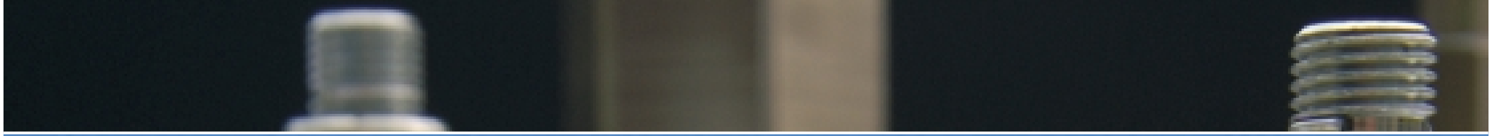

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A NEW TYPE OF RELIEF VALVE

New 'anti shock' relief valves protect against pressure spikes

Peter Robson / Bernd Zähe

Pressure spikes during acceleration or deceleration can be avoided using 'anti shock' relief valves.

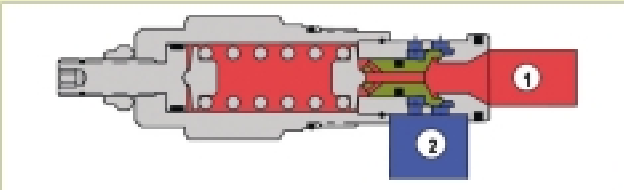
Using a new type of pressure relief valve, pressures can be ramped up and ramped down. The valves work purely mechanically, and protect hydraulic components against pressure spikes that could damage machinery. The valves are available as pure pressure relief valves and as ventable relief valves in different frame sizes. As cartridge valves they can be used in many different types of bodies such as sandwich bodies, line mount bodies, gasket mount bodies and custom assemblies.

Standard pressure relief valves open when the pressure exceeds the setting of the relief valve but often one forgets that the relief valve has a certain response time. Oil and pistons must be accelerated and depending on the design the valve opens only after a certain stroke so within the response time the pressure can rise far beyond the setting of the valve. The severity of the pressure spike depends on the rate of pressure rise in the system. Often the real pressure spikes are much higher than one realizes as the reading is shown on a damped pressure gauge or sample rates of digital pressure transducers are too low.

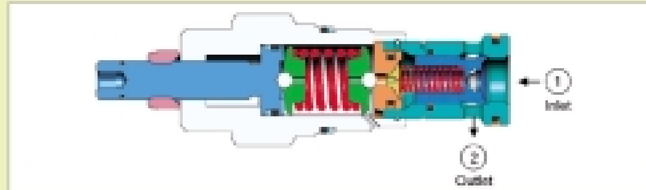
There are simple pressure relief valves with short response times such as direct acting seat type valves. The typical response time of these valves are 2-5 ms while pilot operated relief valves with spool type pistons exhibit longer response times of 10-30 ms.

Fig. 2 shows the typical section of a direct acting pressure relief valve. System pressure at port one of the valve works on both sides of the poppet. The effective area is the differential area. When the pressure differential exceeds the setting, the valve opens a flow path 1-2. The oil jet is deflected to compensate for flow forces and to protect the manifold against cavitation. This type of valve, however, is difficult or impossible to adjust under pressure because the adjusting spring sees full system pressure.

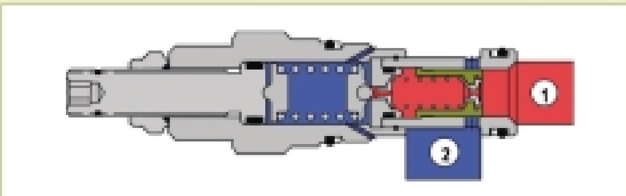
Fig. 3 shows the cross section of a pilot operated pressure relief valve with positive overlap piston. The main poppet opens when pilot oil flows through the pilot stage into port 2. The response time of the valve is longer than that of the direct acting valve. Pilot operated relief valves with positive overlap have a typical response time of 10-30 ms. The valve can be adjusted under pressure since the adjusting spring only sees the low pressure in the return line. The valve has a low hysteresis since the piston sees no soft sealing.



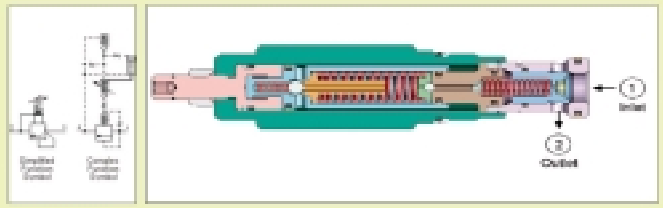
2. **Direct acting pressure relief valve**



4. **Pilot operated seat type relief valve with seated main stage**



3. **Pilot operated pressure relief valve with positive overlap piston**



5. **Cross section of the 'anti shock' relief valve with hydraulic symbol**

Fig. 4 shows a pilot operated seat type relief valve with seated main stage. This valve combines the advantages of both valves described above. The valve has a pressure-balanced poppet, so that pressure differentials from ports 2 to 1 which is from tank to pressure side cannot open the valve. Unlike many other poppet style relief valves, this valve can therefore be used in cross-port relief applications.

All the relief valves shown do not open until the pressure exceeds the setting of the valve but components can also be damaged when the stress changes quickly. A pressure that changes rapidly is more damaging than a pressure that changes slowly. In particular, components made of aluminum can be damaged even at low pressures if these pressures change quickly.

Function of the new 'anti shock' relief valve

The new 'anti shock' relief valve avoids a rapid change of pressure and is illustrated in **Fig. 5**. The valve is essentially a pilot operated seat type valve. Pressure on port one is connected to the main chamber through an orifice in the main poppet. When that pressure exceeds the setting of the valve, pilot oil starts to flow and the main stage opens. At the same time the setting of the valve changes, since pilot oil doesn't flow into tank directly but passes through a relief valve in the pilot stage. The setting of that relief valve is about 10 bar, thus preloading the oil in the pilot chamber. Some of the pressurized oil from the pilot chamber flows through an orifice onto the rear side of the pilot sleeve (blue in fig.5). This pilot sleeve moves at a constant speed against the pilot spring and gradually increases the setting of the valve. The sleeve moves forward until it stops on a land of the adjust screw. The adjust screw therefore dictates the maximum pressure setting as in standard relief valves.

Fig. 6 shows the response of the 'anti shock' relief valve at different settings. In each case the valve sees a rapid increase in flow from 0 to 38 l/min. The valve opens when pressure at port 1 exceeds the initial setting of the valve. From then on the pressure increases following a ramp as the setting of the relief valve increases with the movement of the pilot sleeve. The setting reaches the set maximum within about 300 ms.

Operating point between threshold and maximum setting

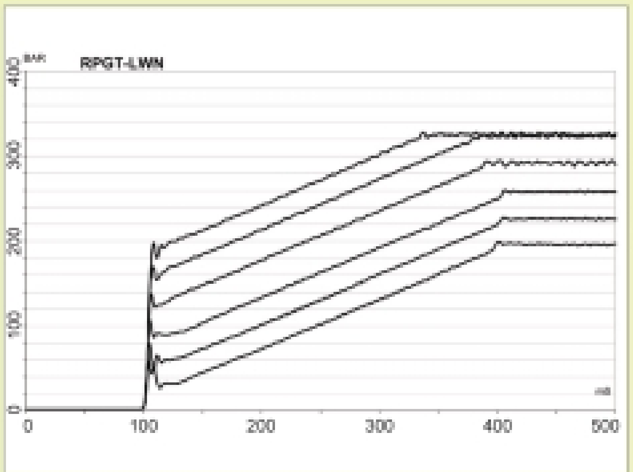
The question arises whether the valve can be used for operating points with a static pressure between threshold and maximum setting. Is the valve open or closed?

There is a pilot flow when the system pressure is between threshold and maximum pressure. That pilot flow keeps the valve set at a pressure that is about 7 bar above the system pressure at port one. The main stage of the valve is closed but the pilot flow would be seen as leakage. Therefore the valve cannot be used as a load holding valve. In the pressure range between threshold and maximum setting, the valve will open only if the pressure rises quicker than the setting of the valve. In that range the valve has an effect similar to a damping accumulator but the valve won't feed oil back into the system. This means that one loses energy but on the other hand this type of damping may be good for the stability of the circuit.

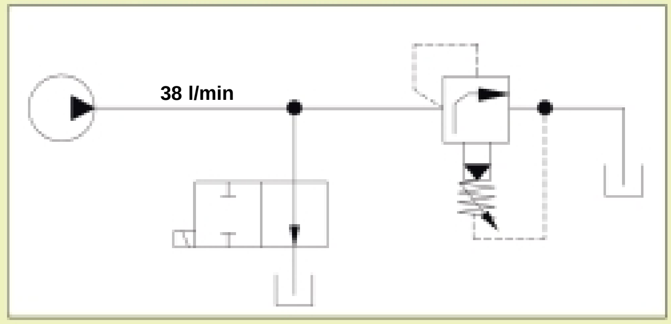
Fig. 6 shows that the threshold (i.e. the initial setting of the valve) follows when the maximum setting of the valve changes. In some applications that threshold is too high and the ramp time is too short. If the valve is used as a start-up valve such as for a pump, a low threshold and a longer ramp time are required. For these applications there is another type of 'anti shock' relief valve which is a ventable 'anti shock' relief valve with a normally open pilot stage.

Performance Comparison

With a pilot operated spool type valve RPGC (lower left curve) the pressure spikes go way above the setting. The spike can be even higher at higher flows or higher rates of pressure rises. The comparison with the pilot operated seat type valve RPGS (upper right

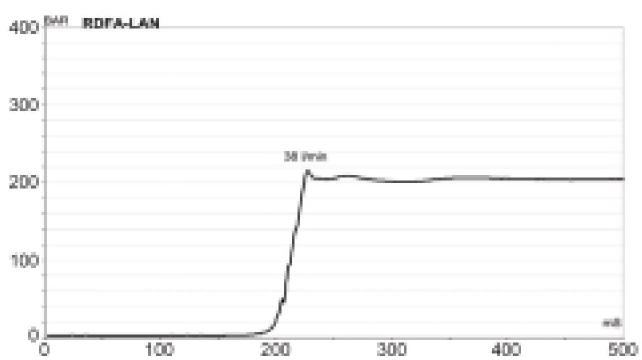


6 a. Pressure vs. time at different settings

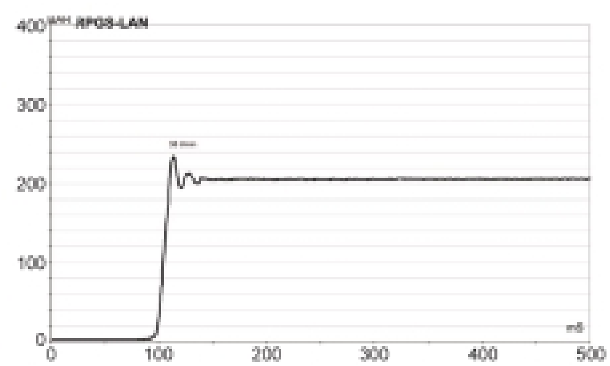


6 b. shows the setup for the test

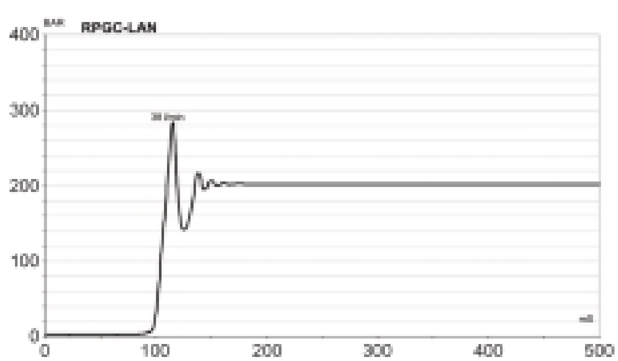
curve) shows that the major portion of the spike is due to the design of the main stage and not to the fact that the valve is pilot operated. The RPGS has a poppet style main stage. The poppet uncovers a flow path on the full circumference at a small stroke. That is why the pressure spike is lower. The direct acting seat type valve RDFA (upper left curve) has even lower pressure spikes. At 38 l/min and the given rate of pressure rise, the pressure hardly exceeds the setting of the valve. The dynamic stress, i.e. the rate of force change, is the lowest when 'anti shock' relief valves RPGT (lower right curve) are used. The pressure rises above the threshold and then rises to the set maximum pressure following a ramp within about 300 ms. In some applications the threshold of the 'anti shock' relief valve is too high. One needs a pressure rise that starts at a low threshold and ramps up over a longer period of time. This is possible with ventable 'anti shock' relief valves.



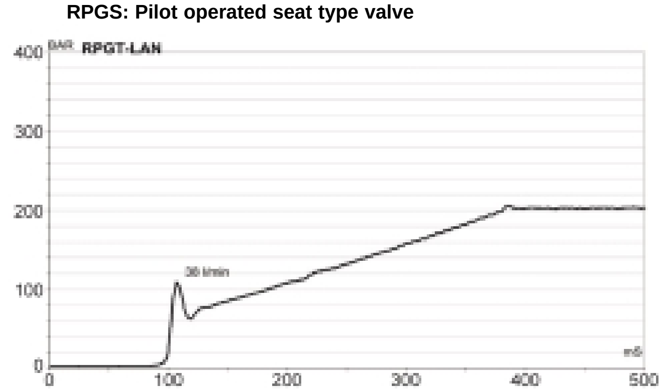
RDFA: Direct acting seat type valve



RPGS: Pilot operated seat type valve

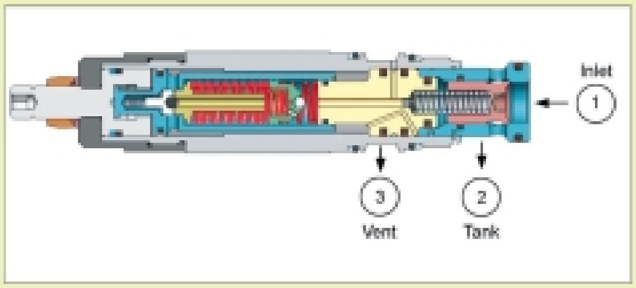


RPGC: Pilot operated spool type valve with positive overlap

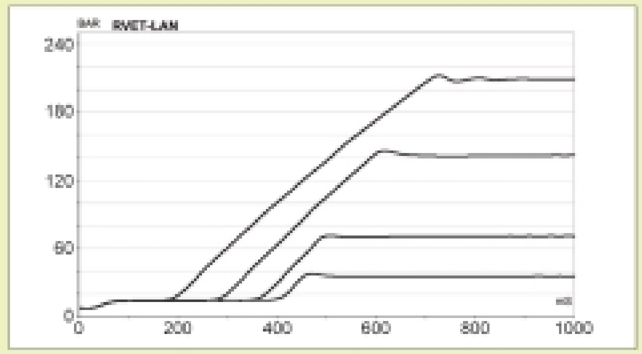


RPGT: 'Anti shock' relief valve

7. Pressure vs. time with four different types of pressure relief valves with a rapid increase of flow through the valve from 0 to 38 l/min
The cross sections for each of the valves are shown in figures 2, 3, 4 and 5



8. Cross section of the ventable 'anti shock' relief valve



9. Pressure rise versus time with the ventable 'anti shock' relief valve at different settings. Each time a solenoid valve closes port three of the vented relief valve. There is always a continuous flow of 38 l/min through the valve

Ventable 'anti shock' relief valve

Fig. 8 shows the cross section of the ventable 'anti shock' relief valve. This valve has an additional third port that can be used to unload or vent the main spring chamber. This lowers the setting of the valve so that a pump sees only the low tank pressure. When port 3 of the valve is closed the setting will ramp up again. A special feature of the valve is the normally open pilot stage. Only after a certain pilot flow has passed through the valve will the poppet of the pilot stage (green in fig. 8) touch the pilot seat. From then on the setting of the valve will increase. **Fig 9.** shows the pressure rise versus time at different settings. Port 3 of the valve can also be continuously closed. The valve then works like a standard 2 port relief valve but with lower thresholds and longer ramp times. The ventable 'anti shock' relief valve is interchangeable with standard ventable relief valves which means that in the same cavity with the same porting the 'anti shock' version or the standard version can be used.

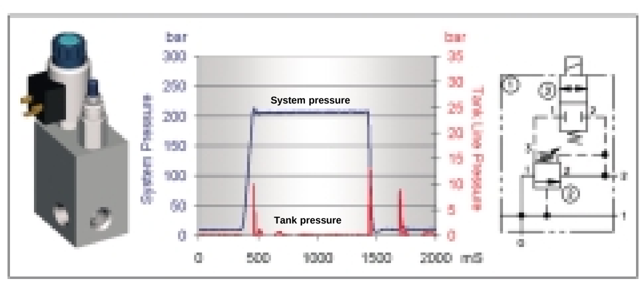
Fig. 10 shows a manifold including a ventable relief valve and a 2/2 solenoid valve. Pressure spikes often occur during loading and unloading in hydraulic systems due to the stiffness in hydraulic pipes, rapid pressure rise or sudden high flow through the valve when unloaded. Experience shows that these pressure spikes often occur in the tank line and generate noise because the tank acts like a resonator. These pressure spikes can also damage filters and coolers in the return line.

Fig. 11 shows the result in the manifold but with a 'anti shock' ventable relief valve and a 'soft shift' solenoid valve. The 'anti shock' relief valve avoids pressure spikes during the pressure build up period. The soft shift solenoid valve avoids pressure spikes in the tank line when unloading.

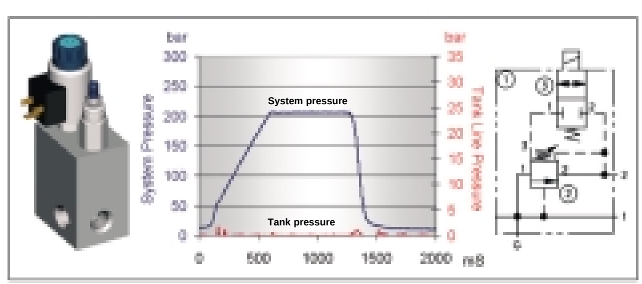
Ventable 'anti shock' pressure relief valve as bypass pressure compensator

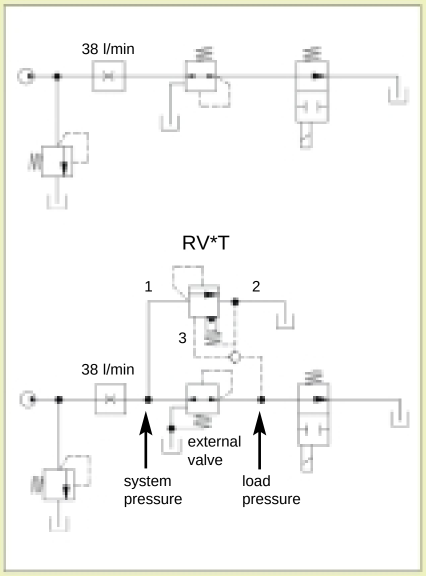
Fig. 12 shows how the ventable 'anti shock' relief valve can also be used as a bypass pressure compensator. Port 1 of the valve connects to the upstream side of an external valve and port 3 connects to the downstream side of the same valve. The external valve is usually a flow control valve but it can be a pressure control valve too. When the pressure drop across that external valve exceeds about 10 bar, the relief valve opens a bypass line to tank (on port 2). Excessive flow then flows to tank and the system pressure is kept at about 10 bar above the load pressure. The main stage of the RV*T provides the bypass pressure compensation and the preload of the main spring determines the pressure drop across the external orifice. At the same time the RV*T works as a pressure relief valve. If the setting of the valve is 140 bar for example, the valve will open if the system pressure exceeds that setting.

10. Ventable standard relief valve and solenoid operated 2/2 way valve and a curve showing system pressure and tank pressure versus time.

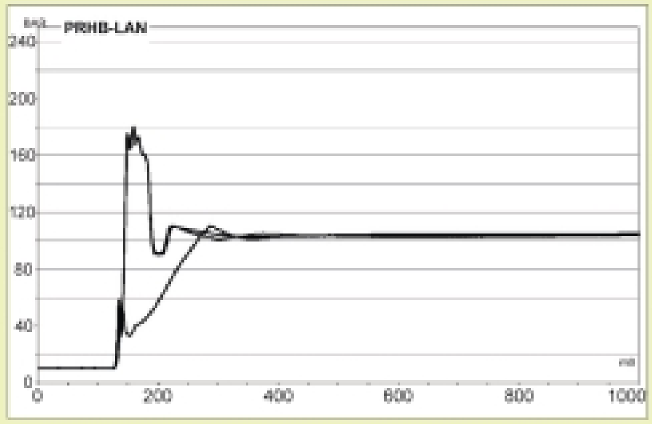


11. Ventable 'anti shock' relief valve and solenoid operated 2/2 way valve showing system pressure and tank pressure versus time.





12. Circuits with pressure control valves. Top circuit: Supply of the pressure control valve from a constant pressure source. Bottom circuit: Additional 'anti shock' relief valve as bypass compensator.



13. Rise of the controlled pressure (load pressure in fig. 12) versus time when the directional closes. It shows the high pressure spike with supply from a constant pressure source or using a standard bypass pressure compensator compared to the smooth pressure build up with a 'anti shock' pressure relief valve as pressure compensator.

The RV*T therefore is a bypass pressure compensator and relief valve at the same time.
Usually bypass pressure compensators are used in combination with flow control valves (orifices or directional valves e.g.). But bypass pressure compensators can also control the pressure drop across pressure control valves. So the RV*T can also be used to control the pressure drop across a pressure control valve. In that case it has further advantages over standard bypass pressure compensators. The circuit in fig. 12 shows a pressure control valve with 38 l/min supply. At first the control pressure downstream is very low because a directional valve downstream is open to tank. When the directional valve closes, the pressure rises to the setting of the pressure control valve (100 bar). The directional valve that is open and then closed is like a cylinder that moves without load and then stops when it hits an object. When in these cases the pressure control valve is supplied from a constant pressure source or from a constant flow source combined with a standard bypass pressure compensator one tends to get pressure spikes the moment the cylinder stops. The pressure spike downstream can even exceed the supply pressure (see curve in fig. 13). If an 'anti shock' ventable relief valve is used as a pressure compensator, the supply pressure will rise following a ramp and the controlled pressure will also rise following that ramp. That means that the cylinder is gently pushed against the load (see 2nd curve in fig. 13). The circuit requires a check valve in the load sensing line (port 3 of the anti shock relief valve) otherwise the load would saturate the pilot stage of the anti shock relief valve and the valve would ramp up too early. The mechanism in the pilot stage of the anti shock relief valve can only cope with small pilot flows. The check valve prevents oil from entering the pilot stage but the bypass compensator sees the load signal. That signal progresses against the direction of the pilot flow. Note that the setting of the ventable anti shock relief valve of 140 bar is above the setting of the pressure control valve at 100 bar. The controlled pressure is not affected by the setting of the relief valve!

Relief Valve	Flow range
RPET L*N	1 - 95 l/min
RPGT L*N	1 - 200 l/min
RPIT L*N	1 - 380 l/min
RPKT L*N	1 - 760 l/min
Vented Relief Valve	
RVCT L*N	60 l/min
RVET L*N	120 l/min
RVGT L*N	240 l/min
RVIT L*N	480 l/min

Summary

The new 'anti shock' pressure relief valves provide a smooth pressure build up following a ramp (ramp time 150-400 ms depending on type of valve). These valves avoid rapid pressure changes and can also be supplied as ventable relief valves where longer ramp time and lower thresholds are required. Typical successful applications are as follows:

- Start-up relief for fixed-displacement pumps to reduce shock and controlled acceleration for longer pump life.
- Cross-line relief in swing circuits and similar hydrostatic systems-especially applications with high inertia loads-protects motors, hoses, and fittings.
- Gently preloads drive systems to remove gear backlash to improve reliability
- Over-pressure protection in systems with damaging pressure spikes (easily applied in low-flow and/or high pressure applications)
- The ventable 'anti shock' relief valves can be used as a bypass pressure compensator and can provide smooth pressure gradients in pressure control circuits.