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CHAPTER 4: PNEUMATIC SYSTEMS

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CONTENTS .... PAGE

INTRODUCTION..4
THE COMPRESSION PROCESS.. 5
PNEUMATIC SOURCES 5
PNEUMATIC SOURCE - EMERGENCY BOTTLES 5
PNEUMATIC SOURCE - MECHANICAL AIR COMPRESSORS................................. 6
TYPES OF COMPRESSORS 7
POSITIVE DISPLACEMENT COMPRESSORS 7
CENTRIFUGAL COMPRESSORS 8
ENGINE DRIVEN COMPRESSORS (EDCS) 9
CENTRIFUGAL LOAD COMPRESSORS 11
HIGH PRESSURE MULTIPLE STAGE PISTON PUMPS 12
PNEUMATIC SOURCE - ENGINE BLEED AIR...12
PNEUMATIC SOURCE – GROUND EQUIPMENT...16
PNEUMATIC SYSTEM DISTRIBUTION 17
THE COMMON BLEED AIR MANIFOLD 17
SUMMARY.. 20
PNEUMATIC SYSTEM COMPONENTS...21
PNEUMATIC DUCTING 21
DUCT NON RETURN VALVES (CHECK VALVES) 21
ELECTRICALLY OPERATED VALVES.. 22
ELECTRICALLY OPERATED VALVES – ENGINE START VALVE........................... 23
PNEUMATICALLY OPERATED VALVES 24
PNEUMATIC ACTUATORS 25
AIR TURBINE STARTER MOTORS 25
PNEUMATIC SYSTEM INDICATION AND WARNINGS.......................................26
PNEUMATIC SYSTEM INDICATIONS.. 26
NORMAL SYSTEM INDICATIONS 27
PNEUMATIC SYSTEMS, REDUNDANCY AND ALTERNATE OPERATIONS....29
PNEUMATIC SYSTEMS.. 29
REDUNDANCY.. 30
ALTERNATE AND EMERGENCY OPERATION 30
DISPATCH WITH INOPERATIVE PNEUMATIC EQUIPMENT.................................. 31
LEAKAGE IN PNEUMATIC SYSTEMS.. 33
PNEUMATIC SYSTEM LIMITATIONS 33

BLEED AIR LIMITATIONS ON MAIN ENGINES 33
BLEED AIR LIMITATIONS ON APUS.. 34
PNEUMATIC SYSTEM TERMINOLOGIES AND DEFINITIONS 34
GENERAL SAFETY PRECAUTIONS RELATING TO PNEUMATIC SYSTEMS......... 34
HIGH PRESSURE PNEUMATIC SYSTEMS 35
HIGH PRESSURE MULTIPLE STAGE PISTON PUMPS 36
PRESSURE REGULATORS 37
PRESSURE REDUCING VALVES 37
OIL AND WATER TRAPS 38
HIGH PRESSURE PNEUMATIC ACTUATORS... 38
SAFETY PRECAUTIONS SPECIFICALLY RELATED TO HIGH PRESSURE PNEUMATIC SYSTEMS.. 40
PNEUMATIC SYSTEMS QUESTIONS 41

INTRODUCTION

Pneumatics is the term used to describe fluid power that transmits force by the use of a compressible fluid, typically air.

The use of high pressure compressed air, instead of hydraulics, to operate equipment on aircraft has been employed in the past but its use is generally declining as hydraulic systems offer greater power and control.

Some older types of aircraft were totally pneumatic with no hydraulics used for any services and aircraft of this type were said to have a “High Pressure Pneumatic System” which operated landing gear, flaps, cargo doors, steering, and brakes. These systems operated at high pressures (3000 PSI) and an example aircraft system is described at the end of this chapter.

For interest, Figure 4-1 compares the advantages and disadvantages of high pressure pneumatic and hydraulic systems when used for aircraft equipment operation such as landing gear and flaps.

PNEUMATIC POWER (compressible)		**HYDRAULIC POWER** (incompressible)
Less power	Power generated for production effort	Enormous power
Lighter as there is no need to return the compressed air to a reservoir after use	Weight of the system infrastructure	Heavier as the fluid must be returned to the reservoir
Unlimited but when engine bleed air is used as the source engine performance suffers	Fluid supply	Limited to the capacity of the reservoir
Poor	Control authority and response	Excellent

Figure 4-1 Comparison of Power to operate Equipment

The term “Pneumatic System” when applied to small aircraft will typically mean a simple system operating at low pressures to provide compressed air for cabin pressurisation, airconditioning and on some aircraft inflatable leading edges for de-icing.

“Pneumatic Systems” on medium and large modern aircraft usually means the system that provides compressed air for cabin pressurisation, airconditioning and many other services. These systems operate at much lower pressures with high volumes of air flow produced. These pneumatic systems will use compressed air taken from the engine compressors which is hot and therefore may be used not only for power but for anti-icing and other heating purposes. This compressed air source is known as “engine bleed air”.

The modern large jet transport aircraft today will typically use pneumatics for airconditioning and pressurisation, main engine starting, de-icing and anti-icing systems and some other services such as cargo heating and hydraulic reservoir pressurisation. These are “Low Pressure Pneumatic Systems” (25-45 PSI).

Modern aircraft will also have some small stored air bottles to operate emergency equipment.

This chapter will describe all of the pneumatic applications employed on all types of aircraft and which may be referred to as individual Pneumatic Systems.

Aircraft pneumatic applications are generally of four types being stored compressed air, low and high pressure mechanically compressed air, bleed air and compressed air supplied by a temporary ground equipment source.

THE COMPRESSION PROCESS

The compression process causes the **temperature**, **volume** and **pressure** values to change. These changes occur in accordance with a combination of Boyle's and Charles' Laws.

Boyle's Law states that the volume of a given mass of gas at a constant temperature is inversely proportional to its pressure.

Charles' Law states that the volume of a given mass of gas at a constant pressure is proportional to its absolute temperature.

The two laws combined suggest that the absolute temperature of a gas is proportional to the product of the volume and the pressure of that gas.

From the perspective of aircraft pneumatic systems this means that when air is;

- Compressed, its pressure and temperature **increases** as its volume **decreases**.
- Expanded, its pressure and temperature **decreases** as its volume **increases**.

PNEUMATIC SOURCES

Aircraft pneumatic sources can be provided by four methods;

- Ground charged stored emergency gas bottles,
- Mechanical air compressors driven by the main engines and APUs,
- Extracting compressed air from the main engine compressor or the APU compressor, and
- Ground equipment compressors temporarily connected to the aircraft for specific reasons.

PNEUMATIC SOURCE - EMERGENCY BOTTLES

Ground charged gas bottles are provided on most aircraft to operate essential equipment in an emergency and are typically filled with <u>nitrogen as it is an inert and moisture free</u> gas.

The common application of gas bottles on older aircraft types was to operate gear down and wheel brakes if the normal hydraulic systems failed. Modern jet transport aircraft no longer use stored bottles for this reason but do use them extensively to open <u>main cabin doors and inflate escape slides</u> for an emergency evacuation.

All emergency bottles are individually charged by maintenance personnel and will be fitted with a pressure gauge visible for preflight check. Charge pressures may be as high as 3000 PSI. They are totally independent of the aircraft's pneumatic system. Refer to Figure 4-2.

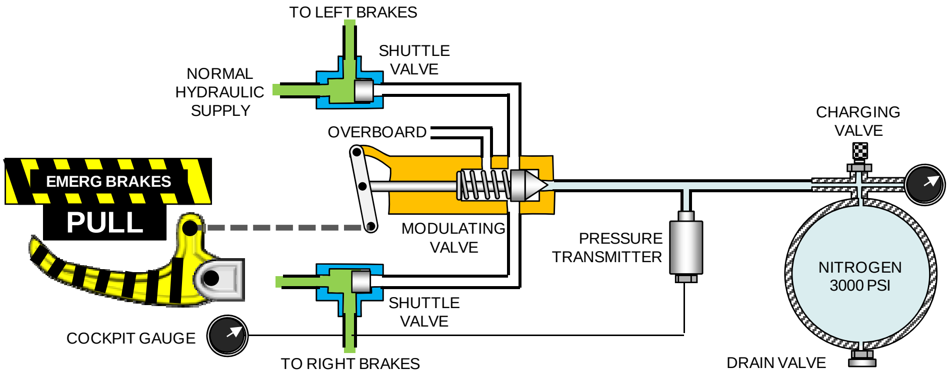

Figure 4-2 Emergency Air Brakes

PNEUMATIC SOURCE - MECHANICAL AIR COMPRESSORS

The driving methods, complexity and output of mechanical compressors vary depending on the type of compressor, aircraft size, engine type and cruising altitude.

Driving Methods

- Driven from the engine accessory gearbox by drive shaft. - called superchargers, cabin blowers or engine driven compressors they are used to supply compressed air for pressurisation and airconditioning.
- Driven by the exhaust gas pressure of a piston engine. - called a turbocharger this compressor may be used for the reasons stated above but is not commonly used.
- Driven by a free turbine or common shaft integrally within an APU.
- Driven from the engine accessory gearbox by drive shaft. - called multi-stage piston pumps they are used by some older aircraft to operate gear, flaps and brakes and maintain pneumatic reservoir pressure.

Complexity and Output Control

❖ Simple compressors with smaller outputs controlled by separate spill valves, choke valves, silencers and flow controllers fitted downstream of the compressor – small to medium piston and turboprop aircraft.

❖ Complex compressors with integrated variable control of a larger outputs and operated by an integral independent hydraulic system. Typically these compressors may be disconnected from the main engine gearbox at pilot discretion if problems occur – large turboprop aircraft.

❖ Compressors integrally constructed as part of the APU provide large variable outputs depending on the pneumatic loads required. – modern jet transport aircraft.

❖ Complex multiple staged piston pumps that can produce high pressures to operate equipment – aircraft with no hydraulic systems.

TYPES OF COMPRESSORS

- Positive displacement compressors
- Centrifugal compressors
- Centrifugal Load compressors
- Multi-stage Piston Pumps

POSITIVE DISPLACEMENT COMPRESSORS

Most common commercial aircraft that operate at high altitude (above 25,000 ft) have multiple engines and at least two compressors. The combined compressor output is typically designed to provide an 8000 ft cabin altitude when the aircraft is operating at its maximum cruise altitude. With a single engine failure or loss of one compressor, the remaining compressor should be able to maintain a cabin altitude of 15,000 ft.

Positive displacement compressors are actually displacing air from outside the aircraft to the cabin interior and since the exhaust air from the cabin is restricted the cabin air forms a backpressure against the compressor output. When operating at low altitudes however, compressor output is far too great due to the air density and most of the produced air charge is dumped overboard via spill valves.

A common type of displacement compressor is the 'Rootes' cabin blower shown in Figure 3-3 which employs rotating rotors to force the air towards the cabin interior.

These units are noisy and produce a pulsating air charge into the ducts thus requiring a silencer to reduce the operating noise. The pulsations and excessive output at low level are controlled by a device called a mass flow controller which dampens pulsations and controls the spill valve to dump or spill excess pressure.

Lastly, the charge air produced by the compressor may have to be heated for airconditioning use by a choke heat valve which increases the back pressure and the charge air temperature.

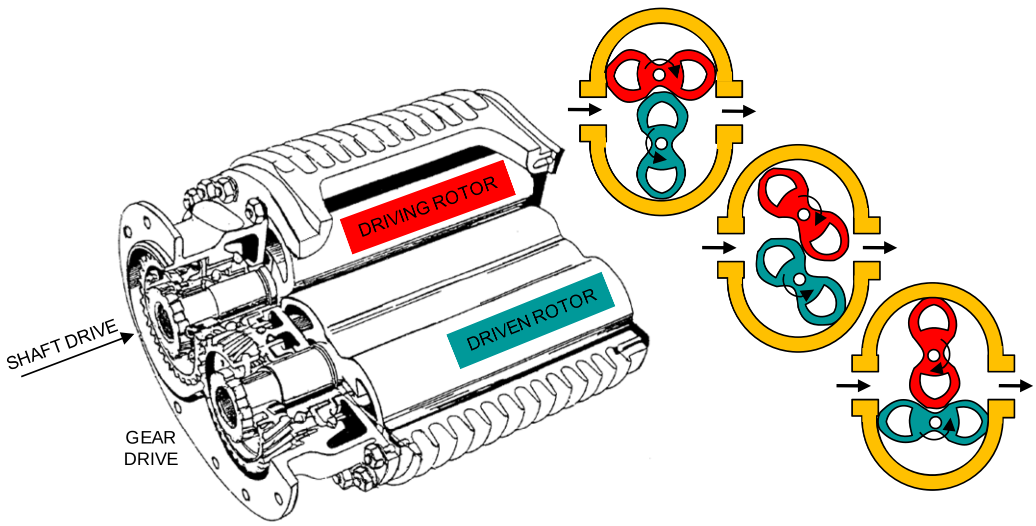

Figure 4-3 Rootes Cabin Blower

In summary a compressor such as this will require the following components to produce an effective pneumatic source; Refer to Figure 4-4.

Spill Valves are designed to allow charge air to spill overboard at low altitudes and progressively close as the ambient density of air decreases with altitude. It is normally controlled by the mass flow controller but also may be operated (to fully open) from the cockpit to avoid engine fire, oil or smoke contamination. Older aircraft would open spill valves during take-off for increased thrust.

Mass Flow Controllers determine the correct mass of air entering the cabin by modulating the spill valve. They also dampen airflow fluctuations caused by RPM changes and compressor pulsations.

Choke Heat Valves are fitted as a means of increasing the charge air temperature under certain conditions, by restricting the flow and creating a greater backpressure.

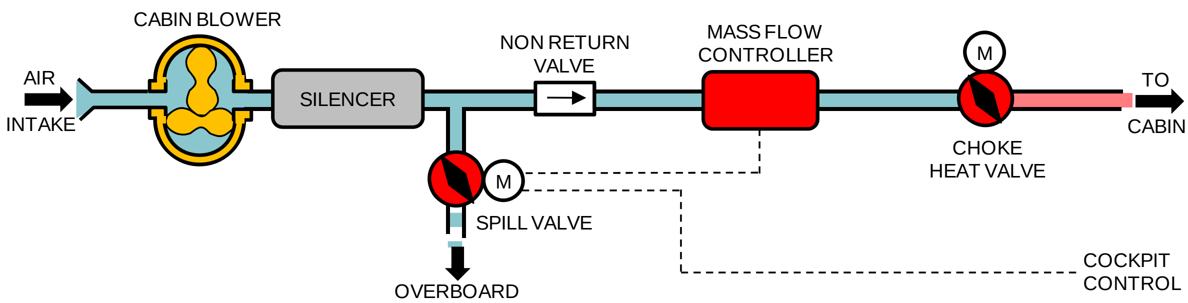

Figure 4-4 Displacement Compressor

CENTRIFUGAL COMPRESSORS

Centrifugal compressors may vary from a simple turbocharger system fitted to piston engine aircraft (refer to Figure 4-5) to complex types used on larger turboprop aircraft and some APUs fitted to modern large transport aircraft. Large mechanically driven centrifugal compressors are referred to as Engine Driven Compressors (EDCs) on main engines and Load Compressors on APUs.

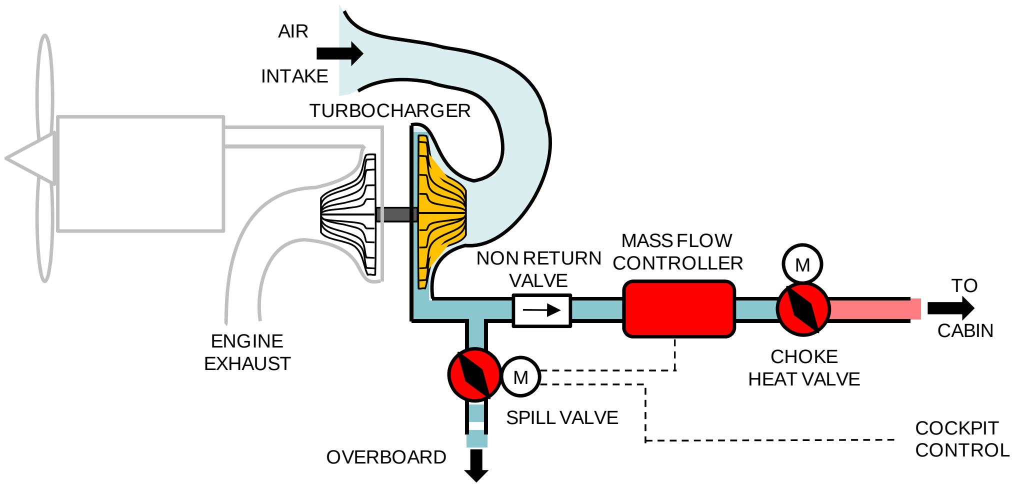

Figure 4-5 Turbocharger

ENGINE DRIVEN COMPRESSORS (EDCS)

Medium to large turboprop aircraft that cruise at altitudes up to 30,000 ft require a more sophisticated centrifugal type compressor to provide pressurisation than a cabin blower or turbocharger mentioned previously. They must provide larger volumes of air and be able to automatically adjust output as air density changes with altitude.

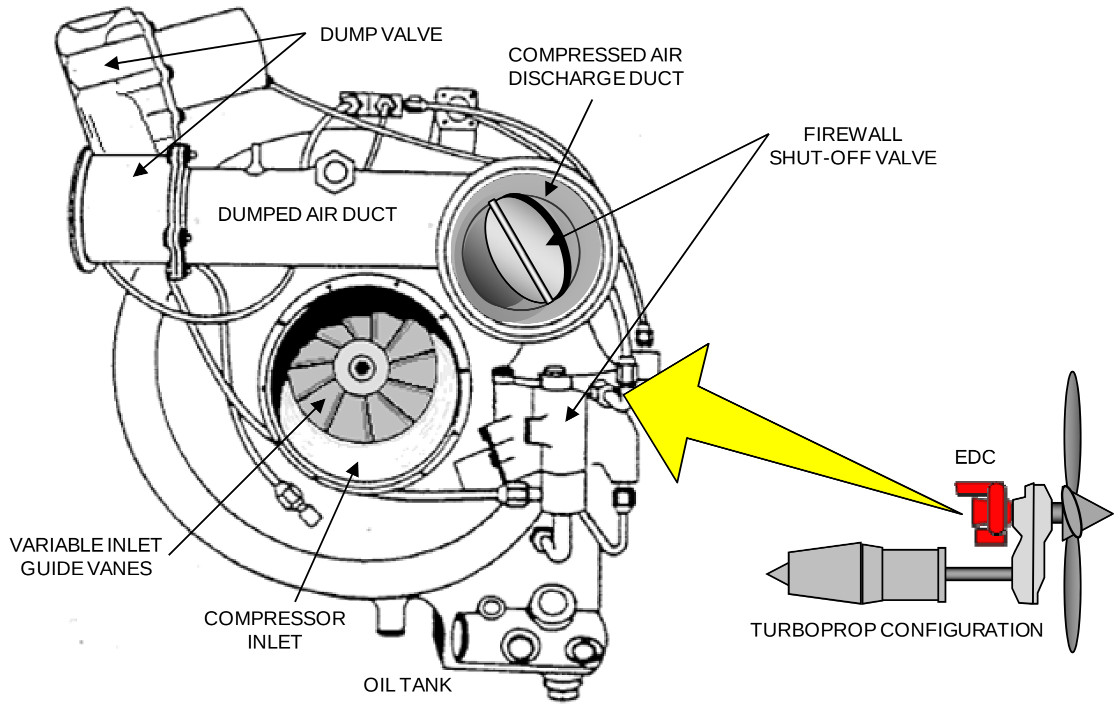

Figure 4-6 Engine Driven Compressor

Large engine driven centrifugal compressors such as the one shown in Figure 3-6 run at speeds in excess of 45,000 RPM and produce 70lb/min of airflow. They are normally driven from the reduction gearbox that is driving the propeller and there will be at least two units fitted for pressurisation redundancy.

Instead of using a simple mass flow controller and spill valve combination as previously discussed, large EDC's will typically use Variable Inlet Guide Vanes (VIGV's) in the compressor intake to adjust the compressor output as the density of air changes with altitude.

Due to the complex control operation and the high speeds involved, EDC's such as this will have an integral pressurised oil system that lubricates the bearings and gears and actuates the movement of the VIGV's. The EDC's oil system is independent of the engine or aircraft systems.

An integral flow sensor constantly monitors the output of the compressor and adjusts the variable inlet guide vanes to maintain the required mass flow of air to the cabin at all aircraft altitudes. The variable inlet guide vanes are positioned hydraulically using the integral lubricating oil. Refer to Figure 4-7.

Although having self controlling VIGV's, EDC's are still fitted with a spill type valve which in this EDC application is called a dump valve. This purpose of the Dump Valve is to allow;

- the EDC to automatically dump the compressor output overboard if an overpressure occurs before causing damage to downstream ducting.
- the crew to unload the compressor at any time if desired.

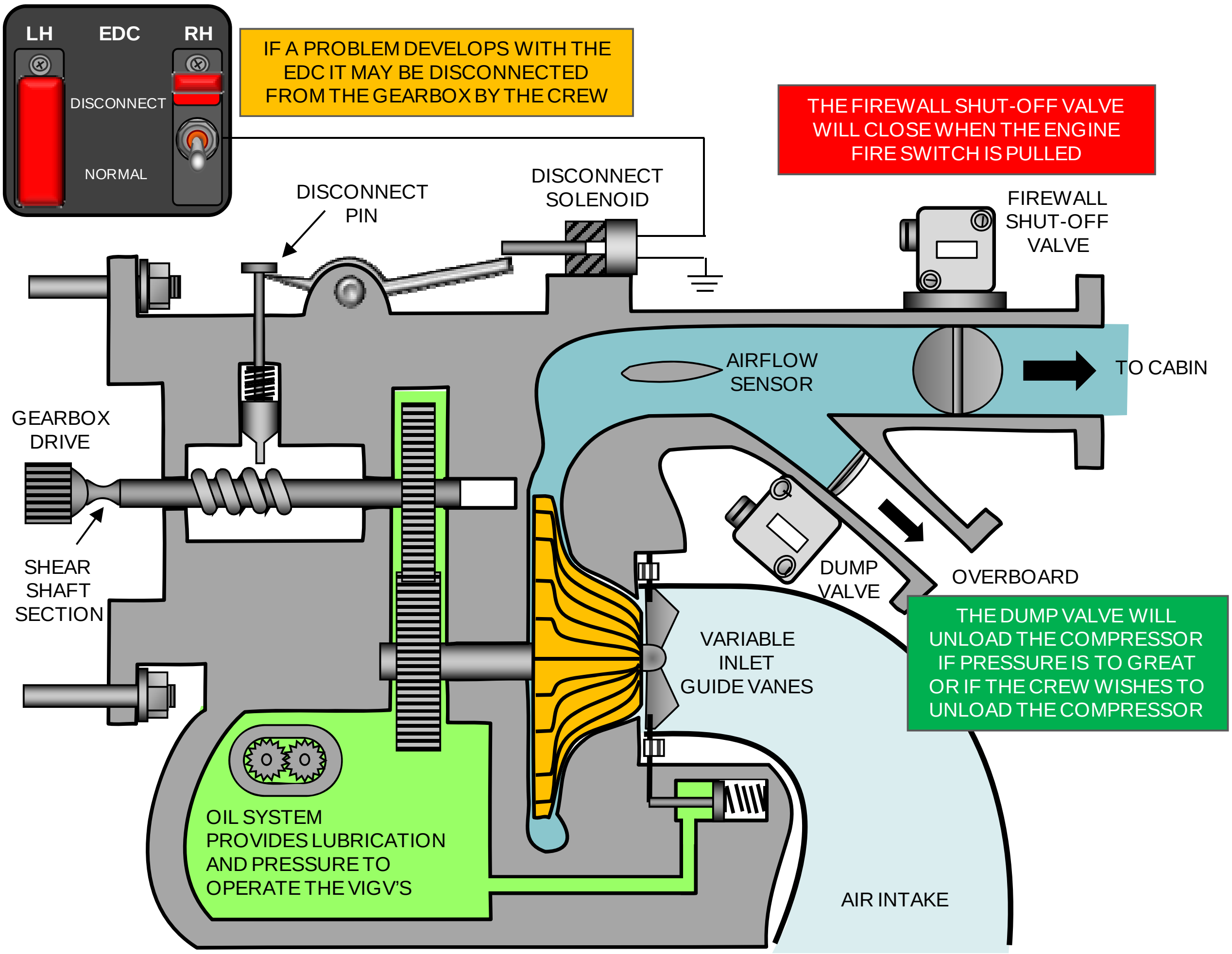

Figure 4-7 EDC, Operation and Disconnection

Normally the self contained oil system will be monitored for pressure and temperature. If oil temperature becomes too high or pressure too low the EDC may be disconnected from the cockpit by the crew before the VIGV's become inoperable.

A solenoid operated trigger allows a disconnect pin to drop into a worm threaded section of the EDC driveshaft. This causes the driveshaft to screw itself out of the reduction gearbox drive socket which disconnects the EDC. <u>Reconnection can only occur on the ground with the engine shutdown</u>.

CENTRIFUGAL LOAD COMPRESSORS

All modern jet transport aircraft are fitted with an Auxiliary Power Unit (APU) to provide electrical and pneumatic power whilst the aircraft is on the ground and main engines are not running. Typically the APU will have an integral centrifugal load compressor to provide the pneumatic power source. The output from the compressor is controlled by variable inlet guide vanes adjusted automatically to suit the required pneumatic loads.

When operating under heavy pneumatic and electrical loads simultaneously the APU will typically automatically reduce pneumatic output to ensure electrical output is maintained correctly.

Two different configurations of APU load compressors are shown in Figures 4-8 and 4-9.

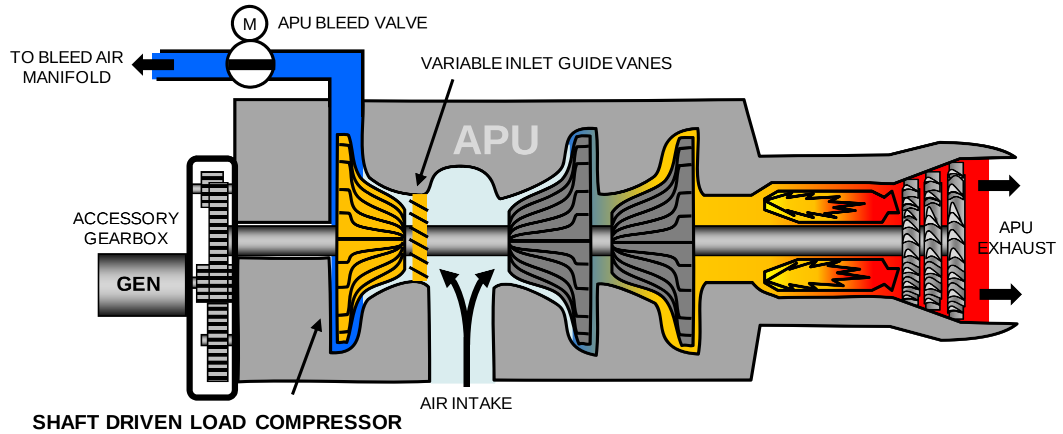

Figure 4-8 Shaft Driven Load Compressor

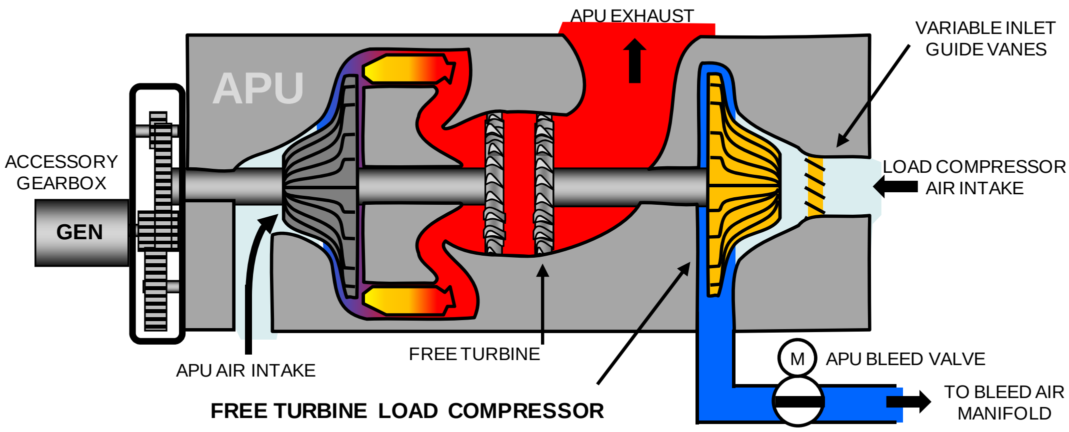

Figure 4-9 Free Turbine Load Compressor

Note that some older APUs, like main engines, will deliver “bleed air” from the APU engine compressor as the pneumatic source.

Most modern APUs may be started in flight to provide electrical and pneumatic power in an emergency although some are limited by specific operating altitudes.

APUs are normally started by an electric motor but on some modern aircraft may be started using bleed air like a main engine.

HIGH PRESSURE MULTIPLE STAGE PISTON PUMPS

This type of compressor is used for HIGH pressure pneumatic systems and will be discussed later in this chapter.

PNEUMATIC SOURCE - ENGINE BLEED AIR

Compressed hot air extracted from the main engine or APU engine compressor(s) is referred to as "bleed air". Note that the compressed air produced by APU load compressors previously described, is also referred to as "bleed air".

All modern jet transport aircraft use some bleed air from the main engines as it readily available in unlimited supply and can be used both for pressure and heating purposes. Very modern aircraft are trying to reduce the use of bleed air from the main engines as it decreases the engine efficiency and therefore causes an increase in overall fuel consumption. Jet transport aircraft in use today will still typically use bleed air for the following equipment or operation;

- main engine starting,
- aircraft airconditioning and pressurisation,
- operating demand hydraulic pumps,
- pressurising hydraulic reservoirs and water tanks,
- heating cargo bays,
- engine anti-icing,
- wing anti-icing,
- operating thrust reversers (some engines),
- operating leading edge devices (some aircraft),
- smoke detectors (some aircraft),
- TAT probe aspiration (some aircraft), and
- creating nitrogen gas (some aircraft).

Depending on the type of engine, bleed air is extracted from different locations and is referred to by the compressor it is extracted from; Refer to Figure 3-10.

- Low Pressure (LP) or Fan air extracted from the LP compressor,
- Intermediate Pressure (IP) air extracted from the IP compressor on a triple spool engine,
- High Pressure (HP) air extracted from the HP compressor.

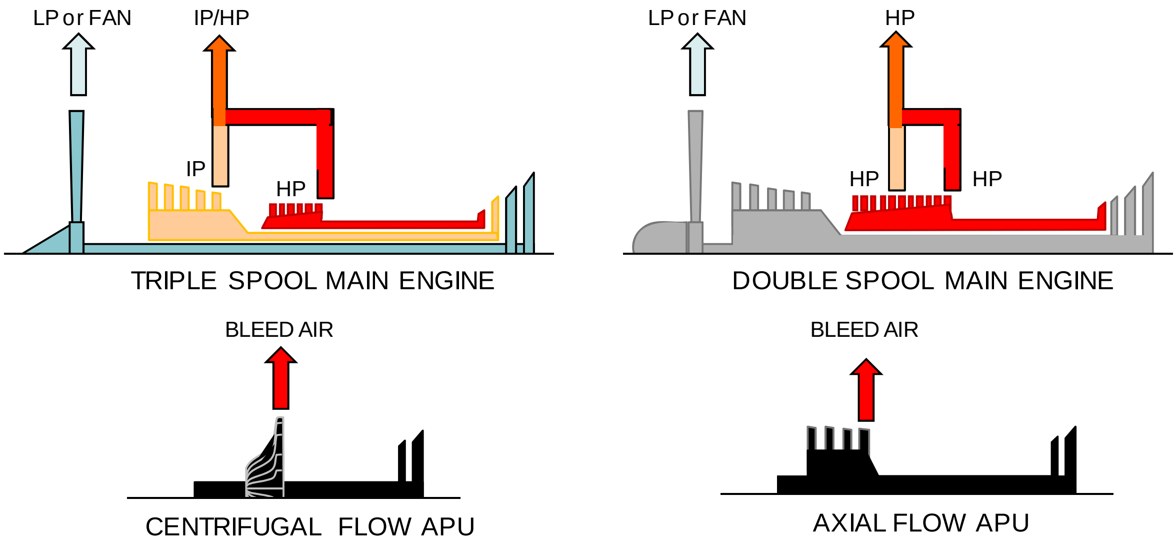

Figure 4-10 Bleed Air Extraction from Engines

Low Pressure or Fan Bleed Air is used in all cases to pre-cool the IP and HP bleed air before it is used by the aircraft's pneumatic system. After reducing the temperature via a heat exchanger the LP or Fan Air is dumped overboard and is not used for any other purpose. The control and modulation of this bleed air is automatically controlled by a Fan Air Modulating Valve.

Intermediate Pressure Bleed Air is used as the primary supply of bleed air during climb and cruise when engine RPM is high. In a double spool engine this source is taken from the high pressure compressor but at a mid stage where temperature and pressure is less. Refer to Figure 4-10. The control and modulation of this bleed air is automatically controlled by the Engine Bleed Valve.

High Pressure Bleed Air is only used to increase flow to the aircraft's pneumatic system when engine RPM is low such as during descent and at idle on the ground. In a double spool engine this source is extracted from the last stage of the high pressure compressor. Refer to Figure 4-10. This bleed air is automatically controlled by the engine's High Stage Valve and when open will join with the Intermediate Pressure Bleed Air to maintain adequate flow and pressure for the pneumatic system. Figure 4-11 illustrates the typical extraction configuration that provides bleed air for;

- the engine itself for nacelle anti-icing and thrust reverser, and
- the Common Bleed Air Manifold from which all other services may draw bleed air.

APU Bleed Air is extracted from one location only and as these are very small engines the temperature of the bleed air does not require any cooling.

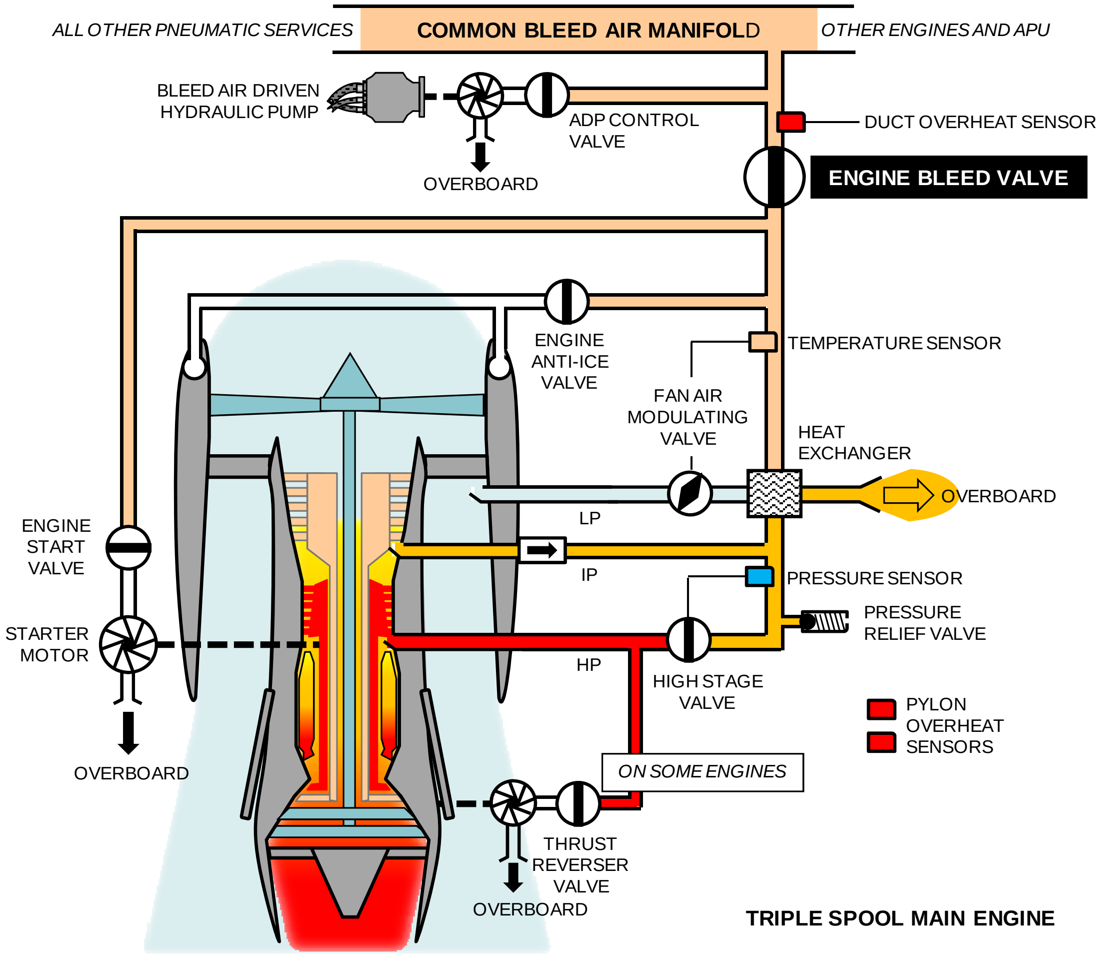

Figure 4-11 Typical Bleed Air Extraction from Large Engines

Engine Bleed Valves are the primary controlling valves that allow each engines bleed air to enter the Common Bleed Air Manifold and the aircraft's pneumatic system. These are complex valves and are actually called Pressure Regulating and Shut-off Valves (PRSOV) but will be named on the cockpit panel as "Bleed Valves". They are electrically switched and pneumatically operated. They will have a cockpit control switch and an indication of their position. They are also closed automatically as a function of pulling the associated engine fire switch. Refer to Figure 4-11.

Engine bleed valves typically perform the following functions:

- regulate the bleed air flow to maintain the correct pressure to the manifold,
- operate as a non return valve to stop reverse flow from the manifold,
- allow reverse flow for engine starting, and
- automatically close if a duct overheat occurs.
- ***Other Pneumatic Valves and Components*** located on the engine and in the engine pylon are listed in the following table. Refer to Figures 4-11 and 4-12 for a description of their location and operation.

VALVE OR COMPONENT	LOCATION	CONTROL	COCKPIT INDICATION	OPERATION
HIGH STAGE VALVE	pylon	automatic	Yes – Indication of open/closed	Controlled by the pressure sensor will OPEN at low thrust settings to maintain flow and pressure and CLOSE at normal thrust settings when pressure is adequate.
IP NRV	pylon	automatic	no	Stops the flow of HP air back into the engine when the high stage valve is open.
PRESSURE RELIEF VALVE	pylon	automatic	no	This is a safety valve to vent excessive duct pressure overboard.
HEAT EXCHANGER	pylon	automatic	no	Removes excessive heat from the IP and LP bleed air (600°C to 200°C).
FAN AIR MODULATING VALVE	pylon	automatic	no	Controlled by the temperature sensor will MODULATE air through the heat exchanger to maintain air to the system at approximately 200°C.
START VALVE	pylon	automatic and manual cockpit control	Yes – Indication of open/closed	Allows bleed air to operate the starter motor until the engine begins accelerating by itself during start.
STARTER MOTOR	engine gearbox	START VALVE	Yes – engine RPM increase	Drives the starter motor which engages with the high pressure spool.
ENGINE ANTI-ICE VALVE	pylon	cockpit control	Yes – Indication of open/closed	Allows bleed air to heat the engine nacelle and other engine components to prevent ice formation. Note that these valves normally default to OPEN when electrical power is lost.
THRUST REVERSER VALVE	pylon	cockpit control	no	Allows bleed air to operate the thrust reverser air motor. Note that many modern engines now use hydraulic power for reversers.
THRUST REVERSER MOTOR	engine reverser	THRUST REVERSE VALVE	Yes – Indication of operation	Drives the thrust reverser mechanism.
ADP CONTROL VALVE	pylon	automatic and cockpit control	no	Allows bleed air to operate the ADP air motor. Note that bleed air is available from the manifold if the engine is inoperative or the bleed valve is closed
ADP AIR MOTOR	pylon	ADP CONTROL VALVE	Yes – Indication of operation	Drives the air driven demand hydraulic pump.
DUCT OVERHEAT SENSOR	pylon	no	Yes – Indication of overheat	This sensor monitors supply air temperature within the duct and will automatically close the engine bleed valve if it is too hot.
PYLON OVERHEAT SENSORS	pylon	no	Yes – Indication of leakage	These sensors monitor the ambient air within the pylon to detect leakage of bleed air. They monitor for excessive ambient temperatures.

Figure 4-12 Engine Pneumatic Valves and Components

Extracting bleed air from the engine compressor(s) reduces the efficiency of the engine to produce maximum thrust. When engines are shutdown during flight or extra bleed air is required for icing conditions aircraft performance will be degraded.

Refer to the Pneumatic System Limitations on Page 25 for more specific information.

PNEUMATIC SOURCE – GROUND EQUIPMENT

One type of ground equipment unit available for jet aircraft is a mobile compressor that can provide compressed air at sufficient pressure and flow rate to start a main engine. It is commonly called a “start cart”.

Some aircraft may be flown with an inoperative APU in accordance with the aircraft’s Minimum Equipment List (MEL) and a mobile compressor or “start cart” will be required to start the first main engine before pushback or taxi.

Mobile compressors are connected to the aircraft’s common bleed air manifold at a point easily accessible under the fuselage. Refer to the example pneumatic system diagrams showing the schematic connection points.

As this is not a common event, the aircraft’s Operating Procedures will detail a specific checklist to follow when using this method to start the first engine. Extra communication will be required between the flight and ground crews, ground safety procedures followed and the aircraft cannot move until the ground compressor is disconnected and towed clear of the aircraft.

Normally, after the first engine is running and providing bleed air, the remaining engines may be started using bleed air supplied from the running engine. This is known as a **CROSS BLEED START.**

When cross bleed starts are conducted the thrust lever of the running engine may have to be advanced to increase bleed air pressure in the manifold. As this will increase noise levels at the ramp a clearance from ATC should be requested first.

Note that a mobile compressor unit is only used for main engine starting and not for other pneumatic services such as airconditioning.

PNEUMATIC SYSTEM DISTRIBUTION

THE COMMON BLEED AIR MANIFOLD

The common bleed air manifold accepts bleed air from all main engines, the APU and when required, ground compressor units. Typically on a large jet transport aircraft the manifold bleed air pressure will be 25 to 40 psi at approximately 100 to 200°C.

All of the aircraft services that require bleed air for pressure or heating requirements may access the bleed air manifold via individual pneumatically operated shut-off valves. For interest, the following are typical services and their approximate bleed air requirements;

- Main Engine starting - 220 lbs/min.
- Air driven hydraulic pump - 120 lbs/min.
- Airconditioning pack - 220 lbs/min for each pack at high flow.
- Wing Anti-ice - 600 lbs/min.
- Leading Edge flaps - 240 lbs/min.

The manifold is located behind the leading edge on each wing and passes through the fuselage where it connects with the APU bleed air ducting. The common bleed air manifold on a large jet transport aircraft can be up to 20 cm in diameter.

It is extremely important that no hot bleed air is allowed to leak into the areas that the manifold passes through as severe wiring damage or explosion due to fuel leakage could occur. Like the engine pylon the entire manifold is monitored by temperature sensors to detect bleed air leakage.

If a leak is detected the sections of the manifold may be closed off by operating **ISOLATION VALVES** which are automatically activated in some aircraft and pilot activated in others. By isolating the leaking section the entire pneumatic system is not lost and pressurisation and other important services are maintained. Refer to Figure 4-13.

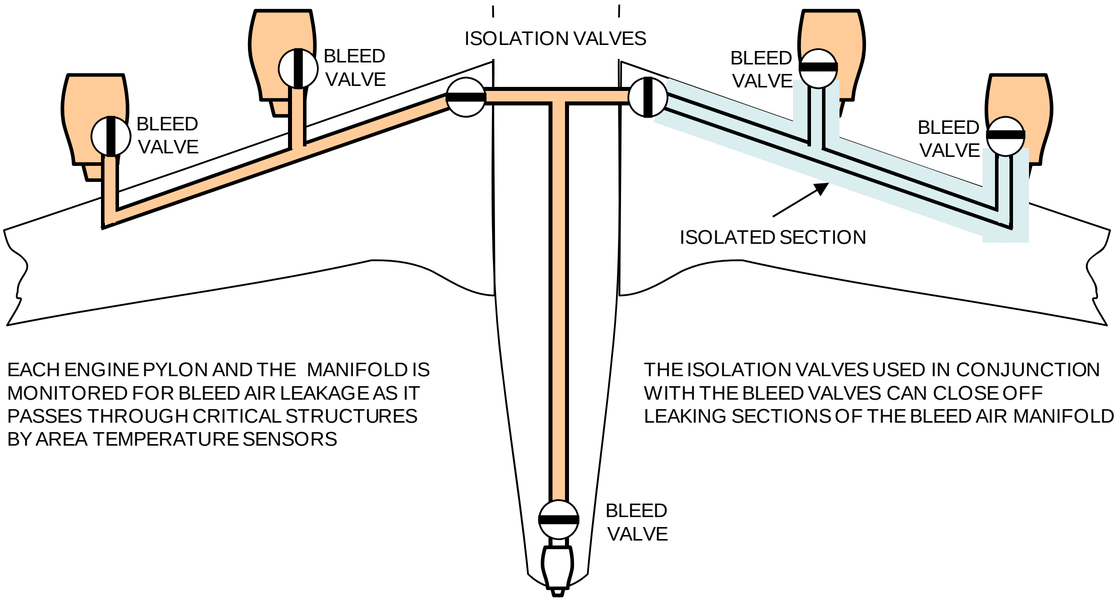

Figure 4-13 Isolating sections of the Bleed Air Manifold

The Common Bleed Air Manifold is sometimes referred to as the Cross Bleed Manifold as it allows bleed air to be passed from the engine(s) on either side of the aircraft to the other for cross bleed engine starting. Refer to Figures 4-14 and 4-15 for example pneumatic systems of modern aircraft.

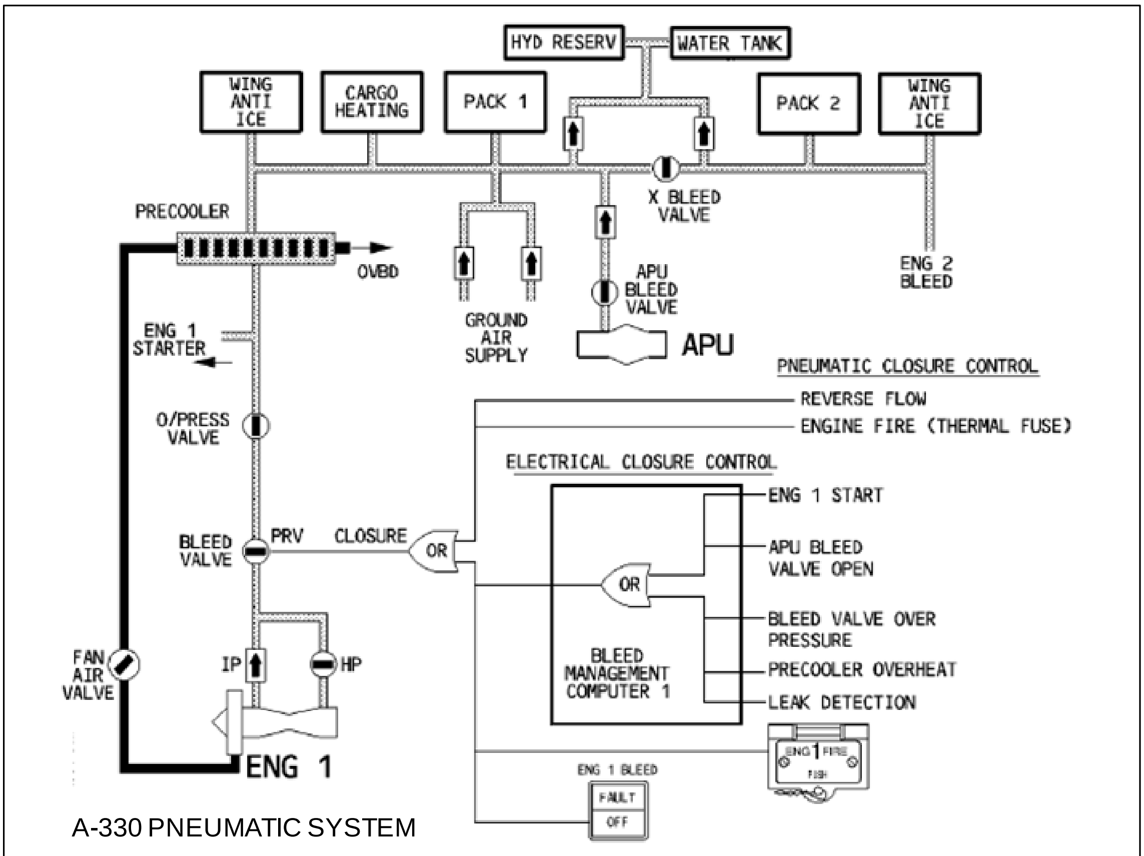

Figure 4-14 Example Pneumatic System – A330

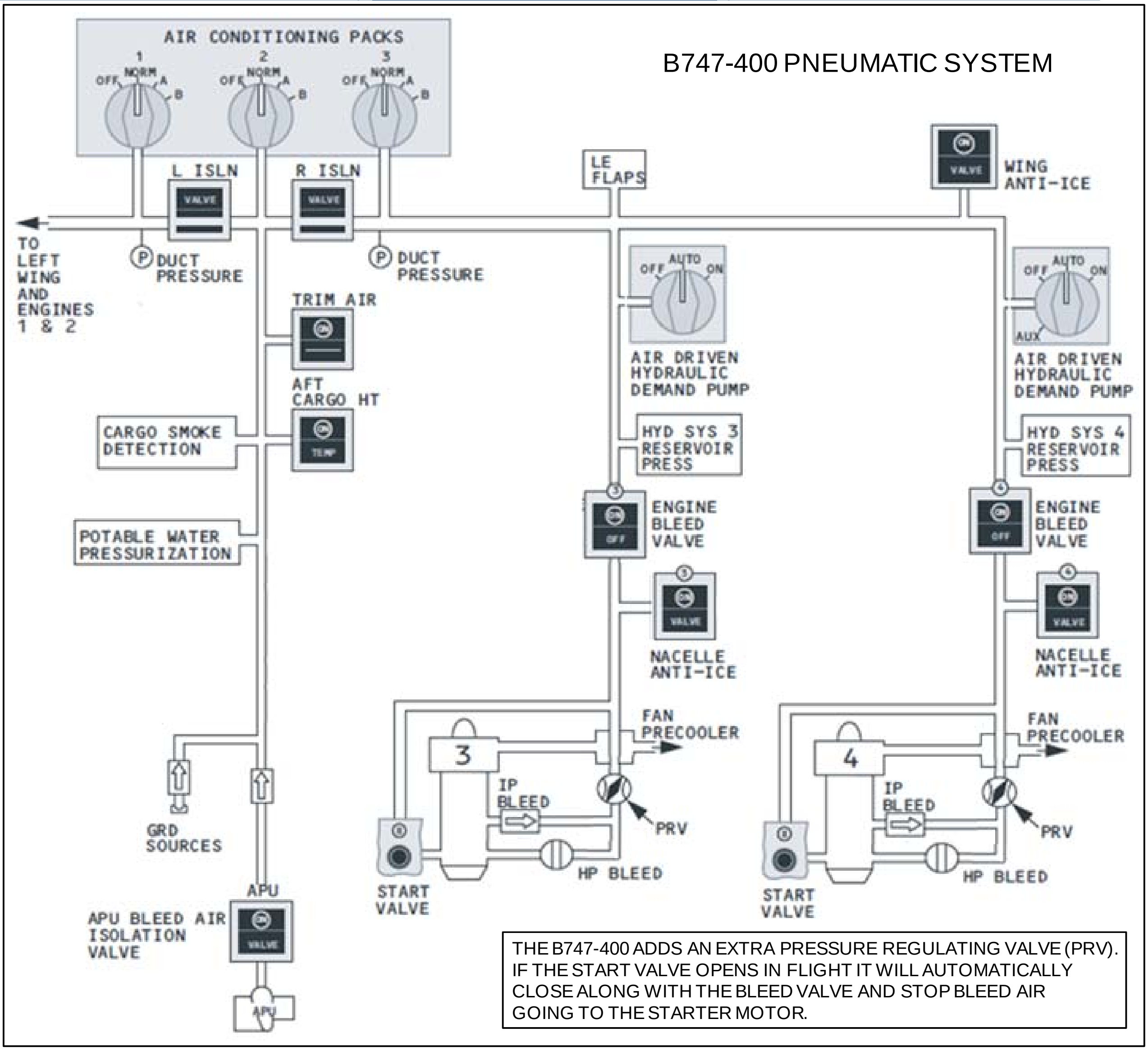

Figure 4-15 Example Pneumatic System - B747-400

For interest on the B777 the APU may be started inflight using bleed air from the main engines if electric start is inoperative.

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.

SUMMARY

There are numerous methods of producing pneumatic power depending on aircraft size, cruise altitudes and equipment requirements. Refer to Figure 4-15 for a summary.

PNEUMATIC SOURCE	COMPRESSOR TYPES	AIRCRAFT TYPES	TYPICAL USES OF PNEUMATICS	COMMENT
AIR BOTTLES	ground charged stored pressure	all types	operation of emergency equipment only	normally charged with nitrogen
MECHANICAL COMPRESSORS	cabin blowers	small/medium transports	airconditioning pressurisation	
	turbochargers	small piston		
	engine driven compressors	turboprops	airconditioning pressurisation	can be disconnected in flight
	load compressors	APUs	starting main engines airconditioning	
	multiple stage piston pump	pneumatically powered aircraft	landing gear brakes flaps	high pressure system older types – not used in modern aircraft
ENGINE BLEED AIR	bleed from engine compressors both hot and cold bleeds	most turboprops	engine anti-ice wing de-ice empennage de-ice cross bleed starting	bleed air can be very hot. there must be a system to detect bleed air leaks.
		most jet engines	airconditioning pressurization driving hydraulic pumps cargo heating engine anti-ice wing anti-ice leading edge devices thrust reversers cross bleed starting	
		some APUs	starting main engines airconditioning	
GROUND AIR UNITS	sufficient to suit the application	turboprops and jet aircraft	for starting main engines when the APU is inoperative	only needed for the first main engine start

Figure 4-16 Summary of Pneumatic Sources

PNEUMATIC SYSTEM COMPONENTS

Similar to a hydraulic system, a pneumatic system will incorporate the use of selector valves, actuators, pressure regulators and relief valves. Components used on smaller systems such as spill valves, mass flow controllers and silencers have been described previously. The following components are more common to large jet transport bleed air systems.

PNEUMATIC DUCTING

Unlike hydraulic piping, pneumatic piping is much larger in diameter and able to carry large volumes of air at relatively low pressure. Made from steel at the engine and aluminum throughout the aircraft it is referred to as ducting. Sealing duct and component connections is achieved easily by flanges, O-ring seals and simple clamps.

Pneumatic ducting that carries bleed air is wrapped in an insulating material to stop heat transfer from the duct to the surrounding areas. Bleed air ducts and fuel pipes should not pass through contained areas in the aircraft structure together due to the fire risk. Refer to Figure 4-17.

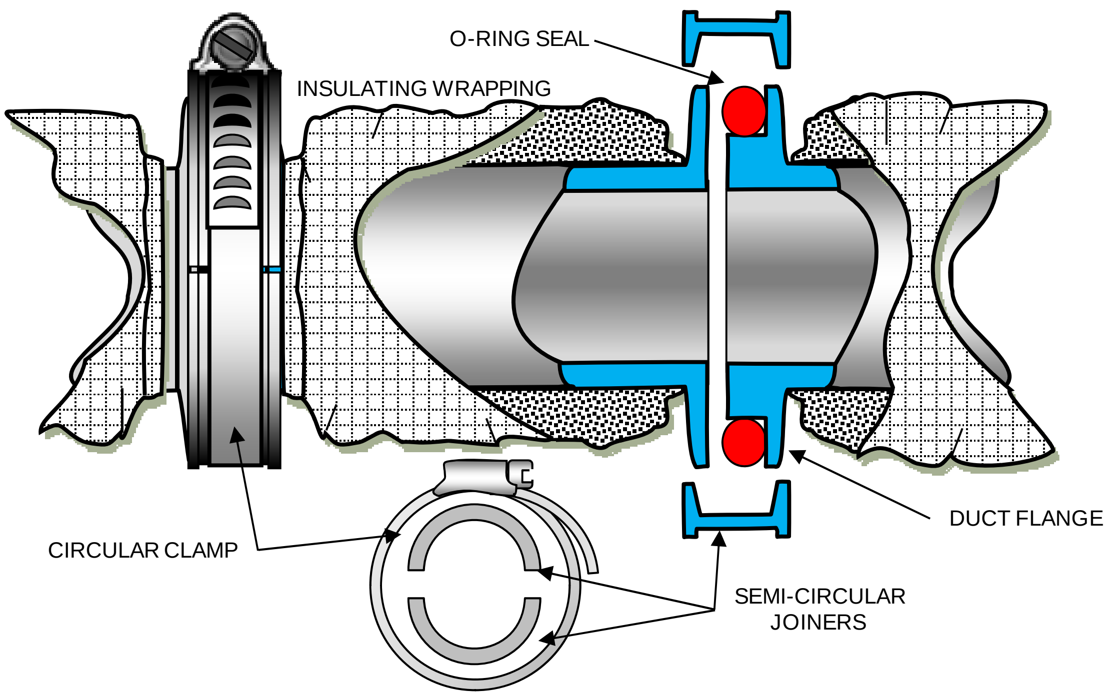

Figure 4-17 Bleed Air Ducting

DUCT NON RETURN VALVES (CHECK VALVES)

Due to the large diameters of pneumatic ducting, non return valves are usually constructed as shown in Figure 4-18 with semi-circular plates that act like the wings of a butterfly. Often referred to as butterfly or flapper valves they are spring loaded to close when no bleed air flow is present. Any flow in the wrong direction forces the plates against small O-ring seals.

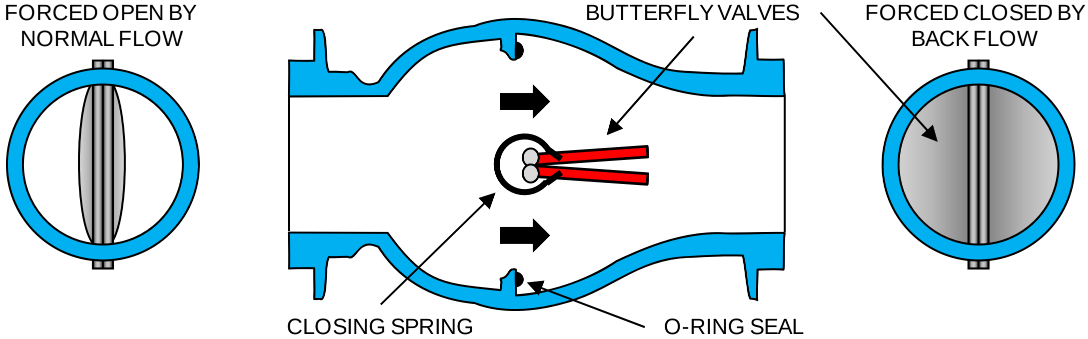

Figure 4-18 Duct Non Return Valve

ELECTRICALLY OPERATED VALVES

Due to the large diameters of pneumatic ducting, the most suitable type of shut-off valve is a circular plate rotating through a 90° angle. This method is used for both electrically driven and pneumatically driven valves. Shown in Figure 4-19 is a simple electrically driven shut-off valve.

Shut-off valves are commonly used as the “selector valve” to operate such equipment as cargo heating, wing anti-ice, hydraulic pumps and airconditioning packs.

Some valves use a combined operation of electrical solenoid and pneumatic operation to act as shut-off valves as described under Pneumatically Operated Valves on Page 17.

A typical example of this special shut-off valve is the engine anti-ice valves which are always held closed by the energized solenoid so that with a total loss of electrical power the valves will open providing anti-ice protection.

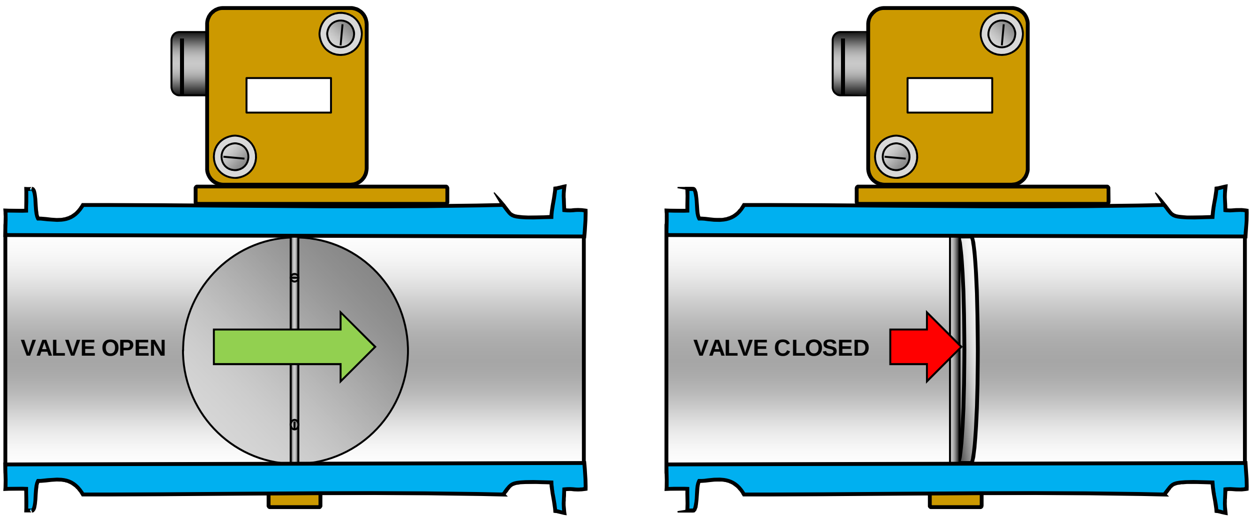

Figure 4-19 Electrically Operated Shut-off Valve

ELECTRICALLY OPERATED VALVES – ENGINE START VALVE

When opened the engine start valve allows bleed air from the common bleed air manifold to power the starter motor. When the engine starts to accelerate by itself the start valve closes to stop the starter motor which in turn disengages from the engine. The start valve must remain closed after the engine has started and during normal engine operation.

If the valve malfunctions and opens in flight the engine must be shut down immediately as severe damage to the starter motor will occur as it attempts to engage with the engine.

Some modern engines have added an extra valve to isolate bleed air from the start valve automatically if it begins to open in flight.

Note that this valve can be mechanically opened by ground engineers to conduct a start if the valve fails to open electrically. Refer to Figure 4-20.

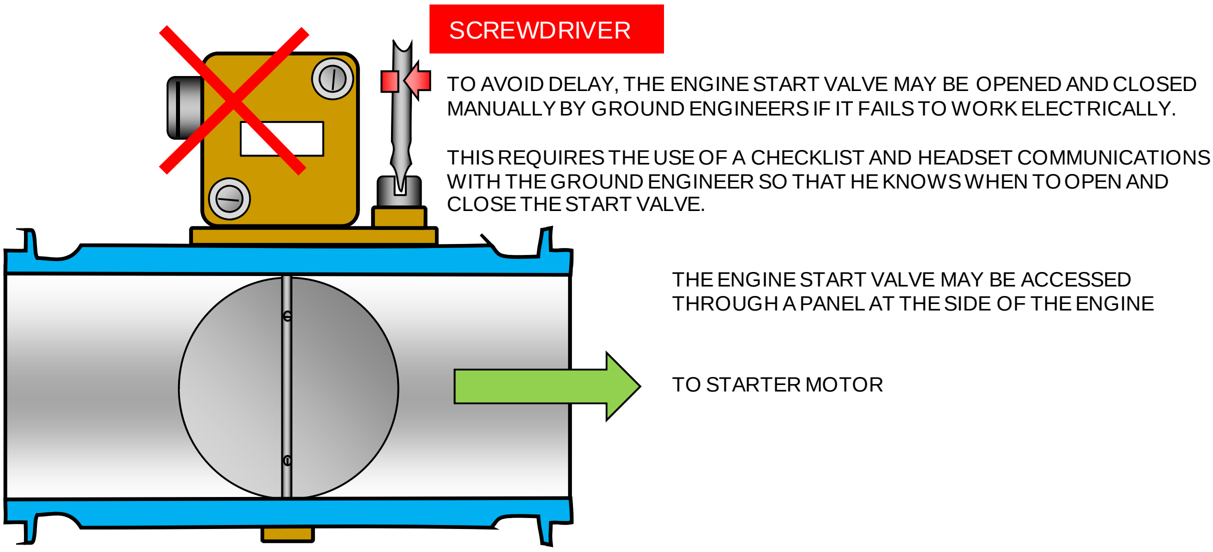

Figure 4-20 Engine Start Valves

PNEUMATICALLY OPERATED VALVES

Pneumatically operated valves use bleed air pressure and spring tension to operate a mechanical butterfly valve. These valves are used as pressure regulators and shut-off valves (PRSOV) and are electrically controlled by solenoids. Refer to Figure 4-21.

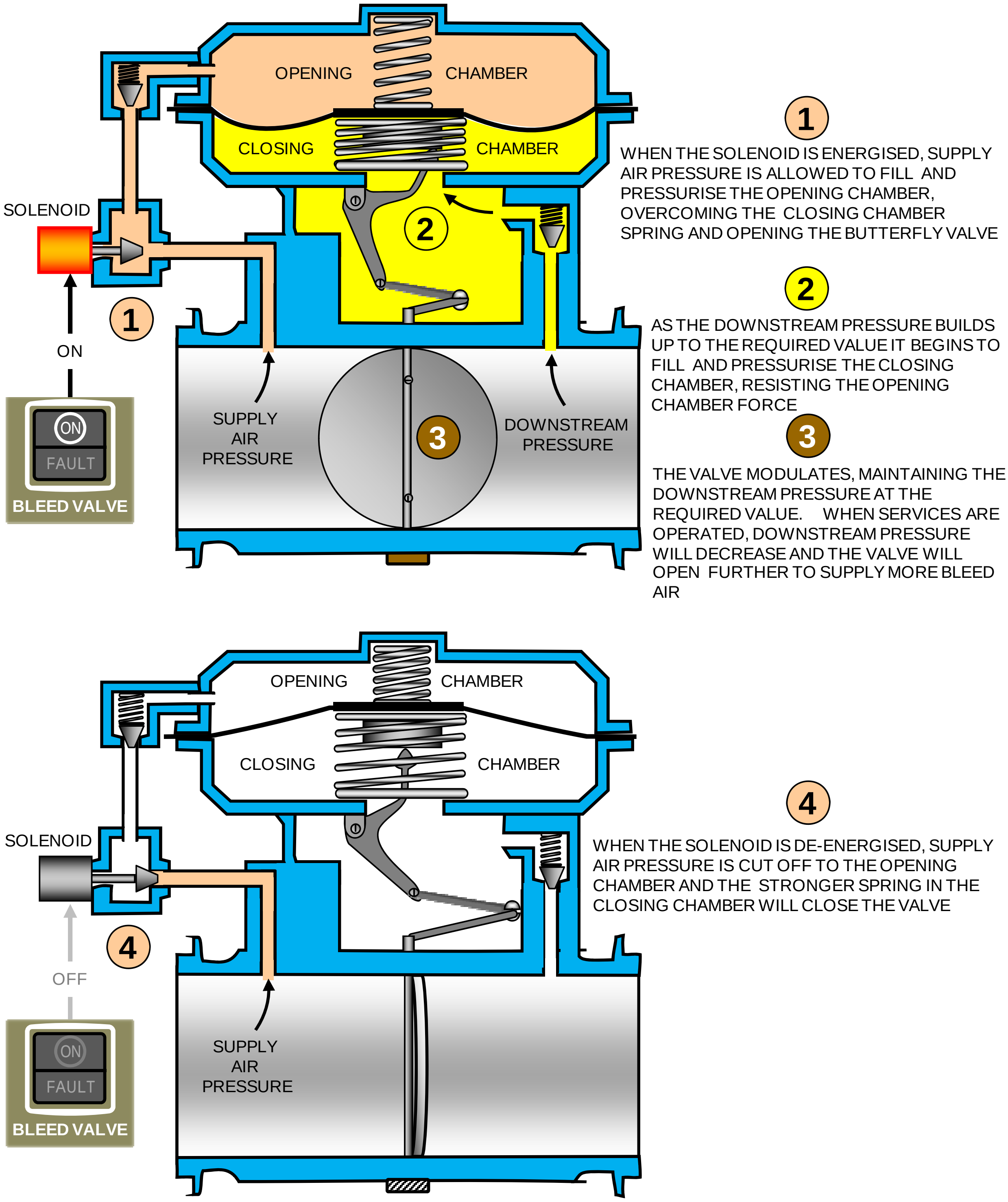

Figure 4-21 Pressure Regulating and Shut-off Valve

PNEUMATIC ACTUATORS

Similar to hydraulics pneumatic actuators can be linear or rotary action. Linear actuators are rarely used on large jet transport aircraft as hydraulics is the preferred method. Most common is the rotary actuator or air motor which is used to drive equipment via gearboxes and screw jack drives. Although noisy when operating the air motor is lightweight and can produce a high torque rotary drive. Refer to Figure 4-22. Typical operations are;

- main engine starting,
- driving demand hydraulic pumps,
- operating thrust reverser cowls, and
- operating leading edge devices.

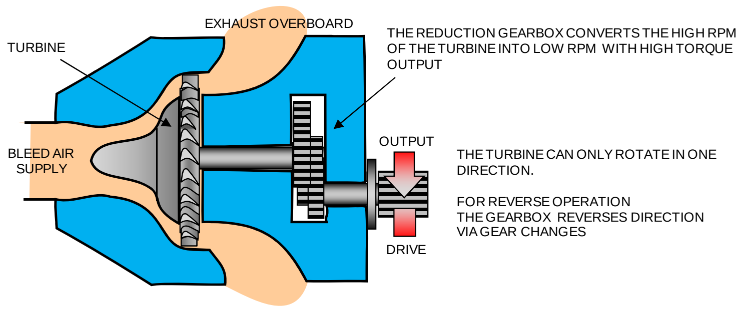

Figure 4-22 Example Air Motor

AIR TURBINE STARTER MOTORS

Using the same principle as described above but larger in size and power the engine starter motor is limited in the time it can be operated due to heat buildup. Refer to Figure 4-23. Typically a starter motor will have “Duty Cycle” time limits. For interest note the following limits when starting engines on the A330 aircraft.

Max continuous operation is 5 MIN,

Two 3 MIN duty cycles and a consecutive 1 MIN cycle is permitted with run down to zero N3,

After one continuous operation, or the three cycles wait 30 MIN to allow starter to cool.

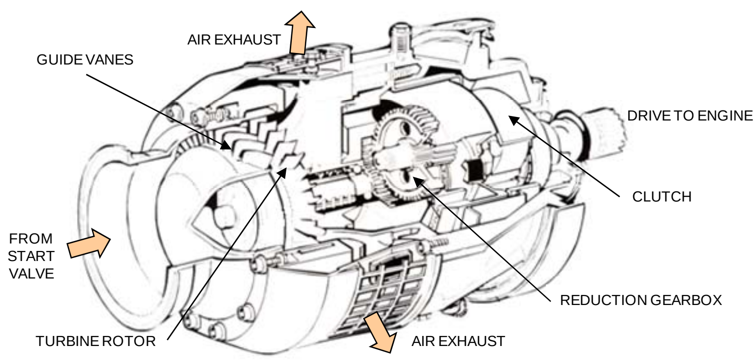

Figure 4-23 Air Starter Motor

PNEUMATIC SYSTEM INDICATION AND WARNINGS

PNEUMATIC SYSTEM INDICATIONS

The cockpit indications of a functioning pneumatic system are primarily temperature and pressure. Depending on the complexity and the technology employed, the pneumatic system(s) will also provide indications to the crew of control/switch status and the equipment status of services operated by the pneumatic system.

The primary indications of temperature and pressure will indicate both normal operation and abnormal or failed operation which will require attention by the crew. Normal and abnormal operation is typically sensed from independent sources and different locations within the pneumatic system. The sensors monitor the system operation and send the information to readouts and alerts in the cockpit, and to any controlling computers. A typical modern pneumatic system is monitored for the following parameters;

- the status of all pneumatic inputs to the common manifold.
- the current pressure in the common manifold,
- the current temperature in the common manifold,
- a dangerously low pressure in the common manifold,
- a dangerously high temperature from any of the inputs into the common manifold, and
- a dangerous leakage of hot bleed air from the common manifold,

Large aircraft normally have a pneumatic control panel in the cockpit commonly referred to as the “Bleed Air Panel”. On older generation aircraft it will contain indicators displaying pressure and temperature, and switches to control operation of valves. The instruments and switches for the system are normally grouped together, and the panel may be marked with a mimic diagram to assist the crew in controlling and isolating bleed air flow.

Modern large aircraft fitted with an ECAM or EICAS will display indications on the display screens leaving only the switches and mimic diagram remaining on the control panel. Additionally the ECAM/EICAS synoptics will display real time operation of the components and bleed air flow with the system.

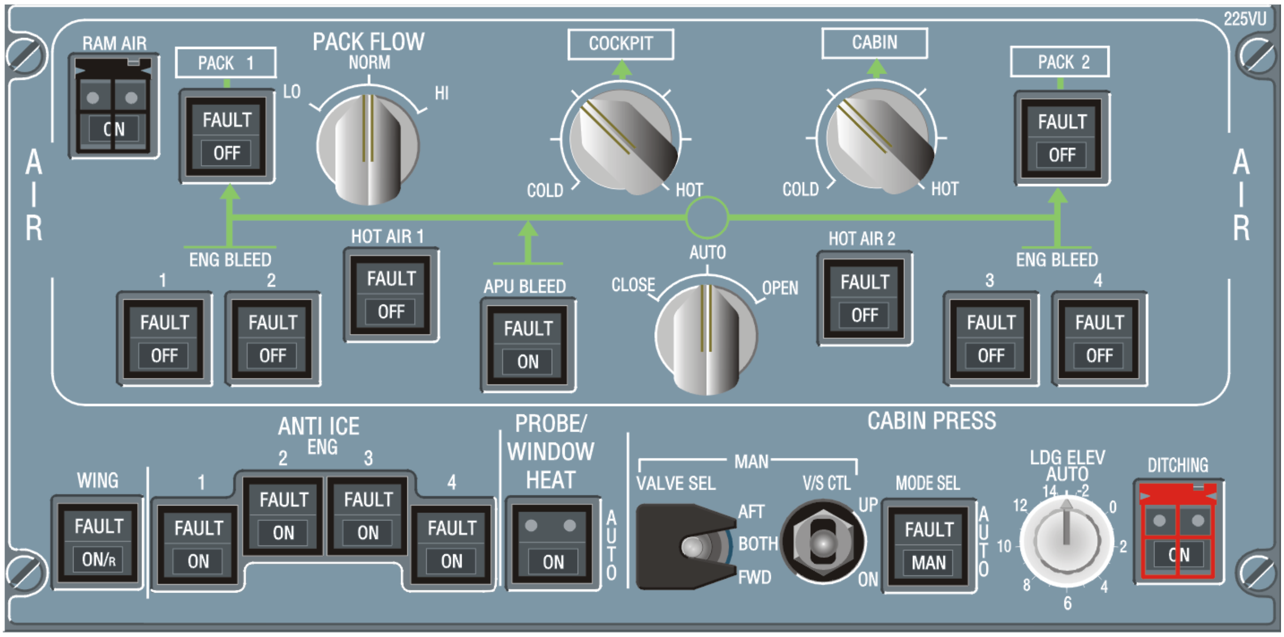

Figure 4-24 Air Control Panel A340

As bleed air is the normal source for airconditioning, pressurisation, cargo heating and anti-icing, these control panels are often included in or co-joined with the Bleed Air Panel. Refer to Figure 4-24.

NORMAL SYSTEM INDICATIONS

The normal visual cockpit indications are provided by either gauges or ECAM/EICAS readouts. These are remote reading indications and receive their information from sensors located as follows;

Temperature - from a point downstream of the engine bleed valves and the pre-cooler using a temperature sensor producing an electrical signal for the cockpit gauge or ECAM.

Pressure - These measure the pressure within the common bleed air manifold downstream of all available pneumatic inputs. There are multiple pressure transmitters to produce at least two electrical signals for the cockpit gauge(s) or ECAM/EICAS for pressure readings on the left and right sides of the aircraft. This ensures that when a bleed air leak has been isolated by the closure of isolation valves the remaining available pressure may be monitored.

Status of Controls and Systems

In modern large aircraft the pneumatic system(s) are continuously monitored by computers. The software is programmed to make the operator aware not only of malfunctions but also to provide prompts for correct switching. Additionally, computers can display real time operational status via synoptic presentations. Synoptic presentations make greater use of colour to indicate the status of components and the system. The following colours are examples of the A340 synoptic. Refer to Figure 3-25.

NAMES OF EQUIPMENT – WHITE *HP, IP, GND, APU, etc.*

NAMES OF PARAMETERS – BLUE *PSI and ℃,*

STATUS OF PARAMETERS – GREEN OR AMBER

GREEN – Normal range 4 to 60 PSI, *Normal range 150 to 260℃*

AMBER – PSI too low or too high, *TEMP too low or too high*

FLOW LINES – GREEN OR NOT SHOWN

GREEN – Bleed air flow

NOT SHOWN – No flow

VALVES – GREEN OR AMBER

GREEN – Valve is in the correct position as commanded by the computer.

AMBER – Valve disagrees with the commanded position.

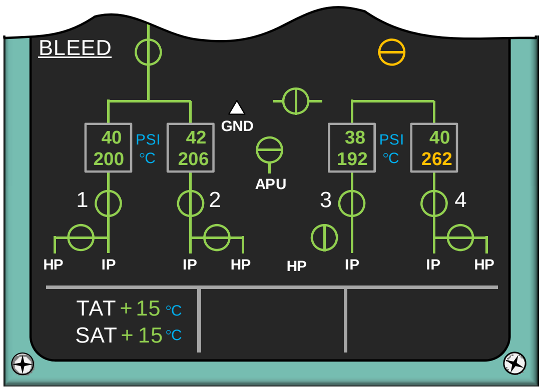

Figure 4-25 Bleed Air ECAM Synoptic A340

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. These are remote reading indications and receive their information from sensors located as follows;

Very High or Very Low Temperature – is normally sensed in the bleed air duct after the pre-cooler. In modern computer controlled aircraft all that is required is to program the computer to alert the crew when an abnormal level is reached. For interest note the following example of the Airbus aircraft;

OVERHEAT (AMBER) *290℃ for more than 5 secs or*

270℃ for more than 15 secs or

257℃ for more than 55 secs.

UNDERHEAT (AMBER) *below 150℃ with wing anti-ice ON.*

Very High or Very Low Pressure – is not normally sensed on older aircraft as pressure relief valves and the operator would respond to these problems. On modern aircraft the computer will alert the crew to abnormalities by monitoring the current pressures. For interest note the following example of the Airbus aircraft;

OVER PRESSURE (AMBER) *above 60 PSI.*

UNDER PRESSURE (AMBER) *below 4 PSI.*

Failures within a bleed air system usually only consist of duct leakages or control valves not operating to the commanded positions. Leakages are corrected by isolation of sections of the duct with some pneumatic services being lost. Important pneumatically operated equipment such as leading edge flaps will have alternate methods of operation. Failures on smaller aircraft will include the mechanical compressor(s) and their associated spill valves.

High Oil Temperature or Low Oil Pressure on large mechanical compressors (EDCs) normally indicates loss of the lubricating and guide vane control oil. An EDC that has high oil temperature or low oil pressure should be disconnected from the gearbox before further significant damage occurs.

PNEUMATIC SYSTEMS, REDUNDANCY AND ALTERNATE OPERATIONS

PNEUMATIC SYSTEMS

The term Pneumatic System is relative to the aircraft or equipment to which it applies. It can mean a simple mechanical compressor system used in smaller aircraft to operate the inflatable leading edges and pressurisation to a more complex system using engine and APU bleed air as the pneumatic source. The design and complexity of pneumatic systems vary from aircraft to aircraft depending on the size and type of aircraft, the manufacturers' philosophy and the requirements for redundancy. An example of this is the older European method of constructing some aircraft that have no hydraulics at all and depend solely on high pressure pneumatic systems to operate.

Unlike hydraulics there is usually only one common pneumatic system which is powered by numerous sources of compressed air and provides a common manifold from which all services are supplied. Some aircraft equipment and services that are operated by pneumatics are very powerful and it is a common preflight practice and good airmanship to check the positions of cockpit controls such as leading edge flaps and airconditioning packs before turning bleed air systems on.

Pneumatic power employed for components that use air motors and other pneumatic actuators can be operated at anytime pneumatic power is available.

Pneumatic power employed for heating such as wing anti-ice or de-ice is normally not available whilst the aircraft is on the ground as the heat provided is too great without rapid airflow.

REDUNDANCY

System redundancy is not only critical for flight safety but also enhances the ability of an aircraft to continue commercial operations safely until maintenance rectification can be carried out.

Pressurisation redundancy via the airconditioning packs is the most important consideration for pneumatic systems and modern large commercial aircraft are required to provide double redundancy for this. Refer to Figure 4-14 as an example of pressurisation redundancy used by Boeing.

ALTERNATE AND EMERGENCY OPERATION

The term alternate operation refers to a mechanism or system that is the alternate to the normal pneumatic method of operation. Some aircraft have both an alternate method and an emergency method for systems and bleed air supply. In some aircraft, the alternate method is referred to as emergency operation.

Aircraft pneumatic systems that typically have an alternate method are listed in the following table, Refer to Figure 4-26.

SYSTEM	NORMAL OPERATION	ALTERNATE	EMERGENCY
Common Bleed Air Supply	Supplied by all operating main engines simultaneously	Supplied by remaining operating main engines simultaneously	Supplied by APU
Individual Engine Anti-ice Supply	Supplied by the individual engine	none	Get out of icing conditions
Individual Engine Thrust Reversers	Supplied by the individual engine	none	Land with no thrust reverse
Leading Edge Flaps	Supplied by the common bleed air manifold	Driven by electric motors	Land with no leading edge flaps
Airconditioning packs	Supplied by the common bleed air manifold	Remaining pack(s) supplied by the common bleed air manifold	Descend to 10,000 ft Ram air ventilation

Figure 4-26 Summary of Alternate and Emergency Operation

DISPATCH WITH INOPERATIVE PNEUMATIC EQUIPMENT

Whilst redundancy is designed primarily for safe flight an added advantage is that aircraft may be dispatched for flight with some components of a pneumatic system inoperative. This does not mean that dispatch is allowed with a total system inoperative. There will be operational restrictions and performance penalties applied in this situation 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 pneumatic equipment that may be carried over for continued aircraft operation are;

- APU,
- Engine and APU Bleed Valves
- Engine Fan Air coolers
- Manifold Isolation Valves
- Engine anti-ice Valves,
- Wing anti-ice Valves,
- Thrust Reversers
- some indication faults.

Typical Malfunction Alerts in Pneumatic 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 pneumatic systems found today. Refer to Figure 4-27.

SYMPTOM OR INDICATION			MOST LIKELY FAULT
CONTROL PANEL/SWITCH	EICAS MESSAGE	BLEED AIR SYNOPTIC	
INDIVIDUAL ENGINE FAULT LIGHT	BLD 1, 2, 3, 4 OVHT BLD 1, 2, 3, 4 BLD 1, 2, 3, 4		Bleed air overheat Bleed air overpressure HP valve open when commanded closed
CLOSED	BLEED ISLN CLOSED C,L,R		Isolation valve remains closed when commanded open or bleed isolation switch is OFF
BLANK	BLEED ISLN OPEN C,L,R		Isolation valve remains open when commanded closed
No switch	BLEED LEAK BODY		High temperature bleed air leak is detected in the body area
	BLEED LEAK L, R,		High temperature bleed air leak is detected in the wing or pack bay area
	BLEED LEAK STRUT L, R,		High temperature bleed air leak is detected in the strut area
	BLEED LOSS BODY		Bleed air from the body duct is no longer available
	BLEED LOSS WING L, R,		Bleed air from the wing duct is no longer available
OFF	BLEED OFF ENG L, R,	Amber colour	Engine bleed valve is closed for a system fault or engine bleed switch is OFF
OFF	BLEED OFF APU	Amber colour	APU bleed valve is closed for a system fault or APU bleed switch is OFF

Figure 4-27 Malfunction Alerts in Pneumatic Systems

LEAKAGE IN PNEUMATIC SYSTEMS

External leakage occurring from a pneumatic system, especially bleed air, is a serious situation and comprehensive monitoring of abnormal temperatures is provided by the aircraft's area sensors. Observation of the manifold pressure while pressurised will be no real indication as the bleed air sources can supply enormous amounts of bleed air to replenish any volume lost via a leak.

If a leak (not discovered by the area temperature sensors) is suspected by slower than normal operation of equipment or poor performance of the airconditioning or wing anti-ice, one method of investigation is possible.

Pressurise the common bleed air manifold and note the pressure at both sides of the aircraft. Close the isolation and source bleed valves and observe the rate at which the trapped pressures deplete. A leak will deplete the pressure rapidly. Note that this could also indicate an internal leak of the isolation valve(s).

Internal leakage within a pneumatic system is difficult to identify as no loss of pressure will be observed. Internal leakage may occur between the chambers of an actuator or selector due to seal wear. The most common symptom is abnormally slow operation of a service such as leading edge flaps which are pneumatic on some aircraft. Isolation valves, non-return valves and some other components may be checked using the procedure above.

PNEUMATIC SYSTEM LIMITATIONS

BLEED AIR LIMITATIONS ON MAIN ENGINES

When bleed air from main engines is used during flight a reduction in engine efficiency occurs as the compressed air that would have contributed to engine thrust is extracted from the compressor(s). With all engines supplying bleed air to the common manifold the loss of individual engine efficiency is minimal. Note however that some aircraft reduce bleed air extraction for take-off by selecting airconditioning packs off. This ensures that the engines are operating at maximum efficiency.

During flight in severe weather conditions that require the use of both engine and wing anti-ice operation, significant loss of thrust due to the extra use of bleed air will require advancing thrust levers to maintain speed. This will result in increased fuel consumption which may be as high as a 15% more than normal.

Additionally, if an engine failure occurs during flight the pneumatic load on the remaining engine(s) is increased significantly. Engine failure in cruise usually requires a descent to a suitable lower level for the remaining thrust available and some aircraft procedures will offer the option of turning one airconditioning pack off to reduce bleed air use. This allows increased drift down ranges and fuel savings.

Lastly, any more than the normal use of bleed air will require a performance penalty to be applied to the aircraft for take-off.

BLEED AIR LIMITATIONS ON APUS

When bleed air from the APU is used to start main engines a minimum amount of pressure must be available in the common bleed air manifold prior to start. The minimum pressure will be stated in the aircraft's Operating Manual.

Attempting a start with bleed air pressure less than the minimum will normally result in a hung or stagnated start of the main engine. For interest the minimum required duct pressure for Boeing and Airbus aircraft is 25 psi (less 1 psi per 1000 ft of pressure altitude).

When APU's are operated in flight to provide bleed air they are typically limited to specific maximum altitudes which will be also stated in the aircraft's Operating Manual.

PNEUMATIC SYSTEM TERMINOLOGIES AND DEFINITIONS

The following table defines old and/or common terms that you may encounter with reference to pneumatic systems. Refer to Figure 4-28.

TERM REFERRED	DEFINITION
Butterfly Valve	A common name for a shut-off or regulating valve that uses a circular plate which is rotated to seal against the interior diameter of the valve body. Typically used to control large mass airflows.
Flapper Valve	Same as a twin butterfly type valve. A non return valve.
Schrader valve	Commonly used gas charging valve fitted to accumulators, shock struts, stored air bottles etc. Valve can be locked once equipment is charged with gas.
Marmon Clamp	The name of a very common type of clamp used to join sections of bleed air ducts and components to the pneumatic system.
Dog Clutch	The name of a device used to disconnect EDCs and Generators from the engine accessory drive gearbox when they are malfunctioning. The dog clutch is activated by the crew and cannot be reset in flight.
Strut (engine)	The streamlined structure that supports the engine from the wing or fuselage. It normally houses the pneumatic valves and precooler associated with the engine.
Pylon (engine)	Same as a strut.
Pylon Valve	Another name for the Engine Bleed Valve because it is located in the pylon.

Figure 4-28 Pneumatic Terms and Definitions

GENERAL SAFETY PRECAUTIONS RELATING TO PNEUMATIC SYSTEMS

Aircraft pneumatic systems can be extremely dangerous.

The leading edge flaps on some older aircraft tend to droop due to gravity when pneumatic pressure is depleted and with the application of system pressure they will suddenly move to the retracted position.

Due to this sudden and rapid movement of some pneumatically controlled equipment it is important to check the aircraft's external situation before allowing bleed air from the APU into the common bleed air manifold whilst the aircraft is on the ground.

If required to operate any pneumatic equipment from the cockpit ensure external observers are posted to ensure personnel remain clear of operating surfaces.

Because of the hazard to personnel it is normal practice not to conduct pre-flight flight control checks or select flaps until after engine start/pushback and the aircraft has cleared the ramp.

Pneumatic leakage, especially bleed air leakage, if felt or suspected should be immediately avoided as the temperature of the bleed air is such that serious injury to personnel can occur. Shut-off all bleed air sources immediately and before attempting further inspection.

HIGH PRESSURE PNEUMATIC SYSTEMS

Some older types of aircraft use high pressure pneumatic systems to operate the services that are normally hydraulically powered on modern aircraft. There are very few aircraft that use this type of system. Refer to Figure 4-29 for an example of a high pressure pneumatic system.

Systems like these are normally charged up by ground supplied compressed air so that the compressors only have to maintain and replenish the system pressure during each flight.

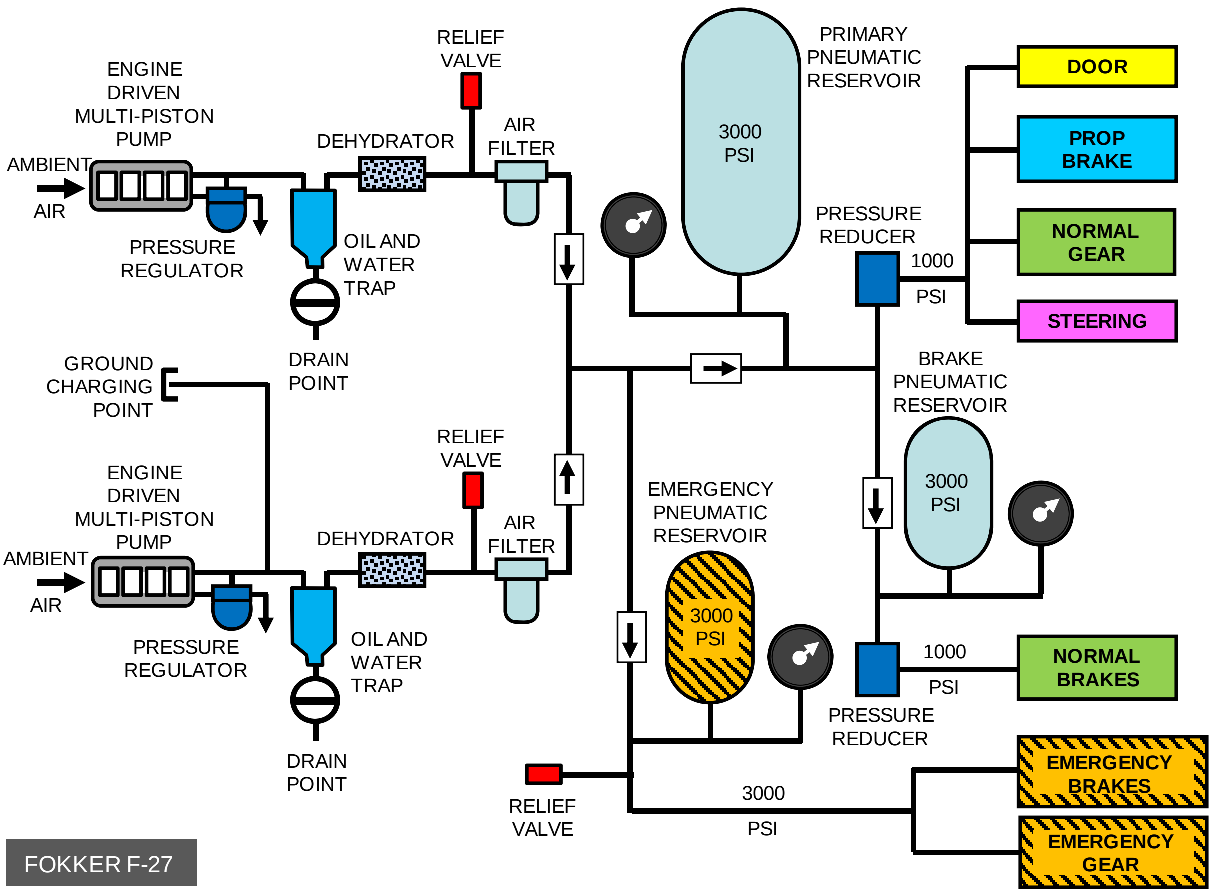

Figure 4-29 HIGH Pressure Pneumatic System – Fokker F-27

The disadvantage with this type of system is the high maintenance activity required to keep the system free of oil and moisture. Oil vapour, dirt and moisture must be removed from the compressed air before it reaches the control valves and actuators.

Filters have to be checked often for accumulated oil and dirt and water must be drained from the traps after each flight. Removing moisture ensures that no ice can form and block the operation of services when operating in cold conditions. Note that a chemical dryer or dehydrator is added to capture any moisture that is not collected by the traps.

Unlike the bleed air systems discussed previously, a high pressure system is similar to a hydraulic system with small diameter high strength piping, hydraulic type check valves, pressure regulators, pressure reducing valves, four way selector valves and piston type pump compressors. Unlike a hydraulic system however, note that the system pressure is not sensed after the pumps but at each individual reservoir.

HIGH PRESSURE MULTIPLE STAGE PISTON PUMPS

The engine driven pumps used for a high pressure system are usually piston type pumps as they have to produce pressures of up to 3000 PSI. Compression occurs in four stages via multiple pistons. Refer to Figure 4-30.

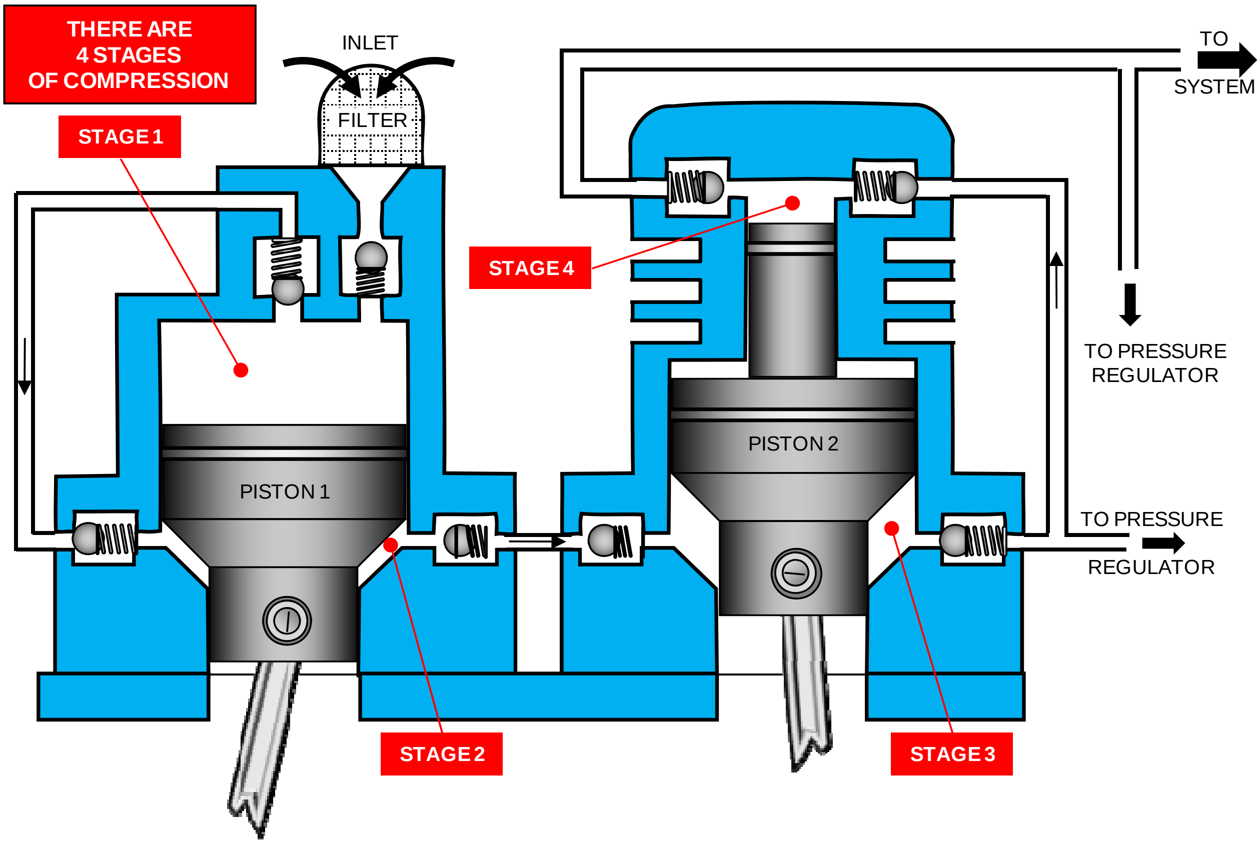

Figure 4-30 HIGH Pressure Multi-stage Piston Pump

PRESSURE REGULATORS

The pressure regulator controls the maximum pressure in the system and off-loads the compressor when the system is idle. When maximum pressure is reached the piston overcomes the spring opening the ball valve and allowing air to exhaust. When system pressure drops below maximum the spring pushes the ball closed and pump output is increased. Refer to Figure 4-31.

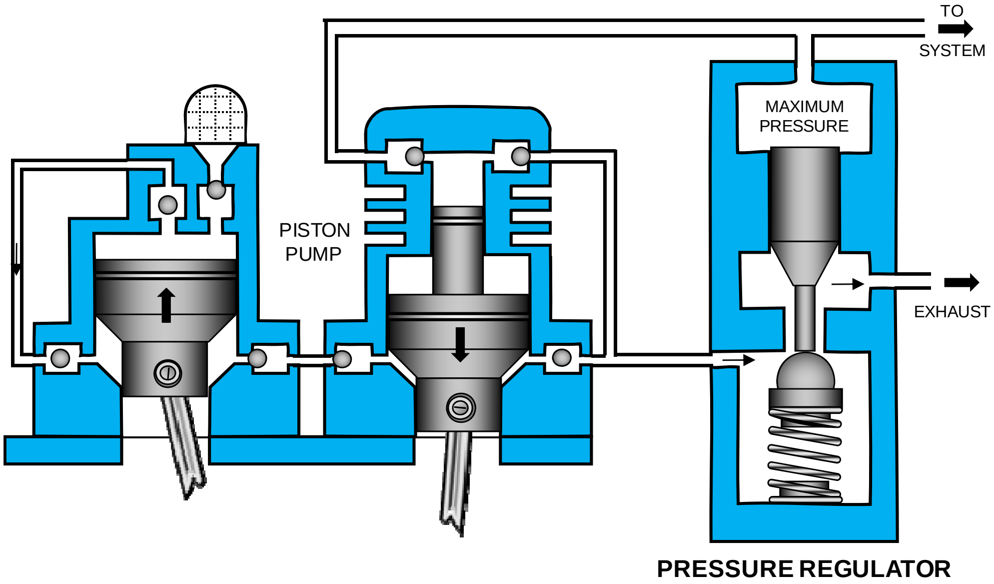

Figure 4-31 Pressure Regulator

PRESSURE REDUCING VALVES

High pressure pneumatic systems that generate a pressure of 3000 PSI for supply will typically reduce the supply pressure down to 1000 PSI to operate the equipment. The device that achieves this is a Pressure Reducing Valve. Refer to Figure 4-32.

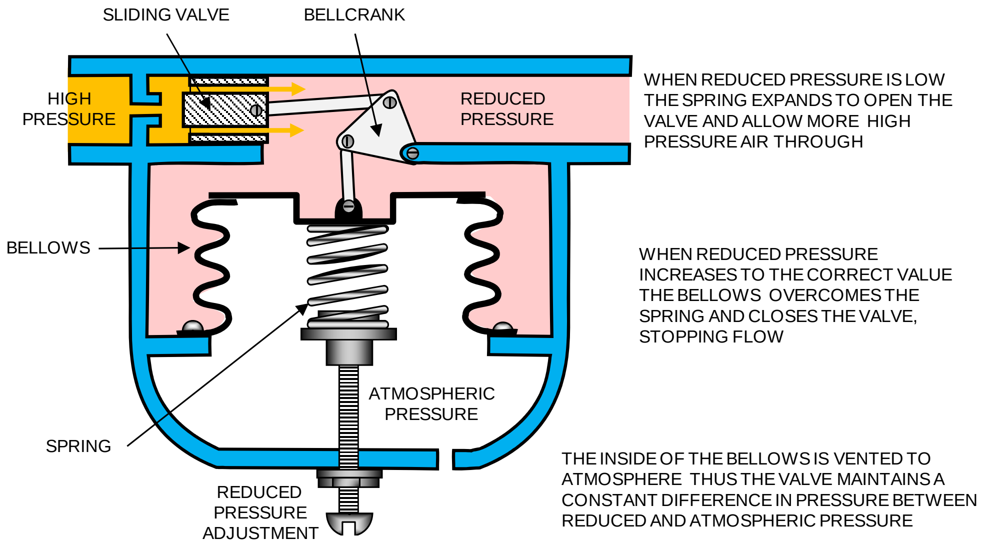

Figure 4-32 Pressure Reducing Valve

OIL AND WATER TRAPS

Oil and water traps are designed to remove any oil or water which may be suspended in the air delivered by the compressor. The internal design stops incoming airflow from stirring any collected sediment and prevents water or sediments from entering the system during aircraft manoeuvres. Oil and water traps are drained daily or immediately after each flight if freezing conditions exist. Refer to Figure 4-33.

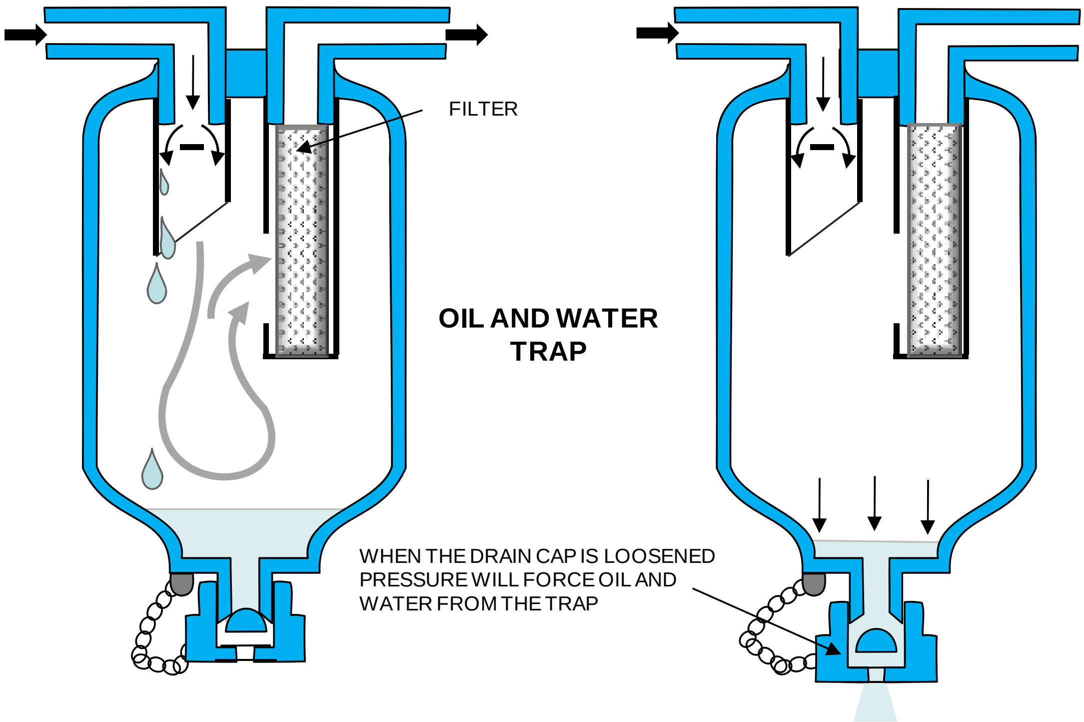

Figure 4-33 Oil and Water Trap

HIGH PRESSURE PNEUMATIC ACTUATORS

As described before there are two types of actuators, rotary and linear. A high pressure system typically uses linear actuators to operate landing gear and other services.

A pneumatic linear actuator differs from a hydraulic actuator in that its action must be "damped" or controlled. This is because compressed air is the fluid medium used and the actuator movements may become jerky and violent.

One method used to dampen violent operation is to place a fixed damper piston inside the hollow ram. The hollow ram is filled with grease and as the ram travels in and out the grease is forced through the annular space between the piston and the inner walls. This provides a constant stabilizing resistance to sudden or rapid movements of the ram.

Note also that the damper piston has a drilled passage and plate valve which allows a faster transfer of grease in one direction but not the other. This feature controls the speed of actuator operation and could be used for example to restrict the rate of extension of a landing gear assembly. Refer to Figure 4-34.

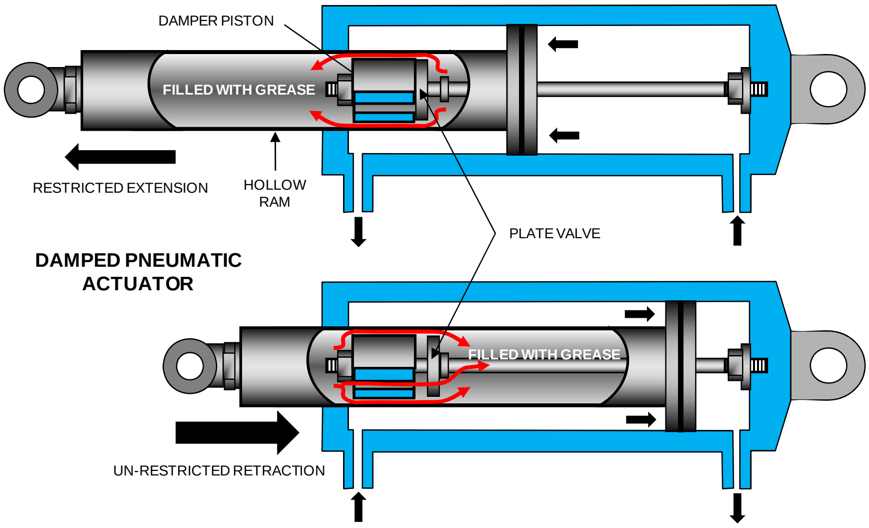

Figure 4-34 HIGH Pressure Damped Linear Actuator

Other HIGH Pressure Pneumatic Valves and Components located throughout the aircraft are listed in the following table. Refer to Figures 4-29 and 4-35 for a description of their location and operation.

VALVE OR COMPONENT	LOCATION	CONTROL	COCKPIT INDICATION	OPERATION
DEHYDRATOR	after the oil and water traps		no	Absorbs any moisture not collected by the trap. Is a container filled with activated alumina which absorbs moisture. It must be regularly changed as it will become saturated over time.
PRESSURE RELIEF VALVE	between compressor and reservoir	automatic	no	This is a safety valve to vent excessive pressure overboard.
FILTER	between compressor and reservoir		no	Removes airborne particles. Fitted with drains to check for water. Are checked for water regularly.
PNEUMATIC RESERVOIRS	Normally 3, for system, brakes and emergency		Yes – Indication of pressure of each reservoir	Wire wound steel containers. Fitted with drains to empty any water or sediment. Are checked for water regularly. Usually charged by ground equipment and are intended to hold pressure indefinitely only being replenished by the aircraft compressors .
CONTROL VALVES	Before the particular equipment actuators	Electric or manual cockpit control	Yes – Indication of equipment operation	Similar to hydraulic selector valves with small diameter ports. The return port will always be to atmosphere as there is no return to the reservoir in a pneumatic system. Electric selectors use solenoids like hydraulic selectors.
PRESSURE MAINTAINING VALVE		automatic	no	Similar to a hydraulic priority valve, it ensures that essential services are supplied even when system pressure is below normal values.

Figure 4-35 HIGH Pressure Pneumatic Valves and Components

SAFETY PRECAUTIONS SPECIFICALLY RELATED TO HIGH PRESSURE PNEUMATIC SYSTEMS

This type of system stores compressed air in three reservoirs at 3000 PSI and therefore even when engines are not operating or ground equipment is not connected the services may be accidentally operated due to the stored pressure.

Pneumatic leakage, especially high pressure leakage, if felt or suspected should be immediately avoided as the pressures involved are such that serious injury to personnel can occur.

PNEUMATIC SYSTEMS QUESTIONS

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

1. The mass flow delivery from engine driven blowers is controlled by;

- **a.** engine speed variations.
- **b.** automatic control devices.
- **c.** spill valves.

2. Pneumatic system air supplied for environmental control systems is;

- **a.** hottest from an engine compressor bleed supply.
- **b.** hottest from a compressor driven by the engine gearbox.
- **c.** the same from both of the above sources.

3. Spill Valves are normally controlled automatically by the;

- **a.** cabin pressure regulator.
- **b.** choke heat valve.
- **c.** mass flow controller.

4. An air to air heat exchanger is provided to;

- **a.** reduce the air supply temperature.
- **b.** increase the air supply temperature.
- **c.** allow an emergency ram air supply.

5. A method used to increase air supply temperature produced by an engine driven compressor is;

- **a.** to fit a combustion heater.
- **b.** to fit a choke valve.
- **c.** to fit the ducting around the engine exhaust.

6. A blower type cabin supercharger uses which of the following to produce compressed air;

- **a.** multiple pistons.
- **b.** rotating impellors.
- **c.** rotating rotors.

7. The purpose of a mass flow controller is to;

- **a.** maintain a constant rate of airflow into the cabin.
- **b.** maintain a constant rate of airflow to drive a turbocharger.
- **c.** control the speed and therefore flow output of an EDC.

8. A choke heat valve provides extra heating by;

- **a.** selecting higher cabin pressure.
- **b.** producing higher duct pressure.
- **c.** requiring higher compressor output pressure.

9. During cruise conditions in a modern large transport aircraft you would expect the pneumatic common bleed air manifold to have an indicated pressure of approximately;

- **a.** 10 to 15 psi.
- **b.** 30 to 40 psi.
- **c.** 300 to 400 psi.

10. In a modern large gas turbine engine the air used for bleed air cooling is extracted from;

- **a.** the LP turbine.
- **b.** the LP compressor.
- **c.** the bypass duct ram air.

11. The HP bleed air shutoff valve should be open at;

- **a.** maximum engine RPM.
- **b.** low engine RPM.
- **c.** cruise RPM.

12. The leakage of bleed air from the common bleed air manifold would be indicated by;

- **a.** a warning of high temperature.
- **b.** a warning of low pressure.
- **c.** both of the above.

13. During normal cruise engine anti-ice is selected ON. Which of the following would you expect the engine(s) to indicate;

- **a.** a decrease in EGT and a decrease in EPR.
- **b.** an increase in EGT and an increase in EPR.
- **c.** an increase in EGT and a decrease in EPR.

14. The valve that allows the engines bleed air to enter the common bleed air manifold is called;

- **a.** the engine high pressure shut-off valve.
- **b.** the engine bleed valve.
- **c.** the engine isolation valve.

15. Pressure regulating and shut-off valves are;

a. actuated electrically but regulate pressure, open and close pneumatically.
b. actuated electrically and regulate pressure, open and close electrically.
c. automatically operate pneumatically whenever air pressure is present in the duct.

16. The common bleed air manifold is typically located;

a. within the trailing edge of the wing structures and through the fuselage.
b. within the leading edge of the wing structures and through the fuselage.
c. within the leading edge of the wing structures but terminates at the fuselage.

17. A characteristic of a cabin blower type compressors is that;

a. they are very noisy in operation.
b. they require a high level of regular maintenance.
c. they do not require spill valves like other compressors.

18. Small individual bottles of compressed gas are commonly used in a modern large transport aircraft for;

a. opening cabin doors in emergencies, inflating tyres and emergency braking systems.
b. opening cabin doors in emergencies, inflating escape slides and maintaining feed pressure on the aircraft water tanks.
c. opening cabin doors in emergencies and powering the inflation mechanism of escape slides.

19. The actual pressure contained within small individual pneumatic bottles may be observed;

a. on the applicable system synoptics displayed on EICAS or ECAM.
b. on small gauges located at the bottle.
c. on a maintenance readout summary from the FMS.

20. The typical pneumatic sources provided on a large jet transport aircraft are;

a. bleed air from main engines, bleed air from the APU, bottles of stored gas for use in emergencies and a connection available for ground supplied compressed air.
b. compressed air from turbochargers, bleed air from main engines, bottles of stored gas for use in emergencies and a connection available for ground supplied compressed air.
c. bleed air from main engines, electric compressed air from the APU, bottles of stored gas for use in emergencies and a connection available for ground supplied conditioned air.

21. It is most important to regularly drain collected water from high pressure pneumatic systems to prevent;

a. water overflowing from the system into electrical equipment.
b. corrosion occurring within the system.
c. the formation of ice within the system.

22. Aircraft that use high pressure pneumatic systems to operate landing gear, brakes and other large services store compressed air in;

a. pneumatic capacitors.
b. pneumatic reservoirs.
c. pneumatic accumulators.

23. Refer to Figure 4-15, Boeing 747-400 Pneumatic System; During a pre-flight with main engines shutdown and the APU running the following checks could be carried out;

a. thrust reverser operation.
b. leading and trailing edge flap operation.
c. nacelle anti-ice operation.

24. Refer to Figure 4-15, Boeing 747-400 Pneumatic System; During flight a duct leak occurs in the leading edge between engines 3 and 4. After the leaking duct section is isolated which services are now inoperative?

a. A/C pack 3, ADP 3 and 4, reservoir pressure 3 and 4, nacelle anti-ice 3 and 4, wing anti ice and L/E flaps.
b. A/C pack 3, ADP 3 and 4, reservoir pressure 3 and 4, nacelle anti-ice 3 and 4 and RH L/E flaps.
c. A/C pack 3, ADP 3 and 4, reservoir pressure 3 and 4 and RH wing anti-ice.

25. Aircraft that use pneumatic systems to operate landing gear, brakes and other large services operate on a supply pressure of;

a. 30 to 40 PSI.
b. 200 to 300 PSI.
c. 2800 to 3200 PSI.

26. Refer to Figure 4-14, Airbus 330 Pneumatic System; The engine bleed valve will close automatically under pneumatic control when the following occurs;

a. reverse flow through the valve, engine fire and over pressure.
b. reverse flow through the valve, engine fire and a leak detected.
c. reverse flow through the valve and engine fire.

27. In a Pressure Reducing Valve used in a high pressure pneumatic system the bellows ruptured the valve would;

a. fully open.
b. fully close.
c. continue to adjust but more slowly.

28. In a Pressure Regulating and Shut-off Valve used in a bleed air pneumatic system the diaphragm ruptured the valve would;

a. fully open.
b. fully close.
c. continue to adjust but more slowly.

29. On an Airbus synoptic display the colour green indicates;

a. monitored parameters are in the normal range.
b. the names of the equipment.
c. the names of the monitored parameters.

30. High pressure pneumatic actuators are damped during travel by;

a. a damping piston moving through contained grease.
b. a damping piston moving through contained air pressure.
c. a plate valve and orifice in the damping piston.