

Hydraulic valves cure the shakes

Motion-control valves solve troublesome equipment-instability problems.

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Key points:

- Overcenter, or motion-control valves, are well suited for load holding and control.
- Standard overcenter valves can solve the vast majority of hydraulic motion-control problems.
- Motion-control valves are adjustable, available in numerous pressure ranges, with many pilot-ratio options, and in many sizes.

Resources:

Eaton Corp., www.eaton.com/hydraulics

Cartridge valves offer the same control options as traditional hydraulic valves but are generally smaller, lighter, and more tolerant of vibration and fluid contamination.

Because they eliminate the need for many of the hoses, tubes, and fittings in a circuit, there are fewer potential leak points.

And combining several cartridge valves in a common manifold, which creates a hydraulic integrated circuit, results in a dedicated package to control specific machine functions, often with considerable cost savings.

One important type of cartridge valve is the overcenter or motion-control valve. Variations abound, but these valves perform three basic functions for both linear and rotary motion, including:

Load holding. An overcenter valve prevents a load from moving when the directional valve is in the neutral position. This lets engineers use open-center directional valves and prevents leakage past the spool of closed-center directional valves.



Cartridge valves from Eaton's Integrated Hydraulics cover a broad range of pressures, flows, and hydraulic operations. They are used in demanding applications that require smooth motion and firm load control.

Load control. Overcenter valves prevent actuators from running ahead of the pump due to load-induced motion. (This occurs, in essence, when gravity pulls the load faster than the pump supplies fluid to move the cylinder rod.) This eliminates cavitation in the actuator and loss of control.

Load safety. In the case of a line break, an overcenter valve on an actuator prevents uncontrolled load movement. On a crane boom, for instance, hose-failure protection is vital as the loss of load control could endanger people and property.

Standard valves

The standard overcenter valve is a pilot-assisted relief valve with an integral free-flow check. Pilot pressure must overcome the spring force, which is counteracted by load pressure. This ensures a gradual opening and metering of flow past the poppet. It differs from a pilot check, where the check valve opens fully as soon as pilot pressure overcomes resistance from pressure in the cylinder port.

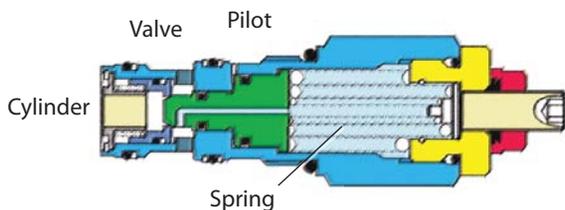
For example, Eaton's Integrated Hydraulics overcenter valves have a poppet that seals flow from an actuator; a check element that permits free flow to the actuator; and a pilot section that opens the poppet, permitting flow from the actuator at a controlled rate.

Two basic designs each have several variants. The direct-acting version, where actuator pressure acts on the full area of the poppet nose, is ideal for flows up to 200 lpm. The differential-area design, where pressure acts on an annular area, is suitable for flows up to 300 lpm. Being poppet valves, both have excellent sealing characteristics. Maximum leakage is 0.5 ml/min for valves up to 200 lpm capacity and 4 ml/min for 300-lpm valves.

The cartridge has three ports: cylinder, valve, and pilot. Pressure exceeding the valve setting applied to the cylinder port opens it as a relief. Pressure applied to the valve port will open a low-pressure check, permitting free flow into the cylinder port. Pressure on the pilot port acts over a larger area on the poppet than the area facing the cylinder port, so the valve will open at a low pressure.

For most applications the relief setting should be approximately 1.3 times the maximum load-induced pres-

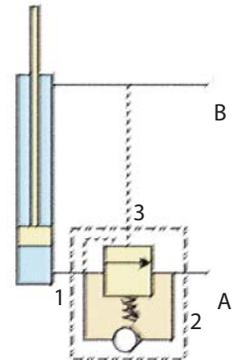
Standard overcenter valve



Standard overcenter valves are pilot-assisted relief valves with an integral free-flow check. For example, in Eaton's Integrated Hydraulics overcenter valves, a poppet seals flow from the actuator; a check element permits free flow to the actuator; and a pilot section opens the poppet and permits controlled flow from the actuator.

Typical installation

An overcenter valve typically mounts in or on the cylinder end cap. The valve's cylinder port connects to the full bore area of the cylinder, the valve port to directional-control line A, and the pilot connects to the cylinder's rod-end inlet and directional-control line B. When pressure at the rod end (line B) reaches pilot pressure, the actuator begins to retract the rod at rated flow.



sure. This ensures that with maximum load on the actuator, the valve remains closed until pilot pressure is applied.

The pilot pressure required to open a valve depends on the pilot ratio — that is the ratio between the relief area and the pilot area. Calculate pilot pressure from:

Pilot pressure = (Valve setting – Load pressure)/Pilot ratio.

Mounting considerations

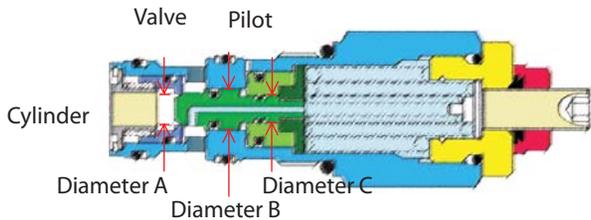
Overcenter valves generally mount in or on the cylinder end cap. As shown in the *Typical installation* graphic, the valve's cylinder port connects to the full bore area of the cylinder, the valve port to directional-control line A, and the pilot to the cylinder's rod-end inlet and directional-control line B. As soon as pressure in the rod-end inlet port (line B) reaches pilot pressure, the cylinder begins to retract the rod at rated flow.

If the load causes an additional increase in flow, the inlet will be starved of oil, and pressure will begin to drop at this port. The pilot senses the pressure reduction, and the spring begins to close the valve to prevent load runaway. In this way, the valve continually meters flow and controls load movements.

When the pressure required to move a load exceeds the pilot pressure needed to fully open the valve, the only restriction is the pressure drop due to flow through the fully open valve. With a standard overcenter valve, the spring chamber vents through the poppet to the valve port, which creates a problem at high or varying back pressures. Pressure in the valve port increases the effective valve setting by a factor equal to the pilot ratio plus one. This means if standing back pressure is 50 bar with a pilot ratio of 5:1, the effective relief setting would increase by 300 bar.

So if applications demand a closed-center directional valve and service-line reliefs, relief valves will limit inlet pressure but not limit an external load. The overcenter valve will not let oil past the seat due to the back pressure created by the service-line relief valves.

Partially balanced



Partially balanced valves, such as Eaton's 1CER Series, perform like standard overcenter valves under most conditions, but back pressure does not affect the relief section.

Balanced valves

Partially balanced valves overcome this problem. These valves work the same as standard valves under most conditions. But back pressure does not affect the relief performance.

The poppet balances back pressure over two areas on the poppet. As shown in the cut-away drawing, the first is an annular area between the seat (diameter A) and center seal (diameter B) on the poppet which acts to open the valve. The second, at the spring end of the spool (diameter C), acts to close the valve. These areas are the same. Therefore the poppet is balanced and pressure in the valve line will not affect relief performance. Note that any back pressure still affects the pilot pressure required to open the valve at a one-to-one ratio.

The advantage is this design

can be used in closed-center directional-valve circuits, letting service-line relief valves operate normally. Most other valves of this type have an atmospheric vent, which limits their use in corrosive atmospheres and makes them prone to leakage.

The valve does have some drawbacks. Because back pressure affects pilot pressure, the valve cannot be used in regenerative circuits on the cylinder's rod-end port. Also, if used with a meter-out proportional system, constantly varying back pressures can cause instability in both partially balanced and standard valves.

For this reason fully balanced versions are available. In this case, the spring chamber vents to atmosphere or to a separate drain port. Any back pressure, therefore, does not affect the valve setting or the required pilot pressure.

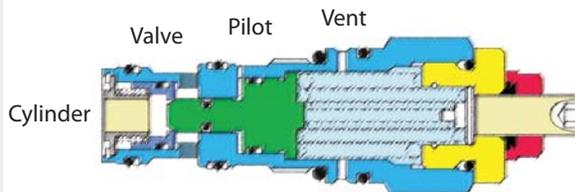
Two-stage valves

Two-stage overcenter valves overcome a problem which has been a continual nuisance to designers of machines with long, unstable booms. Instability problems affect many machines, most noticeably those with high-

capacity cylinders — particularly in conjunction with slender booms subject to varying frictional forces.

The best example is a telescopic handler to extend and retract the boom. At the end of the cylinder's stroke, oil pressure rises to the main relief-valve setting for that part of the system and, by its nature, the motion-con-

Fully balanced



Fully balanced 1CEB Series overcenter valves vent the spring chamber to atmosphere or to a separate drain port. Back pressure, therefore, does not affect the valve setting or required pilot pressure.

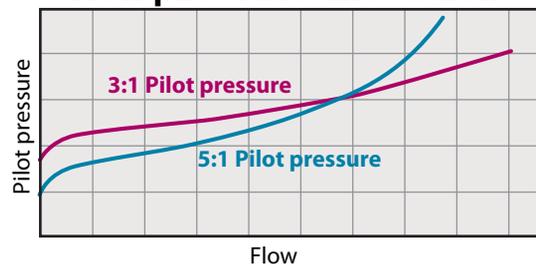
Specifying pilot ratios

Standard, part-balanced, and balanced valves come with various pilot ratios. Which is best for a circuit? A general rule is that high pilot ratios are suitable for constant, stable loads; and low pilot ratios for unstable and varying loads.

The pilot ratio does not necessarily affect working pressure much, given that a system's normal working pressure is often much higher than the pilot pressure required to fully open the valve. If this is the case, then the piloted-open pressure drop determines system efficiency.

The graph shows pressure-drop curves for two valves with different pilot ratios. The higher-pilot-ratio valve is more restrictive than the lower-ratio valve. This shows that above a certain pressure, the lower-pilot-ratio valve is more efficient. Thus, it is important to take into account total performance before specifying an overcenter valve.

How pilot ratio affects flow



Pressure-drop curves for valves with different pilot ratios show that the higher-pilot-ratio valve is more restrictive than the lower-ratio valve. Above a certain pressure, the lower-pilot-ratio valve is more efficient. Thus, it's good practice to consider total performance before specifying an overcenter valve.

trol valve reseats and locks in that pressure (regardless of any load-induced pressure).

When the operator lowers the load, this stored energy sends the valve the message that a heavy load is on the cylinder; therefore, it takes less pilot pressure to open. As a result, the valve opens quickly and dissipates the stored energy, causing a momentary runaway condition. This, in turn, causes a rapid acceleration of the load that is then checked by the motion-control valve and brought under control.

The consequence is an initial instability as a boom retracts that sometimes continues through the entire cylinder stroke. The frequency and magnitude of jerks depends on system stiffness and, in extreme cases, can be unsettling to the operator or even cause loss of load.

Two-stage valves use two springs to control the poppet. The pilot piston only acts on the outer spring, leaving the inner to generate a counterbalance pressure. The two-stage valve overcomes many instability problems by preventing the total decay of stored energy in the cylinder and stopping the valve from overreacting. It lets pressure fall to the counterbalance setting, which can be adjusted depending on the severity of the application.

This back pressure can also help stiffen the boom as it moves through its stroke — for example, when wear pads on the box sections of a telescopic boom generate changing frictional forces. This works well but, with some systems, the valve creates back pressure that causes problems. On certain machines — for instance, when a crowd cylinder bottoms — oil from a slave cylinder must be forced across a relief valve and the boom cylinder creates an induced pressure by virtue of its downward force. It is possible that an unloaded boom will not lower due to the counterbalance pressure. Also, the valve still generates back pressure when in the fully piloted open position, heating the oil and lowering efficiency.

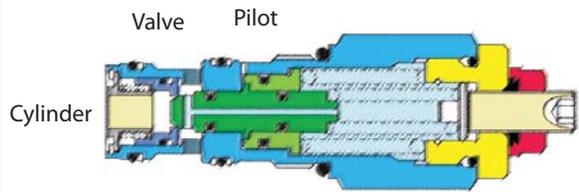
Dual pilot

To overcome these problems, another variant reduces counterbalance pressure as pilot pressure increases. This design has a second pilot ratio that reduces the back pressure applied by the center spring. In fact, the valve can be piloted fully open, eliminating the counterbalance pressure altogether to improve system efficiency.

With a primary pilot ratio of 4:1 and a secondary ratio of 0.5:1, initially unloading stored pressure at a low pilot pressure is followed by a more-gentle reduction as pilot pressure increases. The overall valve setting is a combination of the outer and the inner spring forces divided by the seat area.

Applying two-stage valves involves establishing a range of acceptable settings. For example, say a valve is to be set at 200 bar with a counterbalance pressure between 35 and 70 bar. There are two springs in the valve — the outer one fixed and the inner adjustable. For this application, the outer spring would be set at 165 bar and the inner between

Counterbalanced overcenter valve



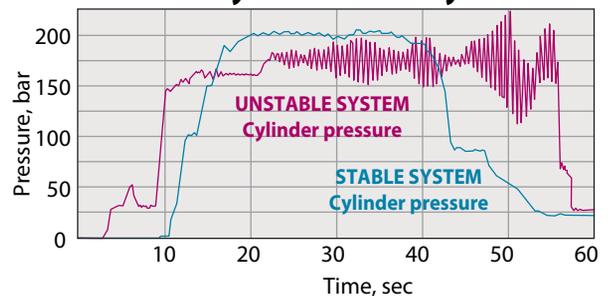
Two-stage overcenter valves, like the 1CEL shown here, use two springs to control the poppet.

35 and 70 bar. This would give the valve an adjustable range of 165 to 235 bar. Given a pilot ratio of 6:1 or 4:1, depending on the type, this extra pressure setting would have little effect on the pilot pressure needed to open the valve during normal operation.

The *System stability* graphs show how counterbalanced overcenter valves can overcome instability headaches.

Successfully applying motion-control valves, particularly in demanding areas, involves resolving numerous factors — only some of which are discussed here. Because motion-control valves are adjustable, available in numerous pressure ranges, with many pilot-ratio options, and in many sizes, they can be readily applied to improve stability. The standard range of valves described here can solve the vast majority of hydraulic motion-control problems, and manufacturers are constantly developing new valves that further improve stability and load control. **MD**

System stability



Counterbalanced overcenter valves can overcome instability headaches. The first graph shows typical reactions in a machine with an unstable boom that gets progressively worse. The second, operating with counterbalanced overcenter valves, dampens the initial instability and counterbalance pressure falls as pilot pressure increases.