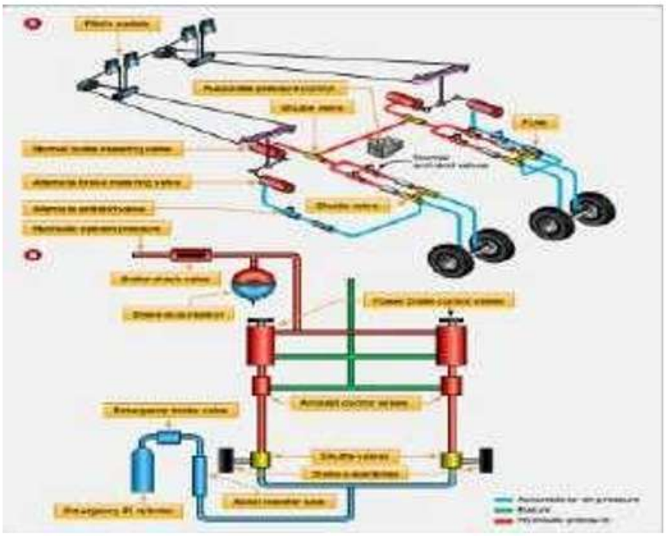

Figure-70 The orientation of components in a basic power brake system is shown in A. The general layout of an airliner power brake system is shown in B.

Power brake systems are constructed to facilitate graduated brake pressure control, brake pedal feel, and the necessary redundancy required in case of hydraulic systemfailure.
Large aircraft brake systems integrate anti-skid detection and correction devices. However, a skid can be quickly controlled automatically through pressure control of the hydraulic fluid to the brakes. Hydraulic fuses are also commonly found in power brake systems. The hostile environment around the landing gear increases the potential for a line to break or sever, a fitting to fail, or other hydraulic system malfunctions to occur where hydraulic fluid is lost en route to the brake assemblies. A fuse stops any excessive flow of fluid when detected by closing to retain the remaining fluid in the hydraulic system. Shuttle valves are used to direct flow from optional sources of fluid, such as in redundant systems or during the use of an emergency brake powersource.

Brake Control Valve/Brake Metering Valve

The key element in a power brake system is the brake control valve, sometimes called a brake metering valve. It responds to brake pedal input by directing aircraft system hydraulic fluid to the brakes. As pressure is increased on the brake pedal, more fluid is directed to the brake causing a higher pressure and greater braking action. A brake metering valve from a Boeing 737 is illustrated inFigure-71.

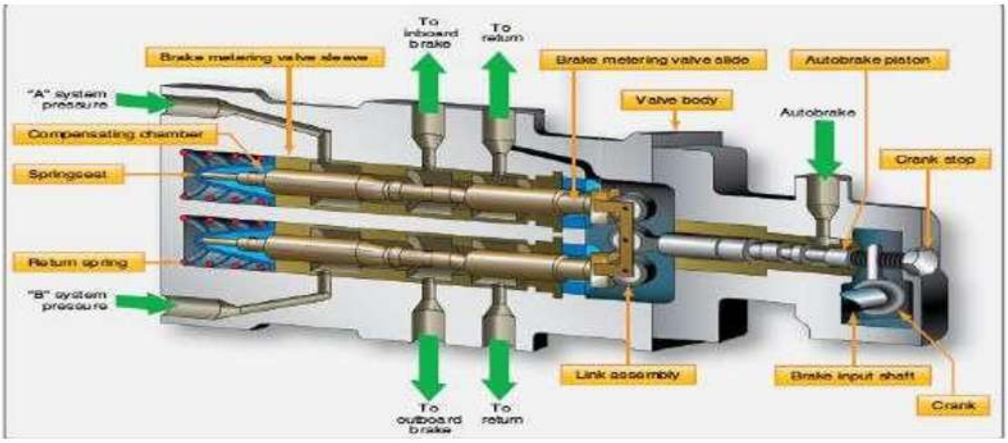

Figure-71 a brake metering valve from a Boeing 737.

A machined slide or spool moves laterally to admit the correct amount of hydraulic system fluid to the brakes. The pressure developed is in proportion to the amount the rudder/brake pedal is depressed and the amount the slide is displaced. The slide/spool also simultaneously controls the return of fluid to the hydraulic system return manifold when brake pressure is released.

Two sources of hydraulic pressure provide redundancy in this brake system. A brake input shaft, connected to the rudder/brake pedal through mechanical linkages, provides the position input to the metering valve. As in most brake control valves, the brake input shaft moves a tapered spool or slide in the valve so that it allows hydraulic system pressure to flow to the brakes. At the same time, the slide covers and uncovers access to the hydraulic system return port asrequired.

When the rudder/brake pedal is depressed, the slide in the metering valve moves to the left. [Figure-71] It covers the return port so pressure can build in the brake system. The

hydraulic supply pressure chamber is connected to the brake system pressure chamber by the movement of the slide, which due to its taper, unblocks the passage between these two. As the pedal is depressed further, the valve slides moves farther to the left. This enables more fluid to flow to the brakes due to the narrowing shape of the slide. Brake pressure increases with the additional fluid. A passage in the slide directs brake pressure fluid into a compensating chamber at the end of the slide. This acts on the end of the slide creating a return force that counters the initial slide movement and gives feel to the brake pedal. As a result, the pressure and return ports are closed and pressure proportional to the foot pressure on the pedal is held on the brakes. When the pedal is released, a return spring and compensating chamber pressure drive the slide to the right into its original position (return port open, supply pressure chamber and brake pressure chambers blocked from eachother).

The metering valve operates as described simultaneously for the inboard and the outboard brakes. [Figure-71] The design of the link assembly is such that a single side of the metering valve can operate even if the other fails. Most break control valves and metering valves function in a similar manner, although many are single units that supply only one brake assembly. The auto brake, referenced in the metering valve diagram, is connected into the landing gear retraction hydraulic line. Pressurized fluid enters this port and drives theslideslightlytothelefttoapplythebrakesautomatically after takeoff. This stops the wheels from rotating when retracted into the wheel wells. Auto brake pressure is withheld from this port when the landing gear is fully stowed since the retraction system isdepressurized.

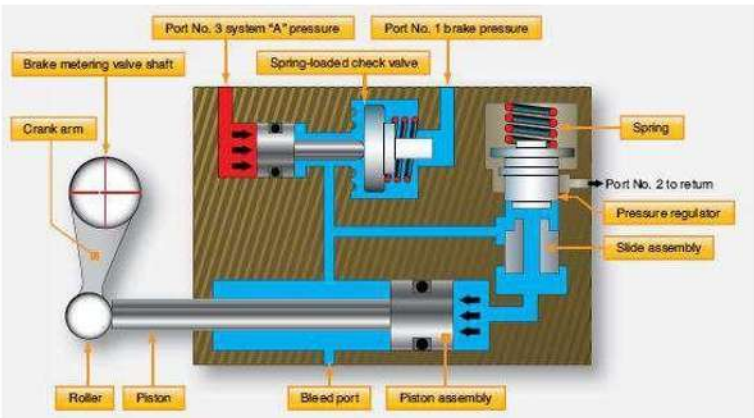

Figure-72 the power brake system on a Boeing737.

The majority of the rudder/brake pedal feel is supplied by the brake control or brake metering valve in a power brake system. Many aircraft refine the feel of the pedal with an additional feel unit. The brake valve feel augmentation unit, in the above system, uses a series of internal springs and pistons of various sizes to create a force on the brake input shaft movement. This provides feel back through the mechanical linkages consistent with the amount of rudder/brake pedal applied. The request for light braking with slight pedal depression results in a light feel to the pedal and a harder resistance feel when the pedals are pushed harder during heavy braking.Figure-72

Emergency Brake Systems

As can be seen in Figure-73, the brake metering valves not only receive hydraulic pressure from two separate hydraulic systems, they also feed two separate brake assemblies. Each main wheel assembly has two wheels. The inboard wheel brake and the outboard wheel brake, located in their respective wheel rims, are independent from each other. In case of hydraulic system failure or brake failure, each is independently supplied to adequately slow and stop the aircraft without theother.

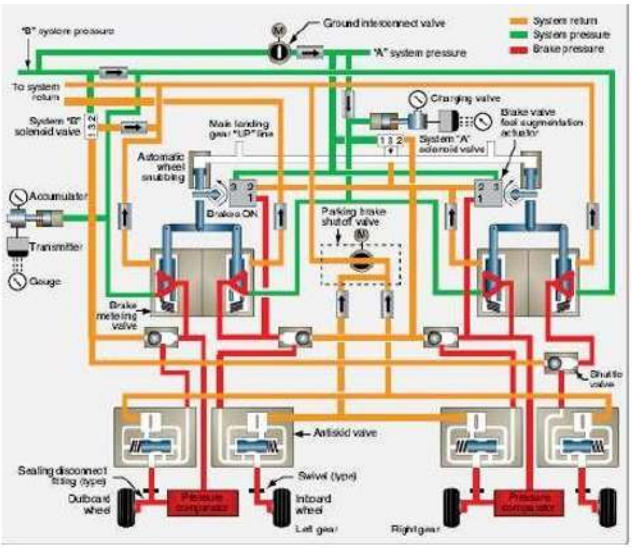

Figure 73 The power brake system on a Boeing 737

More complicated aircraft may involve another hydraulic system for back-up or use a similar alternation of sources and brake assemblies to maintain braking in case of hydraulic system or brake failure.

NOTE: In the segmented rotor brake section above, a brake assembly was described that had alternating pistons supplied by independent hydraulic sources. This is another method of redundancy particularly suitable on, but not limited to, single main wheel aircraft. In addition to supply system redundancy, the brake accumulator is also an emergency source of power for the brakes in many power brake systems. The accumulator is pre-charged with air or nitrogen on one side of its internal diaphragm. Enough hydraulic fluid is contained on the other side of the diaphragm to operate the brakes in case of an emergency. It is forced out of the accumulator into the brakes through the system lines under enough stored pressure to slow the aircraft. Typically, the accumulator is located upstream of the brake control/metering valve to capitalize on the control given by the valve.[Figure-74]

Figure-74 Emergency brake hydraulic fluid accumulators are recharged with nitrogen to deliver brake fluid to the brakes in

the event normal and alternate hydraulic sources fail.
Some simpler power brake systems may use an emergency source of brake power that is delivered directly to the brake assemblies and bypasses the remainder of the brake system completely. A shuttle valve immediately upstream of the brake units shifts to accept this source when pressure is lost from the primary supply sources. Compressed air or nitrogen is sometimes used. A pre-charged fluid source can also be used as an alternate hydraulicsource.
Parking Brake

The parking brake system function is a combined operation. The brakes are applied with the rudder pedals and a ratcheting system holds them in place when the parking brake lever on the flight deck is pulled. [Figure-75] At the same time, a shut-off valve is closed in the common return line from the brakes to the hydraulic system. This traps the fluid in the brakes holding the rotors stationary. Depressing the pedals further releases the pedal ratchet and opens the return linevalve.

Figure-75 The parking brake lever on a Boeing 737 center pedestal throttle quadrant.

Brake De-boosters

Some aircraft brake assemblies that operate on aircraft hydraulic system pressure are not designed for such high pressure. They provide effective braking through a power brake system but require less than maximum hydraulic system pressure. To supply the lower pressure, a brake de- booster cylinder is installed downstream of the control valve and anti-skid valve. [Figure-76] The de-booster reduces all pressure from the control valve to within the working range of the brake assembly. Brake de-boosters are simple devices that use the application of force over different sized pistons to reduce pressure. [Figure-77] Their operation can be understoodthroughtheapplicationofthefollowingequation:

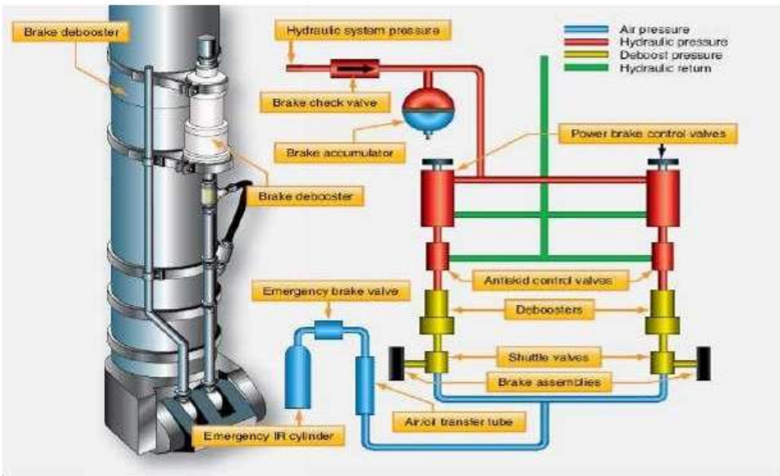

Figure 76 The location of a brake de-booster cylinder on a landing gear strut and the de-booster's position in relation to other components of a power brake system

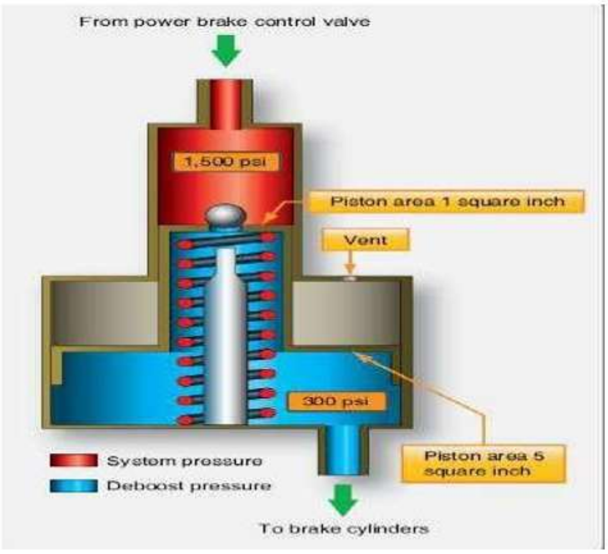

Figure-77 Brake de-boosters.

High-pressure hydraulic system input pressure acts on the small end of a piston. This develops a force proportional to the area of the piston head. The other end of the piston islarger and housed in a separate cylinder. The force from the smaller piston head is transferred to the larger area of the other end of the piston. The amount of pressure conveyed by the larger end of the piston is reduced due to the greater area over which the force is spread. The volume of output fluid increases since a larger piston and cylinder are used. The reducedpressureisdeliveredtothebrakeassembly.The spring in the de-booster aids in returning the piston to the ready position. If fluid is lost downstream of the de-boost cylinder, the piston travels further down into the cylinder when the brakes are applied. The pin unseats the ball and allows fluid into the lower cylinder to replace what was lost. Once replenished, the piston rises up in the cylinder due to pressure build-up. The ball reseats as the piston travels above the pin and normal braking resumes. This function is not meant to permit leaks in the brake assemblies. Any leak discovered must be repaired by the technician. A lockout de- booster functions as a de-booster and a hydraulic fuse. If fluid is not encountered as the piston moves down in the cylinder, the flow of fluid to the brakes is stopped. This prevents the loss of all system hydraulic fluid should a rupture downstream of the de-booster occur. Lockout de- boosters have a handle to reset the device after it closes as a fuse. If not reset, no braking action ispossible.

Anti-Skid

Large aircraft with power brakes require anti-skid systems. It is not possible to immediately ascertain in the flight deck when a wheel stops rotating and begins to skid, especially in aircraft with multiple-wheel main landing gear assemblies. A skid not corrected can quickly lead to a tire blowout, possible damagetotheaircraft,andcontroloftheaircraftmaybelost.

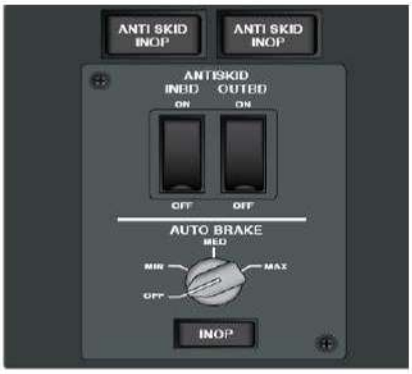

Figure-78 Antiskid switches in the cockpit.

System Operation

The anti-skid system not only detects wheel skid, it also detects when wheel skid is imminent. It automatically relieves pressure to the brake pistons of the wheel in question by momentarily connecting the pressurized brake fluid area to the hydraulic system return line. This allows the wheel to rotate and avoid a skid. Lower pressure is then maintained to the brake at a level that slows the wheel without causing it to skid. Maximum braking efficiency exists when the wheels are decelerating at a maximum rate but are not skidding. If a wheel decelerates too fast, it is an indication that the brakes are about to lock and cause a skid. To ensure that this does not happen, each wheel is monitored for a deceleration rate faster than a preset rate. When excessive deceleration is detected, hydraulic pressure is reduced to the brake on that wheel. To operate the anti-skid system, flight deck switches must be placed in the ON position. [Figure-105] After the aircraft touches down, the pilot applies and holds full pressure to the rudder brake pedals. The anti-skid system then functions automatically until the speed of the aircraft has dropped to approximately 20 mph. The system returns to manualbrakingmodeforslowtaxiandgroundmaneuvering.

There are various designs of anti-skid systems. Most contain three main types of components: wheel speed sensors, antiskid control valves, and a control unit. These units work together without human interference. Some anti-skid systems provide complete automatic braking. The pilot needs only to turn on the auto brake system, and the anti-skid components slow the aircraft without pedal input. [Figure-

78] Ground safety switches are wired into the circuitry for anti-skid and auto brake systems. Wheel speed sensors are located on each wheel equipped with a brake assembly. Each brake also has its own anti-skid control valve. Typically, a single control box contains the anti-skid comparative circuitry for all of the brakes on the aircraft.[Figure-79]

Figure-79 A wheel sensor (left), a control unit (center), and a control valve (right) is components of an antiskid system. A sensor is located on each wheel equipped with a brake assembly. An antiskid control valve for each brake assembly is controlled from a single central control unit.

Wheel Speed Sensors

Wheel speed sensors are transducers. They may be alternating current (AC) or direct current (DC). The typical AC wheel speed sensor has a stator mounted in the wheel axle. A coil around it is connected to a controlled DC source so that when energized, the stator becomes an electromagnet. A rotor that turns inside the stator is connected to the rotating wheel hub assembly through a drive coupling so that it rotates at the speed of the wheel. Lobes on the rotor and stator cause the distance between the two components to constantly change during rotation. This alters the magnetic coupling or reluctance between the rotor and stator. As the electromagnetic field changes, a variable frequency AC is induced in the stator coil. The frequency is directly proportional to the speed of rotation of the wheel. The AC signal is fed to the control unit for processing. A DC wheel speed sensor is similar, except that a DC is produced the magnitude of which is directly proportional to wheel speed. [Figure-80]

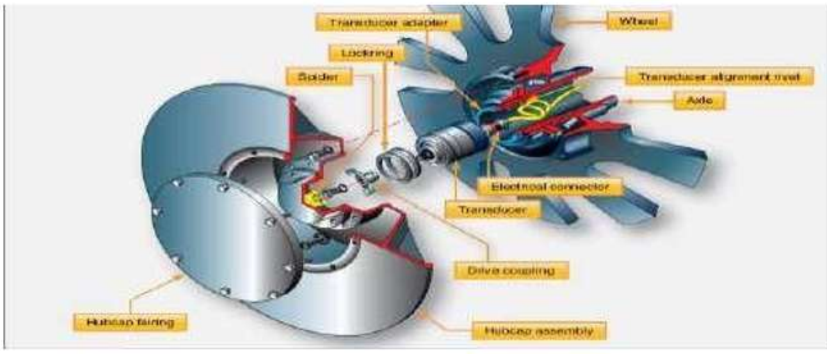

Figure-80 The stator of an antiskid wheel sensor is mounted in the axle, and the rotor is coupled to the wheel hub spider that rotates with thewheel.

Control Units

The control unit can be regarded as the brain of the antiskid system. It receives signals from each of the wheel sensors. Comparative circuits are used to determine if any of the signals indicate a skid is imminent or occurring on a particular wheel. If so, a signal is sent to the control valve of the wheel to relieve hydraulic pressure to that brake which prevents or relieves the skid. The control unit may or may not have external test switches and status indicating lights. It is common for it to be located in the avionics bay of the aircraft. The Boeing anti-skid control valve block diagram in Figure-81 gives further detail on the functions of an antiskid control unit. Other aircraft may have different logic to achieve similar end results. DC systems do not require an input converter since DC is received from the wheel sensors, and the control unit circuitry operates primarily with DC. Only the functions on one circuit card for one wheel brake assembly are shown inFigure-81.

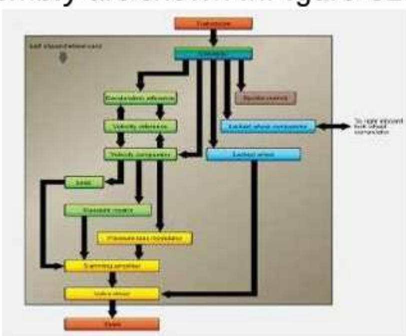

Figure-81 Boeing 737 antiskid control unit internal block diagram.

Each wheel has its own identical circuitry card to facilitate simultaneous operation. All cards are housed in a single control unit that Boeing calls a control shield. The converter shown changes the AC frequency received from the wheel sensor into DC voltage that is proportional to wheel speed. The output is used in a velocity reference loop that contains deceleration and velocity reference circuits. The converter also supplies input for the spoiler system and the locked wheel system, which is discussed at the end of this section. A velocity reference loop output voltage is produced, which represents the instantaneous velocity of the aircraft. This is compared to converter output in the velocity comparator. This comparison of voltages is essentially the comparison of the aircraft speed to wheel speed. The output from the velocity comparator is a positive or negative error voltage corresponding to whether the wheel speed is too fast or too slow for optimum braking efficiency for a given aircraft speed.
The error output voltage from the comparator feeds the pressure bias modulator circuit. This is a memory circuit that establishes a threshold where the pressure to the brakes provides optimum braking. The error voltage causes the modulator to either increase or decrease the pressure to the brakes in attempt to hold the modulator threshold. It produces a voltage output that is sent to the summing amplifier to do this.Aleadoutputfromthecomparatoranticipateswhenthe tire is about to skid with a voltage that decreases the pressure to the brake. It sends this voltage to the summing amplifier as well. A transient control output from the comparator designed for rapid pressure dump when a sudden skid has occurred also sends voltage to the summing amp. As the name suggests, the input voltages to the amplifier are summed, and a composite voltage is sent to the valve driver. The driver prepares the current required to be sent to the control valve to adjust the position of the valve. Brake pressure increases, decreases, or holds steady depending on thisvalue.

Anti-Skid Control Valves

Anti - skid control valves are fast - acting, electrically controlled hydraulic valves that respond to the input from the anti-skid control unit. There is one control valve for each brake assembly. A torque motor uses the input from the valve driver to adjust the position of a flapper between two nozzles. By moving the flapper closer to one nozzle or the other, pressures are developed in the second stage of the valve. These pressures act on a spool that is positioned to build or reducepressuretothebrakebyopeningandblockingfluid

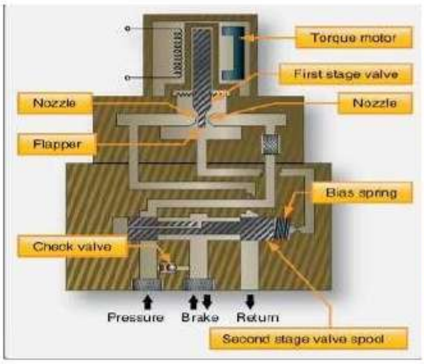

Figure-82An antiskid control valve uses a torque motor controlled flapper in the first stage of the valve to adjust pressure on a spool in the second stage of the valve to build or relieve pressure to thebrake.
Figure-83 Two antiskid controlvalves with associated plumbing and wiring.

ports. [Figure-82] As pressure is adjusted to the brakes, deceleration slows to within the range that provides the most effective braking without skidding. The wheel sensor signal adjusts to the wheel speed, and the control unit processes the change.

Output is altered to the control valve. The control valve flapper position is adjusted and steady braking resumes without correction until needed. Anti-skid control valves are typically located in the main wheel for close access to hydraulic pressure and return manifolds, as well as the brake assemblies. [Figure-83] Systematically, they are positioned downstreamofthepowerbrakecontrolvalvesbutupstream of de-booster cylinders if the aircraft is soequipped.

Touchdown and Lock Wheel Protection

It is essential that the brakes are not applied when the aircraft contacts the runway upon landing. This could cause immediate tire blowout. A touchdown protection mode is built into most aircraft anti-skid systems to prevent this. It typically functions in conjunction with the wheel speed sensor and the air/ground safety switch on the landing gear strut (squat switch). Until the aircraft has weight on wheels, the detector circuitry signals the anti-skid control valve to open the passage between the brakes and the hydraulic system return, thus preventing pressure build-up and application of the brakes. Once the squat switch is open, the anti-skid control unit sends a signal to the control valve to close and permit brake pressure build-up. As a back-up and when the aircraft is on the ground with the strut not compressed enough to open the squat switch, a minimum wheel speed sensor signal can override and allow braking. Wheels are often grouped with one relying on the squat switch and the other on wheel speed sensor output to ensure braking when the aircraft is on the ground, but not before then. Locked wheel protection recognizes if a wheel is not rotating. When this occurs, the anti-skid control valve is signaled to fully open. Some aircraft anti-skid control logic, such as the Boeing 737 shown in Figure-82, expands the locked wheel function. Comparator circuitry is used to relieve pressure when one wheel of a paired group of wheels rotates 25 percent slower than theother. Inboard and

outboard pairs are used because if one of the pair is rotating at a certain speed, so should the other. If it is not, a skid is beginning or has occurred. On takeoff, the anti-skid system receives input through a switch located on the gear selector that shuts off the anti-skid system. This allows the brakes to be applied as retraction occurs so that no wheel rotation exists while the gear isstowed.

Auto Brakes

Aircraft equipped with auto brakes typically bypass the brake control valves or brake metering valves and use a separate auto brake control valve to provide this function. In addition to the redundancy provided, auto brakes rely on the anti-skid system to adjust pressure to the brakes if required due to an impending skid. Figure-84 shows a simplified diagram of the Boeing 757 brake system with the auto brake valve in relation to the main metering valve and anti-skid valves in this eight-main wheelsystem.

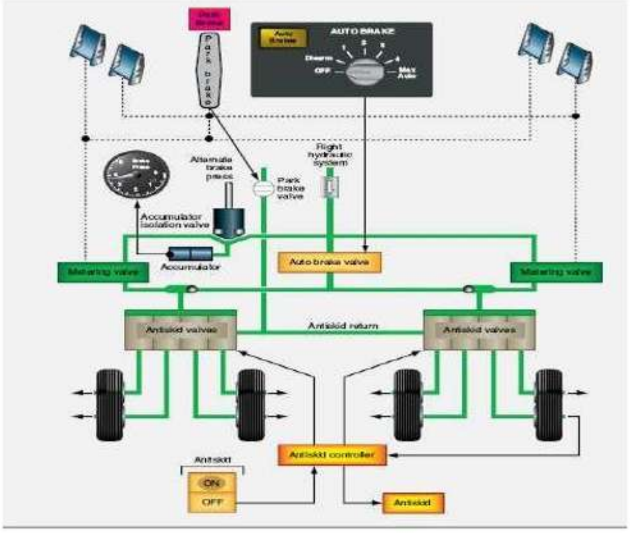

Figure-84 the Boeing 757 normal brake system with auto brake andantiskid.

Anti-Skid System Tests

It is important to know the status of the anti-skid system prior to attempting to use it during a landing or aborted takeoff. Ground tests and in-flight tests are used. Built-in test circuits and control features allow testing of the system components and provide warnings should a particular component or part of the system become inoperative. An inoperative anti-skid system can be shut off without affecting normal brake operation.

Ground Test

Ground tests vary slightly from aircraft to aircraft. Consult the manufacturer's maintenance manual for test procedures specific to the aircraft in question. Much of the anti-skid system testing originates from testing circuits in the anti-skid control unit. Built-in test circuits continuously monitor the anti-skid system and provide warning if a failure occurs. An operational test can be performed before flight. The anti-skid control switch and/or test switch is used in conjunction with system indicator light(s) to determine system integrity. A test is first done with the aircraft at rest and then in an electrically simulated anti-skid braking condition. Some anti-skid control units contain system and component testing switches and lights for use by the technician. This accomplishes the same operational verification, but allows an additional degree of troubleshooting. Test sets are available for anti-skid systems that produce electric signals that simulate speed outputs of the wheel transducer, deceleration rates, and flight/ground parameters. In-flight testing of the anti-skid system is desirable and part of the pre-landing checklist so that the pilot is aware of system capability before landing. As with ground testing, a combination of switch positions and indicator lights are used according to information in the aircraft operationsmanual.

Anti-Skid System Maintenance

Anti - skid components require little maintenance .Troubleshooting anti-skid system faults is either performed via test circuitry or can be accomplished through isolation of thefaulttooneofthethreemainoperatingcomponentsof

the system. Anti-skid components are normally not repaired in the field. They are sent to the manufacturer or a certified repair station when work is required. Reports of anti-skid system malfunction are sometimes malfunctions of the brake system or brake assemblies. Ensure brake assemblies are bled and functioning normally without leaks before attempting to isolate problems in the anti-skidsystem.

Wheel Speed Sensor

Wheel speed sensors must be securely and correctly mounted in the axle. The means of keeping contamination out of the sensor, such as sealant or a hub cap, should be in place and in good condition. The wiring to the sensor is subject to harsh conditions and should be inspected for integrity and security. It should be repaired or replaced if damaged in accordance with the manufacturer's instructions. Accessing the wheel speed sensor and spinning it by hand or other recommended device to ensure brakes apply and release via the anti-skid system is commonpractice.

Control Valve

Anti-skid control valve and hydraulic system filters should be cleaned or replaced at the prescribed intervals. Follow all manufacturers' instructions when performing this maintenance. Wiring to the valve must be secure, and there should be no fluidleaks.

Control Unit

Control units should be securely mounted. Test switches and indicators, if any, should be in place and functioning. It is essential that wiring to the control unit is secure. A wide variety of control units are in use. Follow the manufacturer's instructions at all times when inspecting or attempting to perform maintenance on theseunits.

Brake Inspection and Service

Brake inspection and service is important to keep these critical aircraft components fully functional at all times. There are many different brake systems on aircraft. Brake system maintenance is performed both while the brakes are installed on the aircraft and when the brakes are removed. The manufacturer's instructions must always be followed to ensure propermaintenance.

On Aircraft Servicing

Inspection and servicing of aircraft brakes while installed on the aircraft is required. The entire brake system must be inspected in accordance with manufacturer's instructions. Some common inspection items include: brake lining gear, air in the brake system, fluid quantity level, leaks, and proper bolttorque.

Lining Wear

Brake lining material is made to wear as it causes friction during application of the brakes. This wear must be monitored to ensure it is not worn beyond limitsand sufficient lining is available for effective braking. The aircraft manufacturer gives specifications for lining wear in its maintenance information. The amount of wear can be checked while the brakes are installed on the aircraft. Many brake assemblies contain a built-in wear indicator pin. Typically, the exposed pin length decreases as the

linings wear, and a minimum length is used to indicate the Linings must be replaced. Caution must be used as different assemblies may vary in how the pin measured. On the Goodyear brake described above, the wear pin is measured where it protrudes through the nut of the automatic adjuster on the back side of the piston cylinder.[Figure-85]

Figure- 85 Brake lining wear on a Goodyear brake i s ascertained by measuring the wear pin of the automatic adjuster. The manufacturer's maintenance information must be consulted to ensure brake wear pin indicators on different aircraft are read correctly. On many other brake assemblies, liningwearisnotmeasuredviaawearpin.Thedistance between the disc and a portion of the brake housing when the brakes are applied is sometimes used. As the linings wear, this distance increases. The manufacturer specified at what distance the linings should be changed.[Figure-86]

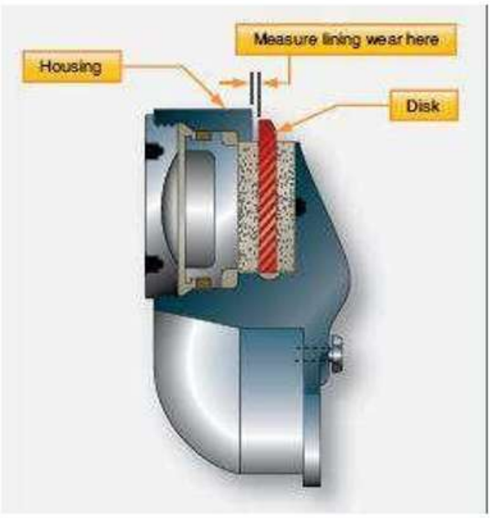

Figure-86 The distance between the brake disc and the brake housing measured with the brakes applied is a means for determining brake lining wear on some brakes.

Multiple disc brakes typically are checked for lining wear by applying the brakes and measuring the distance between the back of the pressure plate and the brake housing. [Figure-87] Regardless of the method particular to each brake, regular monitoring and measurement of brake wear ensures linings are replaced as they become unserviceable. Linings worn beyond limits usually require the brake assembly to be removed forreplacement.

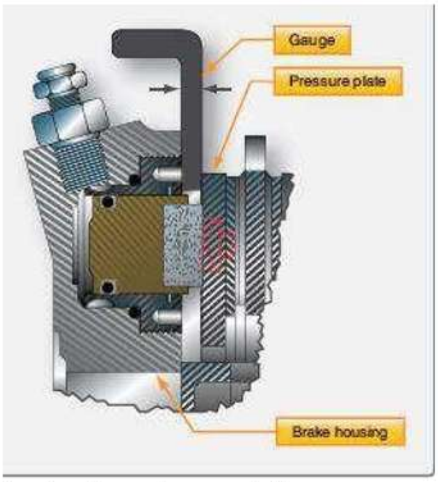

Figure-87 The distance between the brake housing and the pressure plate indicates lining wear on some multiple disc brakes.

Air in the Brake System

The presence of air in the brake system fluid causes the brake pedal to feel spongy. The air can be removed by bleeding to restore firm brake pedal feel. Brake systems must be bled according to manufacturers' instructions. The method used is matched to the type of brake system. Brakes are bled by one of two methods: top down, gravity bleeding or bottom up pressure bleeding. Brakes are bled when the pedals feel spongy or whenever the brake system has beenopened.

Bleeding Master Cylinder Brake Systems

Brake systems with master cylinders may be bled by gravity orpressurebleedingmethods.Followtheinstructionsinthe

aircraft maintenance manual. To pressure bleed a brake system from the bottom up, a pressure pot is used. [Figure- 88] This is a portable tank that contains a supply of brake fluid under pressure. When dispersing fluid from the tank, pure air-free fluid is forced from near the bottom of the tank by the air pressure above it. The outlet hose that attaches the bleed port on the brake assembly contains a shut-off valve. Note that a similar source of pure, pressurized fluid can be substituted for a pressure tank, such as a hand-pump type unit found in somehangars.

Figure-88 A typical brake bleeder pot or tank contains brake fluid under pressure. It pushes the fluid through system to displace any air that may be present.

The bleed port on the brake assembly contains a shut-off valve. Note that a similar source of pure, pressurized fluid can be substituted for a pressure tank, such as a hand-pump typeunitfoundinsomehangars.Thetypicalpressurebleed is accomplished as illustrated in Figure-89. The hose from the pressure tank is attached to the bleed port on the brake assembly. A clear hose is attached to the vent port on the aircraft brake fluid reservoir or on the master cylinder if it incorporates the reservoir. The other end of this hose is placed in a collection container with a supply of clean brake fluid covering the end of the hose. The brake assembly bleed port is opened. The valve on the pressure tank hose is then opened allowing pure, air-free fluid to enter the brake system. Fluid containing trapped air is expelled through the hose attached to the vent port of the reservoir. The clear hose is monitored for air bubbles. When they cease to exist, the bleed port and pressure tank shutoff are closed and the pressure tank hose is removed. The hose at the reservoir is also removed. Fluid quantity may need to be adjusted to assure the reservoir is not over filled. Note that it is absolutely necessary that the proper fluid be used to service any brake system including when bleeding air from the brake lines.
Brakes with master cylinders may also be gravity bled from the top down. This is a process similar to that used on automobiles. [Figure-90] Additional fluid is supplied to the aircraft brake reservoir so that the quantity does not exhaust while bleeding, which would cause the reintroduction of more air into the system. A clear hose is connected to the bleed port on the brake assembly. The other end is submersed in clean fluid in a container large enough to capture fluid expelled during the bleeding process. Depress the brake pedalandopenthebrakeassemblybleedport.Thepistonin

the master cylinder travels all the way to the end of the cylinder forcing air fluid mixture out of the bleed hose and into the container. With the pedal still depressed, close the bleed port. Pump the brake pedal to introduce more fluid from the reservoir ahead of the piston in the master cylinder. Hold the pedal down, and open the bleed port on the brake assembly. More fluid and air is expelled through the hose into the container. Repeat this process until the fluid exiting the brake through the hose no longer contains any air. Tighten the bleed port fitting and ensure the reservoir is filled to the properlevel
Pressurebleeding Gravitybleeding

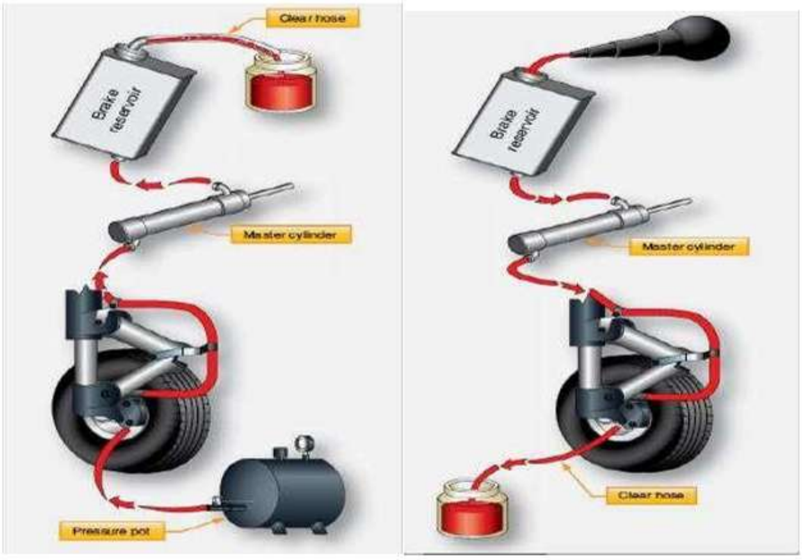

Figure-89 & 90- Arrangement of gravity and pressure bleedingofaircraftbrakesuntilnoairbubblesarevisiblein the hose.

Whenever bleeding the brakes, ensure that reservoirs and bleed tanks remain full during the process. Use only clean, specified fluid. Always check the brakes for proper operation, any leaks when bleeding is complete, and assure that the fluid quantity level is correct.

Bleeding Power Brake Systems

Top down brake bleeding is used in power brake systems. Power brakes are supplied with fluid from the aircraft Hydraulic system. The hydraulic system should operate without air in the fluid as should the brake system. Therefore, bottom up pressure bleeding is not an option for power brakes. The trapped air in the brake system would be forced into the main hydraulic system, which is not acceptable. Many aircraft with power brake systems accept the connection of an auxiliary hydraulic mule that can be used to establish pressure in the system for bleeding. Regardless, the aircraft system must be pressurized to bleed power brake systems. Attach a clear hose to the brake bleed port fitting on the brake assembly and immerse the other end of the hose in a container of clean hydraulic fluid. With the bleeder valve open, carefully apply the brake to allow aircraft hydraulic fluid to enter the brake system. The fluid expels the fluid contaminated with air out of the bleed hose into the container. When air is no longer visible in the hose, close the bleed valve and restore the hydraulic system to normal operation configuration.

Power brake systems on different aircraft contain many variations and a wide array of components that may affect the proper bleeding technique to be followed. Consult the manufacturer's maintenance information for the correct bleeding procedure for each aircraft. Be sure to bleed auxiliary and emergency brake systems when bleeding the normal brake system to ensure proper operation when needed.

Fluid Quantity and Type

As mentioned, it is imperative that the correct hydraulic fluid is used in each brake system. Seals in the brake system are designed for a particular hydraulic fluid. Deterioration and failure occurs when they are exposed to other fluids. Mineral based fluid, such as MIL-H-5606 (red oil), should never be mixed with phosphate-ester based synthetic Hydraulic fluid such as Skydrol®. Contaminated brake/hydraulic systems must have all of the fluid evacuated and all seals replaced before the aircraft is released for flight. Fluid quantity is also important. The technician is responsible for determining the method used to ascertain when the brake and hydraulic systems are fully serviced and for the maintenance of the fluid

at this level. Consult the manufacturer's specifications for thisinformation.
Inspection for Leaks Aircraft brake systems should maintain all fluid inside lines and components and should not leak. Any evidence of a leak mustbeinvestigatedforitscause.Itispossiblethattheleak is a precursor to more significant damage that can be repaired, thus avoiding an incident oraccident. [Figure-91]

Figure-91 The cause of all aircraft brake leaks must be investigated, repaired, and tested before releasing the aircraft for flight.

Many leaks are found at brake system fittings. While this type of leak may be fixed by tightening an obviously loose connection, the technician is cautioned against over tightening fittings. Removal of hydraulic pressure from the brake system followed by disconnection and inspection of the connectors is recommended. Over-tightening of fitting can cause damage and make the leak worse. MS flare-less fitting are particularly sensitive to over-tightening. Replace all fittings suspected of damage. Once any leak is repaired, the brake system must be re-pressurized and tested for function as well as to ensure the leak no longer exists. Occasionally, brake housing may seep fluid through the housing body. Consult the manufacturer's maintenance manual for limits, and remove any brake assembly that seeps excessively.

Proper Bolt Torque

The stress experience by the landing gear and brake system requires that all bolts are properly torqued. Bolts used to attach the brakes to the strut typically have the required torque specified in the manufacturer's maintenance manual. Check for torque specifications that may exist for any landing gear and brake bolts, and ensure they are properly tightened. Whenever applying torque to a bolt on an aircraft, use of a calibrated torque wrench isrequired.
Off Aircraft Brake Servicing and Maintenance

Certain servicing and maintenance of an aircraft brake assembly is performed while it has been removed from the aircraft. A close inspection of the assembly and its many parts should be performed at this time. Some of the inspection items on a typical assemblyfollow.
Bolt and Threaded Connections

All bolts and threaded connections are inspected. They should be in good condition without signs of wear. Self- locking nuts should still retain their locking feature. The hardware should be what is specified in the brake manufacturer's parts manual. Many aircraft brake bolts, for example, are not standard hardware and may be of closer tolerance or made of a different material. The demands of the high stress environment in which the brakes perform may cause brake failure if improper substitute hardware is used. BesuretochecktheconditionofallthreadsandO-ring seating areas machined into the housing. The fittings threadedintothehousingmustalsobecheckedforcondition.

Discs

Brake discs must be inspected for condition. Both rotating and stationary discs in a multiple disc brake can wear. Uneven wear can be an indication that the automatic adjusters may not be pulling the pressure plate back far enough to relieve all pressure on the disc stack. Stationary discs are inspected for cracks. Cracks usually extend from the relief slots, if so equipped. On multiple disc brakes, the slots that key the disc to the torque tube must also be inspected for wear and widening. The discs should engage the torque tube without binding. The maximum width of the slots is given in the maintenance manual. Cracks or excessive key slot wear are grounds for rejection. Brake wear pads or linings must also be inspected for wear while the brake assembly is removed from the aircraft. Signs of uneven wear should be investigated and the problem corrected. The pads may be replaced if worn beyond limits as long as the stationary disc upon which they mount passes inspection. Follow the manufacturer's procedures for inspections and for pad replacement. Rotating discs must be similarly inspected. The general condition of the disc must be observed. Glazing can occur when a disc or part of a disc is overheated. It causes brake squeal and chatter. It is possible to resurface a glazed disc if the manufacturer allows it. Rotating discs must also be inspected in the drive key slot or drive tang area for wear and deformation. Little damage is allowed beforereplacement is

required. The pressure plate and back plate on multiple disc brakes must be inspected for freedom of movement, cracks, general condition, and warping. New linings may be riveted to the plates if the old linings are worn and the condition of the plate is good. Note that replacing brake pads and linings by riveting may require specific tools and technique as described in the maintenance manual to ensure secure attachment. Minor warping can be straightened on some brakeassemblies.

Automatic Adjuster Pins

A malfunctioning automatic adjuster assembly can cause the brakes to drag on the rotating disc(s) by not fully releasing and pulling the lining away from the disc. This can lead to excessive, uneven lining wear and disc glazing. The return pin must be straight with no surface damage so it can pass through the grip without binding. Damage under the head can weaken the pin and cause failure. Magnetic inspection is sometimes used to inspect for cracks. The components of the grip and tube assembly must be in good condition. Clean and inspect in accordance with the manufacturer's maintenance instructions. The grip must move with the force specified and must move through its full range oftravel.

Torque Tube

A sound torque tube is necessary to hold the brake assembly stable on the landing gear. General visual inspection should be made for wear, burrs, and scratches. Magnetic particle inspectionisusedtocheckforcracks.Thekeyareasshould be checked for dimension and wear. All limits of damage are referenced in the manufacturer's maintenance data. The torque tube should be replaced if a limit isexceeded.

Brake Housing and Piston Condition

The brake housing must be inspected thoroughly. Scratches, gouges, corrosion, or other blemishes may be dressed out and the surface treated to prevent corrosion. Minimal material should be removed when doing so. Most important is that there are no cracks in the housing. Fluorescent dye penetrant is typically used to inspect for cracks. If a crack is found, the housing must be replaced. The cylinder area(s) of the housing must be dimensionally checked for wear. Limits are specified in the manufacturer's maintenance manual. The brake pistons that fit into the cylinders in the housing must also be checked for corrosion, scratches, burrs, etc. Pistons are also dimensionally checked for wear limits specified in the maintenance data. Some pistons have insulators on the bottom. They should not be cracked and should be of a minimal thickness. A file can be used to smooth out minor irregularities.

Seal Condition

Brake seals are very important. Without properly functioning seals, brake operation will be compromised or the brakes will fail. Over time, heat and pressure mold a seal into the seal groove and harden the material. Eventually, resilience is reduced and the seal leaks. New seals should be used to replaceallsealsinthebrakeassembly.Acquiresealsbypart

number in a sealed package from a reputable supplier to avoid bogus seals and ensure the correct seals for the brake assembly in question. Check to ensure the new seals have not exceeded their shelf life, which is typically three years from the cure date. Many brakes use back-up rings in the seal groove to support the O-ring seals and reduce the tendency of the seal to extrude into the space which it is meant to seal. These are often made of Teflon® or similar material. Back- up seals are installed on the side of the O-ring away from the fluid pressure. [Figure-92] They are oftenreusable.

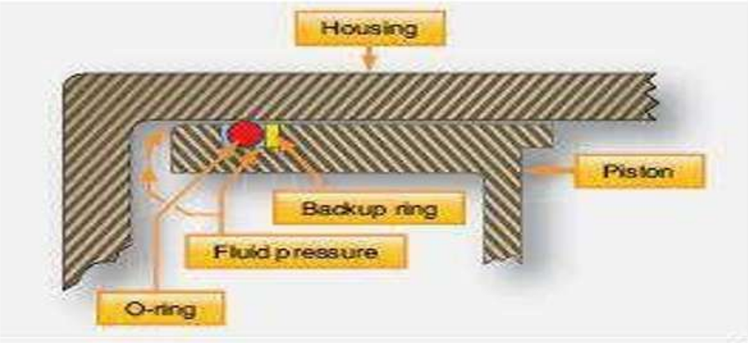

Figure-92 Back-up rings are used to keep O-rings from extruding into the space between the piston and the cylinder. They are positioned on the side of the O-ring away from the fluid pressure.

Replacement of Brake Linings

In general aviation, replacement of brake linings is commonly done in the hangar. The general procedure used on two common brake assemblies is given. Follow theactual manufacturer's instruction when replacing brake linings on any aircraft break assembly.

Brake Malfunctions and Damage

Aircraft brakes operate under extreme stress and varied conditions. They are susceptible to malfunction and damage. Afewcommonbrakeproblemsarediscussedinthissection.

Overheating

While aircraft brakes slow the aircraft by changing kinetic energy into heat energy, overheating of the brakes is not desirable. Excessive heat can damage and distort brake parts weakening them to the point of failure. Protocol for brake usage is designed to prevent overheating. When a brake shows signs of overheating, it must be removed from the aircraft and inspected for damage. When an aircraft is involved in an aborted takeoff, the brakes must be removed and inspected to ensure they withstood this high level of use. The typical post-overheat brake inspection involves removal of the brake from the aircraft and disassembly of the brakes. All of the seals must be replaced. The brake housing must be checked for cracks, warping, and hardness per the maintenance manual. Any weakness or loss of heat treatment could cause the brake to fail under high-pressure braking. The brake discs must also be inspected. They must not be warped, and the surface treatment must not be damaged or transferred to an adjacent disc. Once reassembled, the brake should be bench tested for leaks and pressure tested for operation before being installed on theaircraft.

Dragging

Brake drag is a condition caused by the linings not retracting from the brake disc when the brakes are no longer being applied. It can be caused by several different factors. Brakes that drag are essentially partially on at all times. This can cause excessive lining wear and overheating leading to damage to the disc(s). A brake may drag when the return mechanism is not functioning properly. This could be due to a weak return spring, the return pin slipping in the auto adjuster pin grip or similar malfunction. Inspect the auto adjuster(s) and return units on the brake when dragging is reported. An overheated brake that has warped the disc also causes brake drag. Remove the brake and perform a complete inspection as discussed in the previous section. Air in the brake fluid line can also cause brake drag. Heat causes the air to expand, which pushes the brake linings against the disc prematurely. If no damage has been caused when reported, bleed the brakes to remove the air from the system to eliminate thedrag.

NOTE- At all times, the technician should perform inspections to ensure the proper parts are used in the brake assembly. Improper parts, especial l y in the retraction/ adjuster assemblies, can cause the brakes todrag.

Chattering or Squealing

Brakes may chatter or squeal when the linings do not ride smoothly and evenly along the disc. A warped disc(s) in a multiple brake disc stack produces a condition wherein the

brake is actually applied and removed many times per minute. This causes chattering and, at high frequency, it causes squealing. Any misalignment of the disc stack out of parallel causes the same phenomenon. Discs that have been overheated may have damage to the surface layer of the disc. Some of this mix may be transferred to the adjacent disc resulting in uneven disc surfaces that also leads to chatter or squeal. In addition to the noise produced by brake chattering and squealing, vibration is caused that may lead to further damage of the brake and the landing gear system. The technician must investigate all reports of brake chattering and squealing.

Aircraft Tires and Tubes

Aircraft tires may be tube-type or tubeless. They support the weight of the aircraft while it is on the ground and provide the necessary traction for braking and stopping. The tires also help absorb the shock of landing and cushion the roughness of takeoff, rollout, and taxi operations. Aircraft tires must be carefully maintained to perform as required. They accept a variety of static and dynamic stresses and must do so dependably in a wide range of operatingconditions.

Tire Classification

Aircraft tires are classified in various ways including by: type, ply rating, whether they are tube-type or tubeless, and whether they are bias ply tires or radials. Identifying a tire by its dimensions is also used. Each of these classifications is discussed asfollows.

Types

A common classification of aircraft tires is by type as classified by the United States Tire and Rim Association. While there are nine types of tires, only Types I, III, VII, and VIII, also known as a Three-Part Nomenclature tires, are still in production. Type I tires are manufactured, but their design is no longer active. They are used on fixed gear aircraft and are designated only by their nominal overall diameter in inches. These are smooth profile tires that are obsolete for use in the modern aviation fleet. They may be found on older aircraft.

Type III tires are common general aviation tires. They are typically used on light aircraft with landing speeds of 160 miles per hour (mph) or less. Type III tires are relatively low- pressure tires that have small rim diameters when compared to the overall width of the tire. They are designed to cushion and provide flotation from a relatively large footprint. Type III tires are designated with a two number system. The first number is the nominal section width of the tire, and the second number is the diameter of the rim the tire is designed to mount upon. Type VII tires are high performance tires found on jet aircraft. They are inflated to high-pressure and have exceptional high load carrying capability. The section width of Type VII tires is typically narrower than Type III tires. Identification of Type VII aircraft tires involves a two- number system. An X is used between the two numbers. The first number designates the nominal overall diameter of the tire. The second number designates the sectionwidth. Type

VIII aircraft tires are al so known as three-part nomenclature tires.

Figure-93A Type VIII or three-part nomenclature tire is identified by 3 parameters: overall diameter, section width, and rim diameter. They are arranged in that order with the first two separated by an "X" and the second two separated by a"–."
For example: 18 X 4.25—10 designates a tire that is 18 inches in diameter with a 4.25-inch section width to be mounted on a 10-inch wheelrim.

[Figure-93] They are inflated to very high-pressure and are used on high-performance jet aircraft. The typical Type VIII tire has relatively low profile and is capable of operating at very high speeds and very high loads. It is the most modern design of all tire types. The three part nomenclature is a combination of Type III and Type VII nomenclature where the overall tire diameter, section width, and rim diameter are used to identify the tire. The X and "–" symbols are used in the same respective positions in the designator. When three part nomenclature is used on a Type VIII tire, dimensions mayberepresentedininchesorinmillimeters.Biastires

follow the designation nomenclature and radial tires replace the "–" with the letter R. For example, 30 X 8.8 R 15 designates a Type VIII radial aircraft tire with a 30-inch tire diameter, an 8.8-inch section width to be mounted on a 15- inch wheel rim. A few special designators may also be found for aircraft tires. When a B appears before the identifier, the tire has a wheel rim to section width ratio of 60 to 70 percent with a bead taper of 15 degrees. When an H appears before the identifier, the tire has a 60 to 70 percent wheel rim to section width ratio but a bead taper of only 5degrees.
Ply Rating

Tire plies are reinforcing layers of fabric encased in rubber that are laid into the tire to provide strength. In early tires, the number of plies used was directly related to the load the tire could carry. Nowadays, refinements to tire construction techniques and the use of modern materials to build up aircraft tires make the exact number of plies somewhat irrelevant when determining the strength of a tire. However, a ply rating is used to convey the relative strength of an aircraft tire. A tire with a high ply rating is a tire with high strength able to carry heavy loads regardless of the actual number of plies used in itsconstruction.

Tube-Type or Tubeless

As stated, aircraft tires can be tube-type or tubeless. This is often used as a means of tire classification. Tires that are made to be used without a tube inserted inside have an inner linerspecificallydesignedtoholdair.Tube-typetiresdonot contain this inner liner since the tube holds the air from leaking out of the tire. Tires that are meant to be used without a tube have the word tubeless on the sidewall. If this designation is absent, the tire requires a tube. Consult the aircraft manufacturer's maintenance information for any allowabletiredamageandtheuseofatubeinatubelesstire.

Bias Ply or Radial

Another means of classifying an aircraft tire is by the direction of the plies used in construction of the tire, either bias or radial. Traditional aircraft tires are bias ply tires. The plies are wrapped to form the tire and give it strength. The angle of the plies in relation to the direction of rotation of the tire varies between 30° and 60°. In this manner, the plies have the bias of the fabric from which they are constructed facing the direction of rotation and across the tire. Hence, they are called bias tires. The result is flexibility as the sidewall can flex with the fabric plies laid on the bias.


Figure-94 A bias ply tire has the fabric bias oriented with andacross the direction of rotation and the sidewall. Since fabric canstretch on the bias, the tire is flexible, and can absorb loads.Strengthis obtained by addingplies. Figure-95 A radial tire has the fiber strands of the ply fabric oriented with and at 90° to the direction of rotation and the tire sidewall. This restricts flexibility directionally and the flexibility of the sidewall while it strengthens the tire to carry heavyloads.

Tire Construction

Some modern aircraft tires are radial tires. The plies in radial tires are laid at a 90° angle to the direction of rotation of the tire. This configuration puts the non-stretchable fiber of the plies perpendicular to the sidewall and direction of rotation. This creates strength in the tire allowing it to carry high loads with less deformation. [Figure-95]

An aircraft tire is constructed for the purpose it serves. Unlike an automobile or truck tire, it does not have to carry a load for a long period of continuous operation. However, an aircraft tire must absorb the high impact loads of landing and be able to operate at high speeds even if only for a short time. The deflection built into an aircraft tire is more than twice that of an automobile tire. This enables it to handle the forces during t is useful to the understanding of tire construction to identify the various components of a tire and the functions contributed to the overall characteristics of a tire. Refer to Figure-96 for tire nomenclature used in thisdiscussion.

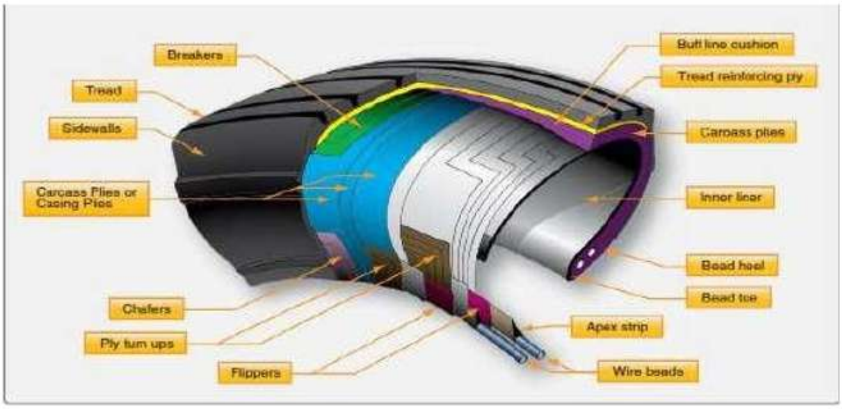

Figure-96 Construction nomenclature of an aircrafttire.

Bead

The tire bead is an important part of an aircraft tire. It anchors the tire carcass and provides a dimensioned, firm mounting surface for the tire on the wheel rim. Tire beads are strong. They are typically made from high-strength carbon steel wire bundles encased in rubber. One, two, or three bead bundles may be found on each side of the tire depending on its size and the load it is designed to handle. Radial tires have a single bead bundle on each side of the tire. The bead transfers the impact loads and deflection forces to the wheel rim. The bead toe is closest to the tire centerline and the bead heel fit against the flange of the wheel rim. An apex strip is additional rubber formed around the bead to give a contour for anchoring the ply turn-ups. Layers of fabric and rubber called flippers are placed around the beads to insulate the carcass from the beads and improve tire durability. Chafers are also used in this area. Chafer strips made of fabric or rubberislaidovertheoutercarcasspliesafterthepliesare

wrapped around the beads. The chafers protect the carcass from damage during mounting and demounting of the tire. They also help reduce the effects of wear and chafing between the wheel rim and the tire bead especially during dynamicoperations.

Carcass Plies

Carcass plies, or casing plies as they are sometimes called, are used to form the tire. Each ply consists of fabric, usually nylon, sandwiched between two layers of rubber. The plies are applied in layers to give the tire strength and form the carcass body of the tire. The ends of each ply are anchored by wrapping them around the bead on both sides of the tire to form the ply turn-ups. As mentioned, the angle of the fiber in the ply is manipulated to create a bias tire or radial tire as desired. Typically, radial tires require fewer plies than bias tires. Once the plies are in place, bias tires and radial tires each have their own type of protective layers on top of the plies but under the tread of the running surface of the tire. On bias tires, these single or multiple layers of nylon and rubbers are called tread reinforcing plies. On radial tires, an under tread and a protector ply do the same job. These additional plies stabilize and strengthen the crown area of the tire. They reduce tread distortion under load and increase stability of the tire at high speeds. The reinforcing plies and protector plies also help resist puncture and cutting while protecting the carcass body of thetire.

Tread

Apex strip Wire beads Tread reinforcing ply Carcass plies Inner liner Bead heel Bead toe The tread is the crown area of the tire designed to come in contact with the ground. It is a rubber compound formulated to resist wear, abrasion, cutting, and cracking. It also is made to resist heat build-up. Most modern aircraft tire tread is formed with circumferential grooves that create tire ribs. The grooves provide cooling and help channel water from under the tire in wet conditions to increase adhesion to the ground surface. Tires designed for aircraft frequently operated from unpaved Surfaces may have some type of cross-tread pattern. Older aircraft without brakes or brakes designed only to aid in taxi may not have any grooves in the tread. An all-weather treads may be found on some aircraft tires. This tread has typical circumferential ribs in the center of the tire with a diamond patterned cross tread at the edge of the tire. [Figure-97] The tread is designed to stabilize the aircraft on the operating surface and wears with use. Many aircraft tires are designed with protective under tread layers as described above. Extra tread reinforcement is sometimes accomplished with breakers. These are layers of nylon cord fabric under the tread that strengthen the tread while protecting the carcass plies. Tires with reinforced tread are often designed to be re-treaded and used again once the tread has worn beyond limits. Consult the tire manufacturer's data for acceptable tread wear and re- tread capability for a particulartire.

Figure-97 Aircraft tire treads are designed for different uses. A is a rib tread designed for use on paved surfaces. It is the most common aircraft tire tread design. B is a diamond tread designed for unpaved runways. C is an all-weather tread that combines a ribbed center tread with a diamond tread pattern of the edges. D is a smooth tread tire found on older, slow aircraft without brakes designed for stopping. E is a chine tire used on the nose gear of aircraft with fuselage mounted jet engines to deflect runway water away from the engine intake(s).

Sidewall

The sidewall of an aircraft tire is a layer of rubber designed to protect the carcass plies. It may contain compounds designed to resist the negative effects of ozone on the tire. It also is the area where information about the tire is contained. The tire sidewall imparts little strength to the cord body. Its main function is protection. The inner sidewall of a tire is covered by the tire inner liner. A tube-type tire has a thin rubber liner adhered to the inner surface to prevent the tube from chafing on the carcass plies. Tubeless tires arelined with a thicker, less permeable rubber. This replaces the tube and contains the nitrogen or inflation air within the tire and keeps from seeping through the carcass plies. The inner liner does not contain 100 percent of the inflation gas. Small amounts of nitrogen or air seep through the liner into the carcass plies. This seepage is released through vent holes in the lower outer sidewall of the tires. These are typically marked with a green or white dot of paint and must be kept unobstructed. Gas trapped in the plies could expand with temperature changes and cause separation of the plies, thus weakening the tire leading to tire failure. Tube-type tires also have seepage holes in the sidewall to allow air trapped between the tube and the tire toescape.

Chine

Some tire sidewalls are mounded to form a chine. A chine is a special built-in deflector used on nose wheels of certain aircraft, usually those with fuselage mounted engines. The chine diverts runway water to the side and away from the intake of the engines. [Figure-97E] Tires with a chine on both sidewalls are produced for aircraft with a single nose wheel.

Tire Inspection on the Aircraft

Tire condition is inspected while mounted on the aircraft on a regular basis. Inflation pressure, tread wear and condition, and sidewall condition are continuously monitored to ensure proper tire performance.

Inflation

To perform as designed, an aircraft tire must be properly inflated. The aircraft manufacturer's maintenance data must be used to ascertain the correct inflation pressure for a tire on a particular aircraft. Do not inflate to a pressure displayed on the sidewall of the tire or by how the tire looks. Tire pressure is checked while under load and is measured with the weight of the aircraft on the wheels. Loaded versus unloaded pressure readings can vary as much as 4 percent. Tire pressure measured with the aircraft on jacks or when the tire is not installed is lower due to the larger volume of the inflation gas space inside of the tire. On a tire designed to be inflated to 160 psi, this can result in a 6.4 psi error. A calibrated pressure gauge should always be used to measure inflation pressure. Digital and dial-type pressure gauges are more consistently accurate and preferred.[Figure-98]
Aircraft tires disperse the energy from landing, rollout, taxi, and takeoff in the form of heat. As the tire flexes, heat builds and is transferred to the atmosphere, as well as to the wheel rim through the tire bead. Heat from braking also heats the tire externally. A limited amount of heat is able to be handled by any tire beyond which structural damage occurs. An improperly inflated aircraft tire can sustain internal damage that is not readily visible and that can lead to tire failure. Tire failure upon landing is always dangerous. An aircraft tire is designed to flex and absorb the shock oflanding.

Figure 98A calibrated bourdon tube dial-type pressure gauge or a digital pressure gauge is recommended for checking tire pressure.

Temperature rises as a result. However, an underinflated tire may flex beyond design limits of the tire. This causes excessive heat build-up that weakens the carcass construction. To ensure tire temperature is maintained within limits, tire pressure must be checked and maintained within the proper range on a daily basis or before each flight if the aircraft is only flown periodically. Tire pressure should be measured at ambient temperature. Fluctuations of ambient temperature greatly affect tire pressure and complicate maintenance of pressure within the allowable range for safe operation. Tire pressure typically changes 1 percent for every 5 °F of temperature change. When aircraft are flown from one environment to another, ambient temperature differences can be vast. Maintenance personnel must ensure that tire pressureisadjustedaccordingly.Forexample,anaircraft

with the correct tire pressure departing Phoenix, Arizona where the ambient temperature is 100 °F arrives in Vail, Colorado where the temperature is 50 °F. The 50°difference in ambient temperature results in a 10 percent reduction in tire pressure. Therefore the aircraft could land with underinflated tires that may be damaged due to over- temperature from flexing beyond design limits as described above. An increase in tire pressure before takeoff in Phoenix, Arizona prevents this problem as long as the tires are not inflated beyond the allowable limit provided in the maintenance data. When checking tire pressure, allow 3 hours to elapse after a typical landing to ensure the tire has cooled to ambient temperature. The correct tire pressure for each ambient temperature is typically provided by the manufacturer on a table or graph. In addition to overheating, under inflated aircraft tires wear unevenly, this leads to premature tire replacement. They may also creep or slip on the wheel rim when under stress or when the brakes are applied. Severely under inflated tires can pinch the sidewall between the rim and the runway causing sidewall and rim damage.

Figure-99 Tires that are overinflated lack adherence to the runway and develop excess tread wear in the center of the tread. Tires that are underinflated develop excess tread wear on the tire shoulders. Overheating resulting in internal carcass damage and potential failure are possible from flexing the tire beyond designlimits.

Damage to the bead and lower sidewall area are also likely. This type of abuse like any over flexing damages the integrity of the tire and it must be replaced. In dual-wheel setups, a severely underinflated tire affects both tires and both should be replaced. Over inflation of aircraft tires is another undesirable condition. While carcass damage due to overheating does not result, adherence to the landing surface is reduced. Over a long period of time, over inflation leads to premature tread wear. Therefore, over inflation reduces the number of cycles in service before the tire must be replaced. It makes the tire more susceptible to bruises, cutting, shock damage, and blowout.[Figure-99]

Tread Condition

Condition of an aircraft tire tread is able to be determined while the tire is inflated and mounted on the aircraft. The following is a discussion of some of the tread conditions and damage that the technician may encounter while inspecting tires.

Tread Depth and Wear Pattern

Evenly worn tread is a sign of proper tire maintenance. Uneven tread wear has a cause that should be investigated and corrected. Follow all manufacturer instructions specific to the aircraft when determining the extent and serviceability of a worn tire. In the absence of this information, remove any tire that has been worn to the bottom of a tread groove along more than 1/8 of the circumference of the tire. If either the protector ply on a radial tire or the reinforcing ply on a bias tire is exposed for more than of the tire circumference, the tire should also be removed. A properly maintained evenly worn tire usually reaches its wear limits at the centerline of the tire.[Figure-100]

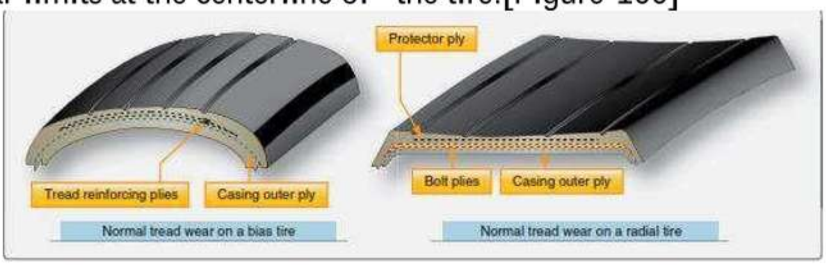

Figure-100 Normal tire wear.

Asymmetrical tread wear may be caused by the wheels being out of alignment. Follow the manufacturer's instructions while checking caster, camber, tow-in, and two-out to correct this situation. Occasionally, asymmetrical tire wear is a result of landing gear geometry that cannot, or is not, required to be corrected. It may also be caused by regular taxiing on a single engine or high speed cornering while taxiing. It is acceptable to remove the tire from the wheel rim, turn it around, and remount it to even up tread wear if the tire passes all other criterion of inspection for serviceability. Removal of a tire before it is worn beyond limits to be eligible for retreading is cost effective and good maintenance practice. Considerable traction is lost when tire tread is severely worn and must also be considered when inspecting a tire for condition.

[Figure-101]Consult airframe manufacturer and tire manufacturer specifications for wear and retread limitations

Figure-101 Tread wear on a bias ply tire (left) and a radial tire (right) show wear beyond limits of serviceability but still eligible to be retreaded

Tread Damage

In addition to tread wear, an aircraft tire should be inspected for damage. Cuts, bruises, bulges, imbedded foreign objects, chipping, and other damage must be within limits to continue the tire in service. Some acceptable methods of dealing with this type of damage are described below. All damage, suspected damage, and areas with leaks should be marked with chalk, a wax marker, paint stick, or other device before the tire is deflated or removed. Often, it is impossible to relocate these areas once the tire is deflated. Tires removed for retread should be marked in damaged areas to enable closer inspection of the extent of the damage before the new tread is installed. Foreign objects imbedded in a tire's tread are of concern and should be removed when not imbedded beyond the tread. Objects of questionable depth should only be removed after the tire has been deflated. A blunt awl or appropriately sized screwdriver can be used to pry the object from the tread. Care must be exercised to not enlarge the damaged area with the removal tool. Once removed, assess the remaining damage to determine if the tire is serviceable. A round hole caused by a foreign object is acceptable only if it is 1/8-inch or less in diameter. Embedded objects that penetrate or expose the casing cord body of a bias ply tire or the tread belt layer of a radial tire cause the tire to become un-airworthy and it must be removed from service. Cuts and tread undercutting can also render a tire un-airworthy. A cut that extends across a tread rib is cause for tire removal. These cansometimesleadtoasectionoftheribtopeelofffthetire.

[Figure-102] Consult the aircraft maintenance manual, airline operations manual, or other technical documents applicable to the aircraft tire in question. A flat spot on a tire is the result of the tire skidding on the runway surface while not rotating. This typically occurs when the brakes lock on while the aircraft is moving. If the flat spot damage does not expose the reinforcing ply of a bias tire or the protector ply of a radial tire, it may remain in service. However, if the flat spot causes vibration, the tire must be removed. Landing with a

Figure-102 Remove an aircraft tire from service when the depth of a cut exposes the casing outer plies of a bias ply tire or the outer belt layer of a radial tire (A); a tread rib has been severed across the entire width (B); or, when undercutting occurs at the base of any cut (C). These conditions may lead to a peeled rib. Figure-103 Landing with the brake on causes a tire flat spot that exposes the under tread and requires replacement of the tire.

A bulge or separation of the tread from the tire carcass is cause brake applied can often cause a severe flat spot that exposes the tire under tread. It can also cause a blowout. The tire must be replaced in either case.[Figure-103] for immediate removal and replacement of the tire. Mark the
area before deflation as it could easily become undetectable without air in the tire. [Figure-104]

Figure-104 Bulges and tread separation are cause for removal of a tire fromservice.
Operation on a grooved runway can cause an aircraft tire tread to develop shallow chevron shaped cuts. These cuts are allowed for continued service, unless chunks or cuts into the fabric of the tire result. Deep chevrons that cause a chunk of the tread to be removed should not expose more than 1square inch of the reinforcing or protector ply. Consult the applicable inspection parameters to determine the allowable extent of chevron cutting.[Figure-105]

aircrafttires. is exposed.

Tread chipping and chunking sometimes occurs at the edge of the tread rib. Small amounts of rubber lost in this way are permissible. Exposure of more than 1 square inch of the reinforcing or protector ply is cause for removal of the tire. [Figure106]
Cracking in a tread groove of an aircraft tire is generally not acceptable if more than ¼-inch of the reinforcing or protector ply is exposed. Groove cracks can lead to undercutting of the tread, which eventually can cause the entire tread to be thrown from the tire. [Figure107]

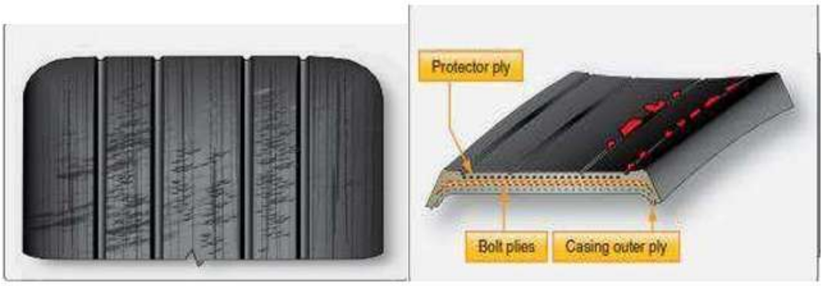

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Figure-105 Chevron cuts in a tire are caused by operation on grooved runway surfaces. Shallow chevron cuts are permittedon Figure-106 Tread chipping and chunking of a tire requires that the tire be removed from service if more than 1 square inch of the reinforcing ply or protector ply

Figure-107 A thrown tread can result from a groove crack or tread undercutting and must be removed fromservice.

Oil, hydraulic fluid, solvents, and other hydrocarbon substances contaminate tire rubber, soften it, and make it Spongy. A contaminated tire must be removed from service. If any volatile fluids come in contact with the tire, it is best to wash the tire or area of the tire with denatured alcohol followed by soap and water. Protect tires from contact with potentially harmful fluids by covering tiresduring maintenance in the landing gear area. Tires are also subject to degradation from ozone and weather. Tires on aircraft parked outside for long periods of times can be covered for protection from theelements.

Sidewall Condition

The primary function of the sidewall of an aircraft tire is protection of the tire carcass. If the sidewall cords are exposed due to a cut, gouge, snag, or other injury, the tire must be replaced. Mark the area of concern before removal of the tire. Damage to the sidewall that does not reach the cords is typically acceptable for service. Circumferential cracks or slits in the sidewall are unacceptable. A bulge in a tire sidewall indicates possible delamination of the sidewall carcass plies. The tire must immediately be removed from service. Weather and ozone can cause cracking and checking of the sidewall. If this extends to the sidewall cords, the tire must be removed fromservice.

Figure-108 Cracking and checking in the sidewall of a tire is acceptable for service as long as it does not extend toor

expose the sidewall carcass plies.

Otherwise, sidewall checking as show in [Figure-108] does not affect the performance of the tire and it

may remain in service. Weather and ozone can cause cracking and checking of the sidewall. If this extends to the sidewall cords, the tire must be removed from service. Otherwise, sidewall checking as show in [Figure-108] does not affect the performance of the tire and it may remain inservice.
Tire Removal

Removal of any tire and wheel assembly should be accomplished following all aircraft manufacturer's instructions for the procedure. Safety procedures are designed for the protection of the technician and the maintenance of aircraft parts in serviceable condition. Follow all safety procedures to prevent personal injury and damage to aircraft parts and assemblies. An aircraft tire and wheel assembly, especially a high pressure assembly that has been damaged or overheated, should be treated as though it may explode. Never approach such a tire while its temperature is still elevated above ambient temperature. Once cooled, approach a damage tire and wheel assembly from an oblique angle advancing toward the shoulder of thetire. [Figure-109]
Deflate all unserviceable and damaged tires before removal from the aircraft. Use a valve core/deflation tool to deflate the tire. Stand to the side—away from the projectile path of the valve core. A dislodged valve core propelled by internal tire pressure can cause serious human injury.When

completely deflated, remove the valve core. [Figure-110]
broken free. Always use proper bead breaking equipment for this purpose. Never pry a tire from a wheel rim as damage to the wheel is inevitable. The wheel tie bolts must remain installed and fully tightened when the bead is broken from the rim to prevent damage to the wheel half mating surfaces. When the bead breaking press contact surface is applied to thetire,itshouldbeasclosetothewheelaspossiblewithout touchingitduringtheentireapplicationofpressure.Tires

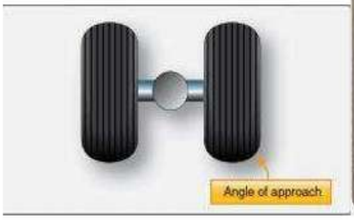


Figure-109 To avoid potential injury, approach a tire/wheel Assembly that has damage or has been overheated at an angle toward the tire shoulder onlyafter it has cooled to ambient temperature.
Figure-110 The tire valve core should be removed after the tireis completely deflated and before the tire and wheel assembly isremoved from the aircraft.

and rims of different sizes require contact pads suitable for the tire. Hand presses and hydraulic presses are available. Apply the pressure and hold it to allow the bead to move on the rim. Gradually progress around the rim until the tire bead is broken free. Ring-type bead breakers apply pressure around the circumference of the entire sidewall so rotation is notrequired.Oncethebeadisbrokenfree,thewheelhalves

A tire and wheel assembly in airworthy condition may be removed to access other components for maintenance without deflating the tire. This is common practice, such as when accessing the brake when the wheel assembly is immediately reinstalled. For tracking purposes, ensure damaged areas of a tire are marked before deflation. Record all known information about an unserviceable tire and attach it to the tire for use by the retread repair station. Once removed from the aircraft, a tire must be separated from the wheel rim upon which is mounted. Proper equipment and technique should be followed to avoid damage to the tire and wheel. The wheel manufacturer's maintenance information is the primary source for dismounting guidelines. The bead area of the tire sits firmly against the rim shoulder and mustbe

may be disassembled. [Figure-111] Radial tires have only one bead bundle on each side of the tire.

The sidewall is more flexible in this area than a bias ply tire. The proper tooling should be used, and pressure should be applied slowly to avoid heavy distortion of the sidewall. Lubrication may be applied and allowed to soak into the tire wheel interface. Only soapy tire solutions should be used. Never apply a hydrocarbon based lubricant to an aircraft tire as this contaminates the rubber compound used to construct the tire. Beads on tube-type and tubeless tires are broken free in a similarmanner.

Figure-111 An electrohydraulic tire bead breaker (left) used on large tires and a manual tire bead breaker (right) used on smalltires.

Tire Inspection Off of the Aircraft

Once a tire has been removed from the wheel rim, it should be inspected for condition. It may be possible to retread the tire at an approved repair station and return it to service. A sequential inspection procedure helps ensure no parts of the tire are overlooked. Mark and record the extent of all damage. Advisory Circular (AC) 43-13-1 gives general guidelines for tire inspection and repair. Tires must only be repaired by those with the experience and equipment to do so. Most tire repairs are accomplished at a certified tire repair facility. When inspecting a tire removed from the aircraft, pay special attention to the bead area since it must provide an air tight seal to the wheel rim and transfer forces from the tire to the rim. Inspect the bead area closely as it is where the heat is concentrated during tire operation. Surface damage to the chafer is acceptable and can be repaired when the tire is retreaded. Other damage in the bead area is usuallycaused

for rejection. Damage to the turn-ups, ply separation at the bead, or a kinked bead is examples of bead area damage that warrant the tire be discarded. The bead area of the tire may sustain damage or have an altered appearance or texture on a tire that has been overheated. Consult a certified tire repair station or re-tread facility when in doubt about the condition observed. The wheel rim must also be inspected for damage. An effective seal without slippage, especially on tubeless tires, is dependent on the condition and integrity of the wheel in the bead seat area. Overheating of a tire weakens it even though the damage might not be obvious. Any time a tire is involved in an aborted takeoff, severe braking, or the thermal plug in the wheel has melted to deflate the tire before explosion, the tire must be removed. On a dual installation, both tires must be removed. Even if only one tire shows obvious damage or deflates, the loads experienced by the mate are excessive. Internal damage such as ply separation is likely. The history of having been through an overheat event is all that is required for the tire to be discarded. Damaged or suspected damaged areas of the tire should be re-inspected while the tire is off the aircraft. Cuts can be probed to check for depth and extent of damage below the tread. In general, damage that does not exceed 40 percent of the tire plies can be repaired when the tire is retreaded. Small punctures with a diameter on the tire inner surface of less than 1/8-inch and a diameter on the outer surface of less than ¼-inch can also be repaired and retreaded. A bulge caused by ply separation is reason to discard a tire. However, a bulge caused by tread separationfromthetirecarcassmayberepairableduring retread. Exposed sidewall cord or sidewall cord damage is unacceptable and the tire cannot be repaired or retreaded. Consult the tire manufacturer or certified retreaded for clarification on damage to a tire.

Tire Repair and Retreading

The technician should follow airframe and tire manufacturer instructions to determine if a tire is repairable. Many example guidelines have also been given in this section. Nearly all tire repairs must be made at a certified tire repair facility equipped to perform the approved repair. Bead damage, ply separation, and sidewall cord exposure all require that the tire be scrapped. Inner liner condition on tubeless tires is also critical. Replacing the tube in a tube-type tire is performed by the technician as are mounting and balancing all types of aircraft tires. Aircraft tires are very expensive. They are also extremely durable. The effective cost of a tire over its life can be reduced by having the tread replaced while the carcass is still sound and injuries are within repairable limits. Federal Aviation Administration (FAA) certified tire retread repair stations, often the original equipment manufacturer (OEM), do this work. The technician inspects a tire to pre-qualify it for retread so that the cost of shipping it to the retread repair facility is not incurred if there is no chance to retread the tire. The tire retreaded inspects and tests every tire to a level beyond the capability of the hangar or line technician. Stereography, an optical nondestructive testing method that provides detailed information about the internal integrity of thetire,isusedbytireretreadrepairfacilitiestoensureatire

carcass is suitable for continued service. Tires that are retreaded are marked as such. They are not compromised in strength and give the performance of a new tire. No limits are established for the number of times a tire can be retreaded. This is based on the structural integrity of the tire carcass. A well maintained main gear tire may be able to be retreaded a handful of times before fatigue renders the carcass un- airworthy. Some nose tires can be retread nearly a dozen times.

Tire Storage

An aircraft tire can be damaged if stored improperly. A tire should always be stored vertically so that it is resting on its treaded surface. Horizontal stacking of tires is not recommended. Storage of tires on a wire rack with a minimum 3–4-inch flat resting surface for the tread is ideal and avoids tire distortion. If horizontal stacking of tires is necessary, it should only be done for a short time. The weight of the upper tires on the lower tires cause distortion possibly making it difficult for the bead to seat when mounting tubeless tires. A bulging tread also stresses rib grooves and opens the rubber to ozone attack in this area. [Figure- 112]Never stack aircraft tires horizontally for more than 6 months. Stack no higher than four tires if the tire is less than 40-inches in diameter and no higher than three tires if greater than 40-inches in diameter. The environment in which an aircraft tire is stored is critical. The ideal location in which to store an aircraft tire is cool, dry, and dark, free from air currents anddirt.

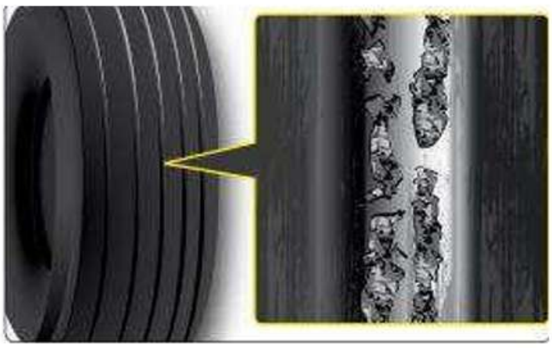


Figure-112 Ozone cracking in a tire tread groove is facilitated by horizontalstacking.

An aircraft tire contains natural rubber compounds that are prone to degradation from chemicals and sunlight. Ozone (O_3) and oxygen (O) cause degradation of tire compounds. Tires should be stored away from strong air currents that continually present a supply of one or both of these gases. Fluorescent lights, mercury vapor lights, electric motors, battery chargers, electric welding equipment, electric generators, and similar shop equipment produce ozone and should not be operated near aircraft tires. Mounted inflated tires can be stored with up to 25 percent less pressure than operating pressure to reduce vulnerability from ozone attacks. Sodium vapor lighting is acceptable. Storage of an aircraft tire in the dark is preferred to minimize degradation from ultraviolet (UV) light. If this is not possible, wrap the tire in dark polyethylene or paper to form an ozone barrier and to minimize exposure to UV light. Common hydrocarbon chemicals, such as fuels, oils, and solvents, should not contactatire.Avoidrollingtiresthroughspillsonthehangar

or shop floor and be sure to clean any tire immediately if contaminated. Dry the tire and store all tires in a dry place away from any moisture, which has a deteriorating effect on the rubber compounds. Moisture with foreign elements may further damage the rubber and fabric of a tire. Dirty areas must be avoided. Tires are made to operate in a wide range of temperatures. However, storage should be at cool temperatures to minimize degradation. A general range for safe aircraft tire storage is between 32 °F and 104 °F. Temperatures below this are acceptable but higher temperatures must beavoided.

Aircraft Tubes

Many aircraft tires accept a tube inside to contain the inflation air. Tube-type tires are handled and stored in similar fashion as tubeless tires. A number of issues concerning the tubes themselves must beaddressed. Tube Construction and Selection

Aircraft tire tubes are made of a natural rubber compound. They contain the inflation air with minimal leakage. Unreinforced and special reinforced heavy duty tubes are available. The heavy duty tubes have nylon reinforcing fabric layered into the rubber to provide strength to resist chafing and to protect against heat such as during braking. Tubes come in a wide range of sizes. Only the tube specified for the applicable tire size must be used. Tubes that are too small stress the tubeconstruction.

Tube Storage and Inspection

An aircraft tire tube should be kept in the original carton until put into service to avoid deterioration through exposure to environmental elements. If the original carton is not available, the tube can be wrapped in several layers of paper to protect it. Alternately, for short time periods only, a tube may be stored in the correct size tire it is made for while inflated just enough to round out the tube. Application of talc to the inside of the tire and outside of the tube prevents sticking. Remove the tube and inspect it and the tire before permanently mounting the assembly. Regardless of storage method, always store aircraft tubes in a cool, dry, dark place away from ozone producing equipment and moving air. When handling and storing aircraft tire tubes, creases are to beavoided.

Figure-113 During inspection, an aircraft tire tube should retain its natural contour. Tubes with thinned areas or that have taken a set should be discarded andreplaced.

These weaken the rubber and eventually cause tube failure. Creases and wrinkles also tend to be chafe points for the tube when mounted inside the tire. Never hang a tube over a nail

or peg for storage. An aircraft tube must be inspected for leaks and damage that may eventually cause a leak or failure. To check for leaks, remove the tube from the tire. Inflate the tube just enough to have it take shape but not stretch. Immerse a small tube in a container of water and look for the source of air bubbles. A large tube may require that water be applied over the tube. Again look for the source of bubbles. The valve core should also be wetted to inspect it for leaks. There is no mandatory age limit for an aircraft tire tube. It should be elastic without cracks or creases in order to be consider serviceable. The valve area is prone to damage and should be inspected thoroughly. Bend the valve to ensure there are no cracks at the base where it is bonded to the tire or in the area where it passes through the hole in the wheel rim. Inspect the valve core to ensure it is tight and that it does not leak. If an area of a tube experiences chafing to the point where the rubber is thinned, the tube should be discarded. The inside diameter of the tube should be inspected to ensure it has not been worn by contact with the toe of the tire bead. Tubes that have taken an unnatural set should be discarded. [Figure-113]

Tire Inspection

It is important to inspect the inside of a tube-type tire before installing a tube for service. Any protrusions or rough areas should be cause for concern, as these tend to abrade the tube and may cause early failure. Follow the tire, tube, and aircraft manufacturer's inspection criterion when inspecting aircraft tires and tubes.

Tire Mounting

A licensed technician is often called upon to mount an aircraft tire onto the wheel rim in preparation for service. In the case of a tube-type tire, the tube must also be mounted. The following section presents general procedures for these operations using tube-type and tubeless tires. Be sure to have the proper equipment and training to perform the work according to manufacturer'sinstructions.

Tubeless Tires

Aircraft tire and wheel assemblies are subject to enormous stress while in service. Proper mounting ensures tires perform to the limits of their design. Consult and follow all manufacturers' service information including bolt torques, lubrication and balancing requirements, and inflation procedures. As mentioned, a wheel assembly that is to have a tire mounted upon it must be thoroughly inspected to ensure it is serviceable. Pay close attention to the bead seat area, which should be smooth and free from defects. The wheel half mating surface should be in good condition. The O-ring should be lubricated and in good condition to ensure it seals the wheel for the entire life of the tire. Follow the manufacturer's instructions when inspecting wheels and the tips provided earlier in this chapter. [Figure114]

Figure-114 The wheel half O-ring for a tubeless tire wheel assembly must be in good condition and lubricated to seal for the entire life of the tire. The mating surfaces of the wheel halves must also be in good condition.

A final inspection of the tire to be mounted should be made. Most important is to check that the tire is specified for the aircraft application. It should say tubeless on the sidewall. The part number, size, ply rating, speed rating, and technical standard order (TSO) number should also be on the sidewall and be approved for the aircraft installation. Visually check the tire for damage from shipping and handling. There should be no permanent deformation of the tire. It should pass all inspections for cuts and other damage discussed in the previous sections of this chapter. Clean the tire bead area with a clean shop

towel and soap and water or denatured alcohol. Inspect the inside of the tire for condition. There should be no debris inside the tire. Tire beads are sometimes lubricated when mounted on aluminum wheels. Follow the manufacturer's instructions and use only then on-hydrocarbon lubricant specified. Never lubricate any tire bead with grease. Do not use lubricants with magnesium alloy wheels. Most radial tires are mounted without lubricant. The airframe manufacturer may specify lubrication for a radial tire in a few cases. When the wheel halves and tires are ready to be mounted, thought must be given to tire orientation and the balance marks on the wheel halves and tire. Typically, the tire serial number is mounted to the outboard side of the assembly. The marks indicating the light portion of each wheel half should be opposite each other. The mark indicating the heavy spot of the wheel assembly should be mounted aligned with the light spot on the tire, which is indicated by a red mark. If the wheel lacks a mark indicating the heavy spot, align the red spot on the tire (the light point) with the valve fitting location on the wheel. A properly balanced tire and wheel assembly improves the overall performance of the tire. It promotes smooth operation free from vibration, which results in uniform tread wear and extended tire life. When assembling the wheel halves, follow manufacturer's instructions for tie bolt tightening sequences and torque specification. Anti-seize lubricants and wet-torque values are common on wheel assemblies. Use a calibrated hand torque wrench. Never use an impact wrench on an aircraft tire assembly. For the initial inflation of an aircraft tire and wheel assembly, the tire must be placed in a tire inflation safety cage and treated as though it may explode due to wheel or tire failure. The inflation hose should be attached to the tire valve stem, and inflation pressure should be regulated from a safe distance away. A minimum of30 feet is recommended. Air or nitrogen should be introduced gradually as specified. Dry nitrogen keeps the introduction of water into the tire to a minimum, which helps prevent corrosion. Observe the tire seating progress on the wheel rim while it inflates. Depressurize the tire before approaching it to investigate any observedissue.
Aircraft tires are typically inflated to their full specified operating pressure. Then, they are allowed to remain with no load applied for 12-hours. During this time, the tire stretches and tire pressure decreases. A 5-10 percent reduction is normal. Upon bringing the tire up to full pressure again, less than 5 percent loss per day of pressure is allowable. More should be investigated.

Tube-Type Tires

Wheel and tire inspection should precede the mounting of any tire, including tube-type tires. The tube to be installed must also pass inspection and must be the correct size for the tire and tire must be specified for the aircraft. Tire talc is commonly used when installing tube-type tires to ensure easy mounting and free movement between the tube and tire as theyinflate.
The technician should lightly talc the inside of the tire and the outside of the tube. Some tubes come from the factory with a light talc coating over the outside of the tube. Inflate the tube so that it just takes shape with minimal pressure. Install the tube inside the tire. Tubes are typically produced withamarkattheheavyspotofthetube.Intheabsenceof this balance mark, it is assumed that the valve is located at the heaviest part of the tube. For proper balance, align the heavy part of the tube with the red mark on the tire (the light spot on the tire). Once wheel balance is marked and the tube balance mark and the tire balance mark are all positioned correctly, install the outboard wheel half so the valve stem of the tube passes through the valve stemopening.
[Figure-115] Mate the inboard wheel half to it, being careful not to pinch the tube between the wheel rims. Install the tie bolts, tighten, and torque as specified. Inflate the assembly in a tire inflation cage. The inflation procedure for a tube-type tire differs slightly from that of a tubeless tire. The assembly is slowly brought up to full operating pressure. Then, it is completely deflated. Re-inflate the tire/tube assembly a second time to the specified operating pressure and allow it to remain with no load for 12-hours. This allows any wrinkles in the tube to smooth out, helps prevent the tube from being trapped under a bead, and generally evens how the tube lays within the tire to avoid any stretched areas and thinning of the tube. The holding time allows air trapped between the tube and the tire to work its way out of the assembly, typically through the tire sidewall or around the valvesstem.

Figure-115 Mounting a tube type tire with the tube valve stem positioned to pass through the outboard wheelhalf.

Figure-116 A typical aircraft tire and wheel balancingstand

Tire Balancing

Once an aircraft tire is mounted, inflated, and accepted for service, it can be balanced to improve performance. Vibration is the main result of an imbalanced tire and wheel assembly. Nose wheels tend to create the greatest disturbance in the cabin when imbalanced. Static balance is all that is required for most aircraft tires and wheels. A balance stand typically accepts the assembly on cones. The wheel is free to rotate. The heavy side moves to the bottom. [Figure-117] Temporary weights are added to eliminate the wheel from rotating and dropping the heavy side down. Once balanced, permanent weights are installed. Many aircraft wheels have provisions for securing the permanent weight to thewheel.

Weights with adhesive designed to be glued to the wheel rim are also in use. Occasionally, a weight in the form of a patch glued to the inside of the tire is required. Follow all manufacturers' instructions and use only the weights specified for the wheel assembly.[Figure-118]
Some aviation facilities offer dynamic balancing of aircraft tire and wheel assemblies. While this 111is rarely specified by manufacturers, a well-balanced tire and wheel assembly helps provide shimmy free operation and reduces wear on brake and landing gear components, such as torquelinks.

Figure 118 A tire balancing patch (left), adhesive wheel weights (center), and a bolted wheel weight

(right) are all used to balance aircraft tire and wheel assemblies per the manufacturer'sinstructions.
Operation and Handling Tips

Aircraft tires experience longer life if operated in a manner to conserve wear and minimize damage. The most important factor impinging on tire performance and wear, as well as resistance to damage is proper inflation. Always inflate tires tothespecifiedlevelbeforeflightformaximumperformance
and minimal damage. An improperly inflated tire has increased potential to fail upon landing due to the high impact loads experienced. The following sections include other suggestions that can extend the life and the investment made in aircrafttires.

Taxiing

Needless tire damage and excessive wear can be prevented by proper handling of the aircraft during taxi. Most of the gross weight of an aircraft is on the main landing gear wheels. Aircraft tires are designed and inflated to absorb the shock of landing by deflection of the sidewalls two to three times as much as that found on an automobile tire. While this enables the tire to handle heavy loads, it also causes more working of the tread and produces scuffing action along the outer edges of the tread that results in more rapid wear. It also leaves the tire more prone to damage as the tread compound opens during this flexing. An aircraft tire that strikes a chuck hole, a stone, or some other foreign object is more likely to sustain a cut, snag, or bruise than an automobile tire due to its more flexible nature. There is also increased risk for internal tire injury when a tire leaves the paved surface of the taxi way. These incidents should be avoided. Dual or multiple wheel main gear should be operated so that all tires remain on the paved surface so the weight of the aircraft is evenly distributed between the tires. When backing an aircraft on a ramp for parking, care should be taken to stop the aircraft before the main wheels roll off of the paved surface. Taxiing for long distances or athigh speeds increase the temperature of aircraft tires. This makes them more susceptible to wear and damage. Short taxi distances at moderate speeds are recommended. Caution should also be used to prevent riding the brakes while taxiing, which adds unnecessary heat to thetires.
Braking and Pivoting

Heavy use of aircraft brakes introduces heat into the tires. Sharp radius turns do the same and increase tread abrasion and side loads on the tire. Plan ahead to allow the aircraft to slow without heavy braking and make large radius turns to avoid these conditions. Objects under a tire are ground into the tread during a pivot. Since many aircraft are primarily maneuvered on the ground via differential braking, efforts should be made to always keep the inside wheel moving during a turn rather than pivoting the aircraft with a locked brake around a fixed main wheeltire.
Landing Field and Hangar Floor Condition

One of the main contributions made to the welfare of aircraft tires is good upkeep of airport runway and taxiway surfaces, as well as all ramp areas and hangar floors. While the technician has little input into runway and taxiway surface upkeep, known defects in the paved surfaces can be avoided and rough surfaces can be negotiated at slower than normal speeds to minimize tire damage. Ramps and hangar floors should be kept free of all foreign objects that may cause tire damage. This requires continuous diligence on the part of all aviation personnel. Do not ignore foreign objectdamage

(FOD). When discovered, action must be taken to remove it. While FOD to engines and propellers gains significant attention, much damage to tires is avoidable if ramp areas and hangar floors are keptclean.

Takeoffs and Landings
Aircraft tires are under severe strain during takeoff and landing. Under normal conditions, with proper control and Maintenance of the tires, they are able to withstand these stresses and perform as designed.

Most tire failures occur during takeoff which can be extremely dangerous. Tire damage on takeoff is often the result of running over some foreign object. Thorough preflight inspections of the tires and wheels, as well as maintenance of hangar and ramp surfaces free of foreign objects, are keys to

prevention of takeoff tire failure. A flat spot caused on the way to the runway may lead to tire failure during takeoff. Heavy braking during aborted takeoffs is also a common cause of takeoff tire failure.

Tire failure upon landing can have several causes. Landing with the brakes on is one. This is mitigated on aircraft with anti-skid systems, but can occur on other aircraft. Other errors in judgment, such as landing too far down the runway and having to apply the brakes heavily, can cause overheating or skidding. This can lead to flat-spotting the tires or blowout.

Hydroplaning

Skidding on a wet, icy, or dry runway is accompanied by the threat of tire failure due to heat build-up and rapid tire wear damage. Hydroplaning on a wet runway may be overlooked as a damaging condition for a tire. Water building up in front of the tire provides a surface for the tire to run on and contact with the runway surface is lost. This is known as dynamic hydroplaning. Steering ability and braking action is also lost. A skid results if the brakes are applied andheld.

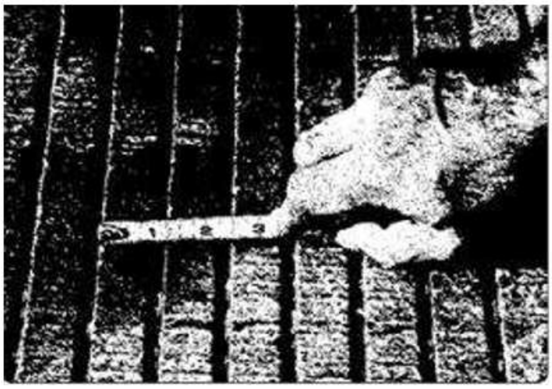


Figure 120 Crosscut runway surfaces drain water rapidly but increase tirewear.

Modern runways are designed to drain water rapidly and provide good traction for tires in wet conditions. A compromise exists in that crosscut runways and textured runway surfaces cause tires to wear at a greater rate than a smooth runway. [Figure 120] A smooth landing is of great benefit to any tire. Much aircraft tire handling and care is the responsibility of the pilot. However, the technician benefits from knowing the causes of tire failure and communicating this knowledge to the flight crew so that operating procedures can be modified to avoid thosecauses.

Introduction

Lighting systems illuminate everything from cargo compartments to the pilots instrument panel. Exterior lights are required to ensure safe operations during night flights. Emergency lights are important for escaping from the airplane in a dangerous situation. The aircraft technician must become familiar with aircraft lighting circuits in order to service these systems properly.

Maintenance and Inspection of Lighting Systems

Most lighting circuits are relatively low maintenance items. Periodic inspections of the wire for chaffing and hardware security, corrosion of components, and general condition of the circuit should be performed during routine inspections.

- Lamp replacement is generally the most needed repair for lighting systems, and one must always be carefully to install the correct bulb. Several variations of a given lamp may fit the same socket. Be sure to install a bulb with the correct voltage and power requirements.
- Before discarding expensive sealed light beams, verify their functionality with Ohmmeter. Corroded contacts may be the cause.
- When dealing with any high-intensity flashing lamp or strobe system, be careful to avoid electrical shock. The system operates on a high voltage and requires a few minutes to discharge itself if the lamp is defective. Always allow a strobe system to stay in the OFF position for approximately five minutes prior to maintenance.
- Halogen and strobe light bulbs are sensitive to the oil or grease which may come from touching the glass portion of the bulb. If ordinary body-grease is left on the glass, it may cause the glass to concentrate heat in that area during operation and crack the glass. Be sure to avoid touching a strobe bulb without the proper protection.

Exterior Lights

There are a variety of exterior lighting systems. These include position, landing, taxi, anti-collision and wing inspection lights.

The exterior lighting system fulfils various functions:

- illuminating the runway and taxiway
- illuminating the wing leading edges and engine air intakes
- indicating the aircraft position and direction
- reducing collision risk in flight and on ground.

Figure 1: Exterior Lights of a commercial Aircraft

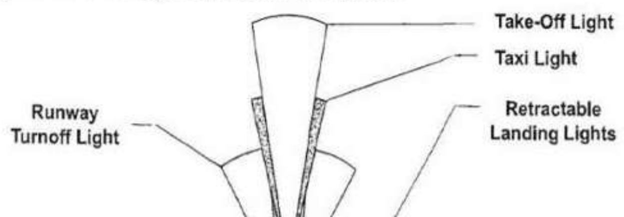
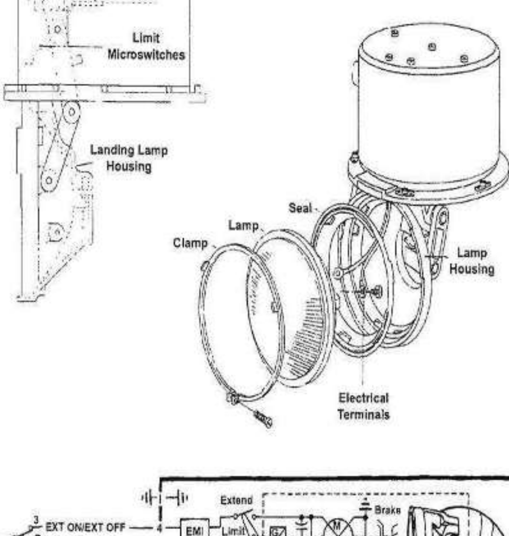


Figure 3: Retractable Landing Light



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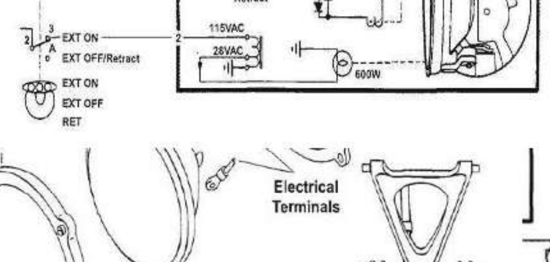
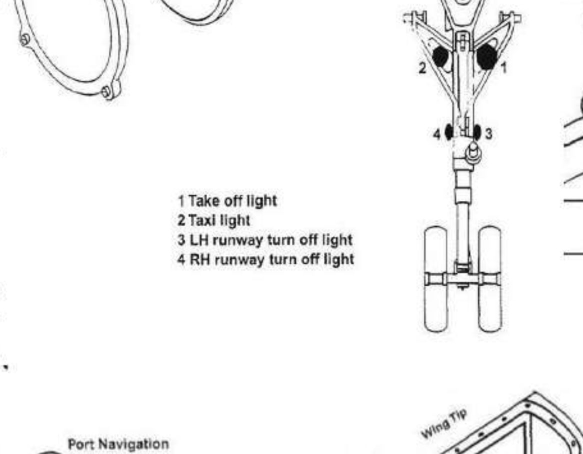


Position Lights

Position lights are used to indicate the positio
tions. If pilots can identify the position of anot
they may safely navigate around that aircraft,
ferred to as navigation lights. One or more posi
wing tip and the tail of the aircraft. The right wi
light, the left a red light and the tail must have
quired on any aircraft certified for night flight.

In commercial aircrafts a dual system gives t
system if one bulb has failed. Bulb replacemen



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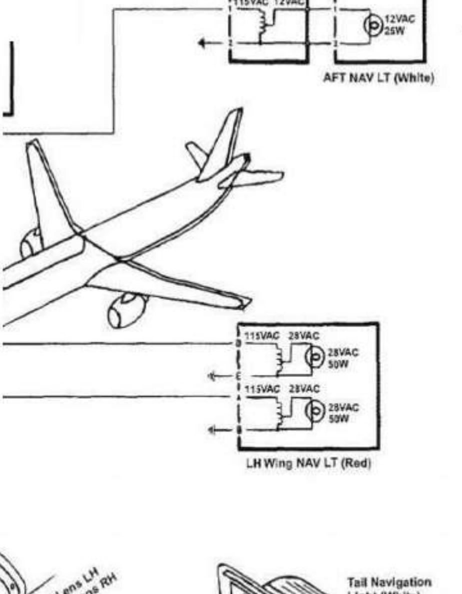
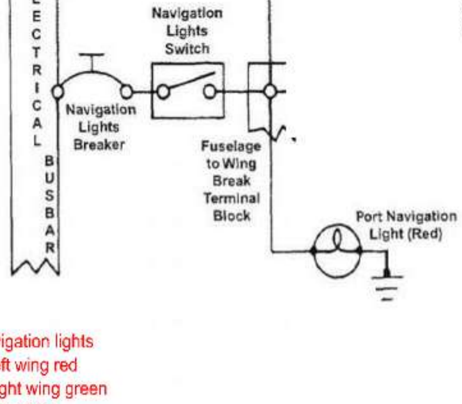
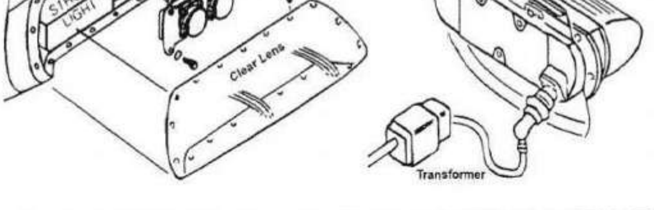


Figure 4: Position Lights





Navigation lights
* Left wing red
* Right wing green
* Tail white

Anti-Collision Light

Anti-collision light are found in two basic styles. Older aircraft were originally equipped with rotating beacons either on top of the vertical stabilizer or on top or bottom of the fuselage. Newer systems utilize solid state electronics to create a flashing- or strobe-type light. The rotating beacon system typically contained a stationary light bulb and a rotating reflector covered by a red glass lens.

Figure 6: Rotating Beacon Light

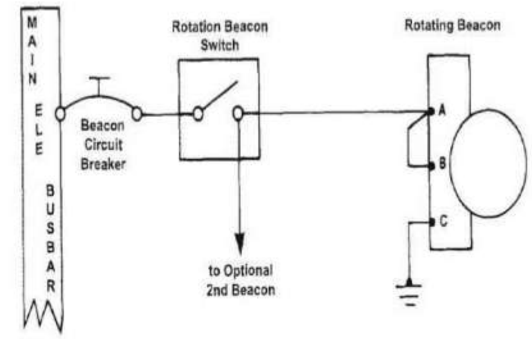
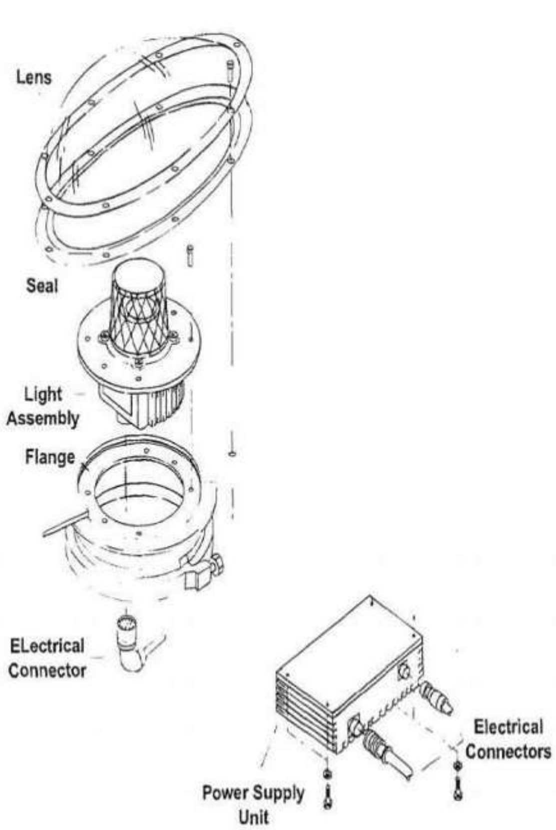


Figure 7: Flashing Beacon Light

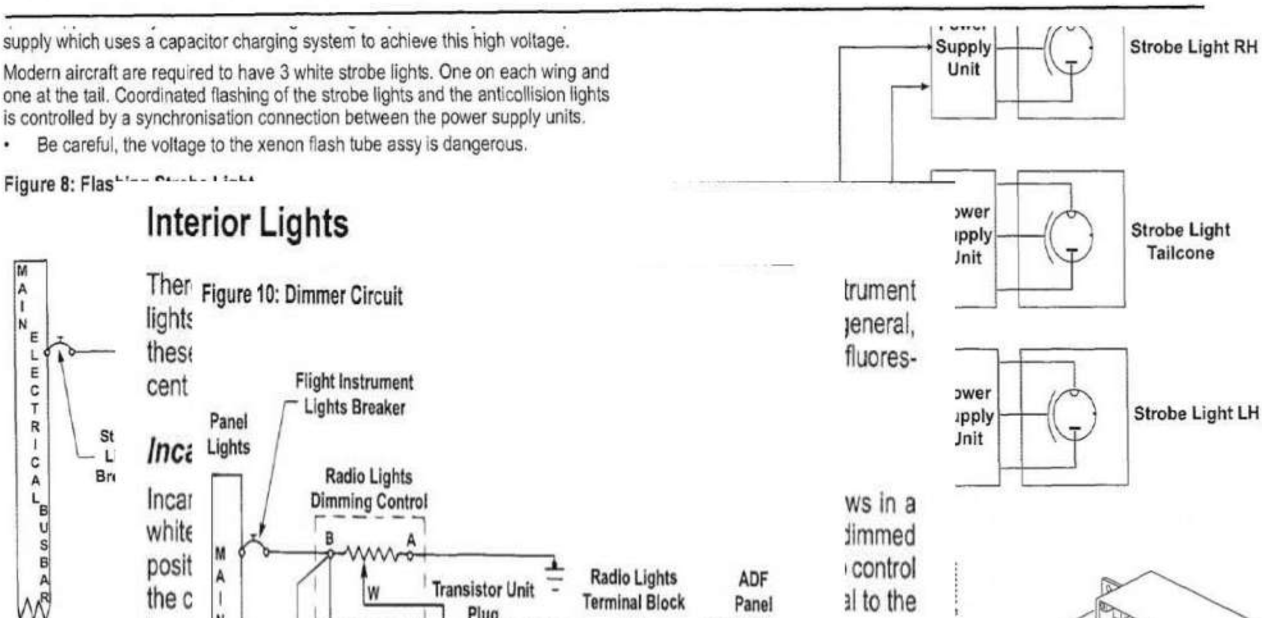


supply which uses a capacitor charging system to achieve this high voltage.

Modern aircraft are required to have 3 white strobe lights. One on each wing and one at the tail. Coordinated flashing of the strobe lights and the anticollision lights is controlled by a synchronisation connection between the power supply units.

- Be careful, the voltage to the xenon flash tube assy is dangerous.

Figure 8: Flas



Interior Lights

Ther ... trument
lights ... general,
these ... fluores-
cent

Inca

Incar ... ws in a
white ... dimmed
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Elec

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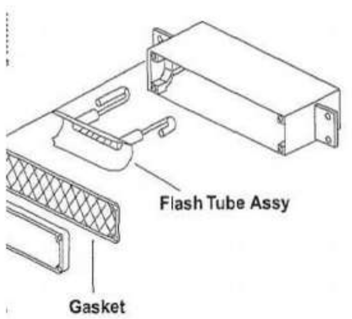
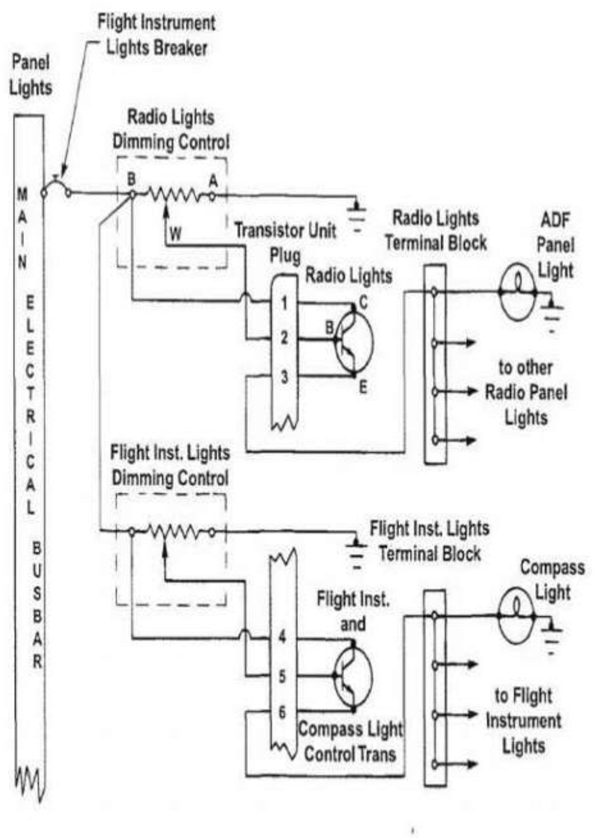


Figure 10: Dimmer Circuit



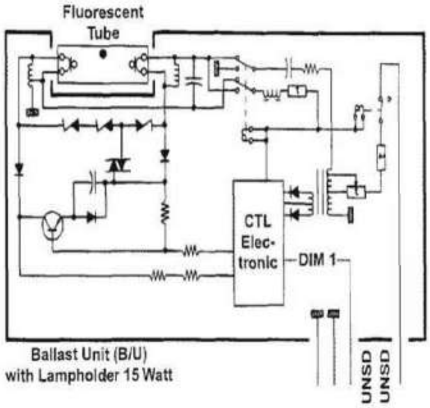
Fluorescent Lights

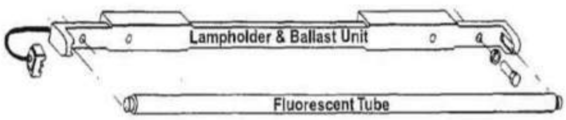
Fluorescent lights are made of a gas-filled glass tube which glows when a high AC voltage is applied to heated electrodes at each end. The electrodes emits electrons. This free electrons strike atoms of mercury vapour in the tube and this produces an ultraviolet light. The invisible ultraviolet light strikes the phosphorous coating on the inside of the tube and it glows in a white light. The conversion of one kind of light to another is known as fluorescence.

Fluorescent lamps are much more efficient than incandescent lamps, however they require the use of ballast-transformers and AC voltage. Therefore, fluorescent lamps are found only on large commercial aircraft.

Fluorescent lamps can operate in a bright or dimmed position. The fluorescent tube is in the dim position when a reduced voltage is applied to the ballast-transformer. In the bright position, the nominal voltage is applied to the fluorescent tube. Today's electronic-ballast's are weight-saving, starting the fluorescent-tube faster, their tube is no more flickering during start and operation.

Figure 11: Fluorescent Armature





Cockpit Lighting

The cockpit lighting system enables the crew to easily see all equipment details, inscriptions and indications, whatever the level of darkness. It is especially used at night.

The cockpit lighting system comprises:

- Dome lights and lighting strips
- Map holder lighting
- Console and floor lighting
- Center instrument and standby compass lighting
- Reading lights and center pedestal lighting
- Outlet plugs and coat stowage lighting.

Dome Lights

Dome lights providing a shadow less general cockpit lighting.

Map Holder Lighting

Map holder lighting is provided at the Captain and First Officer stations.

Console and Floor Lighting

Briefcase stowage, side console and floor lighting is provided at the Captain and First Officer stations.

Center Instrument and Standby Compass

The center instrument panel is illuminated by a set of lights located below the glareshield. The standby compass is provided with integral lighting.

Reading Lights and Pedestal

Individual reading lights are provided at the Captain and First Officer stations. Located in the middle of the overhead panel, a flood light provides illumination of the center pedestal.

Instrument and Panel Integral Lighting

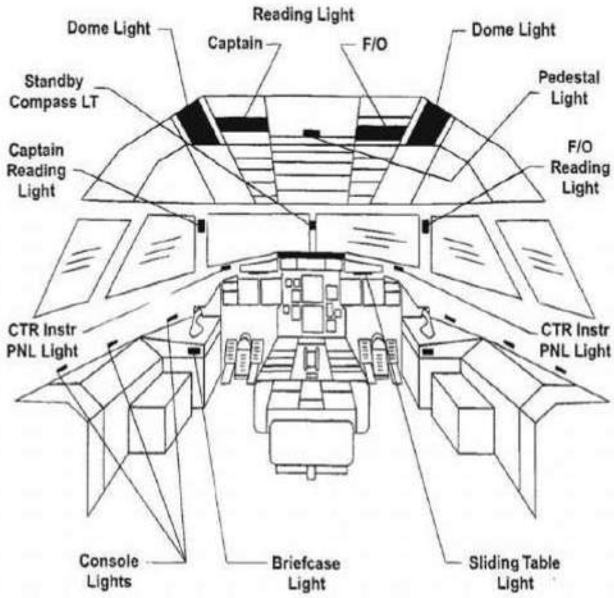
All the instruments installed in the cockpit other than the cathode ray tubes are integrally lit. The lights, illuminating the instruments, are equipped with a dimming control. The instrument and panel integral lighting is achieved in different ways:

- by the miniature lights
- by the Light Emitting Diodes (LEDs)
- by Electro Luminscence (EL)

Annunciator Light Test and Dimming

The integrity of all annunciator lights can be tested and their intensity can be dimmed.

Figure 12: Cockpit Illumination



Emergency Lighting

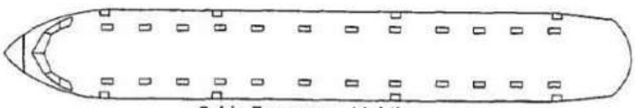
In passenger airplanes there are emergency lights installed to provide illumination of the cockpit and cabin. The power therefore is provided from separate batteries for 15 min. or from the aircraft power distribution system eg:
RH emergency bus, LH emergency bus or batteries.

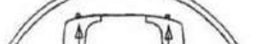
All exits are marked with special signs, guiding the passengers to the doors if dense smoke in the cabin exists.

Exterior lights at over wing emergency doors and other doors illuminating the outside area.

Cabin

Figure 13: Arrangement of Cabin Emergency Lights





Electro Luminescence EL

Electroluminescent strip lighting eliminates the need for bulbs, sockets, diffusers and reflectors. Without filaments to break, the lighting can withstand extreme shock, vibration and high or low temperatures without failure. Numerous tests and operating experience prove that the EL system will continue operating under very high G forces, and after considerable structural damage. Electro Luminescence as an area light source is more easily seen through smoke than are incandescent or other point sources of light at considerably higher brightness.

Figure 14: Escape Path Marking System

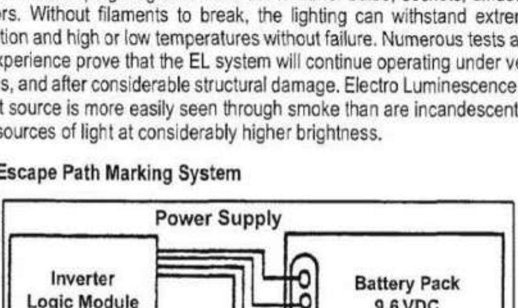
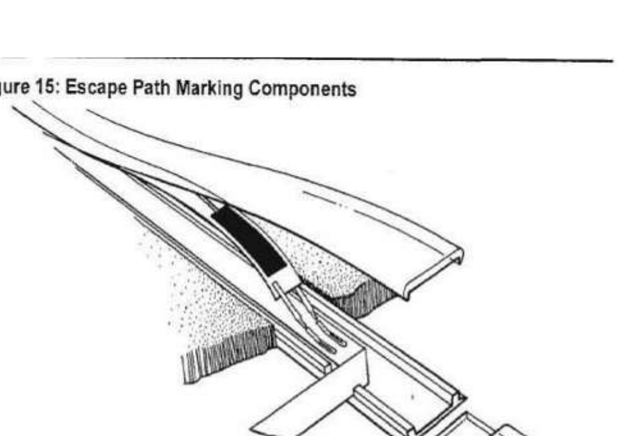


Figure 15: Escape Path Marking Components



OXYGEN SYSTEMS

GENERAL

The atmosphere is made up of about 21% oxygen, 78 % nitrogen, and 1 % other gases by volume.
Of these gases, oxygen is the most important. As altitude increases, the air thins out and air pressure decreases. As a result, the amount of oxygen available to support life functions decreases..
Aircraft oxygen systems are provided to supply the required amount of oxygen to keep a sufficient concentration of oxygen in the lungs to permit normal activity up to indicated altitudes• of about 40,000ft_

Modern transport aircraft cruise at altitudes where cabin pressurization is necessary to maintain the cabin pressure altitude between 8,000 and 14,000 ft. regardless of the actual altitude of the aircraft, Under such conditions, oxygen is not needed for the comfort of the passengers and crew. However, as a precaution, oxygen equipment is installed for use if cabin pressurization fails. Portable oxygen equipment may also be aboard for first-aidpurposes.
With some of the smaller and medium size air• craft designed without cabin pressurization, oxygen equipment may be installed

for use by passengers and crew when the aircraft is flown at high altitudes. In other instances where there is no installed oxygen system, passengers and crew depend on portable oxygen equipment stowed in convenientpositions.
The design of the various oxygen systems used in aircraft depends largely on the type of aircraft, its operational requirements and where applicable the pressurization system, In some aircraft a continuous-flow oxygen system is installed for both passengers and crew. The pressure demand system is widely used as a crew system, especially on the larger transport aircraft. Many aircraft have a combination of both systems which may be augmented by portableequipment,

Continuous Flow System

In simple form a basic continuous-flow oxygen system is illustrated in figure . As shown in the illustration, with the line valve turned "on", oxygen will flow from the charged cylinder through the high-pressure line to' the pressure-reducing valve, which reduces the pressure to that 'required at the mask outlets. A calibrated orifice in the out• lets will control the amount of oxygen delivered to themask.
The passenger system may consist of a series of plug-in supply sockets fitted to the cabin walls adjacent to the passenger seats to which oxygen masks can be connected, or it may be the "drop out" mask arrangement where individual masks are presented automatically to each passenger if pressurization fails. In both cases oxygen is .supplied, often automatically, from a manifold: Any automatic control [e.g; barometric control valve) in. the system can be overridden manually by a member of the crew.

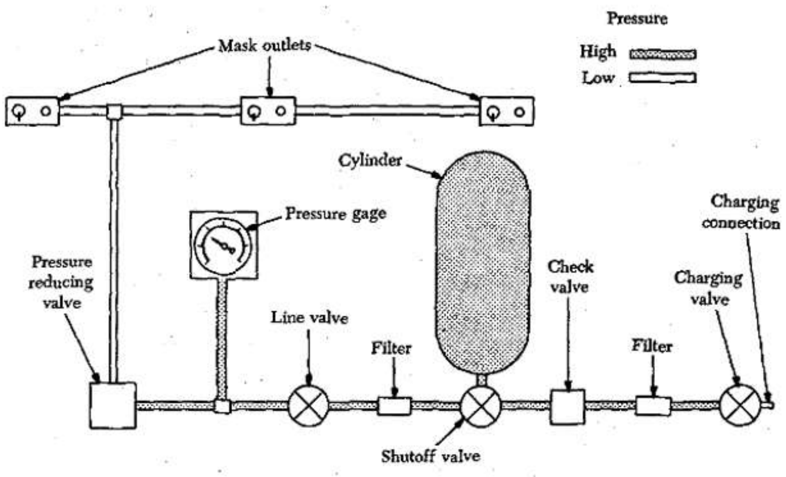


Fig - 1 Continuous flow oxygen system

Pressure-Demand System•

A simple pressure-demand oxygen system is illustrated in figure below. Note that there is a pressure-demand regulator for each crew member, who can adjust the regulator according to his requirements.

PORTABLE OXYGEN EQUIPMENT

Typical portable oxygen equipment consists of a lightweight steel alloy oxygen cylinder fitted with a combined flow control/reducing valve and a pressure gage. A breathing mask, with connecting flexible tube and a carrying bag with the necessary straps for attachment to the wearer, completes theset.

The charged cylinder pressure is usually 1,800 p.s.i.; however, the cylinder capacities vary. A popular size for portable equipment is the 120-liter capacitycylinder.

Depending, on the type of equipment used, it is normally possible to select at least two rates of flow, normal or high. With some equipment three flow rate selections are possible, i.e., normal, high, and emergency, which would correspond to 2, 4, 'and, 10 liters per minute. With these flow rates a 120-1iter cylinder would last for 60, 30, and 12 min., respectively.

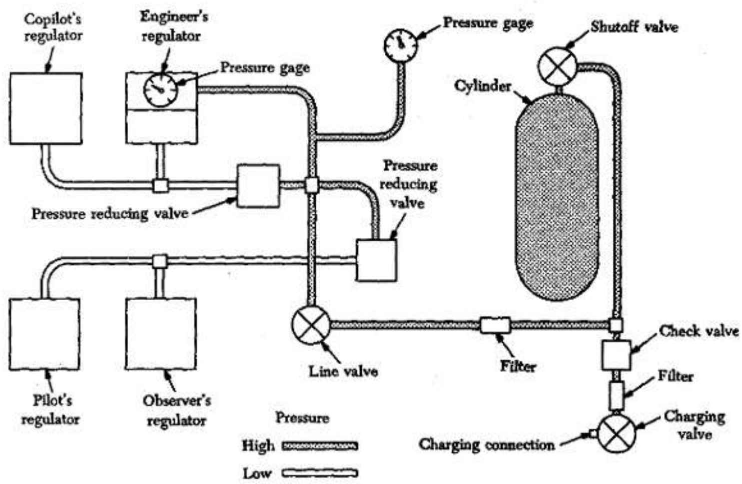


Fig-2 Typical pressure demand oxygensystem

SMOKE PROTECTIONEQUJPMENT

In some instances there is a requirement to carry smoke protection equipment for use by a member of the crew in a smoke' or fume-laden atmosphere. Smoke protection equipment consists of a special smoke protection facial mask with eye protection in the form of 'a clear-vision visor, together with the necessary oxygen supply hose and head straps. Some are designed for use with oxygen from the aircraft oxygen system, and others are self contained portableequipment.

OXYGENCYLINDERS

The oxygen supply is contained in either high• pressure or low-pressure oxygen cylinders. The high-pressure cylinders are manufactured from heat-treated alloy, or are wire wrapped on the outside surface, to provide resistance to shattering. AU high-pressure cylinders are identified by their green color and have the words "AVIATORS' BREATHING OXYGEN" stenciled lengthwise in white, l•in. letters. High-pressure cylinders are manufactured in a variety of capacities and shapes. These cylinders can carry a maximum charge of 2,000 p.s.i., hut are normally filled to a pressure of 1,800 to 1,850 p.s.i There are two basic types of low-pressure oxygen cylinders. One is made of stainless steel; the other, of heat-treated, low alloy steel. Stainless steel cylinders are made non shatter able by the addition of narrow stainless-steel bands that are seam-welded to the body of the cylinder. Low-alloy steel cylinders do not have the reinforcing bands but are subjected to a heat treatment process to make them non shatter able. They have a smooth body with the word "NONSHATTERABLE" stenciled onthem. Both of the low-pressure cylinders come in different sizes and are painted light yellow. This color indicates that they are used for low-pressure oxygen only. The cylinders may carry a maximum charge of 450 psi but are normally filled to a pressure of from 450 to 425 p.s.i, When the pressure drops to 50 p.s.i., the cylinders are considered empty. The cylinders may be equipped with either of two types of valves. One type used is a self opening valve which is automatically opened when the se1f opening valvecoupling assembly attached to the oxygen tubing is connected to the valve outlet. This coup1ing unseats a check. Valve, allowing oxygen from the cylinder to fill the oxygen system under high pressure. the other type is a hand-wheel, manually operated valve. This valve should be safety wired in the "full on" position when the cylinder is installed in the aircraft. This valve should be closed when removing or replacing parts of the oxygen system and when the cylinder is tohe removed from the aircraft. Cylinders are often provided with a disk designed to rupture if cylinder pressure rises to an unsafe value. 'The disk is usually fitted in the valve hody and vents the cylinder contents to the outside of the aircraft in the event of a dangerous pressurerise.

SOLID STATE OXYGEN SYSTEMS

Emergency supplemented oxygen is a necessity in any pressurized aircraft flying above 25,000ft.
Chemical oxygen generators can be used to fulfill the new requirements. The chemical oxygen generator differs from the compressed oxygen cylinder and the liquid oxygen converter in that the oxygen is actually produced at the time of delivery.
Solid-state oxygen generators have been in use for a number of years, dating back to 1920, when it was first used in mine rescues. During World War II the Japanese, British and Americans, all worked to develop oxygen generators for aircraft andsubmarines.
In figure-3 below, 120 standard cubic feet of oxy• gen (101bs.) is shown schematically in the number of cubic inches of spaceit

would occupy as' a gas, a liquid or a solid. In figure -4, the necessary hardware to install and operate the system has been included in the size and weight measurements. A close comparison of these values makes it apparent that the solid state oxygen generator system is the most efficient space wise. Likewise less equipment and maintenance is required for solid state oxygen converters. Integrity inspection is the only requirement until actual use is implemented.
Solid state describes the chemical source, sodium chlorate, formula NaCI03• When heated to 478 degree F , sodium chlorate releases up to 45% of its weight as gaseous oxygen. The necessary heat for de- Composition of the sodium chlorate is supplied by iron which is mixed with thechlorate

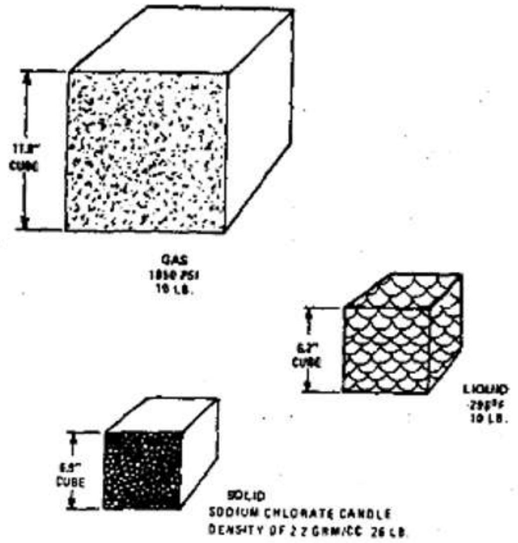


Fig - 3 Volume comparison

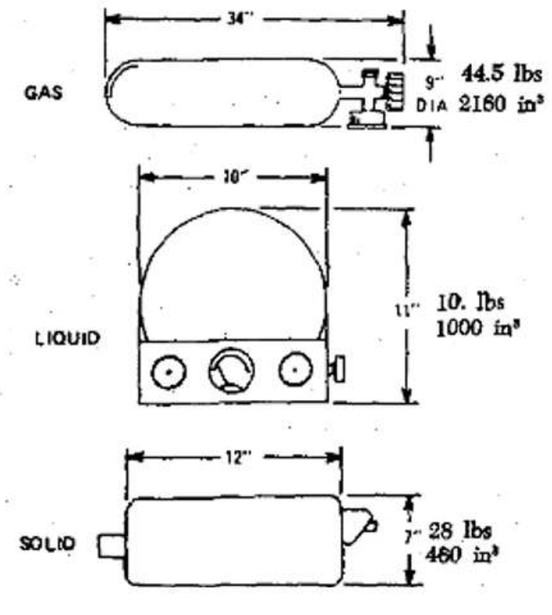


Fig – 4 Weight and volume comparison- gas , liquid and solid oxygen storage

The Oxygen Generator

Figure illustrates a schematic representation of a basic oxygen generator, The center axial position is occupied by a core of sodium chlorate, iron, and some other ingredients mixed together and either pressed or cast into a cylindrical shape. This item has been popularly referred to as an oxy• gen candle, because when it is ignited at one end, it burns progressively in much the same manner as a candle or flare. Surrounding the core is porous packing.It supports the core and filters salt particles from the gas as it flows toward the outlet. A chemical filter and particulate filter at the outlet end of the container provide final clean up of the gas so that the oxygen delivered is medically pure breathing oxygen. An initiation' device is an in• tegral part of the package. This may be either a mechanical percussion device or an. electric squib. The choice depends on the application. The entire assembly is housed in a thin shelled vessel. Often included is a layer of thermal insulation on the inside shell; a check valve seal on the outlet, and a relief valve to protect against an inadvertent over• pressurecondition. In operation, the burning is initiated at one end of the core by activating the squib or percussion device. Oxygen evolution rate. is proportional to the cross sectional area of the core and the burn rate. The burn rate is

determined by theconcentration
•of fuel in the chlorate. In certain cases, one end of the core is larger than the other. The purpose of this is to program a high oxygen evolution rate during the initial few minutes of burning such as is required for an emergency descent sup• ply. Burning continues until the core isexpended.

The simplicity of the process should he readily apparent; likewise, the limitations. There are no on/off valves and no mechanical controllers. Re• fill is accomplished by simply replacing, in total, the entire device. A limitation is that once the generator is initiated, flow is. delivered at a pre• determined rate, thus demand use is not veryefficient.

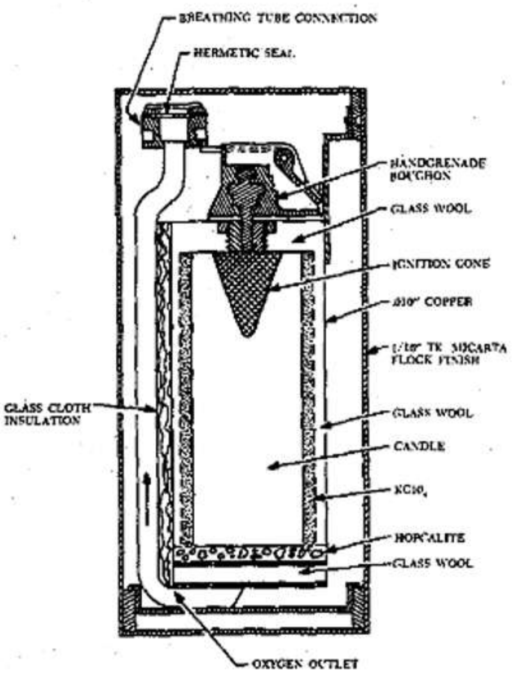


Fig -5 Apparatus for burning candles

In order to keep the process from consuming a great quantity of the oxygen, the quantity of iron is kept to a minimum. There is a tendency toward liberation of small amounts of chlorine. Barium peroxide, or barium dioxide, may be added by the manufacturer to provide an alkaline medium for removing the trace amounts of chlorine that may bepresent. On a volume basis, which is extremely important in the aircraft installation, the storage capacity of oxygen in' candles is about three times that of compressedgas.
A typical three outlet module for a 15 minute decompression emergency descent supply for a supersonic transport (25000 foot max. cabin altitude) weighs less than 0.9 pound and consists simply of a 2.1 inch diameter by 3.55 inch long stainless steel cylinder attached to three man folded hose nipples. The cylinder contains the generator, initiator, salt, fume filter, enough insulation to keep the cylinder surface below 2500 F. duringburning,
a pressure relief plug, and a temperature indicating paint spot for generator status visual inspection. The nipples contain orifices just small enough to assure essentially equal flow to all three masks.
The generators are inert below 4000F. even under severe impact. While reaction temperature is high and considerable heat is produced, the generators are insulated so that the outer surface of the cylinder is cool enough to avoid any fire hazard. The portable units may be held comfort• ably throughout the entire' operation, as the 'heat generated is dissipated steadily over a long period of time, The same insulation works in reverse to delay initiation should a unit be subjected to an external fire. If such a fire is sufficiently pro• longed to ignite the chlorate generator, oxygen production will at a relatively low and continuous rate. In the simple continuous flowsystemsnopressurewouldbegeneratedasalloutletswould

permit unrestricted flow of the oxygen, eliminating the intense jet torch effect if pressurized oxygen infire.
Solid State vs. High Pressure GaseousOxygen

• Elimination of high pressure storage containers -saves weight.
• Elimination of distribution and regulation components- saves weight and maintenance:
• Simplification of individual distribution manifolds and drop-out mechanisms by the use of modular chlorate candle units.
• Improved reliability, hence safety by design of initiation circuitry, such that, an individual malfunction would not make other units in• operative (comparison here would be to ruptured lines, or high leakage in gaseous distributionsystems).
• Simple, visual surveillance of each unit for condition of chlorate candle within the sealed container, by use of inspection window.
• Simple replacement of any unit, should it show any sign of deterioration, by plug-in cartridge, by relatively unskilled services crew; easily checked for installation and readiness for functioning from flightdeck.
Programmed oxygenreleaserates irrespective of the type of emergency.

OXYGEN PLUMBING

Tubing and fittings make up most of the oxygen system plumbing and connect the various components. All lines are metal except where flexibility is required. Where flexibility is needed, rubber hose is used, 'There are several different sizes and types of oxygen tubing •. The one most frequently used in low-pressure gaseous systems is made of aluminum alloy. Tubing made of this material resists corrosion and fatigue, is light in weight, and is easily formed. High-pressure gaseous supply lines' are made from copper alloys. Installed oxygen tubing is usually identified with color-coded tape applied to each end of the tubing, and at specified intervals along its length. The tape coding consists of a green hand overprinted with the words ~BREATHING OXYGEN" and a black rectangular symbol overprinted on a whiteback•ground

OXYGEN SYSTEMFITTINGS

Tube segments are interconnected or connected to system components by fittings. Tubing-to-tubing fittings are designed with straight threads to receive flared tube connections. Tubing- to-component (cylinder, regulator, and indicator) fittings have straight threads on the tubing end and external pipe threads (tapered) on the other end for attachment to the component, as shown infigure

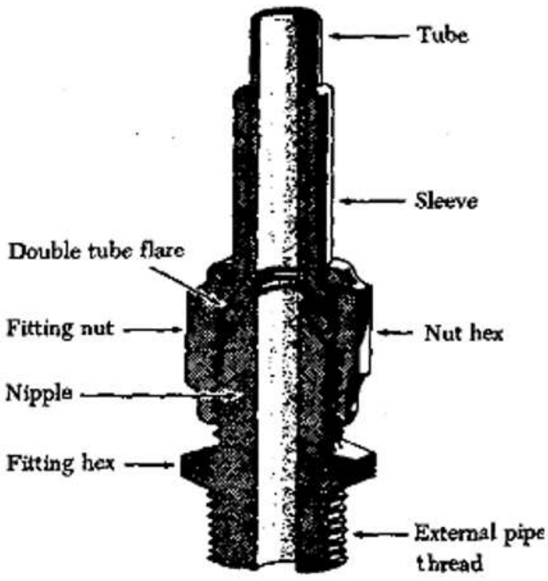
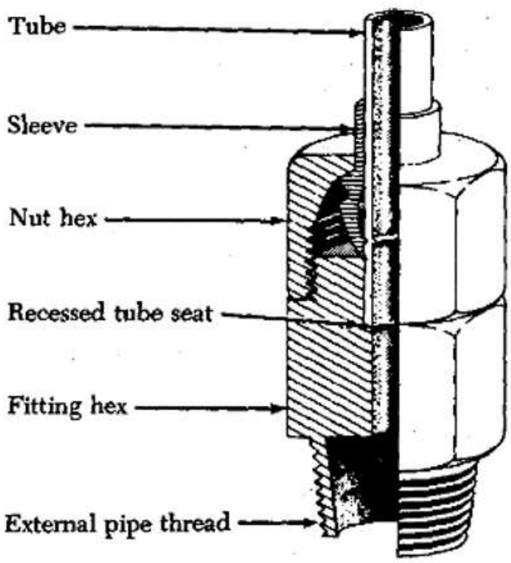


Fig-6 Sectional view of A typical oxygen system fitting

Oxygen system fittings may he made of aluminum alloy, steel, or brass. These fittings may be either of two types, flared or flare less. A typical flared fitting is shown in figure 14-50. A flare less fitting is shown infigure The sleeve in a flare less fitting must be preset before final installation in a flare less seat. Preset• ting causes the cutting edge of the sleeve to grip the tube sufficiently to form a seal between the sleeve and the tubing. The end of the tubing bottoms on the seat of the flare less fitting to provide tube end support afterinstallation.

To seal oxygen system tapered pipe thread connections and to prevent thread seizure, use only an approved ..thread compound. Never use a mixture containing oil, grease, or any other hydrocarbon on any fittings used in oxygen systems

When installing a line, make sure there is proper clearance. The minimum clearance between oxygen plumbing and all moving parts should be 2 in. It is desirable to maintain a 6-in. clearance between oxy gen tubing and electrical wires. When this is not possible, fasten all electrical wires securely with clips so that they cannot come to within 2 in. of the oxygentubing.



OXYGEN VALVES

Five types of valves are commonly found in high-pressure gaseous oxygen systems. These are filler valves, check valves, shutoff valves, pressure reducer valves, and pressure relief valves. Low-pressure systems will normally contain only a filler valve and checkvalves.

The low-pressure filler valve is used on systems equipped with low pressure cylinder. When servicing a low pressure oxygen system. push the recharging adapter into the fiber valve casing. This unseats the filler valve and permit oxygen to flow' from the servicing cart into the aircraft oxygen cylinders. The filler valve contains a spring loaded locking device which holds the re• charging adapter in place until it is released. When the adapter is removed from the filler valve, reverse flow of oxygen is automatically stopped by a check valve. A cap is provided to cover the filler opening and preventcontamination.

Check Valve

Check valves are installed in the line. between cylinder in all aircraft that have more than one storage cylinder. They are provided to prevent a reverse flow of oxygen. Check valves permit the rapid flow of oxygen in only one direction. The direction of unrestricted' flow is indicated by an arrow on the valves.

SHUT OFF VALVE-

Manually controlled two-position (on, off). valves are installed tocontrol.The•flowofoxygenbeingemittedfromacylinder or a bank of cylinders. For normal operation, the bolt which control the valves are safe tied in the "on" position. When beceuary, such .. changing a common _it the. appropriate valve can be closed. AI. a precaution a, when opening a valve, the knob should he ~ slowly to the "on" position. Oath~ the .. rush of highly pressurized oxygen into a depleted system could rupture aline.

PRESSURE--REDUCER VALVES-

In high-pressure oxygen systems, pressure reducing valves are Installed between the supply cylinders and the cockpit and cabin equipment. These valves reduce the high pressure of the oxygen supply cylinders down to approximately 300 to 400 p.s.i. required in the low-pressure part of the system.

PRESSURE--RELIEF VALVES-

A pressure-relief valve is incorporated in the main supply line of a high-pressure system. The relief valve prevents high- pressure oxygen from entering the system downstream of the pressure reducers if the reducer fails. The relief valve is vented to a blow out plug in the fuselageskin.

REGULATORS

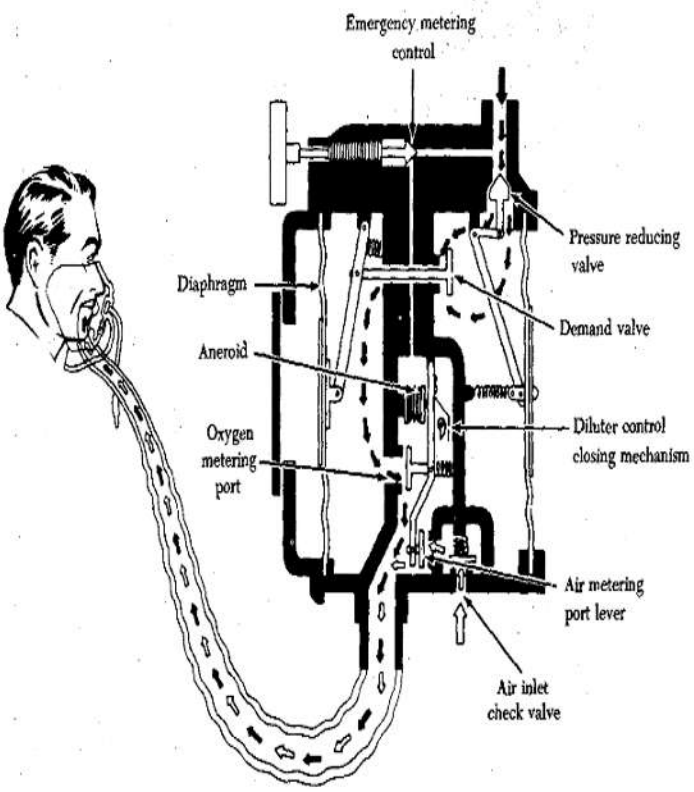
DILUTER-DEMANDREGULATORS

The diluter-demand regulator gets its name from the fact that it delivers oxygen to the user's lungs in response to the suction of his own breath. To pro• long the duration of the oxygen supply, the oxygen is automatically diluted in the regulator with suitable amounts of atmospheric air. This dilution takes place at all altitudes below 34,000ft.

The essential feature of a diluter- demand regulator is a diaphragm-operated valve called the demand valve ,which opens by slight suction on the diaphragm during inhalation and which closes during exhalation. A reducing valve upstream from the demand valve provides a controlled working pressure. Downstream from the demand valve is the diluter control closing mechanism. This consists of an aneroid assembly (a sealed, evacuated bellows) which controls the air inlet valve. When the diluter lever is set in the position marked "normal oxygen:' atmospheric air at ground level is supplied with very little oxygen added. As altitude increases, the. air inlet is gradually closed by the bellows to give a higher concentration of oxygen until at about 34,000 ft. the air inlet is completely closed and 100% oxygen is supplied; As altitude decreases, this process isreversed.

The diluter control can he set by turning the lever to give 100% oxygen at any altitude. At moderate altitudes, however, this causes the oxygen supply to be consumed much more rapidly than normal. The. diluter control should be set at "normal oxygen" for all routine operations. It can be set at "100 percent oxygen" for the followingpurposes:

(1) Protection against exhaust gases or other poisonous or harmful gases in theaircraft,
(2) To avoid the bends and chokes,and
(3) To correct a feeling of lack ofoxygen.



The diluter-demand regulator is provided with an emergency valve, operated by a red knob) on the front of the regulator. Opening this valve directs a steady stream of pure oxygen to the mask, regardless of altitude

When there is sufficient differential pressure across the demanddiaphragm,thedemandvalveopenstosupplyoxygento

the mask. This pressure differential exists during the user's inhalation cycle. After passing through the demand valve, the oxygen is mixed with air that enters through the air inlet port. The mixture ratio is determined by an aner• oid-controlled air metering valve. A high oxygen ratio is provided at high altitudes and a high air ratio at lower altitudes. The air inlet valve is set to permit the airflow to begin at the same time as the oxygenflow.

The addition of air may be cut by turning the oxygen selection lever to "100%." When this lever is in "normal," .air enters through the air inlet port, and the required amount is added to the oxygen to form the correct air I oxygen mixture. Positive pressure at the regulator outlet may be obtained by turning the emergency lever to "on." This mechanically loads. the demand diaphragm to provide positive outletpressure.

Continuous-flow'Regulator

Continuous flow regulators of the hand-adjustable and the automatic type are installed for the crew and passenger oxygen supply respectively. The hand-adjustable, continuous-flow regulator delivers to the user's mask a continuous stream of oxygen at a rate that can be controlled. The system usually contains a pressure gage, a flow indicator, and a manual control knob for adjusting the oxy• gen flow. The pressure gage indicates the p.s.i. of oxygen in the cylinder. The flow indicator is calibrated in terms of altitude. The manual control knob adjusts the oxygen flow. The user adjusts the manual control knob until the altitude of the flow indicator corresponds to the cabin altimeterreading.

The automatic continuous-flow regulator is used in transport aircraft to supply oxygen automatically to each passenger when cabin pressure is equivalent to an altitude of approximately 15,000 ft. Operation of the system is initiated automatically by means of an electrically actuated device. The system can also be actuated electrically or manually should the au•tomatic regulator malfunction.

Upon actuation, oxygen flows from the supply cylinders to the service units. A typical passenger service unit is shown in figure 14-58. During the first few seconds of oxygen flow, 8 pressure surge of •50 to 100 p.s.i. causes the oxygen mask box doors toopen.

Each mask assembly then falls out and is 8118- pended by the actuating attachment on the flexible tubing. The action" of pulling the mask down to a usable position withdraws the outlet valve actuation pin, opening the rotary valve, allowing oxygen to flow ‘to themask

OXYGEN SYSTEM flOWINDICATORS

Flow indicators are used in oxygen systems to give visual indications that oxygen is flowing through the regulator. They do not show how much oxygen is flowing. Furthermore, their operation does not indicate that the user is getting enough oxygen.

In the blinker type indicator, the eye opens and closes each time the user inhales and exhales. To check the Row indicator, set the diluter lever to "100% oxygen" and take several normal breaths from. the mask-to-regulator hose. If the blinker opens and closes easily with each breath, it is in operating condition

PRESSURE GAGES

Pressure gages are usually of the Bourdon tube type. Figure 14- 60 shows the faces of two oxygen gages: (1) A low-pressure gage and (2) a high• pressure gage Because of their connection into a system, the gages do not necessarily show the pressure in each cylinder. If the system contains only one supply cylinder, the pressure gage- will indicate cylinder pressure. In systems where several cylinders are inter connected through check valves, the gage will indicate the pressure of the cylinder having the highest pressure. Immediately after the system has been filled, pressure gage accuracy can be checked by comparing the aircraft pressure gage with the gage on the servicing cart. On low-pressure systems, the aircraft gage should read within 35 p.s.i. of the 425 p.s.i, servicing cart pressure. The same check can be used {or high-pressure systems, but servicing pressure is 1,850 p.s.i. and a to lerance of 100 p.s.i, is allowed. The tolerances shown for pressure gage accuracy are typical and should not be construed as applying to all oxygen systems. Always consult the applicable aircraft maintenance manual for the tolerances of a particular system.

OXYGENMASKS

There are numerous types of oxygen masks in use which vary widely in design detail. It would be impractical to discuss all of the types. It is important that the masks used be compatible with the particular oxygen system involved. In general, crew masks are fitted to the user's face with a minimum of leakage. Crew masks usually contain a microphone. Most masks are the or nasal type, which covers only the mouth andnose.

Large transport aircraft are usually fitted with smoke masks for each crew position. The smoke masks are installed in stowage containers within easy grasp of the individual. These masks provide crew protection in an emergency and are not used frequently like the demand and continuous-flow masks. Smoke mask equipment consists of a Full-face mask, a flexible breathing tube, and a coupling. The coupling connects to a demand regulator. A microphone is permanently installed in the mask.

Passenger masks may be. simple, cup-shaped rubber moldings sufficiently flexible to obviate individual fitting. They may have a simple elastic head strap or they may be held to the face by the passenger AU oxygen masks must be kept clean. This reduces the danger of infection and prolongs the life of the mask. To clean the mask, wash it with a mild soap and water solution and rinse it with clear water. If a microphone is installed, use a clean swab, instead of running water, to wipe off the soapy solution.

SERVICING GASEOUS OXYGEN SYSTEMS

The servicing procedures for..a gaseous oxygen system depend upon the type of system. Before charging an aircraft system, consult the .aircraft manufacturer's maintenance manual Precautions such as purging the connecting hose before coupling to the aircraft filler valve, avoiding overheating caused by too rapid filling, opening cylinder valves slowly, and checking pressures frequently during charging should be considered.

The type of oxygen to he used, the safety precautions, the equipment to be used, and the procedures for filling and testing the system must be observed. Gaseous breathing oxygen used in in aircraft is a special type of oxygen containing practically no water vapor and is at least 99.5 % .pure. While other types of oxygen (welder, hospital) may be pure enough, they usually contain water, which might freeze and block the oxygen system plumbing especially at highaltitudes.

Gaseous breathing oxygen is generally supplied in 220- to 250cu. ft. high-pressure cylinders. The cylinders are identified by their dark green color with a white band painted around the upper part. of the cylinder. The words "OXYGEN AVIATORS' BREATHING" are also stenciled .in white letters, lengthwise along the cylinders,

OXYGEN SERVICE SAFETY

Gaseous oxygen is dangerous and must be handled properly, It causes flammable materials to bum violently or even to explode. Listed below are several precautionary measures to follow:

1. Tag all reparable cylinders that have leaky yea/yes or plugs.
2. Don’t use gaseous oxygen to dust off clothing.
3. Keep oil and grease away from oxygen equipment.
4. Don't service oxygen systems in a hangar because of the increased chances for fire.
5. Valves of an oxygen system or cylinder should not be opened when a flame, electrical arc, or any other source of ignition is in the immediatearea.
6. Properly secure all oxygen cylinders when they are in use.

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GASEOUS OXYGEN SERVICING TRAILERS

Even though several types of servicing trailers are in use, each recharging system contains supply cylinders, various types of valves, and a manifold that connects the high-pressure cylinders to a purifier assembly. In the purifier assembly, moisture is removed from, the oxygen. Coarse particles are trapped in the filter before reaching a reducing valve. The reducing valve has two gages which are used to monitor inlet and outlet pressures respectively. The reducing valve also has an adjusting screw for regulating the outlet pressure. This pressure is discharged into a flexible hose which connects to the charging valve and the adapter. The charging valve controls oxygen flowing away from the servicing trailer, and the adapter connects the recharging equipment to the aircraft fillervalve.

On many aircraft a chart is located adjacent to the filler valve which shows the safe maximum charging pressure for the ambient temperature. This must be observed when charging the system.

It is common practice to have a warning placard cautioning against using oil or grease on the filler connections. Oxygen ground equipment should he maintained to a standard of cleanliness comparable to that of the aircraftsystem.

Leak Testing Gaseous OxygenSystems

This test is performed at different times, depending on the inspection requirements for the particular type of aircraft. The system is allowed to cool, usually 1 hr., after filling before the pressures and temperatures are recorded. After several hours have elapsed, they are recorded again. Some manufacturers recommend a 6•hr. wait, others a 24-hr. wait. The recorded pressures are then corrected for any change in temperature since filling.

Cleaning the OxygenSystem

Always keep the external surfaces of the components of the oxygen system, such as lines, connections, and mounting brackets, clean and free of corrosion and contamination. with oil or grease. As a cleaning agent, use anhydrous (waterless) ethyl -alcohol, isopropyl alcohol (anti-icingfluid)
or any other approved cleaner. If mask-to-regulator hoses are contaminated with oil or grease, the hoses should bereplaced.

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Cleaning Compound, Oxygen System

An approved cleaning formula for use on oxygen systems is available. This mixture of chlorinated, fluorinated hydrocarbons (freon) and isopropyl alcohol is safe for cleaning oxygen system components in aircraft, and for rinsing, flushing, and cleaning oxygen lines. Skin contact and prolonged inhalation of vapors should beavoided.

Purging The OxygenSystem

An oxygen system needs to be purged if: (1) It has been depleted and not re-charged within 2 hrs., (2) if any line or component is replaced, requiring the draining or opening of the system for more than2 hrs., or (3) it is suspected that the system has beencontaminated.

The main cause of contamination in the system is moisture. Moisture in the system may be due to damp charging equipment. In very cold weather the small amount of moisture contained in breathing oxygen can cause contamination, due to repeatedcharging.

Although the introduction of moisture into the aircraft oxygen system can be considerably reduced by using the correct charging procedure, cumulative condensation in the system cannot be entirely avoided. There have been instances where oxygen systems, unused for long periods, have developed an. unpleasant odor which necessitated purging to clear the system of moisture.

Theprocedure for purging mayvary somewhat with each aircraft model. Generally speaking, on aircraft having the filler lines and the distribution lines commonly connected to one end of the storage cylinder, the system can be purged by filling the system with oxygen and then draining it at least three times. On aircraft that have the filler lines connected on one end 0f the cylinder and distribution lines connected to the opposite end of the cylinder, purge the system as follows: With all the regulator emergency valves open, pass oxygen at a pressure of 50 p.s.i. at the filler valve through the system for at least 30 min. Perform this job in a well-ventilated area and observe all fire precautions.

Dry nitrogen and/or dry air may also be used to purge oxygen systems. All open lines must be capped after use, also thesystem lines must be purged of the nitrogen by use ofoxygen.

PREVENTION OF. OXYGEN FIRES OREXPLOSIONS

Many materials, particularly oils, grease, and non-metallic materials,' are likelytoburn whenex•posedtooxygenunder

pressure.Toavoidfireoranexplosionitisessentialthat all oxygen equipment be kept clean and free from oil orgrease
An oxygen fire or explosion depends on a combination of oxygen, a combustible material, and heat. The danger of ignition is in direct ratio to the concentration of oxygen, the combustible nature of the material exposed to the oxygen, and the temperature of the oxygen and material. Oxygen itself doesnotburn but it supports and intensifies a fire with any combustible material When working on an oxygen system it is essential that the warningsandprecautions given in' the air• craft maintenance manual be carefully observed. In general, before any work is attempted on an oxygen system the following fire precautions should betaken:

1. Provide adequate fire-fightingequipment.
2. Display "NO SMOKING"placards.
3. Avoid checking aircraft radio or electricalsystems.
4. Keep all tools and oxygen servicing equipment free from oil andgrease.

Oxygen System Inspection and Maintenance

Oxygen system inspection and maintenance should be accomplished according to these precautionary measures and any in addition to the manufacturer'sinstructions.

1. 1 - Never attempt maintenance until oxygen supply is turnedoff.
2. Fittings should be unscrewed slowly to allow residual pressure todissipate.
3. Plug or cap all open linesimmediately.
4. Do not use masking tape to seal openings: use caps or plugs designed for thatpurpose.
5. Maintain at least 2 inches clearance between oxygen lines and all moving equipment/ parts within the aircraft to prevent the pos• sibility of. wearing oxygenlines.
6. Maintain at least 2 inches clearance between oxygen lines and all electrical wiring in theaircraft.
7. Provide adequate clearance between oxygen lines and all hot ducts,conduitsand equipment to prevent heating of the oxygen sys-tem.
8. Maintain at least 2• inches clearance between oxygen line and all oil, fuel, hydraulic, or other fluid lines to preventcontamination,
9. Do not use lubricants unless specifically approved for oxygen systemuse.
10. A pressure and leak check must he per• formed each time the system is opened formaintenance

AIRBUS A-320

SYSTEM OVERVIEW

The oxygen system consists of:

- crewsystem,
- passengersystem,
- portablesystem.

Crew System

The flight crew oxygen system supplies oxygen to the flight crew. It is used if there is a loss of cabin pressurization or smoke or other hazardous circumstancesarise.

The oxygen is supplied by a high pressure oxygen cylinder to quick donning masks in the cockpit.

Passenger Oxygen System

The passenger and cabin attendant oxygen system is supplied by chemical oxygen generator units located in the cabin, cabin attendant stations, lavatories and galleys.

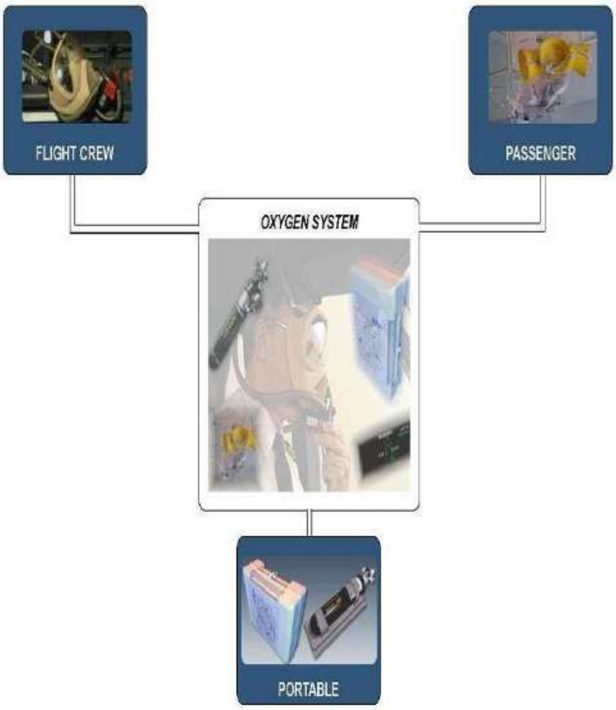
The chemical generator units provide oxygen for a minimum of 13 minutes.

Potable Oxygen System

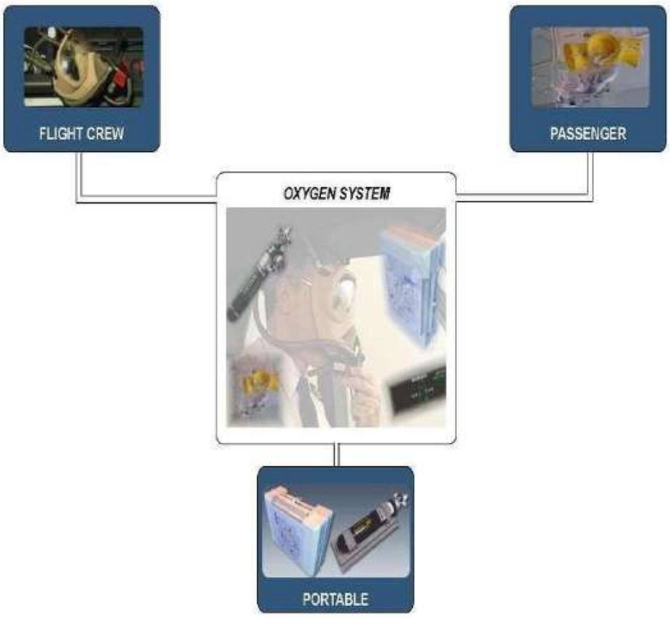
The portable oxygen system supplies oxygen to the passengers, the cabin attendants and the flight crew in anemergency.

The smoke hood system provides breathing means and eye protection for the flight crew members and cabin attendants. It permits them to move freely to extinguish a fire.

The high pressure portable cylinder with continuous flow type masks supplies first aid oxygen for the passengers.



SYSTEM OVERVIEW



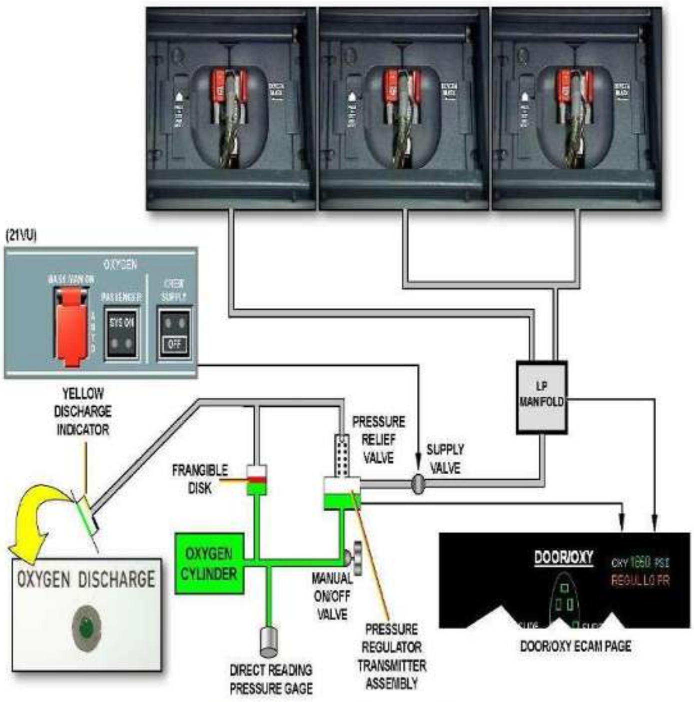
SYSTEM OVERVIEW

FLIGHT CREW OXYGEN SYSTEM

The crew oxygen comes form a high pressure cylinder. This can be isolated for maintenance, by a manual ON/OFFvalve. A direct reading gauge gives an indication of the cylinder pressure.
The cylinder is placed in a cradle and secured by a quick disconnect metallic clamp.
A pressure regulator transmitter assembly is directly connected to the cylinder.

It consists of a high-pressure stage with an integrated pressure transducer for ECAM indication and a low pressure stage.
The pressure regulator regulates the low pressure.
A supply valve opens or closes the crew oxygen supply. The CREW SUPPLY P/B on the oxygen panel controls the supply valve.
High pressure and low pressure protection is achieved by safety devices consisting of a high pressure safety outlet and a low pressure safety outlet. The high pressure safety outlet is a frangible disk type. The low pressure safety outlet is a pressure reliefvalve.
An overboard green discharge indicator is connected to the high pressure safety outlet and to the low pressure safety outlet.
In case of over pressure, the green disk blows out and a yellow indicator is displayed showing that the cylinder has discharged or the pressure relief valve has opened.
A pressure switch and a test port are connected on the lowpressuremanifold.
The low pressure switch indicates a low pressure detected in the LP manifold.It activates a message on the ECAM/DOOR/OXY page.
The mask assembly and the stowage box are installed adjacent to each crew member seat. The stowage box which contains the mask, also controls the flow of oxygen when the mask is pulled out of the box.
To use the mask, squeeze the red clips. This will inflate the mask harness.

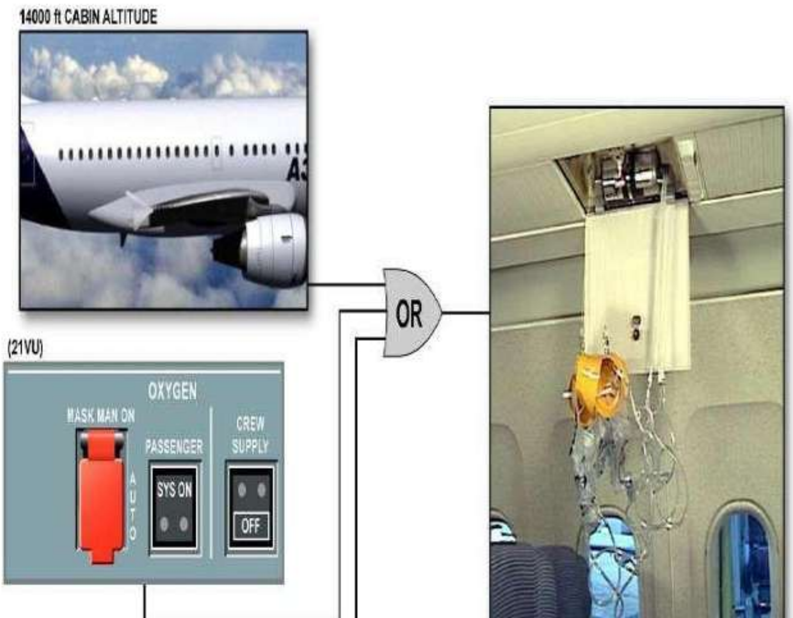
Bring the mask in position and release the red clips. Releasing the red clips will stop oxygen flow to the harness and vent the oxygen remaining in the harness to the atmosphere. Now the mask is ready for use.

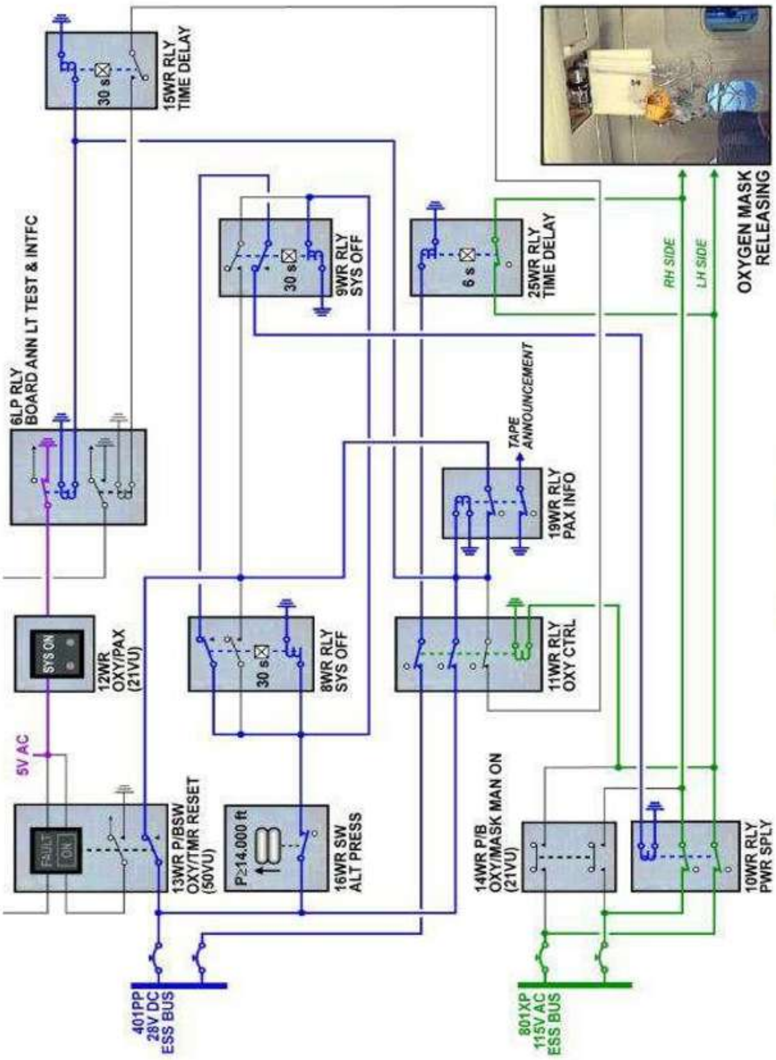


SYSTEM OVERVIEW / FLIGHT CREW OXYGEN SYSTEM

PASSENGER OXYGEN SYSTEM

The masks drop automatically when the cabin altitude is higher than 14000 feet or manually by crew action on the MASK MANual ON pushbutton.
The passenger SYSTEM ON indicator light comes on white when the passenger oxygen system is electrically supplied.
A reset is available to rearm the electrical system after mask re stowage.
A release tool allows manual opening of the door in case of failure of the container door opening system.
When the TiMER RESET pushbutton is pressed, the ON white light of the TMR RESET pushbutton comes on.
The indicator light SYS ON goes off and the taped announcement stops.
On ground, used chemical oxygen units must be replaced and all masks re stowed.
The system is reset by momentarily pressing the TMR RESET pushbutton on the maintenance panel.
If required , test stops are fitted on the mask doors to allow an operational test of the manual mask release system.





AUTOMATIC OPERATION

MASK OPERATION

As soon as the emergency oxygen container doors open, the masks fall out. They are hung on lanyards within the reach of users. When the first user pulls the mask towards his face, the release pin starts the chemical generation. Oxygen flows through the flexible supply hose to the mask. The flow indicator shows a green stripe.

CHEMICAL OXYGEN GENERATION

The chemical generator uses the basic principal of thermal decomposition of sodium chlorate. An indicator turning from yellow to black shows the generator is expended. The chlorate core is fitted in a stainless steel housing. A thermal insulating material is used between the core and the housing. A filter is installed in the outlet end of the housing.

GENERATOR OPERATION

The generator actuator has a spring-loaded striker and a percussion fuse.
A relief valve fitted on the generator housing protects the generator against high internal pressure.

747-400

OXYGEN SUPPLY SYSTEM - DESCRIPTION AND OPERATION

1.

General

A. This procedure describes the operation of the 747-400 Passenger and Crew Emergency Oxygen Supply Systems, and their components.

1. The Supply system is the portion of the Passenger oxygen system that supplies low-pressure oxygen to the Passenger oxygen distribution systems. The Passenger Oxygen Distribution Systems are described in SECTION35-20.

2. The Supply system is the portion of the Crew oxygen system that supplies intermediate pressure oxygen to the flight deck crew oxygen distribution systems. The Crew Oxygen Distribution Systems are described in SECTION35-10.

3. The division between the supply systems and distribution systems is the floor of the Main Passenger Cabin (WL 200). The Supply systems are located below WL200. The Distribution Systems are located aboveWL200

B. The 747-400 Passenger Oxygen System is a gaseous continuous-flow, "Mask-Activated" type system. When actuated, the system will provide a continuous flow of oxygen through the passenger oxygen mask only after the mask user activates the mask.

C. The 747-400 Crew Oxygen System is a gaseous diluter demand type system, which provides oxygen to the flight crew masks at each usersinhalation.

D. The Therapeutic oxygen system can supply oxygen from the passenger oxygen system to passengers who may desire it during normalflight.

E. Oxygen for the Passenger and Crew Oxygen systems are stored in the forward cargo compartment right hand sidewall area, aft of the cargodoor
.

F. Additional Passenger Oxygen System cylinders are also stored in the forward cargo compartmentceiling.

G. In the passenger and crew oxygen systems, high-pressure oxygen (1850 psig) is stored in high pressure oxygen cylinders. Pressure regulators reduce the oxygen pressure to the intermediate system pressure of 600-680psig.

H. Stainless steel tubing is used throughout the high (1850 psig) and intermediate (600-680 psig)pressuresystems.

I. Passenger OxygenSystem:

(1) In the passenger oxygen system, the intermediate oxygen pressure is delivered to the flow control units (FCU), which control the pressure in the low-pressure distributionline.

(2) Actuation of the flow control units can either be automatic by means of the barometric pressure aneroid, or manually by means of the "PASS OXYGEN" momentary toggle switch provided on the P5 overhead panel in the flight deck. The aneroid is an ambient pressure-sensitive device located within theFCU.

(3) When the cabin pressure rises above 13,250 feet to14,500 feet, the aneroid automatically actuates

the FCUs. The "PASS OXYGEN" momentary toggle switch on the flight deck may also be used to manually actuate theFCUs.

(4) Whether the oxygen system is activated automatically or manually, a signal is sent to the FCUs. The FCUs in turn send a pressure surge through the low pressure distribution lines which unlatches the oxygen box doors and deploys the masks for immediate use. A signal is then sent to the EICAS system that displays the "PASS OXYGEN ON" message on the EICAS Upper Display Unit memo page on the flightdeck.

(5) An additional signal sounds a chime in the cabin, and causes the overhead "No Smoking/Fasten Seat Belt" lighted signs toilluminate.

(6) Altitude compensated pressure regulators within the FCUs,andmeteringorificesontheoxygenManifolds, which are located in the PSU, automatically control the quantity of oxygen supplied to each mask.

J. Crew Oxygen System:

(1) In the crew oxygen system, the intermediate oxygen pressure is delivered to the low-pressure regulator. The low-pressure regulator further reduces oxygen pressure from the intermediate pressure (600-680 psig) to the 60 psig to 85 psiglow-pressure required by the crew oxygenmasks.

(2) A pressure relief valve is included in the regulator to protect the system components downstream of theregulator.

(3) The regulator is located in the flight compartment aft right hand sidewall drip shieldarea.

PASSENGER OXYGEN DISTRIBUTION - DESCRIPTION AND OPERATION

1. General

A. This procedure is for 747-400 passenger airplanes with Mask-Activated Oxygen Systems.

B. The Distribution System is the portion of the Passenger oxygen system that distributes oxygen to the passengers and attendants throughout the passengercompartment.

C. The Supply system is the portion of the Passenger oxygen system that supplies low- pressure oxygen to the Passengeroxygen

distribution systems. The Passenger Oxygen Supply Systems are described in.

D. The division between the supply systems and distribution systems is the floor of the Main Passenger Cabin (WL 200). The Supply systems are located below WL200. The Distribution Systems are located above WL200.

E. The Passenger oxygen system is a gaseous continuous-flow type system, which provides a continuous flow of oxygen to the user'smask.

F. In addition to the emergency systems, the Therapeutic oxygen system can supply oxygen to passengers who may desire it during normal flight.

G. High-pressure cylinders, located in the forward cargo compartment, supply both the passenger and crew oxygensystems.

H. Upon system activation, high-pressure oxygen (1850 psig) flows from each cylinder to the high pressure regulator for each cylinder assembly. The high-pressure regulator reduces the oxygen pressure to the intermediate system pressure of 600-680psig.

I. This intermediate oxygen pressure is delivered to the flow control units (FCUs), which control the pressure in the low-pressure distribution system. The distribution system manifold supplies oxygen to the oxygen serviceunits.

J. Oxygen service units are found in passenger service units (PSUs) at each passenger seat locations, lavatories, attendant areas, and crew rest areas (asinstalled).

K. The low-pressure distribution system is not pressurized during normal flight until the FCUs areactuated.

L. However, the low-pressure distribution system is pressurized when the therapeutic system is in use.

2. DistributionTubing

A. The low-pressure distribution tubing comprises the following:
B.
1. The Low-pressure line routing oxygen from the FCUs to the main distributionloop.
2. The main distribution loop that connects to the main and upper deck trunklines.
3. The Left, Center, and Right main deck trunk lines, and associated branch lines that distribute oxygen forward and aft to the main deckPSUs.
4. The upper deck trunk and associated branch lines that distribute oxygen to the upper deckPSUs.
C. Seamless aluminum alloy tubing with welded studs is used for the low-pressure distribution system.

3. Distribution SystemHoses

A. Hoses are used throughout the distribution system where a flexible connection is required. Examples of hose use include:
(1) Connection of trunk lines to branch line tuberuns
(2) Connection of branch lines toPSUs

4. Bleed Relief Valves
(Figure 1)
A. Bleed Relief Valves are located in the distribution system at the ends of the tube runs to provide for the purging of entrapped air during the surge phase of the system start-up. The relief valves are set to vent above the maximum normal system pressure but below the peak surge pressure, thus purging air from the system during the 7-15 second surge phase and returning to the closed position as the system reaches the normal operatingpressure.
B. The Bleed Relief Valves do not operate during operation of the optional Therapeutic oxygensystem.
5. Automatic VentValve
(Figure 1)
A. A single system Automatic Vent Valve is installed to prevent pressure build-up due to flow control valve leakage and variations in barometric pressure when the oxygen system is not in use. The vent valve remains open between 0 and 1 psig. When the oxygen system is activated, the system pressure exceeds 1 psig and the vent valve closes. The vent valve is located at the aft end of the right main deck trunkline.
6. Passenger ServiceUnits
(Figure 2)
A. Passenger Service units (PSUs) can be installed in various locations:
(1) Passenger seatpositions
(2) Lavatories
(3) Attendant seatpositions
(4) Galleys
(5) Crewrests
(6) Over entrywaydoors

B. The service unit door latch mechanisms are actuated by oxygen surgepressure.
C. The passenger seat PSUs are mounted in the cabin stowage bins, slightly forward of each group of passenger seats. Each unit has a compartment with stowage space for the full complement of mask assemblies and a manifold assembly with outlet valves to which masks may be attached.

D. When the door latches of service units are actuated, the compartment door is released, the oxygen masks drop and hang ready foruse.

E. Each flexible hose of an oxygen mask assembly is connected to the manifold assembly. The manifold assembly outlet valve is held closed by an actuating pin inserted into the valve. The actuating pin is connected to the oxygen mask via a retaining ring and a short lanyard. The action of a passenger pulling a mask toward his or her face pulls the lanyard and withdraws the pin, causing the manifoldvalvetoopenandoxygentoflowtothemask.

The outlet valve may be closed by means of a flap-type lever integral with the valve when oxygen is no longer required.

7. Unitized ValveAssembly
(Figure 2)
A. The unitized valve assembly consists of an inlet port assembly, a manifold, mask shutoff valves, mask outlets, and a door latchmechanism.
B. The unitized valve assembly is connected to the low pressure distribution line by a flexible hose at the inlet port. When pressure in the low pressure distribution line rises between 16 and 29 psig, the door latch actuates and opens the oxygen box door. The door latch mechanism can be operated manually for maintenanceaccess.
C. The mask shutoff valves controls the flow of oxygen to the mask outlets after the pintel is removed. The mask shutoff valve is closed when the flap-type lever is in the up position and opened when the flap-type lever is in the down (normal) position.
D. A pintel is inserted into the mask shutoff valve and is connected to the mask hose by a short lanyard. The pintel is used to hold the spring-loaded mask shutoff valve in the closed position. Pulling the mask to the face withdraws the pintel, opening the mask shutoff valve and allows oxygen to flow to the maskoutlets.

E. During normal flight conditions, the mask shutoff valves are in the closed position with the pintel assembly inserted and the oxygen box door held closed by the door latchmechanism.
8. Passenger OxygenMasks
(Figure 2)
A. Upon operation of the door latching mechanism, the oxygen module’s door swings open under gravity. Each mask assembly drops downward and is suspended on a dedicated lanyard. The masks are now prominently displayed in front of and within easy reach of each seated passenger. There is no immediate flow of oxygen to the mask. The passenger pulls down the mask in order to apply it to his or her face for use, and in doing so removes the actuation pin, which operates the manifold-mounted valve, allowing oxygen to flow to the mask. Oxygen will flow only to masks that have had their actuation pin pulled.
B. The passenger oxygen mask assembly is an or on asal cup- shaped continuous flow type unit and is connected to the service units nozzle with flexible plastic tubing. A 1 liter reservoir bag is attached to the face piece with a check valve incorporated at the mask. The mask is designed to conform with facial contours is held in position with an elastic headstrap.
C. The masks are certified toTSO-C64A.
9. Therapeutic OxygenSystem

NOTE: ACTUATING THE THERAPEUTIC OXYGEN SYSTEM DOES NOT ENERGIZE THE DECOMPRESSION

RELAY (R36), NOR RELEASE THE PASSENGER OXYGEN MASKS.
CAUTION: AIRPLANES WITH THERAPEUTIC OXYGEN SYSTEM; BE SURE TO CONNECT AT LEAST ONETHERAPEUTIC OXYGEN MASK WITHIN FIVE MINUTES OF THERAPEUTIC SYSTEM ACTUATION.

F. The optional Therapeutic oxygen system can supply oxygen to passengers who may desire it during normal flight. This system is a permanent installation of the continuous flow type, and is an integral part of the passenger oxygen system. Oxygen for the therapeutic system is supplied from the passenger oxygencylinders.

G. If equipped, the therapeutic oxygen system may be actuated at any cabin altitude during normal flight by operation of the "THERAPEUTIC OXYGEN" switch on the flight deck overhead P5panel.

H. This activates the non-surge FCU only, and slowly pressurizes the entire low-pressure distribution system to approximately 2 psig. A therapeutic mask and hose may be connected to any one of a number of dedicated therapeutic outlet points in the main cabin or upper deck, providing a flow of oxygen to the passenger. These outlets are capable of providing 2 or 4 l pm oxygen topassengers.

I. The therapeutic masks are stored at designated stowage locations. The therapeutic masks are notTSO approved. The therapeutic system is not intended for supplemental oxygenuse.

J. The memo message "THERAP OXYGEN ON" appears on the center EICAS display when the therapeutic system is actuated. Moving the "THERAPEUTIC OXYGEN" switch (on the P5 overhead panel) to the RESET position resets the non-surge FCU, and de-activates the system. This simultaneously extinguishes the "THERAP OXYGEN ON" memomessage.

10. Operation

A. FunctionalDescription

(1) The passenger oxygen system stores oxygen under high pressure and supplies oxygen at low pressure to eachpassenger and attendant. The system is actuated automatically by an aneroid in each flow control unit when cabin altitude reaches or exceeds 13,250 to 14,500 feet. The system can also be activated by operating a switch on the P5 Pilot's Overhead Panel in the event the system fails to activate automatically or at the discretion of the flight crew.

(2) When the system is actuated, high pressure oxygen flows from the cylinder to the pressure reducer. Medium pressure oxygen flows from the pressure reducer to the flow control units and low pressure oxygen flows from the control units to the oxygen boxes. During the first few seconds, the flow control surge units release a pressure surge that opens the oxygen box door, allowing the masks to drop within easy reach of thepassengers.

(3) When the mask is pulled to the passengers face, a short cord attached to the mask hose pulls the pintel assembly from the mask shutoff valves in the unitized valve assembly, allowing the valve to open and oxygen to flow to themask.

(4) The user of the mask inhales pure oxygen until the reservoir bag on the mask is empty, then inhales air during the remainder of the inhalation cycle. The quantity of oxygen supplied to the mask is controlled by the altitude compensation mechanism in the flow control units which senses cabinpressure.

(5) Actuation of the system closes a pressure switch on the low pressure side in the flow control unit (Fig. 8). This switch provides a ground for the R36 decompression relay on the P414 Main Power Distribution Panel and signals the EICAS to display the advisory message " PASS OXYGEN ON".

B. Controls

(1) Normal Control

(a) With 28-volt dc power available at the battery bus, close the OXYGEN VALVE & IND circuit breaker on the P7 Overhead Circuit Breaker Panel and check the EICAS for passenger oxygen system pressure. If system is properly serviced, the aneroid controls in the flow control units automatically initiate oxygen flow to the oxygen box when cabin altitude increases to 13,250 to 14,500feet.

NOTE: ACTUATING THE THERAPEUTIC OXYGEN SYSTEMDOESNOTENERGIZETHEDECOMPRESSION

RELAY (R36), NOR RELEASE THE PASSENGER OXYGEN MASKS.
CAUTION: AIRPLANES WITH THERAPEUTIC OXYGEN SYSTEM; BE SURE TO CONNECT AT LEAST ONE THERAPEUTIC OXYGEN MASK WITHIN FIVE MINUTES OF THERAPEUTIC SYSTEM ACTUATION.

(b) Make sure the oxygen system is pressurized and the circuit breakers are closed for usual operation. Put the THERAPEUTIC OXYGEN switch (M7315), on the Pilot's Overhead Panel (P5), to ON. This will operate the electro-pneumatic flow control unit (M123) and give a signal to the EICAS to show the memo message "THERAP OXYGEN ON". The low pressure distribution lines will become pressurized and oxygen will be available at the therapeutic receptacles. An oxygen mask with a plug-in connector could be connected to the therapeutic receptacle for medical aid or therapeuticuse.

(c) Do these checks when you use the therapeuticoxygen:

NOTE: If the oxygen stays in the system, the pressure in the oxygen system will increase. This will cause the PRA Decompression Announcement to occur if the pressure increases to 5-7PSIG.

1) Make sure that there is no kink in the oxygen mask tube when the therapeutic oxygen system ison.

2) Make sure that the therapeutic oxygen system is not on when you disconnect the therapeutic oxygenmask.

(2) AlternateControl

(a) ThesystemcanbeoperatedbyplacingthePASSOXYGEN switch, on the P5 Pilot's Overhead Panel, in the ON position. This

causes the control unit solenoid to override the aneroid control and open the actuation valves in the electro-pneumatic control units, regardless of cabinaltitude.

NOTE: When the system is pressurized by placing the switch in the ON position, the masks will drop, regardless of cabin altitude.

(3) Flow Control UnitResetting

WARNING: THE FLOW CONTROL UNITS MUST BE RE- SET AFTER THE OPERATION OF THE OXYGEN SYSTEM IS COMPLETE FOR THE SYSTEM TO FUNCTION CORRECTLY AGAIN.

(a) The flow control units must be re-set after the operation of the oxygen system is complete (this includes the optional Therapeutic system) for the system to function correctly again.

1) Reset is accomplished by a solenoid actuated by momentarily moving the PASS OXYGEN switch on P5 Pilot's Overhead Panel to RESET position.

-A
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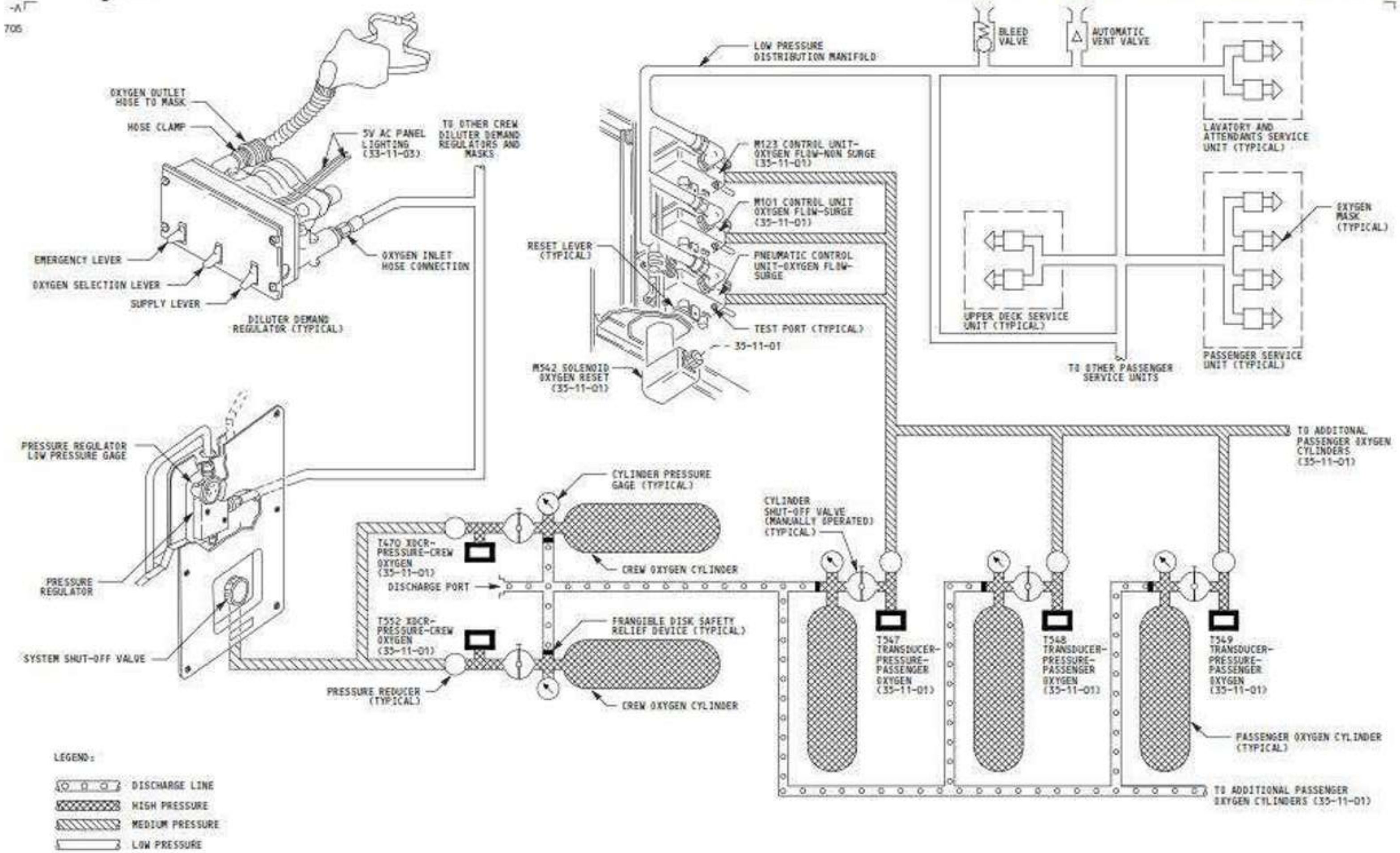
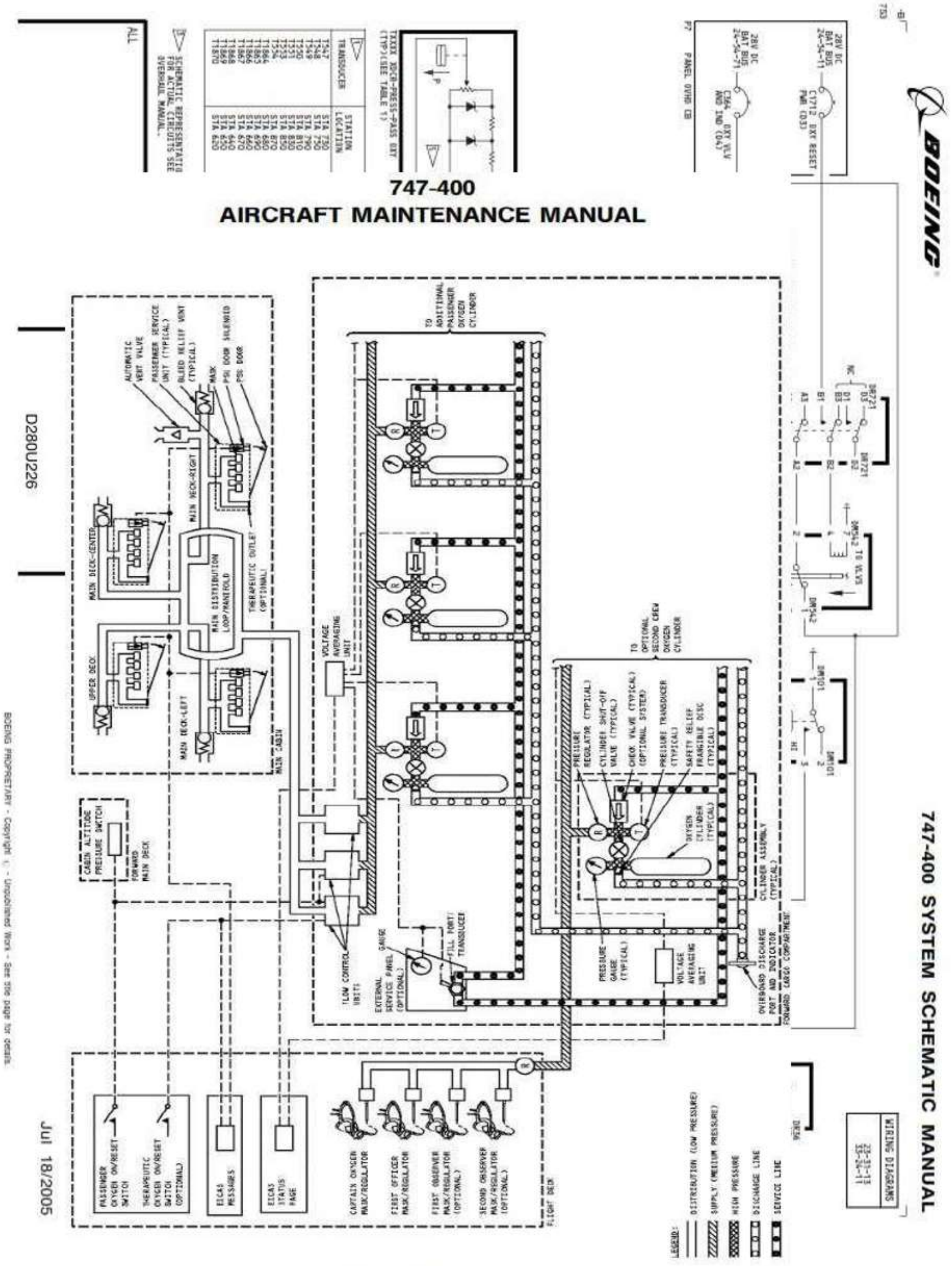

OXYGEN OUTLET HOSE TO MASK
HOSE CLAMP
5V AC PANEL LIGHTING (33-11-03)
TO OTHER CREW DILUTER DEMAND REGULATORS AND MASKS
EMERGENCY LEVER
OXYGEN SELECTION LEVER
SUPPLY LEVER
OXYGEN INLET HOSE CONNECTION
DILUTER DEMAND REGULATOR (TYPICAL)
LOW PRESSURE DISTRIBUTION MANIFOLD
BLEED VALVE
AUTOMATIC VENT VALVE
LAVATORY AND ATTENDANTS SERVICE UNIT (TYPICAL)
M123 CONTROL UNIT-OXYGEN FLOW-NON SURGE (35-11-01)
M101 CONTROL UNIT OXYGEN FLOW-SURGE (35-11-01)
PNEUMATIC CONTROL UNIT-OXYGEN FLOW-SURGE
RESET LEVER (TYPICAL)
TEST PORT (TYPICAL)
35-11-01
M542 SOLENOID OXYGEN RESET (35-11-01)
OXYGEN MASK (TYPICAL)
UPPER DECK SERVICE UNIT (TYPICAL)
TO OTHER PASSENGER SERVICE UNITS
PASSENGER SERVICE UNIT (TYPICAL)
TO ADDITONAL PASSENGER OXYGEN CYLINDERS (35-11-01)
PRESSURE REGULATOR LOW PRESSURE GAGE
CYLINDER PRESSURE GAGE (TYPICAL)
CYLINDER SHUT-OFF VALVE (MANUALLY OPERATED) (TYPICAL)
T470 XDCR-PRESSURE-CREW OXYGEN (35-11-01)
CREW OXYGEN CYLINDER
PRESSURE REGULATOR
DISCHARGE PORT
T552 XDCR-PRESSURE-CREW OXYGEN (35-11-01)
FRANGIBLE DISK SAFETY RELIEF DEVICE (TYPICAL)
SYSTEM SHUT-OFF VALVE
PRESSURE REDUCER (TYPICAL)
CREW OXYGEN CYLINDER
T547 TRANSDUCER-PRESSURE-PASSENGER OXYGEN (35-11-01)
T548 TRANSDUCER-PRESSURE-PASSENGER OXYGEN (35-11-01)
T549 TRANSDUCER-PRESSURE-PASSENGER OXYGEN (35-11-01)
PASSENGER OXYGEN CYLINDER (TYPICAL)
TO ADDITIONAL PASSENGER OXYGEN CYLINDERS (35-11-01)
LEGEND:
DISCHARGE LINE
HIGH PRESSURE
MEDIUM PRESSURE
LOW PRESSURE



Oxygen System

OXYGEN SYSTEM - DESCRIPTION AND OPERATION

General

A. The Crew and Passenger oxygen systems provide supplemental oxygen to the flight crew, passengers and attendants in the event of a cabin decompression or other emergency. B. Portable oxygen and equipment is provided in the event of an in-flight medical, fire, or other emergency

1.INTRODUCTION

This section explains the basic principles, advantages, operation and layouts of aircraft hydraulic power systems. It also describes the various materials used and the function of the associated components that make up, operate and control different types of hydraulic systems and the interface of hydraulic power with other systems Fluid power systems are mechanical systems in which a moving fluid performs work. This fluid may either be a compressible gas or an incompressible liquid. Systems that use compressible fluids (gasses) are called pneumatic systems, and those that use incompressible fluids are called hydraulic systems. Hydraulic power is often used to operate aircraft landing gear, flight controls, flaps and slats, air brakes, wheel brakes, nose-wheel steering, freight doors etc. in conjunction with other systems. This method of operation is termed;Hydraulic Actuation.

Fluid power: The transmission of force by the movement of a fluid. i.e. Hydraulic and pneumatic systems.
Fluid: A substance, either a gas or a liquid, which flows and conforms to the shape of its container.
Hydraulics: A fluid power system, which transmits force through an incompressible fluid.
Pneumatics: A fluid power system, which transmits force through a compressible fluid.

1.1 COMPARISON WITH OTHER POWERTRANSFER SYSTEMS

Hydraulic actuation has the following advantages over mechanical, electrical and pneumatic forms of remote control:

1.1.1 MECHANICALSYSTEMS

a. Hydraulics provides smoother and steadiermovement.
b. Hydraulic power is confined to pipelines and components, which avoids the extra strengthening of airframe structure required for mechanicaloperations.
c. Hydraulics systems have a higher Power/weight ratio than mechanical systems, particularly on large transport aircraft.
d. Installation of hydraulic equipment is simpler. Pipelines between components for example, can be routed around obstructions and structure, whereas to solve this problem mechanically requires the use of levers, guides bell- cranks and pulleys to change direction of mechanical pushrods andcables.
e. Variation in speed of operation can be achieved without the use of complexgearing.
f. Finally, hydraulic actuation normally obtains its power from the aircraft engines, which relieves the pilot of unnecessary fatigue when operating aservice.

1.1.2 ELECTRICALSYSTEMS

The obvious advantage of electrical systems is that cables can be routed around obstructions even easier than pipelines. They are also generally lighter in weight, however, the power required to actuate landing gear and flight controls of large aircraft, would require large electric motors powered by equally large (and heavy) electrical generators, requiring high current cables connecting the system components. Therefore, electrically operated systems are normally limited to lightaircraft.

1.1.3 PNEUMATICSYSTEMS

Some older type aircraft used pneumatics to operate brakes systems and emergency landing gear extension systems. Modern, large transport aircraft use high-pressure pneumatics to actuate systems in high temperature, fire hazard areas such as; jet-engine thrust reversing systems and engine starting operations, also cabin pressurisation and air-conditioning systems. However, the main disadvantage over hydraulic actuation is its compressibility when actuating highly loaded systems such as landing gears and flight control operations. Also, difficulty in detecting leaks in the system, and problems with moisture and corrosion contamination have limited the use of pneumatic power as a remote control system.

Pneumatic power has some advantages such as; lightness and return lines are unnecessary.

1. BASIC HYDRAULICPRINCIPLES

2.1 COMPRESSIBILITY

All liquids have a high resistance to compression. The example in figure 1 shows two cylinders of equal volume, each fitted with pistons, one containing liquid, and the other air. If a force of 20,000 N (Newton's) is applied to the pistons, the decrease in volume of the air is large compared to that of the liquid, which is negligible.

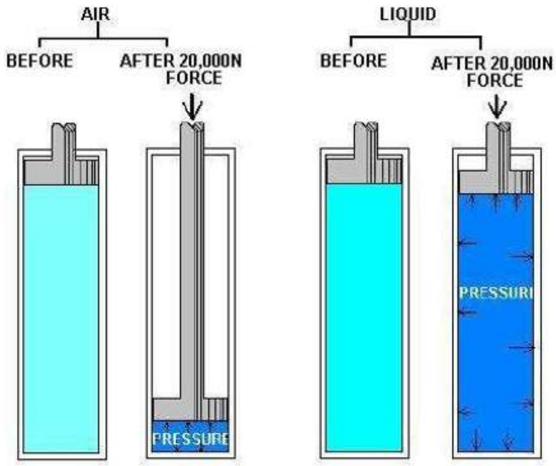


Fig. 11.1 Compressibility of Fluids

2.2 PASCALS LAW OF FLUIDCOMPRESSIBILITY

Power transmission in a closed hydraulic (or pneumatic) system, is best explained by PASCAL'S LAW, which states: "Pressure in an enclosed container is transmitted equally and undiminished to all parts of the container and acts at right angles to the enclosing walls." See figure11.2 Container(a)Container (b)

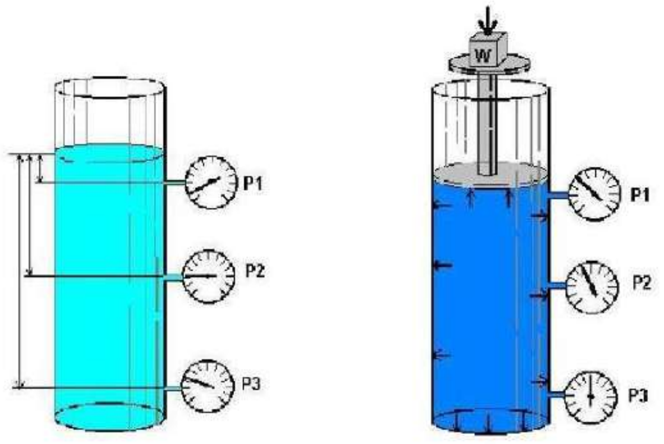


Fig. 11.2 Pascal's Law

2.3 FORCE DUE TO FLUIDPRESSURE

It has been stated that fluid pressure is transmitted equally in all directions, but in hydraulic actuation it is more important to know

the total effect of the pressure upon a particular surface. In figure 3, a pressure of 10 N/mm² is applied to one side of a piston in a cylinder actuator. The piston diameter is 40mm. Its area is: (R^2) 3.142 x 20mm² = 1,256.8mm². Therefore the force (load) that the piston can push is: 10N x 1,256.8mm² = 12,568Nf. See figure 11.3.

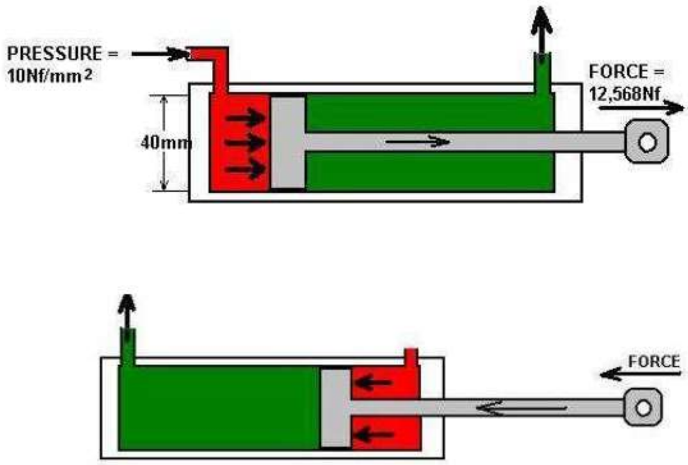


Fig. 11.3 Force by an Actuator, due to Hydraulic Pressure

2.4 DIFFERENTIAL AREA

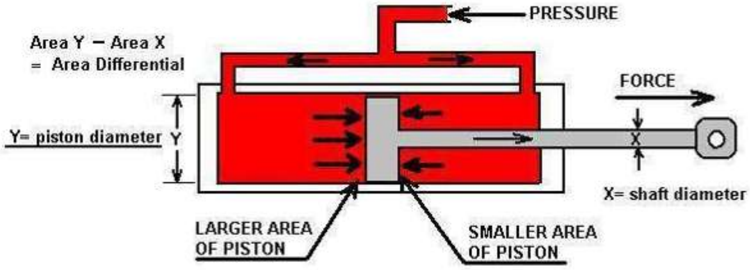


Fig. 11.4 Differential Areas

Another aspect of force produced by a fluid is the effect of differential area. When the two fluid ports are connected together, as in actuator (C) in figure 11.4. The pressure is the same on both sides of the piston. The piston will move to the right. This is caused by the area of the piston being reduced on one side by an amount equal to the cross sectional area of the piston rod.

2. HYDRAULIC FLUIDS

3.1 EFFICIENCY

The efficiency of a hydraulic system is governed by the resistance to motion, which is encountered by the fluid. In practice, a certain amount of force is necessary to overcome friction between pistons and cylinders, piston rods against bearings and seals, etc.

Friction between the fluid and the walls of pipelines and hoses depends upon the:

a. Velocity of the fluid in thepipelines.
b. Bore length and internal finish of thepipelines.
c. Number of bends in the pipelines and the radius of the bends.
d. Viscosity of thefluid.

3.2 PROPERTIES OF AN IDEAL HYDRAULICFLUID

Fluids used in an aircraft hydraulics system must have the following properties:

a. Be as incompressible as possible.
b. Have a very low viscosityrate.

c. Be free flowing over a wide temperaturerange.
d. Be chemicallystable.
e. Not affect, or be affected by the materials in the system components.
f. Must not foam during operation when subject to sudden pressure increases ordecreases.
g. Have good lubrication properties.
h. Have a high flashpoint.
i. Must not deteriorate or formsludge.

Not all fluids have these properties, therefore, the only type of fluid allowed in a specific hydraulic system is that recommended by the manufacturer of the hydraulic components (specified in the Maintenance Manual).

Technical bulletins issued by the fluid manufacturer provide information about the compatibility of the hydraulic fluids with various aircraft materials.

3.3 TYPES OF HYDRAULICFLUID

There are three basic types of hydraulic fluids used in aircraft hydraulic systems: vegetable base, mineral base, and syntheticbase.

1. Vegetable (Castor oil)base,

DTD 900/4081 (MIL- H- 7644) - Golden yellow (or Blue) in colour, used with natural rubber seals. It is inflammable, strips paint and attacks synthetic rubber. It is toxic in a fine spray mist. These systems can be flushed with alcohol. (Only found on very old aircraft types)

2. Mineralbase,

DTD 585 (MIL- H- 5606) - Red in colour, used with synthetic rubber seals. It is a kerosene-type petroleum product with good lubricating properties, but it is inflammable and attacks natural rubber. It can be flushed with naphtha, varsol, or Stoddard solvent. Neoprene seals and hoses may be used with this fluid. Its density and lubricating properties vary with temperature.

3. Synthetic esterbase,

SKYDROL 500B - Purple in colour, used with Butyl, Ethylene Propylene, or Teflon seals. It is fire resistant, strips paint and attacks natural and synthetic rubbers. It can operate in a very wide temperature range: -20ºC (-68ºF) to 107ºC (225ºF).

Skydrol systems can be flushed with trichlorethylene. Components can be cleaned with methyl ethyl ketone (MEK), or isopropyl alcohol.

Skydrol will cause irritation of the skin and burning of the eyes, therefore protective equipment and clothing should be worn when handling this fluid.

CAUTION: These fluids are not compatible with each other and must never be mixed, or used to replace each other.

Note: If a system has been inadvertently serviced with the wrong fluid, the complete system must be drained and flushed with an approved solvent, and all the seals in the system must be replaced. Seals can only be identified by Part number, obtained from the appropriate Illustrated Parts Catalogue.

3.4 SEALS

Seals are used throughout hydraulic and pneumatic systems to minimize internal leakage and the loss of system pressure. The two main types of seals used in aviationare:

a. Gaskets-These are used where there is no relative movement between the surfaces. (Covers, inspection panels and end-plate sealingetc.)

b. Packings-Used where relative movement does exist. (Piston and actuator sealing, rotating shaft sealingetc.)

All rubber seals have a Shelf life starting from the Cure date (Date of manufacture) this shelf life is dependent on the type of material, its use and the conditions of storage.

Note: All rubber items should be stored in a constant, dry and relatively cool environment, away from any form of Ultra- Violet (UV) light, (Sunlight or strong artificial light) and ionised atmospheres. (Storage batteries and strong magnetic fields). Such varying conditions and harsh atmospheres can cause rapid deterioration and reduced self-life of all rubber components.

Rubber seals are supplied individually in hermetically-sealed packaging, the Cure date being clearly marked on each package, together with the manufacturers part number, Batch number and Mil Spec. The seals should be stored in their original, unopened packaging until required for use. The issue ofsealsfromtheBondedStoreshouldbeastheyarereceived.

“First in – First Out”

3.4.1 TYPES OF SEALS

There are many different types of seals available for a variety of applications. Most can be broken down into six general designs:

Chevron/V-ring, U-section, Square section, O-ring, Bonded Seal, Wiper ring, Duplex,

One-way seals:
Both Chevron (V-ring) and U-section seals derive their name from their shape. (See fig. 5) These seals will prevent fluid flow in one direction only. To prevent flow in both directions, two sets of seals must be installed placed back-to-back. (See fig. 6)

Both seal types are used in very high-pressure situations, normally with two or more seals placed together as in fig. 6.
The apex or point of the seal rests in the groove of a back-up ring. A spreader ring is installed in front of the seal and compressed by an adjusting nut, expanding the seals and holding them tight against the actuator cylinder wall.
U-section seals are used in the same manner but with different shaped back-up and seal retaining methods.

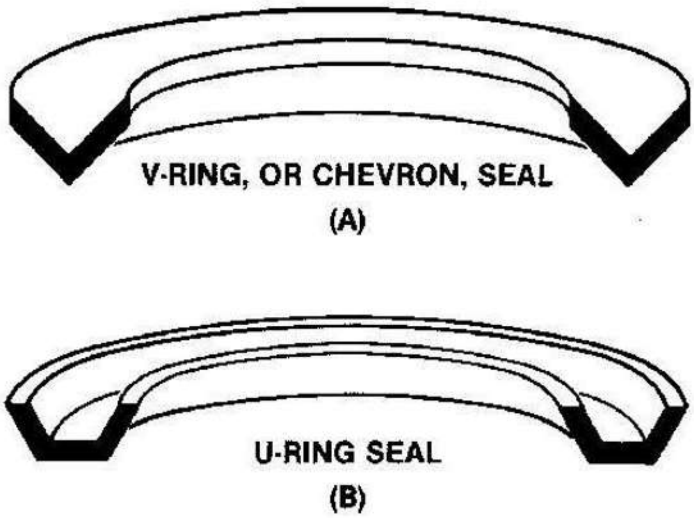


Fig. 11.5 Chevron/V-ring & U-section Seals

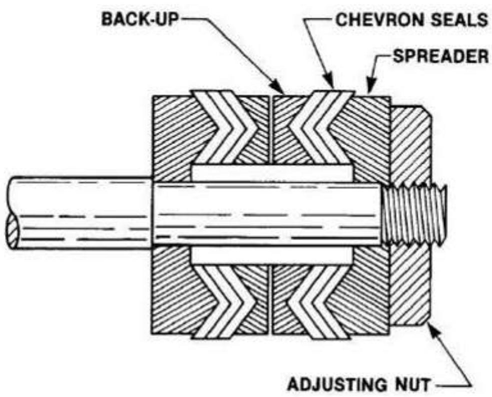


Fig. 11.6 Correct placement of Chevron seals on a double- acting hydraulic piston
Double-acting (Two-way) seals: (Fig.7) are suitable for applications where a positive seal and long life are essential. The "T" section profile provides a stable base thus preventing rolling and spiral failure. The PTFE backing rings positioned either side of the seal prevents extrusion (distortion) of the seal under high pressure and piston speeds.

Note: Extrusion is when the seal is forced to distort and wedge between the piston and cylinder wall due to high pressures and speeds. (See 'O' ring illustrationfig.?)

Duplex seals: (Fig.8) are often installed in accumulators, floating pistons and emergency air circuit components. They consist of an inner layer of soft rubber bonded to a harder outer layer, allowing it to seal against varying oil and air pressures.

Square section seals: (Fig. 9) Often used on piston heads and Landing gear Oleo's. It can withstand high pressures and sudden, high speed piston deflections. Soft metal or Tufnol back-up rings are sometimes installed to provide additional seal compression for good sealing and prevent extrusion.

Wiper Ring Seal: (Fig. 10) This type does not act as a pressure seal, but as a scraper, by removing dirt, oil and water from the piston shaft, preventing damage to the pressure seal, thereby prolonging the pressure seal life.

Note: It is extremely important to ensure the Wiper ring is installed the correct way! Otherwise it will allow FOD to pack up against the pressure seal, causing rapid seal failure and piston shaftwear.

Bonded Seal: (Fig. 11) These seals are fitted to banjo unions, adaptor plugs, flush-mounted components etc. The rubber seal is hermetically bonded to the metal washer and is fitted between the two components thereby compressing the seal to the extent of the metal washer thickness when the components are tightenedtogether.

O-ring Seal: This is the most commonly used double-acting (Two-way) seal used in fluid and pneumatic systems. It can be used either as a gasket or a packing seal in both static and reciprocating applications. The seal fits into a groove in one of the surfaces to be sealed, the depth of which should be 10% less than the seal diameter. (See fig.12). This provides the compression of the seal against the mating component to provide a seal under zero pressureconditions.

Fig. 13 (A) shows the correct sealing condition. Fluid pressure forces the seal against the side of the grove and wedging it tightly against the piston and cylinder wall. With less than 10% "pinch", fluid will leak past the seal under low pressure conditions. (See fig. 13 (B).

In some high pressure applications a back-up ring is installed on the non-pressurised side of the O-ring on one-way operations, but both sides of the O-ring should have back-up rings installed on two-way operations to prevent extrusion of the seal between the piston and cylinder wall. (Fig. 13 (C)).

The mouth of a cylinder in which an O-ring equipped piston fits must be chamfered to avoid cutting or pinching of the O-ring during installation. (Fig. 13 (D)).

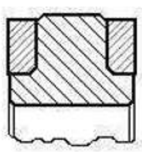


Fig. 11.7 Double Acting seal

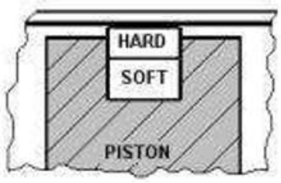


Fig. 11.8Duplex Seal

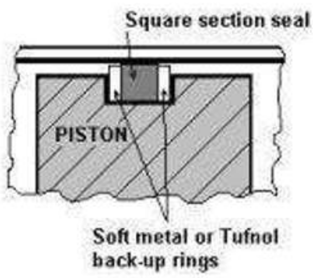


Fig. 11.9 Square SectionSeal

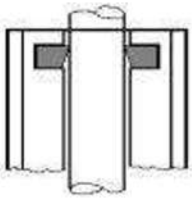


Fig. 11.10 Wiper Ring Seal

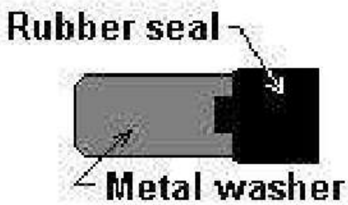


Fig. 11.11 Bonded Seal

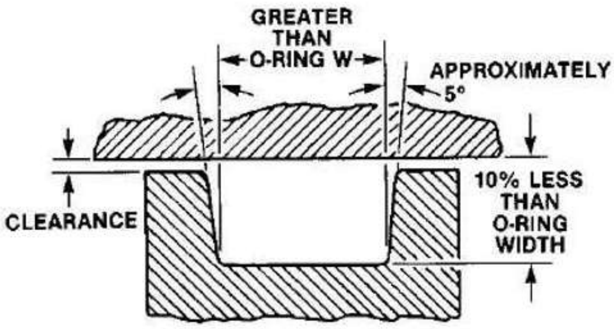


Fig. 11.12 The groove in which an O-ring seal fits should be wider than the O-ring, but the depth should be 10% less than the O-ring diameter.

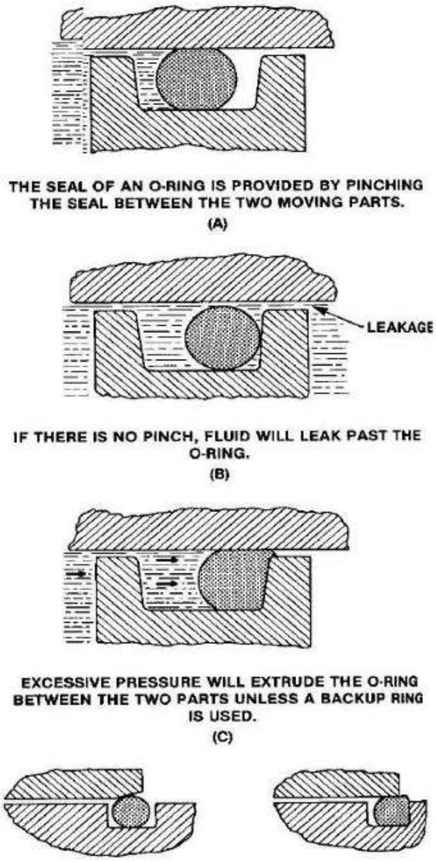


Fig. 11.13 Sealing action of an O-ring

3. HYDRAULIC POWERSYSTEMS

As aircraft have become more complex, the demand for hydraulically operated equipment has increased. Retractable landing gear, wing flaps, brakes, engine cowl flaps, passenger doors and stairs, hydraulically powered flight controls, i.e. elevators, rudders, ailerons, air brakes and lift dump systems, leading edge flaps and slats. On modern aircraft, this demand has warranted the design of a complete and independent; 'Hydraulic Power Supply System' Figure 14 shows a block diagram of a large, jet transport aircraft. To aid in understanding the development of the systems, we will start with a very basic hydraulic system and build on it as we discuss the various components.

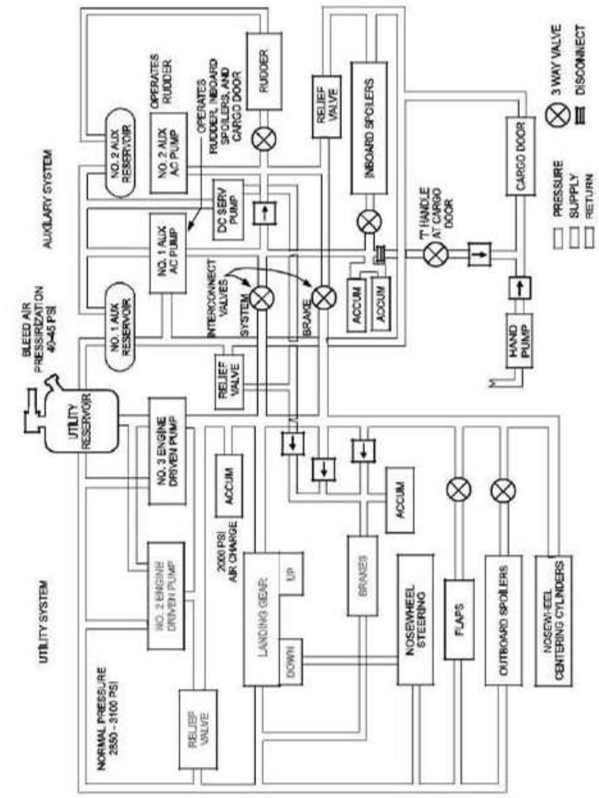


Fig. 11.14 Large Aircraft Hydraulic System

4.1 SIMPLE HYDRAULICSYSTEM

Aircraft hydraulic systems consist of a varying number of components, depending on the complexity of the system; i.e. fluid to transmit the force, pipelines and hoses to carry the fluid to the components, a reservoir to store the fluid, a pump to move the fluid, actuators to change the flow of fluid into mechanical work, and valves to control the flow, direction and pressure of the fluid.

We will start with a simple system and add components to it, thereby developing to a more complex system resembling that which you are likely to encounter in the 'Aircraft Maintenance work-place'.Simple hydraulic system using a Reservoir, hand-pump, non-return valves, double-acting, linear actuator and a three position, selectorvalve.

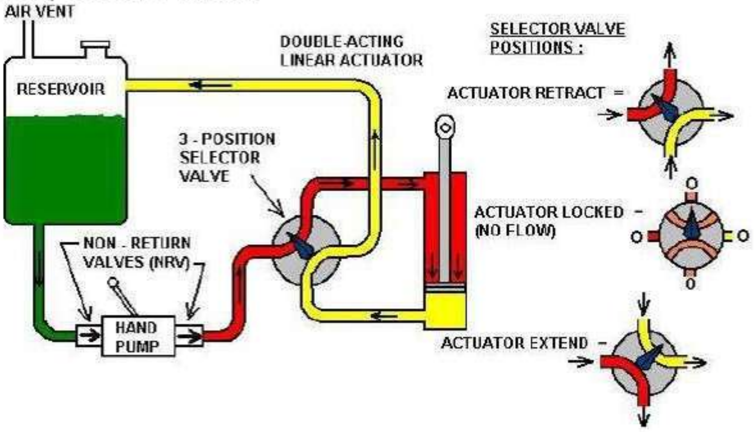


Fig. 11.15 Simple Hydraulic System

4.1.1 OPERATION (FIG. 15)

Hydraulic fluid, stored in the reservoir, is drawn into the hand pump via a pipeline attached to the bottom of the reservoir, through a non-return valve (NRV) and into the hand pump. The pump pushes the fluid through another NRV, via the pressure pipeline, to a 3-position selector valve. Depending on the position selected, it will either direct the fluid through a port, to one side of the double-acting, linear actuator piston, or the other. Or it can be selected to the "Off" position, which locks the fluid in the actuator and prevents any movement of the piston in either direction. Fluid from the "non-pressure" side of the actuator piston is diverted back to the reservoir by another port in the selector valve via a returnpipeline.

By installing an Engine driven pump (EDP) (See figure 16) the pilot is relieved from the physical task of hand pumping, which allows him to concentrate fully on flying the aircraft. The hand pump is still retained however, and is used as an Emergency backup, in case of an EDP failure. The hand pump is also used for testing the hydraulic system when the aircraft is on the ground during servicing operations and to build up the pressure in the system to operate the brakes before the engines arestarted.

The use of an EDP creates a problem in that the pump is still maintaining pressure in the system when it is not needed during cruise flight, thereby wasting valuable engine power. The pump absorbs very little power when it is not moving fluid against an opposition. This problem is overcome by the installation of a pump, unloading valve. (Also called an; Automatic Cut-out valve). This valve relieves the pressure off the pump by diverting the fluid back to the reservoir. The fluid circulates freely from the pump, to the reservoir and back to the pump again with no opposition, thereby using very little engine power. The selector valve holds fluid trapped in the actuator, preventing any movement, or creep of the piston rod. (The actual operation of the unloading valve (cut-out valve) will be discussed in detail in a latersection.)

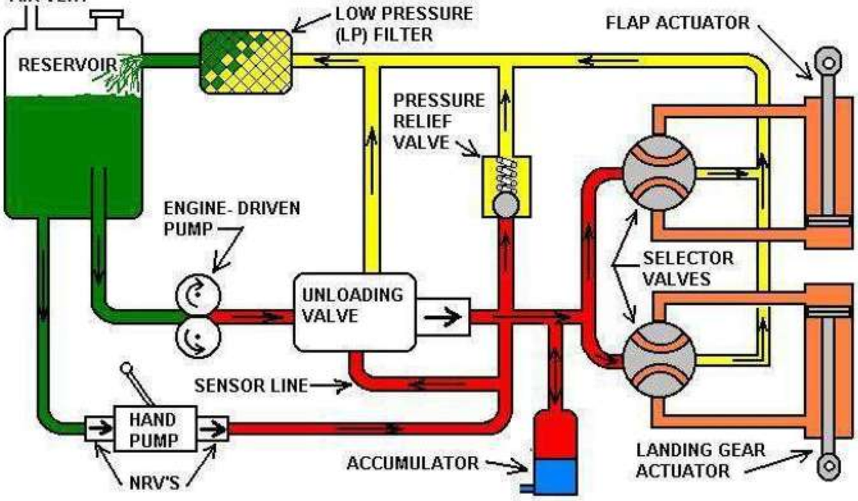


Fig.11.16 Non Self-idling Hydraulic System

When the piston has reached the end of its stroke, pressure will build up in the system. This is relieved by the system pressure relief valve, which dumps the excess pressure fluid back to the reservoir.
To maintain a positive pressure in the system when it is not operating, a non-return valve is installed in the pressure line from the pump, just after the unloading valve. This prevents the back- pressure being sensed by the pump and allows the unloading valve to divert the fluid back to thereservoir.

An accumulator is installed to maintain a pressurised supply of fluid to absorb the initial pressure drop in the system when a selector valve is opened; it also acts as a "shock absorber" to cushion the pressure surges of the fluid when the actuator pistons reach the end of their travel, thus preventing damage to the components. The accumulator has two compartments separated by a movable piston or diaphragm. One compartment is connected to the "pressure manifold" (pressure supply line) the other compartment is charged with air or nitrogen through a charging valve. (Nitrogen is used because all water vapour is removed during the processing of the gas at manufacture and the fact that Nitrogen is an inert gas). This nitrogen pressure is felt across the piston or diaphragm by the system fluid.
To actuate any hydraulic system with the engines running, the pilot places the selector lever in the desired position. (Let us use a "Flap selection as an example) The system senses the "pressure-drop" and pressurised fluid flows from the accumulator, through the selector valve to the desired side of the actuator. The pressure-drop is also sensed by the unloading valve, which stops dumping pressure back to the reservoir via the return manifold and allows full pump pressure to feed the pressure manifold again during the operation of theactuator.

This action also charges up the accumulator again until the system pressure relief valve senses the maximum system pressure, above which the relief valve dumps the excessive pressure back to the reservoir via the return manifold. Also at this time, the unloading valve once again senses the high-pressure build-up and diverts the pump pressure back to the reservoir. The system continues to recycle in this manner whenever there is a demand for hydraulic power.

As we continue to evolve the hydraulic system, you will notice that the reservoir has been altered to include a supply line to the EDP which is set higher in the reservoir than the emergency hand pump supply line. This extension is called a "standpipe" or "stackpipe". Its function is to ensure that sufficient fluid is retained to operate the essential services such as brakes and landing gear extension, in the event of loss of fluid due to an excessive leak, down-stream of the brake and landing gear fluid pressure supply line. If the broken line or leaking component can be isolated, there will still be enough fluid remaining in the reservoir to allow the emergency hand pump to lower the landing gear and operate the brakes.

We can now add a few other items to the system to make it more usable. (Figure 17)

To keep the fluid in the system clean, we need a filter through which all the fluid will pass. A typical location for the filter is in the return line just before the fluid enters the reservoir. This is called the Scavenge or Return filter. Here, it will catch all of the fluid, both that which is used to operate the actuators and that which circulates through the pump via the unloading valve. A second filter is installed immediately after the EDP to protect the rest of the hydraulic system from contamination in case of EDP failure.

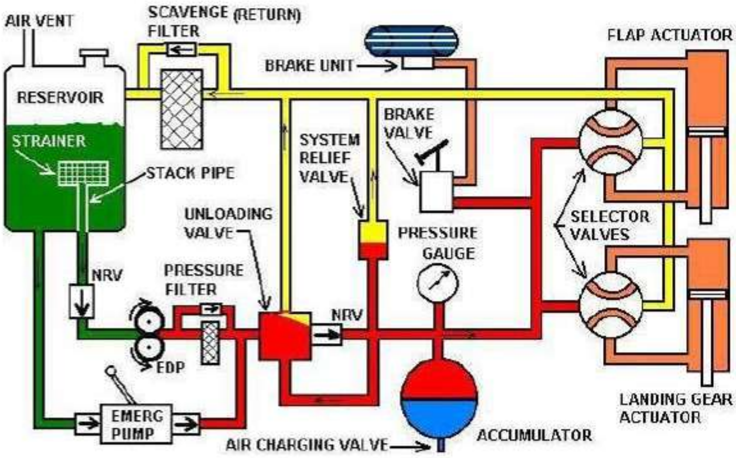


Fig. 11.17 Typical Constant Delivery (non-self idling) Hydraulic Power Circuit

4. SYSTEMCOMPONENTS

5.1 INTRODUCTION

The following paragraphs describe various hydraulic components, including those used in the circuits. Some components are similar in construction and operation, but vary in the function they perform. Therefore, it is usual for the name of the component to indicate its purpose. Unfortunately, due to a difference in the terms used by the various manufacturers, some components with different names serve similar functions, such as a selector valve and a control box act fundamentally as a control valve. However, where different terms are used for similar components, it will be mentioned in the appropriate paragraph.

5.2 RESERVOIR’S

The reservoir stores the hydraulic fluid. It supplies fluid to the system through a pump and receives the return fluid from the system. It accommodates the extra fluid caused by thermal expansion and compensates for slight leaks, which may occur throughout the system. Through its design, it provides a reserve supply of fluid for emergency operation of systems which are essential for flight control and landing. This is done by the installation of a standpipe (stack pipe). It should also be observed that when the actuator piston rod is moved inwards, less fluid is required as the piston rod occupies space within the cylinder. With the actuator in this position, the surplus fluid is stored temporarily in the reservoir until the piston travels in the opposite direction.

5.2.1 VENTEDRESERVOIR

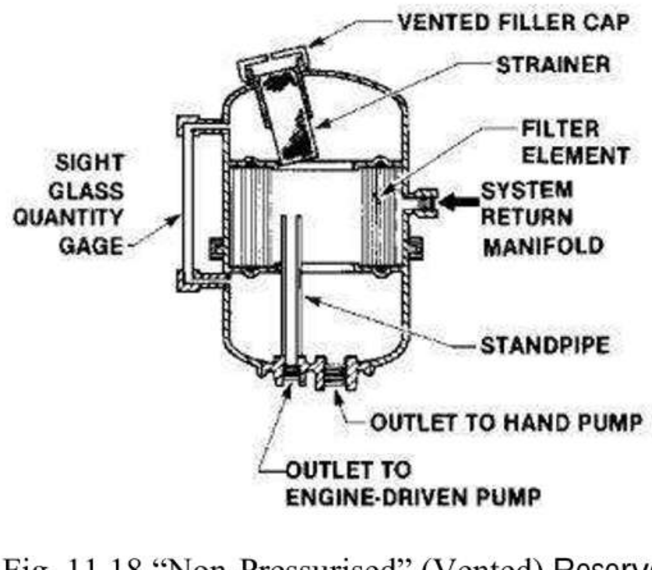


Fig. 11.18 “Non-Pressurised” (Vented) Reservoir

CONSTRUCTION

1. Welded, AluminumAlloy.
2. Vented FillerCap.
3. Metal, gauze strainer, to prevent FOD (Foreign Object Damage) and contamination, during thefillingoperation.
4. Sight glass, Indicating Maximum, Minimum and Normal Operating fluidlevel.
5. Remote level indicator, (To gauge on pilot's instrument panel)
6. Inlet connection. (From system Returnmanifold)
7. Outlet connections, to Engine driven pump, (EDP) and Emergency hand-pump,(EHP)

A Vented reservoir is the type normally fitted to a Piston-engine, un-pressurised, aircraft, which would normally operate below 20,000 feet altitude.

The reservoir is located at a higher level than the EDP's to ensure a positive "head of pressure" supply of fluid throughout all normal flight manoeuvres.

However, when flying through turbulent air, negative "g" forces or high roll angles, could cause a temporary loss of supply to the EDPs' allowing them to "run dry", resulting in pump inlet cavitations. This could seriously damage the pump and cause it to fail. To compensate for this, a low-pressure pump is sometimes installed between the reservoir and the EDP's to ensure a positive head of pressure during such conditions.

5.2.2 PRESSURISEDRESERVOIR

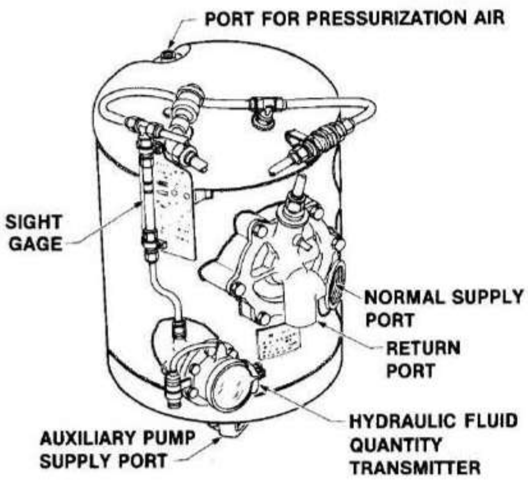


Fig. 11.19 Typical "Pressurised" Reservoir

Jet and Turbo-prop aircraft that fly at altitudes higher than 20,000 feet require the hydraulic reservoir to be pressurises to prevent foaming of the fluid due to the low ambient air pressure at high altitudes, and to prevent pump cavitations in its inlet.

There are several ways in which pressurisation can be achieved:
a A nitrogen chargedcylinder.
b Cabin pressurisationair.

c Engine Compressor/ Bleed air.(P3)
d Hydraulic systempressure

Construction

1. Welded AluminumAlloy.
2. Pressurised via a Pressure Reducing Valve (PRV) from Engine Compressor/ Bleed air, Cabin pressure, or from a Nitrogen storagecylinder.
3. Fluid quantity sight glass. (Indicating Max, Min, and Normal Operating fluidlevels)
4. Max, pressure relief/ depressurisingvalve.
5. Remote fluid level and temperature indicators (To gauges on pilots instrumentpanel)
6. Return fluid de-aerator (Separates any air bubbles (foaming) absorbed into the fluid during pressure changes, allowing de-aerated fluid to fall back into the reservoir.

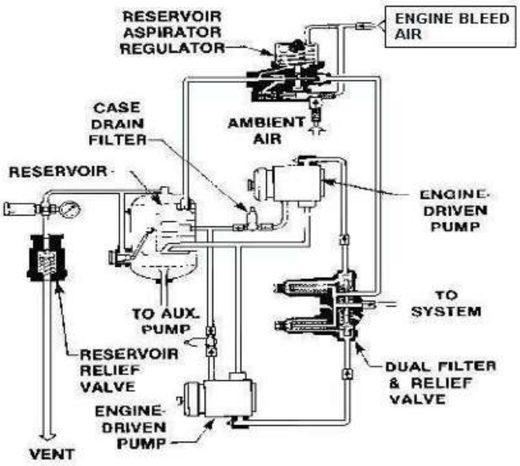


Fig. 11.20 Pressurised" Reservoir using an Aspirator Regulator

Figure 11.20 shows a typical method of pressurising a reservoir using Engine bleed-air (P3) or Pressurised Cabin air. Pressurisation can vary between 30 to 45psi depending on system design. Figure 11.21 shows a typical reservoir pressurised by hydraulic system pressure.

Operation

System pressure act's on one side of a small piston attached to the bottom of the main piston shaft, which exerts pressure on the fluid through the main piston. Pressure ratio's of about 50:1 are common for this type of reservoir. This means that a 3,000 p.s.i. system pressure can pressurise the reservoir fluid to 60psi. The fluid level in this type of reservoir is indicated by the amount the piston sticks out of the body at the bottom of the reservoir. Low fluid level is sensed by the "Level sensing switch", which illuminates a light on the pilots instrument panel. In this pressurised condition, both the return line from the system, and the EDP supply line will bepressurised.

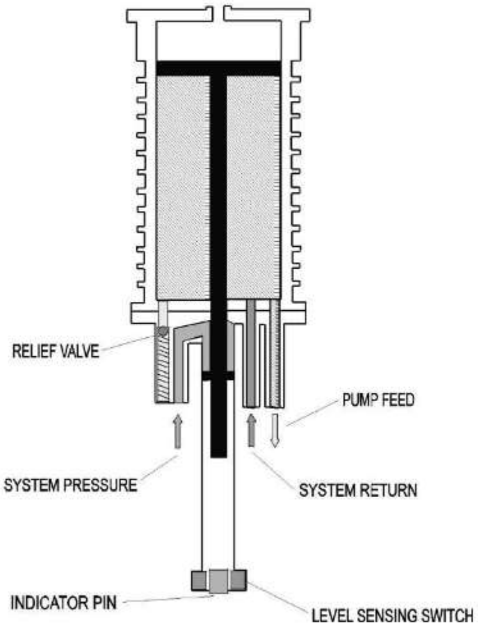


Fig. 11.21 Pressurised Reservoirs

5.2.3 REMOTE SERVICINGPOINT

On modern Jet and Turbo-prop aircraft it is common practice to install a Remote Servicing Point (Fig. 11.22) in a convenient place, with easy access from ground level for maintenance personnel to carryout replenishment of the hydraulic fluid level.

The Service point usually consists of;

a Self-sealing, quick release, fillerpoint
b Handpump.
c Reservoir de-pressurisationvalve.
d Levelindicator.
e SelectorValve

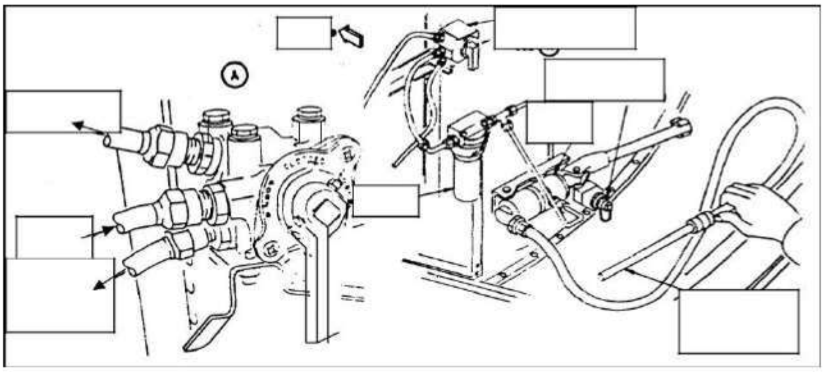


Fig. 11.22 Hydraulic Reservoir, Remote Servicing Poin

The servicing point allows fast and efficient servicing of the complete system contents at all reservoirs. Before connecting to the system, the Maintenance Manual procedures must be followed and all hydraulic systems must be in the prescribed position to ensure the correct fluid level is being indicated. The reservoir de- pressurisation valve must be operated to relieve the reservoirpressure.

5.2.4 FILTERS

The extremely small operating clearances in modern hydraulic pumps, valves and components, require very effective filtration of the fluid. Therefore, filters are rated by the size of particles, which they can arrest. The size of these particles is measured in Microns. One micron is equal to one millionth of a meter or 0.000039 inch. An indication of just how small these particles are can be seen by the information in Fig. 11.23. (E.g. Particles as small as 4 microns are just visible with the naked eye) Filters, which will remove particles less than 10 microns, will maintain a very clean fluid.

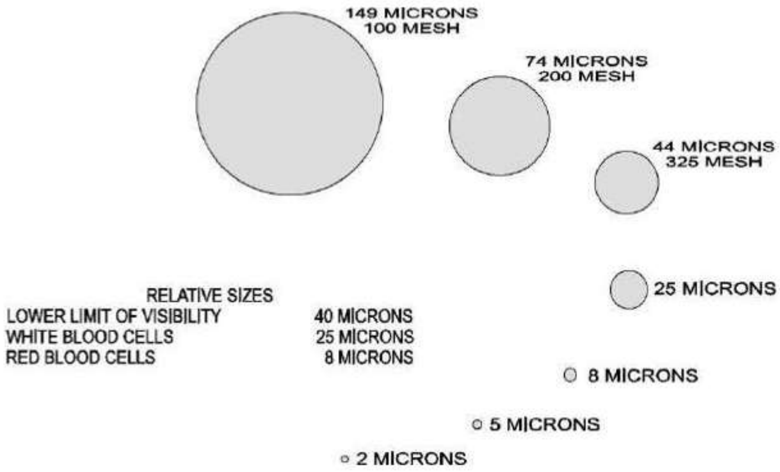


Fig. 11.23 Relative Size of Particles Arrested by a Hydraulic Filter

There are several types of filtration designs; two of the most common types used are shown in Fig. 11.24 & 11.25. The paper element type, (Fig.11.16.) is made of specially treated paper folded into pleats to increase its surface area. The micronic element is wrapped around a spring wire coil to prevent it from collapsingunderhydraulicpressure.Suchfiltersnormallyhavea
bypass valve across the filtering element in case the filter becomes blocked with contamination, in which case the fluid bypasses the filter allowing "unfiltered" fluid into the system rather than "starving the system completely of fluid.
Aircraft hydraulic filters are fitted at strategic locations throughout the system.
The main locations being:
L.P. (Low pressure) filters.
H.P. (High Pressure) filters. By- pass filter.

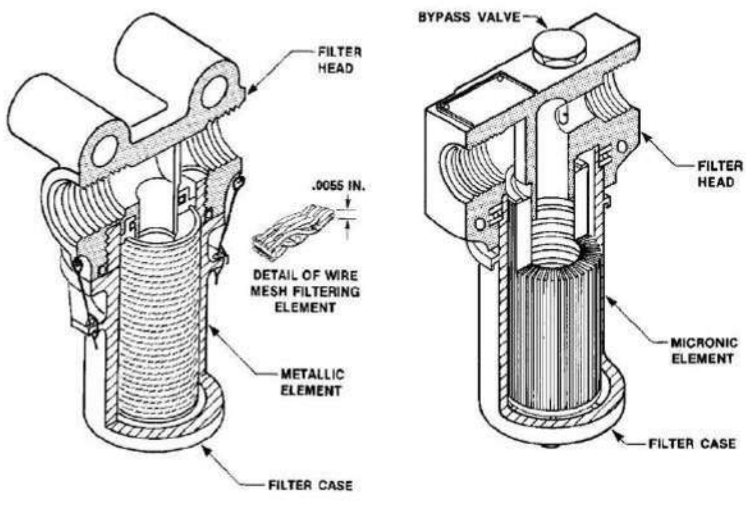


Fig.11.24 Filters

5.3 ACCUMULATORS

5.3.1 PURPOSE

a. To absorb fluctuations inpressure.
b. Toensureimmediateresponseanddeliveryofpressurised fluid on demand.
c. To allow limited operation of systems when the EDP is not running.

Hydraulic fluid is non-compressible, and pressure can only be stored with compressible fluids. The compressibility effect can be gained by the using an accumulator.

5.3.2 CONSTRUCTION

Accumulators are constructed from high-strength materials such as cast, or machined, Aluminum alloys, or stainless steels. They consist of a container divided into two compartments by some form of movable, sealing partition, there are three types commonly used in aircraft hydraulic systems: Piston type, Bladder type, and Diaphragm type. The Piston type, (Figure 11.18) is in the form of a cylinder with a floating piston. One compartment is connected to the system pressure manifold, the other is charged with compressed dry-air, or nitrogen, through a high pressure charging valve. The charging pressure is normally around, 1,500psi. (Approximately half system operatingpressure

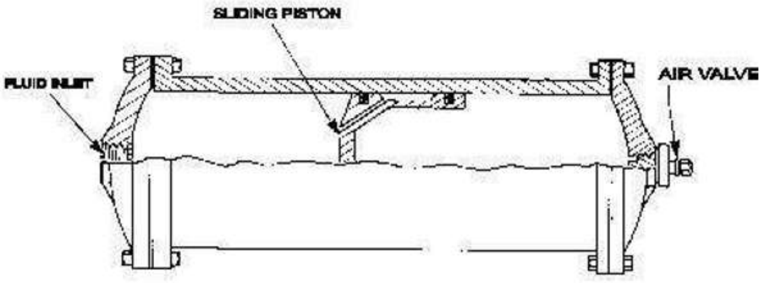


Fig. 11.25 Sliding Piston Accumulator

5.3.3 CHARGINGOPERATION

As the accumulator is charged, (With "zero" system hydraulic pressure) the piston moves to the top of the cylinder until it reaches its full stroke. The nitrogen pressure is then allowed to build up to approximately 1,500psi. The accumulator is now charged. A special, High-pressure (HP) valve, (See Figure.11.19) is then checked for leaks and the dust cap installed. NOTE: HP valve cores are identified by a letter "H", embossed on the end of the stem, and are NOT interchangeable with inner-tube and tubeless tyre cores.

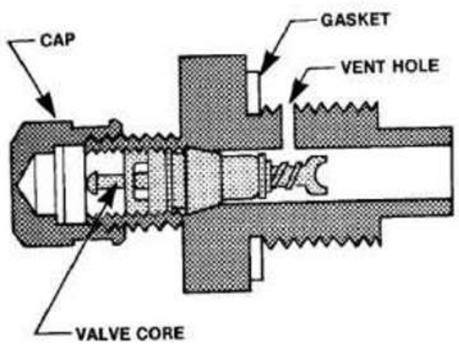


Fig. 11.26 AN812, High Pressure (HP) Air Valve for Accumulators and Air-Oil Shock Struts

5.3.4 BLADDER & DIAPHRAGM TYPEACCUMULATORS CONSTRUCTION:-

Figure. 11.20 (A) & (B).

These accumulators are spherical in shape, usually made of cast, or moulded aluminum, sometimes steel wire wrapped. Others are of stainless steel. Both form two compartments as in the "piston" type. One to accept the dry-air, or nitrogen charge, the other connected to the fluid system pressuremanifold.

OPERATION: -

The operation is similar the "piston" type in that, the lower compartment is charged with dry-air, or nitrogen to a specified pressure, (usually between: 1,200 / 1,500psi).
As pressure builds up in the hydraulic pressure manifold above the nitrogen pressure, hydraulic fluid is forced into the fluid compartment of the accumulator and deflects the bladder, or diaphragm, compressing the nitrogen until maximum system pressure is reached. (Usually around, 2,500 / 3,000 psi), Thereby providing a flexible cushion of In-compressible fluid via the medium of a compressible gas, transferred through a flexible bladder, ordiaphragm. Some systems have a pressure gauge connected to the nitrogen side for quick monitoring during servicing, without disturbing the charge valve.

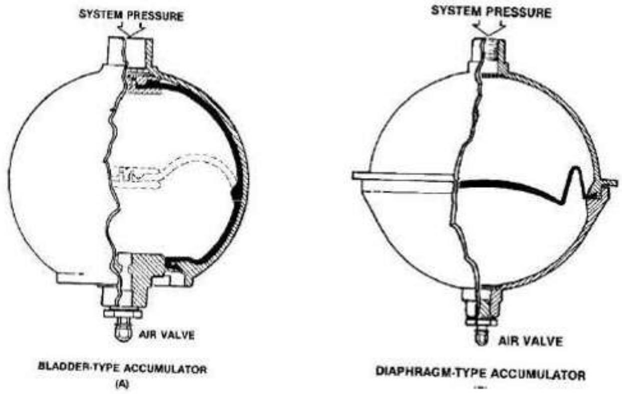


Fig. 11.27 Bladder and Diaphragm Type Accumulators

Charging Valves
On the previous page, Figure 11.26. illustrates a simple high- pressure valve, which seals through the valve core. Figure 11.28 shows two types of metal-to-metal sealing vales which are more commonly used.

The AN6287-1 valve does not depend on the valve core to provide the seal, but seals through metal-to-metal contact between the stem and the valve body. To release air, loosen the swivel nut one turn and de-press the valve core. To charge air, connect the special, high pressure hose fitting and apply pressure through a regulator valve with the swivel nut open at least one full turn.

CAUTION: Use great care and protect eyes and skin while charging, or releasing high pressure air, or nitrogen.
The MS28889-1 valve is also used in many high pressure systems and is similar to the AN6287-1, but with different features.

a. The swivel nut is the same size as the hexagon valve body, whereas the swivel nut on the AN valve issmaller.

b. The stem is retained in the valve body by a roll pin to prevent the stem from being unscrewedfully.

c. There is no valve core in this type, just the metal-to-metal sealingsurface.

CAUTION: ALWAYS install the special, high pressure valve cap after you have checked for leaks, and on completion of the work.

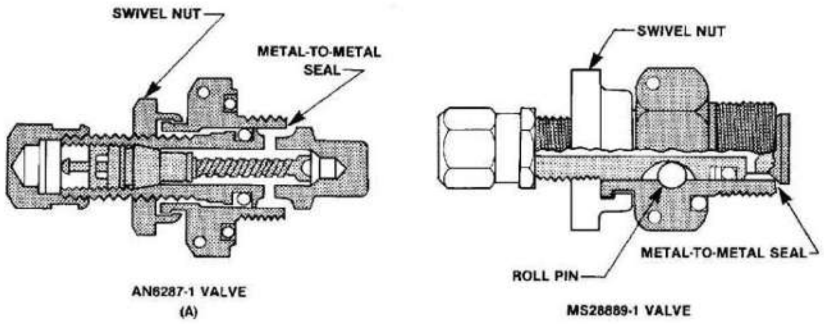


Fig. 11.28 Charging Valves

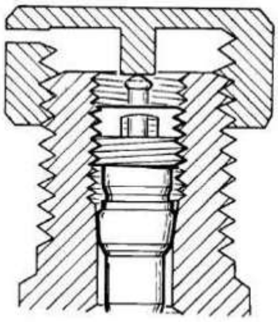


Fig. 11.29 Deflation Cap

Figure. 11.29 Shows a special cap for safely deflating an accumulator, or air-oleo strut under controlled conditions. Screwing on the cap progressively pushes the valve core off its seat slowly, allowing gradual de-pressurisation to take place.

5. PRESSURE GENERATION (HYDRAULIC PUMPS)
Hydraulic power is transmitted by the movement of fluid by a

pump. The pump does not create the pressure, but the pressure is produced when the flow of fluid is restricted. We often use a hydraulic analogy for studying electricity; therefore, we will use our knowledge of electricity to help us understand hydraulic power.

The flow of fluid in a line is equivalent to the flow of electrons in a wire, the current (I). The pressure that causes the flow is the same as the voltage (E), and the opposition to the flow of fluid is the same as the resistance (R). If there is very little friction in the line, very little pressure is needed to cause the fluid to flow. In Fig. 11.30 we have a very simple electrical system, consisting of a battery, an ammeter, a voltmeter, and a resistor. The ammeter measures the flow of electrons in the circuit, and the voltmeter measures the voltage (pressure) drop across the resistor. The hydraulic system in Fig.11.31 is very similar in its operation. The pump moves the fluid through the system and may be compared to the battery, which forces electrons through the circuit. The flow meter measures the amount of flow, the valve acts as a variable opposition to the flow, and the pressure gauge measures the pressure drop across thevalve. When the variable resistor is set to its minimum resistance, the current will be maximum and there will be a minimum voltage drop across the resistor. In the same way, when the valve is fully open, there will be a maximum flow of fluid and a minimum pressure drop across the valve. When the resistance in the electrical circuit is increased, the voltage across the resistor will increase and the current will decrease. In the hydraulic system, as the valve is closed, the flow will decrease and the pressure will increase. When the valve is fully closed, there will be no flow and the pressure will increase to a valueas highas the pump can produce. If the pump is of the constant displacement type, there must be some provision in the system to relieve the high pressure; otherwise the pump will be damaged, or components in thesystemdamaged.

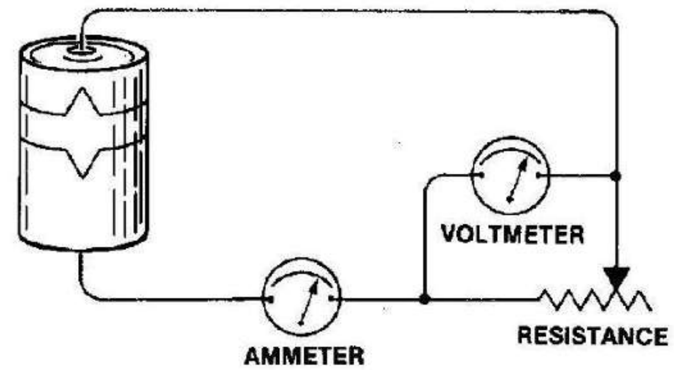


Fig.11.30 In an Electrical System, the Battery causes the flow and the resistance causes the pressure (A)

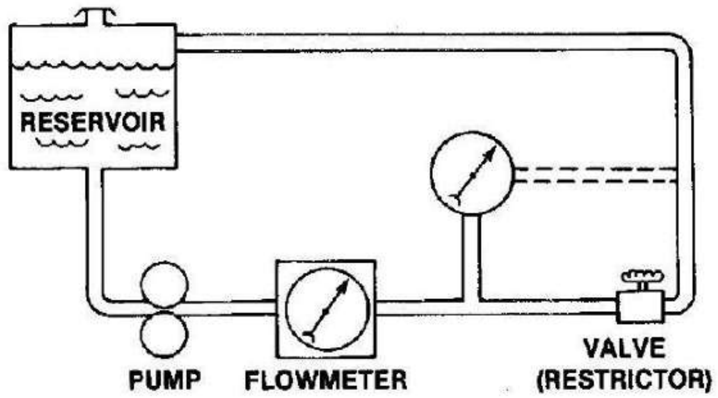


Fig.11.31 In a Hydraulic system the pump causes the flow and the resistors causes the pressure (B)

6.1 HAND PUMPS

Single-action, piston type pumps, move fluid on one stroke only, while double-action pumps move fluid on both strokes. Most modern aircraft hydraulic systems use the double-action type because of their greater efficiency.

Figure 11.32 illustrates the operating principle of a typical double- action hand pump. This type is called a "Piston rod displacement pump" because the pumping action is caused by the difference in area between the two sides of the piston, due to the piston rod area displacement.

In view (A), the handle is pulling the piston to the left. Fluid is drawn in through the inlet check valve, when the piston reaches the end of its stroke, chamber "1" is full of fluid and the inlet check valve closes by the action of its spring.
As the handle is moved to the right, as in view (B), the piston is pushed to the right, forcing fluid through the outlet check valve and into chamber "2". The volume of chamber "2" is smaller than chamber "1" because of the piston rod area; therefore, the excess fluid is displaced through the outlet port.

On the return stroke, (To the left again) the remainder of the fluid in chamber "2" is also displaced through the outlet port. At the same time, a new charge of fluid is being drawn into chamber "1", from the inlet port, through the inlet check valve.

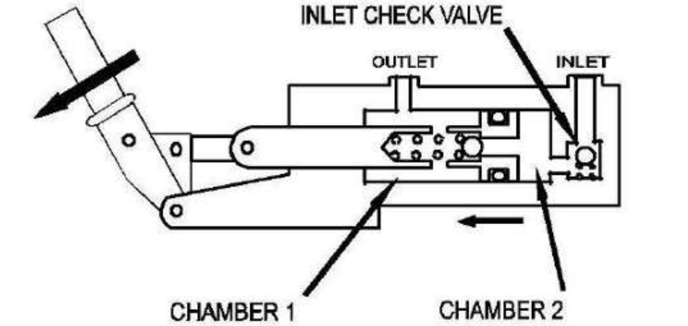


Fig. 11.32 Hand Pump Operation(A)

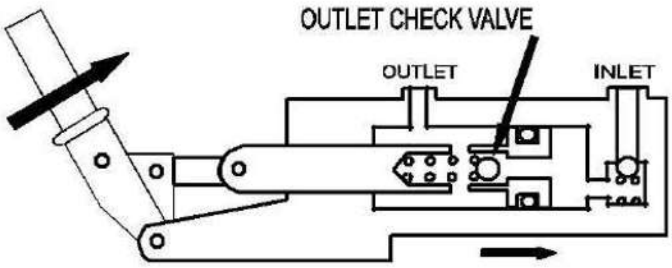


Fig. 11.32 Hand Pump Operation(B)

6.2 SUCTION BOOSTPUMPS

This is a low-pressure pump, (Approx. 100 psi) whose prime

function is to provide a positive pressure to the inlet side of the main system pressure pump, to prevent cavitations. It is located between the reservoir fluid supply and the Engine-driven pump (EDP) inlet. The pump can be mounted independently, or attached to the reservoir.

It is normally powered by a 3-phase electric motor, and in some cases, by a hydraulic motor driven by system pressure.

Many modern hydraulic pumps have a "Spur-gear" type pump built into the body of the main pressure pumps. (This will be discussed in more detail under Variable displacement, piston type pumps).

In the event of a boost pump failure, The EDP (Main pressure pump) and system will still operate, but at a possible reducedefficiency with a risk of cavitation of the EDP in severe cases.

6.3 POWERED PUMPS

The only function of a pump is to move fluid through the system. There are a number of ways powered pumps can do this.

The two basic types are:
1. Constant Volume/Fixed displacement (Non-self idling). Figures. 11.33 &11.34.
2. Constant Pressure/Variable displacement (Self-idling).Figures.11. 43 &11.44.

A Constant Volume/Fixed displacement, (Non-self idling) pump moves a specific volume of fluid for each revolution of the drive-shaft. It requires some form of Regulator, or Relief valve (Sometimes called a; Cut-out, or Unloading valve) in the system to relieve the pressure which builds up when the pump delivers more fluid than the system requires. (See Figs. 11.16, 11.17, and 11.33.).

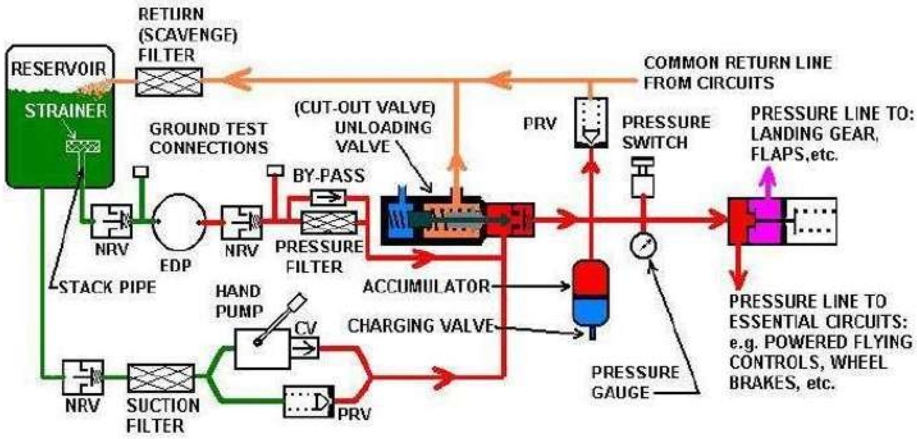


Fig. 11.33 Constant Volume/Fixed displacement (Non-self idling) Pump System

6.3.1 CONSTANT VOLUME FIXED DISPLACEMENT PUMPS
(Non Self- Idling)

The most common type of Constant volume (CV) pump for medium-pressure systems is the Gear pump type. (See Fig. 11.34.)

These pumps are very rugged and dependable, with few moving parts, relatively easy and in-expensive to manufacture, compared with other types.

The left-hand gear is driven by the engine through a splined shaft. This gear rotates in a close fitting housing and drives the right- hand gear housed in the same manner. As the gears rotate in the direction shown, fluid is transported between the teeth around the outside of the gears, from the inlet side of the pump. When the teeth mesh with each other, in the outlet chamber, fluid is displaced into the outlet side of the pump.

A very small amount of fluid is allowed to leak past the gears and around the shaft for lubrication, cooling, and sealing. This fluid drains into the hollow shafts of the gears where it is picked up by the low pressure on the inlet side of the pump.

A relief valve holds the oil in the shafts until it builds up to about 15 psi. This is called; case pressure. This is maintained so that, in the event of the shaft, or seal, becoming scored, fluid will be forced out of the pump rather than air being drawnin.

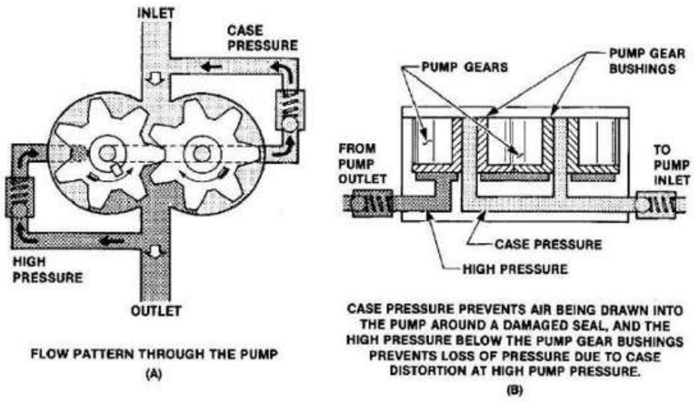


Fig. 11.34 Gear Type HydraulicPump

Spur gear pumps provide a good, non-pulsating, high flow rate, but are limited to pressures up to about 800psi. Because of this, they are more commonly used on smaller aircraft, but also as pressure back-up pumps for the more powerful, piston-type pumps on larger aircraft, whose hydraulic systems operating pressures are between: 1,200 to 3,000psi.

6.3.2 PISTONPUMPS

Aircraft hydraulic systems that require a relatively small volume of fluid under a pressure of 2,500 psi or more, often use fixed-angle, Multi-piston pumps as shown in fig.11.28.

Axial Piston Pump, (Figure. 11.28)

a. This type of pump consists of a bronze cylinder block, rotated by a splined drive shaft, driven by the engine, through a universal link. The cylinder housing is mounted at a fixed angle to the drive shaft and bearing housing. The cylinder block usually has seven, or nine axially-drilled holes, which accommodate, “High precision, close fitting pistons”. These in turn are attached by a ball-jointed rod to a pump drive plate which is rotated by the engine. As the piston and cylinder block assembly are rotated by the drive-shaft, the pistons on one side (upper pistons) are at the bottom of their stroke, and open to the Inlet port due to the angle of the housing. The pistons on the opposite side (Bottom pistons) are then at the top on their stroke, open to the Outlet port. (See fig.11.35)

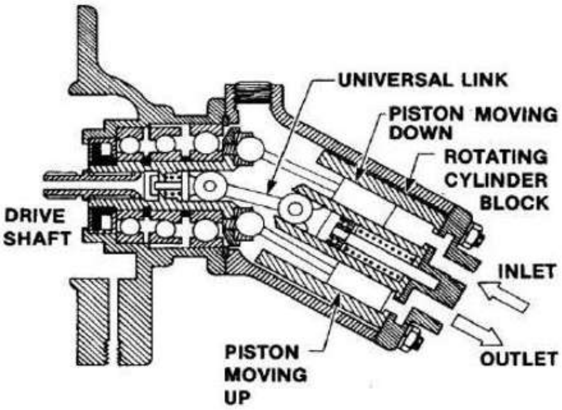


Fig. 1135 Fixed Angle, Axial, Piston Type Hydraulic Pump

The stroke (Displacement) of the piston is dependent on the angle of the cylinder housing to that of the bearing housing. As the whole assembly is rotated, fluid is drawn in by the piston moving down in the one side of the cylinder block, while fluid is being pushed out by the piston moving up in the opposite side of the cylinder block.

A valve plate with two crescent-shaped openings cover the end of the cylinders. One above the pistons moving up, thereby pushing fluid through the Outlet port. The other, above the pistons moving down, drawing fluid into the cylinder, through the Inlet port.

b. Radial PistonPumps

In this type of fixed volume pump, the cylinders are arranged radially around an eccentric crankshaft. (See Fig.11.29A & B). When the crankshaft is rotated, the pistons move outwards in each cylinder, forcing pressurised fluid into the annular outlet port through each cylinder delivery valve. When each piston is at the

bottom of its stroke, the pistons uncover the inlet port, allowing a fresh charge of fluid to enter each cylinder.

The fresh charge of fluid is then compressed as the piston moves outwards again forcing fluid once more through the delivery valve.
This process is repeated with each revolution of the eccentric crankshaft.

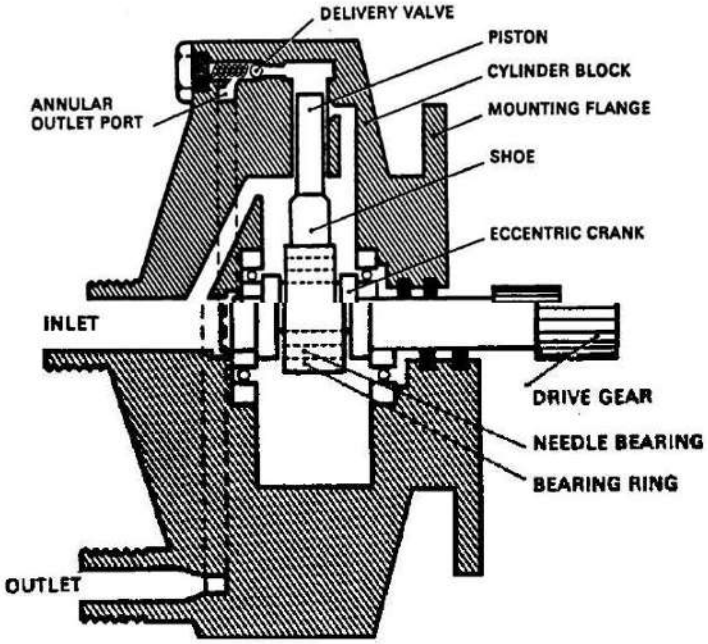


Fig. 11.36 Typical Radial, Piston-type, Hydraulic Pump - Side View

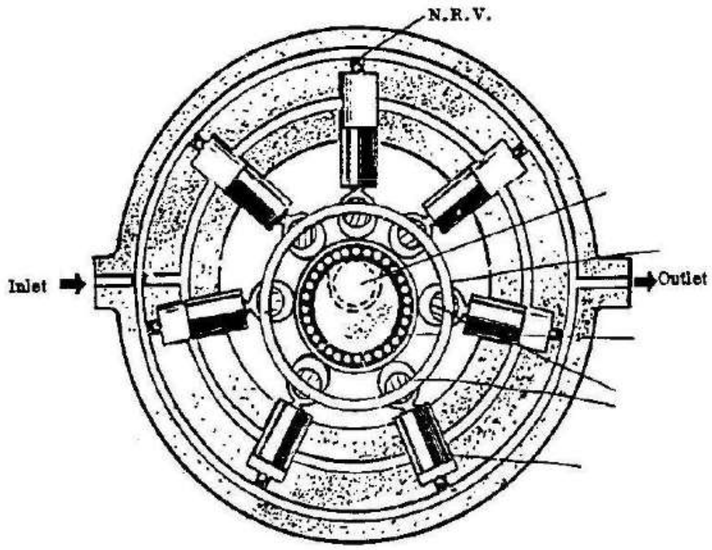


Fig. 11.37 Radial Piston Hydraulic Pump – End View

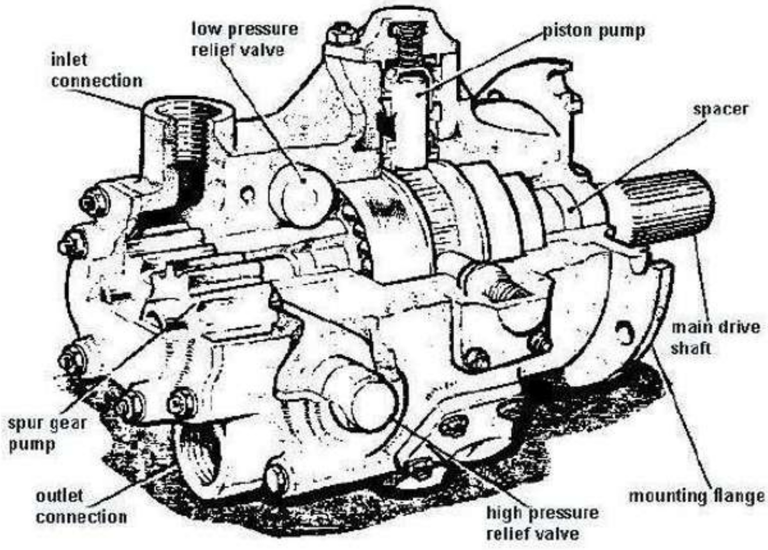


Fig. 11.38 Typical Radial, Piston-type, hydraulic pump Constant Volume/Fixed Displacement

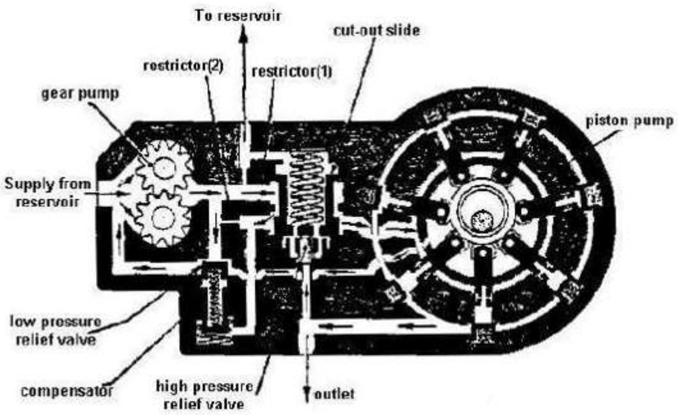


Fig. 11.39 Operation of Radial, Piston-type. (Constant Volume/Fixed Displacement), Pump

These pumps are used in systems, which required moving a large volume of fluid, but at relatively low pressures. The vanes are allowed to float freely in slots machined in the rotor, and are held in place by a spacer. This rotating assembly is attached to a drive shaft and is driven by the engine, or, an electric motor. The rotating assembly is mounted "concentrically" in a ported, steel sleeve which is pressed into a cast, aluminum housing.

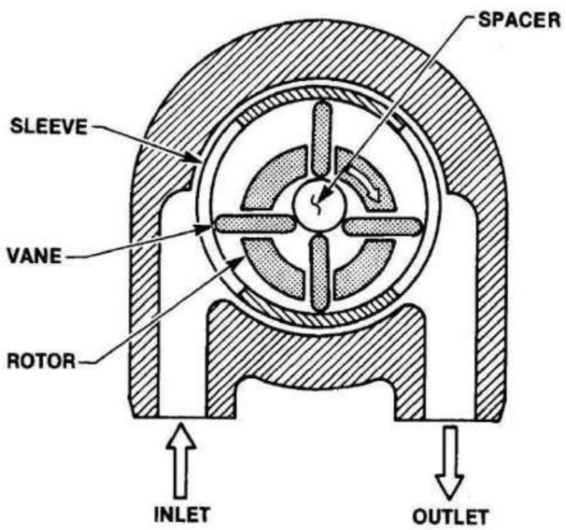


Fig. 11.40 Vane-type Hydraulic Pump (Constant Volume Fixed Displacement

OPERATION: As the rotor turns in the direction of the arrow, (Fig. 11.29) the volume between the vanes on the inlet side increases, while the volume between the vanes on the outlet side decreases. This change in volume draws fluid into the pump through the inlet port, and discharges it through the outlet port and into the system. This type of pump is normally used on light aircraft, particularly in "POWER-PACK" type hydraulic systems, but is more generally used in fuel and pneumatic systems than hydraulic systems.

6.3.3 UNLOADING (CUT-OUT)VALVE

An Unloading (Cut-out) Valve of some sort is needed when a Constant volume/Fixed displacement pump is used to relieve the engine of the pump loading when there is no demand on the hydraulic system.

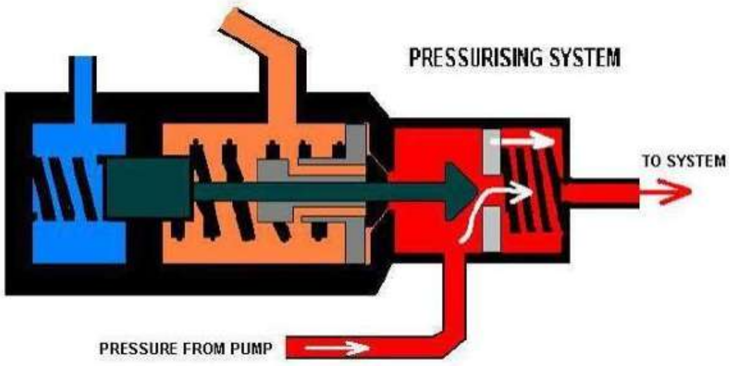


Fig. 11.41 Unloading (Cut-out) Valve during system demand

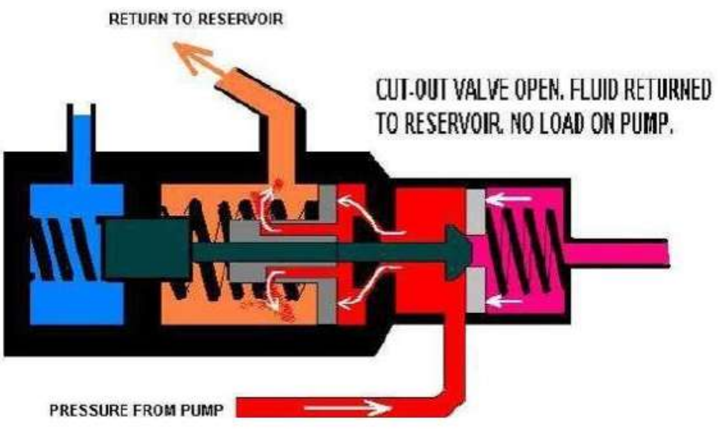


Fig. 11.42 Unloading (cut-out) Valve – Pump Idling Position

6.3.4 CONSTANT PRESSURE/VARIABLE DISPLACEMENTPUMP

A Constant pressure/Variable displacement, (Self-idling) pump, only moves an amount of fluid, which the system requires, hence the term: Variable displacement. As the pressure in the system builds up due to no actuation (no fluid movement), the pump delivery displacement is automatically reduced to no-flow. By varying the pump output, the system pressure can be maintained at a constant, within the desired range without the use of Regulators (Cut-out/Unloading valves). It allows the pumps to turn without delivering fluid to the system. However, this can cause overheating of the pump. To prevent this, fluid is by-passed back to the reservoir, by the LP spur-gear back-up pump, ensuring a continuous flow of fluid through the HP piston pump at all times, even when there is no fluid delivery to the system. Thus providing cooling of thepump.

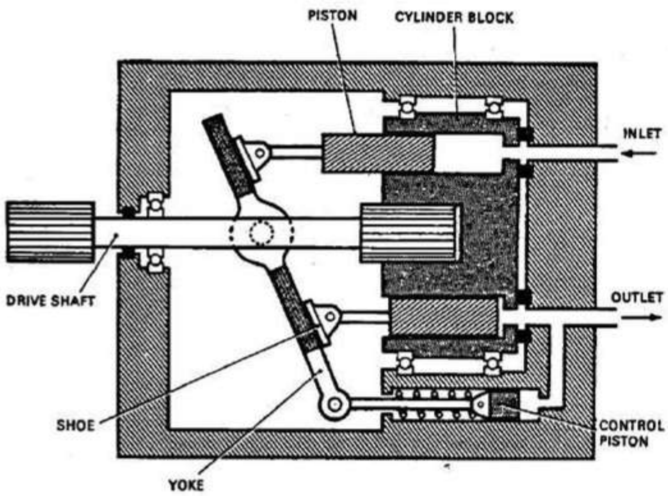


Fig. 11.43 Constant Pressure/Variable displacement, (Self- idling) hydraulic Pump

This type of pump is similar in construction to the fixed volume, axial-piston type, (Figure. 11.28) it is normally a 2 stage pump. The first stage usually consists of a low pressure (LP), high volume, spur gear pump, (similar to the Radial pump shown in (Figure. 11.31). This ensures a positive supply of fluid to the second stage, high pressure (HP), axial, Multi -piston pump, the cylinder block of which is driven by a common drive shaft.

The piston stroke is varied by a Yoke mechanism, sometimes called a Swash-plate, or Cam. (See Figures. 11.36. & 11.37) the pistons are attached to shoes that rotate against the stationary Yoke. The angle between the Yoke and cylinder block is varied, to increase, or decrease the piston stroke. This action is carried out byaServoControlPiston,whichsenses“systempressure”.This

pressure pushes the Servo Control Piston against the return spring pressure, and reduces the Yoke angle, thereby, reducing the HP piston strokes. When the Yoke is at 90º to the drive shaft, (Perpendicular to the pistons) the piston stroke is zero and there is no flow of fluid, therefore, no load on the drive-shaft.

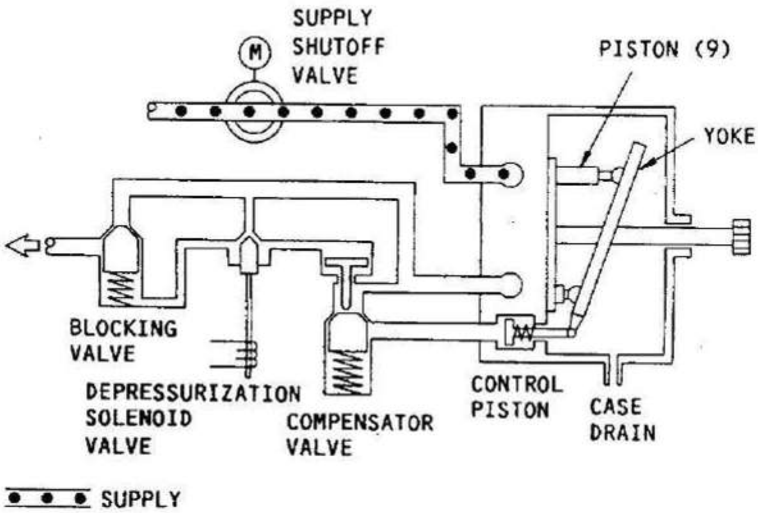


Fig. 11.44 Schematic of Constant Press. /Variable displacement pump

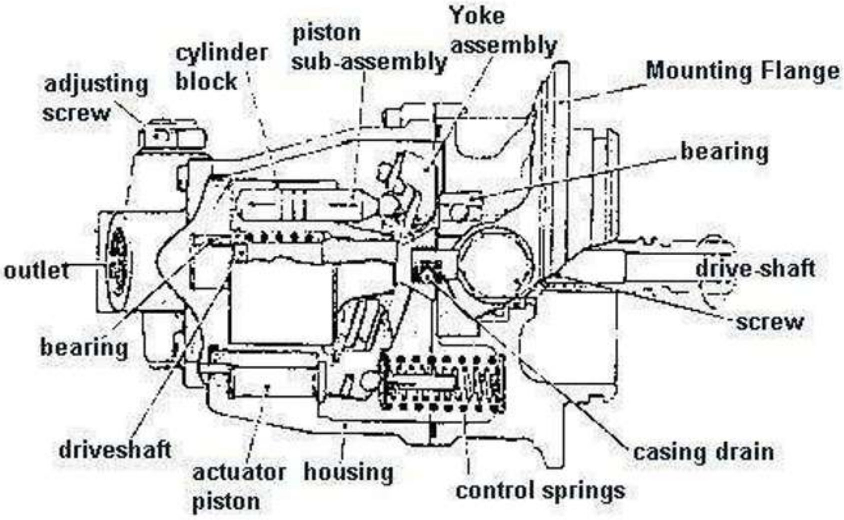


Fig. 11.45 Constant Press/Variable displacement (Self-idling) hydraulic pump

6.3.5 STRATOPOWERPUMPS

As previously discussed, some kind of "unloading valve" is required when using a constant displacement pump. But the same force, (system operating pressure) which controls this valve can be used to control the output of the variable displacement pump. Figures. 11.35, 11.36 and 11.37 show variable displacement pumps, which are controlled by a spring-loaded piston, which moves a pivoted yoke, or swash-plate to adjust the stroke of the delivery pistons, thereby regulating the fluidflow.

Another commonly used variable displacement pump for high pressure aircraft hydraulic systems is the Stratopower demand- type pump illustrated in Figure. 11.38.

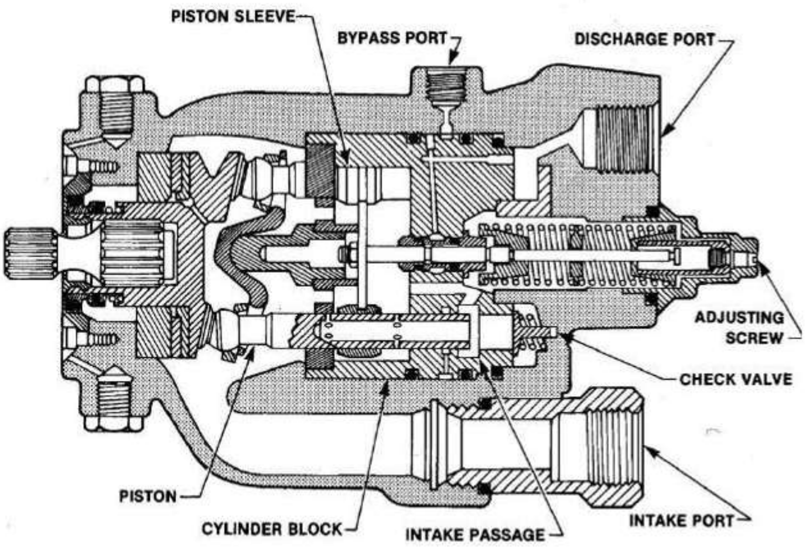


Fig. 11.46 Constant Pressure/Variable displacement, (Self- idling) hydraulic Pump. (Stratopower Pump, demand-type)

This pump uses nine axially-orientated pistons and cylinders. The pistons are driven up and down in the cylinders by a fixed- stroke cam. The stroke of the pistons is the same regardless of system demand. In this type, the effective length of the piston stroke controls the amount of fluid delivered to the system.

This type of pump usually has a delivery capacity of between 22- 37gpm. (Gallons per minute) and maintains a nominal supply pressure of 3,000psi.

6.3.6 OPERATION

The forces which control the pump output and system pressure is between the compensator spring and the compensator stem piston. Pump out-put pressure is ported around the compensator stem which acts as a piston and opposes the compensator spring. As the pressure increases, the stem piston compresses the compensator spring.

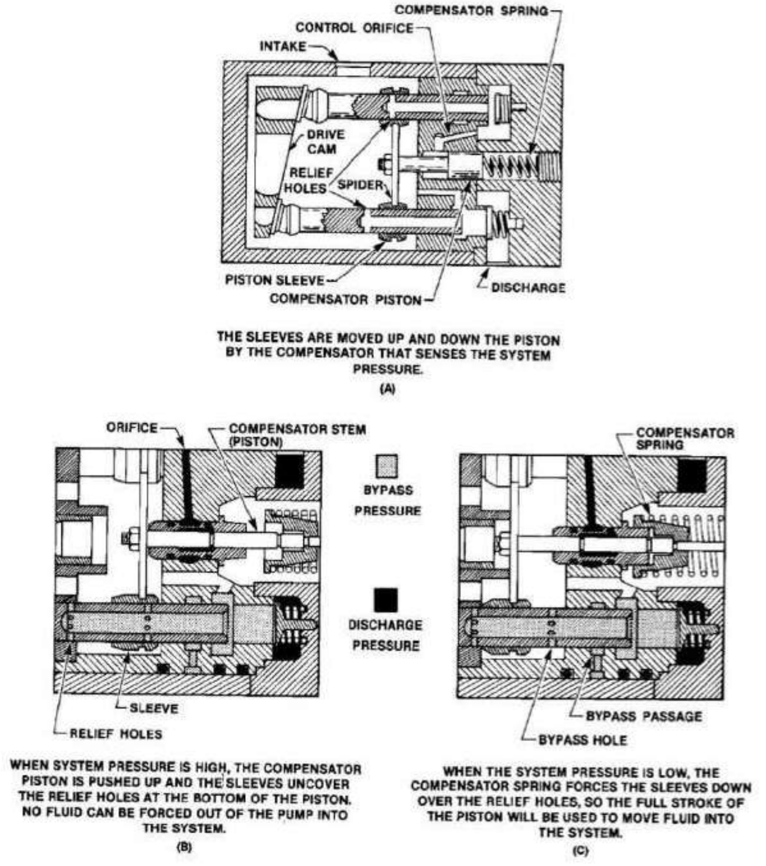


Fig. 11.47 Strat power pump, flow and pressure controlling mechanism.

The spider, which is connected to the compensator stem, moves the sleeves up and down the delivery pistons. When the pressure is high, the stem piston moves the spider, compressing the compensator spring and uncovers the relief holes near the bottom of the delivery pistons during the full stroke. This allows the fluid to be dumped during the compression stroke to the inlet side of the pump, preventing fluid flow through the check-valves and into thesystem.

The pump is allowed to deliver a small amount of fluid even at its minimum stroke to ensure adequate lubrication and cooling of the pump at all times duringoperation.

When system pressure drops, the compensator spring forces the stem and spider assembly down the piston, covering the relief holes at the bottom of the delivery piston stroke. This prevents bleed-off of fluid during the compression stroke. The compressed fluid is then forced out through the check valves and into the system to meet the fluid demand. During any intermediate pressure condition the spider sleeves cover the relief holes at some point along the discharge piston's stroke, thereby maintaining system pressure and fluid flow to the required value. The value of the compensator valve is set by the pressure adjusting screw, which varies the tension of the compensator spring.

6. EMERGENCY PRESSURE GENERATION

A failure of the hydraulic supply circuit may have a disastrous effect on the operation of the aircraft. If such an emergency arises, provision must be made to supply the services which are hydraulically operated by some alternative source of power.

There are several ways in which this can be achieved;

a Hand-pump operated by thepilot,

b Duplication ofsupplies,

c Electrically operated AC or DCpumps,

d Compressed air, Air turbine motor driven pumps,(A.T.M.)

e Ram-air turbine pumps,(R.A.T.)

7.1 HAND PUMPS

The Hand-pump operation has been explained in Chapter 6.1

Almost all aircraft with a hydraulic power system installed have an Emergency hand-pump mounted in the cockpit or flight deck. It is usually mounted and stowed under the floor, between the pilot's seats, thereby allowing either pilot or co-pilot to operate it with relative ease while still flying the aircraft. A quick-release access cover is usually marked in Red or Yellow and Black stripes, indicating; "Emergencyoperation".

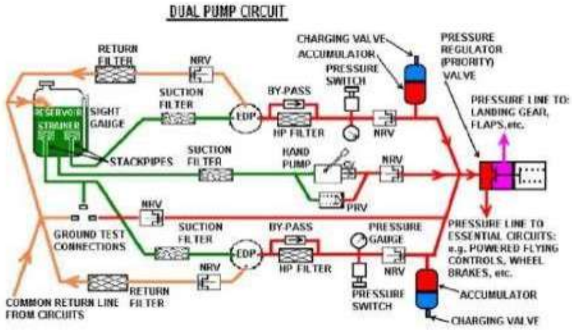
The hand-pump is connected in parallel with the Engine driven pump (EDP) but has an independent fluid supply line from the Reservoir which draws hydraulic fluid from a lower level in the reservoir than the EDP supply; this ensures a positive supply of fluid if the level is low. (See Figure 40)

In some systems the hand-pump is also used to initially pressurise the system to ensure adequate system pressure to operate the emergency or park brake system prior to towing, parking and engine start-up of theaircraft.

7.2 DUPLICATION OFSUPPLY

On Multi-engined aircraft, where hydraulic power is used extensively, and also as a safety factor, it is often necessary to have a power circuit using two or more pumps to meet the demandwhenmostsystemsarebeingoperatedatthesametime.

i.e. (Landing and Take-off) The circuit illustrated in Figure 40 is fitted with two self-idling pumps which, should one pump fail during flight, the remaining pump will still provide fluid flow but at half the normal rate. The primary purpose of the Accumulators in this circuit is to dampen out the pulsation's of the pumps, also to give speedier operation of components when initially selected, and to provide a source of hydraulic power when the engine- driven pumps (EDP's) are not working.



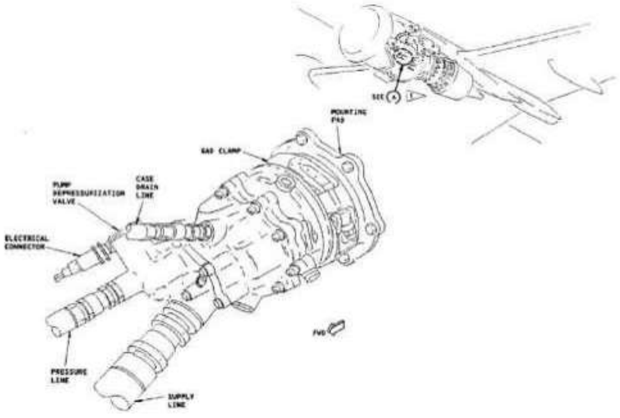


Fig. 11.48 Typical Engine-Driven Hydraulic Pump (EDP) as fitted on Boeing 737

Multi-engined aircraft normally have one EDP mounted on each engine similar to the one in Figure. 41. However, some aircraft like the Lockheed L1011 Tri-Star, have one EDP driven by each wing mounted engine, (No's. 1 & 3 engines.) and two EDP's driven from the rear fuselage mounted engine. (No. 2 engine.) This is to ensure adequate flow and pressure supply to a large and complex hydraulic system and to cater for redundancy and continued safety in the case of an engine or pumpfailure.

Modern Jet transport aircraft now have at least two hydraulic systems completely independent of each other with duplicated actuation of all primary hydraulically powered flight control systems. Figure 42 shows a schematic diagram of the Boeing 737 hydraulic system. This consists of two Main systems (Systems A & B) with EDP's drawing fluid from separate reservoirs and a Standby system as an additional back-up in case of failure of one or both main systems.

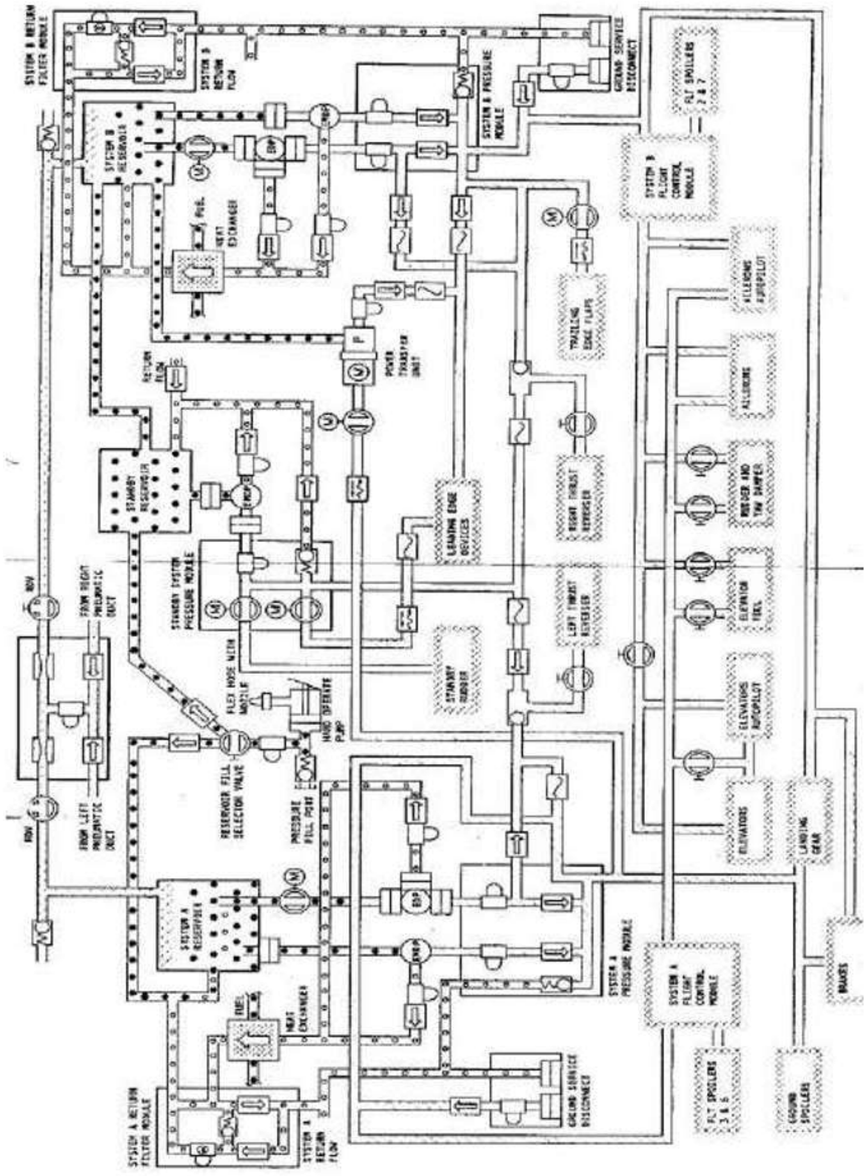


Fig. 11.49 Dual Hydraulic System Schematic Diagram (Boeing 737)

7.3 ELECTRIC MOTOR DRIVEN PUMPS (EMDP'S)115V AC

It is common practice to install Electric Motor Driven Pumps (EMDP) primarily as a back up to the EDP when system demand is high, but also to provide hydraulic power in case of EDP or engine failure.

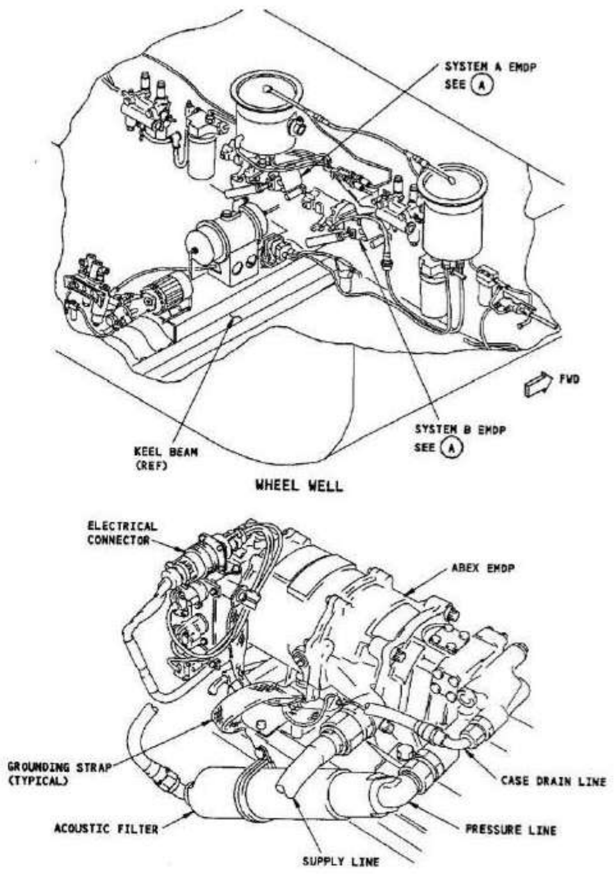


Fig.11.50 Typical 115v. AC Motor-driven Pump as fitted to Boeing 737 aircraft

A three phase 115v AC EMDP is connected to the main hydraulic circuit in parallel with each EDP. It draws its fluid from the same reservoir, but its fluid supply line is mounted lower in the reservoir to ensure a continued supply to the EMDP when the fluid level islow.
These pumps are very similar in operation to the EDP's but witha
lowercapacity,usuallyabout6-10gpm(gallonsperminute)and

maintain a pressure of about 2,700 p.s.i.

Hydraulic fluid enters the pump by way of the electric motor housing to provide cooling of the pump and motor assembly during operation.

On some aircraft a Low capacity (3 g.p.m. at 2,700 p.s.i.) 28v DC motor driven pump is installed as an Emergency hydraulic power source which is also used to provide initial hydraulic pressure to charge up the system for brake operation, prior to towing the aircraft or engine starting.

7.4 AIR TURBINE MOTOR DRIVEN PUMPS (ATM'S OR ATDP'S)

Some aircraft such as the Airbus 300 series and B767 use hydraulic pumps operated by air turbines, which are driven by bleed air from the engines. These Air-turbine driven pumps (ATDP) receives pressurised air from the aircraft's main bleed air system. The flow of air is controlled and modulated by a solenoid operated pressure regulator and shut-off valve to maintain the turbine speed within set parameters. The turbine is connected by a shaft to the pump. (See figure 44)

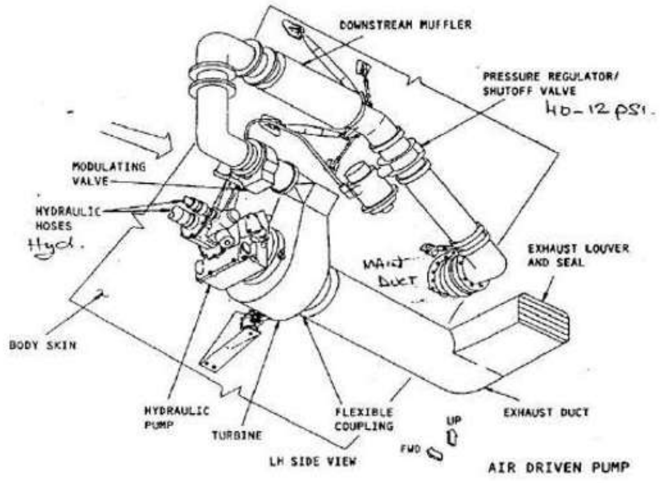


Fig. 11.51 Typical Air Turbine Motor driven hydraulic pump. (ATDP)

7.5 POWER TRANSFER UNITS(PTU'S)

PTU's consist of a hydraulic motor, which is supplied fluid under pressure by one hydraulic system. This motor turns a drive shaft, which powers a hydraulic pump, which is connected to a second hydraulic system in the aircraft. The PTU is an integrated unit housed in one casing. (See Fig. 45) The purpose of the PTU is to use pressure from one system to power the motor which drives the pump to provide pressure in the other system. The PTU motor may be isolated from pressure when system operation is normal but may be selected manually or automatically (by a pressure switch) in the event of a pressure drop or failure of the other system pumps. The B737 incorporates a PTU to supply pressure to the slat system automatically in the case of reducedpressure.

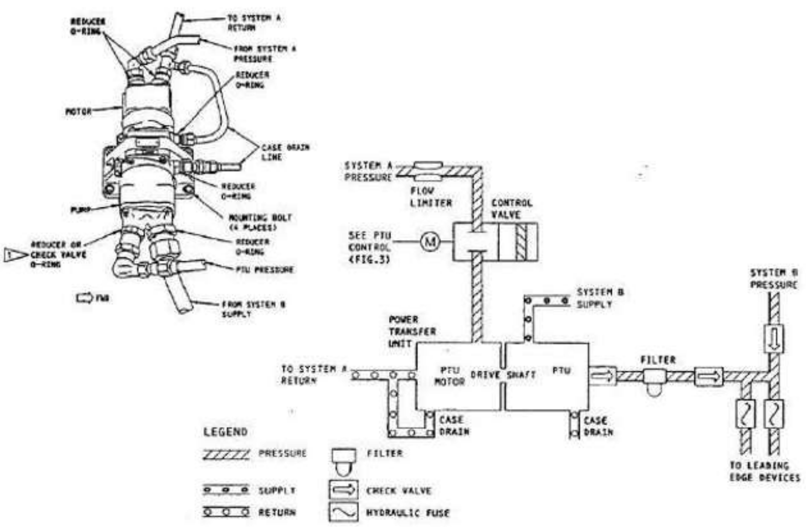


Fig. 11.52 Typical Power Transfer Unit (PTU) Schematic.

7.6 HYDRAULIC RAM AIR TURBINES(HYRAT'S)

HYRATS may be used as an emergency source of hydraulic power in the case of major failure within the normalsystem.

The HYRAT consists of a turbine (similar in appearance to a small propeller) which is normally stowed in a compartment in the fuselage as in the Lockheed L1011 trustier and Boeing 767 aircraft. (See Fig. 46.)

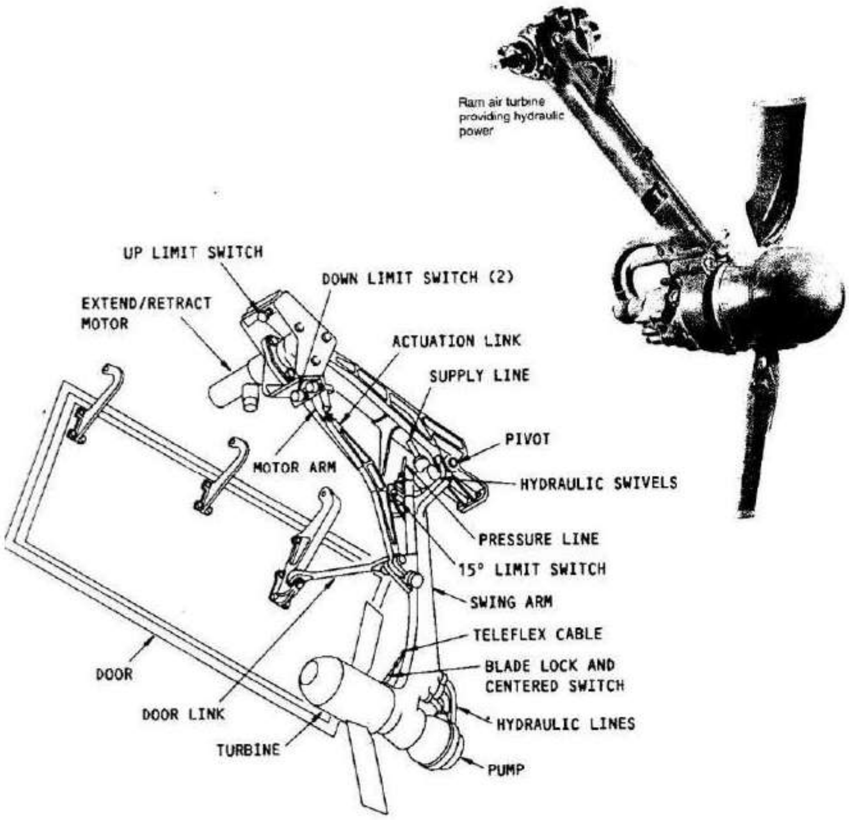


Fig. 11.53 Hydraulic Ram Air Turbine (HYRAT) Pump Unit

It is only deployed in the case of a major hydraulic failure to provide minimum hydraulic supply for the safe recovery of the aircraft. The HYRAT may be deployed automatically or by manual selection. Pressure output is governed by varying the blade angle in response to aircraft speed and pressure demand.

7. HYDRAULICVALVES

The valves used in hydraulic systems may be divided into

pressure control and flow control valves.

a A pressure control valve adjusts, regulates and/or limits the amount of pressure in the power supply system or any componentcircuit.
b A flow control valve selects and directs the flow of fluid through the system or circuit in a particular direction and is not normally concerned with thepressure.

8.1 PRESSURE CONTROLVALVES

8.1.1 PRESSURE RELIEFVALVE

The flaps are comparatively fragile and if they are lowered when the aircraft is flying at high speeds, are liable to be damaged by the airflow. The flaps are designed to be used only when the aircraft is landing or taking-off. To prevent such damage occurring, a pressure relief valve is provided in the circuit. This valve, which acts as a "blow-back" valve, bypasses pressure fluid in the Down line to the return line. In effect, the valve enables the flaps to "blow-back" if they are left down and the aircraft speed is increased. It also prevents the pilot from lowering the flaps at high airspeeds.

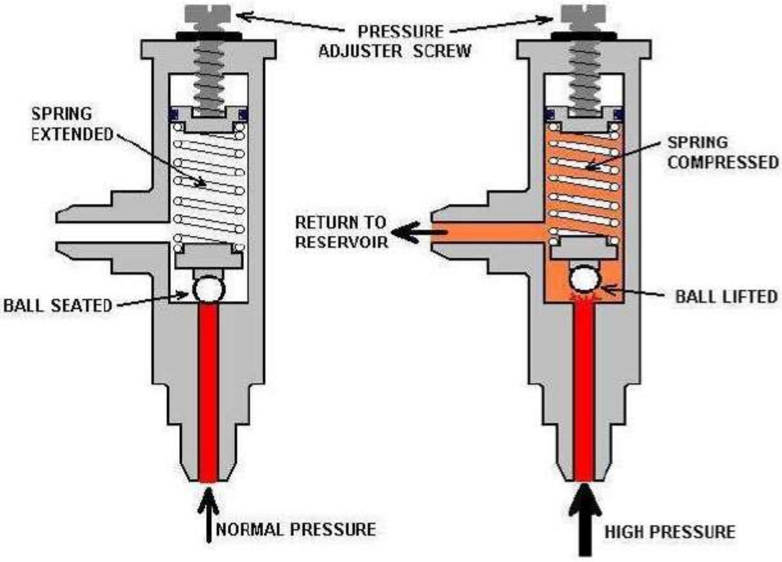


Fig. 11.54 Operation of "Pressure Relief Valve" (PRV)

8.1.2 PRESSUREREGULATORS

In Chapter. 6.3 We discussed the two basic types of pumps used, The Constant Volume/Fixed Displacement (Non-self idling)type.

The Constant Pressure/Variable Displacement (Self-idling) type.

It was stated that; the Non-self idling type required an Unloading, or Cut-out valve to relieve the pressure which builds up in the system when the out-put from the pump is greater than the system demand. It also regulates the system pressure within a normal operating range. A complex Unloading valve was discussed in para: 6.3.3. (Figure 30 & 31.)

A simpler pressure regulator (the Balanced-type), is illustrated in Figure 51.

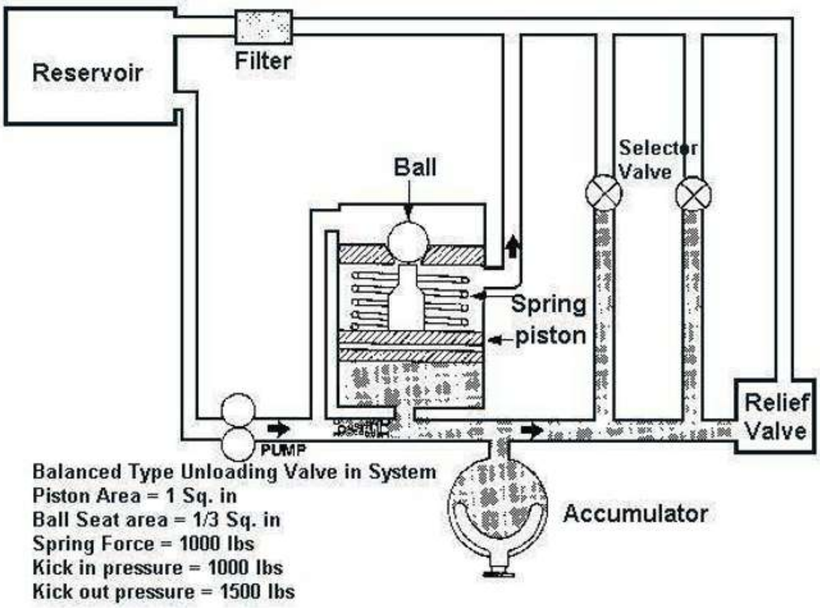


Fig. 11.55 "Balanced-type" pressure regulator valve

OPERATION

The pump delivers a fluid flow through the NRV into the system and charges the Accumulator with fluid and pressure builds up in the system. This pressure is sensed on the under-side of the regulator piston. The same pressure is sensed on the upper surface of the ball, forcing it onto its seat as the pressure increases. The spring is acting downwards against the piston and a balance of forces is reached between the fluid pressure on the ball, the spring pressure on top of the piston, and the system pressure acting upwards under the piston. At the condition of balance, when the pressure is 1,500psi, there will be a force of 1,500 pounds (lbs) pushing up on the piston.

The total downward force of 1,000 lbs applied by the spring and a 1/3 of 1,500 lbs (500 lbs) of fluid force pushing down on the ball. If the system pressure rises above this balanced pressure, the spring pressure is constant and not effected by hydraulic pressure, therefore the piston will move up and lift the ball off its seat. This allows the pump delivery (flow) to return to the reservoir with very little resistance and therefore virtually zeropressure.

The NRV holds the pressure trapped in the system and the accumulator. This condition will continue until the pressure in the system drops to 1,000 psi, at which point the spring will force the piston down, allowing the ball to re-seat and the pressure will rise again to the unloaded pressure of 1,500 psi. This gives a system cycling pressure of: 1,000 – 1,500 psi.

8.1.3 THERMAL RELIEFVALVE

This valve is designed to relieve excessive pressure caused by expansion of the hydraulic fluid due to increase in temperature. It is situated in a pipeline between components where the fluid is in a closed circuit, such as between an NRV and an actuator, where there is a hydraulic lock. The excessive pressure is relieved back to the reservoir via the returnline.

The restrictor pack ensures that only the slow pressure changes from thermal expansion effects the operation of the valve.

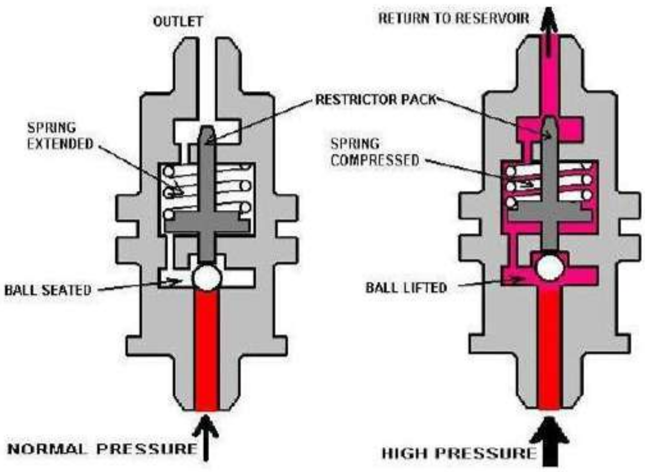


Fig 11.56 Thermal Relief Valve

8.1.4 PRESSURE REDUCINGVALVE

Some hydraulically operated components require a much lower pressure than system pressure to operate them. In such cases a Pressure Reducer Valve similar to the one in figure. 53 are used. This valve reduces system pressure by the action of a balance between hydraulic and spring forces.

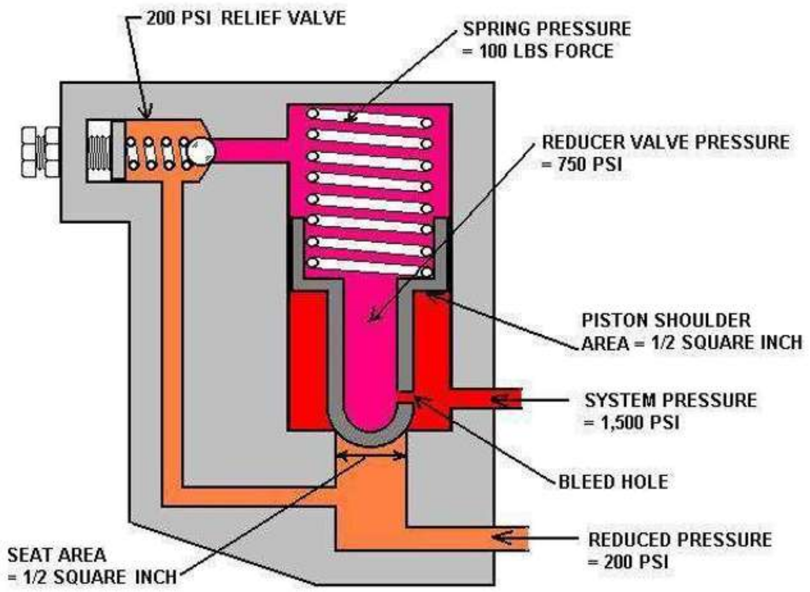


Fig. 11.57 Pressure Reducer Valve OPERATION

Assume that the piston in figure. 53 has an area of one square inch ($1in^2$) and is held on its seat by the large spring with 100 pounds force (LBSF). The piston has a shoulder area of ½ square inch, which is acted on by the full 1,500psi. system pressure. The reducer valve seat area is ½ square inch (Same as piston shoulder) and is acted on by the 200 psi reduced pressure. A small hole in the piston bleeds fluid into the chamber behind the piston and the relief valve maintains this pressure at 750 psi. This relief action is determined by the pressure inside the piston cavity, acting on one side of the relief ball and the spring, and reduced pressure (200psi) acting on the opposite side. When the reduced pressure drops, the hydraulic force on the ball drops, allowing it to unseat. This decreases the hydraulic force on the piston and allows itto move up. Fluid now flows into the reduced pressure line and restores the 200-psi. This increased pressure closes the relief valve so that the pressure behind the piston can again increase up to 750 psi and seat the valve. The small bleed hole also prevents the piston from chattering by giving the piston a relatively smooth action. The piston remains off its seat just enough to maintain the reduced pressure as it is used.

8.2 FLOW CONTROLVALVES

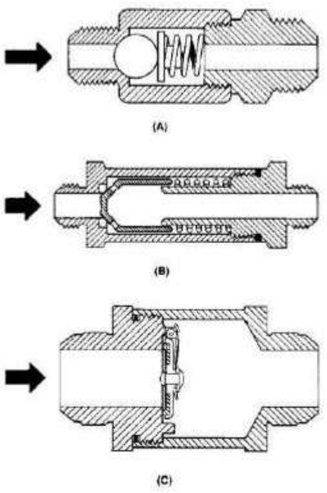
Flow control valves in hydraulic systems control fluid flow and the direction of flow. They may control manually (direct operation by flight or ground crew) or automatically (by flow, pressure or remote sensing devices) Flow Control valves can be mechanically, electrically or hydraulically operated. The valves may be of the ball, sleeve, poppet, rotary, piston or sliding- spooltype.

8.2.1 NON-RETURN (CHECK)VALVE

This valve is the simplest of all flow control valves and is used in most systems. Its basic function is to allow fluid flow in one direction only. The different types are shown in fig. 54. An NRV or Check valve, is always fitted just down-stream of the pump to ensure there is no reverse-flow through the pump which could cause damage to it when stationary or not in use.

Some applications require full flow in one direction and a restricted flow in the other. This valve is known as a Restricted or Orifice Check valve (fig. 55)

NON-RETURN (CHECK)VALVES



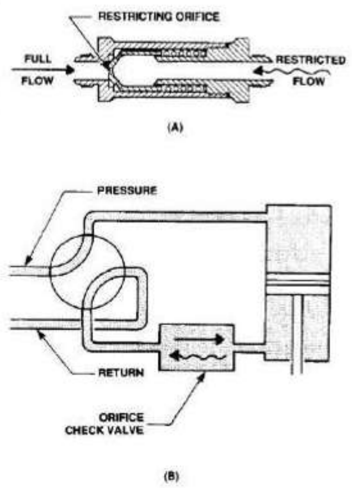


Fig. 11.58 Fig. 11.59

A	Ball Check Valve	A	Orifice Check Valve
B	Cone CheckValve	B	Orifice type, installed in a landing gear system
C	SwingCheck		

Valve(Flapper Valve)

8.2.2 SELECTORVALVES

Selector valves may be considered to be the first valve in the Services System and not part of the Power System.

The purpose of the Selector Valve is to direct fluid to the appropriate side of an actuator, and to provide a return path for the fluid displaced from the opposite side of the actuator, back to the reservoir. Many flow control valves are simple four-way valves, connecting the pressure and return lines to alternate sides of the actuator, without a neutral position, however, control valves in open-centre systems often lock fluid in the actuator while providing an idling circuit for the pump.

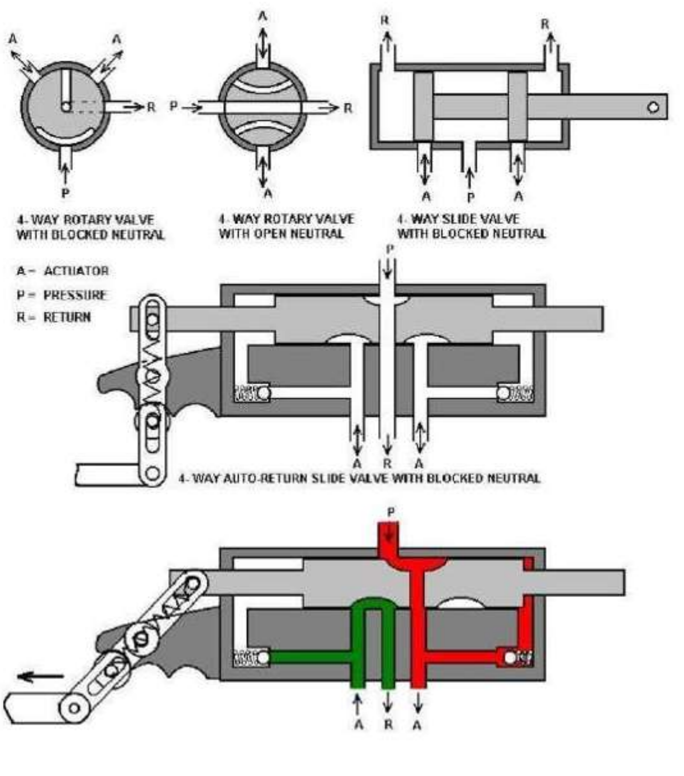


Fig. 11.60 Manual Selector Valves

Figures. 56 Illustrates the Ball, Rotary and Sliding-spool type valves, which are normally used in relatively low-pressure actuation. Higher-pressure systems require a more positive shut- off of fluid flow and Poppet-type selector valves are often used.

OPEN CENTRE, POPPET TYPE, SELECTOR VALVE OPERATION

When the Control Selector handle is in the Neutral position, Poppet valve 3 is off its seat. Fluid flows straight through the valve from the pump to the next selector valve and on to the reservoir. All the other poppet valves are closed.

When Gear Down is selected, movement of the cams causes valve 3 to close, and valves 1 and 4 open, redirecting pump pressure to the Gear Down side of the gear actuator, through valve 4 Fluid on the other side of the actuator piston is then redirected back to the reservoir through valve 1 via the return line. When the actuator reaches the end of its travel, the pressure increases to a specific value and operates a mechanism, which returns the selector handle to the neutral position, thereby closing valves 1 and 4 and reopening poppet valve 3 when Gear Up is selected, valve 3 once again closes and valves 2 and 5 open. This directs pump pressure to the Gear Up side of the actuator through valve 2 Fluid on the other side of the actuator is redirected back to the reservoir through valve 5 via the return line. When the actuator again reaches the end of its stroke, the pressure increase is again sensed by the return mechanism and the selector handle is returned to the Neutral position, thereby closing valves 2 and 5 and reopening poppet valve 3again.
Note: This type of selector requires a pressure-sensing device which moves the selector handle back to the Neutral position when the actuator is fully extended orretracted.

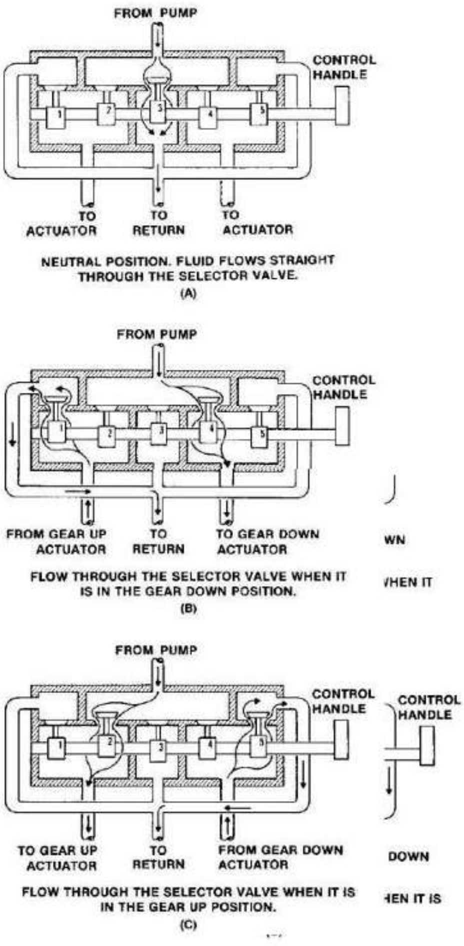


Fig 11.61Open Centre, Poppet Type, Selector Valve

ELECTRICALLY OPERATED SELECTOR VALVES.
These valves use electrically operated solenoids to control the position of a spool valve which, in turn, controls the direction of fluid flow to the system actuator. Switches located on the flight deck, or remote sensors, operate these valves.

The advantage of this type over mechanical valves is the elimination of bulky lever mechanisms, torque tubes, bell-cranks, levers and pulley's, which add extra weight to the aircraft. On large Transport aircraft, this is especially important when considering the large distances from the controlling point to the actuation point. "Fly-by-Wire" systems are modern examples of this method of Power Control.

SINGLE SOLENOID TYPE, SELECTOR VALVE

The selector illustrated in Figure.58 is a Single solenoid, two-way valve. Typically used for emergency operation of the Flaps or Landing Gear.

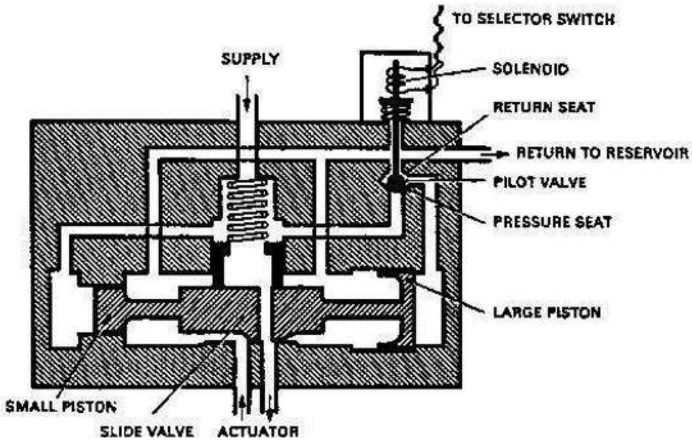


Fig. 11.62 Electrically operated, Slide-valve, Selector (Single Solenoid)

OPERATION

With the solenoid de-energised, the pilot valve is spring-loaded against the return seat, and fluid from the emergency power system passes to both sides of the slide valve. Since the right-hand end of the valve is a larger diameter than the left, the valve is moved to the left by the greater force, and system pressure fluid passes to the actuator to extend its ram. Fluid from the opposite side of the actuator passes through the slide valve, to the reservoir, via the returnline.

With the solenoid energised, the pilot valve is held against the pressure seat, and supply pressure acts on the left-hand side of the slide valve only. The right – hand side being open to return, thereby forcing the slide valve to the right. This directs system pressure fluid to the actuator to retract its ram. Fluid from the opposite side of the actuator, being open to return to the reservoir, via the return line.

DOUBLE SOLENOID TYPE
This valve is similar to the single solenoid valve but is used where the service has intermediate positions. With both solenoids de-energised, the valve will hold the service in any rigid position (Hydraulically locked) but with the supply pressure isolated from the utilitysystem.

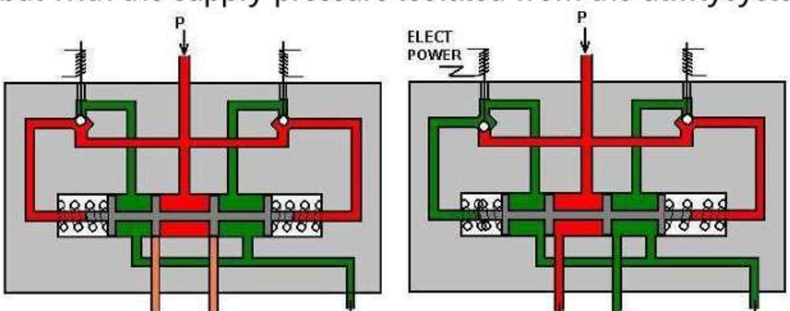


Fig. 11.63 Double Solenoid type Selector valve OPERATION

With both solenoids de-energised the ball valves are held against their respective return seats, (same as the Single Solenoid valve). In this position, system pressure is directed to identical area pistons on both sides of the Spring-loaded shuttle valve. With no hydraulic power in the system, the springs, which are also of equal tension, hold the shuttle valve in the centred position, thereby shutting off, both lines to the actuator and creating a hydraulic lock in the actuator. When the left-hand Solenoid is energised,the

ball valve is held against the pressure seat. This allows the pressure on the left-hand side of the shuttle valve piston to be vented to the return line through the left-hand shuttle valve chamber, thereby, causing a pressure imbalance which forces the shuttle valve to the left. This allows pressure to one side of the actuator, and directs the other side of the actuator to the return line through the right-hand chamber of the shuttlevalve.

8.2.3 PRIORITYVALVES

These valves are similar to Sequence valves except they are opened by hydraulic pressure rather than by mechanical means.

They are called priority valves because such devices as "Wheel- well doors", which must operate first, require a lower pressure than the Main Landing Gear. The valve will shut off all the flow to the Main Gear until the doors have actuated to the fully Open position and the pressure builds up at the end of the actuator stroke. The priority valve senses the pressure build-up and opens, allowing fluid to flow to the Main Gearactuators.

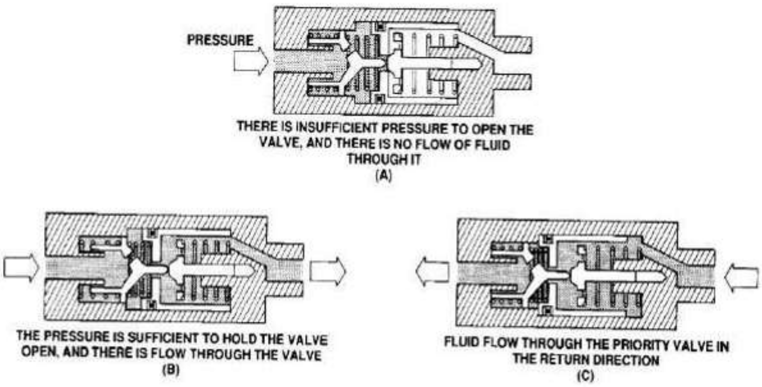


Fig.11.64 Typical Priority Valve Operation

8.2.4 SEQUENCEVALVES

Most modern aircraft with retractable landing gear have landing gear doors, which close in flight to cover the wheel well to ensure a streamlined airflow. When the gear is selected "UP" or "Down", by the pilot, the gear doors must open first before the gear starts to retract. For this reason, a Sequence Valve is sometimes installed. These are usually similar in construction to Check valves (NRV's) which allow a flow of fluid in one direction but may be opened manually to allow fluid to flow in both directions.

These valves are similar to Priority Valves regarding their function, by allowing one hydraulic component to function before another is allowed to function. The difference between them is that Priority valves are controlled by fluid pressure, whereas Sequence valves are controlled by mechanical displacement of a plunger, which moves a Ball valve off its seat to redirect fluid to another component.

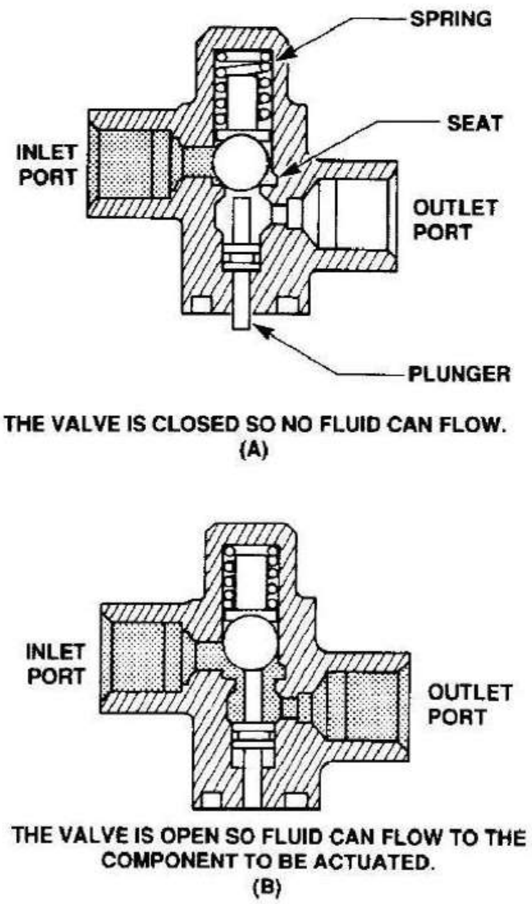
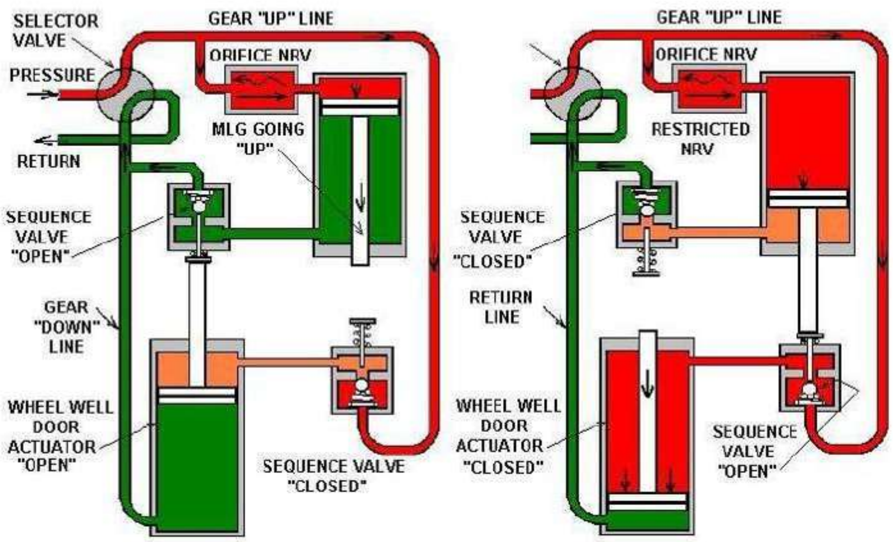


Fig 11.65 Section through a typical Sequence Valve

The illustration in Fig. 62 (below) shows the location and typical use of Sequence Valves in a simple Landing Gear system. It explains the basic sequence of operation as the gear is selected “UP”.



I	Gear selected "UP"	I	Gear fully "UP"
II	Wheel-well door "Fully OPEN"	II	Door Sequence valve "OPEN"
III	Gear retracting	III	Wheel-well door "Fully CLOSED"

Fig. 11.66 Sequence Valve location and operation, in landing gear system

8.2.5 HYDRAULIC FUSES PURPOSE

These special valves are used to block off fluid flow if a serious

leak should develop. There are two types of hydraulic fuse. The first type shuts off the fluid flow if the pressure drop across the fuse falls below a specified limit. The second type shuts off the fluid flow after a specific amount of fluid has flowed through it.

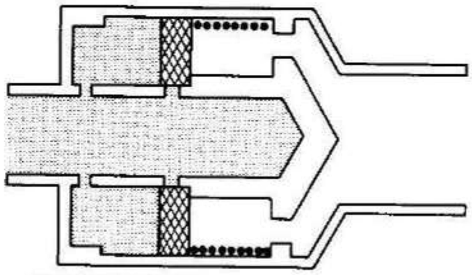


Fig 11.67 Pressure Sensing Fuse Valve Pressure Sensing Fuse Valve

This fuse senses the pressure drop across the valve.

During normal flow through the valve, the spring keeps the piston against its seat. If a serious leak or pipe failure occurs downstream of the outlet (B) the pressure drop is sensed across the piston, which generates a force greater than that of the spring. This allows fluid pressure upstream at the inlet (A) to move the piston to the right, thereby shutting off the fluid flow. This condition will be maintained until the system pressure as inlet (A) is relieved, i.e. the system is shut down, allowing the spring to return the piston to its normal operatingposition.

Flow Sensing Fuse Valve Operation:

This fuse does not operate on the pressure sensing principle.

It will shut off the flow after a given amount of fluid has passed through it.

In the static condition, all the ports are closed off. When fluid begins to flow in the normal direction of operation, system pressure on the sleeve valve moves it to the right against the spring pressure, thereby opening the ports and allowing fluid to flow through the valve. During this time some fluid passes through the metering orifice and progressively moves the piston to the right until it shuts off the primary delivery ports which stops fluidflow.

When fluid flows in the reverse direction, the sleeve valve and the piston are both moved to the left which keeps all the ports open and allows fluid to flow through the fuse unrestricted, in the opposite direction.

Normal operation of the unit protected by this type of fuse doesn't require enough flow to allow the piston to drift completely to the right and seal the primary delivery ports. Only when there is a serious leak will there be sufficient fluid flow to move the piston to the right and close off the primary delivery ports.

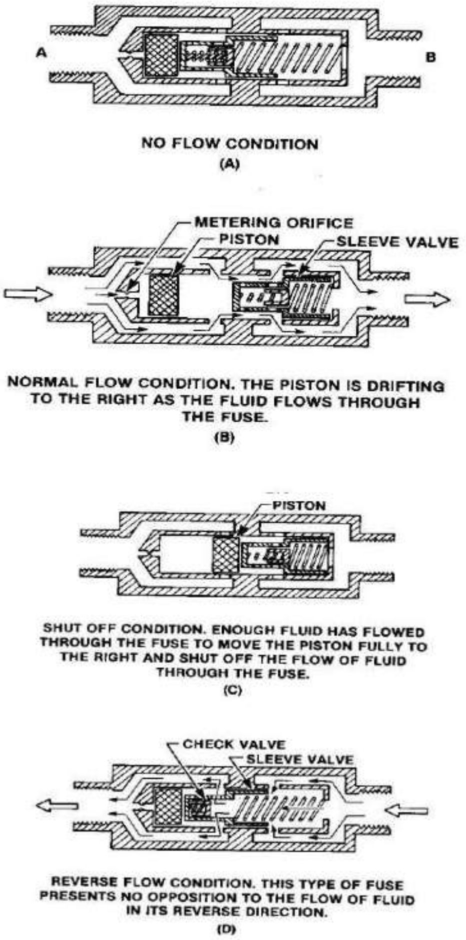


Fig. 11.68 Flow Sensing Hydraulic Fuse

8. POWERDISTRIBUTION

As previously stated, the hydraulic system in an aircraft may be used for operating various services, such as landing gear, flaps, airbrakes, wheel brakes, control surfaces, nose-wheel steering, etc. As it will be necessary to operate these services independently, provision must be made to ensure adequate fluid flow and pressure at all times, not only during operation of all the primary circuits at the same time, but also in the case of a complete failure of one power supply system.

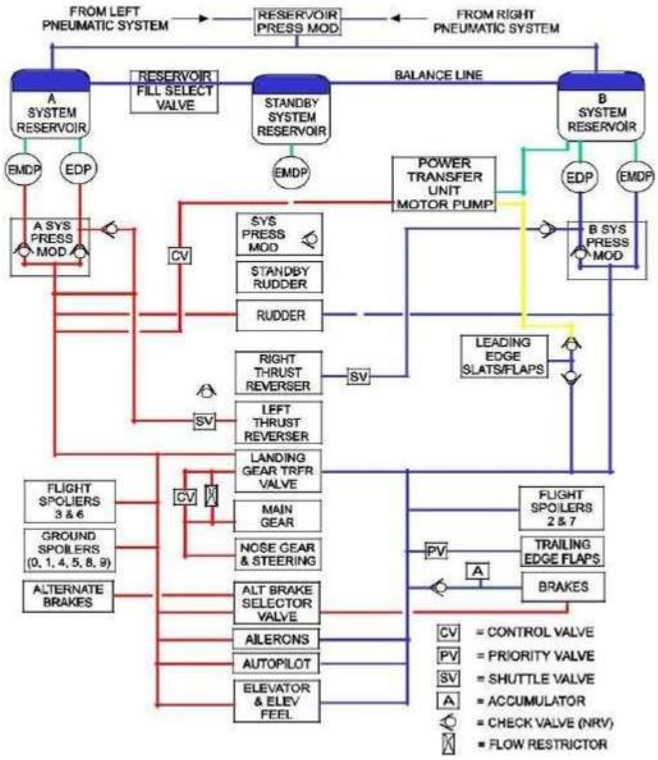


Fig. 11.69 Block diagram of hydraulic power distribution to component circuits

Figure 65 shows a block diagram of a typical hydraulic power distribution system and the supply to the various component circuits. The example shown has two main independent systems, System "A" and "B" with a "Standby" System to cater for redundancy.

The complete hydraulic system consists of:

a. A power circuit,
b. Various componentcircuits.
c. An emergency circuit in the event of hydraulic power failure.

9.1 POWERCIRCUITS

The power circuit supplies fluid to the component circuits and accommodates the fluid returned from these circuits. The system varies with the type of aircraft and may contain more than one Engine-driven pump (EDP). The circuit may be self-idling or non- self-idling. The self-idling circuit is designed to "idle" when the working pressure has been achieved, while in the non-self-idling circuit the pump supplies fluid continuously to the circuit and necessitates the installation of an automatic unloading (cut-out) valve.

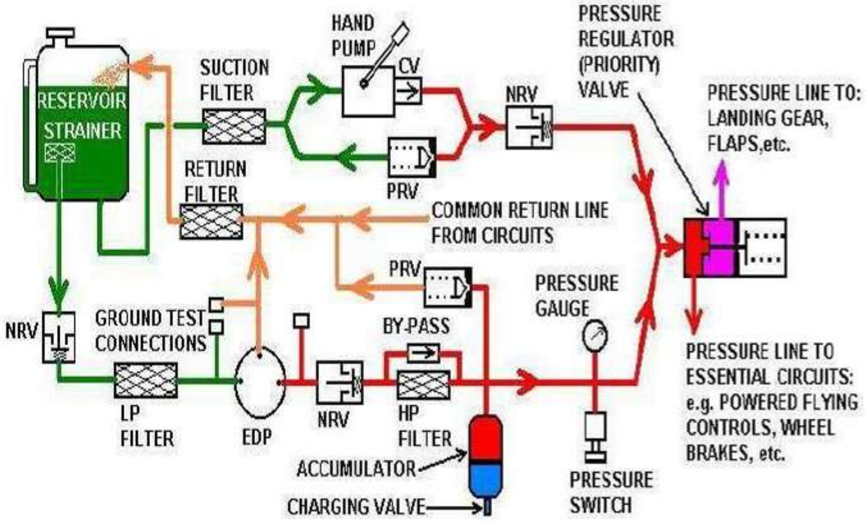


Fig.11.70 Power Circuit "Constant Pressure/Variable displacement", (Self idling) Pump System

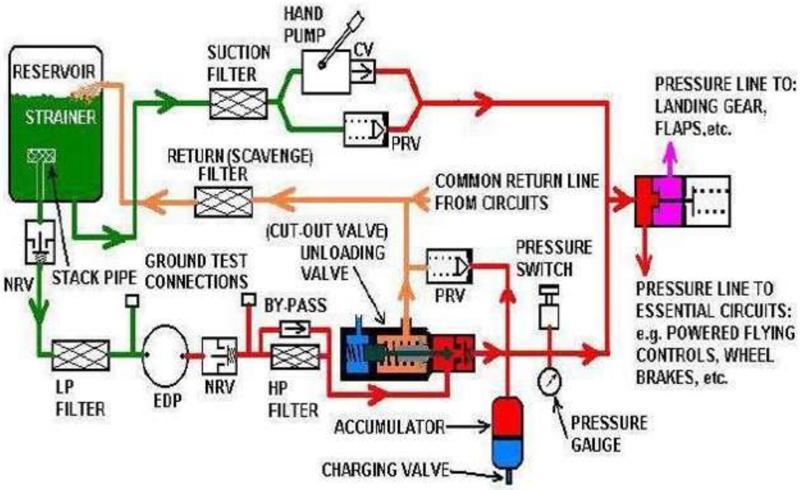


Fig. 11.71 Power Circuit Constant Volume/Fixed

displacement", (Non self-idling) Pump System

Figures 66 & 67 show the differences in the hydraulic power system design when a Constant Pressure/Variable displacement Pump is installed, (Fig. 34 and 35.) Compared to a system that has a Constant Volume/Fixed displacement Pump installed. (Figs. 14, 15, 16 & 17)

9.2 COMPONENTCIRCUITS

Each component (system) has its own hydraulic circuit within the hydraulic system. These circuits are usually connected to a common pressure line and a common return line of a power circuit. Fluid expelled from each component circuit is conveyed back to the reservoir by the returnline.

9.2.1 FLAPS

The flap circuit illustrated in Fig.68 consists of port and starboard flap jacks, synchronising jacks, and various components interconnected by pipelines. As with the landing gear circuit, fluid is supplied by the main system power circuit, to a control (selector) valve, via a Shut-off valve, which directs the fluid to the desired end of the jacks, at the same time connecting the other end of the jacks to the reservoir. A non-return valve before the control valve prevents operation of other services, such as alighting gear, from interfering with theflaps.

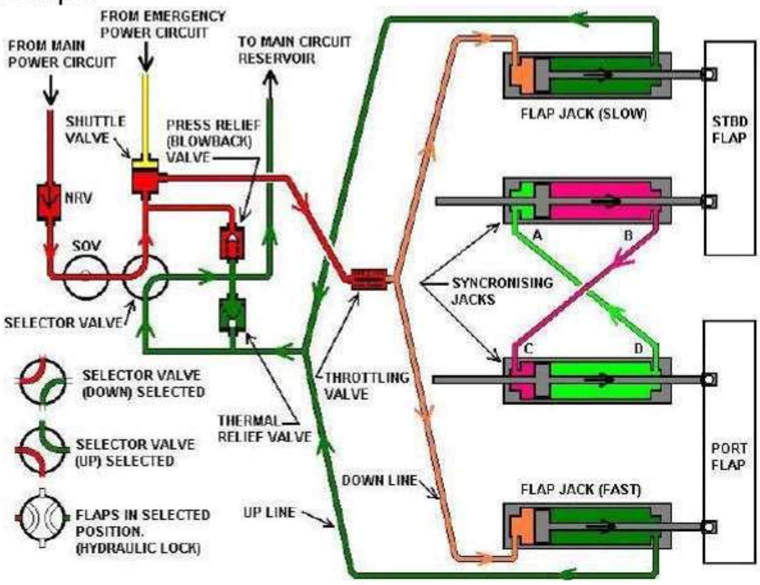


Fig. 11.72Typical Wing Flaps Hydraulic Circuit

THROTTLING VALVE

During flight, it is essential that the Wing flaps are lowered and raised slowly to prevent sudden change in the trim of the aircraft, therefore, a throttling valve is provided in the circuit. This valve reduces the rate of flow of fluid to and from the flap actuators and is normally situated in the DOWNline.

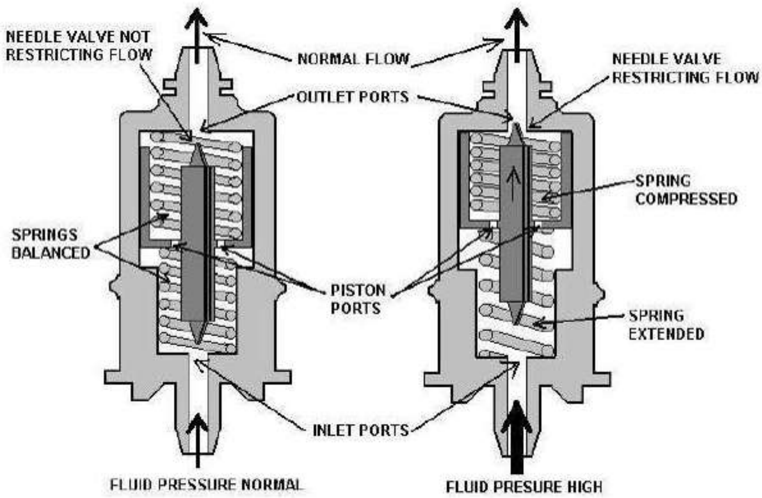


Fig. 11.73 Typical Balanced spring Throttling Valve

This valve, which is a form of two-way restrictor valve, maintains the flow of fluid to and from a service, but at a constant rate.

It automatically sets the flow rate in proportion to the supply pressure and is used to slow down the operation of the flaps.

Hydraulic System Interfaces

Any modern aircraft uses Integrated Modular Avionics (IMA) to interface with the hydraulic system. For example, the Boeing 777 uses four hydraulic interface module (HYDIM) cards for the interface between the hydraulic systems and other airplane systems.

The HYDIM cards receive and transmit data through the ASG cards and the systems ARINC 629 buses. The HYDIM cards also send and get signals through hard-wires.

ARINC 629 Interfaces

The HYDIM cards have these interfaces through the left and right systems ARINC 629 buses:

- Proximity sensor electronic unit(PSEU)
- Flap/slat electronic unit(FSEU)
- Overhead panel ARINC 629 system(OPAS)
- Electrical load management system (ELMS) power management
- APU controller(APUC)
- Air supply and cabin pressure controller(ASCPC)
- Cabin temperature controller(CTC)
- Engine data interface unit(EDIU)
- Autopilot flight director computer(AFDC)
- Airplane information management system(AIMS).

The HYDIM cards also send and receive data through AIMS and the flight controls ARINC 629 buses for these components:

- Primary Flight Computers
- Air Data Inertial Reference Unit(ADIRU).

Hard-wire Interfaces

The HYDIM cards also have these interfaces through hard- wires:

- Hydraulic systemcomponents
- Flight control shutoffvalve
- Landing Gear Truck tilt pressuresensors
- Electrical load management system (ELMS) power management
- Warning electronic system(WES).

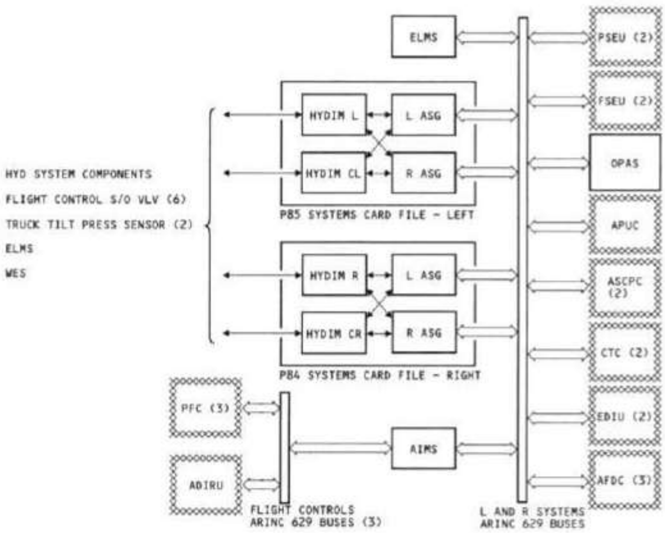


Fig.11.74 Boeing 111 hydraulic system interfaces

Another modern system, the Airbus A350, uses the Control and Display System (CDS) as the primary interface of the hydraulic system with other aircraft systems. The collected data is transmitted through the ADCN and shows on the hydraulic page of the Electronic Centralized Aircraft Monitoring (ECAM) system.

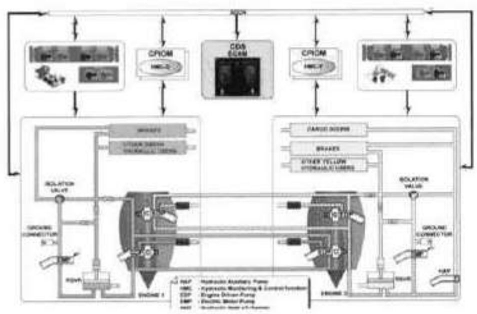


Fig. 11.75 Airbus A350 hydraulic system interfaces Control, Indication and Warning Cockpit Control Panels

Cockpit control of the hydraulic system tends to be very basic. Older aircraft have warning lights for LOW PRESSURE and OVERHEAT. More modern aircraft show only a FAULT light.

There are switches or push buttons to isolate the normal (Engine Driven) pump and switch on the alternate (usually Electric Motor) pump and/or the power transfer unit.

Fig. 11.76 Hydraulic pump switches - early Boeing 737

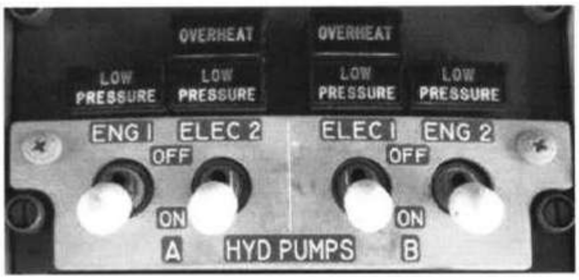


Fig. 11.77 Hydraulic pump switches - later Boeing 737

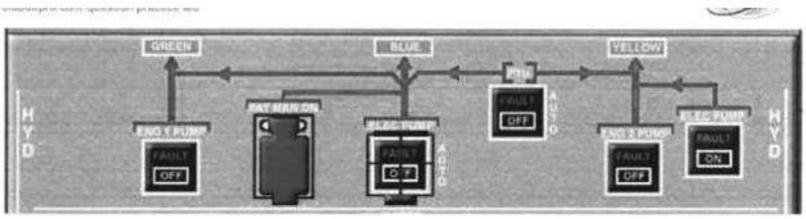


Fig. 11.78 Hydraulic panel - Airbus A320

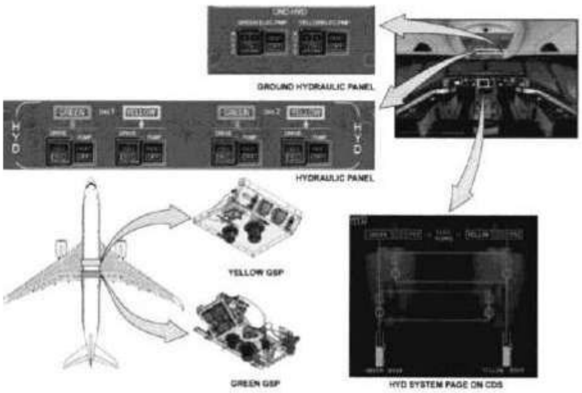


Fig. 11.79 Hydraulic panel - Airbus A350 Flight deck Indications

In many light aircraft, there is often no indication, in the cabin, of hydraulic system operation. Incorrect operation will, therefore, only become known to the pilot when a service is selected. However, an aircraft fitted with a power pack, will normally have a combined warning lamp/master switch on the instrument panel, which will indicate when the pump motor is operating, and will enable correct operation of the system to be determined. Larger aircraft normally have a hydraulic services panel in the crew compartment, which contains indicators covering parameters such as fluid quantity, pressure and temperature, and switches to control operation of emergency pumps and valves. The instruments and switches for each separate hydraulic system are normally grouped together, and the panel may be marked with a mimic diagram to assist the crew in transferring hydraulic power, or in overcoming an emergencysituation.

The following is usually sensed:

- the contents of the hydraulic fluid in the reservoirs (to indicate the fluid contents in each reservoir

and to send signals when the content in the reservoir is below a determinedlevel)
• the output pressure of the pumps by a switch (to monitor the outlet pressure of the hydraulicpumps)
• the pressure in the hydraulic systems (to monitor the hydraulic pressure at different locations. These signals are usuallyused

for indication and to inform e.g. flight control computers, that sufficient pressure is available.)
• the temperature of the hydraulic fluid (to monitor the hydraulic fluid temperature of the hydraulic systems. The temperature sensors are normally installed near the reservoirs on the return pipe and also integrated in each electricpump)
• the internal pressure of the reservoir (to monitor the internal air pressure of the hydraulic reservoirs. If too low, pumps can surge).

The information from the sensors is sent to the cockpit and used for indication and warning. In modern transport aeroplanes, this information is also sent to maintenance computer, which storesdata associated with malfunctions for troubleshooting later.

Figure 11.82 shows a display found on a modern aircraft. Figure 11.83 shows a conventional indication by electro-mechanical gauges.

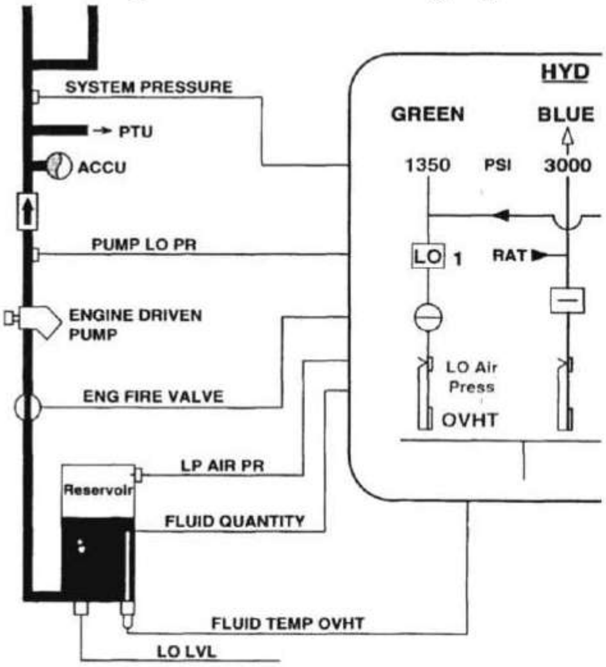


Fig. 11.80 Hydraulic System with Display Indication

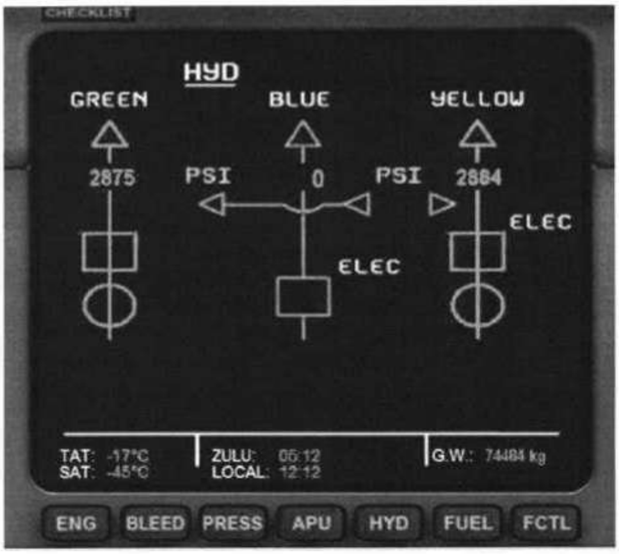


Fig. 11.82 ECAM (Airbus) hydraulics page

Fig. 11.83 Hydraulic gauges - Boeing 737

Module 11.16 Pneumatic/Vacuum (ATA 36)

Pneumatic and vacuum systems on aircraft have historically taken three meanings.

Vacuum System - A system used to supply driving power, in the form of a suction of air, to several gyro instruments, such as the ADI (artificial horizon), HSI (heading indicator) and Turn indicator. The system is used as an alternative to electrical power, and is considered as a failsafe system, in that should the electrical power supply to the aircraft systems fail, then the pilot will still have some essential flight instruments available. The vacuum driven instruments are now used only on light aircraft.

The Vacuum systems are described in Section 11.5.

High Pressure Pneumatic Systems - Extensive high-pressure pneumatic systems powered by engine-driven compressors are generally fitted on the older types of piston-engined aircraft and are used to operate services such as the landing gear, wing flaps, wheel brakes, radiator shutters and, at reduced pressure, de- icing shoes. The use of hydraulics has now superseded this method of power supply but the system will be discussed here briefly.

There are many modern aircraft which also use a smaller system of high-pressure pneumatic air, using air tapped from the latter stages of the turbine engine compressor. This pneumatic power is for the emergency operation of essentialservices.

Low Pressure Pneumatic Systems - These are used on most turbine-engined aircraft for engine starting, de-icing, and cabin pressurization, and are supplied with compressed air tapped from the enginecompressor.

High pressure pneumatic system

The use of a compressed-air system to operate an aircraft services was used on piston-engines transport category aircraft of the 1950s and 1960s, and it usually represented a saving in weight compared to a hydraulic system, since the operating medium is freely available, no return lines are necessary, and pipes can be of smaller diameter. System having operating pressure of up to 24MN/m2(3,500 ib/in2) are in use, andprovide for the repaid operation of services when this is required.

However, compressed air is generally not suitable for the operation of large capacity components, leaks can be difficult to trace, and the result of pipeline or component failure can be veryserious

System Layout

The system illustrated in figure 16.1 contains two separate power circuit, each of which is supplied by a four-stage compressor driven from the gearbox of one main engine. And a common delivery pipe to the high-pressure storage bottle and system services. A multi-stage cooler attached to each compressor cools the air between each of the compression stages, and a means is provided for off -loadig the compressor when the system is not beingused

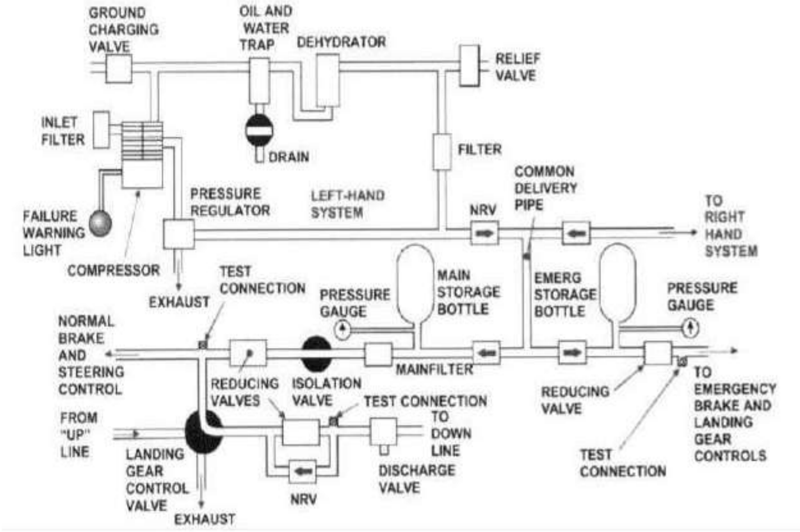


Fig. 16.1 A typical high-pressure pneumatic system

Air is drawn through an inlet filter into each compressor, and is discharged through an oil-and-water trap, a chemical dehydrator, a filter and a non-return valve, to the main storage bottle and system. Overall control of main system pressure is provided by means of a pressure regulator, but pressure relief valves are included to prevent excessive pressures in thesystem, which may be caused by regulator failure or by an increase in temperature in the pipelines andcomponents. Pressure reducing valves are used to reduce the pressure supplied to somecomponents.

A storage bottle for the emergency system is pressurized through a non-return valve from the main system supply, and maintains an adequate supply of compressed air to enable the landing gear and flaps to be lowered, and the brakes to be applied a sufficient number of times toensure a safe landing.

Isolation valves are fitted to enable servicing and maintenanceto be carried out without the need to release all air from the system, and pressure gauges are provided to indicate the air pressure in the main and emergency storagebottles.

Components

The types of components used in a high-pressure pneumatic system will vary considerably between aircraft, but the examples considered in this paragraph are typical of the components which may be found in currentuse.

Compressors

A positive-displacement pump is necessary to raise the air pressure sufficiently for the operation of a pneumatic system, and a piston-type pump is generally used. Some older types of aircraft are fitted with a single-cylinder piston pump, which provides two stages of compression and raises the working pressure to approximately 3 MN/m2 (450 lbf/in2). To obtain higher working pressures further compression stages are required. The compressor is capable of raising air pressure in four compression stages to 24 MN/m2 (3,500lbf/in2).

The compressor illustrated in Figure 16.2has two stepped cylinders, each of which houses a stepped piston; a plunger attached to the head of No.2 piston operates in a small cylinder bored in the head of No.2 cylinder. The reciprocating motion of the main pistons is provided by individual cranks and connecting rods, the cranks being rotated by a common drive gear, and rotating in the same direction. Air passing between each compression stage is routed through an integral cooler, and lubrication is provided by an oil feed connection from the main engine lubricationsystem.

Compression depends on the volume of each successive stroke being smaller than the stroke preceding it; the induction strokes for each cylinder and the four compression strokes are accomplished during each revolution of thecranks.

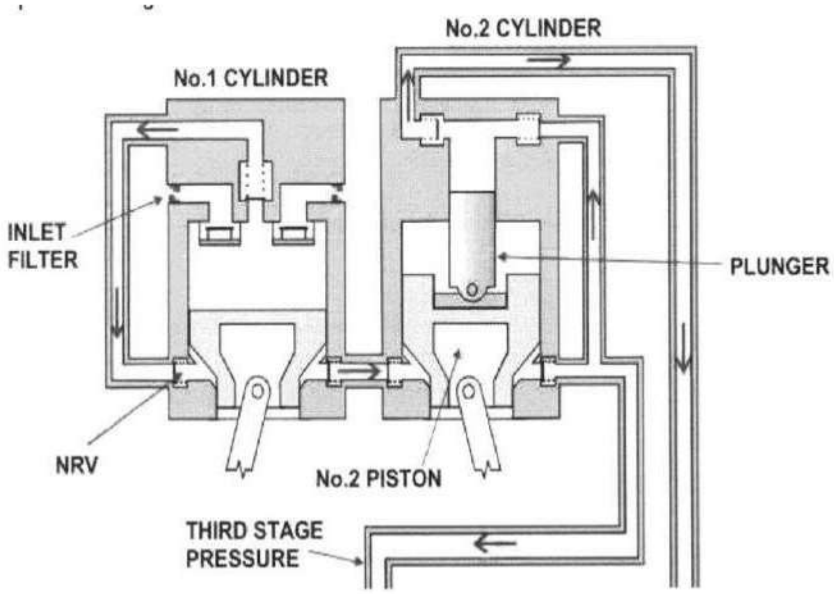


Fig. 16.2 Air compressor

Operation of the compressor is as follows:-

- On the downward stroke of No. 1 piston, air is drawn into the cylinder head through a filter and non-return valve (NRV).
- On the upward stroke of No. 1 piston, air is compressed in the cylinder, opens aNRV in the cylinder head, and passesto the annular space formed between the steps of the cylinder andpiston.

- The next downward stroke of No. 1 piston compresses air in the annular space in this cylinder and forces it through aNRV into the annular space formed between the steps of No. 2 cylinder and piston. No. 2 piston is approximately 90°in advance of No. 1 piston, and is moving upwards as No. 1 piston approaches the bottom of itsstroke.
- On the downward stroke of No. 2 piston, air is compressedin the annular space at the bottom of the cylinder, and passes through aNRV into the small c ylinder formed in No. 2 cylinderhead.
- On the upward stroke of No. 2 piston, the plunger attached to it also moves upwards, further compressing the air in the small cylinder and passing it through a NRV to the system.

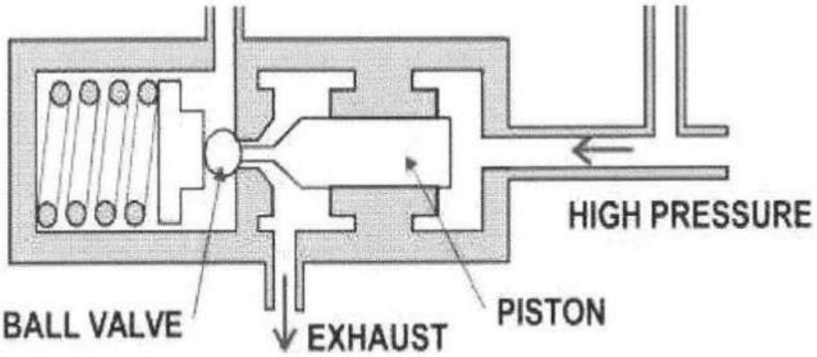
A pressure warning transmitter is fitted at the second-stage outlet, and third-stage pressure is connected to the pressure regulator

Pressure Regulator

The pressure regulator is fitted to control the maximum pressure in the system and to off-load the compressor when the system is idle. With the regulator illustrated in Figure 16.3, system pressure is fed to the top connection and acts on a piston, the lower end of which is in contact with the ball of a spring-loaded ball valve. At the predetermined maximum system pressure, the air pressure on the piston overcomes spring pressure and the ball valve is opened, releasing third-stage compressor pressure to atmosphere and allowing the pump to operate at second- stage pressure only. If any pneumatic services are operated, or a leak exists in the system, the air pressure trapped in the storage bottle and pipelines will drop, and the ball valve in the pressure regulator will close. The compressor will thus bebrought back on line until the maximum system pressure is restored.

Fig. 16.3 Pressure regulator Oil-and-Water Trap

The oil-and-water trap is designed to remove any oil or water which may be suspended in the air



delivered by the compressor. It consists of a casing with inlet and outlet connections at the top and a drain valve in the bottom. Air entering the trap does sothroughastackpipe,whichincludes a restriction and a baffle to prevent the airflow stirring up any liquid or sediment in the bottomof the container. Air leaving the trap also passes through a stack pi pe, to prevent liquid or sediment entering thesystemduring aircraftmanoeuvres.

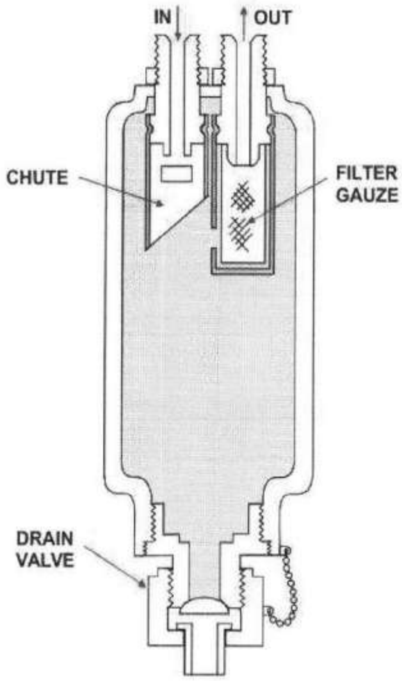


Fig. 16.4 Oil-and-Water trap

Dehydrator

To protect pneumatic systems from malfunctioning due to moisture freezing in the components and pipelines, the com pressed air may be dehydrated by a substance such as activated alumina, or it may be inhibited by a small quantity of methanol vapour. The handling of methanol presents some difficulties, however, and because of its corrosive nature systems must be specially designed for its use; activated aluminais,therefore, more generallyused.

Activated alumina is housed in a container through which the compressed air passes after leaving the oil-and-water trap, and which generally contains a filter at the outlet end. The charge of alumina in the container will gradually become saturated with moisture, andshould be changedat thespecified intervals. The number of flying hours at which the alumina charge is changed is normally determined by the aircraft manufacturer through practicalexperience.

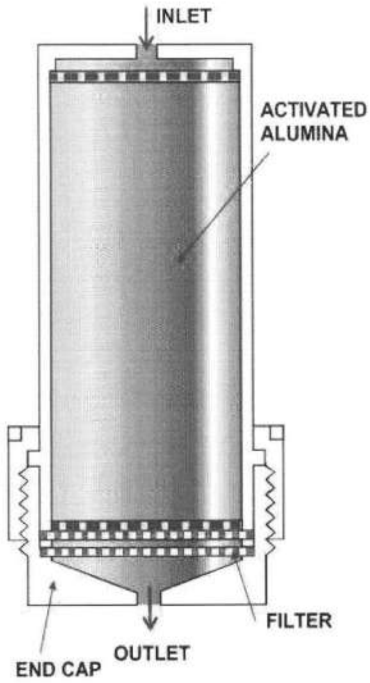


Fig. 16.5 Dehydrator

Storage Bottles

In a pneumatic system the storage bottles provide the reservoir of compressed air which operates all services, the compressors being used to build up system pressure when it falls below the normal level. The volume of the actuators and pipelines determines the size of the bottles required for the normal and emergency operation of the pneumaticservices.

Storage bottles are generally made of steel, andmay be of wire-wound construction for maximum strength. Bottles are generally mounted in an upright position, and a fitting screwed into the bottom end contains the supply connection and, usually, a connection to an associated pressure gauge, together with a drain valve by means of which any moistureor sediment may be removed. Stack pipes are provided at the supply and gauge connections in the fitting, to prevent contamination passing to the system or pressure gauge. Pressure testing of high-pressure storage bottles is required at specified peri ods, and the date of testing is usually stamped on the neck of the bottle.

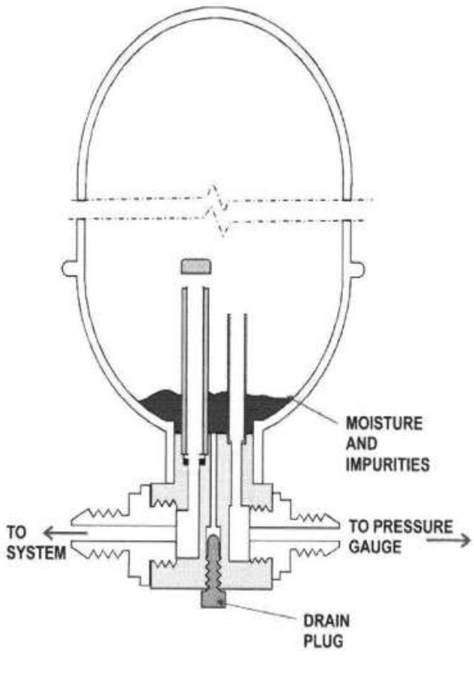


Fig. 16.6 Storage bottle

Pressure Reducing Valves
Some services operate at pressures lower than the pressure available in the air bottle, and are supplied through a pressure reducing valve. This low pressure is, in some instances, further reduced for the operation of, for example, the wheel brakes, by the fitting of a second pressure reducing valve.

Figure 16.7 illustrates the operation of a pressure reducing valve. When pressure in the low-pressure system is below the valve setting, the compression spring extends and, by the action of the bell-crank mechanism, moves the inlet valve plunger to admit air from the high-pressure system. As pressure in the low- pressure system increases, the bellows compresses the spring and returns the inlet valve plunger to the closed position. The inside of the bellows is vented to atmosphere, and the valve thus maintains a constant difference in pressure between the low- pressure system and atmosphericpressure.

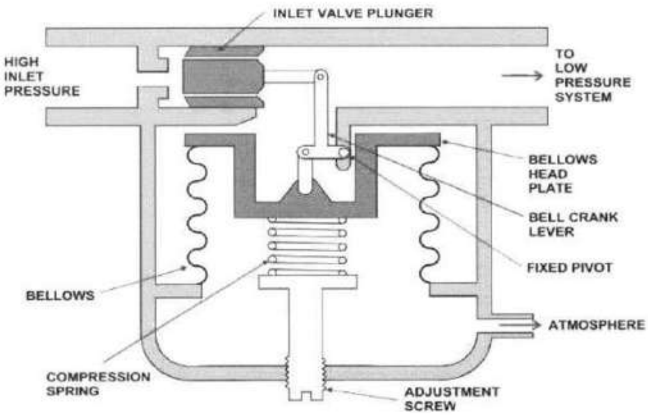


Fig. 16.7 Pressure reducing valve

Pressure Maintaining Valve
A pressure maintaining valve is designed to conserve air pressure for the operation of essential services (e.g. landing gear extension and wheel brake operation), in the event of the pneumatic system pressure falling below apredeterminedvalue.

Figure 16.8 illustrates the operation of a typical pressure maintaining valve. Under normal circumstances air pressure is sufficient to open the valve against spring pressure and allowair to flow to the non-essential services. Should the pressure in the storage bottle fall below a value pre-set bythe valve spring, however, the valve will close (as shown) andpreventair passing to the non-essentialservices.

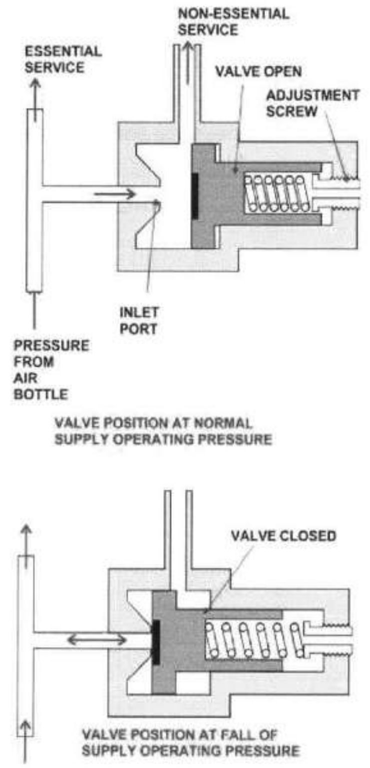


Fig. 16.8 Pressure maintaining valve

Control Valves

Compressed air stored in the bottle is distributed to the various pneumatic services, and directed to the various types of actuators by means of control valves, which may be manually or electricallyoperated.

Electrically-operated Control Valve

The electrically-operated control valve for a pneumatic landing gear retraction system is illustrated in Figure 16.9. Selection of the landing gear position is made by either of two push-buttons (marked 'up' and 'down') which are mechanically interconnected to prevent operation of both buttons at the same time. These buttons, when depressed, supply electrical power to the 'up' or Mown* solenoid as appropriate. Actuation of this solenoid lifts an attached pilot valve, supplying compressed air to the cylinder at the bottom of the associated valve; the piston moves downwards, and the valve guide attached to it opens the inlet valve, admitting compressed air to the appropriate side of the landing gear actuators. At the same time the beam attached to the extension of this piston transfers movement to the valve guide in the opposite valve, allowing air from the opposite side of the actuators to exhaust toatmosphere.

Manually-operated Control Valve

The valve illustrated in Figure 16.10 is a simple two- position valve, and may be used as an isolation valve in some systems. The sleeve valve is operated by a cam, and is spring- loaded to the 'off position; linkage from the cam spindle connects the valve to an operating lever. When used as an isolation valve the operating lever would normally be wire-locked in the 'on' position, and would only be used to permit servicing operations to be carriedout.

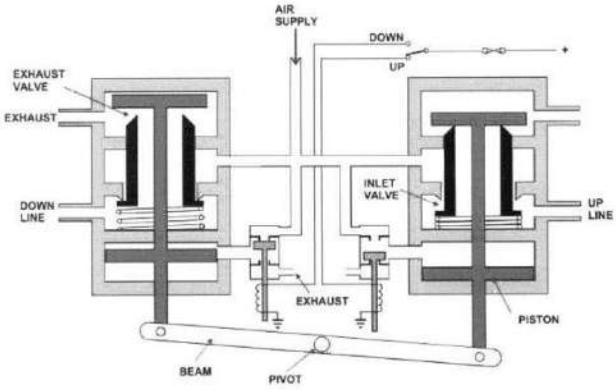


Fig. 16.9 Electrically operated control valve

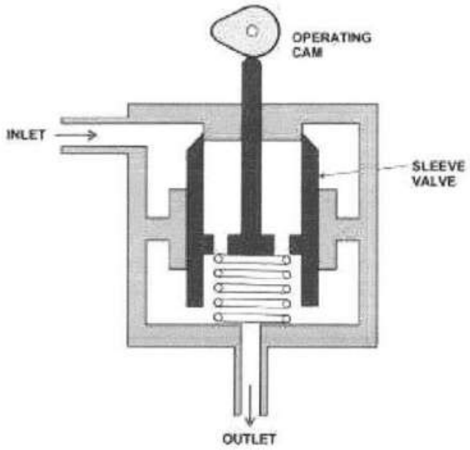


Fig. 16.10 Mechanically operated control valve

Brake Control Valve

Some older types of aircraft may be fitted with a type of brake control valve (known as a dual-relay valve) by means of which total brake pressure is applied by the operation of a single hand- control, and distribution to either or both brakes is effected by means of a mechanical connection to the rudder bar. The type of brake control valve illustrated in Figure 16.11 is used on some modern aircraft, and is operated by linkage from brake pedals attached to the rudder bar; separate valves supply compressed air to the brake units on eachwheel.

Operation of the valve is as follows:-

In the OFF position the inlet valve is closed and pressure in the brake line is connected to the exhaust port.

Pressure applied to the associated brake pedal is transmitted via the brake linkage to the valve sleeve, which moves up to close the exhaust valve. Further pressure applied through the valve sleeve and lower spring tends to open the inlet valve, and air pressure in the brake line combined with the force exerted by the upper and centre springs tends to close it. This produces a balanced condition in which any increase in the force applied to the valve sleeve results in a higher air pressure in the brake line, and a decrease in the force applied to the valve sleeve results in opening of the exhaust valve and a reduction in the air pressure in the brakeline.

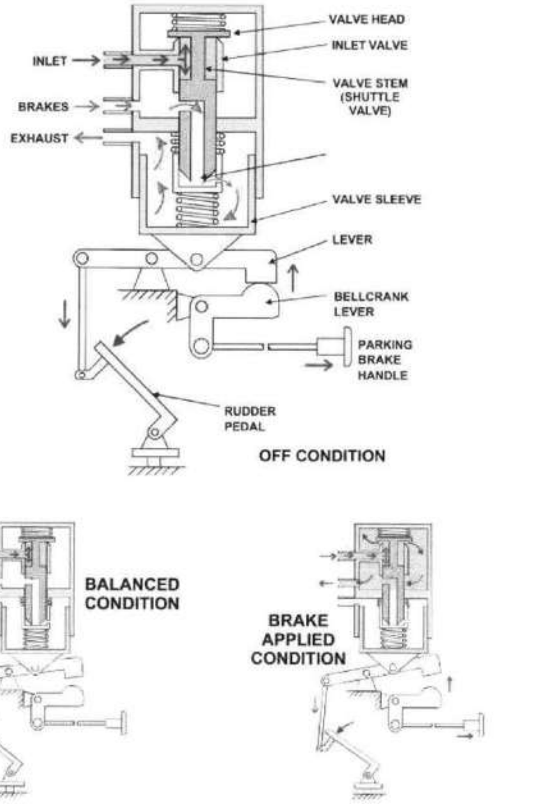
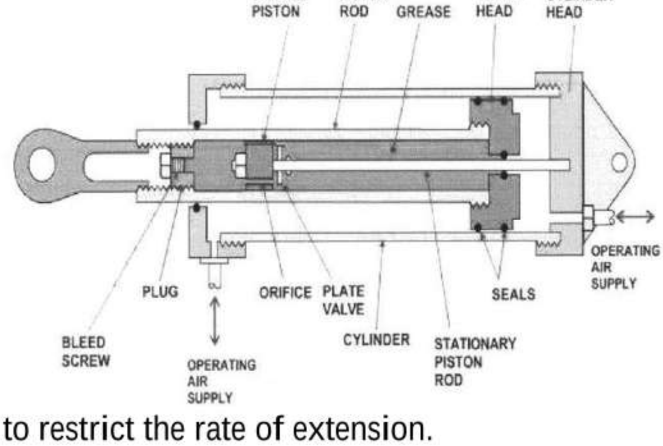


Fig. 16.11 Brake control valve

Actuators

The purpose of an actuator is to transform the energy of the compressed air into linear or rotary motion. Actuators in pneumatic systems are normally of the linear type, and are similar in construction and operation to those described for hydraulic systems. Because of the nature of the operating medium, however, actuators in pneumatic systems are often damped to prevent violent operation of the services. A typical damped actuator is illustrated in Figure 16.12, the damping in this case being obtained by forcing grease through the annular space between the inner wall of the piston rod and a stationary damper piston; an orifice and plate valve in the damper piston provide less damping action when the piston rod retracts than when it extends. This type of actuator could be used, for example, to



operate the landing gear and to restrict the rate of extension.

Fig. 16.12 Actuator

Low Pressure Pneumatic Systems Users

Modem aircraft systems supplied by engine bleed air are typically:

- Air conditioning systems (Air cycle packs, Cabin compressors, Freoncompressors)
- Air driven hydraulicpumps
- Engine startermotors
- Engine thrust reverseractuators
- Anti-ice or de-icing systems for wing, tail and airinlets
- Cargo heating and ventilationsystems
- Galley and Lavatory ventilationsystems
- Water tank pressurizationsystems
- Hydraulic tank pressurizationsystems

Sources
Pneumatic sources in flight are:

- Enginecompressors
- As alternate source: Airborne Auxiliary Power Unit (APU), if designed for bleed air supply inflight.

Pneumatic sources on ground are:

- Mobile starter units or ground pneumatic networks - fixed installed in hangars or on thetarmac.

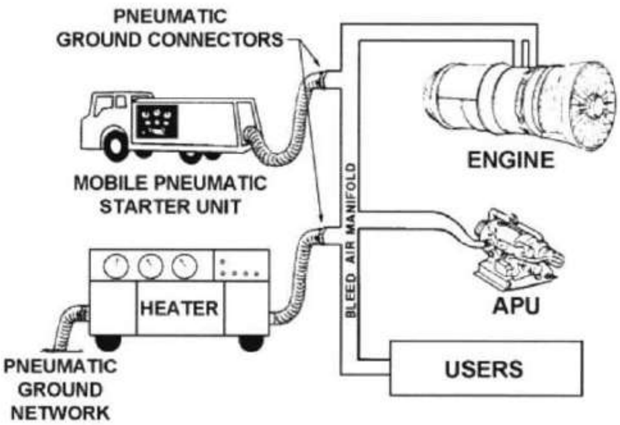


Fig. 16.13 Pneumatic Sources Distribution and Control Main Components

- Ground PneumaticConnection

Pneumatic hose adapter with integrated check valve.

- High Pressure ControlValve

This is used to determine the source of engine compressor stage.

- LP CheckValve

Prevents reverse flow to the engine low stage compressor.

- APU • Pressure RegulatingValve
- Enginecompressors Shuts off or regulates the pneumatic supplypressure.
- Over PressureValve

Closes in case of malfunction of the pressure regulating valveto protect the users against over pressure.

- Fan AirValve

Regulates the pneumatic supply temperature.

- HeatExchanger

This is used to cool the pneumatic air with fan air.

- Isolation Valve

This is used to split or connect the different pneumatic systems.

- APU BleedValve

Shuts off or allows APU bleed air supply.

- Manifold Failure SensingElement

This is used to detect bleed air leaks or duct rupture.

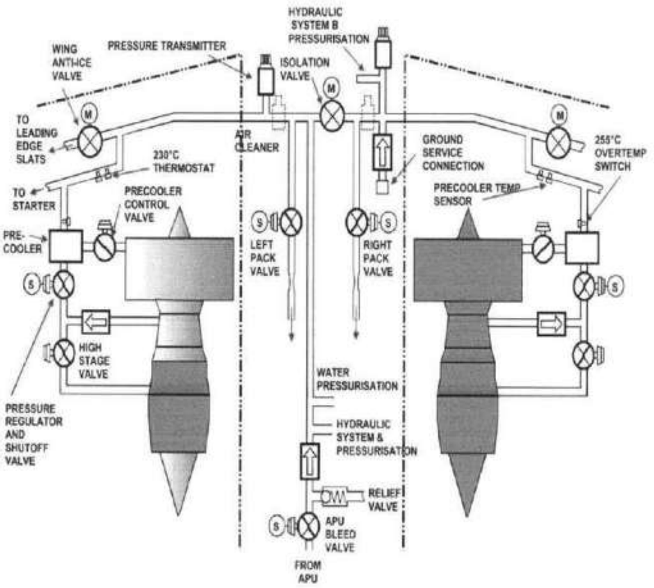


Fig. 16.14 Typical Pneumatic System Lay-Out

Engine Bleed Air

The engine bleed air system consists of the power source (the engine compressors) and the control devices. These control devices regulate temperature and pressure during system operation.

Because of the great variation of air output available froma gas turbine engine between idle and maximum power there is a need to maintain a reasonable supply of air during low power operation as well as restricting excessive pressure and temperature when the engine is at maximumpower.
Fig. 16.15 Engine bleed system

Compressor Stage Selection

The air is ducted from two different stages of the compressor, a low pressurestage and a high pressure stage. The high pressurecontrol valve is used to determine thesourceofengine compressorstage.

When low stage air is insufficient for the pneumatic system to maintain the prescribed flow or temperature requirements, the high pressurecontrol valve will open and allow high stage air to enter the bleed air ducting, so increasing the engines outputof bleedair.

As the output of the compressor air depends on engine power, the high pressure control valve will be open at low power (during descent or idle). As the engine power increases low stage air pressure will increase and close the valve, so in normal cruise flight bleed air will come from thelow stage.

The high pressurecontrol valve is normally pneumatically actuated and may be controlled by solenoids or a torquemotor.

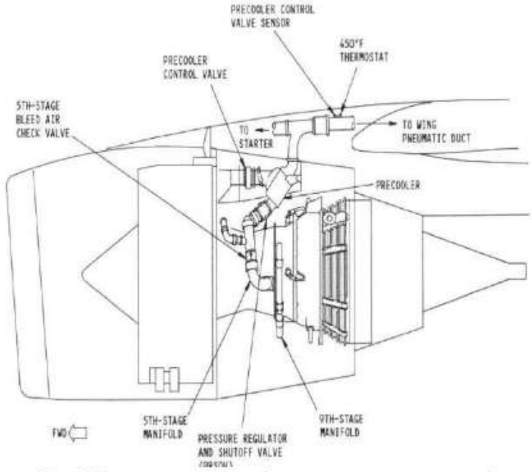
The LP check valve prevents reverse flow to the engine low stagecompressor.

Pressure Regulation

The pressure regulating valve shuts -off or regulates the pneumatic supply pressure to a constant value. The valve is pneumatic actuated and electrically controlled by a shutoff solenoid or a torque motor, depending on aircraft type. In caseof electrical power loss, the valve opens and regulates aconstantpressure.

Temperature Regulation

The fan air valve regulates the amount of fan cooling airflow via the heat exchanger to control the required pneumatic temperature. The valve is normally pneumatically actuated with control pressure



from a thermostat or from an electrically controlled torque motor, depending on the aircrafttype.

Fig. 16.16 Engine bleed air system

Engine Bleed Air Control System

The engine bleed air system is normally controlled and monitored by a Pneumatic System Controller (PSC) or a Bleed Monitoring Computer (BMC).

The controller or computer receives all the necessary input signals from the engine pneumatic system sensors, valves and bleed air control switches to monitor the system or shut off the system in case of dangerous conditions. It provides warning and status signals for the indication on the Engine WarningDisplay.

The controller contains also a Built-In-Test Equipment (BITE) to localize and store the failures of the faulty bleed air components. For troubleshooting, the BITEsystem can be used via a Centralized Fault Display System(CFDS).

Functional Description

The bleed air is normally supplied from the engine low pressure compressor stage to minimize the engine fuel consumption. During low engine speed, if the low stage pressure and temperature is insufficient, the air is supplied from the high pressure compressor stage. The transfer from one bleed stage to the other is achieved by the High Pressure Valve (HPV). The HPV is pneumatically controlled and connected via a coupling sense line with the Pressure Regulating Valve (PRV). The HPV is spring loaded closed and starts to open at 8 PSI high stage pressure. It regulates the downstream pressure to 36PSI.

The HPV closes if:

- the high stage pressure exceeds 100 PSIor
- the low stage pressure exceeds 36 PSIor
- the Pressure Regulating Valve (PRV) is closed. (ThePRV

discharges the HSV opening pressure to ambient via the coupling sense line)

The Pressure Regulating Valve (PRV) regulates the pneumatic supply pressure to 44 PSI. The PRV is pneumatically operated and controlled by the Temperature Limiting Thermostat (TLT) via a sense line. To prevent a pneumatic overheat condition, the TLT reduces the PRV outlet pressure progressively if the pneumatic supply temperature exceeds a maximum limit (>235^). The PRV is spring loaded closed and starts to open at 8 PSI upstream pressure.

The TLT vents the PRV opening pressure to ambient for closing the valve if:

- a reverse flow condition exists (PRV upstream pressure lower than downstream pressure)or
- the Solenoid in the TLT isenergized.

The Solenoid in the TLT is energized if:

- the ENG BLEED P/B is in “OFF” positionor
- the ENG FIRE P/B is pushedor
- the Engine Starter Valve is openor
- the APU supplies the respective pneumatic systemor
- the BMC detects an over pressure condition (>56 PSI)or
- the BMC detects an over temperature condition (>257“C)or
- the BMC detects a leak in the respective pneumaticsystem.

The Over Pressure Valve (OPV) prevents excessive pneumatic supply pressure.

The valve is pneumatically actuated and normally spring loaded open: It start to close if the upstream pressure exceeds 75 PSI and is fully closed at 85 PSI. The OPV re-opens if the pressure decreases below 35PSI.

The pneumatic supply temperature is reduced if necessaryin the heat exchanger with cooling air from the engine fan compressor. The Fan Air Valve (FAV) regulates the cooling air flow via the heat exchanger. The Fan Air Valve is spring loaded closed and pneumatically controlled to open by the Temperature Control Thermostat (TCT) via a sense line. The TCT modulates the Fan Air Valve to control the pneumatic temperature at200„C.

The Regulated Pressure Transducer (RPT) sends the PRV downstream pressure signal to both BMCs for pressure indication and failure monitoring.

The Transfer Pressure Transducer (TPT) sends the transfer pressure (upstream pressure of the PRV) to the BMC. The signal is used for failure monitoring of the PRV andHPV.

The Temperature Sensor (TS) is a dual sensor and sends the pneumatic supply temperature to both BMCs. The signal is used for temperature indication and failuremonitoring.

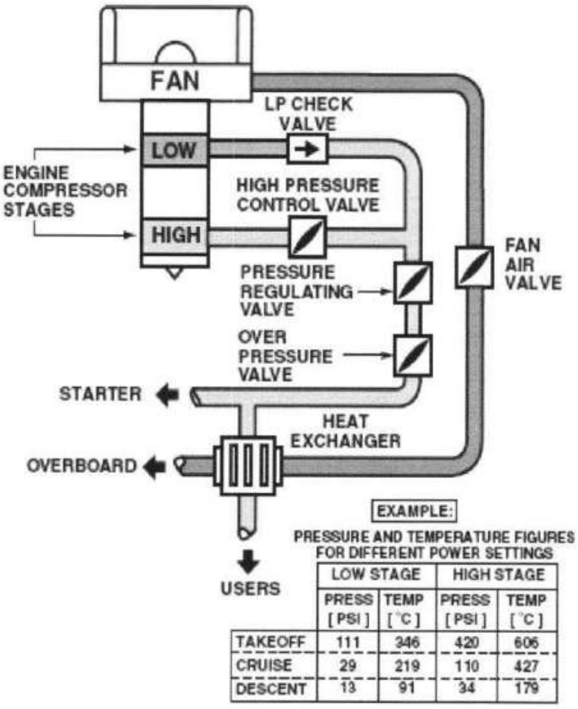
The BMC illuminates the FAULT light in the ENG 1 BLEED P/B if:

- the regulated pressure is > 57 PSIor
- the regulated temperature is >257 „Cor
- the BMC detects a leak in the respective pneumatic system or
- thePRVfailstocloseduringenginestartorAPUBleed

supply or

- the PRV fails to close if the engine is notrunning.

The FAULT light extinguishes when the ENG 1 BLEED P/B is set to OFF position provided the failure cause isremoved.



	LOW STAGE		HIGH STAGE	
	PRESS [PSI]	TEMP [°C]	PRESS [PSI]	TEMP [°C]
TAKEOFF	111	346	420	606
CRUISE	29	219	110	427
DESCENT	13	91	34	179

Fig. 16.17 Example of an Engine Bleed Control System (Airbus A320)

APU Bleed Air Supply System
There are different APU bleed air supply systems installed in modern aircraft. The system varies with the respective APU Type.

Most APUs are designed for bleed air extraction on ground only. If an APU is designed for bleed air extraction in flight, then the bleed air extraction is normally limited up to a specific flight altitudeonly.

APU bleed air supply has normally a higher priority than engine bleed air supply. That means the engine bleed supply is automatically inhibited if APU bleed is selected.

Three different APU bleed air supply systems are used

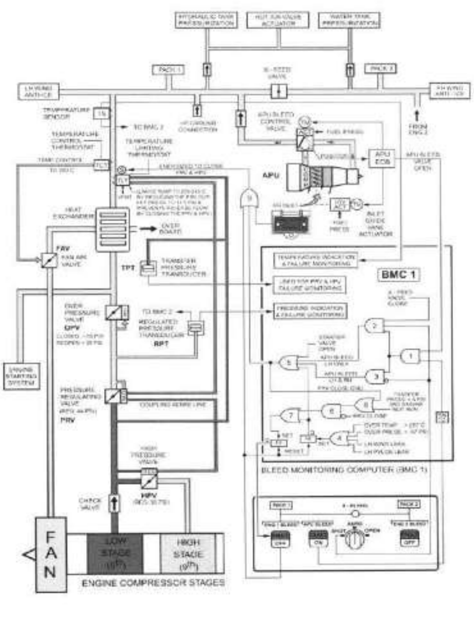


Fig. 16.18 APUs which extracts the bleed air from the compressor of the power section. (Example: Boeing747)

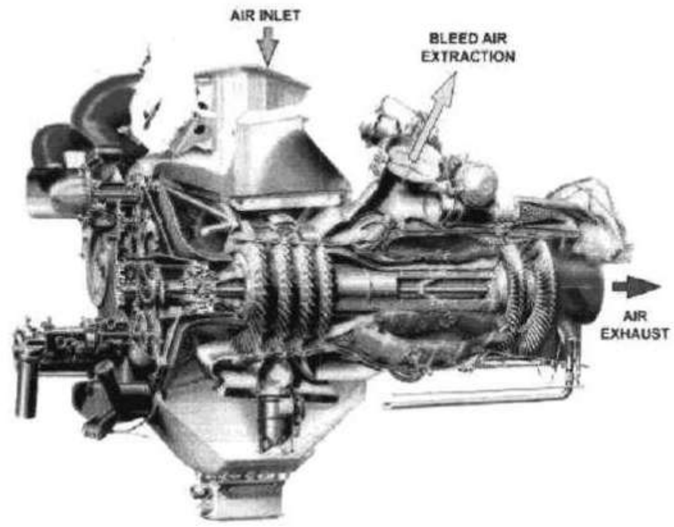


Fig. 16.19 APUs which extracts the bleed airfroma separate load compressor driven by the turbine ofthe power section (Example: AirbusA330)

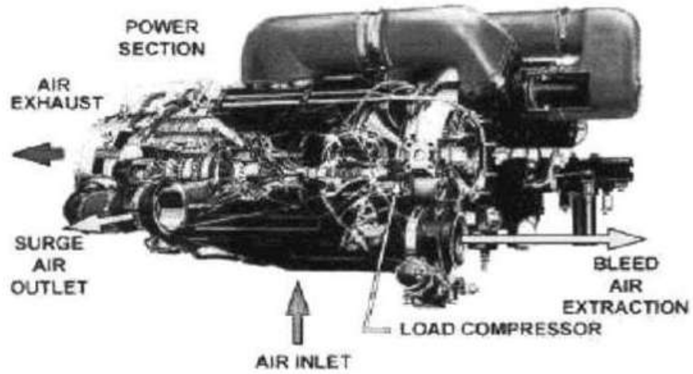


Fig. 16.20 APUs with two shafts (N1 & N2) which extracts the bleed air from the N1-Compressor driven from the N1- Turbine (Example: MD-11)

APU Bleed Air Control System

The APU bleed air control system consists of two main systems;

- the Inlet Guide Vane (IGV) control systemand
- the bleed controlsystem.

The Inlet Guide Vane control system controls the position of the load compressor inlet guide vanes in order to avoid overtemperature (high EGT) of the powersection.

The bleed control system controls the APU Bleed ControlValve in order to avoid load compressor surgecondition.

IGV Control System

The APU load compressor, driven with a constant speed from the turbine of the APU power section, supplies the APU bleed air. The quantity of APU bleed air can be controlled with the load compressor inlet guide vanes. The inlet guide vanes are moved by the IGV actuator. The IGV actuator is fuel pressure actuated and electrically controlled by a torquemotor.

The APU ECB controls the torque motor according to the aircraft pneumatic demand signals for air conditioningoperation or engine start. The bleed air quantity is limited by the APU Exhaust Gas Temperature (EGT). The EGT-limit varies with the APU air inlet temperature. The actual EGT increases with the APU load. That means with a high APU generator load the APU bleed air supply will be automatically reduced. (APU electrical power supply haspriority).

If no APU bleed air is selected or during APU start sequence, theIGVswillbecontrolledtoclosetounloadtheAPUshaft.

Above 20,000 ft flight altitude, the IGVs will be controlled to close. For this function the ECB uses the pressure signal from the air inlet pressure sensor. (APU bleed air can normally be used up to a specified flight altitudeonly).

Bleed Control System

The APU bleed control valve controls the air from the load compressor to the pneumatic system or to the APU exhaust duct. The valve actuator is fuel pressure operatedandcontrolled by a torquemotor.

The APU ECB controls the torque motor in order to avoid load compressor surge condition and to supply the aircraft pneumaticsystem.

To provide this function, the ECB needs input signals from several sensors.

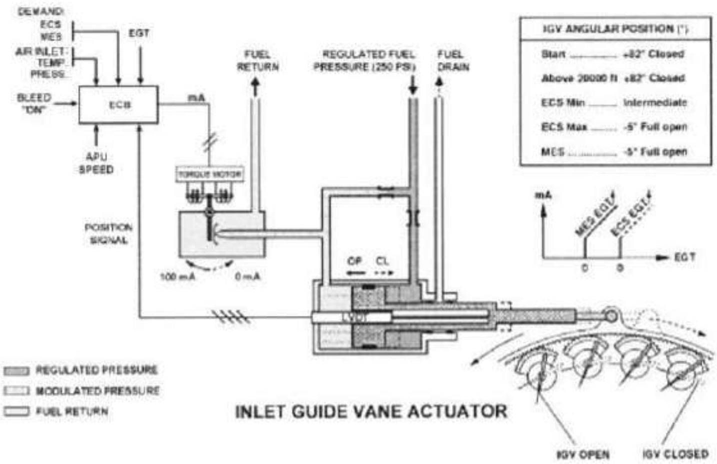


Fig. 16.21 Inlet guide vane system - operation

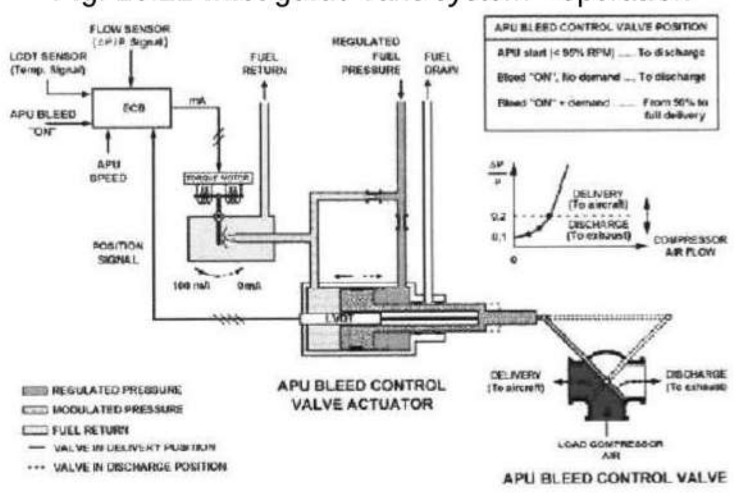


Fig. 16.22 Air bleed system - operation

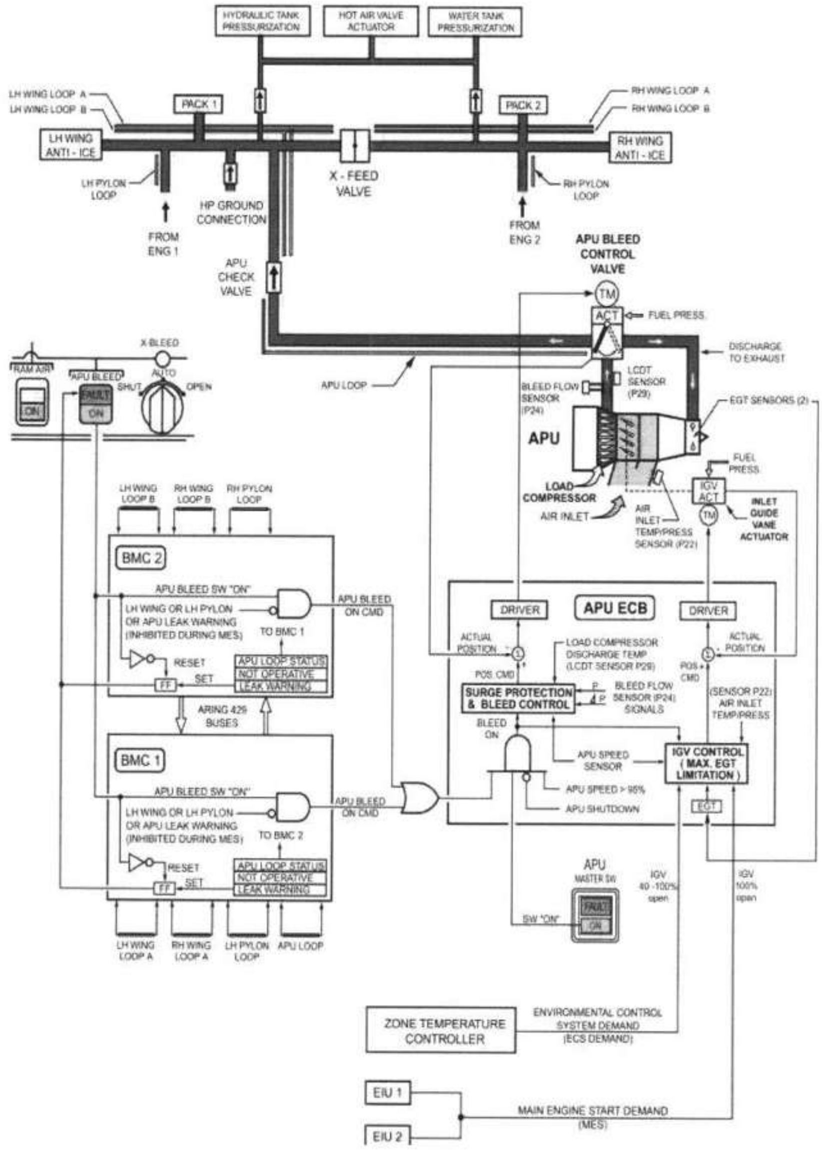


Fig. 16.23 APU bleed air control system (AirbusA320)

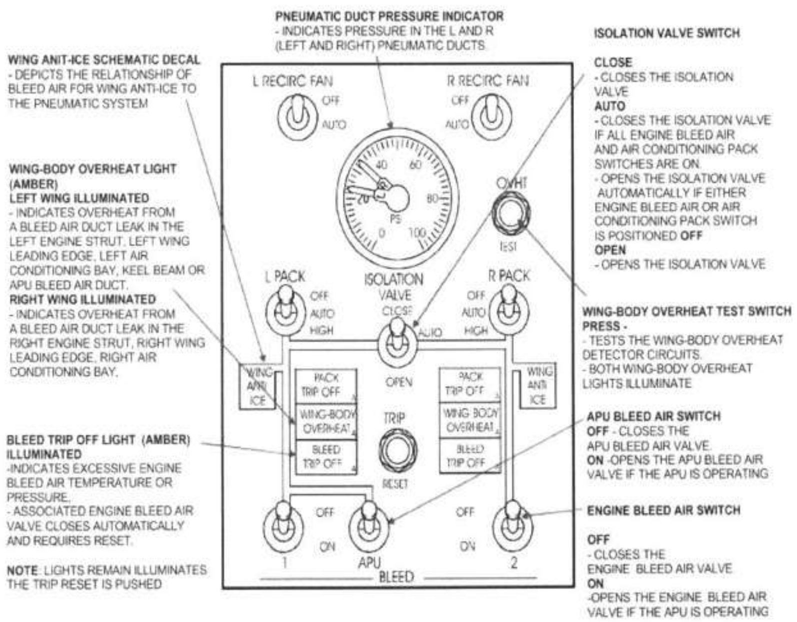


Fig. 16.24 Pneumatic system control panel Indications and Warnings Indications

To monitor the pneumatic system,normally pneumatic pressure and temperature indicators are installed in the cockpit. On newer aircraft this indications may be shown on a system display screen.

Warnings
To alert the flight crew if dangerous or abnormal conditions in the pneumatic system exists warning and caution lights are provided in the cockpit.

Typical Warning lights are:

- "PNEUM TEMP HI" This warning light comes on, if the pneumatic temperature exceeds a set threshold(255^)
- "PNEUM MANFLD FAIL" This warning light comes on, if a duct rupture or a leak in a pneumatic manifold is detected.
- Typical Caution lightsare:
- "PNEUM ABNORM" This caution light comes on, if the pneumatic pressure or temperature is abnormal or valves and sensorsfail.
- "USE ENG PNEUM SUPPLY" This caution light comes on, if the pneumatic system is still supplied by the APU to remember the pilots that they must use theenginepneumatic supplysystem.

On newer airplanes similar warnings may also be shown on a system or warning display screen.

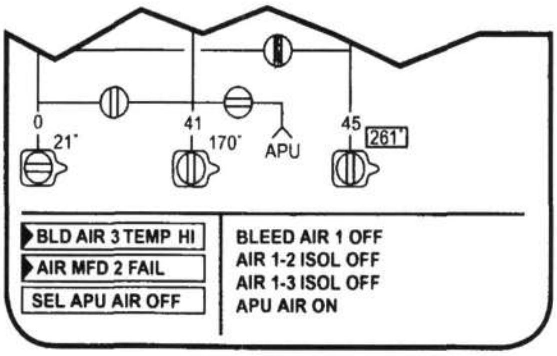


Fig. 16.25 System display

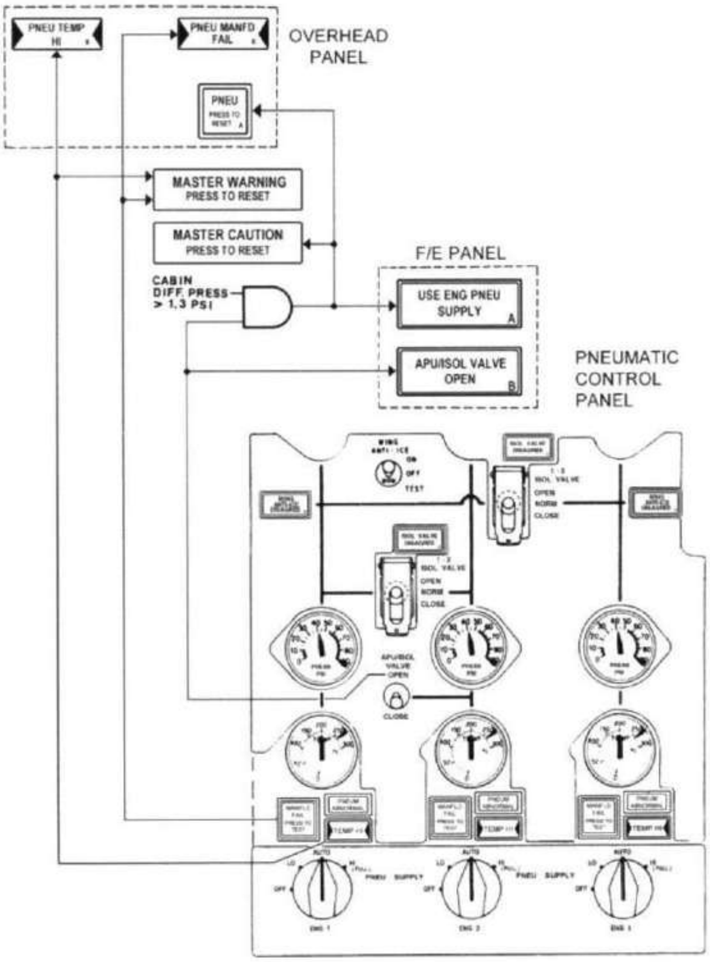


Fig. 16.26 Example of Pneumatic IndicationsandWarnings

Example of a Pneumatic System display

PNEUMATIC PRESSURE		
30P SI	Green	Becomes amber if lower than 4 psi or in case of overpressure detected (above 57 psi).

PNEUMATIC TEMPERATURE		
160°C	Green	Became amber in case of overheat or low temperature detection.

Overheat is detected if the temperature exceeds:
- 290°C for more than 5 sec or,
- 270°C for more than 15 sec or,
- 257°C for more than 55 sec.

Low temperature is detected if the temperature is lower than 150°C.

NOTE:
On ground with engine at idle, depending on ambient temperature, the pneumatic temperature may be lower than 150°C (displayed amber)

ENGINE IDENTIFICATION (1/2)
Normally white. Becomes amber when engine N2 below idle

PRESSURE REGULATING VALVE		
⦶	Green	valve open.
⊖	Green	valve fully closed.
⦶	Amber	valve disagree in open position.
⊖	Amber	valve disagree in close position.

HIGH PRESSURE CONTROL VALVE		
⦶	Green	HP control valve fully closed.
⊖	Green	HP control valve not fully closed
⊖	Amber	HP control valve disagree in closed position.

Fig.16.27

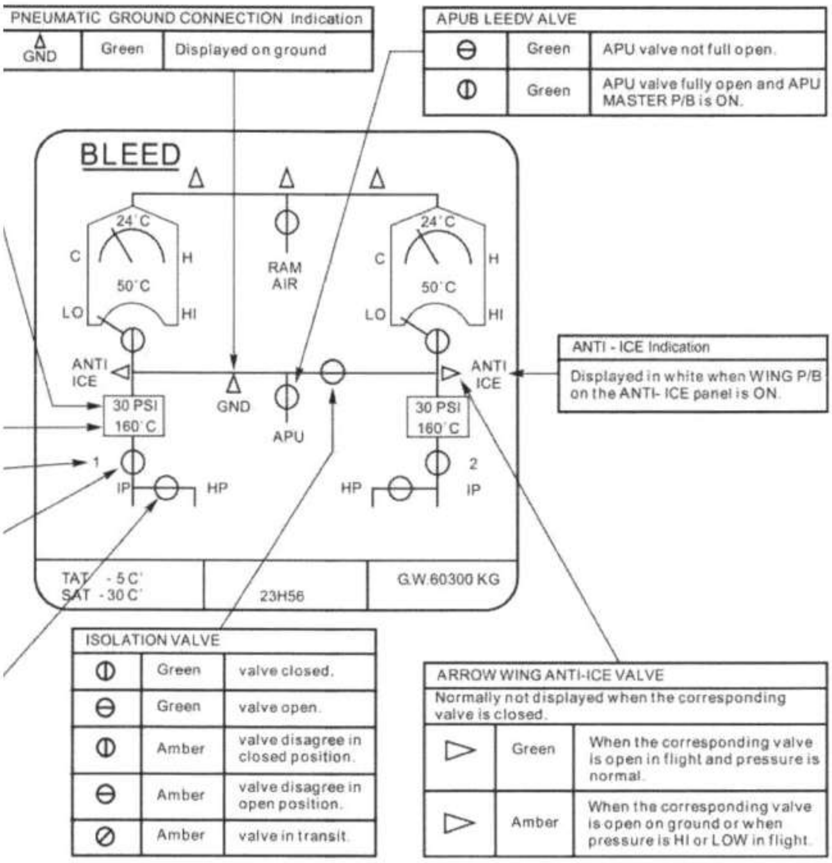


Fig. 16.28

Pneumatic Leak Warning Systems

Pneumatic leak warning systems are important to prevent overheat conditions and structure damage in case of a pneumatic duct leak or rupture. In modern aircraft the systemis also used to provide an automatic shut off of the affected pneumaticsystem.

Three different techniques are applied to monitor a pneumatic manifold leak or duct rupture:

Leak detection by thermal switches

This method use thermal switches connected in parallel to the warning light and if applicable to the automatic shut off circuit. The thermal switches close if the overheat setting is reached and open after cooldown.

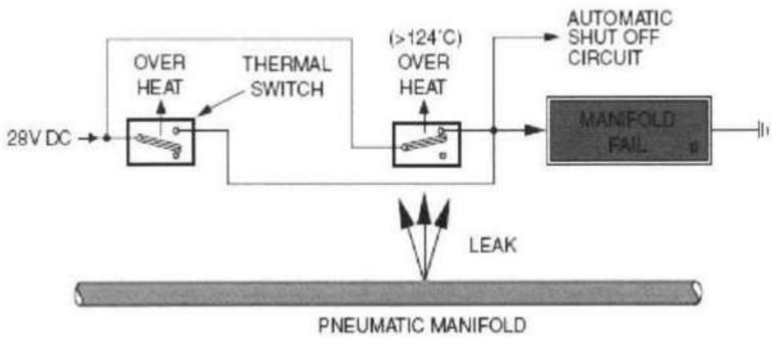


Fig. 16.29 Leak detection by thermalswitches Leak detection by manifold failureloops

This method is used in modern aircraft. The manifold failure loop is a grounded flexible metallic tube filled with a salt mixture. Included in the tube is a conductor insulated by the salt crystal. The conductor is connected via plugs and wires to the sensingdevice.

If the temperature of the salt mixture reaches the overheat setting, the salt melts and provides a current flow to energizethe sensing relay or amplifier. After cooldown the salt will crystallize again and interrupt the current for the sensingrelay.

The sensing device with the loop test circuit is normally incorporated in a pneumatic controller. But it can also be a separate unit called the Manifold Failure Controller (MFC).

The advantage of this detection system is that in case of a single open loop, the leak warning is not lost. The overheat setting of the loops may by different depending on the type of salt mixture. To monitor longer pneumaticducts,multiple loops are connected inseries.

The detection system can be tested by energizing a test relay. The test relay opens the loop circuit and sends a ground signal through the loops to energize the sensing relay. The test makes sure that no loop has an open circuit and the sensing relayand the warning light isfunctional.

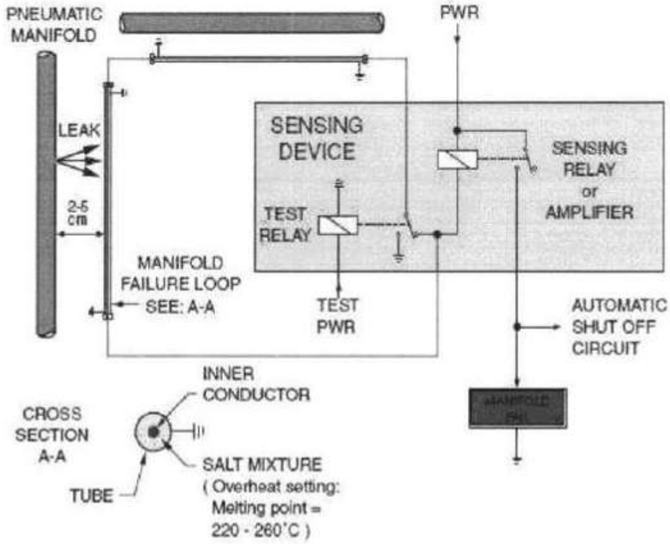


Fig. 16.30 Leak detection by manifold failure loops

Leak detection by pressure switches

There are aircraft which have, for safety reasons,doublewalled pneumatic ducts in the pressurized zones. A leak of the inner duct is monitored by a pressure switch and indicated by a duct leak light located on the maintenance testpanel

After repair of the leaky dut, the duct leak light must be resetby pressing the reset button on the maintenancepanel.

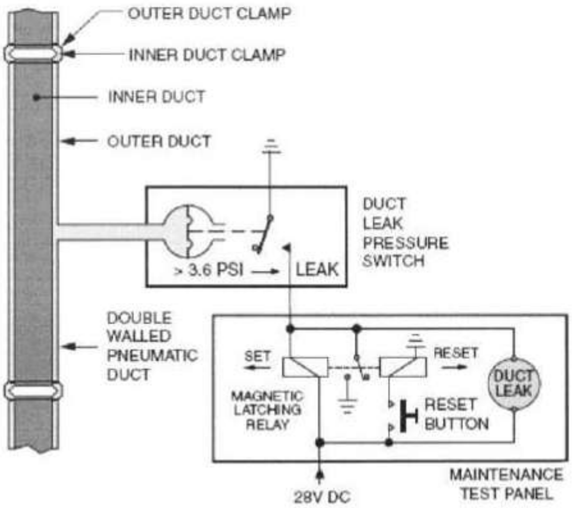


Fig. 16.31 Leak detection by pressure switches Interfaces with other Systems

Aircraft pneumatic systems may have interfaces with following other aircraft systems:

- Air ConditioningSystem
- Auxiliary Power Unit(APU)
- Wing and Tail Anti-IceSystem
- Engine and APU Fire ExtinguishingSystem
- Engine Thrust Control and LimitingSystem

Interfaces with the Air Conditioning Systems

In some aircraft the pneumatic supply temperature is controlled according the air conditioning system flowdemand.This allows a more economical pneumatic system operation and therefore a significant fuel reduction during cruiseflight.

- Example:MD-11:

The use of the more expensive high stage air is optimized without reducing any passenger comfort.

- Example:A330/A340:

The regulated pneumatic supply temperature from the engine will be reduced from normal 200^ to 15013 in case of low pack temperatu re demand if the Wing Anti-Ice system is not in use.

On some aircraft the pneumatic supply pressure will be automatically reduced if the pneumatic supply temperature becomes too high. This should prevent a possible pneumatic overheat condition by reducing the bleed air flow via the heat exchanger.

- Example:MD-11:

The pneumatic supply pressure will progressively decrease if the pneumatic temperature exceeds243C.

Interfaces with the APU

In modern aircraft:

The engine pneumatic system supply isautomatically cut -off or inhibited if the APU supplies the respective pneumatic system.

The APU pneumatic supply pressure will automatically increase for engine starting or high air conditioning cooling demand.

Interfaces with the Wing and Tail Anti-Ice Systems

The pneumatic supply temperature from the engine will be automatically increased for wing and tail anti-ice system operation.

Interfaces with Engine and APU Fire Extinguishing Systems
The bleed air supply from the respective engine or APU is automatically cut-off, if a fire procedure is initiated (fire handleactuated).

Vacuum Pump:

1. A vacuum pump is a device that removes gas molecules from a sealed volume in order to leave behind a partial vacuum. Used in many industrial and scientific process e.g. plastic molding. Production of electrical lamp, vacuum tube, CRTS, semiconductorprocessing.
2. In order to overcome the major draw back of the venturitube, that is its susceptibility to ice, aircraft were equipped with Engines Driven vacuum pump and the gyro instrument were driven by air pulled through the instrument by the suction produced by thesepump.
Suction relief value maintained the desired pressure (usually about four inches of mercury) on the attitude gyro instruments and a needle valve between one of the attitude indicator and Turn Slip indicator restricted the airflow to maintain the desired 2 inches of suction in itscase.

3. Pump can be broadlycategorized:-
a. Positive Displacement Pump: use a mechanism to repeatedly expand a cavity allows gases to flow in from the chamber, seal off the cavity nd exchange it to the atmosphere. They are the most effective for low vacuum. Manual water pump is a example of positive displacement pump. Inside the pump, a mechanism expands a small sealed cavity to reduce its pressure below that of atmosphere. Because of the pressure differential, same fluid from the chamber is pushed in to the pumps small cavity. The pump cavity is then scaled from the chamber, opened tothe

atmosphere, and squeezed back to a minute size.

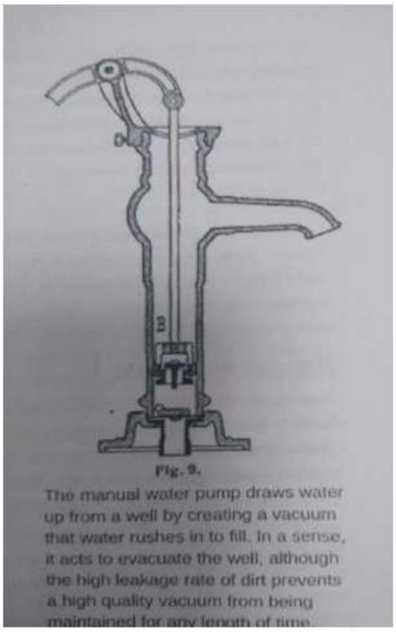


Fig. 1

b. Momentum Transfer Pump: also called molecular pump, use high speed jets dense fluid or high speed rotation blades to knock gas molecules out of chamber. These pumps in conjunction with one or two positive displacement pump are the most common configurations used to achieve high vacuum. Pumping in these pump is only possible below pressure of about 0.1 KPA.
c. Molecular Pump: Sweeps out a larger area than mechanical, and do so more frequently making them capable of much higher pumping speed these pumps are of twotypes:
a. DiffusionPump
b. Turbo MolecularPump

Fig. 2

Diffusion pump blow out gas molecules with jet of oil or mercury.

Turbo Molecular Pump : uses high speed fans to push the gas. Both of these pumps will stall and fail to pump if exhausted directly to atmosphere, so they were exhausted to a lower grade vacuum created by a mechanicalpump.

d. Regenerative Pump: this pump utilizes vortex behavior of the fluid (air). The construction is based on the concept of centrifugal pump, consists of several sets of perpendicular teeth on the rotor circulating air molecules inside stationary hollow grooves. They can reach to 1X105 mbar directly exhaust to atmosphericpressure.

e. Dry Pump: It is drived by the accessory section of the engine. The direction of the rotations is depending on theengine.

It has inner and outer shaft and receptacle arrangement for drive of the pump. Provision is made for a shear of the shaft prior to damage of either the engine or the pump should an internal failure for the pump occur. Pump shaft is attached to a rotating cylinder to which are attached a series of carbon vanes and do not require any lubrication as the vanes are made of carbon graphite material provide their own lubrication. The wear anyway at a predeterminedrate.

Rotating vanes are kept firm against the stationary barrel by centrifugal force. These vanes "float" a precise angle and ride against the stationary barrel of pump housing. The angle and fit of the vanes when riding on the stationary barrel must be carefully controlled to provide for the optimum service life and offer the full volume. These pumps do not required oilseparator.

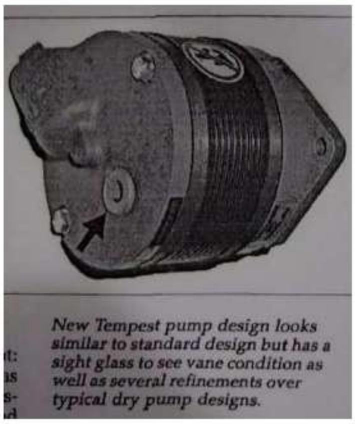


Fig. 3

Disadvantage

- Inside of the pump should be cleaned perfectly
- Any solid particles drawn with the system through the suction relief value can damage the carbon vanes, and this can lead to destruction of thepump.

Note: to prevent particles entering the relief value its air unit is covered with a filter, and this must be cleared or replaced at the interval recommended by the aircraftmanufacture.

f. VanePumps:

1. Vane type pumps or wet type, with cast iron housing and steel vanes Engine oil was metered with the pump to provide sealing, lubrication, cooling and then this oil, along with the air, was blown through oilseprator where the oil collected on baffles and was returned to the engine crank case. The air was then exhausted over board. They are most common source of vacuum for gyros.

Maintenance of pump: Regular maintenance of the system is necessary. System should be carefully examined for:

- Cleanliness around the pump (correct level and forleak)
- System operational check with gauge reading, verified by calibratedinstruments.
- Replacement of air filter at regular interval as specified in maintenancemanual.
- Inspection of deteriorated hoses, loose fittings.
- Replacements of pumps and drive couplings according to pumpmanufactures.

Reasons for pump failure:

- Poor or nomaintenance
- Improper installation (suffix CW orCC)
- Adverse operating environments (excess heat)
- Leak in systems (pump to work harder, causes heating ofpump)
- Clogged and dirtyfitter.
- Fluid contamination (mostly vacuum pumps runs on dry condition for proper operation)
- Foreign objects (pieces of hoses, thread sealants).

Vacuum Toilets: Are used in the aircraft when we flush the system it opens a valve in the sever line and the vacuum in the line sucks the contents out of the bowl and into atank.

Advantage of Vacuum Toilets:

- They use very litterwater
- They can use much smaller diameter sewerpipes. Vacuum Gyro System Consits of FollowingParts
- Filter
- SuctionGauge
- Attitude & DirectionalGyro
- Pressure ReliefValve
- Engine driver vacuum pump with airexhaust
- Warning light (in some cases) will illuminates whenthe suction drops below 4.5inchesHg

Instruments Used In Aircraft: which are using vacuum

a. Attitude Indicator

- HeadingIndicator
- Gyro Instruments are also driven by vacuum and theyare:
- Attitude Indicator
- DirectionalGyro
- Turn &bankindicator


Heading indicator
Vacuum relief valve
Overboard vent line
Vacuum pump
Suction Gauge
Attitude indicator
Vacuum air filter

Fig. 4

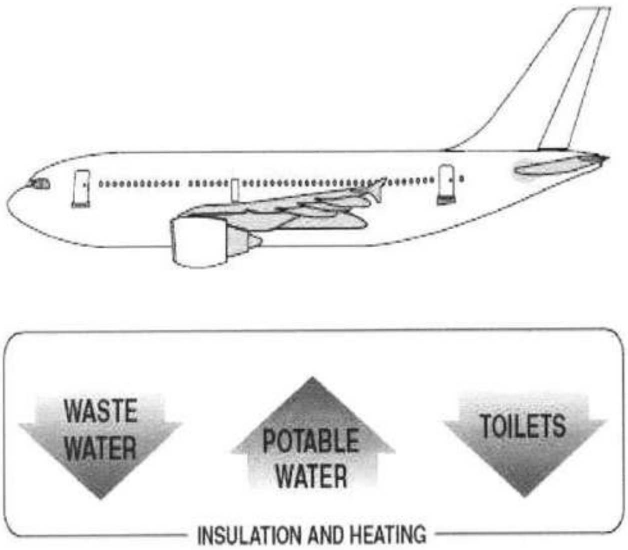
Module 11.17 WATER/WASTE (ATA 38)

Overall System Lay-out

The water and waste system of transport aeroplanes normally include the following sub- systems:

- Potablewater
- Wastewater
- Toiletsystem
- Insulation and heatingsystem.

The insulation and heating system is independent, but installed in all other subsystems is to protect them



from freezing.

Fig. 17.1 Water and waste sub-systems

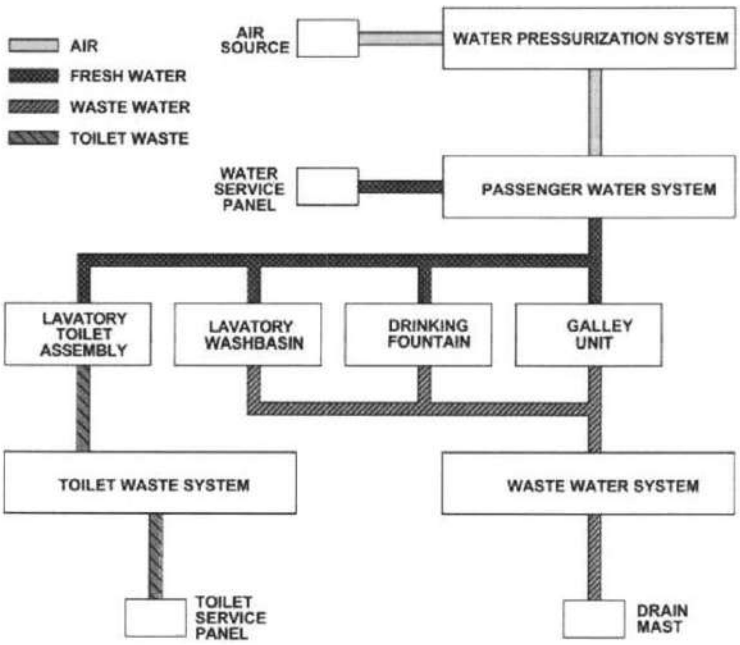


Fig. 17.2 Water and waste sub-systems Potable Water System

System

It is very important for health of passengers and crew to care for good water quality in the potable water system. For this reason, the system is periodically disinfected by the maintenance crew. The system must be rinsed carefully after disinfection; otherwise the water would taste unpleasant afterservicing.

Another aspect which must be handled carefully is the winter operation. When the aeroplane is parked outside for a long ground-time and the outside air temperature drops near freezing point or bellow, the system must be completely drained. Otherwise water can freeze, damage the system components and leak after thawing.

The potable water system is a closed system pressurized with air from the pneumatic system (when it is operating) or its own electrical motor driven air-compressor. Potable water is stored in one or more tanks bellow the cabin floor. The amount of installed tanks and waterquantity

Short range aircraft (≈150 pax):	≈ 200 ltr
Mid range aircraft (≈230 pax):	≈ 400 ltr
Long range aircraft (≈350 pax):	≈ 800 ltr

The system is insulated to prevent water leaks and ice build-up.

While airborne, the aircraft uses bleed air to pressurize the water system ; on the ground it uses air from the service panel pressure port.

If no bleed air is available, an electrical compressor starts automatically when air pressure is not sufficient for normal operation of potable water system.

Potable water is piped to the galleys and lavatories. Manual shut- off-valves isolate the washbasin and toilet from the water system. These valves, easily identifiable by OPEN and SHUT legends, are behind an access door under the toilet bowl (on washbasin side). A placard inside the access door gives instructions on this valve operation.

The system can be filled or drained from the service panel at the bottom of the fuselage. For filling, the quantity is preselected on

the forward attendant's panel.

Indicators on the forward attendant’s panel show how much
water the water tanks contain.

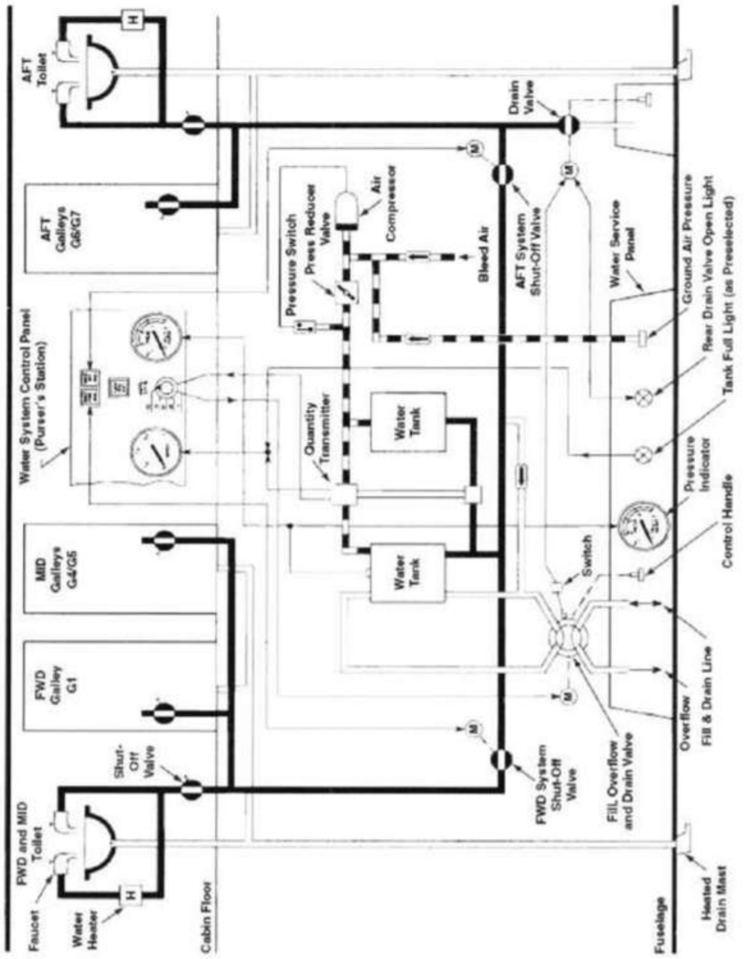


Fig. 17.3 Water System

Supply

The tanks are commonly in the pressurized zone of the fuselage, installed bellow the cabin floor.

Because the water taps are located at a higher level than the tanks, it is necessary to pressurize the system. So water can flow to the taps. Air pressure is normally taken from the pneumatic or the air conditioning system. On ground, when these are not pressurized, the system holds the pressure by means of check valves. If water is used in this condition, the pressure willdrop.

Some aircraft are provided with air compressor pumps which automatically start when the system pressure drops to a minimum. There is normally an air pressure port installed in the service panel for maintenance work on the system (i.e. component replacement and leaktest).

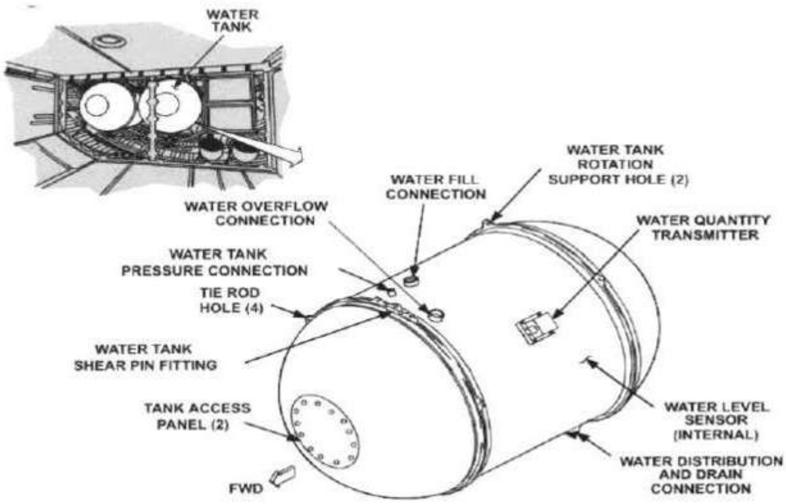


Fig.17.4 Potable water tanks

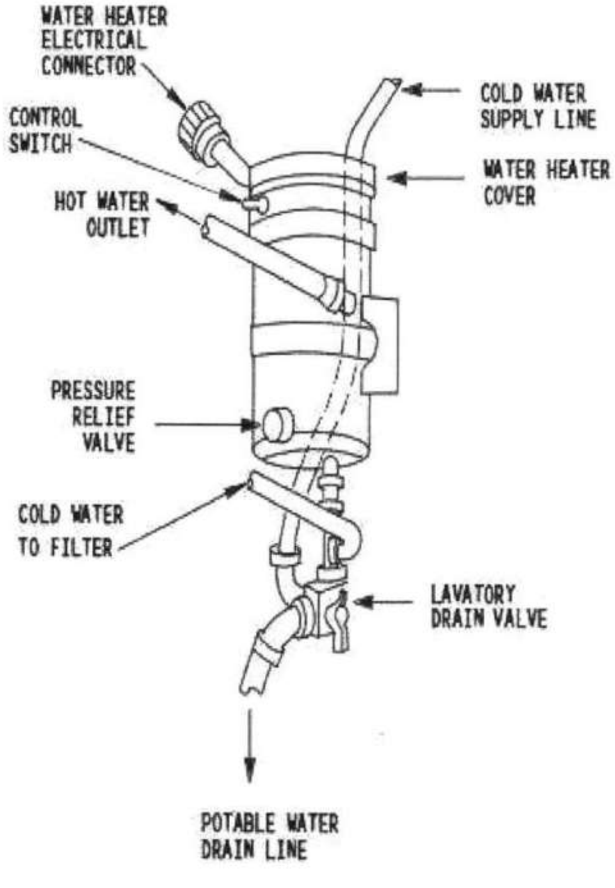


Fig.17.5 Potable water heater

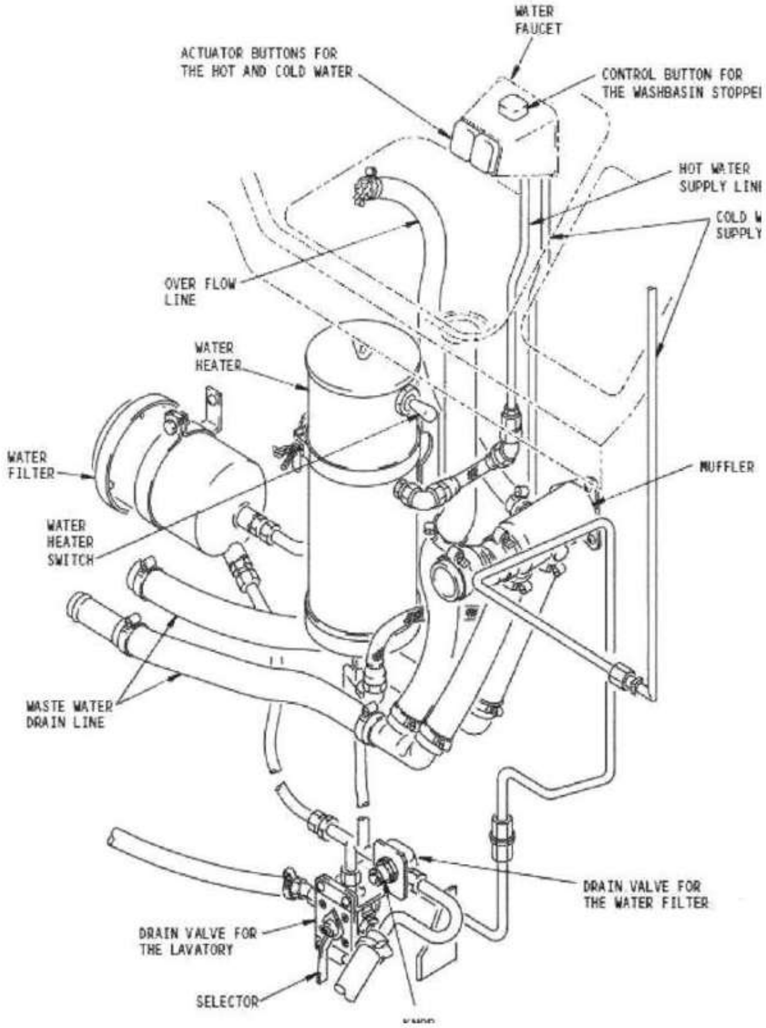


Fig. 17.6 Potable water component layout

Distribution
Water system consumers are spread in the whole cabin cause the water lines to pass cold sections of the fuselage. In these zones the plumbing must be insulated or heated, normally it is done electrically. These heaters are usually of the low wattage type.

Cabin lay-out of transport aeroplanes is often changed, lavatories and galleys are moved. To permit this the plumbing is designed in such a way that facilitates such changes.

The distribution system is normally divided into sections which are provided with independent shut-off valves, so, in case of leaking or maintenance work each galley or toilet can be isolated from the supplysystem.

Toilet
Cold and hot water is available in the toilets. Cold water is directly routed to the taps, but hot water passes through an in- line electrical water heater installed in each toilet. The heaters are provided with thermostats that regulate the water outlet to approximately 45C.
The water heater capacity is dependent on the aircraft installation, 1.5 L being typical. With the control switch in the ON position power is supplied to the electrical water heater element and an indicator light. An overheat switch limits case temperature typically to=82C.
If overheat occurs, the switch interrupts power to the heater and light. The light will not illuminate if the switch is in the OFF position or the overheat switch is open. The light does not indicate that the wateris hot. If overheat occurs in the system shown, the overheat switch mustbe reset manually. A pressure relief valve prevents tank over- pressurization.

Toilet vacuum flushing systems are supplied with potable water for rinsing the toiletbowl.

Each toilet is equipped with its own water shut-off valve; this feature allows isolation of defective orleaky components from the main system. Shut-off valves are marked to facilitate identification by the flightcrew.

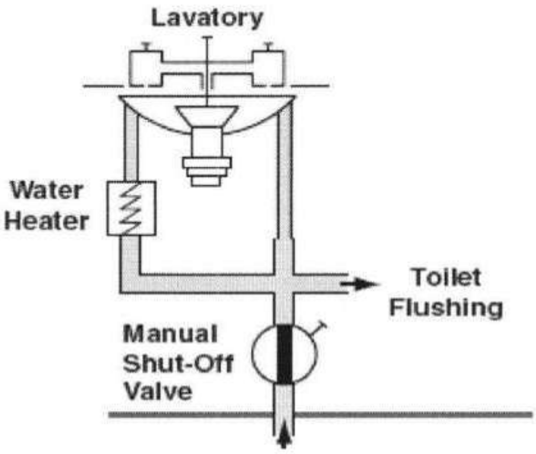


Fig.17.7 Lavatory water supply Galleys

Galleys are usually provided with cold water taps, coffee-makers and water boilers (tea water).

Each galley is equipped with its own water shut-off valve; this feature allows isolation of defective or leaky components from the mainsystem

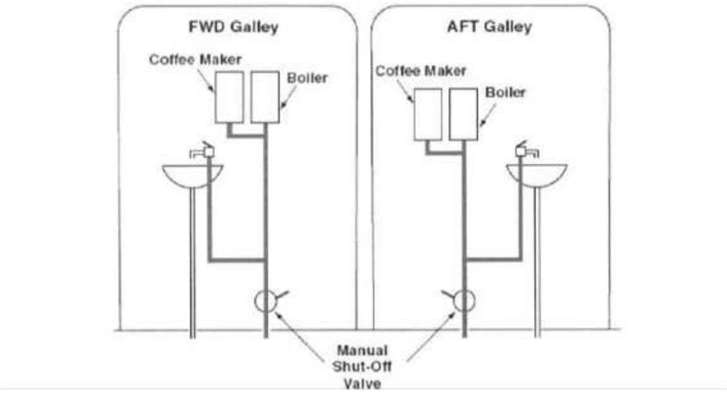


Fig.17.8 Galley supply Servicing and Draining Service panel

The water service panel is located in the lower side of the fuselage, usually positioned in an area which will not interfere with other servicing and loading activities during turn-around checks. This is the left side, between the passenger doors or the aft section of the pressurized zone. The following servicing features are usually available from the service panel:

- fill port
- drainport
- control handle (permits draining and filling oftank)
- overflow and ventport
- air pressureport
- water quantityindicator
- valve position indicatorlamps
- tank full indicatorlamps
- fill-quantitypre-selection

Fill and Overflow Valve

The fill and overflow valve is used to fill the potable water tank to the capacity determined by thestandpipe.

With the handle in the open position (located in the water service panel) the tank fill line is connected to service panelfillport.

At the same time the overflow line from the tank is connected to the overflow line on the servicepanel.

In the closed position, the valve seals the tank so that it can bepressurized.

Drain Valve

The drain valve is used for draining the potable water tank. The valve must be located at the bottom of the tank. The valve is manually operated and is located in the water service panel.

When the valve is open, water drains from the tank through a drain line, and then goes overboard.

Water Tank Quantity Indication

The quantity indication shows the amount of water in the tank.

The quantity transmitter is located in the water tank and the indicator can be in one of the aircraft galleys and or in the water-servicing panel, depending upon the aircraft type.

A typical system consists of a float with internal magnets

surrounding a tube with a number of magnetically operated switches at various heights within it. The indicator consists of a number of lights with quantity indications marked upon them.

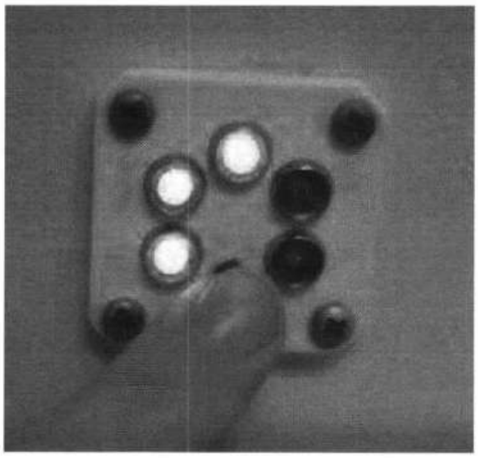


Fig.17.9 Quantity indication (Boeing 737)

The magnets on the float close the associated switch causing the associated indicating lights to illuminate.

Another principle consists of a quantity transmitter, which operates as a variable capacitor and uses the water in the tank as the variable component. Any increase of water in the tank increases the output signal; any decrease in water decreases the output signal. Two quantity indicators are supplied with a transmitter output signal. The signal to the service panel indicator moves a pointer over a scale calibrated in incrementsof volume. Nowadays there is an indicator in the cabin. The signal to the attendant panel LED indicator shows the percentage of volume if the panel push switch is pressed.

On some aeroplanes, it is possible to preselect the desired water quantity prior to filling the system.

When the preselected water quantity is reached the system will automatically close the fill/drain valve and route the filling water through the overflow/vent lines to the outside.

The quantity pre-selection panel can be installed in the purser panel (cabin) or in the service panel. Potable water systems which are not provided with a quantity pre-selection system usually use the water tank quantity signal to close the fill/drain valve when the tank is full.

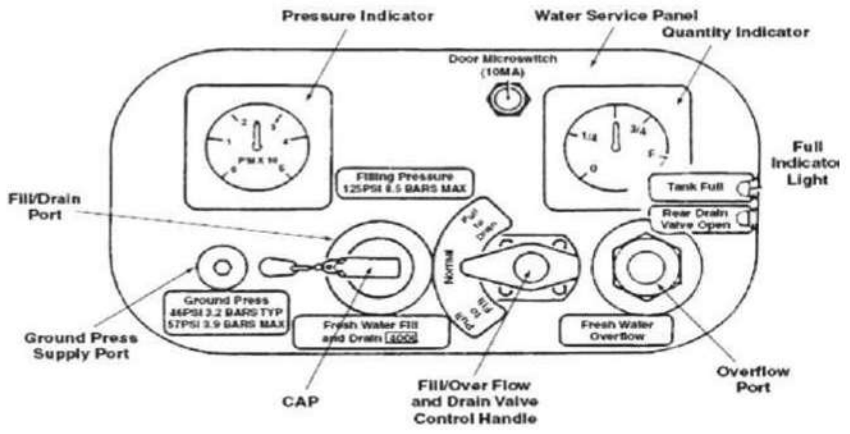


Fig.17.10 Potable water servicing panel Water Tank Pressurisation System

The water tank pressurization system provides a pressure head to force water from the tank through the distribution lines to the galleys and lavatories. The pressurization consists of an air filter, pressure regulator, relief valve, check valve and tubing. Airis supplied to the tankfromthepneumatic manifold through a micronicfilter and a pressure regulator. The pressure regulator reduces the pressure to a typical value between 25 and 50 PSI. A pressure relief valve prevents over-pressurization of the tank. This valve is set to a higher pressure than the regulated pressure. During maintenance, the tank can be pressurized by connecting an air source to the air valve on the water service panel.

There is usually only one service panel installed, which allows filling, monitoring and draining of the system. The control handle is connected (mechanically or electrically) to the drain, filling and vent/overflowvalves. Because servicing panels are installed in the outside fuselage skin, they are normally heated to prevent ice build-up due to leaking water.

On some aeroplanes there is more than one drain valves installed, to facilitate draining the tanks and the whole plumbing. These valves are electrically controlled from the fill and drain handle in most aeroplanes, a manual operating handle is usually installed in each such valve as a backup operationprovision.

Waste Water System

Two kinds of system lay-out are normally used in transport aeroplanes:

- overboardsystem
- internal tanksystem

Overboard Waste Water Systems

In such systems, waste water from the toilet and galley sinks is drained overboard through drain masts. Drain masts are heated to prevent freezing in flight and during winter operation.

Under each sink, a float valve is provided to prevent a leakage of the cabin air pressure through the drain lines. On ground the drain valve is open. During flight, the valve is held closed by pressurized cabin air. The valve opens when the waste water, which enters the valve, has built- up enough pressure to displace thediaphragm.

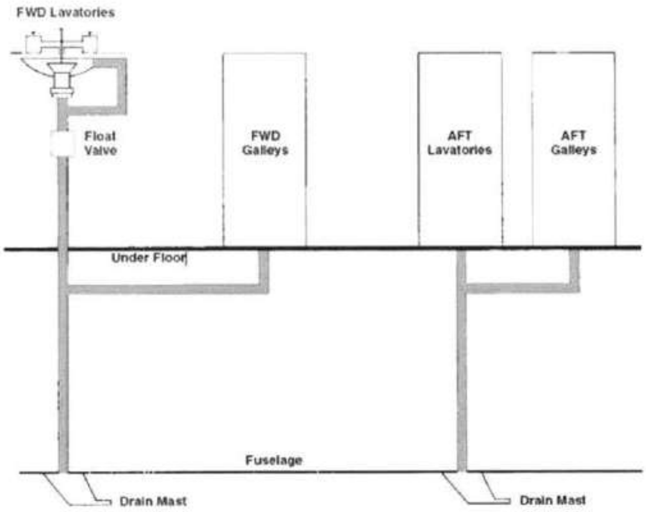


Fig.17.11 Overboard waste water

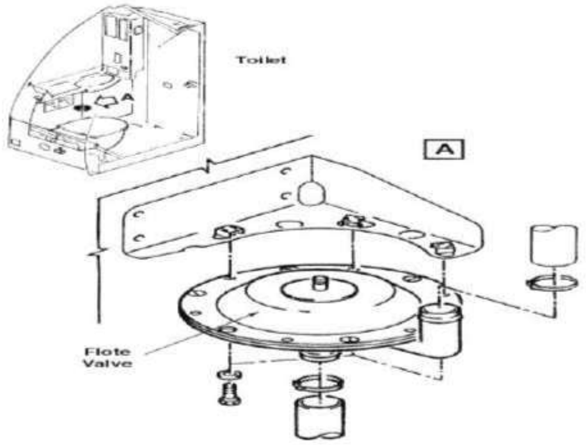


Fig.17.12 Float valve

Internal Tank Waste Water System
In some aeroplanes waste water is routed to the toilet waste water tanks, via a drain valve which opens when the toilet bowl is flushed.

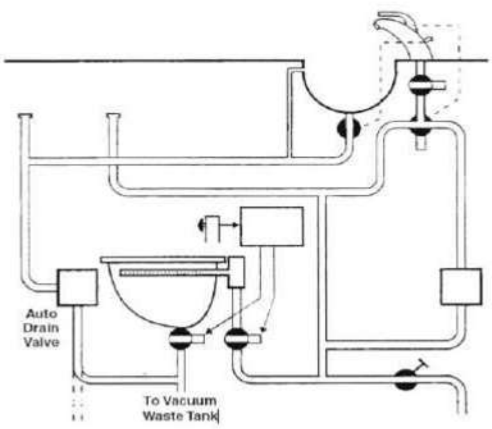


Fig.17.13 Internal tank waste water system
Differential pressure forces waste from toilet bowls into waste storage tanks. On the ground, and at

altitudes below 16,000 feet, a vacuum generator produces the necessary pressuredifferential.

Clear water from the potable water system flushes the toilets. A flush control unit in each toilet controls the flush sequence.
The Vacuum System Controller (VSC) furnishes operational information (including the waste level in the storage tank) to the flight attendant's panel, A manual shut-off valve on the lower right-hand side of the toilet bowlisolatesan inoperative toilet.

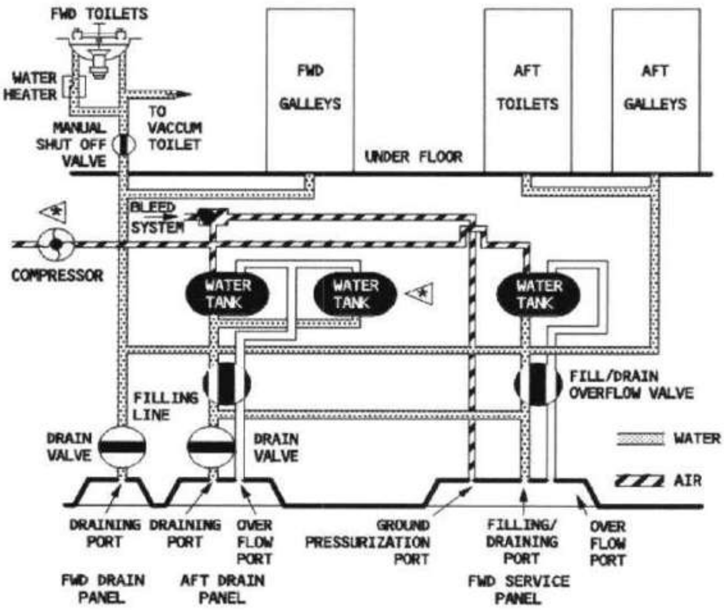


Fig.17.14 Internal tank waste water system

Toilet System
The lavatories provide sanitary facilities for passengers and crew. The number and location of lavatories depends upon the manufacturer and the airline.

The waste disposal systems provide a means of maintaining each lavatory toilet in a clean and sanitary condition. To achieve these, a chemical-water solution is used. This solution is blue coloured and odorizing additives are mixed init.

Two kinds of system lay-out are normally used in passenger transport aeroplanes:

- self-contained toiletsystem
- vacuum toiletsystem

Self-contained ToiletSystems
Each lavatory is provided with its own waste tank, which holds the accumulated waste material. The toilet bowl is directly mounted on the top of the waste tank.

The waste tank is initially filled with the minimum amount of flush fluid (chemical-water solution), which is a disinfectant, dye and deodorant. A pump is installed in each tank, which uses the chemical-water solution to flush the bowl. This allows the toilet to be used about 100 times before it requires servicing.

Flush Sequence
When the flush control is activated, the motor operates a pump inside the tank and pumps flushing fluid

into the bowl flush ring. The motor drives the pump impeller and filter basket.
The filter basket surrounds the pump inlet to prevent objects from entering the pumpinlet.
A fixed wiper blade on the outer surface of the impeller housing keeps the surface of the filter basket open.
The flush sequence is controlled by an electric circuit and normally lasts for around 10 seconds. The following precautions are general, for specific precautions refer to the aircraft maintenance manual;

- On completion of maintenance on toilet systems all tools should be thoroughlycleaned.
- Hands should be cleaned before eating orsmoking.
- Do not flush toilet if the tank is empty as overheating could occur to thepump.
- Mop up all spilt liquids immediately to prevent corrosion occurring to the aircraftstructure.
- Take care when servicing toilet systems that the toilet fluid does not come into contact with the skin or the eyes as it is toxic.

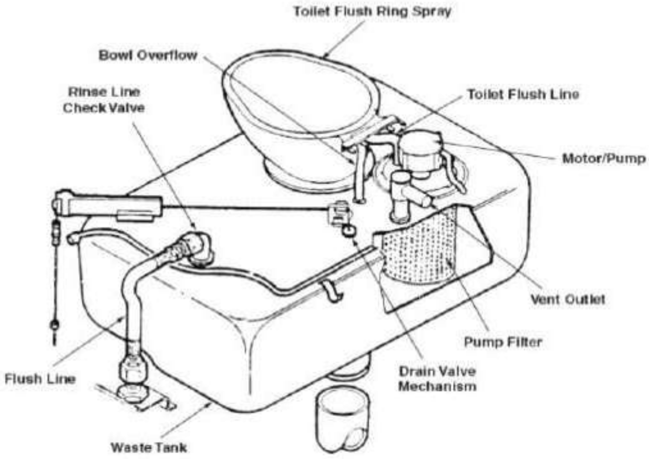


Fig.17.15 Self contained toilet system

Toilet Tank

The toilet waste tank is under a shroud in each lavatory.

The shroud covers the top of the tank and contains the toilet seat and cover. Each tank consists of a fibreglass tank with a laminated stainless steel orfibreglass top. Flushing equipment consists of a flush handle, timer, pump-filter assembly, and related pipe-work. All of these items except the flush handle and timer, are attached to the top of the tank, the handle and timer are attached to the toilet cabinet. A stainless steel toilet bowl is attached to the tank top. The bowl is fitted with a hinged separator, which hides the tank contents from view. A perforated flush line is used for cleaning the inside of the tank.

The toilet tank is vented through a venturi to atmosphere, which prevents any odoursfrom the tank from entering the lavatory. The tank is held in position by tie down rods. It is positioned over a hole in the floor, which is connected to an exterior drainline.
The floor forms a catch basin, which is drained to an exterior drain line. These drains are necessary, as toilet waste is extremely corrosive to the aircraft structure as well as being unhygienic.

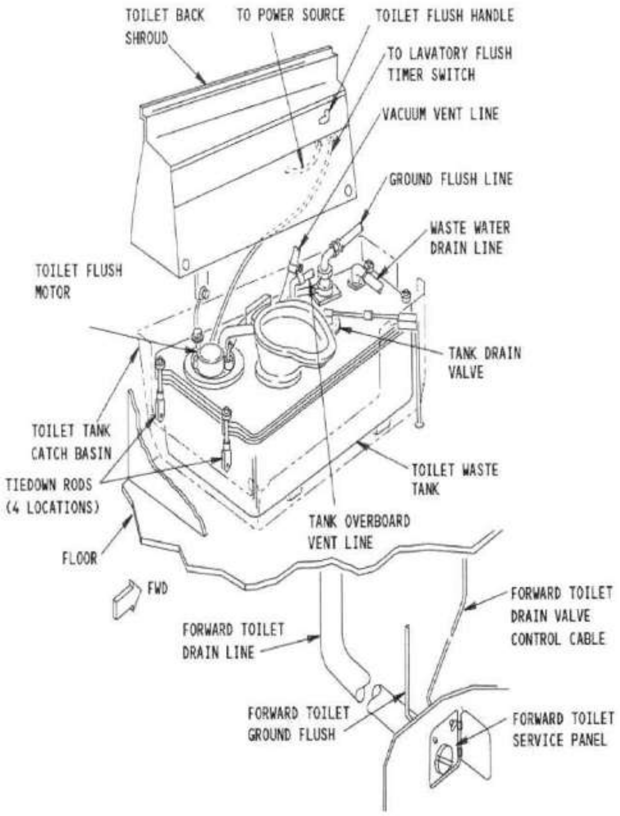


Fig.17.16 Self contained toilet system

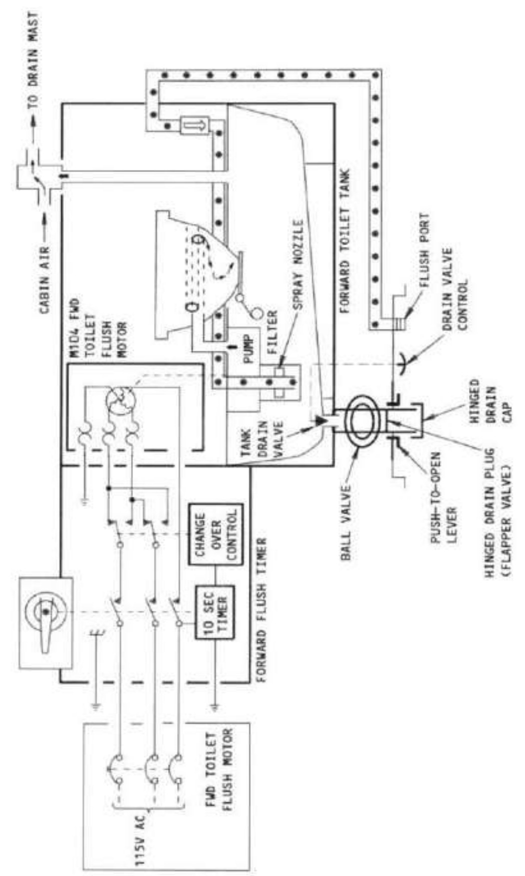


Fig.17.17 Self contained toilet system schematic

Toilet Flush Pump Motor

The toilet flush pump-filter assembly allows flushing of the toilet bowl with the fluid in the toilet tank. The pump-filter assembly is attached to the top of the tank and protrudes into the tank.

The assembly consists of an electrically driven pump and gears that rotate in the filter basket. The fluid basket surrounds the pump inlet to prevent objects entering the pump.

A fixed wiper blade on the outer surface of the filter removes objects that may become attached to the filter.

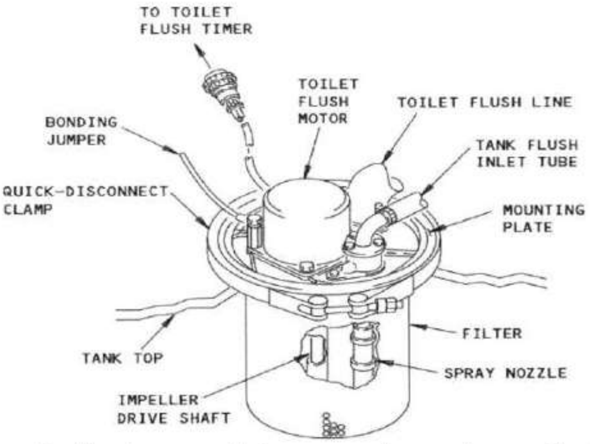
Fig.17.18 Toilet flush pump, motor and filter Toilet Tank Drain Valve

The toilet tank drain valve is used during servicing of toilets for draining the toilet tank.

The valve is located inside of the toilet tank. The valve consists of a spring loaded telescoping guide tube enclosed by a rubber boot, with the valve seat against a hole at the bottom of the tank.

A cable, with a quick disconnect is attached to the top of the telescoping tube.

During servicing, the valve is opened by a cable connected to the drain valve handle located in the



servicepanel.The handle in the servicing panel can be pulled and locked in place thus allowing the drain valve to remainopen.

The valve closes by action of the compressed spring in the telescoping guide tube when the operating handle is unlocked and released.

Toilet Drain Plug Flapper Valve
The toilet flapper prevents draining of the toilet tank when the cap is opened.

Service Panel
There is a service panel installed near each toilet group. Depending on the aeroplane type, two or three panels are placed along the bottom half of the fuselage. The panels normally contain waste water flush and fill fittings, a drain outletfor draining sewage from the toiletwaste tanks, one manual control handle per toilet which controls the tank drain valve, and a ventoutlet.

The service panel drain outlets contain expanding type plug valves in addition to external flap valves which provide suitable cabin pressure sealing.

Fig.17.19 Toilet draining and flushing

Fig.17.20 Service panel and waste water holding tank

Vacuum Toilet System

Newer aeroplanes are equipped with one or two waste vacuum tanks connected to all toilet bowls by means of a pipeline system. These tanks store water and waste during normal operation.

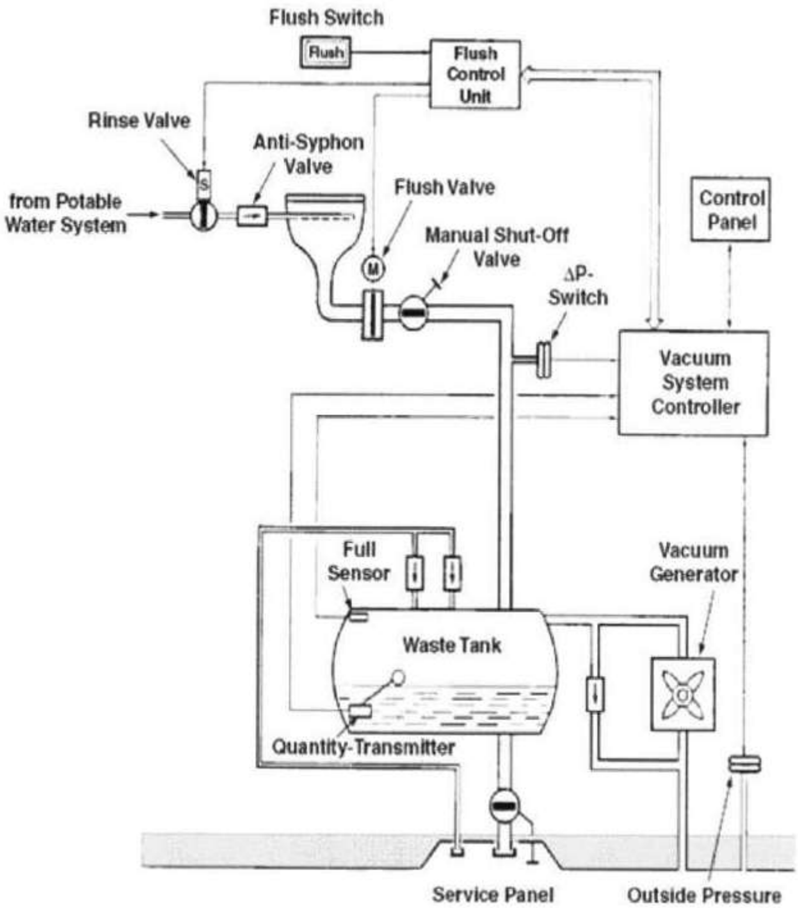


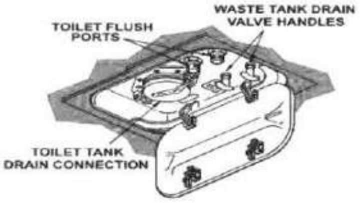
Fig.17.21 Vacuum toilet system lay-out

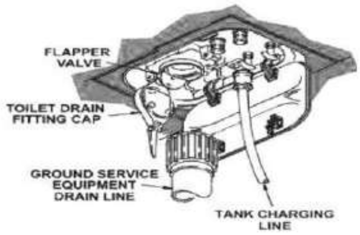
The toilet bowl in the individual lavatories is provided with a flush control system and a shut-off valve, which can be actuated manually in case of system malfunction. It may be useful if the flush system fails to close in order to restore operational capability of the other toilets.

A pressure differential moves the waste from the toilet bowls to the waste tanks. On the ground and below 16,000 ft (4,850 m) altitude, high speed blowers generate required pressure differential (AP).

Clean water from the potable water system is used for bowl flushing.

A computer is installed to control and monitor the vacuum and waste system. The computer:





Enables toilets to flush checks the waste waterlevel monitors the input of the altitude pressure switch controls the vacuumblower delivers indication and status signals to the indication panel delivers information to the on board maintenance system allows testing from the on board maintenance system deactivates the system in case ofmalfunction.

Rinse Valve Assembly
The Rinse Valve Assembly contains a solenoid-operated rinse valve that opens for one second when the toilet is flushed.

Flush Valve Assembly
The Flush Valve Assembly houses a motor-operated valve for toilet flushing. A manual handle on the front of the toilet

assembly can be used to close the valve.

Anti-Siphon Valve
An Anti-Siphon Valve, on the back of the assembly, is in the rinse water line between the rinse water header and the rinse water valve. It prevents water from being drawn back into the potable water system from the rinse header.

Flush Control Unit
The Flush Control Unit sequences the timing of the flush cycle. The flush handle activates the unit.

Toilet Bowl Module
The Toilet Bowl is constructed of stainless steel coated with Teflon. It has rinse nozzles and a rinse water header around its top.

Manual Shutoff
The manual handle on the front of the toilet module is accessed under the front of the toilet shroud. Removal of shroud is not required to operate the shutoff valve. Removing the entire shroud accesses the toiletassembly.

Separator
Each waste tank has a line-replaceableliquidseparator located inside the top of the tank. The separator

prevents liquid and waste material from venting overboard. The top of the tank holds the liquid separator in place; it is secured by a clampassembly.

Rinse System

Each waste tank has its own rinse system. Rinse spray nozzles located near the top of the tank spray fluid on the inner face of the point level sensors to clean them. The rinse nozzle is connected to a line from the waste service panel. The rinse line contains a replaceable filter assembly and pre-charge valve. The pre-charge valve, located above the tank, is electrically operated and has a manual override lever. This valveis controlled (open or close) by the tank continuous level sensingsystem.

Level Sensors

Each waste tank has two point level sensors and a continuous level sensor system. The point level sensors are located near the top of the tank and are secured by clamp assemblies. These sensors sense a tank full or not full condition. A "tank full" signal from both (AND logic) sensors will disable the toilets connected to that tank and provide indication. A continuous level sensor assembly is mounted on each tank drain and vent lines. This sensor provides a signal for quantity indication and control of the pre-chargevalve.

There are two point level sensors per tank connected to each logic control module. Both point level sensors are required to signal the module for a TANK FULL system shutdown. A LAV INOP switch light on the aft right attendant's panel also indicates system shut-down. This switch light also serves as a remote means to conduct a test of the "TANK FULL" circuit. The point level sensors are monitored for cleanliness. The logic control module continuously monitors the sensor face for cleanliness. Should the point level sensor become "fouled" (dirty) a signal will illuminate a SENSOR FOULED light at the aft attendant's panel and at the service and drain panel and provide a message on theEICAS

maintenance page.

Drain Valves

There is one drain valve per tank. The valve is located below and slightly inboard of the tank. Both valves connect to a "Y" fitting that goes into the waste disposal service panel. Each valve has its own Teleflex cable that connects to the waste service panel. Each valve opens individually when its cable is pulled. Both tanks can be drained at the same time by pulling both cables at the same time.

Vacuum Blowers

The vacuum blowers are mounted to a support structure outboard of the waste tanks. The blowers operate with 115 volts AC, 3-phasepower.Automatic resetting thermal switches in the motor windings will shut down the motor at a given temperature. The blowers are shock mounted and are attached to the tanks with rubber hoses. A replaceable filter for motor cooling air is located around the middle of theblower.

There is one continuous level sensor system per tank connected to each logic control module. A variable tank quantity signal is provided through the logic control module to selector switches and one quantity indicator. A signal is also provided for control of the pre-chargevalve.

Servicing

Normally one exterior waste system service panel allows single point servicing of the waste system.

The panel has:

- a waste drain-lineconnection
- flush-line-connections
- a door limitswitch
- the controllever

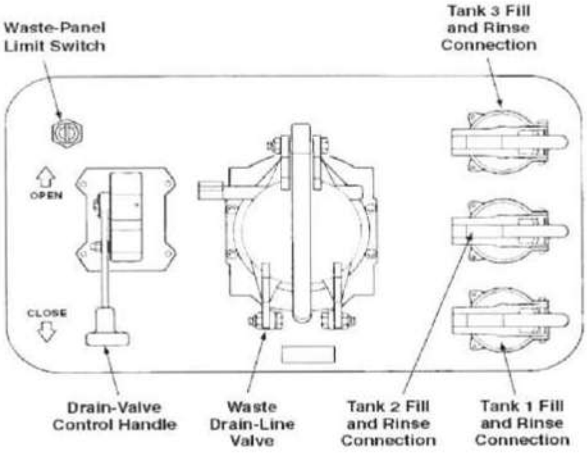


Fig.17.22 Service panel

Fig.17.23 Service panel

The drain lines allow flushing the tanks after draining them and to pre-charge the tanks with a small amount of chemical- water solution (normally 13 litres per tank). The service panel is heated to preventfreezing.

Corrosion Aspects

Toilet products in contact with aluminium and/or magnesium alloys provide a strong electrolyte for corrosion to take place, and microbiological corrosion is also a serious problem in structural areas beneath aircraft toilets.

In design, use of titanium pipes for toilet waste, effective drainage from crevices in structures of any leakages, and easily accessible inspection areas are effective measures to combat the corrosion threat, as is regular inspection checksfor corrosion and cleanliness are essential in the maintenance of suchareas.

Additional corrosion inhibition such as LPS-3 is also used frequently.

On Board Maintenance Systems (OMS)Applications

The OMS is composed of several applications dedicated to the support of aircraft maintenance tasks:

- The Central Maintenance System(CMS)
- The Data Loading and ConfigurationSystem
- The Aircraft Condition Monitoring System(ACMS
- The electronic-Logbook(eLogbook)
- The electronic documentation: AirN@V(on Airbus aircraft), Minimum Equipment List (MEL)and

Configuration DeviationList(CDL)

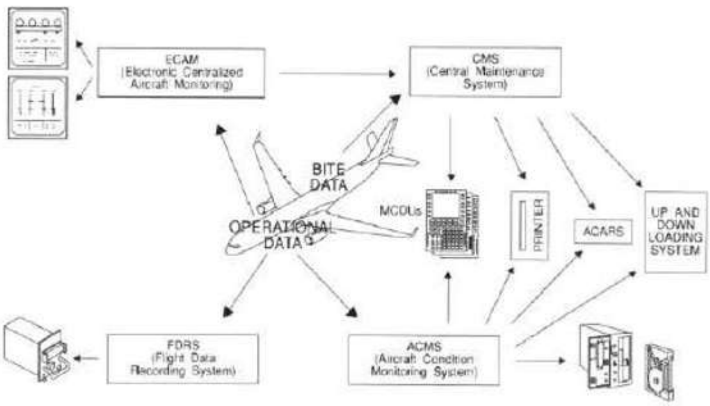


Figure 18.1: On Board MaintenanceFacilities

Central Maintenance System (CMS) Overview

The function of the Central Maintenance System (CMS) is to centralize the data related to aircraft fault events.

The Central Maintenance System (CMS) acquires aircraft fault symptoms from the aircraft systems and in particular from the BITEs of the Line Replaceable Units (LRUs) and the Line Replaceable Modules (LRMs).

The CMS has two operating modes:

- The normal mode (on ground and inflight)
- The interactive mode (only onground)

In normal mode, the CMS:

- provides system continuous monitoringdetectsand identifiesfailures
- centralizes failure events and parameters sent by the BITEsgeneratesreports

The CMS interactive mode gives access to:

- interactive systemtests
- systemsmonitoring
- maintenancehistory

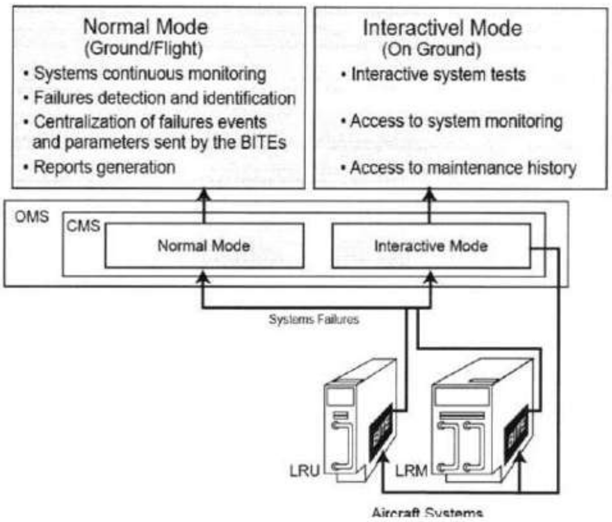


Figure 18.2: Central Maintenance System overview

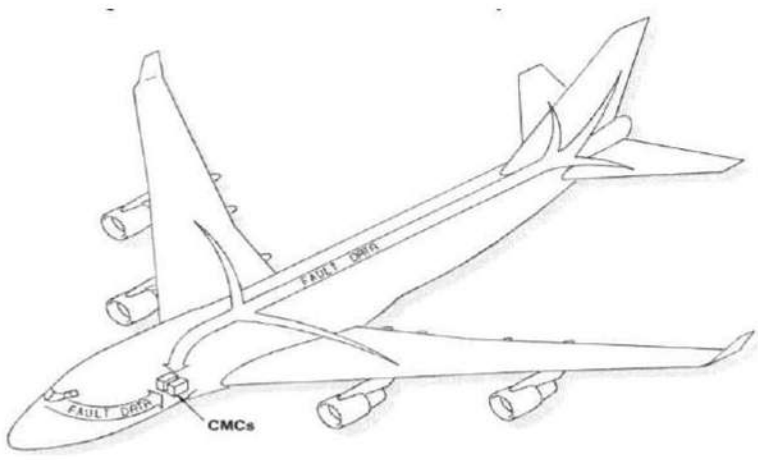


Figure 18.3: Central Maintenance System overview Data Acquisition

The acquisition of aircraft system data is performed by four major electronic systems:

- The Electronic Centralized Aircraft Monitoring (ECAM) system which monitors the operational data in order to display warnings and systeminformation
- The Flight Data Recording System (FDRS) which is mandatory and records aircraft operational parameters for incident investigationpurpose
- The Central Maintenance System (CMS) which monitors the BITE data in order to record the systemfailures
- The Aircraft Condition Monitoring System (ACMS) which records significant operational

parameters in order to monitor the engines, the aircraft performance and to analyze specific aircraft problems.

Data Consolidation

In normal operation, the ECAM permanently displays normal aircraft parameters and the ACMSand FDRS permanently record aircraft system parameters.When an anomaly is detected by an aircraft system, the ECAM displays the abnormal
parameter or function and its associated warning and the CMS records the failure informationdetected by the system BITE

Data Retrieval
- All the information can be retrievedthrough:
- The cockpit Multipurpose Control DisplayUnit,
- The ECAMdisplays,
- The cockpitprinter,
- The downloadingsystem,
- A ground station viaACARS,
- Therecorders.

Data Analysis

Maintenance operations can be divided into three groups:
- Minor troubleshooting which is performed with the help of the ECAM and the CMS and the printed or ACARS down- linkedreports.

- In-depth troubleshooting which is performed with the help of the CMS and the ACMS and printedreports.

- Long term maintenance which is performed with the help of the ACMS and the FDRS through printed ACARS down-linked and downloaded reports or recordedtapes.

Central Maintenance Computers (CMC)

The Central Maintenance Computer (CMC) centralizes and memorizes failure messages produced by the system BITE and warnings generated by the Flight Warning Computers (FWCs). The CMC lets the maintenance personnel make system operational tests, functional checks and read-out of BITE memory through the Multipurpose Control Display Unit(MCDU).

The CMC builds up reports using memorized failures and warnings. These reports can be printed, using the onboard printer, or transmitted to the ground, using the Air Traffic Service Unit(ATSU). They can also be displayed on the MCDU.
NOTE: Note: a CMC2 can be optionally installed.

AIRcraft Maintenance ANalysis (AIRMAN), which is an optional ground-based software dedicated to optimize the maintenance of fly-by-wire Airbus aircraft, analyses mainly the
following data:

- Real Time Warning (RTW) and fault messages(RTF),

- The Post Flight Report (PFR) at the end of theflight.

AIRMAN gives to each event a link to the Trouble Shooting Manual (TSM) and the related documents.

The AirN@vtroubleshooting task is reached directly by hyperlinks from the AIRMAN application.

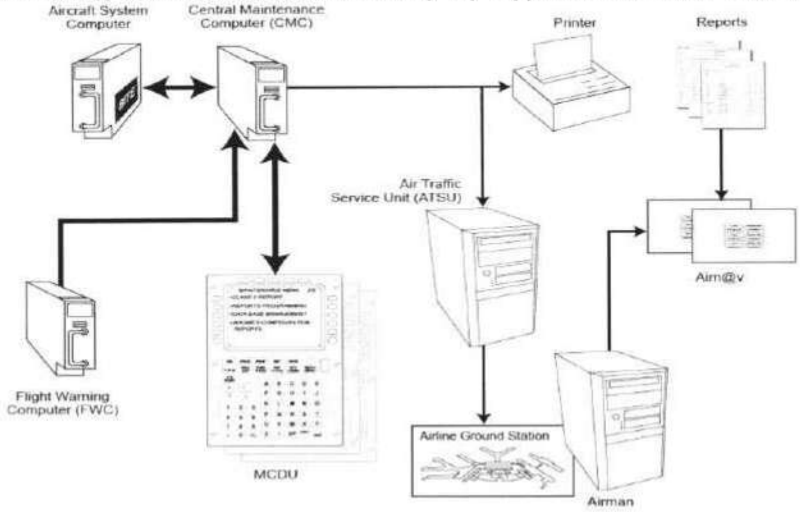


Figure 18.4: The Central Maintenance Computer interfaces (Airbus)

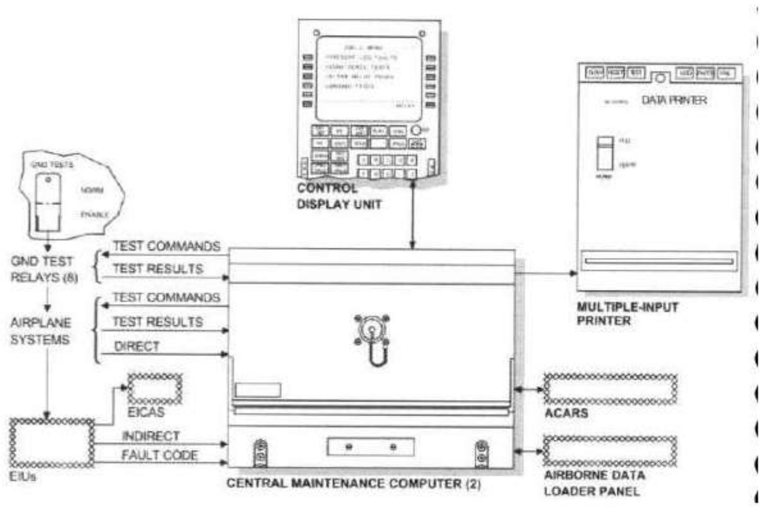


Figure 18.5: The Central Maintenance Computer interfaces (Boeing)

A Typical CMS Architecture

The following description is that of the Airbus A380 CMS.
The CMS Application is hosted in the server units (ANSU-OPS), itcentralises all faults data of both Avionics World and Avionics Domain systems (see Chapter 13.22).

This information is: fault messages (generated by the BITE of the equipments), advisories (from Control and Display System - CDS) and warnings/flight phases (from the Flight Warning System (FWS)).The CMS also acquires logbook entries.

The CMS is also linked to the onboard documentation for troubleshooting procedures and has the capability to share data with other Onboard Maintenance System Applications through the shared database.
The HMIs, which are used to control the CMS are:

- The CAPT and F/O Onboard InformationTerminals (OITs)

- The Onboard Maintenance Terminal(OMT)
- The Portable Multipurpose Access Terminal(PMAT)
- The Printer 1 (for maintenancereports)

Note that the CMS can communicate with the operational ground centres via service providers in order to enable maintenance data exchange.

Failure Classification

A class is associated to each fault message. Here is the list of failure class on the A380:

- Class 1: Any detected failure generating a Flight Deck Effect.

- Class 2: not used anymore.

- Class 3: Any detected failure generating a Cabin Effect but with neither safety nor A.A. regulation involvement (passengers comfortonly).

- Class 4: Any detected failure with neither Flight Deck Effect nor Cabin Effect but to be fixed within a time period (timelimited).

- Class 5: Any detected failure with neither Flight Deck Effect nor Cabin Effect and without safety involvement or time limitation, but generating a Flight Deck Effect or Cabin Effect (potential aircraft delay) when combined with one or several otherfailure(s)

- Class 6: Any detected failure with neither Flight Deck Effect nor Cabin Effect and without safety involvement or time limitation but having an impact on aircraft performances (economicalconsequences).

- Class 0: Failure message where the operational effect of a detected failure is not known by the monitoring unit ("class-less" failuremessage).

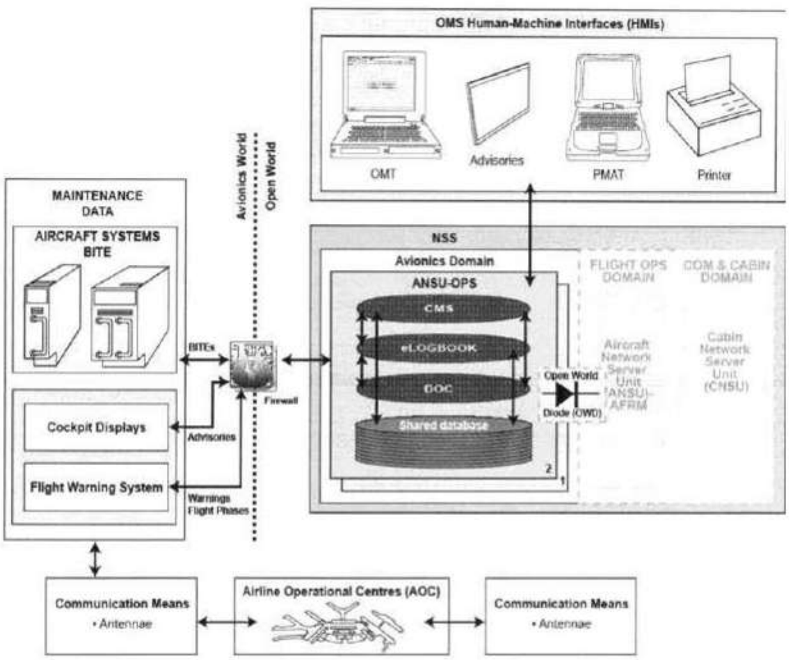


Figure 18.6: Typical CMS architecture (Airbus A380) Post Flight Report and System Report

The failure information is available in various reports. The reading of the failure information can be done from two different MCDU menus depending on whether the aircraft is in flight or on ground.

The SYSTEM REPORT / TEST function is available on ground only. It allows a dialogue between the CMC and the system computers. The SYSTEM REPORT / TEST menu page presents the list of all the systems connected to the CMC, sorted per ATA chapter.

The maintenance PFR can only be printed on the ground. It summarizes and displays the list of the ECAM warning messages and the fault messages, from the last flight, with their triggering time, flight phase and ATA reference. There data is used to enter the troubleshooting manual (TSM) in AirN@V. It helps the maintenance crew perform the troubleshooting.

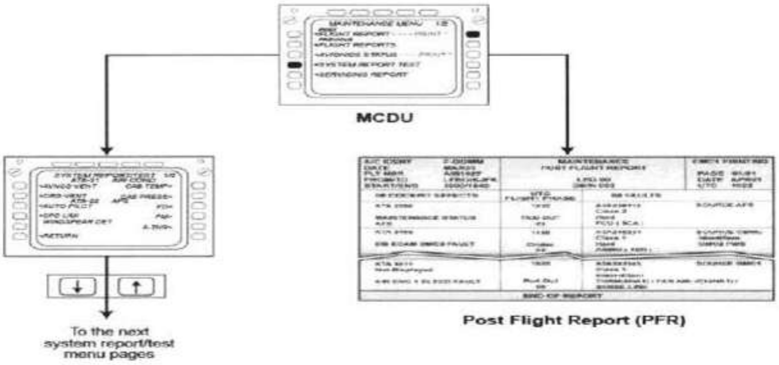


Figure 18.7: CMS Post Flight Report (PFR) and System Report

Airman (Airbus)

AIRcraft Maintenance ANalysis (AIRMAN) is a ground-based software developed for Airbus aircraft dedicated to the identification and the management of unscheduled maintenance.

AIRMAN receives and analyses the aircraft status information generated by the Onboard Maintenance System (OMS) and also e- logbook data. The information is automatically transmitted to the ground by the aircraft's communication system.

These information sources are synthesized, combined with Airbus's and the Airline's own technical documentation and presented through a user-friendly interface. Aircraft status information is sent to AIRMAN while the aircraft is both in flight and on ground. Message analysis also takes place in real-time.

These capabilities maximize the time available for appropriate maintenance actions to be determined and preparations to be made.

AIRMAN is capable of analyzing an aircraft's fault history and consequently identifying and prioritizing predictive maintenance actions.

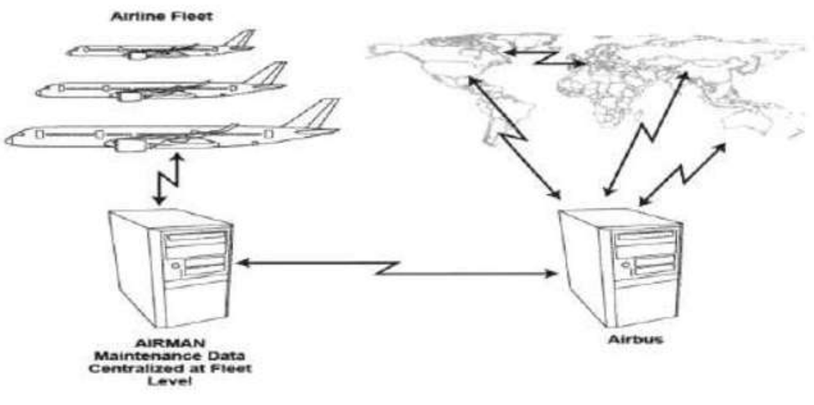


Figure 18.8: Airman overview

This aircraft maintenance philosophy is based on the following steps:

- Fault detection made by the computersbites
- Cockpit effects as lags on Display Units, andwarning generated by the Flight Warning System(FWS)
- Centralization and correlation by theOnboard Maintenance System (OMS) of BITEfaults
- Cockpit effects and related maintenanceprocedures
- Generation of Post Flight Report (PFR)
- Fault event data reporting through the logbook(Option)
- Fault event data and reports transmission to AIRMAN (option) for maintenance support onground

Figure 18.9: Airman maintenance philosophy Built-In-Test Equipment (BITE) Philosophy

General

A system is composed of LRUs which can be; computers, sensors, actuators, probes, etc. Most of these Line Replaceable Units (LRUs) are controlled by digital computers. For safety reasons, these LRUs are permanently monitored, they can be tested and troubleshooting can be performed. In each system, a part of a computer is dedicated to these functions; it is called Built-In-Test Equipment (BITE). In some multi-computer systems, one computer is used to concentrate the BITE data ofthe

system.During normal operation, the system is permanently monitored: internal monitoring, input/output monitoring, link monitoring between LRUs within the system.

Fault Detection

If a failure occurs, it can be a permanent (consolidated) or an intermittent failure.

Fault Isolation

After failure detection, the BITE is able to identify the possible failed LRUs and can give a snapshot of the system environment when the failure occurred.

Data Storage

All the information necessary for maintenance and troubleshooting is stored in a non-volatile memory.

BITE Concepts

The BITE information stored in the system BITE memories is sent to a centralized maintenance device. The manual tests (SYSTEM TEST and SPECIFIC TESTS) can be initiated via this centralized maintenance device.
Its main advantages are:

- Single interface location(cockpit).
- Easy faultidentification.
- Reduction of the troubleshootingduration.
- Simplification of the technicaldocumentation.
- Standardization of theequipment.

BITE Tests

The test functions can be divided into four groups
- Power UpTest

The power up test is a safety test. The purpose of a safety test is to ensure compliance with the safety objectives. It is executed only on ground after long power cuts (more than 200ms). Its duration is a function of the system which is not operational during the power up test.If the aircraft isairborne, the power up test is limited to a few items to enable a quick return to operation of the system. The typical tasks of a power up testare:

- Test ofmicroprocessor,
- Test ofmemories,
- Test of ARINC429
- Test various i/ocircuits,
- Configurationtest.

- CyclicTests

These tests are carried out permanently. They do not disturb system operation. The typical tasks of a cyclic test (also known as IN OPERATION TEST) are;Watchdog test (a watchdog is a device capable of restarting the microprocessor ifthe software fails), and RAM test. Permanent monitoring is performed by the operational program (e.g. ARINC 429 messagesvalidity).

- SystemTest

The purpose of this test is to offer to the maintenance staff the possibility to test the system for troubleshooting purposes.
This test can be performed after the replacement of an LRU in order to check the integrity of the system or sub-system. It is similar to the POWER UP TEST but it is more complete. It is performed with all peripherals supplied.
- SpecificTests

For some systems, specific tests are available. The purpose of these tests is to generate stimuli to various command devices such as actuators or valves. They can have a major effect on the aircraft (automatic moving of slats or flaps, engine dry cranking).

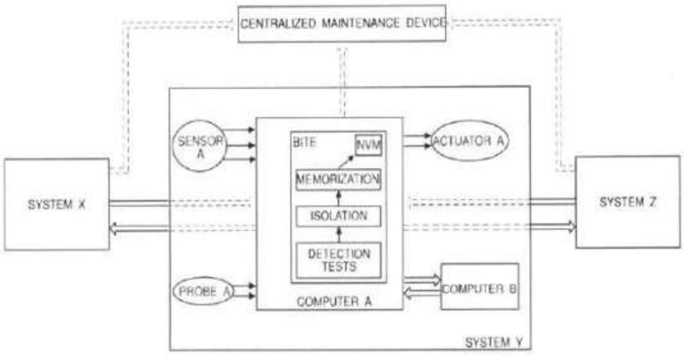


Figure 10.10: BITE interface

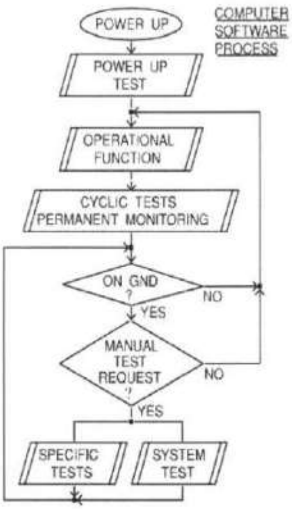


Figure 18.11: BITE philosophy

BITE Architecture General

The Central Maintenance System (also known as the Centralized Fault Display System) is composed of one or two Maintenance Computers and the aircraft system BITEs.

Built-In-Test circuits are built into most system LRUs. The CMC interfaces are:

- MCDUs,
- aprinter,
- the Aircraft Communication Addressing and Reporting System(ACARS),
- a data loader known as the Multifunction Disk Drive Unit(MDDU),
- The Central Maintenance Computer(CMC).

The Central Maintenance Computers continuously scan the buses coming from the aircraft ssystems.Ifa failure message from a system BITE is present on a bus, the CMC or CFDIU copies and stores it.Theyalso store the Electronic Centralized Aircraft Monitoring (ECAM) messages generated by the Flight Warning Computers.Ineach aircraftsystem computer, a BITE monitors the system and memorizes the failures. The systems are divided into four types, depending on their capabilities and their connection to theCMCs.

- Multipurpose Control and Display Unit(MCDU)

The Multipurpose Control and Display Unit is the operator's interface with the Central Maintenance System. Any two of the three MCDUs may be operated simultaneously.

Printer

Most of the Central Maintenance System reports may be printed. The printer provides then Post Flight Report (PFR) print which is the main maintenance tool.

- Aircraft Communication Addressing andReporting System(ACARS)

Data may also be transmitted to the ground through the Aircraft Communication Addressing and Reporting System (ACARS).

Multifunction Disk Drive Unit (MDDU)

Data may also be loaded into the CMCs through the Multifunction Disk DriveUnit.

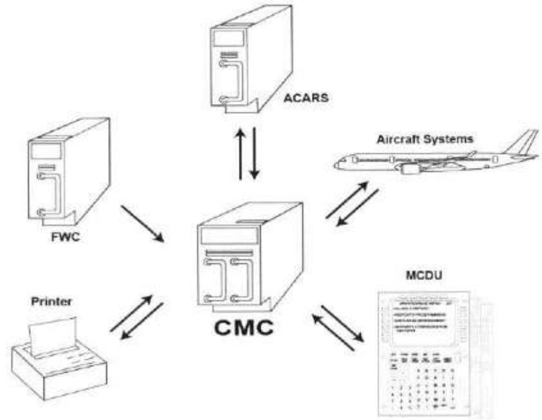


Figure 18.12: CMCinterfaces

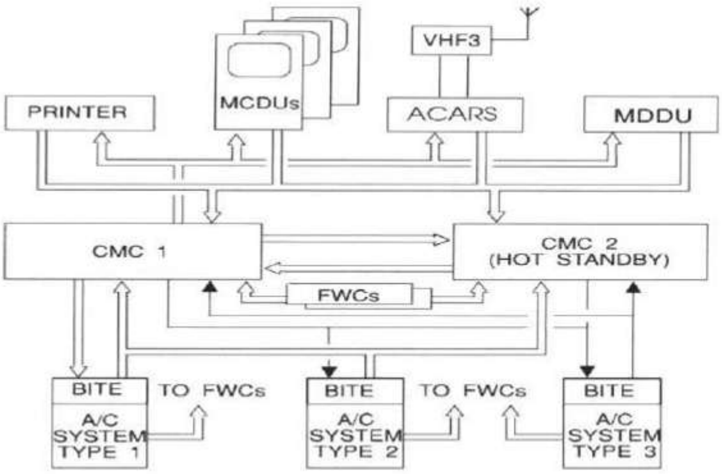


Figure 18.13: CMC and BITE system architecture Aircraft Condition Monitoring System (ACMS) Overview

The Aircraft Condition Monitoring System (ACMS) main function is to support scheduled and preventive maintenance by monitoring the efficiency and degradation of the aircraft systems and environment.

The ACMS monitors:

- Engines
- Aircraftsystems
- Aircraft performances and to do an in-depth troubleshooting

To achieve these functions, the ACMS is able to:

- Generate reports (automatically ormanually)
- Recorddata
- Display aircraft parameters inreal-time

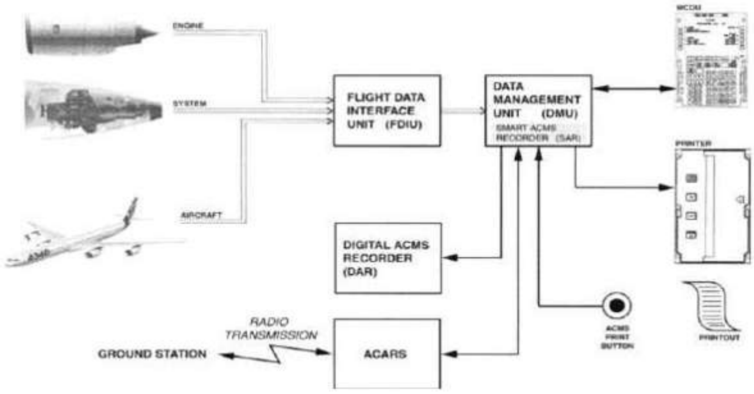


Figure 18.14: ACMS overview

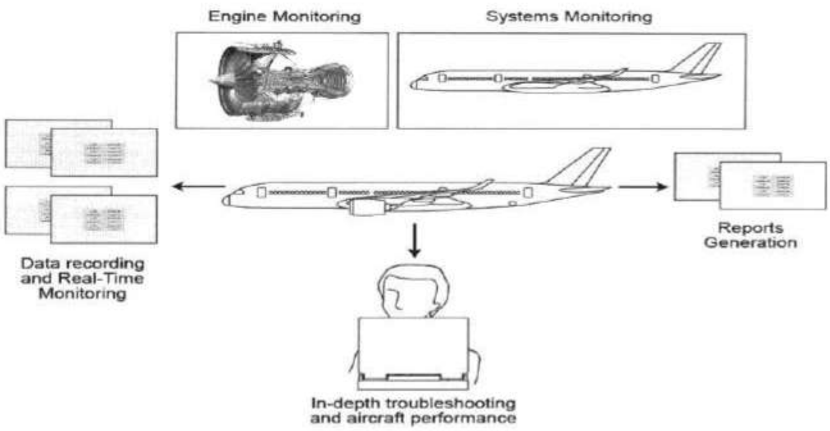


Figure 18.15: ACMS general function

Architecture

The ACMS consists of:

The Data Management Unit (DMU) including a Smart ACMS Recorder (SAR). The DMU may contain a Personal Computer Memory Card International Association (PCMCIA) interface, or a flash drive,Flight Data Interface Unit (FDIU),an “on-ground” equipment called Ground Support Equipment (GSE),an optional Digital ACMS Recorder (DAR).

Other units may be utilised depending on the aircraft type and the associated level of technology employed therein.

- Data Management Unit(DMU)

The DMU collects, stores and processes various aircraft system data. This data can be stored in the internal DMU memory, the PCMCIA card or the DAR, if installed. The collected data is used to generate various condition reports. These reports can be stored in the internal DMU memory or on the PCMCIA card.

• The Flight Data Interface Unit(FDIU)

The FDIU is part of the Flight Data Recording System. It sends the same parameters as the Digital Flight Data Recorder (DFDR) to the DMU. These parameters will be recorded on the
PCMCIA card. Various aircraft systems are connected to the FDIU. These input sources provide the FDIU with engine parameters, APU parameters and aircraft parameters.

• Smart ACMS Recorder (SAR)

The SAR is a DMU function. This function allows the recording of compressed data, programmable through the GSE. SAR data can be stored in the internal DMU memory or on
the PCMCIA card.

• Digital ACMS Recorder(DAR)

The purpose of the DAR is to store data on an optical disk for on- ground performance, maintenance or condition monitoring tasks.
Pre-programmed selection of data can be done
through the GSE. DAR data can also be stored on the PCMCIA card.

• Multipurpose Control and Display Units(MCDU)

The MCDU is connected to the DMU, to display data, program and also control the system. Compared to the GSE, the programming facilities offered by the MCDU are very limited.

The main functions of the MCDU within the ACMS are:

• Online display of selectedparameters,
• Display of the list of the stored reports and sarfiles,
• Manual request of reports and sar/darrecording.

Printer

The printer is used to print reports generated by the DMU as well as most of the ACMS MCDU displays. The printer can be automatically controlled by the DMU, manually controlled via the MCDU or activated using the ACMSPRINT pushbutton.

Aircraft Communication, Addressing and Reporting System (ACARS)

The Aircraft Communication Addressing and Reporting System can be used to send reports and to broadcast parameters generated by the ACMS to a ground station via radio transmission.

• VHF Voice DataRadio,
• Satellite Communication Systemor
• Gate-Link acting as a Wireless Local Area Network (LAN) when aircraft is onthe
ground

The download of reports can be automatically initiated by the DMU or manually initiated from the MCDU.

The Centralized Data Acquisition Module (CDAM)The CDAM is used on the New Technology aircraft (such as the Airbus A380). ACMS data are acquired through the Centralized Data Acquisition Module (CDAM). The CDAM acquiresdata

from all types of aircraft equipment which can be Line Replaceable Units (LRUs), LRUs with AFDX interface, and Line Replaceable Modules (LRMs).
The CDAM hosts three applications:

- The Flight Data Interface Function (FDIF) for Flight Data Recorder(FDR)
- The ACMS-Real Time (RT) Application for ACMS acquisition andpre-processing
- The Remote Server Acquisition (RSA) for NSS Applications dataacquisition

The ACMS-RT function acquires and processes approximately 120,000 parameters via the ADCN.

The ACMS-RT Application provides the following functions:

- acquisition of aircraftparameters
- unidirectional transmission of acquired aircraft parameters to the NSS ACMSApplication
- monitoring of events (logic of aircraft data) to trigger subsequently these functions generation of reports (Airbus definedor Airlineprogrammed)
- generation of Smart Access Recorder (SAR) and Digital ACMS Recorder (DAR)files

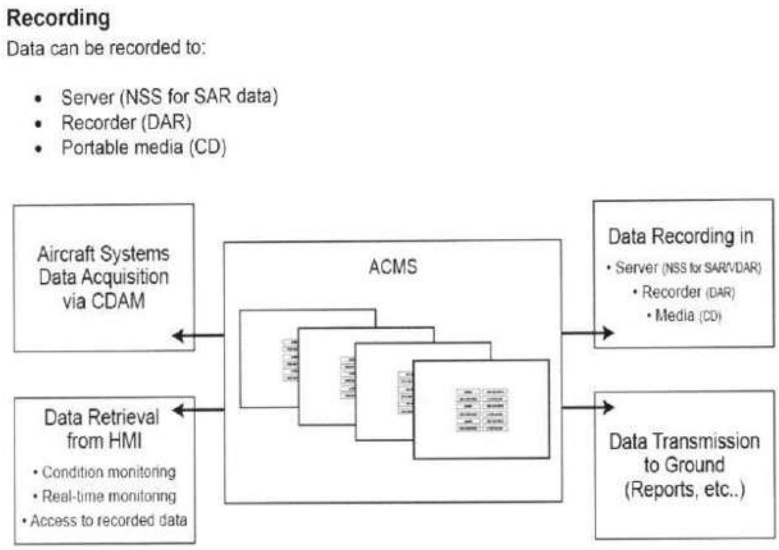


Figure 18.16: ACMS functions

The ACMS Application does a post-processing of data acquired from the CDAM.In addition, the ACMS Application manages the

storage of this data in the shared database.DAR files can be stored either in the DAR directly from the CDAM, or in the virtual DAR (VDAR) in the shared database, via the VDAR Application.

Note that all this data can also be printed or sent to the ground.

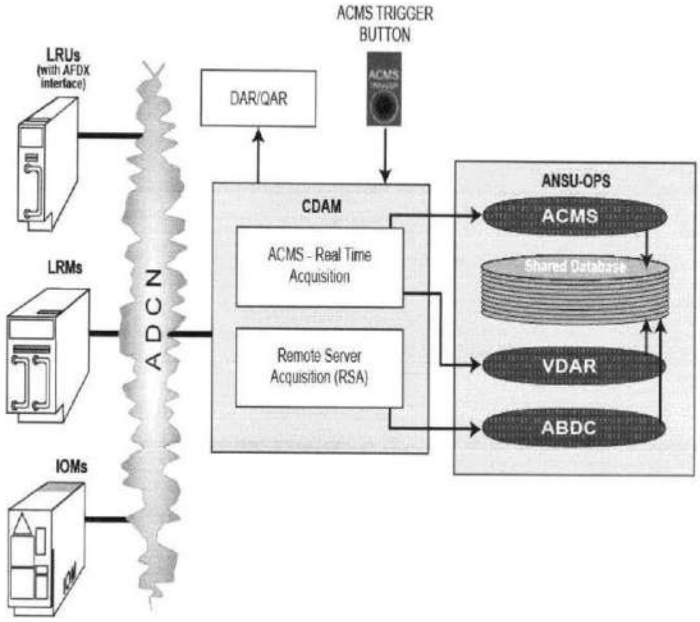


Figure 18.17: CDAM architecture ACMS Reports

- The ACMS can generate two kinds of reports:

- Airbus defined reports: Standardreports
- Airlines programmed reports: AirlineReports

Up to 100 reports can be generated by the ACMS:
- 30 alreadypredefined
- 15 for each type of engine and about 10 for systemreports
- up to 64 airline programmablereports

Standard reports have only limited customization capability (threshold adjustment). Airline engineering is also able to program SAR and DAR content and trigger logic.

<01> ENGINE CRUISE REPORT
<02> AIRCRAFT CRUISE PERFORMANCE
<03> ENGINE CLIMB
<04> ENGINE TAKE OFF REPORT
<05> ENGINE REPORT ON REQUEST
<06> GAS PATH ADVISORY-ABNORMAL CONDITION
<07> GAS PATH ADVISORY-LIMITCONDITION
<08> ENGINE MECHANICAL ADVISORY REPORT
<09> ENGINE START SUMMARY
<10> ENGINE ABNORMAL START REPORT
<11> ENGINE GROUND RUN-UP REPORT
<12> ENGINE FLIGHT PROFILE REPORT
<13> ENGINE FLIGHT SUMMARY REPORT
<14> THRUST REVERSER REPORT
<15> CRUISE STABILITY STATISTIC REPORT
<16> APU ABNORMAL SHUTDOWN REPORT
<17> APU START/MES/COOL-DOWN REPORT
<18> LANDING GEAR PROXIMITY SENSORS REPORT
<19> AGS/TCS/CPCS REPORT
<20> LANDING GEAR EXTENSION/RETRACTION REPORT
<21> DOORS REPORT
<22> BLEED VALVES REPORT
<23> BCS REPORT
<24> NOSE WHEEL STEERING REPORT
<27> HAND LANDING REPORT
<28> RAMP REPORT

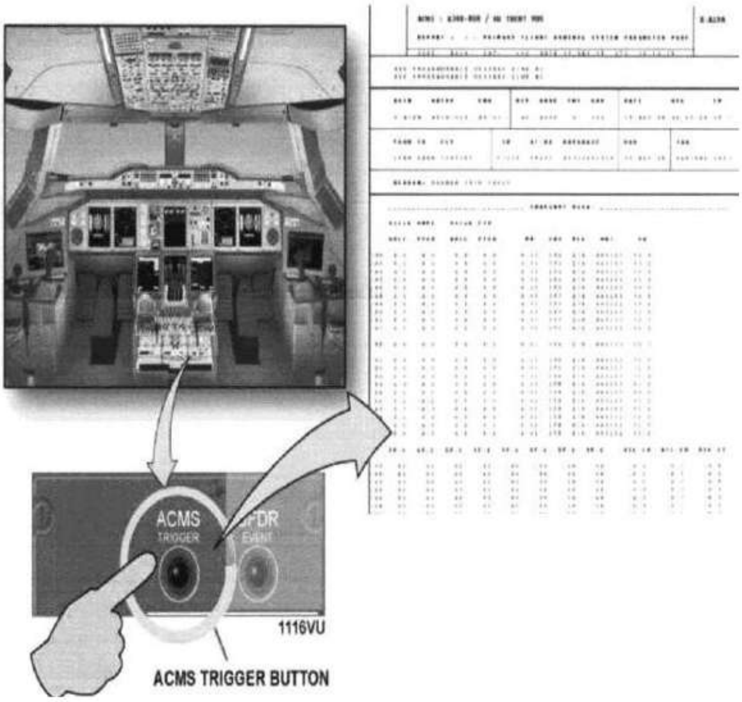
ENGINE REPORT
SYSTEM REPORT

+64 AIRLINE PROGRAMMABLE REPORTS

Figure 18.18: ACMS reports (example: Engine) ACMS Reports Manual Trigger

An ACMS Remote trigger button is installed (for example in

the centre pedestal). If activated by the flight crew this button triggers predefined reports for post flight investigation depending on the flight phase. This Trigger mechanism is based on the ACMS Flight Phase and is programmed in the ACMS. The same can be used by maintenance crew, for example



during Engine Run-up.

Figure 18.19: ACMS manual trigger report generation ACMS Data Retrieval

ACMS real time parameters can be displayed on the OMS HMI, but it is also possible to record, print and send to ground snapshots of these real-time parameters.

ACMS reports and SAR files can be shown on OMS terminals, recorded in the shared database or in CD, printedortransmitted to the ground.DAR files can be retrieved likeACMS reports and SAR files but in addition DAR files can be retrieved directly from the DAR Recorder at theshop.

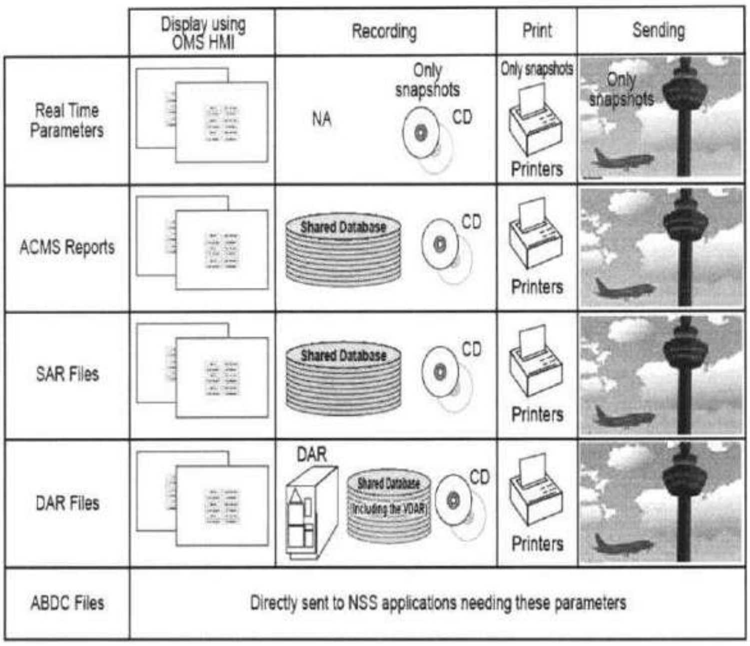


Figure 18.20: ACMS reports and data retrieval Ground Support Equipment (GSE)

The GSE is based on a compatible personal computer able to read

3.5 inch floppy disks and PCMCIA disks. The GSE software provides the following mainfunctions:

Reconfiguration function and Readout function

The reconfiguration function allows the configuration of the customer database (trigger conditions, layout of recordingspace). The readout function allows display, print out and analysis of recordeddata.

DataLoader

The data loader is used to upload data into the ACMS (operational software, customer databases), download data on a 3.5 inch floppy disk or flash drive for GSE analysis (reports, SAR data).

PCMCIA Interface

The PCMCIA interface accepts high capacity and removable PCMCIA disks. On the PCMCIA disk can be stored ACMS reports, SAR data, DFDR data and DAR data. The disk space ratio is programmable by the GSE. The PCMCIA interface can also be used as a portable data loader to upload ACMS software and databases or to download recordeddata.

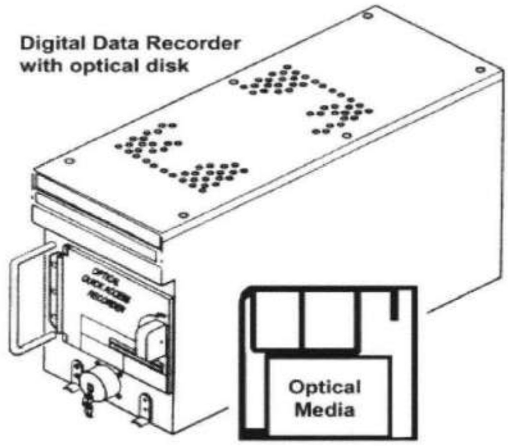


Figure 18.21: DDR with recording disk

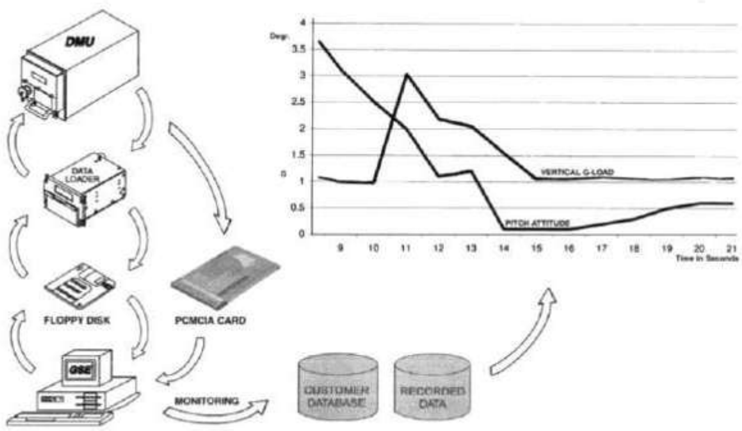


Figure 18.22: Ground Support Equipment

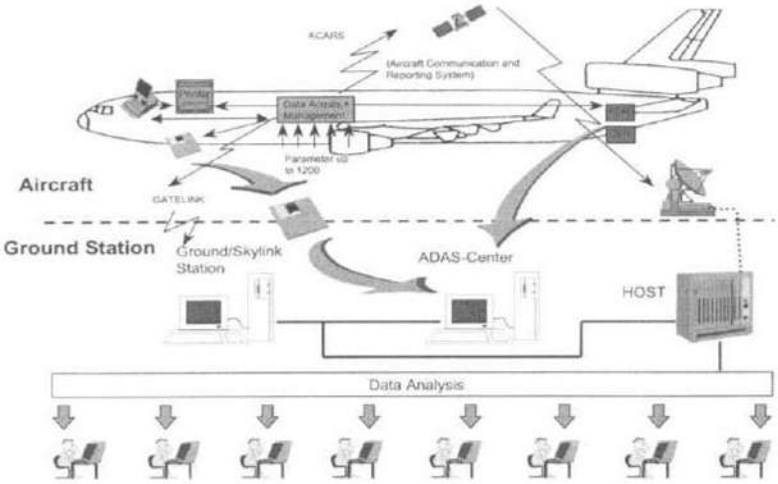


Figure 18.23: Aircraft Data Acquisition System and ground based Data Analysis

Data Loading Systems General

The data loading system is an interface between the aircraft computers and ground data processing equipment used to update software and databases or to retrieve aircraft system
data.

Multipurpose Disk Drive Unit (MDDU)

Used on older aircraft types, the Multipurpose Disk Drive Unit (MDDU) can operate in two modes: automatic mode and manual mode.The manual mode is only used to download data while the automatic mode is used to both upload and download data. According to the operation to be performed, the disk which isusedhas to contain specific information (e. g. configuration file). The data loading system includes two rotary selectors for system selection. It also includes a Multipurpose Disk Drive Unit (MDDU).If the Multipurpose Disk Drive Unit is not installed, Up and Down Loading functions can be performed through a connector by using a portable data loader.Before performing an uploading operation, refer to the relevant procedure for the corresponding system in the Aircraft Maintenance Manual.

The MDDU contains:

- An electronic unit composed of a power supply,Input /output and CPU / Floppy Disk Drive Controlboards,
- A Disk Drive installed on shockmounts,
- A window with 16-character alphanumerical LCDdisplay,
- A door providing access to the DiskDrive.

The data support is a 3.5 inch double face, high density disk (1.44 megabytes).This disk is in MS-DOS format. It can be read or written on ground by IBM-PC compatible Ground Support Equipment (GSE).

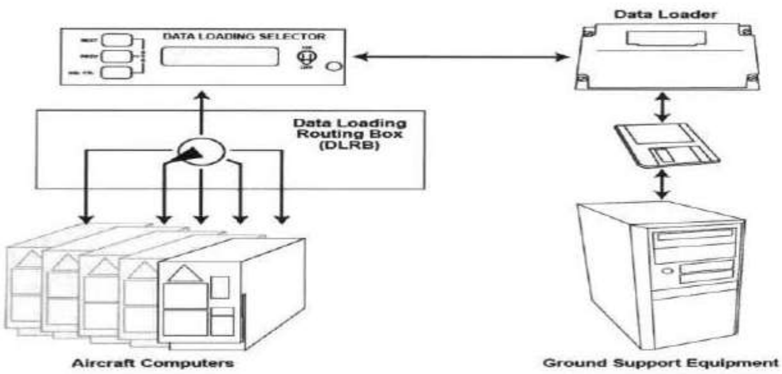


Figure 18.24: Up and Down Loading system

Abnormal Operation

Other messages displayed on the MDDU window inform the operator of the transfer status:

- TRANSFER FAILURE: If the MDDU has to stop data transfer (up or down loading) for any reason, thismessage isdisplayed.

- INIT FAIL: The MDDU displays this message if a hardware failure is detected during the self-test. In this case, the MDDU stops alloperations.

- DISK ERROR: If the MDDU cannot read or write data disk (incorrect formatting,write-protected, disk damaged, etc.), it will interrupt operations and display this message.

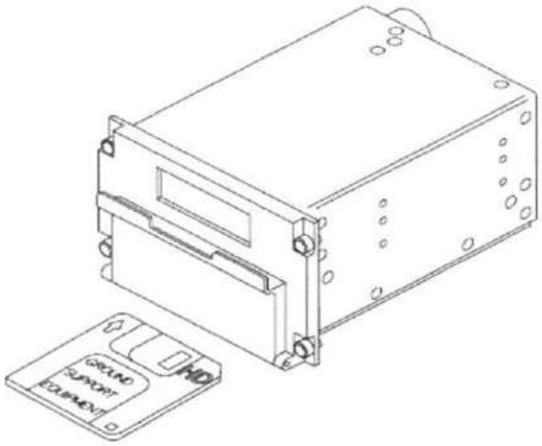


Figure 18.25: Multipurpose Disk Drive Unit MDDU

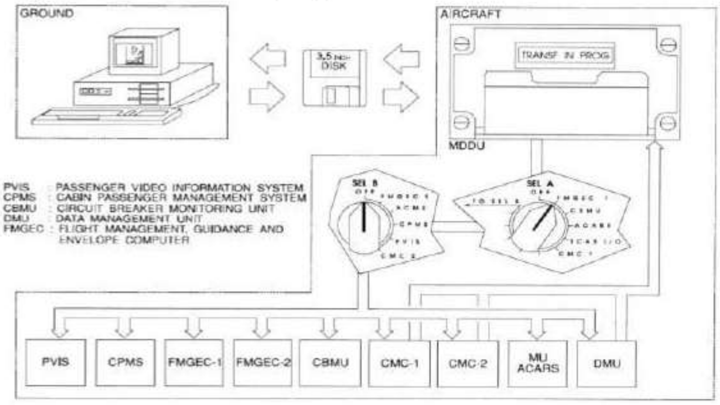


Figure 18.26:

Uploading

The aircraft system computers use the loading system to update their database (for example the FMGEC Flight Management Guidance and Envelope Computer) or to modify parts of their operational software (for example the ACARS Management Unit).
An upload procedure is a data transfer from the Repository or from another media, to the "target hardware".

An uploading can be carried out:

- From the Repository to an aircraftcomputer
- From a dedicated source (CD, DVD, etc) to theRepository
- Or directly from a CD/DVD to an aircraftcomputer

This loading operation may be required for example; to load a new software issue, or to update software as a requirement of a Service Bulletin or Airworthiness Directive.

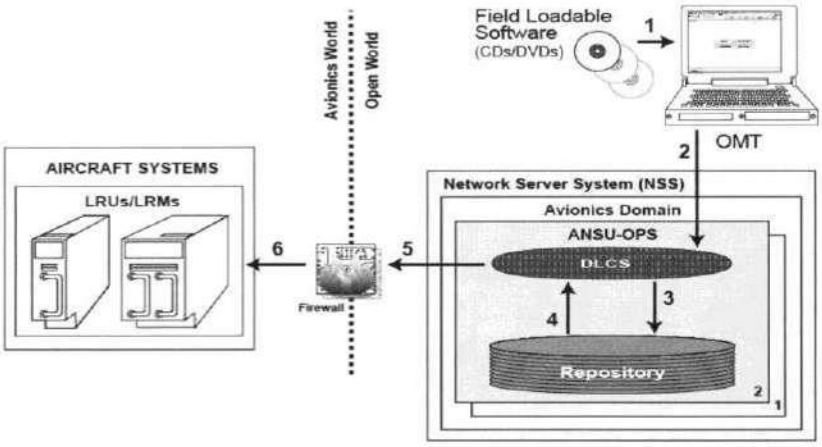


Figure 18.27:Uploading to DLCS or Repository Downloading

A downloading procedure is a data transfer from a computer to a storage media. First the operator must select the file(s) to download, and then the storage media.

The Repository

The media containing software loaded onto aircraft computers are not kept onboard the aircraft.TheRepository has been defined to store a copy of the loads and batch files running on the aircraft.Itscapacity is initially set at 10 gigabytes.TheRepository is only accessible by the DLCS for read and write functions. The Repository management function allowsthe addition or deletion of software. The deletion of software from the Repository frees up storage space. Note that it is possible to delete from the Repository software which is installed in a targetcomputer.

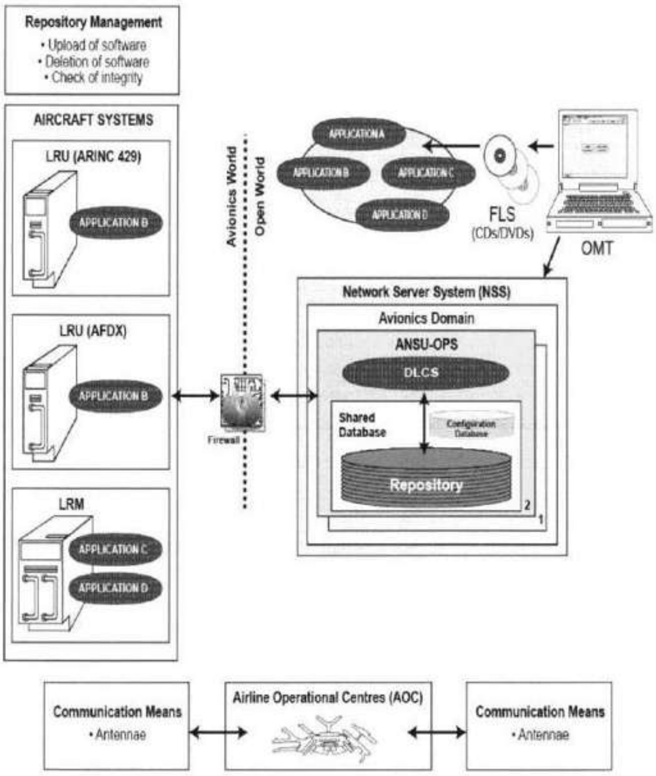


Figure 18.28: Software loading on a modern transport aircraft

New Technology Uploading and Downloading

The Airbus A380 uses a system called the Data Loading and Configuration System (DLCS) manages all data loading and configuration functions of the Avionics World and of the Network Server System (NSS) Avionics Domain (see Chapter 13.22).

The DLCS has four sub-functions:
- the Data Loading management for up/down loading procedures
- the aircraft configuration monitoringthe Repository (onboard software database) Managementthe Software Pin Programming (SPP)Management

These functions manage the field loadable software stored in aircraft computers and/or in the Repository.
- The Data Loading functionmanages:
- The upload of a software from CDs orDVDs
- The downloadingoperations

The Configuration Management function permits:
- compare two configurations of the aircraft at two different dates
- access configurationhistory
- access current aircraft configuration
- customize configurationnames

Note that the Configuration management and control is an Airline Responsibility
- The Repository Management function whichpermits:
- The addition of software in thedatabase
- The deletion of software from thedatabase
- The display of the software loaded in thedatabase

- Integrity checks ofrepository

The Software Pin Programming shows and makes the modification of aircraft computers configuration (option activation, etc...) by configuration software loading.All DLCS functions are accessible from onboard maintenance terminals, via the Onboard Maintenance System (OMS) Human-Machine Interface (HMI).

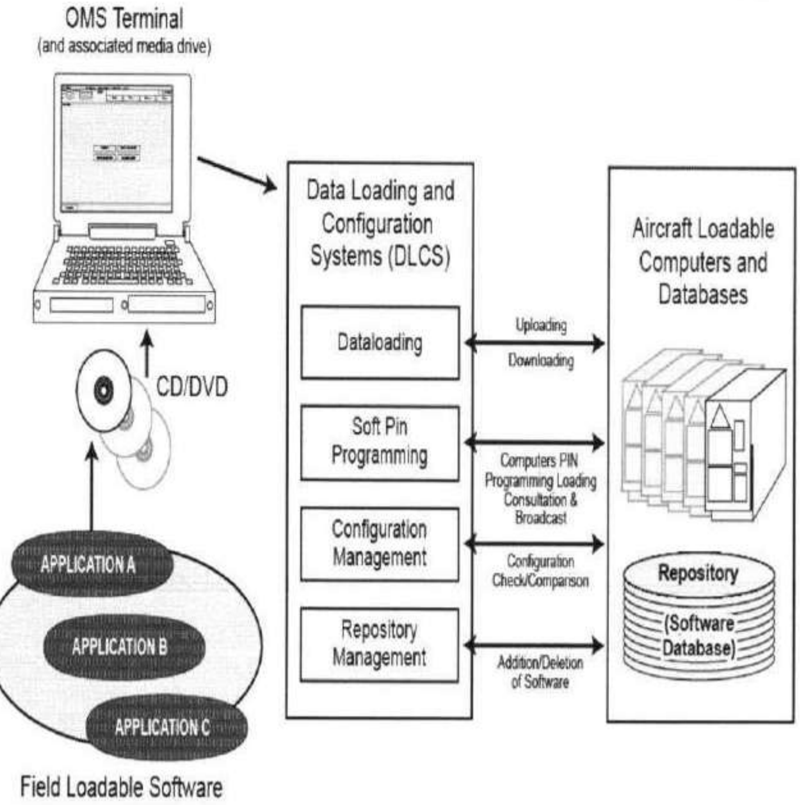


Figure 18.29: DLCS interfaces (A380)

The DLCS has an Application hosted in the Aircraft Network Server Units-OPerationS (ANSUs- OPS) of the Avionics Domain (NSS).This DLCS Application is used to manage software data loading and configuration.

The DLCS Application stores and retrieves software to/from the Repository in the shared database hosted in ANSU-OPS, and in aircraft computers as:

- Line Replaceable Units(LRUs)
- LRUs with Avionics Full Duplex Switched Ethernet (AFDX)interface
- Line Replaceable Modules(LRMs)

The DLCS Applications are also connected to the e-Logbook and to the aircraft documentation (ex: AirN@V), to ease maintenance procedures.

- The HMIs which are used to control the DLCSare:
- The CAPT and F/O Onboard Information Terminals (oits)
- The Onboard Maintenance Terminal(OMT)
- The Portable Multipurpose Access Terminal(PMAT)
- The Printer (for maintenancereports)

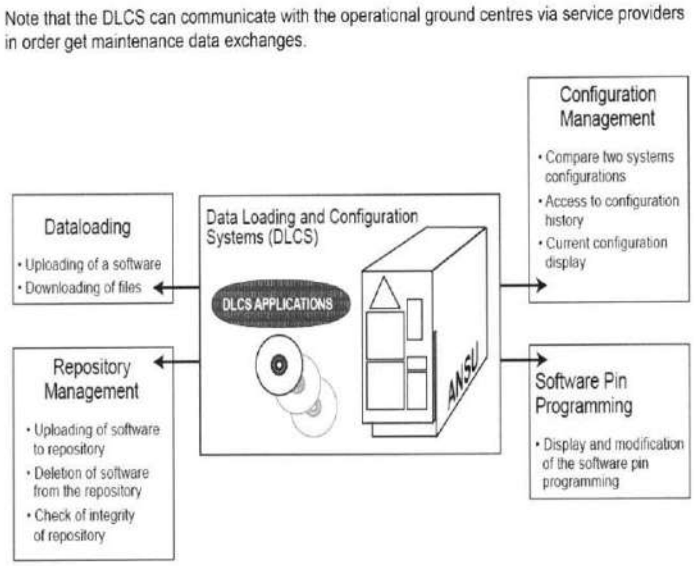


Figure 18.30: DLCS functions (A380) Pin Programming

Hard Pin Programming

Hard Pin Programming is the function of configuring a particular LRU or LRM for a specific aircrafttype,or a specific location (such as the Flight Management Computer, whichcanbelocatedintheleftorRightsideofthecockpit).

The pin programming is carried out by the maintenance technician at installation of the LRU/LRM via one or more DIP switches or configuration of jumperleads.

Soft Pin Programming

Software Pin Programming (SPP) function objective is to complete the Hard Pin Programming, when consequences of erroneous data are not major.Systems for which the consequence of erroneous data is critical still remain hard pin programmable (ex: Flight Management (FM)).For SPP applicable systems (ex: Brake Control System (BCS), Flap System), the DLCS Application is used to upload the SPPs and their history and currentstatus.

Note that both Hard and Soft pin status can be consulted from the OMS.

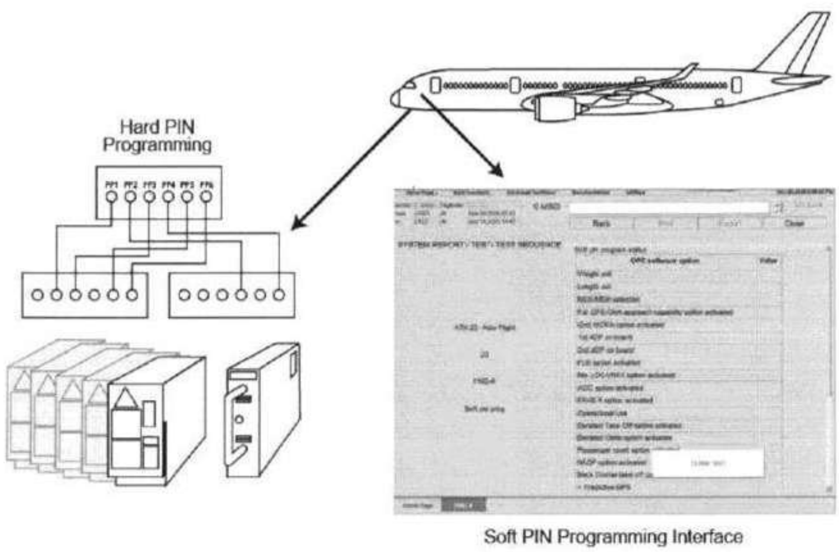


Figure 18.31: Hard and Soft Pin Programming

Electronic Library System (ELS) General

The Electronic Library System (ELS) is an information management system designed to provide airline personnel with timely access to the information necessary to operate and maintain an aircraft. The system provides airline flight, maintenance, and cabin crews with instantaneous access to information contained in tens of thousands of pages of operational manuals, procedures, and navigation charts. Wherever possible, the information is provided in a task- oriented manner so that it can be used more efficiently and accurately. The long-term objective of the ELS is to eliminate the airline's need to carry and update paper documentation on board theaeroplane.

In addition to timely access to information, flight crews will also have enhanced avionics functionality due to ELS mass storage capabilities. Maintenance crews will benefit because the Onboard Maintenance Systems (OMS) will be combined with the Electronic Library System in an integrated maintenance and fault- reporting environment. In addition to the benefits of cabin crew access to operational and procedural information, the mass storage and file server function contained within the ELS allows new levels of passenger servicecapabilities

The airborne Electronic Library System is only a portion of the overall ELS solution. Extensive ground applications using the information to be contained in the airborne system are already in place at most airlines today. The challenge for the industry is to provide the airlines with an airborne system that complements existing and future ground-based systems. The goal is to have a common source database for all facets of airline operations (dispatch, flight operations,maintenance, inventory/parts control, etc.).

Information updates to the airborne system and communications between the ground-based and airborne systems are accomplished through the emerging Gate-link concept and other existing and planned communication channels. In the long term, the very-high bandwidth Gate- link interface will allow the aircraft to park at the gate and "log in" as a node on the airline's computer network. Bidirectional Gate-link information transfers between the aircraft and airline ground-based operations centres will ensure accurate and up-to-date information on the aircraft while significantly simplifying the update process.

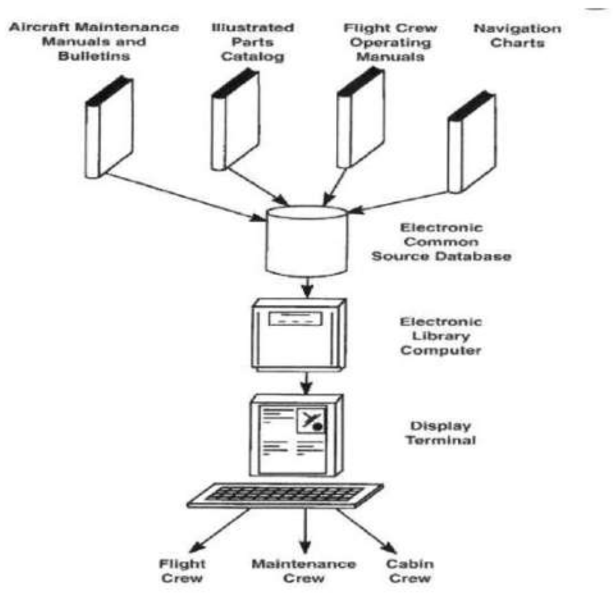


Figure 18.32: Concept

Architecture

The evaluation system consisted of a monochromatic active- matrix liquid crystal display (LCD), an avionics-quality optical disk drive, a prototype ARINC 744A printer, and a workstation platform. The user input device to the liquid crystal display consisted of a capacitive touch screen overlay on the display surface. Flight crews accessed desired information by simply touching the display screen in the appropriate areas. The system did not include a keyboard for user input. Direct text entry for airport directory or word searches was implemented with a “soft” keyboard function displayed on the screen. Integrating the input device directly with the display also helped conserve the space necessary for installing the display on the flight deck. This is particularly important for fleet-wide ELS installations that may include flight decks with limited space.

The integrated touch screen input device and a fibre-optic interface to the display simplifies the wiring installation.

Software provides an accurate and complete functional representation of the envisioned final product. The system included simple “page turning” functions as well as more advanced retrieval techniques such as text and graphical hyperlinking. Great care was taken in the design of the graphical user interface (GUI) to ensure intuitive and consistent operation.A subset of all manuals and navigation charts carried in flight crew kit bags are stored digitally on the opticaldisk.

Digital data was delivered and stored in multiple formats, including compressed bitmap, text, and vector graphic formats. This data set included sections from the Flight Crew Operating Manual, Aircraft Flight Manual, Airport Analysis Manual, Aircraft Maintenance Manual, AircraftSchematic

Manual,Illustrated Parts Catalogue and MinimumEquipment List (MEL). Digitized versions of airport terminal charts were provided by Jeppesen,Inc. The electronic system would not only eliminate the bulky weight carried on the aircraft (up to 90 kilograms carried by international flight crews) but, more importantly, significantly reduce the cost of producing, updating, distributing, and maintaining the existing paper information. Furthermore, users recognized the potential benefit from task-oriented organization of information and that an ELS would allow this potential to berealized.

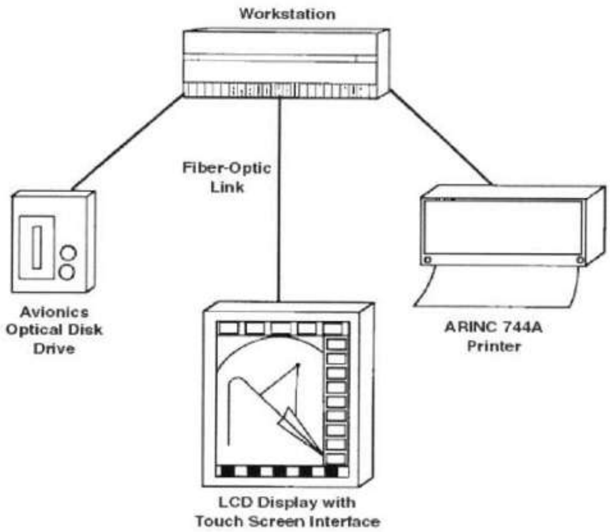


Figure 18.33: Electronic Library System

Airborne Printer General

The printer comprises the following functional sub-assemblies: a front panel with pushbuttons and indicators,

- an electronic part consisting of a Central ProcessingUnit, printer controller and power supplyboards,

- a mechanicalblock.

The printer allows to printout of the CentralMaintenance System reports and additional printouts from:

- the Aircraft Condition Monitoring System (ADAS,AIDS orACMS),
- the Aircraft Communication Addressing and Reporting System(ACARS),
- the Flight Management, Guidance and Envelope System (FMGES)
- the Engine Interface Vibration Monitoring Unit(EIVMU orEVMU)

Paper

The printer works as a non-impact thermal printer which only works on special heat sensitive paper. The paper can be inserted via an access door incorporated in the front panel. The printer is loaded with a correct size of paper roll (108 or 216 mm). Printer Controls

The printer face features pushbutton switches and annunciator lights, i.e.

- TEST switch is used to perform a functionaltest.
- SLEW switch is used to exitpaper.
- “PAPER ALARM” pushbutton switch includesan

AMBER caution light.

- “OFF" pushbutton switch includes a status indicatorlight.

Control Through MCDU

The SYSTEM REPORT/TEST function of the CMS MCDU menu is only available on ground and gives access to the interactive mode.

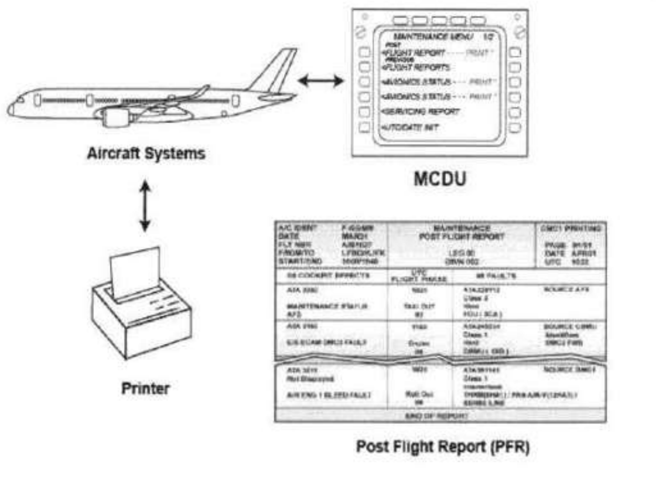


Figure 18.34: Printer interface

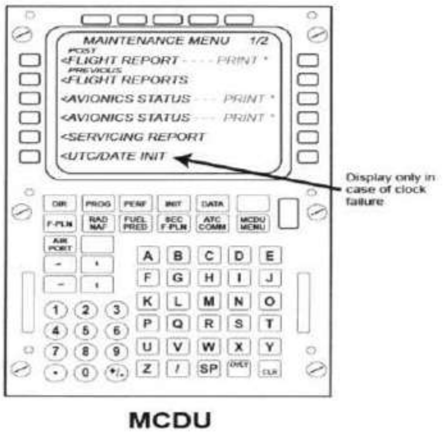


Figure 18.35: Control via the MCDU Paper Loading

A red line marked on the paper indicates that the supply roll must be replaced.

Open the printer and insert a new roll. Verify that the heat sensitive side is facing against the print head. Close the printer and initiate a test print.

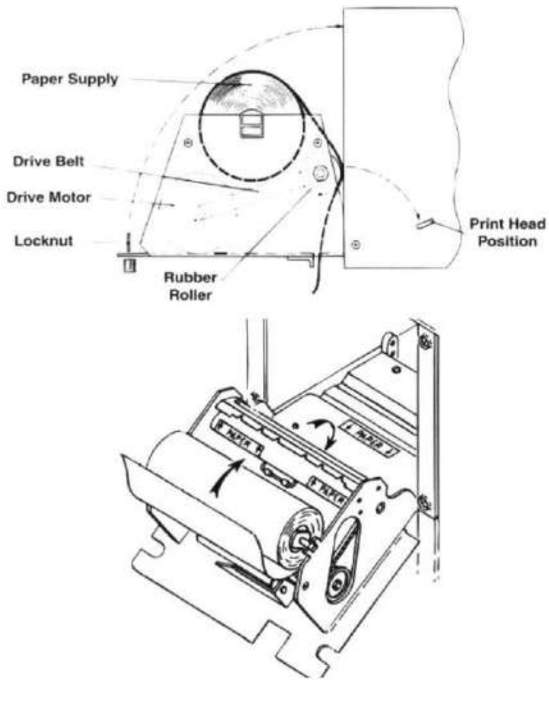


Figure 18.36: Paper transport Dot Matrix Printing Technology

This printer has a 64 ASCII character set and prints this in a 10x16 dot matrix, with a speed of 160 lines per minute. The printer receives the data as serial ASCII or ARINC code from one or more different aircraft systems.Status lines ABC, or ARINC 429 signals feeding back the printer status to the sender, is the so called “Handshake”.

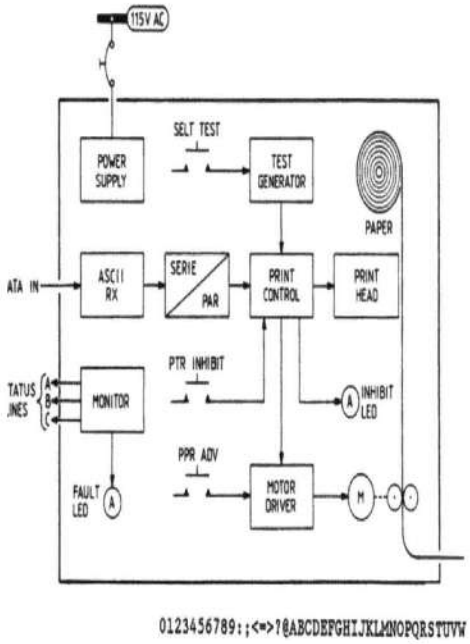


Figure 18.37:Blockdiagram

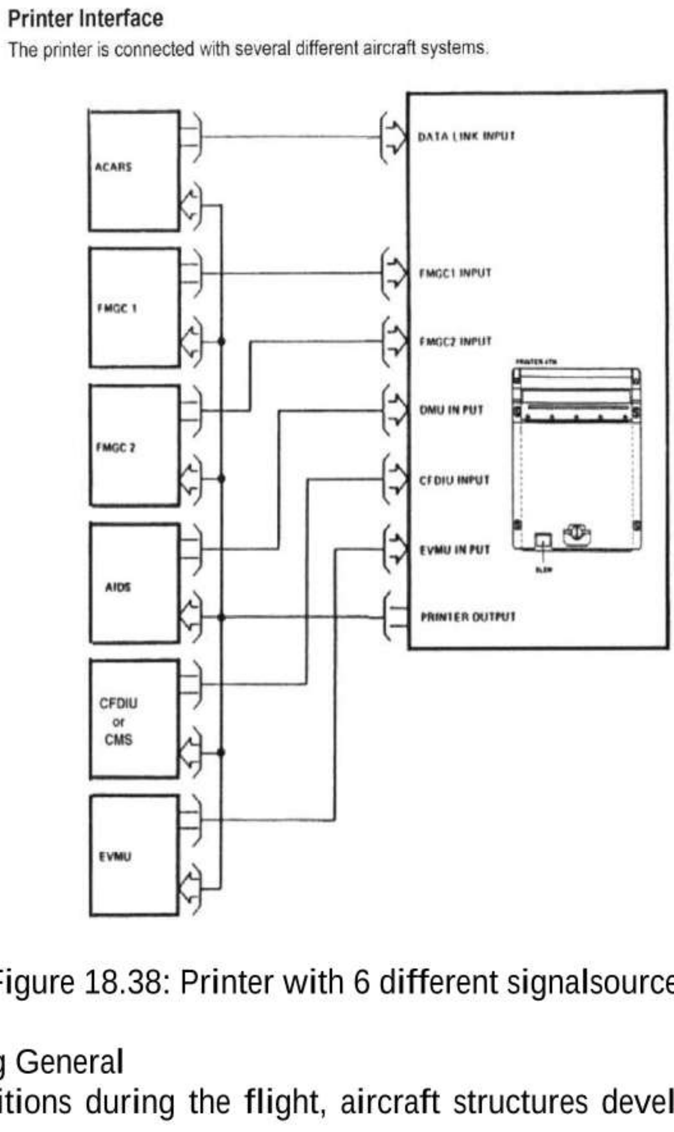


Figure 18.38: Printer with 6 different signalsources

Structure Health Monitoring General

Due to various stress conditions during the flight, aircraft structures develop various kinds of defects which include stress corrosion, cracks, accidental damage, impact damage, delaminations, debondings, water ingress, damage due to loads/strain.

Structure monitoring comprises the instrumentation of a structure with a sensor system that monitors how the surroundings load the structure. An advanced software system receives the data, interprets it and reports the structure's condition to the operator. Real-time feedback to the operator means that overloading may be avoided and any damage to the structure may be discovered quickly. Comprehensive knowledge of the objective condition of the structure allows condition-based maintenance, black-box recorder functionality and investigation of incidents.

An ideal SHM system for aircraft covers the inspection and integrity of the entire aircraft including various functional segments viz. airframe, structure and power plant and their corresponding subsystems. Such a fully fledged SHM system is still far from full scale deployment as many practical challenges remain unsolved. Some of these practical issues faced in implementing smart sensors in SHM systems are given below.

Sensors

The sensor system, unlike the human nervous system, is hybrid and involves a variety of sensors due to the inspection requirements of the aircraft structures. Airbus and Boeing identified few critical aircraft components and inspection

techniques that will use the SHM system. Varied sensor inputs need to be simultaneously analyzed to present a holistic state of health. Sensor optimization might vary for the same area under inspection depending on the global health and local health considerations. Every sensing mechanism needs to be accurate, low cost, robust, maintainable, repairable and need to be certified regulatory organizations for the acceptable limits, to be qualified for onboard implementation. Further, sensors need to be suitable for wireless transmission to central station.

Wireless Communication

Wireless communication brings in additional complexities related to energy efficiency ofcommunication protocols. Other challenges include data and time synchronizations, dealing
with data losses and need for large data management techniques.

Sensor Integration

Sensors and communication mechanism need to be suitable enough either to be bonded or integrated into the structure without causing unacceptable deviations in the structural integrity.
Hence, the manufacturing area is also being researched to develop the structures integrated with sensors.

Sensor Data Processing

In order to interpret data from various sources, it is required to identify effective data normalization and data fusion techniques. As the data acquisition is continuous, large data storage, retrieval and processing techniques need to be identified. Appropriate data filters needto be put in place to deal with the bad or corrupted sensor data.This is very important to minimize the false calls which may impact aircraft operator.

Damage Evolution and Prognosis

Mechanisms need to be evolved to evaluate micro-scale damage up to the system level failure. Failure methods need to be integrated into the package to perform an effective evaluate damage evolution. There is also a need for near term damage progression assessment to initiate the maintenanceschedules.

Conclusion

SHM as a concept is matured and now identified as one of the key enabling technologies to ensure the integrity of future aircraft structures. SHM along with advanced alloys, composites and hybrid materials will revolutionize both airframe and engine structures of future aircrafts.

SHM can help in increasing the structural allowables with higher confidence removing the conservatism in the current designs. This will reduce structural weight leading to reduced acquisition and maintenance costs. SHM enabled structures need to be designed differently using integrated systems approach considering both mechanical aspects of structure and sensor technologies. The sensor integration with structure is very critical and sensor locations should not become damage initiation locations. Use of SHM can translate to over 40% of reduction in the maintenance cost through inspection time and cost savings. Thus SHM is one of the enabling technologies to revolutionize the future aircraft design, development and maintenance.

Fatigue

It is extremely important that the level of fatigue, imposed on an aircraft structure and associated components can be monitored and recorded so that the respective fatigue lives are not exceeded. Several methods have been developed to assistin the vital tasks involved withSHM.

Fatigue Meters

Fatigue meters are used to check overall stress levels on aircraft and to monitor the fatigue history of the aircraft. Fatigue meters also allow a check to be made on the moment in time when the aircraft exceeds the design limits imposed on it.

Strain Gauges

Strain gauges may be used to monitor stress levels on specific aircraft structures. Strain gauges are thin-foil electrical resistor elements that have been bonded to the aircraft structure during manufacture. Their resistance varies proportional to the applied stressloading.

Fatigue Fuses

Fatigue fuses are metallic fuses, which are bonded to the structure and which fail at different fatigue stresses. The electrical current flowing through the fuse, will vary and so provide an indication of the stress level.

Intelligent Skins Development

Modern developments in aircraft structures will allow the structures to be designed and built with a variety of sensors and systems embedded into the structure and skin. This would mainly be restricted to structures manufactured from composite materials. One major benefit of this is to allow the structure to monitor its own loads and fatigue life.

Damage Tolerance Monitoring

The term “Damage Tolerance Monitoring” describes correctly what it exactly does. A good example is the permanent monitoring of the vertical acceleration of an aircraft during landing. A hard landing can seriously damage the structure and must be avoided.If it happens; the computer registers the excessive acceleration during touchdown. This is reported, for example, to the pilot or maintenance personnel and the necessary action can be carried out.

GENERAL CONCEPTION OF INTEGRATED MODULAR AVIONICS AND ITS ADVANTAGES:
IMA (Integrated modular avionics) concepts which replace numerous separate processors and line replacable units (LRU) with fewer, more centralized processing unit are promising significant weight reduction and maximum savings in the new generation of commercial airlines.
According to Boeing by using IMA approach it was able to save 2000 lbs off the avionics suite of the new generation 787 dreamliner versus previous comparable aircraft. Airbus said its IMA approach reduces half the part number of processor units for the new A380 avionics suite.
It is not just IMA module themselves and reducing the number of LRUs, IMA brings a more efficient network for the aircraft. From an airline standpoint fewer types and varieties of spares should drive higher reliability and therefore less maintenance.
In earlier airplane similar concept was used like B-777 AIMS cabinet was used where core processor module and input-output module, data buses and backplanes were used for limited number of system for the same purposes.
Some believe that IMA concept originated in USA with the new F-22 and F-35 fighter aircraft and then migrated to commercial jetliner. Others say modular avionics concept with integration has been used in business jets.

But regardless of where it originated, IMA is the trend of future due to economics of fuel saving derived from less weight and lower maintenance cost. It also offer an open architecture allowing for the use of common software which makes upgrades and changes with cheaper and easier toaccomplish.
An IMA operator can upgrade software without having to upgrade hardware and vice versa.
Using elements common to different computer module makes maintenance of the computer less expensive. Since the same part (or card) can be used in any of the IMA computers, inventory in the shop is smaller. The advantage is less expensive maintenance.
While adopting the general concept of shared resources B-787 and A-380 approaches to IMA differ. Both aircraft have applications for specific LRUs that are on the plane and individual components for certain systems.
In short main advantages of IMA are:- Improved reliability
Decreased cost-(maintenance cost and fuel cost) Decreased weight

Basic layout and its operation of A-380 and B-787 are given below also B-777 very basic lay out given forcomparison:

A 380 Avionics Networks and IMA
1. System Description

General
All aircraft systems communicate with each other using two redundant avionics networks, instead of conventional wiring.
These aircraft systems are monitored and controlled by:
- Conventional avionics, with computers that are assigned to specific systems,or
- Integrated Modular Avionics (IMA), with computers that can monitor and control several via severalapplications.

Integrated Modular Avionics (IMA)
The IMA is composed of:
- Core Processing Input/output Modules (CPIOMs) that are directly connected to the avionics networks. Each CPIOM can monitor and control several aircraftsystems.
- Input/output Modules (IOMs) that act as an interface for conventional avionics that cannot directly connect to the avionicsnetworks.

For redundancy purposes, each conventional avionics is connected to two IMOs to enter the avionics networks.

Avionics Network

All Aircraft systems are connected to both avionics networks.

The information that comes from the Aircraft system is transmitted to the avionics networks via various entry points, referred to asswitches.

These switches automatically manage the communication between the aircraft systems.

- They connect the aircraft systems to thenetworks.
- The route the information that is exchanges between the applicablesystems.

Note: The critical systems can always communicate with each other via conventional wiring to ensure that communication remains possible, if both avionics networks fail.

A380 Avionics Networks and IMA

1. SystemDescription

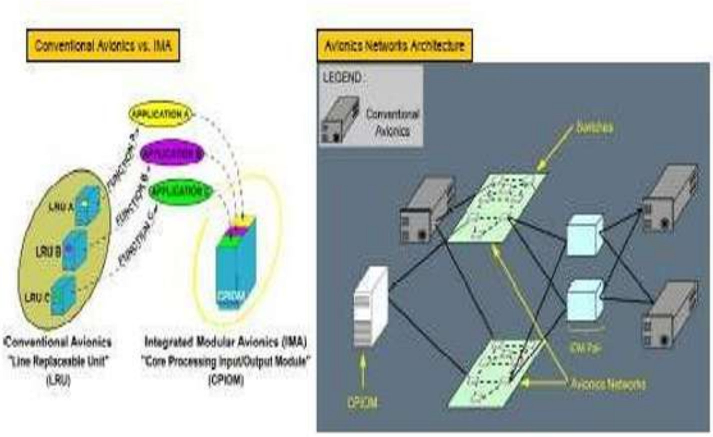


Fig. 19.1

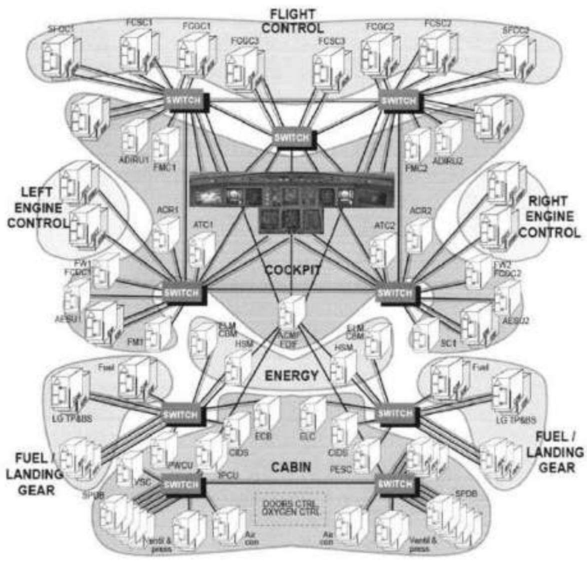


Fig. 19.2 Functional domain of open IMA system communicate with The ADCN (AirbusA-380)

Integrated Modular Avionics & Avionics Data Communication Network

Introduction General

Integrated Modular Avionics (IMA) & Avionics Data Communication Network (ADCN) supply shared avionics resources and powerful data exchange capability to various A/C systems

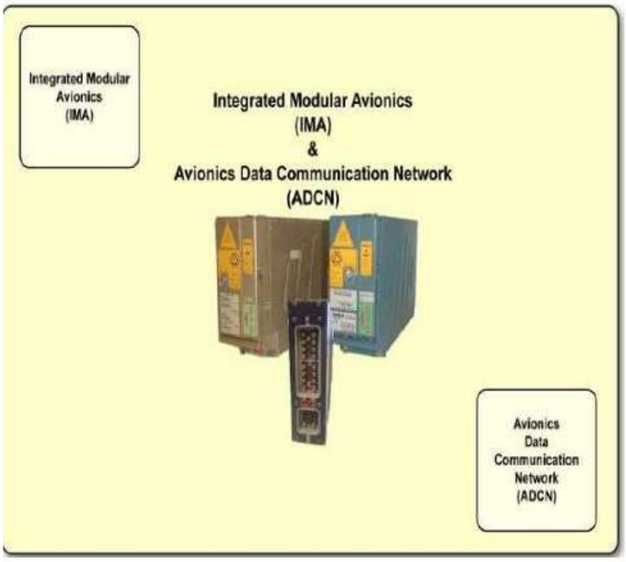


Fig. 19.3

Integrated Modular Avionics Presentation General

Thanks to the view avionics concept Integrated Modular Avionics (IMA), most of the conventional LRU function are done by avionics applications. Theses independent applications are hosted in shared IMA modules, called Core Processing Input/output Modules (CPIOMs). As a consequence, IMA concept reduces the maintenance cost due to less spare computers.

Each CPIOM integrates new hardware and software technologies and hosts these independent applications in the same computing and memory resources, and also supplies an Input/output interface service to some of the conventional avionics.

Moreover, in order to satisfy the high demand of conventional avionics, this service capability has been increased thanks to additional IMA modules called Input/output Modules (IOMs).CPIOMs and IOMs are Line Replaceable Modules (LRMs). These LRMs dialogue through the Avionics Data Communication Network (ADCN) by the means of communication technology developed from a non-aeronautical standard, which has been adapted to aviation constraints.
This technology is called Avionics Full DupleX Switched Ethernet(AFDX).

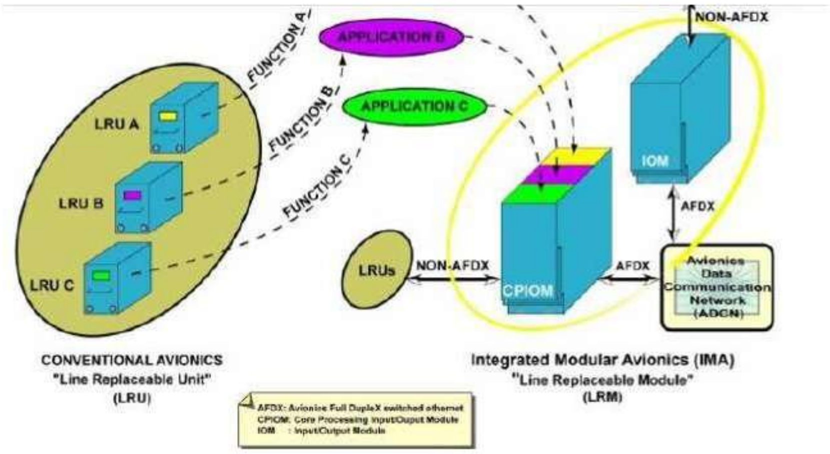


Fig. 19.4

Integrated Modular Avionics Presentation CPIOM

The CPIOM integrates shared memory and computing resources execute independently its hosted avionics applications.

The addition the CPIOM processes independently specific input/output data for each application. This data is AFDX data when the applications dialogue through ADCN and non-AFDX data when they dialogue directly with conventional LRUs. There are 7 types of CPIOM, each one identified by a letter (A to G):

A. PNEUMATIC+OPTIONAL AIRCONDITIONING
B. AIRCONDITIONING
C. COCKPIT+FLIGHTCONTROLS
D. DATA LINK
E. ENERGY
F. FUEL
G. LANDINGGEAR

Each type is associated to a specific part number. CPIOMs with the same part number are interchangeable but may require a software reconfiguration.

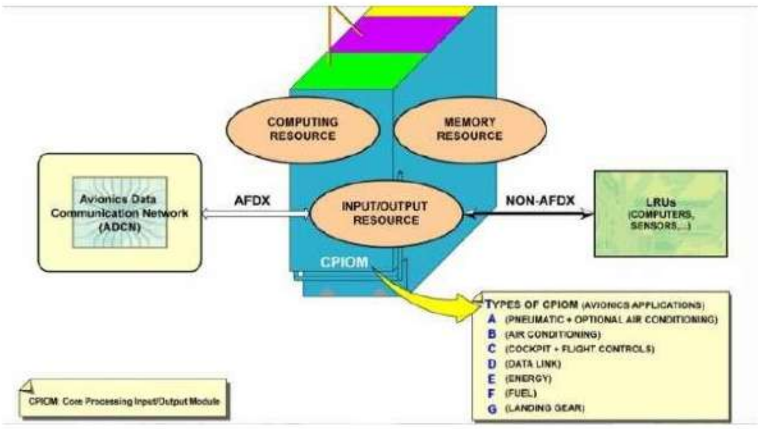


Fig. 19.5 CPIOM

Integrated Modular AvionicsPresentation IOM

The IOM does not host avionics applications.
The IOM converts non-AFDX data, coming from conventional LRUs, into AFDX data used within the Avionics Data Communication Network (ADCN) and vice versa.
There is only one type of IOM identified by the letter A. All IOMs fully interchangeable.

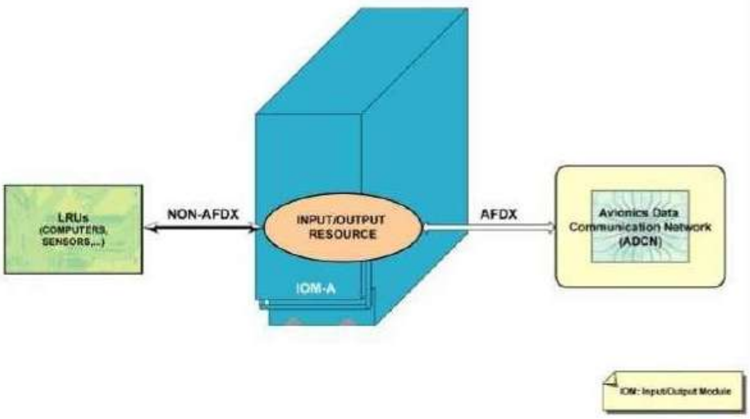


Fig. 19.6 IOM

Avionics Data Communication Network Presentation General

On the A380, computers are structured within an Avionics and an Open world. The Avionics world gathers the aircraft systems supplied within 7 functional areas, related to:

- Flight Control and Auto Flight
- Cockpit
- EngineControl
- Energy
- Pneumatic andCabin
- Fuel
- LandingGear

These functional areas group LRUs and / or Line Replaceable Modules (LRMs) that share a common interest or characteristics.
The open world hosts mainly avionics, flight operations, communication, and Cabin applications.
For security reason, 2 firewalls protect the Avionics world against malicious data coming from open world. Within the avionics world, the A/C systems computers exchange operational and maintenance data. For most of them, this exchange is done through the Avionics Data Communication Network (ADCN). This network is based on a Communication technology developed from a non-aeronautical standard, which has been adapted to aviation constrains. This technology is called Avionics Full DupleX switched Ethernet (AFDX). The ADCN supports also data loadingoperations.

ADCN Subscribers

The A/C system computers connected directly to the ADCN are the LRMs, which are Core Processing Input/output Modules (CPIOMs) or Input/output Modules (IOMs) and the LRUs including an AFDX interface. These computers are called ADCN subscribers. The communication between the ADCN subscribers is done through the AFDX technology. The other LRUs, not including an AFDX interface, are connected to the ADCN through itssubscribers.

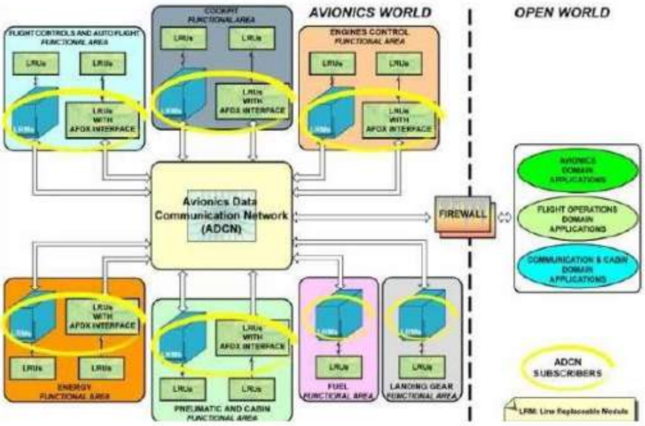


Fig. 19.7 General and ADCN Subscribers

Avionics Data Communication Network Presentation ADCN & AFDX Technologies

The ADCN is supported by the AFDX technology. The AFDX is a communication technology based on commercial Ethernet protocol adapted to aeronautical constraint to meet the avionics requirements. It gives the followingadvantages:

- Secure and reliablecommunication
- High data rate 10 and 100Mb/s.
- Flexibility for future developments of systemarchitecture
- Lesswiring

The ADCN is made of AFDX switches and AFDX cables. TheAFDX switches are electronic devices. They manage the data traffic on the network between the connected subscribers. Indeed,the AFDX switches receive data from an ADCN subscribers or from others switches, analyze and route it to one or several appropriate recipients through AFDX cables.

The AFDX cable is a Full Duplex physical link between a subscribers and an AFDX switch and between two AFDX switches. The term Full Duplex means that the subscribers can simultaneously transmit and receive on the same link.

This link is a STAR QUAD cable, composed of four wires uniformly twisted, one pair for transmission and one pair for reception. For availability reasons, the ADCN implements redundant networks A and B thanks to the redundant switches. Moreover the ADCN supports the “SIDE1/SIDE2” segregation principle at the systems level.

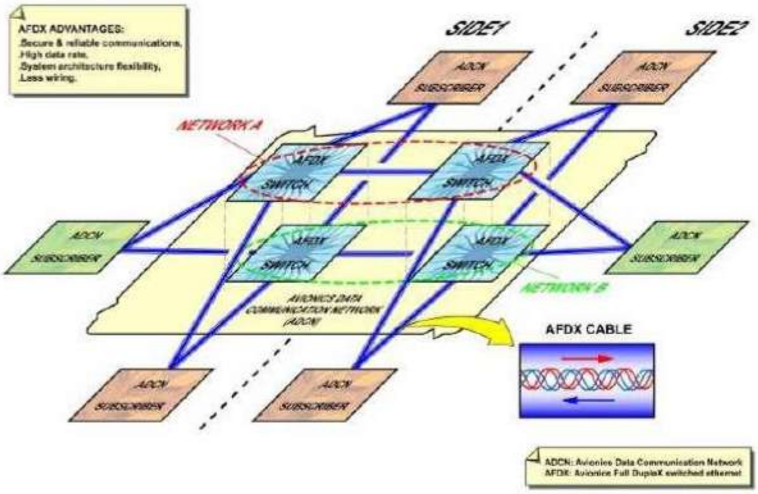


Fig. 19.8 ADCN & AFDX Technologies

Avionics Data Communication Network Presentation The ADCN Overview

The Avionics Data Communication Network is composed of 16 switches, 8 per network, and related AFDX cables. These switches interconnect the aircraft systemscomponents:

- 8 input Output Modules(IOMs)
- 22 Core Processing Input Output Modules(CPIOMs)
- 50 Line Replaceable Units (LRUs) with AFDX interface plus 2optional

Note that the 22 CPIOMs are classified in 7 types:

- 4 are in typeA
- 4 are in typeB
- 2 are in typeC
- 2 are in typeD
- 2 are in typeE
- 4 are in typeF
- 4 are in typeG

Pairs of superposed switches show the full network redundancy.

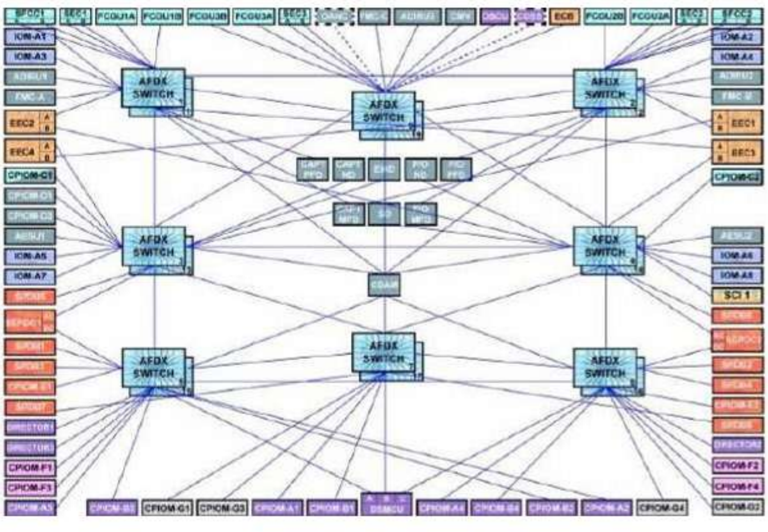


Fig. 19.9

Integrated Modular Avionics Description (3) General

Thanks to the new avionics concept Integrated Modular Avionics (IMA), most of the conventional LRU functions are done by avionics applications. These independent applications are hosted in shared IMA