

Chapter 10 Directional Control valves

10.1 Check Valves

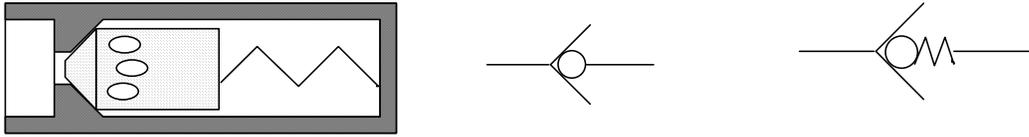


Figure 10.1 Check valve

Two conditions: free flow or "checked" flow

Usually has a cracking pressure of 69 Pa – 104 Pa (10 -15 psi)

If used with a large spring the cracking pressure is 520 Pa (75 psi) (typically)

10.2 Examples of using check valves:

10.2.1 Use of a check valve as a pilot pressure source.

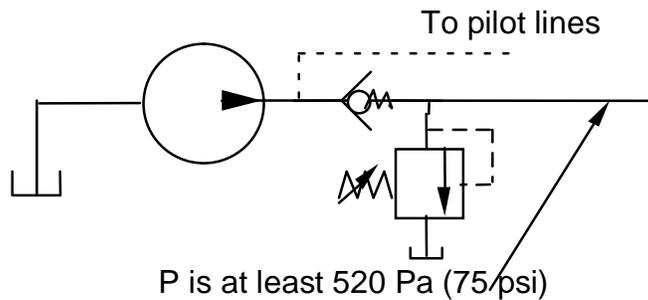
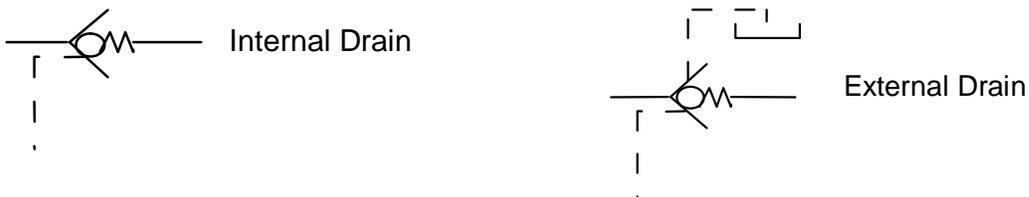


Figure 10.2 Check valve as a pilot pressure source

This application ensures that as long as the pump is running, a pilot pressure of 520 Pa is available for other circuits even if the main line pressure is lost.

10.2.2 Pilot Operated C.V.

There are two types: internal and externally drained and they have a significant effect on sizing and application.



10.2.2.1 Pilot operated check valve, internally drained

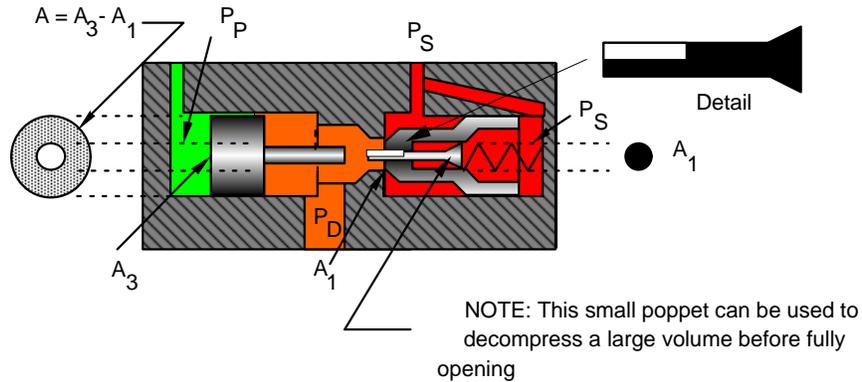


Figure 10.3 Pilot operated check valve

Force Balance

$$P_P A_3 = P_D (A_3 - A_1) + P_S A_1 + Kx$$

$$P_P = (P_S - P_D) \frac{A_1}{A_3} + P_D + \frac{Kx}{A_3}$$

Note A_3/A_1 is called the PILOT RATIO and is labeled as **R**: It is used to determine the pressure at which the pilot will open.

$$P_P = \frac{(P_S - P_D)}{R} + P_D + \frac{Kx}{A_3}$$

NOTE: If $P_D \neq 0$, problems can occur since the opening pilot pressure will be a function of both P_S and P_D .

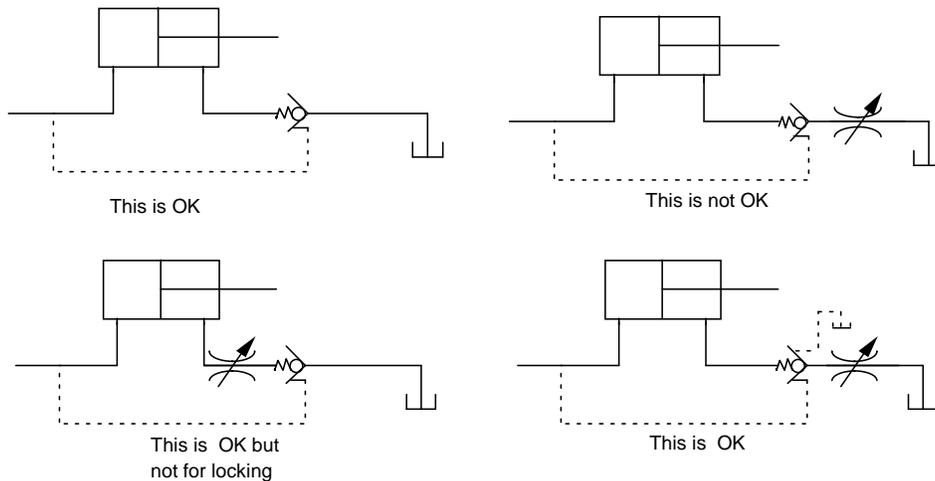


Figure 10.4 Pilot operated check valve configurations

10.2.2.2 Pilot operated check valve, externally drained

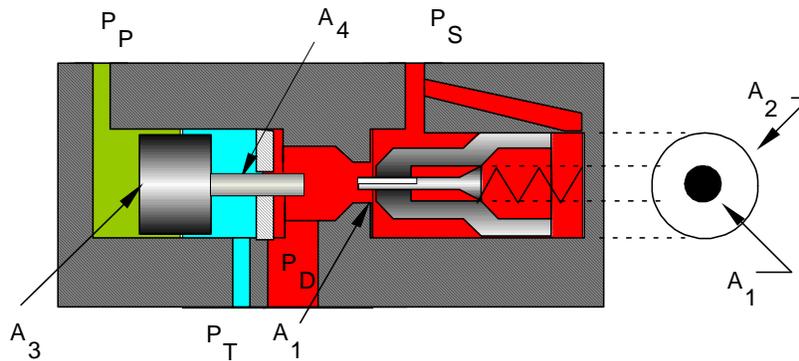


Figure 10.5 Pilot operated check valve, externally drained

In this configuration, the chamber of A_4 is at tank pressure. Thus P_p is relatively insensitive to P_D

Pilot ratio is thus $\frac{A_3}{A_1} = R$

Opening forces $P_p A_3 + P_D A_1$

Closing forces $P_S A_1 + P_D A_4 + \text{Spring}$

or $P_p = (P_S - P_D) \frac{A_1}{A_3} + P_D \frac{A_4}{A_3} + C$, where C is the spring force

so $P_p = \frac{P_S - P_D}{R} + P_D \frac{A_4}{A_3} + C$

Compare to internal drain

Since $A_4 \ll A_3$, P_p is
not as dependent on
 P_D for external drain.

$$P_p = \frac{P_S - P_D}{R} + P_D + C$$

10.2.3 Example of using pilot checks

The following examples show how a pilot operated check valve is often used.

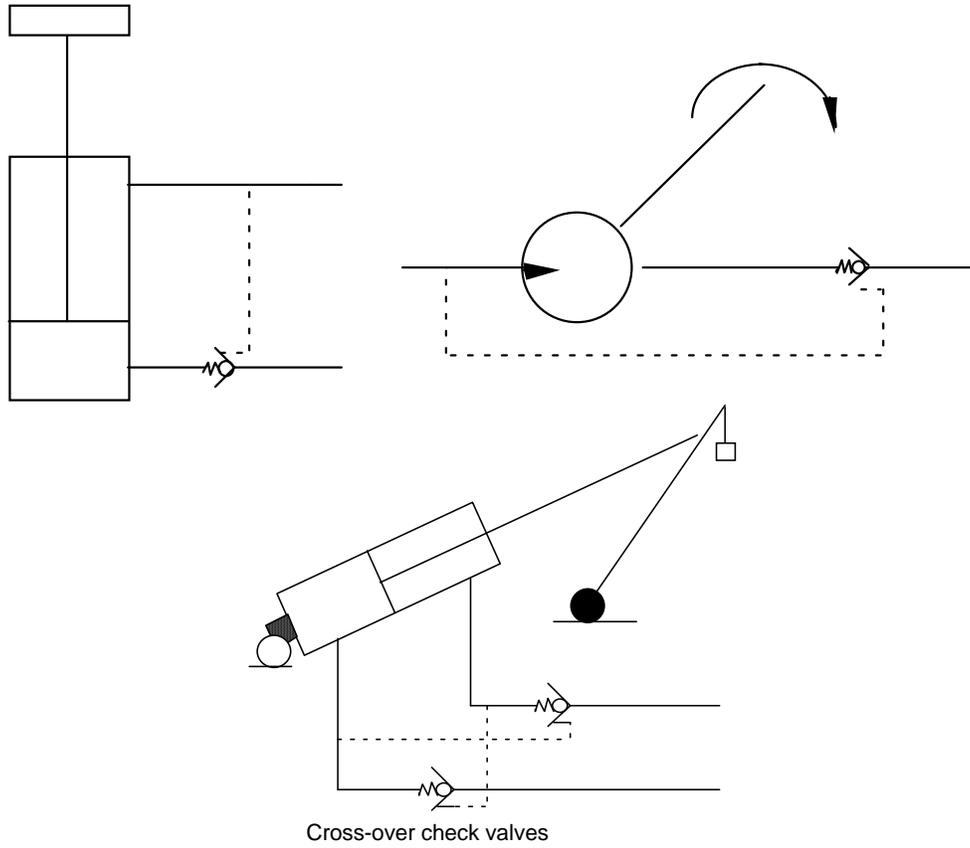


Figure 10.6 Pilot operated check valve applications.

10.2.4 Example

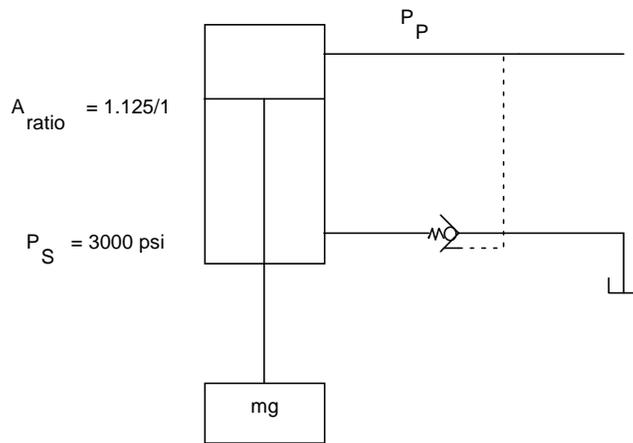


Figure 10.6 System for example calculation

We will use this example using imperial units.

Internal Drain:
$$P_P = \frac{3000\text{psi} - 0}{3} + 0 + 75$$

(Assume 3:1 pilot Ratio and 75 psi spring) $P_P = 1075$ psi

\therefore Pilot pressure is 1075 psi to open.

Now: This means that P_P must > 1075 psi. This will increase the P_S to 3000 psi + A_{ratio} $1075 = 4200$ psi. But, P_P will now increase since P_P is also a function of P_S , that is

$$P_P = \frac{P_S - P_D}{R} + P_D + C = \frac{4200}{3} + 0 + 75 = 1478$$

So P_P must increase to 1478 psi - But that increases P_S and so on.

Eventually, a balance will occur.

\therefore We must modify our equation to reflect this situation.

$$P_P = \frac{\frac{LP}{AR_V} + C}{1 - \frac{AR_C}{AR_V}} \quad P_D = 0$$

LP = Load induced
pressure (original)
C = spring constant factor
AR_v = Pilot ratio
AR_c = $\frac{\text{area blind end}}{\text{area rod end}}$

In our example, LP = 3000
C = 75
AR_v = 3
AR_c = 1.125

$$\therefore P_P = \frac{\frac{3000}{3} + 75}{1 - \frac{1.125}{3}} = 1720 \text{ psi}$$

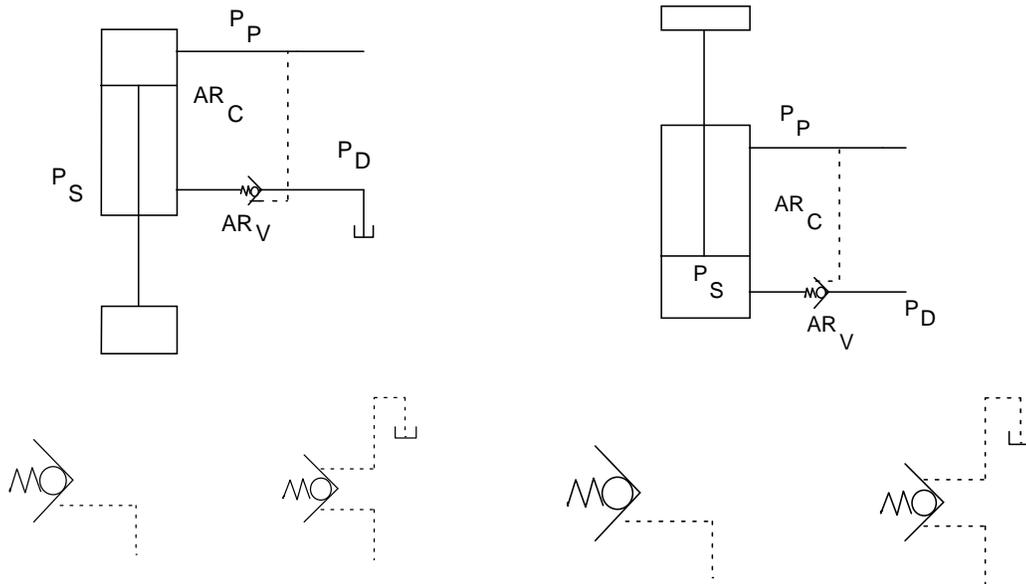
Note: Pressure P_S will now be
 $3000 + 1720 \text{ AR}_c = 4935$ psi

DANGER!!
This is even larger if
a down stream pressure
exists.

If there is a residual pressure P_D due to a valve downstream, then

$$P_P = \frac{\frac{LP - P_D}{AR_V} + P_D + C}{1 - \frac{AR_C}{AR_V}}$$

10.2.5 Summary



$P_P = \frac{LP - P_D}{\frac{AR_V}{1 - \frac{AR_C}{AR_V}} + P_D + C}$ $P_S = LP + P_P (AR_C)$	$P_P = \frac{LP - P_D}{\frac{AR_V}{1 - \frac{AR_C}{AR_V}} + P_D \frac{A_4}{A_3} + C}$ $P_S = LP + P_P (AR_C)$	$P_P = \frac{LP - P_D}{\frac{AR_V}{1 - \frac{AR_C}{AR_V}} + P_D + C}$ $P_S = LP + \frac{P_P}{AR_C}$	$P_P = \frac{LP - P_D}{\frac{AR_V}{1 - \frac{AR_C}{AR_V}} + P_D \frac{A_4}{A_3} + C}$ $P_S = LP + \frac{P_P}{AR_C}$
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10.2.6 Some special considerations.

- After a check valve (CV), one must use either a counterbalance valve (CBV) or flow control to prevent erratic free fall of load.
- If a pilot operated C.V. is to be used, then the pilot line must be at tank sometime so that the CV can close.
- When using a pilot C.V., always use a floating center valve to prevent drift in the actuator.

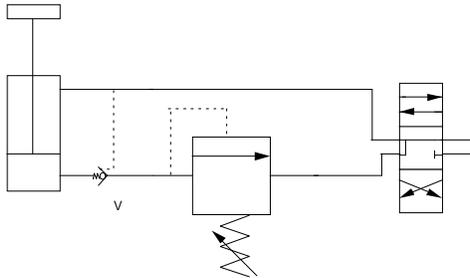


Figure 10.8 example

Consider Figure 10.7 Recall that most pilot C.V. have a small poppet inside the main poppet as illustrated.

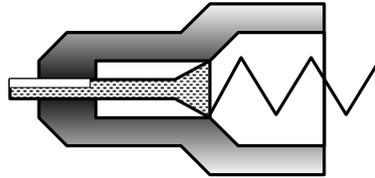


Figure 10.9 small poppet

This small poppet can be used to decompress a closed volume slowly and then move fluid through the main poppet at a lower pressure.

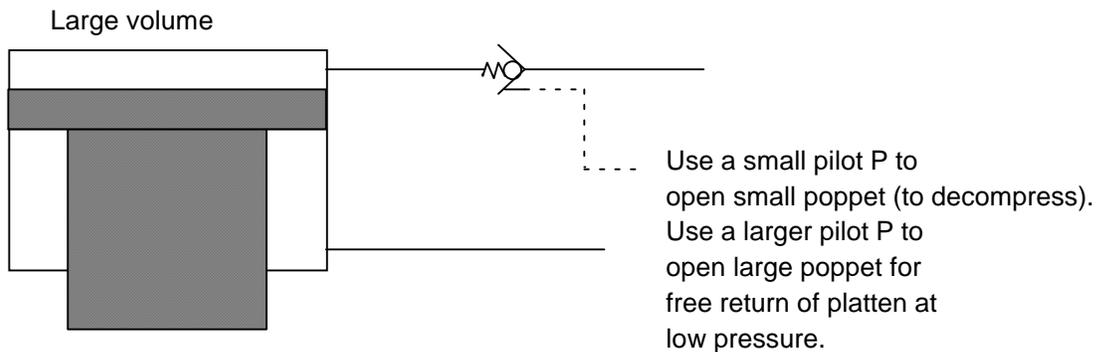
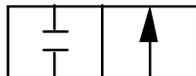


Figure 10.10 Pilot check valve to decompress a large volume

Pressure settings can become a problem since the pilot pressure necessary to open the small poppet is $< P_P$ main poppet.

10.3 Two-Way Valves



- Are spool type or rotary
- Are actuated by solenoids, mechanically, hydraulically

10.4 Three-Way Valves

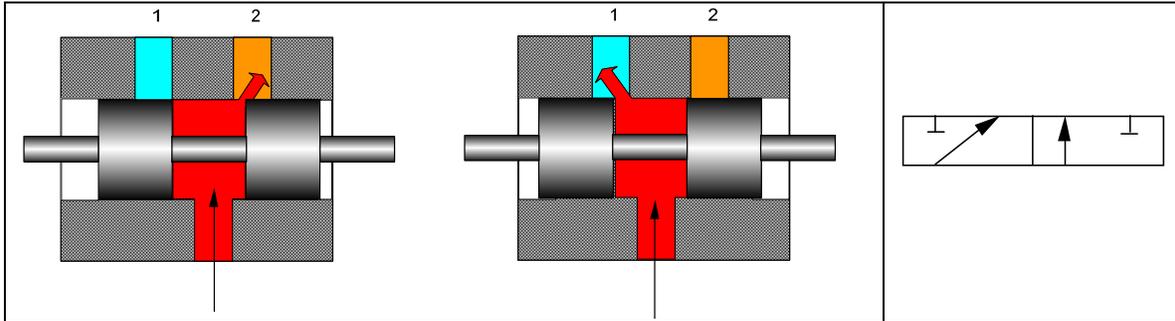


Figure 10.11 Three way spool valve

10.5 Shuttle Valves

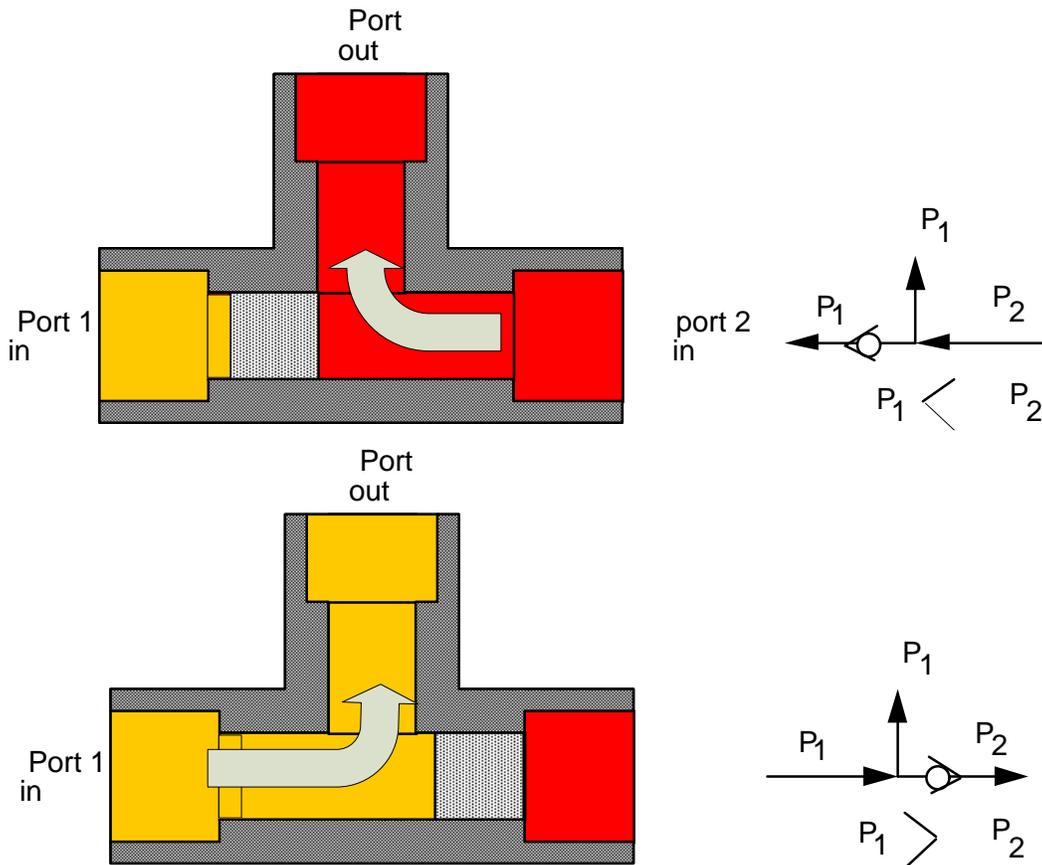


Figure 10.12 Shuttle valve

10.5 Four-way Valves

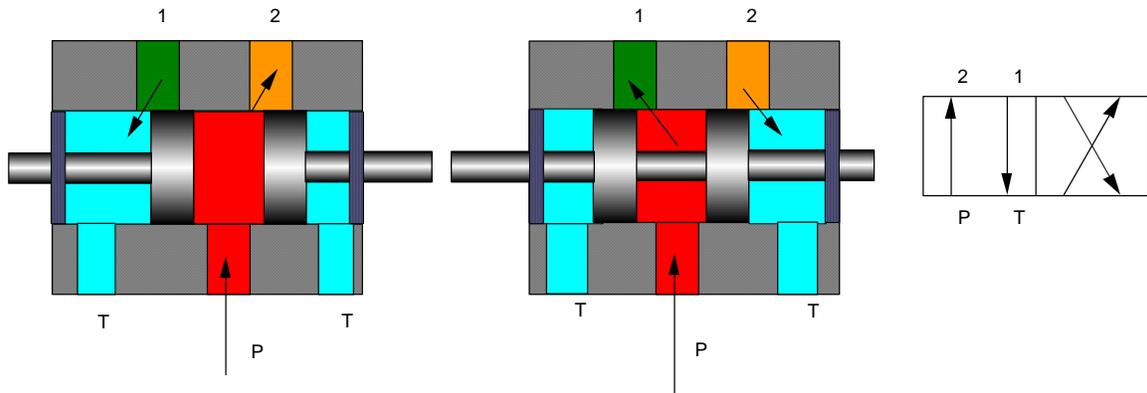


Figure 10.13 Four way valve

These valves can be shifted manually, or by solenoid (direct and pilot)

Figure 10.14 Manually Operated Four-Way Valve

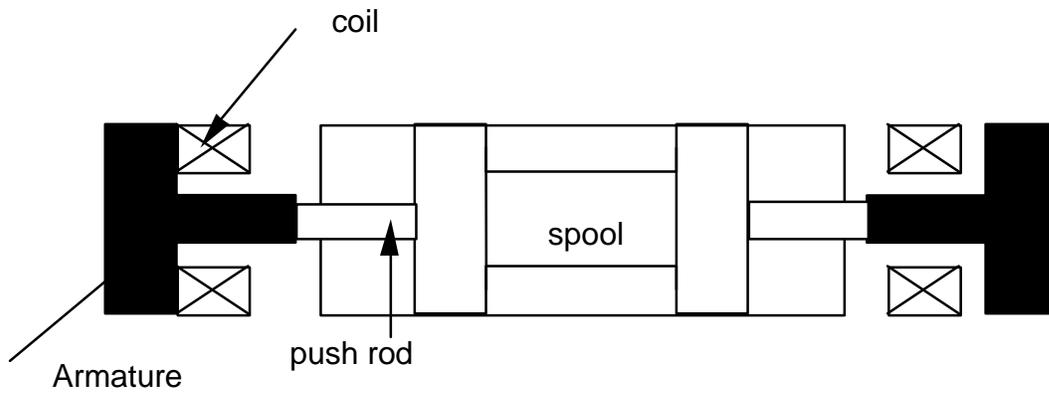


Figure 10.15 Solenoid-operated spool valve

In many cases, two stage or pilot valves are used to actuate the main spool. This is shown in Figure 10.14

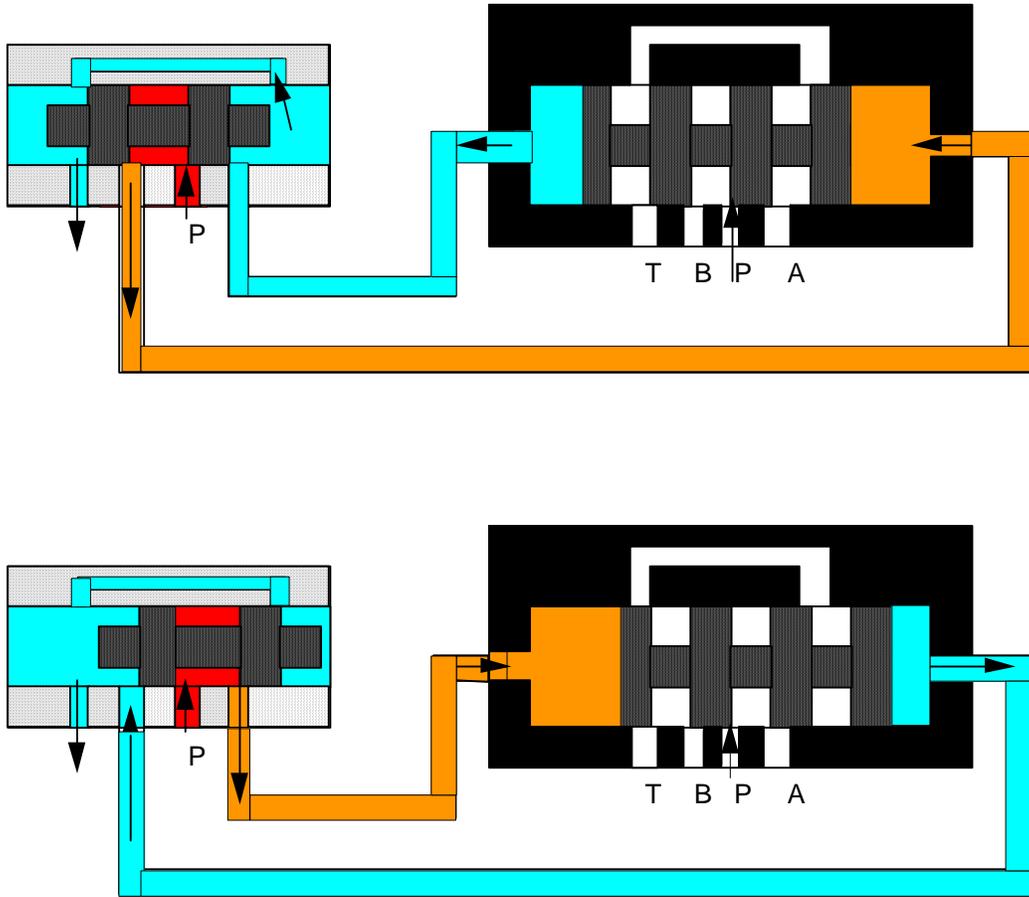


Figure 10.16 Pilot operated spool valve- basic principle

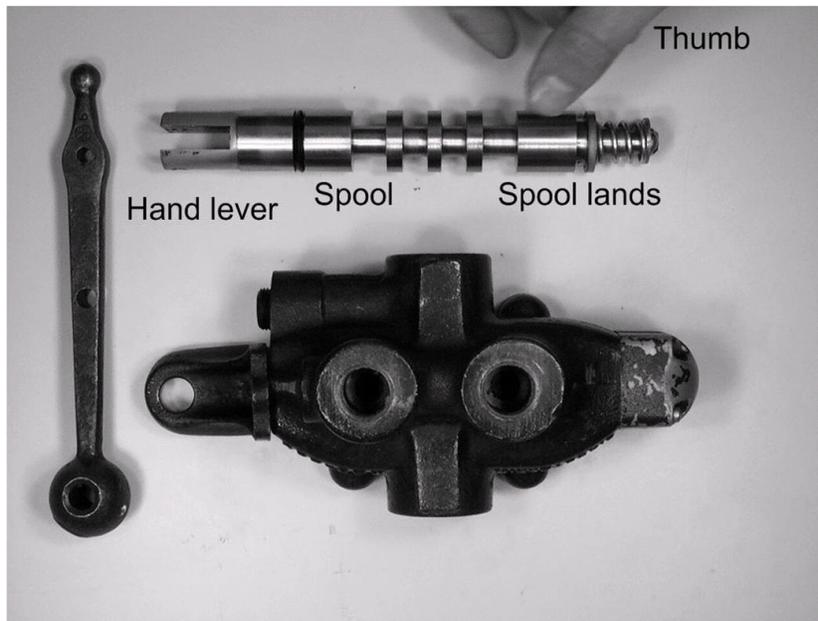


Figure 10.17 Hand operated spool valve

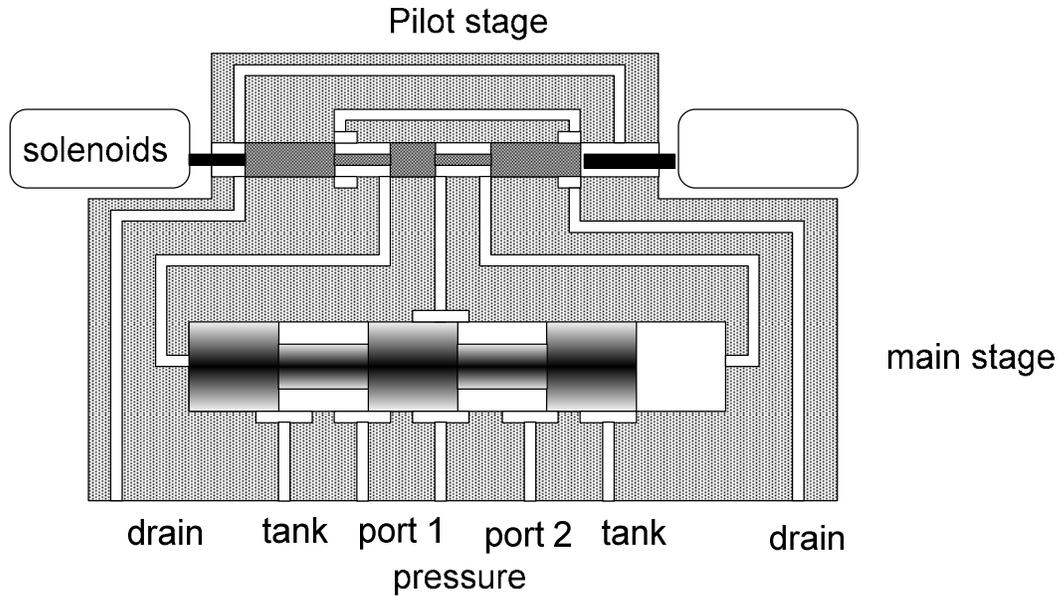


Figure 10.18 Solenoid-pilot operated four-way valve

For pilot operated valves, a higher pressure must be ensured for switching. This can be accomplished by using a check valve.

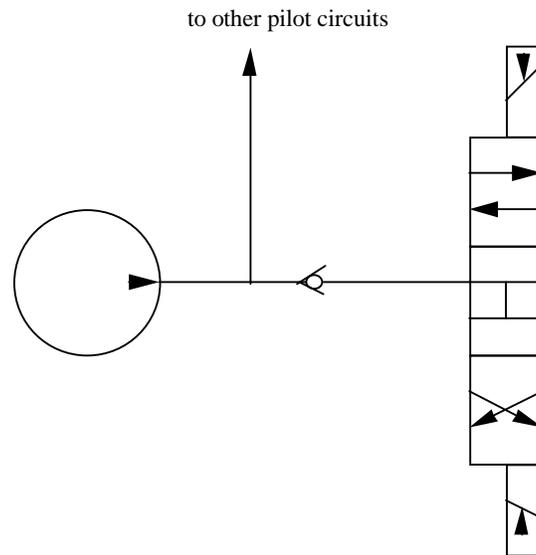


Figure 10.19 Maintaining positive pressure for pilot operated valves.

In many cases, three positions are available in directional valves. The centered positions can vary and are demonstrated below.

Types of centers

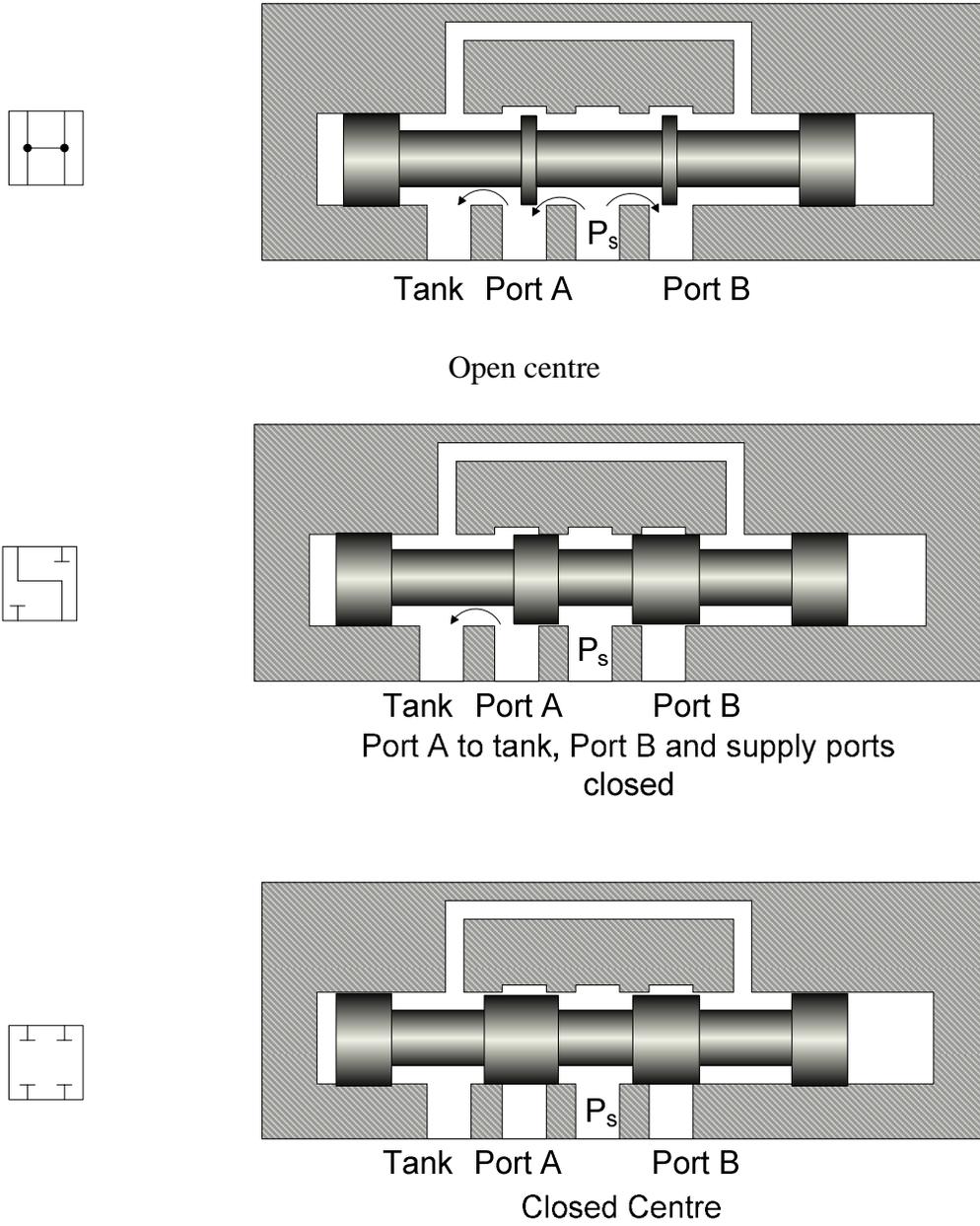
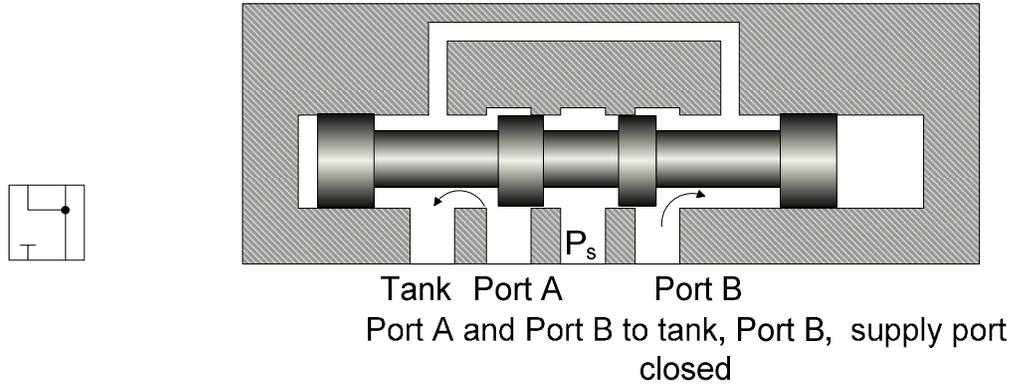


Figure 10.20 Centre types for valves



Floating centre

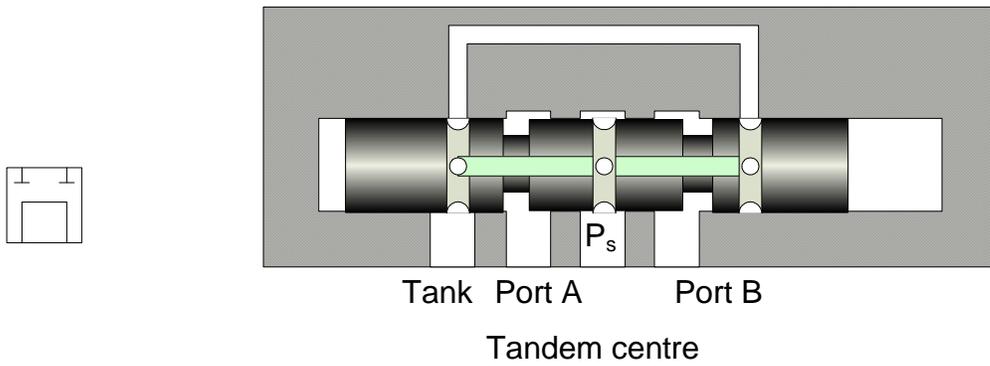
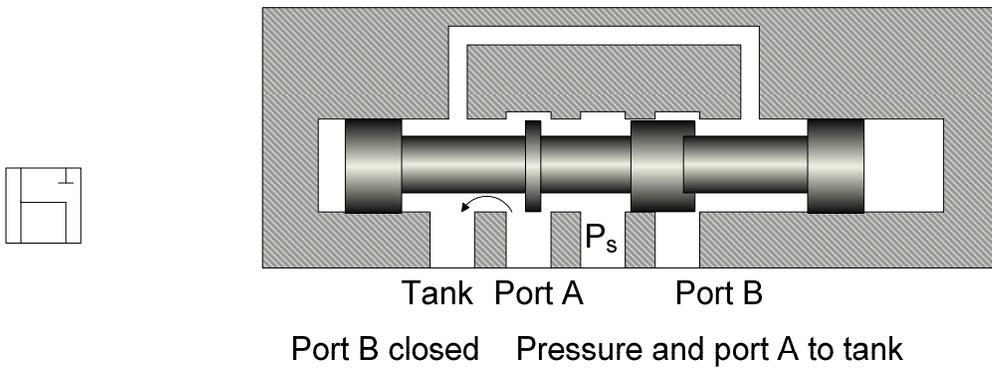


Figure 10.20 Centre types for valves (cont.)