2A-36-10: General

The G550 pneumatic system uses high temperature pressurized air from the compressor section of the left and right engines, Auxiliary Power Unit (APU) bleed air or external air cart to supply the following aircraft systems that require a modulated pneumatic source:

- Air conditioning and pressurization
- Pressurization safety valve
- Wing anti-ice
- Engine starting
- Pressurized door seals and aircraft water system
- True Air Temperature (TAT) probe airflow (on the ground only)

Airflow is supplied to aircraft systems through a bleed air manifold connected to both engines and the APU. The manifold also has a connection to allow an external cart to provide pressurized air for engine starting or air conditioning on the ground. Air supplied by the engines is temperature and pressure regulated by Bleed Air Controllers (BACs) that monitor the air supply with sensors within the ductwork. The engine BACs draw air from either the fifth (5^{th}) mid-stage or the high temperature eighth (8^{th}) stage of the compressor sections of the engines, depending upon the engine power settings and bleed air demand. Temperature of the air is regulated by selective switching between compressor stages for a source of supply air and by passing the supply air through a precooler heat exchanger that uses ambient air drawn into the engine at the fan intake stage of the compressor. Pressure is controlled through regulator and shutoff valves that vary the size of the valve orifice in the manifold. Air supplied by the APU or a ground cart is not regulated. The temperature and pressure of air from the APU is a function of APU speed and ambient conditions. APU bleed air is used primarily only on the ground for air conditioning and engine starting, but can be used to supply the air conditioning packs up to fifteen hundred feet (1,500 ft) for enhanced takeoff performance or as a source of air to assist inflight engine starts in abnormal operations. A full description of the pneumatic system components is found in:

- 2A-36-20: Pneumatic System Control, Distribution and Indication

2A-36-20: Pneumatic System Control, Distribution and Indication

1. **General Description:**

   Pressurized high temperature air is drawn from the fifth (5^{th}) or eighth (8^{th}) stage of the engine compressor and modulated by Bleed Air Controllers (BACs) prior to being introduced into the bleed air manifold to supply aircraft systems that operate pneumatically. The left and right engine BACs communicate with the respective Modular Avionics Units (MAUs) , left engine with MAU #1, right engine with MAU #2 to obtain bleed air requirements, engine speed data and ambient air conditions. The MAUs also provide pneumatic system oversight, communicating bleed air temperature, pressure and engine valve status furnished by the BACs to the Monitor and Warning System (MWS) and the Central Maintenance Computer (CMC).

   For ground operations and some limited fight conditions, the Auxiliary Power Unit (APU) can furnish unregulated bleed air to the supply manifold for engine starting and air conditioning pack operation. An external air cart can also be connected to the supply manifold for engine starting or air conditioning provided Direct Current

(DC) electrical power is available to energize the system switches and valves.

The pneumatic system encompasses the following installations and components:

- Bleed Air Controllers
- Bleed Air Manifold Supply Manifold and Isolation Valve
- Bleed Air Distribution Ducts
- Auxiliary Power Unit (APU) Bleed Air
- Ground Air Connection
- Bleed Air Control Panel
- Synoptic and System Window Displays

2. Description of Subsystems, Units and Components:

A. Bleed Air Controllers (BACs):

A BAC for each engine is installed in the forward right hand bulkhead of the baggage compartment. The BACs are microprocessors that provide the control signals for the engine bleed valves, pressure regulator / shutoff valves and precoolers. The BACs open and close the engine bleed and regulator / shutoff valves in response to commands from the pushbutton switches on the BLEED AIR Control Panel located on the cockpit overhead and in response to feedback from pressure and temperature sensors in the supply manifold (see Figure 1).

Once the engine bleed valves are open, the BACs modulate the position of the bleed valves, regulator / shutoff valves and precooler operation to meet the supply demands of the wing anti-ice system, air conditioning packs, pressurized door seal, pressure relief valve, water system pressurization, ground TAT probe aspiration and to provide the spin-up impetus for engine starting. See the illustration of the pneumatics system in Figure 2 - for simplification only the right engine is shown, the left engine installation is identical.

Under normal operating conditions, the major demand on the pneumatic system is to supply the air conditioning packs for cabin pressurization and temperature control. The BACs open the fifth (5^{th}) stage bleed valves of the engines to supply forty plus or minus three point five (40±3.5) psi of pressurized air that is temperature modulated to four hundred plus of minus ten degrees Fahrenheit (400°±10 F / 204°C). Temperature modulation is accomplished by routing the engine bleed air that is normally at a temperature of six hundred twenty degrees Fahrenheit (620°F / 326°C) through a precooler. The precooler is a heat exchanger that contains cold ambient air extracted from the fan inlet stage of the engine to circulate within the precooler and is then exhausted overboard through louvers in the engine pylon. The BACs vary bleed air valve openings and the amount of fan stage air to the precooler to obtain the required temperatures measured by sensors at the precooler inlet and outlet. Pressure modulation is accomplished by the BACs using readings from the pressure sensors in the supply manifold to control the regulator / shutoff valve located upstream of the precooler in the supply manifold.

If the engines are operating at low power settings as during descents or when the aircraft is at low speeds when in a holding pattern, the pressure and temperature of the fifth (5^{th}) stage bleed air may not be sufficient to satisfy demand. Under these conditions the BACs will supplement fifth (5^{th})

stage bleed air if the drops below fourteen plus or minus two (14±2) psi with air extracted from the eighth (8^{th}) stage of the engine compressor that is hotter and at a higher pressure. The two bleed valves are connected to a common supply duct that includes a check valve to prevent the more highly pressurized eighth (8^{th}) stage air from entering into the fifth (5^{th}) stage of the engine. The BACs control the aperture of the two bleed valves and the regulator / shutoff valves to satisfy pressure and temperature requirements.

Although both engines and are normally used to provide bleed air to both air conditioning packs for cabin pressurization and temperature control, a single engine can provide sufficient airflow to operate both air conditioning packs provided the engine power setting is high enough that a bleed air pressure of at least twenty-five (25) psi is maintained. However, if a malfunction results in only one air conditioning pack available for pressurization and temperature control, the BAC for the engine associated with the operating pack changes the setting the regulating / shutoff valve to provide bleed air of at least thirty-five (35) psi by opening both bleed valves if needed.

Another adjustment is made by the BACs if wing anti-ice is required with only one engine operating or if a failure results in only one wing anti-ice valve functioning. In either condition an increased amount of high temperature air is required in order for one engine or wing anti-ice valve to supply sufficient heat to both wings to prevent the formation of ice. In this instance the BAC associated with the operating engine or wing anti-ice valve increases the temperature threshold of the air exiting the precooler to five hundred plus or minus ten degrees Fahrenheit (500±10°F / 260°C).

The BACs also act as the control authority for operation of the wing anti-ice valves when wing anti-ice is selected on manually or automatically by signals from the ice detectors. The BACs monitor the temperature within the wing anti-ice ducts along the leading edge of the wing and modulate the wing anti-ice valves to maintain the leading edge at a temperature of one hundred thirty degrees Fahrenheit (130°F / 54.4°C). For more information regarding the functions of the BACs and wing anti-ice, see Section 2A-30-40: Wing Anti-Ice System.

B. Bleed Air Supply Manifold and Isolation Valve:

Bleed air from both engines is fed into a common supply manifold located in the aft equipment bay. The manifold is divided into two halves by the isolation valve. In normal inflight operation each engine supplies bleed air to the dedicated air conditioning pack and wing anti-ice valve, so the isolation valve is normally closed. The isolation valve is opened to allow a single bleed air source to supply the manifold during several other normal and abnormal conditions. The isolation valve is controlled by a electric solenoid, but is powered by pneumatic pressure - i.e. there must be pressure available from a bleed air source to move the valve to the commanded position.

Both the APU and external air supply bleed air ducts enter the supply manifold on the right side, so the isolation valve must be opened to allow APU or external air to be used for starting both engines or powering both air conditioning packs. If an engine failure or malfunction in one of the BACs or associated valves and controls leaves only one engine bleed air

source available, the isolation valve must be opened to allow the operation of both air conditioning packs or if the use of both wing anti-ice valves is desired. The isolation valve must also be opened if bleed air is to be used to assist in the air starting of an engine.

Control of the isolation valve position is also interfaced with the operation of the MASTER CRANK and MASTER START switches on the ENGINE START panel. Depressing either of these switches during the normal or alternate start sequence automatically opens the isolation valve. For more information regarding the operation of the isolation valve during engine starting, see Section 2A-80-00: Engine Starting.

C. Bleed Air Distribution Ducts:

After engine bleed air has been modulated by the BACs and introduced into the common supply manifold, the air is distributed to meet the requirements of aircraft systems though a system of ducts. Each air conditioning pack has an independent duct plumbed into the supply manifold, with the left and right packs connected on the respective sides of the isolation valve. For more information regarding bleed air supply to the air conditioning packs, see Section 2A-21-20: Airflow and Temperature Control.

Supply ducts for the left and right wing anti-ice are also connected on the respective sides of the isolation valve, but the wing anti-ice supply ducts incorporate a crossover manifold downstream of the supply manifold that enables a single anti-ice duct to supply both wings. For more information regarding wing anti-ice bleed air ducting see Section 2A-30-40: Wing Anti-Ice System.

Pressurized air supplied to the baggage door seal, TAT probes, water system and the pressurization relief valve is drawn from a shared duct that is configured as a shunt around the isolation valve in order to permit any bleed air source to supply these systems. The baggage door seal supply line incorporates a pressure regulator to reduce the bleed air supply to eighteen (18) psi to avoid damaging the inflatable seal.

D. Auxiliary Power Unit (APU) Bleed Air:

The APU is capable of supplying unregulated bleed air for engine starting on the ground and to assist windmill engine starting in the air and supplies bleed air for operation of the air conditioning packs on the ground and in the air up to an altitude of fifteen hundred feet Above Ground Level (1,500 ft AGL) as sensed by the radio altimeter. The APU air supply is introduced into the common supply manifold on the right side of the isolation valve through a duct shared with the connection for a ground air source. The duct contains a check valve to prevent engine bleed air from entering into the APU supply duct to preclude the interruption of air flow within the APU while it is running. APU air operation is monitored by MAU #1.

Control of the APU air is through the pushbutton switch labelled APU on the BLEED AIR Control Panel on the cockpit overhead. Depressing the switch while the APU is operating will open the Load Control Valve (LCV) of the APU, allowing bleed air drawn from the compressor stage of the APU to enter the supply manifold. The ON legend within the switch will illuminate when the LCV is open. The manifold isolation valve will also open, making APU air available for air conditioning pack operation and engine starting. Since there is no BAC for APU air and APU operation is governed by an

Electronic Control Unit (ECU) that controls APU rpm to one hundred percent (100%) within temperature limits, the amount of bleed air produced by the compressor section will vary with density altitude. Typically, on the ground at an airport near sea level elevation, the bleed air output will be approximately forty-two to forty-three (42-43) psi.

Although APU air is normally only used to start engines or supply air conditioning packs on the ground, an interlock is incorporated into the circuitry of the engine and APU air switches that will allow the APU to continue to supply bleed air for air conditioning and pressurization up fifteen hundred feet (1,500 ft AGL). Altitude sensing is derived from the same data provided by the radio altimeter to the ice detector circuits. Allowing the APU rather than the engines to supply air conditioning pack requirements during takeoff enhances engine thrust and allows better short field and/or high altitude performance. To employ this bleed configuration, both engine bleeds are selected to the on (switch depressed) position, the air conditioning packs are selected on and the APU bleed is selected to the on (switch depressed) position. The engine bleed switch legends will indicate OFF and the APU bleed switch legend will illuminate ON until the aircraft reaches fifteen hundred feet (1,500 ft AGL) at which time the OFF legends in the engine bleed switches will extinguish and the APU bleed switch ON legend will extinguish and the isolation valve will close, with no interruption to the bleed air flow to the air conditioning packs. The APU is then normally selected off in not required for electrical power.

If the APU is required as an alternate electrical power source during flight (the APU cannot be used to supply air conditioning packs except during enhanced takeoffs), starting the APU above thirty five thousand feet (35,000 ft) is assisted by a Bleed Air Augmentation Valve (BAAV) that opens to port pressurized air from the bleed air supply manifold into the APU air scoop intake duct, thereby increasing airflow to the APU to promote starting.

Operating engine bleed air and/or APU air may also be used to assist in increasing the rotational speed of an engine during an airstart, provided the aircraft altitude is below thirty thousand feet (30,000 ft). (If the Full Authority Digital Engine Control (FADEC) of the engine being started determines that an increase in engine rpm is required, a CAS message reading “Assisted Airstart” will be displayed.) If APU air is to be used to contribute bleed air pressure during this procedure, it is best accomplished at lower altitudes since it requires that the air conditioning packs be turned off.

E. Ground Air Connection:

An external ground air cart may by used for engine starting or to supply the air conditioning packs if the APU is inoperative. A panel on the underside of the aircraft below the aft equipment bay contains the plug in connector that accommodates the hose from the ground cart. The connector is plumbed to a duct shared by the APU air input to the supply manifold on the right side of the isolation valve, so the isolation valve must be opened to route ground air to the left engine or air conditioning pack. Electrical power is required when using the ground air cart in order to actuate the isolation valve and the air conditioning pack control valves.

F. Bleed Air Control Panel:

The pushbutton switches for controlling the bleed air system are located on the BLEED AIR Control Panel on the top right hand corner of the overhead panel. The switches are located within a graphic on the panel depicting the ducting shared by the bleed air system. The graphic extends down to the TEMP CONTROL panel immediately below to illustrate the supply to the air conditioning packs. The engine bleed air switches are normally selected to the depressed or ON position. The OFF legend within a switch will illuminate if the switch is selected off or if there is a malfunction. The APU bleed switch is normally off, but when selected to the depressed or ON position, the ON legend within the switch will illuminate. The isolation valve control switch, labelled ISOLATION is above an indicator that corresponds to the valve position. When the isolation valve is open, the indicator bar lines up with the line graphic depiction of the supply manifold indicating that the valve is open, connecting both sides of the manifold. When the valve is closed the bar indicator below the switch is perpendicular to the graphic of manifold. A line of the graphic also indicates the connection point of APU air to the right of the isolation valve.

G. Synoptic and System Window Displays:

Display information is generated from data furnished by the BACs and the APU LCV to the MAUs. The MAUs furnish information to the Advanced Graphics Modules (AGMs) that formulate the Synoptic and Systems Windows for the Display Units (DUs). The MAUs also communicate with the MWS that generates Crew Alerting System (CAS) messages.

The primary window for monitoring the bleed air system is the ECS / Pressure synoptic 2/3 window. The window contains the following graphics indicating the state of system operation:

- Simplified depictions of major system ducts shown as green lines
- Circular icons surrounding a bar line representing engine pressure regulator / shutoff valves, the APU LCV and the isolation valve. The valves are depicted in white if closed, green if open and system operation is normal or amber if a malfunction exists.
- Engine bleed precoolers are represented by rectangular icons parallel to and inboard of the engines. The rectangles are shown in dim white if the engines or bleed air switches are off, green if operating and precooler outlet temperature is between one hundred and five hundred fifty degrees Fahrenheit (100°F≤ T ≤550°F), or depicted in amber if outlet temperature is less than one hundred degrees Fahrenheit (T ≤100°F) for more than thirty (30) seconds, precooler outlet temperature reaches five hundred fifty degrees Fahrenheit (T ≥550°F), precooler inlet temperature reaches seven hundred sixty-five degrees Fahrenheit (T ≥765°F), or if manifold pressure drops below five (5) psi for more than ten (10) seconds or reaches seventy-five psi (psi ≥75).
- Digital indications of the precooler inlet and outlet temperatures are shown with the inlet temperature below the precooler rectangle and outlet temperatures inboard of the rectangle. The resolution of the display is to one degree Fahrenheit (1°F). The color of the digital displays will change to indicate operational parameters: white if the precooler inlet temperature is between one hundred fifty and seven

hundred sixty-five degrees Fahrenheit (150°F≤ T ≤765°F) or precooler outlet temperature is between one hundred and five hundred fifty degrees Fahrenheit (100°F≤ T ≤765°F), or the digits will be shown in amber if the readings are below or above these ranges.

- Digital indications of supply manifold pressures with a one (1) psi resolution shown immediately below the precooler outlet temperature displays. The color of the digits reflects operational parameters: white if pressures are between five and seventy-five psi (5≤ psi ≥75) or amber if pressure is lower than five psi (psi ≤5) for more than ten seconds or exceeds seventy-five psi (psi ≥75).

Digital indications of supply manifold pressure are also shown on the following display options:

- Summary synoptic 2/3 window
- Engine start system 1/6 window
- APU / Bleed system 1/6 window

For a complete description of the bleed air system indications shown on the synoptic and system windows, see Section 2B-07-00 of this manual.

In addition to the color changes in bleed system indications on the synoptic and system pages, the MWS will generate CAS messages when the following thresholds are exceeded:

- Supply manifold pressure is less than five psi (psi <5) for more than ten (10) seconds
- Supply manifold pressure exceeds seventy-five psi (psi >75)
- Precooler inlet temperature exceeds seven hundred sixty-five degrees Fahrenheit plus or minus ten degrees (T >765°F±10° / 407°C±5.6)
- Precooler outlet temperature exceeds five hundred fifty degrees Fahrenheit plus or minus ten degrees (T >550°F±10° / 288°C±5.6)

3. Controls and Indications:

(See Figure 1.)

A. Circuit Breakers (CBs):

The following CBs protect the pneumatic system:

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L BLEED AIR CONT	LEER	E-10	L ESS DC Bus
R BLEED AIR CONT	REER	E-9	R ESS DC Bus
BLD AIR ISO VLV SOL	LEER	E-7	L ESS DC Bus
APU CONT #1	LEER	C-13	L ESS DC Bus
APU CONT #2	REER	C-11	R BATT Bus

B. Crew Alerting System (CAS) Messages:

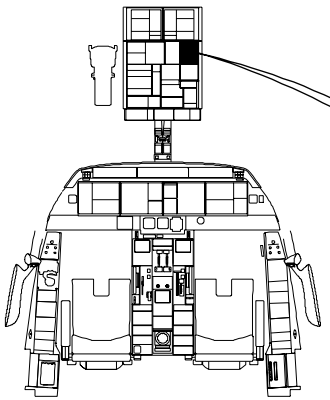
The following CAS messages are associated with the pneumatic system:

Area Monitored:	CAS Message:	Message Color:
Bleed Air Controller interface with MAU	BAS Fail, L-R	Amber
Bleed Air Switch Relay	BAS Off, L-R	Amber
Precooler Inlet / Outlet Temperature	Bleed Air Hot, L-R	Amber
Isolation valve, L-R Engine Bleed Valves, APU LCV, MASTER CRANK and MASTER START switches	Bleed Configuration	Amber
Bleed Air Manifold Pressure Sensor	Bleed Pressure High, L-R	Amber
Bleed Air Manifold Pressure Sensor	Bleed Pressure Low, L-R	Amber
Engine FADEC	Assisted Airstart	Blue
Bleed Air Controller not receiving inputs from MAU	BAS Default Mode, L-R	Blue
Bleed Air Controller or MAU interface	BAS Maintenance Reqd, L-R	Blue
APU Bleed ON with APU not up to operating speed or Engine Bleed not selected ON	Bleed Configuration	Blue
Supply Manifold Isolation Valve Switch	Isolation Valve Open	Blue

4. Limitations:

A. Flight Manual Limitations:

The APU can be used to supply pressurization airflow in conjunction with engine bleeds OFF takeoffs up to 1500 ft AGL. The APU may be used for starter-assisted main engine starts below 30,000 ft if required.



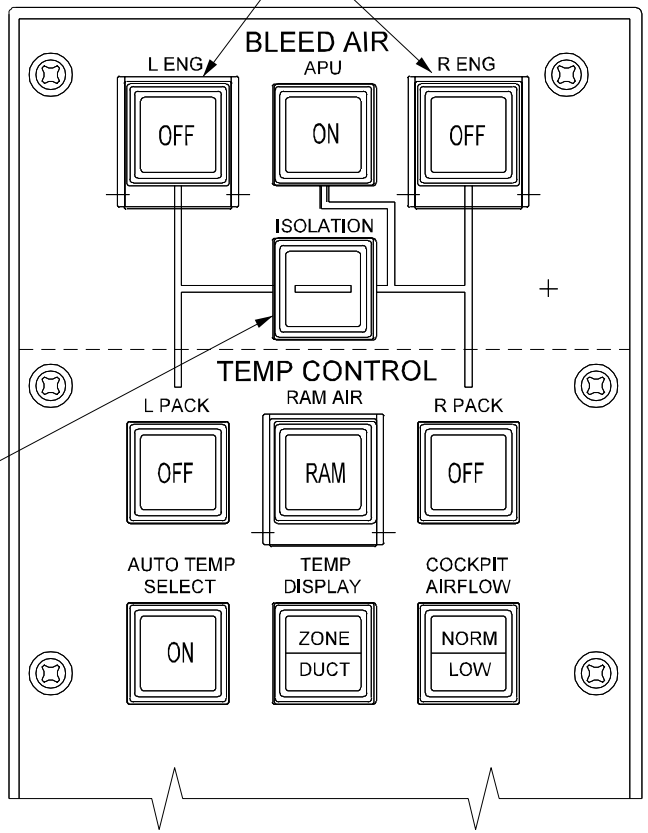
L ENG / R ENG BLEED AIR

When selected to ON:

- Amber OFF legend is extinguished.
- Essential (ESS) 28V DC Bus power is provided to the associated system (L ESS DC for L ENG side; R ESS DC for R ENG side).
- Associated Bleed Air Controller performs BIT check and establishes operational parameters.
- Associated manifold pressure regulator valve is opened, allowing bleed air to using systems.
- APU bleed air is inhibited when sufficient engine bleed air is available (APU Bleed Air Interlock).

When selected to OFF:

- Amber OFF legend illuminates.
- Associated manifold pressure regulator valve closes.
- Power is removed from associated system.
- APU air is available when selected.



ISOLATION

When manually or automatically selected open (on ground):

- White bar in switch capsule illuminates.
- Left and right bleed air manifolds are combined.
- Crossbleed air from opposite engine is available.
- APU air is available for ECS packs and engine starting.

When manually or automatically selected open (in air):

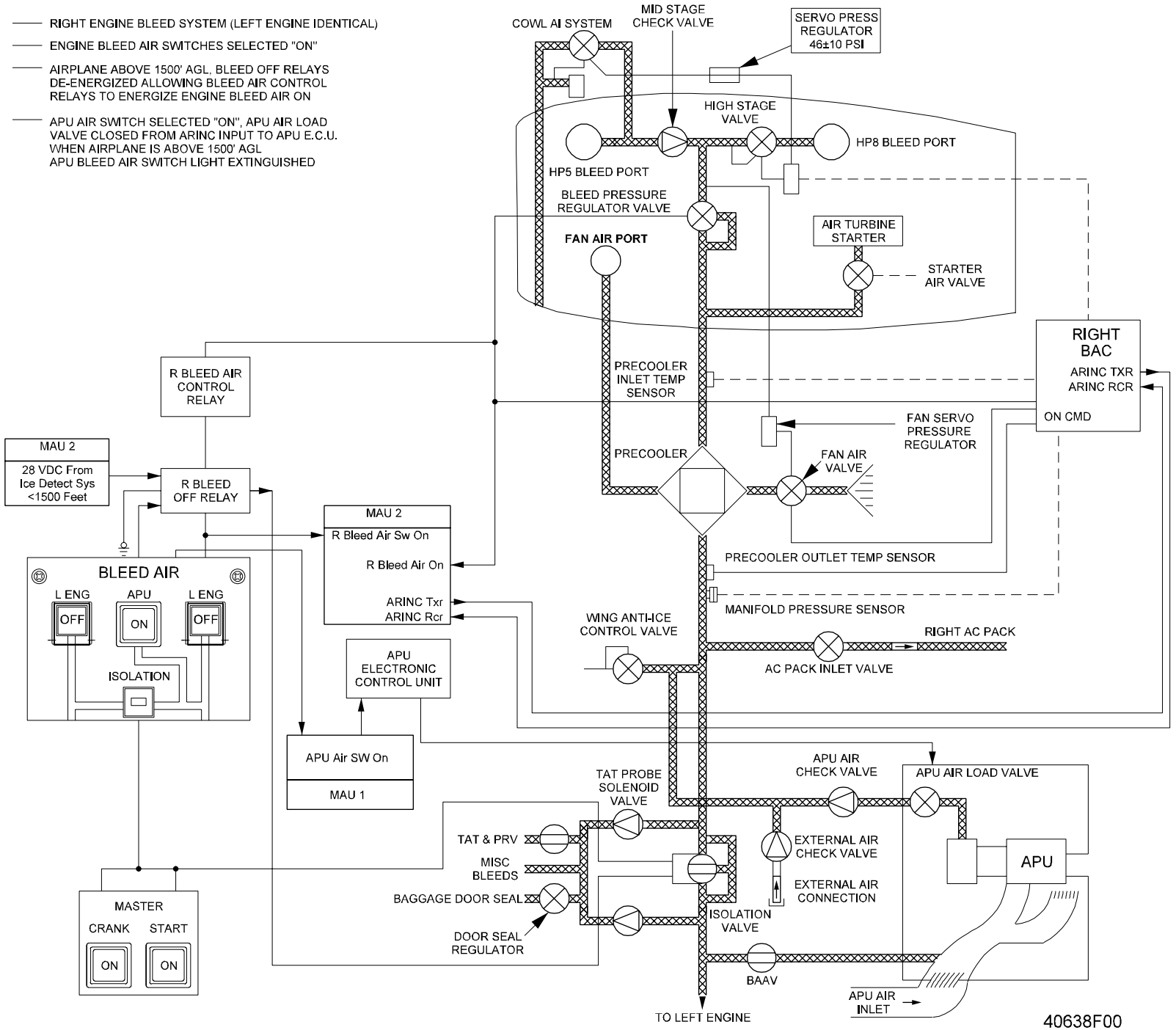
- Same conditions listed above are present except APU air is available for engine starting only.

When selected to OFF:

- White bar in switch capsule extinguishes.
- Left and right bleed air manifolds are isolated.
- Crossbleed air from opposite engine is inhibited.
- APU air is available for R ENG bleed air manifold only.

43043F00

Pneumatics System
Controls and Indications
Figure 1



Pneumatics System Diagram
Figure 2