CHAPTER 21 - ENVIRONMENTAL CONTROL

TABLE OF CONTENTS

LIST OF FIGURES

GENERAL

The ECS (Environmental Control System) is designed to provide adequate levels of purity, humidity, temperature and pressure on aircraft compartments, on ground and airborne.

The environmental control is possible by means of:

- ***Compression Stage:*** compressed air from engine compression stage is bled from both engines, delivering it to the cooling pack at the proper pressure and temperature (refer to CHAPTER 36 - PNEUMATIC).
- ***Temperature Control:*** a double temperature control valve, placed just before each cooling pack, allows setting temperature in the cockpit and cargo cabin independently.
- ***Cooling Pack:*** two separate air conditioning packs are fitted with a compressor-turbine set and heat exchangers to cool the compressed air from the related engine.
- ***Distribution and Recirculation:*** air from cooling packs is driven to the cockpit and cargo compartment separately. Several fans are installed along the aircraft to ensure avionics compartments cooling and constant airflow in cockpit and cargo cabin.

  There are two fans to cool the underfloor compartment.
- ***Pressurization Control:*** two outflow valves control pressurization inside the aircraft and maintain differential pressure inside limits.

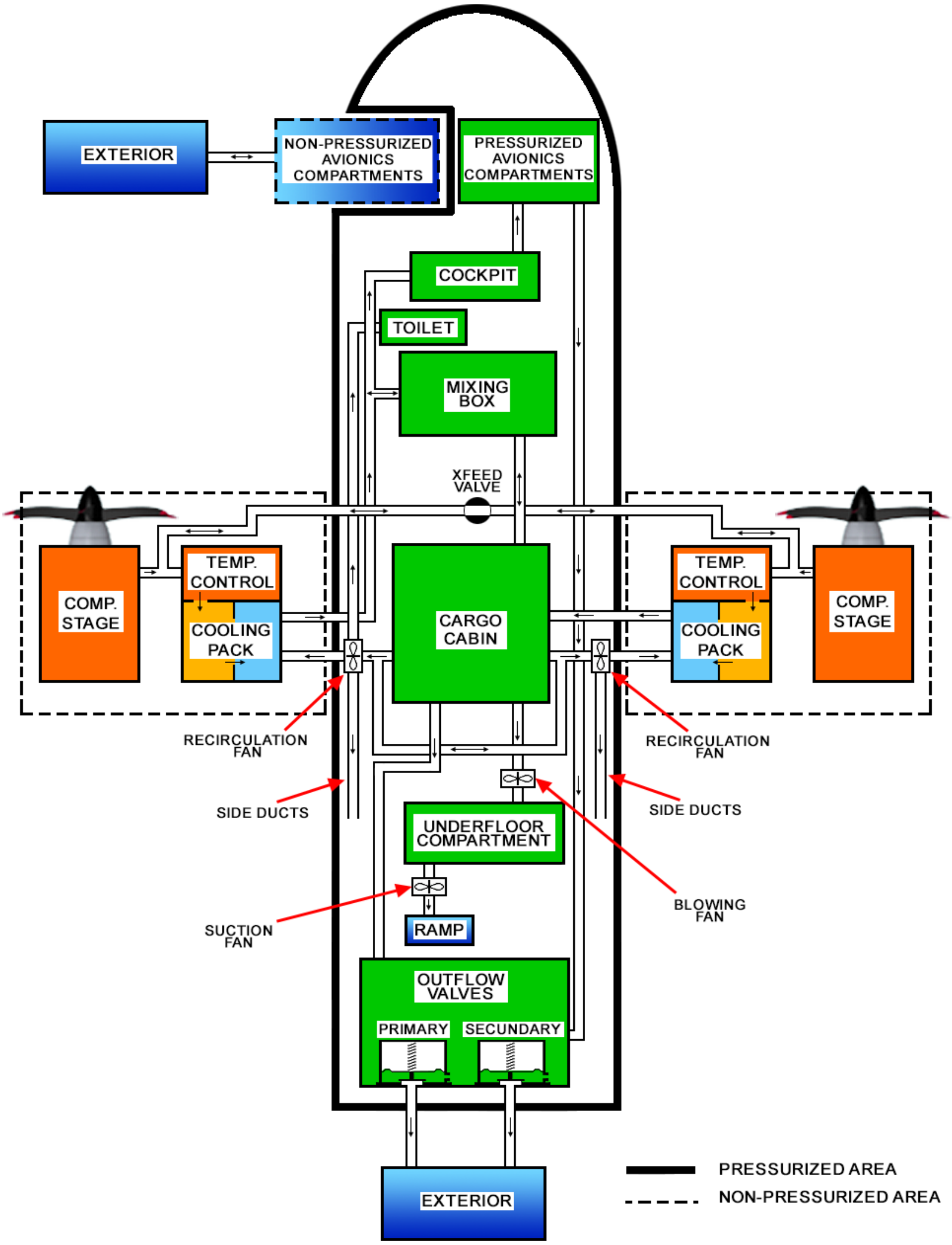


Figure 21-1 Environmental Control - Architecture

There are also exterior air inlets located around the aircraft.

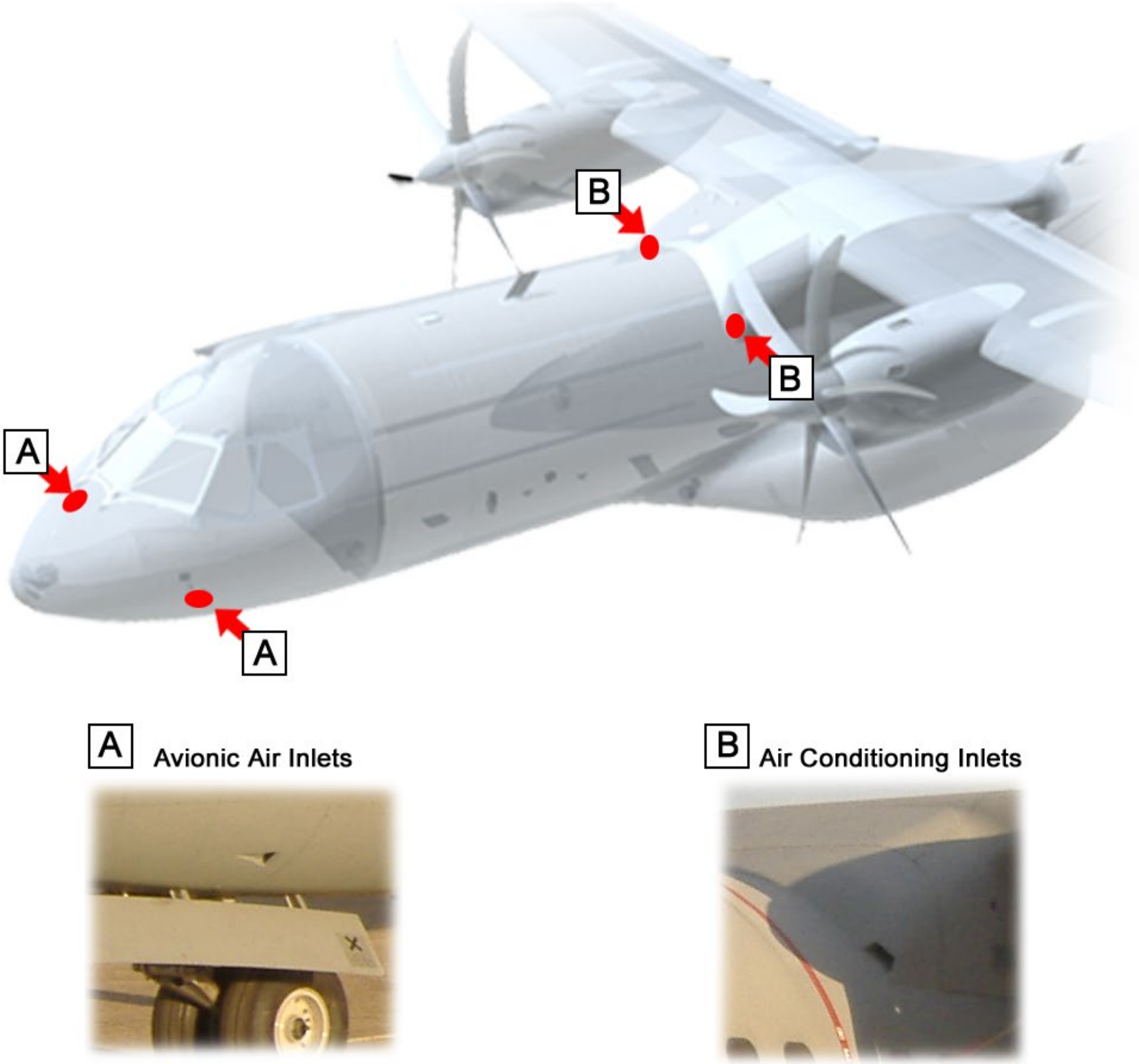


Figure 21-2 Aircraft Air Inlets

TEMPERATURE CONTROL

The air conditioning temperature control includes those components and units to detect, control and display the air temperature, which is going to be used in pressurized areas.

DESCRIPTION

The main components are:

– ***Double Temperature Control Valves:*** located just before each air conditioning pack, and are electrically operated by automatic or manual temperature controllers.

– ***Automatic Temperature Controllers:*** one for the cockpit and another for the cargo compartment, they adjust the shortage or the excess of temperature, in relation to the desired temperature set, regulating the double temperature control valves.

– ***Manual Temperature Controller:*** it receives input signals from the TEMP CONTROL (CKPT, CAB) knobs to adjust the double temperature control valves.

– ***Temperature Sensors:*** there are two temperature sensors, one in each air conditioning pack discharge (send signals to the automatic temperature controllers), another two in the cockpit/cargo cabin manifold supply (send signal to O.TEMP MAN pushbutton), and another four in the cockpit/cargo cabin (two of them send signal to automatic temperature controllers and the other two to the CABIN TEMP indicator).

– ***AIR CONDITIONING Control Panel:*** located in the overhead panel, enables system management and monitoring.

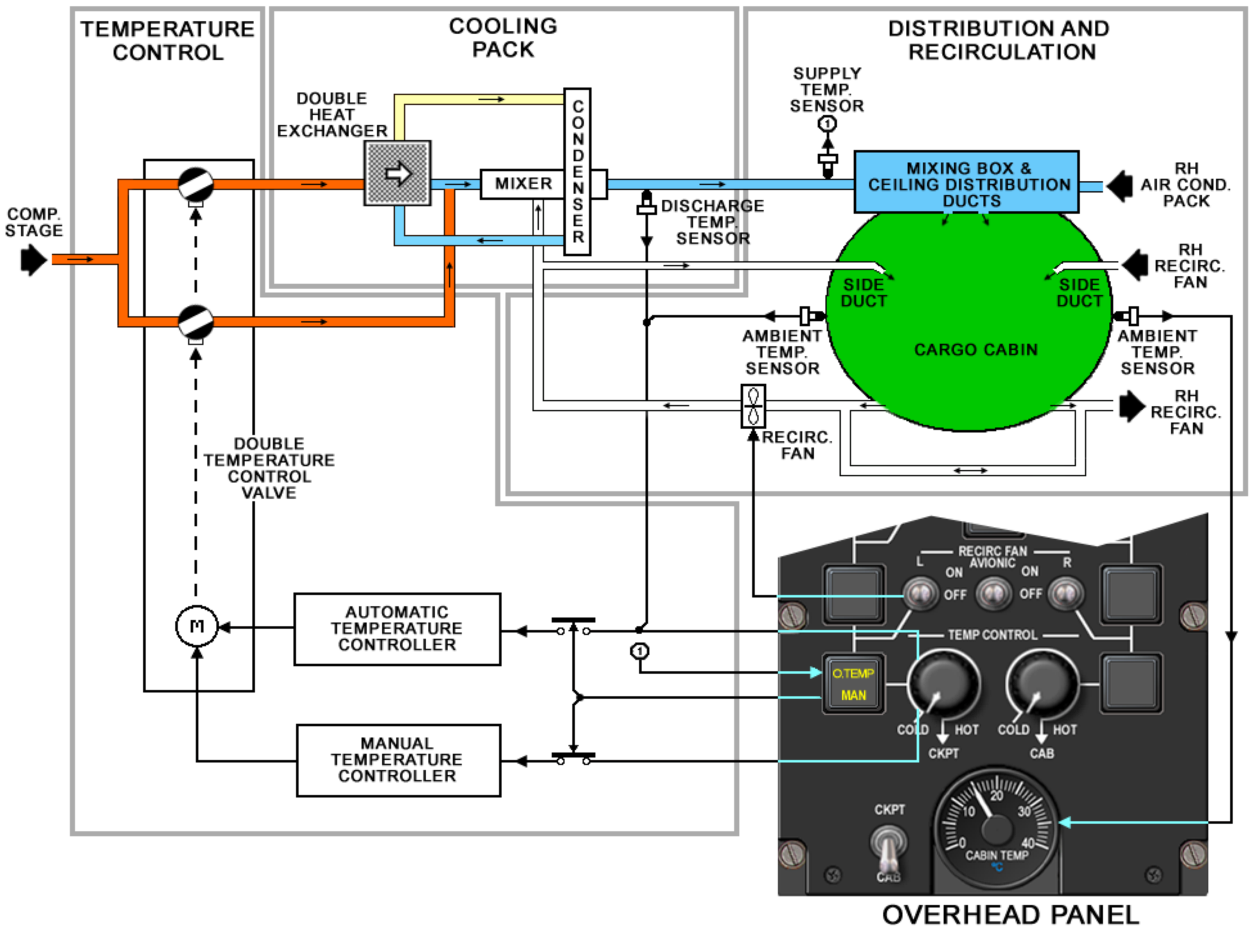


Figure 21-3 Temperature Control - Architecture

OPERATION

The system has two modes of operation:

– ***Automatic Mode:*** the temperature is automatically controlled by automatic temperature controllers and setting the TEMP CONTROL (CKPT, CAB) knobs at the desired temperature. In this configuration, the automatic temperature controllers compare input signals from cockpit or cargo cabin temperature sensors, the related air conditioning pack discharge temperature sensor and the TEMP CONTROL (CKPT, CAB) knobs to adjust the double temperature control valves.

– ***Manual Mode:*** the manual temperature controller is not able to adjust automatically, so crewmembers are responsible to adjust the temperature through TEMP CONTROL (CKPT, CAB) knobs and checking the temperature in the CABIN TEMP indicator.

In these two modes, temperature is controlled by the double temperature control valves, allowing hot bleed air flow regulation to the primary and secondary heat exchanger from one valve, and directly to the turbine (without passing across heat exchangers) from the other valve. The two flows of air come together in the turbine to be led to the mixer.

CONTROLS AND INDICATORS

(1) O.TEMP / MAN Pushbuttons:

- *O.TEMP (amber) light on:* the system has detected a temperature above 88ºC in the manifold supply. The light will remain while having over temperature. This light can be turned on in automatic or manual mode.
- *Pressed (amber MAN light on):* the system is in manual mode.

(2) TEMP CONTROL (CKPT, CAB) Knobs:

select the average temperature in the cockpit (CKPT) and cargo cabin (CAB). The range of the average temperature is approximately from 18ºC to 30ºC.

(3) CABIN TEMP Indicator:

shows the temperature, in Celsius degrees, of the selected compartment from 0ºC to 40ºC.

(4) Indicated Temperature Selector:

- *CKPT:* the CABIN TEMP indicator shows the cockpit temperature.
- *CAB:* the CABIN TEMP indicator shows the cargo cabin temperature.

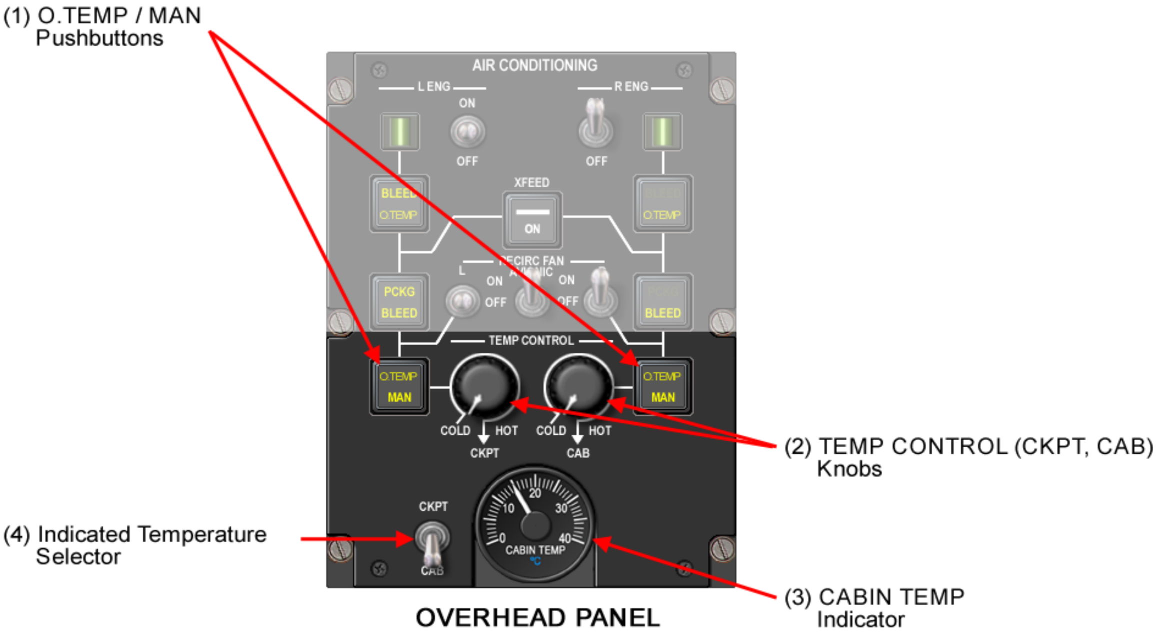


Figure 21-4 Temperature Control - Controls and Indicators

COOLING PACK

Its function is to cool the compressed bleed air from engines, in order to satisfy the demanded temperature selected by crewmembers in each compartment, cockpit and cargo.

DESCRIPTION

The system includes two independent air conditioning packs, which receive compressed bleed air from their engine. Packs are equipped with all necessary components to provide outlet cool air with adequate purity, humidity and temperature regulation. They are located in the belly fairing.

The main components are:

– ***Air-conditioning Packs:***
  - ***Double Temperature Control Valves:*** (refer to TEMPERATURE CONTROL, in this chapter).
  - ***Double Heat Exchanger:*** there are two air-to-air heat exchangers (primary and secondary) in each pack exposed to ram air inlet in order to cool hot bleed air from the engine in the primary heat exchanger and from the ACM (Air Cycle Machine, in concrete Compressor) in the secondary heat exchanger.
  - ***ACM (Air Cycle Machine):*** is compound by a fan, which forces ram air to pass across the two heat exchanger, a compressor, which compress and warms bleed air from the primary heat exchanger, and a turbine, which expand and cools bleed air from the secondary heat exchanger. The fan, the compressor and the turbine are part of the same shaft.
  - ***Condenser:*** it is responsible for the purity and humidity process.
  - ***Water separator:*** it is responsible for the purity and humidity process.

– ***AIR CONDITIONING Control Panel:*** (refer to CHAPTER 36 - PNEUMATIC).

OPERATION

Hot air is bled from compressor stage in each engines, then led to the Double Temperature Control Valve (DTCV), where the hot stream is split, part of it goes toward heat exchangers (Main flow) and compressor-turbine set and the other part is directly led to the turbine (Secondary flow). The DTCV controls either rate flows, how much is going to be cooled, or not in relation to the crewmembers temperature setting.

To decrease the temperature, the main flow rate is increased and the secondary flow is decreased. To increase the temperature, the main flow rate is decreased and the secondary flow is increased. The main flow goes to the primary heat exchanger, where it is partially cooled by ram air. It is then led to the compressor of ACM where its pressure increases as well as its temperature. In order to limit hot temperature after being compressed in the compressor of ACM, the flow is led to a secondary heat exchanger.

To cut down the high humidity existing after this process, the flow is led through the hot side of the Condenser/Mixer forcing the condensation. A high-pressure water separator is the responsible to remove water condensation (the water recovered is atomized in the dynamic air inlet at the heat exchangers entry).

The cool dry air is then used to drive the turbine of the ACM, which drives the centrifugal compressor and the fan of the ACM, allowing the system to operate autonomously when the aircraft is parked or at slow speed.

The fan is used to force the ram airflow to impact both heat exchangers, assuring optimum cooling process. When the main flow has passed across the turbine of the ACM, it is mixed with the secondary flow where the temperature is controlled by air conditioning pack discharge sensor which sends a signal to automatic temperature controller.

To reduce bleed air extracted from the engines, thus allowing more power available, the air from cargo compartment is recirculated and mixed in the condenser/mixer and then lead again to the flow distribution system.

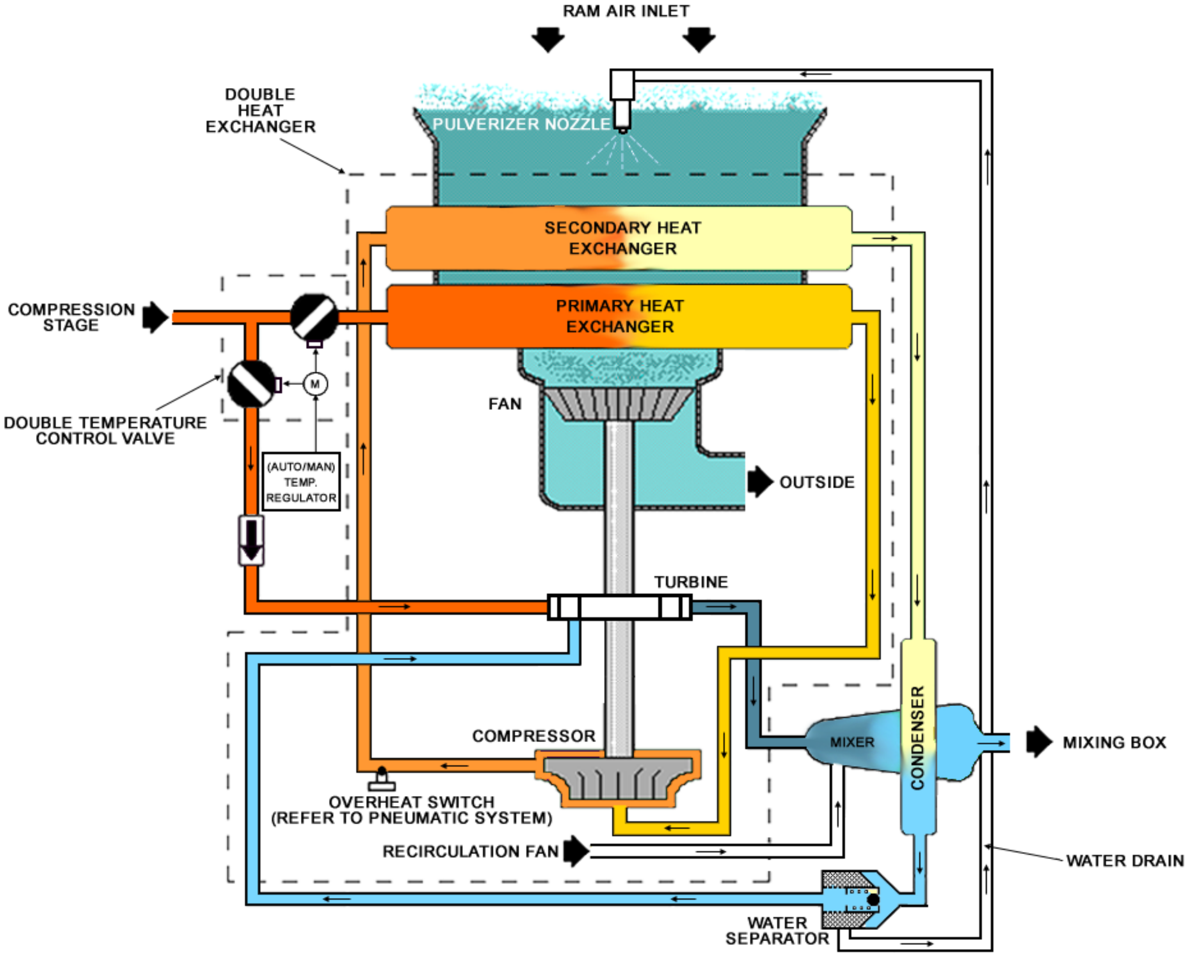


Figure 21-5 Cooling Pack

DISTRIBUTION AND RECIRCULATION

Its function is to distribute uniformly the air previously conditioned around pressurized areas. The avionics cooling is also included in the distribution system.

DESCRIPTION

Part of the air the cargo compartment is recirculated to reduce bleed air.

The main components are:

- ***Ceiling Distribution Ducts and Outlets:*** located around the cockpit and the ceiling of the cargo cabin, uniformly distribute air conditioned.
- ***Recirculation Fans:*** located in the floor of the cargo cabin, two centrifugal fans (one per pack) collect air from the cargo cabin to recirculate it.
- ***Avionics Fans:*** located in the cockpit and cargo cabin floor, three avionics fans which cool the avionics equipments in pressurized and non-pressurized compartments.
- ***Underfloor Compartment Fans:*** two fans, a blowing and suction fan which are intended to ventilate the underfloor and extract the heat from it.
- ***AIR CONDITIONING Control Panel:*** located on the overhead panel, enables system management and monitoring.
- ***FOOT HEAT Knobs:*** located in both consoles, control the foot heat outlets.

OPERATION

The left hand air conditioning pack supplies air conditioning to the cockpit and the right hand air conditioning pack to the cargo cabin. There is a small junction between the left and right air conditioning systems, in the mixing box, to ensure an adequate flow distribution to each area, and a continuous supply of air to both compartments. Then, if one of them fails, the remaining one supplies air to both compartments through the connection in the mixing box.

The air conditioning is supplied to the cockpit through two ceiling outlets, two console outlets (butterfly type valves) and two foot outlets in the foot area. Air is also supplied to the windshield for demisting purpose (refer to CHAPTER 30 - ICE AND RAIN PROTECTION).

The air conditioning is supplied to the cargo cabin through ceiling outlets.

The recirculation fans take air from the cargo cabin to move part of it to the side ducts in the cargo cabin, and to the mixer section of the condenser/mixer in both packs (this action prevents ice formation inside the condenser section of the condenser/mixer). In case of a recirculation fan failure, the remaining one is able to recirculate air for both packs due to the interconnection between both recirculation systems (preventing ice formation in both condensers).

The left hand recirculation fan also supplies air to the toilet.

There is also a connection between the recirculation system and the cabin smoke detection (refer to CHAPTER 26 - FIRE PROTECTION).

The underfloor ventilation system consists in two fans located under the floor in the cargo cabin. The blowing fan extracts air from the recirculation system and introduces it into the underfloor through the outflows of a ventilation line. A suction fan extracts hot air from the underfloor through the intakes of a ventilation line running along the underfloor and discharges the hot air in the ramp area in order not to affect the cabin ambient temperature.

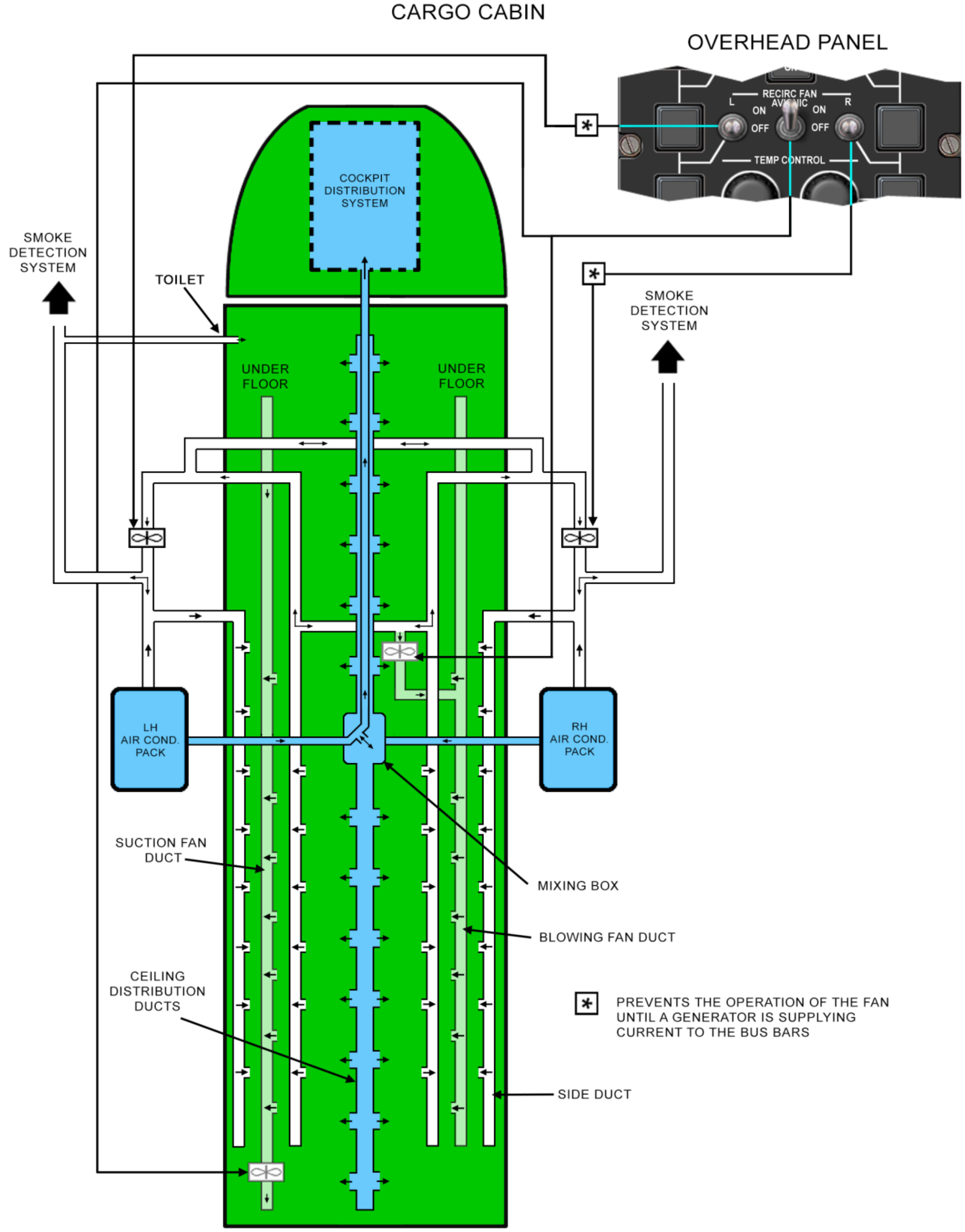


Figure 21-6 Distribution and Recirculation in the Cargo Cabin

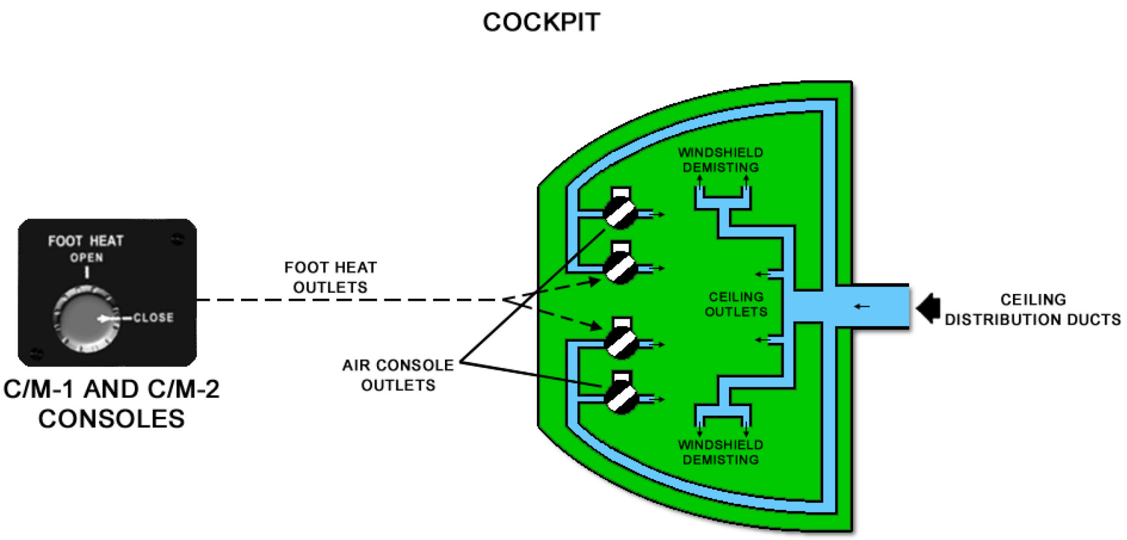


Figure 21-7 Distribution and Recirculation in the Cockpit

Pressurized avionics compartments are cooled by air intakes from the cockpit, which led it across manifolds, to end around avionics equipments. It is possible thanks to a fan placed under the floor in the cargo cabin. This fan is also responsible to extract the air previously put in the pressurized avionics compartments to prevent heat dissipated from avionics equipments, and it is discharged near the outflow valves to be expulsed out of the aircraft.

A pair of axial fans, which take air from the cockpit, cool non-pressurized avionics compartments on ground. While airborne, only two NACA ram air inlets can cool these non-pressurized avionics compartments.

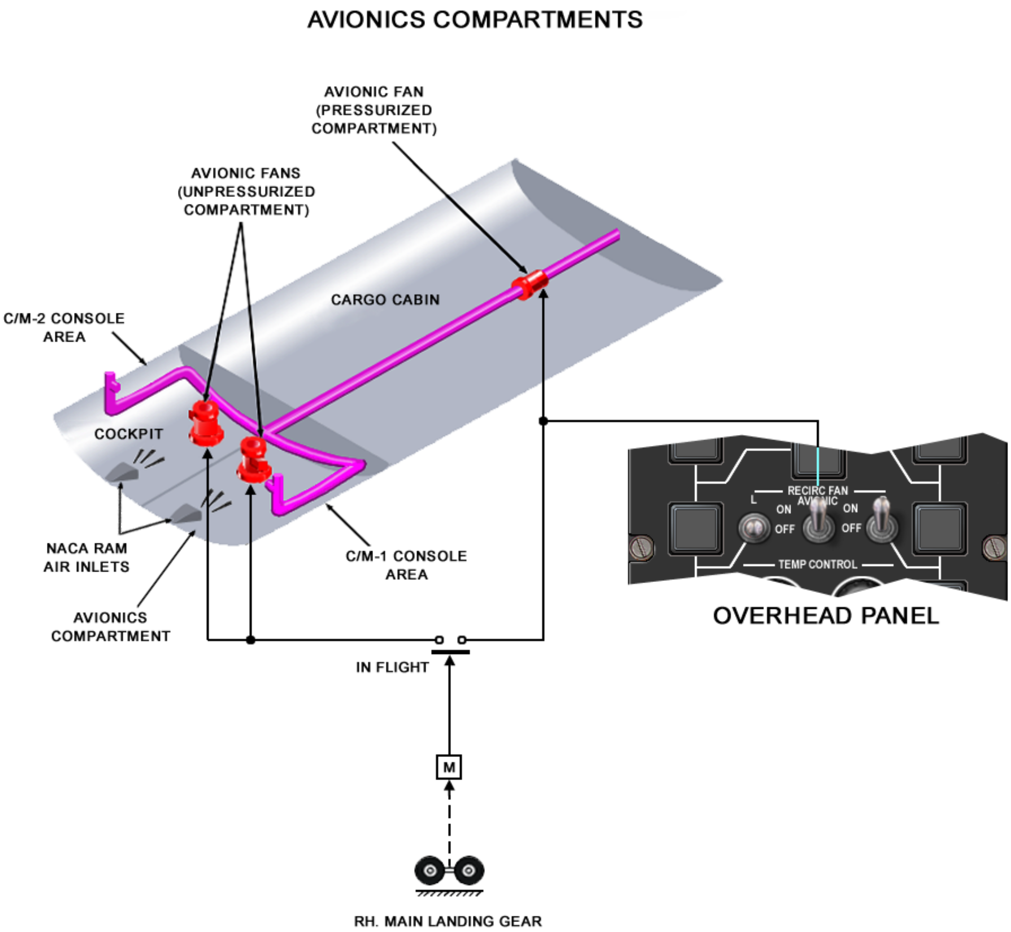


Figure 21-8 Distribution and Recirculation in the Avionics Compartments

CONTROLS AND INDICATORS

(1) RECIRC FAN (L, R) Switches:

- *ON:* turns on the recirculation fan only on its side.

(2) RECIRC FAN AVIONIC Switch:

- *ON:* turns on the avionic fans.

  Also turns on the underfloor compartment fans.

(3) ECS FANS Pushbutton:

- *Pressed:* verifies annunciators status on ECS FANS pushbutton.
- *APB (amber) light on:* there is a malfunction in the avionics fans.
- *UV (amber) light on:* there is a malfunction in the underfloor blowing fan.
- *UE (amber) light on:* there is a malfunction in the underfloor suction fan.

(4) FOOT HEAT Knob:

- *OPEN:* foot outlet is fully opened.
- *CLOSE:* foot outlet is closed.

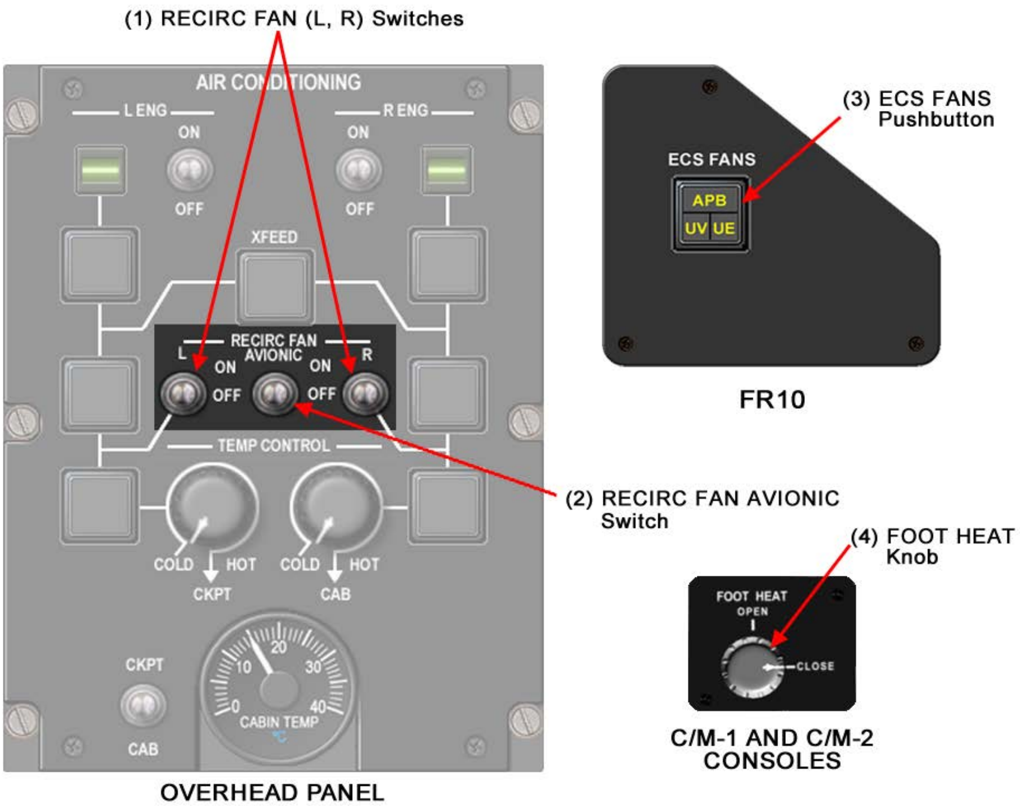


Figure 21-9 Distribution and Recirculation - Controls and Indicators

PRESSURIZATION CONTROL

Its function is to create a controllable pressure atmosphere inside the aircraft, without exceeding structural limits (maximum differential pressure allowed is 5.77 psi).

DESCRIPTION

The pressurized area includes cockpit, cargo cabin and pressurized avionics compartments and are sealed areas. Door microswitches (included cargo door) configuration allows crewmembers to know through the external doors lights indicator if pressurization is possible. The air conditioning system is the responsible for injecting compressed air inside the pressurized area in order to increase differential pressure between the inside and outside of the aircraft.

The main components are:

- ***Primary and Secondary Outflow Valves:*** located in the ramp, their function is to extract air or not, as required, from the pressurized aircraft area to maintain pressurization inside correct ranges in either automatic or manual mode.
- ***Static Ports:*** there are two, they supply static pressure to the outflow valves.
- ***Automatic Pressure Controller:*** in automatic mode, controls the electro-pneumatic transfer valve according to the pre-recorded program.
- ***Safety Valves:*** there are four safety valves, two for maximum positive (+5.67) and two for maximum negative (-0.47) differential pressure.
- ***Cabin Pressure Indicators:*** enables to check differential pressure, cabin altitude and cabin rate of climb.
- ***Cabin Pressure Control Panel:*** enables system management and monitoring.

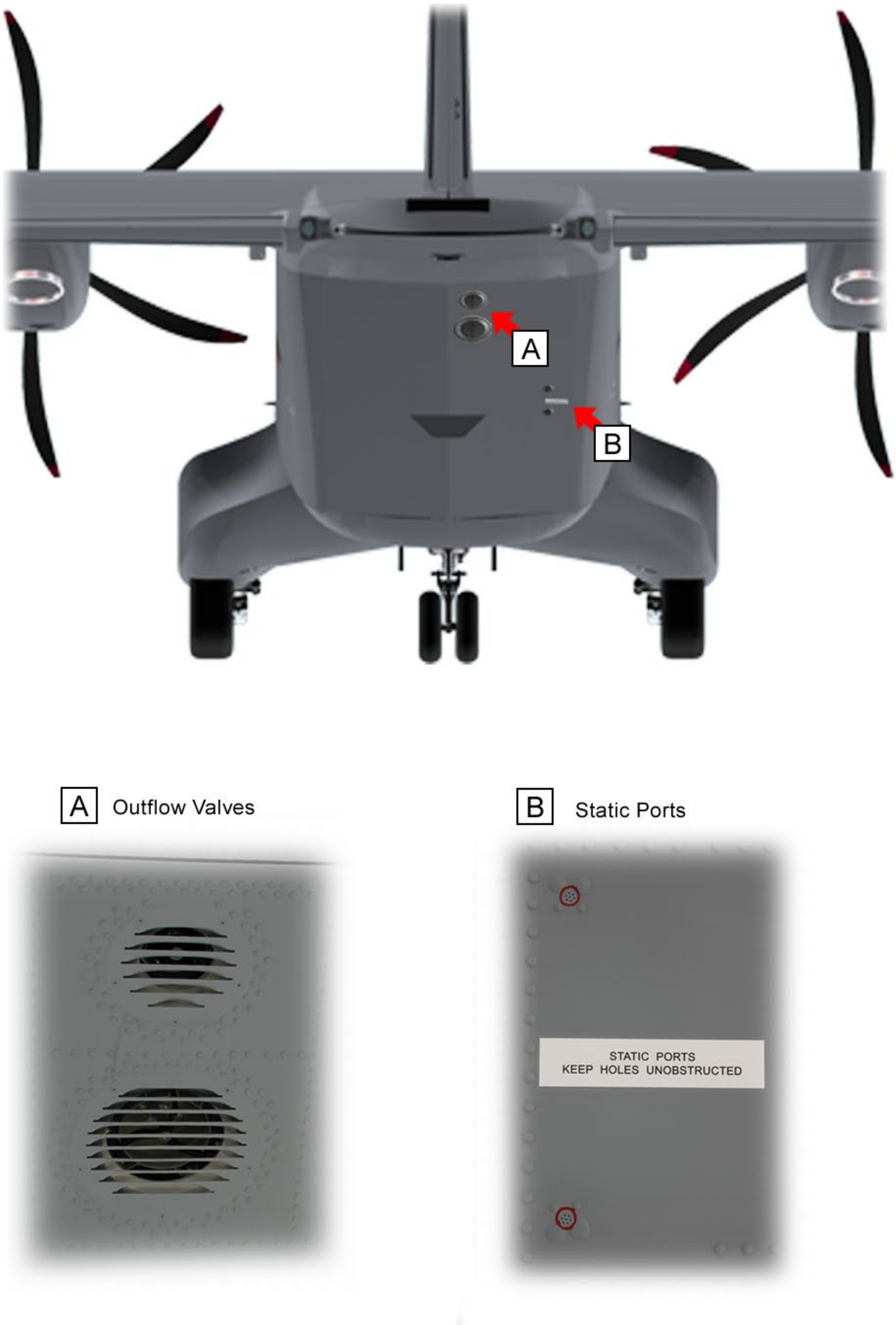


Figure 21-10 Pressurization Control - Components

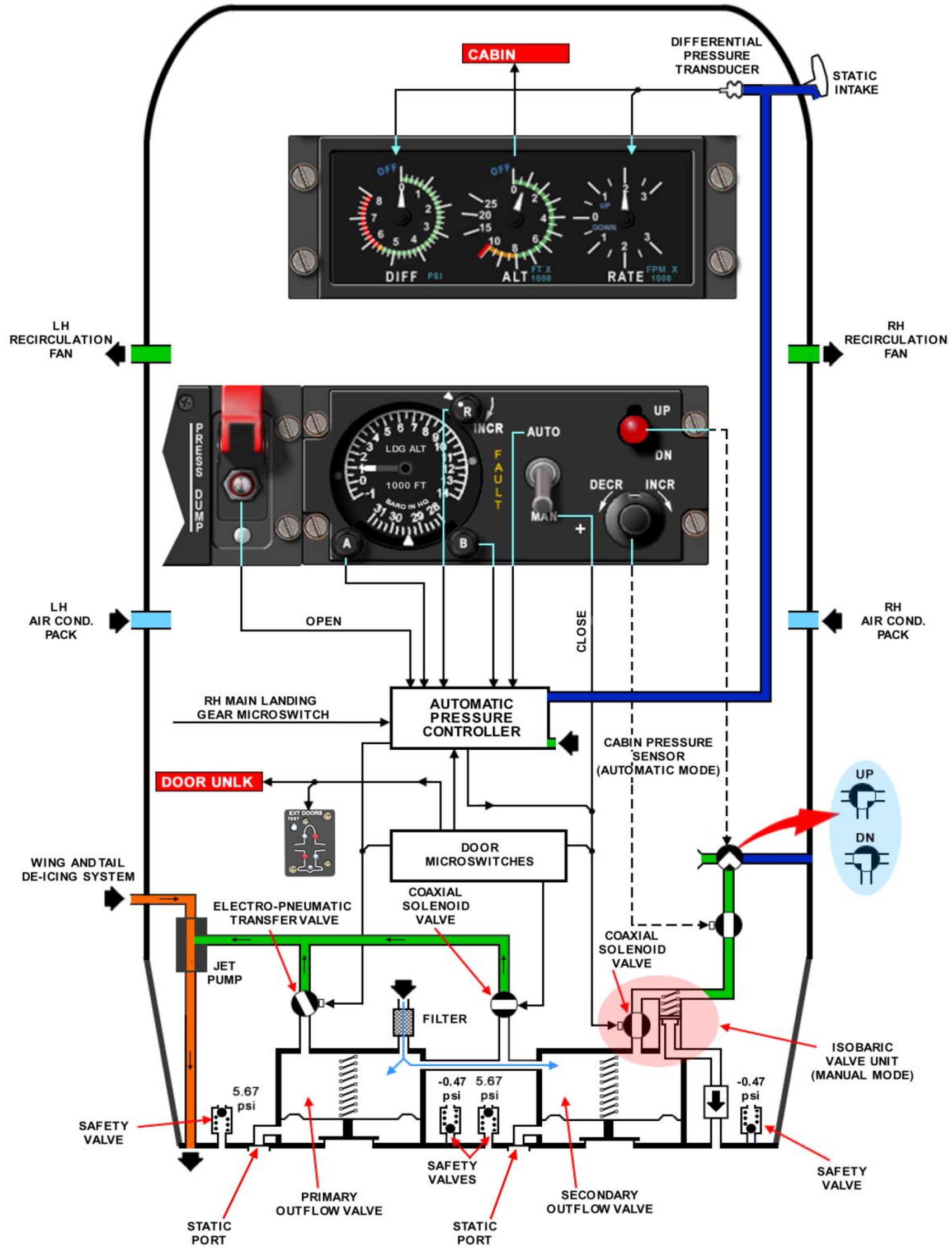


Figure 21-11 Pressurization Control System

OPERATION

The system has two modes of operation:

– Automatic Mode
– Manual Mode

These modes are only available if all the doors are closed, because if one of the doors or cargo ramp is unlocked (refer to CHAPTER 52 - DOORS), the coaxial solenoid valve will be open, resulting in the impossibility to pressurize the aircraft

In both modes, if the cabin altitude is above 10000 feet, the CABIN caution will be displayed in the IEDS.

AUTOMATIC MODE

To configure the aircraft in automatic mode, the pressurization mode selector must be set in AUTO. In this configuration, the system carries out a PBIT meanwhile FAULT light comes on for 3 seconds. At this moment, the primary outflow valve is controlled by the automatic pressure controller, and the secondary outflow valve is a slave one. The electro-pneumatic transfer valve and the jet pump, which carries out a pressure reduction by Venturi phenomena, regulate the process of opening the two outflow valves. The automatic mode keeps the differential pressure always below 5.58 psi.

The crewmembers just have to set landing altitude, rate of cabin vertical speed and airfield pressure in the related A,R and B knobs. The system is then controlled by the automatic pressure controller.

If the SOV (Shut Off Valve) of the wing and tail de-icing system is closed, automatic mode is not available (refer to CHAPTER 30 - ICE AND RAIN PROTECTION).

To understand the automatic mode, the operation is briefly described for each flight phase:

– ***On ground:*** the automatic pressure controller receives a signal from the right main landing gear switch, and when the engines are working, the outflow valves open to keep differential pressure at zero. In take-off run, when PL's are increased, the outflow valves start closing in order to pre-pressurize the aircraft decreasing the cabin altitude 140 ft below the airfield altitude to damp pressure variation in the take-off phase.
– ***Climb:*** once airborne, the automatic pressure controller regulates the outflow vales in order to increase the cabin altitude, initially at or below that of the R knob setting. The selected rate will be the maximum the cabin can get, provided the aircraft does not climb at an abnormally high rate.
– ***Cruise:*** the automatic pressure controller reverts to cruise mode when the vertical speed is at or less than 100 fpm. Below 19500 ft, the differential pressure will be lower than 5.58 psi, and starting from 19500 ft, the differential pressure will be 5.58 psi. The cabin pressure will be different at every flight level.
– ***Descent:*** the automatic pressure controller reverts to descent mode when the vertical speed is -200 fpm or more. The outflow valves are open to decrease cabin altitude at or below that of the R knob setting.
– ***Landing:*** when landing, the automatic pressure controller receives a signal from the right main landing gear switch and opens the outflow valves to reduce to zero the differential pressure.

The following figure shows the most common pressurization profiles in AUTO mode, according to the program which regulates and limits the automatic pressure controller.

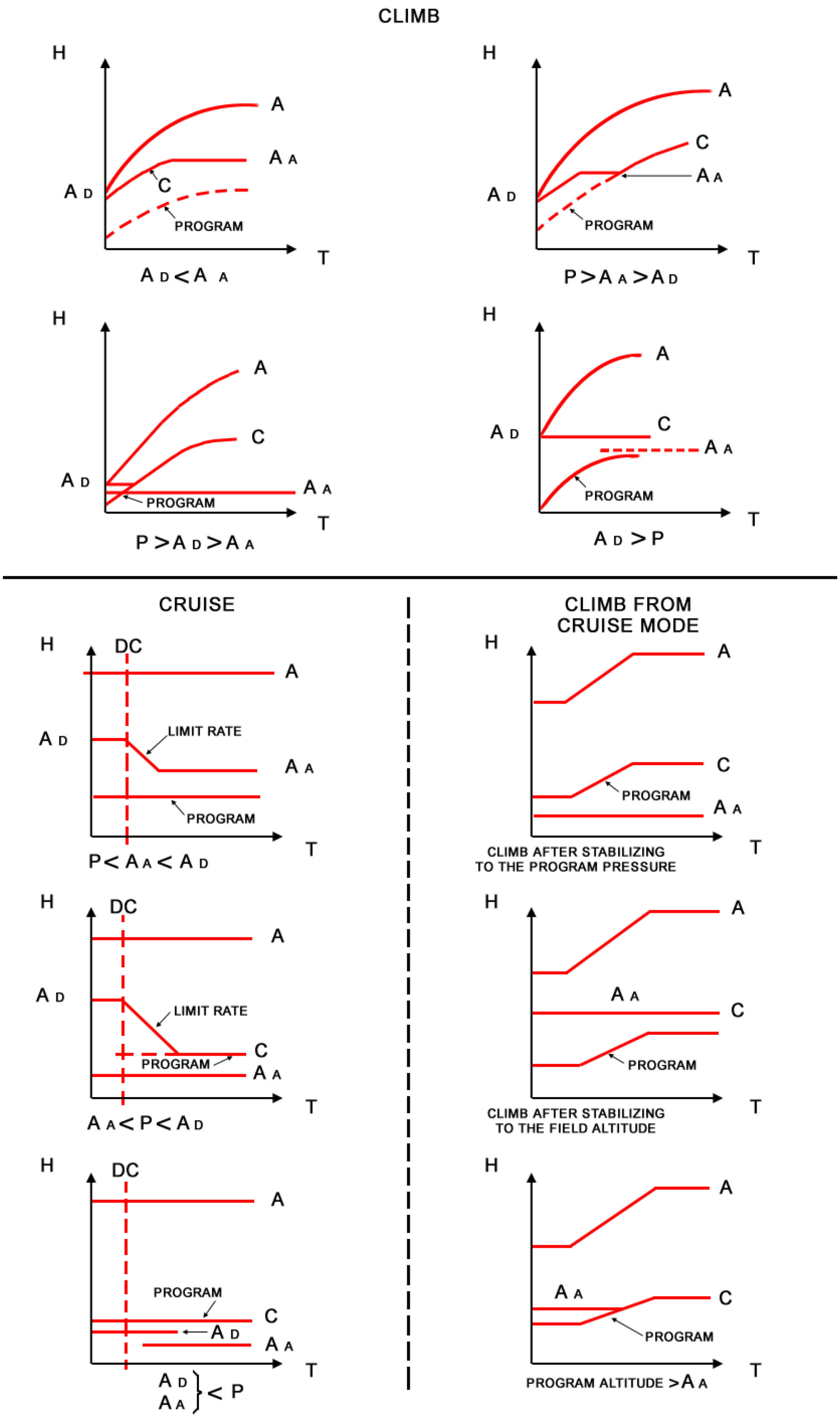
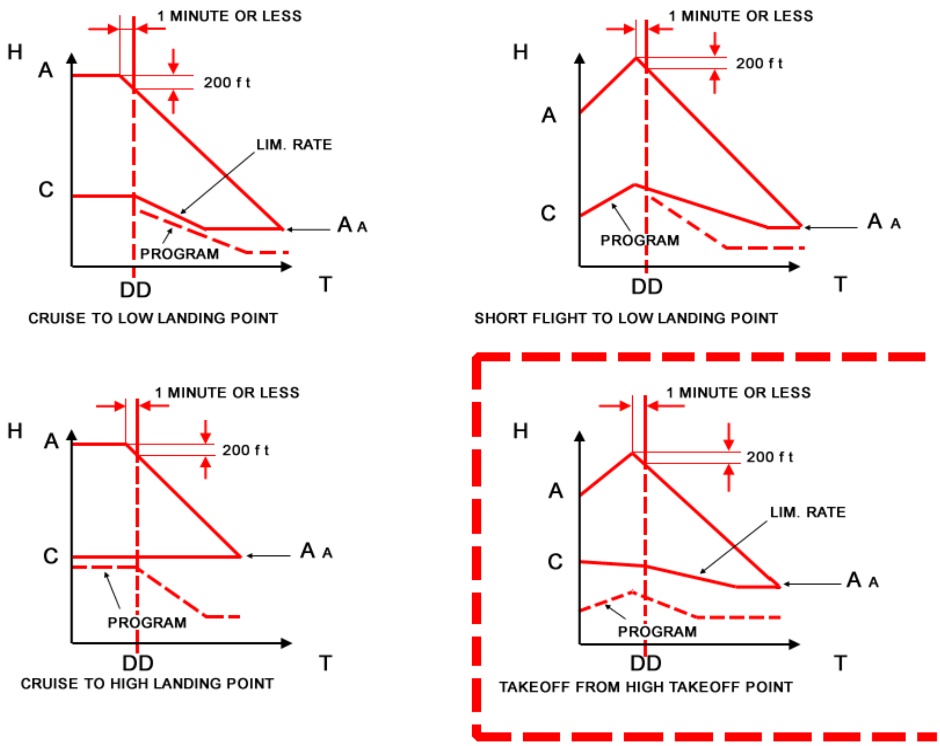
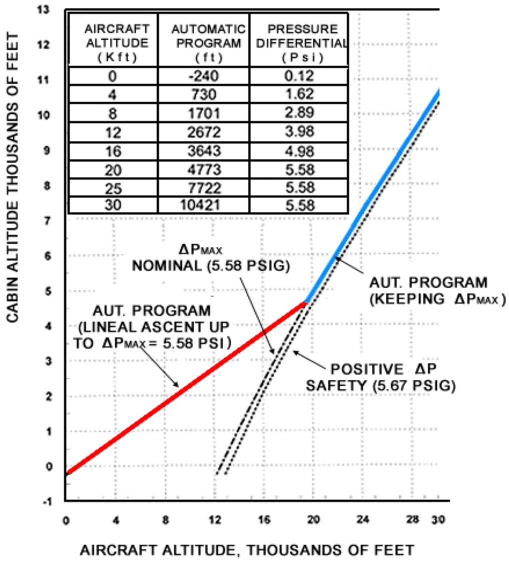


Figure 21-12 Pressurization Control - Automatic Operating Profiles (Sheet 1 of 2)

DESCENT MODE



ALTITUDE COMPARATIVE GRAPHIC



AIRCRAFT ALTITUDE (Kft)	AUTOMATIC PROGRAM (ft)	PRESSURE DIFFERENTIAL (Psi)
0	-240	0.12
4	730	1.62
8	1701	2.89
12	2672	3.98
16	3643	4.98
20	4773	5.58
25	7722	5.58
30	10421	5.58

KEY

H = ALTITUDE
T = TIME
A = AIRCRAFT ALTITUDE (Pext)
C = CABIN ALTITUDE (Pint)
A_D= TAKEOFF FIELD ALTITUDE
A_A= LANDING FIELD ALTITUDE
P = AUTOMATIC PROGRAM ALTITUDE
DC= CRUISE MODE DETECTION POINT
DD= DESCENT MODE DETECTION POINT
C_R= CRUISE

Figure 21-12 Pressurization Control - Automatic Operating Profiles (Sheet 2 of 2)

MANUAL MODE

To configure the aircraft in manual mode, the pressurization mode selector must be set in MAN. In this configuration, the automatic pressure controller is disengaged and manual control is available through the isobaric valve unit, which closes its coaxial solenoid valve. Moreover, the primary outflow valve becomes the slave one.

The manual cabin altitude selector is used to send a signal to the isobaric valve unit, forcing the secondary outflow valve to open or close. The crewmembers can manually select or regulate the rate using the manual cabin rate of change knob.

NOTE

Moving selector to MAN position, cabin pressure increases in approximately 0.7 PSI.

NOTE

In manual mode, a residual differential pressure remains even after landing. This must be removed by setting the manual cabin altitude selector switch to UP, and by using the PRESS DUMP switch

In order to fully depressurize the cabin in manual mode, it is necessary to keep the Manual Cabin Altitude Selector in the UP position, then move to ON the PRESS DUMP switch, in order to release the residual differential pressure.

AUTOMATIC TO MANUAL MODE

The change from automatic to manual mode is available, if the pilot desires so, selecting MAN in the pressurization mode selector. In manual mode, the coaxial solenoid valve in the isobaric valve unit closes keeping the last reference pressure in the isobaric valve unit control chamber. At the same time, disconnection of the power supply from the automatic pressure controller closes the electro-pneumatic transfer valve, causing the primary outflow valve to use the pressure of the secondary outflow valve as reference.

CONTROLS AND INDICATORS

(1) R Knob:

- *Fully turned to the left:* rate of climb and descent are 0 (+/- 50) fpm.
- *Facing the bug and the triangle marks:* maximum rate of climb is 600 fpm and maximum rate of descent is 400 fpm.
- *Fully turned to the right (INCR):* maximum rate of climb is 2500 (+/- 50) fpm and maximum rate of descent is 1666 (+/- 50) fpm.

(2) Manual Cabin Altitude Selector:

- *UP:* increases the cabin altitude.
- *DN:* decreases the cabin altitude.

(3) Pressurization Mode Selector:

- *AUTO:* the automatic mode is engaged.
- *MAN:* the automatic pressure controller is disconnected.

(4) Manual Cabin Rate of Change Selector:

- *INCR:* increases manually the rate of change of the cabin altitude.
- *DECR:* decreases manually the rate of change of the cabin altitude.

  The range available is from 100 to 3500 fpm when the manual cabin altitude selector is in UP.

  The range available is from 500 to 3000 fpm when the manual cabin altitude selector is in DN.

(5) FAULT Light:

- *On:* a failure has been detected.

  It also comes on momentarily if the PRESS DUMP switch is set to ON, or if any of the door or ramp micro-switches is open.

(6) B Knob:

adjusts the QNH (real pressure at the related airfield) to correct pressure from the standard atmosphere.

(7) A Knob:

adjusts the airfield altitude (elevation).

(8) LDG ALT Indicator:

it shows A and B selections.

(9) PRESS DUMP Switch (Under Guard):

- *On:* opens the two outflow valves.

(10) Differential Pressure Indicator:

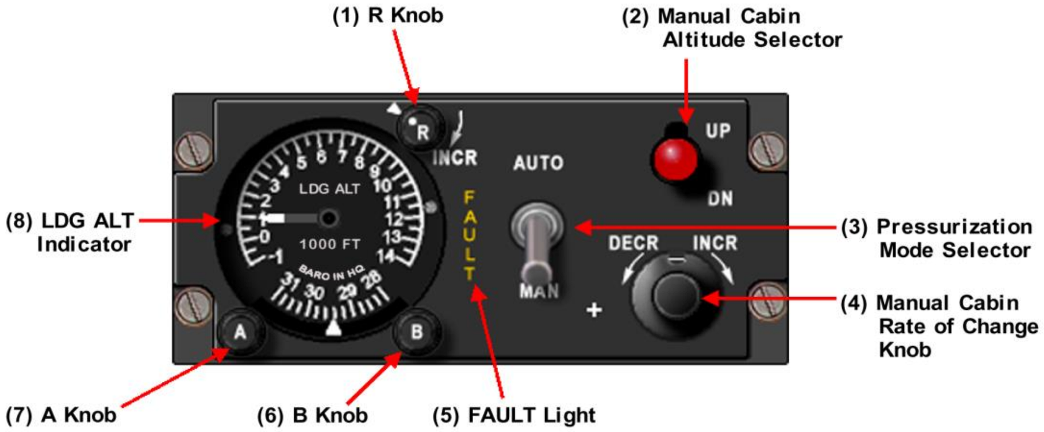
shows the differential pressure (in psi) between pressurized area of the aircraft and the exterior static pressure.

(11) Cabin Altitude Indicator:

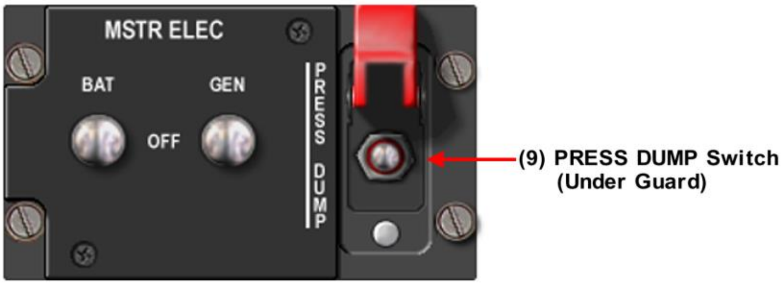
shows the altitude (in thousands of feet) of the pressurized area of the aircraft.

(12) Cabin Rate of Change Indicator:

shows the rate of change (in thousands of feet per minute) for the pressure altitude of the pressurized area.



OVERHEAD PANEL



OVERHEAD PANEL

OVERHEAD PANEL

Figure 21-13 Pressurization Control - Controls and Indicators

Intentionally Left Blank