Logic Elements with a Directional Function

1 Basic types of control.

Dependent upon the required valve function, the following points must be considered:

- what is the most suitable control and
- what is the correct logic element to use.

For example, influence over the switching speed and not least the selection of the logic element size must be considered.

Let us first of all remind ourselves of the effective areas of the basic element.

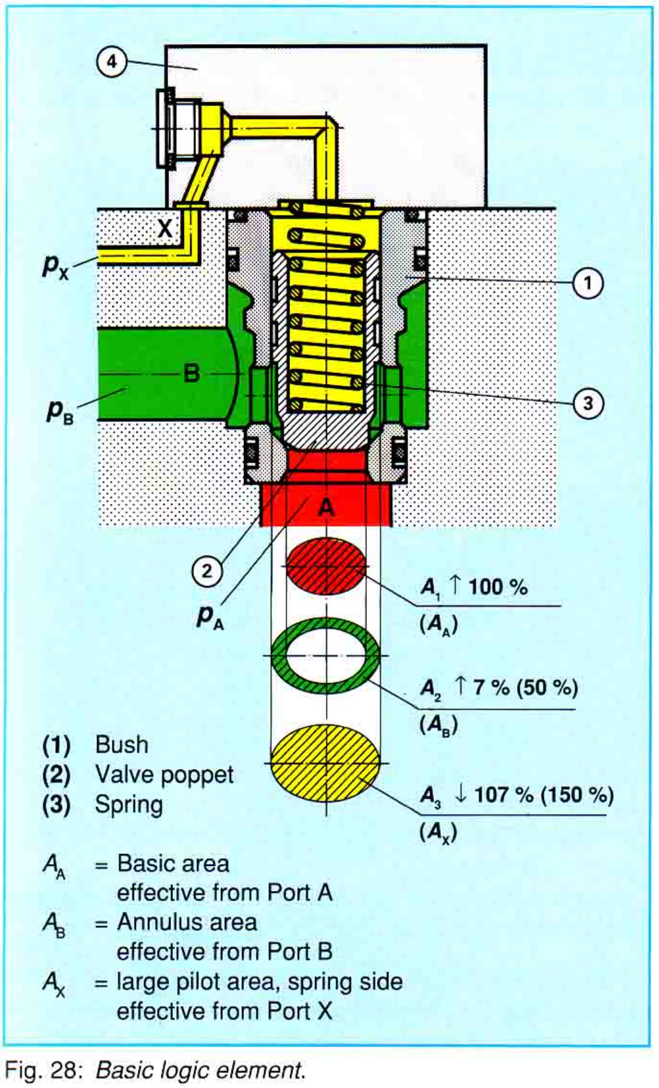


Fig. 28: *Basic logic element.*

In addition to the logic element itself, the manifold block (5) as a housing, and also the control cover (4) are important.

Types of control.

Basically, the pilot oil can be taken from:

- port A
- port B
- port A and B
- an external source.

The switching functions and characteristics arising from these controls will be made clear in the following sectional drawings and valve symbols.

Notes on the illustrations.

In order to make the function and the pressure dependent operation clearer, the logic element has been illustrated by means of a sectional drawing.

So that the function may also be made clear in the circuit diagrams, and that the illustration may be converted into symbols, three variations of symbol are shown:

Schematic symbol illustration.

This type of symbol has become firm practice, as the principle of the element construction is also shown, and it is then simple to understand what will happen in the circuit.

The symbol is laid out in DIN 24342, appendix 1. (Special symbols for the illustration of the function of logic elements are not standardised at the moment).

Symbols to the illustration rules of DIN 1SO 1219.

Pilot controls shown by symbols under this heading are put together under the illustration rules of DIN ISO 1219, and published in DIN 24342, appendix 1 (installation dimensions for logic elements).

Replacement Symbol.

This illustration of the function is made extremely simple. As these symbols may also be found on circuit diagrams, they appear here for completeness.

Practice orientated symbols.

In connection with the basic types of pilot control, a sample over-view of practically orientated symbols of, these controls are shown as in manufacturers' catalogues.

2 Pilot control fluid taken from port A

2.1 Direct control (without pilot valve)

Function: A to B blocked
B to A free flow

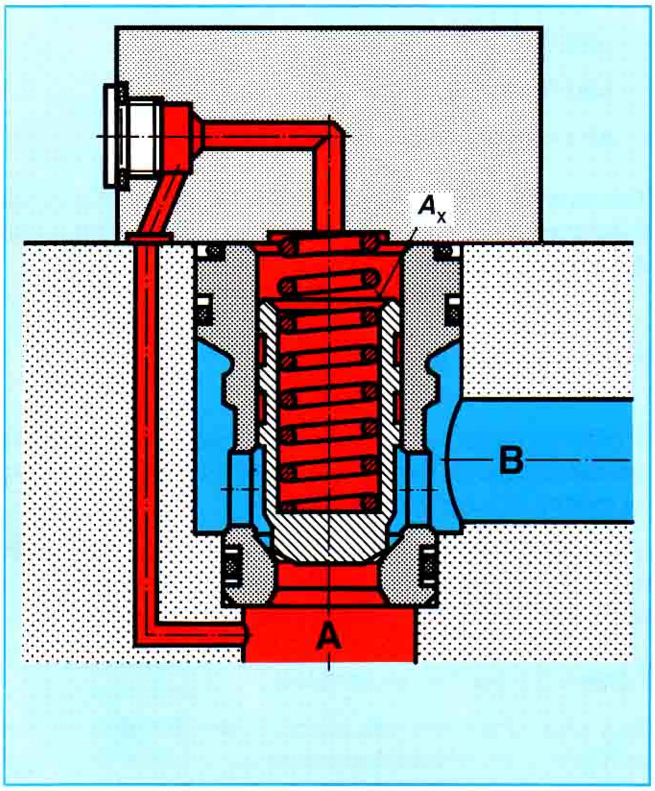


Fig. 29: *Logic element with control from side A.*

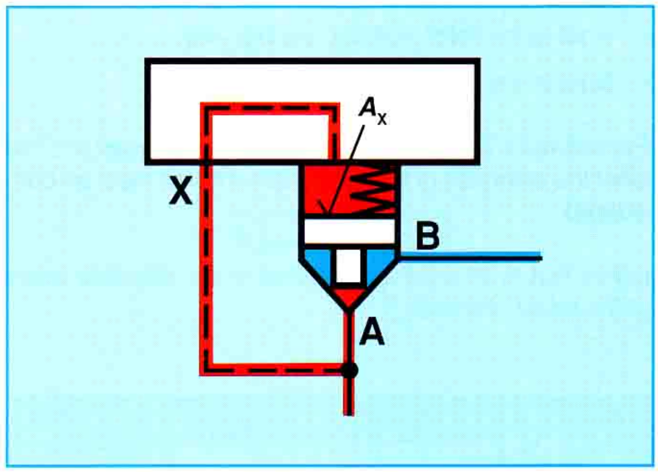


Fig. 30: *Symbol with schematic illustration of construction.*

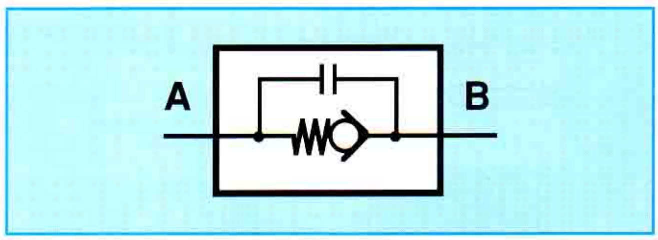


Fig. 31: *Symbol approximating DIN ISO 1219*

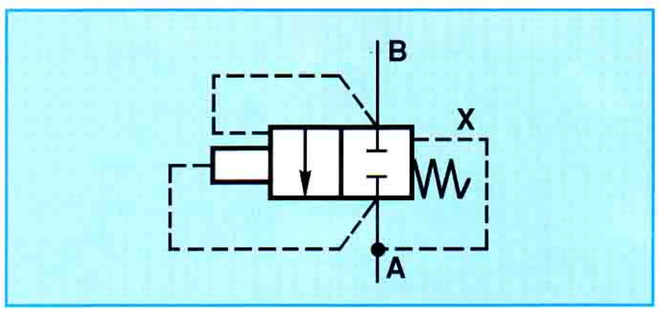


Fig. 32:
Symbol according to the illustration rules of DIN ISO 1219.

In this first example, the pilot control line from port A is led to control area A_X *(Fig. 29)*. Pressure present in A works simultaneously on area A_A and area A_X, and thus together with the spring holds the valve poppet closed as A_X is greater than A_A. Flow from A to B is blocked and the valve cannot open.

The question is now: "Is the valve leak free from A to B?"

At the isolation point between A and B, we have a poppet valve (2) *(Fig. 33)*. In spite of this, the valve is not leak free. The valve poppet (the isolating element) is carried by it's upper part running in the bush. Port B and the spring chamber *(Fig. 33)* are separated by means of this upper part which inevitably has a clearance in the bore (1) as in a directional spool valve. If different pressures occur between port B and the spring chamber, leakage occurs at this point. From *Fig. 31*, the extension to the non return valve symbol makes it clear, that some leakage occurs round this check valve.

On the other hand, the isolation of B from A in *Fig. 43*, with pilot control from side B is leak free, as in this case the running clearance separates chambers in which the pressure in the same. Port A and B, which are at different pressures, are separated by the valve poppet.

These considerations on the leak tight sealing of logic elements apply to all controls, and are dependent upon both the pilot control of the logic element and on the type of pilot valve used.

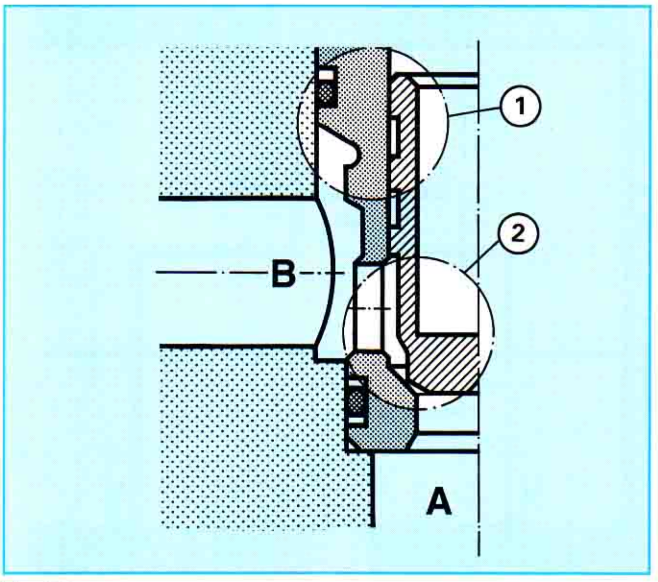


Fig. 33

Let us now consider the function when Port A is at zero pressure and pressure is present at Port B *(Figs. 34 and 35).*

Pressure in B is effective on the annulus A_B in an opening direction. The areas A_A (in an opening direction) and A_X (in a closing direction) are both at zero pressure. The spring is actually pressing the valve poppet on to it's seat. When the force = pressure p_B x area A_B overcomes this spring force, the valve poppet will lift against the spring allowing flow from B to A.

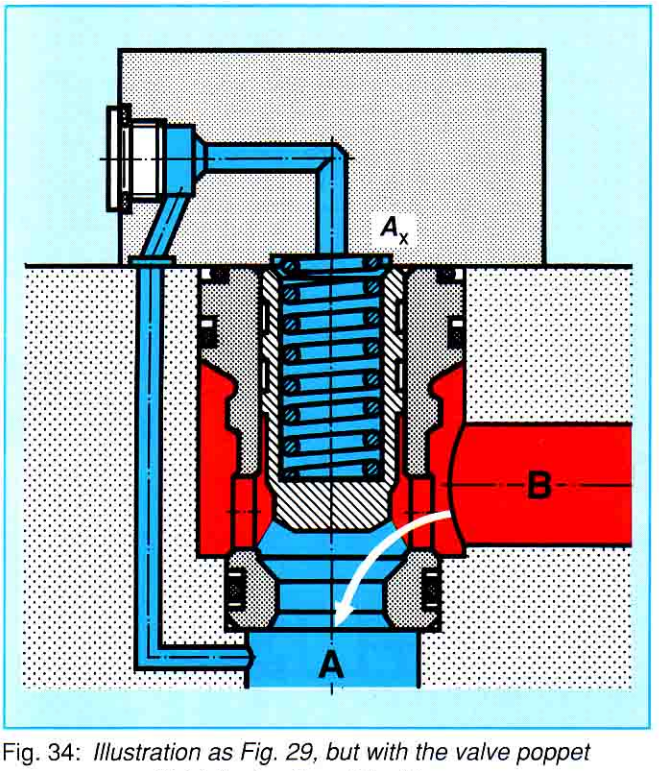


Fig. 34: *Illustration as Fig. 29, but with the valve poppet open (fluid flowing from B to A).*

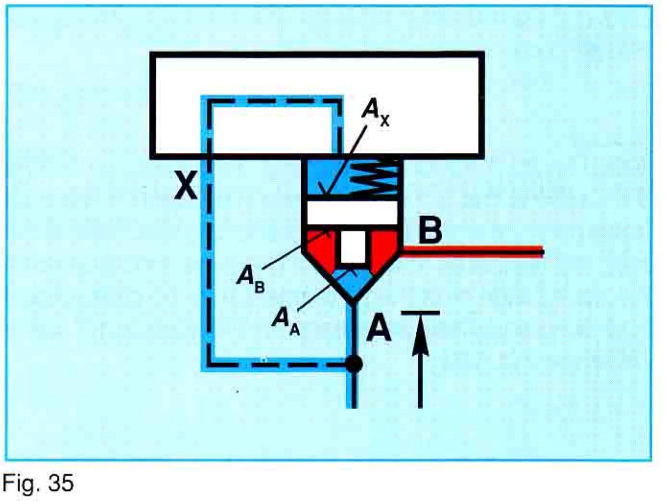


Fig. 35

2.2 Pilot control from port A, Pilot valve in the control line

Function:

Pilot valve in rest position:
at the logic element A to B blocked
B to A free flow

Pilot valve in operating position:
at logic element A ↔ B free flow

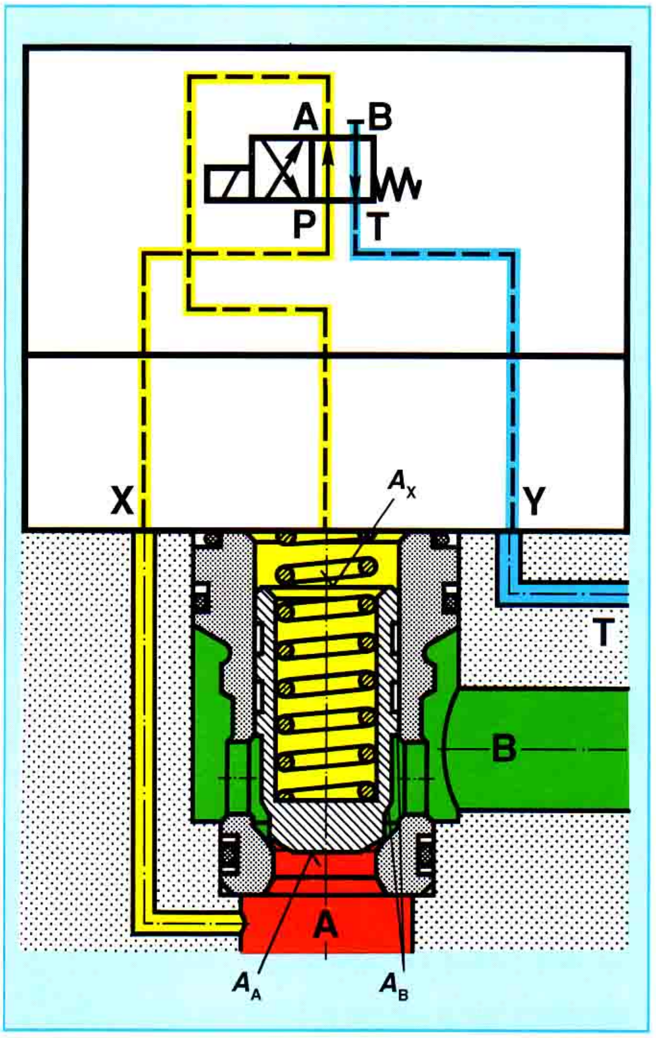


Fig. 36: *Logic element with control from A. Pilot valve in the control line.*

As in *Fig. 29*, the pilot control in *Fig. 36* is from port A. The difference is that a directional valve has been introduced in the pilot line which allows the switching functions of the logic element to be influenced. The large control area on the spring side of the logic element may be pressurised and de-pressurised by means of the directional valve *(also see Fig. 28)*.

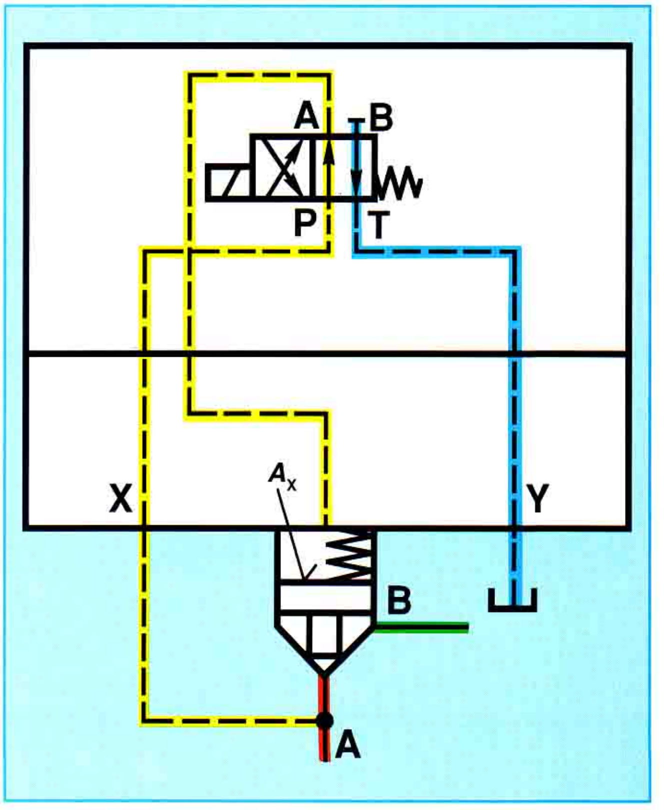


Fig. 37: *Symbol with schematic illustration of construction.*

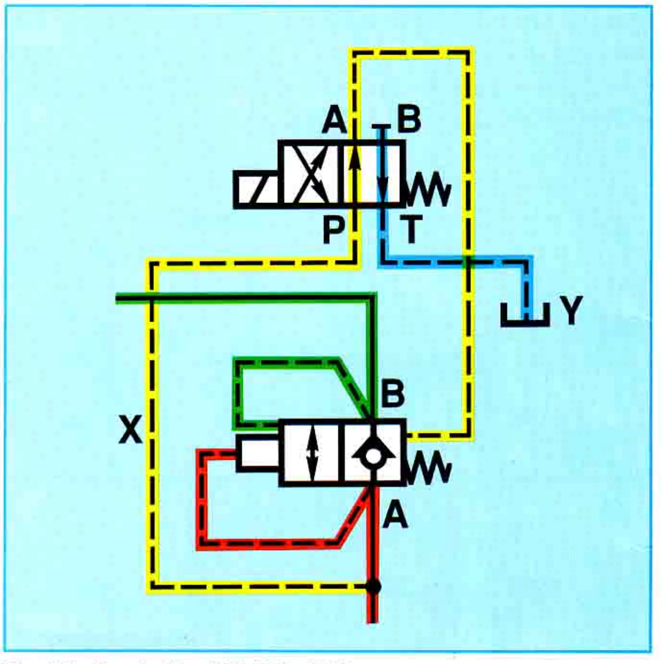


Fig. 38: *Symbol to DIN ISO 1219.*

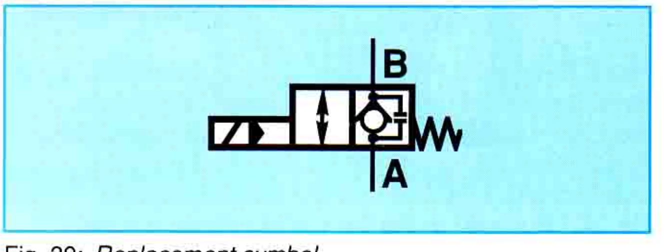


Fig. 39: *Replacement symbol.*

Pilot valve in the rest position *(Fig. 36)*

With the pilot valve in the rest position, the spring holds the logic element onto the seat. The pressure in port A (*red*) takes effect via the yellow pilot line X and connection P to A in the pilot valve to the control area A_X. The main poppet is thus held on the seat with any pressure drop from A (*red*) to B *(green)*. Any connection A to B remains blocked. Let us now make this clear by adding a few values . A possible circuit example is shown in *Fig. 40* with element (2.0).

The element used is size 32 with a 2 bar spring and annular area 50 %.
= 1.85 bar cracking pressure A to B ($p_X = p_A$)
i.e. cracking pressure area refers to A_A

A_A ($=A_1$) = 5.30 cm^2
A_B ($=A_2$) = 2.74 cm^2
A_X ($=A_3$) = 8.04 cm^2.

(The values are taken from Data Sheet RE 81010 from Mannesman Rexroth).

assumed: p_A= 280 bar (system pressure).
p_B= 150 bar (resulting from the load on the cylinder)

Forces in the opening direction

$$F\uparrow = p_A \times A_A + p_B \times A_B$$
$$= 280 \text{ bar} \times 5.3 \text{ cm}^2 + 150 \text{ bar} \times 2.74 \text{ cm}^2$$
$$= 1895 \text{ daN}$$

Forces in a closing direction

$$F\downarrow = p_A \times A_X + \text{spring force}$$
$$= 280 \text{ bar} \times 8.04 \text{ cm}^2 + 1.85 \text{ bar} \times 5.3 \text{ cm}^2$$
$$= 2261 \text{ daN}$$

The logic element thus remains closed.

Note:
As explained in *section 2.1*, sealing with the valve closed in this configuration is not leak free.

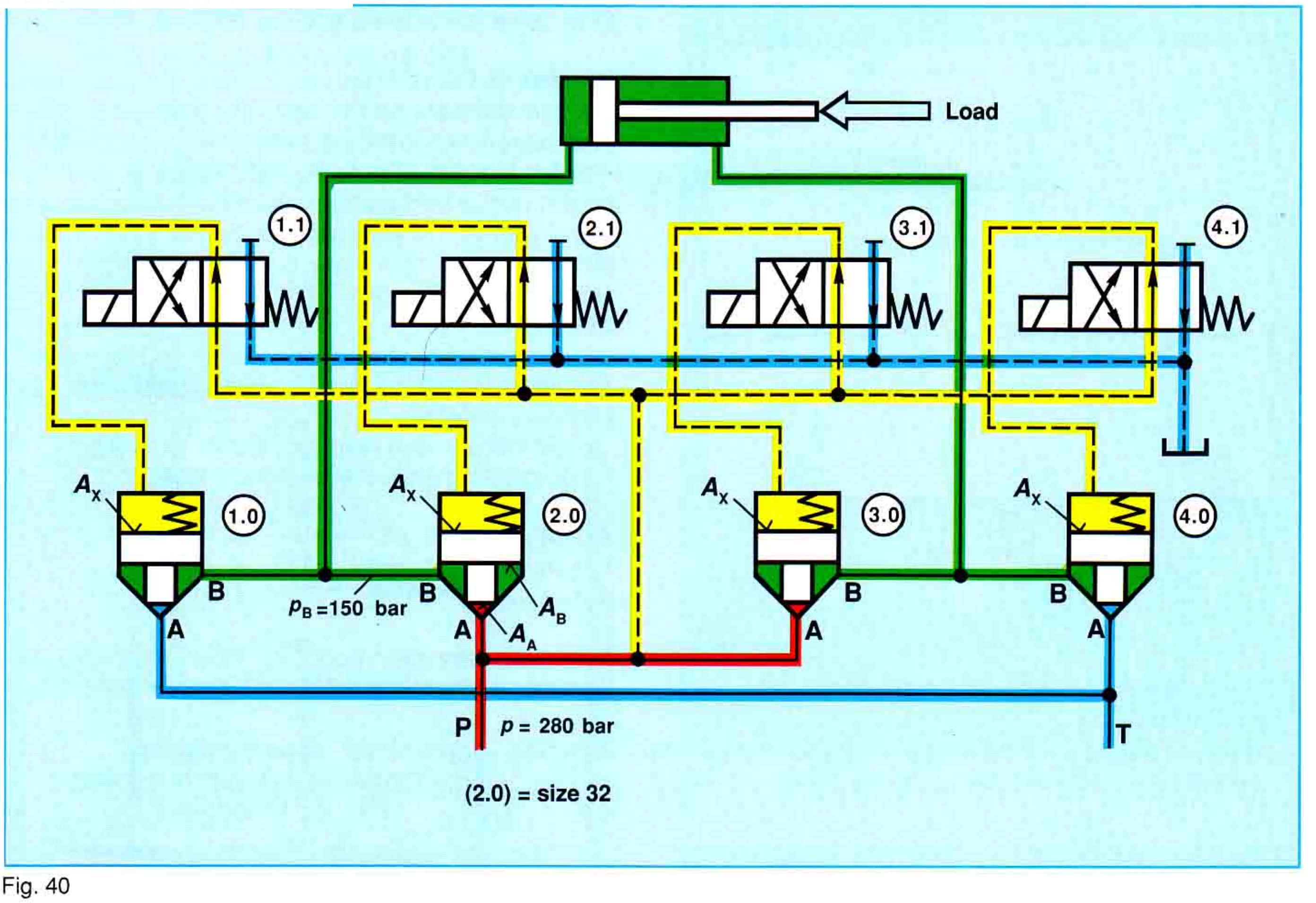


Fig. 40

In order to illustrate the importance of considering which pressures operate when and where, we will alter the conditions within the system. The pump is now switched off and and p_A = 0 bar. The load remains present as before.

$F_{Opening}$ = 0 x 5.3 cm² + 150 bar x 2.74 cm²
= 411 daN

$F_{Closing}$ = 0 x 8.04 cm² + 1.85 bar x 5.3 cm²
= 9.8 daN

Logic elements (2.0) and (1.0) are now opened against their springs via area A_B.

The load will then fall.

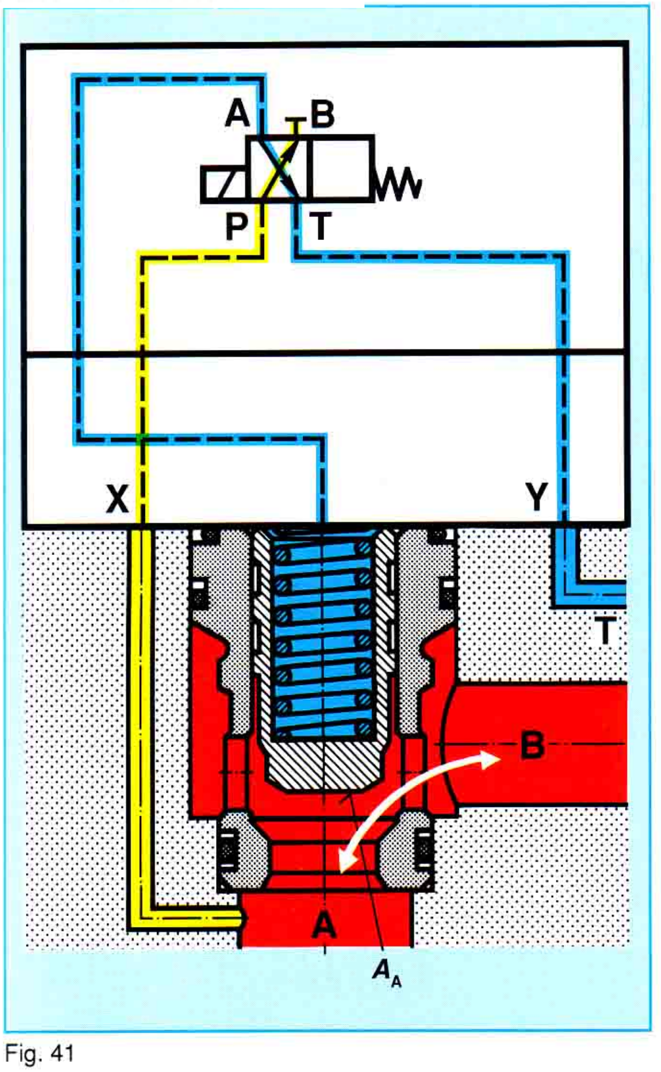


Fig. 41

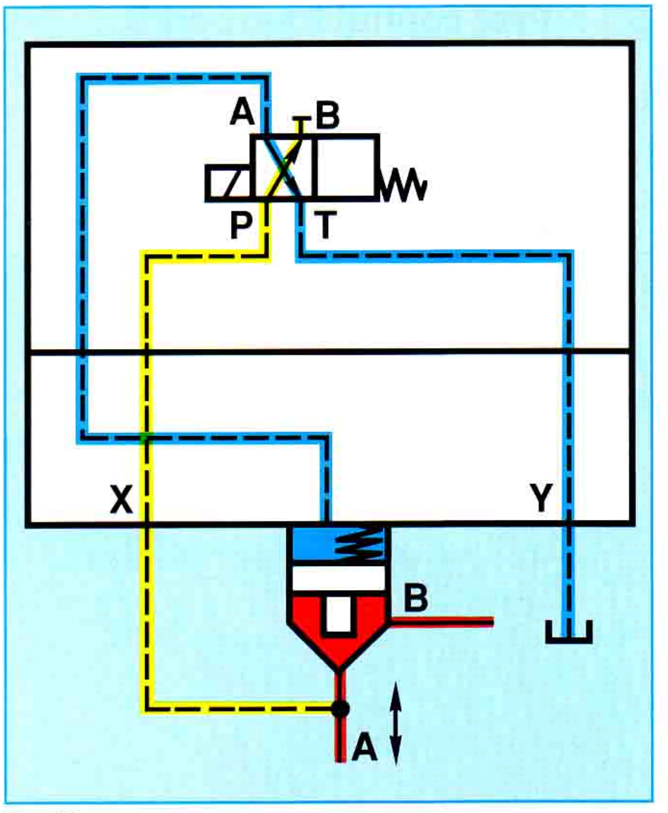


Fig. 42

Pilot valve in operated position.

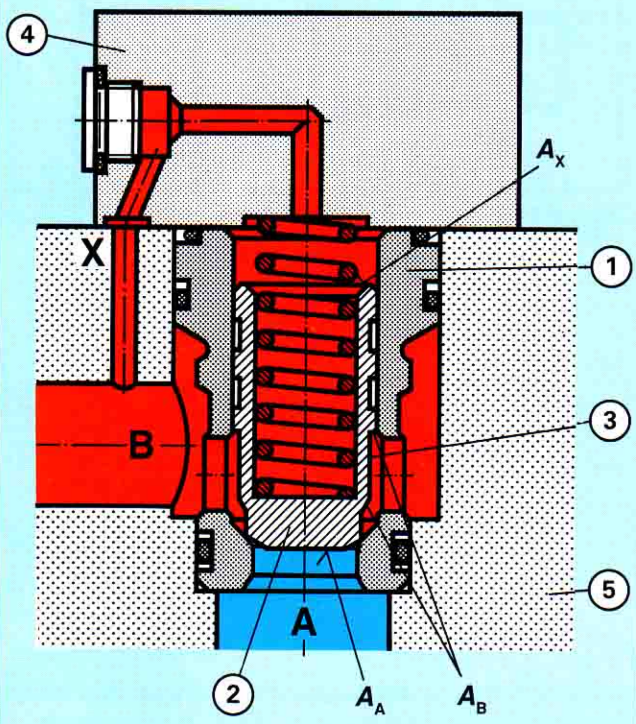
In *Figs. 41 and 42*, the valve is shown with the spring chamber of the logic element unloaded by the pilot valve (Port A to T).
The pilot pressure line from Port A of the logic element is blocked at the pilot valve.
Thus the logic element can be opened both from Port B, and from Port A via the area A_A, giving free flow from A to B.

With the pilot valve in the operated position the free flow through the logic element is possible in both directions.

At zero pressure, the valve naturally remains closed due to the spring.

3 Pilot control from port B

3.1 Pilot control from port B (without pilot valve).



(1) Bush
(2) Valve poppet (isolating element)
(3) Spring
(4) Control cover
(5) Manifold block

Fig. 43: *Logic element with control from Port B.*

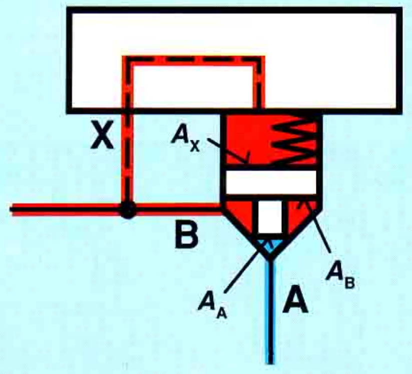


Fig. 44: *Symbol with schematic illustration of construction.*

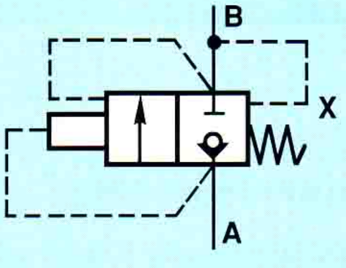


Fig. 45: *Symbol to DIN ISO 1219.*

Fig. 46: *Replacement symbol.*

We will now assume that pressure is being applied on Port B, and that Port A is at zero pressure. The pressure is effective on the annulus area A_B and via the pilot line onto the large control area A_X. The poppet thus remains closed and Port B is isolated from Port A *(Figs. 43, 44 and 45)*.

If the logic element is now applied as a non return valve, this is the normal control to be selected (low opening pressure).

Looking once more at *Fig. 31*, the isolation B to A is now leak free with the control coming from Port B as the two chambers separated by the running clearance between the poppet and the bush are at the same pressure.

If fluid now flows into the valve from Port A, valve poppet (2) will be pushed by the fluid flow against the spring, and the valve will operate as a simple non return valve allowing free flow from A to B. As the poppet lifts, fluid from the control chamber is displaced via pilot Port X into Port B *(Figs. 47 and 48)*.

The cracking pressure required is determined by the spring fitted and the area A_A.

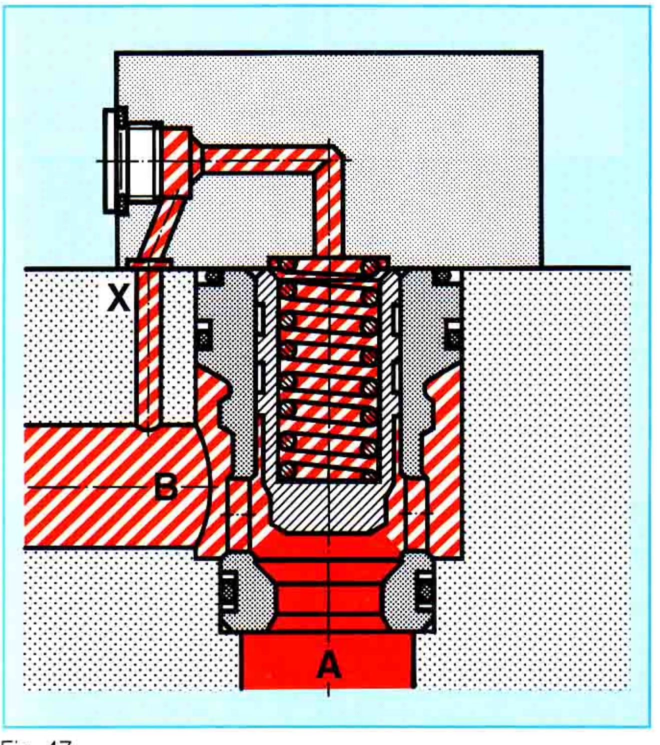


Fig. 47

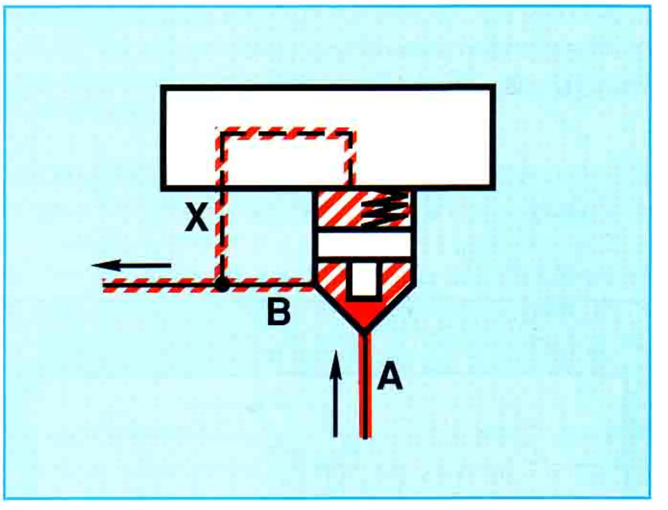


Fig. 48

As shown in this example, this is a pure non return valve function (A to B free flow, B to A blocked).

3.2 Pilot control from port B, Pilot valve in the control line.

We will also study this type of pilot control with a pilot valve in the control line in some detail.

Function:

Pilot valve in rest position:
at logic element A to B free flow
B to A blocked

Pilot valve in the operated position:
The logic element A ↔ B free flow

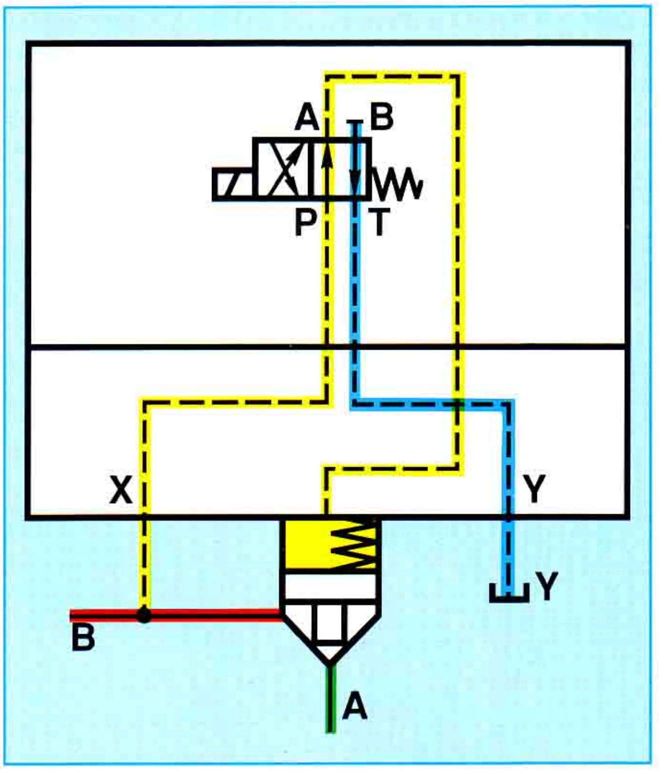
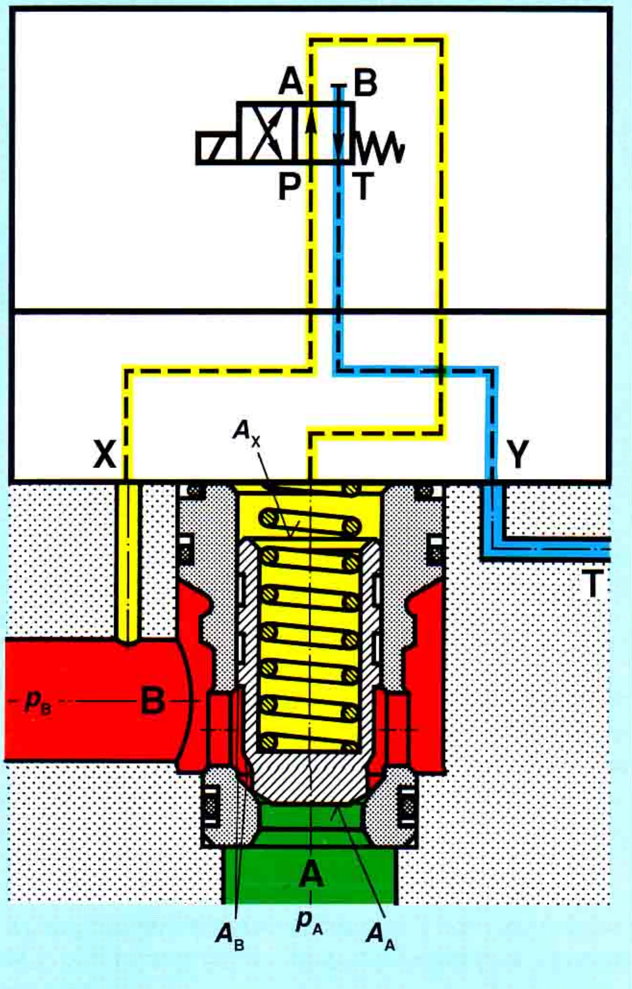


Fig. 50: *Symbol with schematic illustration of construction.*



A *(green)* service port to main valve
B *(red)* service port to main valve
X *(yellow)* pilot control line

Fig. 49

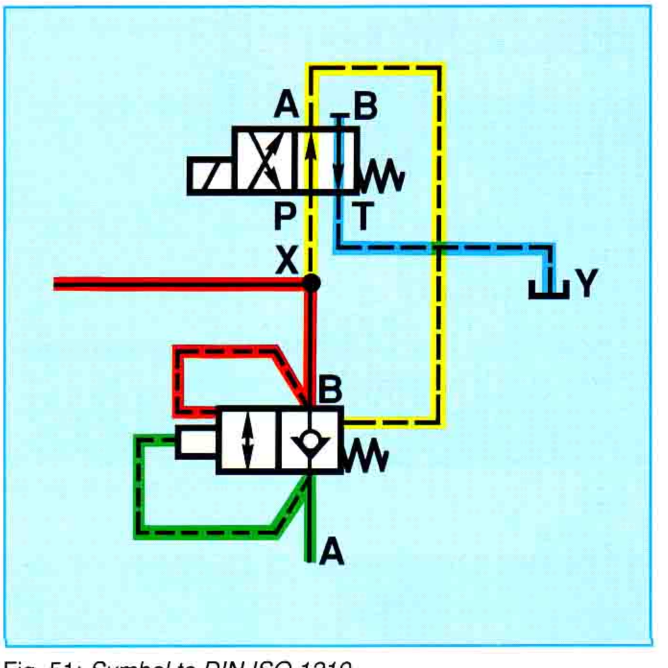


Fig. 51: *Symbol to DIN ISO 1219.*

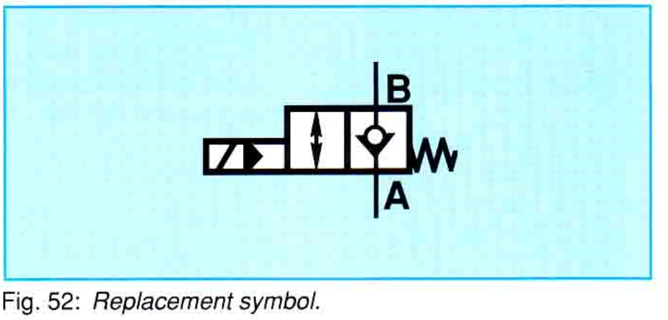


Fig. 52: *Replacement symbol.*

And now let us try to follow the operation of the valve through *Figs. 49, 50 and 51*.

Pilot Valve in the rest position.

The pilot line now leads from Port B of the logic element via the 4/2 way pilot valve (P to A) into the spring chamber of the logic element.

With the pilot valve de-energised, pressure in Port B of the logic element operates on annulus area A_B (in an opening direction) and via the pilot line to the large control area A_X (in a closing direction). The spring also holds the main logic element poppet onto it's seat. Connection from B *(red)* to A *(green)* remains blocked.

As shown in *Fig. 49,* the separation between B *(red)* and A *(green)* is indeed leak free. But this does not apply to the complete control. As may be seen from the symbol, we have a spool valve as pilot valve and thus leakage from B (red) via P to T (for example). For totally leak free control a poppet type directional valve must be used as the pilot valve.

If fluid now flows from Port A ($p_A > p_B$), the logic element will open when pressure at A_A overcomes the spring force. Fluid from the control area A_X will pass via pilot valve Ports A and P to Port B of the main valve, thus allowing the valve to open.

This is once more the non return valve function as already shown in *Fig. 43*.

Pilot valve operated (crossed arrow symbol) *Figs. 53 and 54*

When the pilot valve is operated, the large control area A_X is connected via Ports A and T of the pilot valve to tank. Area A_X is thus at zero pressure. The logic element can thus open for flow from A to B via area A_A, or B to A via area A_B against the spring.

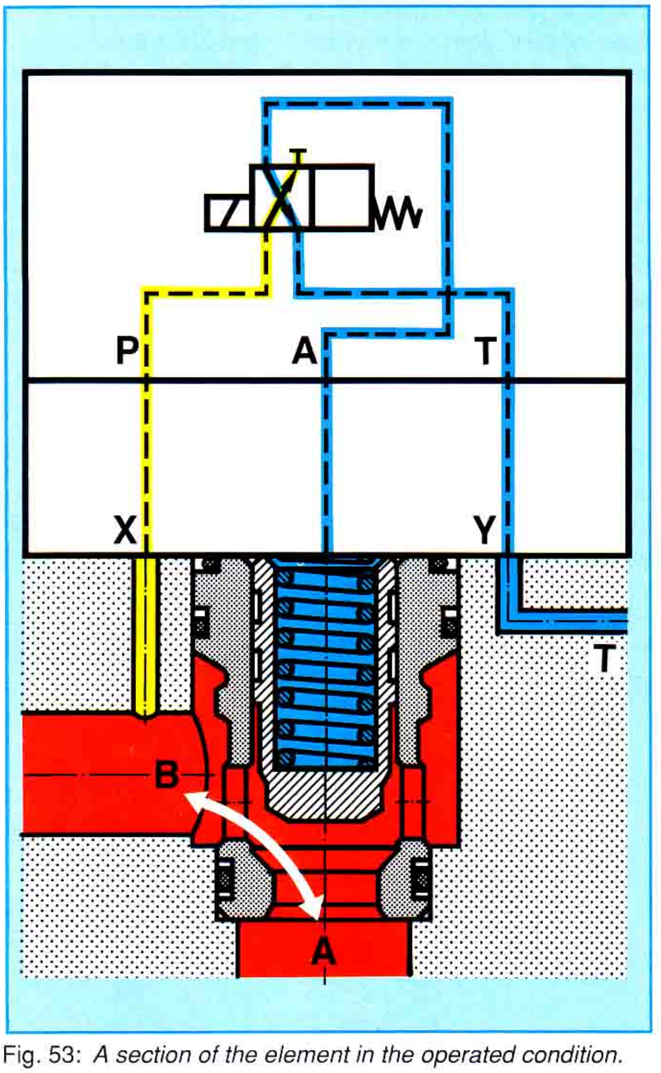


Fig. 53: *A section of the element in the operated condition.*

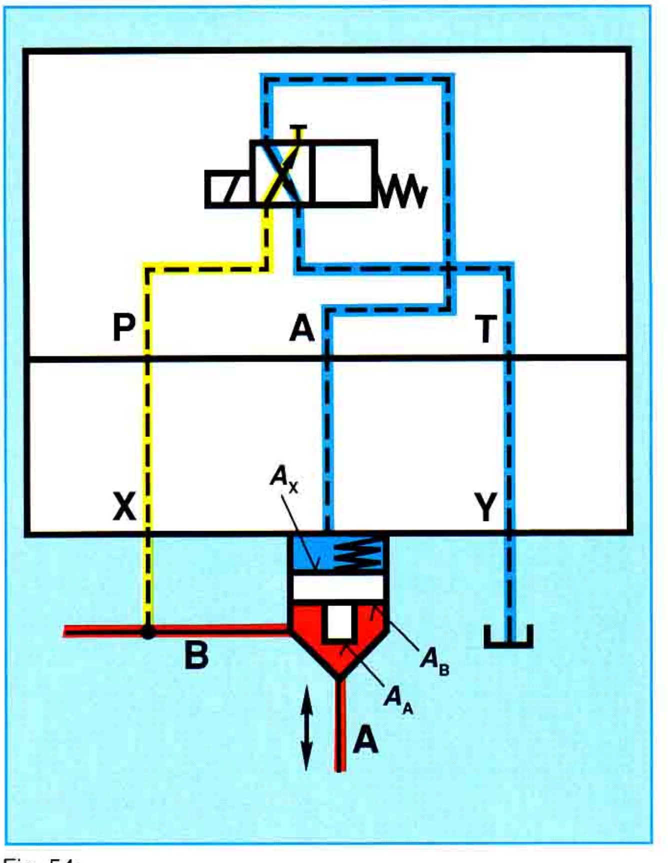


Fig. 54:
Schematic illustration of element in the operated condition.

It should also be noted here, that the main poppet only opens when fluid flows.

4 Pilot control from ports A and B

If it is required to hold the main poppet closed from both sides, (blocked A to B and B to A) this can be achieved by feeding oil simultaneously from B *(green)* and A *(red)* via a shuttle valve and from there via the yellow line to the control area A_X of the main valve. Thus, which ever is the higher pressure is effective on area A_Z, regardless of the port at which it originates.

Function:

Pilot valve in rest position:
at logic element A ↔ B blocked

Pilot valve in operated position:
at logic element A ↔ B free flow

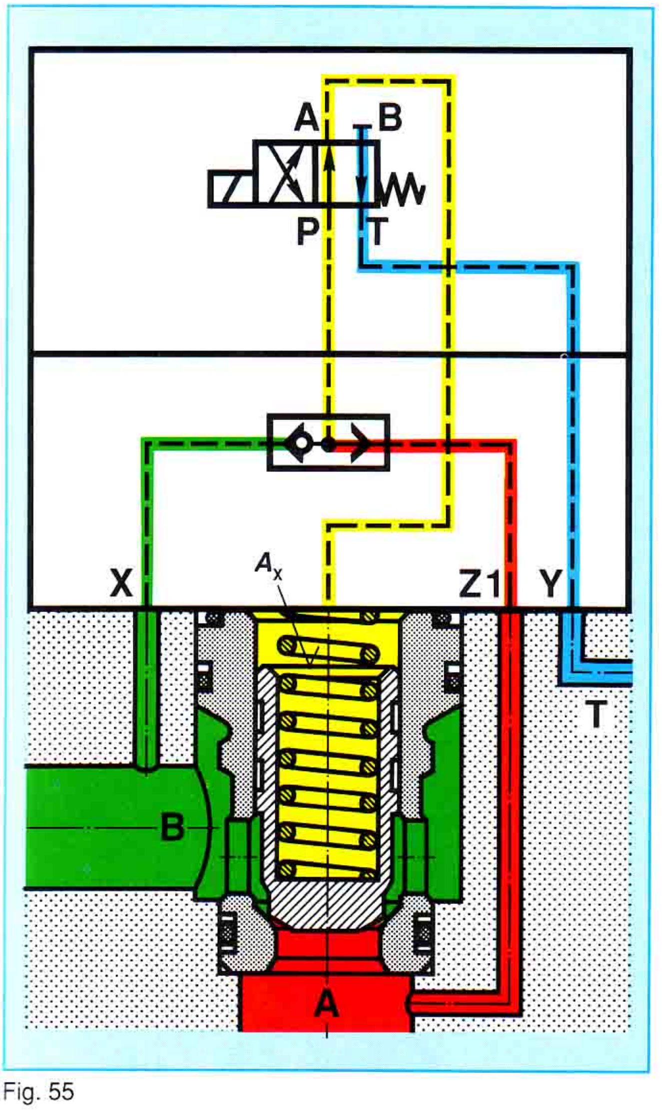


Fig. 55

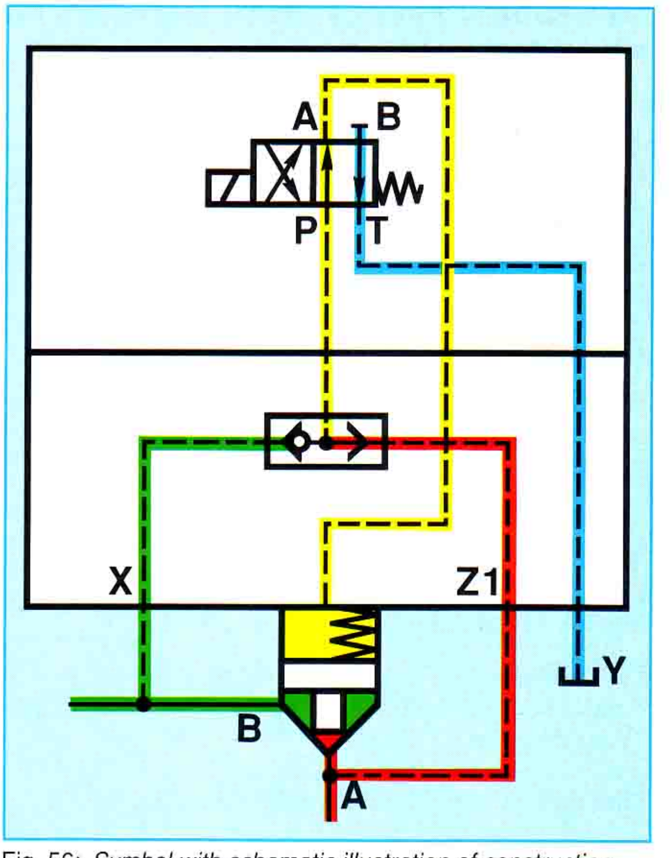


Fig. 56: *Symbol with schematic illustration of construction.*

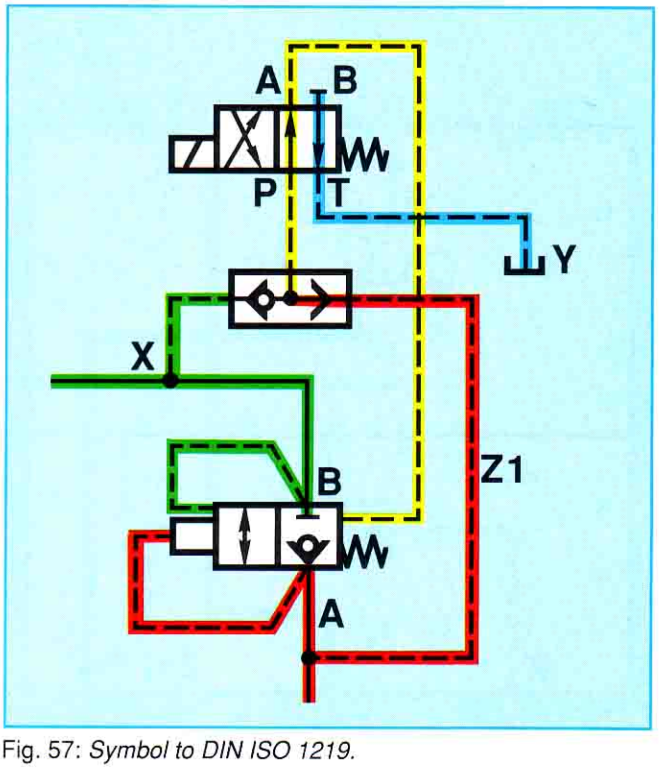


Fig. 57: *Symbol to DIN ISO 1219.*

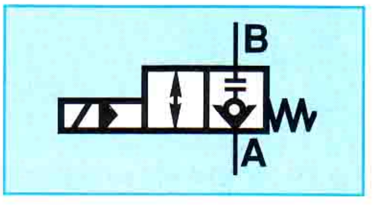


Fig. 58:
Replacement symbol.

The function of the circuit with the pilot valve in the rest position *(Fig.55)*

If the pressure comes from Port A, it passes via the shuttle valve and ports P and A of the pilot valve to control area A_x of the logic element, which is thus held closed. The main valve can thus not open from A to B.

If the pressure now rises on Port B *(green)* to a higher level than that on Port A *(red)*, or for example, if the pressure at Port A falls below that at Port B, then the ball in the shuttle switches to the other side.

In our example in *Figs. 55, 56 and 57*, this means, that the *red* pilot line (which now is at a lower pressure) is isolated.

The logic element can therefore not open to allow flow B to A.

In the rest position of the pilot valve the main valve is thus blocked in each direction.

If a directional poppet valve is used as a pilot valve, leak free cut-off from A to B is achieved, whilst leakage can occur from A to B.

Pilot valve in the operated position *(Fig. 59)*

Operating the pilot valve causes control area A_x of the main valve to be connected via Ports A and T of the pilot valve to tank. On the other hand, the pilot oil supply line from shuttle valve is blocked. Control area A_x is thus at zero pressure and the logic element can open allowing flow in either direction.

Instead of the shuttle valve, 2 non return valves may be installed (1 in the X line, and 1 in the Z1 line).

This is possible, as the fluid in this case, only flows in one direction through the pilot line.

The advantage of applying 2 non return valves is the possible simplification of the manifold block.

It is also worth mentioning however, with very low pressure differences between Ports A and B (Z1 and X), that the ball of the shuttle valve may not be operated correctly.

The reason for this lies in the difference in working areas on the ball, as in practice the sealing edge is not the theoretical line contact but is actually a small area contact.

The pressure difference between Ports A and B must therefore be at least 5 %.

In addition, the pressure change-over must occur suddenly, if the logic element is to remain closed **during** this pressure change-over.

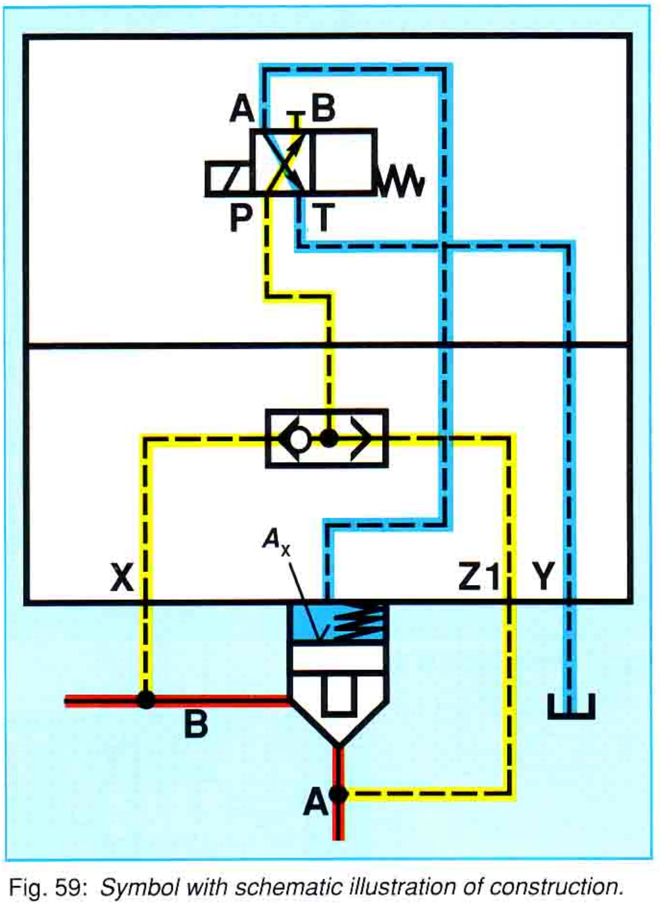


Fig. 59: *Symbol with schematic illustration of construction.*

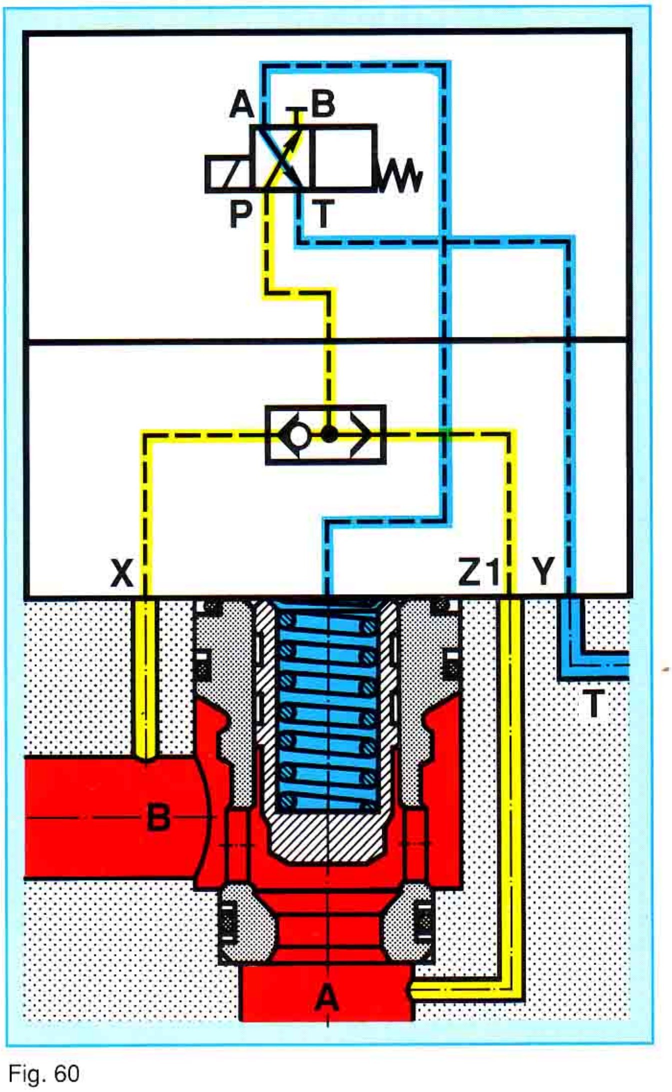
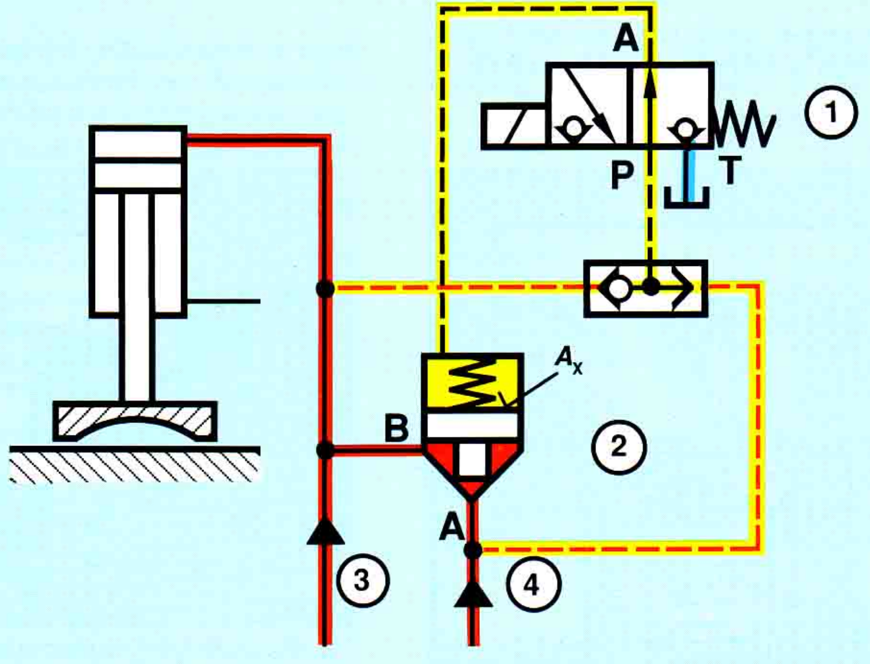


Fig. 60

Application example

Fig. 61 shows a part of a control circuit.



(3) HP High pressure Q_{Pump} e.g. 6 L/min
(4) LP Low pressure Q_{Pump} e.g. 500 L/min

Fig. 61

This example shows a cylinder which must travel forward relatively quickly and then hold a high force at high pressure when it has reached it end position.

For the fast approach speed, the pilot valve (in this case a directional poppet valve) is operated. Flow from the low pressure pump can then flow via Ports A and B of logic element (2) to the cylinder. As soon as the directional poppet valve (1) is returned to it's rest position, the higher of the two pressures on Ports A and B operate via the shuttle valve and the pilot valve onto control area A_x The logic element is then closed to flow in both directions. The small high pressure pump continues to pump oil into the cylinder. When the end position is reached, a high holding pressure is built up.

5 External pilot operation

With external pilot operation of logic elements, it becomes once more clear that the valve operates purely on a pressure basis.

Whether the valve poppet allows flow between Ports A and B or not, depends upon the pressures present in A, B and X.

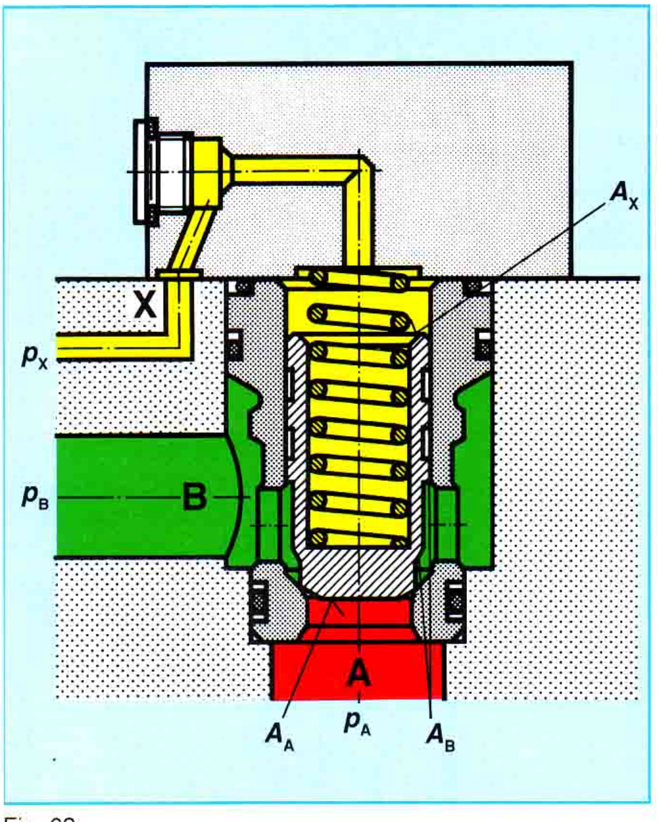


Fig. 62

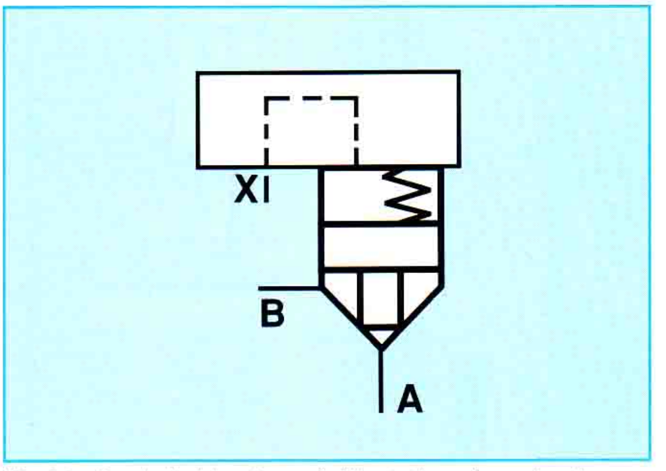


Fig. 63: *Symbol with schematic illustration of construction.*

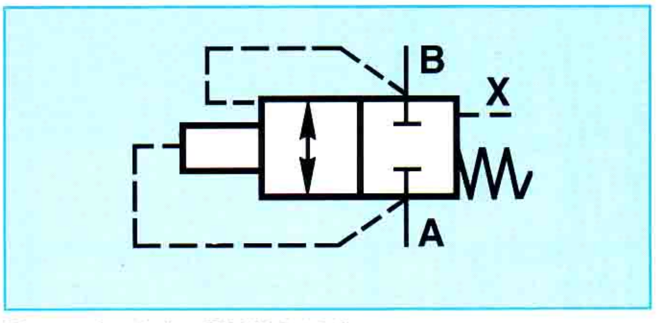


Fig. 64: *Symbol to DIN ISO 1219.*

In order to be able to state whether the logic element is opened or closed, the formula used in the numerical example *(Fig. 40)* for the forces in the opening and closing direction must once again be used:

<u>Forces in the opening direction</u>

$F\uparrow = p_A \cdot A_A + p_B \cdot A_B$

<u>Forces in a closing direction</u>

$F\downarrow = p_A \cdot A_X$ + spring force

6 Examples of practically based symbols taken from a manufacturers catalogue.

The symbol *(black)* shows the actual model of logic element with which the function is achieved. The function is then achieved by the addition of corresponding connections shown in red in the examples *(Figs.65, 66 and 67)*.

In *Fig. 65* the control from connection A corresponds to the example in *Fig. 29*. Further examples of this model are shown in *Figs. 43 and 62*.

In *Fig. 66*, a control example similar to *Fig. 36* is shown. By suitable connections, the function shown in *Fig. 49* can also be achieved.

The function shown in *Fig. 55* can be achieved with a logic element and control cover as shown in *Fig. 67*. If a directional poppet valve is fitted in place of the directional spool valve, then the example shown in *Fig.61* is achieved.

In addition to the control covers shown here, many other variations are obviously possible. For example, the control cover may also include a built in shuttle valve, but not when the directional valve must also be built on. In this case, the control valve must be mounted separately.

Further examples are described in the section " Control Variations".

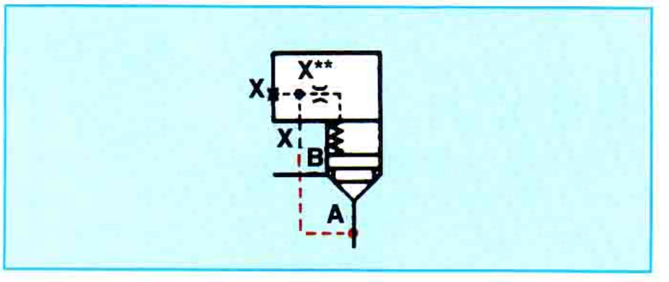


Fig. 65: *Control cover with remote control connections.*

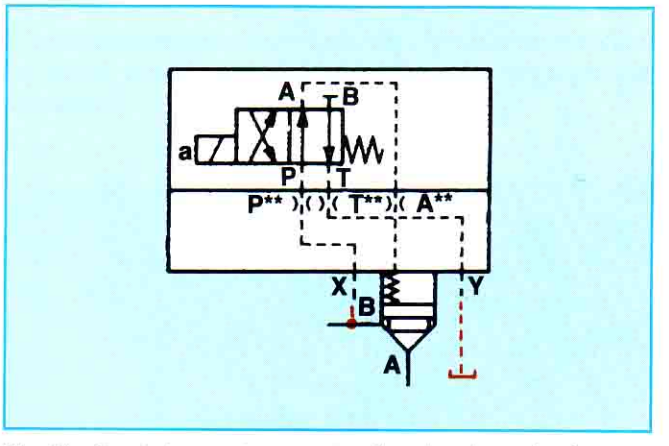


Fig. 66: *Control cover to accept a directional spool valve, or a directional poppet valve.*

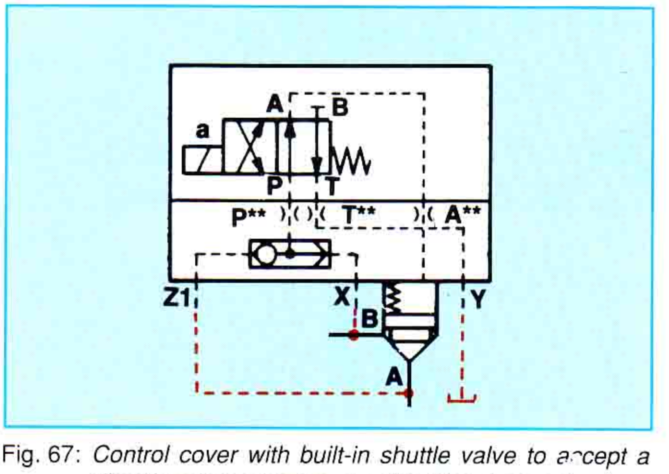


Fig. 67: *Control cover with built-in shuttle valve to accept a directional spool valve or a directional poppet valve.*