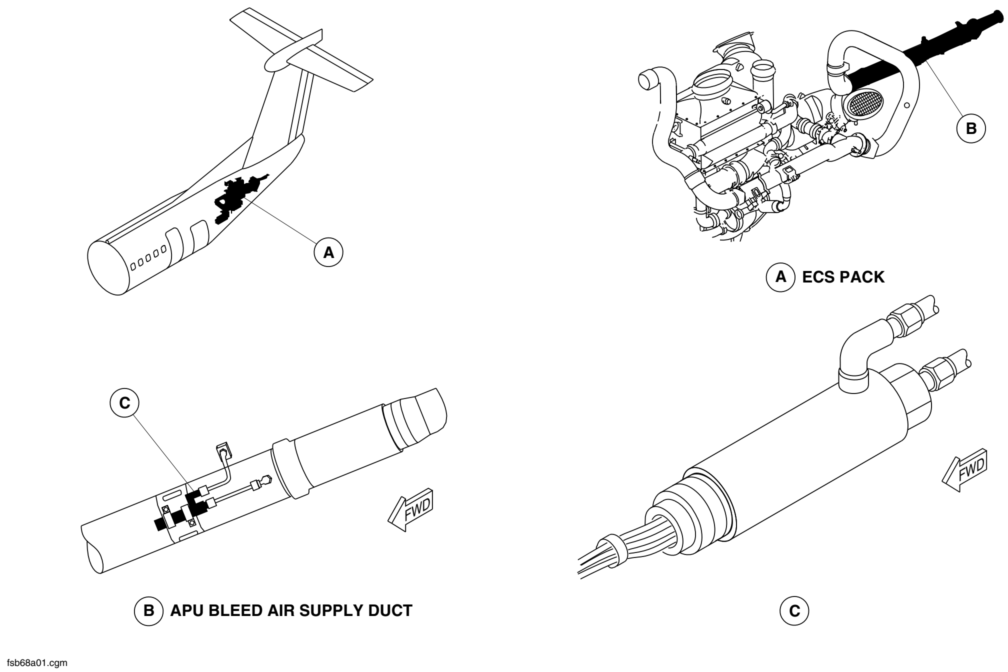
OVERPRESSURE SWITCH
Figure 20



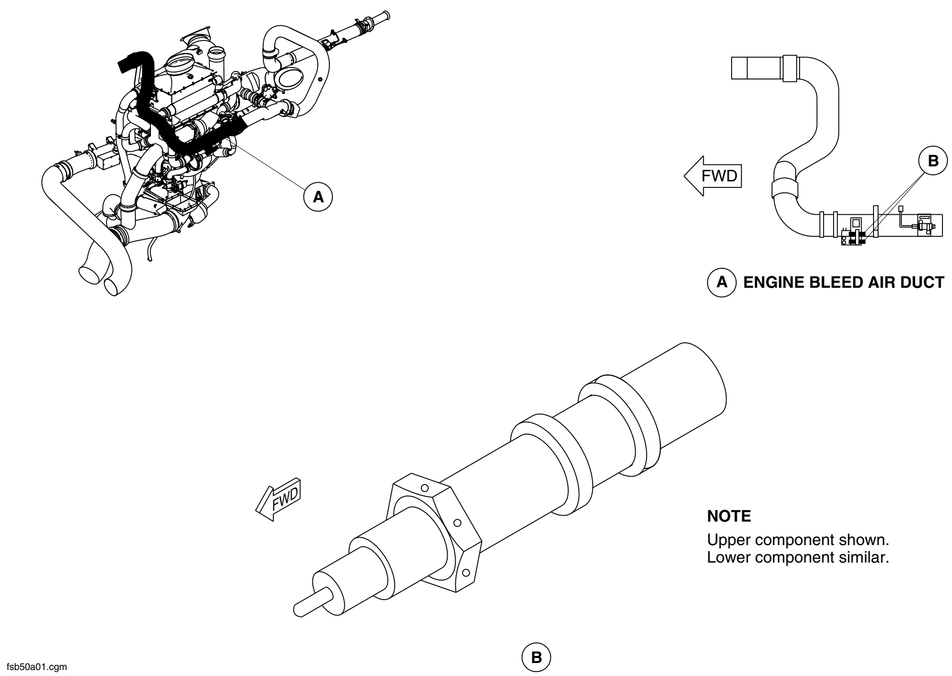
WING PRESSURE DIFFERENTIAL SENSOR
Figure 21



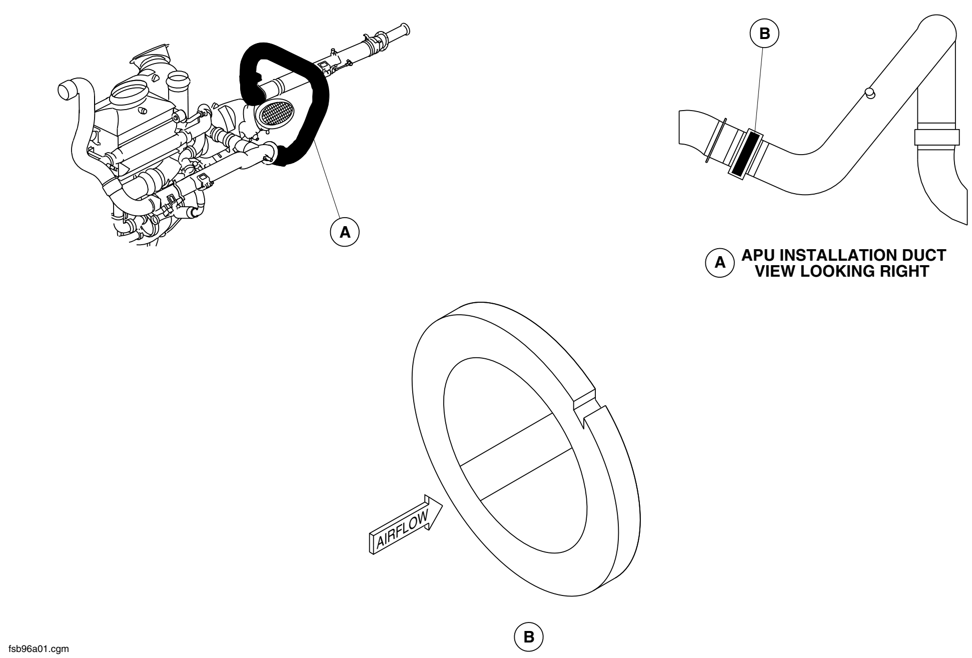
WING DUCT CHECK VALVE
Figure 22



APU PRESSURE DIFFERENTIAL SENSOR
Figure 23



AFT FUSELAGE DUCT LEAK OVERTEMPERATURE SWITCH
Figure 24



APU CHECK VALVE
Figure 25