CHAPTER 11
AIR CONDITIONING

INTRODUCTION

The air-conditioning and temperature control systems for the Gulfstream IV provide for comfortable cabin and cockpit temperatures throughout the complete operating envelope of the aircraft. The normal source of air for air conditioning is bleed air from the engines. The APU is an alternate source and provides heating and cooling of the occupied areas when the aircraft is on the ground. An approved external air supply can be connected to an adapter to provide air conditioning on the ground when the other air sources are not available.

GENERAL

The air-conditioning system consists of a three-wheel air-bearing air cycle machine (ACM) packaged refrigeration unit, in which control over the cabin and cockpit temperature is accomplished by means of mixing hot compressed air and refrigerated compressed air. The dual pack concept provides redundancy in case one unit fails. The term air cycle means 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.

SYSTEM DESCRIPTION AND OPERATION

GENERAL

During normal in-flight operation, hot compressed air is supplied from the bleed-air manifold (Figure 11-1). This air, which is temperature and pressure-controlled, can be obtained from either or both engines at the selection of the crew. Cooling is provided by air cycle cooling equipment (Figure 11-2), consisting of a primary heat exchanger, a secondary heat exchanger, and an air cycle machine, which are capable of reducing the temperature of the air from the bleed-air manifold to values above freezing. Humidity reduction is accomplished by a mechanical

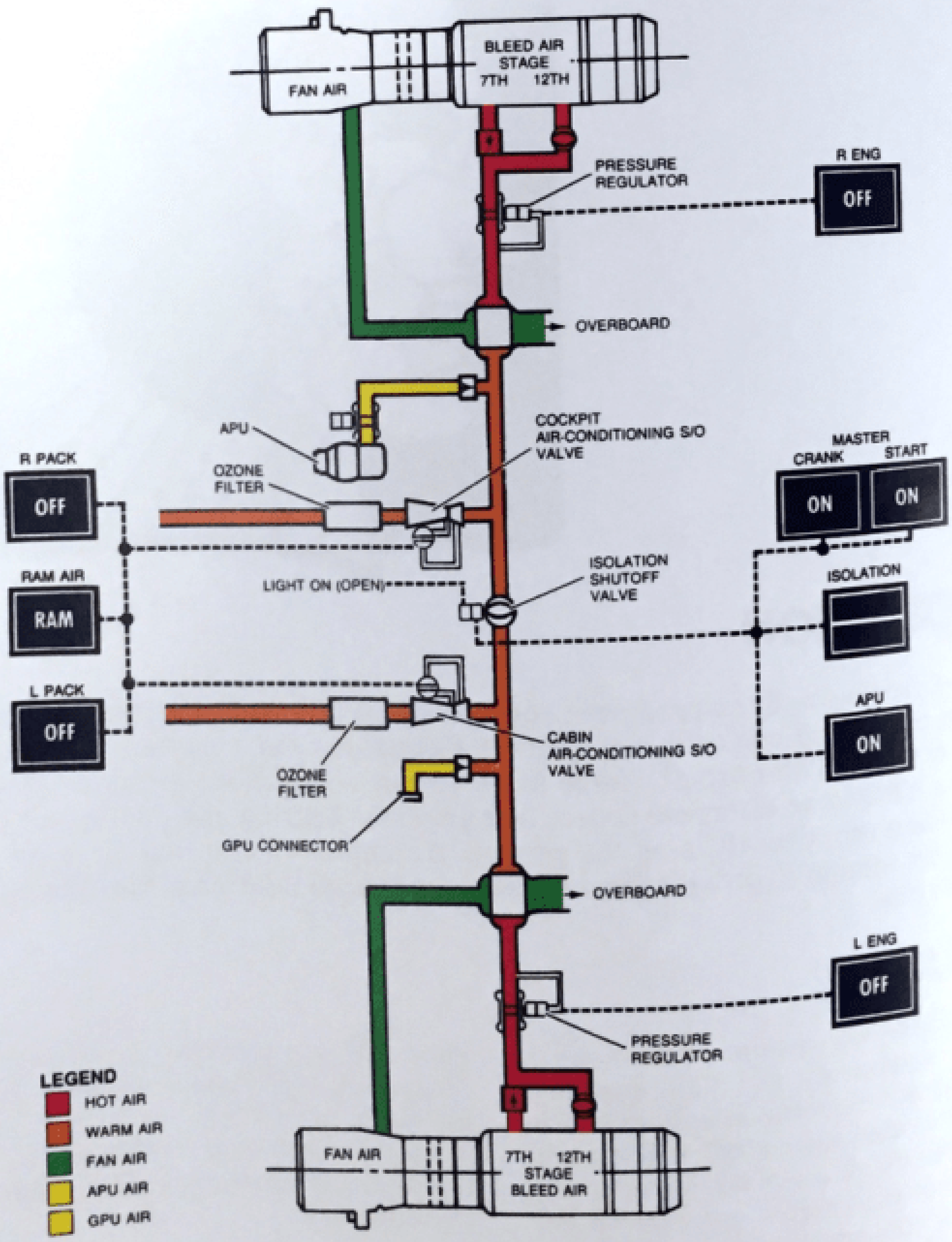

Figure 11-1. Bleed-Air Manifold

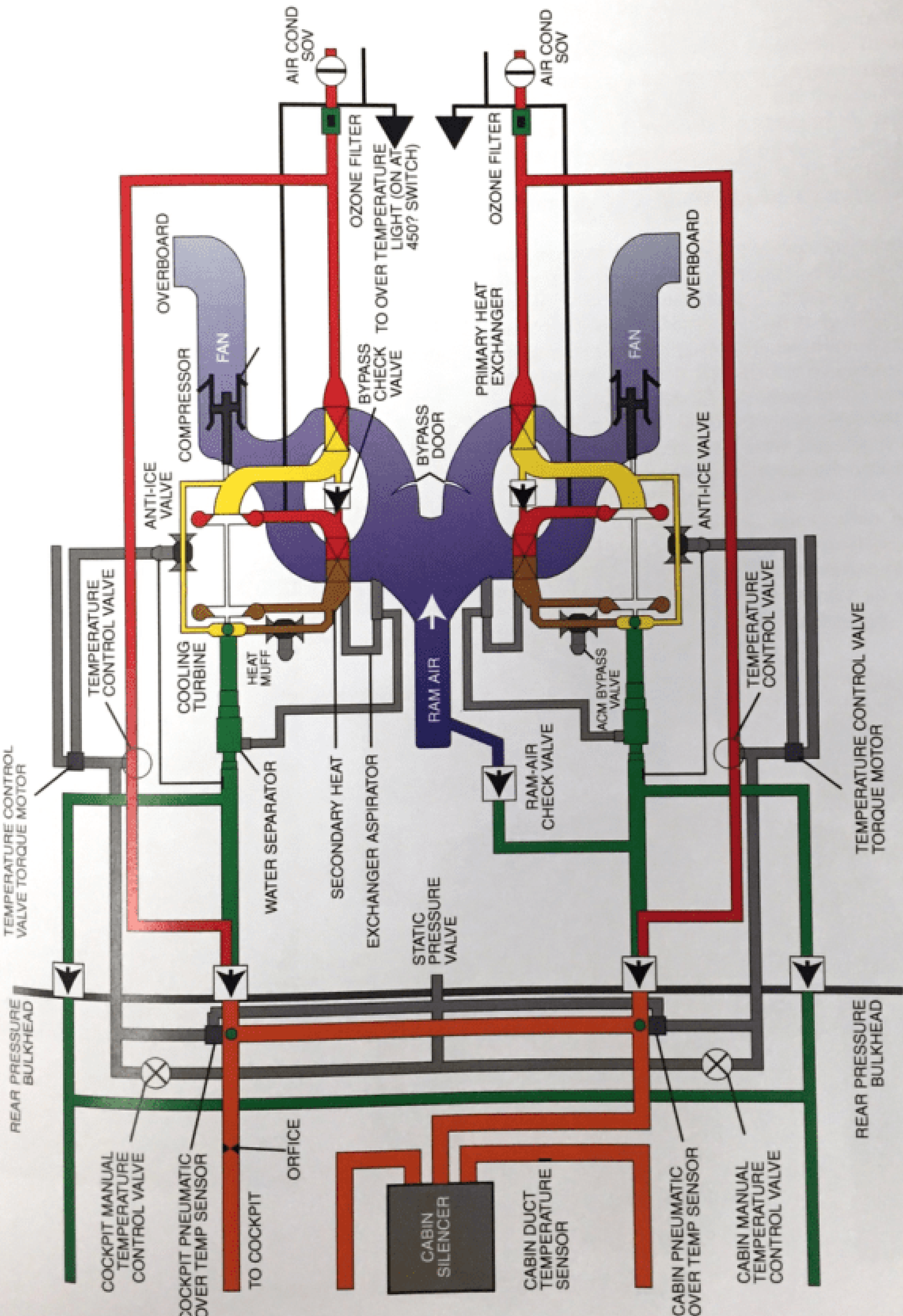

Figure 11-2. Air-Conditioning System

water separator. Temperature control of the occupied areas is accomplished by varying the amounts of hot bleed air which bypasses the cooling equipment. Separate temperature control is provided for the cabin and the cockpit with controls located on the overhead panel in the cockpit. A manual system provides additional control over the system in the event of a failure of the electronic control components.

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 APU supplying the bleed-air manifold. Ground operation of the air-conditioning system is essentially the same as in flight, with the addition of ram-air flow across the heat exchangers induced by cooling fans. Provisions are also made for an external air connection for use with an external ground source of bleed air for the bleed-air manifold.

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 thus the air-conditioning system. This is accomplished by use of the ISOLATION valve switch (Figure 11-3).

Ram-air ventilation is provided from the dorsal fin ram-air duct (Figure 11-4) during certain emergency procedures.

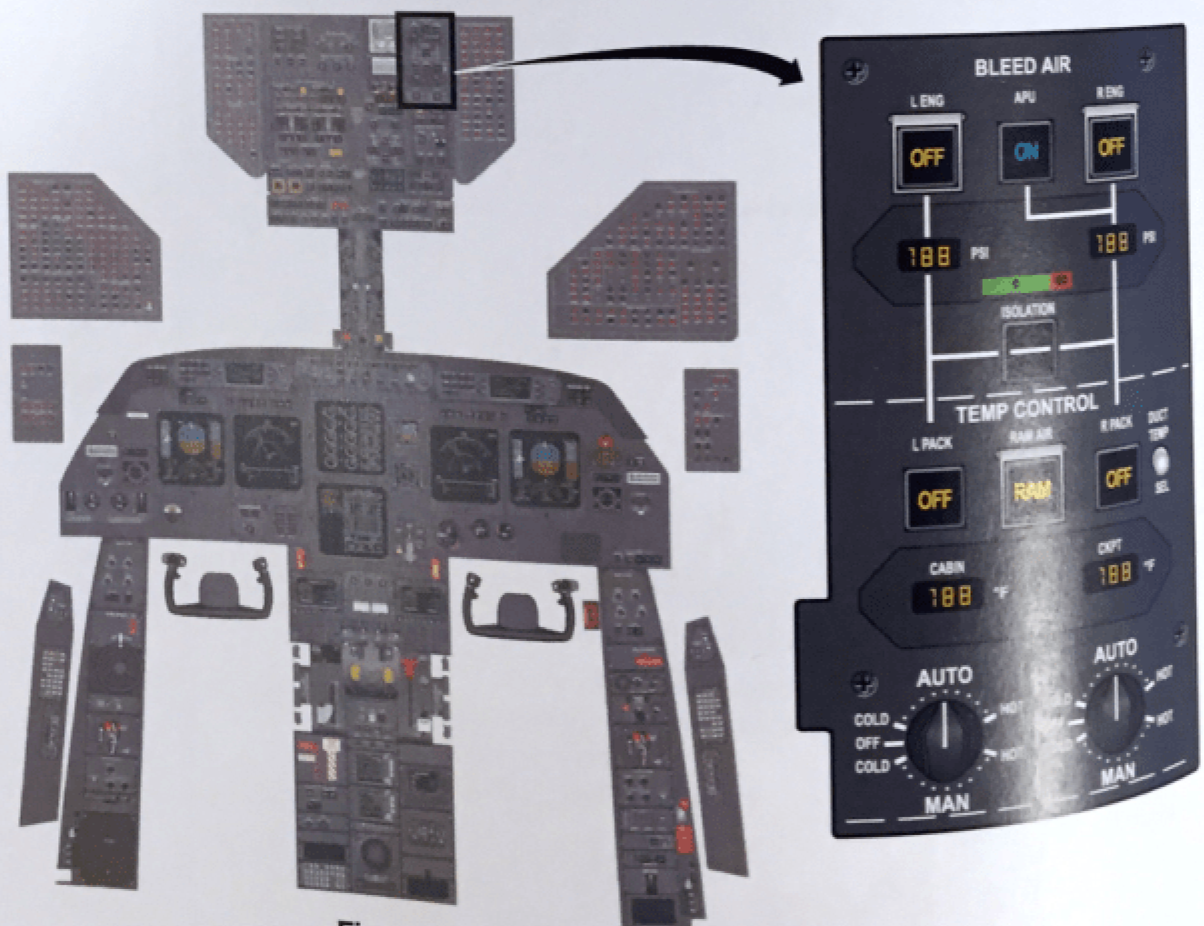

Figure 11-3. ISOLATION Valve Switch

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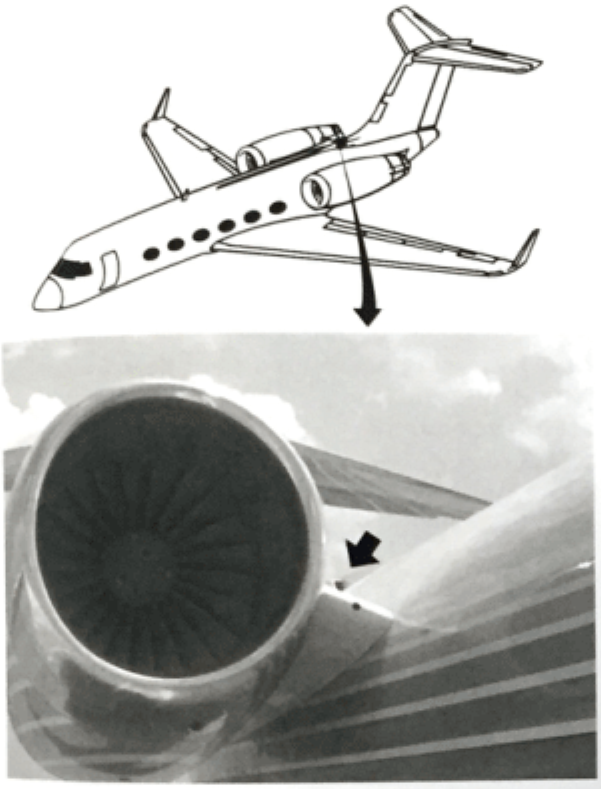

Figure 11-4. Dorsal Fin Ram-Air Inlet

AIR CONTROL COMPONENTS

Bleed-Air Manifold

The bleed-air manifold is used as the source of bleed air for the air-conditioning system. This air is available from one or both engines, the APU, or an external air supply (ground use only).

The bleed-air manifold delivers air to using systems, one being the air-conditioning system. The air temperature is approximately 400°F at a maximum of approximately 40 psig. The air is delivered to the air-conditioning shutoff and flow-regulating valves (shutoff valves) through T-fittings in the bleed-air manifold in the tail compartment.

Air-Conditioning Shutoff and Flow-Regulating Valves

These valves serve two functions in the air-conditioning system:

- As a shutoff valve for the air-conditioning system when system operation is terminated.
- As a flow regulator when the air-conditioning system is in operation. The valve is a pneumatically operated device with an internal electrical solenoid. An internal shutoff electrical solenoid, when energized, closes this valve, preventing any air from entering the air-conditioning system and ending operation of the system. With a source of air in the bleed-air manifold and the shutoff solenoid deenergized, the valve butterfly moves toward the open position and airflow starts again. This valve functions as a flow-regulating device to maintain a maximum of 28 ppm airflow.

Electrical shutoff solenoid energizing causes the valve to be pressurized to the fully closed position. There are several ways to energize the solenoid and close the valve:

- Place the RAM AIR switch to RAM.
- Place the right or left PACK control switch off.
- When on the ground, aircraft SNs 1156 and subsequent and those with ASC 135, selecting the START or CRANK MASTER switch ON will close the left valve.
- On the ground, the discharge side of either ACM compressor has reached 450°F.
- When on the ground, depress either engine starter switch.

TEMPERATURE CONTROL SYSTEM

It is the position of the temperature control valve (Figure 11-5) which determines compartment temperature by mixing hot and refrigerated air to attain the desired compartment temperature.

In order to control the compartment temperature, the position of the appropriate temperature control valve must be varied accordingly. All temperature control devices in this system are directed toward the control of the temperature control valves.

Cabin/Cockpit Temperature Selector

General

The dual selector (see Figure 11-3) is used to automatically or manually set a desired cabin or cockpit temperature. Both are physically and operationally independent from the other and are installed in the cockpit overhead.

Operation

The selector provides automatic and manual temperature control selection by rotation of the control knob clockwise and counterclockwise from the 9 o'clock OFF position. The control functions are obtained through approximately 330° rotation of the selector shaft. There is a detent region of approximately 20 to 30° at the OFF position, within which no signal is applied to the temperature control valve from either the manual selector or the temperature controller. Rotating the shaft out of this detent area in a clockwise direction places the temperature control system in the automatic mode of operation at the minimum selectable temperature (60°F). Further clockwise rotation through 150° of rotation linearly increases the selected temperature to the maximum value (80°F).

Rotation of the selector knob out of the detent area in the counterclockwise direction places the temperature control system in the manual, although still electric, mode of operation with the temperature control valve fully closed. Further rotation of the knob through 150° in the counterclockwise direction progressively opens the valve to the fully open position, thereby increasing the temperature.

Some aircraft have been outfitted with additional manual temperature controls located aft of the baggage door. These pneumatic controls are dependent on a minimum 3 psid cabin pressure for opening of the temperature control valves.

Cabin/Cockpit Temperature Control Valve

The temperature control valve is a two-inch diameter pneumatic modulating butterfly valve. With no pneumatic pressure applied to its diaphragm chamber, an internal spring mechanism maintains the butterfly in the closed position. The valve requires pneumatic pressure to open the butterfly and the amount of opening is controlled by varying the pneumatic pressure applied. The pneumatic control pressure (left servo control system) originates at a T-fitting upstream of the valve. Duct pressure is then routed to a servo air pressure regulator and torque motor.

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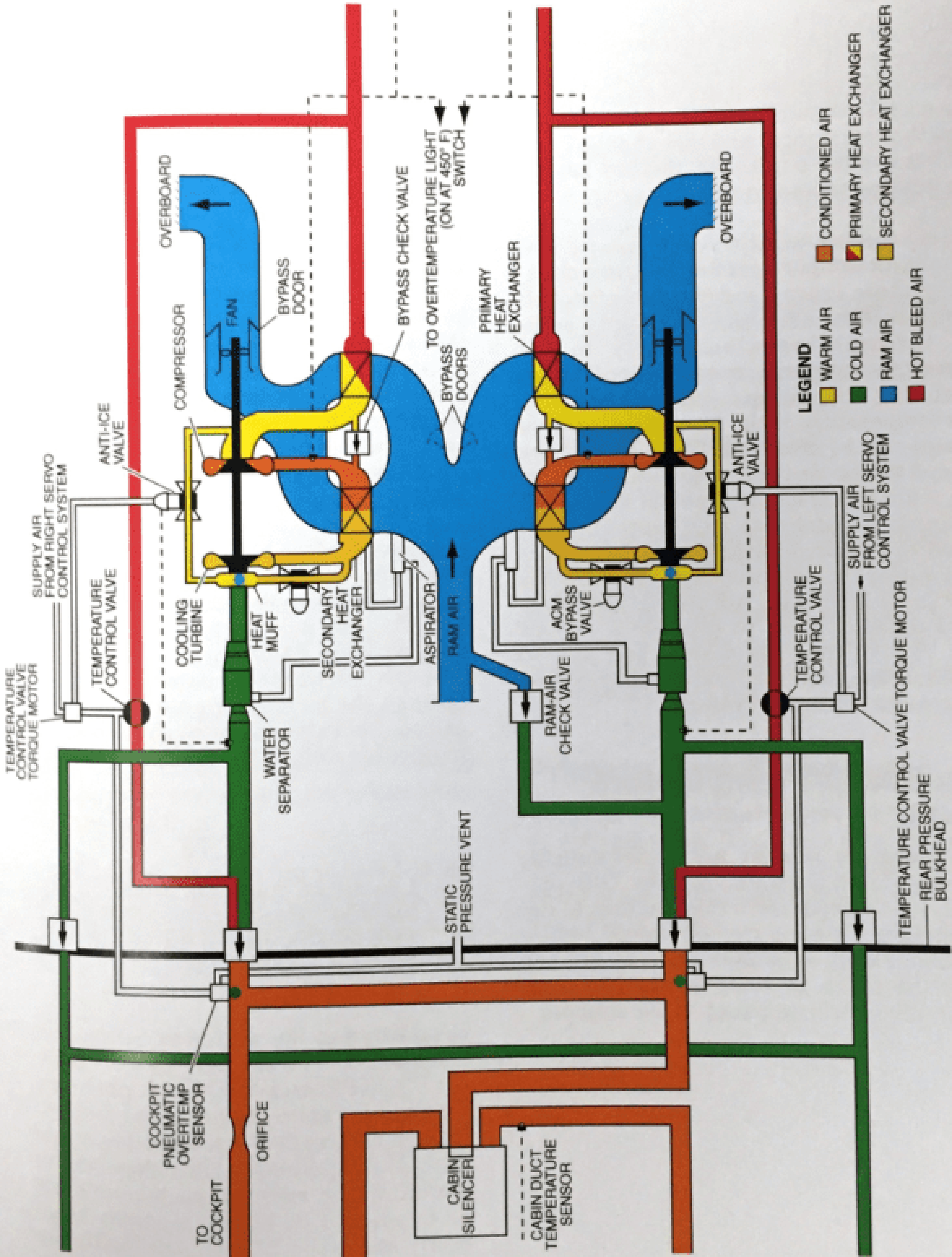

Figure 11-5. Refrigeration Unit

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Cabin/Cockpit Temperature Controllers

The crew exercises control over the compartment temperature by manipulation of the selector rheostat, located on the overhead panel in the cockpit. Manually moving the rheostat changes the resistance, and this change is reflected back to the controller, thereby adjusting the desired temperature.

Five temperature-sensitive elements, two cabin/cockpit temperature sensors, one cockpit temperature sensor, and two cabin/cockpit duct temperature anticipators, supply additional information electrically to the cabin/cockpit temperature controller relating compartment temperature, duct temperature, and the temperature of the air exhausted from the compartment involved. These factors are compared to the desired temperature information from the selector rheostat and solid-state controller, and then a DC output signal is routed to the air pressure regulator valves which control the cabin/cockpit temperature control valve positions. Additional functions of the anticipator are to provide a rate of change control over the system and also to sense when the duct temperature has reached the maximum allowable value.

Cabin/Cockpit Temperature Sensors

The temperature sensors are dual-element, 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), the overhead panel in the cockpit.

Crossover Function Operation

To pressurize both refrigeration units using both engines, position the L and R ENG BLEED AIR switches to ON. This energizes both bleed-air pressure regulator and shutoff valves open, allowing bleed-air pressure to the air-conditioning shutoff and control valves. Placing the L and R PACK switches to ON allows bleed air to flow through these valves to the refrigeration units, where it is conditioned to the desired temperature and routed to the cabin/cockpit.

In the event of the loss of one engine, place the BLEED AIR switch for the operating engine to ON and the inoperative engine BLEED AIR switch to OFF. Placing the ISOLATION switch to OPEN allows the single engine to pressurize the whole bleed-air manifold. For full air conditioning place the L and R PACK switches to ON.

In the event of the loss of one refrigeration unit, place the inoperative side PACK switch to OFF, and ensure that the BLEED AIR switch and PACK switch for the operating side are in ON. With the PACK switch for the operative side ON, bleed air is routed from the engine through the air-conditioning system shutoff and control valve and through the operating refrigeration unit to the cabin or cockpit.

NOTE

> Crossover plumbing allows conditioned air from the operating pack to feed into the area of the aircraft with the pack selected off.

In addition to the source selection switches, there are two TEMP CONTROL knobs, with AUTO, OFF, and MANUAL positions, that vary temperature range setting from HOT to COLD. During dual-pack operation cabin and cockpit temperatures are independently regulated. Cabin and cockpit temperatures may be monitored by digital readouts located directly above the TEMP CONTROL knobs.

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DISTRIBUTION SYSTEM

Downstream of the temperature control valves, the hot bleed 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 have separate temperature control valves and distribution systems.

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 non-controllable foot outlets, one each on the pilot side and the copilot side.

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.

Cabin and cockpit air check valves are installed in the compartment ducting. They allow air to pass only in a forward direction. Should the air attempt to reverse flow, the valves close and prevent backflow.

Cabin and cockpit silencers are installed in the ducting under the floor for noise attenuation. The silencer function is to suppress the air noise from the engine bleed-air ducts.

REFRIGERATION SYSTEM

Bleed air which does not bypass the temperature control valves is routed into the refrigeration unit. The refrigeration unit consists of the following major components:

- Primary heat exchanger
- ACM and ACM overtemperature thermal switch
- Secondary heat exchanger
- Mixing muff, screen, and bypass duct assembly
- Water separator anti-ice valve with associated sensor
- Water separator unit
- Cooling fan

Cooling is accomplished by heat exchangers and an expansion turbine. Dehumidification is accomplished by a mechanical water separator, which is prevented from icing by means of an anti-ice system. Airflow across the heat exchangers is automatically maintained with a ground cooling fan.

Primary Heat Exchangers

The primary heat exchangers are the first stage of refrigeration. They use ram air from the dorsal fin ram-air inlet as a coolant. These single-pass heat exchangers are mounted in the tail compartment.

Air Cycle Machine

The air cycle machine (ACM) is an expansion turbine which reduces temperature by causing the air to perform useful work, and 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 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.

Secondary Heat Exchangers

Heat exchangers are installed adjacent to the primary heat exchangers in the tail compartment. These heat exchangers also use ram air from the dorsal fin ram-air inlet as a coolant.

Water Separator System

Expansion through the cooling turbine reduces discharge temperatures below [redacted] temperatures and forces moisture [redacted] air to condense.

Water Separators

The water separators provide a mechanical means of water removal and consist of two sections: the inlet section is a coalescer and makes a few large drops from many small droplets by passing the droplet-laden airstream through a coarse mesh cloth bag while the second section accomplishes the actual water removal.

Water extracted from the air is also sprayed into the secondary heat exchanger cooling air inlet to assist in cooling.

Water Separator Anti-ice System

On a cool, moist day cooling turbine discharge temperatures fall low enough that water is not only condensed but freezes. To prevent the bag of the water separator from becoming clogged with ice crystals and restricting the airflow, a water separator anti-ice system is installed.

Water Separator Anti-ice Valve

This [redacted]e is a butterfly-type shutoff and modulati[redacted]alve. The unit controls the refrigeration unit cold air outlet temperature to a minimum of 37°F (nominal) by modulating the flow of compressor inlet air to the anti-ice muff at the turbine discharge.

Water Separator Anti-ice Sensor

The water separator anti-ice sensor is a pneumatic thermostat, installed on the discharge side of the water separator. This thermostat is set to maintain the valve position so that the air moving through the water separator is held at a temperature of approximately 37°F.

The system design is such that maximum utilization can be made of refrigeration and dehumidification systems regardless of high or low humidity conditions, or high or low altitude conditions, with the sensor exercising control over the valve and the system.

Bootstrap Overtemperature Warning System

Incorporated on the discharge side of the bootstrap unit compressor section is a 450°F thermal switch. It is the function of this switch to sense discharge temperature of the bootstrap compressor section. If there were no airflow or retarded airflow across the heat exchangers, compressor discharge temperature would rise. As a result this switch closes at 450°F and completes a circuit to the L/R COOL TURB HOT display (EICAS).

An additional function of this warning device is in ground configuration. If the trip temperature is reached on the ground, a circuit is completed to the EICAS to alert crewmembers. The same circuit is completed through ground configuration of the nutcracker system to close the air-conditioning shutoff valve of the affected pack.

NOTE

In flight, the switch gives a warning only to crewmembers. On the ground, the switch gives a warning and shuts off the air conditioning of that pack.

Ground Air Conditioning

Ground air conditioning presents additional requirements to the system. On the ground there is no ram air and thus no coolant airflow across the primary and secondary heat exchangers. This airflow must be supplied; otherwise, the refrigeration equipment overheats. In addition there are times when air-conditioning system operation must be terminated due to high demands from the bleed-air manifold, such as during engine starts. Being a self-supporting aircraft, it must be capable of being air-conditioned using the APU even if the main engines are not operating. Airflow through the system when in ground operation is the same from the bleed-air manifold to the compartment outlets.

Cooling Fan

A turbofan is installed downstream of the ACM in the dorsal fin ram-air duct. The fan assembly, rigidly fixed to the armature of the ACM, provides airflow across primary and secondary heat exchangers whenever air conditioning is in operation. Air for cooling is delivered through the ram-air inlet in flight and a flapper valve in the refrigeration unit on the ground. All air is then ported overboard.

Cooling Air Distribution

Dehumidified, refrigerated air from the discharge side of the water separator is ducted forward, the main portion joining that part of the hot air which passed through the temperature control valves to become temperature-controlled air. Also, refrigerated air from the 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 the installation to the cockpit and cabin, the number of eyeball outlets depending on the number of seats installed. The air from the outlets is dehumidified and refrigerated.

RAM-AIR VENTILATION SYSTEM

In the event of an emergency, the crew can ventilate the aircraft by use of ram air scooped in through a dorsal fin ram-air inlet. A line is tapped into the ram-air duct just upstream of the 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. If ram-air duct pressure is above refrigerated air duct pressure, the check valve opens and admits ram air to the refrigerated air line. Airflow moves forward through the cabin duct check valve into the distribution system.

The check valve allows airflow to move only from the ram-air duct into the system ducting. In normal operation, with air-conditioning operation, duct pressure is always above ram-air pressure; consequently, the ram-air check valve is held closed, maintaining system integrity.

Selection of ram-air ventilation is accomplished using the RAM AIR switch located on the overhead panel. Placing the switch to RAM supplies 28 VDC from the essential DC bus to both of the air-conditioning shutoff valves. This energizes the valve solenoids and stops air conditioning. As duct pressure drops, ram pressure predominates across the ram-air check valve and allows ram-air ventilation.