Our brave new world of Hydraulics provides technology to industry that is ever improving and more complex. The demand for machines that think for themselves reducing human error have inspired the engineering fraternity to ever greater feats of hydraulic ingenuity.

The simple directional valve has become an electronically controlled mechanism that provides fine control to the movement of machinery. The pump has become more efficient by adding feedback controls in the form of pressure compensation and load sensing, providing stable controlled flow to a pre-determined level to reduce energy losses. Even some actuators have built in transducers to provide position feedback completing the loop.

It is a shame that when using this modern technology the simpler and most important valve in a system can be as crude as a ball on a seat. The humble relief valve takes a back seat to the point where great effort is made not to allow this valve its rightful roll in providing the ultimate system protection. "Don't let it operate because it is noisy" or "we can not guarantee that the pressure control will be consistent". "The valve opens too soon and does not close quickly enough".

From the main system relief to the safety relief there are valves available that are equally advanced in their innovation and technology as the higher profile pumps, directional control valves and actuators. The problem is that many engineers do not understand the reasons for the different designs and their individual applications or how to assess the performance. This article will attempt to throw some light on what is available and where to apply the different designs.

It is true that the simplest relief valve is a ball sitting on a seat with a spring keeping it closed until the pressure over the area of the seat is high enough to allow the valve to open and allow flow to pass. The flow capacity is limited by the size of the seat and the pressure difference across the opening. To get more flow across the valve the ball has to move further back against the spring increasing the force and therefore the required pressure. A basic relief valve curve will look like Graph 1.

Graph 1 is based on a poppet style direct acting relief. The cracking pressure is the point "A" at which the pressure over the area of the seat is the same as the spring force. The initial opening characteristic "B" depends on the cone angle of the poppet, the second section of the curve "C" depends on the relationship between the design of the poppet and its movement which is effected by the rate of the spring, generally the higher the spring rate the steeper the gradient. As more flow passes through the valve the relief curve will meet the orifice curve "D".

The performance of a direct acting relief valve can be altered by innovative poppet design.

By using the flow forces to help open the valve the effect of a high rate spring can be reduced and the gradient be kept relatively flat.

Figure 1 shows a section through a typical relief valve where the poppet design allows for a relatively low pressure rise due to increase in flow. A problem with this type of valve is that too much flow can cause the valve to have a negative pressure rise causing the valve to go unstable with fluctuating pressure.

The re-seat and repeatability of the valve depends upon the hysteresis. Internal seals cause friction against the bore as the valve tries to close. If a seal is under pressure then the hysteresis increases, graph 2.
Relief Valves

Graph 2. Relief Curve showing the effect of hysteresis
1DR30-10S SET @ 100Bar CRACK PRESSURE
FLOW = 30L/MIN
P/BAR PRESSURE VS FLOW

A poppet valve should not leak more than 1/3 cc/min up to the cracking pressure allowing it to be placed in a line where low leakage is important, and performing duties such as a service line relief.

A simple relief valve like this will give cost effective relief protection to small systems or where the valve is not the main pressure control but a pressure limiting device.

Figure 2 shows a typical pilot operated, spool type relief valve that gives good control over varying flows. This valve, due to its design, allows a high flow to pass with very little rise in inlet pressure. The valve has a good re-seat and good repeatability due to there being no internal seals. A pilot operated relief valve is suitable as a main pressure control but due to the two stage design it is not suitable for safety applications where speed of operation is important. In the case of a rapid increase in inlet pressure the system will be subject to a longer pressure spike than if a direct acting valve where used.

Increasing the flow capacity of a direct acting valve by reducing the area over which the spring would have to be of excessively high rate which would give an unacceptably steep relief curve.

They are not generally suitable for high flows because the spring would have to be of excessively high rate which would give an unacceptably steep relief curve.

Graph 3. Comparison of Pilot and direct acting differential area type opening curves

Graph 4. Opening characteristics of pilot style relief

Figure 3 shows a differential area poppet type relief valve that has the capability of very fast action and a high flow capacity for its size. The internal seal is subject to inlet pressure so the valve will display relatively poor re-seat characteristics.
The design of the poppet is such that as the valve begins to open the flow past the poppet draws oil from the spring chamber (by venturi effect over the small holes in the poppet annulus) causing initial over opening. This removes most of the pressure spike. The valve is therefore highly suitable as protection for actuators.

Graph 3 shows a comparison between the typical opening characteristics of a pilot style valve and a differential area direct acting valve with the special poppet described above. The difference between the opening characteristics of a pilot style relief valve and a direct acting spool type relief valve are shown in graph 4 & 5 respectively, graph 4 clearly illustrating the pressure spike permitted by the pilot style valve.

Figure 4 shows a spool type direct acting relief valve. These are suitable for low pressure systems where stable or constant operation is required. They provide quiet operation even with fluctuating pressures. The spool opens up a ring of holes in the sleeve that gives a more gradual increase in flow area than a poppet valve.

Spool valves will give between 50 and 100cc/min leakage before they open.

The four main types of relief valve as detailed above cover most applications but there are many variations on a theme that give flexibility to a systems design.

Ventable relief valves, figure 5, are used to provide an unloading function, presenting an ability to be remotely operated and the possibility of switching between more than one pressure.

Unloading relief valves or ‘kick down’ valves, figure 6, provide an off load of pressure when the setting is reached, the valve remains fully open until the pressure falls to zero. This removes any force created by an actuator that could cause mechanical damage within a system.

In order to simplify the design of a circuit and reduce its cost system designers frequently require a valve to perform additional functions, two such valves are shown below, figure 7 a relief valve in conjunction with bypass check and figure 8 a cross line relief valve.

When designing hydraulic systems it is important to consider the performance of the minor components such as relief valves. These may be minor in cost but they have a major impact in terms of value. A poor relief valve can effect the efficiency and life of a complete machine.

From overall pressure control to actuator protection the relief has to be of the correct type to ensure sound performance and component integrity.

There are also electrically controlled proportional valves available that tie in with electronic systems. That is another subject but they should never be allowed to replace the humble mechanical relief valve, the correct application of which can permit a machine to operate to its optimum performance over a long period.