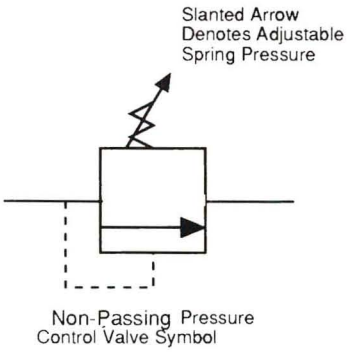
CHAPTER 11

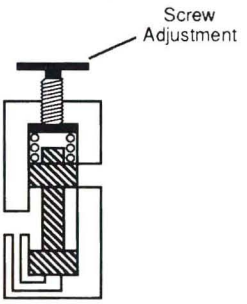
Pressure Control Valves

As we have seen, maximum system pressure can be controlled with the use of a normally non-passing 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 and flow is diverted to tank. This type of normally non-passing pressure control is known as a relief valve.



pressure adjustment

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



uses of a non-passing pressure valves

Normally non-passing pressure control valves have many uses in a hydraulic system. Besides using the valve as a system relief, a non-passing 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.

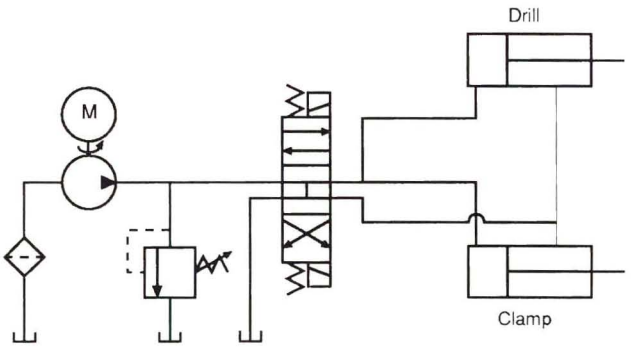
sequence valve

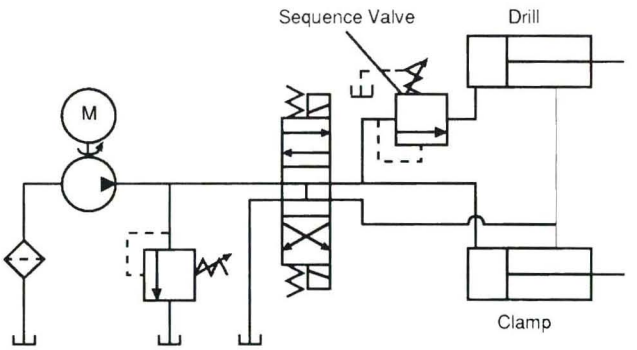
A normally non-passing pressure control valve which causes one operation to occur before another is referred to as a sequence valve.

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.

Flow to the drill cylinder is blocked. Therefore, the clamp cylinder will extend first. When the clamp contacts the work piece, the pump applies more pressure to overcome the resistance. This rise in pressure actuates the spool in the sequence valve. Primary and secondary passages connect. Flow goes to the drill cylinder.

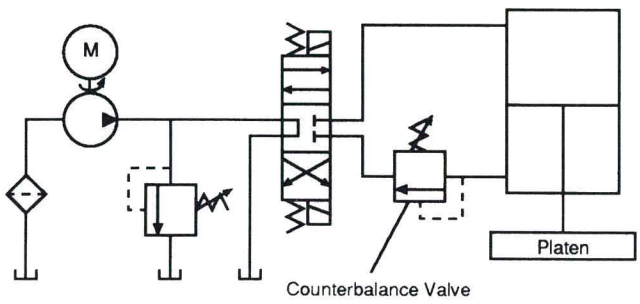




counterbalance valve

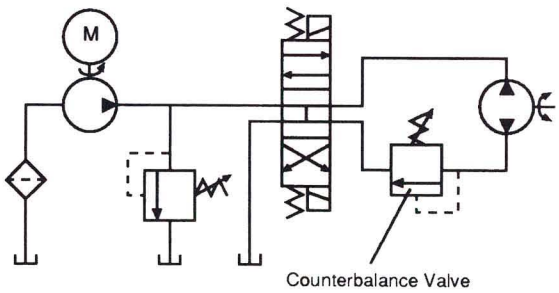
A normally non-passing pressure control valve can be used to balance or counteract a weight such as the platen of a press. This valve is called a counterbalance valve.

counterbalance valve in a circuit



In a press circuit, when the directional valve directs flow to the cap end of the cylinder, the weight of the platen attached to the cylinder rod will fall uncontrollably. Pump flow will not be able to keep up.

To avoid this situation, a normally non-passing pressure valve is located downstream from the press cylinder. The spool in the valve will not connect primary and secondary passages until a pressure, which is sensed at the bottom of the spool, is greater than the pressure developed by the weight of the platen. (In other words, when fluid pressure is present at the cap end of the piston.) In this way the weight of the platen is counterbalanced throughout its downward stroke.

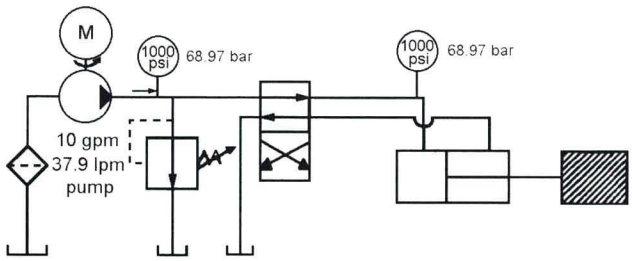


A counterbalance valve can also be used to retard the spinning motion of a weight attached to a motor shaft.

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 outlet of the motor, will not open until pressure is present at the motor outlet. This pressure counteracts the force of the spinning weight.

simple relief valve

A simple relief valve basically consists of valve body with a spool which is biased by a heavy spring. When pilot pressure at the spool end opposite the spring is high enough, the spool moves up opening a path to tank for pump flow.



In the circuit illustrated, the simple relief valve is set to relieve 10 gpm (37.9 lpm) when pressure at pump outlet reaches 1000 psi (68.97 bar). This does not mean that at a pressure level of 1000 psi (68.97 bar), the valve suddenly opens dumping flow to tank. The valve opens at a point below 1000 psi (68.97 bar) bleeding off fluid to tank and progressively bleeds more off as 1000 psi (68.97 bar) is approached.

In the previous lesson, we saw that clearances between moving parts of a pumping mechanism acted like restrictions allowing flow to slip back to pump inlet. As wear became excessive, the size of the restriction increased so much that pump/electric motor could have its total flow leak back to pump inlet. A relief valve can be thought of somewhat in the same manner.

The moving part inside a relief valve forms a restriction back to tank as the valve is operating. The restriction begins to appear in the system when a predetermined pressure level is reached. As system pressure and pilot pressure at the bottom of the spool increases, the size of the restriction also increases allowing more flow back to tank. At the pressure setting of the valve, the size of the restriction is large enough to accept all pump flow.

When pressure in a system drops below valve cracking pressure, the opening to tank through the valve disappears from the circuit.

relief valve setting affected by temperature

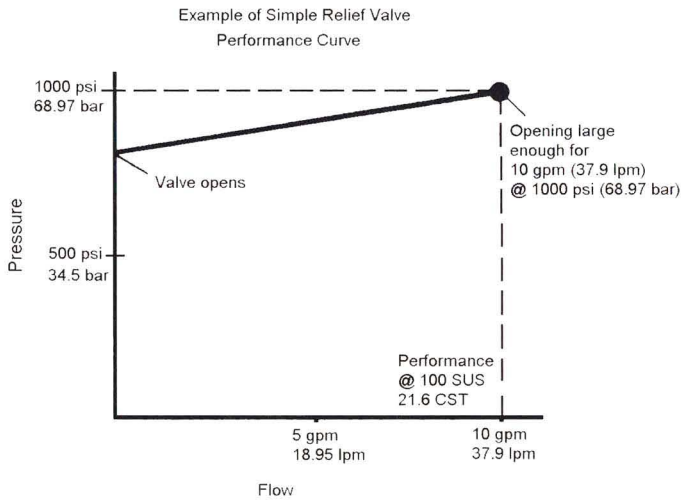
Since the opening through a relief valve is actually a restriction, flow through it is affected by temperature just as with any other restriction.

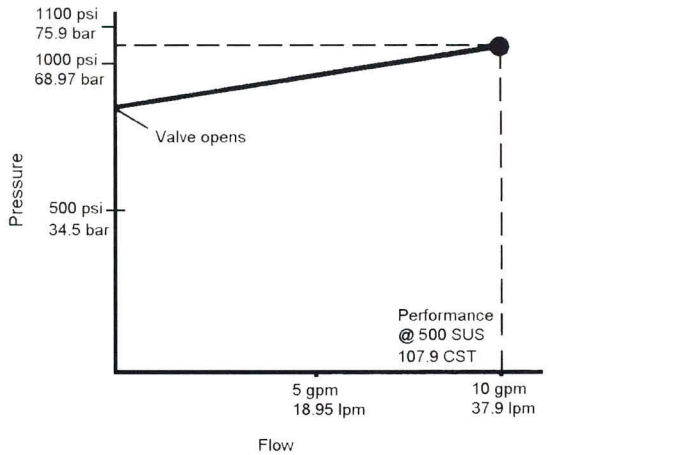
With a relief valve in a system set to relieve 10 gpm (37.9 lpm) at 1000 psi (68.97 bar), 10 gpm (37.9 lpm) can be pushed through the relief valve opening when 1000 psi (68.97 bar) is present at the valve inlet. This assumes that the liquid viscosity remains constant.

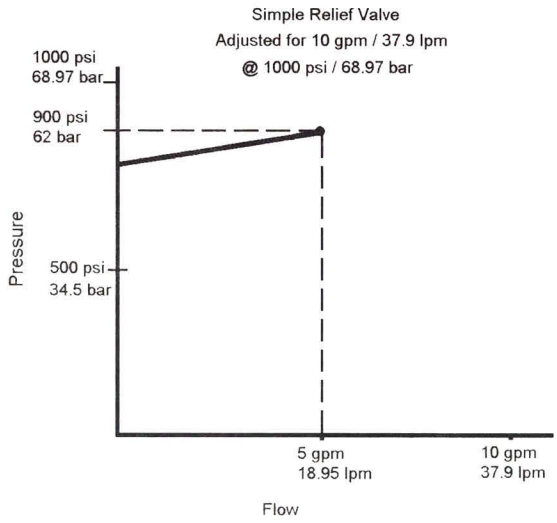
With fluid in a machine reservoir at room temperature, its viscosity might be 400-500 SUS (86.3 - 107.9 CST). If the system relief valve were adjusted to handle 10 gpm (37.9 lpm) at 1000 psi (68.97 bar) while at this viscosity, pump pressure might be limited to only 900 psi (62 bar) or less once the fluid heated up. With fluid at operating temperature and its viscosity decreased to 100 SUS (21.6 CST), 10 gpm (37.9 lpm) could be pushed back to tank through the valve with less pressure.

The opposite also occurs when the relief valve is set at operating viscosity. At start up, this will mean that pump pressure could approach 1100 psi (75.9 bar).

In a system where maximum pump pressure is rather critical, the system should be allowed to warm up before relief valve adjustments are made.





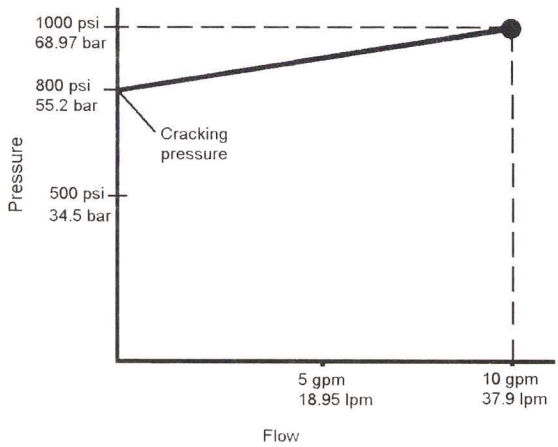


relief valve setting affected by pump wear

Setting of a relief valve is affected by pump wear.

With a relief valve set to relieve 10 gpm (37.9 lpm) at 1000 psi (68.97 bar), a pump flow of 10 gpm (37.9 lpm) can pass through the relief valve opening once 1000 psi (68.97 bar) is present at valve inlet. As the pump wears, discharge flow decreases and less flow passes through the relief valve. Pump/electric motor pressure will decrease as its flow dumps over the relief valve.

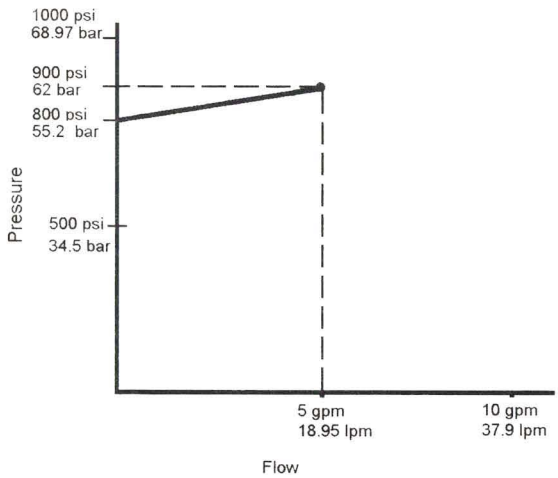
With a relief valve adjusted for 10 gpm (37.9 lpm) at 1000 psi (68.97 bar), system relief valve pressure might be only 900 psi (62 bar) as a reduced flow of 5 gpm (18.95 lpm) passes through the valve. It would appear that the relief valve setting was changed.



cracking pressure - simple relief valve

Cracking pressure is the point at which a relief valve begins to open a flow path back to tank. This point for a simple relief valve is somewhat below the relief valve setting. Simple relief valves have characteristically early cracking pressures.

In the illustrated performance curve for a simple relief valve, the valve is set to relieve a pump flow of 10 gpm (37.9 lpm) when pressure reaches 1000 psi (68.97 bar). The curve points out that the valve cracks open at 800 psi (55.2 bar) increasing in size as pump pressure approaches 1000 psi (68.97 bar). Finally, at 1000 psi (68.97 bar) the size of the restriction through the valve is large enough to accept 10 gpm (37.9 bar).



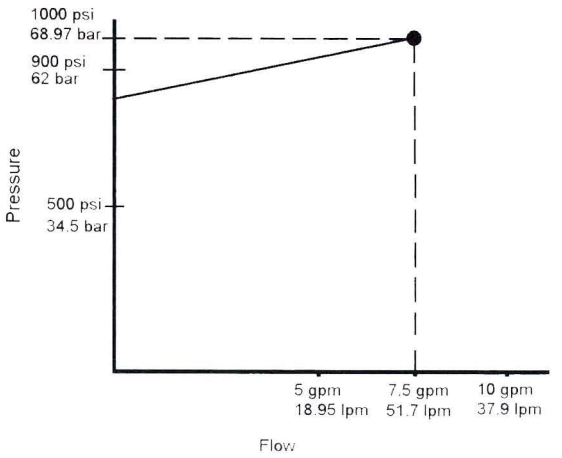
system affected by early cracking pressure

A relief valve with an early cracking pressure can be a disadvantage for a system. Assume that a pump/electric motor develops 750 psi (51.7 bar) to push a flow of 10 gpm (37.9 lpm) out to an actuator. 550 psi (37.9 bar) is required for the load; 200 psi (13.8 bar) is used to overcome liquid resistances. With a simple relief valve set for 1000 psi (68.97 bar), the valve remains closed; all pressurized liquid flow is directed toward the work load.

If work load pressure increases to 700 psi, (48.28 bar) then pump/electric motor must increase its output pressure to 900 psi (62.1 bar). (Discharge flow assumed constant.) With a cracking pressure

of 800 psi (55.2 bar), the valve at the current pump pressure is bleeding off 5 gpm (18.95 l/min) of pump flow back to tank. This means actuators are not filled as quickly and work is performed at a slower rate. It also means heat is unnecessarily being generated as fluid passes through the relief valve restriction.

If work load pressure were 750 psi (51.7 bar), pump/electric motor might develop 950 psi (65.5 bar) to push its flow out to the system. With this being higher up on the relief valve curve, more flow passes to tank. At this point, rod speed decreases even more since a greater amount of flow is dumping back to tank; and, more heat is generated unnecessarily.



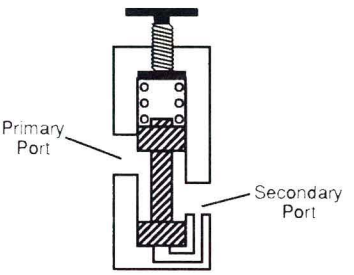
normally passing pressure valve

A normally non-passing pressure control valve has primary and secondary passages disconnected, and pressure at the bottom of the spool is sensed from the primary port.

A normally passing 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 usually is a normally passing pressure control valve.

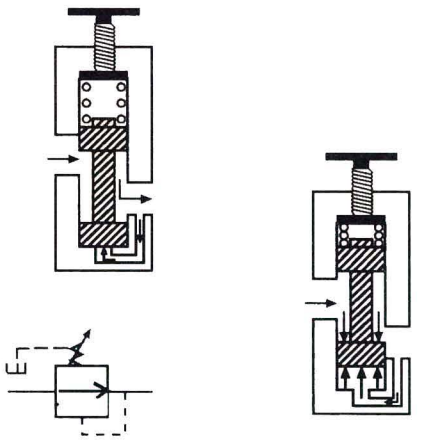


Pressure Reducing Valve

how a pressure reducing valve works

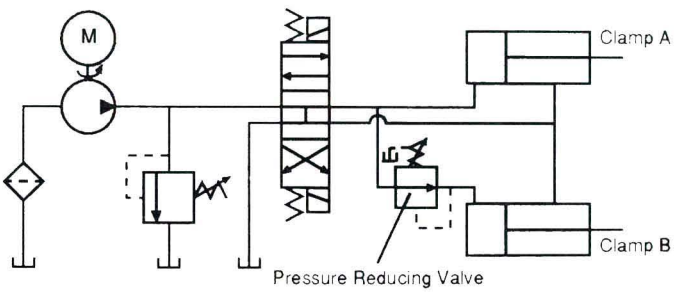
A pressure reducing valve operates by sensing fluid pressure after it has passed through the valve. As pressure downstream equals the setting of the valve, the spool is partially closed causing a restricted flow path. This restriction turns any excess pressure energy ahead of the valve into heat.

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


Normally Passing Pressure Control Valve Symbol

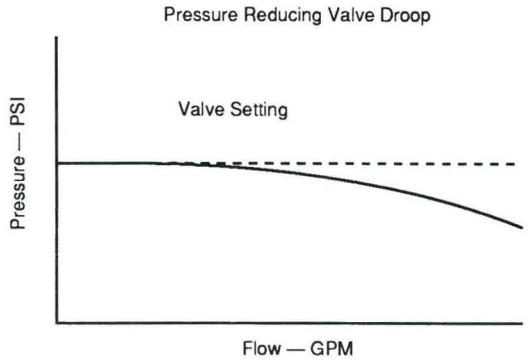
pressure reducing valve in a circuit

The illustrated clamp circuit requires that clamp cylinder B apply a lesser force than clamp A. A pressure reducing valve placed just ahead of clamp



cylinder B will allow flow to go to the cylinder until pressure reaches the setting of the valve. At this point, the valve spool is actuated causing a restriction to that leg of the circuit. Excess pressure ahead of the valve is turned into heat. Cylinder B clamps at a reduced pressure.

pressure reducing valve droop



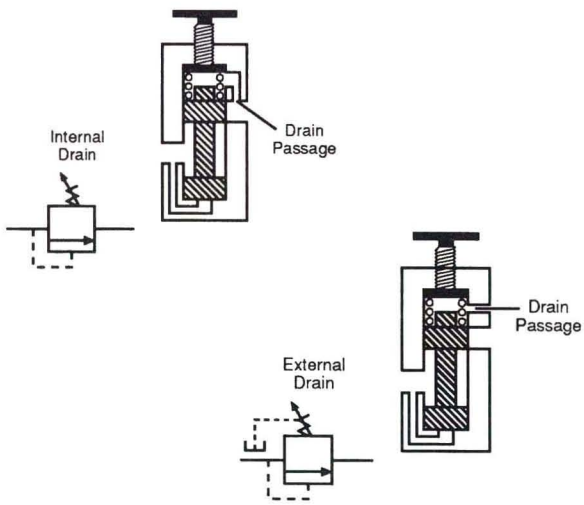
With the same valve setting, the reduced pressure downstream from a pressure reducing valve will be lower when the valve is handling its rated flow than when it is operating under deadheading conditions as in a clamp circuit. This difference in reduced pressures is known as pressure reducing valve droop. Droop is a characteristic of all reducing valves and becomes more pronounced as system pressure rises and flow increases.

A 15 gpm (56.85 lpm) pressure reducing valve could droop 50 psi (3.45 bar) at its rated flow and rated operating pressure. A 100 gpm (37.9 lpm) pressure reducing valve may droop as much as 150 psi (10.3 bar).

drains

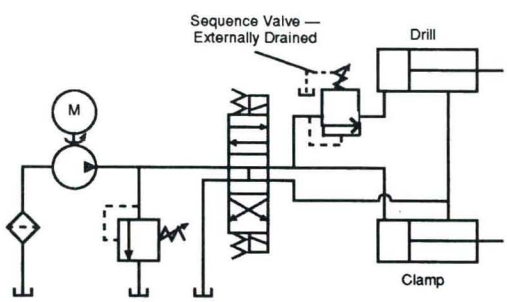
The spool in a pressure control valve moves within a passage. There is some leakage of fluid into the passage above the spool. This is a normal occurrence which serves to lubricate the spool.

In order for a pressure valve to operate properly, the area above the spool must be continuously drained so that the liquid does not impair the movement of the spool. 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

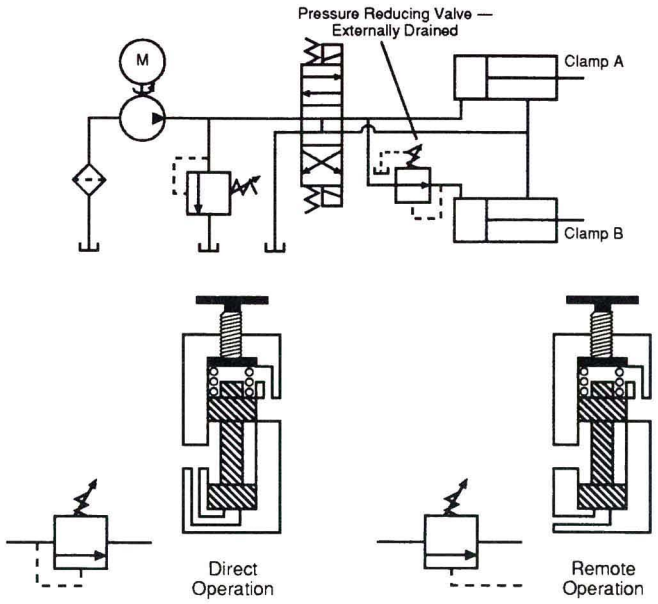
If the secondary passage of a pressure valve is a pressure line (or in other words does work) as in sequence valve and pressure reducing valve applications, the drain passage is connected to tank by means of a separate line. This is an external drain.

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 non-passing 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 non-passing pressure control valve which directs flow to tank when pressure in a remote part of a system reaches a predetermined level.

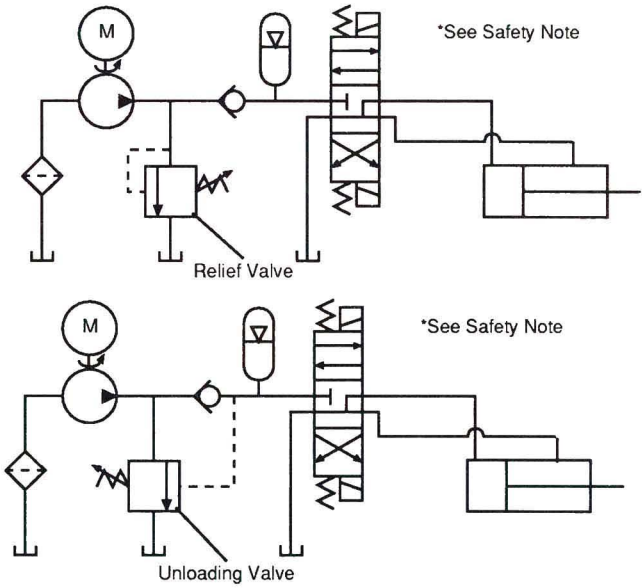
unloading valve in a circuit

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

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 to the valve setting.

The pump is not required to apply a high pressure to operate the unloading valve because the valve is operated from pressure in another part of the system.

Since pressure applied by the pump is negligible, so is the horsepower.



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

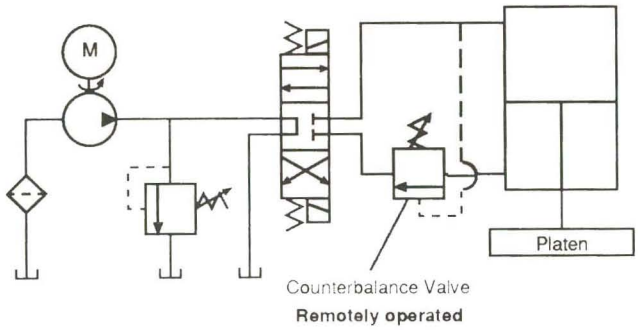
remotely operated counterbalance valve

A directly operated counterbalance valve, positioned downstream from a cylinder supporting a heavy platen, effectively balances or cancels out the weight of the platen. If the platen is required to move through the material during the pressing process, the weight of the platen does not add to the total pressing force. 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

With remote operation, the platen is still balanced on its downward stroke and use can be made of the platen's weight in pressing. If the platen attempts to pull away from fluid flow, pressure will drop off in the upstream cylinder line as well as in the pilot line. The valve will close and allow the flow to catch up. During the pressing operation, the valve will be wide open. No back pressure will act on the rod end side of the piston. The platen's weight can be added to the pressing force.



NOTE: This simplified circuit may need refining to achieve a smooth operation.

directly operated counterbalance valve in a motor circuit

A motor circuit is illustrated which uses a directly operated counterbalance valve to control the run-away tendency of a spinning load. With the valve set for 800 psi (55.2 bar), 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 (55.2 bar) more than the work load pressure. This is a disadvantage which is overcome by a brake valve.

brake valve

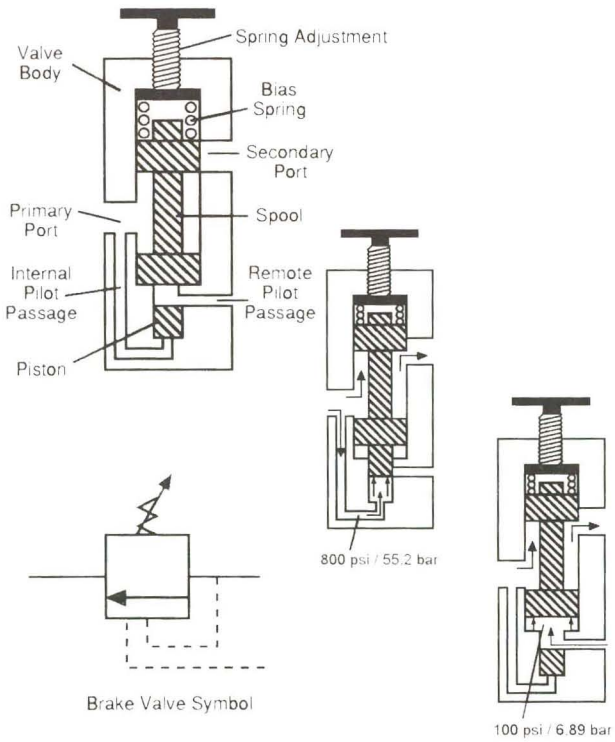
A brake valve is a normally non-passing pressure control valve with both direct and remote pilots connected simultaneously for its operation. This valve is frequently used with hydraulic motors instead of a directly operated counterbalance valve.

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 non-passing valve. Assume that the spring biasing the spool is adjusted for 800 psi (55.2 bar) direct operation. When pressure in the internal pilot passage reaches 800 psi (55.2 bar), the piston moves up pushing the spool and opens a passage through the valve.



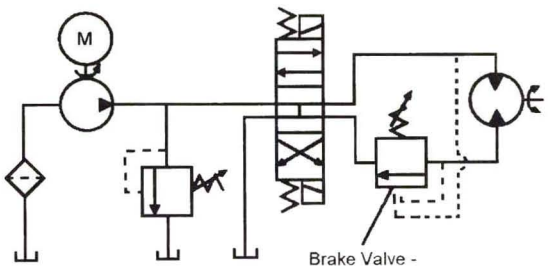
If pressure falls below 800 psi (55.2 bar), the valve closes. This operates as the directly operated counterbalance valve which we saw earlier.

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 (6.89 bar) 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 (55.2 bar), the valve will be open when 100 psi (16.89 bar) 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/ 68.97 bar) If the load attempts to run away pressure drops off in the motor inlet line. The brake valve closes and does not reopen until a back pressure of 800 psi (55.2 bar) is generated to slow down the load.

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



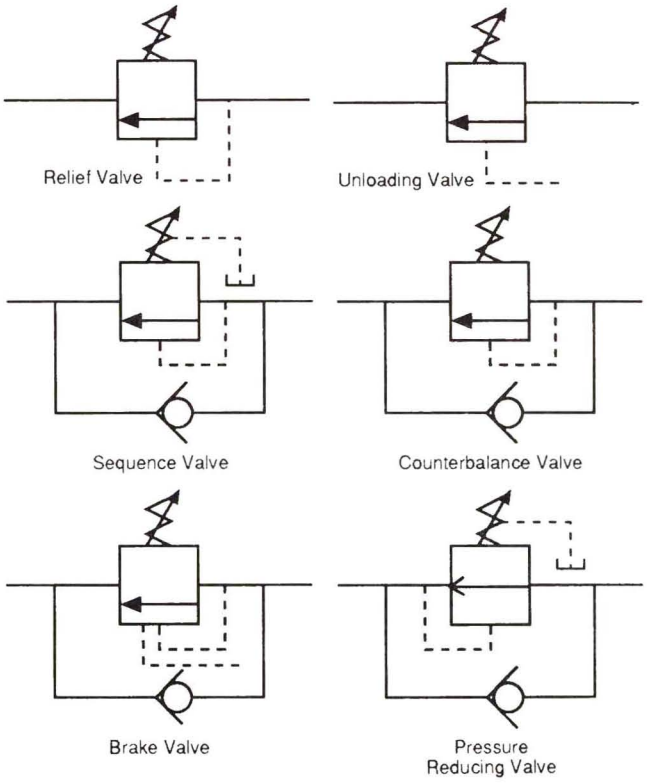
Brake Valve - Remote and direct operated simultaneously

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 non-passing 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 passing 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.



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 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.

terms and idioms associated with pressure control valves

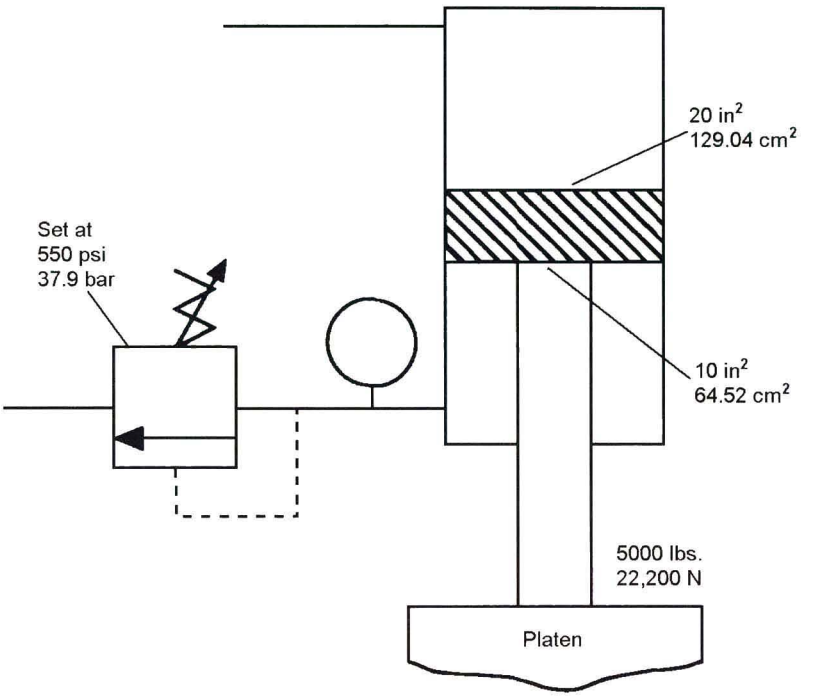
DIRECT OPERATED - We have been referring to "direct operated" as meaning that the valve's spool is piloted or actuated by an internal pilot line within the valve body. "Direct operated" is also commonly used to denote that the spool in the valve is held biased by spring pressure.

DUMPING OVER THE RELIEF VALVE - flow passing through the relief valve.

exercise
pressure control valves
40 points

1. In the diagram, the directly operated counterbalance valve is set at 550 psi (37.9 bar).

   A. What does the gage read when the platen is not moving and is being suspended in mid-stroke? _____

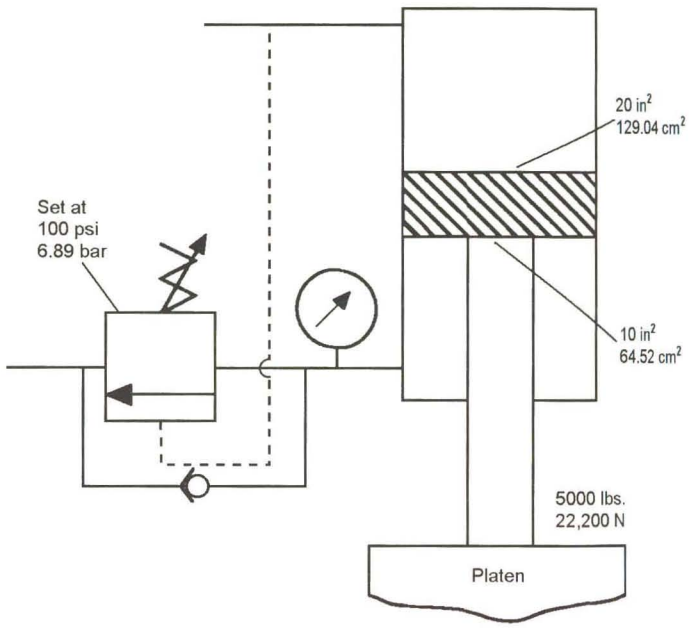


   B. What does the gage read when the platen is approaching the material to be pressed? _____

   C. Assume that the system relief valve is set for 1000 psi (68.97 bar) and that the movement of the cylinder rod is severely restricted once the platen contacts the material to be crushed. What is the maximum pressing force if the platen moves through the material during the pressing operation? _____

2. In the diagram, the remotely operated counterbalance valve is set at 100 psi (6.8 bar).

   A. What does the gage read when the platen is not moving and is being suspended in mid-stroke? _____



   B. What does the gage read when the platen is approaching the material to be pressed? _____

   C. Assume that the system relief valve is set for 1000 psi (68.96 bar) and that the movement of the cylinder rod is severely restricted once the platen contacts the material to be crushed. What is the maximum pressing force if the platen moves through the material during the pressing operation? _____

pressure control valves (cont.)

3. SITUATION: The clamp cylinder must extend first and clamp at a pressure of 500 psi (34.48 bar).

   PROBLEM: Add the appropriate valves.