ENVIRONMENTAL AND TEMPERATURE CONTROL

GENERAL

The Environmental Control System (ECS) consists of three subsystems. The Environmental Control Unit (ECU), which produces cold air from engine bleed air, Temperature Control System (TCS), and the Service Air system.

ENVIRONMENTAL CONTROL UNIT (ECU)

The tailcone-mounted ECU is designed to take hot engine bleed air from both engines and produce cold air for use in the temperature and distribution system. This conditioned air also serves as the source of pressurization for the entire pressure vessel. The ECU consists of a primary heat Exchanger, secondary heat exchanger, Air Cycle Machine (ACM), water separator, and an overtemperature switch.

Precooled (475° (±25°) F) engine bleed air enters the ECU through two interconnected Mass Flow Control Valves. The flow control valves drop the pressure of the bleed air and control the flow to the ECS. System flow is approximately 22 lbs./min (11 lbs./min/engine) at sea level. Bleed air is then cooled to 200-300°F prior to entering the Air Cycle Machine (ACM). Once the air enters the ACM it is compressed raising the temperature to approximately 300-400°F. This compressed air then flows to Secondary Heat Exchanger where it is cooled to 100-150°F. Air from the Secondary Heat Exchanger returns to the ACM and is expanded. This expansion process provides energy to drive the compressor as well as the fan that draws ambient air into the primary and secondary heat exchangers. As the air is expanded, it will cool to approximately 32°F on a hot day. On a normal or cold temperature day the turbine outlet temperatures can go well below freezing.

When the outlet temperature of the air from the turbine drops below the ambient air dewpoint, the water vapor is condensed out of the air in liquid form. With the outlet temperatures below freezing, the water vapor will freeze creating ice particles. In order to prevent these ice particles from freezing over the water separator and blocking airflow, cold turbine inlet air is mixed with hot engine bleed air. The low limit temperature control valve modulates bleed air to maintain a temperature of 32-35°F.

Air leaving the water separator is routed to the rest of the airplane via the temperature control ducting. Air out of the ECU is always modulated at a temperature of 32-35°F. Cabin heat is produced using air that has bypassed the ECU and mixed with cooled air to maintain the desired temperature.

PRIMARY AND SECONDARY HEAT EXCHANGERS

The primary and secondary heat exchangers are joined as a unit and arranged in parallel with ram airflow. A ram air scoop located at the fillet fairing of the vertical tail supplies air for the heat exchangers. On the ground the ACM requires an additional cross-sectional area in order to pull enough air across the heat exchangers. For this purpose an impeller is installed within the ACM driven by a turbine creating enough suction to open an auxiliary door at the ram air duct. Air is drawn from both the ram air scoop and a set of louvers in the fillet fairing through the door in the ram air duct, across the heat exchangers, and out the right hand side of the airplane through the ACM exhaust grill. Fan inlet pressure is boosted by ram air in flight.

AIR CYCLE MACHINE (ACM)

The ACM consists of a compressor, turbine, and fan that are mounted by a common shaft supported by air bearings. No oil is required for these bearings as they ride on a film of compressed air. The shaft is supported during startup by thin overlapping spring-loaded foils. These foils keep the shaft centered until enough air pressure is generated to lift the air bearings. The shaft will not move freely by hand as a result of the grip from the foil segments. The ACM requires approximately 5 PSIG to spool up the rotating equipment and bring the air bearings into effect. After spool up, the rotating equipment does not contact the foils. The air bearings will support ACM rotation down to approximately 1.5 PSIG.

WATER SEPARATOR

A mechanical water separator is integrated into the ECU to provide a means of extracting water droplets out of the air. If the air temperature entering the water separator is above the dewpoint, all of the water is in vapor form and cannot be extracted. During the expansion process, the air temperature typically drops below the dewpoint and condenses into very small water droplets in the air stream. Since these droplets are too small to centrifuge out of the air, they pass through a coalescer sock inside the water separator. This sock combines the smaller droplets so the water can be forced to the outer shell by centrifugal force.

The water droplets from the water separator are collected in the outer shell where they are passed into a drain system to be sprayed on the Secondary Heat Exchanger. This increases the cooling efficiency of the exchanger.

The coalescer assembly contains a relief feature in the event that the sock becomes plugged or frozen over. A spring loaded relief valve will open to allow bypass of the water separator to make sure of a constant supply of airflow to the airplane.

OVERTEMPERATURE SWITCH

An over temperature switch is mounted in the compressor discharge outlet duct. Switch actuation is set to 420°F. The switch will deactivate at 380°F. The over temperature switch protects the ACM from excessively high temperatures. Upon sensing an over temperature condition, the switch closes the L and R mass flow regulating shutoff valves, opens the emergency pressurization valve and activates both the EMERGENCY PRESSURIZATION and ACM O'HEAT EICAS messages. On the ground the switch closes the mass flow shutoff valves and annunciates the ACM O'HEAT EICAS message.

AIR DISTRIBUTION SYSTEM

The cabin and cockpit air distribution systems direct the flow of fresh temperature conditioned air for a comfortable and well-ventilated cabin and cockpit. Air distribution is made up of three distinct networks: lower cabin air distribution, cockpit air distribution, and overhead cold air distribution.

LOWER CABIN AIR DISTRIBUTION

The lower cabin air distribution system supplies conditioned air through the L lower supply duct. When the air enters the cabin it is diverted forward along several paths; the L armrest and foot warmer ducts, dropped aisle ducts on the L side of the dropped aisle, and the R armrest and foot warmer ducts. The foot warmer and armrest ducting is of a piccolo tube design allowing air to flow evenly over the length of the cabin. The L side ducting extends from the aft cabin forward to the main entrance door. Right side ducting is extended from aft cabin forward to just aft of the cabin/cockpit divider. A duct at the forward side of the aft pressure bulkhead connects the L and R sidewall ducts.

COCKPIT AIR DISTRIBUTION

The cockpit air distribution system is supplied with conditioned air through the R lower supply duct. The air enters the aft cabin and is ducted underneath the floorboard towards the cockpit. When reaching the cockpit, the air is split into sidewall diffusers, side window defog, torso WEMACS and foot warmers. The sidewall diffusers, foot warmers, and dual torso WEMACS, are also supplied by recirculation fans located in the distribution ducting. The RECIRC AIR CABIN and COCKPIT switch-annunciators, located on the Pressurization/Environmental Control Panel, control the fans electrically. Two positions are available NORM/HI. Recirculation fans pull the ambient air from the cockpit environment and force it through the ducts feeding the WEMACS, sidewall diffusers, and side window defog.

Condensation on the cockpit side windows is prevented by the use of frost panes that keep moist cockpit air from coming in contact with the cold outer window surface. Conditioned air from the cockpit supply is fed between the panes from the bottom of the window. A small vent hole, placed in the upper corner of the frost pane, allows the air to flow over the pane and into the cockpit.

OVERHEAD COLD AIR DISTRIBUTION

The overhead cold air distribution originates at the ECU. Air is ducted through the PSU panel to the airplane occupants. The left and right cold air distribution is supplied to the cockpit and cabin by overhead WEMAC outlets. One outlet is provided for each passenger seat and flight crew position. Operation of the WEMAC outlets is independent of one another for the full open to full closed positions.

Cold air continuously pressurizes the overhead ducting when the engines are running and bleed air is being supplied. A series of piccolo holes in the overhead allows for air overflow if the WEMACs have all been closed.

BULKHEAD CHECK VALVES

There are three check valves in the cabin/cockpit environmental system. Two are located on the left side of the airplane within the over wing fairing. One is in the cockpit supply line on the right side of the airplane in the over wing fairing. The left side valves provide air to the cabin. The right side provides air to the floor and armrest ducting in the cabin. The check valves are a quad flapper design, spring loaded closed. Primary purpose for the check valves is to permit conditioned air to flow into the cabin air distribution system and prevent pressurization loss in the event of a duct failure.

TEMPERATURE CONTROL SYSTEM

The basic operation of the Temperature Control System is to mix a stream of cold air (32°F to 35°F) from the ECU outlet with hot bleed air 475° (±25°F) from downstream of the Mass Flow Valves. Environmental air supply is mixed proportionally, as selected by the temperature controller, to maintain a comfortable temperature in the cabin/cockpit.

A dual zone temperature control system is installed. A DC digital controller provides independent control and selection of cockpit and cabin temperature as well as providing low limit control for the ECU.

Three temperature control valves (cockpit, cabin, and ECU low limit), three duct sensors, two zone temperature sensors, two duct overheat switches, and a temperature controller that is integrated into the Temperature Control selector/indicator comprise the system. The temperature controller processes signals from the flight crew inputs and positions the temperature control valves accordingly.

The front face of the Temperature Control selector/indicator contains system controls along with a numerical display showing the selected temperature, measured zone, or the measured air supply temperature. Zone and supply temperatures are taken directly from the zone sensors or duct sensors respectively. A control knob at the center of the selector/indicator allows the flight crew to cycle between current cockpit/cabin zone temperatures, when in the CKPT or CAB position. Two select (SEL) positions for the cockpit or cabin allow the flight crew to select the desired temperature by using the CKPT TEMP SEL or CAB TEMP SEL knobs to control cabin or cockpit temperature. Selectable temperatures range from 65°F - 85°F. A MANUAL position is provided to allow the supply temperature to be manually controlled by the flight crew.

A DC digital controller modulates the temperature control valves based on select knob and zone sensor inputs. These input signals are compared to their respective set points. If a correction to maintain the desired temperature is necessary, the controller sends a DC signal to the appropriate temperature control valve. Valve modulation then occurs in the open or closed direction sending more or less flow to the respective compartment. The ECU limit control operates similarly at a fixed range of 32°F to 35°F.

The passenger using the Remote Temperature Controller located in the cabin can select cabin temperature. The flight crew can disable the Remote Temperature control by pressing the CABIN TEMP CONTROL LOCAL/REMOTE switch-annunciator located on the Pressurization/Environment control panel on the copilot's instrument panel.

TEMPERATURE CONTROL VALVES

Three temperature control valves are utilized to regulate the amount of hot bleed air mixed with ECU cold air. Two of the temperature control valves are located just right of the ACM while the third is located aft of the ACM. The valves are butterfly type valves controlled by a DC motor. The DC motor receives a signal from the controller to position the butterfly to modulate the flow of bleed air to the conditioned air ducts.

DUCT TEMPERATURE SENSORS

The duct temperature sensors monitor the temperature of the air entering the cabin and cockpit air distribution system and signal the logic for the temperature control system in the controller portion of the environmental control panel. Three sensors are provided. One is located in the cabin conditioned air duct just upstream of the pressure penetration (left-hand side), the second in the cockpit conditioned air duct just upstream of the pressure penetration (right-hand side) and the third is located upstream of the water separator.

ZONE TEMPERATURE SENSORS

A cockpit zone temperature sensor is located in the return side of the recirculation air loop on the right hand side of the cockpit. The cabin zone temperature sensor is located in the return side of the recirculation air loop near the aft pressure bulkhead. Sensors are mounted in the recirculation loop so cabin/cockpit air flows across the sensor; this provides a more accurate sample of zone temperature. The sensors monitor the temperature of the air in the cockpit and cabin and provide a reference temperature to the temperature controller.

TEMPERATURE CONTROLLER

The temperature controller consists of cabin and cockpit temperature selectors, a digital temperature indicator and a display selector. The cabin temperature selector and the cockpit temperature selector are rotary switches (CABIN TEMP SEL and CKPT TEMP SEL) incorporating both auto and manual mode controls. The temperature indicator provides digital temperature readout of the selected switch position. Switch positions provide temperature readouts of the cabin zone temperature, cockpit zone temperature, cabin supply duct temperature, cockpit supply duct temperature, selected cabin temperature, and selected cockpit temperature. The temperature controller has system diagnostic capabilities that are performed each time power is applied to the controller. The diagnostics identify and report nine potential error conditions.

DUCT OVERHEAT TEMPERATURE SENSOR

Two duct overheat temperature sensors are provided, one for the cabin and one for the cockpit system. The cockpit overheat sensor is located in the cockpit supply duct just upstream of the pressure vessel penetration in the lower, aft, RH cabin. The cabin overheat sensor is located in the cabin supply duct just upstream of the pressure vessel penetration in the lower, aft, LH cabin. The duct overheat sensors are designed to illuminate the DUCT O'TEMP COCKPIT or CABIN EICAS message when the temperature at the duct exceeds approximately 300°F.

TEMPERATURE CONTROL SELECTOR

Figure 2-29

ENVIRONMENTAL SYSTEM

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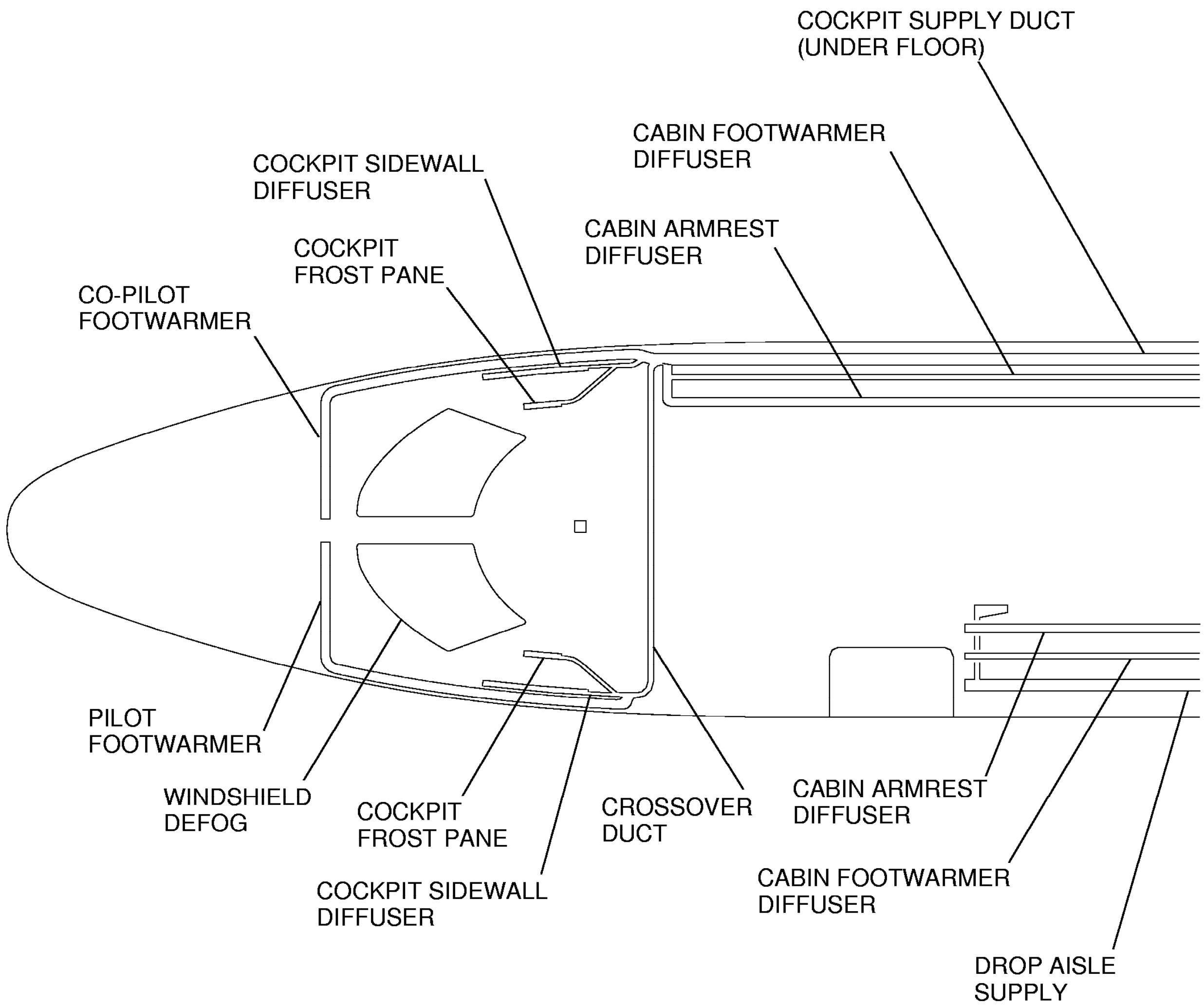

Figure 2-30 (Sheet 1 of 2)

ENVIRONMENTAL SYSTEM

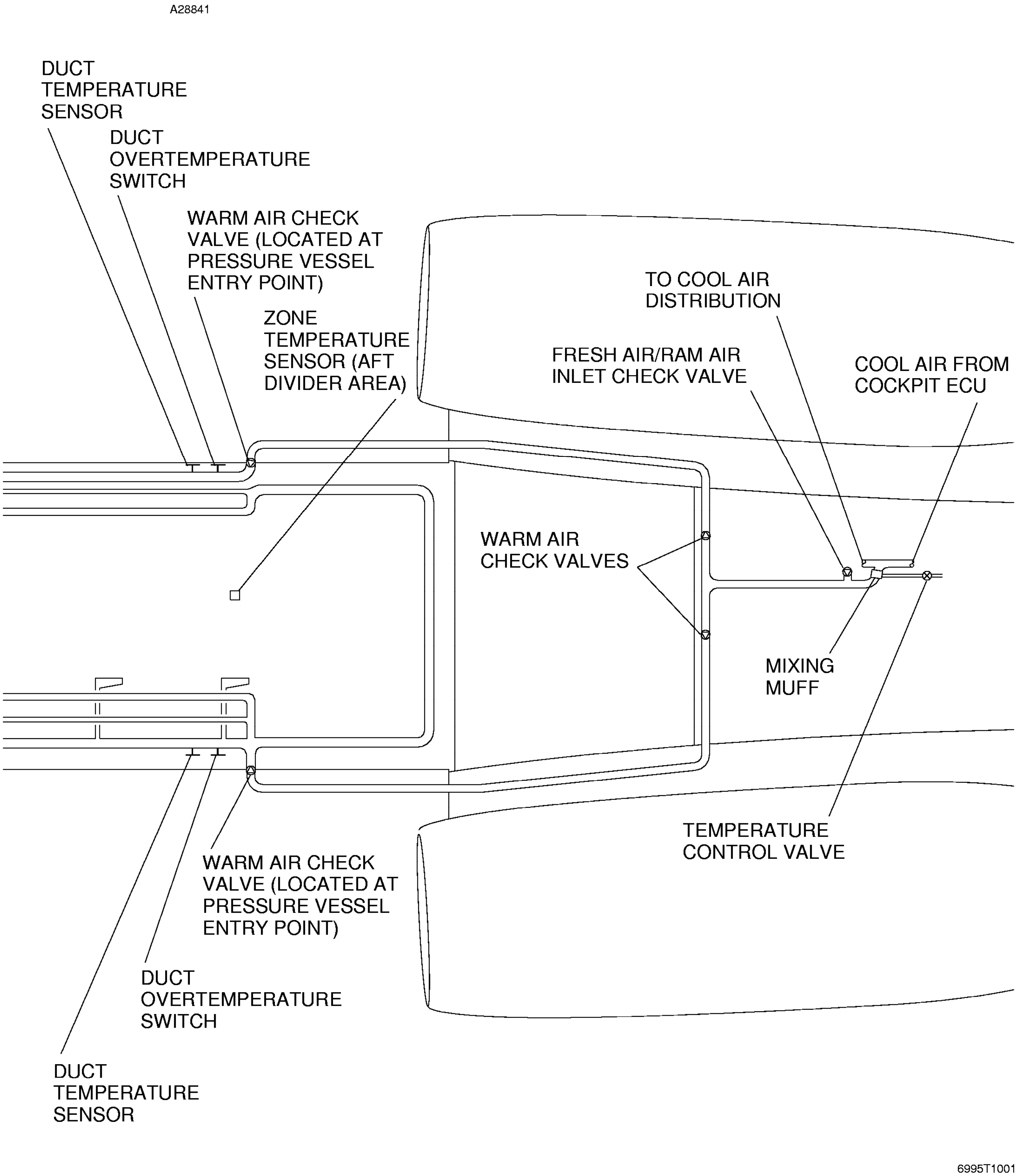

Figure 2-30 (Sheet 2)