INTRODUCTION

Hydraulics is based on a very simple fact of nature - you cannot compress a liquid. You can compress a gas (think about putting more and more air into a tire, the more you put in, the higher the pressure). If you're really strong you can compress a solid mass as well. But no matter how much pressure you apply onto a liquid, it isn't possible to compress it. Now if you put that liquid into a sealed system and push on it at one end, that pressure is transmitted through the liquid to the other end of the system. The pressure is not diminished.

Aircraft Hydraulics Definition

It is a system where liquid under pressure is used to transmit this energy. Hydraulic systems take engine power and convert it to hydraulic power by means of a hydraulic pump. This power can be distributed throughout the airplane by means of tubing that runs through the aircraft. Hydraulic power may be reconverted to mechanical power by means of an actuating cylinder, or turbine.

(1) - A hydraulic pump converts mechanical power to hydraulic power
(2) - An actuating cylinder converts hydraulic power to mechanical power
(3) - Landing Gear
(4) - Engine power (mechanical HP)

If an electrical system were used instead of a hydraulic system, a generator would take the place of the pump and a motor would take the place of the actuating cylinder

Some Hydraulic Systems in Aircrafts

1. Primary control boosters
2. Retraction and extension of landing gear
3. Sweep back and forth of wings
4. Opening and closing doors and hatchways
5. Automatic pilot and gun turrets
6. Shock absorption systems and valve lifter systems
7. Dive, landing, speed and flap brakes
8. Pitch changing mechanism, spoilers on flaps
9. Bomb bay doors and bomb displacement gears

2.Principles of Operation

Part of the hydraulic system is the actuating cylinder whose main function is to change hydraulic (fluid) power to mechanical (shaft) power. Inside the actuating cylinder is a piston whose motion is regulated by oil under pressure. The oil is in contact with both sides of the piston head but at different pressures. High pressure oil may be pumped into either side of the piston head.

The selector valve determines to which side of the actuating cylinder the high pressure oil is sent. The piston rod of the actuating cylinder is connected to the control surface.

As the piston moves out, the elevator moves down. As the piston moves in, the elevator moves up. The selector valve directs the high pressure oil to the appropriate side of the piston head causing movement of the piston in the actuating cylinder. As the piston moves, the oil on the low pressure side returns to the reservoir since return lines have no pressure!

The differential in oil pressure causes movement of the piston. The force generated by this pressure difference can be sufficient to move the necessary loads. Each cylinder in the plane, boat, etc., is designed for what it must do. It can deliver the potential it was made for; no more, no less. Air loads generally determine the force needed in aircraft applications.

Hydraulic System

A hydraulic system transmits power by means of fluid flow under pressure. The rate of flow of the oil through the system into the actuating cylinder will determine the speed with which the piston rod in the actuating cylinder extends or retracts. When the cylinder is installed on the aircraft, it is already filled with oil. This insures that no air bubbles are introduced into the hydraulic system, which can adversely affect the operation of the system.

Pascal's Theory

In a confined stationary liquid, neglecting the effect of gravity, pressure is distributed equally and undiminished in all directions; it acts perpendicular to the surface it touches. Because the actuating cylinder is not vented, the force delivered through the piston to the surface of the fluid is translated into a pressure on the surface of the fluid.

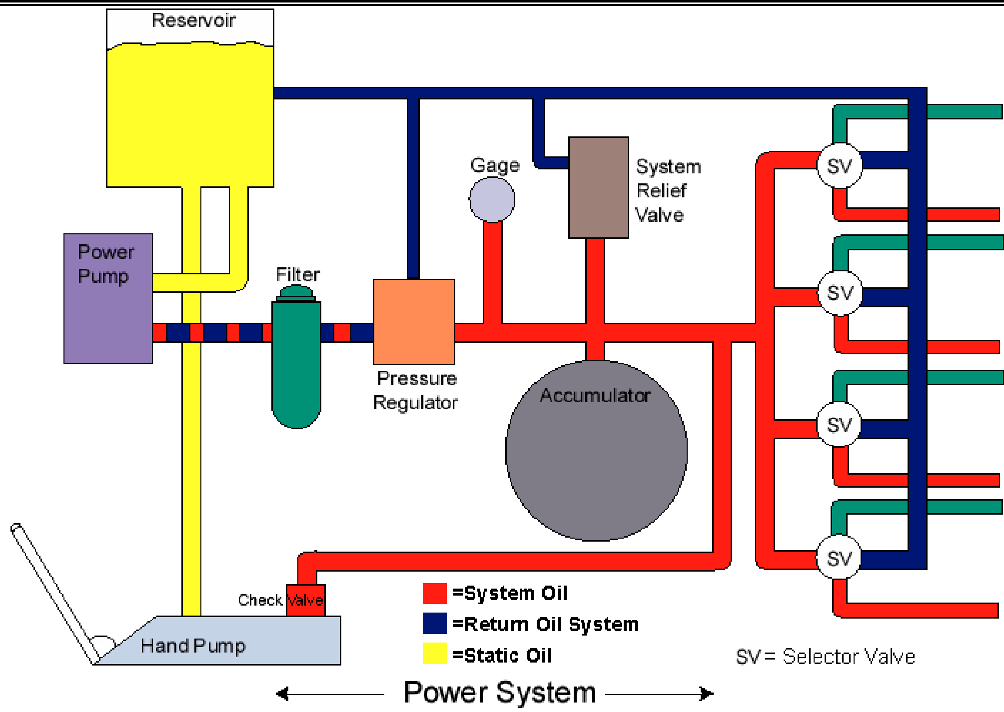
The pressure (p) acting on the incompressible oil does work [(pressure) x (Area of piston) x (piston's stroke) = Work].

3.Hydraulic Pressure Regulated Power System

The system in drawing below represents a pressure regulated power system comprised of two parts:

1) the power system, and

2) the actuating system part of the overall hydraulic system.



Parts of the Power System

1. *Reservoir* -- holds an extra supply of fluid for system from which oil was drawn when needed, or oil was returned to it when not needed.
2. *Accumulator* -- absorbs pulsation within the hydraulic system and helps reduce "linehammer effects" (pulses that feel and sound like a hammer has hit the hydraulic tubes). It is an emergency source of power and it acts as another reservoir.
3. *Filter* -- removes impurities in the hydraulic system and in the reservoir. The reservoir has one big filter inside the tank.
4. *Power Pump* -- it changes mechanical horsepower (HP) to hydraulic HP.
5. *System Relief Valve* -- relieves pressure on system as a safety.measure and takes over as a pressure regulator when pressure regulator fails.

6. *Pressure Regulator* -- as the name implies, regulates the pressure in the hydraulic system. When it senses a built-up in pressure in the lines to the selector valves, it acts so that the system automatically goes to bypass.

4.Aircraft Hydraulic System Reservoir

Functions of the Reservoir

1. Provides air space for expansion of the oil due to temperature changes
2. Holds a reserve supply of oil to account for
   a. thermal contraction of oil.
   b. normal leakage - oil is used to lubricate piston rods and cylinder seals. When the piston rod moves, it is scraped to remove impurities that might collect on the rod when returning into actuating cylinders. If many actuating cylinders are operating at the same time, then the amount of oil lost is greater.
   c. emergency supply of oil - this case occurs only when the hand pump is used.
   d. volume changes due to operational requirements - oil needed on side 2 of piston head is less than that needed on side 1 of cylinder piston (which occurs during actuation).
3. Provides a place to remove air or foam from liquid.
4. Provide a pressure head on the pump, that is, a pressure head due to gravity and depends upon the distance of the reservoir above the power pump.

The best shape is a domed cylindrical shape. Not only can it be mounted easily, but it can be made to order.

5.Aircraft Hydraulic System Power Pumps

Function:

1. The function of the hydraulic system power pump is to change mechanical horsepower to hydraulic horsepower.

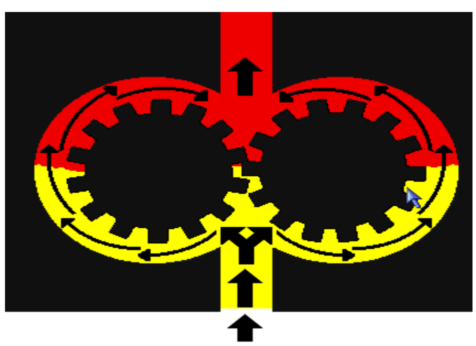
Types of Power Pumps

There are two types of power pumps, a gear pump and a piston pump.

1. Gear pumps have efficiencies that average about 70-80% overall efficiency, where overall efficiency is defined as:
   overall efficiency = (mechanical efficiency)*(volumetric efficiency)
   Gear pumps move fluid based upon the number of gear teeth and the volume spacing between gear teeth.
2. Piston pumps move fluid by pushing it through the motion of the pistons within the pump. They can generate overall efficiencies in the 90-95% range.

Principles of Operation:

Gear type pumps are ideal when working with pressures up to 1500 lb./sq.in. As mentioned previously, the volumetric efficiency of gear pumps depends upon the number of teeth, the engine speed and the tooth area.



As the liquid comes from the reservoir, it is pushed between the gear teeth. The oil is moved around to the other side by the action of the drive gear itself and sent through the pressure line. What makes the oil squeeze in between the gear teeth? gravity and the pressure head. To prevent leakage of oil from the high to the low pressure side from occurring, you can make the gears fit better.

You might want to increase the pressure used to move the fluid along. However, the higher the pressure, the higher the friction loading on the teeth. Friction will develop heat which will expand the gears and cause the pump to seize (parts will weld together and gears will stop rotating). In order to stop this, you can have the pump case, the gears, and the bearings made out of different materials, (e.g., steel gears [1-1/2 inch thick], bronze bearings, aluminum casing). Normally, the gear speed is higher than the engine speed (normally 1.4 times the engine speed).

Oil can leak over and under the gears. To prevent leakage, you can press the bearings up against the gears. This decreases seepage but this decreases the mechanical efficiency when friction increases. Even though oil acts as lubricant, seizing can occur when oil is drained from the hydraulic system.

As mentioned previously, we can push the bearings up against the gears to decrease leakage. As F increases, M decreases, thus, the gears and bushing increase in friction and mechanical efficiency decreases. When you increase the pressure on the inlet side of the pump, leakage will increase around the gears. To reduce the leakage, you must push the bearings and gears closer, causing an increase in friction. That is why inlet pressures over 1500 lb/sq in, are not used.

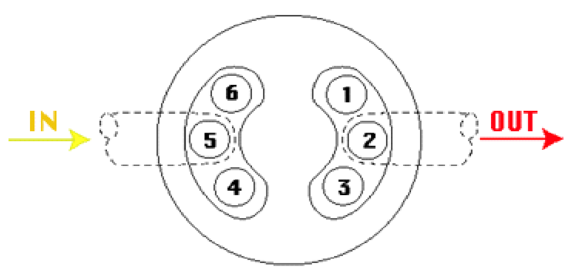
Principle of the Shear Shaft

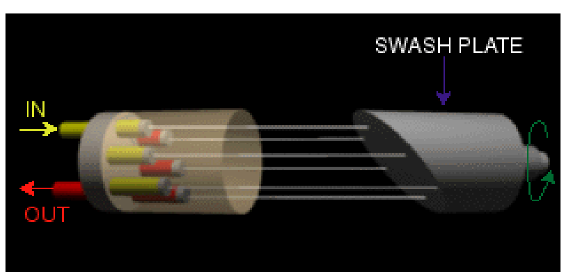
Gear pumps are built using a shear shaft principle. That is, if the pump fails, the shear shaft breaks and this allows each of the gears to rotate in its own part of the system (pump side or engine side) and nothing else will happen to the system. This phenomenon is similar to a fuse in an electrical system. When the electrical system overloads, the fuse breaks, causing the circuit to break without damaging the rest of the electrical circuit.

Principle of the Reciprocating Piston Pump

These kind of pumps attain volumetric efficiencies of up to 98% and they can maintain pressures from 1500 to 6000 psi. They can achieve overall efficiencies of up to 92% and can move fluid volumes up to 35 gallons per minute.

As the cylinder block rotates, space between the block and the pistons increase, letting in more oil. As the block rotates from bottom dead center, the reverse occurs and the pistons push oil out through the outlet. When the pistons move down, the suction caused by the vacuum from the space, created by the movement of the piston, pulls in oil. Changing the angle between the swash plate and the cylinder block gives a longer pumping action and causes more fluid to be pulled in. As the cylinder block rotates, the piston cylinder openings over the inlet and the outlet vary. When cylinders 4-6 take in hydraulic fluid and act as the inlet to the pump, then cylinders 1-3 push the hydraulic fluid out and act as outlet to the pump.





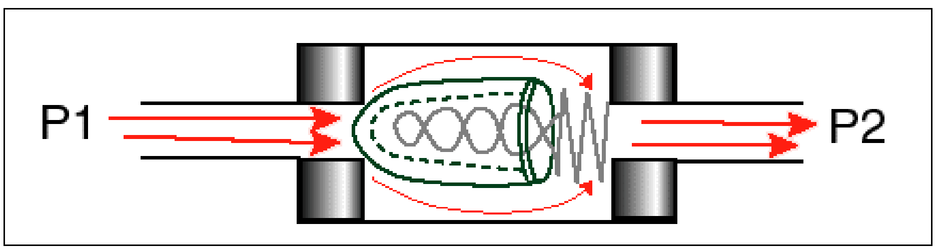
As the shaft and swash plate rotate, the piston will suck oil into the cylinder block and as the shaft and swash plate keep on rotating, the piston pushes oil out through the outlet. Pumps can be made to move more or less oil volume.

6.Hydraulic System Check Valves

Function of Check Valves

Check Valves are hydraulic devices which permit flow of fluid in one direction only.

Check Valve Used In Aircrafts



Poppet type valve is the preferred type that is used in hydraulics now. The front of the poppet (left side of the picture above) sits snugly on the hard seat (darker shaded areas on the left side). The poppet works on the following principle. When high pressure fluid (with pressure P_1) comes in on the left, it forces the poppet open. Since $P_1>P_2$, the force on the left side of the poppet (F_1) is greater than the force due to the spring (F_2) and is just enough to open the poppet. But, when flow stops, or there is a high pressure flow from the right side of the poppet, then $P_2>P_1$ and the pressure forces the poppet against the valve seat, closing off the opening. Thus the fluid is allowed to flow through in one direction only.

Check valves are designed so as not to tolerate leakage. The purpose of the light spring is only to keep the poppet on the seat.

Most manufacturers use sharp-edged, very hard seats and soft, maybe plastic, poppets. Parallel seats are very good except that they are too prone to trapping contaminants between the seat and the poppet.

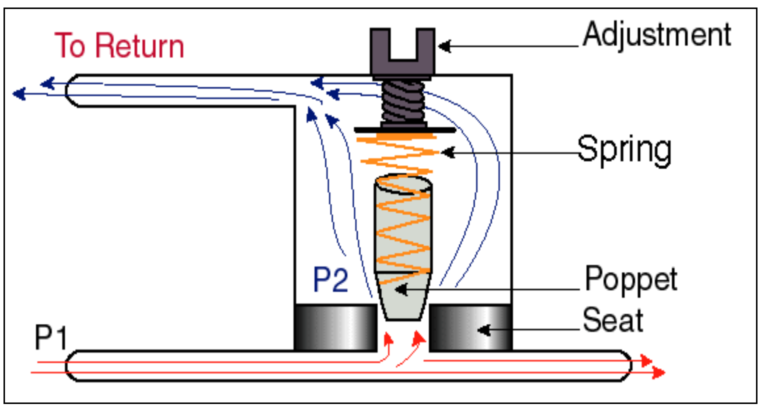
7.Pressure Control

(Pressure limiting device-relief valves)

Function

To limit the pressure of some section of the hydraulic system when the pressure has reached a predetermined level. That pressure level may be considered dangerous and, therefore, must be limited.

Principle of Operation



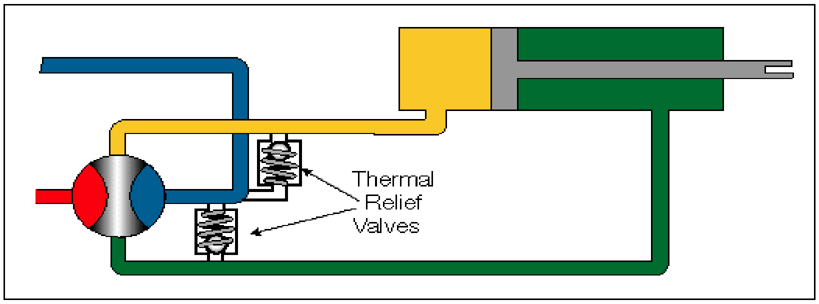
The adjustment screw at the top of the pressure relief valve is set for a certain pressure value, let us call it P_2. In general, even with a pressure of P_1, the poppet would lift up, except that the spring is strong and has downward force forcing the poppet closed. Poppet will not move until a pressure greater than that required is felt by the system (i.e., $P_1>P_2$). When the pressure increases, the poppet will move up, forcing the excess

liquid to move through opening at high velocity. On other side of seat, pressure is zero because the back side of the relief valve is connected to the return line. When the pressure in the system decreases below maximum, poppet will return to its seated position, sealing the orifice and allowing the fluid to follow its normal path. These type of pressure relief valves are only made to be used intermittently.

Circuits Using Pressuring Limiting Devices (PLDs)

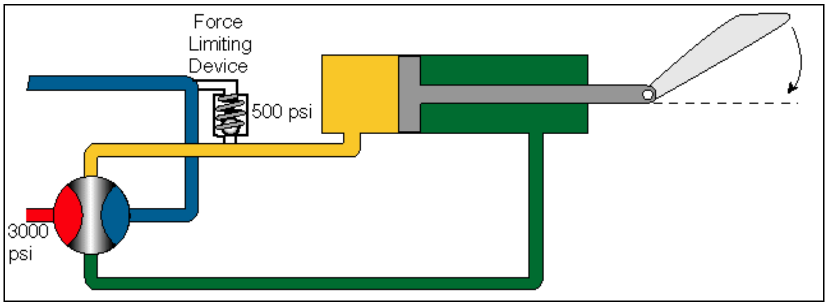
1. The power system where the system relief valve is used to back up the regulator is an example of a use of the PLD. In such a system, the pressure setting, P_2, is set 125% above the system pressure. Rate of flow is dependent upon engine speed.

2. Thermal relief valves are set at 150% of system pressure. When the temperature (T) changes, the liquid expands more than the expansion of the hydraulic tubing. Since T increases, the pressure (P) increases. Thus, the tubing will burst unless there are thermal relief valves in the system. Set at one pressure, the thermal relief valves are connected to the return lines because the pressure there is close to nil. This only works when the selector valve is set in the neutral position.

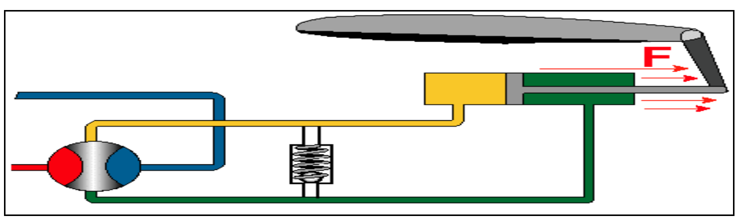


3. Force Limiting Device (FLD). Suppose that we want 1000 pounds of force to move a certain control surface. But our system can deliver 3000 pounds per square inch. If that pressure can be delivered on a 2 square inch piston head that moves the control surface, we would be= 6000 lb, a much higher force than is needed. We can put a force limiting relief valve (FLD) which would limit the force to 1000 lb by adjusting the FLD to act when the pressure reaches 500 psi

(1000 lb/ 2 square inches).



5. Blow up devices. When a plane is coming in for landing on a carrier deck, the brakes are set and the selector valve is put at neutral. If the plane is waved off on its landing attempt, the brakes must retract quickly so that the plane does not stall. Therefore, when the pilot is waved off, he will push the throttle to get more speed to get away from carrier. In doing so, the air pressure force acting on the brakes, F, is so great that it moves the brake. In doing so, the piston moves to right, causing fluid to flow and to push on the relief valve. This action allows more oil into the other line which in turn pushes on the piston and repeats the process. After the pilot reacts to this situation, he will change the selector valve position (if he has to change it), to move the b

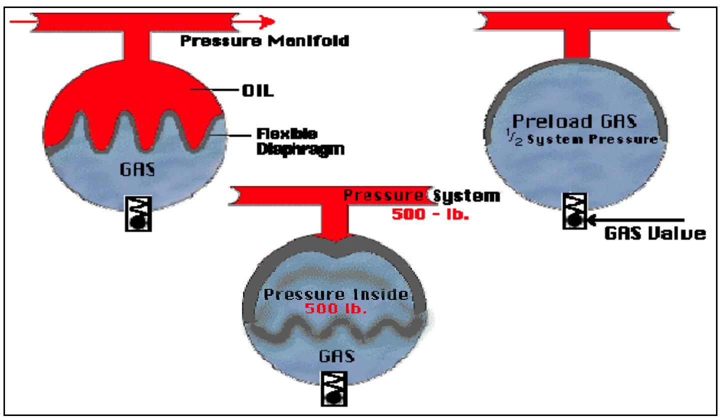


8.Hydraulic System Accumulator

Principle of Operation

At the bottom of the accumulator is a gas valve. Compressed gas at about one half the system pressure is let into the accumulator through the gas valve. This forces the diaphragm that separates the oil side from the gas side to "pop" up towards the oil side. Then oil is sent through the system. When the system pressure reaches a point when it is greater than the pressure of the accumulator, the diaphragm will deploy (inflate). Using Boyle's Law, the compressed gas will increase in pressure as its volume decreases. The diaphragm will move up or down, depending on system pressure.

When the diaphragm is at half way, the gas volume will be ½ as much as it was initially, while the accumulator pressure will be twice as much as its pre-load pressure (i.e., 1/2 system pressure). Therefore when the accumulator is at half volume of gas, it will be charged at full system pressure.



Uses of an Accumulator

1. Absorbs the shocks due to rapid pressure variations in a hydraulic system
2. Helps maintain a constant pressure within the hydraulic system
3. Helps the hydraulic pump under peak pressure loads
4. It is an emergency source of power (the braking system has its own accumulator)

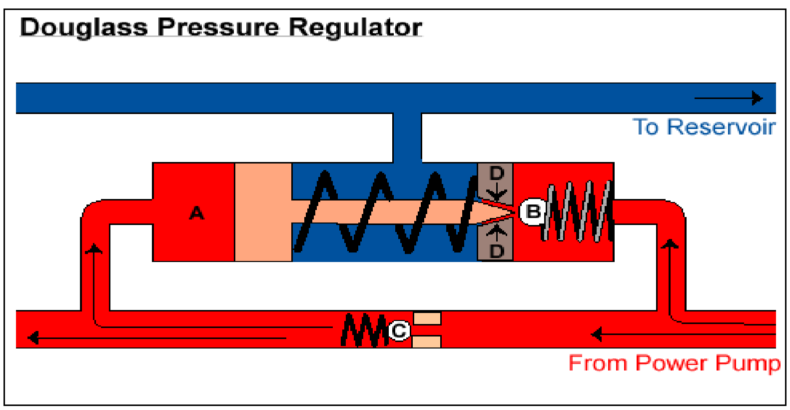
The preload is checked every day. Nitrogen and helium are preferred to compressed air. Oxygen leaks into the oil will cause spontaneous combustion and that is why it is not used in the accumulator. Carbon dioxide (CO_2) is not used because it liquefies at 800 or 900 psi (which is considered low pressure compared to the pressure requirements of the system).

The accumulator has to withstand about 450,000 lb of force. The spherical shape is used because a monocoque (single shell) body is the strongest and can withstand high pressures before failing.

9.Pressure Regulation in Hydraulic Systems

If a system relief valve (SRV) were used to regulate pressure, it would have to be replaced in a very short time. This would be due to the overuse of the SRV and the failure of the spring's elasticity. If the SRV were used, the oil pushing on the spring-ball combination would cause tremendous vibrations and heat would be dissipated by the oil under high pressure attempting to push the ball away from the seat to get to the low pressure side.

Douglass Pressure Regulator



When an actuating cylinder finishes its motion and stops, a high pressure will be felt through the system. If so, this high pressure oil coming from the power pump (right side of diagram) will keep check valve C open and also act on piston A. In its movement, piston A pushes Ball B off seat D. The oil, taking the passage of least resistance, goes through passage D into the center chamber back to the reservoir. The pressure on the right side of check valve C will drop and will be less than the pressure on the left side of C, therefore, causing the ball to seat itself in check valve C. When the

hydraulic system pressure drops, the pressure on piston A decreases, causing a decrease in pressure on B as well. The path of least resistance through D will close and the oil will move in the direction towards check valve C. Now, because the pressure on the right side of C is greater than on the left of C, the check valve will be forced open and the oil will move toward the selector valve side of the system (left side of diagram). The range of operation of the pressure regulator is defined by the difference in force required for bypass and the force required at actuation.

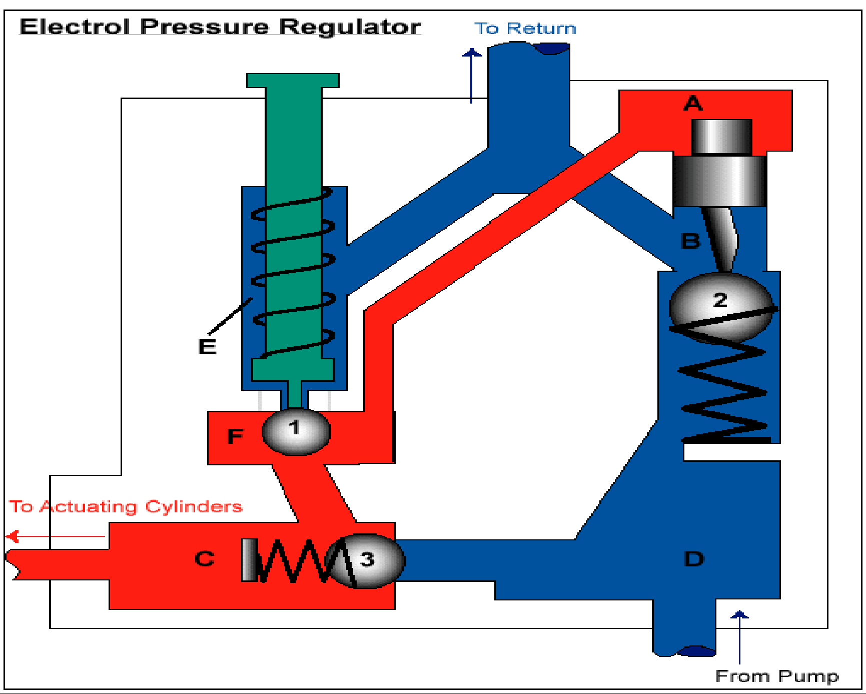
Electrol Pressure Regulator

The dual purpose of a pressure regulator is to reduce the load on the hydraulic pump when not needed and to keep the hydraulic pressure within the operating range of the hydraulic system.

When the hydraulic pump is charging the system, balls 1 and 2 are seated on their seats but ball 3 is letting oil pass through to the actuating cylinders. When actuation stops, the pressure in the system builds to maximum. The spring holding ball 1 onto the lower seat is designed to withstand the force produced by the maximum pressure of the hydraulic system. As maximum pressure is reached, ball 1 is made to move to the upper seat, thereby letting high pressure oil reach the A side of piston. But, ball 3 has already moved to its seat due to the higher pressure felt on side C than on side D. Therefore, oil coming from the hydraulic pump is at a charging pressure less than the maximum pressure of side A of the piston, causing the piston to move down, in turn pushing ball 2 down. Oil, wanting to take the path of least resistance, goes by ball 2 to the return line.

If actuation restarts, then pressures at C side of ball 3, at A side of piston and at F side of ball 1 decreases. Ball 1 falls onto the lower seat, since the spring force is greater than the force generated by the hydraulic system's oil pressure. Piston A will then move up due to the pressure drop on side A, causing ball 2 to close the orifice to the return line. The oil being pumped from the hydraulic pump now has greater pressure on side D of ball 3, causing the ball to move to the left and the hydraulic system oil goes in the direction of the actuating cylinder.

The range of operation depends on ball 1. As you can see, if the force of the spring holding ball 1 is to be overcome, a certain pressure (equal to the spring force divided by the opening's cross-sectional area) at the lower seat would be needed. If the ball were to move upward to the upper seat, the exposed surface area of the ball on which the pressure acts would increase (while the spring force would essentially remain the same) thereby causing the pressure in the system to decrease. Ball 1 would then move from the lower seat to the upper seat very quickly as more surface area is exposed, causing the pressure required to move the ball to drop. When the pressure delivered is much higher than the pressure required to move the ball, then the ball will move quickly and bang shut against the upper seat. The opposite reaction occurs when the pressure in the system is lowered to within operational limits.



10.Hydraulic System Hand Pumps

Functions

1. Hydraulic system hand pumps are used to test the hydraulic system when the plane is on the ground; and,
2. acts as an Emergency system of power

Principles of Operation

The hand pump converts the power of a human being to hydraulic horsepower. For this reason, such pumps are used in older model aircraft.

Types

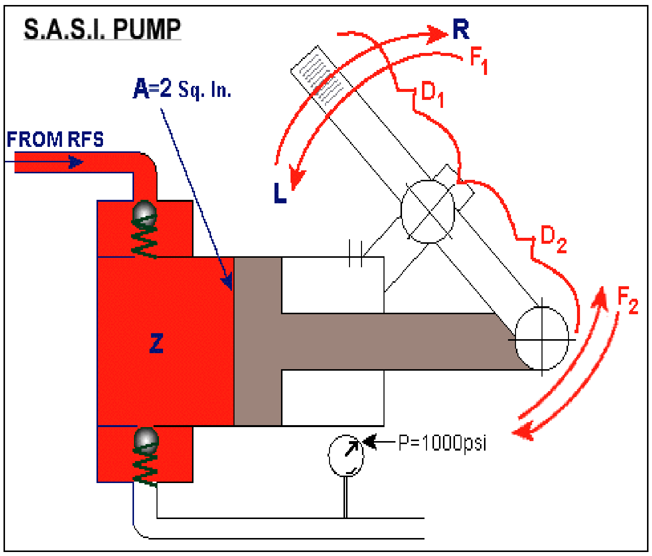
There are several types of handpumps.

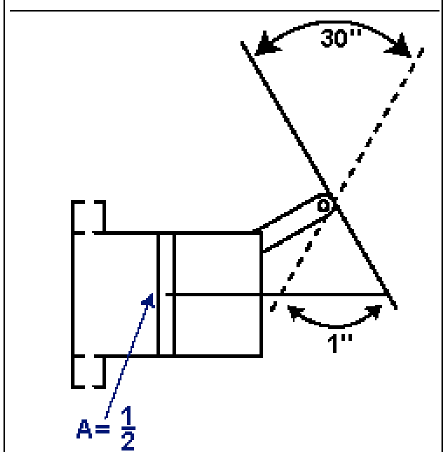
1. Single action - single impulse (S.A.S.I.)
2. Double action - double impulse (D.A.D.I.)

Analysis of a S.A.S.I. Pump

The pump works on the principle of mechanical advantage. When pilot moves the handle away to L (see diagram below), a low pressure is caused to form in the chamber of the pump, Z. Since the reservoir liquid pressure is greater than the pressure in Z, liquid is forced around the check valve from the reservoir line. When the pump handle is moved to R, a positive pressure will form in Z, causing the check valve to the reservoir side to close. Since the hydraulic system liquid is incompressible, it is forced out through the bottom check valve to the system line.

Suppose the force delivered by the pilot was F_1 = 100 lb, at a distance D_1 = 20 inches from the pump handle pivot, and suppose that D_2 = 1 inch from the pivot to the pump piston. Then by moment equilibrium ($F_1D_1=F_2D_2$), the force acting on the piston would be F_2 = 2000 lb. If the piston area on which the oil acts is A = 2 square inches, then the pressure developed is $\frac{F}{A} = \frac{2000}{2} = 1000 \text{ psi}$

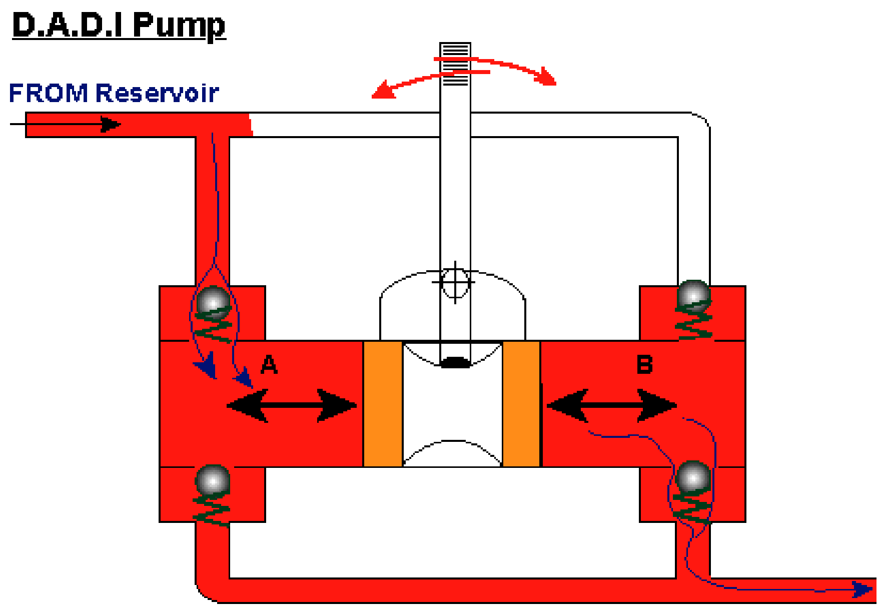




The volumetric output $V = \text{stroke} \times \text{Area}$. In this case, $D2 \times A = 1 \text{ in.} \times 2 \text{ sq.in.} = 2 \text{ cubic inches}$. But a man's average output is about 50 lb for F_1. Therefore, the piston area must be made half its present size (if the pressure is to remain constant). Thus, volumetric output will then decrease to 1 cu. in., since $D2 \times A = 1 \text{ inch stroke} \times 1 \text{ square inch area}$.

Analysis of a D.A.D.I. Pump

The DADI pump works in the same way that the SASI pump works, except that while chamber A is filling up from the reservoir, chamber B is pumping oil to the system.



11.Flow Control

Selector Valves

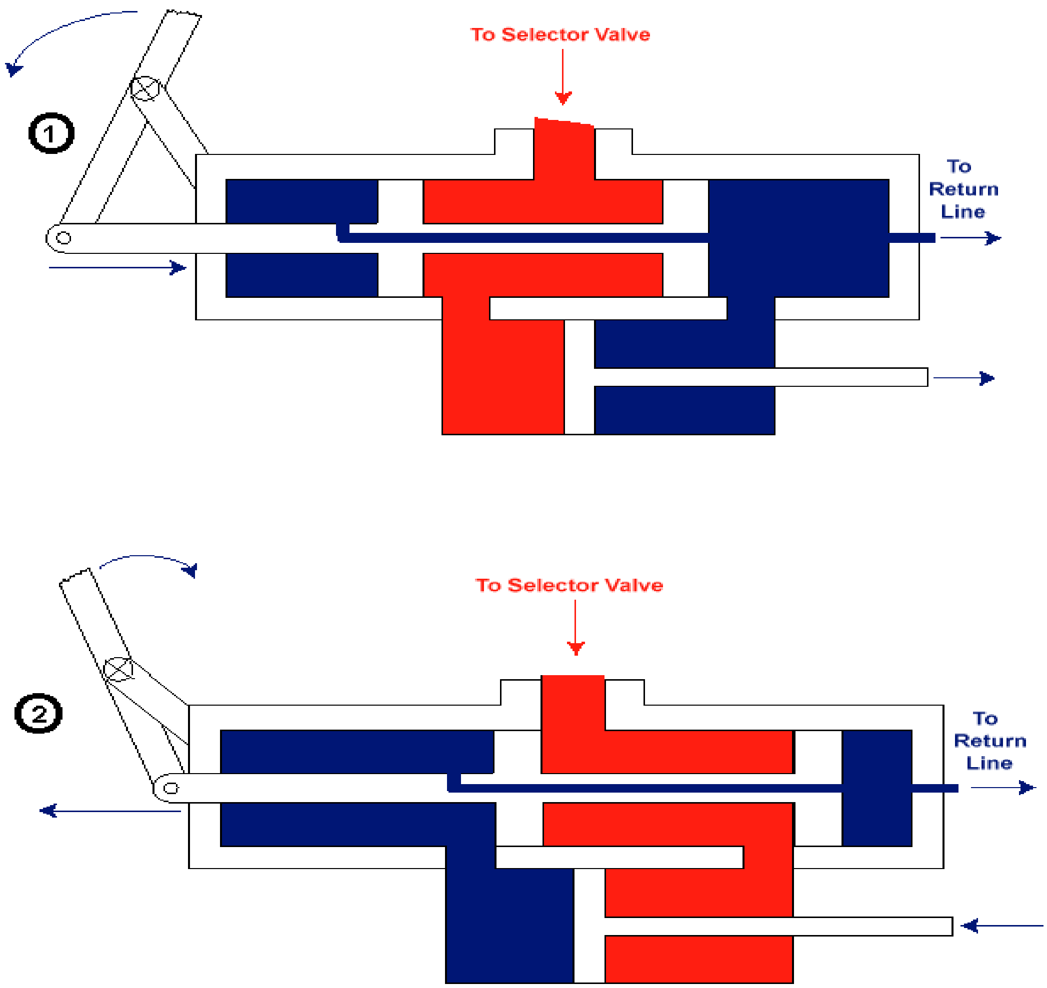
Selector valves are used as (1) directional control devices to insure the movement of the hydraulic fluid flow in the proper direction, and (2) as stop-locks to lock the selector switch in a certain position.

Types

There are two types of selector valves. They are piston type and poppet type.

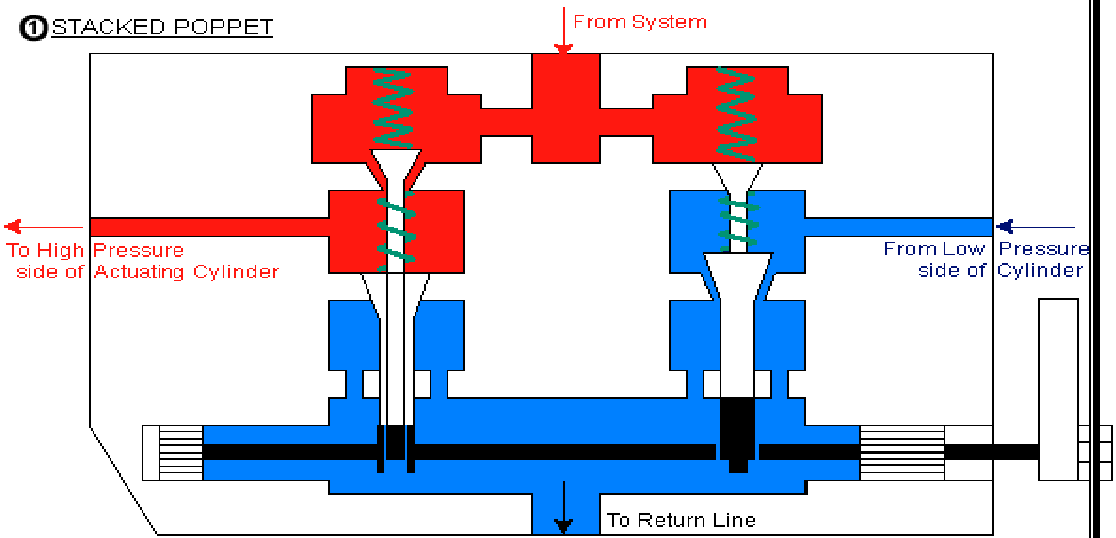
Piston Type

Positions 1, 2 and 3 (shown below) are representative positions for the piston-type selector valve. Position (1) is the position of the selector valve, for example, upon the extension of the landing gear or the lowering of flaps. Position (2) is the position of the selector valve upon retraction of the landing gear or the raising of the flaps. Position (3) is the stop-locking position of this type of valve. This piston type valve uses the Vickers spool mechanism in which the piston "lands" isolate the high pressure oil from the low pressure oil.

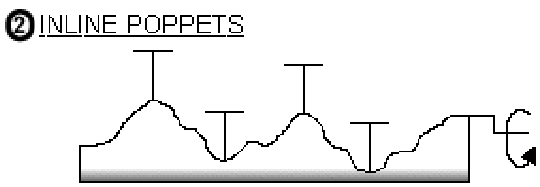


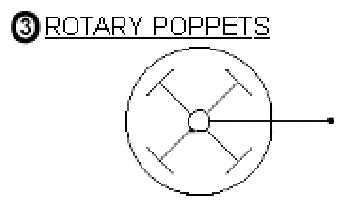
Poppet Type - Stacked Poppet

In this type valve, any movement of the handle (at the lower right of the diagram) changes the camshaft and cam settings, thereby opening and closing the poppet valves and letting high and low pressure oil to the proper sides of the actuating cylinder and return line, respectively.



In in-line poppets, the poppet valves are set up along a cam shaft, in the same manner as for the intake and exhaust valves of a car engine. The camshaft is represented by the "sinusoidal" line in the diagram below. However, the motion of the poppets are controlled by the pilot.





These mechanical type selector valves require a fair amount of tubing. In order to reduce the amount of tubing, electric switches have been used to operate solenoids which operate the selector valves. This has the added advantage of reducing the wasteful motions of pilot. This is type of combined electronic circuits and hydraulic system is called electrohydraulics.

12.Flow Restrictors

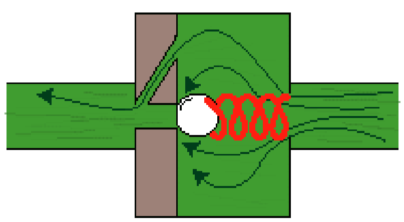
Since the speed of the actuating cylinder is determined by the rate of flow of the hydraulic fluid, we may need a device to control the rate of flow. This device is called a flow restrictor. Since none of the selector valves meter the flow, we must use the restrictor.

There are four types of restrictors:

1. one way fixed restrictor
2. one way variable restrictor
3. two way fixed restrictor
4. two way variable restrictor

The One Way Fixed Restrictor

The One Way Fixed Restrictor is not used all the time, but, it is being used more than the other types of restrictors. It is a check valve type restrictor with a drilled hole through the seat to the other side of the check valve. When the flow pressure seats the check valve ball (i.e., flow moving from right to left), some of the fluid can still reach the other side through the drilled hole in the seat. However, since the hole size is fixed, the amount of fluid passing through the passage to the other side is also fixed.



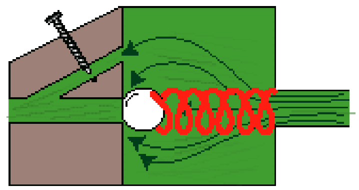
ONE WAY FIXED

The Two Way Fixed Restrictor

The Two Way Fixed Restrictor is not used because it restricts the flow on the side of the restrictor where we want the flow to occur normally. Because the passage size is fixed, the amount of fluid moving from right to left, or vice versa, is fixed, as well.

The One Way Adjustable Restrictor

The One Way Adjustable Restrictor is being used nowadays. It is the same as the One Way Fixed Restrictor but the amount of fluid passed through the drilled opening in the seat is regulated by means of an adjustment screw.



ONE WAY ADJUSTABLE

The Two Way Adjustable Restrictor

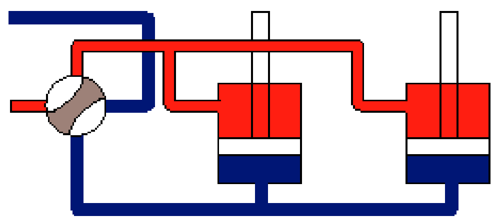
The Two Way Adjustable Restrictor is the same as the Two Way Fixed Restrictor, but it also has an adjustable screw that can be used to further restrict the amount of hydraulic fluid passing through the opening.

13.Synchronizing Circuits

During aircraft turns or maneuvers, if wing air loads on one wing are greater than loads on the other wing, and, we attempt to sweep the wings back or sweep them forward, these motions will occur so unevenly that probable loss of aircraft and pilot will result. Therefore, if we want to synchronize our sweepback motion, we must use devices called flow equalizers.

Another example where flow equalizers are needed is in case of air-to-air missile attack. Suppose our selector valve is set to neutral and we try to get away from a rocket missile by turning right or left. The pressure forces on the wings would be so unequal that the wing actuating cylinder (of the wing undergoing the smaller turn radius) would act as a pump, since its greater pressure loading would cause wing sweepback. The hydraulic fluid would be pushed out of one cylinder and the only path that it could take

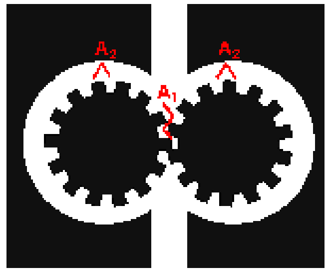
would be to the other wing's actuating cylinder, causing that cylinder's wing to go in the opposite direction to that of the first wing. This would be catastrophic.



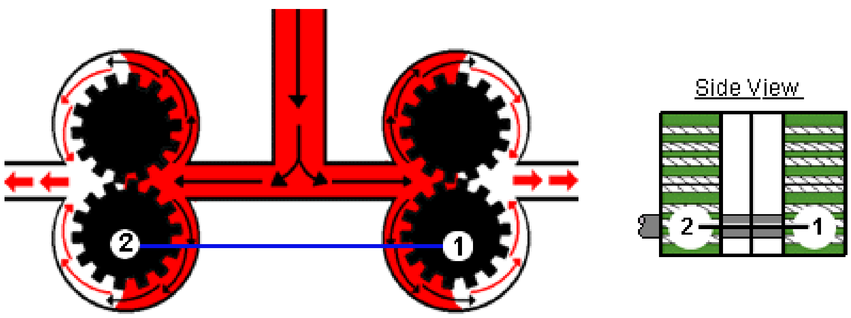
If a downward force is applied to the left piston and the selector valve is closed, the oil is forced into the right cylinder causing the right piston to move up--a motion opposite to what is needed.

Flow Equalizer

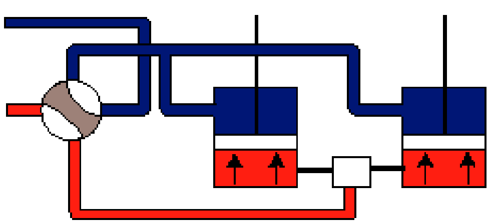
A device that may be used as a flow equalizer is a power pump **that is run in reverse.** If the power pump direction were reversed, the flow would push on the outer teeth of the gear and not on the meshing teeth at the center because the oil can't be compressed. Since fluid moves towards the meshed teeth at the center of the pump (A_1), as well towards teeth closest to pump casing (A_2), and since the fluid pressure acts on twice the teeth area (A_2) than at A_1, the gear direction reverses, as compared to the direction of operation of a power pump.

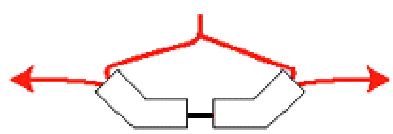


Thus the flow equalizer is made up of two power pumps placed side by side in which the drive gears of both pumps are connected (see the side view for the figure below). The main figure shows the two power pumps of the side view, cut along the side view's centerline and opened like a book. When one drive gear turns (2), it causes the other to turn as well (1) through the connection. Since the volumetric output per revolution is the same for both sides, we have found the right device to keep synchronization.

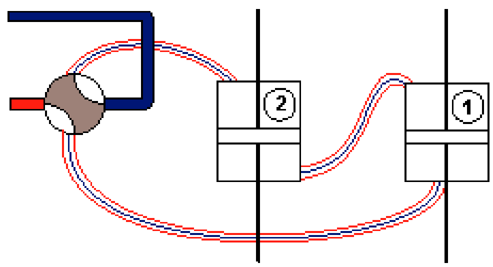


This kind of power pump is set between the two cylinders requiring equalization and would channel the flow to both cylinders (as shown below left). The VICKERS EQUALIZER setup is shown below right, where the VICKERS pumps are connected by a shaft at the center of the diagram. Input is at the top of the pumps and outputs are shown by the arrows.



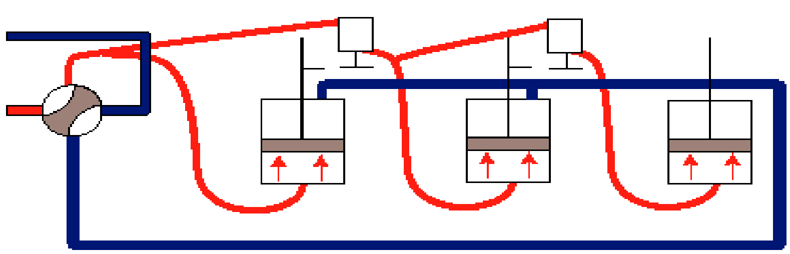


You should never connect the actuation cylinders of the two wings is series, since this type of circuit, for it to work, would require cylinder (1) to put out twice the fluid pressure, or even more, in order to operate itself and cylinder (2) [see the figure below). The hydraulic fluid in this series type of circuit will burst the hydraulic tubing, due to the fluid pressures required to operate both actuating cylinders, and, because this type of circuit does not compensate for expansion or contraction of the hydraulic fluid. The tubing between cylinders and to the selector valve can transmit high pressure hydraulic fluid as well as return line pressure hydraulic fluid.



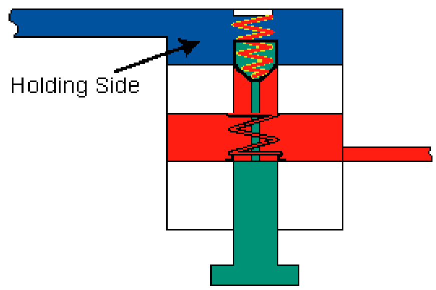
Sequencing Circuits

These circuits are used to cause certain operations to occur in a particular sequence. Sequencing circuits have been used, for example, for the complete ejection of a pilot from the plane. The sequencing valve is such that it sends hydraulic fluid through the valve to the other sequencing valves and actuating cylinders. As the piston rod (of the extreme left cylinder) moves upward, it activates the sequencing valve releasing hydraulic fluid to the next cylinder.

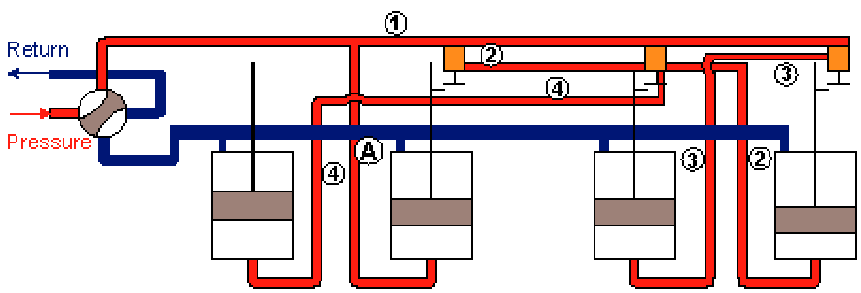


Sequencing Valve Operation

As the actuating cylinder piston moves upward, it hits the rod of the sequencing valve (shown in bottom). The rod, in turn, moves up into the sequencing valve pushing the poppet up and releases the hydraulic fluid from the holding side (top) to the releasing side (middle), permitting it to go to the next cylinder and sequencing valve.

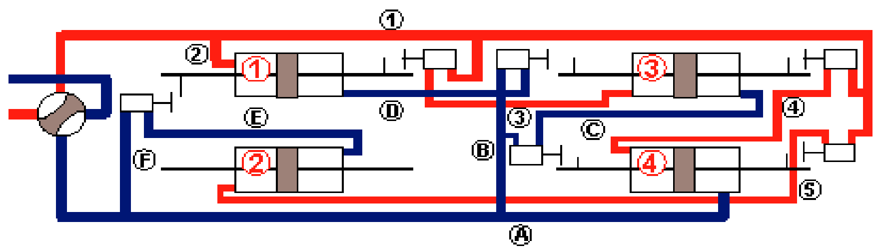


In the diagram below, the system is set so that the sequence of actuation is 2,4,3,1.



Double Sequence

We can design a system so that it can perform a double sequence of actuations. In the diagram below, the system is set so that when the selector valve is open to the "red" side, the sequence of events from left to right is 1,3,4,2 (cylinder numbers in red). When the selector valve is open to the "blue" side, the sequence of events goes from right to left and is 4,3,1,2.



By proper connection of the sequencing valves and actuating cylinders, any sequence of events can be made to occur.

14.Actuation Cylinders

The function of the actuating cylinder is to take the pressure and hydraulic fluid flow and change them into either linear or rotary motion. The ones that have been employed more commonly are the double action actuating cylinders, because they work in both directions.

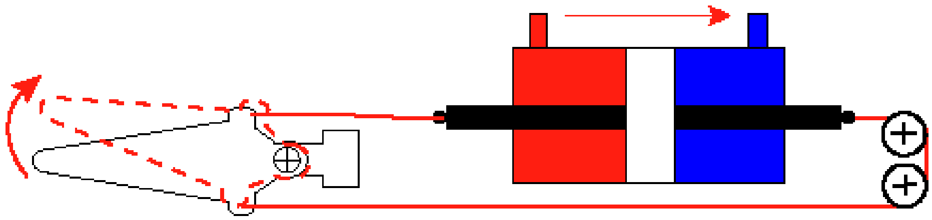
A. Single Piston, Single Rod

This type of actuating cylinder has one piston connected to one rod. Such a device requires the piston rod to move into the actuating cylinder to cause one motion to occur and to move out of the cylinder to cause the reverse motion to occur.

B. Single Piston, Double Rod

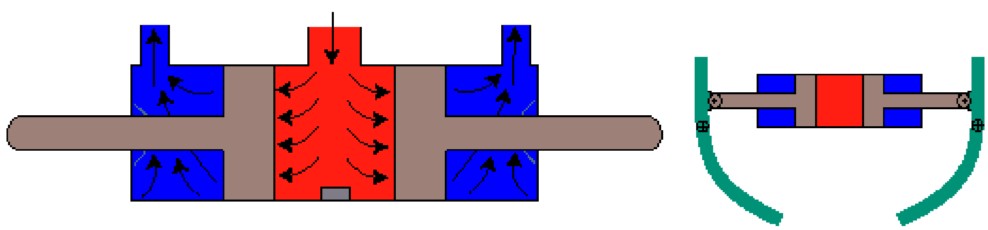
This is an equal displacement cylinder and could be used on an aileron system or an automatic guidance system .

The piston ends can be attached to a pulley system that can pivot a control surface. The motion of the piston to the right, due to high pressure fluid in the left side of the actuating cylinder, can be activate the pulley system and pivot the control surface upward. By reversing the flow, the opposite motion will occur.



C. Double Piston, Double Rod

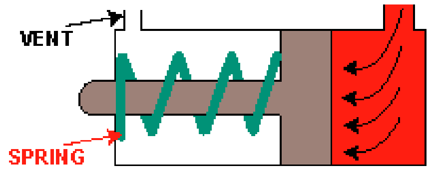
This type of actuating cylinder would be used on bomb bay doors (figure shown below right). High pressure fluid enters the center section of the cylinder, acting on the two pistons simultaneously. The rods would be extended outward, causing the doors to rotate open. When the high pressure fluid enters the two end sections, this operation is reversed, closing the bomb bay doors.

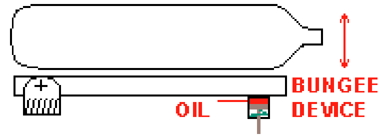


Single Action Cylinders

Bungee Type- this type of actuating cylinder is used where gravity or weight can act as high pressure oil. Either a rubber mass or a spring loading device counteracts the weight. Its disadvantages include:

1. The decrease in piston stroke on account of weight and size of spring or inserted rubber mass;
2. The fact that oil on the spring side of the piston must move both the piston and the spring;
3. The size and weight of the spring to do the job might be too great.

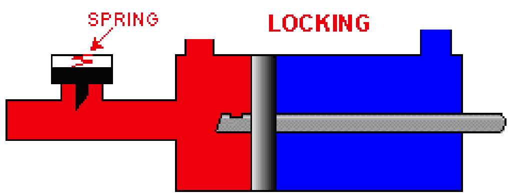




Locking Cylinder

The locking cylinder is a cylinder which has a locking device attached to it. This cylinder is a "fail-safe" design so that it will not actuate beyond some given point.

- The locking cylinder is part of the *Fail-safe design philosophy*: if the cylinder is malfunctioning, it should fail in a position that is safe for the rest of the flight.

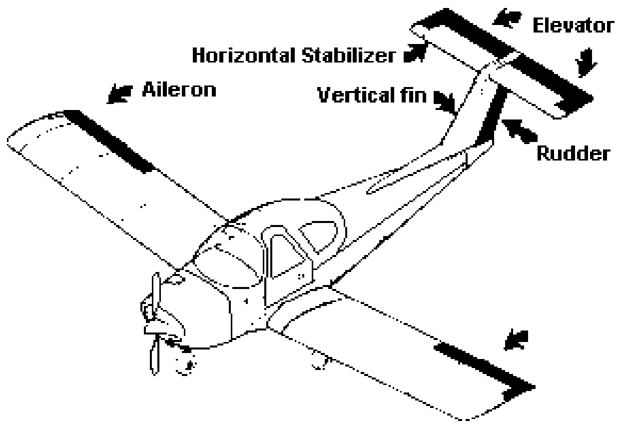


Stationary Piston-Moveable Cylinder

Whenever we don't want the piston rod to extend into an environment that can damage the rod or contaminate the hydraulic fluid (for example, a stream of sea spray or in the path of little pebbles when landing or taking off from a rough airstrip), we make the piston cylinder extend instead of the piston rod. The type of cylinder we use is the stationary piston moveable cylinder.

15.CONCLUSION

Real planes have segments called ailerons inserted in the wings and segments called rudders and elevators inserted respectively in the vertical fin and horizontal stabilizer. The pilot controls their position from the airplane cockpit. When the pilot moves them into the air-stream, they cause the plane to react to air pressure. The pilot uses them to go right or left and also up and down.



Hydraulic systems determine flight worthiness, usability and reliabity

Advantages of Hydraulic Systems Over Other Systems

1. It is lighter in weight than alternate existing systems.
2. It is dead beat, that is, there is an absence of sloppiness in its response to demands placed on the system.
3. It is reliable; either it works or doesn't.
4. It can be easily maintained.
5. It is not a shock hazard; it is not much of a fire hazard.
6. It can develop practically unlimited force or torque.

The actuating cylinder can change hydraulic power to linear or rotating motion. It has a reduction gear in it to reduce rotating motion to that amount which is needed.

Previously, systems used to control motion by using steel cables connected by pulleys between the controlling mechanism (such as the pedals) and the controlled surface (such as the rudder). The cables were affected by expansion rates of the cables due to temperature changes. Hydraulic systems can control motion without worrying about the effect of temperature since it is a closed system (not open to the atmosphere) compared to a cable system. This means better control of the plane and less lag time between the pilot's movement to control the plane and the response by the control surface.

Usually there are 3 sets of hydraulic systems in a commercial aircraft.

SYSTEM A USES [above 3100 psi]:-

1.PRIMARY FLIGHT CONTROLS [LID][LEFT, INBOARD, DOWN]

2.T/E FLAPS.

3.L/E FLAPS AND SLATS.

4.INBOARD FLIGHT SPOILERS.

5.GROUND SPOILERS.

6.L/G EXTENSION AND RETRACTION.

7.THRUST REVERSER.

8.NOSE WHEEL STEERING.

9.BRAKES [INBOARD].

SYSTEM B USES [below 2800 psi]:-

1.PRIMARY FLIGHT CONTROLS.

2.OUTBOARD FLT SPOILERS.

3.OUTBOARD BRAKES.

STANDBY SYSTEM USES:-

1.STANDBY RUDDER.

2.L/E DEVICES [FLAP + SLAT] EXTENSION OMLY.

3.THRUST REVERSERS.

Hydraulic Fluids

Hydraulic fluids that have been used are of several types: water-based, mineral-based and synthetic type oils. Each has its advantages and disadvantages. Though several types are listed here, newer types of oils are being developed.

A. Water-based MIL-O-7083 type hydraulic fluid has been used in naval aircraft because it is not flammable. However, it is still corrosive. It is a water based lubricant which is chemically treated. Its commerical name is HYDROLUBE
B. Mineral-based petroleum oil MIL-O-5606 has been used by NATO. Old name of this type fluid is AN-VV-O-366. It has a cherry red dye added to it.
C. Synthetic Oils have much appeal. They are non-flammable and work over a wide temperature range. One such synthetic oil is known as Skydroll 500 and it has a purple or green color. It is made from a phosphate-ester base.

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2. **iha@tut.fi.com**
3. WILLIAM NEESE. A. AIRCRAFT HYDRAULIC SYSTEMS, Pearson edu.

ABSTRACT

Hydraulic systems provide a means of remotely controlling a wide range of components by transmitting a force through a confined fluid.

Because hydraulics can transmit high forces rapidly and accurately along lightweight pipes of any size, shape and length, they are the prime source of power in aircraft systems such as flying controls, flaps, retractable undercarriages and wheel brakes.

Modern aircrafts include many different types of subsystems. These subsystems are very closely interlinked to each other. One of these subsystems is hydraulic subsystem, which is usually used for actuating most of the mechanical subsystems, such as landing gear, flight control surfaces, weapons system etc. Thus the hydraulic system is a very essential part of the aircraft and its reliability and functionality are very essential to the flight worthiness of the whole aircraft.

CONTENTS

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JANHARLAL.E.M.