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AIRFRAME AND SYSTEMS
CHAPTER 3: HYDRAULIC SYSTEMS

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INTRODUCTION

Hydraulics is the science of fluid in motion and when applied to aircraft technology, is used to describe a means of transmitting power from one place to another by means of fluid pressure.

The use of fluid pressure to provide power transmission has a number of advantages over the use of mechanical linkages. Firstly, a fluid can be easily directed through pipes to the more inaccessible places whereas mechanical linkages require more room, stronger supports and are more complex. Additionally, the power that can be transmitted is large in comparison to the weight of equipment used.

All liquids have a very high resistance to compression and when a liquid is subjected to pressure its reduction in volume is very small. It is this fact that is responsible for the positive action associated with hydraulic systems. For example, a pressure of about 5000 pounds per square inch (psi) would be needed to reduce the volume of a liquid by 1%, the same pressure applied to air, initially at atmospheric pressure, would compress it to about 1/300th of its original volume, therefore we can disregard the amount by which fluid is compressed in hydraulic systems.

HYDRAULIC PRINCIPLE

Blaise Pascal (1623-1662), an eminent French mathematician found that when a force is exerted on a confined fluid, the pressure is transmitted equally and undiminished in all directions. Pascal's Law only applies to a confined fluid when the liquid is not in motion. Refer to Figure 3-1.

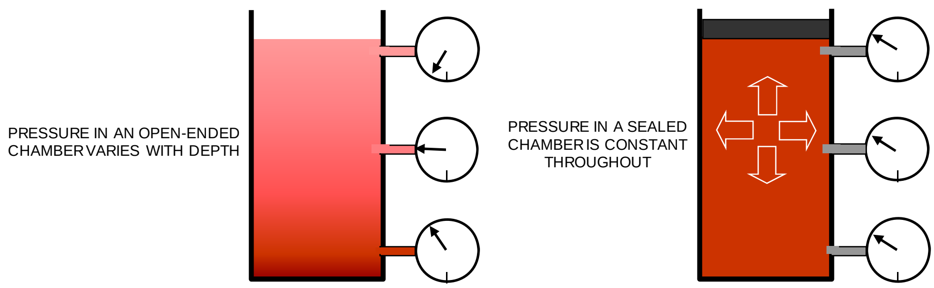


Figure 3-1 Pascal's Law

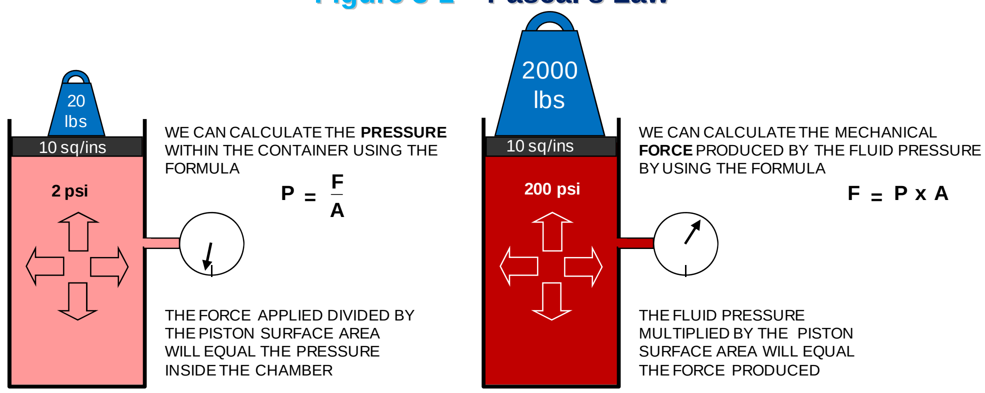


Figure 3-2 Pressure and Force Calculation

Using the formulas shown in Figure 3-2 calculations of fluid pressure and mechanical force can be made of a confined fluid.

MECHANICAL ADVANTAGE

Using the equation, Pressure = Force/Area; it can seen that in each section of the enclosed system in Figure 3-3, the pressure is 10 lbs. per square inch. By application of force to piston 'A' a mechanical advantage can be achieved, i.e. ratio of force produced to force applied such that in respect of 'A' and 'C' of the example shown there is a mechanical advantage of 1000 lbs: 10 lbs, i.e. 100 : 1.

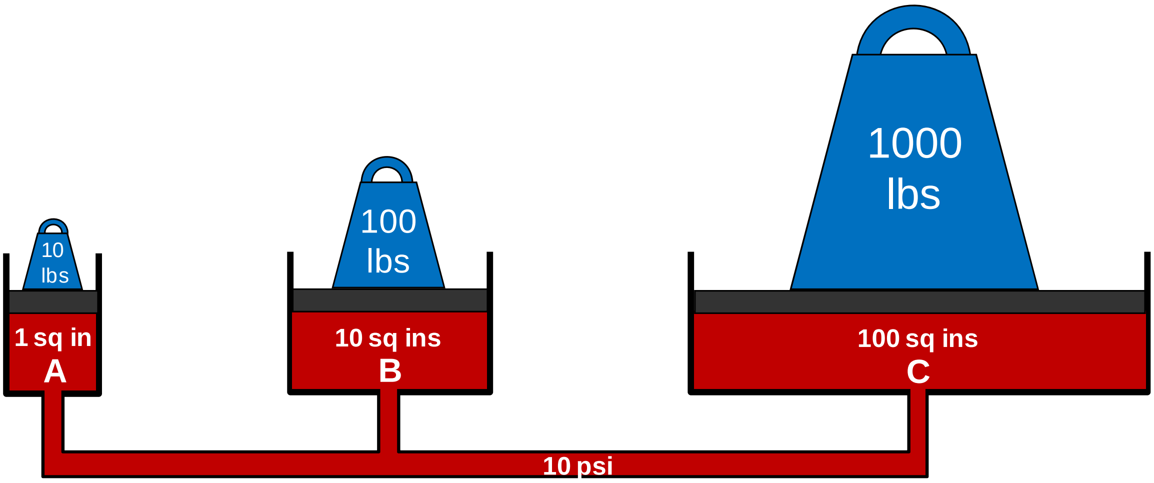


Figure 3-3 Mechanical Advantage

Consider the action of inflating a bicycle tyre. By pushing a hand pump piston along the length of its cylinder a volume of air equal to the length of stroke multiplied by piston area, is forced into the tyre. Because a tyre has a much larger volume, the amount by which the tyre rises is small in comparison with the length of the stroke. This concept is similar to the idea behind the hydraulic actuator or "jack". If a piston of 10 sq. in. cross section area is moved downwards through 10 in. then the fluid displaced will be 100 cu. in. The displaced fluid can only move towards 'B'. But in B the movement of 100 cu. in. of fluid is over an area of 50 sq. in., and therefore the level will rise 2 in. Refer to Figure 3-4.

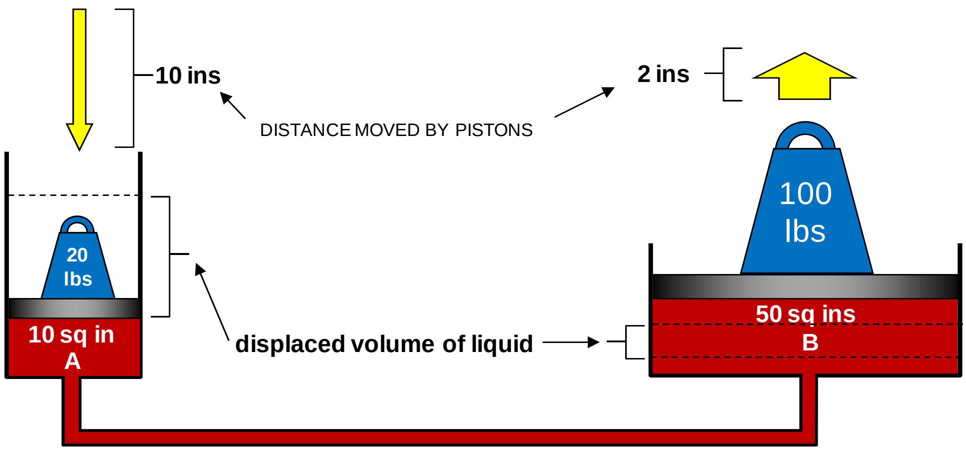


Figure 3-4 Displaced Volume

By applying a force of 20 lbs at A such that the piston moves through 10 in, then at B the 100 lbs would be moved up through 2 in. Alternatively, one can consider that the work put in at 'A' will be equal to the work achieved at 'B'.

i.e. Force (A) x distance moved (A) = Force (B) x distance moved (B).

20 lbs x 10 in = 100 lbs x 2 in.

Finally, it should be noted that force can be gained at the expense of distance and vice versa, and the ratio of force 'A': force 'B' or distance moved 'A' to distance moved 'B', the mechanical advantage is 5:1.

HYDRAULIC FLUID

To ensure proper operation and correct maintenance of hydraulic systems, the correct type of fluid must be selected as the fluid also provides a means of lubrication and cooling for the hydraulic system. There are a number of desirable properties for hydraulic fluids used in aircraft systems. They are;

Fluid Properties

- Low Viscosity - The fluid should be free flowing, not creating much friction between itself and the components of the hydraulic system,
- Non Corrosive - This is necessary so that the hydraulic lines and components do not decompose,
- Non Flammable or Fire resistant - Important in case of an aircraft accident,
- ❖ Low Freezing Point,
- ❖ Slow to Evaporate - In high operating temperatures the fluid must be slow to evaporate.
- ❖ Stable - There should be no tendency for the fluid to decompose or form gum.
- ❖ Non Toxic - Essential for people who service the equipment,
- ❖ Coloured - This assists leak detection, and identification of liquid.

Fluid Types There are three types of fluid available, two of them in current use on large commercial aircraft. Each type is approved for a particular function or aircraft type. To assist in the correct recognition of hydraulic fluids they are coloured. It is critically important to observe the following limitations with regard to hydraulic fluids.

Different fluid types <u>cannot be mixed as their combination may result in gelling or coagulation.</u> This will result in internal leakage and possible eventual corrosion of actuators and other components resulting in system failure.

Specified fluid type must be used for the system. Using a different fluid type will cause the failure of any rubber components in the system such as seals and hoses resulting in system failure.

Castor or Vegetable Based Fluid - e.g. Lockheed 22 / MIL-H-7644

This type of fluid is now almost obsolete. It has poor high temperature qualities. It is either yellow or colourless. Vegetable based fluids are used in conjunction with natural rubber seals and hoses.

Mineral or Petroleum Based Fluid - e.g. DTD 585 / **OM – 15** / MIL - H - 5606

This was the most commonly used hydraulic fluid. It is still typically used in the under-carriage shock struts of large aircraft. This type of fluid is flammable. It is coloured **red**. Mineral based fluids are used in conjunction with neoprene rubber (synthetic) seals and hoses.

Synthetic Based Fluid - e.g. **Skydrol** 500

Skydrol is a phosphate-ester based fluid. It possesses good fire-resistant properties and is used in the majority of modern aircraft where the greater temperature range of the fluid is an advantage. The colour coding is either **purple** or **green**, dependant on function. Skydrol is prone to moisture contamination, it will more readily leak from worn seals and once leaked will cause lifting of paint and deterioration of electrical insulation. Special types of this fluid have been developed which are lower in specific gravity, offering weight savings for larger commercial aircraft. Synthetic based fluids are used in conjunction with butyl rubber (synthetic) seals and hoses.

HYDRAULIC SYSTEM BASICS

Operation - The starting point of a hydraulic system is the production of a constant oil pressure at a consistent, adequate and responsive flow rate. The components that produce this are the reservoir, pump, filter and accumulator.

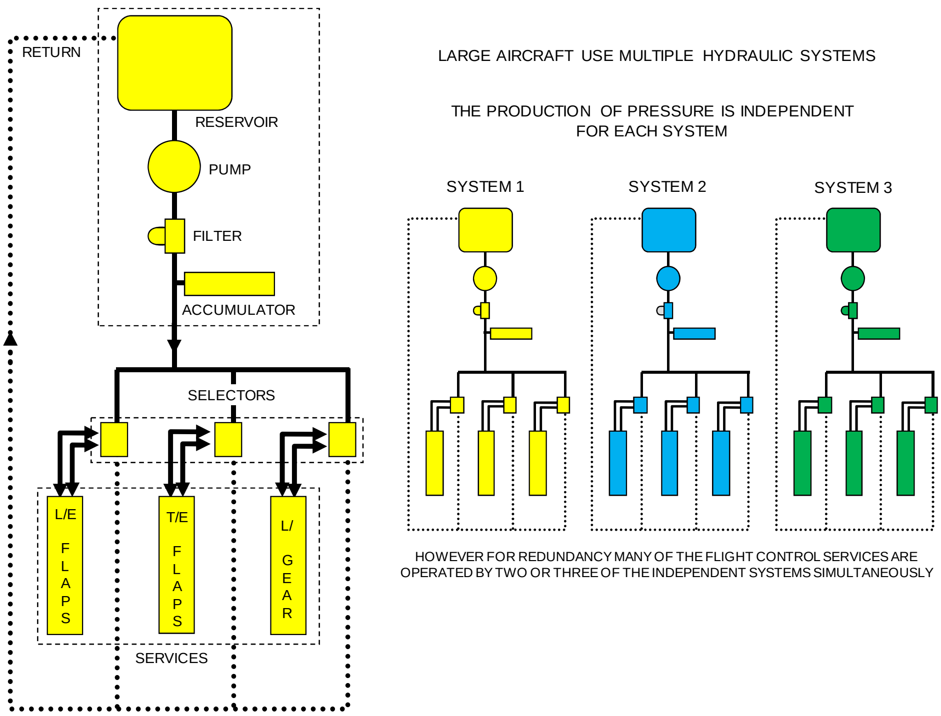


Figure 3-5 Hydraulic System Basics

After pressure and flow is produced it is directed it to the various services using mechanically or electrically operated selector valves.

Each of the services such as flaps, landing gear and flight controls contain the actuators or hydraulic motors that will convert the pressure into mechanical operation.

Finally to maintain the system in constant operation the flow of oil that has been produced and used must be returned back to the starting point to maintain the cycle. Refer to Figure 3-5.

Large aircraft use multiple hydraulic systems both to operate the many services that use hydraulics and to provide adequate redundancy for failures of individual systems. Refer to Figure 3-5.

Operating Pressure - The early hydraulic systems had operating pressures of around 1500 PSI due to the pump technology used. The hydraulic pumps were of a simple design (discussed later) and normally only had to operate a minimum of amount of equipment such as gear, flaps, speed brakes and wheel brakes.

With the advent of powered flight controls that require rapid response rates and better pump design, the hydraulic system operating pressure increased to a general value used by all aircraft of **3000 PSI**. For some equipment particularly wheel brakes this pressure is too responsive and typically the braking system of an aircraft will have a pressure reducing valve incorporated to make the brakes easier to control.

For interest, the very latest of aircraft such as the Airbus 380 and the Boeing 787 have further increased hydraulic system operating pressure to 5000 psi and this will probably become the future standard. Obviously by increasing the operating pressure a greater mechanical force can be extracted from the hydraulic actuators.

A modern hydraulic system includes many individual components, each with a specific function to perform within the system. The individual components and their function will be discussed on the following pages starting with the hydraulic pump.

HYDRAULIC PRESSURE PRODUCTION

HYDRAULIC PUMPS

The purpose of the pump is to supply a fluid flow to the hydraulic system. In order that a pump can provide the pressure to operate a system, a resistance to fluid flow must be provided. The continued flow of fluid from the pump against the resistance will then cause the pressure to rise until it is high enough to operate the hydraulic service.

Alternatively, if the service is not selected, once the output pressure reaches design system operating pressure, either the fluid flow will be by-passed to the reservoir or the pump will reduce output accordingly. There are two basic groups of pumps to begin with; they are hand operated pumps and driven pumps.

Hand Pumps are typically used in older systems or smaller aircraft to provide an emergency means of operating services when the driven pump fails. Modern large aircraft rarely use hand pumps for this purpose as there is adequate hydraulic redundancy in their designs. More common reasons for the use of the hand pump is to fill hydraulic reservoirs from a central hydraulic service point and to operate cargo doors when no electrical power is available.

Hand pumps are either single or double action. Single action (one pumping stroke for two strokes of the handle) are rarely found on aircraft. The double action type has a pumping stroke with each stroke of the handle.

Driven pumps can be operated by many different driving methods and this will be discussed in the following paragraphs. Driven pumps are either gear type or piston type in construction.

Gear Type Pumps are generally found in the low pressure systems and provide pressures up to 1500 psi. The pump consists of two steel gears, one of which is driven by the engine or by some other power unit, such as an electrical motor. At a constant RPM, the pump delivers a constant volume of fluid.

Refer to Figure 3-6; Gear 'A' rotates clockwise and gear 'B' anticlockwise. A reduction of pressure occurs in the inlet side, which results in further fluid being drawn into the pump. Fluid trapped between the teeth and the pump housing is carried around as the gears rotate and is forced through the outlet or pressure side of the pump.

As this pump will always produce flow when it is operating, a separate pressure regulating valve will be needed to control the system pressure within design range.

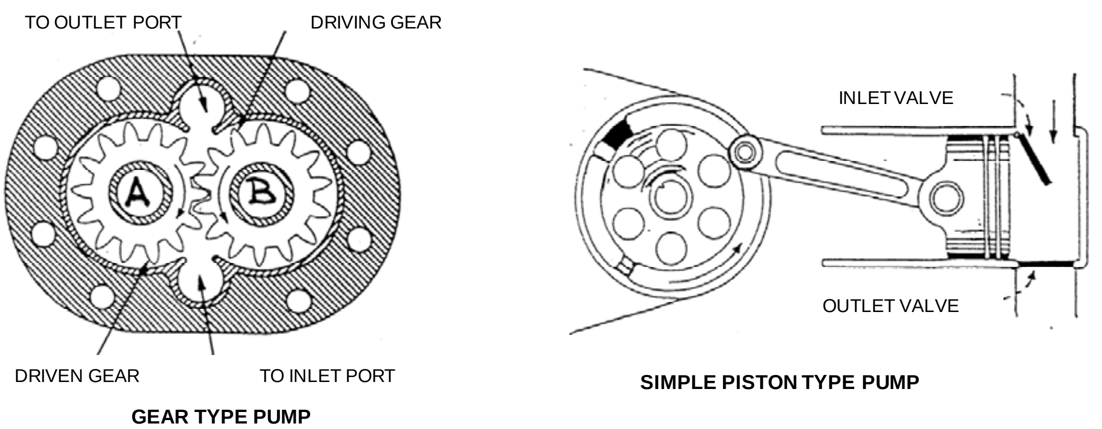


Figure 3-6 Gear and Simple Piston Type Pumps

Piston Type Pumps also produce a constant volume for a given RPM. In its simple form as illustrated in Figure 2-6, it is not very efficient, but modern aircraft pumps are multi-cylinder and capable of delivering pressures up to 5000 psi.

Modern multi-piston pumps are further divided into constant delivery or variable displacement types.

Constant Delivery Piston Pumps are sometimes known as constant volume or fixed delivery type pumps. This is because they deliver a fixed quantity of fluid regardless of system pressure demands. This being the case, the quantity of fluid delivered per minute will depend on the pump RPM.

If a constant delivery pump is used in a system where the pressure must be maintained at a constant value, the system must incorporate a pressure regulator such as an automatic cut-off valve or if the pump is driven by an electric motor a pressure cut-out switch.

These pumps are typically used for special circumstances such as an emergency pump or ground operation pump. Refer to Figure 3-7.

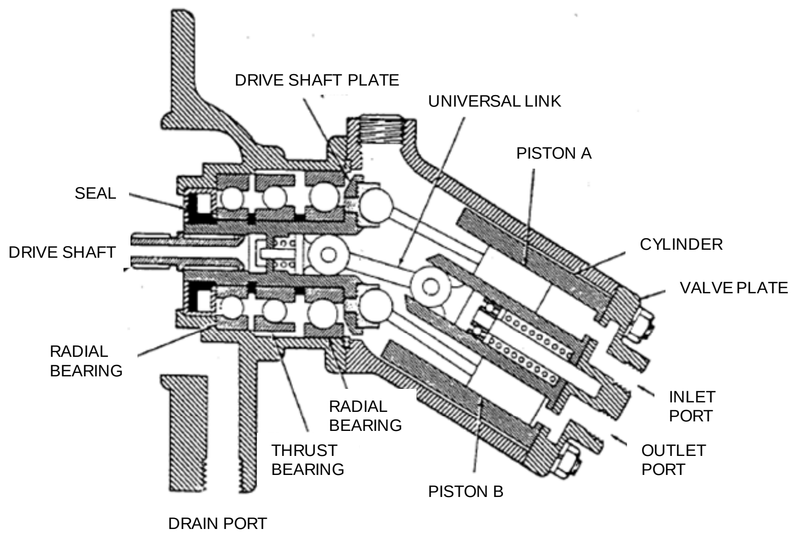


Figure 3-7 Constant Delivery Piston Pump

Variable Displacement Piston Pumps are the type most commonly in use on modern aircraft. This type will supply the varying demands of a typical hydraulic system. The pumps are capable of supplying up to 3,500 psi at a volume of 0 to 40/50 Gallons per Minute (GPM). There are typically two of these pumps in each hydraulic system, usually driven by different methods.

A constant system pressure is maintained by this type of pump, so there is no need to include a pressure regulator or cut-out switch in the hydraulic system.

Where the previous Constant Delivery Type had a fixed piston angle relative to the driveshaft, the Variable Delivery Type can automatically adjust the relative angle of the pistons to the driveshaft by using a 'swashplate'.

This allows the pump to vary the volumetric output as required to maintain the system pressure. Refer to Figure 3-8.

An accumulator is normally included in the system downstream of the pump, to assist the pump when maximum demand is required.

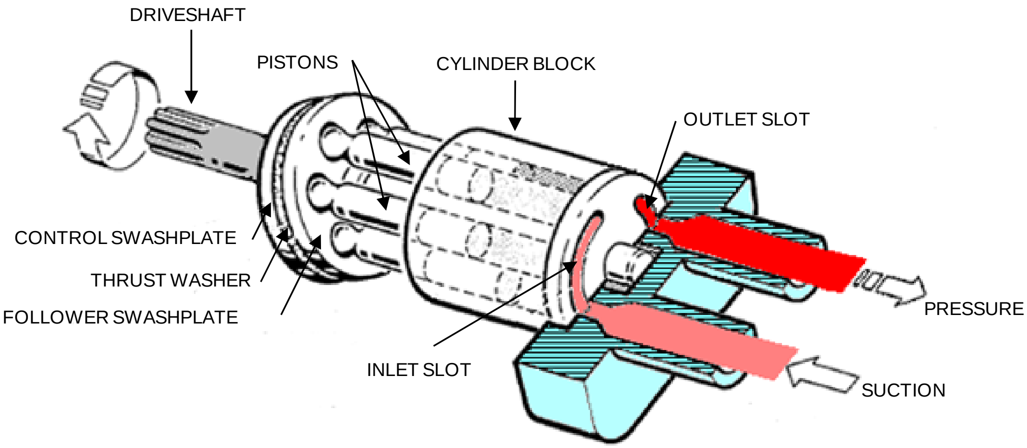


Figure 3-8 Variable Displacement Piston Pump

For example, if hydraulic actuating units are in operation then the swashplate mechanism automatically increases the volume of fluid flow from the pump.

If actuating units are not in use, then the swashplate mechanism reduces fluid flow. Refer to Figure 3-9.

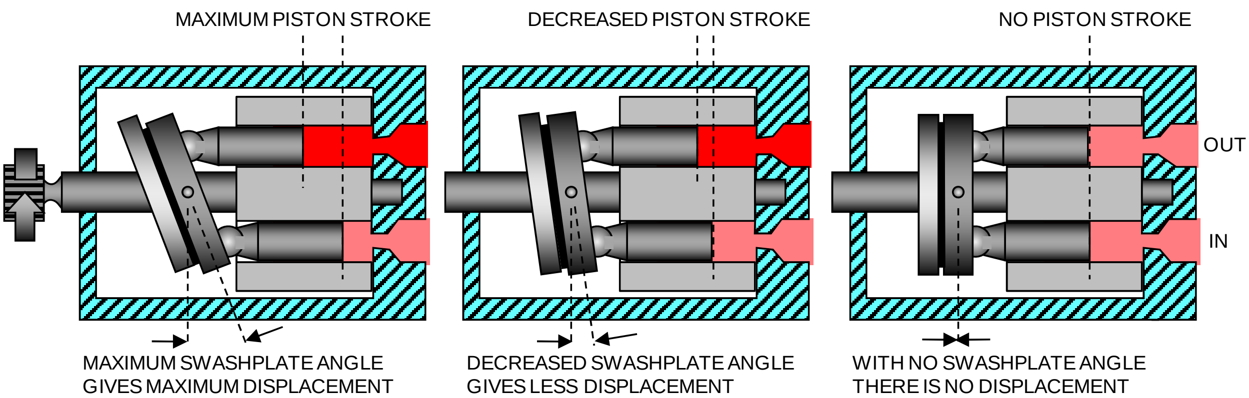


Figure 3-9 Operating Principle of the Variable Displacement Piston Pump

HYDRAULIC PUMP DRIVES

Driven hydraulic pumps either of constant delivery or variable displacement types can be operated by a variety of methods; They are engine driven, bleed air driven, AC and DC electric motors, ram air driven and by hydraulic motors powered from another system;

Engine Driven - Engine Driven Pumps (EDP's) are normally attached to and driven by the accessory gearbox of the engine. EDP's are typically of the variable displacement type and are the main or primary pump of the system. For interest a typical EDP on a large aircraft will produce a flow rate of 40 GPM at 3000 psi.

The drive shaft of an EDP incorporates a device known as a shear-shaft, which in the case of pump seizure or extreme loads will shear or break, preventing further damage to either the pump or the accessory drive. Refer to figure 3-10.

Because EDPs are located on the accessory gearbox the hydraulic supply oil from the reservoir must be able to be shut-off in the case of an engine fire. One of the many functions of the engine fire switch (when operated) is to close off the supply of hydraulic oil to the EDP.

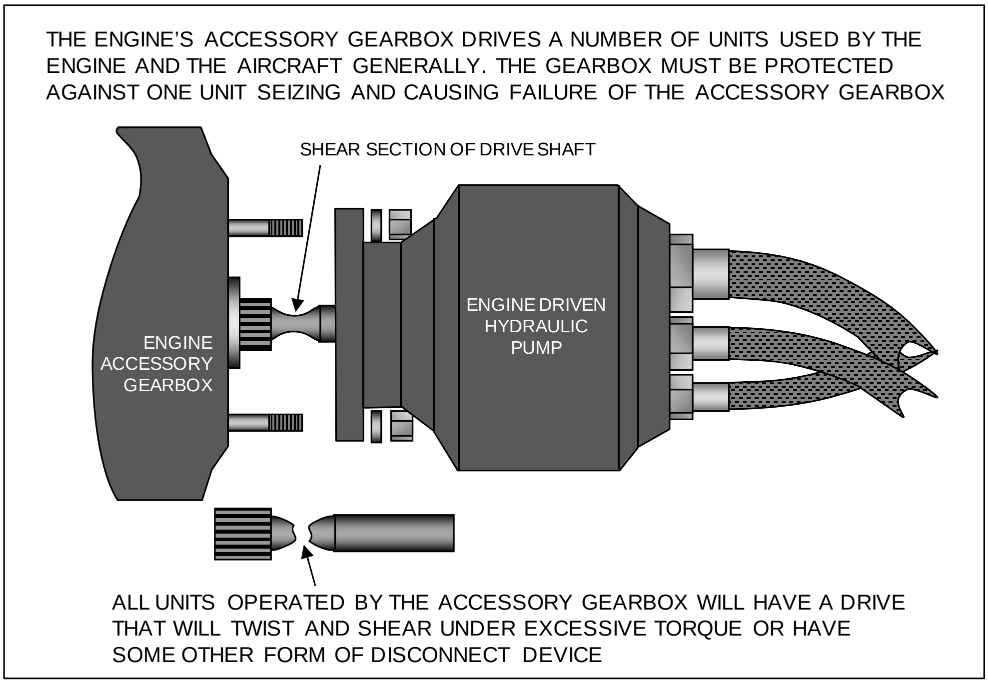


Figure 3-10 EDP Shear Shaft Drive Coupling

Air Driven - Air Driven Pumps (ADP's) are driven by an air motor using bleed air supplied from the engine compressors via the common bleed air manifold. ADP's are typically of the variable displacement type and usually of the same capacity as the EDP. As they use engine bleed air which is uneconomical in terms of engine fuel consumption they are typically used as the standby pump of the system. For interest the abbreviation "ADP" on some aircraft refers to an Auxiliary Driven Pump which may be driven by bleed air or electric motor.

AC Electric Motor - AC Motor Pumps (ACMP's) are driven by three phase AC electric motors, the primary advantages being that with an engine shutdown the hydraulic system is not lost with the engine and that the hydraulics can be operated on the ground from APU electrical power. Additionally, ACMP's can be positioned at locations anywhere in the aircraft as they are independent of the engines. ACMP's are typically of the variable displacement type and are used as the main or standby pump of the system. Their output can be as high as an EDP and will normally shutdown automatically if the electric motor overheats to prevent fires.

DC Electric Motor - DC Motor Pumps (DCMP's) are normally small and are driven using a small DC electric motor. They are used for specific circumstances such as brake pressure for towing and emergency brakes. Typically the motor is powered from the battery bus and the pump will be a constant delivery type. The output from this pump is significantly less than the above pumps.

Hydraulic Motor – Not a common method but used on some aircraft is the Power Transfer Unit (PTU). Aircraft with multiple hydraulic systems can use a serviceable system to operate a system that has a failed or shutdown engine pump by driving a hydraulic motor <u>mechanically attached</u> to another hydraulic pump belonging to the failed system.

Ram Air - Ram Air Turbines (RAT's) are stowed within the fuselage or wing and when required are deployed into the airstream by electric motor or spring. Ram airflow will rotate the propeller or turbine at sufficient RPM to drive a constant delivery type pump. The pump output is directed only to the flight controls. This method of pump drive is designed to allow the crew to land the aircraft with a loss of all engines and electrical power. Refer to Figure 3-11.

All of the above pumps will have a <u>pressure sensor located immediately downstream</u> to alert the crew of pump failure or low pressure except in the case of the RAT which will indicate positive pressure when airspeed is sufficient to drive the turbine.

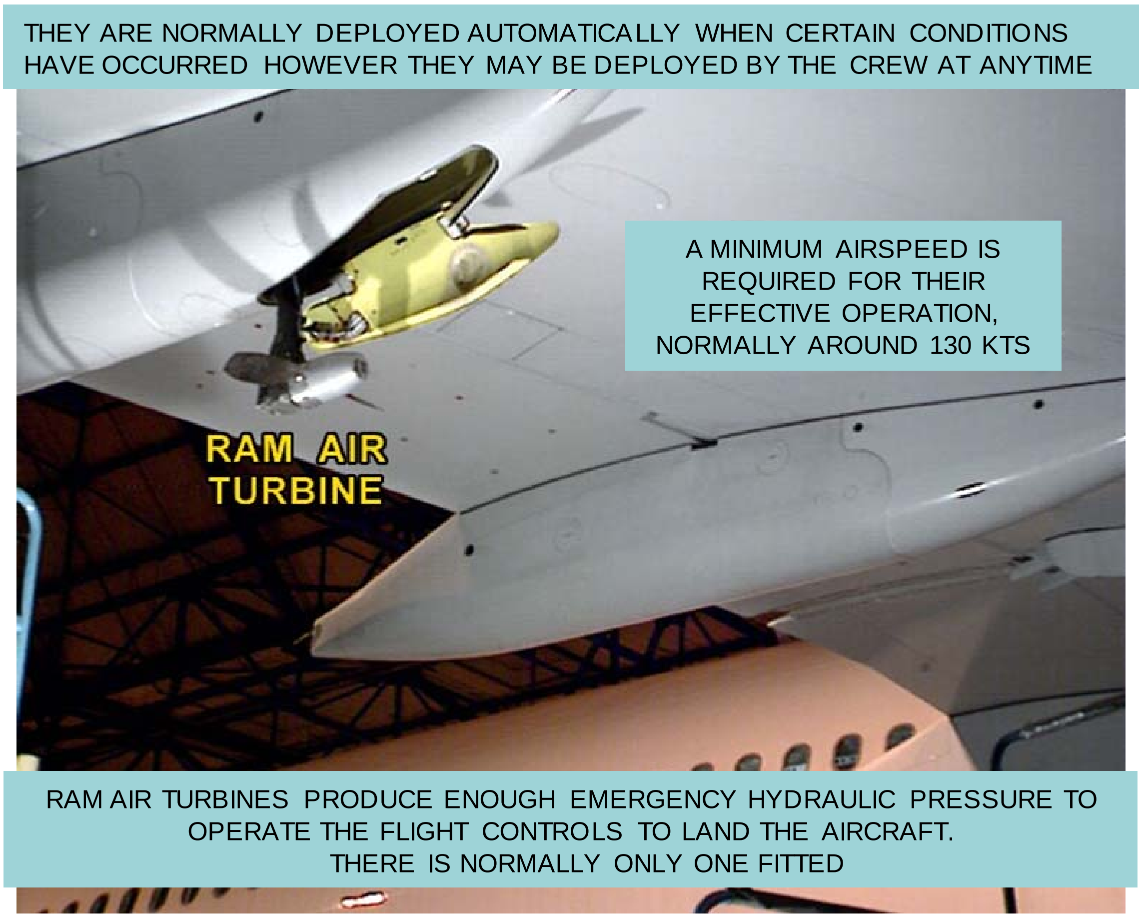


Figure 3-11 Ram Air Turbine

HYDRAULIC PUMP APPLICATION

The aircraft manufacturer designs the system so that it has ample capability to operate all of the hydraulically operated services as well as providing redundancy for normal operation. Additionally, some critical services such as flight controls and brakes are given extra redundancy with emergency pumps and other devices.

Services such as flight controls require pressure and flow all of the time during flight and this is maintained by the systems main or **PRIMARY** pump. These will be variable displacement type pumps as they can react quickly to changing flow requirements and are controllable electrically.

When services that are normally at rest are operated such as the landing gear, extra flow will be required otherwise the system will suffer a significant pressure reduction and slow operation of the normal services.

Therefore the system will normally have a second pump, typically of the same capacity and type, to become automatically active and maintain adequate pressure and flow only whilst the extra service is operating. This is referred to as the standby or **DEMAND** pump.

Because the demand pump is of the same capacity as the primary pump it also doubles as an **ALTERNATE** pump if the primary pump fails in flight.

When multiple hydraulic failures of the primary and demand/alternate pumps occur that result in a severe emergency additional smaller constant delivery pumps are used to provide sufficient pressure for critical hydraulic services such as basic flight controls and brakes. These are referred to as **EMERGENCY** pumps.

Lastly, from the maintenance perspective it is an advantage to have some pumps available for use that do not require the engines to be operating and therefore hand pumps and small electrically driven constant delivery pumps may be present in the system. Typically these are referred to as **SERVICE** pumps.

Figure 3-12 is a summary of all the pumps we have covered. It includes some commonly used symbols found within aircraft operating manuals.

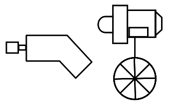
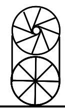
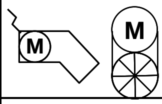
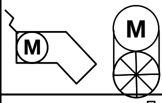
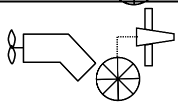
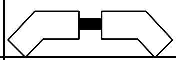
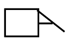
DRIVEN METHOD	COMMON NAME	PUMP TYPE	TYPICAL PUMP APPLICATION	IN OPERATING MANUALS		COMMENTS
				ABBREV	SYMBOLS	
ENGINE GEARBOX	ENGINE DRIVEN PUMP	VARIABLE DISPLACEMENT	PRIMARY SYSTEM PUMP	EDP		WILL HAVE A SHEAR SECTION DRIVE AND SUPPLY OIL CAN BE SHUT OFF
BLEED AIR	AIR DRIVEN PUMP	VARIABLE DISPLACEMENT	DEMAND/ ALTERNATE SYSTEM PUMP	ADP		
AC ELECTRIC MOTOR	AC MOTOR PUMP	VARIABLE DISPLACEMENT	PRIMARY OR DEMAND SYSTEM PUMP	ACMP		
DC ELECTRIC MOTOR	DC MOTOR PUMP	CONSTANT DELIVERY	EMERGENCY OR SERVICE PUMP	DCMP		NORMALLY A BATTERY SUPPLY
RAM AIR PROPELLER	RAM AIR TURBINE	CONSTANT DELIVERY	EMERGENCY PUMP	RAT		DEPENDS ON A MIN AIRSPEED FOR PRESSURE
HYDRAULIC MOTOR	POWER TRANSFER UNIT	CONSTANT DELIVERY	EMERGENCY PUMP	PTU		
HAND OPERATED	HAND PUMP	PISTON	EMERGENCY OR SERVICE PUMP	HAND		

Figure 3-12 Hydraulic Pump Summary

HYDRAULIC COMPONENTS

RESERVOIRS

The reservoir serves as a storage place for the supply of fluid to the system and also carries an additional quantity to allow for fluid lost through minor leakage. Under conditions of thermal expansion the reservoir will hold excess fluid forced out of the hydraulic units. When units are actuated, different volumes of liquid are required as piston rods move inside their cylinders. The reservoir will accept and store surplus fluid, or alternatively supply an increased demand. There will normally be an observable level change when the landing gears are extended or retracted.

During the passage of fluid around a system, air bubbles invariably become trapped. On return to the reservoir the bubbles will dissipate into the space above the fluid level. Therefore, the reservoir acts as a place where the fluid can be purged of air.

A typical reservoir has a strainer to prevent foreign matter from entering the tank, a vent to allow air to leave or enter the reservoir when the fluid level rises or falls, and baffles to prevent splashing of fluid.

A sight gauge enables the fluid contents to be viewed, the level of which should, as stated in the relative maintenance manual, be around 90 % full. Overfilling, however, could cause rupture of the system in the event of a high fluid volume return from a retracting piston.

The reservoir quantity should only be checked and refilled with the system “depressurised”, that is, with no pressure in the system and with the correct configuration of the actuators; for example gear down.. On modern aircraft checking and filling of reservoirs is done remotely from a hydraulic service centre located in the underside of the fuselage.

In the event of a major leak in the hydraulic lines, fluid supplied to the pump would then be lost through that leak. The use of a standpipe prevents the system pump from receiving fluid once the fluid falls below the standpipe. The remaining fluid in the reservoir will then be available for emergency pump operation. Most reservoirs will have a sensor to warn the crew of very low levels.

For aircraft that fly at high altitude where the atmospheric pressure is correspondingly low, the reservoir is pressurised to ensure that the hydraulic pump receives a constant supply of fluid and therefore does not cavitate.

The common method used to pressurise reservoirs in jet aircraft is to introduce air from an engine compressor (bleed air) into the reservoir, controlling the pressure by means of a pressure regulating device. The purpose of pressurisation is to ensure a positive flow of fluid to the hydraulic pump during high altitude flights. Refer to Figure 2-13.

For aircraft with no compressed air available another method of pressurising a reservoir is the use of an air injector or aspirator. A venturi-type air injector is installed in the return line to the reservoir and the return fluid, under pressure, is passed through it. An air line connected into the fitting permits air to enter the return fluid line. This results in air being injected into the fluid which is carried to the reservoir, where it is trapped, thus causing an increase in pressure in the reservoir. Excess pressure is passed off through a pressure-relief valve in the reservoir vent line.

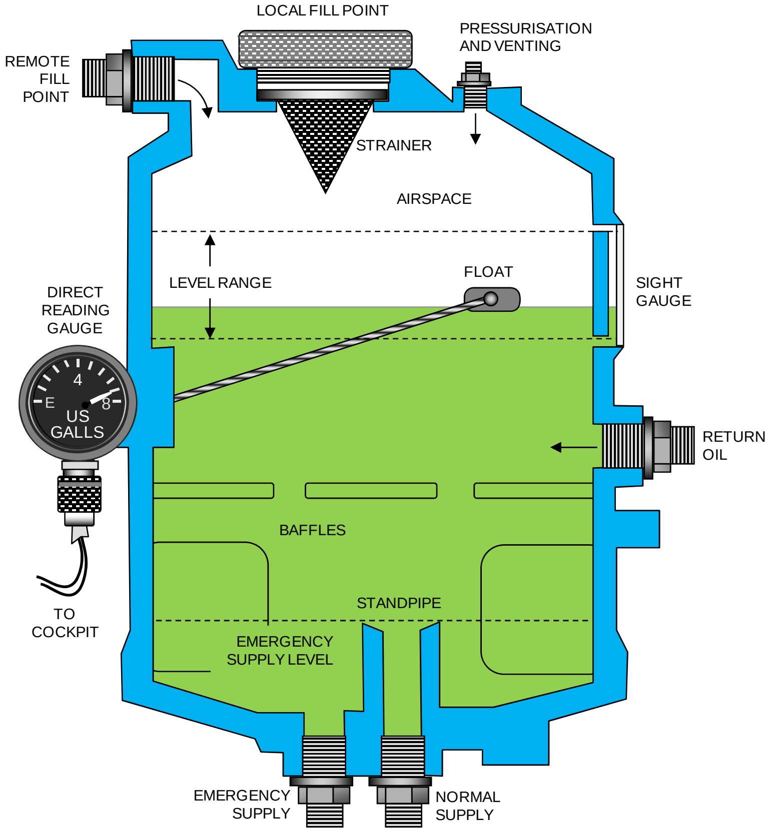


Figure 3-13 Hydraulic System Reservoir

Most reservoirs in modern large aircraft are commonly located inside the pylon or strut joining the wing to the engine nacelle. As discussed previously when the reservoir supplies an EDP the supply fluid is shut-off as a function of actuating the fire switch for that engine. Refer to Figure 3-14.

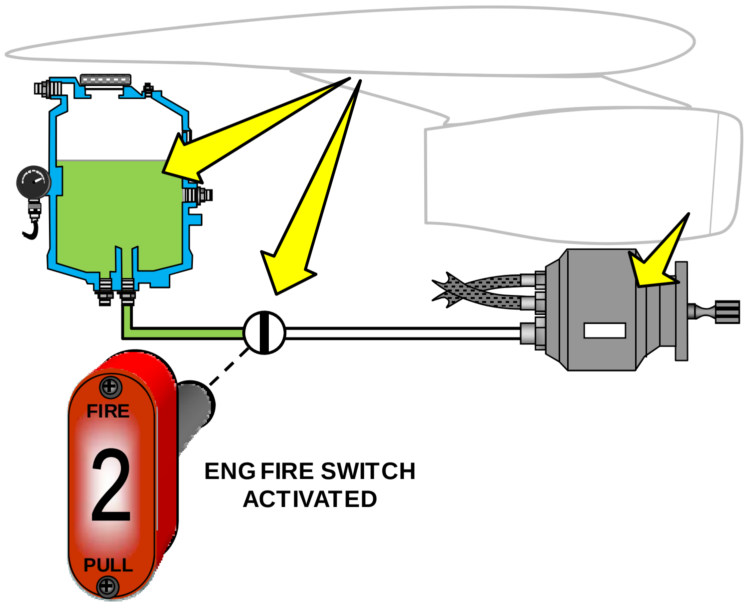


Figure 3-14 Hydraulic Supply Shut-off to EDP

ACCUMULATORS

The accumulator is basically a storage device for small or large amounts of hydraulic fluid kept pressurised by a gas charge, typically nitrogen. Depending on its size and relative location within a system it can perform a number of functions. There may be more than one accumulator in a hydraulic system. Accumulator functions and locations will be discussed in the following paragraphs but for now let us examine the types of accumulator construction. There are two basic types of accumulator design, they are bladder and floating piston. Refer to Figure 3-15.

Bladder - A hollow sphere is fitted with a synthetic rubber diaphragm. One section of the accumulator is charged with dry air or nitrogen to a value of one third or one half of the normal hydraulic system operating pressure. This is referred to as the accumulator pre-charge pressure and can be read on the pressure gauge attached to all hydraulic accumulators. The accumulator is charged through a Schrader valve, with the hydraulic system not operating and therefore without the presence of fluid on the other side of the diaphragm. On operating the hydraulic pump, fluid pressure will build up, compressing the gas until both fluid and gas pressures are equal.

Floating Piston - Most modern aircraft hydraulic systems have floating piston type accumulators, which have a much larger capacity than the bladder type. The same gas value, charging method and fluid pressure build up occurs as mentioned above. It is important that you understand the correct method of reading the pre-charge gas pressure because when hydraulics are turned on, the reading is no longer valid.

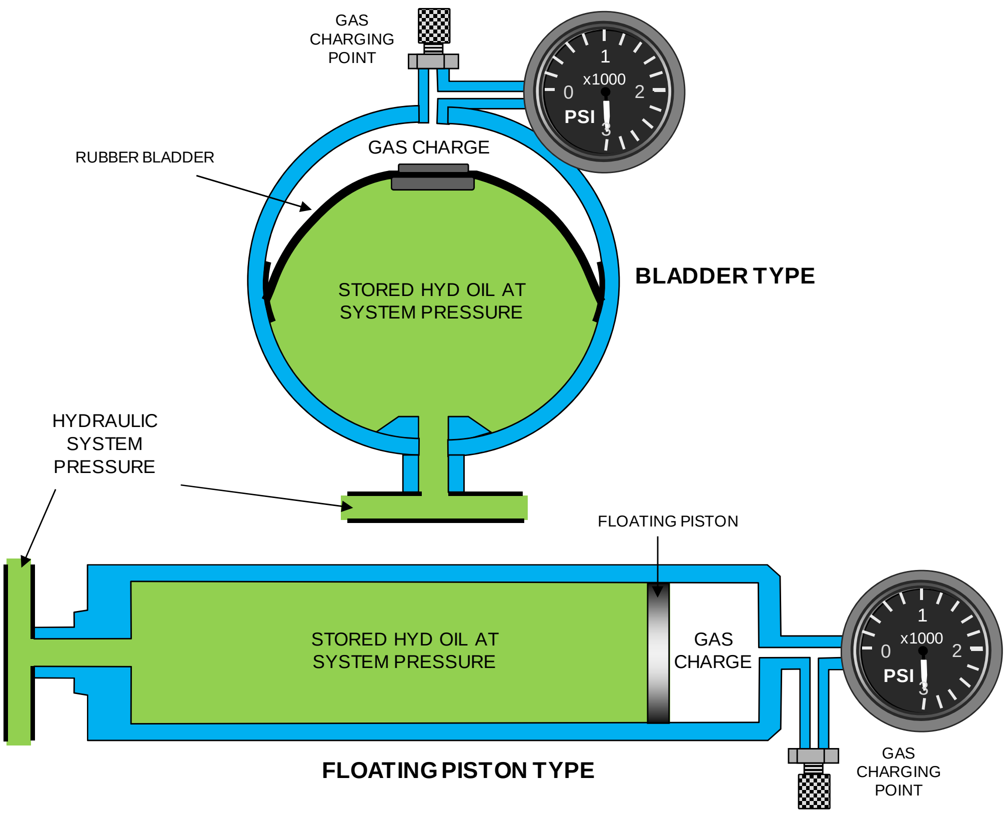


Figure 3-15 Hydraulic Accumulator Types

From Figure 3-16 it can be seen that when hydraulics is turned on, fluid under pressure begins entering the accumulator and the gas will compress until both fluid and gas pressures are equal. Therefore it can be stated that to correctly check the accumulator pre-charge gas pressure hydraulic pressure must be fully depleted. Accumulator pre-charge gas pressures can only be checked at the accumulator.

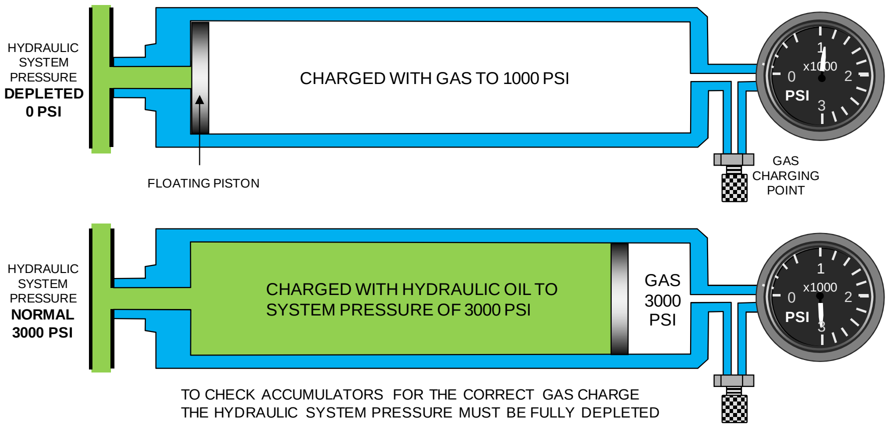


Figure 3-16 Checking Accumulators for Pre-charge Gas Pressure

Accumulators store system pressure by loading fluid against a gas pre-charge and depending on their size and location, can be used for any of the functions listed below;

- to assist the hydraulic pump with output when several services are being operated, thus reducing pressure fluctuations,
- to provide pressure for emergency hydraulic operation when the hydraulic pump is inoperative,
- to provide pressure for park brakes,
- to prevent repeated cut-in and cut-out of the pressure regulator or pump surging,
- to dampen the shock of selector valves closing, and
- to compensate for minor leaks.

A typical modern aircraft with multiple hydraulic systems will have accumulators positioned at various points in the systems to accomplish the above functions. Typical positions in hydraulic systems are depicted in Figure 2-17.

When a large hydraulic service such as landing gear is operated, system pressure will immediately begin to decrease as more fluid is suddenly required for the gear actuators. The variable displacement pump will adjust to provide the extra flow but the initial fluid is supplied by the accumulator.

When system pumps have failed the accumulator can provide stored pressure and fluid to services such as wheel brakes or gear down. These operations will be limited of course to the amount of stored fluid.

For example a "brake accumulator" will provide approximately six moderate brake applications or three hard applications. Typically, the "brake accumulator" also serves to maintain the park brake pressure for up to approximately 25 hrs.

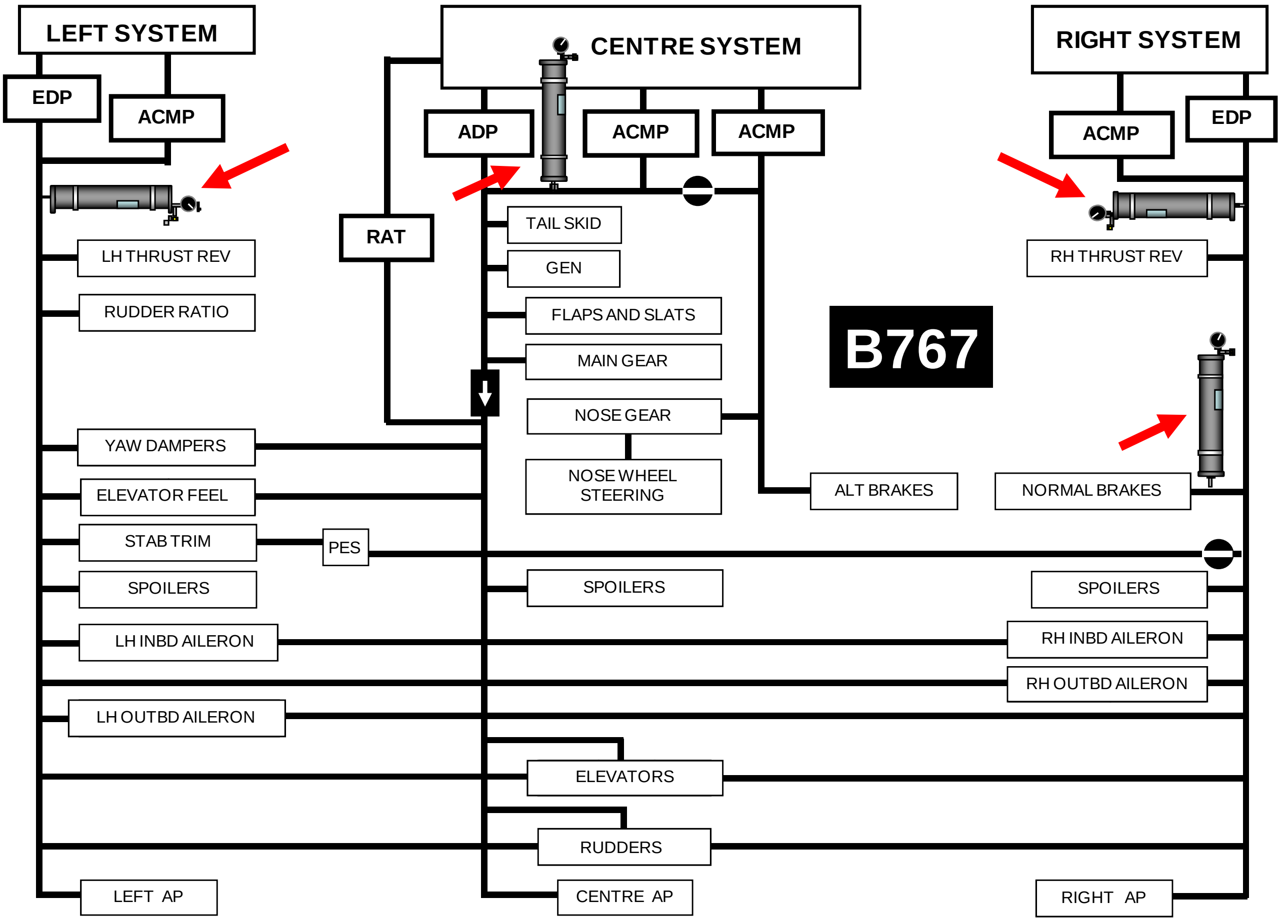


Figure 3-17 Typical locations of Accumulators

FILTERS

The importance of clean hydraulic fluid can be understood when it is known that clearances within some hydraulic pumps and actuators are measured in millionths of an inch. With such close tolerances a very minute particle could interfere with proper operation. The hydraulic fluid holds in suspension tiny particles of metal that are deposited during the normal wear of selector valves, pumps, actuators, etc. Such minute particles of metal may injure the units and parts through which they pass if they are not removed by a filter.

The filter is a screening, or straining device, used to clean the hydraulic fluid and prevent foreign particles and contaminating substances from remaining in the system and there are generally three levels of filtration within a hydraulic system.

Firstly a filter is often included in the reservoir at the fill point to catch particles that may be introduced during replenishment.

Secondly, large "system" filters are placed downstream of the pump(s) to filter the fluid before entering the system and/or in the return line from the system before entering the reservoir. These filters are normally micronic elements made of fibrous material. Because they are the system filters they incorporate a bypass function that allows fluid to flow around the filter should it become blocked. This still allows the pump to power the system.

When a filter is located downstream of the pump(s) it is known as a High Pressure (HP) filter. Conversely, a filter placed in the return line to the reservoir is referred to as a Low Pressure (LP) filter. Actuation of the bypass function in the filter may cause a caution light in the flight station to come on, and a red "pop-up" indicator on the filter body to be displayed. If this occurs the system must be checked for serviceability before flight. Refer to Figure 3-18.

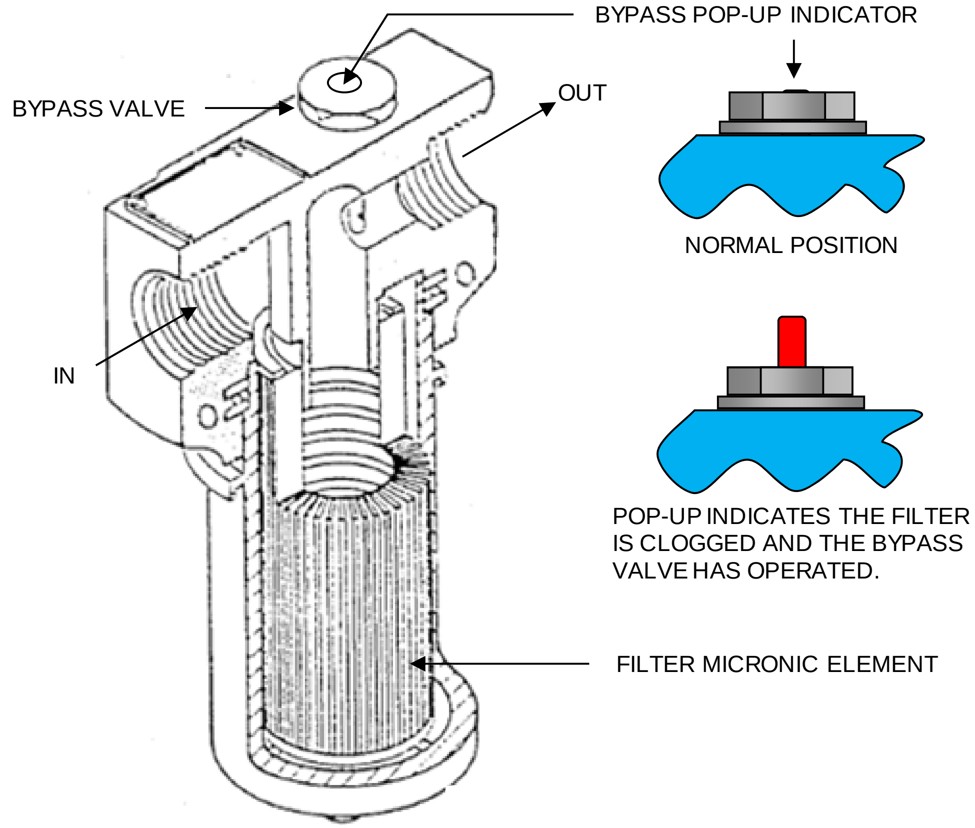


Figure 3-18 System Filter

Lastly, sintered metal, or a stack of disks placed very close together form extremely fine filters that are placed inside individual hydraulic components such as flight control actuators to protect them from damage.

HYDRAULIC OIL COOLERS

Hydraulic oil becomes very hot during normal system operation and must be cooled to maintain the desired fluid properties discussed earlier. The common method used is to pass the return hydraulic oil through heat exchangers located in the aircraft fuel tanks. To ensure adequate cooling some aircraft will have a stated minimum amount of fuel that is required in specific fuel tanks for hydraulic cooling.

Hydraulic systems in large aircraft will have a warning to the crew if the hydraulic fluid is overheated.

SYSTEM SENSING DEVICES

Located throughout the hydraulic system are sensors to monitor the system operation and send the information to readouts and alerts in the cockpit, and to any controlling computers. A typical hydraulic system is monitored for fluid quantity, fluid temperature and system pressure. The individual sensors, locations, operation and subsequent indications of these devices will be discussed in HYDRAULIC INDICATIONS AND WARNINGS on following pages.

HYDRAULIC VALVES

A modern hydraulic system contains many “valves” designed to perform specific functions during normal flight operation and these are discussed in the following pages.

Some of the valves are basically the same but when used in certain applications have different names. Many of the valves work autonomously without commands from computer or crew whilst others are controllable.

Lastly there are valves that are only used for conducting maintenance on the hydraulic system and are not used during normal flight operations. The following are the valves that will be discussed;

- Check and Orifice Check Valves and Restrictors,
- Pressure, Thermal and Load Relief Valves,
- Pressure Reducing Valves,
- Hydraulic Fuse Valves,
- Shuttle Valves,
- Sequence Valves,
- Priority Valves,
- Shut-off Valves,
- Automatic Cut-out Valves (pressure regulators),
- Quick Disconnect Valves, and
- Control or Selector Valves.

CHECK VALVES

The term ‘check valve’ is the common term applied to the Non-return Valve which allows the flow of fluid in one direction but not in the other. This valve is frequently used within hydraulic systems to stop reverse flow through failed pumps and to trap pressure when park brakes are applied. They are a simple valve typically located in a line of piping and sometimes referred to as an “in-line” check valve. Refer to Figure 3-19.

Many of the actuating devices and selector valves used in a hydraulic system have “integral” check valves fitted internally to prevent leakage back through the valve. They work in exactly the same way as the in-line type check valves.

A variation of the common Check valve is the Orifice Check Valve which is typically used in the landing gear hydraulic lines.

An orifice check valve is designed to provide free flow of hydraulic fluid in one direction and restricted flow in the opposite direction. Refer to Figure 3-19. One of the most common applications of this device is in the "UP" line of a landing-gear system. Since the undercarriage is usually quite heavy, it will tend to fall rapidly upon lowering, unless some means of restricting its movement is used. Since the "UP" line is the return line for hydraulic fluid, any restriction in this line will limit the movement of the gear.

Thus, the gear movement must await the flow of the return fluid as it moves towards the down position. When used in this application, the valve must be adjustable to allow the extension rate of the landing gear to be controlled. This is accomplished by an adjustable screw and locking nut which adjusts the size of the drilled passage, thus allowing more or less fluid to pass, thereby allowing the rate at which the fluid returns to the reservoir.

An orifice check valve is also used in some flap control systems. Because of the air pressure on the flaps during flight, there is a continuous force tending to raise the flaps to a streamline position.

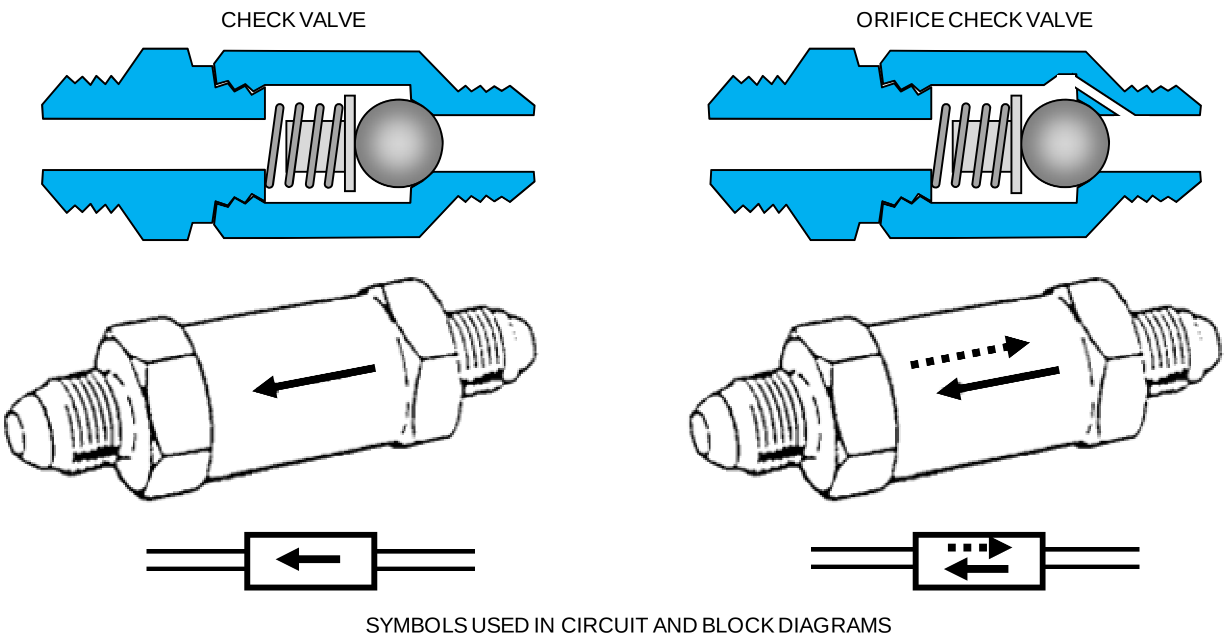


Figure 3-19 Non-return (check) Valves

RESTRICTORS

At any time the normal flow rate of fluid has to be slowed an in-line restrictor may be used. Using a smaller diameter orifice the restrictor will restrict flow equally in both directions.

RELIEF VALVES

Relief valves are used within hydraulic systems to relieve forces when they become excessive and risk damaging hydraulic lines, hydraulic seals, components and structures. Detailed below are three examples of specific relief valves.

Pressure Relief valves are often referred to as system safety valves. Their purpose in the hydraulic system is to prevent excessive pressure developed by the pump from damaging the system. They are usually installed in the system after the pressure regulator. There are numerous types of pressure relief valves, the more common type being the ball type. Refer to Figure 2-20.

When system pressure becomes excessively high, the pressure overcomes the spring tension and allows fluid to flow to the return port. A pressure adjusting screw is provided on top of the spring to adjust the crack pressure of the unit. The return fluid is returned to the reservoir via the normal system return line.

Thermal Relief valves are similar to a normal relief valve. However, thermal relief valves are installed in parts of the hydraulic system where fluid pressure is trapped and may need to be relieved because of the increase of pressure caused by higher temperatures. During flight it is quite likely that fluid in many of the hydraulic lines will be at a low temperature. When the aircraft lands, this cold fluid will be trapped in the undercarriage lines, flap lines and other parts of the systems because selector valves are in a closed position.

These lines are called the static lines of the system. The fluid temperature increases due to warm air on the ground and results in fluid expansion, which could cause damage unless thermal relief valves are fitted. Thermal relief valves are adjusted to operate above normal system pressure and hence they do not interfere with normal operation.

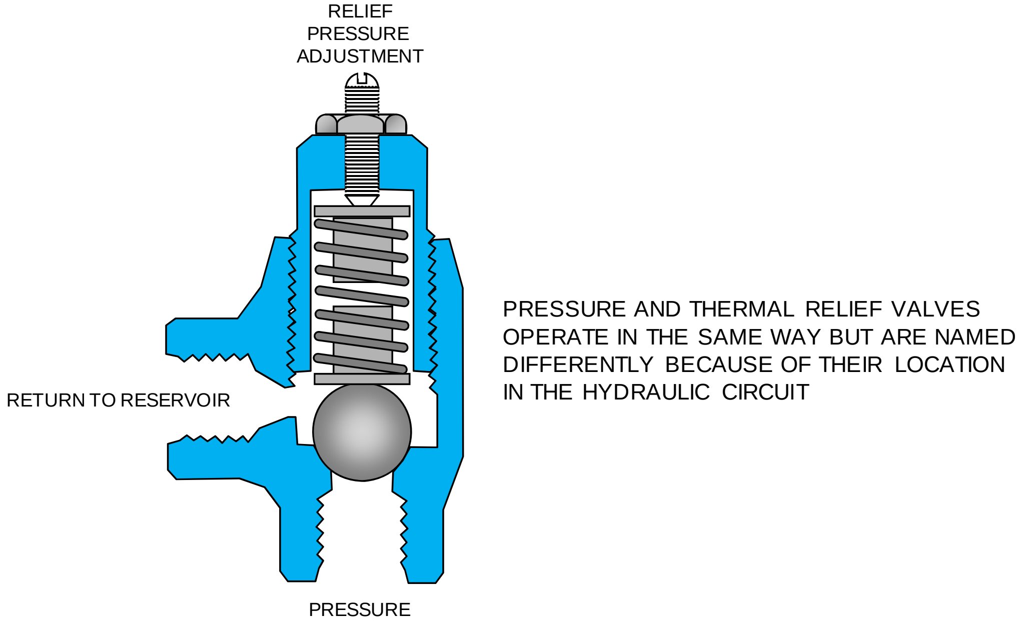


Figure 3-20 Pressure or Thermal Relief Valve

Load Relief valves are specifically designed to relieve excessive load on a hydraulically actuated structures such as flaps. Flaps on large commercial aircraft are normally Fowler flaps with multiple flap sections and when extended to the fully down position are under great pressure from the airflow at higher airspeeds. Although flap position maximum airspeed limits are known by pilots there are occasions when the load relief valve will operate to relieve excessive load on the flaps.

Flap load relief is typically only available for the last two flap selections towards fully extended. The load relief valve will not allow flaps to be extended if the airspeed is above the maximum limit for the position selected. The flap handle can be selected but the flaps will not extend and an alert or caution light (FLAP LOAD RELIEF) will illuminate. When airspeed decreases below the limit the flaps will begin extending to the selected position.

Additionally, if flaps are already positioned at the landing selection and airspeed increases above the limit, the load relief valve will operate and retract the flaps to the next position towards up. The flap handle will remain at the landing position and the alert will illuminate as before. When airspeed decreases below the limit the flaps will return to the selected position. Load relief valves are actuated by sensing airspeed, not actual load force on the flap panels.

PRESSURE REDUCING VALVES

Some parts of the hydraulic system require a lower pressure than that of the main system to operate effectively. Items such as the auto-pilot servos, and brake units, require only 500 psi or less to operate. Rather than installing a separate pump to supply these items, a pressure reducer can be installed to decrease individual sub-systems pressure. Refer to Figure 3-21.

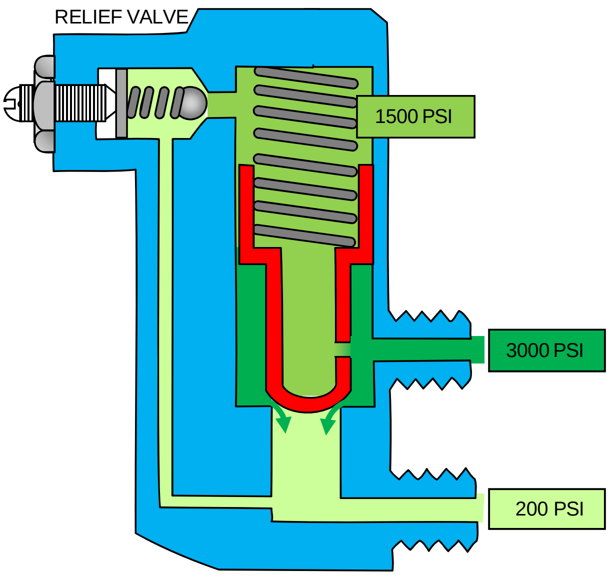


Figure 3-21 Pressure Reducing Valve

HYDRAULIC FUSE VALVE

A device designed to seal off a broken hydraulic line that has occurred downstream from the hydraulic fuse and thus prevent excessive or total loss of fluid. It will permit normal flow in the line; but if the flow increases above an established level, the valve (piston) in the fuse closes the line and prevents further flow.

Hydraulic fuses are normally fitted to protect flexible hydraulic lines exposed to external conditions such as brake lines adjacent to the landing gear wheels.

Maintenance actions are required to reset the hydraulic fuse. Refer to Figure 3-22.

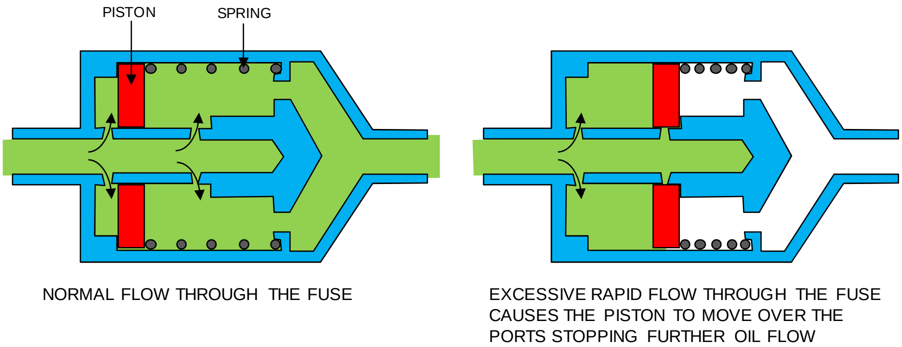


Figure 3-22 Hydraulic Fuse Valve

SHUTTLE VALVES

In hydraulic systems it is necessary to provide alternate or emergency sources of power with which to operate critical parts of the system. This is particularly true of the undercarriage and brakes in the case of hydraulic failure.

Sometimes the undercarriage is operated by an emergency hand pump and sometimes by a volume of compressed air or gas stored in a high pressure air bottle. In either case, it is necessary to have a means of disconnecting the normal source of hydraulic power and connecting the emergency source. This is the function of the shuttle valve. Refer to Figure 3-23.

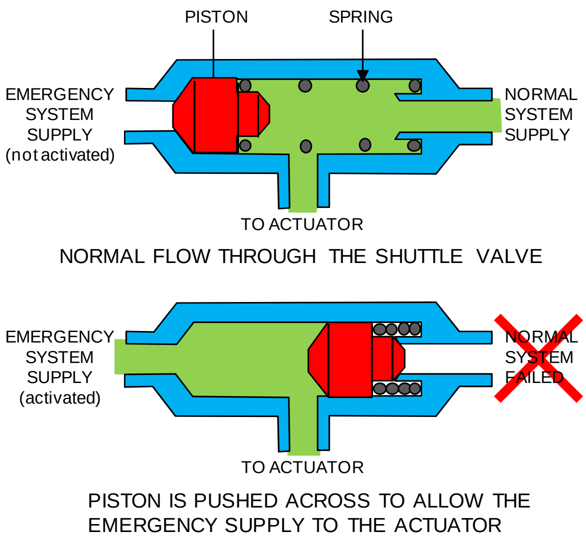


Figure 3-23 Shuttle Valve

SEQUENCE VALVES

Sequence valves are used to control a number of hydraulic actuators in a specific operational sequence.

A common example is the use of this valve in a landing gear system where the doors must be opened before the undercarriage is extended, and the undercarriage must be retracted before the doors are closed. They are sometimes referred to as timing valves.

Sequence valves are operated mechanically by components of the landing gear. Refer to Figure
3-24.

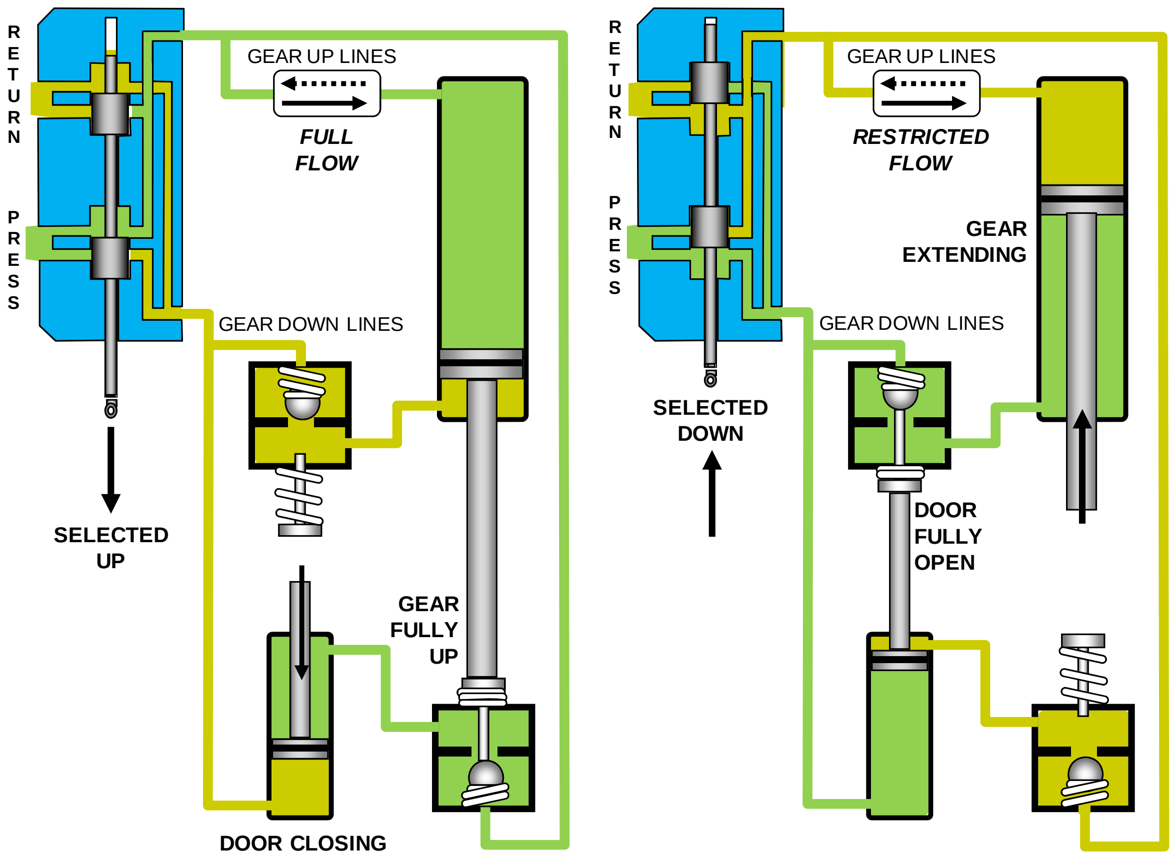


Figure 3-24 Sequence Valve Operation

PRIORITY VALVES

Priority valves are used to give hydraulic priority to certain actuators. They respond to low and high pressures for operation.

They can be used as <u>sequence</u> valves for the landing gear instead of mechanical sequence valves. When used in landing gear applications, they sense that the doors and up-locks require less pressure to operate than the gear itself. Low pressure is allowed to pass by the sequence valve and pressurise the door actuator. When the actuator has bottomed out, the pressure builds up and opens the sequence valve which then diverts pressure through to the landing gear actuator.

Priority Valves are also used by some aircraft to prioritise hydraulic services when system pressure is low. For example, In the event of low hydraulic pressure in Airbus aircraft, a priority valve cuts off hydraulic power to heavy load users (emergency generator, nose wheel steering, landing gear) in order to keep the pressure for normal braking and flight controls. Refer to Figure 3-25.

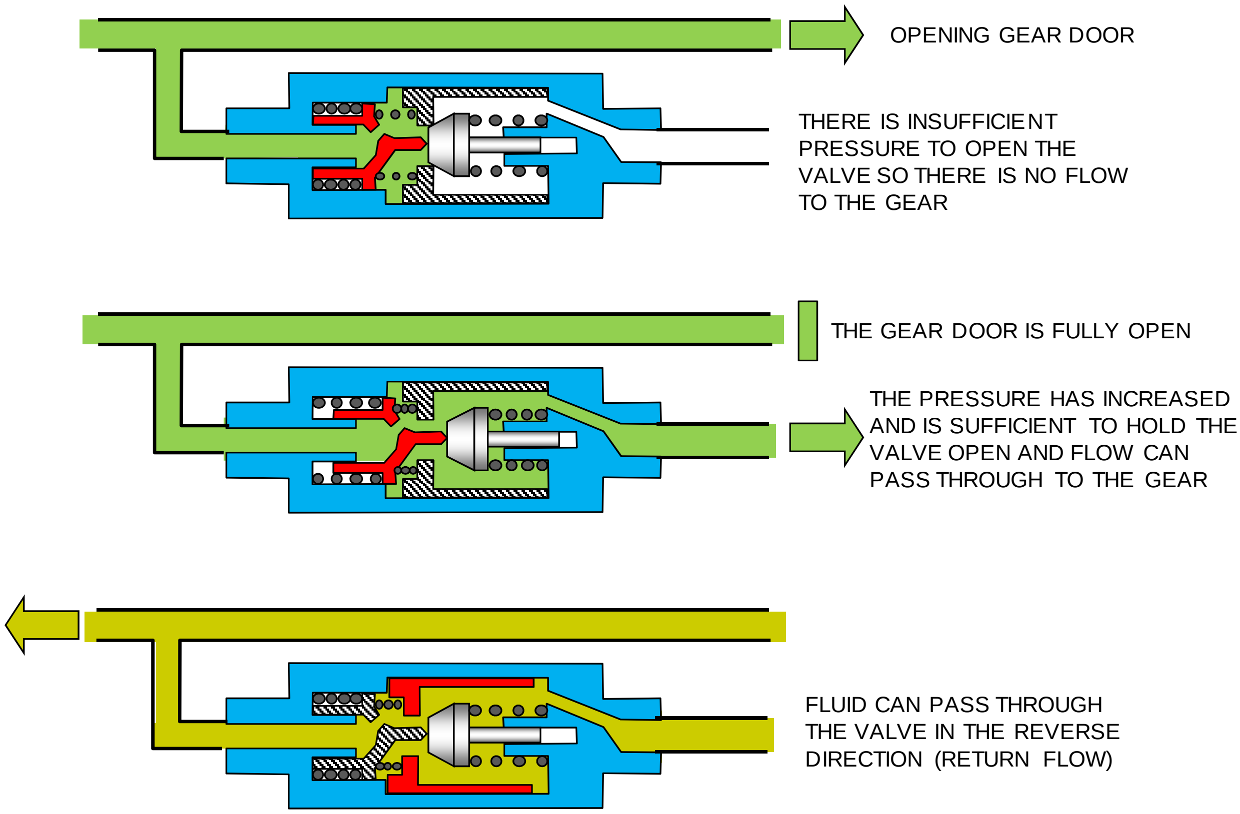


Figure 3-25 Priority Valve Operation

SHUT-OFF VALVES

As the name implies the hydraulic shut-off valve is used to shut-off fluid flow. Valves may be electrically or mechanically operated. There are numerous locations within hydraulic systems where shut-off valves are used by the crew for normal and emergency operation as well as valves specifically for ground maintenance only. One very important shut-off valve relates to engine fires.

As most primary hydraulic pumps are engine driven, a method of isolating the hydraulic fluid from the engine driven pump must be provided in case of a fire developing in the engine nacelle. The shut-off valve, is normally located so that it will allow other pumps in the system, if available, to still operate while isolating the supply to the EDP. The valve is usually controlled by the emergency shutdown switch or fire handle.

The following table lists some of the common applications of hydraulic shut-off valves. Not all hydraulic systems will have all of these applications. Refer to Figure 3-26.

NORMALLY OPERATED BY	CONTROLLED	PURPOSE
Operator	Electrically as a function of the Engine Fire Switch	To shut-off hydraulic supply to the EDP in the case of engine fire
Operator	Electrically by cockpit switch	To shut-off hydraulic pressure to the stabilizer trim hydraulic motor in the case of a runaway stabilizer
Operator	Electrically by cockpit switch	If a leak occurs in the normal system; To shut-off the normal hydraulic supply from the reservoir so that fluid remains for emergency supply
Flap protection system	Electrically by Flap protection system	If the flaps become asymmetric during travel to shut-off hydraulic pressure so that no further travel can take place
Brake system	Electrically by brake anti-skid sensors	During braking the anti-skid system will shut-off brake pressure if a skid is sensed (called an anti-skid valve)
Operator	Electrically or mechanically by cockpit switch or handle	Older aircraft; with a hydraulic system failure the operator may revert to full mechanical control of flight controls. The hydraulic input line is shut-off to prevent the possibility of inadvertent hydraulic inputs
Hydraulic Management Computer	Electrically by system pressure sensors	To shut-off (isolate) some unimportant services if main system pressure becomes dangerously low. When system pressure returns to normal the valve will re-open. Used to prioritise flight controls over other systems. Called a priority valve by Airbus.
Maintenance	Electrically by cockpit switch	To shut-off hydraulic pressure to flight controls whilst maintenance is being conducted for personnel safety
Maintenance	Mechanically by controls in wheel wells	To shut-off hydraulic pressure to landing gear whilst aircraft is on jacks for personnel safety and retraction/extension tests
Maintenance	Electrically by cockpit switch	To shut-off and trap hydraulic pressure to certain systems to measure leak rates
Maintenance	Mechanically by controls in wheel wells	To shut-off hydraulic fluid leaking whilst brake units are changed

Figure 3-26 Common Applications of Shut-off Valves

AUTOMATIC CUT-OUT VALVES (PRESSURE REGULATORS)

Hydraulic systems that use a constant delivery pump will require a means of regulating the system pressure so the output of the pump cannot increase to a value that would cause severe damage to the system. As discussed previously a variable delivery hydraulic pump regulates its own output and therefore does not require a separate pressure regulator.

A typical type of pressure regulator used on older aircraft is the Automatic Cut-Out Valve (ACOV). It performs two functions:-

1. to control and maintain the normal pressure in the system at a pre-determined value, and
2. to relieve the pump of its load when the system is not in use.

Briefly, as pressure is building up in the system, the force on the piston will be less than the combined force of the piston spring and the force acting to seal the check valve. Therefore the fluid will flow around the by-pass line thus building up system pressure. When pressure has built up to working level, a means must be found to divert the output of the pump back to the reservoir. This is achieved as the pump output increases sufficiently to overcome the spring and push the piston upward. The piston rod displaces the check valve which opens the port to allow pump output to return to the reservoir via the return line. Refer to Figure 3-27.

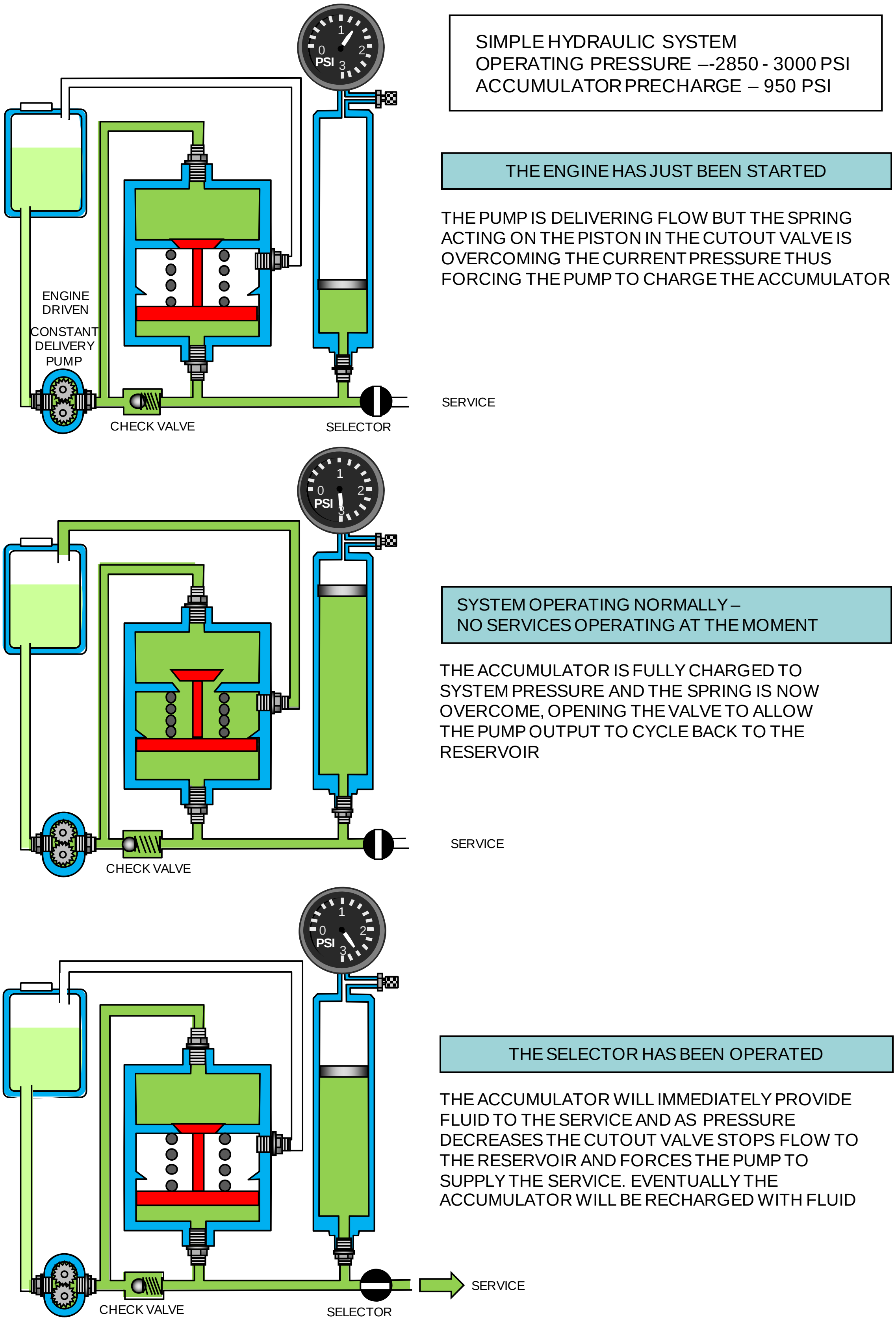


Figure 3-27 Automatic Cut-out Valve

QUICK DISCONNECT VALVES

Modern hydraulic systems are fully sealed to prevent contamination of the oil and the introduction of air into the system.

Most large hydraulic systems will incorporate quick disconnect couplings so that hydraulic lines can be separated for maintenance purposes without losing hydraulic fluid. This is necessary for the removal of major components such as the engines where the EDP (remaining with the engine) will have to be disconnected from the aircraft hydraulic system.

Additionally, to enable the system to be replenished without opening the reservoir, quick disconnect couplings are fitted to allow an external filling cart to be connected. Refer to Figure 3-28.

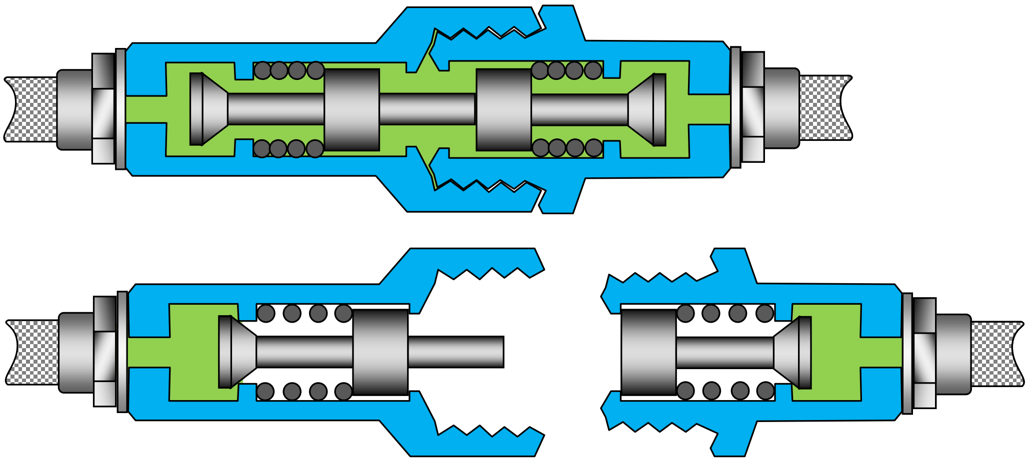


Figure 3-28 Quick Disconnect Valves (coupling)

CONTROL OR SELECTOR VALVES

Control or Selector valves are used to control the direction of movement of hydraulic powered actuating units. A selector valve provides a path for the simultaneous flow of hydraulic fluid in to and out of a hydraulic actuating cylinder. The simplest type of valve is merely an on-off valve to open or close a passage.

However, more usually the actuating cylinder is required to reverse operation. In such cases it is necessary to incorporate a four-way valve which permits fluid flow in either direction. Selector valves generally are rotary or piston (inline) type and may be controlled mechanically or electrically. Refer to Figure 3-29.

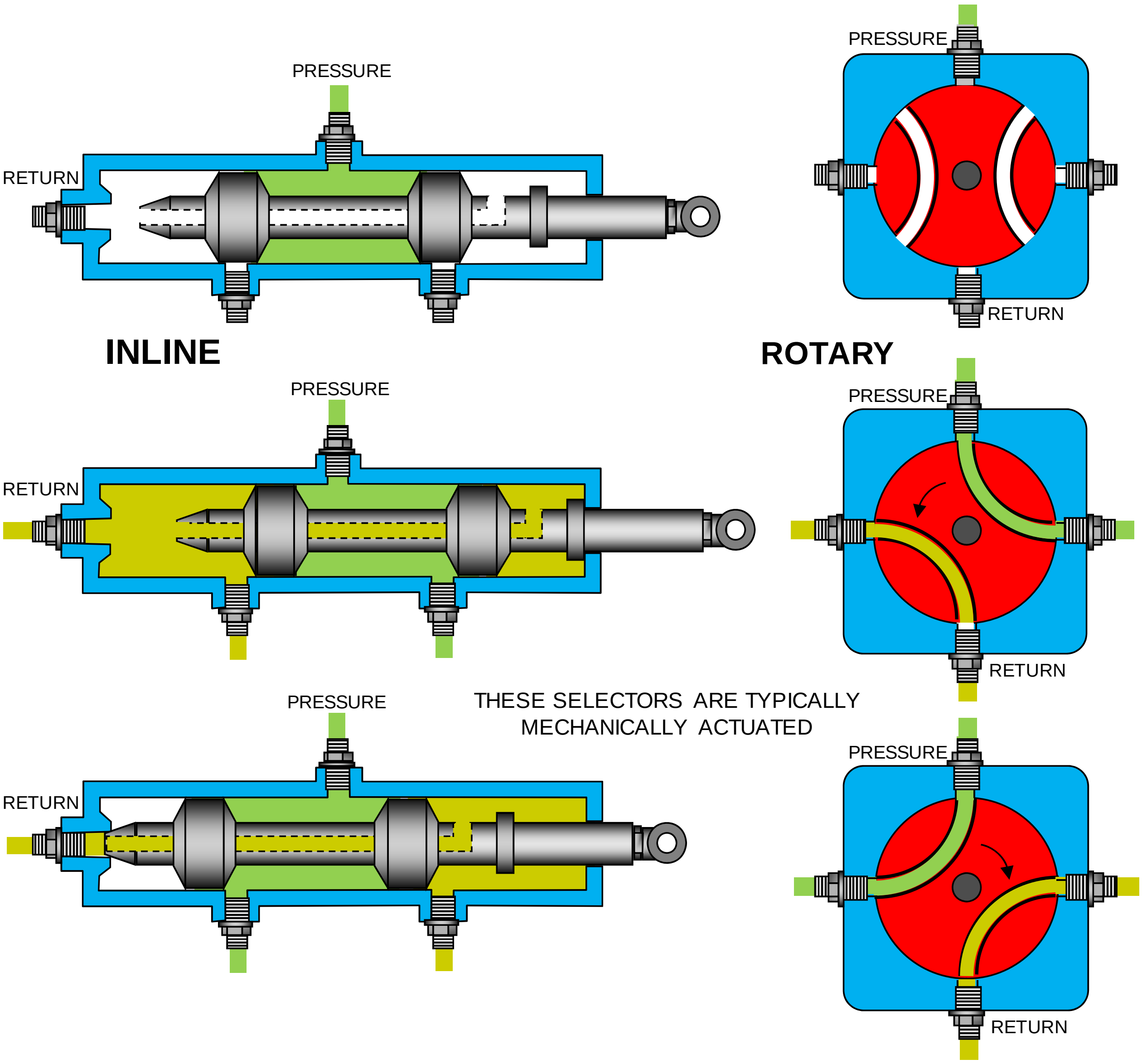


Figure 3-29 Inline and Rotary Selector Valves

Rotary Selector valves are normally operated mechanically and may have an 'open' or 'closed' centre. The choice of mechanical or electrical actuation depends on factors including the size and simplicity of the aircraft, whether the selector is operating a vital or emergency service and thus remains independent of electrical system failure and weight. Refer to Figure 3-30 and the discussion of OPEN and CLOSED centre hydraulic systems on Page 44.

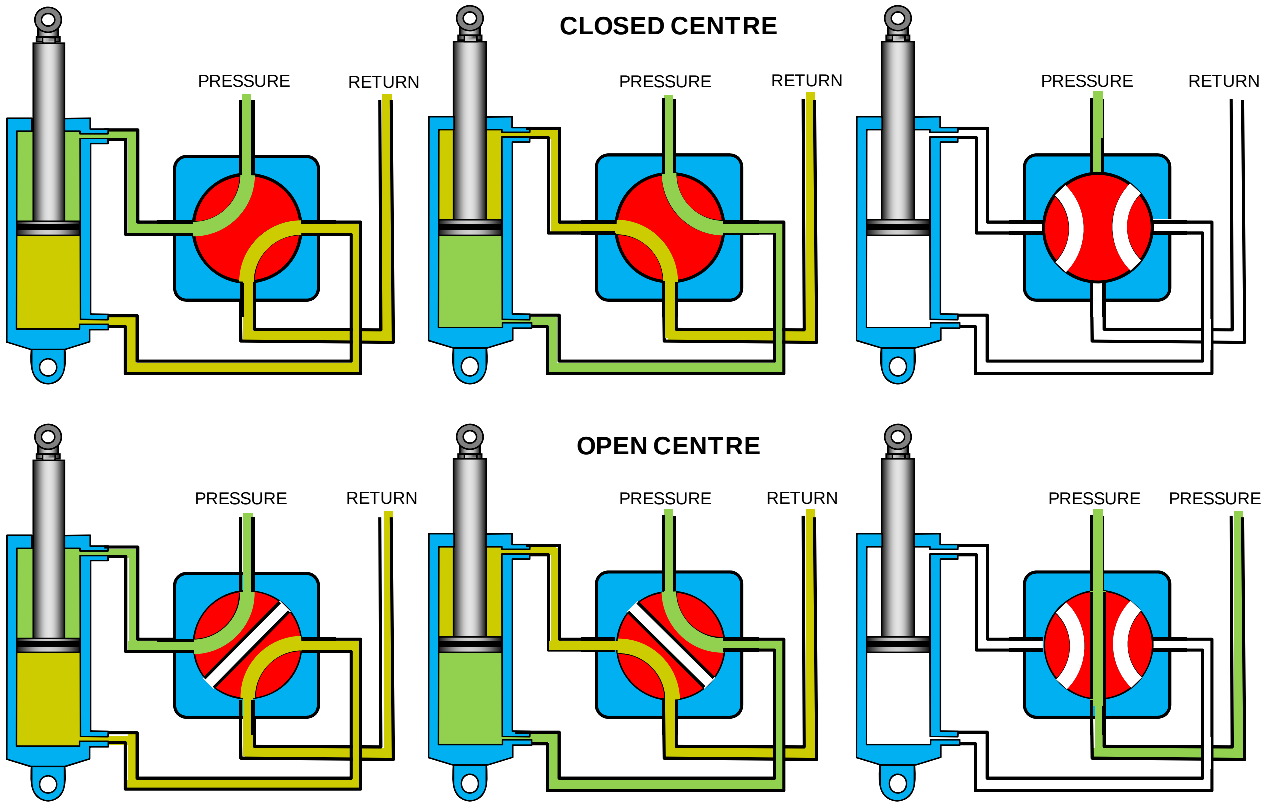


Figure 3-30 Open and Closed Centre Selector Valves

Piston (inline) Selector valves are normally operated mechanically in their simple form as illustrated in Figure 3-29.

Electro-hydraulic Selector Valves Selector valves in modern aircraft are typically electrically actuated by solenoids.

The solenoids, one at each end of the piston valve, become small electromagnets when energised attracting the valve in the required direction to port fluid to and from the actuator.

Depending on the type of service being operated, some solenoids will be deactivated when the service has reached the desired position even though the switch in the cockpit remains selected. For example gear up and down.

In some applications of this valve the solenoid/piston operation may be operated by hand at the selector valve if the power supply fails. Refer to Figure 3-31.

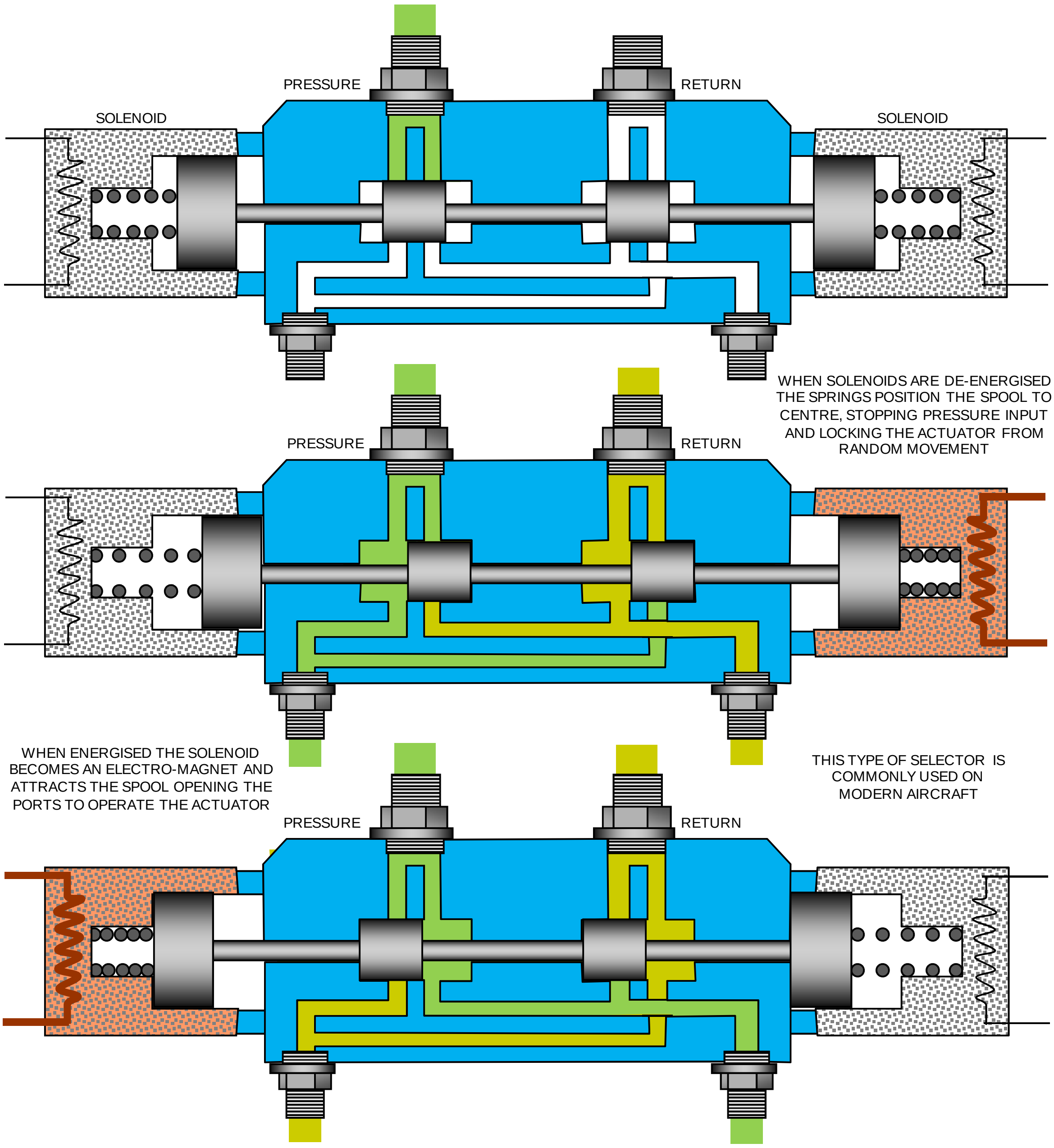


Figure 3-31 Solenoid Operated Selector Valve

HYDRAULIC ACTUATORS

The actuator is the device that converts the force produced by the fluid pressure into useful mechanical operation of the services. Hydraulic actuators can produce mechanical force in both a linear and a rotary motion. The most common and powerful is the linear type actuator, sometimes referred to as a hydraulic jack, which uses a piston and ram combination to produce mechanical force. There are various types of linear actuators which are used for different applications. Refer to Figure 3-32.

Double Acting actuators provide force in both directions and are controlled by four-way selector valves. They are typically used to operate landing gears.

Single Acting actuators operated hydraulically in only one direction and are spring loaded to return in the opposite direction. They only require a simple selector for operation and are commonly used for brake application. Modern large aircraft sometimes use single acting actuators for spoilers and gear bogie positioning.

Non-Compensated (double acting) actuators produce a greater mechanical force in one direction due to the piston having a greater surface area on the side without the ram. They are suitable for use where a larger force is needed in one direction such as lifting the landing gear.

Compensated (double acting) actuators produce an equal mechanical force in both directions as the surface area on each side is equal due to the addition of another matching ram. The additional ram does nothing but equal the surface area of the piston. Compensated actuators are primarily used for flight controls and nose wheel steering on smaller aircraft.

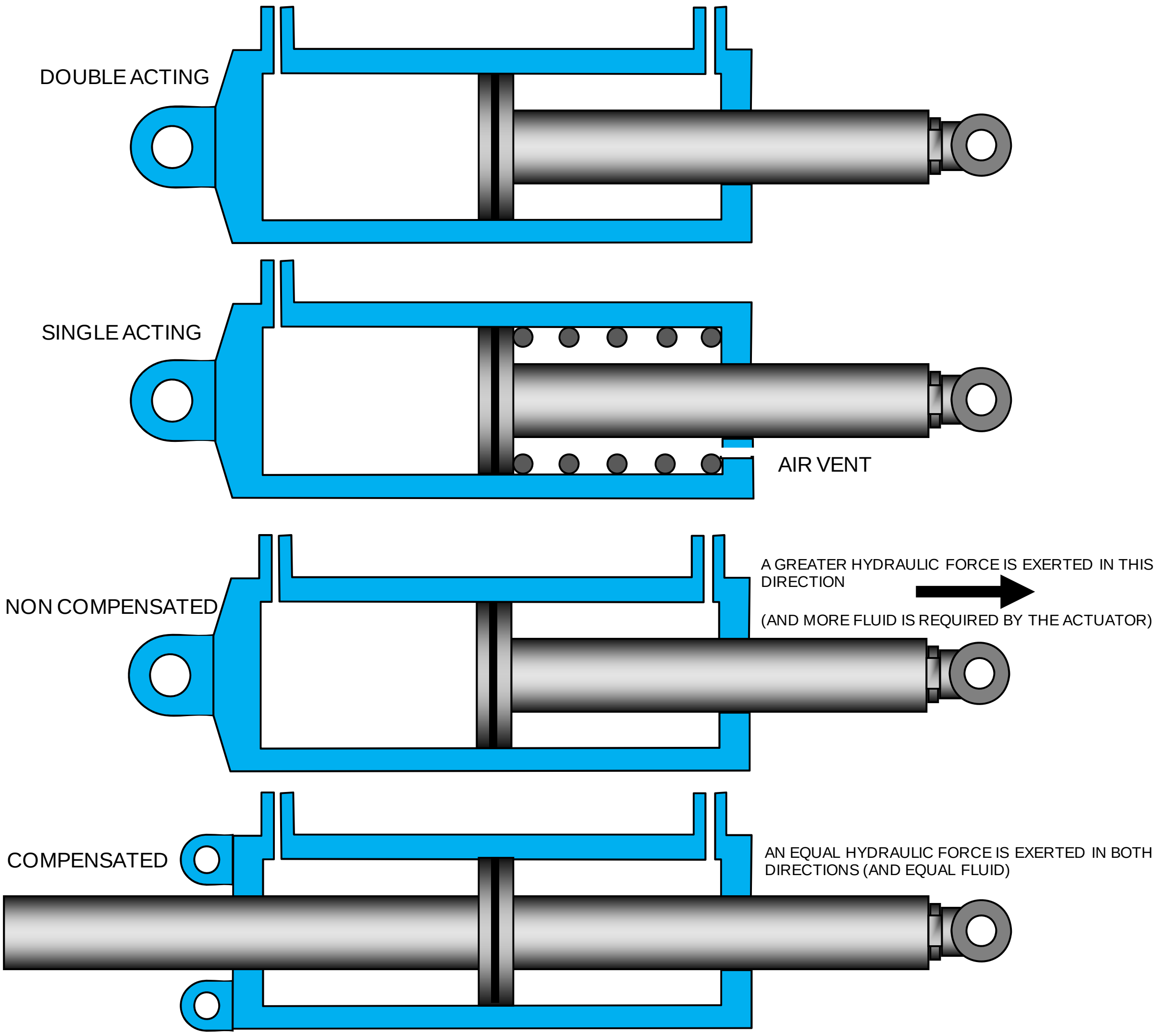


Figure 3-32 Types of Actuators

Tandem Actuator is a term used to describe an actuator (normally flight control) that operates using two hydraulic systems simultaneously. Constructed as one assembly the single actuating ram has two pistons, each one being operated by a different system via a single eight-way selector valve. The advantage of a tandem actuator is that it will continue to operate with a loss of one hydraulic system. Shown in Figure 3-33 is a double acting, compensated, tandem actuator.

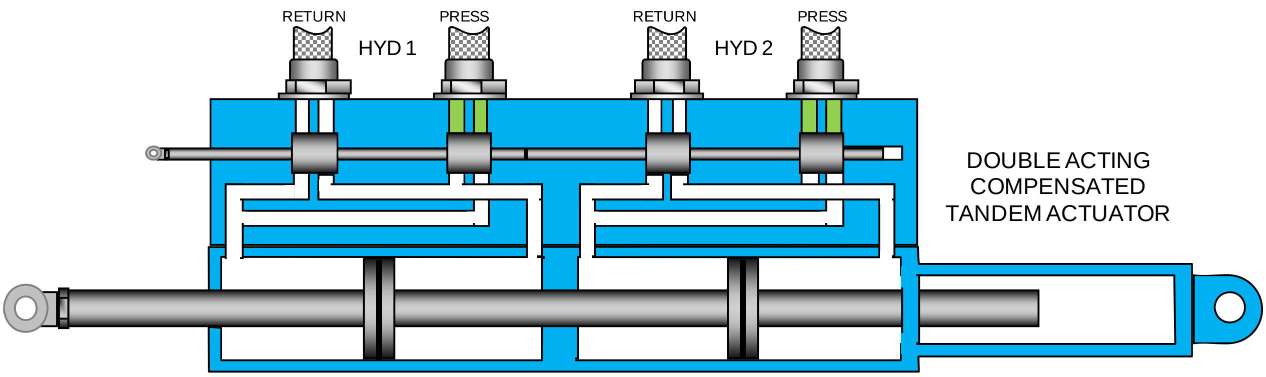


Figure 3-33 Tandem Actuator

HYDRAULIC MOTORS

The rotary motion actuator is commonly referred to as a hydraulic motor and is basically a constant delivery hydraulic pump working in reverse. By adding a reduction gearbox to the motor the required mechanical advantage can be achieved to operate services such as leading and trailing edge flaps. Refer to Figure 3-34.

It is common practice to position two hydraulic motors driving the one gearbox, each motor being supplied by a different hydraulic system.

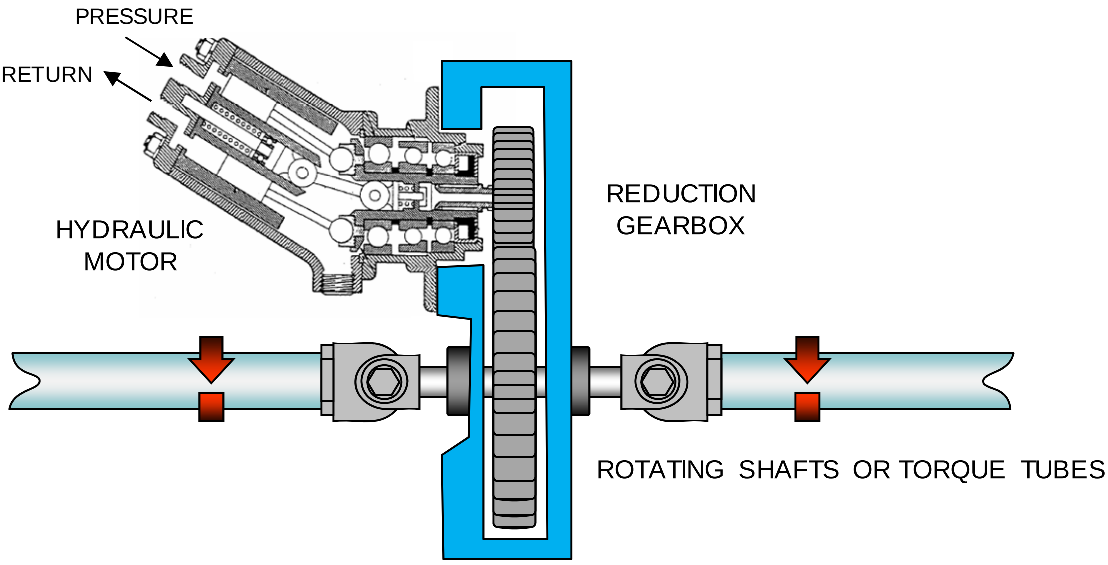


Figure 3-34 Hydraulic Motor

From the hydraulic motor assembly, rotating shafts called torque tubes extend outward within the wings to smaller gearboxes positioned for each flap panel. The smaller gearboxes drive screw jacks or bellcrank assemblies to move the flaps or leading edges. This method of operation ensures that all flap panels move equally and simultaneously. Refer to Figure 3-35.

In some aircraft the hydraulic motors are used to provide a source of rotational power to drive emergency generators and other hydraulic pumps belonging to separate hydraulic systems.

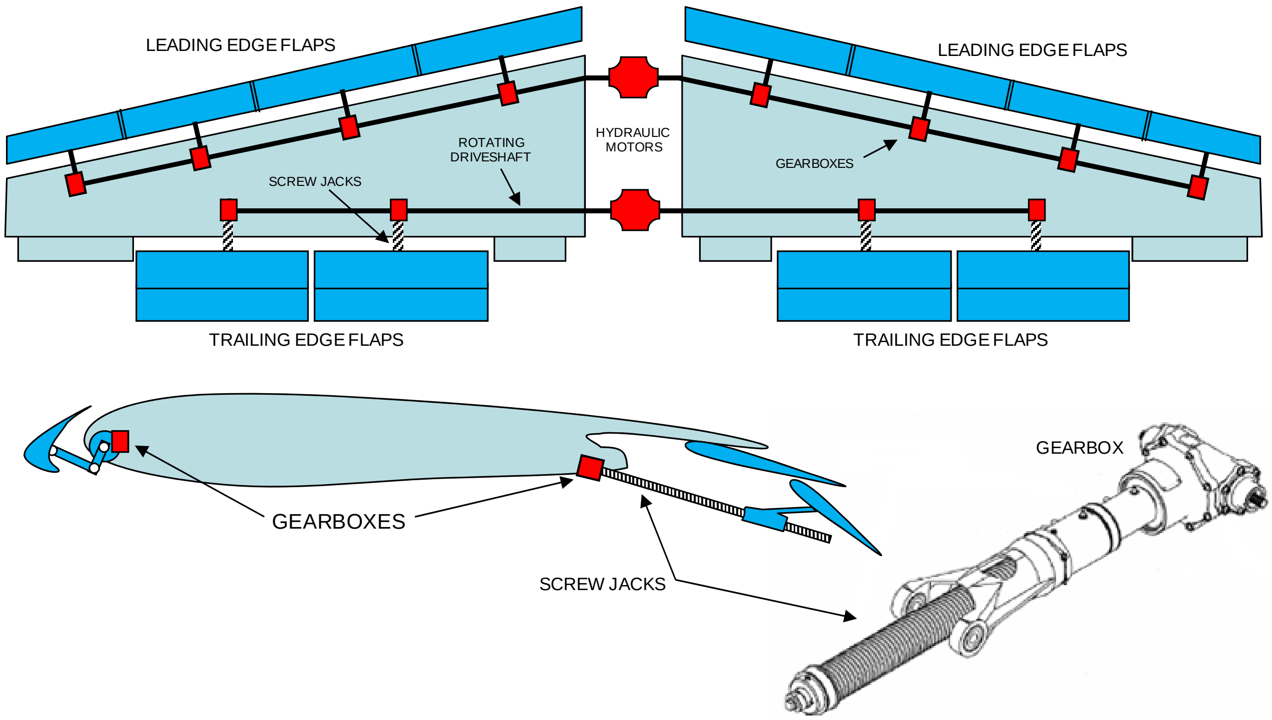


Figure 3-35 Hydraulic Motors and Flap Drives

HYDRAULIC CONTROL FEEDBACK

When hydraulic services are operated that use simple linear actuators such as the landing gear, the final position of the actuator can only be, fully retracted or fully extended. When these positions are reached, electrical micro-switches are normally used to “feedback” the selected position to the cockpit or in some cases the solenoid operated selector valve.

However, hydraulic actuators used for flaps, flight controls and nose wheel steering will need the position feedback to be infinitely variable as they are required to stop and maintain position at any point in the actuator’s travel range.

Control of the actuator at any selected position is accomplished by the selector valve moving to a centralised or “neutral” position, shutting off both supply and return to the actuator. As the fluid cannot flow in either direction, the actuator is effectively locked in the selected position. This is hydraulic control feedback. The positioning of the selector valve to the neutral position may be done in various ways;

Manually by the Operator This form of control feedback would be when the operator holds the selector valve in one direction, observing visually until the actuator or service reaches the desired position, then moving the selector to neutral to hold the desired position hydraulically. An example would be operating a rear cargo ramp/door on a large military aircraft.

Mechanical Feedback to the Selector Valve This feedback situation is typically applied to nose wheel steering operation. When a steering input is made, cables via a "rocker arm" position the selector valve to port fluid to the actuator, turning the nose wheels. The mechanical cable arrangement feeds back the amount of wheel turn to the selector valve via the rocker arm and when the amount of turn is achieved, positions the selector back to neutral. Refer to Figure 3-36.

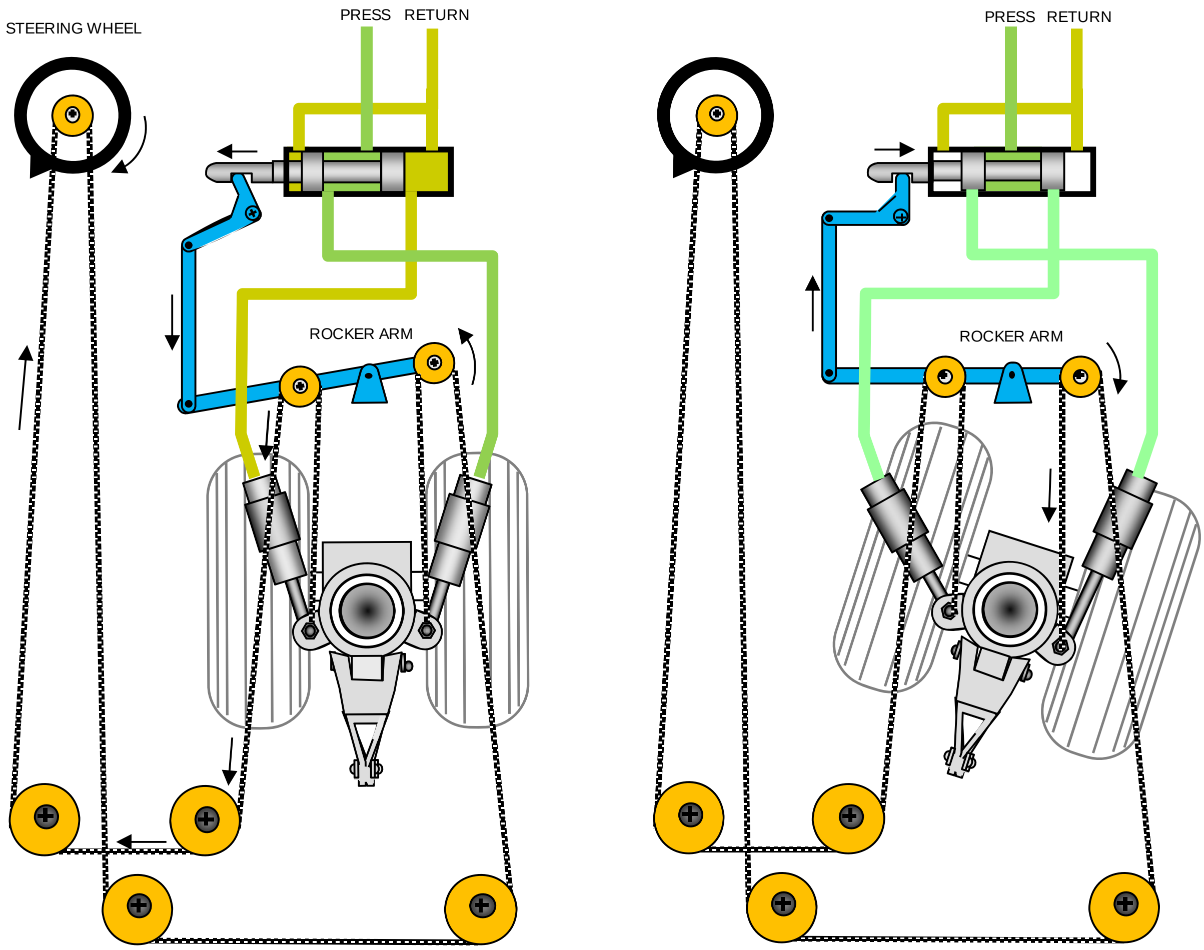


Figure 3-36 Mechanical Feedback to the Selector Valve

Fixed input to a travelling Selector Body Some flight control actuators have their selectors integrated within the body of the actuator. The actuator body is connected to the flight control surface instead of the ram. When a new position (input) is made by the pilot the selector piston ports fluid to drive the actuator. As the actuator/selector body moves the flight control surface, the selector piston (input) which has remained fixed, will eventually cut-off the fluid supply, thus holding the flight control in position. Refer to Figure 3-37.

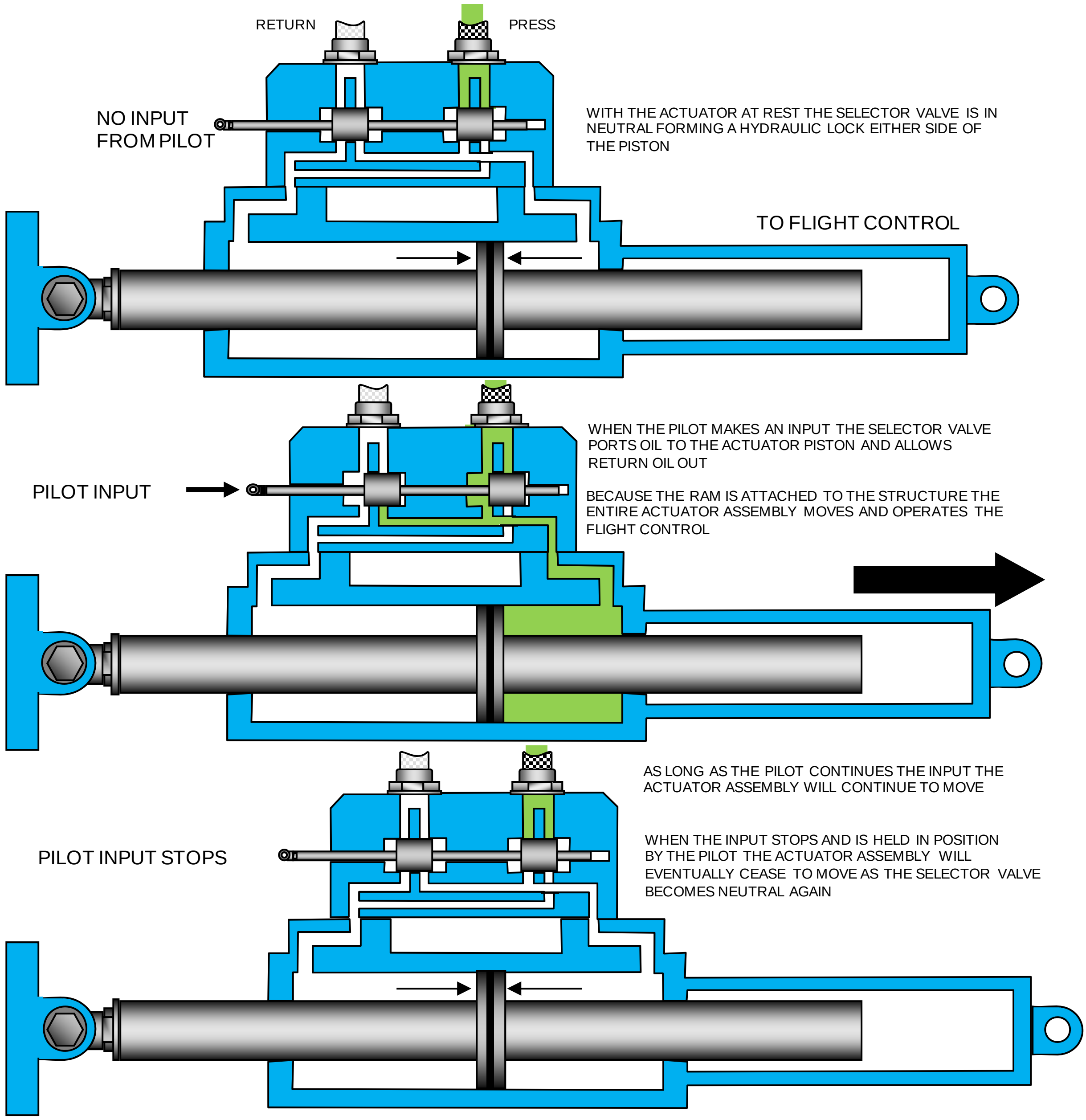


Figure 3-37 Travelling Selector Valve

Electronic Computer Control Most modern large aircraft now use some form of computer control for flight controls. Even when the pilot is flying the aircraft with the autopilot disengaged the computer will ensure that maximum control surface loading and rate of movement is not exceeded by the pilot.

Inputs made by the pilot are measured by potentiometers, assessed by the computer and a command is sent to the selector to drive the actuator. The flight control computer will consider such things as airspeed, g load, degree of pilot input, rate of pilot input, current position of the flight control and other algorithms before issuing commands to the selector. When the flight control has achieved the position that satisfies the input the selector is commanded to neutral.

HYDRAULIC SEALS AND SEALING METHODS

Hydraulic systems and the individual components within depend on a variety of seals to prevent internal and external leakage of fluid.

Internal leakage within components such as actuators, pumps and selector valves drastically reduce the efficiency of their operation. Minor external leakage from pipe joints and components are a sign of loosening connections and may indicate the potential for a major leak to occur in the future. Hydraulic seals are fundamentally of two types being static and dynamic;

Static seals are not subject to movement and are normally placed between two stationary parts of the system or component. They are only required to hold pressure in one direction and are sometimes referred to as “gaskets”. Pipe joints, pipes connecting components to the system and caps are examples of static seals. They may be rubber, aluminium, copper, tungsten or other materials depending on the application. Refer to Figure 3-38.

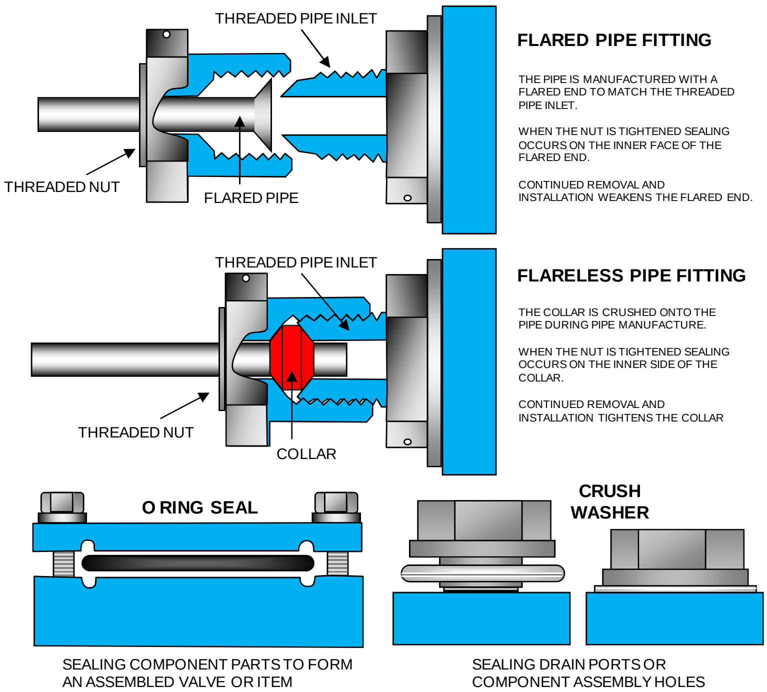


Figure 3-38 Static Seals

Dynamic seals are subject to constant movement, typically piston/cylinder operation, and must prevent leakage of fluid from either direction across the piston. This type of seal may be referred to as "packing". The selection of seal profile and size is important as the seal must not create excessive friction, inhibiting the piston movement.

When dynamic seals are used in applications such as actuator rams, landing gear oleo struts and accumulators the movement may cause the seal to roll and pinch. To prevent this from occurring, teflon back-up seals are used on each side of the actual seal. Refer to Figure 3-39.

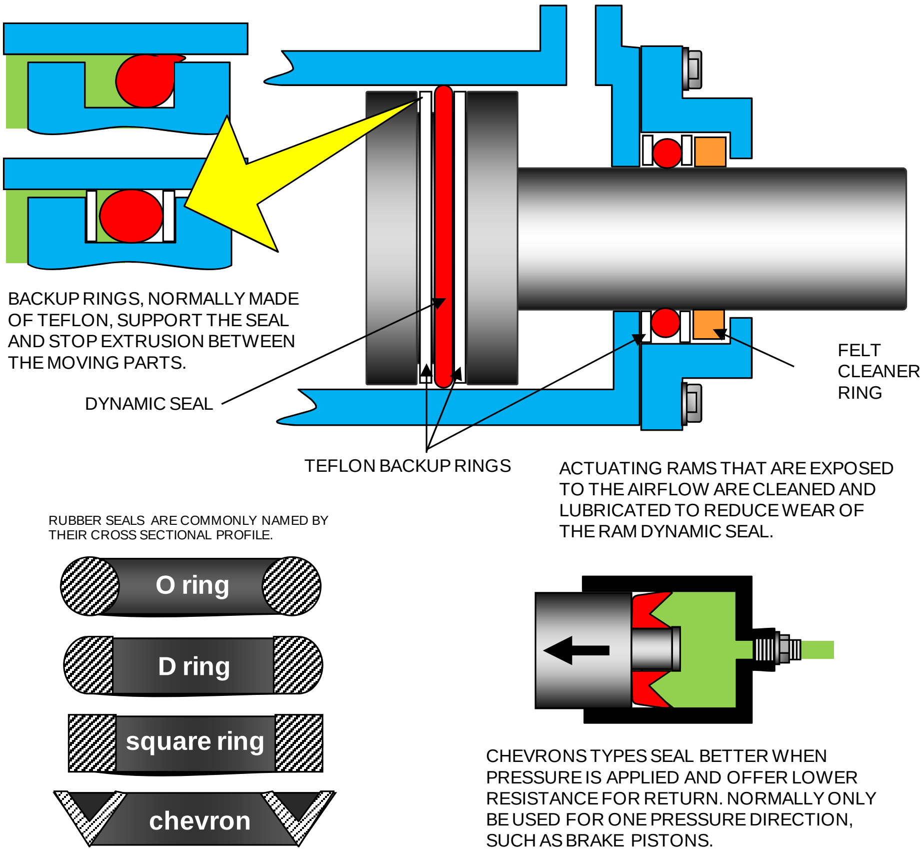


Figure 3-39 Dynamic Seals

The cross sectional profile normally determines the common name applied to different seals. "O" rings and "D" rings are typically used in both static and dynamic applications whereas "chevron" type seals are designed specifically for dynamic operation. Refer to Figure 3-39.

To prevent excessive wear of dynamic seals they must remain lubricated by the hydraulic fluid. Actuator rams and landing gear shock struts are subject to exposure to the elements and this tends to "dry" the rams of any residual hydraulic fluid.

To relubricate the ram prior to passing back into the cylinder and past the dynamic seal an additional felt ring is fitted on the "dry" side of the dynamic seal. This ring, referred to as a "wiper ring" lubricates and cleans the ram as it slides into the actuator body. Refer to Figure 3-39.

Another sealing method used within components of hydraulic systems is the "metal to metal" seal. Primarily found in piston hydraulic pumps and very small selector valves the machined tolerance between the piston and cylinder is so precise that an effective seal is created. Refer to Figure 3-40.

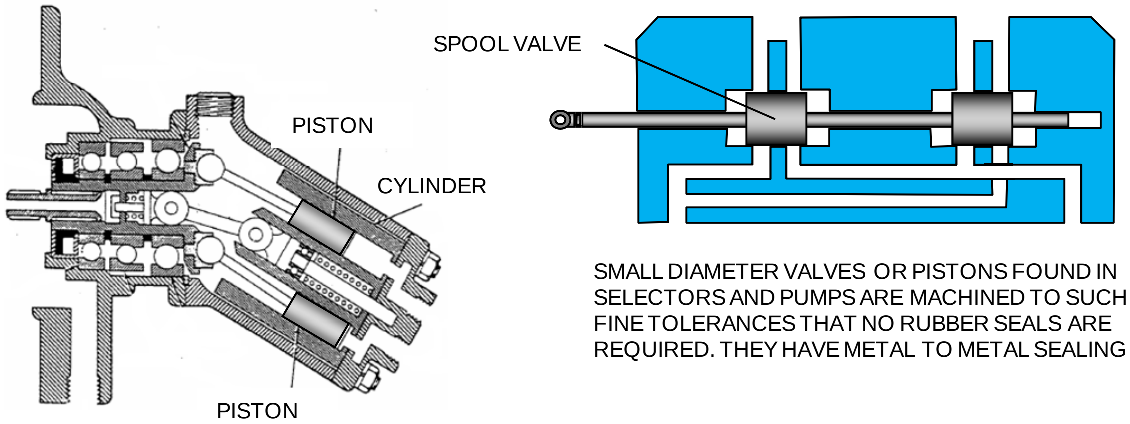


Figure 3-40 Metal to Metal sealing

HYDRAULIC FLUID SAFETY PRECAUTIONS

When external leakage is observed from hydraulic systems extreme care should be taken as a drip or weep may be the precursor to a bigger fracture.

Hydraulic fluid under 3000 psi pressure is extremely dangerous if it escapes from even the tiniest of fractures.

If injected into skin tissue the toxicity is such that amputation of the hand/arm is the typical result. Do not attempt to feel for or fix leakage with systems pressurised.

HYDRAULIC SYSTEM INDICATION AND WARNINGS

HYDRAULIC SYSTEM INDICATIONS

The cockpit indications of a functioning hydraulic system are primarily quantity, temperature and pressure. Depending on the complexity and the technology employed, the hydraulic system(s) will also provide indications to the crew of control/switch status, flap and gear position, flight control and spoiler position and other services operated by the hydraulic system.

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

- the status of reservoir pressurisation
- the current quantity of fluid in the system reservoir,
- a dangerously low level in the system reservoir,
- a dangerously high temperature of the hydraulic fluid in the system or individual pumps,
- the current pressure of the hydraulic system,
- a dangerously low pressure (failure) of the hydraulic system, and
- a dangerously low pressure output (failure) of the individual hydraulic pumps within a system.

Large aircraft normally have a hydraulic control panel in the cockpit. On older generation aircraft it will contain indicators displaying 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 emergency situation.

Modern large aircraft fitted with an ECAM or EICAS will display indications on the display screens leaving only the switches and mimic diagram remaining on the hydraulic control panel. Additionally the ECAM/EICAS synoptics will display real time operation of the components and fluid flows of the system. Refer to Figure 3-42.

NORMAL SYSTEM INDICATIONS

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

Quantity - from the reservoir using a float or capacitance sensor producing an electrical signal for the cockpit gauge or ECAM/EICAS. Reservoirs may also have a local sight gauge (clear window) or direct reading gauge for servicing purposes.

ECAM/EICAS will typically provide a maintenance alert when the normal level is getting low. During high altitude flight and low hydraulic activity the fluid can become very cold which can influence the quantity reading, so the quantity sensing system may be automatically compensated for temperature.

Temperature - from the reservoir using a temperature sensor producing an electrical signal for the cockpit gauge or ECAM/EICAS. Some hydraulic systems also monitor the temperature coming from the case drain line of individual hydraulic pumps within a system.

Pressure - This measures the "system" pressure at the hydraulic manifold downstream of all available pumps (primary and demand). It uses a pressure transmitter to produce an electrical signal for the cockpit gauge or ECAM/EICAS. To help protect the sensitive pressure transmitter but still provide an accurate reading a fluid pressure relay may be used. This device converts the full system pressure down to a lower but accurate representative pressure for the transmitter.

Nitrogen Pressure of Accumulators – Remember that all hydraulic systems have accumulators which are pre-charged with nitrogen.

Direct reading pressure gauges are typically fitted close to the accumulator charging point. <u>Accumulator pre-charge gas pressure can only be checked at the accumulator.</u>

Hydraulic Pressure of the Brake Accumulator – The brake accumulator is primarily used for <u>emergency braking</u> and maintaining pressure for the <u>Park Brake</u> when set.

A gauge or readout in the cockpit will provide the <u>hydraulic pressure</u> available from the Brake Accumulator. The gauge is only applicable for the Brake Accumulator.

Status of Controls and Systems - In older generation large commercial and smaller types of aircraft the operator monitors system(s) operation by checking switch positions, observing gauges and being alert to caution annunciators illuminating. The operator depends heavily on checklists and regular scanning of gauges to maintain an awareness of the system status. The use of colour in older aircraft is normally limited normally to AMBER caution lights when malfunctions occur. Refer to Figure 3-41.

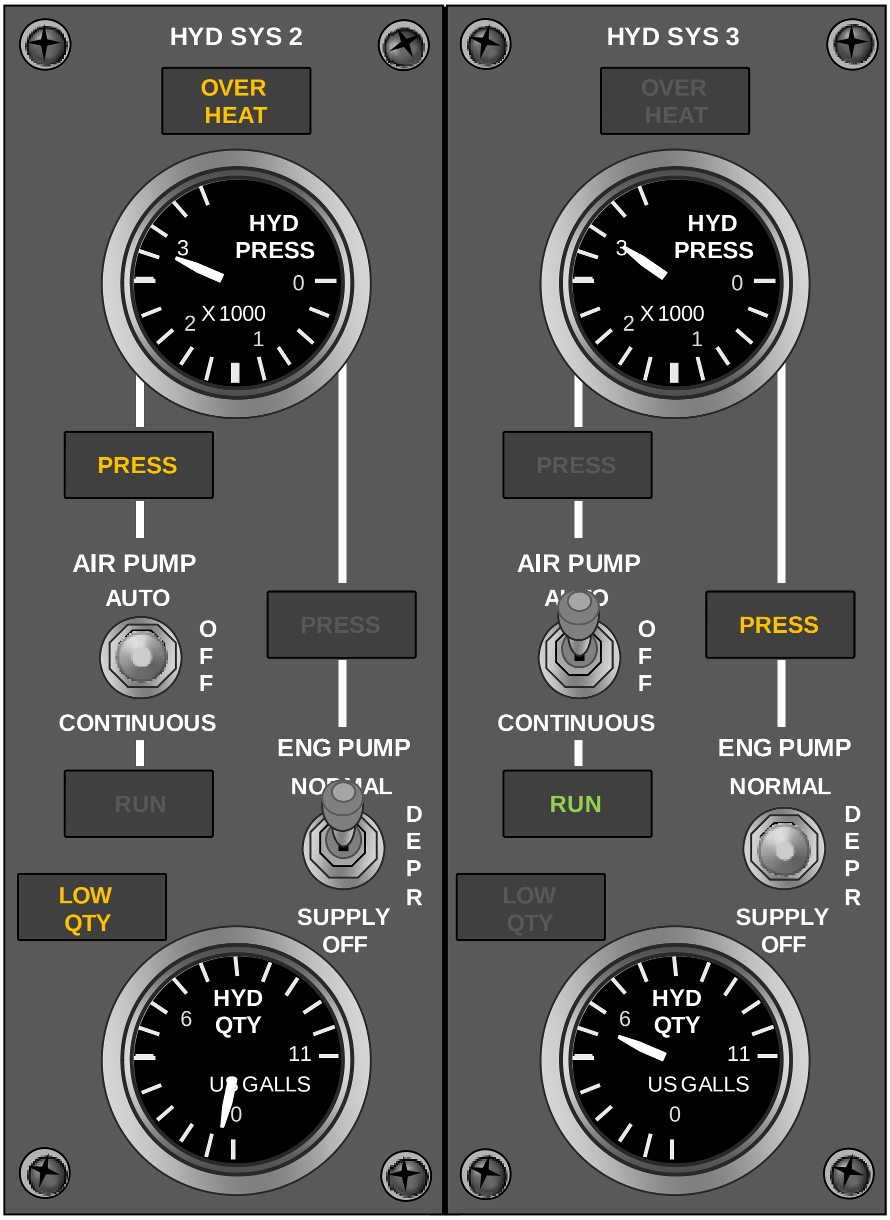


Figure 3-41 Hydraulic Systems 2 and 3 (B747 Classic FE Panel)

In modern large aircraft the hydraulic systems are continuously monitored by computers. The software is programmed to make the operator aware not only of malfunctions but also to provide prompts for correct switching. Additionally, computers can display real time operational status via synoptic presentations. Refer to Figure 3-42.

Synoptic presentations make greater use of colour to indicate the status of components and the system. The following colours are examples of the B747-400 synoptic.

GREEN – Real time hydraulic flows,

WHITE – Normal operation of component,

BLUE – Component selected on but in standby mode, and

AMBER – Component is off when it should be on or it has a fault.

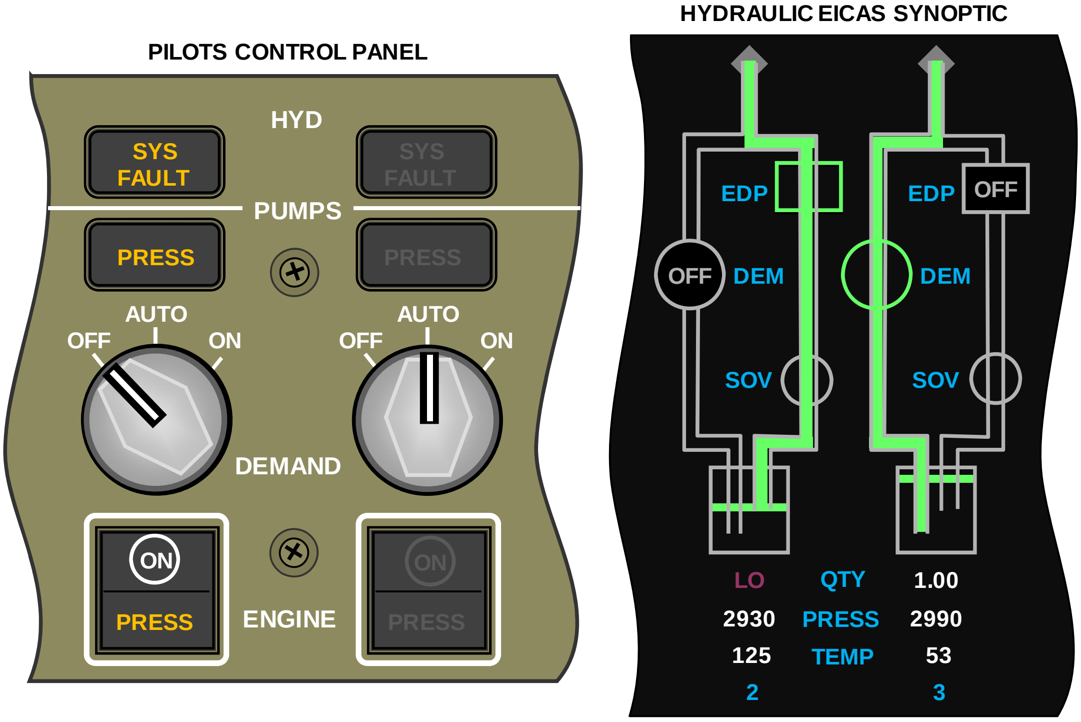


Figure 3-42 Hydraulic Systems 2 and 3 (B747-400 Pilots Panel)

Compare the presentation of controls and indication of identical hydraulic systems in the previous illustrations of the B747 Classic and the B747-400. Refer to Figures 3-41 and 3-42.

ABNORMAL SYSTEM INDICATIONS AND FAILURE

The abnormal or failure cockpit indications are provided by either individual annunciator lights or ECAM/EICAS caution advisories. They will be an AMBER caution light or advisory and will require the crew to take some action immediately. There will be a checklist to follow for these problems. These are remote reading indications and receive their information from sensors located as follows;

Very Low Quantity - from the reservoir typically using a very low level position from the above quantity measuring system. This indicates a severe loss of fluid (probably a leak) and action should be taken to stop further oil loss if possible.

Very High Temperature - normally sensed from the reservoir or the case drain line of individual pumps and/or in the case of electrically driven pumps the electric motor body. The electric motor driving the pump will normally shutdown automatically in the event of overheat and can only be reset after maintenance.

Low Pressure – normally refers to individual pumps within a system. It is normally sensed by a pressure switch immediately downstream of each individual pump within the system. This measures the individual output pressure of each pump and indicates the pump cannot deliver sufficient flow to maintain normal pressure.

Low System Pressure – normally sensed by a pressure switch downstream of ALL pumps within a system. It refers to the total system and would only illuminate if all pumps had failed.

HYDRAULIC SYSTEMS, REDUNDANCY AND ALTERNATE OPERATION

HYDRAULIC SYSTEMS

The term Hydraulic System is relative to the aircraft or equipment to which it applies. It can mean a very simple system as used in light aircraft to operate the flaps to a very complex combination of numerous individual systems found in modern large commercial aircraft.

The design and complexity of hydraulic systems vary from aircraft to aircraft depending on the size and type of aircraft, the manufacturers' philosophy and the requirements for redundancy. An example of this is the European method of identifying multiple hydraulic systems in an aircraft by colour unlike the American method of numbers or position.

Aircraft equipment and services that are operated by hydraulics are very powerful and it is a common preflight practice and good airmanship to check the positions of cockpit controls such as landing gear, flaps and spoilers before turning hydraulic systems on. There have been many occasions in past years where maintenance engineers have suffered serious injury as a result of the hydraulic systems coming on line and suddenly moving flight controls or other services.

Hydraulic systems that use AC Motor Pumps (ACMPs) can be operated at anytime electric power is available, normally from the APU or ground power. Systems that use Engine Driven Pumps (EDPs) will only come on line when engines are started which has the disadvantage of the crew not being aware of any hydraulic associated problems until after engine start and pushback.

From a basic starting point we may define two fundamental types of hydraulic systems being the "open-centre" and "closed-centre" types.

Open-Centre Systems are commonly found on light aircraft. The main advantage of this system is its simplicity, and the main disadvantage is that only one service can be operated at a time. When no services are being operated, the pressure in the system is at a low value, with pump output passing directly to the reservoir.

This system uses selectors that have ***open centres***. Refer to the description of hydraulic selectors. The diagram provided shows the principle of a simple open-centre system. Refer to Figures 3-43 and 3-30.

Closed-Centre Systems are typically used for modern larger aircraft. The advantage of this system is that more than one service can be operated simultaneously. With this type of system, operating pressure is maintained in that part of the system which leads to the selector valves, and some method is used to prevent over-loading the pump. In systems which employ a constant delivery pump, an automatic cut-out valve is fitted, to divert pump output to the reservoir when pressure has built up to normal operating pressure. In systems where a variable displacement pump is used, system pressure is controlled by the pump.

This system uses selectors that have ***closed centres***. Refer to the description of hydraulic selectors. The diagram provided shows the principle of a simple closed-centre system. Refer to Figures 3-43 and 3-30.

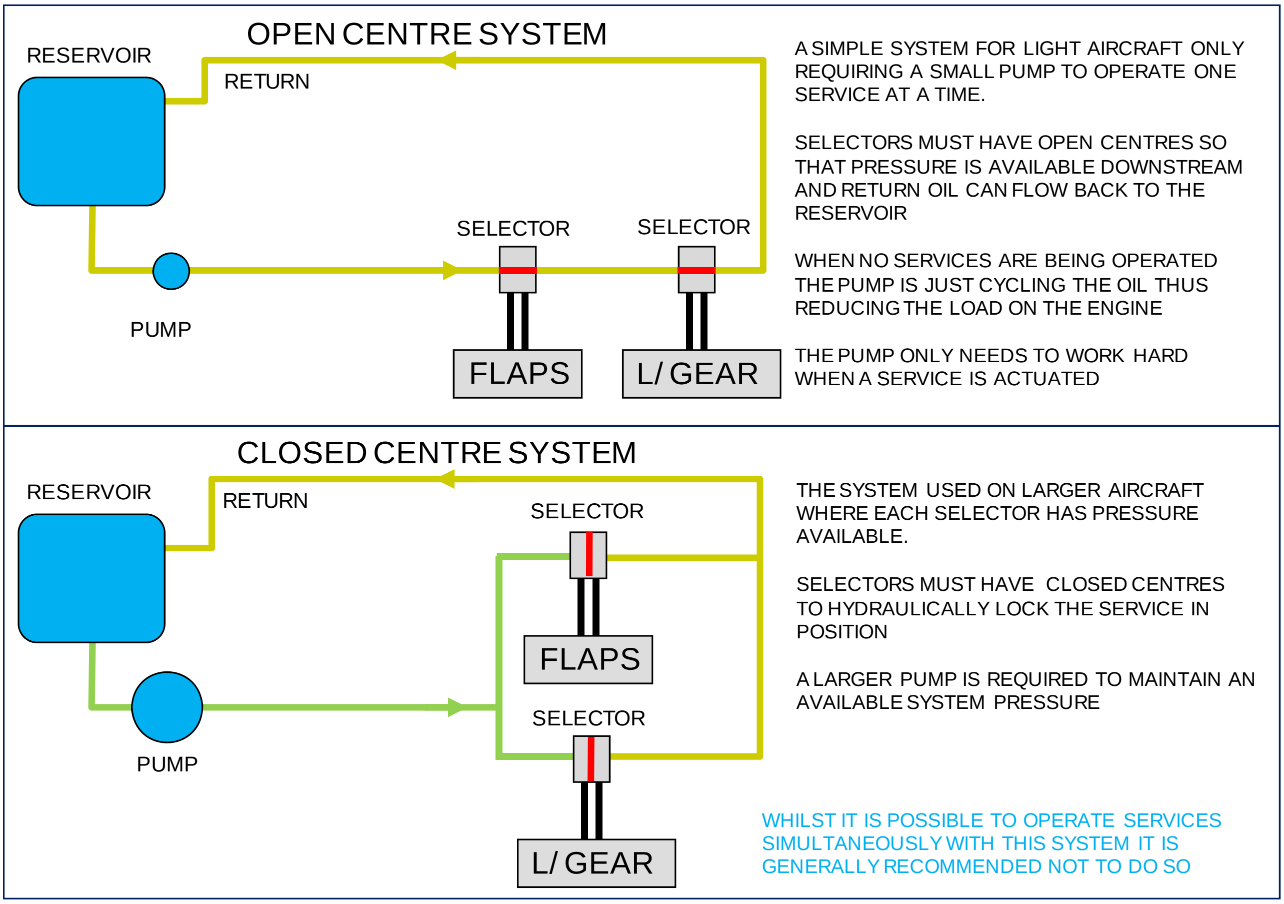


Figure 3-43 Open and Closed Centre Hydraulic Systems

HYDRAULIC PACKS

A hydraulic pack system is one in which most of the major components (with the exception of the actuators, and, with some systems, the pumps), are included in one self-contained unit. The system may operate on either the open-centre or the closed system principle, and is widely used in the light aircraft.

MULTIPLE HYDRAULIC SYSTEMS

As we have seen large aircraft may have up to four main hydraulic systems. Each may be the primary source of hydraulic power for several hydraulically operated systems or devices, and may also be the back-up or standby source for other systems.

Depending on the number of hydraulic backups a device may have, (which is usually dependant on the importance of that device to flight safety), we refer to it as having double or triple redundancy.

Each system is completely separate and a leak or failure in one system will not cause a leak or failure in another system.

Hydraulic systems are increasingly being used to operate most of the services used on a modern large commercial aircraft.

The following systems may use hydraulics as the normal method of operation;

- primary flight controls (ailerons, elevators, rudder, elevons) using two or three systems,
- flight control artificial feel units,
- horizontal stabilizer (stabilizer trim) using two systems,
- rudder ratio,
- leading edge flaps using two systems,
- trailing edge flaps using two systems,
- speed brakes and spoilers using two or three systems,
- pitch and yaw dampers,
- autopilot using two or three systems,
- engine thrust reversers,
- landing gear and tail skids using one or two systems,
- normal and alternate brakes using two systems,
- nose wheel and body gear steering using one or two systems, and
- cargo doors and ramps.

Refer to Figures 3-44 and 3-45 as examples of multiple hydraulic installations.

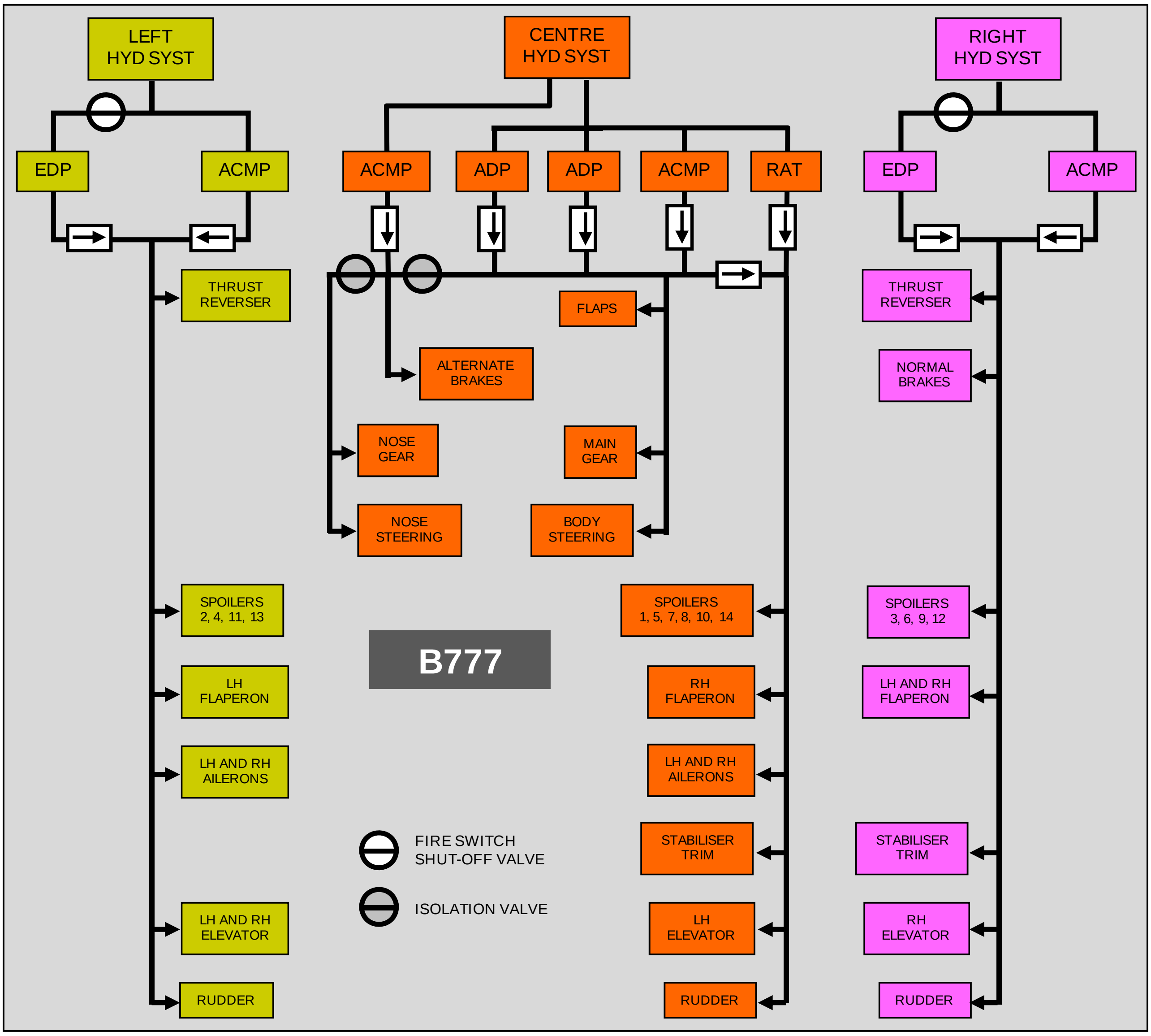


Figure 3-44 Boeing 777 Hydraulic System

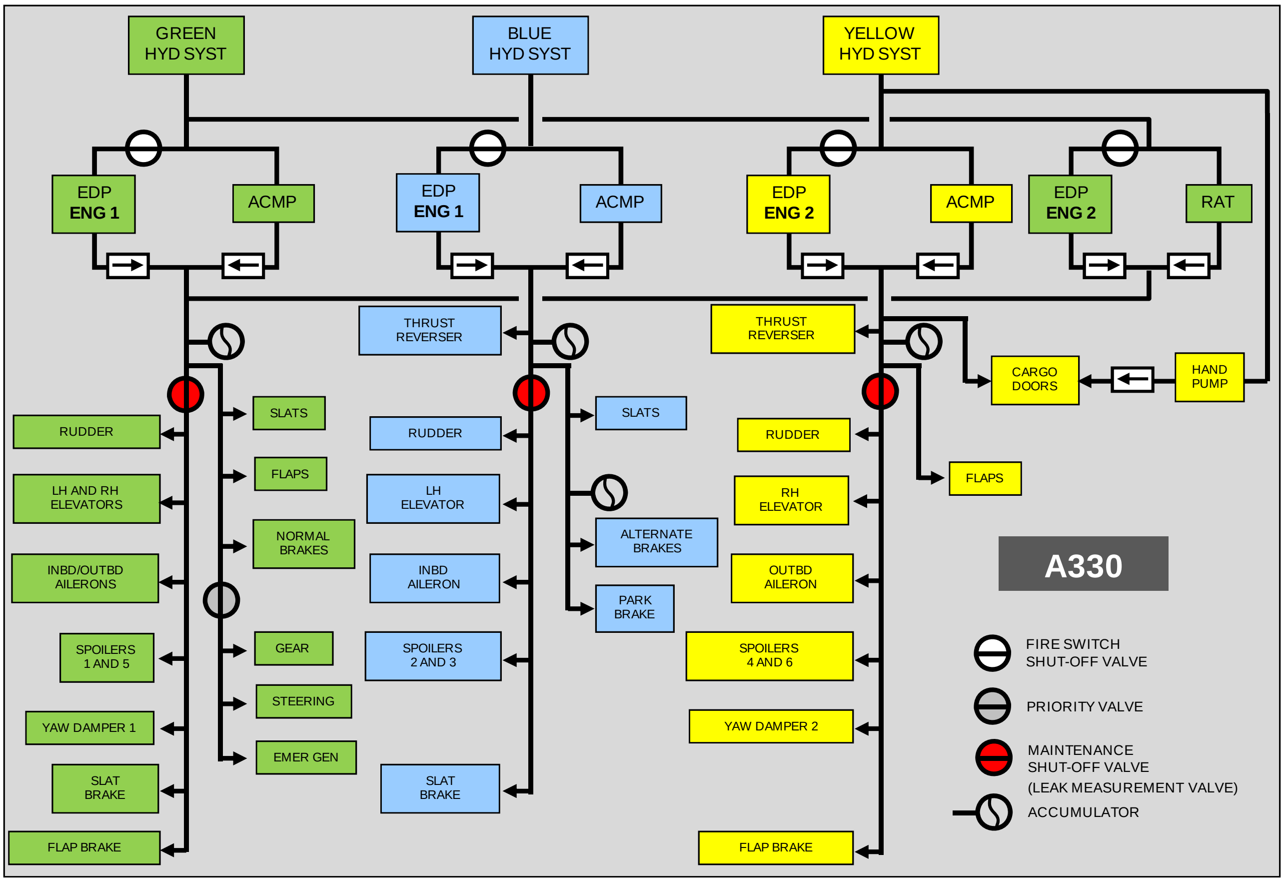


Figure 3-45 Airbus 330 Hydraulic System

REDUNDANCY

System redundancy is not only critical for flight safety but also enhances the ability of an aircraft to continue commercial operations safely until maintenance rectification can be carried out. Many systems other than hydraulic are dual redundant allowing an on time dispatch of the aircraft when one system fails.

Flight control redundancy is the most important and modern large commercial aircraft are required to provide triple redundancy for this. Refer to figure 3-46 as an example of flight control redundancy used by Airbus.

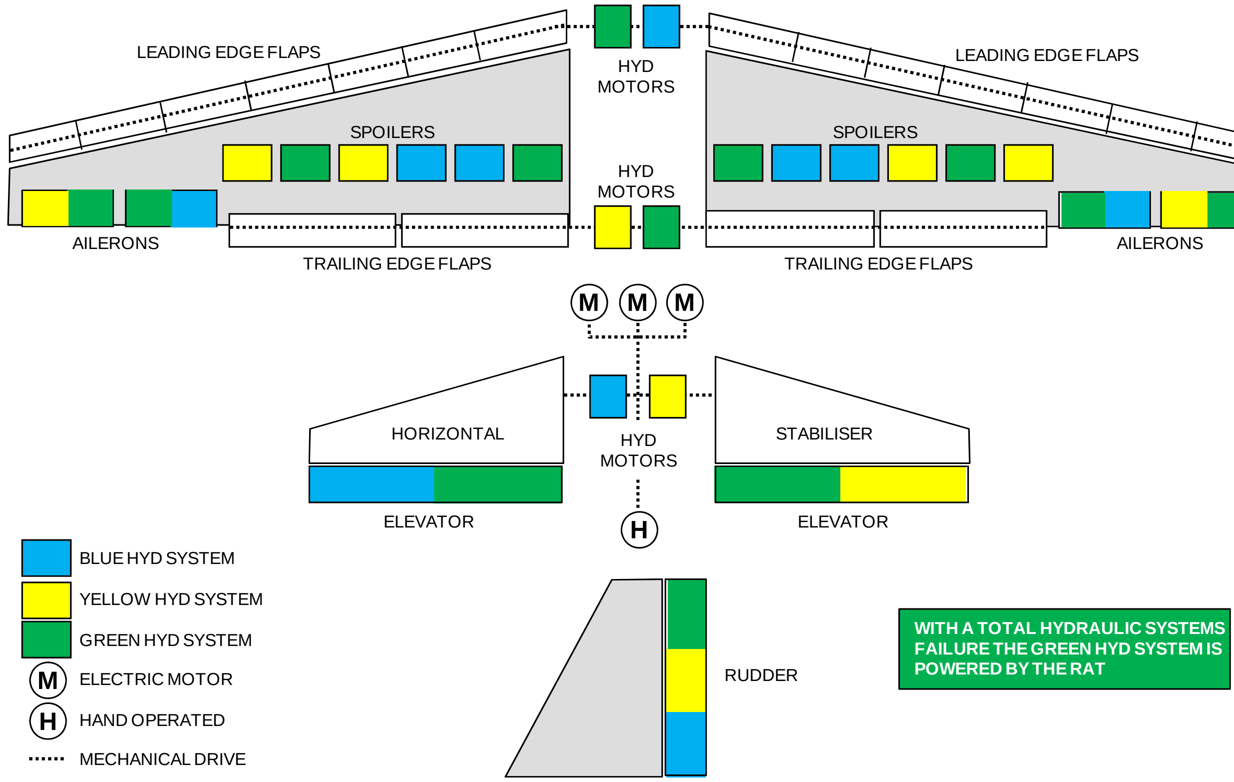


Figure 3-46 Flight Control Redundancy

Redundancy of systems other than primary flight controls is often achieved by utilizing other hydraulic or non-hydraulic methods such as hand pumps, electric motors, hand cranked gearboxes, free fall and stored air bottles. This is referred to as alternate and/or emergency operation.

ALTERNATE AND EMERGENCY OPERATION

The term alternate operation refers to a mechanism or system that is the alternate to the normal hydraulic method of operation.

Some aircraft have both an alternate method and an emergency method for systems such as wheel brakes.

In some aircraft, the alternate method is referred to as emergency operation.

Aircraft hydraulic systems that typically have an alternate method of listed in the following table, Refer to Figure 3-47.

SYSTEM	NORMAL OPERATION	ALTERNATE	EMERGENCY
Primary Flight Controls	Supplied by three hydraulic systems simultaneously		Supplied by one RAT
Primary Flight Controls	Supplied by two hydraulic systems simultaneously		Reversion to manual control
Leading Edge Flaps	Supplied by two hydraulic systems simultaneously	Driven by electric motors	
Trailing Edge Flaps	Supplied by two hydraulic systems simultaneously	Driven by electric motors	
Horizontal Stabiliser Trim	Supplied by two hydraulic systems simultaneously	Driven by electric motors	Hand actuated crank
Spoilers	Supplied by two hydraulic systems simultaneously		
Landing Gear (down only)	Supplied by one hydraulic system	Uplocks released by electric motor gear free falls	Uplocks released mechanically gear free falls
Landing Gear (down only)	Supplied by one hydraulic system	Hand pump down	Air bottle down
Wheel Brakes	Supplied by one hydraulic system with a specific brake accumulator	Supplied by another hydraulic system	Supplied by another hydraulic system or air bottle
Cargo Doors	Supplied by one hydraulic system	Hand Pump Hand actuated crank	

Figure 3-47 Summary of Alternate and Emergency Operation

DISPATCH WITH INOPERATIVE HYDRAULIC EQUIPMENT

Whilst redundancy is designed primarily for safe flight an added advantage is that aircraft may be dispatched for flight with some components of a hydraulic system inoperative. This does not mean that dispatch is allowed with a total system inoperative. There will be operational restrictions and performance penalties applied in this situation and flights will normally only be approved until the aircraft returns to home base.

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

- Primary or Demand Pumps,
- Brake Units, and
- Thrust Reversers.

COMMON FAULTS IN SIMPLE SYSTEMS

The following table details some of the common faults associated with older generation smaller aircraft with simple hydraulic systems. Refer to Figure 3-48.

SYMPTOM OR INDICATION	MOST LIKELY FAULT
Poor response of hydraulic brakes.	Air in hydraulic lines
Slow fluctuations of the pressure gauge when hydraulic service is selected (e.g. During operation of a jack).	Low accumulator pre-charge pressure.
Periodic fluctuations in system pressure.	Large internal leak.
Violent fluctuations in manifold pressure.	Air in the system.
Frequent cut-in and cut-out of unloading valve. (Note : This may not be noticeable on pressure gauge.)	Small internal leak or Low accumulator pre-charge pressure.
Low hydraulic pressure.	Insufficient fluid or Faulty pressure regulator
Excessive hydraulic pressure.	Faulty pressure regulator.
Foaming in reservoir. (Un-pressurised tank)	Insufficient fluid
Flaps are selected down but fail to lower	Faulty selector valve or Faulty by-pass valve.
Pump overheats and binds.	Insufficient fluid.

Figure 3-48 Common Faults in Hydraulic Systems

TYPICAL MALFUNCTION ALERTS IN HYDRAULIC SYSTEMS

The following table details some examples of the malfunction alerts and possible faults that are presented to the crew in switches and on ECAM/EICAS in modern hydraulic systems found today. Refer to Figure 3-49.

SYMPTOM OR INDICATION			MOST LIKELY FAULT
CONTROL PANEL/SWITCH	EICAS MESSAGE	HYD SYNOPTIC	
SYS FAULT	>HYD QTY HALF	actual quantity	Low reservoir quantity, Hydraulic quantity is 1/2 of normal level
	>HYD QTY LOW	LO	Low reservoir quantity, Hydraulic quantity is 0.34 of normal level
	HYD OVHT SYS	actual temperature	High fluid temperature, Excessive hydraulic system temperature
	HYD PRESS SYS	actual pressure	Low output press, loss of system pressure
PRESS	HYD PRESS ENG	Amber colour	Engine pump output pressure is low
PRESS	HYD PRESS DEM	Amber colour	Demand pump output pressure is low
PRESS	OFF	OFF	Pump is turned off when it should be on

Figure 3-49 Malfunction Alerts in Hydraulic Systems

LEAKAGE IN HYDRAULIC SYSTEMS

External leakage occurring from a hydraulic system may be observed by the depletion of normal quantity in the system reservoir or visible stains or fluid leakage from hydraulic components. Typically, hydraulic components located under panels and hidden from view will have small drain holes present in the covering panels so that leakage may be easily observed.

Internal leakage within a hydraulic system is difficult to identify as no loss of quantity will be observed. Internal leakage may occur between the chambers of an actuator or selector due to seal wear. The most common symptom is abnormally slow operation of a service such as landing gear (retraction) or failure to achieve full travel/deflection. Constant internal leakage may cause overheating of the system. Airbus aircraft have specific leak measurement valves used by maintenance (on the ground) to check for system leakage.

HYDRAULIC SYSTEM TERMINOLOGIES AND DEFINITIONS

The following table, Figure 3-50, defines old and/or common terms that you may encounter with reference to hydraulic systems.

TERM REFERRED	DEFINITION
Hydraulic Services	A general term used to describe all of the various sub-systems within a hydraulic system such as the flaps, spoilers, gear, brakes, flight controls, etc.
Hydraulic Lock	When a selector valve is moved to the neutral or centered position the fluid on both sides of the actuator piston is trapped at equal pressure. This provides for a locked position of the actuator until the selector valve is moved again. This is a normal action. Sometimes leakage within the selector valve assembly allows pressure to build on the dry side of the selector valve piston causing it to hydraulically jam or lock. The operator cannot move the selector valve in either direction and the service is said to have a "hydraulic lock". Only by depressurising the system can the selector be moved and the lock broken.
Hydraulic Manifold	The distribution point in the system after the pump and accumulator where pressure is available to be used by the different hydraulic services. It can be a simple large pipe with several smaller pipes distributing fluid from it or a structure that incorporates the filter, pressure relief valve and the system pressure transmitter and distribution pipes.
Hydraulic Jack	A cylinder and piston type hydraulic actuator.
Jack Stalling	The air load on a control surface is equal or stronger than the hydraulic force available causing the actuator to "stall" before full travel is achieved.
Pump Cavitation	Occurs when the supply fluid coming from the reservoir is of insufficient flow to satisfy the pump's suction requirement.
Cavitation	When heavy assemblies such as the landing gears are selected down the force of gravity will tend to pull the gears down faster than the hydraulic system can supply the flow.
Check valve	Same as a Non Return Valve.
Free Fall	Allowing the normally hydraulically operated equipment to fall due to gravity with no hydraulic pressure applied – normally only the landing gear – note that fluid that was present in the landing gear actuators will be returning to the reservoir under some pressure caused by the weight of the landing gear. By restricting this flow the gear will not fall at a rapid rate and cause damage to the gear structures.
Hydraulic Hammer	A loud and rapidly repeating banging noise heard from the system. Caused by flowing oil suddenly being stopped then released then stopped again in a cyclic manner. Typically caused by a faulty selector valve. The same as water hammer.
Bleeding	A method of removing trapped air within a hydraulic system by allowing fluid to flow out or "bleed" from the system releasing the air bubbles to atmosphere.
Hydraulic misting	Some very small (pin hole) hydraulic leaks at high pressure (3000 psi) cause the oil to form a mist surrounding the leak point. In a misted state some hydraulic fluids are flammable. Stay clear of this area and do not attempt to locate the leak point.
Olive	Same as the collar on a flareless pipe fitting.
Ferule	Same as the collar on a flareless pipe fitting.
Port	An opening within a valve or other hydraulic device that allows fluid to pass through.

TERM REFERRED	DEFINITION
Ported to	When fluid is directed to flow to an actuator or other hydraulic device.
Ram	Same as the piston part of a cylinder and piston actuator.
Spool	A spool or spool valve is the cylindrical selector shaft within an inline selector.
Quill shaft	Same as the shear section in an EDP drive shaft.
Auxiliary Demand Pump (ADP)	ADP is normally the abbreviation for Air Driven Pump however the B747-400 uses both bleed air driven and electric driven pumps in the role of demand pumps hence the term Auxiliary Demand Pump.
Schrader valve	Commonly used gas charging valve fitted to accumulators, shock struts, stored air bottles etc. Valve can be locked once equipment is charged with gas.
Flap Overload Valve	Same as a flap Load Relief Valve
Maxeret Unit	See Landing Gear and Associated Systems
Leak Measurement Valve	An Airbus term that describes a shut-off valve used by maintenance to isolate some systems and measure leak rates
Case drain line	A hydraulic line that drains a small flow of hydraulic fluid from the case or body structure of the hydraulic pump. This fluid removal assists in pump cooling and is returned to the reservoir.
Teflon Ring	Teflon is the common name applied to a hard white plastic like substance that is very slippery to the touch. It is used extensively in the form of a ring to provide support to rubber dynamic seals.
Gasket	A common term applied to a static seal made of any material and used on any type of system.
Priority Valve	A pressure operated type of Sequence Valve.
Priority Valve	A term used by Airbus for a pressure operated shut-off valve used to give priority to flight controls when hydraulic system pressure is low.
Packing	A common term applied to a dynamic hydraulic seal

Figure 3-50 Hydraulic Terms and Definitions

GENERAL SAFETY PRECAUTIONS RELATING TO HYDRAULIC SYSTEMS

Aircraft hydraulic systems can be extremely dangerous. The control surfaces on many large aircraft tend to droop due to gravity when hydraulic pressure is depleted and with the application of system pressure will suddenly move to the position commanded by the control column or sidestick.

Due to this sudden and rapid movement of hydraulically controlled equipment such as flight controls, spoilers and landing gear doors it is important to check the aircraft's external situation before operation of any hydraulically operated equipment whilst the aircraft is on the ground.

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

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

Hydraulic oil leaks, if observed from a system that is actually pressurised at the time should be immediately avoided as the potential for further rupture is high and this could result in death or serious injury to personnel being struck by a stream of high pressure fluid. Depressurise the system before attempting any further inspection of leakage.

HYDRAULIC SYSTEMS QUESTIONS

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

1. "Pressure in a confined fluid is transmitted equally and undiminished in all directions throughout the fluid". This statement is known as:-

   a. Bernoulli's Theorem.
   b. Pascal's Law.
   c. Charle's Law.

2. Pascal's Law applies to a fluid when the;

   a. the fluid is in motion and is not confined.
   b. the fluid is not in motion and is confined.
   c. the fluid is in motion and is confined.

3. In an aircraft hydraulic system the force produced by a piston is found by :-

   a. pressure on piston multiplied by the surface area of piston.
   b. pressure on piston divided by the surface area of piston.
   c. pressure on piston multiplied by piston travel distance.

4. The hydraulic fluid typically used in landing gear shock struts is;

   a. mineral based oil (OM-15.
   b. vegetable based oil (L-22).
   c. synthetic based oil (S-500).

5. The specified hydraulic fluid must be used in the system for the following reason;

   a. to stop corrosion of components.
   b. to suit the metals used in the system flexible lines.
   c. to suit the type of seals used within the system.

6. A weeping hydraulic leak from a system using Skydrol 500 may be detected by;

   a. a red coloured stain on painted surfaces.
   b. a yellow coloured stain on painted surfaces.
   c. a deterioration of painted surfaces.

7. The hydraulic fluid most commonly used on modern aircraft is Skydrol 500 as it;

   a. has a greater temperature range.
   b. is more viscous than alternatives.
   c. has a low flash point.

8. Hydraulic systems using mineral base fluid should be fitted with;

a. only natural rubber seals.
b. natural and synthetic rubber seals are both acceptable.
c. only synthetic rubber seals.

9. In modern large transport aircraft you would expect the hydraulic system(s) normal operating pressure to be;

a. 1500 or 3000 psi.
b. 3000 or 5000 psi.
c. 1000 to 3000 psi.

10. In modern large transport aircraft the system(s) hydraulic fluid is typically cooled by;

a. cooling fins on the hydraulic pumps.
b. heat exchangers in the hydraulic reservoirs.
c. heat exchangers in the fuel tanks.

11. The main filter in a hydraulic system is normally fitted with a bypass valve to allow continued operation if the filter becomes clogged. A bypassed filter may be recognised by;

a. a red pop-up indicator located at the reservoir.
b. a caution light in the cockpit.
c. slightly faster operation of hydraulic services.

12. A pressure regulator;

a. is not normally fitted to a system containing a variable displacement hydraulic pump.
b. will relieve the load on a variable displacement type pump to ensure system pressure does not become too high.
c. is not required with a constant displacement type pump.

13. A double acting hand pump when incorporated in a hydraulic system would be typically used as a:-

a. demand or alternate pump.
b. service or emergency pump.
c. primary or emergency pump.

14. The purpose of the hydraulic accumulator is;

a. to provide a suitable location to take the hydraulic pressure.
b. to dampen pulsations within the hydraulic system and supply a reserve of hydraulic power.
c. to provide air pressure to resist hydraulic pressure so that a pressure reading can be made.

15. The reservoir stand pipe is for the purpose of;

a. preventing foaming
b. keeping an even level in the reservoir.
c. ensuring a supply of fluid in the emergency pump.

16. In an aircraft designed to operate at high altitudes provision is made to pressurise the hydraulic reservoir. This is to;

a. ensure the supply of fluid to the reservoir inlet.
b. reduce cavitation and increase pump efficiency.
c. form a reserve pressure for emergency.

17. In a reservoir, the hand pump supply line is normally located;

a. above the power pump supply outlet.
b. at 90 degrees from the power pump supply outlet.
c. below the level of the power pump supply outlet.

18. An orifice check valve differs from a normal check valve in that;

a. it has an orifice in the body to observe correct operation.
b. it allows flow in both directions.
c. it allows flow in only one direction.

19. Pressure reducing valves are used to;

a. reduce normal system operating pressure for some particular services.
b. reduce the pressure produced by a constant delivery pump.
c. reduce the return pressure so the reservoir does not become overpressurised.

20. Hydraulic Fuses are typically used to protect against;

a. loss of essential services such as flight controls when pressure is low.
b. overheating of electrically driven hydraulic pumps.
c. excessive loss of fluid.

21. One of the common uses of a Shut-off valve in a hydraulic system is to;

a. shut-off electrical control of the RAT.
b. shut-off the reservoir pressurization when a leak occurs.
c. shut-off pressure to allow maintenance activities to be conducted.

22. An Automatic Cut-out Valve is typically used to control system pressure output from a;

a. emergency hand pump.
b. engine driven constant delivery pump.
c. engine driven variable delivery pump.

23. Hydraulic connections that are fitted with Quick Disconnect Valves allow components to be changed quickly without depleting;

a. the systems hydraulic fluid quantity.
b. the systems operating pressure.
c. the systems operating temperature.

24. The Selector Valve used to control a double acting actuator would typically have;

a. three ports.
b. four ports.
c. two ports.

25. The main difference between an "open-centre" and "closed centre" system is;

a. no pressure exists in the open-centre system except that due to fluid friction when no units are in operation.
b. fluid under system pressure is trapped in the open-centre system when the selector valves are in a neutral position.
c. no pressure exists in the closed-centre system except that due to fluid friction when no units are in operation.

26. The purpose of an aspirator in a hydraulic system is to;

a. build up system pressure.
b. prevent reversal of fluid flow.
c. pressurise the reservoir.

27. The purpose of a thermal relief valve is to;

a. allow hydraulic lines to expand and contract.
b. relieve excess pressure caused by overheated trapped hydraulic fluid.
c. relieve excess pressure caused by overheating power pumps.

28. A flap overload valve is used to;

a. prevent lowering flaps at too high an IAS.
b. release hydraulic pressure when flap is fully extended.
c. permit flaps to be operated manually.

29. A sequence valve ensures;

a. flaps are operated before landing gear.
b. certain mechanisms operate after others.
c. flaps are operated before landing gear but only with regard to retraction when airborne.

30. A pressure regulator is located;

a. between power pump and pressure manifold.
b. between reservoir and power pump.
c. between selector valve and actuator.

31. The function of a pressure regulator in a hydraulic systems is;

a. to maintain system working pressure below a maximum value.
b. to relieve the power pump when the system is in the "off load" condition.
c. to prevent the power pump over-speeding as the system comes to the "on load" condition.

32. One reason for fitting an accumulator in a hydraulic system is to;

a. absorb pressure surges.
b. provide increased brake pressure for ground operations.
c. provide an adequate pressure for automatic retraction braking.

33. In most hydraulic systems the accumulator is located;

a. between the pump and the actuating units.
b. between the cutting units and the tank.
c. in the flap and brake system low pressure lines.

34. The shear shaft in a hydraulic pump is for what purpose;

a. it functions as a clutch.
b. it protects the hydraulic pump and the engine accessory drive from extreme loads.
c. it permits the gear unit to slip in the event of high pressures.

35. A hydraulic actuating cylinder can be described as a device for;

a. converting hydraulic pressure to mechanical motion.
b. controlling the direction of flow of hydraulic pressure.
c. transforming mechanical motion into hydraulic pressure.

36. A hand pump usually discharges directly to the;

a. power pump.
b. pressure manifold.
c. pressure regulator.

37. If the system reservoir serves power and hand pumps and it runs dry;

a. the power pump will starve first.
b. the hand pump will starve first.
c. both will go out of action at the same time.

38. A pressure gauge in a hydraulic system is positioned to indicate;

a. accumulator air pressure.
b. accumulator pressure.
c. manifold pressure.

39. The hydraulic fluid reservoir is provided to;

a. absorb excess temperatures.
b. retain accumulator pressure for the operation of the emergency hand pump.
c. provide a reserve that will make up for losses due to leakage.

40. If the pressure of static fluid in the main pressure manifold is 3000 psi, the pressure of static fluid in a smaller diameter pipe leading from the manifold would be;

a. less than 3000 psi.
b. the same as the main pressure manifold (3000 psi).
c. more than 3000 psi.

41. What happens to the hydraulic fluid in a system when it is heated;

a. it expands.
b. It contracts
c. nothing happens.

42. The cockpit control switch for a system "demand" pump would typically have the following selections;

a. OFF, AUTO and STBY.
b. ON, AUTO and EMERG
c. OFF, ON and AUTO.

43. Trapped air in a wheel brake hydraulic system may be removed by;

a. operating the brake units multiple times until air is removed.
b. bleeding the brake units until air is removed.
c. continue resetting the hydraulic fuse valve until air is removed.

44. Cockpit indications relating to hydraulic systems malfunctions are typically coloured;

a. green.
b. amber.
c. red.

45. Refer to Figure 3-45, Airbus 330 Hydraulic System; The "emergency" pump is part of what system;

a. the blue system.
b. the yellow system.
c. the green system.

46. Refer to Figure 3-46, Flight Control Redundancy; With a loss of the yellow hydraulic system the horizontal stabilizer would be operated by;

a. the blue system.
b. electric motors.
c. hand operated trim wheel.

47. Refer to Figure 3-45, Airbus 330 Hydraulic System; In normal cruise conditions if the No.2 engine EDP pressurising the green system failed, you would expect the following;

a. the RAT to begin operating automatically.
b. the green system ACMP to begin operating automatically.
c. no other pumps to begin operating automatically.

48. Refer to Figure 3-44, B777 Hydraulic System; What systems can provide wheel braking;

a. right and centre systems.
b. right and left systems.
c. right system only

49. If a hydraulic system pump was found to be unserviceable prior to dispatch, recommended advise could be sought from;

a. the Company operating procedure for hydraulics systems.
b. the aircraft's MEL.
c. the aircraft's CDL.