AIR CONDITIONING AND PRESSURIZATION SYSTEM — SYSTEM DESCRIPTION

1. General

A. Description

The environmental control system provides for pressurization, heating, cooling, ventilation and the means for reduction of humidity in flight or on the ground. True air conditioning is classified as heating or cooling as necessary to maintain a specific level of temperature within the occupied areas of the aircraft, regardless of the ambient temperatures or the operating conditions. Pressurization is the control over the pressure within the occupied areas. Supplemental cooling air to the left radio rack, right radio rack, nose compartment, cockpit pedestal, Cathode Ray Tube (CRT) display No. 1 and CRT display No. 2 is provided by mounted fans. The cooling fans help to prevent avionics and electronics equipment from overheating and malfunctioning by circulating air over and around equipment.

The air conditioning system is a 3-wheel, air bearing, Air Cycle Machine (ACM), packaged refrigeration unit, which controls the cabin and cockpit temperature by means of mixing hot compressed air and refrigerated compressed air. The dual pack concept provides redundancy in case one unit fails. By air cycle, it is meant that cooling is provided by means of a thermodynamic cycle using only air as the medium (as opposed to vapor cycle systems which employ Freon or other similar gases). The system also employs water separation for humidity reduction.

The pressurization system consists of electronic sensing and regulating devices which control the amount of air leaving the aircraft. A pneumatic safety valve is also incorporated, which will automatically regulate the maximum pressure in the aircraft should the automatic electronic control system fail to function properly. If required, the safety valve will limit the maximum pressure buildup within the pressurized areas (safety pressure relief) and also is the primary control device over the maximum negative pressure (vacuum differential). Suitable controls and indications for the system are located in the cockpit to enable the crew to perform programming, select automatic or manual modes of control, observe the status of the system with appropriate indicators and be alerted to possible malfunctions by means of appropriate warning devices.

During normal in-flight operation, hot compressed air is supplied from the bleed air manifold. This is High Pressure (HP) bleed air which is temperature and pressure controlled and can be obtained from either or both engines by the selection of the crew. Cooling is provided by air cycle cooling equipment consisting of a primary heat exchanger, a secondary heat exchanger and a air cycle machine which are capable of reducing the temperature of the air from the bleed air manifold to values below ambient. Humidity reduction is accomplished by a mechanical water separator. Temperature control of the occupied areas is accomplished by varying the amounts of hot bleed air manifold air which bypasses the cooling equipment. Separate temperature control is provided for the cabin and the cockpit through controls located in the cockpit overhead panel.

A feature of the air conditioning system is that it functions independently when on the ground. Although the main engines are not operating, and without a ground pneumatic supply (ground cart) or external electrical supply, complete air conditioning is provided by the auxiliary power unit supplying the hot compressed air for the bleed air manifold. The ground operation of the air conditioning system is essentially the same as in flight except that air flow across the heat exchangers is achieved by the use of a pneumatically driven cooling fan which is rigidly attached to the ACM turbine wheels by a common drive shaft. Provisions are also supplied for an external air connection, whereby an external ground hot compressed air source may be used to supply the bleed air manifold and in turn the air conditioning system.

Should either or both engines be operating, the crew may select either or both engines as a supply of hot compressed air for the bleed air manifold and in turn the air conditioning system, in the same manner as for the in-flight operation.

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Ram air ventilation is provided from the dorsal fin ram air duct during certain emergency procedures.

Normal control over occupied area pressure is exercised by the crew through a completely electronic pressurization system, which features two modes of control over the outflow valve from two different electrical sources, backed up by a purely pneumatic safety valve in the event of total electrical malfunction. Normal flight operation is programmed by the crew through controls located in the overhead panel and copilot lower outboard instrument panel. A minimum of actions are required in flight since the majority of the programming can be accomplished by the crew while on the ground before takeoff. The system features barometric correction capabilities and programming of all flight and landing settings. These settings may be changed by the crew enroute if necessary. It utilizes the latest analog devices incorporated with reliability, safety and passenger comfort as the prime considerations.

Numerous safety and backup devices are provided in the overall system, including:

- Manual electrical control over the system should the automatic system malfunction or if selected by crew
- Depressurization rate detection and limiting
- Pressurization rate limiting (pneumatic)
- Independent safety pressure relief and maximum vacuum differential relief (pneumatic)

2. Major Component Locations

UNIT	NO. PER A/C	LOCATION
Nose compartment cooling fan	1	Nose avionics bay, Fuselage Station (FS) 63
Nose compartment commutating module	1	Nose avionics bay, FS 63
Cabin DFRN PRESS indicator (digital)	1	Cockpit overhead panel
CABIN ALT indicator (digital)	1	Cockpit overhead panel
Cabin RC indicator (digital)	1	Cockpit overhead panel
CABIN PRESSURE CONTROL	1	Cockpit overhead panel
BLEED AIR indicator	1	Cockpit overhead panel
CABIN / CKPT TEMP CONTROL indicator (digital)	1	Cockpit overhead panel
Cabin temperature selector rheostat (MAN)	1	Cockpit overhead panel
Cockpit temperature selector rheostat (MAN)	1	Cockpit overhead panel
L BLEED AIR circuit breaker	1	Pilot Overhead circuit breaker panel
R BLEED AIR circuit breaker	1	Pilot Overhead circuit breaker panel
CKPT/CABIN TEMP IND circuit breaker	1	Pilot Overhead circuit breaker panel
CABIN PRESS 28V circuit breaker	1	Pilot Overhead circuit breaker panel
AIR INLET DOOR circuit breaker	1	Pilot Overhead circuit breaker panel
CABIN PRESS 115V circuit breaker	1	Pilot Overhead circuit breaker panel

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UNIT	NO. PER A/C	LOCATION
CABIN PRESS IND circuit breaker	1	Pilot Overhead circuit breaker panel
L BLEED AIR IND circuit breaker	1	Pilot Overhead circuit breaker panel
R BLEED AIR IND circuit breaker	1	Pilot Overhead circuit breaker panel
BLEED AIR ISO S/O V circuit breaker	1	Pilot Overhead circuit breaker panel
CKPT TEMP CONT circuit breaker	1	Pilot Overhead circuit breaker panel
L AIR COND circuit breaker	1	Pilot Overhead circuit breaker panel
R AIR COND circuit breaker	1	Pilot Overhead circuit breaker panel
SGL PACK circuit breaker	1	Pilot Overhead circuit breaker panel
CABIN TEMP CONT circuit breaker	1	Pilot Overhead circuit breaker panel
ADC XFER circuit breaker	1	Pilot Overhead circuit breaker panel
NUTCRACKER circuit breaker	1	Copilot Overhead circuit breaker panel
WARN LTS PWR #1 circuit breaker	1	Pilot circuit breaker panel
WARN LTS PWR #2 circuit breaker	1	Pilot circuit breaker panel
WARN LTS PWR #8 circuit breaker	1	Pilot circuit breaker panel
WARN LTS PWR #10 circuit breaker	1	Pilot circuit breaker panel
PED COOL FAN circuit breaker	1	Copilot circuit breaker panel
LH RR COOL FAN circuit breaker	1	Copilot circuit breaker panel
NOSE COMPT COOL VLV circuit breaker	1	Copilot circuit breaker panel
DISPLAY MASTER #1 circuit breaker	1	Copilot circuit breaker panel
DISPLAY MASTER #2 circuit breaker	1	Copilot circuit breaker panel
DADC #1 circuit breaker	1	Copilot circuit breaker panel
DADC #2 circuit breaker	1	Copilot circuit breaker panel
DISPLAYS FAN #1 circuit breaker	1	Copilot circuit breaker panel
DISPLAYS FAN #2 circuit breaker	1	Copilot circuit breaker panel
RH RR COOL FAN circuit breaker	1	Copilot circuit breaker panel
RH RR FAN CONT circuit breaker	1	Copilot circuit breaker panel
Cabin pressurization selector	1	Copilot outboard skirt panel
Radio rack fan conrol panel	1	Copilot side console
Cabin / cockpit temperature control sensor	1	Left side of pedestal
Cockpit pedestal cooling fan	1	Lower rear of pedestal

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UNIT	NO. PER A/C	LOCATION
CRT display cooling fan	2	Under cabin floor, FS 95, WL 81 - Left and right side
Cockpit temperature sensor	1	Cockpit, FS 133 - Right side
Left radio rack cooling fan	1	Left radio rack (floor level), FS 181 - 193
Air Data Computer (ADC)	2	Left and right radio rack
Cabin differential pressure transducer	1	Right radio rack, FS 133
Cabin pressure power supply	1	Right radio rack, FS 133
Airflow sensor	1	Right radio rack (mounted to Right cooling fan)
Outflow valve	1	Right radio rack, FS 140 - right side
Safety valve	1	Right radio rack, FS 155 - right side
Commutating module	1	Right radio rack, FS 158 - 169
Right radio rack cooling fan	1	Right radio rack, FS 158 - 169
Pressurization transducer	1	Right radio rack, FS 165 - right side
Pressurization rate switch	1	Right radio rack, FS 181 - right side
Cabin press warning (aneroid) switch	1	Right radio rack, FS 181 - left side
Resistors	2	Main junction & relay box / panel (324/325)
Cabin / cockpit temperature controller	2	Entrance compartment (FLR-15)
L and R CRT commutating module	2	Under FLR-15, FS 158 -169
Cabin duct temp anticipator sensor	1	Under Baggage Floor, FS 527 (FLR-58)
Cockpit silencer	2	Forward Cabin (FLR-22 and FLR-26)
Cabin silencer	1	Aft Cabin (FLR-56)
Cockpit duct temp anticipator sensor	1	Main Wheel Well, FS 452
Cabin temperature control sensor	2	Location determined by furnishing agency
Cabin / cockpit face air duct check valve (1.5 in. diameter)	2	Tail compartment, FS 580 - Left and right sides
Cabin / cockpit air duct check valve (3.0 in. diameter)	2	Tail compartment, FS 580 - Left and right sides
Water separator anti-ice sensor	2	Tail compartment, FS 620 - Left and right sides
Bypass duct assembly	2	Tail compartment, FS 620 - Left and right sides
Water separator anti-ice valve	2	Tail compartment, FS 640 - Left and right sides
Bleed air pressure transducer	2	Tail compartment, FS 650.75 - Left and right sides

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UNIT	NO. PER A/C	LOCATION
Primary heat exchanger	2	Tail compartment, FS 659 - Left and right sides
Secondary heat exchanger	2	Tail compartment, FS 659 - Left and right sides
Water separator cooling fan	2	Tail compartment, FS 659 - Left and right sides
ACM bypass shut-off valve	2	Tail compartment, FS 659 (top) - Left and right sides
ACM bypass check valve	2	Tail compartment, FS 659 - Left and right sides
Servo air pressure regulator valve	2	Tail compartment, Approx. FS 660 - Left and right sides
ACM compressor outlet overheat	2	Tail compartment, FS 665 (top) - Left and right sides
Ram air check valve	1	Tail compartment, FS 666 - Left side
Air cond shut-off and flow regulating valve	2	Tail compartment, FS 682.25 (top) - Left and right sides
Cabin / cockpit ozone converter	2	Tail compartment, FS 705.625 - Left and right sides

3. Major Components

A. Bleed Air Manifold

The bleed air manifold is utilized as the source of hot compressed air for the air conditioning system. This air is available from one or both engines and APU or external air supply (on ground only).

The bleed air manifold delivers air to using systems, one of which is the air conditioning system. The air is delivered at approximately 400°F and at a maximum of approximately 40 psig. This air is delivered to the air conditioning shut-off and flow regulating valves (hereafter known as the air conditioning shut-off valves) through T-fittings in the bleed air manifold located in the tail compartment. See Figure 1.

B. Air Conditioning Shut-off and Flow Regulating Valve

This valve can serve as a shut-off valve for the air conditioning system when system operation is to be terminated or as a flow regulator when air conditioning system is in operation. The valve is a pneumatically operated device with an internal electrical solenoid. As in all pneumatically operated valves in this system, upstream duct pressure is used as the operating force. The valve is a 2 1/2 inch normally open butterfly type device which incorporates as part of the assembly a servo, an actuator and a venturi body. See Figure 1.

An internal shut-off electrical solenoid, when energized, ports operating air from the upstream side (bleed air manifold) of valve directly into diaphragm chamber and closes the valve. This prevents any air from entering the air conditioning system, thus operation of system is terminated. With a source of air in the bleed air manifold and shut-off solenoid de-energized, valve butterfly moves toward the open position and airflow through venturi body starts again. As this valve functions as a flow regulating device, airflow through the venturi portion of the valve, coupled with inlet air pressure, creates a differential across the differential pressure servo. This signal starts to modulate the valve butterfly toward the closed position. A second signal comes from the altitude bias servo aneroid bellows, which adjusts the preload spring tension on the differential pressure servo, thereby causing airflow to be controlled commensurate with aircraft altitude (ambient barometric pressure).

Electrical shut-off solenoid energizing will cause valve to be pressurized to the full close position. There are three ways to energize solenoid and close the valve:

- Placing right or left PACK CONT switches OFF
- On the ground, if discharge side of either ACM compressors reach 450°F (ground configuration only)
- When crew depresses either ENGINE START selector switch to START position the left pack solenoid is energized when MASTER CRANK START switch is selected)
- The RAM switch on cockpit overhead panel will close both air conditioning shut-off valves

In all of the above, air conditioning must be terminated because of a malfunction of some component in the refrigeration system on ground.

NOTE: As the various electrical circuits which control the air conditioning shut-off valves are involved with devices concerned with other parts of the system, these involvements will be covered later in this chapter. Refer to the Wiring Diagram Manual for electrical schematics.

Downstream of air conditioning shut-off valve, the duct splits into two paths, one going to primary heat exchangers which is the first stage of cooling and the other forward to cabin and cockpit temperature control valves which is the bypass route.

C. Temperature Control System

From discharge side of the air conditioning shut-off valve, hot compressed air can take two available paths, through refrigeration unit or through temperature control valves. Amount of hot compressed air which will flow through the temperature control valves into outlet ducting is based on butterfly valve position. The remainder of hot compressed air from air conditioning shut-off valve must go through the refrigeration unit to be reduced in temperature and then rejoin the hot air downstream of temperature control valves in right proportion to become temperature controlled air. It is the position of temperature control butterfly valve which determines compartment temperature by mixing hot and refrigerated air to attain the desired compartment temperature. See Figure 1.

In order to control compartment temperature, position of the appropriate temperature control valve must be varied accordingly. All temperature control devices in a system of this type are directed toward control of the temperature control valves. There are several units which comprise each valve system which will be discussed together.

The temperature control valve system for cabin / cockpit consists of the following units:

- 2 Cabin / cockpit temperature control valves
- 2 Air pressure regulator valves
- 2 Cabin / cockpit temperature controllers
- 2 Cabin / cockpit temperature selectors
- 1 Cockpit duct temperature sensor
- 2 Cockpit temperature control sensors
- 2 Cabin temperature control sensors
- 1 Cabin duct temperature sensor
- 2 Cockpit temperature sensors

All of the above units have a function in operation of the temperature control valve as follows:

(1) Cabin / Cockpit Temperature Control Valves

Each of the two temperature control valves is a 2 inch diameter pneumatic modulating butterfly valve. The valve is normally closed. With no pneumatic pressure applied to its

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diaphragm chamber, an internal spring mechanism will maintain butterfly in the closed position. The valve requires pneumatic pressure to open butterfly and the amount of opening may be controlled by varying pneumatic pressure applied. Each valve is controlled by pneumatic pressure which originates at a T-fitting upstream of the valve which comes from left or right servo control system respectively. Duct pressure is then routed to a device known as the servo pressure regulator valve.

(2) Air Pressure Regulator Valves

The air pressure regulator valves control pressure to the temperature control valves in accordance with a signal received from electrical control devices. The valve converts an electrical signal into a pneumatic signal. This pneumatic signal in turn positions the temperature control valve accordingly. The valve reflects information supplied to it from certain electrical control devices.

The electrical control devices which supply the air pressure regulator valves with temperature information consist of 2 controllers, 4 thermostats and 2 anticipators.

(3) Cabin / Cockpit Temperature Controllers

The controller is a solid state box which interprets the various inputs and sends an electrical signal to the air pressure regulator valves. Input power for the air pressure regulator valve is from 28 V essential dc bus through appropriate circuit breakers and control switches. The crew exercises control over compartment temperature by manipulation of the selector rheostat located on the overhead panel in cockpit. Manually moving rheostat changes the resistance. This change is reflected back to the controller, therefore the crew has informed controller of desired temperature. Refer to the Wiring Diagram Manual for electrical schematic. See Figure 5.

Six temperature sensitive elements per system (2 cabin / cockpit temperature control sensors, 2 cabin / cockpit temperature sensor and 2 cabin / cockpit duct temperature anticipators sensors) supply additional information electrically to the cabin / cockpit temperature controller relating compartment temperature, duct temperature and temperature of air exhausted from the compartment involved. These factors are compared to desired temperature information from the selector rheostat and solid state controller then provides dc output signal to the air pressure regulator valves to control cabin / cockpit temperature control valves position. Additional functions of anticipator are to provide a rate of change control over the system and also to sense when duct temperature has reached a maximum allowable value.

(4) Cabin / Cockpit Temperature Control Sensors

The temperature sensors are dual elements consisting of two separate sections. One section provides temperature information to the cabin / cockpit temperature controllers, while the other element is actually a temperature bulb for the cabin air temperature indicator (digital) which is located in the overhead panel in cockpit. On Aircraft having ASC 162 a third sensor is added. It is used for temperature indication only. Refer to the Wiring Diagram Manual for electrical schematic. See Figure 5.

NOTE: The cabin / cockpit thermostats are identical parts. The thermostats are identical for interchangeability purposes.

(5) Anticipators

The anticipator elements consist of a triple thermistor sensing element whose connections terminate at a common disconnect. It is duct mounted downstream of the temperature control

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valve in the temperature controlled air duct, but upstream of the actual compartment outlet. Refer to the Wiring Diagram Manual for electrical schematic. See Figure 5.

The three independent sensing elements which comprise this unit are:

- A lagged element which is provided with a thermal barrier (this is part of the rate of change circuit of controller)
- An unlagged element which is directly exposed to airflow in duct (this is part of the rate of change circuit of controller)
- A high limit element which is part of the duct temperature limiter circuit within controller

The cabin and cockpit anticipators are identical, interchangeable units. Due to the fact that all three parts of element are hard wired into a common plug and common housing, a malfunction of any one of the three parts requires removal and replacement of entire unit.

(6) Cockpit Temperature Sensor (Cockpit Only)

This sensor consists of a single thermistor sensing element with a single disconnect providing the electrical connections. This unit works with the compartment thermostat to feed temperature information into controller. The cockpit sensor is located on FS 133 bulkhead, forward right side.

(7) Temperature Control Valve

Incorporated in aircraft air conditioning system is a crossover capability. In the event of major component failure, the crew can manually select the remaining operative system by placing L or R PACK CONT switch to OFF. If necessary, crew may place both systems off by selecting L and R PACK CONT switches to OFF.

An explanation of the operation of this crossover function is as follows:

(a) To pressurize both refrigeration units using both engines select L and R ENG BLEED AIR switches to ON. This will energize both bleed air pressure regulator and shut-off valves to open allowing bleed air pressure to be delivered to the air conditioning shut-off and control valves. Placing L and R PACK switches ON, bleed air pressure will be allowed to flow through these valves and to refrigeration units where air will be conditioned to desired temperature and delivered to cabin / cockpit.

(b) In the event of loss of one engine, BLEED AIR switch for operating engine will be selected ON and inoperative engine BLEED AIR switch OFF. The ISOLATION switch will be placed in OPEN allowing the single engine to pressurize the whole bleed air manifold. To obtain full air conditioning, place L and R PACK switches ON.

(c) In the event of loss of one refrigeration unit, select inoperative side OFF and ensure BLEED AIR switch of operating side is ON. Place TEMP CONTROL switch for operative side to ON and bleed air will be routed from engine through the air conditioning system shut-off and control valve through the operating refrigeration unit to cabin / cockpit.

NOTE: Due to the crossover ducting, cabin overhead outlets on both sides will be operative. The main system supply lines also have a crossover duct allowing the main ducts to be operative during single pack operation.

In addition to the source selection switches, there are two TEMP CONTROL knobs labeled AUTO-OFF-MANUAL that have variable temperature range settings from HOT to COLD. When in single pack operation only the temperature control valve of operating pack can be controlled. During dual pack operation cabin and cockpit temperatures are independently regulated. Cabin and cockpit temperatures may be monitored by digital read outs located directly above the TEMP CONTROL knobs.

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D. Distribution System

Downstream of the temperature control valves the hot compressed air which passed through the valves is joined by that portion of the air which was refrigerated. The hot and cold air are mixed downstream of the valves to become temperature controlled air. The cabin and cockpit having separate temperature control valves and distribution systems will be covered separately.

The cockpit distribution system consists of the ducting from the cockpit temperature control valve, the refrigerated air duct, an air duct check valve, a silencer and four outlets in the cockpit. There are two controllable side (or shoulder) outlets and two noncontrollable foot outlets, one each on the pilot side and the copilot side. See Figure 1.

The cabin distribution system consists of ducting from the cabin temperature control valve, refrigerated air check valve, a silencer and two baseboard shaped outlets running practically the entire length of the cabin on both sides. A fluted skirt near the floor level allows the air from the baseboard to enter the compartment.

(1) Cabin and Cockpit Air Check Valves

These are swing checks installed in the compartment ducting. They will only allow air to pass in a forward direction. Should the air attempt to reverse and pass in a rearward direction, valves would close preventing backflow.

(2) Cabin and Cockpit Silencers

Each compartment ducting incorporates a silencer installed under the floor for noise attenuation. These silencers are located as follows:

- Cockpit silencer - approximately FS 219 to 255, forward section of cabin
- Cabin silencer - approximately FS 498 to 534, aft section of cabin

These silencers function to suppress the air noise coming from the engine bleed air ducts.

E. Refrigeration System

Bleed air not bypassing the temperature control valves is routed into the refrigeration section of aircraft. See Figure 1. This system consists of the following major components:

- Primary heat exchanger
- Air Cycle Machine (ACM) and ACM overtemp thermal switch
- Secondary heat exchanger
- ACM bypass check valve bypass duct assembly
- Water separator anti-ice valve with associated sensor
- Water separator unit

Cooling is accomplished by two methods, heat exchangers and by an expansion turbine (air cycling machine). Dehumidification is accomplished by a mechanical water separator which is prevented from icing by means of an anti-ice system.

(1) Primary Heat Exchanger

The primary heat exchanger is the first stage of refrigeration. It utilizes ram air from the dorsal fin ram air inlet as a coolant. This is a single pass heat exchanger mounted on left and right sides of tail compartment.

Just downstream of the outlet of the primary heat exchanger the duct takes a two way split, one duct going into the eye of compressor section of air cycle machine and the other bypassing the entire air cycle machine and secondary heat exchanger. This air passes through the water separator anti-ice valve into the anti-ice muff assembly.

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(2) Air Cycle Machine (ACM)

The ACM is an expansion turbine which reduces temperature by causing the air to perform useful work and in doing so causes a pressure and temperature drop. The work extracted from the airstream in the turbine section is absorbed by operating a compressor wheel which is directly shafted to the turbine wheel located in a separate chamber on the upstream side of the unit. A large percentage of the work which is extracted from the airstream by the turbine is used by the compressor wheel. As the compressor wheel is performing work on the upstream air its pressure and temperature are increased. This is called the bootstrap principle which is actually a pressure recovery system used in modern air cycle systems.

With the ACM in full operation (no air going through the anti-ice valve), the airflow would be through the compressor section through the secondary heat exchanger into the nozzle of the turbine section, then out the eye of the turbine section into the mixing muff.

The ACM check valve is provided to permit air flow around the compressor section of the ACM when pressure ratios are less than 1.0 It also prevents reverse flow when ratios are greater than one. This unit is a pneumatically actuated, spring-loaded closed, split flapper in line check valve. The valve is located in a 1.5 inch duct between the primary and secondary heat exchangers (between the ACM compressor inlet line and compressor outlet line). See Figure 2.

NOTE: The following are recommended air conditioning pack operations using APU air:

- On aircraft with air cycle machines P/N 2204700-01-01 through 2204700-4-1, operate both packs whenever APU is the bleed air source.
- On aircraft with air cycle machines P/N 2204700-05-01 and subsequent, operate single pack as provided in this section. Operate right pack whenever APU is the bleed air source and engine starting will occur. Operate left pack whenever APU is the bleed air source and engine starting will not occur. These procedures will reduce the thermal transients on the APU turbine and reduce cabin pressure surges (bumps).

(3) Secondary Heat Exchanger

This is a single pass heat exchanger which is installed adjacent to the primary heat exchangers in the tail compartment, left and right sides. This heat exchanger also utilizes ram air from the dorsal fin ram air inlet as a coolant.

(4) Cooling Fan

Ground air conditioning presents additional requirements to the system. On the ground there is no ram air, thus no coolant airflow across primary and secondary heat exchangers. This airflow must be supplied, otherwise the refrigeration equipment will overheat. In addition there are times when air conditioning system operation must be terminated due to high demands from bleed air manifold, such as during engine starts. Being a self-supporting aircraft it must be capable of being air conditioned by use of the APU even if main engines are not operating. With few exceptions, airflow through the system when in ground operation is the same from the bleed air manifold to the compartment outlets. The essential difference is in the source of ram airflow for heat exchangers. This is accomplished through a 3-bladed axial flow fan which is an integral component of the ACM. It is physically attached to a common shaft with the compressor and turbine wheels of the ACM and rotates in consonance with them. It provides cooling air flow across the primary and secondary heat exchanges whenever the air conditioning unit is in operation. Air for cooling is delivered through the dorsal fin ram air inlet inflight and through that inlet plus a flapper door in the refrigeration unit ducting on the ground. All air is then ported overboard. The cooling fan cannot be individually controlled.

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(5) ACM Bypass Shut-off Valve

Included in the Environmental Control System (ECS) are two ACM bypass shut-off valves and associated ducting. The ACM bypass shut-off valves are 1.5 inch nominal diameter valves which allow airflow around the turbine section of the ACM whenever open. The unit receives its signals from the air data computer which opens valves at an altitude of 42,000 feet or greater and closes valves at an altitude of 40,000 feet or less. The valve is spring-loaded to close in event of failure. The valve contains a visual position indicator and a relief regulator for actuator overpressure protection. See Figure 3.

When the solenoid valve is energized, inlet air upstream of the valve's butterfly valve is admitted to the actuator diaphragm. When this pressure overcomes the spring force, the butterfly valve moves to the open position. When the solenoid valve is de-energized, actuator pressure is vented through the solenoid valve allowing the actuator spring to close the butterfly valve.

F. Water Separator System

Expansion through the cooling turbine reduces discharge temperatures below ambient temperatures and the low discharge temperature forces moisture in the air to condense. This moisture would produce high humidity and greatly lessen passenger comfort if not removed.

The water separator provides a mechanical means of water removal and consists of two sections. The inlet section is a coalescer (meaning "to cause to come together"). It makes a few large drops from many small droplets by passing the moisture laden airstream through a coarse mesh cloth bag and a set of swirl vanes. The airstream is forced to swirl or spin so that the large drops are spun to the outside walls by centrifugal force, where they are collected by the second section, or collector and deposited into the water separator sump. From the sump, water taken out of the air is plumbed to the secondary heat exchanger through a water spray aspirator (single stage jet pump) to assist in cooling the air. The separator is capable of removing approximately 80% of all water passing through it, including water vapor.

The water separator also contains a relief valve, which, if the cloth coalescer bag is clogged, will bypass the air through the unit. In this case, dehumidification will not take place.

G. Water Separator Anti-Ice System

Normally, cooling turbine discharge temperatures fall low enough so that water is not only condensed, but will freeze. To prevent the coalescer bag of the water separator from becoming clogged with ice crystals and restricting airflow, a water separator anti-ice system is installed. The system consists of the water separator anti-ice valve (anti-ice air modulating valve), and a combination anti-ice sensor and controller. The components are located in the tail compartment. See Figure 4.

As can be seen from Figure 1 or Figure 4, the anti-ice valve will bypass extremely warm primary heat exchanger air around the ACM and secondary heat exchanger when open. This air is directed into the mixing muff, upstream of the water separator, increasing the temperature of the air arriving at the coalescer and preventing the bag from freezing.

(1) Water Separator Anti-Ice Air Modulating Valve

The anti-ice air modulating valve is a 1.5 inch butterfly-type shut-off and modulation valve. The valve consists of a control pressure port, torque motor and modulation valve, and butterfly-type diaphragm controlled shut-off valve. A visual position indicator is located on the bottom of the valve (butterfly shaft).

The anti-ice air modulating valve is mounted on the refrigeration unit, on the mixing muff assembly at the ACM turbine outlet. The valve controls the refrigeration unit cold air outlet

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(mixing muff) temperature to a minimum of 37 ±2°F (nominal) by modulating the flow of primary heat exchanger discharge air to the mixing muff, which is upstream of the water separator. When cooling turbine discharge temperatures are below the nominal 37°F, as sensed by the water separator anti-ice sensor and controller (located immediately downstream of the water separator), the valve is commanded to modulate open, adding warm air to the cooler turbine discharge air.

The anti-ice air modulating valve is spring-loaded closed, pneumatically actuated and torque motor controlled. Regulated control bleed air pressure is ported to the supply nozzle of the torque motor. As the electrical signal to the torque motor is increased, the flapper moves to increase the supply area and reduce the vent area, thereby applying actuating pressure to the pneumatic actuator. When this pressure overcomes closing spring force, the valve modulates toward the open position. Valve position is therefore a function of torque motor input current, as dictated by signals sent from the water separator anti-ice sensor and controller.

NOTE: The anti-ice air modulating valve has its own torque motor, but not an air pressure regulator. The 8 ±1 psi regulated air source is being supplied to the torque motor by the on-side cabin / cockpit temperature control servo air pressure regulator and torque motor assembly.

(2) Water Separator Anti-Ice Sensor and Controller (Combination Unit)

The water separator anit-ice sensor and controller is an electrical device that is installed at the discharge side of the water separator. The unit provides an electrical signal to the anti-ice air modulation valve to control the water separator discharge temperatures to 37 ±2°F (nominal).

This unit consists of a temperature sensor and an electronic controller packaged as a single assembly.

The controller housing and cover are constructed of lightweight aluminum alloy and resembles the other controllers used elsewhere in the pneumatic systems. It contains the appropriate electronic components, most of which are mounted on a single circuit board and controls water separator / turbine discharge temperatures.

The sensor probe contains glass-bead type thermistor sensing elements. The thermistors are mounted in the aluminum alloy probe, with windows in the end to expose the tips of the thermistors to the duct airflow.

The sensor / controller circuitry accepts temperature signals from the sensor probe of the unit and compares them with a fixed reference signal. The resulting error signal is processed by an amplifier to generate the required output signal to the valve.

H. Compressor Outlet Overtemperature Warning System

Incorporated on discharge side of compressor section is a 450°F thermal switch. It is the function of this switch to sense discharge temperature of the compressor section. If there were no airflow or retarded airflow across heat exchangers, compressor discharge temperature would rise. This switch would close its contacts at 450° ±15°F and complete a circuit to the L/R COOL TURB HOT display on the Engine Instrument and Crew Alerting System (EICAS).

An additional function of this warning device is in ground configuration. If trip temperature is reached on the ground, a circuit is completed to EICAS to alert crew members. The same circuit is completed through ground configuration of nutcracker system, to solenoid of air conditioning shut-off valve, to terminate air conditioning of aircraft. See Figure 1. Refer to the Wiring Diagram Manual for electrical schematic.

NOTE: In flight, switch only gives a warning to crew members. It is at their discretion what corrective action they take.

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On ground, switch gives a warning and shuts off air conditioning.

I. **Cooling Air Distribution**

Dehumidified, refrigerated air from discharge side of water separator is ducted forward, the main portion joining that part of the hot air which passed through temperature control valves to become temperature controlled air. Also, refrigerated air from end unit is ducted into one line which serves furnishing agency installed eyeball outlets. A check valve is installed in each line to prevent backflow. Provisions are incorporated for the furnishing agency to complete this installation to the cockpit and cabin, the number of eyeball outlets dependent on the number of seats installed. This is dehumidified, refrigerated air.

J. **Ram Air Ventilation System**

In the event of an emergency, crew can select to ventilate aircraft by use of ram air scooped in through a dorsal fin ram air inlet. In Figure 1, note the line tapped into the ram air duct just upstream of primary heat exchanger. This line is routed to the ram air check valve and then to the downstream side of the left water separator refrigerated air duct. Airflow will move forward through cabin and cockpit duct check valves into the distribution system.

The check valve will only allow airflow to move from ram air duct into the system ducting. In normal operation, with air conditioning system operating, duct pressure is always above ram air pressure and consequently the ram air check valve will be held closed maintaining system integrity.

Selection of ram air ventilation is accomplished by means of the RAM AIR switch being selected to ON, located in the overhead panel in the cockpit. Placing the switch to ON will supply an electrical feed from essential dc bus to air conditioning shut-off valves. This will energize the valve solenoids and stop air conditioning. As duct pressure drops, ram pressure will predominate across the ram air check valve and ram air ventilation will be in evidence.

Returning RAM AIR switch to OFF will de-energize the air conditioning shut-off valve solenoid, establishing airflow from the bleed air manifold and system will return to normal operation. The ram air check valve is located in tail compartment.

NOTE: In ram air ventilation, crew has no control over pressure or temperature of air as it completely bypasses the temperature control valves.

K. **Cockpit / Cabin Air Temperature Indication**

A cabin air temperature indicator (digital) is installed in overhead panel in cockpit above air conditioning system control switches. This indicator is a dc, resistance type, remote indicating digital device which receives its signal from a temperature bulb which is an integral part of the cabin thermostat assembly. Refer to the Wiring Diagram Manual for electrical schematics. The other part of the thermostat assembly is the sensing device for the cabin temperature control system. A common plug is provided to make the electrical connections to both elements and they are not replaceable individually. The whole assembly must be removed in the event of a malfunction of either element.

The location for this sensing element is determined by the furnishing agency in accordance with the interior design of the compartment.

The indicator incorporates internal lighting which is powered from the 5 Vac lighting control system.

Power for indicator is from the essential 28 Vdc bus through the CKPT/CABIN TEMP IND circuit breaker located in pilot overhead circuit breaker panel in the cockpit.

The indicator is a three cube, seven segment digital device calibrated in degrees Fahrenheit and wired to give a maximum reading of 199.

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L. Cabin / Cockpit Ozone Converter

The ozone converters form part of the aircraft air conditioning system for cabin and cockpit. Ozone converters are installed downstream of the air conditioning shut-off and flow control valve on left and right sides of tail compartment, at FS 705.625. The converters are sealed units, 6.875 inches in diameter and 13 inches in length, allowing no internal maintenance or cleaning. These converters are designed to reduce cabin ozone concentration to a maximum of 0.1 part per million by volume.

M. Cooling Fans

(1) Radio Rack Cooling Fans

(a) Left Radio Rack Cooling Fan

Supplemental cooling for left hand radio rack is provided by a fan mounted at bottom of the radio rack near floor and rack. Since fan is not thermostatically controlled, it runs whenever LH RR COOL FAN circuit breaker is depressed on copilot circuit breaker panel. The fan is powered from the essential 28 Vdc bus.

NOTE: Should it become necessary to replace fan, it is recommended by manufacturer to also replace the associated commutating module at the same time.

(b) Right Radio Rack Cooling Fan

Supplemental cooling for the right hand radio rack is provided by an ac voltage fan. The fan is mounted just below bottom shelf and directs cooling air through the outflow valve. The fan is only for ground operation.

Power for fan comes from the right main 115 Vac and essential 28 Vdc buses through RH RR COOL FAN and RH RR FAN CONT circuit breakers located on copilot circuit breaker panel. On copilot right side console, the radio rack fan control panel annunciates status of the system. Normal system operation is in the AUTO mode. Operation of fan is controlled by a switch located on the main entrance door which activates the fan whenever entrance door is fully opened. There is no thermostatic control for operating fan. For maintenance purposes, RH RR FAN MANUAL ON switch located on system monitor panel in right hand radio rack can be activated to allow fan to run when main entrance door is closed. Refer to Wiring Diagram Manual for electrical schematic

(2) Nose Compartment Cooling Fan

In nose compartment, supplemental cooling air to equipment is necessary whenever aircraft is on ground, power for the dc voltage fan comes from right main 28 Vdc bus through NOSE COMPT COOL FAN and NOSE COMPT COOL VLV circuit breakers. Refer to the Wiring Diagram Manual for electrical schmetic.

When aircraft is on ground and temperature in nose compartment goes above 90° F, nose cooling thermal switch in nose compartment causes 28V to energize the nose compartment fan relay sending a signal to nose compartment cooling valve to open and operate fan. Air conditioned air from cockpit is aimed to the nose compartment for component cooling. Whenever this occurs, two amber N COOL VALVE OPEN warning lights on pilot and copilot glareshield panel come on.

When aircraft is in flight, nose compartment cooling valve automatically closes and fan is de-energized through the interlock switch with main gear nutcracker relay. Failure of cooling valve to close in flight is indicated by the N COOL VALVE OPEN warning lights coming on.

(3) Cockpit Pedestal Cooling Fan

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Supplemental cooling air for cockpit pedestal is provided by a fan that is mounted in the aft rear of pedestal. Air is pulled into pedestal and circulated to the components mounted in pedestal. Power for the fan is from right main 28 Vdc bus through PED FAN COOL circuit breaker located on copilot circuit breaker panel. Since fan is not thermostatically controlled, it continually runs whenever circuit breaker is depressed. Refer to the Wiring Diagram Manual for electrical Schematic.

(4) Cathode Ray Tube Display Cooling Fan

Supplemental cooling is necessary to left and right CRT displays that are mounted in the main instrument panel. Both fans are located under the cabin floor, FS 90 - 95, WL 81 on left and right sides of cockpit. A duct system that has a series of smaller ducts is connected from the fan and mounted behind the main instrument panel. CRT display cooling fans draw ambient air from the cockpit through filters to the CRTs and instruments mounted in the instrument panel. Cooling air flows out over the CRTs. Ducts then carry circulated air to fans to be exhausted under the cockpit floor. Refer to the Wiring Diagram Manual for electrical schematics.

Fans operate on power that comes from essential and right main 28 Vdc buses through DISPLAYS FAN #1 and DISPLAYS FAN #2 circuit breakers, applying power to left and right CRT commutating modules respectively. The commutating modules sense the rotation speed of fan motors and sends out a warning signal when motor speed falls below a certain parameter. The modules provide necessary voltage to drive both fans. Each fan works independently of the other, so if one fan stops operating, the other will continue operating.

NOTE: Should it become necessary to replace fan for either side, it is recommended by the manufacturer to also replace the associated commutating module at the same time.

A display panel located in cockpit overhead panel which has three light switches: PILOT, EICAS and COPILOT. When aircraft is in ground mode and any of these switches is pressed on, both CRT fans are energized to operate. When aircraft is in the air mode, both fans are always operating. The three switches have no control over operation of the fans when aircraft is in the air mode.

(5) Commutating Module

There are four commutating modules installed in the aircraft and used in conjunction with the four cooling fans that provide supplemental cooling air to the electronic equipment. All four commutating modules function in the same manner. Refer to the Wiring Diagram Manual for electrical schematics.

These modules are located as follows:

- Right radio rack
- Nose avionics bay
- Two modules located under FLR-15 (cabin floor), first floor panel inside main entrance door

NOTE: Should it become necessary to replace a commutating module, it is recommended by manufacturer to also replace the associated fan at same time.

The commutating module senses fan speed and sends out a warning signal should speed of fan fall below a certain output level. The module motors are conventional dc voltage motors, except that the conventional style brush / commutator system has been replaced by a non-contacting commutating system. This brushless system takes the form of a Hall-effect generator, photo-optic cell or an inductor (fed by a local oscillator) in conjunction with switching transistors.

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(6) Radio Rack Fan Control Panel

Located on copilot right side console is the radio rack fan control panel. The control panel has four indicator lights to provide operator the following status information.

- RH RR FAN FAIL
- LH RR FAN FAIL
- RH RR FAN AUTO
- RH RR FAN MANUAL ON

The function of these status lights is to annunciate system condition of cooling fans that are mounted in left and right hand radio racks. Whenever system is in normal operation, it is in the AUTO mode and RR FAN AUTO light is on. Normal operation is right hand fan being controlled by main door hinge switch that turns fan on automatically when door is fully opened. There is no thermostatic control provided. Refer to the Wiring Diagram Manual for electrical schematics.

When maintenance is being performed and main entrance door is closed, right hand fan can be turned on by placing RH RR FAN switch on right hand radio rack system monitor panel to ON. The cockpit control panel RH RR FAN MANUAL ON light will be on and RH RR AUTO ON light will be off.

An airflow sensor is mounted in the air discharge path of the right hand radio rack fan. In the event of reduced airflow from fan, control panel RH RR FAN FAIL light will come on. For left hand radio rack fan, LH RR FAN FAIL light will come on if speed falls below an acceptable limit.

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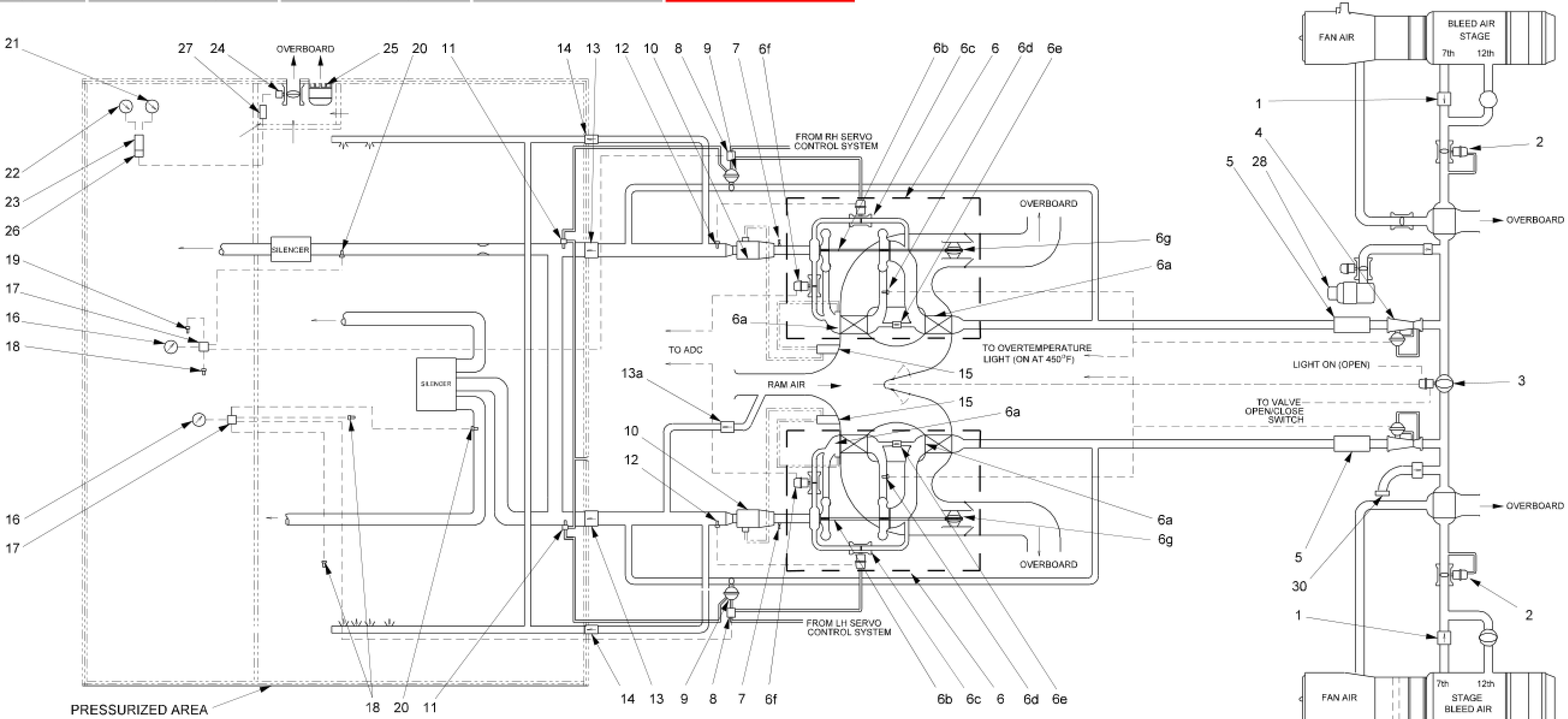

ITEM NO	DESCRIPTION	QTY PER AIRCRAFT
1	VALVE, L.P. BLEED AIR CHECK	2
2	VALVE, BLEED AIR PRESSURE REG. & S/O	2
3	VALVE, BLEED AIR ISOLATION S/O	1
4	VALVE, AIR CONDITIONING SYSTEM SHUTOFF & FLOW CONTROL	2
5	FILTER, CABIN/COCKPIT OZONE	2
6	REFRIGERATION UNIT	2
(a)	PRIMARY/SECONDARY HEAT EXCHANGER	4
(b)	AIR CYCLE MACHINE (ACM)	2
(c)	ANTI-ICE MODULATING VALVE	2
(d)	OVERTEMPERATURE SWITCH	2
(e)	ACM BYPASS CHECK VALVE	2
(f)	ACM BYPASS SHUTOFF VALVE	2
(g)	COOLING FAN	2
(h)	BYPASS DUCT ASSEMBLY	2
7	VALVE, TURBINE DISCHARGE WATER DRAIN	2
8	VALVE, SERVO AIR PRESSURE REG.	2
9	VALVE, CABIN/COCKPIT TEMPERATURE CONTROL	2
10	SEPARATOR, WATER	2
11	SENSOR, CABIN/COCKPIT DUCT OVERTEMPERATURE	2
12	SENSOR, WATER/SEPARATOR ANTI-ICE CONTROLLER	2
13	VALVE, CABIN/COCKPIT AIR CHECK	2
13a	VALVE, RAM AIR CHECK	1
14	VALVE, CABIN/COCKPIT FACE AIR CHECK	2
15	WATER, SPRAY ASPIRATOR	2
16	SELECTOR, CABIN/COCKPIT TEMPERATURE	2
17	CONTROLLER, CABIN/COCKPIT TEMPERATURE	2
18	SENSOR, CABIN/COCKPIT TEMPERATURE CONTROL	3
19	SENSOR, COCKPIT TEMPERATURE CONTROL	1
20	SENSOR, CABIN/COCKPIT DUCT TEMPERATURE ANTICIPATOR	2
21	MANUAL CABIN PRESSURE	1
22	CONTROLLER, CABIN PRESSURE	1
23	TRANDUCER, CABIN PRESSURE	1
24	VALVE, CABIN AIR OUTFLOW	1
25	VALVE, CABIN PRESSURE SAFETY	1
26	EMI FILTER, CABIN PRESSURE CONTROL	1
27	SWITCH, EMERGENCY CABIN PRESSURE RATE	
28	AUXILIARY POWER UNIT (APU)	
29	VALVE, APU AIR CHECK	
30	NIPPLE, CHECK VALVE & AIR START ASSY	1

LEGEND

(double line)	BLEED AIR & AIR COND DISTRIBUTION LINES
(solid line)	PNEUMATIC CONTROL SYSTEM
(dashed line)	ELECTRICAL LINES

Air Conditioning System – Block Diagram
Figure 1

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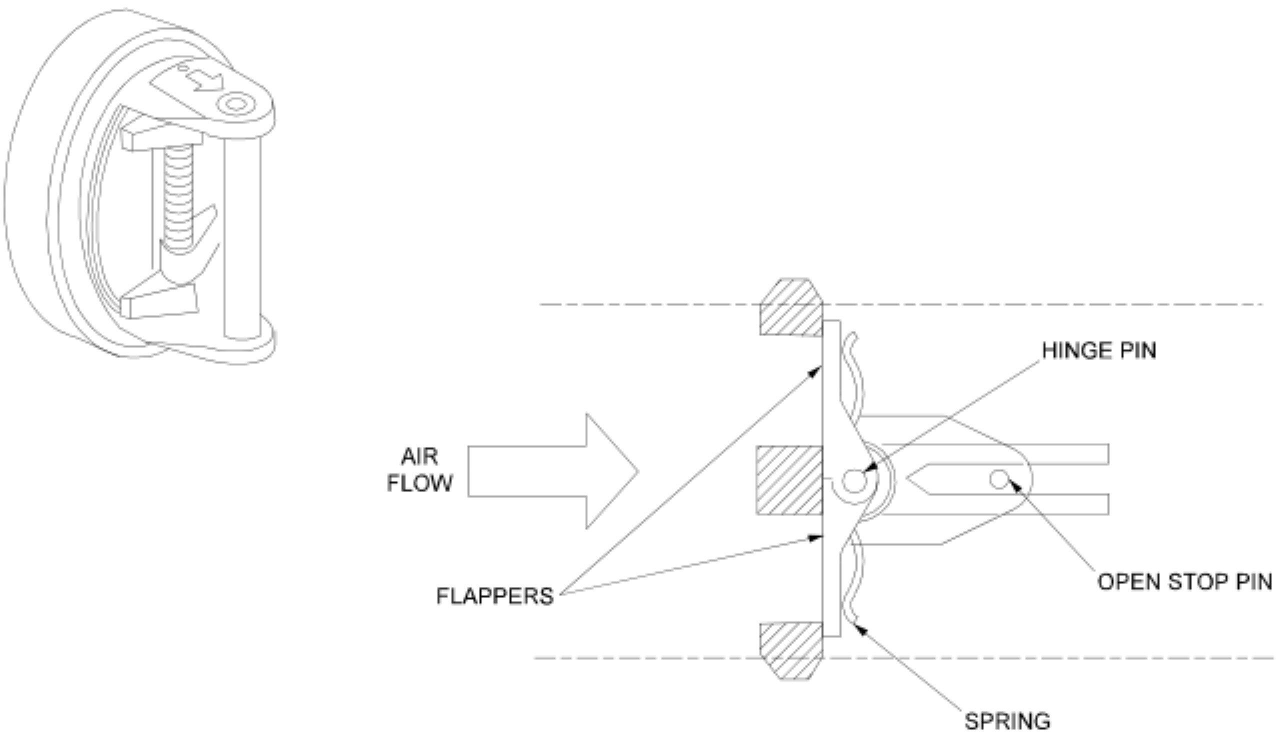

Air Cycle Machine Bypass Check Valve
Figure 2

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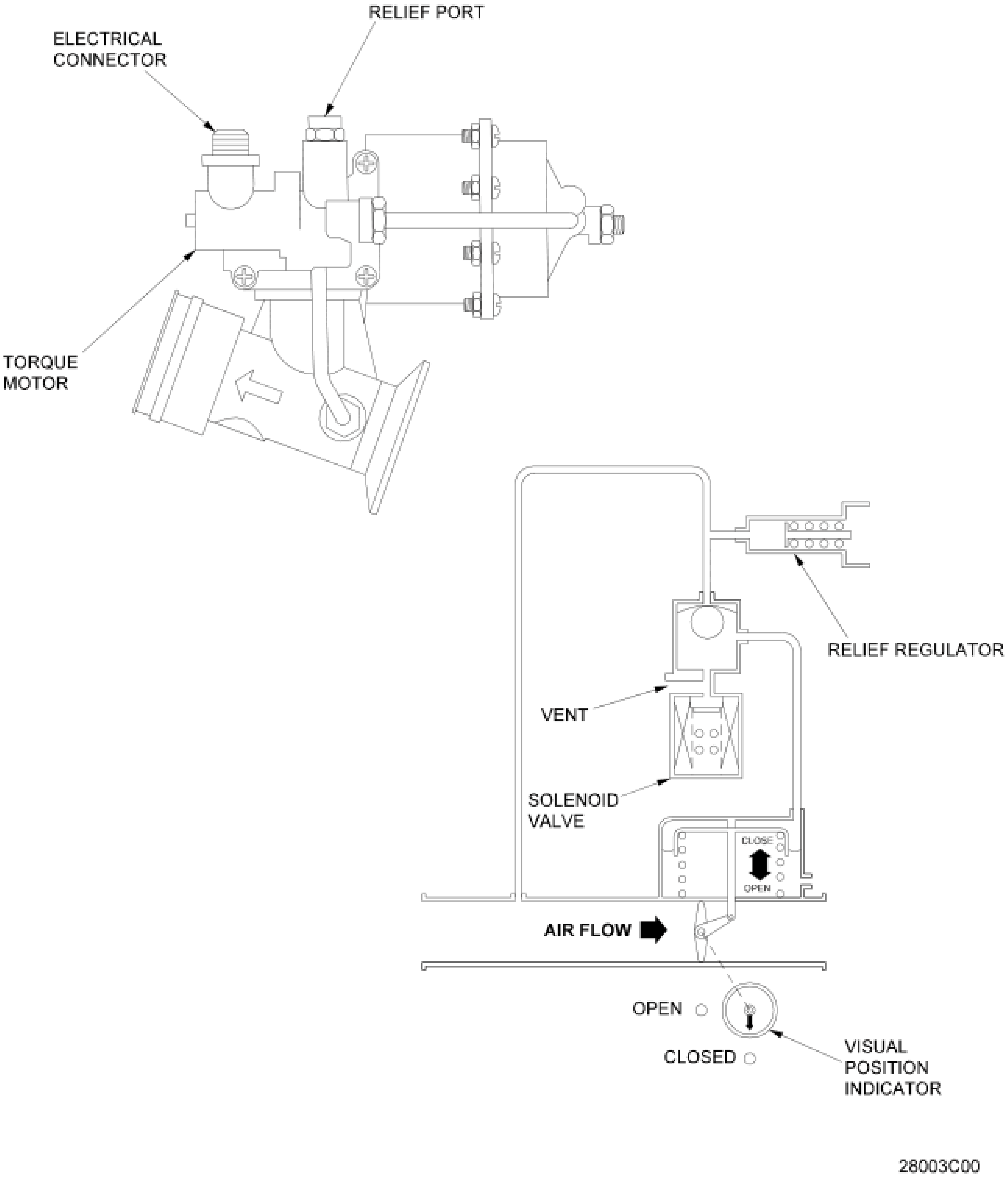

Air Cycle Machine Bypass shut-off Valve
Figure 3

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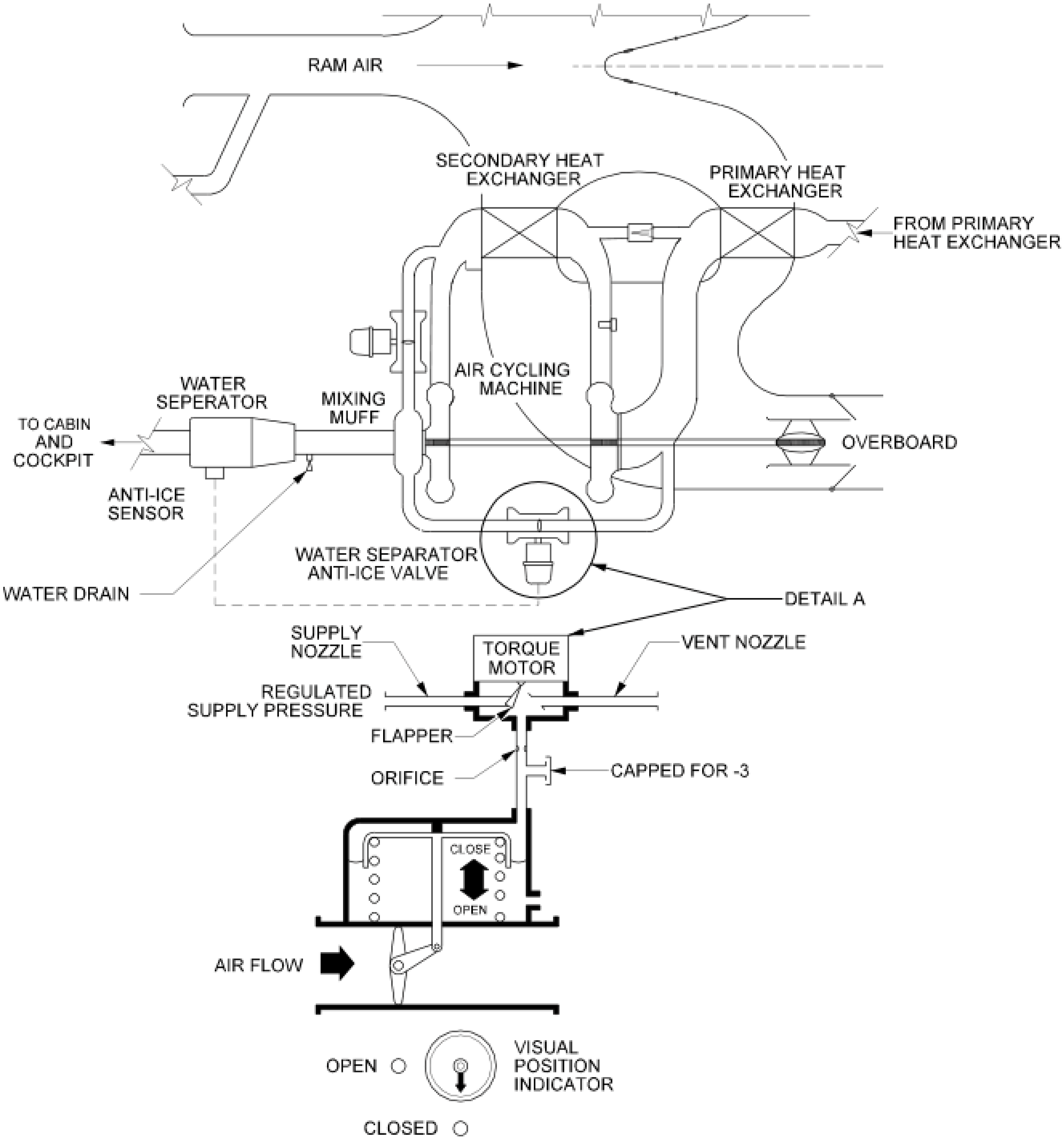

Water Separator and Anti-Ice System - Block Diagram
Figure 4

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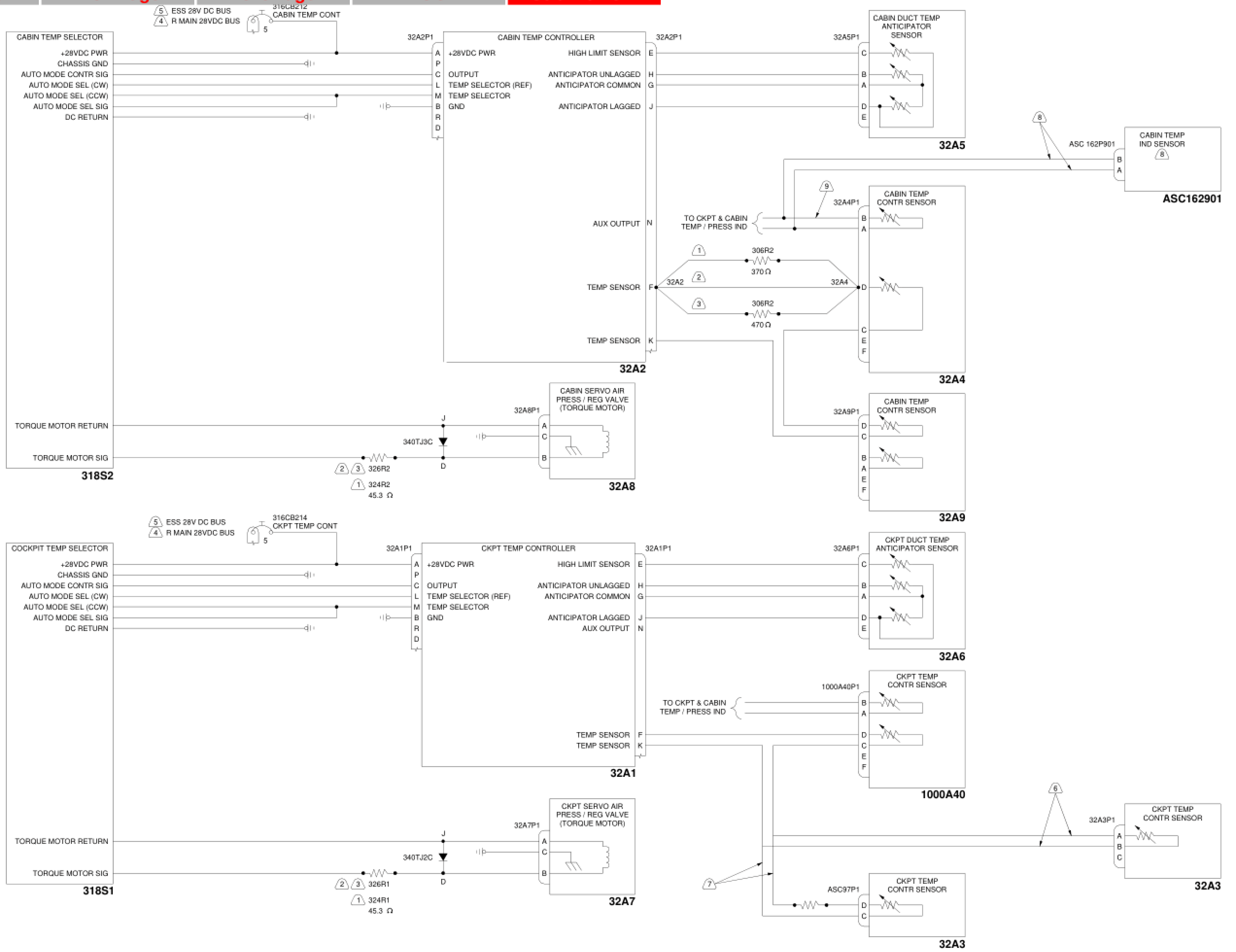

CALLOUT(S):

1. AIRCRAFT 1000, 1002 - 1005
2. AIRCRAFT 1006 - 1023
3. AIRCRAFT 1001, 1024 AND SUBSEQUENT
4. AIRCRAFT 1000, 1002 - 1119 EXCLUDING 1034 NOT HAVING ASC 170
5. AIRCRAFT 1000, 1002 - 1119 EXCLUDING 1034 HAVING ASC 170 AND AIRCRAFT 1001, 1034, 1120 AND SUBSEQUENT
6. AIRCRAFT 1000 - 1143 NOT HAVING ASC 97
7. AIRCRAFT 1000 - 1143 HAVING ASC 97 AND 1144 & SUBSEQUENT
8. AIRCRAFT HAVING ASC 162A
9. AIRCRAFT NOT HAVING ASC 162A

Air Conditioning Temperature Control – Electrical Schematic
Figure 5

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