Chapter 10

Non Return Valves

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1 General

Non return valves are used in hydraulic systems to stop flow in one direction and to allow free flow in the opposite direction. They are also known as check valves.

non return valves are designed with seats and hence are able to isolate circuits with no leakage. Balls, plates, poppets or poppets with soft seals are used as isolating elements.

The advantage of using a ball as a seal is that it can be produced economically. The disadvantage is that the ball is deformed a little during operation, i.e. the seat presses into the ball. As the seat does not always press onto the same point, this leads to leakages after a while. The ball needs to be additionally controlled, so that the seat is not knocked out of true (e.g. by spring loading and flow forces).

On the other hand poppets always resume the same position due to their control. After a short period of operation the poppet has penetrated the seat and and the valve is completely sealed. Production of poppets is not as easy or cheap as that of balls. Mannesmann Rexroth non return valves primarily contain poppets as the isolating element due to their higher operating safety factor.

Poppets with soft seals are only suitable for use in systems with low operating pressures and low flow velocities. However, they do have the advantage that inaccuracies in manufacturing of poppet seats can be compensated for.

Depending on application, non return valves may be categorised into 3 groups (see *fig. 1*).

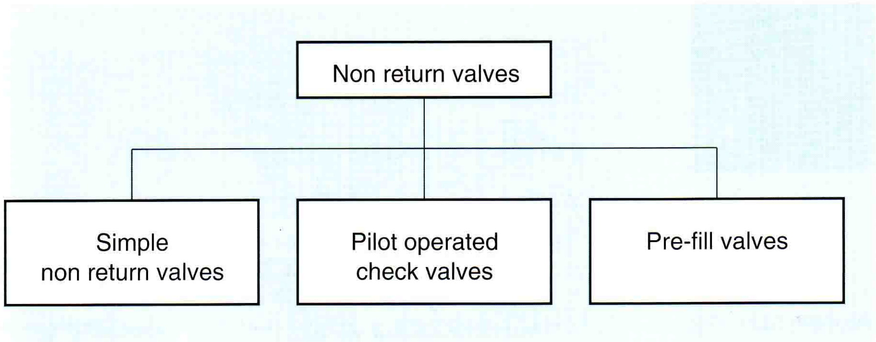
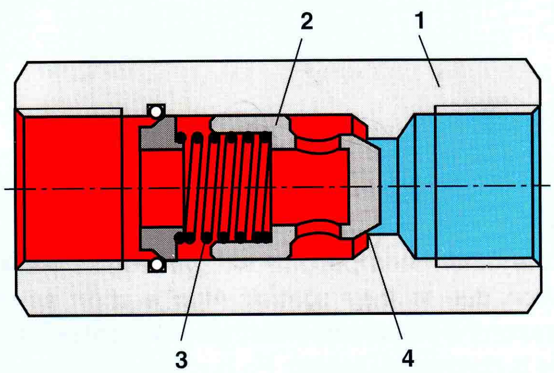


Fig. 1: *Types of non return valves*

2 Simple non return valves



→ flow shut off
← free flow

Fig. 2: *Pipe mounted non return valve*

Fig. 2: *Non return valves*

These valves (*figs. 2 and 3*) basically comprise housing (1) and hardened piston (2), which is pushed onto the seal seat (4) by means of spring (3).

When there is flow through the valve in the direction of the arrow, the poppet is lifted from its seat by the fluid pressure and allows free flow. In the opposite direction, the spring and the fluid push the poppet onto the seat and close the connection.

The cracking pressure depends on the spring selected (its compression) and the pressurised poppet surface area, and is generally between 0.5 and 5 bar, depending on the application.

A non return valve without spring must always be fitted vertically. The isolating element then remains on the seat in the no flow condition due to gravity.

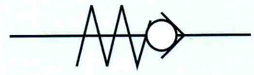


Fig. 4: *Non return valve*

Non return valves are available for

- sub-plate mounting
- pipe mounting (threaded connections)
- pipe mounting (flanged connections)
- as cartridge elements or
- as sandwich plate valves

Important parameters

Sizes:	6 to 150
Flow:	up to 15 000 L/min (at v_{oil} = 6 m/s)
Operating pressure:	up to 315 bar
Cracking pressure:	without spring; 0.5; 1.5; 3 or 5 bar

These valves are used

- For by-passing throttling points
- For shutting off one direction of flow
- As by-pass valves, e.g. for by-passing a return line filter when a particular back-pressure has been reached due to contamination or
- As pre-tensioning valves (holding valves) to create particular backpressures in circuits

The so-called "rectifier circuit" is achieved by connecting four non return valves as shown in the diagram (*fig. 5*). It is used mainly in connection with flow control valves or pressure control valves. With this circuit, the fluid must flow through the valve in the same direction for forward flow (red) and return flow (green) (*figs. 5 and 6*).

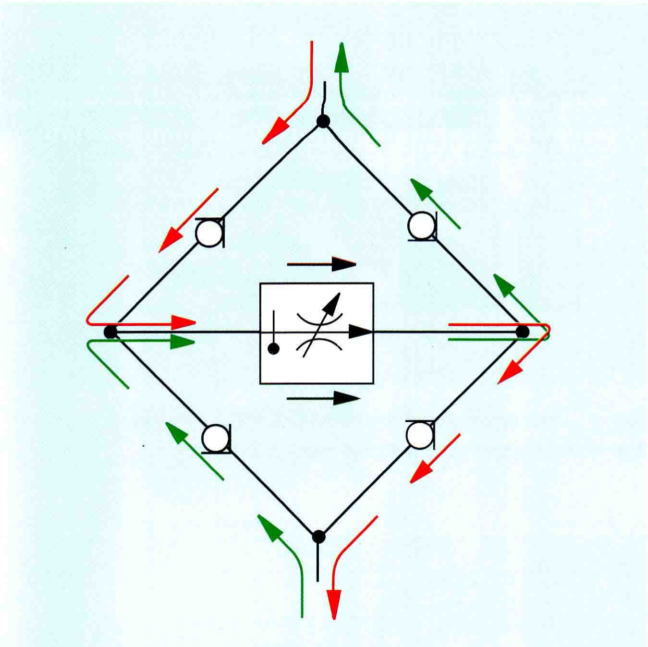


Fig. 5: *Circuit diagram for rectifier circuit*

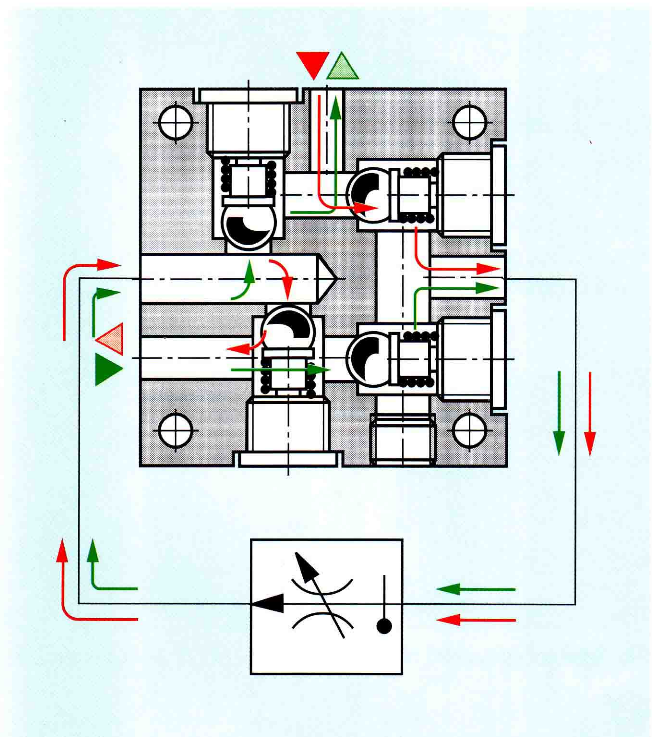


Fig. 6: *Rectifier sandwich plate, type Z4S*

3 Pilot operated check valves

As opposed to the simple non return valves, pilot operated check valves may also be opened in the direction of closure.

These valves are used, for example:

- to isolate working circuits under pressure
- to prevent the load from dropping, if a line should break
- to prevent creep movements of hydraulically loaded actuators

There are two types of pilot operated check valves.

3.1 Model without leakage port (valves, type SV)

Free flow is from A to B in the valve shown in *Fig. 7*.

Fluid pressure acts on area A_1 of the main poppet (1) and lifts this poppet from its seat against spring force (3). No flow is allowed in direction B to A, which corresponds with the function of a normal check valve.

Pilot piston (4) opens the valve. This piston is pushed to the right due to the pilot oil being fed into port X, and thus opens the main poppet (1) once a specified pilot pressure has been reached.

The pilot pressure required corresponds to the ratio of area A_1 to the area of the pilot spool. Usually this ratio is approx. 1:3.

Once the pilot pressure has been reached, the complete area A_1 is abruptly opened. This may result in decompression shocks, especially if large volumes under pressure are freed. These compression shocks not only cause noise, but also stress the complete hydraulic system, especially the screws and moving valve parts.

For applications, where these effects must be avoided, the valve is designed with pre-opening (pilot poppet) (see *fig. 8*).

When pressure is applied to control port X, the pilot spool 4 is pushed to the right. First the pilot poppet (2) and then the main poppet (1) are thus pushed from their seats. When the pilot poppet is opened, only a small area is open to flow. This causes the cylinder to decompress slowly before the complete area is opened by opening the main poppet. Flow is from B to A in the valve. This design allows the fluid under pressure to decompress slowly.

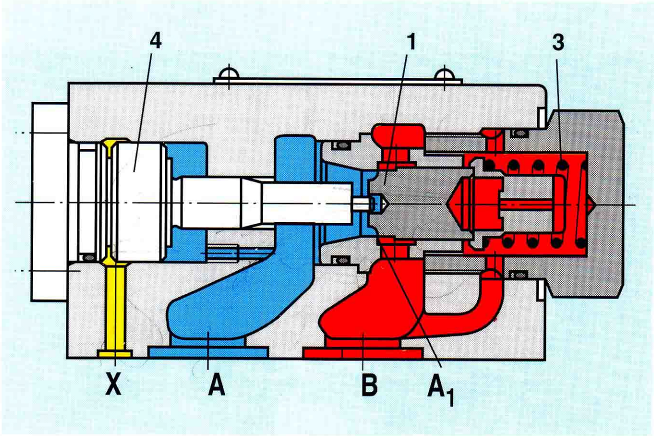


Fig. 7: *Pilot operated check valve without pre-opening of the main poppet and without case drain port*

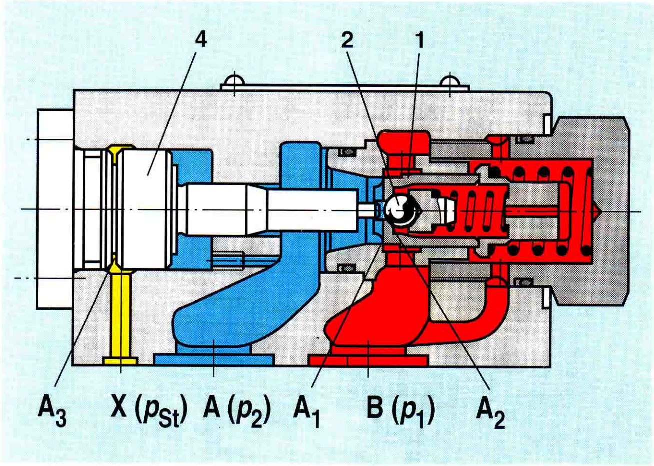


Fig. 8: *Pilot operated check valve with pre-opening of the main poppet and without drain case port*

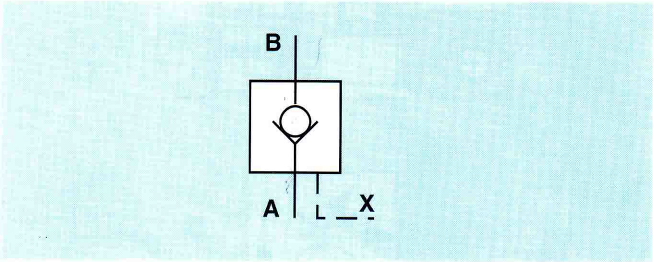


Fig. 9: *Pilot operated check valve without case drain port*

A certain minimum pilot pressure is required, so that the valve can also be reliably controlled by means of the control piston.

Below is shown how the required pilot pressure can be determined. The symbols used in the calculations are as follows:

p_{St} = pilot pressure
p_1 = pressure at port B of the valve
p_2 = pressure at port A of the valve
A_1 = area of main poppet
A_2 = area of pilot poppet
A_3 = area of control spool
A_K = area of cylinder piston
A_R = area of cylinder annulus
F = cylinder load
F_F = spring force with friction

Balance of forces at valve, see *fig. 8*

$$p_{St} \bullet A_3 = p_1 \bullet A_1 + F_F + p_2 \bullet (A_3 - A_1)$$

$$A_3 > A_1 \qquad (1)$$

This calculation is valid for zero pressure at port A ($p_2 \approx 0$ bar). Pressure at port A would act at the control spool in opposition to the pilot pressure.

Balance of forces at cylinder, see *fig. 10*

$$p_1 \bullet A_R = p \bullet A_K + F$$

$$p_1 = p \bullet \frac{A_K}{A_R} + \frac{F}{A_R} \qquad (2)$$

If equation 2 is substituted into equation 1 and solved for p_{St}, the required pilot pressure is produced for port X for the check valve without leakage port.

$$p_{St} \geq \left(p \bullet \frac{A_K}{A_R} + \frac{F}{A_R}\right) \bullet \frac{A_1}{A_3} + \frac{F_F}{A_3} \qquad (3)$$

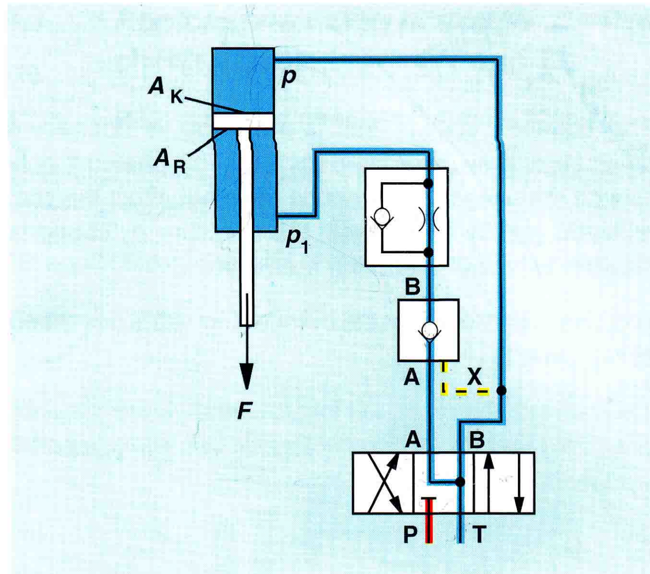


Fig. 10: *Circuit diagram*

3.2 Model with leakage port (Valves, type SL)

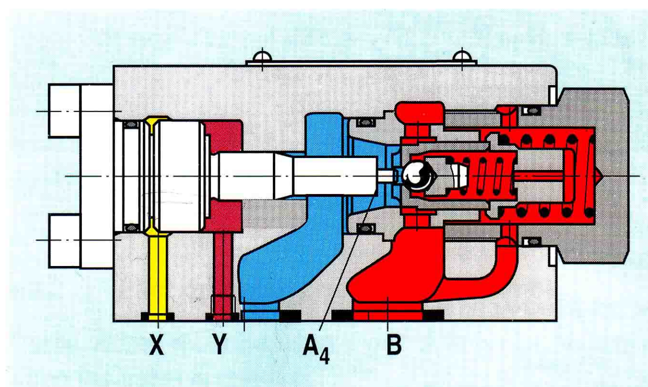


Fig. 11: *Pilot operated check valve with pre-opening of the main poppet and case drain port*

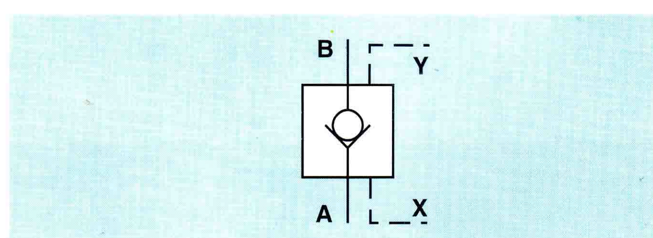


Fig. 12: *Pilot operated check valve with case drain port*

The difference to valve type SV is the additional drain port Y. The annulus area of the control piston is separated from port A. Pressure at port A affects only surface A_4 of the control spool (*fig. 11*).

Balance of forces at valve

$$p_{St} \bullet A_3 = p_2 \bullet (A_4 - A_1) + p_1 \bullet A_1 + F_F \qquad (4)$$

The equation shows, that if the valve is opened, a pressure p_2 may be created ($p_2 > 0$). This pressure only acts on the push rod and hence does not effect the pilot pressure greatly. In general, the pressure p_2 supports the pilot pressure due to the area ratio.

The balance of forces at the cylinder (*fig. 10*) is described by equation 2.

If equation 2 is substituted into equation 4, the required pilot pressure to open the check valve with leakage port is produced.

$$p_{St} \geq p_2 \bullet \frac{A_4 - A_1}{A_3} + \left(p \bullet \frac{A_K}{A_R} + \frac{F}{A_R}\right) \bullet \frac{A_1}{A_3} + \frac{F_F}{A_3} \qquad (5)$$

From the theoretical considerations (equations 3 and 5), it can be seen that check valve, type SV (without leakage port) must not be pressurised at port A, but this is permitted in check valve, type SL (with leakage port).

Check valves, types SV and SL are available for

- sub-plate mounting
- pipe mounting (threaded connections) (*fig. 13*)
- pipe mounting (flanged connections)
- as cartridge elements or
- as sandwich plate valves (*fig. 14*)

Important parameters

Sizes:	6 to 150
Flow:	up to 6400 L/min
Operating pressure:	up to 315 bar

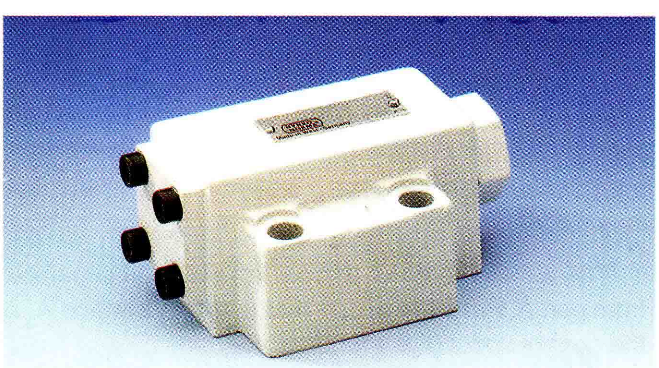


Fig. 13: *Pilot operated check valve*

By fitting two pilot operated check valves (1) and (2) in one housing, a double pilot operated check valve, type Z2S, is obtained (*fig. 14*).

There is free flow in direction A_1 to A_2 or B_1 to B_2, while flow is blocked from A_2 to A_1 or B_2 to B_1. If, for example, there is flow from A_1 to A_2, control spool (3) is pushed to the right and pushes the poppet of the check valve (2) from its seat.

The connection from B_2 to B_1 is now open. The valve therefore operates at flow direction B_1 to B_2.

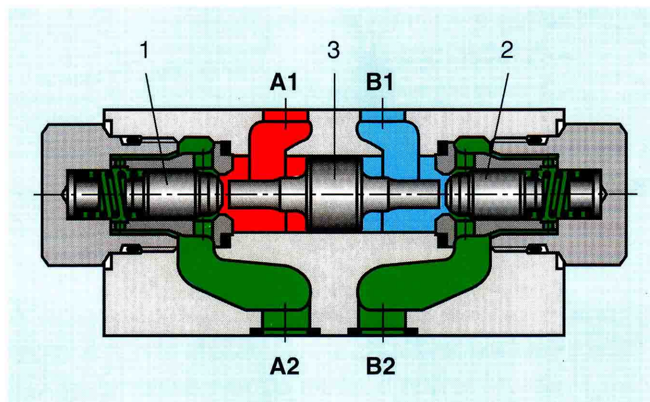


Fig. 14: *Double check valve for sandwich plate mounting, type Z2S*

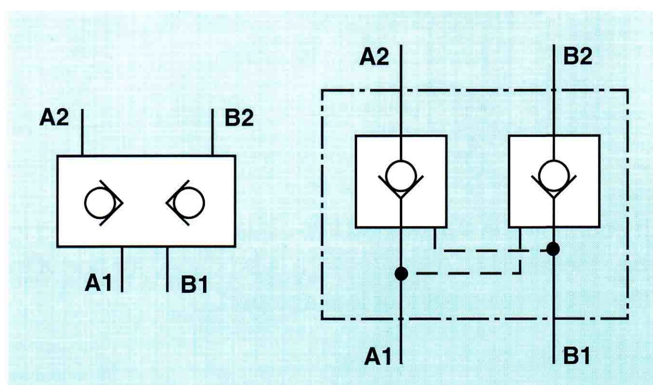


Fig. 15: *Symbols for double check valves (left: simplified symbol, right: detailed symbol)*

The circuit example below shows the task of the double check valve:

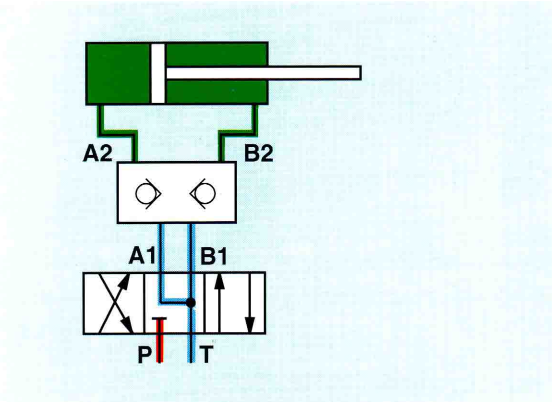


Fig. 16: *Circuit example*

Both parts of the cylinder are closed leakfree. At any desired idle position, the cylinder cannot be moved, even by an external force.

This means, for example, that a cylinder under load will not begin to 'creep', even during a long idle period.

In order to guarantee safe closing of both valve poppets, both actuator ports (A and B) must be unloaded when the directional valve is in its neutral position by connecting these parts to the return line.

A double check valve is generally fitted as a sandwich plate between the directional control valve and the subplate.

Important parameters

Sizes:	6 to 25
Flow:	up to 300 L/min
Operating pressure:	up to 315 bar
Cracking pressure:	1.5; 3; 7.5 and 10 bar (sizes 6 and 10) 2.5; 5; 7.5 and 10 bar (sizes 16 and 25)

3.3 Applcations using pilot operated check valves, types SV and SL

3.3.1 Pilot operated check valve, type SV

These valves may be used, if port A is at zero pressure when the valve is opened.

No additional connection of leakage line Y is necessary.

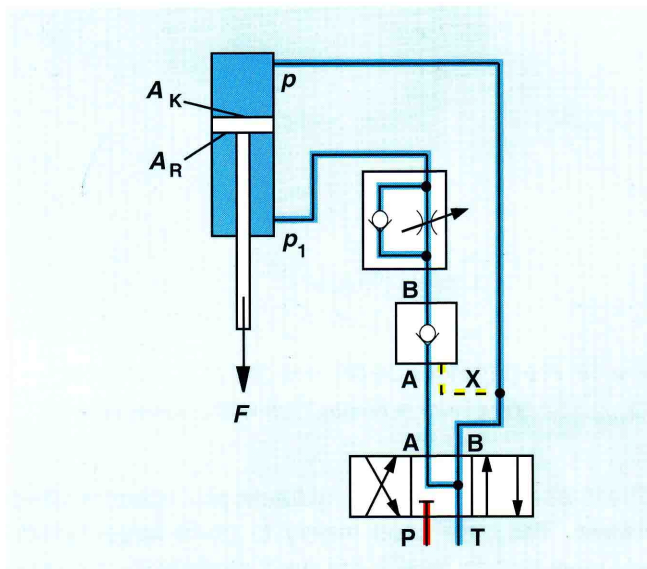


Fig. 17: *Use of pilot operated check valves, type SV*

3.3.2 Pilot operated check valve, type SL

These valves must be used if port A is under pressure when the valve is opened.

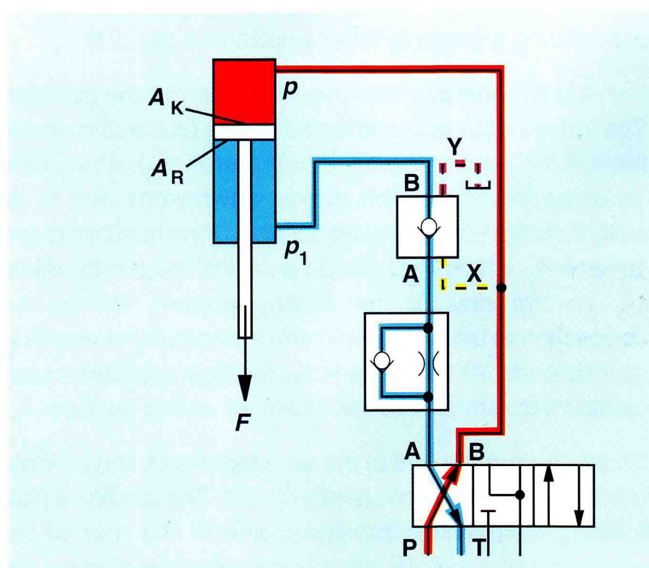


Fig. 18: *Use of pilot operated check valves, type SL, port A (for example) is subject to a back pressure due to the throttle check valve*

3.4 Pre-fill valves

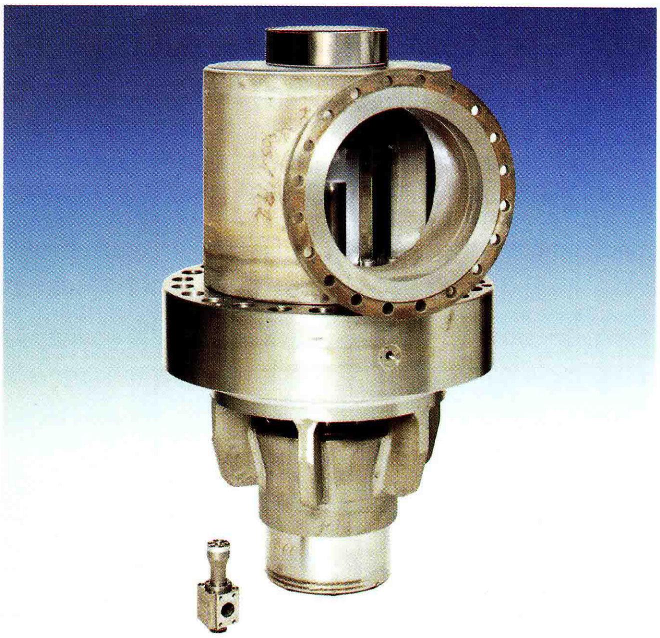


Fig. 19: *Pre-fill valve, type SF, size 500 (p_{max} = 350 bar; Q_{max} = 50 000 L/min) in comparison with a valve, size 40*

Prefill valves are large size hydraulic pilot operated check valves. They are used mainly to prefill large cylinder volumes and to isolate the main working circuit under pressure, for example, in presses.

The valve shown in *fig. 20* comprises pilot poppet (1) and main poppet (2) which are held on their seats by spring (3). The force of this spring only exceeds the weight of the poppet by a small amount. Spring (4) pushes the control piston (5) into start position.

The function will be described in more detail by considering a press cylinder application (*fig. 21*).

Port A is connected with a pre-fill tank above the cylinder. The valve poppets are affected by the oil column above them. If the piston rod side (annulus area A_R) of the press is unloaded, the piston moves downwards due to its weight. A negative pressure occurs in the chamber above surface A_K which also affects port B of the pre-fill valve, i.e. on the rear of the closing poppet. Hence the connection to tank is opened and the cylinder sucks oil in as it extends. At the same time, the high pressure pump usually delivers oil into the chamber above surface A_K.

Shortly before the end of the working stroke, the cylinder is braked to the desired press speed. The pressure now building up (working pressure) affects the rear of the valve poppet via prefill valve port B and thus isolates the working circuit from the tank.

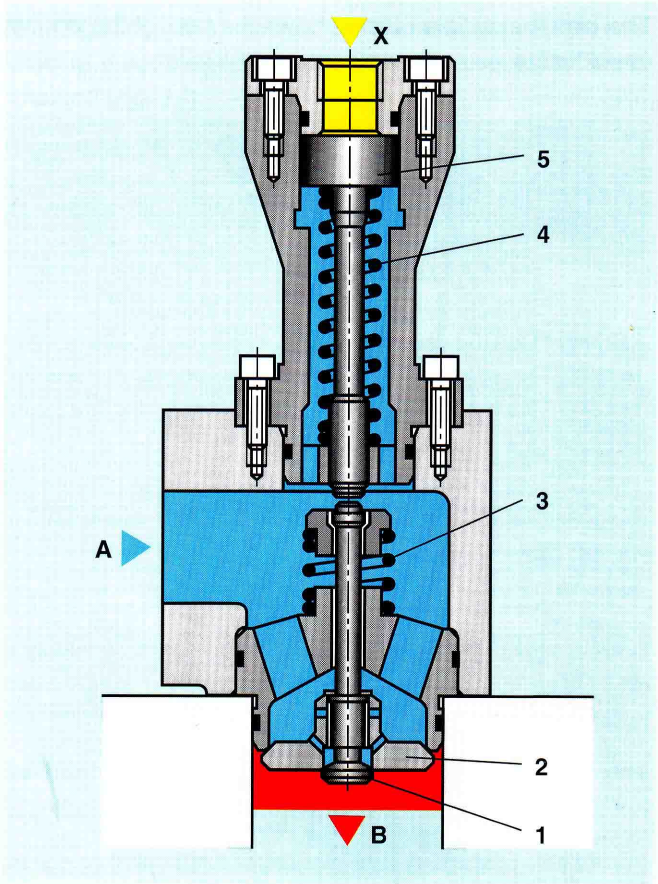


Fig. 20: *Pre-fill valve with pre-opening poppet*

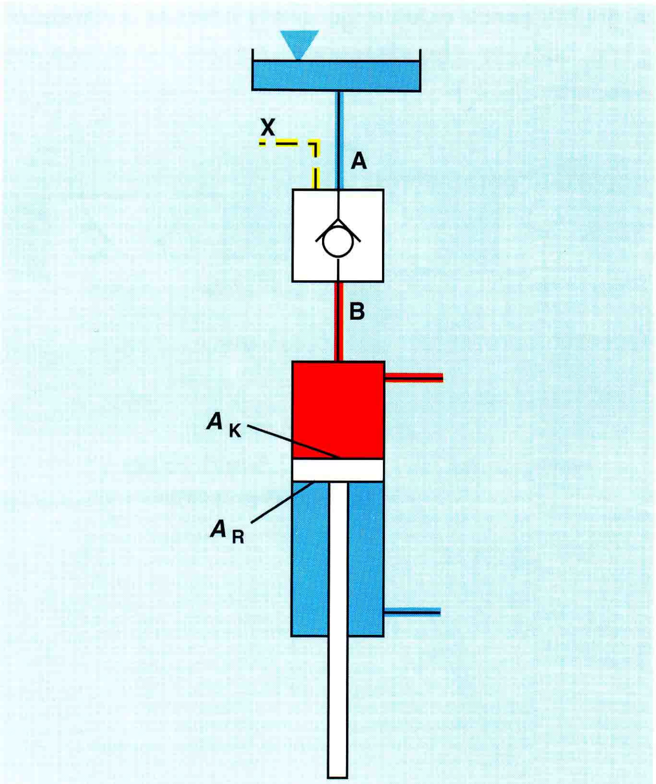


Fig. 21: *Circuit example*

After the working stroke, the press cylinder must retract. By switching over the control elements, pressure affects, for example, the annulus area A_R, and by means of prefill valve control port X, control spool (5). It pushes open the pilot opening poppet (1) and then the main poppet (2). The fluid above the surface A_K can now be pushed back into the pre-fill tank. The cylinder can retract again.

Depending on application, prefill valves can be fitted with or without pilot opening poppets.

The pilot pressure may be calculated in the same way as for the pilot operated check valves mentioned in sections 3.1 and 3.2.

Larger valves are always fitted with pilot opening poppets.

Pre-fill valves are available for

- flanged connections
- tank mounting
- manifold mounting

Important parameters

Sizes:	40 to 500
Flow:	up to 50 000 L/min (at v_{oil} = 6 m/s)
Operating pressure:	up to 350 bar
Cracking pressure:	without spring; 0.5; 1.5 or 3 bar

4 2- way cartridge valves (logic elements)

A special type of non return valve is the 2-way cartridge valve, also known as a logic element. They are described in detail in the manual "The Hydraulics Trainer, Volume.4".