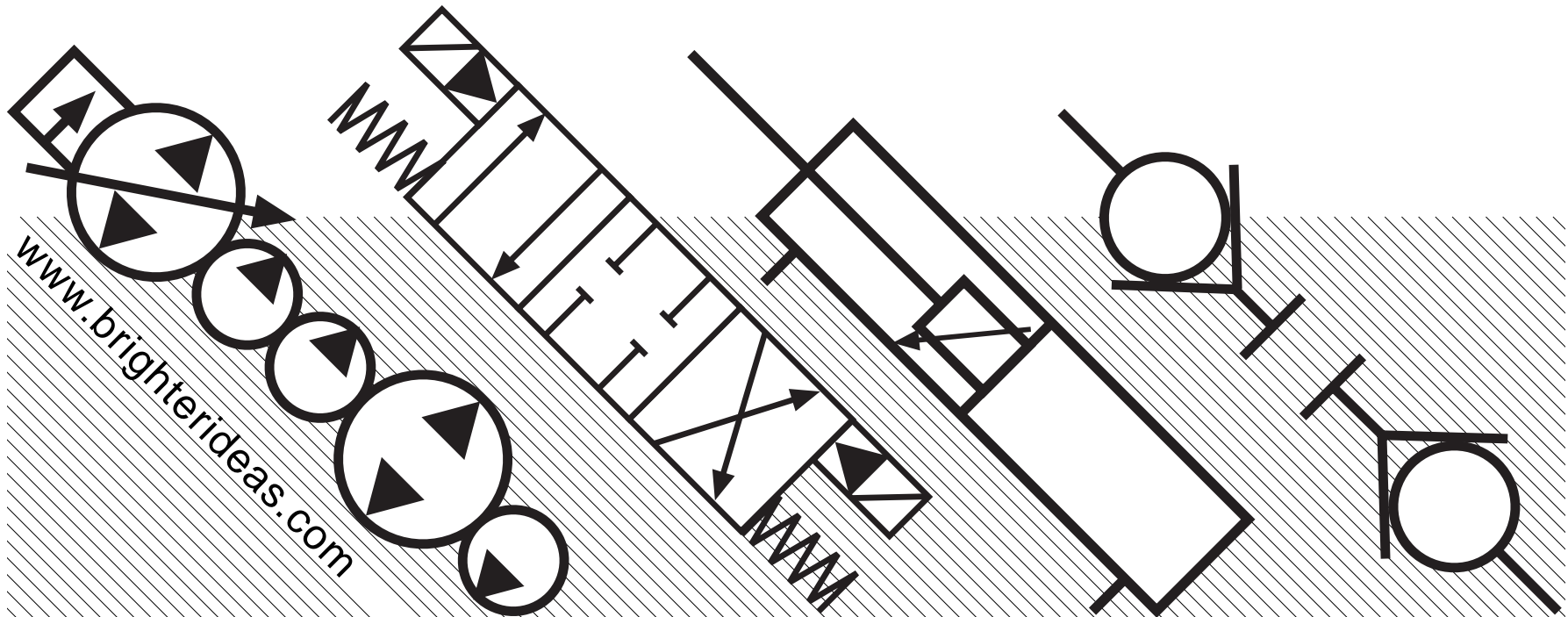


# The Secret of Hydraulic Schematics



© 1997 - 2006 Sullivan Training Systems  
brighterIDEAS for Education & Training



# Table of Contents

The Secret to Reading and Interpreting Hydraulic Schematics .....	1
Hydraulic System Schematics .....	1
Reservoirs .....	2
Hydraulic Lines, Tubes & Hoses .....	3
Pumps .....	5
Hydraulic Motors .....	7
Hydraulic Cylinders .....	8
Area, Volume & Cycle Time .....	10
Pressure Control Symbols .....	11
Pressure Relief Valve .....	12
Sequence Valve .....	13
Pressure Reducing Valve .....	14
Directional Control Valves .....	15
Two Position Flow Control Valves .....	17
Three Position Flow Control Valves .....	18
How Valves Are Actuated .....	19
Flow Control Mechanisms .....	20
Fluid Conditioning Mechanisms and Symbols .....	21
Accumulators .....	22
Miscellaneous Mechanisms and Symbols .....	23



# The Secret to Reading and Interpreting Hydraulic System Schematics

The secret to being successful at reading and interpreting a schematic for a hydraulic system is really quite simple. Very often, technicians will forget that the symbols on schematics are really a completely different language of pictographs — *pictures of what the object does* — used to represent the component. As you read this manual and begin to study the symbols inside, go to the extra effort to try and figure out why the symbols are drawn as they are. If you think about it, pumps will look like what pumps do, and all of the other symbols will come close to looking like what they are intended to be.

As you read the schematic, remember the following:

1. You already have a good idea of what the machine does and how the components work.
2. The schematic is a picture of the machine, which does what you understand.
3. Therefore, whether it looks like it or not, **the schematic and the machine match.**

Don't forget what you already know when you pick up a schematic — use what you know to force the schematic to make sense. Take the time to learn what the system is supposed to do. This is what a schematic is for — to teach why a system does what it does.

**If you get lost**, remember that you always have to have fluid flowing, and as it flows it follows this path: starting at the pump, fluid flows from high pressure to low, and ends up back at the reservoir.

**Good luck.**

# Reservoirs

Reservoirs are used to contain fluid, provide cooling, separate out air and sludge, and provide a head pressure to the pump if the reservoir is pressurized.



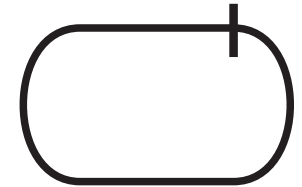
VENTED RESERVOIR



PRESSURIZED RESERVOIR

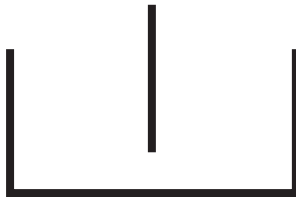


PRESSURIZED RESERVOIR



PRESSURIZED RESERVOIR

Reservoirs can also be drawn to show the point of connection for suction and return lines.



VENTED RESERVOIR  
OIL RETURN ABOVE OIL LEVEL



VENTED RESERVOIR  
OIL RETURN BELOW OIL LEVEL



VENTED RESERVOIR  
SUCTION LINE  
ATTACHED TO BOTTOM

# Hydraulic Lines, Tubes & Hoses

Hydraulic lines, tubes and hoses (or any other conductor) that carry the fluid between components is drawn as a line.



PRESSURE OR  
RETURN LINE



OIL FLOWS  
IN ONE DIRECTION



OIL FLOWS  
IN BOTH DIRECTIONS



PILOT LINES



DRAIN LINES



FLEXIBLE LINE



GASEOUS SUPPLY  
SHOWING DIRECTION



OUTLINE FOR  
ENCLOSURE



INSTRUMENT  
LINE

# Hydraulic Lines, Tubes & Hoses (continued)

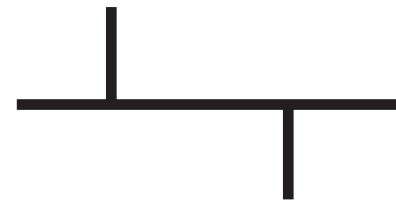
Connections for lines and hoses are shown below. Pay particular attention to the presence of a “dot” at the intersection of lines. If there’s no “dot” visible and lines cross, the lines do not connect. If lines intersect but one line ends, then even without a “dot” the lines do connect.



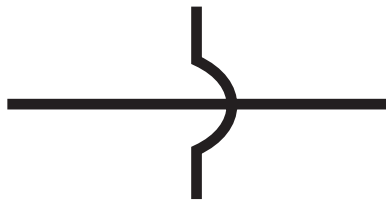
LINES  
CONNECTED



LINES  
CONNECTED



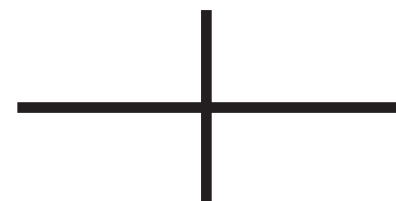
LINES  
CONNECTED



LINES NOT  
CONNECTED



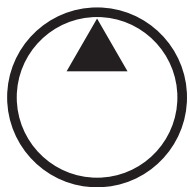
LINES NOT  
CONNECTED



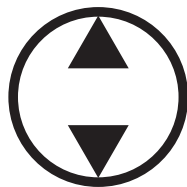
LINES NOT  
CONNECTED

# Pumps

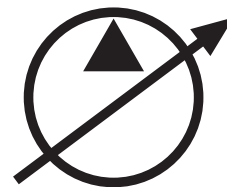
Pumps are drawn as circles with triangles pointing outward from the center. The triangle represents the direction that fluid flows out of the pump and should be viewed as an arrow. A single arrow shows a one-direction (unidirectional) pump, while two arrows indicate a reversible (bidirectional) pump. A diagonal arrow cutting across the pump body indicates the pump displacement (output flow and volume) can be adjusted. A small rectangle on the side of the pump with a small arrow inside indicates that the pump output is compensated (adjusted or controlled) by a pressure signal from a pilot line.



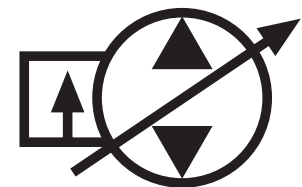
FIXED DISPLACEMENT  
UNIDIRECTIONAL



FIXED DISPLACEMENT  
REVERSIBLE



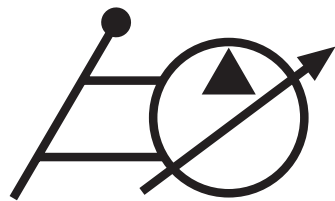
VARIABLE  
DISPLACEMENT



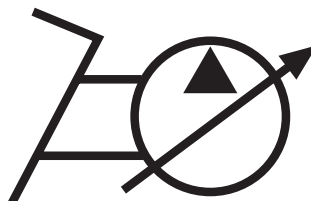
VARIABLE DISPLACEMENT  
PRESSURE COMPENSATED

# Pumps (continued)

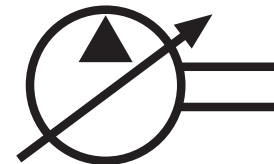
Pumps are also drawn to indicate how their output can be controlled. Note that the attachments to the pumps look like the components they represent. The lever and pedal look like a lever and pedal. The drive shaft is shown as a pair of lines on the side of the pump, either with or without an arrow showing the direction of rotation. Pumps can also be drawn as stacks, which indicates that all pumps are driven by the same driveshaft or PTO.



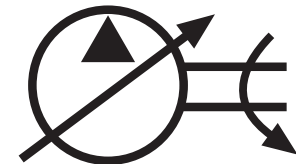
LEVER  
CONTROLLED



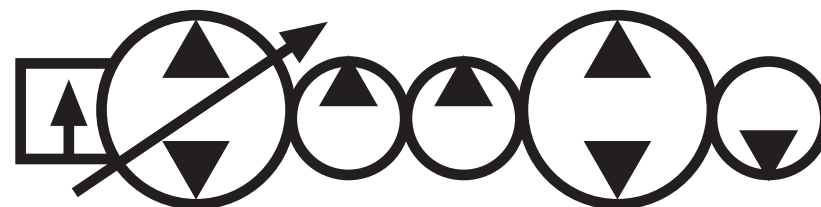
PEDAL  
CONTROLLED



PUMP WITH  
DRIVE SHAFT



DRIVE SHAFT  
SHOWING DIRECTION



PUMP STACK

# Hydraulic Motors

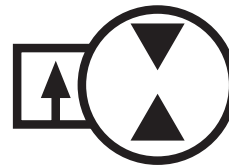
Hydraulic motors are actually hydraulic pumps that work in reverse. Except for a few minor differences pumps and motors are virtually identical. Use the same rules to interpret motor symbols as you would pump symbols.



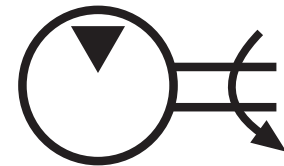
NON-REVERSIBLE  
MOTOR



REVERSIBLE  
MOTOR



BI-DIRECTIONAL  
PRESSURE COMPENSATED



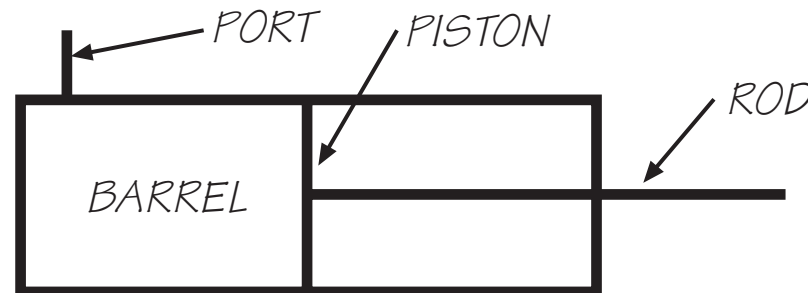
MOTOR WITH  
DRIVE SHAFT

# Hydraulic Cylinders

Hydraulic cylinders convert fluid power to linear mechanical power. Fluid under pressure pushes against the ends of the piston to move it in order to move some other mechanism. Cylinders are drawn as rectangles with lines in the center to represent the **piston**, and lines through the ends to represent the **rod**. **Fluid ports** are shown on the outer ends of the **cylinder barrel**.

A **single-acting cylinder** only has one port so that fluid under pressure only enters one end and pushes only in one direction. The cylinder reverses by opening a valve to let gravity or a spring return the piston to the other end.

A **double-acting cylinder** has ports at each end so pressurized fluid will enter both ends and push against the piston in both directions.



TYPICAL HYDRAULIC CYLINDER

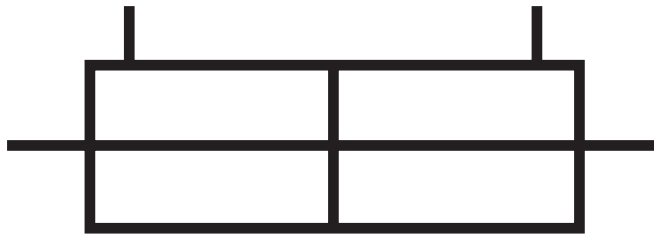
# Hydraulic Cylinders (continued)



SINGLE-ACTING CYLINDER



DOUBLE-ACTING CYLINDER



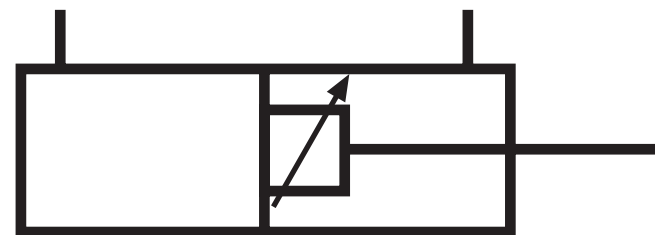
DOUBLE ROD-END CYLINDER



DIFFERENTIAL CYLINDER



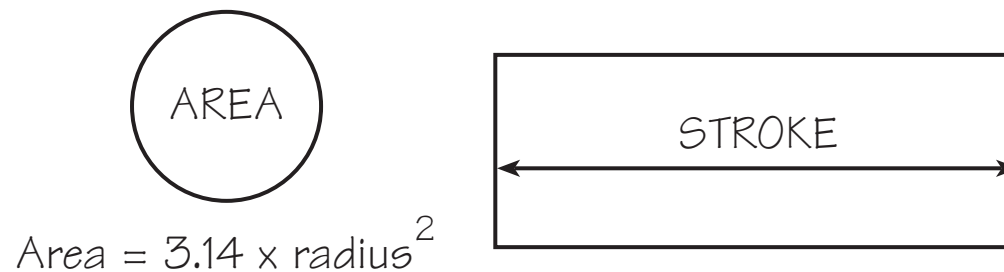
SINGLE ROD END WITH A  
FIXED CUSHION AT BOTH ENDS



SINGLE ROD END WITH ADJUSTABLE  
CUSHION ON ROD END ONLY

# Area, Volume & Cycle Time

The speed at which a cylinder moves is based upon the **fluid flow rate** (in gallons/minute or cubic feet/minute) and the volume (displacement) of the piston. “**Cycle time**” is the time it takes a cylinder to move its full length, and is found by dividing the **displacement of the cylinder (area x stroke)** by the flow rate, then multiplying by **60 seconds**. Cycle time is critical in diagnosing a hydraulic problem.



$$\text{VOLUME (CID)} = \text{Area} \times \text{Stroke}$$

$$\text{CYCLE TIME} = (\text{Volume/Flow Rate}) \times 60$$

$$\frac{150 \text{ cu. in. cylinder}}{450 \text{ cu. in. per minute flow}} \times 60 \text{ sec} = 0.333 \times 60 = 20 \text{ sec}$$

**Volume** and **Displacement** are the same, and are found by multiplying area times length. When calculating cycle time, make sure you use the same units of measurement. Cubic feet per minute cannot be used with gallons, and vice versa.

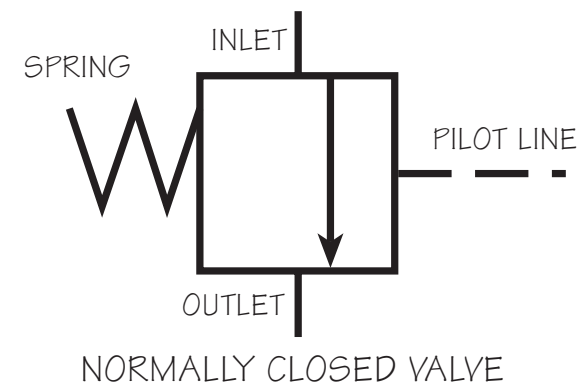
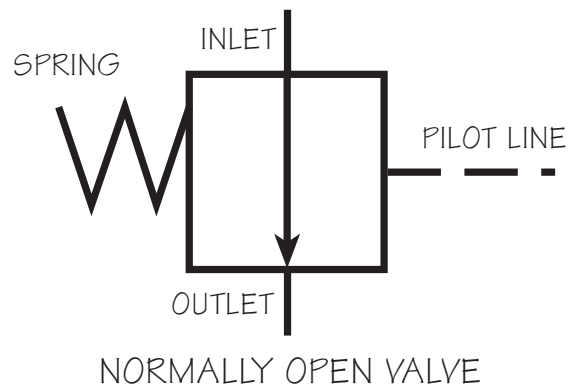
# Pressure Control Symbols

Hydraulic pressure is controlled through the use of **valves** that open and close at different times to allow fluid to be **bypassed from points of high pressure to points of low pressure**. The basic valve symbol is a square which represents the valve body or **spool**. An arrow in the center represents the path oil takes through the valve.

Pressure control valves are typically **pilot operated** — that is, the valve is moved automatically by hydraulic pressure and not by a person. Pilot oil pressure is resisted by a spring, which can often be adjusted. **The higher the spring tension, the more fluid pressure is required to move the valve.**

To visualize the operation of this type of valve, imagine that the entire square will move away from the pilot line and towards the spring. If the valve is **normally-open**, fluid flow will be cut off by the pilot line. If the valve is **normally-closed**, the pilot line will cause oil to start flowing.

Valves can either be on/off valves with no flow in the middle, or infinitely variable, which means flow will gradually increase or decrease as pilot pressure increases and/or decreases.



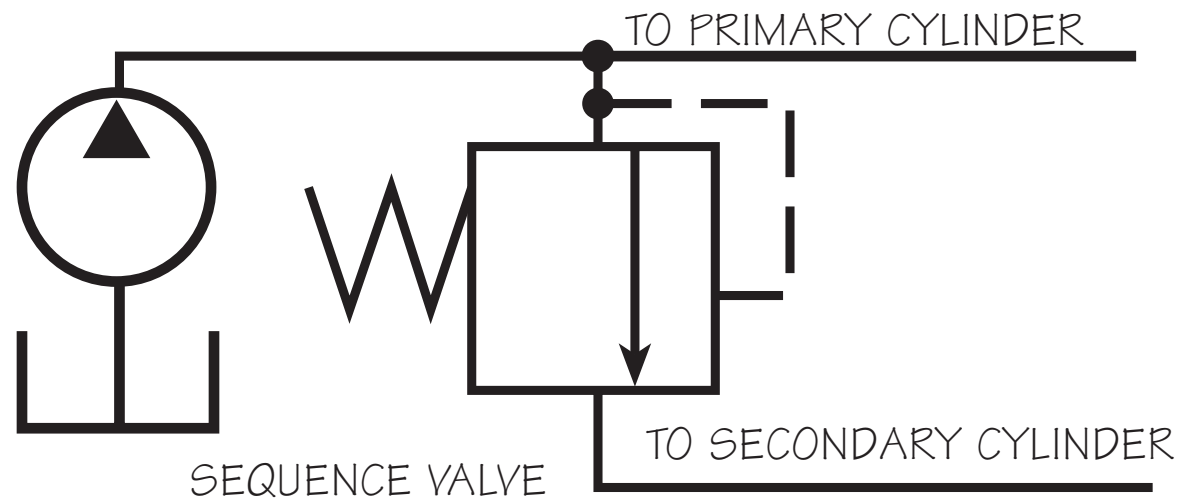
# Pressure Relief Valve

A pressure relief valve is a normally closed valve that senses the high pressure at its inlet. As the pressure at the inlet increases, the pressure in the pilot line begins to push against the valve body (spool). As the valve body moves, the ports begin to line up and fluid will begin flowing through the relief valve. The relief valve typically dumps back into the reservoir. Most relief valves are infinitely variable.



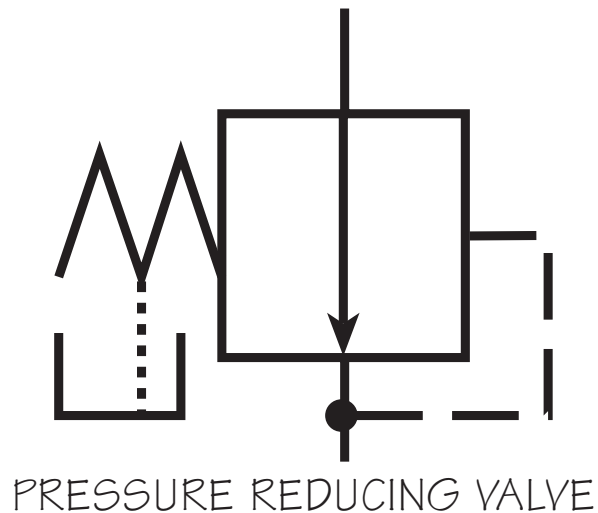
# Sequence Valve

A sequence valve is a normally closed valve that opens once the inlet pressure reaches a pre-set point. This type of valve is designed to allow different components to act “sequentially”, meaning one after the other. Once the primary actuator reaches the limit of its travel fluid pressure in the feed line will rise. This rising pressure opens the sequence valve which allows fluid to flow through it to the secondary cylinder.

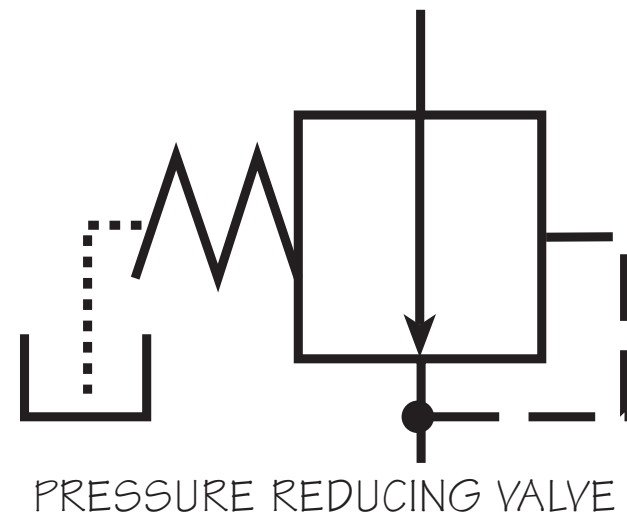


# Pressure Reducing Valve

A pressure reducing valve is a normally open valve that senses the outlet pressure going to an actuator. As the pressure in the outlet increases, pilot pressure increases which gradually closes the reducing valve. As the valve closes, oil from the high pressure side of the valve is directed back to the reservoir which dumps pressure at the outlet.



OR

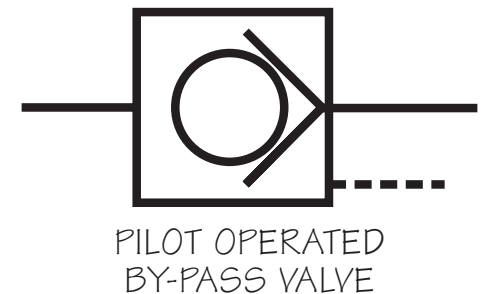
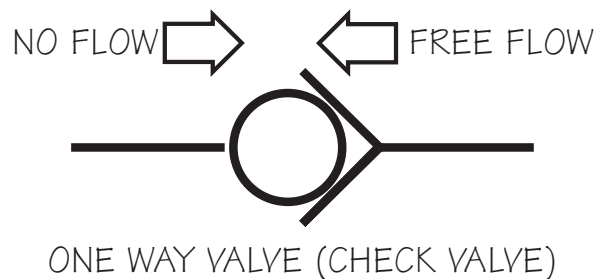


# Directional Control Valves

The direction that fluid flows in a line can be controlled by using valves which *allow* flow in only one direction. These valves are typically referred to as “check valves” because they “check” the flow if it tries to reverse. These valves can have simple check balls or can have machined pop-pet type valves. They can also be more complex pilot operated valves that have spools.

In the case of a ball check valve, the allowed flow is **opposite the arrow, or towards the ball**. If the valve has no spring, the valve offers resistance to flow only in the “closed” direction; in the “open” direction the valve moves with any movement of fluid and does not have a pressure setting.

If the check valve has a spring it will oppose flow in the “open” direction up to the point where hydraulic pressure overcomes spring tension. Check valves can also be pilot operated.

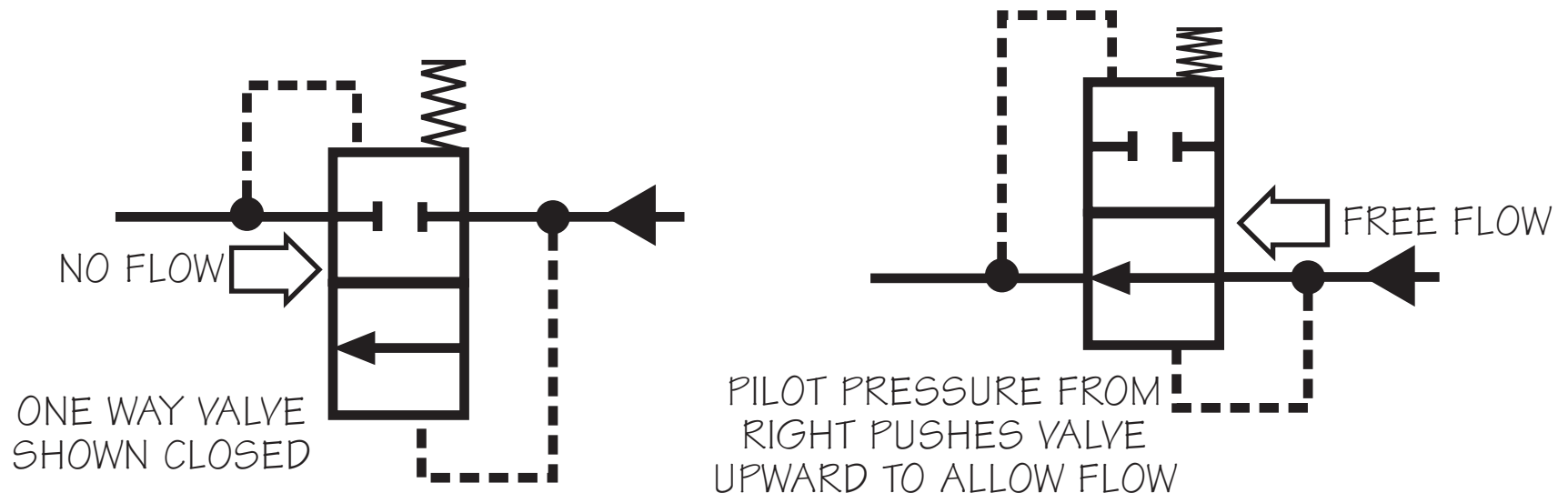


# Directional Control Valves (continued)

Another method of drawing check valves (directional valves) is using composite symbols as in the previous sequence. This method contains a blocked path and a free path. The dashed lines represent pilot pressure lines. As pressures increase on the blocked side of the valve, that pilot line moves the valve to reduce or cut off supply, depending upon whether the valve is normally open or closed.

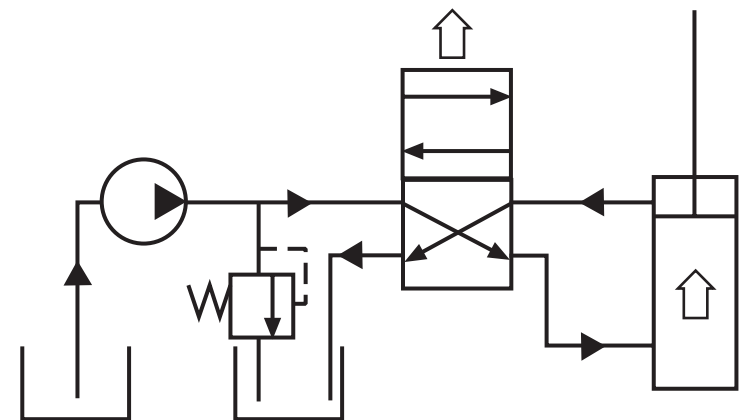
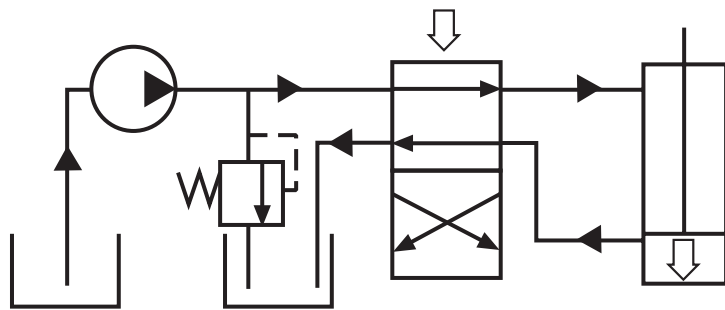
The spring keeps the valve in the **normal position**. If pressure builds up on the flow side of the valve, the pilot line pressurizes and moves the valve into the open position, compressing the spring in the process, and allowing oil to flow. If the flow attempts to reverse, the other pilot line pressurizes and adds to spring pressure to close the valve, cutting off flow.

These valves are commonly referred to as flow dividers or flow control valves. This type of valve can be a pressure relief valve or pressure reducing valve depending upon location of pilot source and spring setting.



# Two Position Flow Control Valves

Two position flow control valves typically are used to make the flow reverse to an actuator in a simple system, although other arrangements are possible. The valve **spool** slides long-ways to allow one or the other valve position to direct flow. Because these valves have no center position they must be used with a pressure relief valve that opens to dump system pressure when the actuator bottoms out.



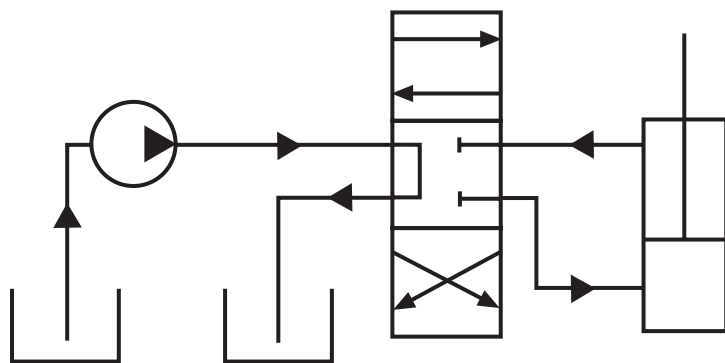
Note that the **direction of oil flow does not change on the pump side of the valve**. The direction changes only *after* the valve “flip-flops” the flow to redirect pressure to the retracted side of the cylinder.

# Three Position Flow Control Valves

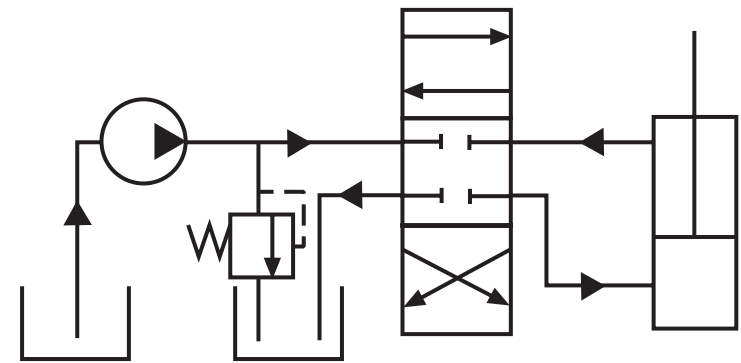
Flow control valves are drawn as composite symbols using squares to represent the valve spool. To visualize the operation of these valves it's necessary to imagine them moving long-ways with the spool sliding to move the different flow arrows into a position to allow oil to flow through them.

The centers of the valves determine what type of system is in use. An **“open center”** system uses valves that allow oil to flow through them at all times — out of the pump and back into the reservoir — when no actuators are in use. This system does not require a pressure relief valve.

A **“closed center”** system uses valves that block flow through them when no actuators are in use, thereby “liquid locking” the system. In this type of system a pressure relief valve is mandatory to prevent the system from destroying itself when the valves are in the center.



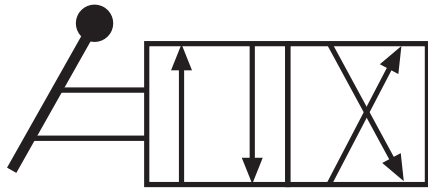
OPEN CENTER VALVE & SYSTEM



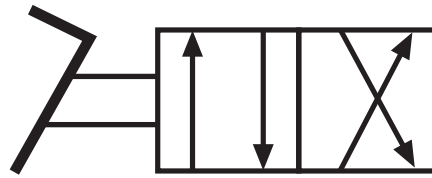
CLOSED CENTER VALVE & SYSTEM  
WITH PRESSURE RELIEF VALVE

# How Valves Are Actuated

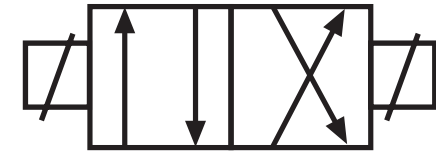
There are a variety of ways to actuate control valves. These include manually by hand with a lever, manually by foot with a pedal, with an electric solenoid (coil), using external pilot pressure, using a spring, using internal pilot pressure, or using any combination of the above.



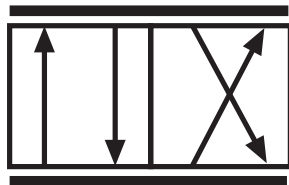
LEVER CONTROLLED



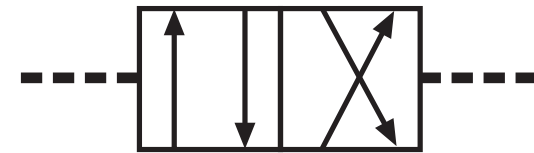
PEDAL CONTROLLED



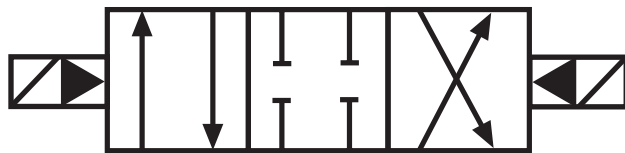
SOLENOID CONTROLLED



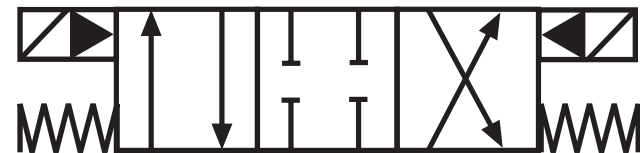
INFINITELY VARIABLE  
(NOT JUST ON AND OFF)



PILOT PRESSURE  
CONTROLLED



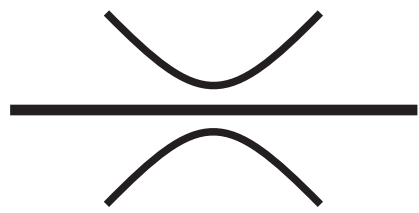
SOLENOID OPERATED WITH  
INTERNAL PILOT PRESSURE



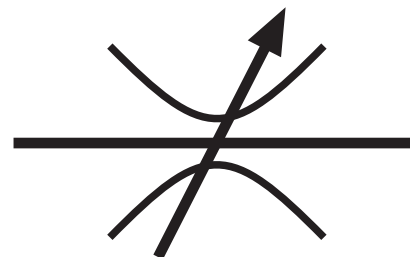
SOLENOID OPERATED WITH INTERNAL  
PILOT PRESSURE AND SPRING CENTERING

# Flow Control Mechanisms

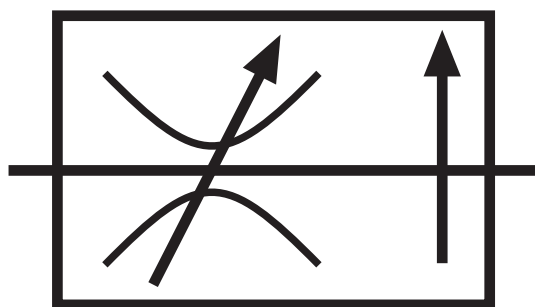
Sometimes it's necessary to slow down flow or to create a pressure drop at some point in the system. This is done with a restrictor (snubber) that is similar to a fuel jet. Snubbers are drawn to represent a pinch in the line, and can either be fixed or variable, and can be controlled by other systems as well — such as being temperature or pressure controlled.



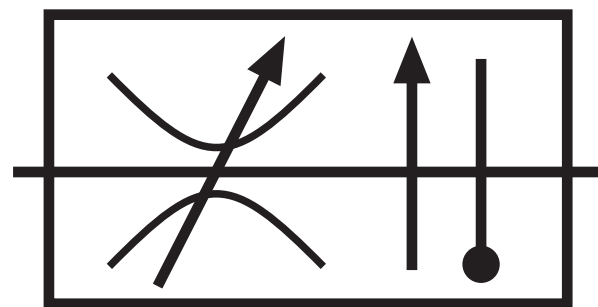
FIXED RESTRICTOR



ADJUSTABLE RESTRICTOR



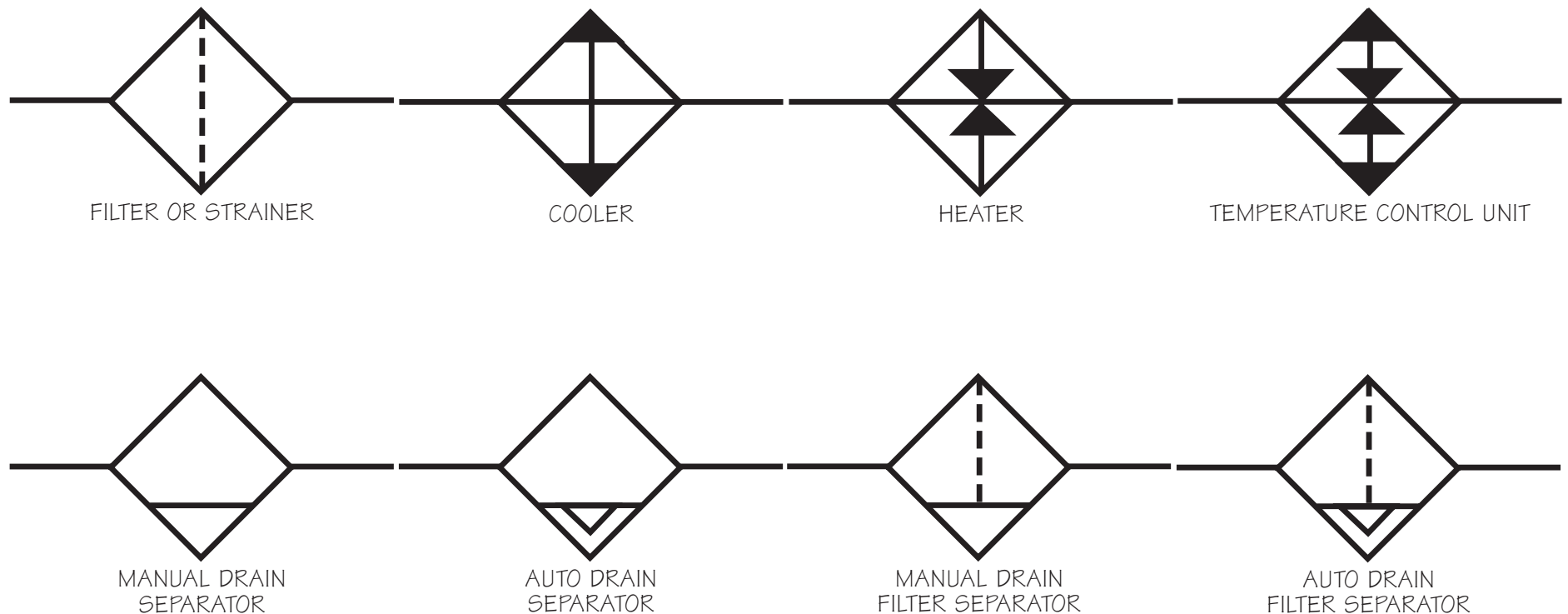
ADJUSTABLE  
RESTRICTOR  
PRESSURE COMPENSATED



ADJUSTABLE RESTRICTOR  
PRESSURE & TEMPERATURE  
COMPENSATED

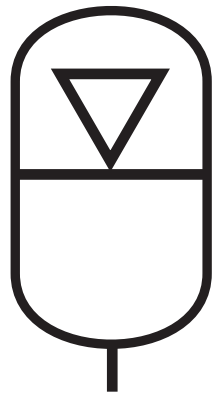
# Fluid Conditioning Mechanisms and Symbols

Oil is conditioned by various mechanisms. “Conditioned” implies that the condition of the oil is changed from one state to another. Typical conditioners are filters, heaters and coolers. In addition, these mechanisms can contain drains of various sorts.

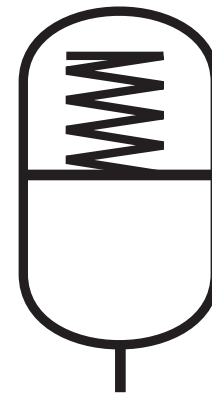


# Accumulators

Hydraulic accumulators act as shock absorbers for the system. They are installed in parallel with the pump and do several things. They provide a small amount of emergency flow for steering and brakes, dampen out oscillations in pressure (keeping pressure constant), and provide flow when components move and activate. They're drawn as ovals with a line in the center which represents the diaphragm or piston that separates the oil from the nitrogen or spring.

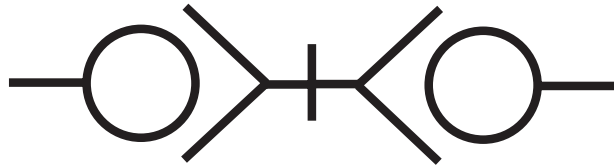


PNEUMATIC  
(GAS FILLED)  
ACCUMULATOR



SPRING  
LOADED  
ACCUMULATOR

# Miscellaneous Mechanisms and Symbols



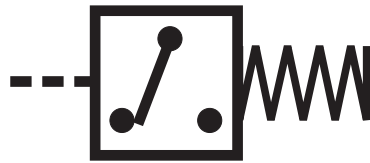
QUICK DISCONNECTS  
(CONNECTED)



QUICK DISCONNECTS  
(DISCONNECTED)



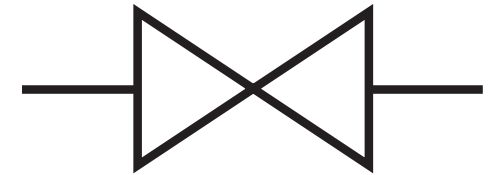
SPRING



PRESSURE SWITCH



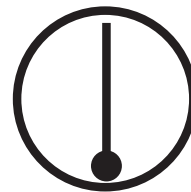
RATCHETING DETENT  
ON VALVE



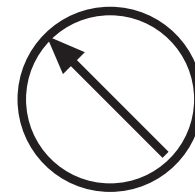
MANUAL SHUTOFF VALVE



TEST POINT FOR GAUGE



TEMPERATURE  
INDICATOR



PRESSURE  
INDICATOR

©1997 - 2006  
Sullivan Training Systems  
115 Honeysuckle Lane  
Durham NC 27703  
919-957-1800

[www.brighterideas.com](http://www.brighterideas.com)

brighterIDEAS in Technician Training

This text may be reproduced for training purposes by any person or school provided that it is duplicated in its entirety, complete with all logos and identifying marks. Modification of this document in any way constitutes a violation of this agreement.

Please visit our website to view the new tools and texts currently available.

Feel free to email this document at will to friends and colleagues who work with hydraulics.

