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CHAPTER 6: AIR-CONDITIONING SYSTEMS

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INTRODUCTION

Modern commercial aircraft are required to operate in the extremes of the atmosphere, at altitudes above 35,000 FT with temperatures of -55°C and land at airfields with temperatures of +50°C. Throughout these operating extremes passengers must be supplied with a comfortable environment in which to travel.

Other considerations are that the sophisticated electronic equipment and computers used in today's aircraft require specific temperature ranges to operate efficiently. Additionally, cargo bays require special attention as the commercial airfreight of fresh produce and livestock continues to grow.

Modern airliners which now may carry in excess of 500 passengers require multiple complex computer controlled airconditioning units to achieve these requirements.

Small and medium sized aircraft obviously do not need complex systems like the ones found on large commercial aircraft and therefore a wide variety of airconditioning systems is present in aircraft today. Airconditioning systems are divided into two basic groups. They are;

- systems for unpressurised aircraft, and
- systems for pressurised aircraft.

UNPRESSURISED AIRCRAFT

Unpressurised aircraft normally operate up to 10,000 FT and being mostly "light" aircraft cannot afford to add the additional weight of a system that will provide refrigerated air on the ground or at lower altitudes. These aircraft depend on the fact that as altitude increases the ambient air temperature decreases.

A system to heat incoming cold ram air is normally all that is required for this type of aircraft.

PRESSURISED AIRCRAFT

Pressurised aircraft may vary in size from small corporate to large jet transport aircraft and depending on the number of passengers carried and the interior air volume will have multiple variations of refrigerated airconditioning systems. The systems will of course generally provide airconditioning to the same areas that are pressurised. Some areas outside the hull need to be ventilated for cooling and fume extraction. Refer to Figure 6-1.

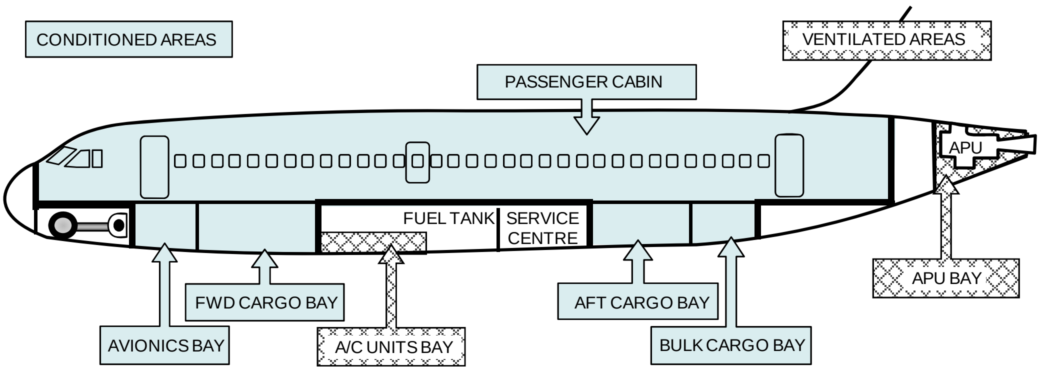

Figure 6-1 Conditioned and Ventilated Areas

In some modern pressurised aircraft the combination of the airconditioning and pressurisation systems is commonly referred to as the Environmental Control System (ECS). The control panel in the cockpit will likely be named the ECS or AIR Panel and will contain the controls for both systems.

Environmental control or airconditioning can be divided into distinct stages starting from supply air input and finishing at exhaust air control. At each stage of the process, changes are made to the supply air to condition it for passengers and crew.

STAGES	BASIC STAGES OF THE ENVIRONMENTAL CONTROL SYSTEM
AIR SUPPLY	The air supply is typically bleed air taken from the common bleed air manifold. The bleed air manifold is charged with air from the engines and APU. On large aircraft the engine bleed air must be pre-cooled before entry into the bleed air manifold. All individual engines and the APU are capable of supplying sufficient bleed air for the ECS.
TEMPERATURE CONTROL	From the bleed air manifold the supply air enters an airconditioning unit or “pack”. The pack reduces the temperature of the supply air to a generally acceptable temperature for the cabin and removes almost all of the moisture contained in the supply air. Large commercial aircraft are required to have at least two packs for ECS redundancy, some have three.
DISTRIBUTION	From the pack(s) the supply air is humidified to improve passenger comfort and distributed into specific temperature zones within the cabin. Each zone will require a different temperature dependent on passenger load and volumetric area. As supply air enters each zone its temperature is adjusted to suit the requirements of that zone. Normally incoming air enters from the top of each zone. Including crew rest areas a large aircraft can have up to six zones.
RECIRCULATION AND FILTRATION	From the floor level of each zone the used cabin air is drawn through a range of different air filters by recirculating fans. The fans force the filtered air back to the same distribution entry points mentioned above. This filtration and recirculation of the cabin air reduces the need for fresh supply air to be used which in turn decreases overall fuel consumption.
EXHAUSTING AND PRESSURISING	Finally, cabin air is exhausted overboard through the modulating cabin outflow valves already discussed in Chapter 4, Pressurisation Systems, which causes pressurisation to occur.
SUB-SYSTEM	SUB-SYSTEMS OF THE ENVIRONMENTAL CONTROL SYSTEM
AVIONICS COOLING	Conditioned air from the cockpit and the avionics bay is extracted by fans and forced into forward cargo bay. This maintains conditioned airflow across the equipment and provides sufficient heating of the cargo bay. When the aircraft is on the ground avionics conditioned air is forced overboard to ensure adequate cooling.
CARGO BAY HEATING	As described above the forward cargo bay is heated from the avionics and cockpit extracted air.The aft and bulk cargo bays however are typically heated directly from the common bleed air manifold via thermostatically controlled valves.
PERSONAL HEATING AND AREA VENTING	Most aircraft provide individual heating devices for the pilots which may be electrical or via specific distribution ducting. Toilets and galleys typically vent cabin conditioned air to very small overboard exit holes on the fuselage.
USING GROUND EQUIPMENT	The ECS infrastructure provides a connection point for ground airconditioning equipment when the APU is not running.
EMERGENCY VENTILATION	With a loss of all airconditioning units pressurisation cannot be maintained and a descent to 10,000 FT will be required. The ECS provides a ram air vent which may

	be opened to provide fresh air to the cabin.

Figure 6-2 ECS Stages and Sub-systems

Additionally, sub-systems of the ECS will provided specific cooling, heating and venting of compartments and equipment. Refer to Figure 6-2.

There are two basic types of airconditioning systems used in pressurised aircraft. They are;

- AIR CYCLE SYSTEMS - Cooling some of the supply air using ram air heat exchangers and cooling turbines and then mixing with hot supply air to achieve the desired temperature, and
- VAPOUR CYCLE SYSTEMS - Cooling some of the supply air using condensers, evaporators and a refrigerant gas then mixing with hot supply air to achieve the desired temperature.

Most medium to large commercial aircraft use the first method and some smaller aircraft the second. The second type is rarely used.

AIRCONDITIONING CONSIDERATIONS AND REGULATIONS

HUMAN CONSIDERATIONS

British Civil Airworthiness Requirements state the requirements for pressurised cabins and some of these are detailed in Chapter 4, Pressurisation Systems. Regulations also require that four factors are controlled for passengers in a pressurised and airconditioned environment. They are;

- provision of fresh air,
- temperature,
- humidity,
- air purity, and
- ventilation.

Provision of Fresh Air must occur regularly to satisfy the oxygen requirements of the human body. This is particularly necessary if smoking is permitted in the cabin area. Requirements state that;

- one (1) pound of fresh air per person per minute shall be the minimum provided.
- this may be reduced to 0.5 pounds per person in case of emergency, such as engine failure or failure of the compressor or blower.

It should be appreciated that modern aircraft supply far in excess of the requirements.

Temperature suitable for the cabin of passenger carrying aircraft is considered to be between 18°C and 24°C. This range, whilst ideal, will not be achievable all of the time and will need to be modified to suit local atmospheric conditions, such as ground operations in extremely hot locations.

Humidity decreases with altitude. At sea level the moisture content of air is approximately 0.4% while at 30,000 FT it has dropped to 0.03%. This lack of moisture can causes a dryness of skin and other ailments such as headache, dry throats and eyes. The ideal humidity is 60% at 18°C, however it would require a large volume of water to be carried to supply this amount of humidity at altitudes of 30,000 FT or more. This would result in a large weight penalty and is not commercially realistic, therefore 30% is considered to be sufficient for the safe operation of the aircraft while at the same time maintaining passenger comfort. Most modern aircraft are fitted with humidifiers to assist in maintaining a comfortable humidity within the cabin.

Air Purity is essential for the health of all persons on the aircraft. The air used for airconditioning must be free from all impurities, such as oil vapour or burnt fuel. Great care is taken in the design of the airconditioning system to ensure that no impurities are allowed into the air supply. Carbon monoxide contamination must not exceed 1 part in 20,000. Additionally, the cabin air in modern aircraft is recycled and filtered through ionisation filters to maintain air purity.

Ventilation via ram air and/or ventilation fans must be provided when the aircraft is on the ground and during unpressurised flight.

EQUIPMENT CONSIDERATIONS

The avionic equipment, computers and aircraft batteries are all designed to operate within a reasonable temperature range and since this equipment produces heat when operating most of the time they are being cooled.

The avionics bay is located within the pressurised hull of the aircraft and therefore is able to use airconditioned air for equipment cooling. Most of the individual computers and avionic components are protected from dust entry by local filters integrated into their casing.

FREIGHT AND LIVESTOCK CONSIDERATIONS

Apart from the passengers luggage a great deal of freight is carried on passenger transport aircraft including live animals. Provision therefore must be made to condition the air entering the cargo bays to a comfortable temperature. Apart from livestock survivability this prevents the possibility of containers within luggage from freezing and exploding.

AIR SUPPLY AND TYPES OF SYSTEMS

The air supply for an aircraft's airconditioning system is normally one of two options. They are;

- ram air for unpressurised aircraft systems, and
- compressed air for pressurised aircraft systems.

RAM AIR SUPPLY

Small to medium sized unpressurised aircraft use ram air to ventilate the aircraft during flight. Ram air inlets are normally positioned to maximize ram air induction without increasing drag and are typically found at the nose behind the propeller or integrated into the leading edges of the wings or vertical stabilizer. The ram air temperature will of course decrease with altitude and most of the time at high cruise altitudes will require heating to condition the air for crew and passenger comfort. Unpressurised aircraft will normally be fitted with a heating unit to increase the temperature of the ambient ram air. There are two common methods used to heat ram air. They are;

- engine exhaust muff heating for small aircraft, and
- utilizing a combustion heater for medium size aircraft.

These systems will be discussed in further detail later.

COMPRESSED AIR SUPPLY

Obviously pressurised aircraft require a compressed air supply for pressurisation. As they cannot use ambient ram air to cool the cabin the airconditioning system itself must produce both hot and cold air to be mixed for an ideal cabin temperature. Additionally, airworthiness regulations require minimum airflow rates, humidity control and air supply redundancy.

Dependent on the size of aircraft and engine type there are three common methods of compressed air supply. They are;

- cabin displacement blowers for small piston engine aircraft,
- engine driven compressors for medium to large turbo-prop aircraft, and
- engine and APU bleed air for medium to large jet aircraft.

These systems will be discussed in further detail later.

AIRCONDITIONING COMPONENTS

The following components are not fitted to all airconditioning systems as there are simple and complex systems for different aircraft types. The application of these components will become obvious when the individual systems are described later in this chapter.

RAM AIR INLETS

Ram air inlets for ventilation of the cabin in <u>unpressurised aircraft</u> are normally positioned to maximize ram air induction without increasing drag and are typically found at the nose behind the propeller or integrated into the leading edges of the wings or vertical stabilizer.

Ram air inlets and exhaust outlets for heat exchanger cooling in <u>large pressurised aircraft</u> are typically located on the underbelly of the aircraft between the wing roots. Refer to Figure 6-3.

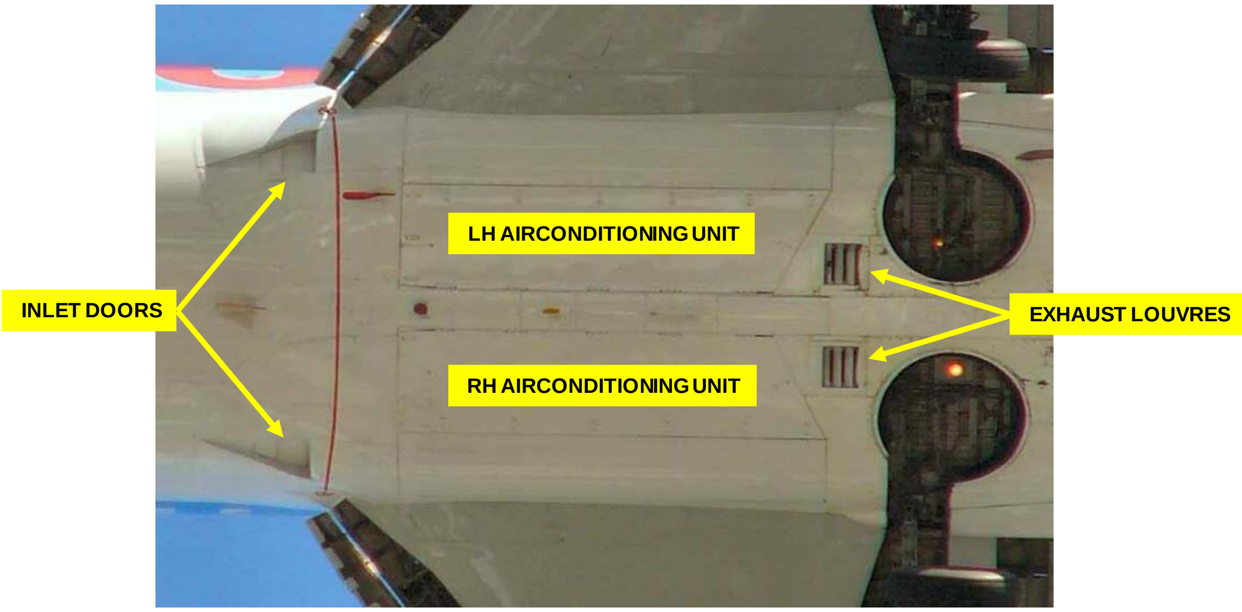

Figure 6-3 Ram Air Inlets and Exhaust for Heat Exchanger Cooling

ENGINE EXHAUST MUFF

An exhaust muff is a sealed outer tube that surrounds the exhaust manifold. Heat from the manifold is transferred to the ram air as it progresses towards the cabin. Typically used only on small single engine piston aircraft. Refer to Figure 6-4.

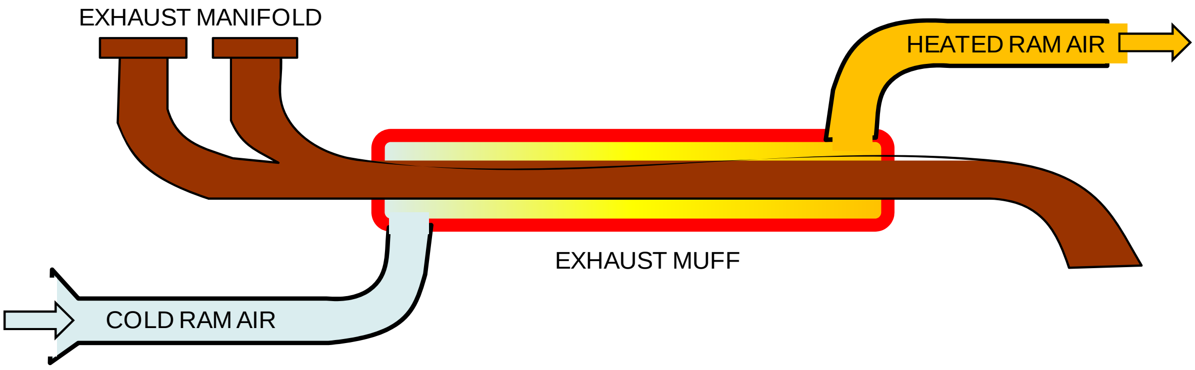

Figure 6-4 Exhaust Muff

COMBUSTION HEATER

Similar to an exhaust muff, cold ram air is directed through a sealed outer tube which contains a combustion chamber which is sealed from the ram air to be heated. The combustion chamber receives blower forced air and fuel which is ignited by a continuously operating igniter (spark plug).

Typically used for larger aircraft a combustion heater may be used at low airspeeds and on the ground as the incoming ram air is boosted by an electric fan. Refer to Figure 6-5.

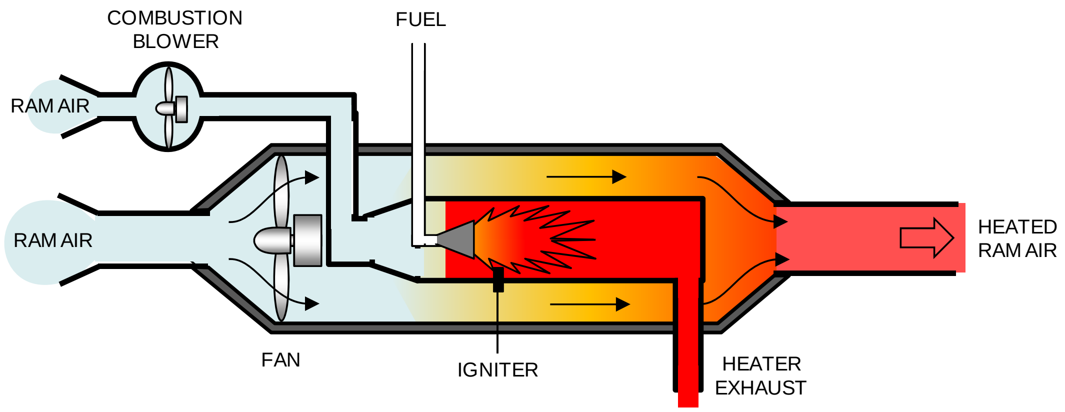

Figure 6-5 Combustion Heater

CHOKE HEAT VALVE

Supply air that is compressed by a Cabin Blower is sometimes too cold to be useful for heating purposes and can be made hotter by restricting or "choking" the blower output. This is done using a choke heat valve controlled by the airconditioning system. Refer to Figure 6-6.

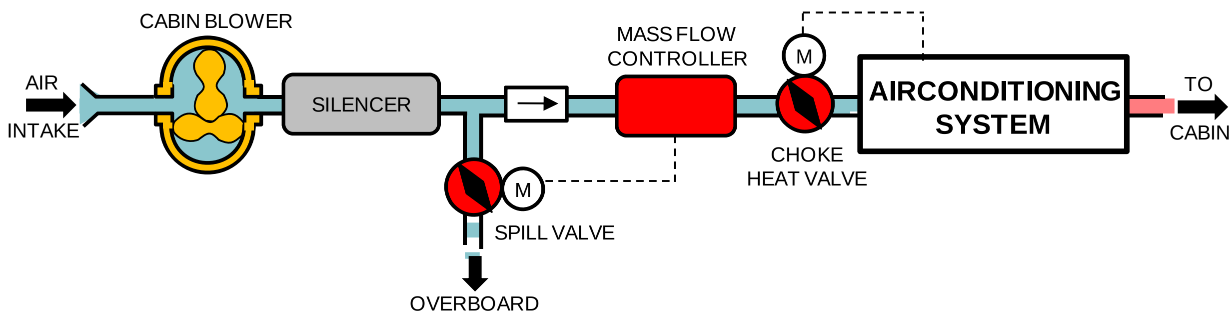

Figure 6-6 Choke Heat Valve

HEAT EXCHANGERS

Heat Exchangers are located inside a tunnel like duct that is positioned in the underbelly of the aircraft. The duct accepts ram air via a controllable inlet door. The ram airflow absorbs heat from the supply air via the heat exchanger matrix and exits through louvres which may be controllable on some aircraft. Refer to Figures 6-3 and 6-7.

Some aircraft, when on ground, spray water onto the front of the heat exchanger for greater cooling effect. The water is extracted from the water separator which is another component described later.

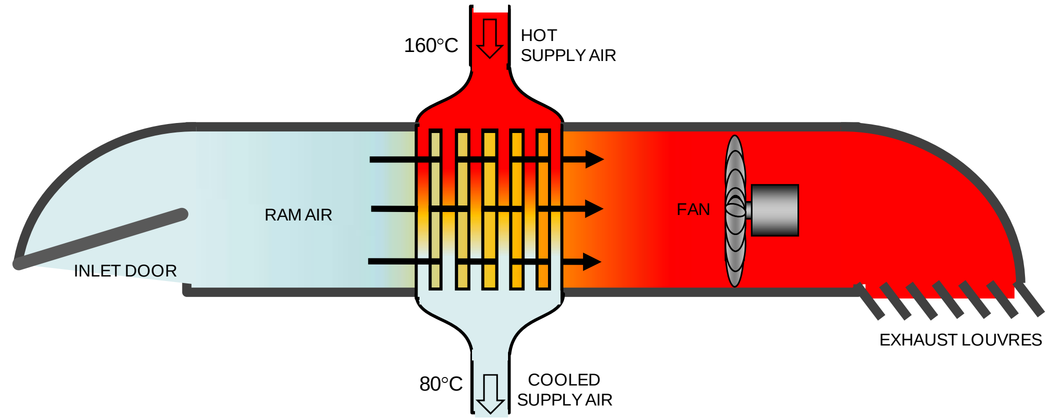

Figure 6-7 Heat Exchanger

COOLING FANS

Almost all aircraft that use heat exchangers located within a ram air duct or tunnel as previously described, will have a fan to boost airflow through the heat exchanger as ram air ceases with the aircraft on the ground. Refer to Figure 6-7 to observe the location of the fan. The fan may be powered using one of the three following methods. They are;

- an electric motor which is switched on automatically via ground/air logic,
- a bleed air motor which is switched on automatically via ground/air logic, or
- mechanically driven from the cooling turbine all of the time.

COOLING TURBINES

Cooling Turbines extract heat energy from the supply air by two methods. They are;

- air expansion – where by increasing the velocity of the air and reducing its pressure will also reduce its temperature , and
- energy conversion – where by causing the air to do work it will lose heat. The turbine drives a compressor or fan so the heat energy of the supply air is converted to kinetic energy. Refer to Figure 6-8.

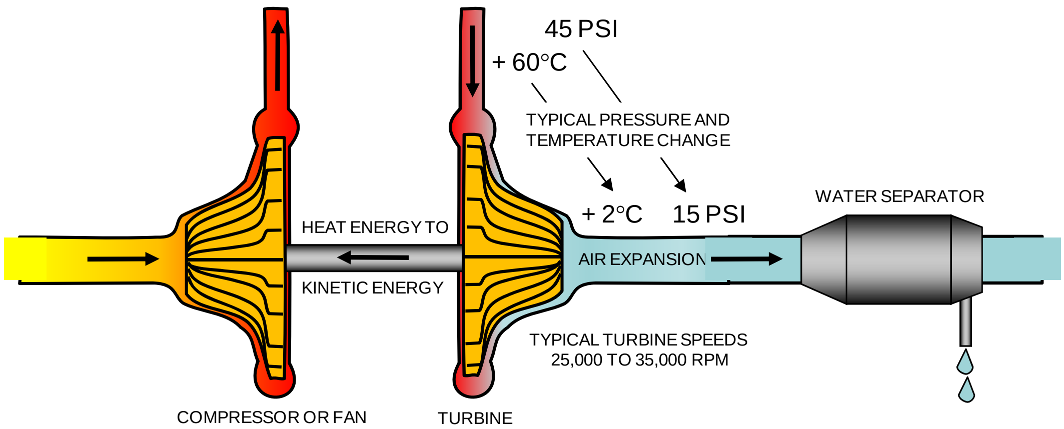

Figure 6-8 Extracting Heat Energy from Supply Air

WATER SEPARATORS

Water Separators use the principle of centrifugal force to separate moisture from the supply air. An internal supported fibrous coalescer bag causes the moisture to coalesces as it passes through forming water droplets. The swirling airflow then throws the water to the outside of the collector where it falls to the bottom and enters the sump. A by-pass valve allows airflow should the coalescer bag become blocked. The collected water can be dumped overboard or used for other purposes such as;

- ❖ spraying over the input side of the heat exchanger whilst the aircraft is on the ground producing a greater temperature drop through the heat exchanger, or
- ❖ providing a supply of water to the humidifier unit.

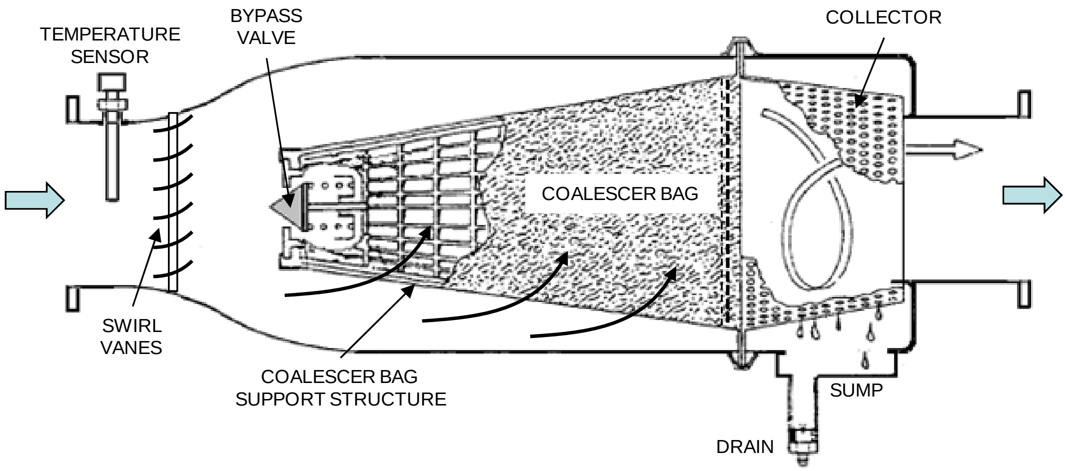

Figure 6-9 Water Separator

The moisture laden supply air entering the water separator can be cold enough to form ice. If allowed to accumulate, ice may reduce or actually block flow through the water separator. This will affect system operation and could cause damage to ducting or other components. A sensor, either temperature or pressure related, is fitted at the entrance of the water separator to detect the formation of ice (approximately +2°C) and when detected will automatically cause adjustments to increase the incoming air temperature to melt the ice. Refer to Figure 6-9.

HUMIDIFIERS

The water separator, described previously, can remove up to 70% of the moisture content of the supply air. This is necessary for passenger comfort in areas of high relative humidity, however, as aircraft altitude increases the relative humidity will decrease and consequently the airflow to the cabin will be below the airworthiness humidity requirements.

To correct this, aircraft use a humidifier to maintain the required relative humidity in the cabin when flying at high altitude. A water reservoir, pressurised by bleed air, supplies water to the diffuser in the humidifier. The rate of water input is automatically controlled by a humidity sensor.

The system is normally switched on automatically by a pressure switch at a predetermined altitude, normally around 20,000 feet, and will be selected off again on descent, at about 20,000 feet, to prevent fogging of the windows.

Humidifiers may have an ON/OFF control switch in the cockpit. Refer to Figure 6-10.

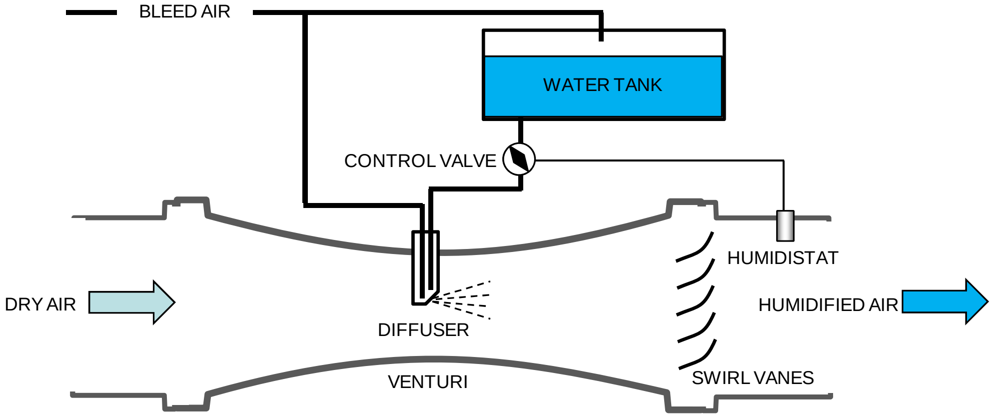

Figure 6-10 Humidifier

TEMPERATURE CONTROL VALVES

Within the airconditioning system cold and hot air streams will eventually be mixed together to produce the airflow to the cabin at the requested temperature. In simple systems a Y shaped body with connected butterfly valves can perform this function. Refer to Figure 6-11.

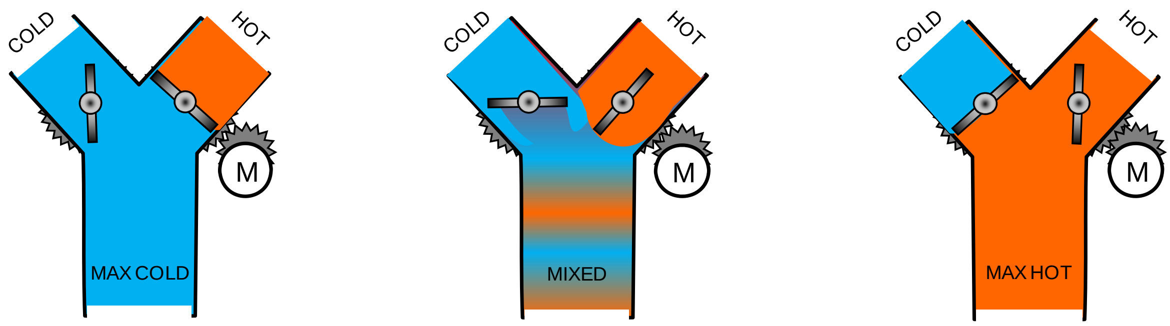

Figure 6-11 Temperature Control Valve

In more complex air cycle systems output temperature control is accomplished by computer controlled manipulation of many valves and other components. Refer to the Airconditioning Systems Description later in this Chapter.

RECIRCULATING FANS

Electric recirculating fans extract used air from the cabin, normally at floor level, where it is filtered and returned to the input ducting. This reduces overall bleed air use which results in significant fuel savings.

FILTERS

Recirculated air is filtered below floor level through particle and ionizing filters to enable the continued use of the same cabin air for fuel savings.

Registers and Gaspers

Conditioned air entering the cabin passes through fixed or controllable and sometimes directional outlets which are referred to as registers. One of these outlets provides the coldest possible conditioned air to each individual passenger.

Referred to as a gasper it will be described in Airconditioning Systems Description later in this Chapter.

COMPRESSORS

Compressors of different types may be employed in airconditioning systems and will include those driven by cooling turbines, other mechanical means or electric motors.

Types and function will be described in Airconditioning Systems Description later in this Chapter.

EVAPORATOR

An evaporator is similar to a heat exchanger which transfers heat energy between separate fluids, however it is referred to as an evaporator as it evaporates a liquid into a gas.

This component is part of a VAPOUR CYCLE system only, which will be described in Airconditioning Systems Description later in this Chapter.

CONDENSER

A condenser is similar to a heat exchanger which transfers heat energy between separate fluids, however it is referred to as an condenser as it condenses a a gas into a liquid.

This component is part of a VAPOUR CYCLE system only, which will be described in Airconditioning Systems Description later in this Chapter.

OTHER CONTROL VALVES

All types of airconditioning systems or units will contain control valves to turn units on and off, modulate airflow and temperatures and actuate components. These will normally be butterfly type valves which have been discussed in Chapter 4 Pneumatic Systems.

There will be three types of valves. They are;

- valves that control airflow ON or OFF
- valves that MODULATE airflow to control temperature or mass flow, and
- valves that perform both functions.

Their correct names and function will be described in Airconditioning Systems Description later in this Chapter.

CONTROL PANELS AND TEMPERATURE CONTROLLERS

In small to medium aircraft often the heating controls are not grouped into a single panel due to the system design and available space. Temperature adjustment of these systems is mainly done by the crew feeling the temperature and adjusting the heater output.

In large pressurised transport aircraft a single control panel will be provided. The control panel will likely be named the ECS or AIR Panel and will contain the controls for Bleed Air Supply, Airconditioning, Pressurisation, and other associated sub-systems such as cargo heating and avionics cooling.

WARNING

> The pressurisation of the aircraft depends entirely on the availability of bleed air via the airconditioning systems, therefore before selecting Engine Bleed Valves, Manifold Isolation Valves or Airconditioning Units to OFF or CLOSED consider the impact to pressurisation supply.

Very modern aircraft often now provide additional Temperature Control Panels in the cabin and crew rest areas for cabin crew to adjust temperatures.

Temperature Controllers (computers), always duplicated for redundancy, provide the complex control of the valves and ram air inlet/exhaust doors to maintain the temperatures required by the settings on the Control Panels.

ELECTRIC HEATERS

All aircraft have particular areas within the cockpit, cabin and crew rest areas that are difficult to condition effectively by distributed airflow.

These areas will normally be heated using simple electric heaters and may include heated floor or wall panels, pilots seat shoulder pads and fan forced heaters for crew rest areas.

MASS FLOW CONTROLLERS

The mass flow controller is normally associated with smaller systems using mechanical compressors and has been described in Chapter ?, Pressurisation Systems.

The Pack Shut-off and Flow Control Valve performs this function on bleed air systems.

SUMMARY

The following table is a summary of the components that relate to aircraft airconditioning systems. Refer to Figure 6-12.

COMPONENTS	FUNCTION	USED IN	COMMENT
RAM AIR INLETS/EXHAUST	PROVIDES SUPPLY AIR FOR A RAM AIR SYSTEM AND COOLING AIR FOR OTHER SYSTEMS	ALL SYSTEMS	
EXHAUST MUFF	PROVIDES HEATING	RAM AIR SYSTEMS	Small piston engine aircraft only
COMBUSTION HEATER	PROVIDES HEATING	RAM AIR SYSTEMS	Larger piston engine aircraft
CHOKE HEAT VALVE	IMPROVES HEATING	RAM AIR SYSTEMS	Small piston engine aircraft only
HEAT EXCHANGERS	PROVIDES COOLING OF SUPPLY AIR	AIR CYCLE SYSTEMS	
COOLING FANS	MAINTAINS AIRFLOW WHEN RAM AIR NOT PRESENT	AIR CYCLE SYSTEMS	
COOLING TURBINES	EFFICIENTLY REDUCES SUPPLY AIR TEMPERATURE	AIR CYCLE SYSTEMS	
WATER SEPARATORS	REMOVES MOISTURE FROM COLD AIR EXITING COOLING TURBINE	AIR CYCLE SYSTEMS	
HUMIDIFIERS	ADDS MOISTURE TO CABIN AIR BEFORE ENTERING CABIN	AIR CYCLE SYSTEMS	Not fitted to all aircraft
TEMPERATURE CONTROL VALVES	CONTROLS THE MIXING OF HOT AND COLD AIR	ALL SYSTEMS	
RECIRCULATING FANS	RECIRCULATES USED CABIN AIR	AIR CYCLE SYSTEMS	Not fitted to all aircraft
FILTERS	CLEANS RECIRCULATED AIR	AIR CYCLE SYSTEMS	Not fitted to all aircraft
REGISTERS/ GASPERS	CONTROLLABLE OUTLET CABIN VENTS	ALL SYSTEMS	
COMPRESSORS	CONNECTED TO COOLING TURBINES TO BOOTSTRAP THE TURBINE	AIR CYCLE SYSTEMS	Typically driven by turbine
COMPRESSORS	COMPRESS THE GAS IN A VAPOUR CYCLE SYSTEM	VAPOUR CYCLE SYSTEMS	Typically driven by electric motor
EVAPORATOR	EVAPORATES A LIQUID INTO A GAS	VAPOUR CYCLE SYSTEMS	
CONDENSER	CONDENSES A GAS INTO A LIQUID	VAPOUR CYCLE SYSTEMS	
OTHER CONTROL VALVES	SHUT-OFF VALVES MODULATING VALVES SHUT-OFF AND MODULATING VALVES	ALL SYSTEMS	
CONTROL PANEL	CONTROL THE AIRCONDITIONING, VENTILATION, HUMIDITY AND CARGO HEATING	ALL SYSTEMS	On large modern aircraft one control panel for the system and sub-systems
ELECTRIC HEATERS	HEAT SPECIFIC AREAS	ALL SYSTEMS	
MASS FLOW CONTROLLER	CONTROLS THE MASS FLOW OF SUPPLY AIR	SIMPLE SYSTEMS	Typically used for systems with mechanical compressors

Figure 6-12 Summary of Components

AIRCONDITIONING SYSTEMS DESCRIPTION

RAM AIR SYSTEMS

On small single engine piston aircraft a common method is to direct ram air around the hot exhaust manifold using an exhaust muff and then on to the cabin. Obviously it is critical that the manifolds exhaust gas should not leak into the ram air as it passes through the muff and aircraft using this system are normally fitted with sensor inside the cabin to detect the presence of carbon monoxide. Additional separate ambient ram air inlets are provided for cabin ventilation when heating is not required. Refer to Figure 6-13.

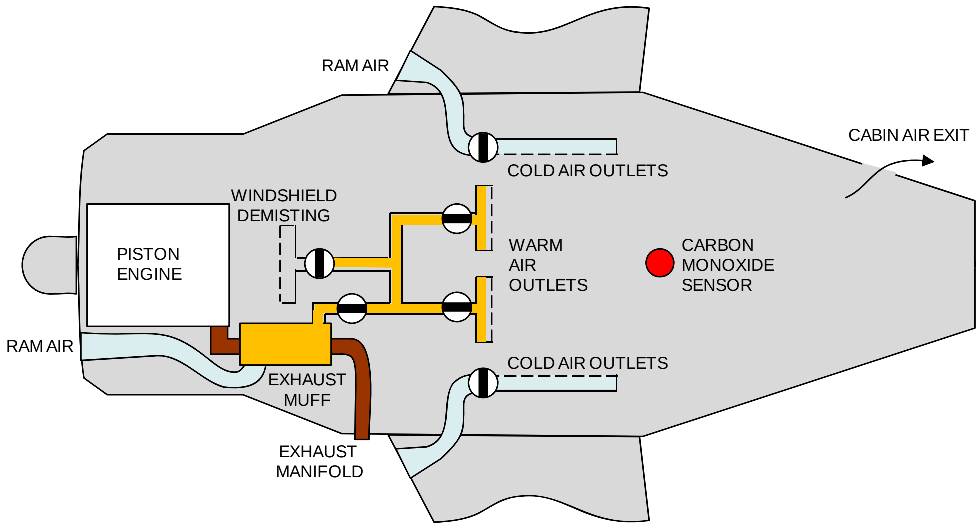

Figure 6-13 Simple Manifold Heating System

On larger aircraft the most common method is a self contained combustion heater unit which normally uses the same fuel used by the piston engines.

Ram air is forced into the inner chamber by a combustion blower where fuel is sprayed into the airflow across a continuously sparking igniter plug.

The hot air heats the chamber and is then exhausted overboard. The ram air flow is passed around the outside of the combustion chamber where it absorbs heat and is then distributed to the cabin area.

A ventilation fan supplements the airflow when the aircraft is at low airspeed and on the ground.

A supply of unheated air is still available to the cabin when the combustion heater is operating. Temperature control is achieved by a cabin thermostat in the hot air outlet from the blower. A desired temperature is selected on the control panel in the flight station.

If the actual temperature as sensed by the thermostat is below the desired temperature, the thermostat will allow fuel to flow to the combustion chamber.

Once the temperature has reached the desired level, the thermostat stops fuel flowing to the combustion chamber.

The cycle is repeated as long as the system is selected on. Refer to Figure 6-14.

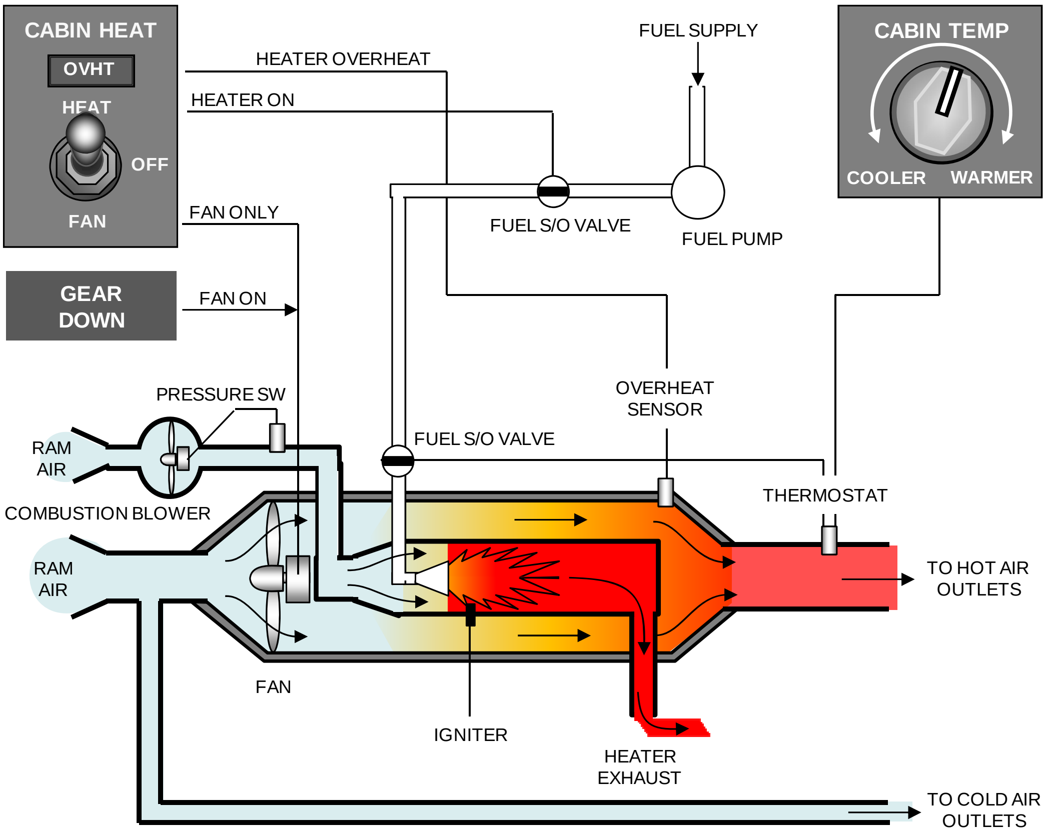

Figure 6-14 Combustion Heater System

COMPRESSED AIR SYSTEMS

Aircraft that are pressurised will need a more complex airconditioning system than the simple heating systems already described. Typically, after the conditioned air is delivered to the cabin the exhaust to atmosphere is controlled to provide pressurisation. As cold ram air cannot be used, the airconditioning system in a pressurised aircraft must be able to both heat and cool the cabin.

Supply air that is compressed by a Cabin Blower is sometimes too cold to be useful for heating purposes and can be made hotter by restricting or "choking" the blower output. This is done using a choke heat valve controlled by the airconditioning system. Refer to Figure 6-6.

Supply air from an EDC or bleed air supply is of sufficient temperature and only requires cooling.

Cooling the air below ambient temperature becomes the most complex part of the airconditioning system, particularly on the ground and at low altitudes when operating in hot conditions.

An arrangement of ram air heat exchangers and cooling turbines are most commonly used to produce cold air. This method is referred to as AIR CYCLE cooling.

Another method may be employed which is known as VAPOUR CYCLE cooling which is similar to motor vehicle airconditioning, but this is not common.

AIR CYCLE COOLING

Air cycle cooling is the preferred method for most modern jet and turbo-prop transport aircraft. It uses the principles of surface heat exchange, air expansion and energy conversion to cool the supply air. The two components that achieve this are the heat exchanger and the cooling turbine.

Unfortunately, reducing the pressure and temperature of the supply air at the turbine exit produces large amounts of moisture which if not separated out will travel through the ducting and into the cabin.In very humid climates some of this moisture (condensation) can be seen exiting the vents in the cabin and on some occasions will collect and form puddles of water in the ducting only to spill out on passengers at take-off when the aircraft's body angle changes.

To remove the moisture produced, a water separator is normally fitted immediately downstream of the cooling turbine. As the temperature drop across the turbine assembly can be large enough to create ice particles, this may reduce the flow through the water separator, and affect system operation.

As part of the temperature control system, an ice limiting function is provided. When ice begins to forms at the inlet to the separator, it is detected. This induces a signal to the temperature control logic which adjusts valves to melt the ice.

AIR CYCLE cooling is normally achieved using three types of systems. They are;

- brake turbines
- fan turbines, and
- turbo-compressor (bootstrap)

Brake Turbine Systems are lightweight systems using a single heat exchanger located in a ram air tunnel. The compressed air supply or "charge" air is cooled by the heat exchanger before driving the turbine where the greatest cooling takes place.

The turbine drives the compressor which takes in ambient pressure air and expels it through a restriction. The restricted compressor output causes a back pressure which automatically controls (RPM) or "brakes" the turbine, hence the name.

The restriction applied to the compressor output can be a jet pump which induces flow through the tunnel and heat exchanger particularly when the aircraft is on the ground

The controlling components of this system are the system shut-off valve, a ram air door and a temperature control valve. The output of the cooling turbine is mixed with the output of the heat exchanger by the temperature control valve to achieve the required temperature.

Air delivered to the cabin passes through a water separator to remove the moisture produced by the turbines cooling effect. Refer to Figure 6-15.

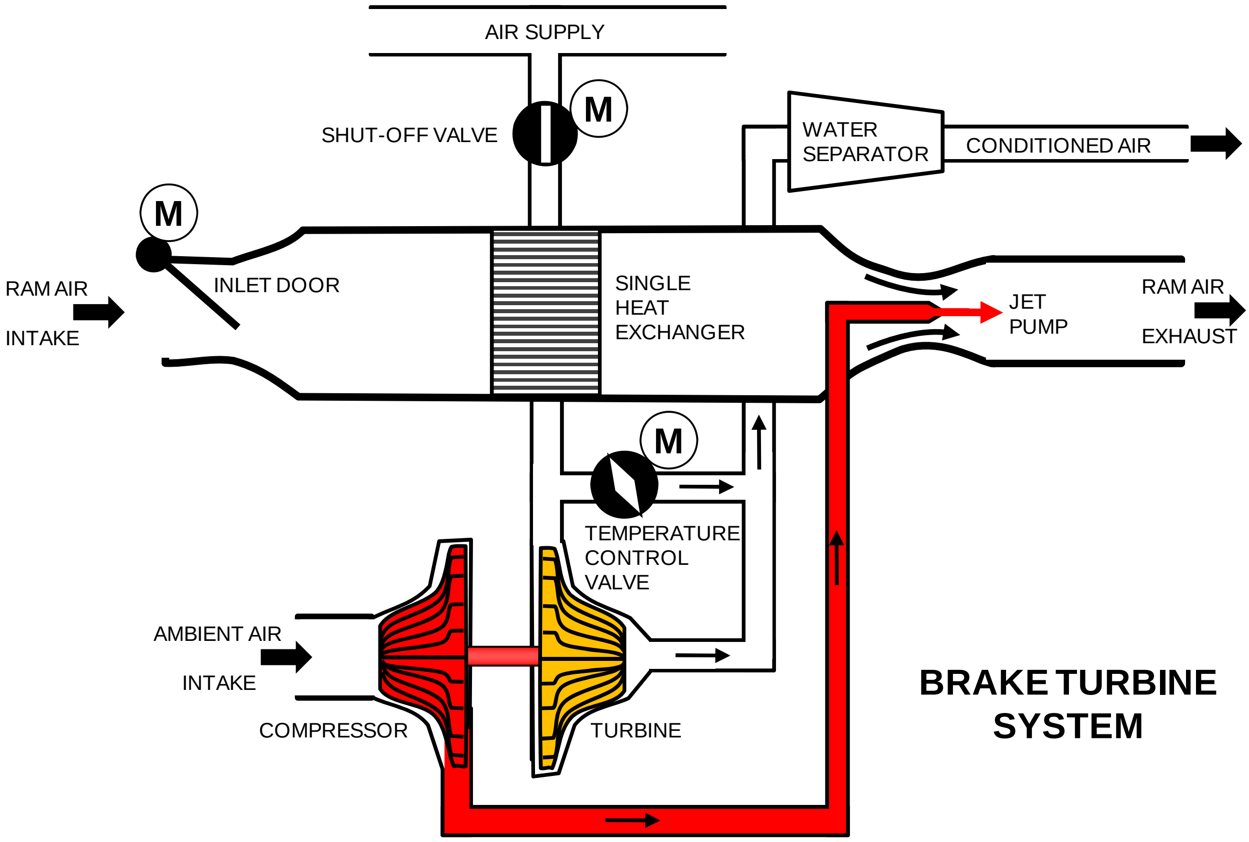

Figure 6-15 Brake Turbine System

Fan Turbine Systems or Turbo-fans are a refined version of the brake turbine system, in which, instead of a compressor, the turbine drives a fan of sufficient capacity to draw the required volume of cooling airflow through the heat exchanger.

This is a light and compact system relying on high turbine speeds for better cooling effect and of course is not dependent on ram air for ground operation. The controlling components and conditioned airflow is similar to the brake turbine system. Refer to Figure 6-16.

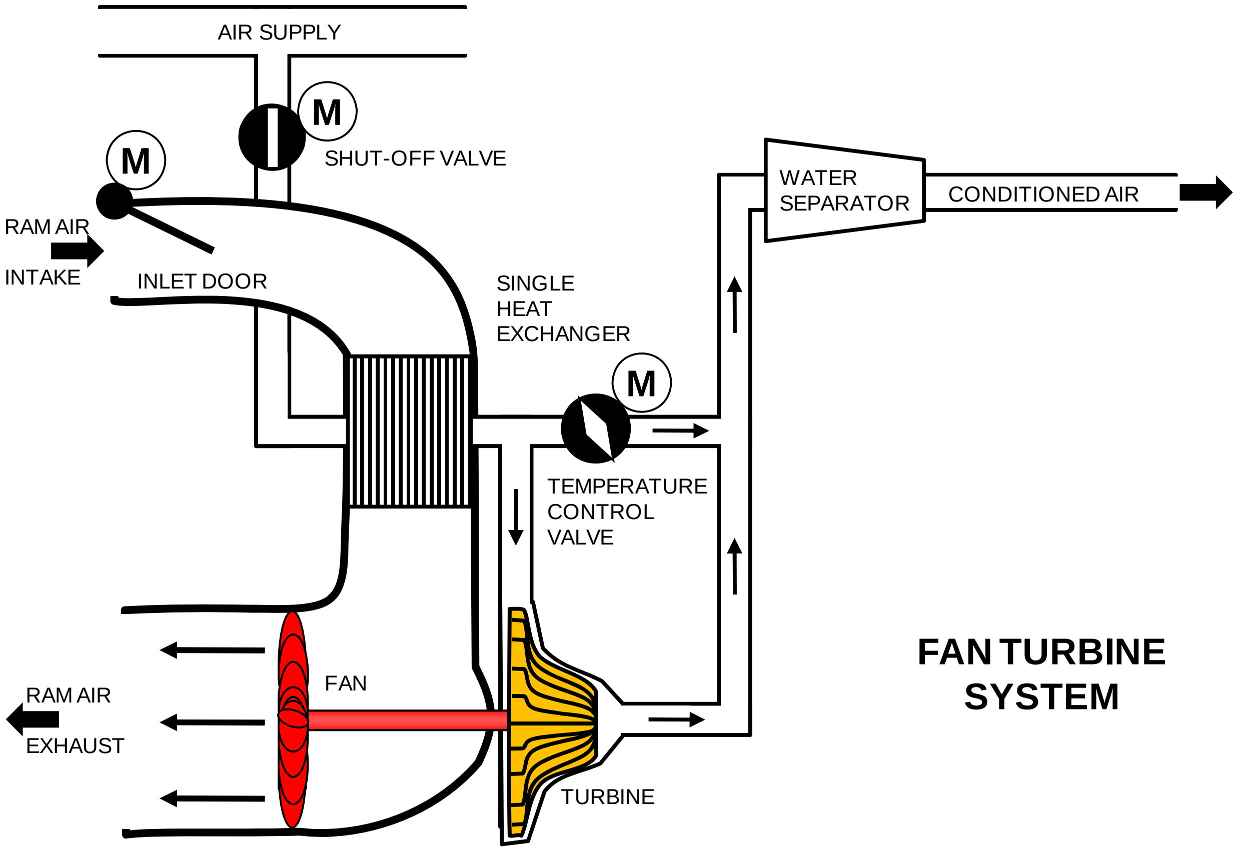

Figure 6-16 Fan Turbine System

Turbo-Compressor or Bootstrap Systems are the most popular of the air cycle systems in current use in modern aircraft. They are very efficient and may be used on all types of jet and turbo-prop aircraft as bleed air usage is minimal. The significant difference from the types previously described is the provision of a second heat exchanger and an Air Cycle Machine (ACM) or bootstrap turbine/compressor unit.

In the bootstrap system the turbine drives a compressor that raises the supply air pressure after it has passed through the primary heat exchanger.

This air then passes through the secondary heat exchanger where its temperature is lowered again, but its pressure has increased slightly. This drives the turbine which in turn drives the compressor. As the turbine is required to do work driving the compressor the heat energy is converted to kinetic energy, thus lowering the temperature of the air exiting the turbine.

It can be seen that in this system the turbine/compressor combination or Air Cycle Machine (ACM) actually creates its own temperature and pressure rise, thus it is said to be picking itself up by the bootstraps. Temperature drops in excess of 100°C are not uncommon in this type of system. Refer to Figure 6-17.

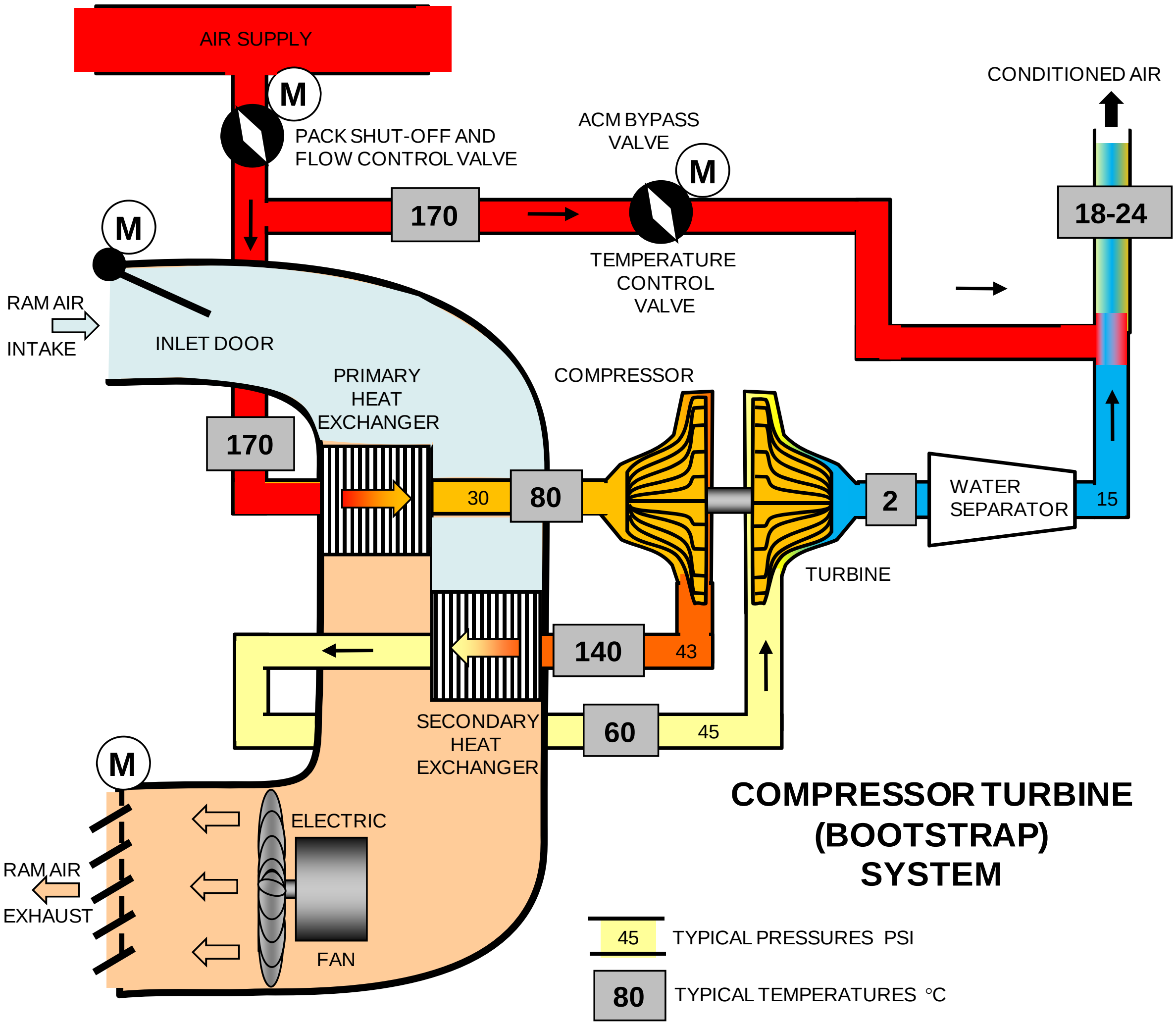

Figure 6-17 Bootstrap System

The system shown in Figure 6-17 is a simple version of a Turbo-Compressor system. Actual Turbo-Compressor systems used by Boeing and Airbus in modern large aircraft have additional valves and normally drive the heat exchanger cooling fan from the bootstrap turbine. For interest only, refer to the actual Airbus system example located at the end of this Chapter.

VAPOUR CYCLE COOLING

Another method of airconditioning available for use in aircraft is the VAPOUR CYCLE system.

This system is suitable for use on small aircraft and as a supplemental sub-system on some larger aircraft types. It is never used for the main system on large transport aircraft. The principle is the same as used in motor vehicles, home airconditioning and refrigerators. On large transport aircraft this type of system will normally only be found in the galley refrigerators on board the aircraft.

The Vapour Cycle uses the principle that during evaporation of a liquid it absorbs heat from its surroundings. By using a liquid with a low boiling point to absorb heat from the cabin air supply the temperature of the cabin air supply is chilled. Typically the refrigerant used is Freon which boils at approximately 3.5°C at sea level pressure. The refrigerant circulates in a closed circuit and alternates between vapour and liquid phases. It is compressed, cooled, expanded and heated in that order. Refer to Figure 6-18.

The refrigerant is held in a reservoir (receiver dryer) and is drawn through an expansion valve by the compressor. The **EVAPORATOR** (heat exchanger) causes the refrigerant to expand causing a reduction in pressure and therefore boiling point, enabling the fluid to absorb more heat from the air supply. The heated vapour exits from the evaporator and is compressed.

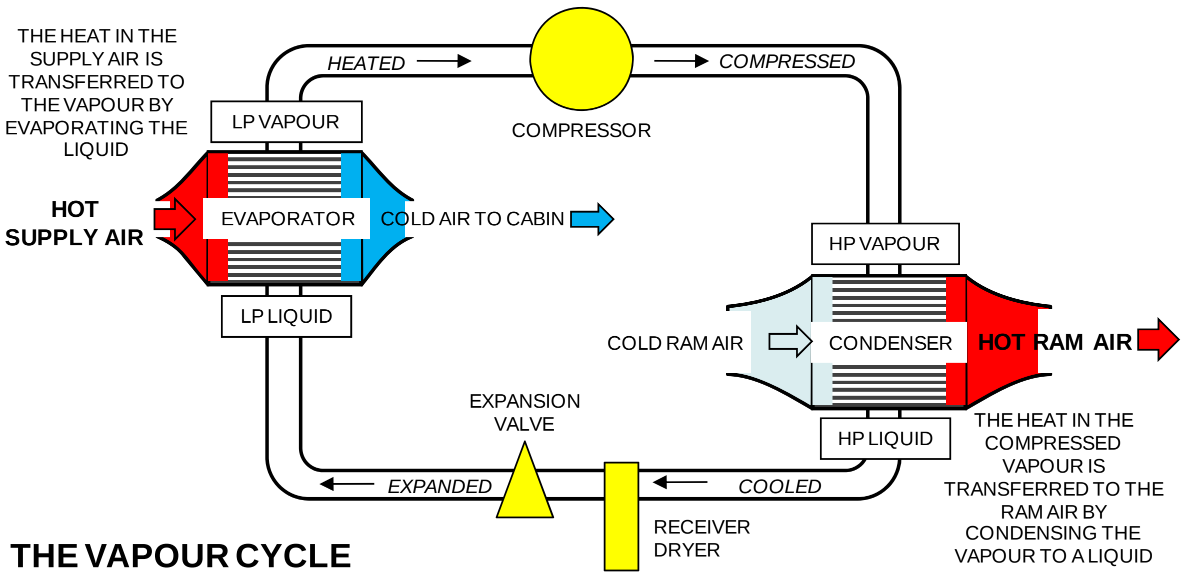

Figure 6-18 Vapour Cycle Principle

The **COMPRESSOR** raises the pressure and therefore the boiling point of the refrigerant before it passes through the second heat exchanger, known as the condenser. Cold ram air passes over the **CONDENSER** and cools the refrigerant, which turns back to a liquid giving up the heat it absorbed to the ram air. The liquid continues on to the reservoir and the cycle starts again. Refer to Figure 6-19 for an example aircraft vapour cycle system.

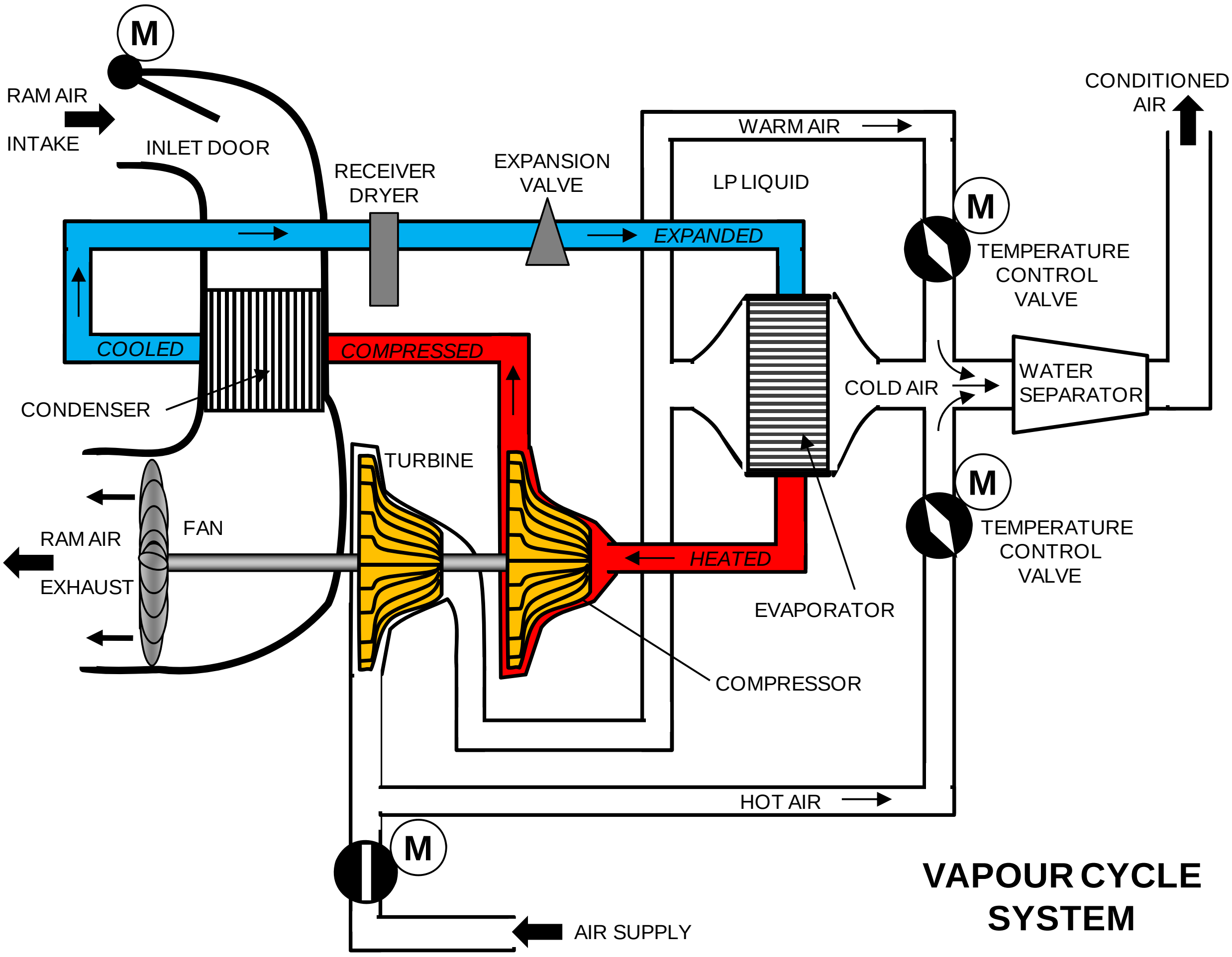

Figure 6-19 Vapour Cycle Airconditioning System

The compressor in this system is driven by a bleed air turbine but the typical driving method is by electric motor. The refrigerant Freon is a hydro-carbon and does great damage to the environment if allowed to escape to the atmosphere. Special handling requirements exist for the charging and draining of the system.

TEMPERATURE CONTROL STAGE The three air cycle systems described above, although different, have all achieved the same result and that is to condition the supply air to a comfortable temperature range of approximately 18 – 24°C and to remove almost all of the moisture produced in the cooling process.

Each airconditioning unit described above is commonly referred to as a “Pack”. All large jet transport aircraft are required to have at least two airconditioning “Packs” for redundancy and their outputs will eventually join together in a large common Conditioned Air Manifold.

Each pack is controlled by a Pack Controller which controls and modulates the operation of the bypass valve, inlet and exhaust doors and the cooling fan to produce conditioned air in the basic temperature range of 18-24°C. A Master Temperature Controller in turn commands the operation of each individual Pack Controller to make changes to achieve the cabin temperature required. Refer to Figure 6-20.

The Pack Controller also monitors the pack for ice formation at the water separator inlet and overheating at the compressor outlet.

- If ice formation begins the Pack Controller adjusts or opens valves to melt the ice.
- If overheating occurs the Pack Controller will close the Pack Valve which shuts down the pack. This is commonly referred to as a "pack trip" and when the pack has cooled a "reset" may be attempted by the crew.

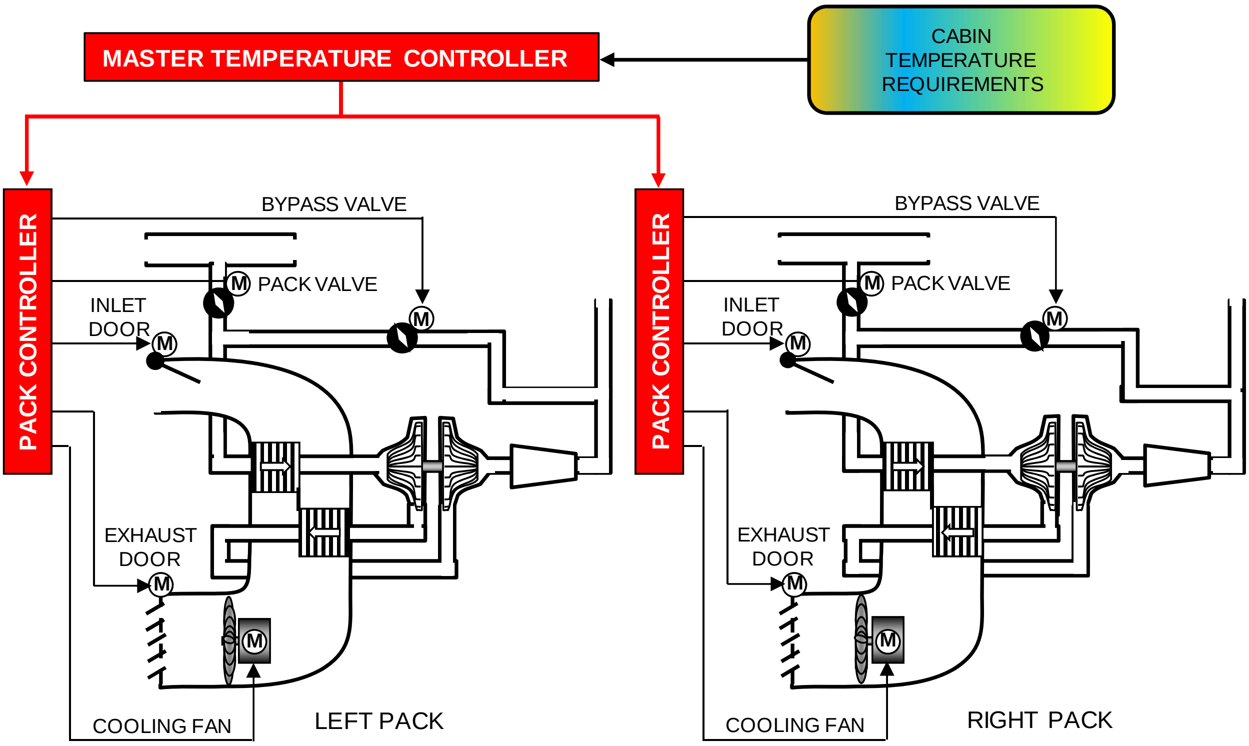

Figure 6-20 Pack Control

In modern aircraft the Pack Controllers are obviously digital computers and are duplicated for each pack. Normally named A and B, the controllers change over at each touchdown with one controller becoming the back-up if the other fails.

Modern aircraft offer a pack selection of LOW FLOW which when selected will reduce the airflow from the packs to approximately half of the normal output. This selection may be used when the aircraft is in the cruise and passengers are sleeping or there is minimal activity in the cabin. This selection reduces the volume of supply bleed air extracted from the engines resulting in significant fuel savings. In older aircraft the packs can be operated in a MANUAL mode where the operator can control the position of the bypass valve and inlet door manually. Careful monitoring of temperatures is required to prevent overheating and ice formation.

There is no manual operation of airconditioning packs on modern aircraft as an automatic default run position will occur if both A and B pack controllers (computers) fail.

<u>DISTRIBUTION STAGE</u> The next stage of the ECS process is humidifying the supply air, distributing it to the cockpit and cabin areas whilst simultaneously making fine adjustments to the temperature to suit the requirements of each area or zone.

Humidifiers, already described, return moisture to the supply air on its way to the distribution manifold. Regulations state that at least 30% relative humidity is required for passenger comfort. From the distribution manifold, individual ducts direct air to each cabin zone.

Each cabin zone and the cockpit will require slightly different air temperature inputs depending on the actual temperature present and any requested changes to temperature made by the crew.

The Master Temperature Controller commands both packs to produce the air temperature needed by the zone requiring the coldest air. All of the other zones will need warmer air and this is added as the air enters each zone. The added hot air comes directly from the Common Bleed Air Manifold and is independent of the airconditioning packs. The added hot air is referred to as **TRIM AIR** in Boeing aircraft and **HOT AIR** in Airbus aircraft. Refer to Figures 6-21 and 6-22.

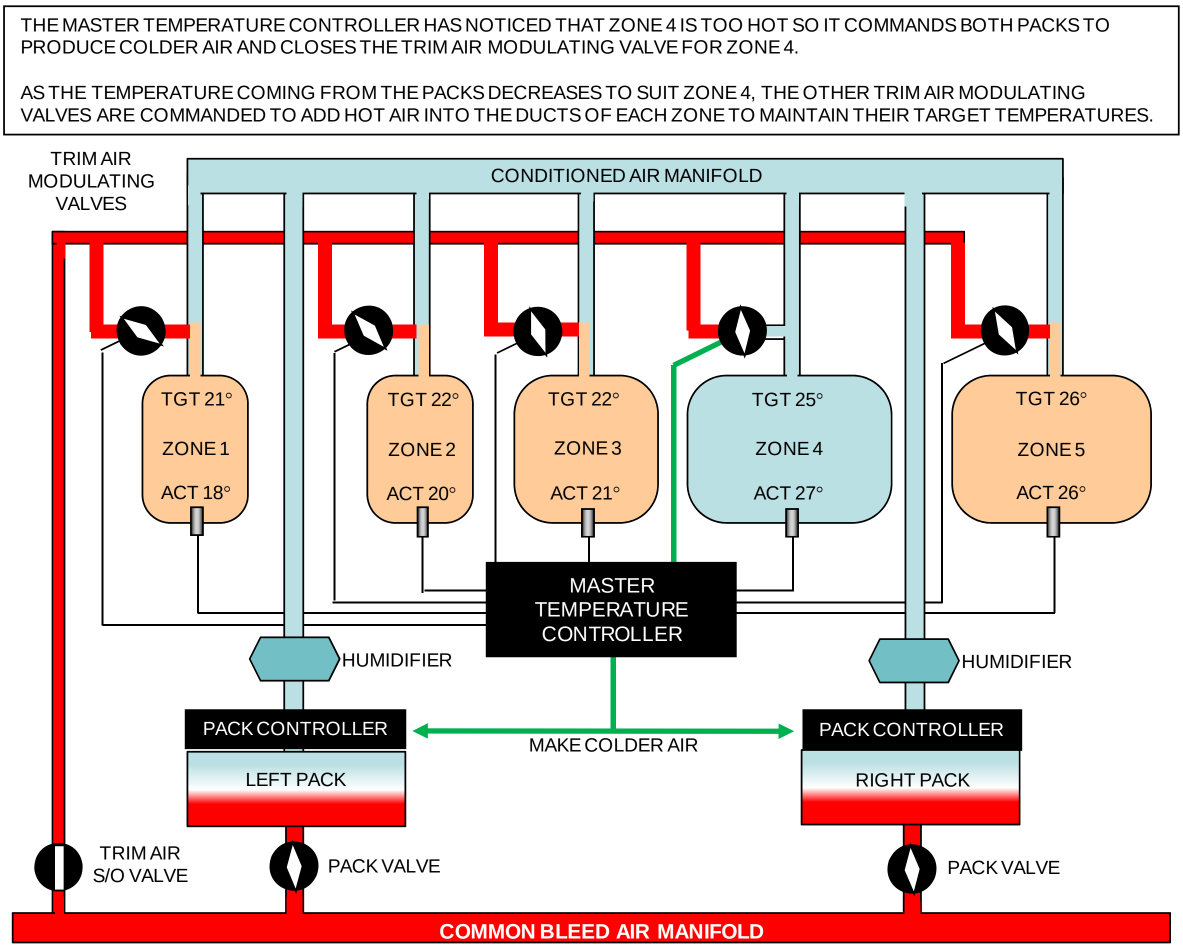

Figure 6-21 **Distribution and Zone Temperature Adjustment**

In Figure 6-21 you can see that the Master Temperature Controller is aware of the actual (ACT) temperatures in each zone and is constantly adjusting the packs and the trim air modulating valves to achieve the zone target (TGT) temperatures. The zone target temperatures are set by the crew in the cockpit and the cabin.

In both older and modern aircraft ZONE temperature control (Trim Air Modulating Valves) is AUTOMATIC once a target temperature is set, however a MANUAL mode is available if this fails. The operator must closely monitor the actual temperatures in each zone and manually adjust the Trim Air Modulating Valves accordingly.

Lastly, all large transport aircraft normally provide each passenger with a directionally adjustable air outlet located above each seat. This is known as a gasper and the airflow from this outlet is taken directly from the output of the packs before it is trimmed with hot air for each zone. The gasper air is fan forced and is selected ON/OFF in the cockpit.

Normally selected ON when the aircraft is on the ground it provides each passenger with cooling air even when the ambient cabin temperature may be hot due to ground conditions. Refer to Figure 6-23.

RECIRCULATION and FILTRATION STAGE The next stage of the ECS process is to recirculate and filter the used cabin and cockpit air for continued use.

Cabin and cockpit air is extracted and forced through filters located underfloor by electric recirculating fans. The filtered air is then ducted back into the Conditioned Air Manifold where it mixes with fresh incoming air from the packs. The recirculating fan(s) are may be switched ON/OFF in the cockpit. Refer to Figures 6-22 and 6-23.

This process drastically reduces the volume of supply bleed air extracted from the engines resulting in significant fuel savings.

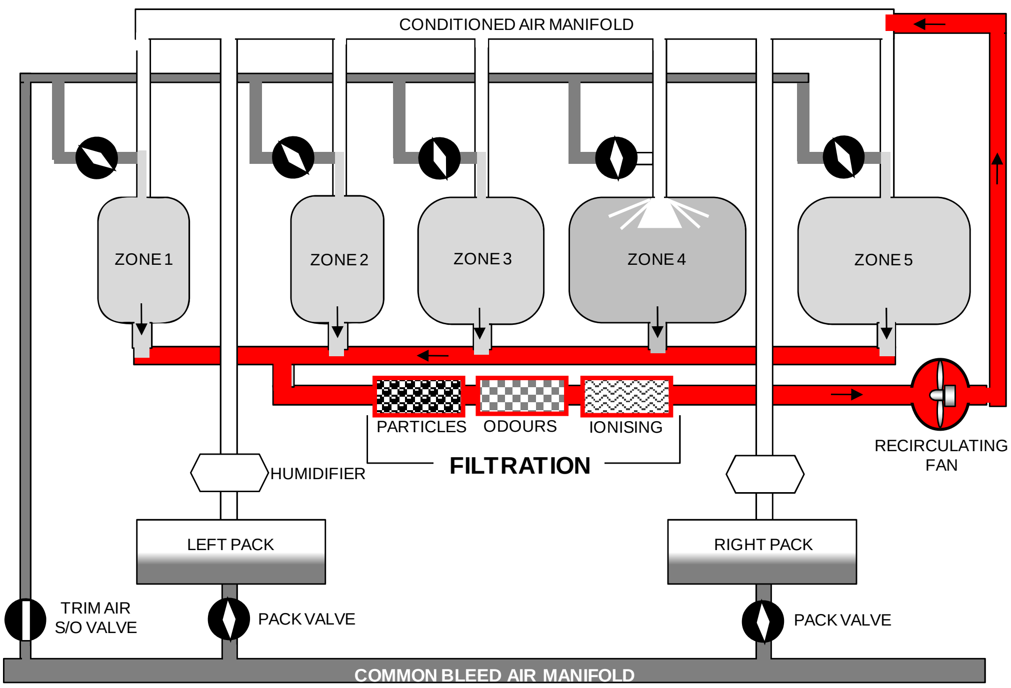

Figure 6-22 Recirculation and Filtration

EXHAUSTING and PRESSURISING STAGE The last stage of the ECS process is to allow some air to escape via the Cabin Outflow Valves. This part of the process has been discussed in Chapter 7, Pressurisation Systems. Note that the aircraft will have a number of very small fixed outlets that continuously allow cabin air to escape for fume or odour removal.

Refer to Figure 6-23.

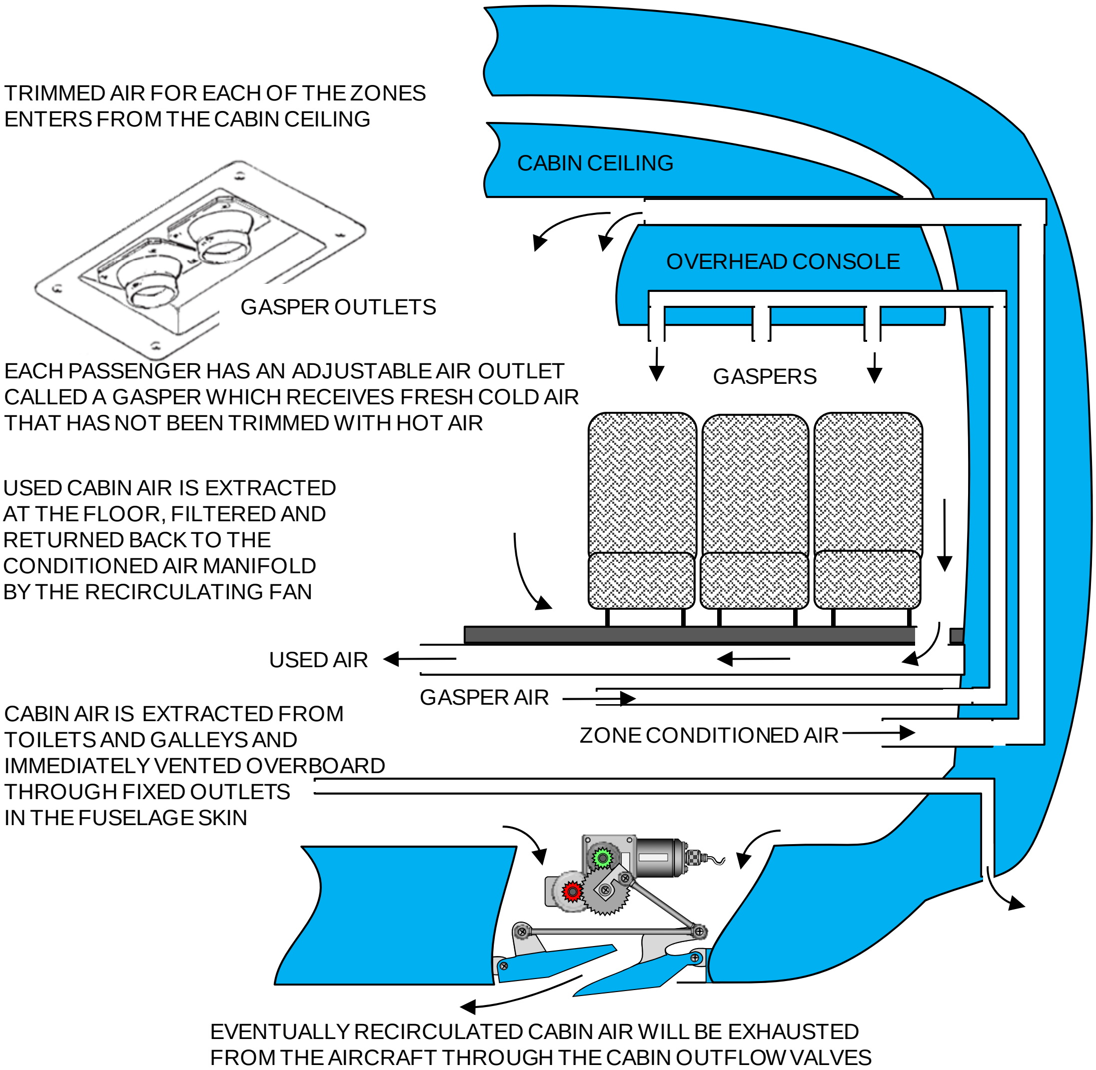

Figure 6-23 Zone Air, Gasper Air, Recirculated Air and Vented Air

AIRCONDITIONING SYSTEM INDICATIONS AND WARNINGS

AIRCONDITIONING SYSTEM INDICATIONS

All medium to large pressurised aircraft will have an ECS Control Panel in the cockpit. On older generation aircraft it will contain the controls, indications and annunciator lights associated with the packs and zone temperature. In modern aircraft the indications and alerts will appear on the ECAM or EICAS pages leaving only the controls on the ECS panel.

NORMAL SYSTEM INDICATIONS

The cockpit indications of a functioning airconditioning system are different between older and more modern generation aircraft, however the following indications are commonly found in all types. They are;

- the position of the bypass valve or temperature control valve,
- the temperature output of the bootstrap compressor,
- the temperature output of the bootstrap turbine,
- the positions of the trim air modulating valves,
- the actual temperature entering each zone or the target temperature, and
- the actual temperature in each cabin zone.

The following illustration provides an example of an older generation ECS Control Panel which has a comprehensive array of automatic and manual controls, gauges and indicators. The airconditioning packs on this aircraft can be operated in MANUAL thus requiring more indications for the operator. Refer to Figure 6-24.

Figure 6-24 ECS - Analog Controls and Presentation

Modern large aircraft fitted with an ECAM or EICAS will display some of the above indications in digital format leaving only the switches required for normal operation on the ECS Control Panel. Refer to Figure 6-25.

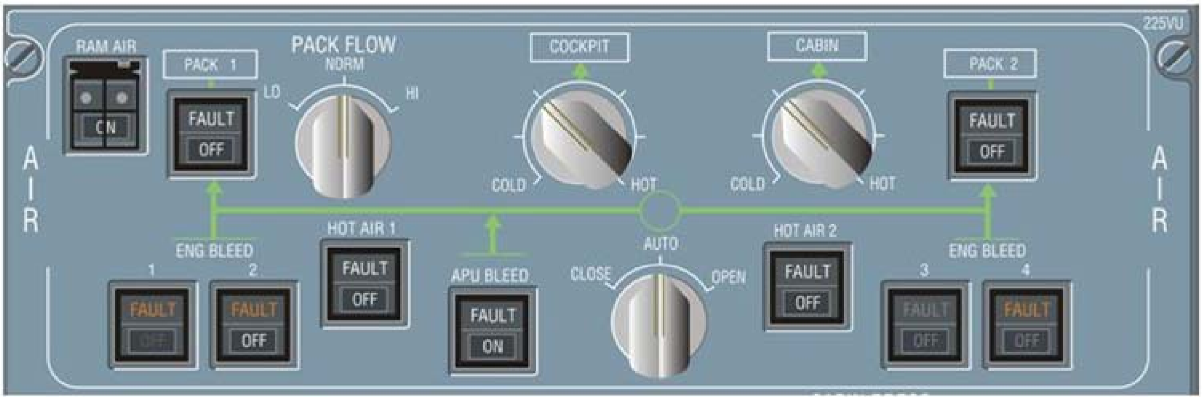

Figure 6-25 ECS – Modern Controls

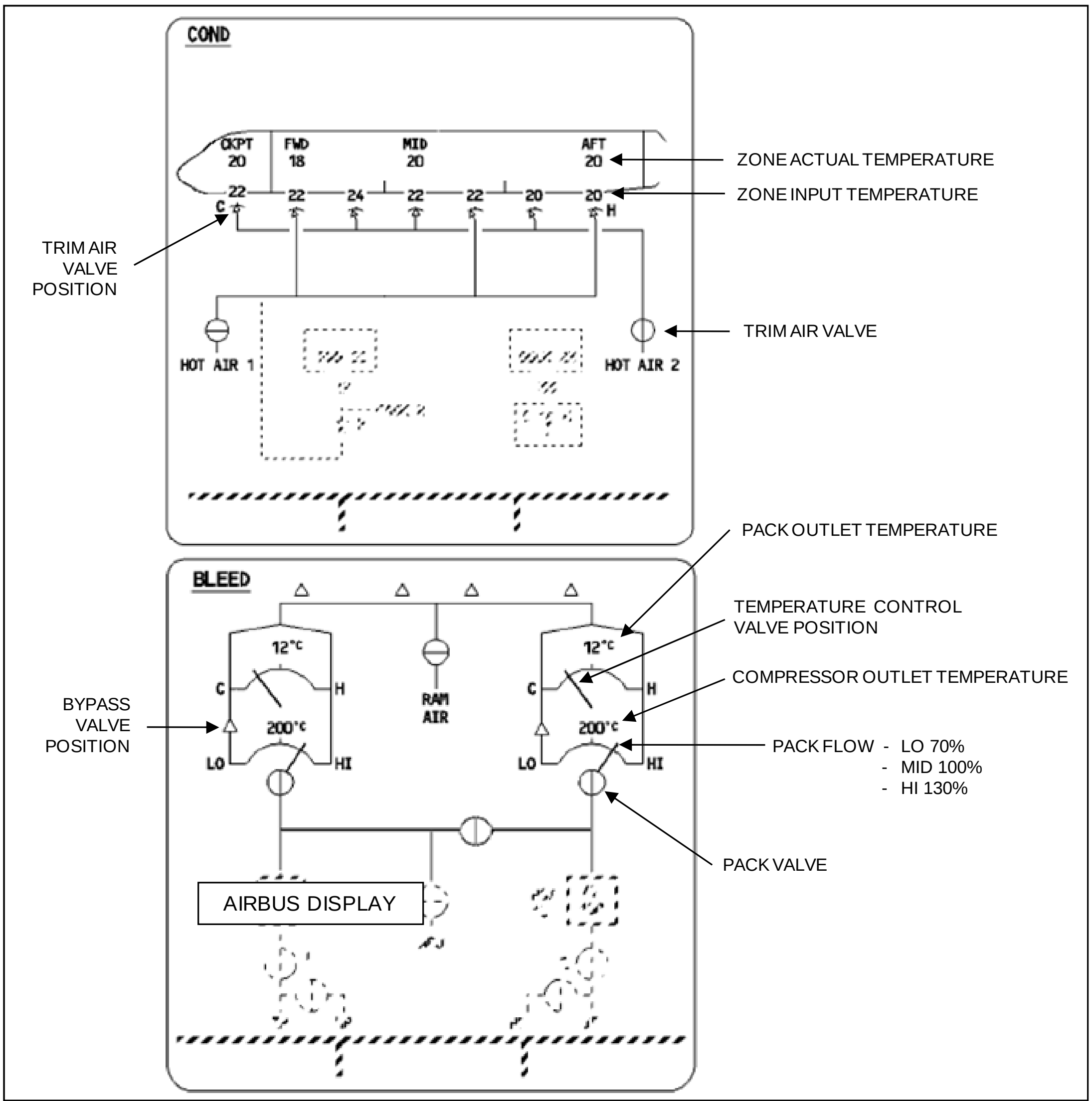

Figure 6-26 ECS – Digital Presentations

Status of Controls and Systems

In modern large aircraft the ECS is continuously controlled and monitored by computers. The software is programmed to make the operator aware not only of malfunctions but also to provide the current position of controls and mode status. Synoptic presentations make greater use of colour to indicate the status of components and the system. Colours follow the same pattern as previously described in other Chapters. Refer to Figure 6-26.

ABNORMAL SYSTEM INDICATIONS AND FAILURE

The abnormal or failure cockpit indications are provided by either individual annunciator lights or ECAM/EICAS caution advisories. They will be an AMBER caution light or advisory and will require the crew to take some action immediately. There will be a checklist to follow for these problems.

Pack Overheat (Pack Trip) **(caution) –** a pack overheat will occur if the pack controller senses too high a temperature at the output of the compressor. The pack controller shuts down the pack automatically by closing the pack valve and a fault light/alert will be annunciated to the crew.

<u>This is referred to as a pack trip</u>. The operator should turn the pack switch to OFF and after a reasonable time use the pack reset switch to reset the overheat switch and try to restart the pack.

If the temperature is still too high the pack will not start and the operator should allow more time for cool down.

Note that pack trips normally only occur on the ground in very hot conditions when the airconditioning is set for full cold output.

For interest Airbus aircraft ventilate (using fans) the compartment in which the packs are located to assist in cooling during ground operations.

Zone Overheat (Zone Trip) **(caution) –** if the trim air entering the zone becomes too hot the master temperature controller will close the trim air modulating valve for that zone and a fault light/alert will be annunciated to the crew. This is referred to as a zone trip.

The operator should turn the zone switch to OFF and after a reasonable time use the zone reset switch to reset the overheat switch and try to restore automatic operation for that zone.

TYPICAL MALFUNCTION ALERTS IN AIRCONDITIONING SYSTEMS

The following table details some examples of the malfunction alerts and possible faults that are presented to the crew in switches and on ECAM/EICAS in modern pressurisation systems found today. Refer to Figure 6-27.

ALERT MESSAGE	ALERT LEVEL	AURAL	FAULT
PACK OVERHEAT	CAUTION	SINGLE CHIME	Compressor outlet temperature >260°C Pack outlet temperature >95°C
DUCT OVERHEAT	CAUTION	SINGLE CHIME	Zone input temperature >88°C
PACK SW OFF (with no failure)	CAUTION	SINGLE CHIME	Pack switch turned OFF for no reason
CABIN FAULT	CAUTION	SINGLE CHIME	Recirculation fan failure
FAULT LIGHT (in switches)	CAUTION	SINGLE CHIME	Check ECAM for further information about the fault

Figure 6-27 Malfunction Alerts in Modern Airconditioning Systems

AIRCONDITIONING SYSTEM REDUNDANCY AND ALTERNATE OPERATIONS

ALTERNATE AND EMERGENCY OPERATION

The term alternate operation normally refers to a mechanism or another system that is the alternate to the normal method of operation. For airconditioning there is no alternate system, only alternate operation.

All large transport aircraft are required to have at least two airconditioning packs for redundancy. Some aircraft have three packs.

In older generation aircraft a MANUAL mode is available to the crew for alternate operation. The operator can control the inlet door and bypass valve manually. Careful monitoring of temperature indications is required to maintain acceptable cabin temperatures.

In modern aircraft with a failure of both automatic control computers the packs will automatically default to an alternate program that sets inlet/exhaust doors and valves to a fixed position that provides an acceptable temperature. There is no MANUAL mode option in modern aircraft. The aircraft's airconditioning system alternatives are listed in the following table. Refer to Figure 6-28.

NORMAL OPERATION	FIRST ALTERNATE	SECOND ALTERNATE	EMERGENCY
OLDER AIRCRAFT Each pack has a pack controller for AUTO mode	Pack may be operated in MANUAL mode	The other pack is sufficient for pressurisation	If all packs fail, descend the aircraft to 10,000 ft and open ram air ventilation
MODERN AIRCRAFT Each pack has two controllers for AUTO mode	Switch to other controller if it does not occur automatically	If both controllers fail pack will default to fixed positions The other pack is sufficient for pressurisation	If all packs fail, descend the aircraft to 10,000 ft and open ram air ventilation

Figure 6-28 Summary of Alternate and Emergency Operation

DISPATCH WITH INOPERATIVE AIRCONDITIONING EQUIPMENT

Whilst redundancy is designed primarily for safe flight an added advantage is that aircraft may be dispatched for flight with some components of an airconditioning system inoperative. There will be operational restrictions and flights will normally only be approved until the aircraft returns to home base.

Authority to dispatch with inoperative equipment is detailed in the aircraft's Minimum Equipment List (MEL) publication. Examples of typical inoperative airconditioning equipment that may be carried over for continued aircraft operation are;

- Gasper fans,
- Recirculation fans,
- Numerous venting fans, and
- Some indication faults

EQUIPMENT BAY COOLING

AVIONICS OR ELECTRICAL EQUIPMENT COMPARTMENT

Almost all large jet transport aircraft position the avionic, electronic and major electrical equipment in one location within the forward belly of the aircraft. This location is typically below the floor of the flight deck in a pressurised compartment which is accessible during flight. On double decked aircraft, access is possible through a hatch in the cabin floor.

The centralisation of the equipment in one large compartment provides a single point access for avionics/electrical maintenance, the ability to cool almost all of the heat generating equipment at one location, and the ability to detect and extract any smoke generated from overheated equipment. Refer to figure 6-29.

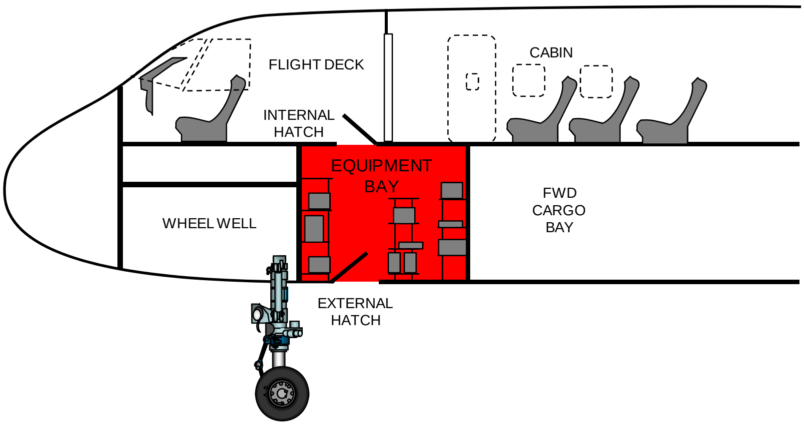

Figure 6-29 Electrical Equipment Centre

The heat generated by the array of electronic equipment in the compartment is significant. Not only does the electronic equipment add to the problem of keeping the aircraft cool, the actual efficiency of the equipment is also affected. To keep the equipment compartment cool a special sub-system of the ECS is used. Refer to Figure 6-30.

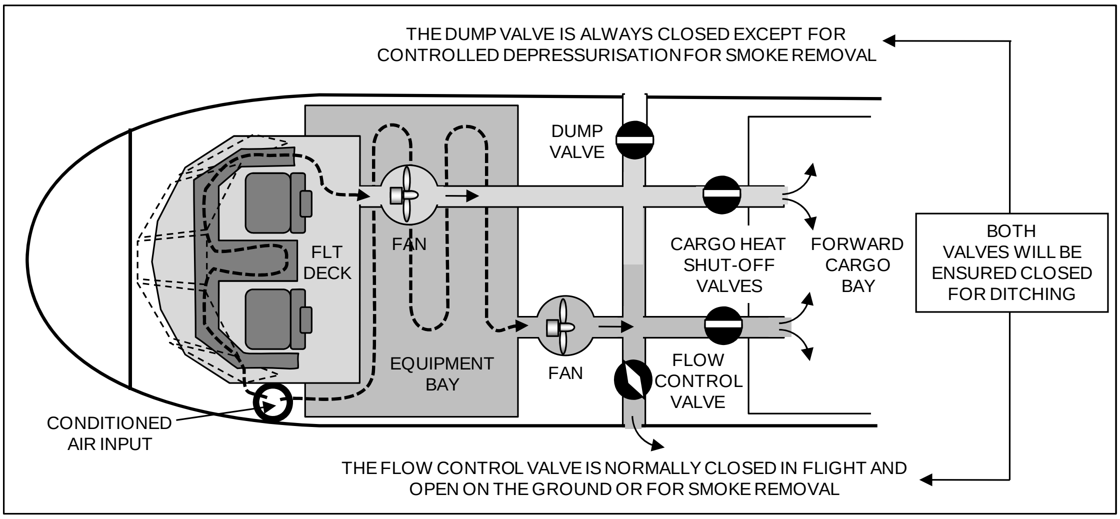

Figure 6-30 Electrical Equipment Bay and Flight Deck Cooling

Typically the equipment bay cooling system extracts conditioned air from the flight deck and the equipment bay and fan forces the heated air;

- overboard through a special valve when the aircraft is on the ground, and
- into the forward cargo bay or directly to outflow valves in flight.

CARGO BAY HEATING

FORWARD, AFT AND BULK CARGO BAY CONDITIONING

Most modern large transport aircraft are configured with three cargo holds or bays below the passenger deck. This includes freighter aircraft which will of course have a main freight deck replacing the passenger deck. The forward and aft bays are used to load standard size containers and will have integrated floor mounted electrically driven rollers to position the containers. The bulk cargo bay is designed for odd shaped and miscellaneous cargo including live animals. Refer to Figure 6-31.

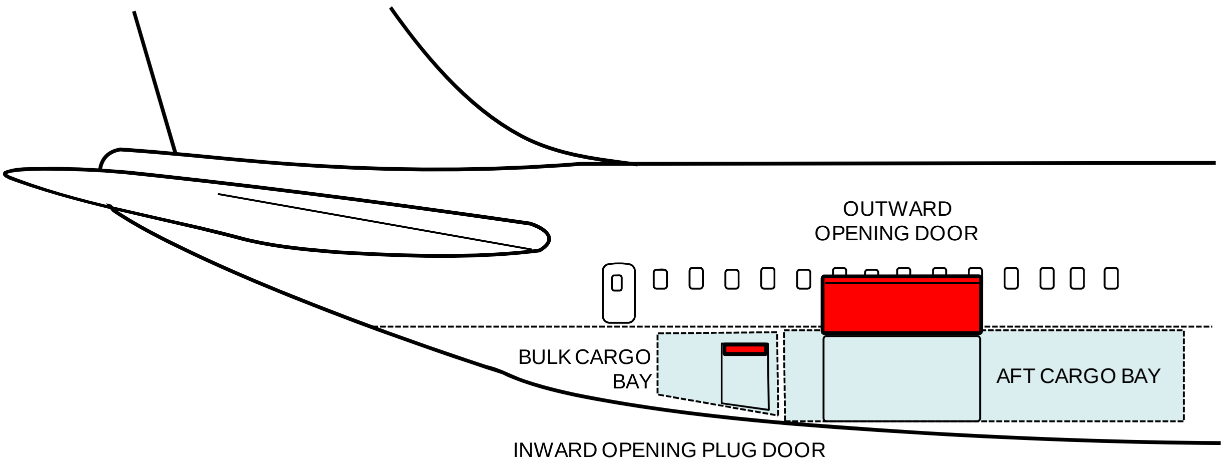

Figure 6-31 Aft and Bulk Cargo Bays

Forward Cargo Bay Heating is usually achieved by allowing the hot air extracted from the cockpit and electrical equipment bay to flow into the bay. Refer to Figure 6-30. Typically this is more than enough to heat the bay but some aircraft may have additional hot air inputs as described for the Aft and Bulk Cargo Bays. In the event of smoke extraction from the equipment bay or a cargo fire the cargo heat shut-off valves will close automatically.

Aft and Bulk Cargo Bay Heating requires a sub-system to maintain a desired temperature condition. Normally this is achieved by using hot bleed air taken directly from the Common Bleed Air Manifold. Some aircraft use exhausted cabin air reheated by electric heaters but this is not common.

Thermostatically controlled switches located in the cargo holds automatically maintain the desired temperature by modulating the inflow of bleed air. A control switch is located in the flight station to allow the system to be turned on and off. Refer to Figure 6-31. In the event of an overheat or cargo fire the shut-off valve will close automatically.

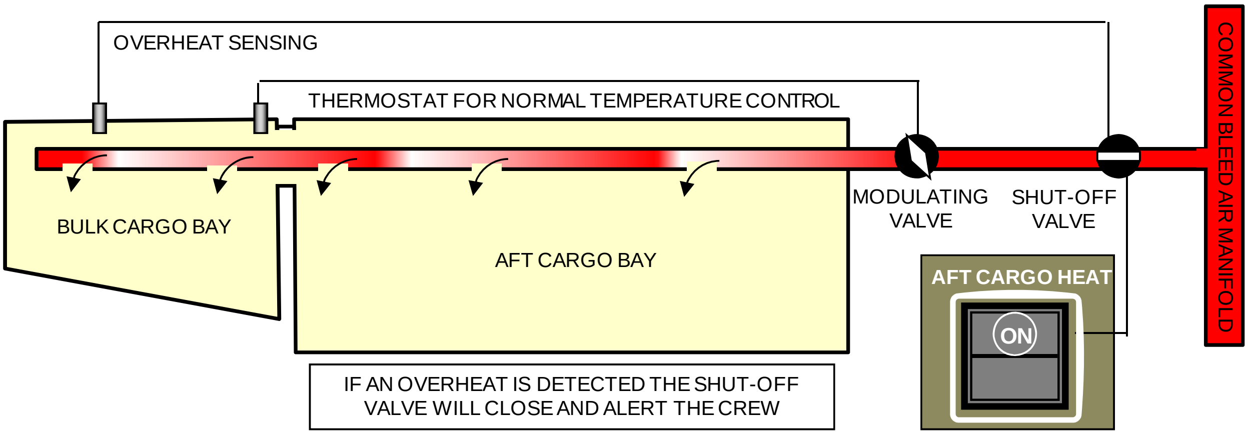

Figure 6-32 Aft and Bulk Cargo Bay Heating

PERSONAL HEATING AND AREA VENTING

SPECIFIC AREAS NEEDING HEATING AND VENTILATION

Pilot Seat Positions need specific heating as the flight deck is more exposed to extremes of cold and heat due to the large areas of glass. At night at high altitudes the normal flight deck conditioned air cannot adequately condition all of the cockpit space particularly the rudder pedal areas. Specific ducting and outlet vents are provided to direct warm air onto the pilot's feet and side windshield edge.

In the other case when the cockpit is exposed to strong sun, sometimes only on one side, the crew will typically turn flight deck temperature down to suit the exposed pilot thus requiring the other pilot to use their heating outlets. Very modern aircraft are fitted with electric shoulder heaters integrated within the seat back.

Crew Rest Areas are constructed within unusual sections of the aircraft either above or below the main passenger deck and whilst normal cabin conditioned air is used some areas need additional electrical heating.

Toilets and Galleys need to be ventilated constantly to extract fumes and this is done by allowing conditioned cabin air to enter the space and be extracted to atmosphere through fixed diameter holes in the fuselage.

USING GROUND EQUIPMENT

GROUND EQUIPMENT FOR AIRCONDITIONING THE AIRCRAFT

Under normal circumstances the aircraft's APU can supply sufficient bleed air to operate all of the airconditioning packs when the main engines are shutdown. On occasions when the APU is inoperative a ground airconditioning unit may be connected for passenger comfort.

Connection is normally made beneath the aircraft adjacent to the leading edge wing roots and the <u>conditioned air is ducted directly to the main Conditioned Air Manifold</u>. Refer to Figure 6-33.

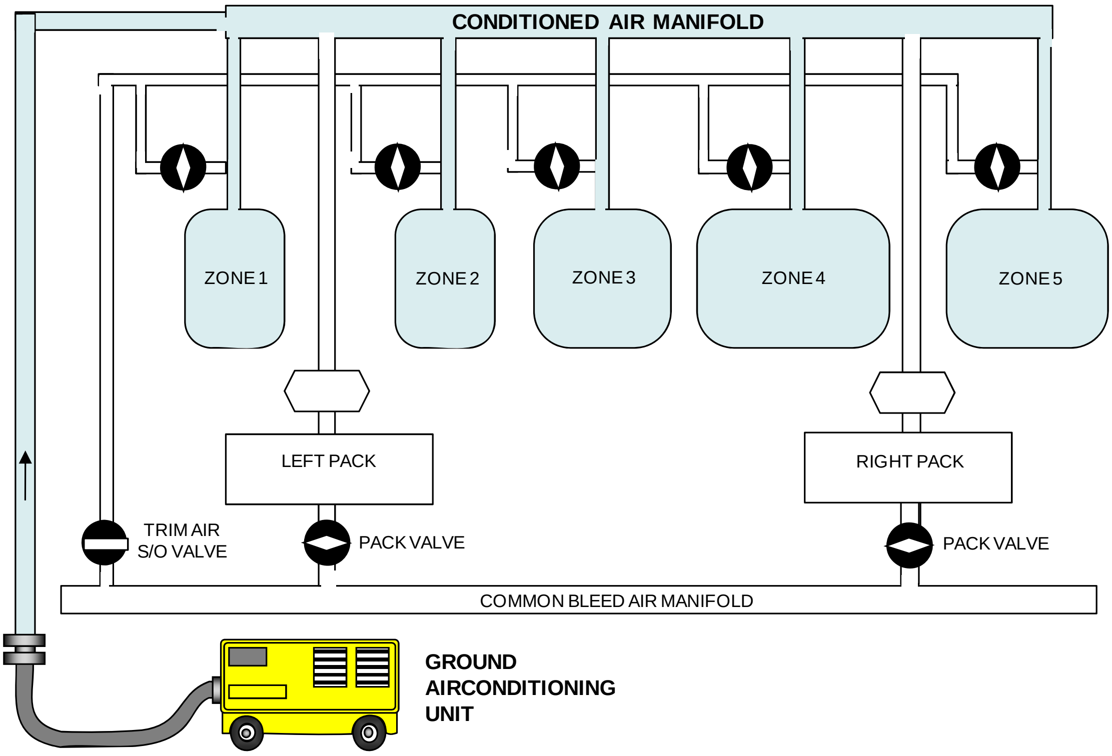

Figure 6-33 Connection of a Ground Airconditioning Unit

EMERGENCY VENTILATION

RAM AIR VENTILATION

If a situation arises where all airconditioning packs are inoperative and the aircraft is operating in a depressurised condition fresh ram air may be selected for ventilation of the cabin.

Selected by the flight crew the Ram Air Vent allows fresh air to directly enter the Conditioned Air Manifold and thus through the normal cabin ducting. Obviously no temperature adjustment can be made to this air source. Refer to Figure 6-34.

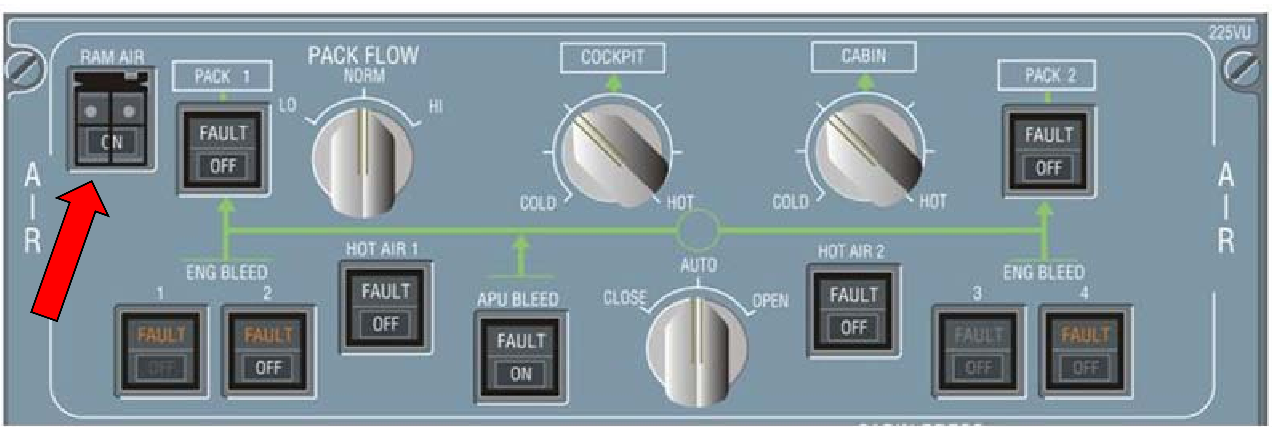

Figure 6-34 Ram Air Vent Control

AIRCONDITIONING SYSTEM TERMINOLOGIES AND DEFINITIONS

The following table defines old and/or common terms that you may encounter with reference to airconditioning systems. Refer to Figure 6-35.

TERM REFERRED	DEFINITION
ACM	Air Cycle Machine – one of the names used to describe a bootstrap turbine –see bootstrap.
Bootstrap	A name given to the combination of a turbine and compressor unit that helps itself by the compressor driving its own turbine and the turbine in turn driving its own compressor.
Cabin Cooling Turbine	one of the names used to describe a bootstrap turbine –see bootstrap.
CAU	Cold Air Unit – one of the names used to describe a bootstrap turbine –see bootstrap.
Charge air	Another term used for supply air.
Coalescer Bag	A fibrous bag located within in the water separator in an air cycle system on which the moisture that condenses from the air may coalesce.
EEC	Electrical Equipment Centre – another name for the avionics/equipment compartment
Exhaust Muff	A close fitting cowl that surrounds the exhaust manifold of a piston engine through which passes ram air to be heated for cabin heating. Also called a heating muff.
Gasper	The small individual air outlet above each passenger and crew member that provides cold air taken directly from the output of the packs. The gasper system can be turned ON or OFF from the cockpit.
Hot Air	The Airbus term used to describe Trim Air in ECS diagrams and synoptics
Hygrostat	A sensor for sensing the percentage of humidity within air. Same as a humidistat.
Lower Lobes	The Boeing term used to describe the cargo bays in ECS diagrams and synoptics
MEC	Main Equipment Centre – another name for the avionics/equipment compartment
MLC	Main Load Centre – another name for the avionics/equipment compartment
Pukka Louvre	One of the names given to gasper outlets
Register	A name applied to the air outlets (hot or cold) in the cabins of smaller aircraft. A vent or grill.

Figure 6-35 Airconditioning Terms and Definitions

EXAMPLE AIRCONDITIONING PACK

Airbus 330 and 340

For interest observe how Airbus has structured its airconditioning pack based on an Air Cycle System but driving the cooling fan from the bootstrap turbine to increase its workload and providing a special valve specifically to combat icing at the water separator. Also note the comprehensive indications provided to the crew on the ECAM page.

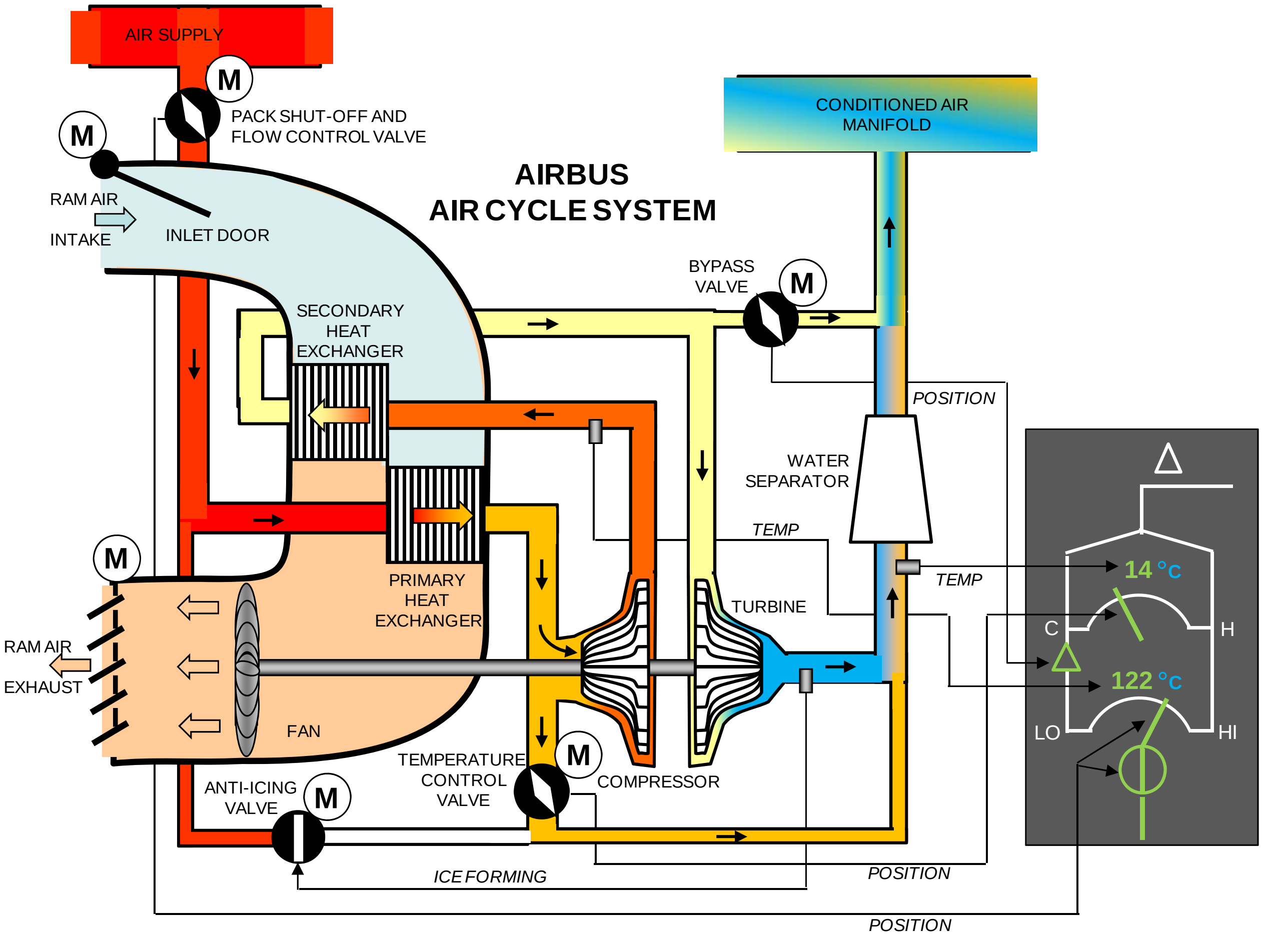

Figure 6-36 Airbus Airconditioning Pack Schematic

AIRCONDITIONNG SYSTEMS QUESTIONS

The following questions will examine your understanding of airconditioning systems and their operation. The answers may be found in the text or diagrams of this Handbook.

1. An exhaust muff is;

- **a.** an exhaust muffler used to reduce exhaust noise.
- **b.** an exhaust catalytic converter to reduce carbon emissions.
- **c.** an exhaust shroud to capture exhaust heat.

2. In an emergency such as engine failure the minimum amount of fresh air that must be provided by the ECS is;

- **a.** 0.5 pound per person per minute.
- **b.** 1.0 pound per person per minute.
- **c.** 0.5 pound per passenger per minute and 1.0 pound per crewmember.

3. The temperature considered to be ideal for passengers is approximately;

- **a.** 18 to 24°F.
- **b.** 18 to 24°C.
- **c.** 18 to 24° approximately.

4. The purpose of a "choke valve" is to;

- **a.** choke the output of an engine to control backpressure.
- **b.** choke the output of a compressor to increase backpressure.
- **c.** stop a compressor choking when backpressure is too high.

5. Heat exchangers in an airconditioning system are used to;

- **a.** cool ram air.
- **b.** heat supply air.
- **c.** cool supply air.

6. A coalescer bag would be found inside;

- **a.** a carbon filter.
- **b.** a mass flow controller.
- **c.** a water separator.

7. On a hot day with the aircraft on the ground you would expect to see the following indications on the ECS panel;

a. inlet door partly open, exhaust door fully open and the bypass valve almost open.
b. inlet door fully open, exhaust door fully open and the bypass valve almost closed.
c. inlet door fully open, exhaust door fully open and the bypass valve fully open.

8. The output of a displacement blower is controlled by a;

a. shut-off valve.
b. choke valve.
c. spill valve.

9. An vital sensor fitted to aircraft that use an exhaust muff would be;

a. a temperature sensor.
b. a carbon monoxide sensor.
c. a pressure sensor.

10. You would find a “jet pump” in;

a. a brake turbine system.
b. a fan turbine system
c. a turbo-compressor system.

11. The term “trim air” relates to;

a. cold air that adjusts zone input air.
b. hot air that adjusts zone input air.
c. hot air that adjusts zone exit air.

12. The most likely location in an airconditioning system that would form ice would be;

a. the entrance to the water seperator
b. the exit of the water seperator.
c. the entrance to the humidifier.

13. The refrigerant used in vapour cycle systems is;

a. argon.
b. freon.
c. PCP.

14. Areas of an aircraft that are typically airconditioned are;

a. cabin, cockpit, nose radome, APU compartment and bulk cargo bay.
b. cabin, cockpit, APU compartment and forward cargo bay.
c. cabin, cockpit, aft cargo bay and avionics bay.

15. The purpose of a mass flow controller is;

a. unload the compressor for take-off.
b. control the airflow from the compressor.
c. adjust airflow for the passenger mass.

16. Recirculating fans are used to;

a. recirculate used air back to the common bleed air manifold.
b. recirculate cabin air to the equipment bays.
c. recirculate cabin air back to the conditioned air manifold.

17. Gasper air is sourced from;

a. the ram air vent.
b. the trim air manifold
c. the pack outlet air.

18. The reason that modern airconditioning systems recirculate and filter air is to;

a. assist in maintaining pressurisation at high aircraft altitudes.
b. reduce the overall use of bleed air.
c. ensure no fumes from the engine bleed air can contaminate the cabin air.

19. The term “bootstrap” relates to a;

a. turbo-compressor system.
b. brake turbine system.
c. vapour cycle system.

20. A ground airconditioning unit may be connected to ……………………………. for passenger comfort when the aircraft is on the ground and the APU is inoperative;

a. the bleed air manifold.
b. the conditioned air manifold.
c. the trim air manifold.

21. The typical location of ECS ram air inlet doors on large jet transport aircraft is;

a. below the radome at the nose of the aircraft.
b. below the leading edges of the wings.
c. between the wing root leading edges in the fuselage belly.

22. Vapour cycle systems are most likely to form ice at the;

a. humidifier.
b. evaporator.
c. condenser.

23. In an air cycle airconditioning system the secondary heat exchanger;

a. is upstream of the compressor.
b. is downstream of the turbine.
c. is downstream of the compressor.

24. A “pack trip” normally means;

a. the pack has overheated and gone into manual mode.
b. the pack has overheated and shut itself off.
c. the pack has formed ice and shut itself off.

25. The primary purpose of the cooling fan located in the ram air duct of an air cycle system is to;

a. maintain airflow through the heat exchangers on the ground.
b. maintain airflow through the heat exchangers if the inlet door fails closed.
c. keep the pack compartment cool when the aircraft is on the ground.

26. The minimum percentage of relative humidity that should be provided to passengers on a modern aircraft is;

a. 60%.
b. 30%.
c. 15%.

27. The pack reset switch is used to;

a. restart a pack that has shut down.
b. reset a pack trip.
c. select the back-up pack temperature controller.

28. When an airconditioning pack is being operated in MANUAL mode the operator controls the positions of;

a. the exhaust door and the bypass valve.
b. the inlet door, the exhaust door and the bypass valve.
c. the inlet door and the bypass valve.

29. Air conditioning packs receive supply air from;

a. the common bleed air manifold.
b. the conditioned air manifold.
c. the trim air manifold.

30. If you selected MANUAL mode on a zone control switch you would then be in control of;

a. the master temperature controller.
b. the trim air modulating valve.
c. the trim air manifold shut-off valve.