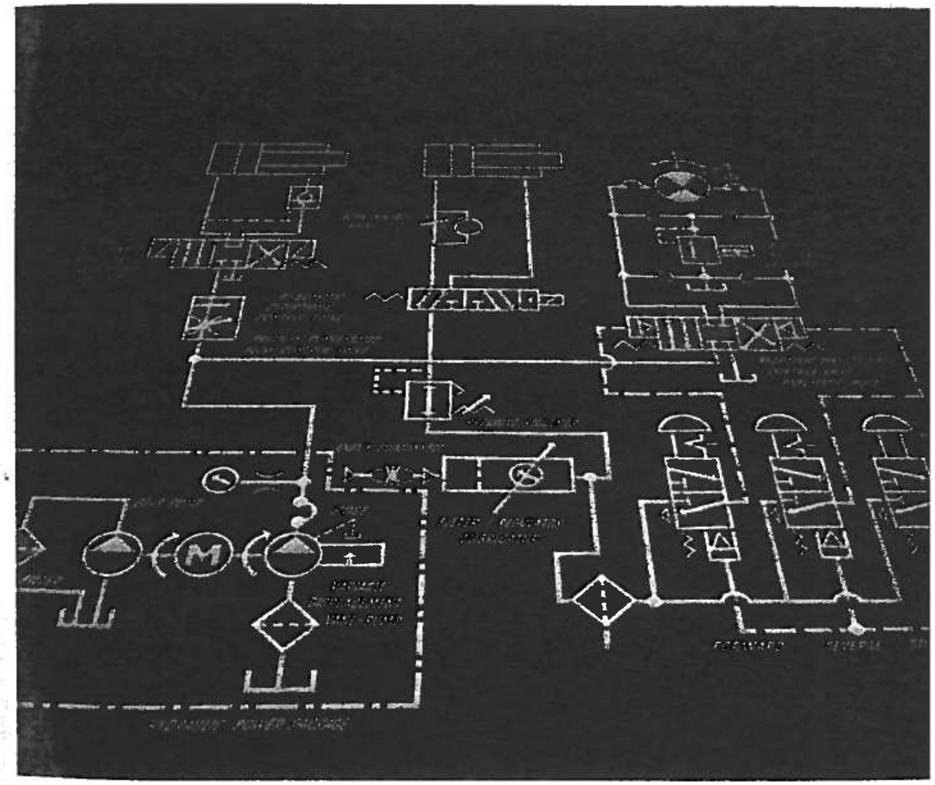
Parker Training

Fluid Power Basics

Bulletin 0239-B1



Fluid Power Basics

Parker

Motion & Control
Training Department

Parker Hannifin Corporation
Motion Control Training Dept. W3MC01
6035 Parkland Blvd.
Cleveland, OH 44124-4141
Tel: (216) 896-2577
Fax: (216) 514-6738
Web site: http://www.parker.com

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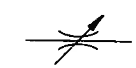
Lesson 9

Flow Control Valves

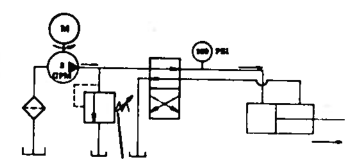
A flow control valve in a fluid power system reduces flow rate to an actuator and consequently slows actuator speed by acting as a restriction.



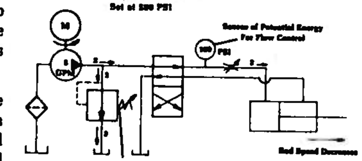
Adjustable Flow Control Valve Symbol

hydraulic control of flow

The function of a flow control valve in a hydraulic system is to reduce a pump's flow rate in its leg of a circuit. It performs its function by being a higher than normal restriction for the system. To overcome the restriction, a positive displacement pump applies a greater pressure to the liquid which causes some of the flow to take another path. This path is usually over a relief valve, but may be to another leg of a system.



In the circuit illustrated, a 5 GPM pump applies to the liquid whatever pressure is necessary to get its flow out into the system. If there is no load at the cylinder, this pressure energy will be changed into heat because of a liquid's viscosity, friction, and changing direction.



If a flow control valve which restricted pump flow were placed in the circuit, the pump would still attempt to push its total volume through the valve. When the pressure ahead of the valve reached relief valve setting, some flow would be diverted over the relief valve. The rate of flow through the flow control valve at that time will be something less than 5 GPM, yet the pressure ahead of the flow control will be up to the relief valve setting. (In the example circuits used in this section, we will assume that the pressure differential through a directional valve and any associated piping is zero.) As far as the flow control valve is concerned, this increased pressure is a source of potential energy which it changes into kinetic energy (rate of flow). The degree to which this happens is dependent on the flow control's orifice.

Orifice

Orifice Symbol

orifice

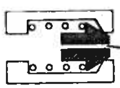
An orifice is a relatively small opening in a fluid's flow path. Flow through an orifice is affected by three factors:

1. size of the orifice
2. pressure differential across the orifice
3. temperature of the fluid

orifice size affects flow

The size of an orifice controls the flow rate through the orifice. A common, everyday example of this is a garden hose which has sprung a leak. If the hole in the hose is small, the leak will be in the form of a drip or spray. But, if the hole is relatively large, the leak will be a stream. In either case, the hole in the hose is an orifice which meters a flow of water to the surrounding outside area. The amount of flow which is metered depends on the size of the opening.

fixed orifice



Drilled Hole

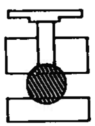
Check Valve

A fixed orifice is a reduced opening of an unadjustable size. Common examples of fixed orifices used in hydraulics are a pipe plug or check valve with a hole drilled through its center, or a commercial, factory preset flow control valve.

variable orifice

Many times, a variable orifice is more desirable than a fixed orifice because of its degree of flexibility. Ball valves, globe valves, and needle valves are examples of variable orifices.

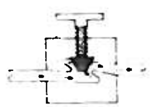
ball valve



Ball Valve

A ball valve has a flow path straight through its center. The size of the orifice is changed by turning the handle which positions a ball with a cross drilled hole across the fluid path.

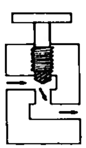
globe valve



Globe Valve

A globe valve does not have a straight-through flow path. Instead, the fluid must bend 90° and pass through an opening which is the seat of a plug or globe. The size of the opening is changed by positioning the globe.

needle valve



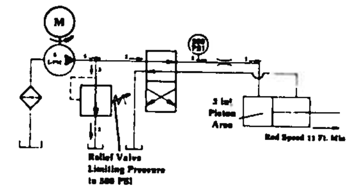
Needle Valve

The fluid going through a needle valve must turn 90° and pass through an opening which is the seat for a rod with a cone-shaped tip. The size of the opening is changed by the positioning of the cone in relation to its seat. The orifice size can be changed very gradually because of fine threads on the valve stem and the shape of the cone.

A needle valve is the most frequently used variable orifice in an industrial hydraulic system.

orifice in a circuit

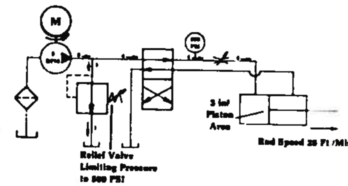
The circuit illustrated consists of a 5 GPM positive displacement pump, relief valve, directional valve, a fixed orifice, and a cylinder which has a piston area of 3 in².



With the relief valve set at 500 PSI, the pump attempts to push its 5 GPM flow through the orifice. Because of the size of the orifice opening, only 2 GPM passes through the orifice before the pressure reaches the relief valve setting of 500 PSI. (This of course, happens instantly.) Two GPM passes through the orifice and out to the actuator. Three GPM goes over the relief valve. The piston rod moves at the rate of 11 ft./min.

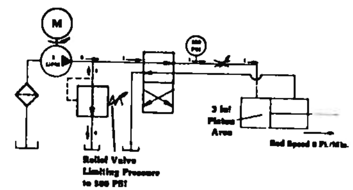
$$\underset{\text{(ft./min.)}}{\text{rod speed}} = \frac{\text{GPM} \times 19.25}{\text{piston area (in}^2\text{)}}$$

If a needle valve were used in the same circuit, the speed of the rod could be easily changed.



needle valve orifice increased

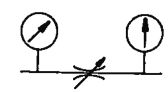
Turning the knob out and opening the needle valve orifice allows more flow to pass through the valve and out to the cylinder before the relief valve setting is reached. Rod speed increases.



needle valve orifice decreased

Turning the knob in and decreasing the needle valve orifice allows less flow to pass through the needle valve before the 500 PSI relief setting is reached. Rod speed decreases since the cylinder receives less flow.

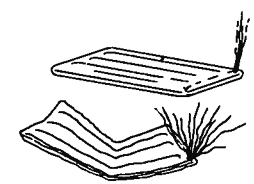
pressure differential affects flow



As we changed the size of the needle valve orifice in the circuits just described, the pressure differential across the orifice was 500 PSI. Pressure ahead of the orifice was at the relief valve setting of 500 PSI. Pressure after the orifice was the work-load pressure. Since the cylinder pushed against no load, we assumed this pressure to be zero. In each case then, the total 500 PSI ahead of the orifice was used to develop a flow through the orifice.

Flow through an orifice is affected by pressure differential. Since pressure in a hydraulic system is potential energy, the greater the difference in pressure across the orifice, the more flow will be developed.

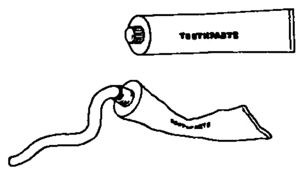
examples from everyday life



After a day at the beach or camping in the woods, a plug is removed from an air mattress so air can escape.

If air is allowed to escape by itself, the mattress takes a while to collapse because the pressure differential is small.

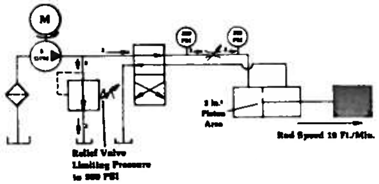
If the mattress were squeezed, air comes rushing out. Squeezing results in the development of a higher pressure inside the mattress. Pressure differential from within the



mattress to the atmosphere has increased. The harder the mattress is squeezed, the more pressure is developed, and the larger the rate of air flow.

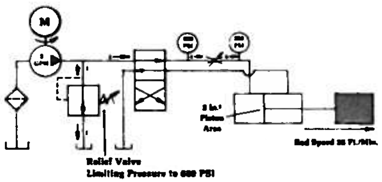
Gently squeezing a full tube of toothpaste results in a small amount of toothpaste on the toothbrush.

If a full tube of toothpaste were lying on the floor with the cap off and were accidently stepped on, a large amount of toothpaste would be on the floor. Pressure differential from within the tube to the atmosphere is greater when the tube is stepped on than when it is squeezed.



needle valves in a circuit affected by pressure differential

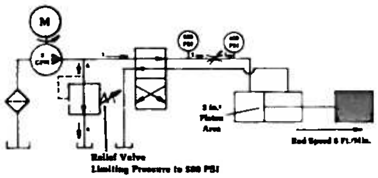
In the circuit illustrated, the needle valve is adjusted to restrict the 5 GPM pump flow. Relief valve is set at 500 PSI. Pressure ahead of the needle valve is the 500 PSI relief valve setting. The pressure required to overcome the resistance of the work load is 200 PSI. 200 PSI of the 500 PSI ahead of the needle valve is used to overcome the resistance of the load. The remaining 300 PSI is used to develop a fluid flow through the needle valve. In this particular instance, the 300 psi pressure differential across the needle valve results in a flow of 3 GPM and a rod speed of 19 ft./min. Two GPM returns to tank through the relief valve.



relief valve setting increased

With the work-load pressure and the setting of the needle valve remaining the same, relief valve setting is increased to 600 PSI.

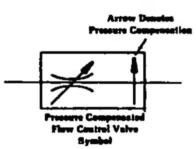
Now 600 PSI is the pressure ahead of the needle valve. 200 PSI of the 600 PSI is used to overcome the resistance of the load. The resulting 400 PSI pressure differential develops a flow of 4 GPM through the needle valve. One GPM passes over the relief valve. Rod speed increases to 26 ft./min.



work-load pressure increased

With the relief valve setting again at 500 PSI and with the same needle valve adjustment, work-load pressure has increased to 400 PSI because of a larger load. 500 PSI is the pressure ahead of the needle valve. 400 PSI of the 500 PSI is used to overcome the resistance of the load. The remaining 100 PSI develops a 1 GPM flow through the needle valve. Four GPM is dumped over the relief valve. Rod speed decreases to 6 ft./min.

The greater the pressure differential across the needle valve, the larger the flow rate through the valve.



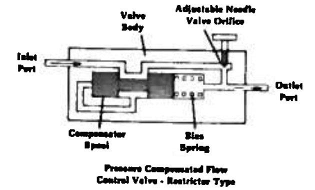
Pressure Compensated Flow Control Valve Symbol

pressure compensated flow control valve

As can be seen from the previous examples, any change in pressure ahead or after a metering orifice affects the flow through the orifice resulting in a change of actuator speed. These pressure changes must be neutralized, or compensated for, before an orifice can precisely meter fluid.

Needle valves are designated non-compensated flow control valves. They are good metering devices as long as pressure differential across the valve remains constant. If more precise metering is required, a pressure compensated flow control valve is used; that is, a flow control which makes allowances for pressure changes ahead or after the orifice.

In industrial systems, restrictor type pressure compensated flow control valves are the most common.



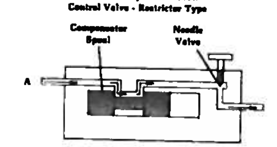
Pressure Compensated Flow Control Valve - Restrictor Type

what a restrictor type pressure compensated flow control valve consists of

A restrictor type pressure compensated flow control valve consists of a valve body with inlet and outlet ports, a needle valve, a compensator spool, and a spring which biases the spool.

how a restrictor type pressure compensated flow control valve works

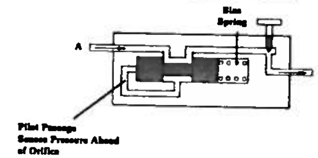
To determine how a restrictor type valve works, we will examine its operation step by step.



With the compensator spool fully shifted toward side A, any pressurized fluid flow entering the inlet port will arrive at the needle valve.

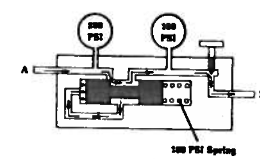
With the spool shifted slightly toward side B, pressurized fluid flow is blocked through the valve.

To keep the flow path through the valve open, a spring biases the compensator spool toward side A.

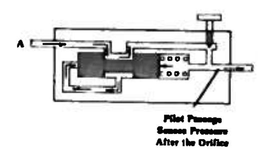


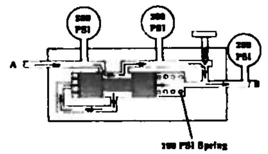
Pressure ahead of the needle valve is sensed at the A side of the spool by means of an internal pilot passage. When fluid pressure at this point tries to become more than the pressure of the spring, the spool will move toward side B.

With the needle valve orifice adjusted for something less than pump flow, pressure ahead of the needle valve wants to climb to the relief valve setting. When the pressure attempts to rise above the value of the compensator spring, the spool moves and restricts flow to the needle valve. As the fluid passes over this restriction, all of the pressure energy in excess of the value of the spring is turned into heat. For example, if the spring had a value of 100 PSI and the relief valve were set at 500 PSI, fluid pressure at the valve's inlet will be 500 PSI. But, the compensator spool reduces the pressure before it gets to the needle valve by transforming 400 PSI into heat energy as the fluid passes through the restriction. This means that regardless of what the pressure is at the flow control inlet, the pressure ahead of the needle valve to develop flow will always be 100 PSI.



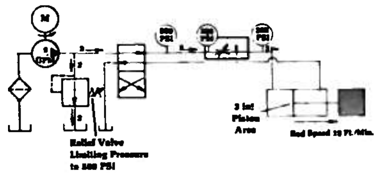
As we have seen from previous circuits using needle valves, controlling pressure ahead of an orifice is only half the battle. A fluctuation in pressure after the orifice must also be compensated for. In other words, a constant pressure differential is required. To accomplish this, a pilot passage which senses pressure downstream from the needle valve is directed to the bias spring chamber. Now two pressures bias the spool toward side A—spring pressure and fluid pressure after the needle valve.





If the spring has a value of 100 PSI, fluid pressure ahead of the orifice would be limited to 100 PSI above the pressure after the orifice. As long as the relief valve is set high enough, the pressure differential across the needle valve orifice will always be the value of the spring which in this case is 100 PSI. In this way, the same amount of pressure is available to develop a flow through the orifice regardless of pressure fluctuations.

restrictor type pressure compensated flow control valves in a circuit

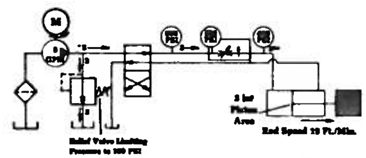


In the circuit illustrated, the restrictor type pressure compensated flow control valve is set for 3 GPM. Relief valve setting is 500 PSI. Work-load pressure is 200 PSI. The spring biasing the compensator spool has a value of 100 PSI.

During system operation, the work-load pressure of 200 PSI, plus the 100 PSI spring, bias the compensator spool.

The pump attempts to push its total flow of 5 GPM through the needle valve orifice. When pressure ahead of the needle valve reaches 300 PSI, the compensator spool moves and causes a restriction for the incoming fluid. The pressure at the flow control inlet rises to the relief valve setting of 500 PSI. As the fluid passes over the restriction made by the compensator spool, 200 PSI of the 500 PSI is transformed into heat. The pressure ahead of the needle valve is limited to 300 PSI. Of this 300 PSI, 200 PSI is used to overcome the resistance of the load; 100 PSI is used to develop a flow rate through the needle valve orifice. The flow rate in this case is 3 GPM. The remaining 2 GPM is dumped over the relief valve.

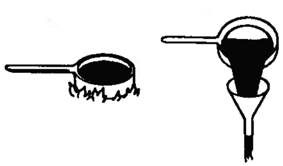
work-load pressure and relief valve setting increased



If the work-load pressure were increased to 400 PSI, or if the relief valve setting were reset to 600 PSI, 100 PSI would still be available to develop a flow rate through the needle valve. As long as the relief valve setting is 100 PSI higher than the work-load pressure, or in other words high enough to operate the compensator spool, a constant rate of flow of 3 GPM will be delivered to the cylinder.

temperature affects flow

So far, it has been shown that flow through an orifice is affected by the size of the orifice and the pressure differential across the orifice. Flow through an orifice is also affected by temperature which changes a liquid's viscosity.

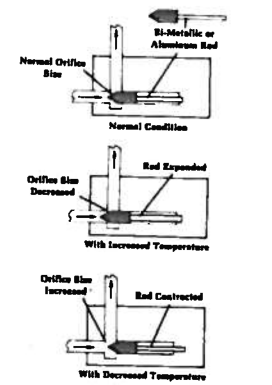


For example, pouring a viscous liquid like cold molasses from a sauce pan, through a funnel is a time-consuming job. Heating the sauce pan results in the molasses flowing readily through the funnel. Rate of flow through the funnel increases because heating reduces a liquid's viscosity.

Just like any mechanical, electrical, or pneumatic system, hydraulic systems are not 100% efficient. While in operation this inefficiency shows up in the form of heat which reduces a liquid's viscosity. Like heated molasses, the fluid flows more readily through an orifice. If the pressure differential across a metering orifice and the size of an orifice are kept constant,

the flow rate through the orifice and to the actuator will increase with a rise in temperature. If precise actuator speed is necessary, a change in temperature must be compensated for.

temperature compensation with a metal rod



One method of temperature compensation is the use of a bi-metallic or aluminum rod. The rod is attached to the movable section of a variable orifice and controls the size of the orifice with a change in temperature.

how temperature compensation with a metal rod works

The flow rate through an orifice tends to become greater as temperature increases. The heat expands the rod which pushes the movable section of the orifice toward its seat, decreasing the opening. The flow rate for the heated fluid through the smaller orifice is the same as the flow rate through the normal orifice before heating. Consequently, flow rate is not affected by an increase in temperature.

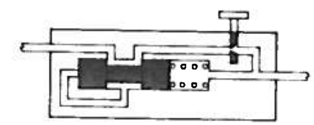
If temperature is decreased, flow rate tends to become less. The decreased temperature causes the rod to contract which pulls the movable section away from its seat, increasing the opening.

The flow rate for the cooled fluid with the larger orifice is the same as the flow rate through the normal orifice before it was cooled. Therefore, flow is not affected by a decrease in temperature.

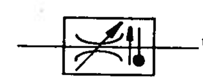
temperature compensation with a sharp edge orifice

Laboratory experiment has shown that when liquid passes through a properly shaped orifice with a sharp edge, rate of flow is not affected by temperature. The manner in which liquid is sheared, while moving across a sharp edge, is of such a character that it actually cancels out or neutralizes the effect of a fluid's viscosity. The reason this occurs is not clearly understood but its effect results in very accurate control.

temperature-pressure compensated flow control valve

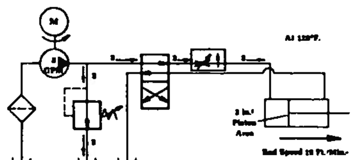


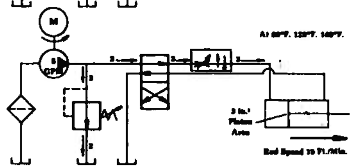
Temperature compensation using a sharp edge orifice is a non-moving type compensation which disregards the effects of temperature over a given range. It is very difficult to design and manufacture an orifice of this type because the characteristics of the orifice must fall within certain mathematical boundaries and the orifice must be precision machined and held to very close tolerances. Most manufacturers of temperature compensated flow control valves use a sharp edge orifice.



temperature-pressure compensated flow control valve in a circuit

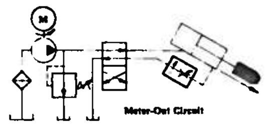
In the circuit illustrated, a pressure compensated flow control valve will control the operating speed of the cylinder



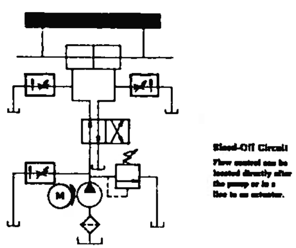


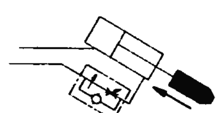

Meter-In Circuit W/Restrictor PC Flow Control

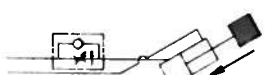
Relief Valve Actuated


Meter-Out Circuit

Relief Valve Actuated


Bleed-Off Circuit


Meter-Out Circuit


Meter-In Circuit

effectively as long as the temperature remains at a constant 120°F.

The operating temperature of industrial hydraulic systems may range from 80°F in the morning to 140°F in the afternoon. As a result the operating speed of the actuator changes over the course of the day.

If the speed of an actuator must be precise throughout the workday, a temperature-pressure compensated flow control could be used.

meter-in circuit

Up to this time, when the operation of a particular flow control was described in a circuit, the flow control was positioned in the circuit directly before the actuator whose speed it was controlling. In this arrangement, all the flow is measured as it enters the actuator. This is termed a meter-in circuit.

A meter-in circuit is used to control the speed of an actuator which works against a positive load. In other words, while the orifice is metering fluid to an actuator, the work-load pressure is continuously a positive value. An example of a constant load would be any load which is vertically lifted.

meter-out circuit

In some cases, the work load changes direction (load passing over the center point of an arc) or the work load pressure suddenly changes from full to zero pressure (drill breaking through stock). This causes the load to run away.

A flow control valve placed at the outlet port of an actuator controls the rate of flow exiting the actuator. This is a meter-out circuit and gives positive speed control to actuators used in drilling, sawing, boring, and dumping operations. A meter-out circuit is a very popular industrial hydraulic flow control circuit.

bleed-off circuit

Another type of flow control circuit is the bleed-off circuit. In this circuit, the flow control valve does not cause an additional resistance for the pump. It operates by bleeding-off to tank a portion of the pump's flow at the existing system pressure.

A bleed-off circuit can be used in any application where precision flow regulation is not required; and where the load offers a constant resistance as in reciprocating grinding tables, honing operations, and vertically lifting a load.

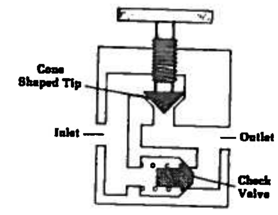
reverse flow through a flow control valve

In the examples seen so far, flow to an actuator was described as being controlled in one direction only. But cylinders and motors usually work in two directions. It is often not required, and even undesirable, to reduce the speed of an actuator in the opposite direction.

To bypass a flow control valve when retracting a cylinder or reversing a hydraulic motor, a check valve is used.

- **For additional information concerning hydraulic flow control valves, see Parker-Hannifin Design Engineers Handbook.**

pneumatic flow control valve



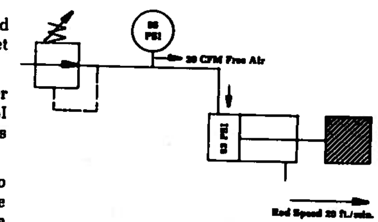
Pneumatic Flow Control Valve

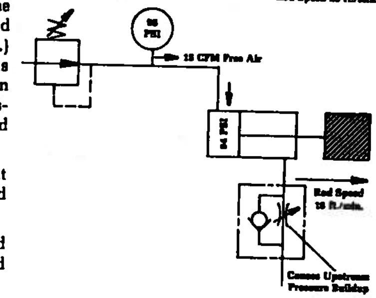
The most common type of flow control valve found in a pneumatic system is a needle valve with a bypass check.

Air passing through a needle valve must turn 90° and pass through an opening which is the seat for a rod with a cone-shaped tip. Size of the opening is changed by the positioning of the cone in relation to its seat. Orifice size can be changed very gradually because of fine threads on the valve stem and the shape of the cone.

A needle valve flow control is equipped with a check valve for reverse free flow.

pneumatic control of flow





Speed at which a pneumatic actuator does work is determined by how quickly the actuator can be filled with air at its inlet and exhausted of air at its outlet.

We have seen that a pressure regulator will influence actuator speed by portioning out to its leg of a circuit a few more PSI than just to equal the load resistances at an actuator. This additional pressure is used to develop air flow.

In the circuit illustrated, an actuator requires 93 PSI to overcome load resistances. (Load resistances in this case are a combination of the resistance offered by an object at the point of work plus the resistance offered by the trapped compressed air to exhaust from the rod side of the cylinder.) A regulator positioned upstream, portions out 95 PSI to its leg of the circuit. 93 PSI of the regulator pressure is used in overcoming load resistances. The remaining 2 PSI is transformed into a 20 CFM flow of free air. The cylinder rod speed is 20 feet per minute.

If a flow control were used in a meter-out application, that is, flow is restricted as air is exhausted, rod speed could be reduced.

In restricting exhaust air, a pressure buildup occurs in the rod side of the cylinder. This adds to the load resistance and results in less pressure available to develop flow.

From the circuit illustrated, it can be seen that with a needle valve restricting exhaust flow a pressure buildup occurs upstream. This pressure resists the outward movement of the cylinder and results in 94 PSI of the 95 PSI being used to overcome load resistances. The remaining 1 PSI develops less of a flow rate causing a decreased rod speed.

- **For additional information concerning pneumatic flow control valves, see Parker-Hannifin Design Engineers Handbook, Section g.**
- **For additional information concerning the rod speed of a pneumatic cylinder, see Parker-Hannifin Design Engineers Handbook, Section b.**

lesson review

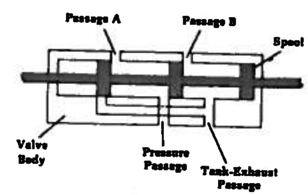
In this lesson dealing with flow control valves we have seen that:

- Speed of a hydraulic actuator is the direct result of the GPM flowing into the actuator.
- Speed of a pneumatic actuator is determined by how quickly it can be filled with air at its inlet and exhausted of air at its outlet.
- Flow control valves in a fluid power system reduce flow rate to an actuator and consequently retard actuator speed by acting as a restriction.
- In a hydraulic system, the higher pressure applied by a positive displacement pump to the liquid causes excess flow to take another flow path which is usually over a relief valve.
- Flow control valves control flow by means of an orifice.
- Flow through an orifice is affected by the size of the orifice, pressure differential across the orifice, and temperature of the fluid.
- The larger the size of an orifice, the greater the flow rate through the orifice.
- Examples of variable orifices used in hydraulics are ball valves, globe valves, and needle valves.
- The greater the difference in pressure across an orifice, the more flow will be developed.
- The most common type of pressure compensated flow control found in a hydraulic system is the restrictor type flow control.
- In a hydraulic system, flow rate through an orifice and to an actuator will increase with a rise in fluid temperature.
- Temperature compensation is accomplished with a sharp edge orifice or temperature-sensitive metal rod.
- Meter-in flow control circuits control flow to an actuator.
- Meter-out flow control circuits control flow discharging from an actuator.
- Bleed-off flow control circuits take a portion of pump flow and direct it back to tank.
- To bypass a flow control valve, a check valve is used.
- The most common type of flow control valve found in a pneumatic system is a needle valve.
- In restricting air exhausting from an actuator, a flow control valve causes a pressure buildup to occur which adds to the load resistance and results in less pressure available to develop flow.

Lesson 10

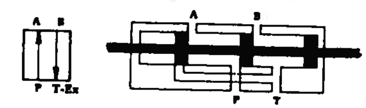
Directional Control Valves

A directional control valve consists of a body with internal flow passages which are connected and disconnected by a movable part. This action results in the control of fluid direction.

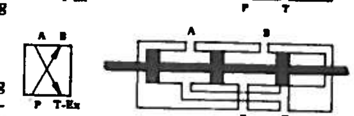


4-way directional valve

The directional valve we have seen earlier in the simple hydraulic system consisted of a pressure passage, two actuator passages, and a tank passage. The directional valve in the simple pneumatic system consisted of a pressure passage, two actuator passages, and an exhaust passage. These valves are known as 4-way valves since they have four distinct passages within the valve body.

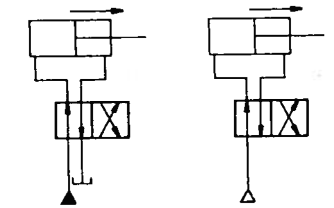


The function of a 4-way directional valve is to cause reversible motion of a cylinder or motor. To perform this function, the spool connects the pressure passage with one actuator passage. At the same time, the spool connects the remaining actuator passage with the tank or exhaust passage.



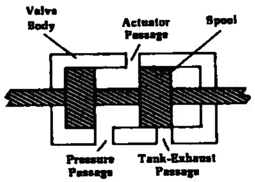
4-way directional valves in a circuit

Since all valves consist of a body and an internal moving part, the moving part of all valves has at least two positions— both extremes. These two positions in a directional valve are depicted by two separate squares. Each square shows by means of arrows how the spool is connecting the passage



within the body in that position. When the valve is shown symbolically, the two squares are connected together. But, when placed in a circuit, one square, and only one square, is connected in the circuit in any one instant. With this arrangement, the condition within the valve is shown while an actuator (cylinder, motor) is moving in one direction. To picture the actuator moving in the opposite direction, the other square of the symbol is mentally slid into the circuit.

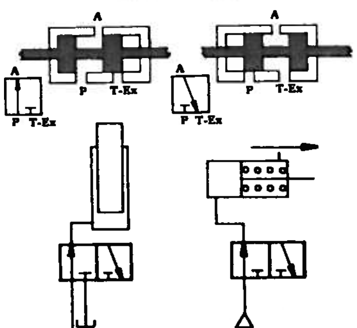
A directional valve symbol, which shows only two spool conditions within a body, is known as a two-position valve.



3-way directional valve

A 3-way directional valve consists of three passages within a valve body—pressure passage, one actuator passage, and tank-exhaust passage.

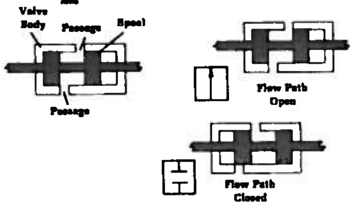
The function of this valve is to pressurize and drain one actuator port. When the spool of a 3-way valve is in one extreme position, pressure passage is connected with the actuator passage. When in the other extreme position, the spool connects actuator passage with tank-exhaust passage.



3-way directional valves in a circuit

A 3-way directional valve is used to operate single-acting actuators like rams and spring-return cylinders. In these applications, a 3-way valve directs pressurized fluid flow to the cap end side of the cylinder. When the spool is shifted to the other extreme position, flow and pressure to the actuator are blocked. At the same time, the actuator passage is connected to the tank-exhaust passage. The actuator is returned by some other method.

Industrial pneumatic systems many times use 3-way directional valves. In industrial hydraulic applications, 3-way valves are not generally found. If a 3-way function is required, a 4-way valve is converted to a 3-way by plugging an actuator port.

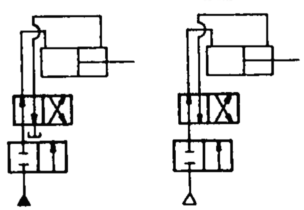


2-way directional valve

A 2-way directional valve consists of two passages which are connected and disconnected. In one extreme spool position, the flow path through the valve is open. In the other extreme, the flow path is blocked.

2-way directional valve in a circuit

A 2-way directional valve gives an on-off function. This function is used in many systems to serve as a safety interlock and to isolate and connect various system parts.

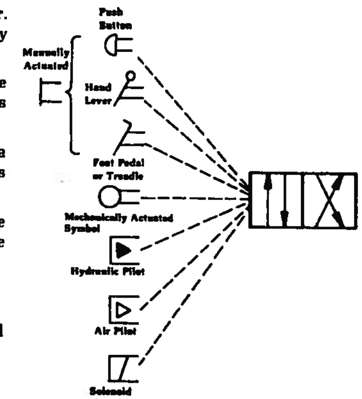


directional valve actuators

We have seen that a directional valve spool can be positioned in one extreme position or the other. The spool is moved to these positions by mechanical, electrical, pneumatic, hydraulic, or human energy.

Directional valves whose spools are moved by muscle power are known as manually operated or manually actuated valves. Various types of manual actuators include levers, push buttons, and pedals.

A very common type of mechanical actuator is a plunger. Equipped with a roller at its top, the plunger is depressed by a cam which is attached to an actuator.



Manual actuators are used on directional valves whose operation must be sequenced and controlled at an operator's discretion.

Mechanical actuation is used when the shifting of a directional valve must occur at the time an actuator reaches a specific position.

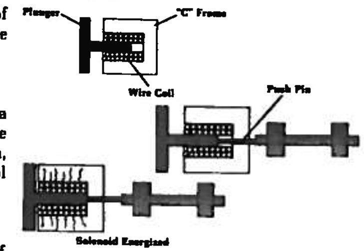
Directional valve spools can also be shifted with fluid pressure either pneumatic or hydraulic. In these valves, pilot pressure is applied to the spool ends or to separate pilot pistons.

solenoid operation

One of the most common ways of operating a directional valve is with a solenoid.

what a solenoid consists of

A solenoid is an electrical device which consists basically of a plunger, "C" frame, and wire coil. The coil is wound inside the "C" frame. The plunger is free to move inside the coil.

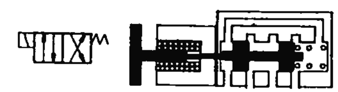


how a solenoid works

When an electric current passes through a coil of wire, a magnetic field is generated. This magnetic field attracts the plunger and pulls it into the coil. As the plunger moves in, it contacts a push pin and moves the directional valve spool to an extreme position.

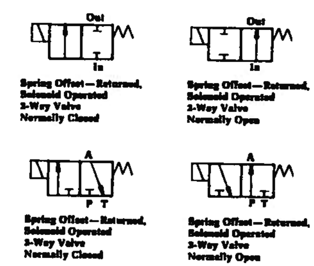
spring offset—spring returned

A two position directional valve generally uses one type of actuator to shift a directional valve spool to an extreme position. The spool is generally returned to its original position by means of a spring. Two position valves of this nature are known as spring offset valves in hydraulic systems and spring returned valves in pneumatic systems.



normally open and normally closed valves

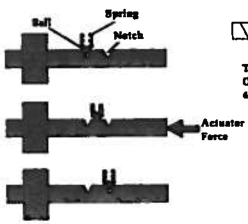
Spring offset-returned 2-way and 3-way valves can be either normally open or normally closed; that is, when the actuator is not energized, fluid flow may or may not pass through the valve. In a two-position 3-way valve, since there is always a passage open through the valve, normally closed usually indicates that the pressure passage is blocked when the valve actuator is not energized.



When spring offset-returned directional valves are shown symbolically in a circuit, the valve is positioned in the circuit to show its normal condition.

detents

If either of two actuators is used to shift the spool of a two positon valve, detents are sometimes used. A detent is a locking device which helps keep a spool in the desired shifted position.



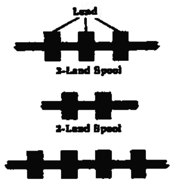
Two Position, Solenoid Operated, Detented, 4-way Directional Valve

In our illustration of a detent, the spool is equipped with notches or grooves. Each notch is a receptacle for a spring-loaded movable part. In the detent illustrated, the movable part is a ball. With the ball in the notch, the spool is held in position. When the spool is shifted, the ball is forced out of one notch and into another notch.

Directional valves which are equipped with detents are found more frequently in pneumatic systems than hydraulic systems.

hydraulic directional valves

Few distinctions have been made between directional valves used in hydraulic systems vs. pneumatic systems. Both types of valves have many similarities, but we would now like to concentrate on some individual characteristics. One of these characteristics in hydraulic valves is the spools.



3-Land Spool

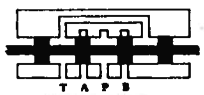
2-Land Spool

4-Land Spool

directional valve spools

The spool in the 4-way directional valve which we have seen consists of a shaft with three skirts spaced apart equally. These skirts are known as lands. And, the spool is identified as a 3-land spool.

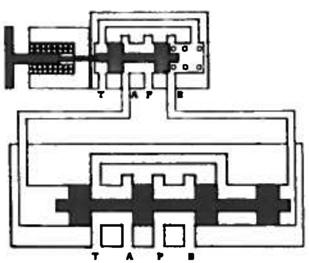
Most industrial hydraulic directional valves have either 2-land or 4-land spools. Directional valves with small flow ratings are generally equipped with 2-land spools, while the 4-land spools are most frequently found in valves with large flow ratings.



Subplate-Mounted 4-Way Body with 4-Land Spool

subplate-mounted 4-way valves

The bodies of the 4-way directional valves which have been illustrated had pump and tank passages situated on one side. The two actuator passages were positioned on the opposite side of the body. This arrangement closely followed the symbol for the valve. But, for ease in installation and servicing, most industrial hydraulic directional valves are subplate mounted; that is, they are bolted to a plate to which system piping is connected. The ports of subplate-mounted valves are located on the bottom surface of the valve body.



Spring Offset, Solenoid Controlled, Pilot Operated, 4-Way Directional Control Valve

solenoid controlled, pilot operated directional valve

One of the most common means of operating a directional valve is with a solenoid. However, a disadvantage is that the shifting force which can be developed by a solenoid of reasonable size, is limited. In large valves, the force required to shift a spool is substantial. As a result, only smaller valves use solenoids for shifting directly. Larger hydraulic directional valves (35 GPM and larger) use pilot pressure for shifting.

In these larger directional valves, many times a small directional valve is positioned on top of the larger valve. Flow and pressure from the small valve is directed to either side of the large valve spool when shifting is required. These valves are designated solenoid controlled, pilot operated directional valves. They are commonly referred to as piggy-back valves.

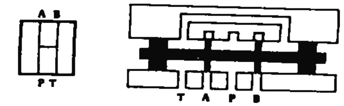
center conditions

In referring to the various possible flow paths available through a directional valve, the flow paths as the spool was in either extreme was considered only. But, there are intermediate spool positions. Four-way directional valves used in the mobile industry very frequently have several intermediate positions between the extremes.

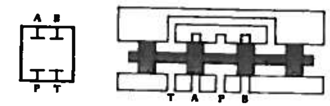
Industrial hydraulic 4-way valves are generally three position valves consisting of two extreme positions and a center position.

The two extreme positions of industrial 4-way directional valve are directly related to an actuator's motion. They are the power positions of the valve. They control the movement of an actuator in one direction and then in the other direction. The center position of a directional valve is designed to satisfy a need or condition of the system. For this reason, a directional valve's center position is commonly referred to as a center condition.

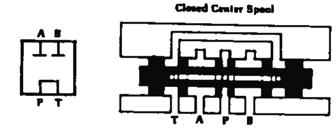
There are a variety of center conditions available with 4-way directional valves. Some of the more popular center conditions are the open center, closed center, tandem center, and float center. These center conditions can be achieved within the same valve body simply by using the appropriate spool.



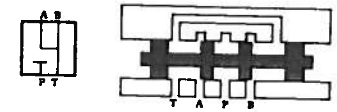
Open Center Spool



Closed Center Spool



Tandem Center Spool



Float Center Spool

open center condition

A directional valve with an open center spool has P, T, A, and B passages all connected to each other in the center position.

An open center allows free movement of an actuator while pump flow is returned to tank at a low pressure.

NOTE: When a three position valve is shown in a circuit, connecting lines are joined to the center block.

closed center condition

A directional valve with a closed center spool has P, T, A, and B passages all blocked in the center position. A closed center stops the motion of an actuator and allows each individual actuator in the system to operate independently from one power supply.

tandem center condition

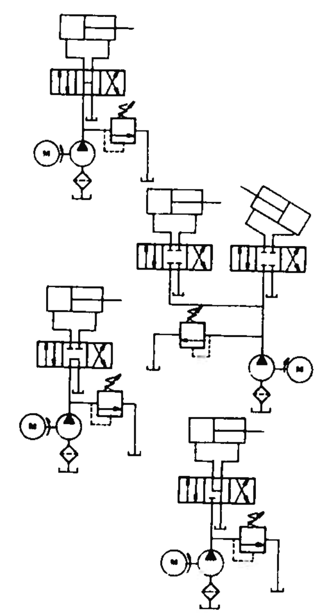
A directional valve with a tandem center spool has P and T passages connected, and A and B passages blocked in the center position.

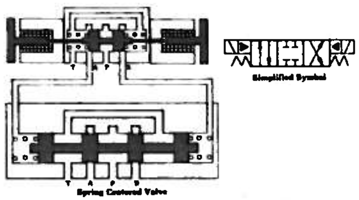
A tandem center condition stops the motion of an actuator, but allows pump flow to return to tank without going over a relief valve.

float center

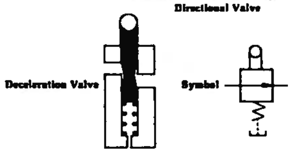
A directional valve with a float center spool has the P passage blocked, and A, B, and T passages connected in the center position.

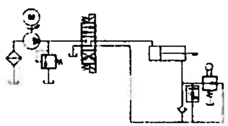
A float center condition allows independent operation of actuators tied to the same power source and allows free movement of each actuator.

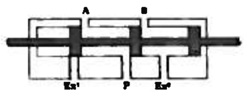




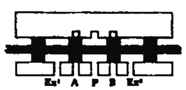
Solenoid Controlled, Pilot Operated Directional Valve

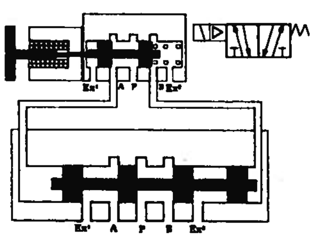






5-Ported, 4-Way Valve





Spring Returned, Solenoid Controlled, Pilot Operated Directional Valve

Exhaust Center

Pressure Center

Blocked Center

spring centering

Directional valves with three positions must have the ability to hold the spool in the center position.

Spring centering is the most common means of centering a directional valve spool. A spring centered valve has a spring located at each end of the valve spool. When the valve is actuated, the spool moves from the center position to one extreme, compressing a spring. When the valve is de-actuated, the spring returns the spool to the center position.

deceleration valve

A deceleration valve is a cam operated two-way valve with a tapered spool.

As a cam depresses the plunger, flow through the valve is gradually cut-off. This valve causes a cylinder rod to be slowed down in mid-stroke where cylinder cushions are not in effect.

The plunger spring chamber is externally drained.

Deceleration valves are frequently used to decrease cylinder speed before going into a work operation.

pneumatic directional valves

Spool type 4-way directional valves used in a pneumatic circuit many times have five ports—pressure port, two actuator ports, and two exhaust ports. The pressure port is connected to system pressure after a regulator. Actuator ports are connected to inlet and outlet ports of a cylinder or motor. Each exhaust port serves an actuator port. A valve of this type is commonly referred to as a 5-ported, 4-way directional valve.

sub-base mounting

Pneumatic directional valves are frequently bolted to a base to which system piping is connected. This is known as sub-base mounting.

Sub-base mounted directional valves afford ease in servicing since existing piping does not have to be disturbed for valve installation or removal.

solenoid controlled, pilot operated directional valve

In large size pneumatic directional valves, shifting of a directional valve spool is performed by pilot pressure from a small solenoid operated directional valve. This type of valve is known as a solenoid controlled, pilot operated directional valve.

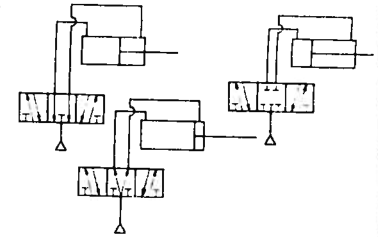
When the small pilot valve is mounted directly on top of the main valve, it is known as a piggy-back valve.

center conditions

In referring to the various possible flow paths available through a pneumatic directional valve, the flow paths as the spool was in either extreme was considered only. These positions are directly related to an actuator's motion. They are the power positions of the valve.

The center position of a directional valve is designed to satisfy a need or condition of the system. For this reason, a directional valve's center position is commonly referred to as a center condition.

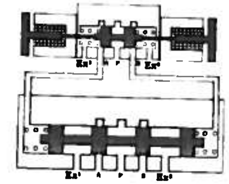
There are primarily three center conditions of 4-way pneumatic directional valves which are commonly in use—exhaust center, pressure center, and blocked center. An exhaust center has pressure passage blocked with actuator passages exhausted. A pressure center has exhaust passages blocked and actuator passages pressurized. A blocked center position has all ports blocked.



spring centering

Directional valves with three positions must have the ability to hold the spool in the center position.

Spring cnetering is a common means of centering a pneumatic directional valve spool. A spring centered valve has a spring located at each end of the directional valve spool. When the valve is actuated, the spool moves from the center position to one extreme, compressing a spring. When the valve is de-actuated, the spring returns the spool to the center position.



Spring Centered Valve

Simplified Symbol

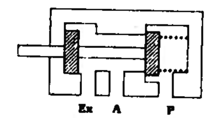
poppet valves

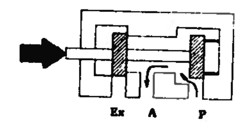
A directional valve basically consists of a body with internal passages which are connected and disconnected by a movable part. The movable part which was described to this point, has been a sliding spool. Another very popular movable part for pneumatic directional valves is a poppet.

Directional valves which employ poppets for their movable part are suited for use where high flows are encountered. Since a poppet opens up a relatively large hole in a short stroke, poppet valves have an inherent characteristic of fast response with minimum wear.

3-way function

A poppet valve can easily function as a 3-way valve, that is, it can alternately pressurize and exhaust one actuator port. The poppet is spring returned and it can be either normally open or normally closed just as any 3-way valve.

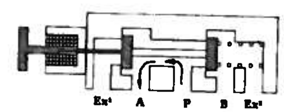


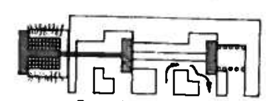


poppet 4-way valve

From the illustration it can be seen that the 4-way poppet valve is actually made up of two 3-way functions. One actuator passage is normally open; the other is normally closed. With solenoid de-energized, compressed air passes from pressure to actuator passage A while passage B is exhausted. When the solenoid is energized, air passes from pressure to actuator passage B. Actuator passage A is exhausted.

Poppet valves can be pilot operated and have the same center conditions as spool valves.





- **For additional information concerning directional control valve operation and troubleshooting, see Parker-Hannifin Design Engineers Handbook, Section c.**

lesson review

In this lesson dealing with directional control valves we have seen that:

- Directional valves can perform a 4-way, 3-way, or 2-way function.
- 4-way directional valves cause a reciprocating motion of a cylinder or motor.
- 3-way valves alternately pressurize and drain one actuator port.
- 2-way valves give an on-off function.
- Directional valves can be operated by mechanical, manual, electrical, or pilot pressure means.
- One of the most common ways of operating a directional valve is with an electrical solenoid.
- Two position directional valves are many times spring offset or spring returned.
- 2-way and 3-way valves can be normally open or normally closed.
- Directional valves can be equipped with detents which help maintain a shifted position.
- The skirts on a directional valve spool are known as lands.
- Many times hydraulic valves are subplate-mounted for ease in installation and servicing.
- Large hydraulic directional valves use pilot pressure for spool shifting.
- Industrial hydraulic 4-way valves are generally three position valves.
- The two extreme positions of a 4-way directional valve are the valve's power positions which are directly related to actuator motion.
- A center position of a directional valve is designed to satisfy a need or condition of the system.
- Open center, closed center, tandem center, and float center are popular center conditions for industrial hydraulic valves.
- Spring centering is a common way of centering hydraulic three position directional valves.
- Deceleration valves cause a load to be slowed down in mid-stroke where cylinder cushions are not in effect.
- Pneumatic 4-way directional valves are many times 5-ported.
- Pneumatic directional valves are commonly sub-base mounted.
- Larger size pneumatic directional valves are pilot operated.
- There are primarily three center conditions of pneumatic directional valves—blocked center, pressure center, exhaust center.
- Spring centering is a common way of centering pneumatic three position directional valves.
- Besides a spool, another very popular movable part for a pneumatic directional valve is a poppet.

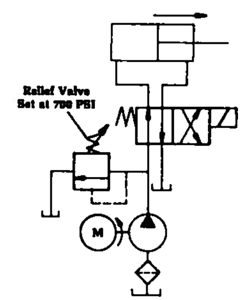
Lesson 11

Simple Pressure Control Valves

In this lesson, we will concentrate on simple pressure control valves. A simple pressure control is a pressure valve which has its movable part biased by spring pressure only.

hydraulic pressure control valves

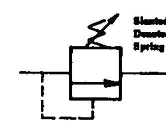
As we have seen, maximum system pressure can be controlled with the use of a normally closed pressure valve. With the primary port of the valve connected to system pressure and the secondary port connected to tank, the spool in the valve body is actuated by a predetermined pressure level at which point primary and secondary passages are connected, diverting flow to tank. This type of normally closed pressure control is known as a relief valve.



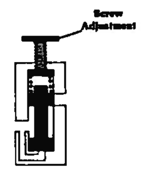
In the circuit illustrated, the relief valve is set at 700 PSI. When the cylinder reaches the end of its stroke, pump pressure will increase to the 700 PSI set pressure at which time the relief valve will be opened. Flow will return to tank through the valve as long as 700 PSI is maintained in the system. If pressure drops, the valve closes.

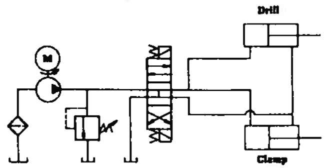
pressure adjustment

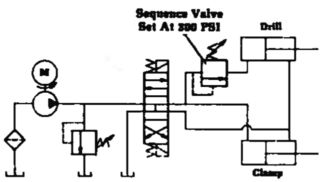
In a pressure control valve, spring pressure is usually varied with a screw adjustment which compresses or decompresses the spring.

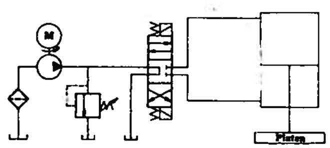


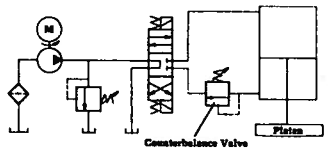
Normally Closed Pressure
Control Valve Symbol

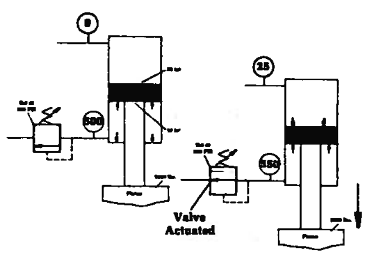












uses of a normally closed pressure valve

Normally closed pressure control valves have many uses in a hydraulic system. Besides using the valve as a system relief, a normally closed pressure control can be used to cause one operation to occur before another. It can also be used to counteract external mechanical forces in the system.

sequence valve

A normally closed pressure control valve which causes one operation to occur before another is referred to as a sequence valve.

sequence valve in a circuit

In a clamp and drill circuit, the clamp cylinder must extend before the drill cylinder. To accomplish this, a sequence valve is positioned in the leg of the circuit just ahead of the drill cylinder. The spring in the sequence valve will not allow the spool to connect primary and secondary passages until pressure is high enough to overcome it.

In the circuit illustrated, the sequence valve setting is 300 PSI. Clamp cylinder requires 100 PSI to extend. Assume that the relief valve is set high enough.

When the directional valve is shifted, flow to the drill cylinder is blocked by the normally closed valve. With 100 PSI at the clamp cylinder, clamp extends and contacts the work piece. The pump applies more pressure. When 300 PSI is reached, the spool in the sequence valve is actuated, causing primary and secondary passages to be connected. Flow passes to the drill cylinder. Thus, the clamp cylinder extends before the drill cylinder brings the drill to the work.

counterbalance valve

A normally closed pressure control valve can be used to "balance" or counteract a weight attached to a cylinder rod or motor shaft. This valve is called a counterbalance valve.

counterbalance valve in a circuit

In the example illustrated, we have a 5000 lb. platen hanging from a cylinder rod with a cross sectional area of $10 in^2$. Cylinder piston has an area of $20 in^2$. The hanging platen generates 500 PSI in the rod side of the cylinder. Counterbalance valve is set for 550 PSI.

With the system in an idle condition, pressure at the cap end of the cylinder is zero and pressure at the rod side is 500 PSI. The platen is suspended because the normally closed pressure valve positioned at cylinder outlet, will not open until 550 PSI.

NOTE: A counterbalance valve will not keep a load suspended in mid-stroke indefinitely. Just like all valves of spool construction, they leak. After a time the load will drift down.

When the directional valve is shifted for the press stroke, pressure builds on the cap side of the cylinder piston. When that pressure reaches 25 PSI, an additional 50 PSI will be

generated at the rod side of the piston. Total pressure is now 550 PSI. The normally closed counterbalance valve opens and allows the platen to descend.

If the platen attemps to run away, pump flow will be unable to fill the cylinder quickly enough. Pressure at the cap end side will drop below 25 PSI resulting in less than 550 PSI at the rod side. The counterbalance valve closes.

As long as the cylinder rod is extending, the counterbalance valve is open and rod side pressure is 550 PSI.

A counterbalance valve can also be used to retard the spinning motion of a weight attached to a motor shaft.

A hydraulic motor which is turning a heavy wheel, may run away once the momentum of the wheel has built up. A counterbalance valve positioned at the motor outlet, will remain closed until pressure is present at the motor outlet. This pressure counteracts the force of the spinning weight.

A counterbalance valve is a normally closed valve which remains closed until sufficient pressure is present upstream. This pressure is then used to counteract or balance external mechanical force.

normally open pressure valve

Unlike a normally closed valve, a normally open pressure valve has primary and secondary passages connected, and pressure at the bottom of the spool is sensed from the secondary port.

pressure reducing valve

A pressure reducing valve is a normally open pressure control valve.

how a pressure reducing valve works

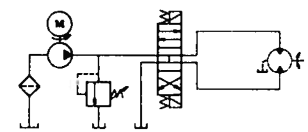
A pressure reducing valve operates by sensing fluid pressure after it has passed through the valve. As pressure downstream equals the setting of the valve, the spool is partially closed causing a restricted flow path. This restriction turns any excess pressure energy ahead of the valve into heat.

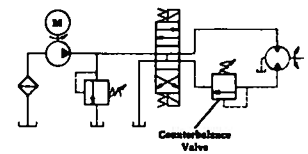
If pressure after the valve drops off, the spool will open and allow pressure to build once again.

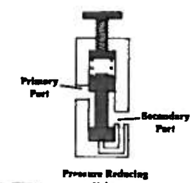
pressure reducing valve in a circuit

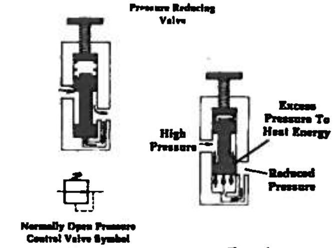
In a dual clamp circuit, when both clamp cylinders are connected to the same power source, two different clamping pressures may be obtained with the use of a pressure reducing valve.

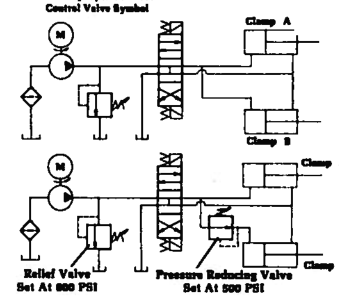
In the clamp cylinder illustrated, clamp B is required to clamp at 500 PSI and clamp A at 800 PSI. A pressure reducing valve set for 500 PSI, is positioned just ahead of clamp cylinder B. When the directional valve is shifted and the clamps contact the work piece, pressure at clamp A will build to the relief valve setting of 800 PSI. Pressure at clamp B will be 500 PSI. The pressure reducing valve transforms 300 PSI of the system's 800 PSI potential energy into heat energy.

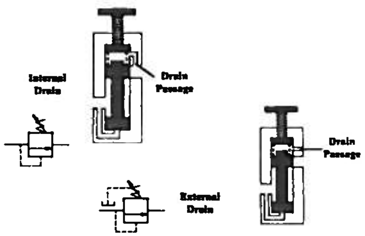










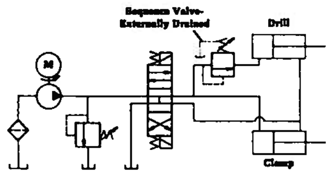


A pressure reducing valve is a normally open valve which transforms any excess pressure energy above its setting into heat energy. The result is a reduced downstream pressure.

drains

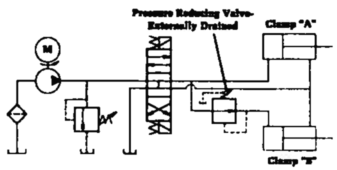
The spool in a pressure control valve moves within a passage. There is some leakage of fluid into the passage above the spool. This is a normal occurence which serves to lubricate the spool.

In order for a pressure valve to operate properly, the area above the spool must be continuously drained so that liquid does not hinder spool movement. This is accomplished with a passage within the valve body which is connected to the reservoir.



internal drain

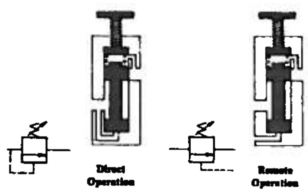
If the secondary passage of a pressure valve is connected to the reservoir, as in relief valve and counterbalance valve applications, the drain passage is internally connected to the valve's secondary or tank passage. This is known as an internal drain.



external drain

If the secondary passage of a pressure valve is a pressure line (or in other words does work) as in sequence valve and pressure reducing valve applications, the drain passage is connected to tank by means of a separate line. This is an external drain.

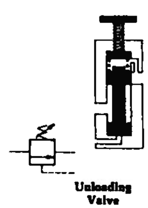
Sequence valves and pressure reducing valves are always externally drained.



direct and remote operation

Up to this point, we have seen that pressure controls sense pressure from a passage within the valve body. In normally closed valves, pressure is sensed from the primary passage. In a pressure reducing valve, pressure is sensed from the secondary passage. This type of pressure sensing is identified as direct operation.

Pressure control valves can also sense pressure in another part of a system by means of an external line. This is remote operation.



unloading valve

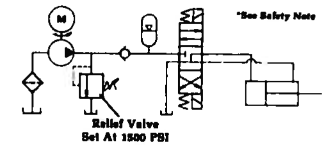
An unloading valve is a remotely operated, normally closed pressure control valve which directs flow to tank when pressure in a remote part of a system reaches a predetermined pressure level.

unloading valve in a circuit

A directly operated relief vlave used in an accumulator circuit means that once the accumulator is charged, pump flow returns to tank at the relief valve setting. This is a waste of horsepower and an unnecessary generation of heat.

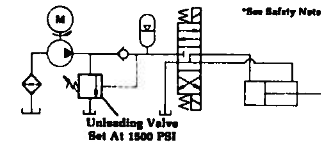
In the circuit illustrated, a 10 GPM pump flow passes through a check valve and to an accumulator. When the accumulator is charged to the 1500 PSI relief valve setting, pump flow

returns to tank over the relief valve. In this condition the system is wasting 8.7 horsepower. (HP = GPM x PSI x .000583)



A remotely operated unloading valve, with its pilot line connected downstream from the check valve, will allow pump flow to return to tank at a minimum pressure when the accumulator is charged.

In the accumulator circuit using an unloading valve, when the accumulator is charged to the unloading valve setting of 1500 PSI, the normally closed valve is actuated, dumping flow back to tank at a low pressure. The valve remains open as long as pressure downstream from the check valve is maintained at 1500 PSI. Pressure upstream from the check valve is whatever pressure the pump applies to return its flow to tank through the unloading valve. The check valve in this instance acts as an isolator.



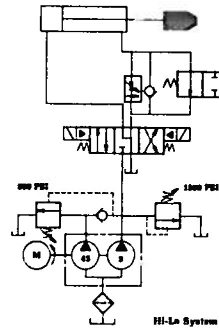
*Safety Note: In any accumulator circuit, a means should be available of automatically unloading the accumulator when the machine is shut down.

An unloading valve is a normally closed pressure valve which allows pump flow to return to tank at a relatively low pressure when a pressure level is reached in a remote part of the system. Since pressure applied by the pump is low, so is horsepower.

hi-lo system

Another common application of an unloading valve is a hi-lo system.

A hi-lo system consists of two pumps—one high volume, the other low volume. This system is used to give a rapid advance, feed, and rapid return. The total volume of both pumps is delivered to the system until the work load is contacted. At this point, system pressure increases causing the unloading valve to function. The flow from the large volume pump is directed back to tank at minimal pressure. The small volume pump continues to deliver flow for the high pressure feed part of the operation. Both volumes join together to return the cylinder.

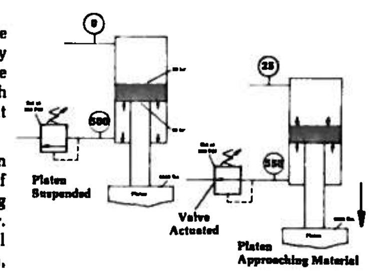


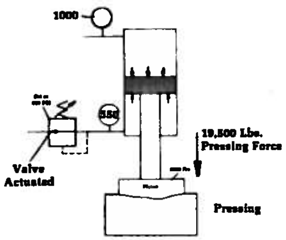
Hi-lo systems give fast cycle time and at the same time unload the large volume pump when its flow is not needed.

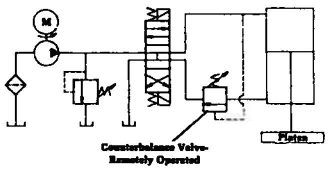
directly operated counterbalance valve in a press circuit

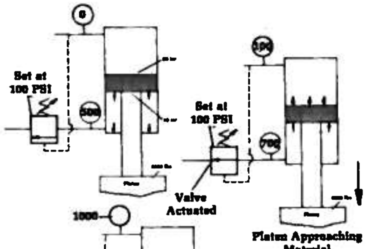
We have seen that a directly operated counterbalance valve positioned downstream from a cylinder supporting a heavy weight, effectively balances or cancels out the weight. If the weight is a platen and the platen is required to move through the material during the pressing process, platen weight cannot be added to the total pressing force.

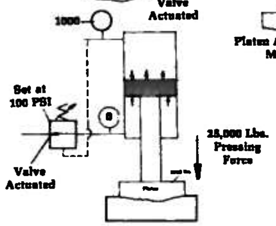
Returning to a previous example, we find a 5000 lb. platen hanging from a cylinder rod with a cross sectional area of 10 in². Cylinder piston has an area of 20 in². The hanging platen generates 500 PSI in the rod side of the cylinder. Counterbalance valve setting is 550 PSI. When the directional valve is shifted and 25 PSI is developed at the cylinder piston, 550 PSI is present in the rod side of the cylinder. Counterbalance valve opens and the platen descends.

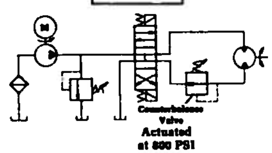












Assume now that the system relief valve is set at 1000 PSI and that the movement of the cylinder rod is severely restricted once the platen contacts the material to be crushed. During the crushing operation, 1000 PSI is present at the cap end side of the piston and 550 PSI is at the rod end side. This is a total downward force of 25,000 lbs.—20,000 lbs. (1000 PSI x 20in²) and 5,000 lbs. (platen weight). The total upward force is 5,500 lbs. (550 PSI x 10in²). This equals a net pressing force of 19,500 lbs. The weight of the platen is effectively cancelled out. If this is undesirable, the pilot line of the valve is remotely connected to the other cylinder line.

remotely operated counterbalance valve in a circuit

In the example, we have practically the same situation as seen previously, except that the counterbalance valve is set at 100 PSI and is remotely operated. Pressure generated by the hanging platen is still 500 PSI, but this does not affect the counterbalance valve since it is operated by pressure from the other cylinder line.

When the directional valve is shifted and 100 PSI is developed at the cylinder piston, 700 PSI is developed in the rod side of the cylinder. Through the remote pilot line, this same 100 PSI actuates the counterbalance valve, lowering the load. The load is counterbalanced in its downward movement because 7000 lbs. (5000 lbs. + (1000 PSI x 20in²) acting down equals 7000 lbs. (700 PSI x 10in²) acting up.

Assume now that the system relief valve is set at 1000 PSI and that the movement of the cylinder rod is severely restricted once the platen contacts the material to be crushed. During the crushing operation, 1000 PSI is present at the cap end side of the piston. This pressure also results in the counterbalance valve spool being pushed completely open. Pressure at the rod side of the cylinder is now zero. With no back pressure in the cylinder, the total pressing force is 25,000 lbs. (5000 lbs. + (1000 PSI x 20in²). Platen weight is added to the total pressing force.

Remotely operated counterbalance valves are typically used on presses where the platen moves through the material during the pressing process. Since the setting of a remotely operated counterbalance valve is not determined by the weight of the load, the valve is also found on systems where weight may change from operation to operation.

directly operated counterbalance valve in a motor circuit

A motor circuit is illustrated which uses a directly operated counterbalance valve to control the runaway tendency of a spinning load. With the valve set for 800 PSI, a back pressure is always present while the load is spinning. This pressure keeps the load from running away from pump flow, but it also means that pressure at motor inlet must be 800 PSI more than the work load pressure. This is a disadvantage which is overcome by a brake valve.

brake valve

A brake valve is a normally closed pressure control valve

with both direct and remote pilots connected simultaneously for its operation. This valve is frequently used with hydraulic motors instead of a directly operated counterbalance valve.

what a brake valve consists of

A brake valve consists of a valve body with primary and secondary passages, internal and remote pilot passages, spool, piston, bias spring, and spring adjustment.

how a brake valve works

A brake valve is a normally closed valve. Assume that the spring biasing the spool is adjusted for 800 PSI direct operation. When pressure in the internal pilot passage reaches 800 PSI, the piston moves up pushing the spool and opening a passage through the valve. If pressure falls below 800 PSI the valve closes. This operates as the directly operated counterbalance valve which we saw earlier.

The piston on which the internal pilot pressure acts, has much less cross sectional area than the spool. The area ratio is frequently 8:1. With the remote pilot connected to the opposite motor line, a pressure of only 100 PSI is needed to open the valve since it acts on the bottom of the spool with eight times more area than the piston.

brake valve in a circuit

With a brake valve set for 800 PSI, the valve will be open when 100 PSI is present in the motor inlet line. Pressure at motor inlet will be whatever it takes to turn the load only (assuming that this pressure is above 100 PSI). If the load attempts to runaway, pressure drops off in the motor inlet line. The brake valve closes and does not reopen until a back pressure of 800 PSI is generated to slow down the load.

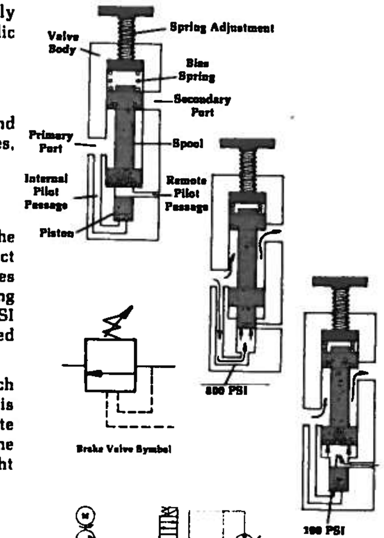
A brake valve is a normally closed pressure control valve whose operation is directly tied to the needs of a motor load.

reverse flow

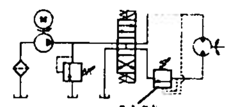
A normal requirement of all pressure valves, except relief and unloading valves, is that reverse flow must be able to pass through the valve.

Since normally closed pressure valves sense pressure from the primary passage, as soon as flow is reversed, pressure in the primary passage falls off. The spool is de-actuated. Primary and secondary passages are disconnected. Flow through the valve is blocked. Since we cannot go through the valve, we go around the valve by using a check valve.

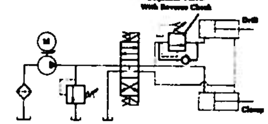
Normally open pressure valves sense pressure from the secondary passage. It would appear that as long as reverse flow pressure ahead of the valve remains below valve setting, passage through the valve will remain open and no check valve is required. This is true. However, any rise in pressure above the setting will result in the spool being slammed shut. As a precautionary measure, many times a check valve is used with a pressure reducing valve for reverse flow.



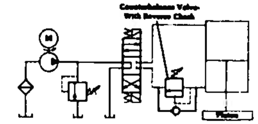
Brake Valve Symbol



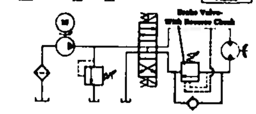
Brake Valve-Remote and Direct Operated Simultaneously



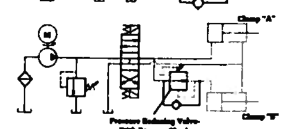
Sequence Valve-With Reverse Check



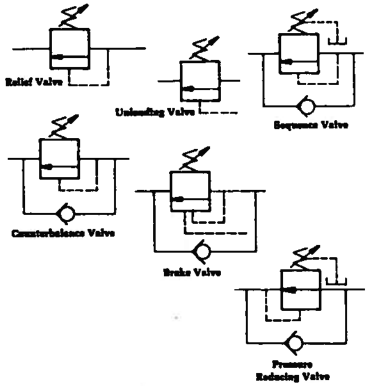
Counterbalance Valve-With Reverse Check



Brake Valve-With Reverse Check



Pressure Reducing Valve-With Reverse Check



generalizations about pressure control valves

Some generalizations can be made about pressure control valves:

A. Pressure control valves, whose secondary ports are pressurized, have external drains. (Sequence and pressure reducing valves)

B. Pressure control valves, whose secondary ports are connected to tank, generally have internal drains. (Relief, unloading, counterbalance, and brake valves.)

C. To pass reverse flow through a normally closed pressure control valve, a check valve is used.

pressure control valve symbols

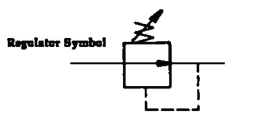
From the beginning of the lesson we have been building the symbols for the various types of pressure control valves. The complete symbol for each valve is illustrated.

pneumatic pressure control valves

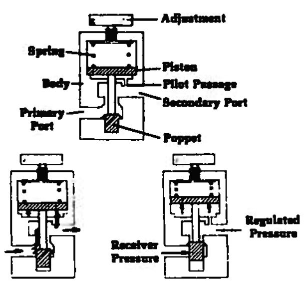
Pressure in a pneumatic system must be controlled at two points—after the compressor and after the air receiver tank.

As we have seen, the maximum air pressure developed by a compressor is controlled automatically by a pressure sensing system. This system designates when the compressor is turned on and off and in effect determines the operating pressure range of a compressor. If this system happens to fail, a safety relief is actuated limiting maximum pressure to a safe level.

pressure regulator



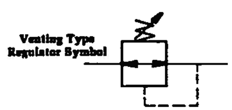
We have also seen that a pressure regulator was required after an air receiver tank so that the potential energy of the stored compressed air could be portioned out to an actuator downstream.



Being a normally open valve, a pressure regulator positioned after an air receiver allows compressed air to expand to a point downstream. As pressure after the regulator rises, it is sensed in an internal pilot passage leading to the underside of a piston. The piston has a large surface area exposed to downstream pressure and is quite sensitive to downstream pressure fluctuations. When downstream pressure is high enough, the piston moves upward, pulling the poppet. The poppet, once it seats, does not allow pressure to continue building downstream. In this way, a constant source of compressed air is made available to an actuator downstream.

A pressure regulator also insures that stored energy in an air receiver is not unnecessarily wasted.

venting-type regulator

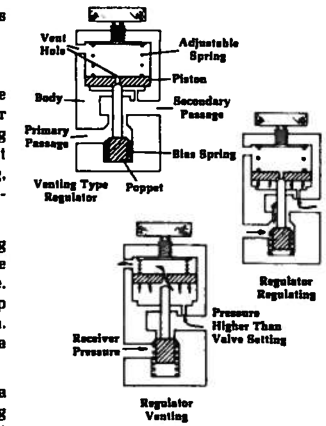


A venting-type regulator limits downstream air pressure to a level lower than in an air receiver. At the same time, it may act as a relief valve for its leg of the circuit in case of any pressure buildup.

what a venting-type regulator consists of

A venting-type regulator basically consists of a body with

primary and secondary passages, poppet with a light bias spring, a piston with a vent hole, and an adjustable spring.



how a venting-type regulator works

A venting-type regulator reduces downstream pressure in the same manner as an ordinary regulator. As pressure rises after the regulator, it is sensed in an internal valve passage leading to the underside of the piston. When the force generated at the piston is large enough to compress the adjustable spring, piston and poppet move upward, limiting maximum downstream pressure.

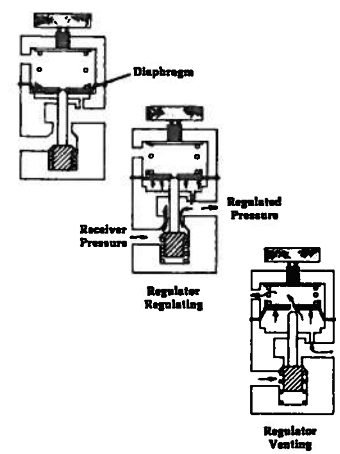
The difference in operation between a nonventing and venting regulator is in the action taken when a pressure above the setting of the regulator, is present in a downstream line. This higher pressure could be the result of a pressure buildup caused by leakage or a load pushing in a cylinder piston. It could also be the result of adjusting the regulator to a lower setting.

When a higher-than-set pressure appears downstream from a venting-type regulator, pressure acts on the piston pushing it up. At the same time, the poppet is pushed up by its light bias spring. With the poppet seated, the piston continues to move until a vent hole is exposed at its center. Excess pressure is bled off through this hole.

When downstream pressure returns to the desired level, the piston reseats onto the poppet stem and pressure regulation resumes.

Most pressure regulators found in an industrial pneumatic system, are of the venting type.

diaphragm regulator



Another very common type of pressure regulator uses a diaphragm in place of a piston. Operation of a diaphragm regulator is the same as a piston type.

An example of a venting-type diaphragm regulator is illustrated.

• **For additional information regarding pressure regulator applications and characteristics, see Parker-Hannifin Design Engineers Handbook, Section g.**

lesson review

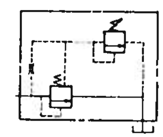
In this lesson dealing with simple pressure control valves, we have seen that:

- Simple pressure control valves have their movable parts biased by spring pressure only
- In a hydraulic system, normally closed pressure control valves can be positioned in the system to perform various functions.
- The name of a normally closed pressure control valve is primarily determined by where it is positioned in a hydraulic circuit and what function it performs.
- A relief valve is a normally closed valve which diverts flow to tank at a predetermined pressure level.
- An unloading valve is a normally closed valve which diverts flow to tank when a predetermined pressure level is reached at a remote system point.
- A sequence valve is a normally closed pressure valve which causes one operation to occur before another by blocking fluid passages until a set pressure is reached.
- A counterbalance valve is a normally closed pressure valve which counteracts or balances a weight attached to a cylinder rod or motor shaft by causing a back pressure to be developed.
- Counterbalance valves can have direct and remote operation.
- A brake valve is a normally closed pressure control valve whose operation is simultaneously controlled by direct and remote pilots.
- A pressure reducing valve is a normally open pressure control valve which senses downstream pressure and turns excess pressure energy above its setting into heat.
- Pressure control valves whose secondary ports are pressurized, have external drains.
- Pressure control valves whose secondary ports are connected to tank, have internal drains.
- To pass reverse flow through a normally closed pressure control valve, a check valve is used.
- Pressure regulators in an industrial pneumatic system are most often venting-type rather than non-venting regulators.
- A diaphragm type regulator is a common type of pressure regulator found in an industrial pneumatic system.

Lesson 12

Pilot Operated Pressure Control Valves

Unlike a simple pressure control valve where a spool is held in its normal position by spring pressure only, a pilot operated valve has its movable part held in position by both spring and fluid pressure, or with fluid pressure only.

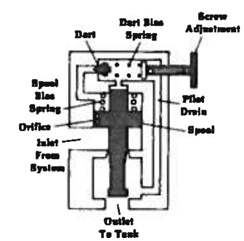


Pilot Operated Relief Valve Symbol

hydraulic pilot operated pressure valves

One of the biggest reasons for using a pilot operated valve rather than a simple pressure valve is its degree of flexibility.

To understand the operation of a pilot operated pressure control valve, we will concentrate on the operation of a pilot operated relief valve.



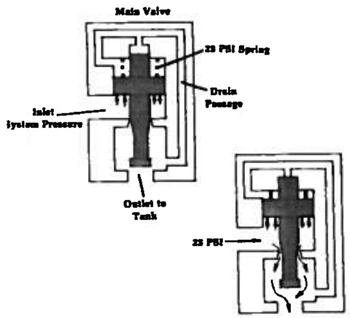
what a pilot operated relief valve consists of

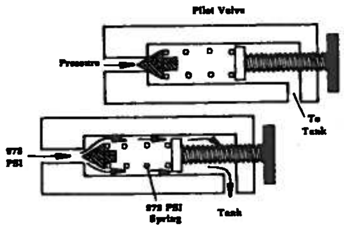
A pilot operated relief valve consists of two valves—a main valve and a pilot valve. The main valve is made up of a body with inlet and outlet ports, a spool with an orifice, and a spool bias spring.

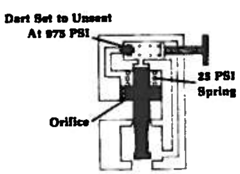
The pilot valve consists of a dart, dart bias spring, and screw adjustment.

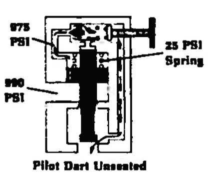
how a pilot operated relief valve works

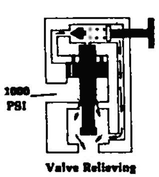
To understand the operation of a pilot operated relief valve, we will look at the independent operation of the main valve and the pilot valve. The main valve spool is biased by a light spring. The stem of the main valve spool plugs the outlet to











tank. System pressure acts on the area under the spool skirt. Any leakage passed the spool is internally drained back to tank through a passage in the valve body.

If the spring biasing the main valve spool has a value of 25 PSI, the spool will be pushed up and system flow will pass to tank when system pressure reaches 25 PSI. In this way, the valve functions as any of the spring biased pressure control valves which we have seen up to this time.

The movable part of the pilot valve is a dart. The area of the dart exposed to hydraulic pressure is relatively small. The spring which biases the dart on its seat is rather stiff. The combination of small area and stiff spring means that the dart will remain seated until a high pressure is reached.

If the spring biasing the dart has a value of 975 PSI, the dart will remain seated until this pressure is reached. At this time, the dart will unseat and flow will pass to tank. Consequently, pressure is limited to 975 PSI. In this manner, the pilot valve also acts like any of the spring biased pressure control valves we have seen previously.

The pilot valve is a simple, spring-biased pressure control which handles small flows at high pressures. The main valve is also a simple, spring-biased pressure control which handles larger flows at low pressure. By using the two together, large flows can be handled at high pressures.

In a pilot operated relief valve, the main valve spool is biased by light spring pressure and fluid (pilot) pressure in the spring chamber. The maximum fluid pressure which is allowed to bias the spool is determined by the setting of the pilot valve.

To allow pressure to accumulate in the spring chamber, an orifice or hole is drilled through the main valve spool skirt.

To illustrate the operation of a pilot operated relief valve, assume that the spring biasing the main valve spool has a value of 25 PSI and that the pilot valve will limit the pilot pressure in the spring chamber to 975 PSI.

With a system pressure of 800 PSI, 800 PSI is acting to push the spool up. 800 PSI is transmitted through the orifice to the spring chamber and acts to hold the spool down. The areas exposed to pressure on either side of the spool skirt are equal. Therefore the spool is balanced except for the 25 PSI spring. Consequently, there is a hydraulic pressure of 800 PSI trying to unseat the spool and a total hydraulic and mechanical pressure of 825 PSI keeping the spool seated.

With a system pressure of 900 PSI, 900 PSI at the bottom of the spool acts to push the spool up. A total mechanical and hydraulic pressure of 925 PSI acts to keep the spool down.

When system pressure rises to 990 PSI, 990 PSI will act to push the spool up. Since the pilot valve is set to limit the fluid pressure in the spring chamber to 975 PSI, the pilot valve dart is unseated and the pilot pressure above the spool is 975 PSI. This is a total hydraulic and mechanical pressure of 1000 PSI acting to hold the spool down. The total pressure

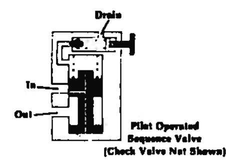
acting down is still more than the pressure acting up. The maximum pressure which can bias the spool in the down position is 1000 PSI. If pressure below the spool attempts to rise above 1000 PSI, the spool will be pushed up and flow will pass to tank.

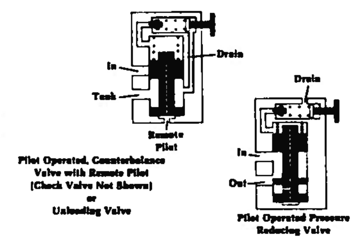
In our example, up to a pressure of 975 PSI, the total mechanical and fluid pressure biasing the spool will be 25 PSI greater than system pressure. Between 975 PSI and 1000 PSI, the difference becomes less until at any pressure over 1000 PSI the main valve spool is unseated.

other pilot operated pressure control valves

In addition to relief valves, sequence, counterbalance, unloading, and pressure reducing valves can also be pilot operated.

Just as relief valves, the other pilot operated pressure controls consist of a pilot valve and main valve. The spools in these valves are different from a relief valve spool, but pilot pressure is still sensed through a passage in the main valve spool.

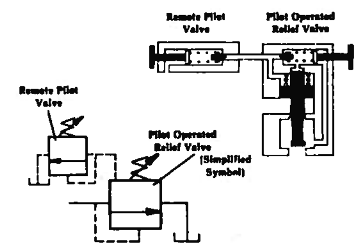




remote pilot adjustment

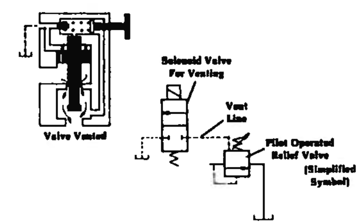
Since fluid pressure is used to bias the main valve spool, a pilot operated pressure control valve can be adapted for remote adjustment. With an additional pilot valve connected to the spring chamber of a pilot operated valve, the maximum pressure in that spring chamber will be limited to the setting of the remote pilot valve if that setting is lower than the main pilot valve. With this arrangement, the remote pilot valve can be mounted on a panel for ease in adjustment by a machine operator.

In the illustration of remote adjustment, a remote pilot valve is used in conjunction with a pilot operated relief valve. This is a very common application. However, pilot operated unloading, counterbalance, sequence, and pressure reducing valves can also be remotely adjusted.



venting a pilot operated relief valve

"Venting" a relief valve refers to releasing the fluid pressure biasing the main spool of a pilot operated relief valve. By releasing this pilot pressure, the only pressure holding the spool closed is the light pressure of the spring. This results in the pump applying a relatively low pressure to return its flow to tank.

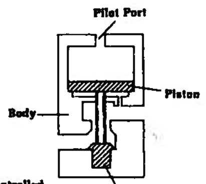


Venting a system's relief valve is an important consideration during machine idle time. When no useful work is being done by the system, it is an unnecessary waste of horsepower to direct flow to tank at a high relief valve setting.

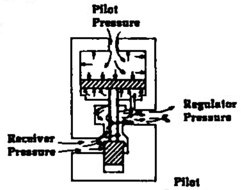
Venting a pilot operated relief valve is a common practice in industrial hydraulic systems.

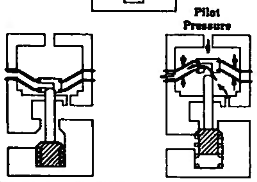
pilot controlled regulator

A pilot controlled regulator replaces the adjustable main spring with air pilot pressure.



Pilot Controlled Regulator





Diaphragm Pilot Controlled Regulator—Venting Type

Venting

One advantage of a pilot controlled regulator over a simple regulator, is that regulator pressure can be adjusted remotely.

what a pilot controlled regulator consists of

A pilot controlled regulator basically consists of a valve body with primary and secondary passages, piston, and a poppet biased by a light spring.

how a pilot controlled regulator works

A pilot controlled regulator operates basically in the same manner as an ordinary regulator. The difference is that air pressure acts against the piston instead of spring force.

As pressure after the regulator rises, it is sensed in an internal valve passage leading to the underside of the piston. When the force generated at the bottom of the piston is greater than the force developed on top of the piston, poppet and piston move regulating pressure.

Pilot controlled regulators can be of the venting or nonventing types. They can also be equipped with diaphragms instead of pistons.

- **For additional information concerning pilot controlled regulators, see Parker-Hannifin Design Engineers Handbook, Section g.**

lesson review

In this lesson dealing with pilot operated pressure control valves, we have seen that:

- A pilot operated pressure valve has its movable part held in its normal position by both spring and fluid pressure.
- One of the biggest reasons for using a pilot operated valve rather than a simple pressure valve is its degree of flexibility.
- A pilot operated valve consists of a main valve and a pilot valve.
- A pilot valve and main valve act together to handle relatively large flows at high pressure.
- Relief, unloading, sequence, counterbalance, and pressure reducing valves can all be pilot operated.
- Pilot operated valves can be remotely adjusted and controlled.
- Pilot operated relief valves can be vented so that a pump is unloaded during idle time.
- One advantage of a pilot controlled regulator over a simple regulator, is that regulator pressure can be adjusted remotely.
- A pilot controlled regulator replaces the adjustable main spring with air pilot pressure.

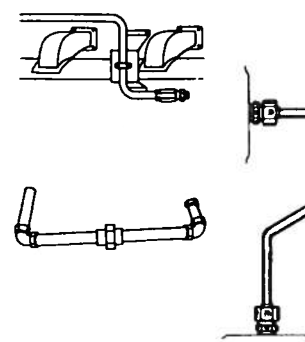
Lesson 15

Fluid Conductors and Connectors

Relief valves, regulators, pumps, compressors, cylinders, and other fluid power components have little reason for existing for their own sakes. They are designed to be used together in a fluid power system.

Many times the method of marrying interacting components of a system is a minor consideration. We know that there must be some sort of fluid-carrying link between components, but the way it is done is sometimes considered arbitrary. This attitude may result in a system which is inefficient, unsafe, unattractive, and difficult to service.

Conductors of a fluid power system are basically of three types: pipe, tubing, and hose. In this lesson, we will consider each type, its typical connectors, and some installation considerations.



pipe

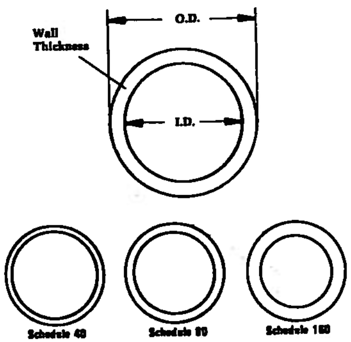
Pipe is a rigid conductor which is not intended to be bent or shaped into a configuration.

pipe materials

Pipe can be manufactured and purchased in a variety of materials such as cast iron, steel, copper, aluminum, brass, and stainless steel.

Pneumatic fluid power systems generally require a corrosion resistant pipe. Hydraulic systems use steel pipe.

Galvanized pipe is not recommended for use in hydraulic systems because the zinc coating of the pipe interacts unfavorably with oil.



id - od — wall thickness

Any tubular material like pipe has an outside diameter (OD), an inside diameter (ID), and a corresponding wall thickness.

The inside diameter of a pipe, or any fluid-carrying conductor, is an important consideration. For if the ID is too small, a large amount of friction results which translates into undesirable system inefficiency and wasted energy.

Wall thickness of a fluid conductor determines the conductor's pressure rating. Wall thickness of a pipe is identified by its schedule number which is a designation of the American National Standards Institute (ANSI). There are ten schedule numbers ranging from 10 to 160. Schedule numbers 40, 80, and 160 are the most commonly used pipe in a fluid power system. Schedule 40 pipe has a wall thickness rated for low pressure. Schedule 80 is high pressure pipe. Schedule 160 is rated for very high pressure.

Hydraulic fluid power systems generally use Schedule 40 steel pipe in pump suction and system return lines with Schedule 80 and 160 steel pipe in pressure lines. Pneumatic systems generally use Schedule 40 steel pipe.

HYDRAULIC PIPE SPECIFICATIONS (Dimensions)

Nominal Size	Pipe OD	INSIDE DIAMETER Schedule 40	Schedule 80	Schedule 160
1/8	.405	.269	.215	
1/4	.540	.364	.302	
3/8	.675	.493	.423	
1/2	.840	.622	.546	.466
3/4	1.050	.824	.742	.587
1	1.315	1.049	.957	.815
1 1/4	1.660	1.380	1.278	1.160
1 1/2	1.900	1.610	1.500	1.338
2	2.375	2.067	1.939	1.689
2 1/2	2.875	2.469	2.323	2.125
3	3.500	3.068	2.900	2.624

pipe size

Originally, pipe was manufactured with one wall thickness and pipe size was indicated by its actual inside diameter.

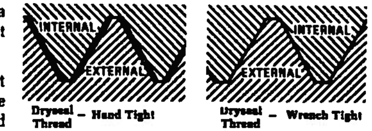
Ends of a pipe were threaded so that connections could be made. Thread sizes were identified with the pipe size on which it was used and not by its actual dimension. A half inch pipe thread was a little larger than a half inch.

As time passed, the wall thickness of pipe had to be increased to keep pace with rising working pressure requirements. Since pipe thread sizes required OD's of specific dimensions, a pipe's outside diameter remained fixed. Increased wall thickness was accomplished at the expense of reducing the inside diameter. This meant that a pipe's indicated size no longer denoted the actual pipe ID.

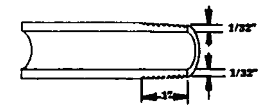
Pipe size is indicated by a nominal designation. From the illustrated chart it can be seen what ID's are available for several nominal sizes of various wall thicknesses. The chart shows that a particular pipe size designation indicates neither ID, OD, nor wall thickness.

pipe threads

Pipe connections are made by means of threaded joints. To join a pipe to a component or pipe fitting, a threaded end of a pipe (male end) is screwed into a female thread of a component or fitting.



Dryseal Thread – Hand Tight   Dryseal Thread – Wrench Tight



Pipe Thread Taper

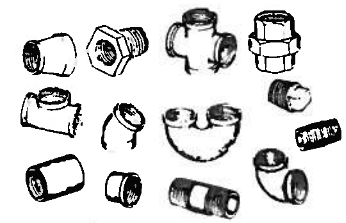
Pipe threads have another function besides joining and that is sealing. To form a seal, pipe threads are tapered on the diameter 1/16 in. per inch of length. As a male pipe thread tightens into a female pipe thread, the metal-to-metal interference which occurs is intended to form a seal. In actual practice, however, thermal changes, vibration, system shock, or an imperfect thread match may tend to destroy the sealing capabilities of the metal-to-metal joint. For this reason, thread sealants of various types are commonly used to help make and maintain the seal.

pipe fittings

Since pipe is a heavy walled, rigid conductor, it is not intended to be bent or twisted into a configuration which fits a specific machine. Pipe fittings must be used.

Pipe fittings are available in various shapes such as tees, crosses, elbows, etc. Many of these shapes are illustrated.

Customarily, fluid power systems which work at relatively low pressures have used threaded pipe fittings as connectors.



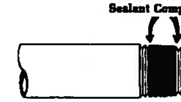
Pipe Fittings

pipe installation considerations

Threading of pipe requires removal of metal. This means bare metal is exposed at the thread.

When a threaded connection is made, it is advised that some sort of protective and sealant compound be applied to the threads to avoid corrosion and effect a seal. Protecting pipe threads from corrosion will aid in the event the joint has to be broken.

Protective and Sealant Compound



It is advised that when any type of sealant and protective coating is applied to a pipe thread, the coating should be applied up to the second pipe thread from the end only. This avoids contaminating the system with the coating material.

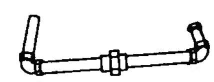
There is a caution when screwing in a pipe. Since pipe threads are tapered, the more a pipe is screwed into a component housing or fitting, the more likelihood of rupturing the housing or fitting from the wedging action of the joint.

tubing

Tubing is a semirigid fluid conductor which is customarily bent into a desired shape.

Tubing

The use of tubing as conductors gives a modern, neat appearing system; a system less susceptible to leaks and vibration; and a system whose conductors can be easily removed and replaced for maintenance purposes.

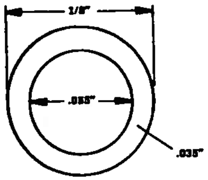


Pipe

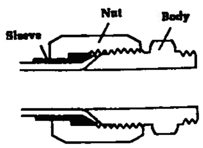
tubing materials

Tubing is made from a variety of materials including steel, copper, brass, aluminum, stainless steel, and plastic.

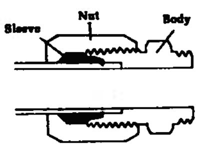
Hydraulic fluid power systems generally use steel tubing.



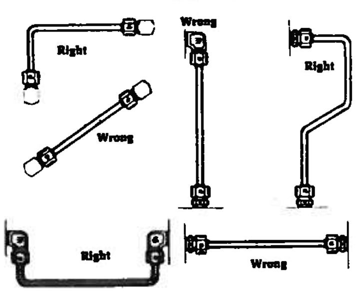
Tube OD	Wall thickness	Tube ID
1/8	0.028 .032 .035	0.069 .061 .055
3/16	0.032 .035	0.1235 .1175



Flared Fitting



Flareless Fitting



tubing size

Just as other tubular materials, tubing is measured by its outside diameter, inside diameter, and wall thickness. The inside diameter determines how much fluid flow the tubing can efficiently pass. Wall thickness determines the maximum pressure at which the material can be used for any given inside diameter.

Tubing size is indicated by its actual outside diameter. For example, 1/8 in. tubing has an actual outside diameter of 1/8 in. Tubing inside diameter depends on wall thickness. This can be seen from the chart designating tubing sizes.

tube fittings

Tubing is connected to system components and to other conductors by means of tube fittings.

Basically, there are two types of tube fittings used in fluid power systems. These are flared fittings and flareless fittings.

flared tube fitting

A flared tube fitting consists of a body, sleeve, and nut.

When using a flared fitting, the nut and sleeve are slipped over the tubing end. The tubing is then flared. (In the United States, tubing is usually flared to 37° or 45° depending on the fitting used.) When the nut is screwed onto the body, it draws the sleeve and tubing flare against the body forming a seal.

flareless tube fitting

A flareless fitting consists of a body, sleeve, and nut.

To use a flareless fitting, the nut and sleeve are slipped over the tubing. Then the tubing is inserted into the fitting body where it butts up against a shoulder. As the nut is screwed onto the body, the sleeve bites into the tubing. As the nut is turned farther, a ledge of tube material forms ahead of the sleeve causing it to bow. The bowed sleeve acts like a spring, insuring that the nut is held in place against vibration.

tubing installation considerations

In general, conductors of a fluid power system should be kept short and as straight as possible. This is one of the factors in an efficient system. However, tubing runs should not be assembled in a straight line. Bends in tubing absorb vibrations and compensate for the strain of thermal expansion and contraction. Some correct and incorrect tubing installations are illustrated.

- **For further tubing and tube fitting considerations, see Parker-Hannifin Design Engineers Handbook, Section J.**

hose

Hose is a flexible fluid conductor which can adapt to machine members which move.

hose construction

Hose is made up of three basic elements—inner tube, reinforcement, and cover.

The inner tube is the lining of a hose which contacts a fluid. Inner tube materials are designed to be compatible with the fluid being conducted.

Hose reinforcement is the fabric, cord, or metal layers which surround an inner tube. These elements give strength to the hose to withstand internal pressures and external forces.

A hose cover is the outer hose layer. It is designed to protect the inner tube and reinforcing layers from chemical attack, mechanical damage, sunlight, and abrasions.

hose size

Hose size is customarily given by a dash number which offers some identification as to its inside diameter. Dash numbers indicate 16ths of an inch. A -8 is equivalent to 8/16 in. or 1/2 in. A -8 hose means that the inside hose diameter is 1/2 in. or a little less.

ID size variations from the dash number identification is dependent on the type of hose.

hose pressure classifications

The type and number of reinforcing layers of a hose determine under what system conditions it may be used. Hose pressure classifications are suction, medium pressure, high pressure, and very high pressure.

hose fittings

Hose is connected to system components and to other conductors by means of hose fittings. Hose fittings are classified as permanent or reusable.

permanent hose fitting

With a permanent hose fitting, the hose is inserted into the fitting between nipple and socket. The socket is then crimped or swaged to hold the hose. Barbs on the outside diameter of the nipple insure that the hose is securely held in place.

reusable hose fittings

Reusable hose fittings are screwed or clamped to a hose end. They can be removed from a worn hose and reassembled onto a replacement hose.

Skive, no-skive, and clamp type fittings are commonly used hose fittings for hydraulic systems.

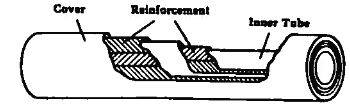
A skive type fitting is a screw-on design for use on hoses with a thick outer cover. This cover is removed (skived) from the ends prior to fitting installation.

A no-skive type fitting is a screw-on design for use on hose with a thin outer cover. This cover does not require removal prior to fitting installation.

A clamp type fitting is designed with a barbed nipple which is inserted into a hose. Two clamp halves are then bolted together to provide a leakproof grip.

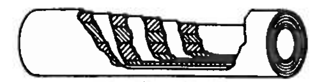
quick couplings

Quick disconnect couplings are found on systems where rapid

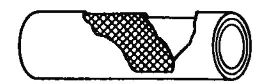


Hose Construction High Pressure Hose

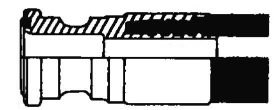
Medium Pressure Hose



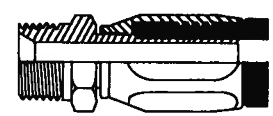
Very High Pressure Hose



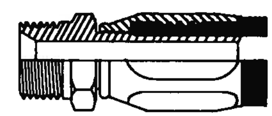
Suction Line



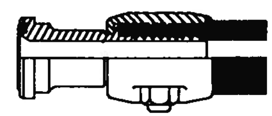
Permanent Hose Fitting



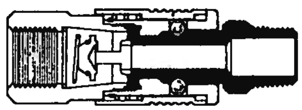
Skive Fitting

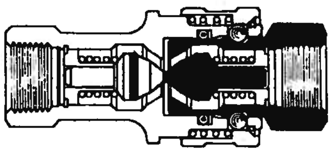


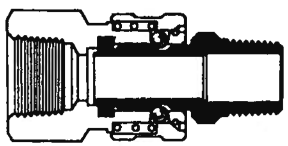
No-Skive Fitting

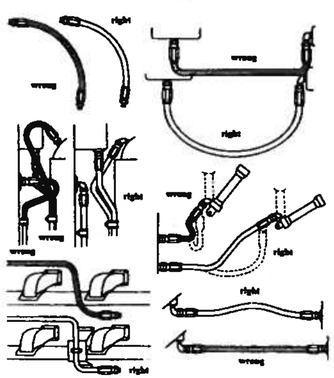


Clamp Type Fitting


Single Shut-off


Double Shut-off


Strait-Thru



and repeated connecting and disconnecting of fluid conductors without the use of tools is demanded. One half of the quick coupling is usually attached to a flexible line like a hose.

Quick couplings are made up of male and female halves. The female half is sometimes referred to as the "socket" or "coupler body". The male half is sometimes called the "plug" or "nipple body".

Quick couplings are commonly locked in place with detented balls or rollers.

There are basically three types of quick couplings—single shutoff, double shutoff, and straight-thru.

Single shutoff couplings are typically used with pneumatic systems. The female coupling half includes a check valve shutoff. The male half does not.

Double shutoff couplings are used in hydraulic systems. The double shutoff design has a check valve shutoff in each coupling half.

Straight-thru couplings are used on systems where unrestricted flow is required. Since these couplings are not equipped with check valves, a shutoff valve is usually installed in the line.

- **For additional information regarding quick disconnect couplings, see Parker-Hannifin Design Engineers Handbook, Section j.**

hose installation considerations

During operation, hose should not be scraped or chafed. This eventually weakens the hose.

Hose should not be twisted during installation or system operation. Twisting a hose reduces life considerably and may help in loosening hose fittings. A twisted hose can be easily detected by examining the line along the hose cover. It should not appear twisted.

Hose should not be stretched tightly between two fittings, but allowed to sag a little. When hose is subjected to system pressure, it expands in diameter and shrinks in length.

Examples of correct and incorrect hose installations are illustrated.

- **For additional information regarding hose and hose fittings, see Parker-Hannifin Design Engineers Handbook, Section j.**

lesson review

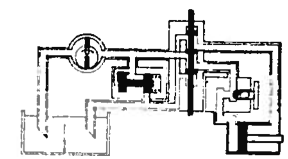
In this lesson dealing with fluid conductors and connectors, we have seen that:

- A poor selection of a fluid conductor may result in a system which is inefficient, unsafe, unattractive, and difficult to service.
- Pipe, tubing, and hose are the three types of fluid conductors commonly found in a fluid power system.
- Pipe is a rigid conductor which is not intended to be bent or shaped into a configuration.
- Pneumatic systems generally require corrosion resistant pipe.
- Pipe size is indicated by a nominal designation.
- Wall thickness of a pipe is identified by a schedule number.
- Pipe connections are made by means of pipe threads.
- Pipe threads in the United States are tapered on the diameter 1/16 in. per inch of length.
- Since pipe is a rigid conductor, pipe fittings are used to form a configuration which fits a specific machine.
- When a threaded pipe connection is made, it is advised that some sort of protective and sealant compound be applied to the threads to avoid corrosion and effect a seal.
- Tubing is a semirigid fluid conductor which is customarily bent into a desired shape.
- Tubing size is indicated by its outside diameter.
- Tubing is connected to system components and to other pieces of tubing by means of tube fittings.
- Tube fittings are classified as flared or flareless.
- Tubing runs should not be assembled in a straight line.
- Hose is a flexible fluid conductor which can adapt to machine members which move.
- Hose is constructed of three basic elements—inner tube, reinforcement, and cover.
- Hose size is customarily given by a dash number which offers some indication as to its inside diameter.
- Hose is connected to system components and to other conductors by means of hose fittings.
- Hose fittings are classified as permanent or reusable.
- Quick disconnect couplings are found on systems where rapid and repeated connecting and disconnecting of fluid conductors without the use of tools is demanded.
- Hose should not be scraped, twisted, or stretched tightly between two fittings.

Summary

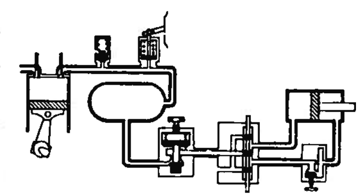
Fluid Power Systems

Fluid power systems have been developing rapidly over the past thirty-five years. Fluid power filled a need during World War II for an energy transmission system with muscle which could be easily adapted to automated machinery.



Simple Hydraulic System

Today, fluid power technology is seen in every phase of man's activities. Fluid power is found in areas of manufacturing such as metal forming, plastics, basic metals, and material handling. Fluid power is evident in transportation as power and control systems of ships, planes, and automobiles. The environment is another place fluid power is hard at work compacting waste materials and controlling flood gates of huge dams. Food processing, construction equipment, and medical technology are a few more areas of fluid power involvement. Fluid power applications are only limited by imagination.



Simple Pneumatic System

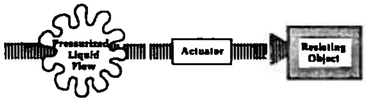
This course has pointed out the elements which make up a fluid power system and the basic principles by which it operates. We have illustrated how simple a fluid power system can be and how easily it can control energy. However, we would not want you to leave the course with the notion that fluid power is the only way to transmit energy. This idea may do more harm than good.

Each system, regardless of the type, has its own advantages and disadvantages. Each has applications where it is best suited to do the job. This is probably the reason you won't find a fluid power-wristwatch, or hoses carrying fluid power replacing electrical power lines.

Knowing what we do about fluid power, in this last section let us look at some desirable characteristics of a fluid power system in relation to electrical and mechancial systems. Then we will compare a hydraulic system with a pneumatic system.

fluid power systems vs. mechanical systems

Some desirable characteristics of fluid power systems when compared with mechanical transmission systems:



Hydraulic Transmission of Energy

A fluid power system is often a simpler means of transmitting energy. There are fewer mechanical parts in an ordinary industrial system.

Since there are fewer mechanical parts, a fluid power system is more efficient and more dependable. In the common industrial system, there is no need to worry about hundreds of moving parts failing, with fluid as the transmission medium.

Mechanical Transmission of Energy

With fluid as the transmission medium, various components of a system can be located at convenient places on the machine. Fluid power can be transmitted and controlled quickly and efficiently up, down, and around corners with few controlling elements.

Since fluid power is efficiently transmitted and controlled, it gives freedom in designing a machine. The need for gear, cam, and lever systems is eliminated since fluid power systems can provide infinitely variable speed, force, and direction with simple elements.

Pneumatic Transmission of Energy

Since fluid power can be easily controlled, it can be readily adapted to automated machinery. Large forces can be controlled by small signals.

fluid power systems vs. electrical systems

Some desirable characteristics of fluid power systems when compared with electrical transmission systems:

Electrical Transmission of Energy

Mechanical force and motion controlled by a fluid power system can be more easily controlled. Speed, direction, and force are controlled by the simple use of valves.

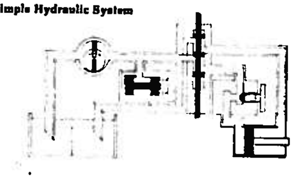
Since forces can be easily controlled, mechanical elements controlled by a fluid power system can be readily stalled for indefinite periods without damage.

Fluid power components are often smaller than comparable electrical units performing the same job.

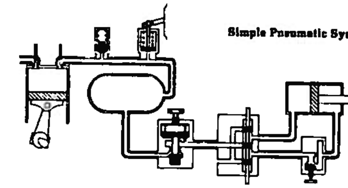
hydraulic systems vs. pneumatic systems

Now, let us look at some hydraulic system characteristics and compare them with a pneumatic system.

Simple Hydraulic System



Simple Pneumatic System



Hydraulic System (with positive displacement pump; without accumulator)	Pneumatic System (with positive displacement compressor and air receiver tank)
1. Pump develops a constant flow and applies necessary pressure to do so. Flow is constant. Pressure varies.	1. Compressor delivers volumes of compressed air to air receiver. This is potential energy which is stored.
2. Positive displacement pump develops hydraulic power (GPM x PSI) which is used immediately by system.	2. Positive displacement compressor develops volumes of potential energy (compressed air) which is stored.
3. Fluid flow depends on in^3 pump displacement times motor RPM.	3. Fluid flow depends on pressure differential between compressed air source and a point downstream.
4. Shock tendency when fluid greatly accelerated or decelerated.	4. Smooth acceleration and deceleration of actuators.
5. High pressure differential indicates much pressure energy changing to heat. System runs hot.	5. High pressure differential indicates much pressure energy changing to air flow. System runs cool since air expanding.
6. Hydraulic oil is natural lubricant.	6. Air requires lubrication.
7. Industrial systems work at 3000 PSI and above.	7. Industrial systems work at 150 PSI maximum. Not economically feasible to generate high pressure air.
8. No need for corrosion resistant materials.	8. Corrision resistant materials a must.
9. Leakage of common hydraulic fluid is a fire hazard and housekeeping problem.	9. Leakage of compressed air not flammable but costly over a long run.
10. Generally not used on fast cycling actuators.	10. Ideal for fast acting applications.
11. Proper operation of components dependent on clean hydraulic fluid.	11. Proper operation of components dependent on clean compressed air.