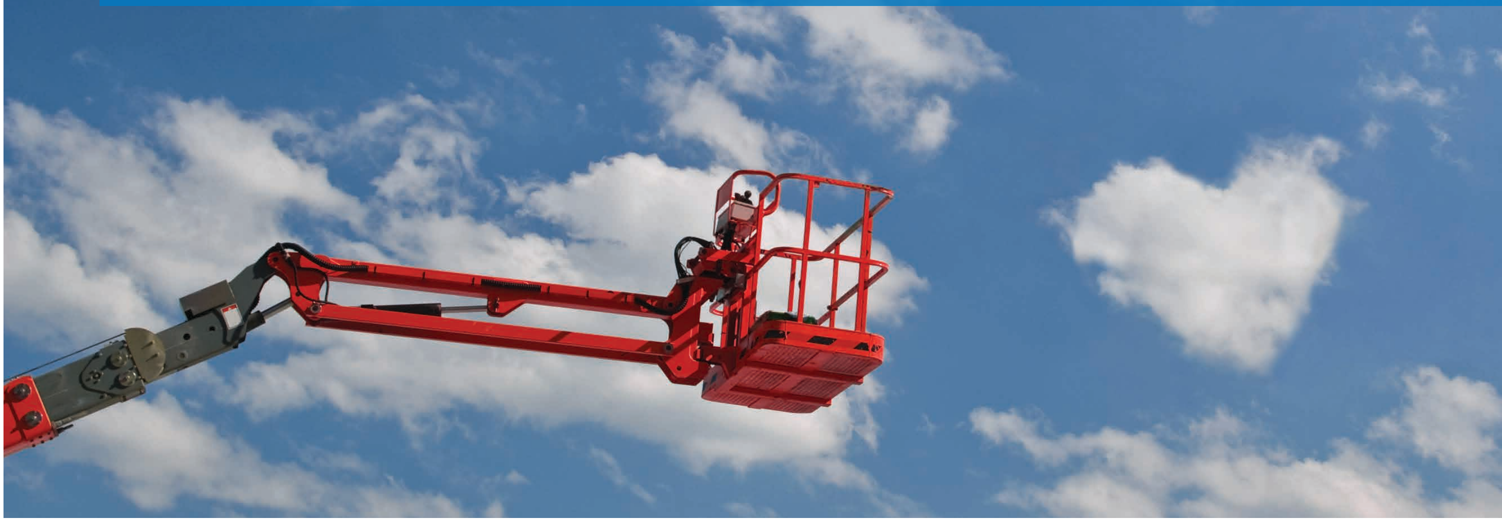
Eaton counterbalance valves



Demystifying pilot ratios in overcenter valves

Maurice A. J. Ashmore,
Global chief Engineer SICV & HIC at
Eaton's Hydraulics business Warwick UK

Introduction

A common challenge in the design of hydraulically operated machines is selecting the right pilot ratio to use within the overcenter valve. In fact, many in the industry would say it's the "be-all and end-all" factor when it comes to machine stability. That's why many users demand for their replacement valve to have the same pilot ratio as its predecessor to avoid any surprises.

Despite its importance, there is a lot of mystery in the nuances surrounding the pilot ratio. In this article, we'll try to clear up some of these details and provide some considerations for choosing an efficient solution in the overcenter valve.

What is a pilot ratio?

An overcenter, or counterbalance, valve is a pilot assisted-relief valve with a free flow check. The pilot ratio refers to the ratio, or difference, between the pilot pressure area and the relief area as shown in Figure 1 below.

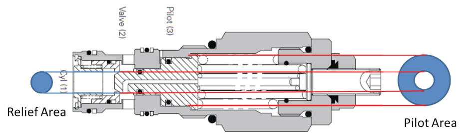


Figure 1

For the valve to open as a relief, pressure must be generated with resultant force that is sufficient to overcome the spring force. For most applications, the relief settings suggested are 30 percent above the maximum load induced pressure to ensure the machine can hold to its maximum capacity at all times – while also accounting for any system hysteresis.

During normal operation, pressure is typically applied to a separate port, normally taken from the other side of the actuator, where the area is larger than the relief seat area. This action causes the valve to open at a lower pressure.

The pilot ratio is important in this scenario because it controls the range of pressure needed to take the valve from closed to fully open. It is also subject to variations in pilot pressure as the load changes due to mechanical advantage, machine unsteadiness or general unstable conditions. A lower pilot ratio requires greater pilot

Powering Business Worldwide

pressure difference to fully open the valve and, any given load pressure change does not affect the valve, as much as for a high pilot ratio (See Figure 2 below).

	Pilot Ratio	1	2	3	4	5	6	7	8	9	10
Relief Setting	Load pressure	Pilot pressure required to open the valve									
4000	100	3900	1950	1300	975	780	650	557	488	433	390
4000	200	3800	1900	1267	950	760	633	543	475	422	380
4000	300	3700	1850	1233	925	740	617	529	463	411	370
4000	400	3600	1800	1200	900	720	600	514	450	400	360
4000	500	3500	1750	1167	875	700	583	500	438	389	350
4000	600	3400	1700	1133	850	680	567	486	425	378	340
4000	700	3300	1650	1100	825	660	550	471	413	367	330
4000	800	3200	1600	1067	800	640	533	457	400	356	320
4000	900	3100	1550	1033	775	620	517	443	388	344	310
4000	1000	3000	1500	1000	750	600	500	429	375	333	300
4000	1100	2900	1450	967	725	580	483	414	363	322	290
4000	1200	2800	1400	933	700	560	467	400	350	311	280
4000	1300	2700	1350	900	675	540	450	386	338	300	270
4000	1400	2600	1300	867	650	520	433	371	325	289	260
4000	1500	2500	1250	833	625	500	417	357	313	278	250
4000	1600	2400	1200	800	600	480	400	343	300	267	240
4000	1700	2300	1150	767	575	460	383	329	288	256	230
4000	1800	2200	1100	733	550	440	367	314	275	244	220
4000	1900	2100	1050	700	525	420	350	300	263	233	210
4000	2000	2000	1000	667	500	400	333	286	250	222	200
4000	2100	1900	950	633	475	380	317	271	238	211	190
4000	2200	1800	900	600	450	360	300	257	225	200	180
4000	2300	1700	850	567	425	340	283	243	213	189	170
4000	2400	1600	800	533	400	320	267	229	200	178	160
4000	2500	1500	750	500	375	300	250	214	188	167	150
4000	2600	1400	700	467	350	280	233	200	175	156	140
4000	2700	1300	650	433	325	260	217	186	163	144	130
4000	2800	1200	600	400	300	240	200	171	150	133	120
4000	2900	1100	550	367	275	220	183	157	138	122	110
4000	3000	1000	500	333	250	200	167	143	125	111	100
4000	3100	900	450	300	225	180	150	129	113	100	90
4000	3200	800	400	267	200	160	133	114	100	89	80

Figure 2

Instability can occur when the valve overreacts due to changes in load or mechanical friction within the machine. A low pilot ratio limits the movement of the poppet, therefore restricting the change in flow caused by the opening and closing of the valve.

As the load pressure increases, the difference between the pilot pressure required for each ratio gets smaller – meaning a minor change in pilot ratio has little effect. For example: with a relief setting of 4,000psi and a load pressure of 2500psi for a 4:1 vs a 6:1 pilot ratio, the pilot pressure required to open the valve varies by only 125psi which is only 5 percent of the load pressure and 3 percent of the set pressure.

For each valve size different pilot ratios are interchangeable so users can change the ratio by replacing the cartridge in the cavity of the manifold block or the cylinder in case of an unforeseen issue. Generally, the more unstable the load, the lower the pilot ratio should be to optimize machine stability.

Keeping thing steady

At Eaton, we designed our overcenter valve solution to be intrinsically more stable addressing challenges with pilot ratio by leveraging a direct-acting design. Using this approach, as opposed to a differential-area design, the main spring has a higher rate. The stiffness of the spring relates directly to the responsiveness of the valve to pressure fluctuations. For any change in load pressure, the valve will be less sensitive and not open as rapidly, reducing the rate of increase in the opening orifice and therefore the change in flow.

To help put this in context, imagine driving in your car with the suspension at a very soft setting. This action can cause the car to bounce at the slightest change in road conditions. Adjusting it to a stiffer setting of suspension, the car becomes more stable on the road with less rock and roll.

This is the principle Eaton uses to maintain stability with the overcenter valve while accommodating more efficient higher pilot ratios. The stiffness of the spring increases the pressure override when used as a relief valve. The relief function is designed to remove pressure spikes and as thermal relief – not so much as a full flow relief valve.

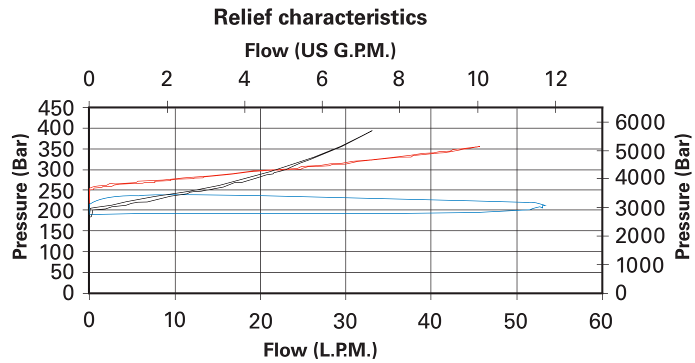


Figure 3

Figure 3 shows the relief performance of three different manufacturers' overcenter product fittings in the same cavity. The blue line is a differential area design where small changes in pressure opens the valve quickly. This causes a more rapid opening of the valve when either the load pressure or the pilot pressure changes. Without significant hysteresis, this valve would always be unstable. The black line and the red line are direct acting designs where it takes a greater pressure difference to increase the flow, making them less likely to react to transient pressure changes.

In Summary

While there is a lot that goes into creating a stable machine, selecting the right pilot ratio for the overcenter valve remains a crucial consideration. To address more unstable loads, leveraging lower pilot ratios will provide better control. As the load pressure increases, changes in pilot ratio have very little effect on stability or performance.

While pilot ratios play an important role in ensuring stability, the design of the valve also affects the intrinsic stability of the product. Deploying an overcenter valve with steeper relief pressure override characteristics, as found in direct-acting design models, provides a more stable overall system. Bringing a higher rate of spring and more rigidity to the system, the platform can help users avoid the loss of machine control and ensure safety for personnel and property.

Powering Business Worldwide

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

Printed in USA
Document No. E-VLSC-TT003-E
May 2018