

Figure 1: 1CE Standard Overcenter Valve

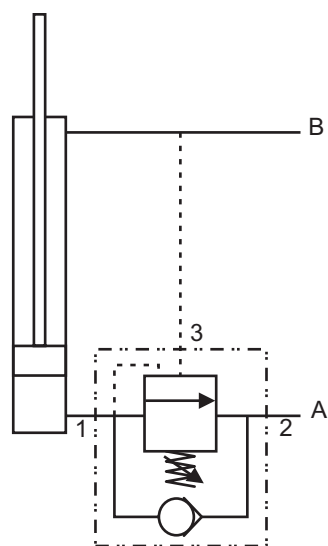
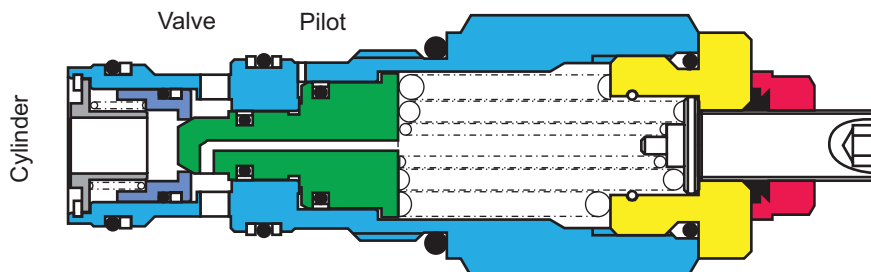


Figure 2

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There are now many types of overcenter or motion control valves available to the designer of hydraulically operated machines, each one has its own place and specific benefits to the user. The function of these valves can be divided into three basic groups.

1. Load Holding; where the overcenter valve prevents the movement of a load when the directional valve is in the neutral position. Permitting the use of open center directional valves and negating leakage past the spool of closed center directional valves.
2. Load Control; where the overcenter valve prevents the actuator running ahead of the pump due to the load induced energy thereby eliminating cavitation in the actuator and loss of control.
3. Load Safety. In the case of hose failure an overcenter valve mounted onto or into an actuator will prevent uncontrolled movement of the load. When a boom is used as a crane then hose failure protection is vital as the loss of load control could cause damage to people or property.

Each of these functions is applicable to linear or rotary motion.

The standard overcenter valve (fig 1) can be described as a pilot assisted relief valve with an integral free flow check. The difference between this design of valve and a pilot check is that the check valve

will open fully as soon as the pilot pressure is sufficient to open the valve because the only resistance to opening is the pressure locked in to the cylinder port. With an overcenter valve the pilot pressure has to overcome the force of the spring which is reduced by load pressure. This ensures a gradual opening and a metering of the flow as it passes the poppet. Integrated Hydraulics overcenter valves consist of a poppet that seals flow from an actuator, a check element, which permits free flow to the actuator and a pilot section that opens the poppet allowing flow from the actuator at a controlled rate. There are two basic designs, each with several variants. The direct acting design, whereby the pressure in the actuator acts on the full area of the nose of the poppet, is ideal for flows up to 200 L/min whereas the differential area design, whereby the pressure acts on an annular area, is suitable for flows up to 300 L/min. Being of poppet type both designs exhibit excellent leakage characteristics with maximum leakage of up to 0.5 ml/min for valves up to 200 L/min capacity and up to 4ml/min for valves with 300 L/min capacity.

The cartridge has three ports, a cylinder port (1), a valve port (2) and a pilot port (3). If pressure, above the setting of the valve is applied to the cylinder port it will open as a relief. When applied to the valve port pressure will open a low pressure check allowing free flow into the cylinder port.

Pressure applied to the pilot port acts over a larger area on the poppet than the area referenced to the cylinder port, so the valve will open at a low pressure.

For most applications the relief setting should be approximately 1.3 times higher than the maximum load induced pressure. This ensures that with the maximum load on the actuator the valve will remain closed until pilot pressure is applied. The pilot pressure required to open the valve will depend on the pilot ratio that is the ratio between the relief area and the pilot area. The pilot pressure can be calculated:

$$\text{Pilot pressure} = \frac{\text{Valve Setting} - \text{Load Pressure}}{\text{Pilot Ratio}}$$

A typical application would entail mounting the overcenter valve in or on the end cap of a cylinder (fig 2). The cylinder port of the valve being connected to the full bore area of the cylinder, the valve port to the directional control line A and the pilot connected to the annulus inlet, line B and so to the directional control line B. As soon as the pressure rises in the inlet port of the annulus (line B) to retract the rod to a point where it reaches the required pilot pressure the actuator will begin moving at the flow at which the pressure setting was made. If the load causes the flow to

increase then the inlet will be starved of oil and the pressure will begin to drop at this port. The reducing pressure will be sensed at the pilot allowing the spring to begin to close the valve preventing load run-away. In this way the valve will continually meter, controlling the load throughout its movement. When the pressure needed to move the load is higher than the pilot pressure needed to fully open the valve the only restriction produced is the pressure drop due to flow in the fully open condition.

With the standard overcenter the spring chamber is vented through the poppet to the valve port which creates a problem if there are varying or high back pressures. Pressure in the valve port increases the effective setting of the valve by a factor equivalent to the pilot ratio plus one. This means that if there is a standing back pressure of 50 bar with a pilot

Any back pressure therefore, does not affect the setting of the valve or the amount of pilot pressure needed.

ratio of 5:1 the effective relief setting would be increased by 300 bar. This creates problems if the application demands a closed center directional valve and the utilization of service line reliefs. The relief valves will operate to limit inlet pressure but will not act if there is an external load which needs to be limited. The overcenter will not allow oil past the seat due to the back pressure created by the service line relief valves. To overcome this problem the part balanced 1CER series was created (fig 3).

The 1CER series overcenter valve performs in the same

way as the standard valve under most conditions. But the relief section of the valve is not affected by back pressure.

The poppet is designed to balance back pressure over two areas on the poppet. The first is a annular area between the seat (dia a) and the center seal (dia b) on the poppet which acts to open the valve and the second at the spring end of the spool (dia c) acting to close the valve. These areas are the same, the poppet is therefore balanced and so pressure in the valve line will not affect the relief performance of the valve. It must be noted that the pilot pressure required to open the valve is still affected on a one to one ratio by any back pressure.

The advantage of this design is the ability to use the valve on closed center directional valve systems allowing service line relief valves to operate as

normal. Most other valves of this type on the market have an atmospheric vent which limits their use in corrosive atmospheres and are prone to leakage.

The 1CER valve does have some draw backs in certain applications. Because the pilot pressure is affected by back pressure the valve can not be used in regenerative circuits on the annular port of the cylinder. Also if used with a meter out proportional system the constantly varying back-pressures can cause both the part balanced and the standard valve to go unstable. For this is the reason the fully balanced version, 1CEB series (fig 4) is available. In this case the spring chamber is vented to atmosphere or to a separate drain port.

Any back pressure therefore does not affect the setting of the valve or the amount of pilot pressure needed.

For the standard, Part Balanced and Balanced valves there are various pilot ratios available to the system designer, which is best for his 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 the working pressure by much given that the normal working pressure of a system 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 will determine the systems efficiency.

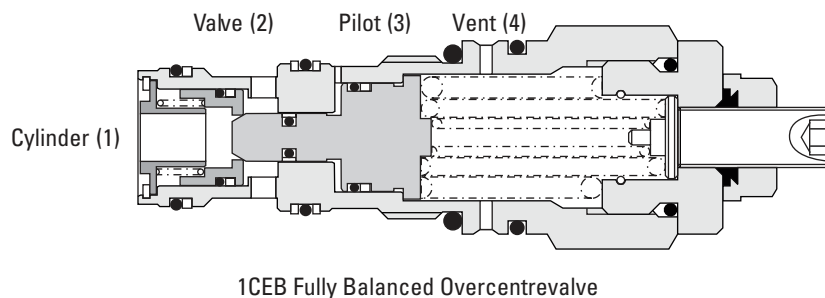


Figure 3

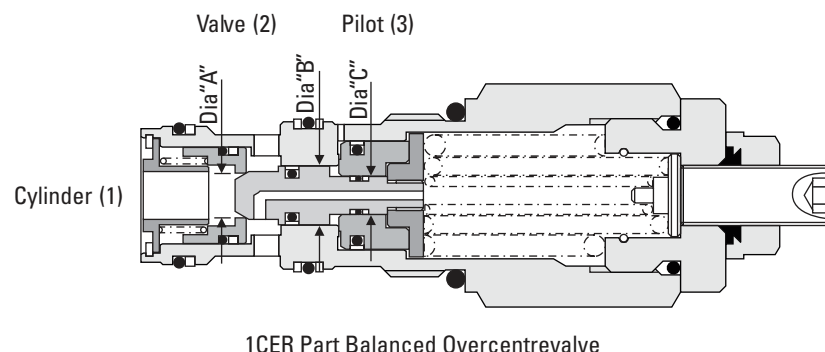
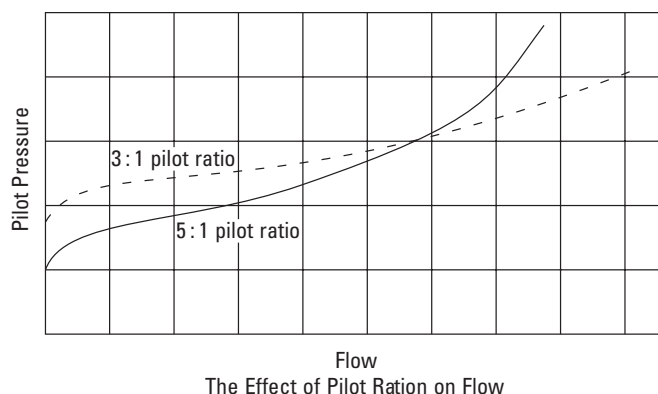


Figure 4



Graph 1

Graph 1 shows the pressure drop curves of two valves with different pilot ratios. The higher pilot ratio valve is more restrictive than the low pilot ratio valve. This shows that above a certain pressure the lower pilot ratio valve is more efficient than the higher pilot ratio valve. It is important that the total performance is taken into account before specifying an overcenter valve.

The two stage overcenter valve, 1CEL (Fig 5) has been developed to overcome a problem which has been a continual nuisance to designers of machines incorporating long unstable booms. Instability problems affect many machines, most noticeably those with high capacity cylinders particularly in conjunction with slender booms that are subject varying frictional forces. The best example is the Telescopic Handler that usually has a long cylinder to extend or retract its boom. At the end of its stroke the pressure of the oil within a cylinder rises to the setting of the main relief valve for that part of the system and by its nature, the motion control valve re-seat locks in that pressure (irrespective of any load induced pressure). When the operator lowers the load, this stored energy gives 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 very quickly and allows the stored energy to dissipate causing a momentary runaway condition, this causes a rapid acceleration of the load that is then checked by the motion control valve and brought under control. The consequence of this is an initial instability as a boom is retracted; the number of jerks will depend on the stiffness of the system at the time of lowering. This instability can sometimes continue through the whole of the cylinder's stroke, its magnitude, in extreme cases, can cause severe operator insecurity or even the loss of a load.

The 1CEL valve uses two springs to control the poppet, only the outer spring being effected by the pilot piston, leaving the inner to generate a counterbalance pressure. The two-stage valve has overcome many instability problems by

preventing the total decay of the stored energy in the cylinder and stopping the valve over reacting. It allows the pressure to fall to the counterbalance setting, which can be adjusted dependant upon the severity of the application. This back pressure can also help to stiffen the boom during its movement further through its stroke, for example when wear pads on the box sections of a telescopic boom create changing frictional forces. This works well but with some systems, the backpressure created by this valve causes problems due to the reduction in available force. On certain machines, when for instance a crowd cylinder is bottomed, the oil from a slave cylinder has to be forced across a relief valve; 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 in the fully piloted open position the valve still generates a backpressure heating the oil and creating inefficiency.

To overcome these problems another variant is available in which the counterbalance pressure is reduced as the pilot pressure increases. This design has a second pilot ratio, which acts to reduce the backpressure applied by the center spring. Indeed the valve can be piloted fully open, eliminating the counterbalance pressure altogether so improving the efficiency of the system. With a primary pilot ratio of 4:1 and a secondary

ratio of 0.5:1 the initial unloading of the stored pressure happens at a low pilot pressure

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followed by a more gentle reduction as the pilot pressure increases. The overall setting of the valve is a combination of the outer and the inner spring forces divided by the seat area.

The practical application of either of these valves involves the establishing a range of acceptable settings. For example, the requirement is for the valve to be set at 200 bar (3000psi) with a counterbalance pressure between 35 and 70 bar (500-1000psi) - there are two springs within the valve, the outer one is fixed and the inner adjustable. For this application the outer spring would be set to give 165 bar (2400psi) and the inner adjustable between 35 and 70 bar (500-1000psi). This would give the valve an adjustable range of 165-235 bar (2400-3400psi). 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.

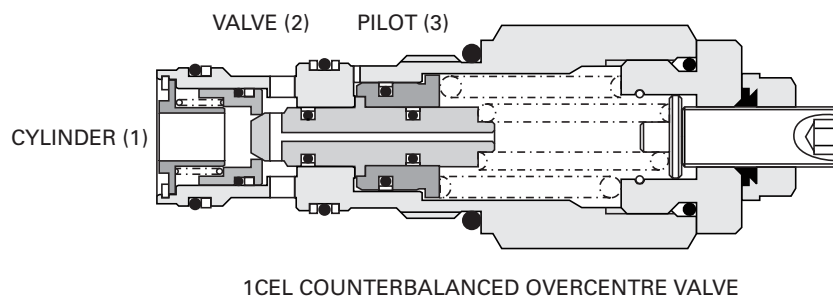


Figure 5

Graph 2 shows a typical recorded instability picking up machine frequencies and getting worse and Graph 3 shows the counterbalanced overcenter valves preventing the problem getting worse, dampening out the initial instability and the counterbalance pressure falling as the pilot pressure increases.

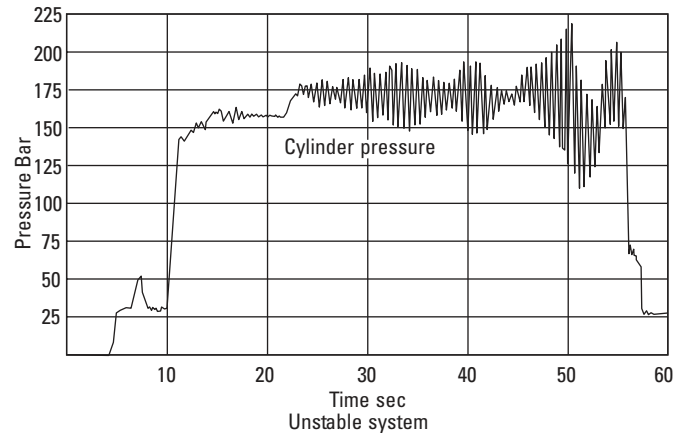
The zero differential range of load control valves 1CPB (fig 6) have been designed with 'BoomLoc' hose rupture valve applications in mind. Typically the valve is piloted open from the hydraulic remote control operating the main directional spool valve. By setting the overcenter to open just after the main valve it will control the flow rate at low speed but as the overcenter opens more rapidly than the directional valve the directional valve will control the flow

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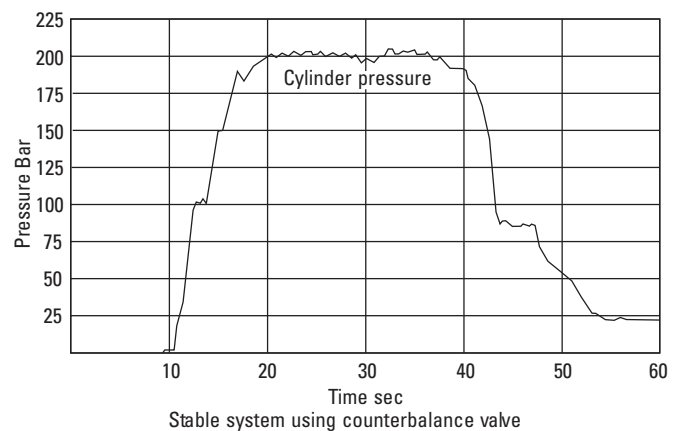
rate at higher speeds. It is a pilot operated metered poppet valve. The poppet seals against a tapered seat, as the pilot pressure increases the poppet will move off the seat. Flow is dependant upon the axial movement of the poppet which in turn is dependant upon the force exerted by pilot pressure balanced by that exerted by the spring. The poppet is hydraulically balanced so this valve is unaffected by valve line AND cylinder pressure but it will not provide any relief function. If over pressure, shock or thermal relief are required a second relief element is required.

The successful application of motion control valves, particularly in areas that are demanding involves the anticipation and resolution of numerous factors only some of which can be discussed in this article. Motion control valves are adjustable, are available in several pressure ranges with many pilot ratio options. Most of the valves fit in a common cavity (the exception being the fully balanced, 1CEB and zero differential, 1CPB versions when required with an external rather than an atmospheric vent) and are available

in sizes from 30 to 300 L/min. The flexibility of cartridge valve technology can therefore be easily applied to bring stability. The standard range of valves described here can be used to solve the vast majority of motion control problems and we are constantly developing new valves that will further improve stability and load control.



Graph 2



Graph3

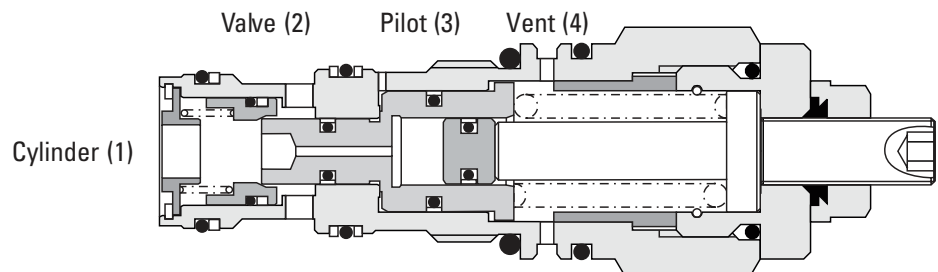


Figure 6

1CPB(D) Zero Differential Overcentre Valve