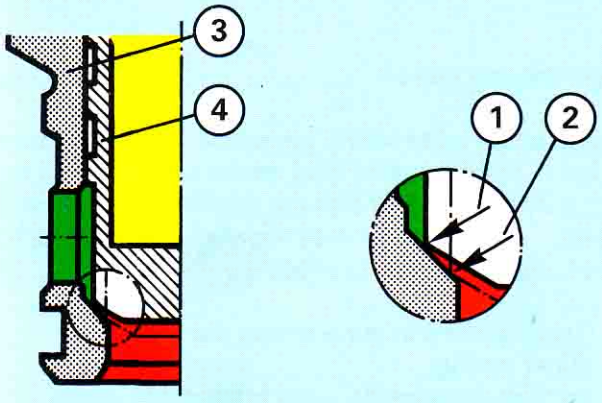
Directional Functions: Variations and Application Notes.

1 Area ratios on the valve poppet.

When studying the basic element, it becomes clear that three areas and the pressures working on these areas are important when considering the functioning of the element:

Area A_A	This is the area connected to Port A and is taken as 100 %.
Area A_B	This is the annulus area at Port B and can be either 7 % or 50 % of area A_A dependent upon the valve model.
Area A_X	This is the area at Port X and is equal to the sum of the areas A_A and A_B.

How are the different annular areas achieved?



(1) Position of seat with 7 % annular area.
(2) Position of seat with 50 % annular area.
(3) Bush
(4) Valve poppet

Fig. 68

From *Fig. 68* it becomes clear that the "basic area" A_A varies with the position of the contact point, although this is always taken as the "100% value.

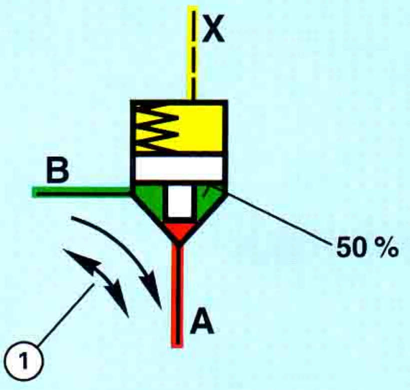
To take a numerical example:

Logic element size 25:

	annular area 50 %	annular area 7 %
Area A_X	4.91 cm^2	4.91 cm^2
Area A_A	3.30 cm^2	4.60 cm^2
Area A_B	1.61 cm^2	0.31 cm^2
Area ratio A_A: A_B	≈ 2:1	14.3:1

Table 1

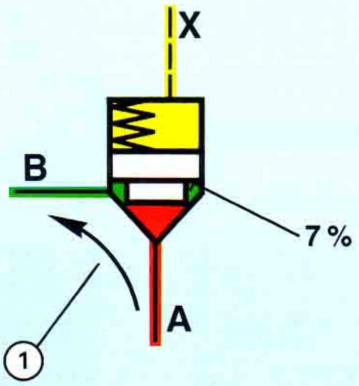
If the directional flow is to be exclusively from B to A then the model with A_B = 50% should preferably be employed *(Fig.69)*.



(1) Recommended directions of the flow

Fig. 69

If the directional flow is exclusively from A to B then the model with $A_B = 7\ \%$ should preferably be used (Fig. 70).



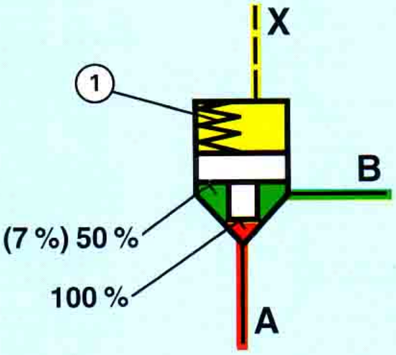
(1) Recommended direction of flow

Fig. 70

In addition to the direction of flow and area ratio, the leakage oil, the opening pressure which must operate against area A_X and the spring installed must all be considered.

Example: Logic element size 32.

Cracking pressure approx. 1 bar (referred to 100% area).



(1) 1 bar spring

Area	Cracking pressure for flow direction	
A_B	A to B	B to A
= 50 %	0.91 bar	1.77 bar
= 7 %	0.64 bar	9.80 bar

Fig. 71

If flow is required from B to A with a 7% annular area, the opening pressure would be 9.8 bar. It must also be mentioned here, that the area ratios are only applicable to the valve when it is closed.

2 Choice of springs

The spring installed has an influence on both the static and the dynamic characteristics of the logic element.

Various springs are available, and a model without a spring is also available. The spring is normally rated against the cracking pressure of the valve e.g:

Cracking pressure	approx. 0 bar (no spring)
	approx. 0.5 bar
	approx. 1.0 bar
	approx. 2.0 bar
	approx. 3.0 bar
	approx. 4.0 bar

The cracking pressure is referred to area A_A for the 50 % model.

The exact values for the cracking pressure must be taken from the relevant data sheets under consideration of the area ratios and the direction of flow as described above.

Models with area ratios $A_B = 50\ \%$ and $A_B = 7\ \%$ contain the same spring.

Opening the valve

When opening the valve, the spring has almost no influence on the opening time, as the system pressure is normally much higher than the cracking pressure of the spring. For the same reasons,when the valve is fully open, the spring has no effect.

- Logic element in the pressure line
  4 bar spring
  (e.g. as a non return valve in the pump outlet)
  The spring offers little resistance in comparison to the higher system pressure.
- Logic element in the tank line
  0.5 bar spring
  Here the spring has a noticeable effect on the resistance
  (fit a 0,5 bar spring if no other requirements are placed on the closing time),
- As a "standard" one can always fit a
  2 bar spring.

Closing the valve

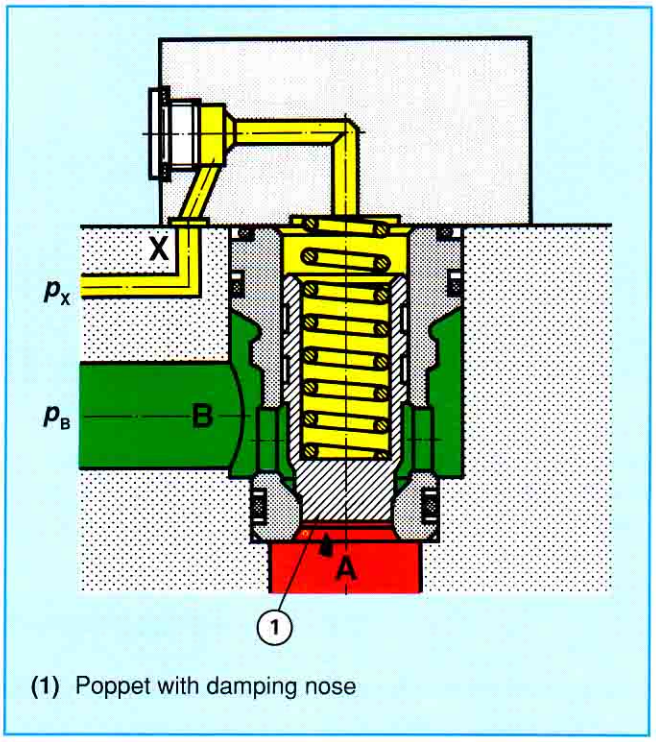
At first, when closing the valve, the only force available is that of the spring. Only when the closing operating has started, is a pressure forced added to that of the spring force. This depends upon the area ratio and the pressure drop between ports A and B.

In practice, this means:

Strong spring → rapid closing
Weak spring → slow closing

3 Damping nose

Logic elements can be supplied either with a damping nose *(Figs. 72 to 74)* or without a damping nose *(Figs. 75 to 77)*.



(1) Poppet with damping nose

Fig. 72: *Logic element with damping nose.*

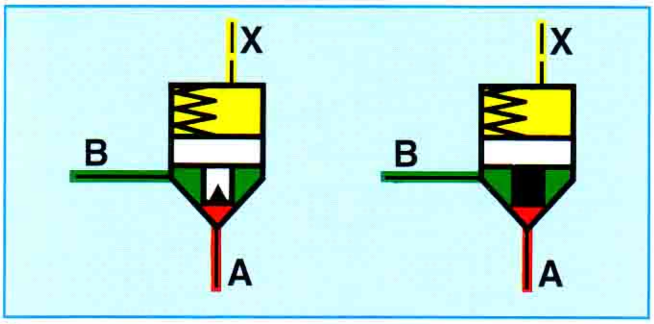


Fig. 73:
Schematic symbols of a logic element with a damping nose.

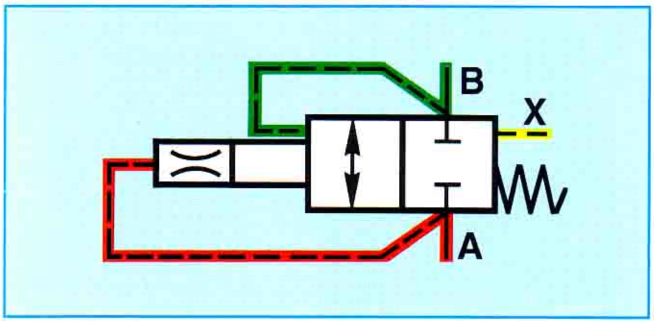
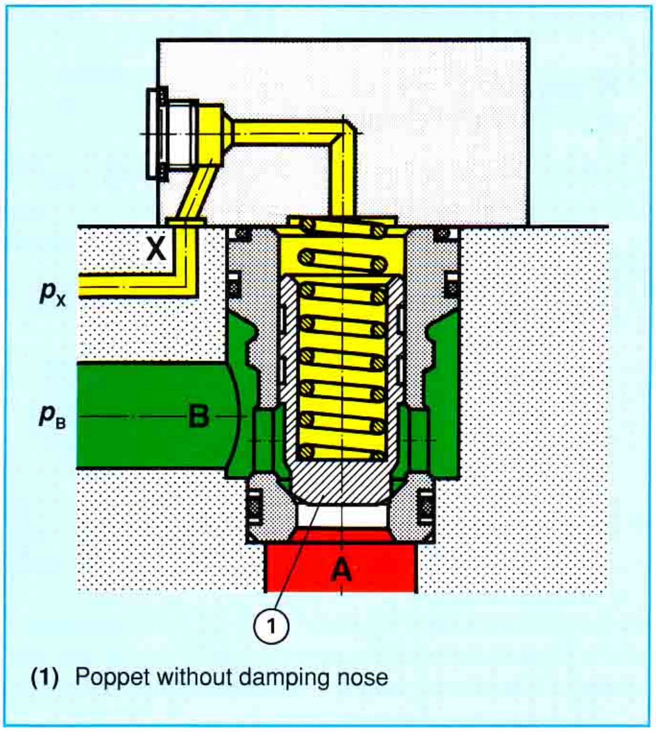


Fig. 74: *Symbol to DIN ISO 1219*



(1) Poppet without damping nose

Fig. 75: *Logic element without damping nose.*

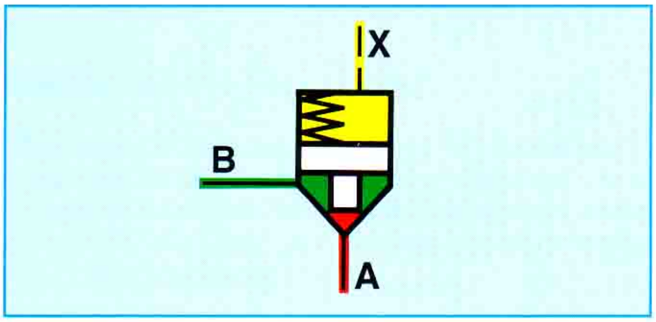


Fig. 76:
Schematic symbol of a logic element without a damping nose.

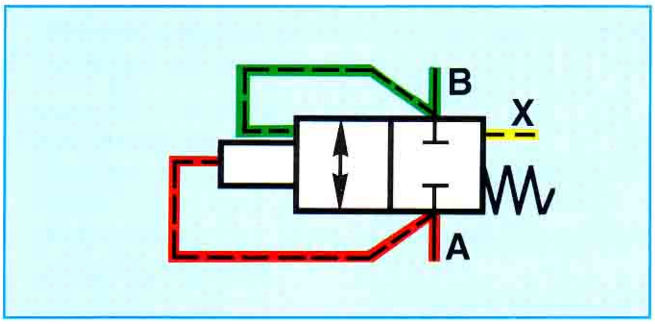


Fig. 77: *Symbol to DIN ISO 1219.*

Models with a damping nose have slower opening and closing times, but it should be noted, that the directional flow must also be considered. This statement is thus mainly valid for flows A to B. The longer it take for the poppet to clear the opening, the smoother is the opening process.

If on the other hand, we consider the closing operation with a flow from B to A, the last part of the closing stroke is subject to a more rapid closing operation due to the rising differential pressure. This causes the valve to slam onto it's seat (with a metallic bang).
In addition, the damping nose gives a delayed action and a higher pressure drop *(diagrams 1 and 2)* at the valve poppet. In order that the pressure drop should not be too high, elements fitted with a damping nose have a longer stroke than those without. This also results in a larger control volume being required.

Example: Logic Element size 32

Valve type	pilot volume
with damping nose	9.8 cm^3
without damping nose	7.4 cm^3

Table 2

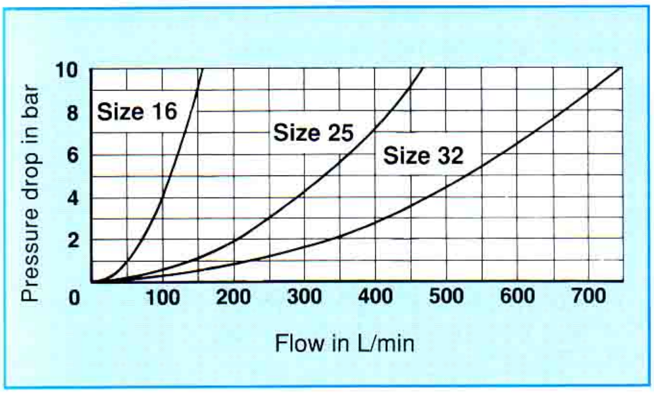


Diagram 1: *Pressure drop - flow curve for logic elements with damping nose.*

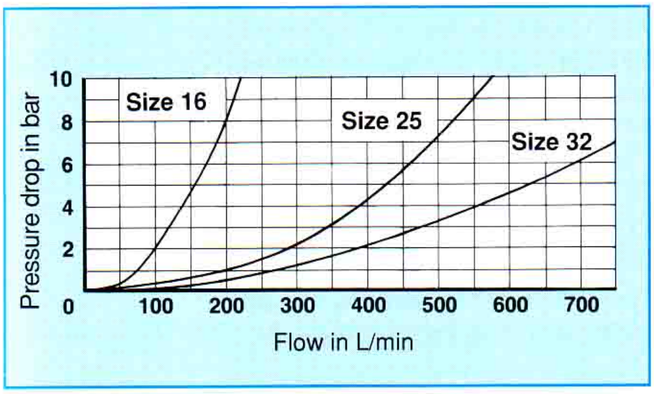


Diagram 2: *Pressure drop - flow curve for logic elements without damping nose.*

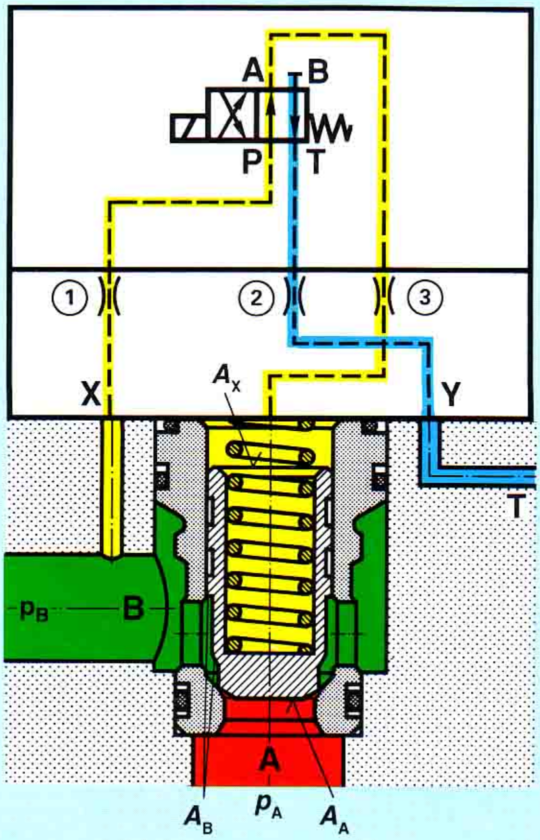
Typical examples of logic elements applied with a damping nose:

- Decompressing a cylinder to tank
- Changing over from fast traverse to creep speed
- smooth operation of a cylinder
- smooth deceleration of a moving mass
- control of the speed of a cylinder
  (logic element plus cover with stroke limiter)

4 Control of operating time.

The operating time of logic elements can be influenced in both the opening and the closing directions. This is achieved by means of orifices which limit the flow rate of fluid passing to and from the spring chamber of the valve.

Example: *(Fig. 78)*



Possible orifice arrangements.

- **(1)** Orifice in the P line.
  (Referred to the directional valve port)
- **(2)** Orifice in the T line.
- **(3)** Orifice in the A line.
  (Or in the B line if port A of the directional valve is blocked, and port B is connected to the spring chamber).

Fig. 78

Basic effect of the orifice arrangement.

Orifice (1) The oil flowing into the spring chamber is throttled and the closing operation of the valve is influenced.

Orifice (2) The oil flowing from the spring chamber is throttled and so the opening speed of the valve is influenced.(The permissible pressure on the T port of the directional valve must be observed.)

Orifice (3) The oil flowing in both directions to and from the spring chamber is flows via the orifice. The opening and closing operations of the valve are both influenced.

Dependent upon the size and position of the orifices, the operating times can be determined,

Selection of orifices.

The size of the orifices required depends upon the volume of the spring chamber, the required operating time (both opening and closing) and the pressure drop which will occur across each orifice.

Selection procedure.

- Determination of the oil volume to be passed.

$$Q = \frac{V}{t}$$

V = control volume dependent upon size of logic element.
e.g. size 40 without damping nose.
V = 16,6 cm^3

This volume corresponds to the full stroke of the valve poppet. The opening or closing operation is however not a constant function.
When opening, the maximum pressure drop is at first converted into a maximum flow velocity. As the valve opens progressively, both the pressure drop and the flow velocity show a corresponding fall. In practice, it can be taken that in normal cases (operational times normally in the order of 40 ms) that the maximum cylinder velocity will be achieved at approximately at 30% of the stroke of the valve poppet.

Thus $V = 0.3 \cdot 16.6\ cm^3 = 4.98\ cm^3$
t = required operational time, e.g. $t = 40\ ms = 0.04\ s$

$$Q = \frac{4.98\ cm^3}{0.04\ s} = \frac{0.00498 \cdot 60}{0.04} = 7.47\ L/min$$

- Pressure drop across the orifice.

As has already been explained, this does not remain constant during the full stroke of the logic element.
For calculation purposes, we therefore take 2/3 of the maximum operating pressure as a practical value.

e.g. p_{max} = 280 bar

$$\textbf{Pressure drop used} = \frac{2}{3} \cdot 280 = 187\ \textbf{bar}$$

- If the logic element is opened to provide a connection to the cylinder (for example) a mean pressure drop between the maximum system and the working pressure is employed.

- Selection of orifice from the operating curves *(diagram 3)*

For $Q \approx 7.5$ L/min and $\Delta p \approx 185$ bar gives an orifice size between 1.0 and 1.2 mm.
This gives rise to an orifice taken as the "standard orifice" for size 40 elements.

If we choose a larger orifice, the operating time will be shorter. However, in practice a compromise must be achieved between rapid and smooth operation. Taking an operating time of 40 ms achieves a reasonably smooth operation and in most cases does not mean too much loss of time.

Notes on operating times.

- Opening times of logic elements

The shortest possible operating times correspond to the operating times of the pilot valve i.e. from the signal input to the start of opening of approximately 25 to 30 ms.
The operating time of the valve poppet alone (from fully closed to fully opened) is dependent upon the element size. For example, size 16 has a time of 10 ms.

- Closing times of logic elements.

The closing is heavily dependent of the operating conditions i.e. upon the pressure drops occurring.
With a size 16 valve unloaded to tank, the closing time is approximately 20 to 25 ms.

Size	16	25	32	40	50	63	80	100
Standard orifice diameter in mm	0.7	0.8	1.0	1.2	1.5	1.8	2.0	2.5

Table 3

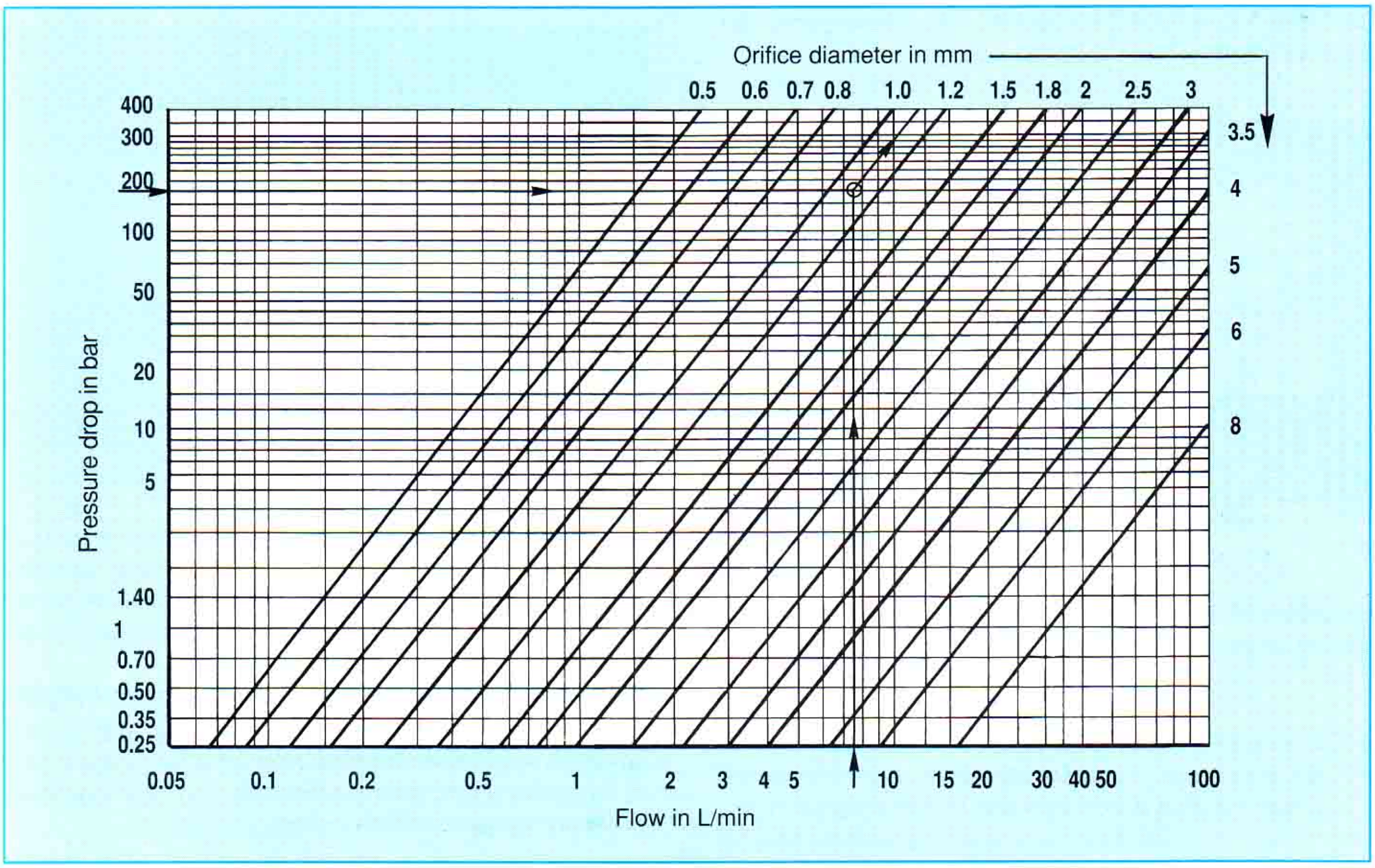


Diagram 3: *Curves for the selection of orifices*

5 Active and passive control

Dependent upon the arrangement of control lines and orifices, two principles of operation are to be found. These are **active control** and **passive control.**

Active control

In an active control the oil from the control chamber is evacuated completely. There is no continuous pilot oil supply. The valve poppet always opens completely.

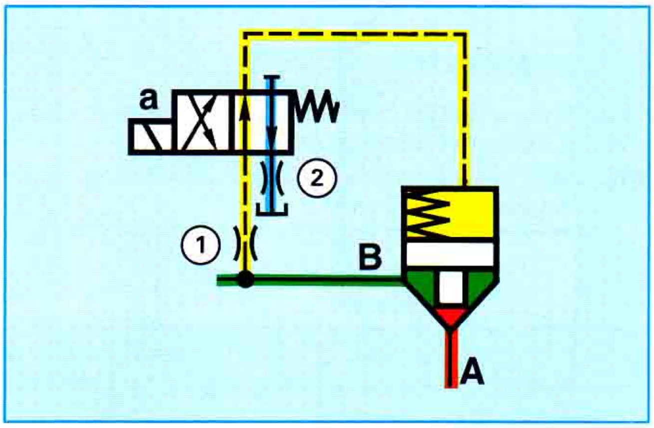


Fig. 79: Active control

If an orifice (1) is installed, the closing time can be varied. By fitting orifice (2) in the tank port, the opening time can be controlled.

Passive control.

Under passive control, a continuous flow of pilot oil to tank is present during the opening of the element, and also whilst the element remains open. *(Figs. 80 and 81).*

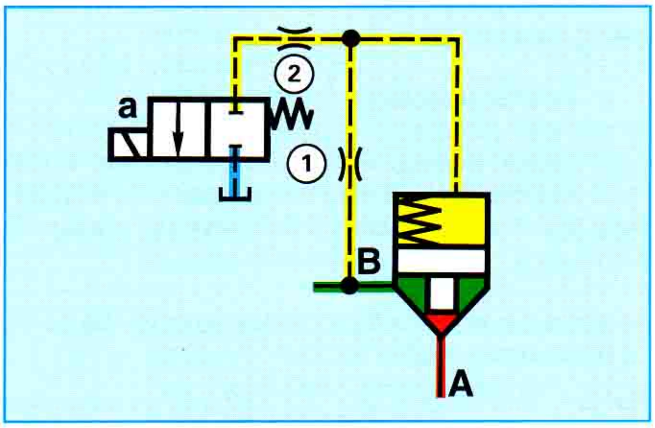


Fig. 80

The closing time is only dependent upon orifice (1). The opening time can be controlled by orifice (2). The degree of control can only be roughly determined, as in addition to the oil flowing from the main poppet, the fluid flowing via orifice (1) must also pass via orifice (2).

It should be noted here, that because of the continuous flow of pilot oil, the main valve poppet is never entirely unloaded (e.g. if it is required both to produce a light pre-load and a short operational time).

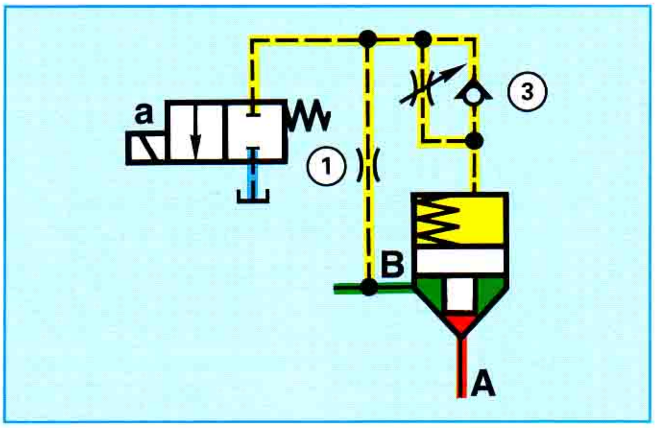


Fig. 81

Both of the points applicable to *Fig. 80* –the pre-load on the main poppet and poor determination of opening time– are overcome by means of a throttle/non return valve (3) in the control line to the logic element in *Fig. 81*.

However, passive control permits a number of elements to be controlled by one pilot valve. In addition, this type of control is required where pressure reduction, sequencing or flow control functions are required *(see the chapter on pressure valves and flow control functions).*

Leakage characteristics.

In order to be able to determine whether a logic element circuit will be leak free or not, the direction of flow, the position of the pilot oil take-off, and the type of pilot control valve must be considered.

a **Pilot oil take-off and pressure applied to port A**
(Fig. 82)

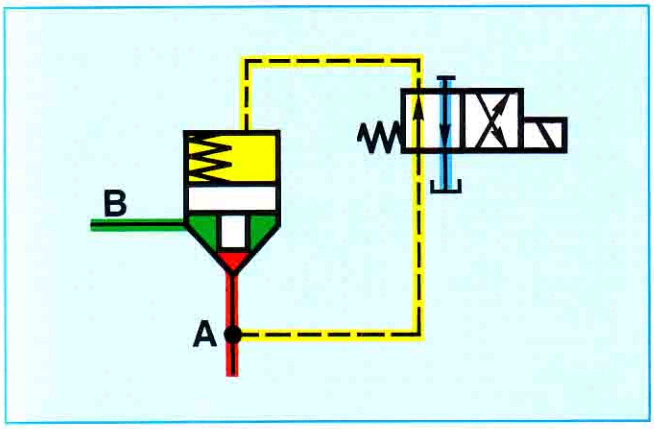


Fig. 82

Closure from A to B is not leakage free, as a running clearance must be present between the spring chamber and port B. This gives rise to leakage. As the pilot valve is a spool valve, this also has internal leakage.

b **Pilot oil take-off and pressure applied to port B**
(Fig. 83)

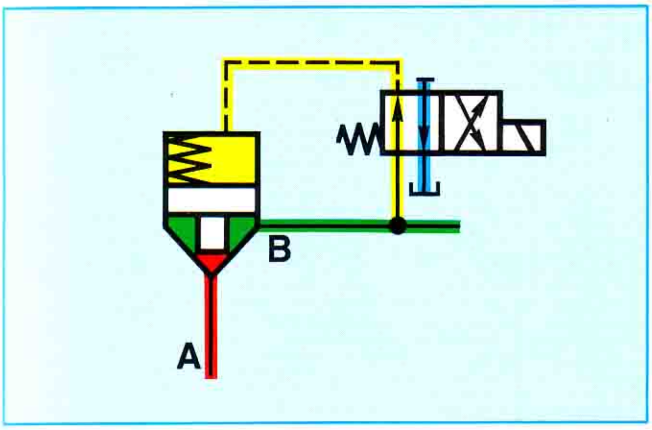


Fig. 83

Closure from B to A is leak free, as the pressure in the spring chamber is the same as that in port B. The sealing point between A and B is formed by the valve seat.

However, the overall control still has a leakage path through the spool of the pilot valve.

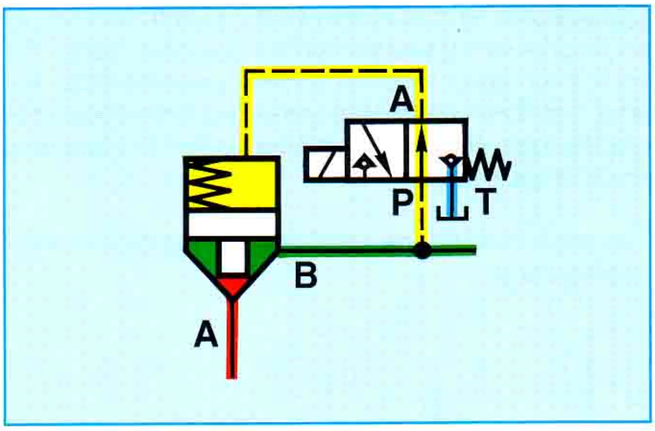


Fig. 84

If the overall control must be leak free, a poppet type pilot valve must be installed instead of the spool valve. *(Fig. 84).*

Power limits

In the case of a logic element, there is no actual power limit such as that found in a directional spool valve. As flow is increased, the pressure drop between ports A and B increases. The higher this pressure ratio is, the more firmly the valve operates (opening and closing).

The project engineer must therefore set an applicational limit dependent upon the acceptable pressure drop across the element.

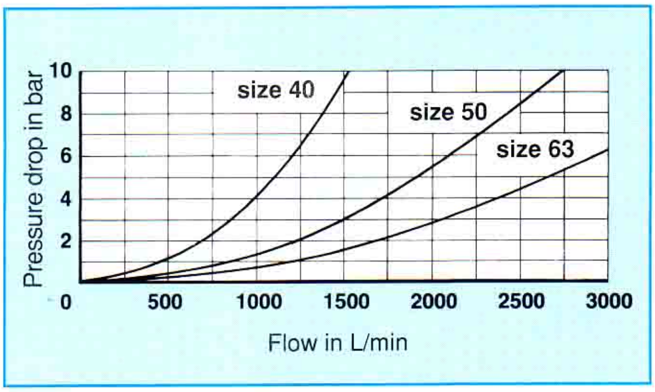


Diagram 4: *Pressure drop curves for logic element without damping nose.*

Thus, for example, the flow through a size 40 valve can exceed 1500 L/min *(see diagram 4)* if the project engineer accepts the high pressure drop.

If the direction of flow from B to A is now considered at low flows (less than 1 metre per second) it is possible that the poppet may flutter. In flow direction A to B, this can occur at flows below 0.5 m/s. Low flow velocities mean very small flows referred to the valve size.

Should fluttering occur it may be possible to cure this by altering the spring strength for one of a lower rating. The valve then opens wider for a lower pressure drop. Another possibility where widely differing flows occur is to employ logic elements of different sizes in place of a single large element.

This must naturally be considered at the project engineering stage.