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An introduction to logic elements • Logic elements, directional functions • Directional functions: model variations and application notes • Logic elements, pressure control functions • Logic elements, flow control functions • The design of a control system with logic elements • Examples of controls using logic elements

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Logic Element Technology

A text and reference book
on logic elements

Arno Schmitt
Mannesmann Rexroth GmbH, Lohr am Main/FRG

Editor
Rudi A. Lang
Mannesmann Rexroth GmbH, Lohr am Main/FRG

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Telex 06-89418

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Foreword

Logic element technology, which was originally given a euphoric reception as being the substitute for all conventional control units, has now established a firm niche for itself as an extension to spool valve technology. In many instances, it is an economic alternative to conventional circuitry. Particularly where the system must be made extremely compact, this technology shows considerable advantages.

In many cases, experiences gained with spool valves can be carried over directly into logic element technology without considering specific characteristics. However, in contrast to spool valve technology, logic element technology requires a certain amount of abstract thought. One must think in terms of pressure. In this respect, this book will certainly prove its worth.

The author clearly illustrates the points to be observed in planning, designing, and producing hydraulic systems when using logic elements. Diagrams and illustrations explain the multiplicity of functions which can be achieved with these valves, while lesser known, overly specialised models and variations have been deliberately excluded.

The design of a circuit using logic elements is given its own chapter, as are the examples of the practical examples controls already in use.

These two chapters are certainly not the only ones which will provide practical help to both users and those involved in both basic training and further education when moving into this area of technology.

Hydraulic control and drive technology encompasses an ever broadening area in career based education and training.

This book should provide the basis to provide those interested with up to date information on this technology. It is the result of considerable cooperative effort. We would therefore like to thank the author Arno Schmitt, and also Messrs Heino Försterling and Michael Reinert. Without their work, this book could not have been produced in its present form.

Mannesmann Rexroth GmbH
Lohr am Main

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Logic elements, flow control function

The Design of a Control using Logic Elements

Examples of practical controls using logic elements

Index of key words

An Introduction to Logic Element Technology

1 Description and Duty

"2-Way Cartridge Valves" is the official designation of these control elements under the German standard DIN 24342. They are, however, more commonly known as "Logic Elements". Under certain circumstances, they may also be considered as individual resistance elements.

How do these valves fit into the pattern of hydraulic control elements?

The basic element is a 2/2 way valve i.e. a valve with 2 service ports and 2 operating positions "open" and "closed". They are designed for installation within a manifold, which does not sound at all complicated.

Why then is it necessary, to study these elements so extensively, show their exact function, and how can there be so many control and model variations as illustrated in the following chapters.

What duties can a Logic Element fulfil within a hydraulic circuit?

With suitable control to both the main circuit and the pilot circuit, the logic element can influence the volume and direction of flow or pressure of a hydraulic fluid.

The element can thus have the following functions:

- Directional functions
- Flow control functions
- Pressure control functions

From this statement, it already becomes clear that logic elements have a wide range of applications.

Fig. 1: *2-way cartridge valve (logic element) consisting of a bush, a control poppet and a spring.*

Fig. 2: *Control cover with remote control connection.*

Fig. 3: *Control cover with built on directional spool valve.*

2 The basic element and its function

First of all a look at the basic element.

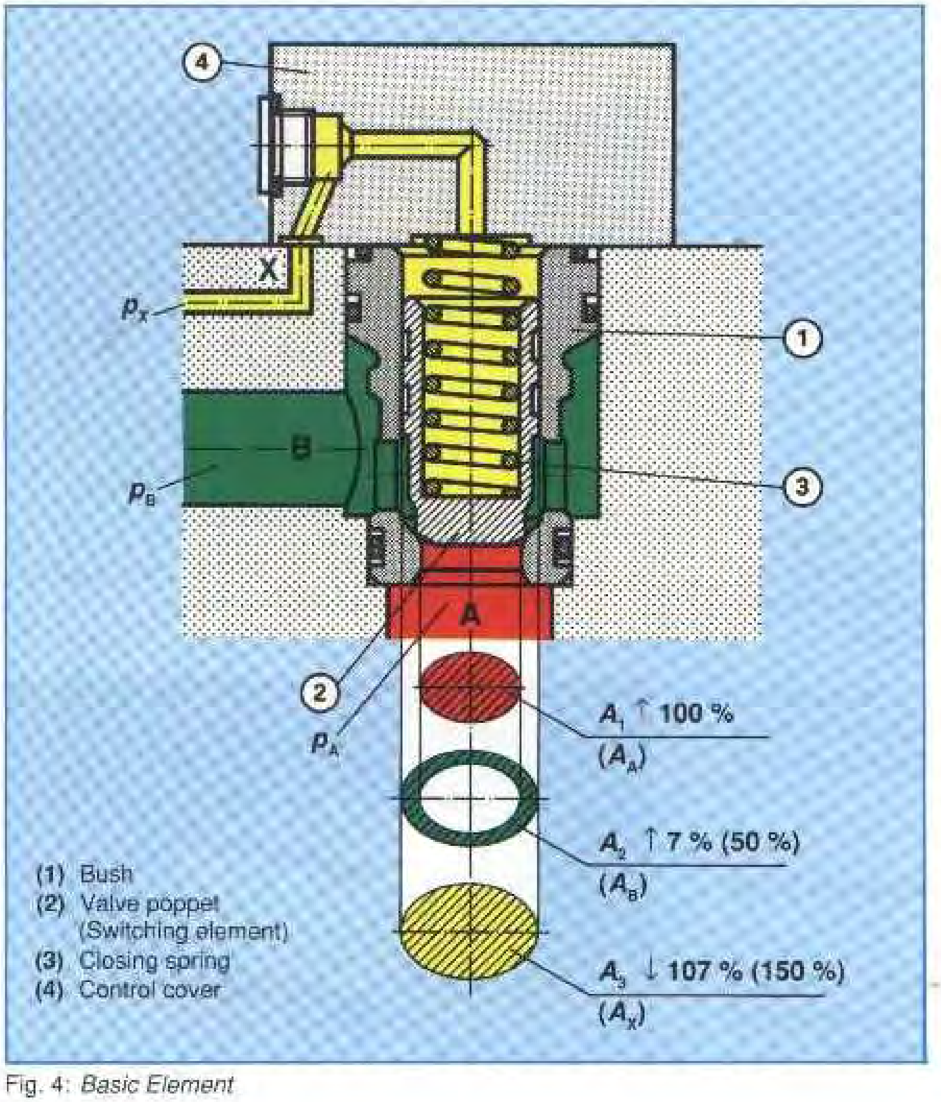


Fig. 4: *Basic Element*

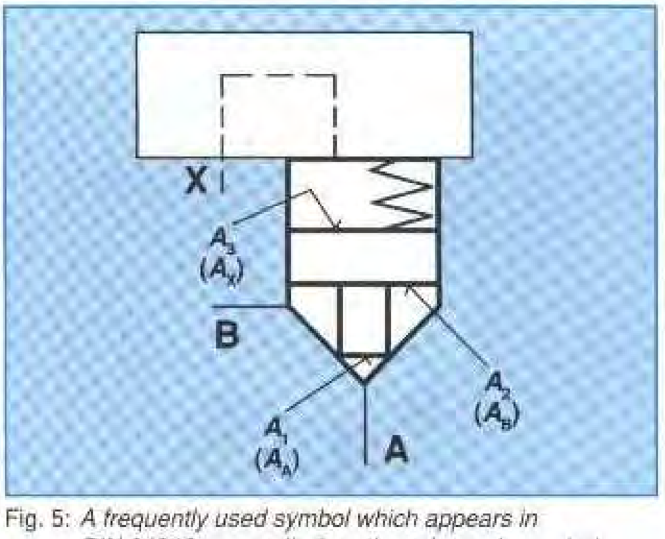


Fig. 5: *A frequently used symbol which appears in DIN 24342, appendix 1 as the schematic symbol for these units.*

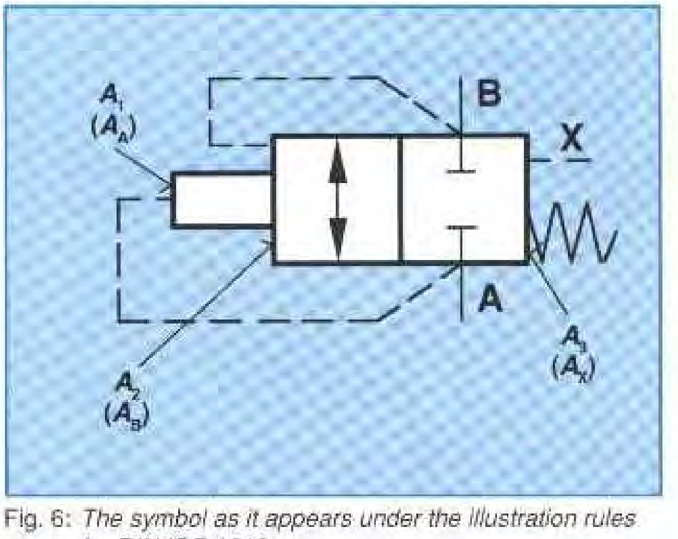


Fig. 6: *The symbol as it appears under the illustration rules for DIN ISO 1219.*

Logic elements *(Fig: 4)* consist basically of cartridge assembly with a bush (1), the valve poppet (2) and closing spring (3) together with a control cover (4). The cartridge assembly, is designed to fit within a cavity standardised under DIN 24342, and is held in place and sealed by cover (4).

The manifold block then acts as the valve housing and contains ports A and B together with the pilot control lines. The control cover contains the pilot control drillings and thus also acts as the connection between the pilot side of the main valve (spring side and connection X) and the pilot control valves.

Whether ports A and B of the valve poppet (2) are connected or isolated from each other depends on the areas A_1 (A_A), A_2 (A_B) and A_3 (A_X) with the pressures present on these areas, and also upon the spring force.

The operation of logic elements is always purely pressure dependent.

The three areas which are important for the functioning of the valve are:

- the area of the valve seat (A_1) or (A_A), are termed the basic areas
- the annulus area at port B (A_2) or (A_B) is taken as 50% of the basic area in standard valves (e.g. in Mannesmann Rexroth), but other areas e.g. up to 100% are also available.
- the area on the spring side (A_3) or (A_X) is the sum of areas A_1 and A_2.

The following is then valid

Areas A_A and A_B operate in an opening direction. Area A_X and the spring have a closing effect on the valve. The effective direction of operation of the resulting force determines whether the logic element will open or close. When no pressure is applied to the valve, the poppet sits down on it's seat. By applying pressure to area A_X usually from port A, or port B, or A and B via a shuttle valve, the valve poppet can allow a free connection A to B.

Closing forces

$\Downarrow p_X \cdot A_X$

$\Downarrow$ Spring

Opening forces

$\Uparrow p_A \cdot A_A$

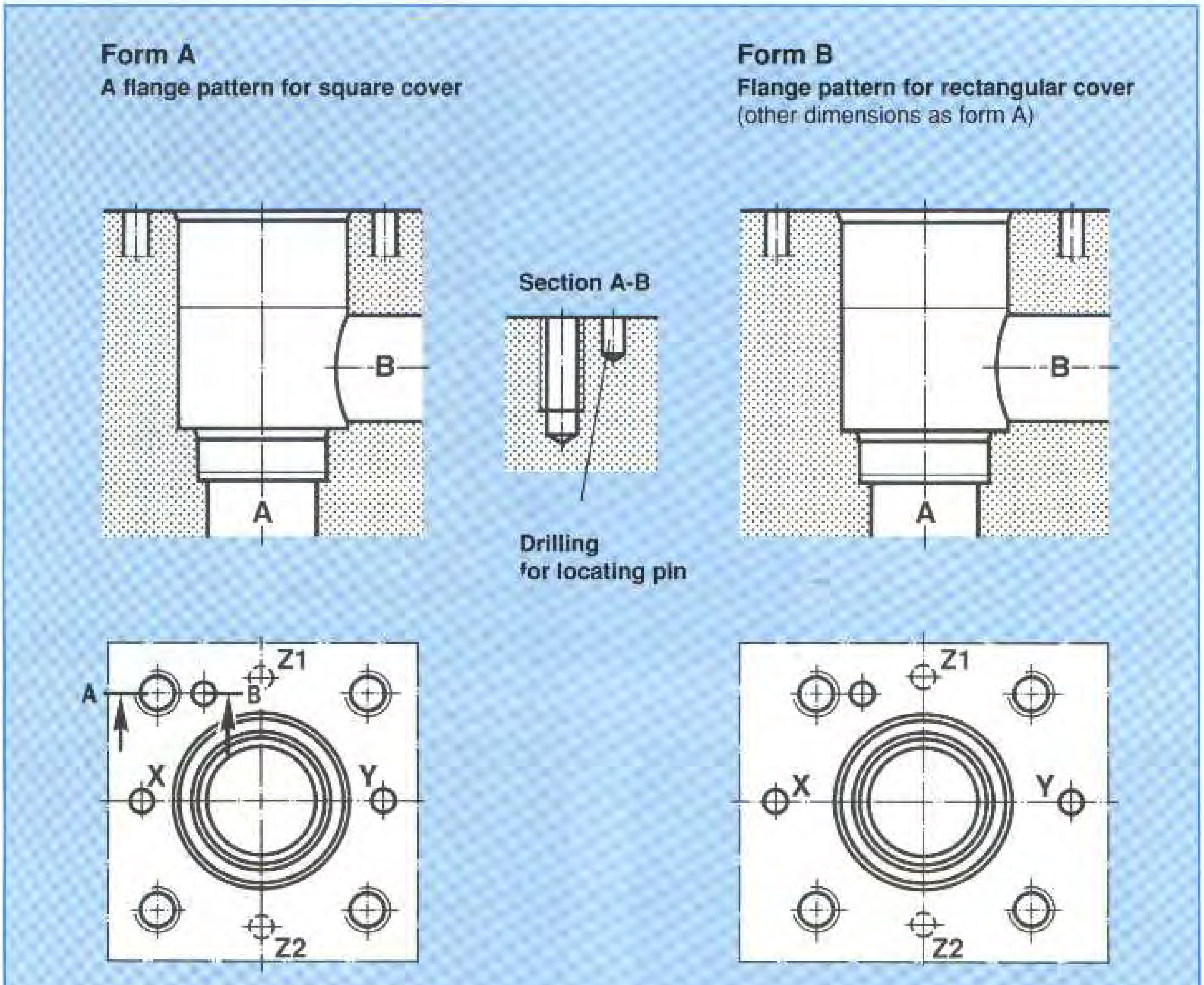
$\Uparrow p_B \cdot A_B$

3 Standards

Cavity to DIN 24342

Within this standard, the bore to accept these logic elements, together with the whole connection area is standardised for sizes 16 to 63 and also for sizes 80 and 100, together with the necessary or possible drillings. Furthermore, (e.g. in Mannesmann Rexroth), sizes 125 and 160 are also available. The exact dimensions of the individual sizes can be seen in an overview in the appendix.

At this point, it is important to note, that in spite of the standardisation of the cavity, the logic elements are not always definitely interchangeable. An example of this is when the control drilling is to be found within the valve poppet.

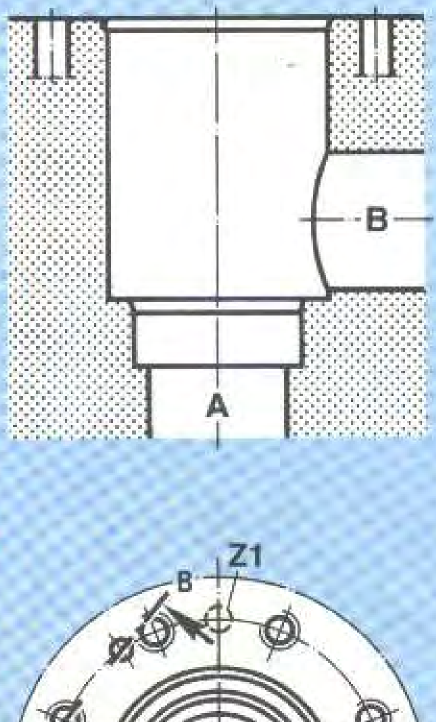


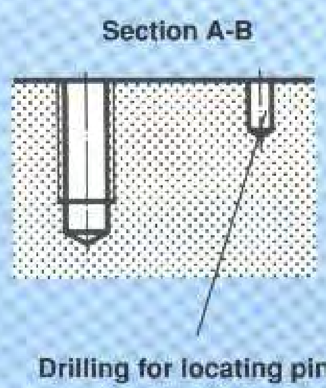
A, B	Service ports
X	Pilot feed connection
Y	Pilot drain connection
Z1, Z2	Additional pilot connection
Z1	Preferred feed connection
Z2	Preferred drain connection

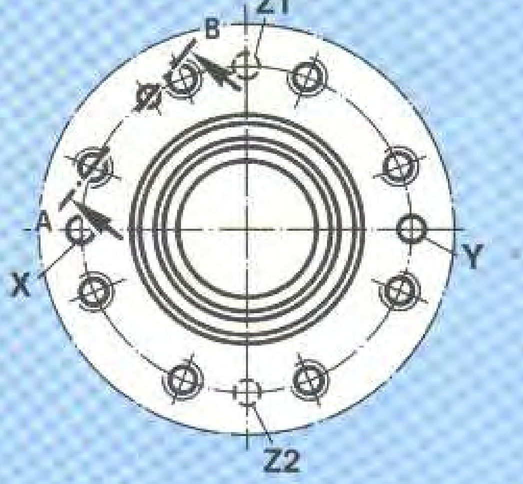
Fig. 7: *Bore dimensions for logic elements sizes 16,25,32,40,50 and 63 (four hole flange).*

Form C

A flange pattern for a circular cover.







A,B	Service ports
X	Pilot feed connection
Y	Pilot drain connection
Z1,Z2	Additional pilot connection
Z1	Preferred feed connection
Z2	Preferred drain connection

Fig. 8: *Bore dimensions for logic elements sizes 80 and 100.*

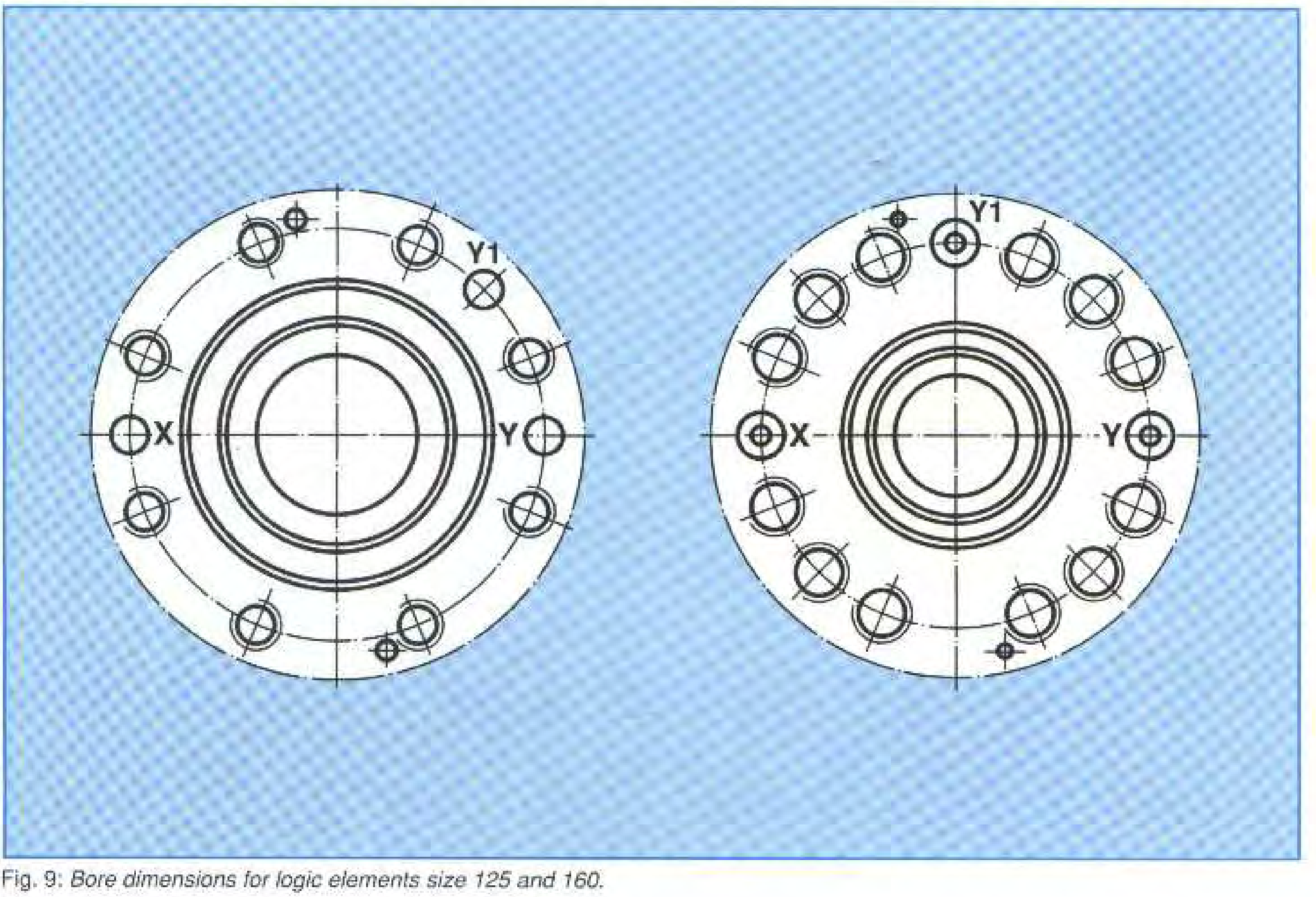


Fig. 9: *Bore dimensions for logic elements size 125 and 160.*

4 Application and Characteristics

Today, we find logic elements applied in the drive and control of:

- presses
- injection moulding and die casting machines
- machine tools
  (especially in broaching machines)

Further applications are in:

- the steel industry
- mobile hydraulics

Application in these areas has resulted from the specific requirements of these installations and the characteristics of logic elements.

They are only applied where economic and where technical advantages over conventional hydraulic products are to be found. Each case must therefore be studied individually.

The main advantages of logic elements can be listed as follows:

- large flow range
- compact installation dimensions
- directional, pressure and flow control valve functions or multiple functions within a single unit
- pressure tight sealing (dependent upon control)
- extremely short operational times possible
- gentle operation possible
- minimal pressure peaks
- unlimited holding time
- minimal wear - long service life
- high functional reliability
  (low sensitivity to dirt)
- practically no power limits
- high permissible operating pressures
- standardised installation dimensions

Due to the complexity of modern pilot controls, and without a closer knowledge of the characteristics of these elements, understanding and judging these advantages is very difficult.

This gives rise to the saying which was once made in connection with logic elements:

"Logic elements are both "famous" and "infamous". One can do practically anything with them, but they do practically anything **they** wish, if one does not understand their characteristics."

The following examples, descriptions and notes should help to ensure that the second part of this saying will no longer apply to <u>you.</u>

5 Typical circuits for logic elements

5.1 Directional valve circuits The control of 4 logic elements each with a separate pilot valve.

As a simple example of the control of logic elements, we will look at the control of a cylinder using "standard technology". A 4/3 way directional valve (*Fig. 10*) will then be replaced by logic elements, each with it's own individual control. (*Fig. 11*).

If one first of all compares the circuit with the 4/3 way spool valve with that necessary for logic elements, the immediate feeling is one of amazement that so much effort is required to apply logic elements. Even without going into the details of the application, it can be clearly seen that to replace directional control valves with a logic element circuit, at least in the smaller sizes, is not sensible.

However, this example should be used not as a basis for the technical or economic advantages of the system, but to gain some understanding of the arrangement of logic elements within the circuit and the functions they perform.

Description of circuit.

At rest, the pressure present in P via the control lines *(yellow)* and the pilot valves (1.1) to (4.1), *and the small 4/2 directional valves),* is present on the large control area A_x of the logic elements (1.0) to (4.0). In this way, all the logic elements are held closed. Pump P *(red)*, tank T *(blue)* together with the service lines *(green)* to the cylinders are blocked. This corresponds to the blocked centre position of the 4/3 way directional valve.

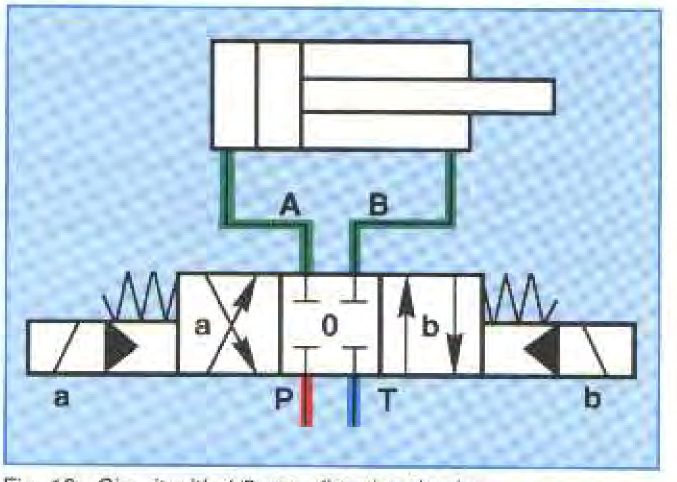


Fig. 10: *Circuit with 4/3 way directional valve.*

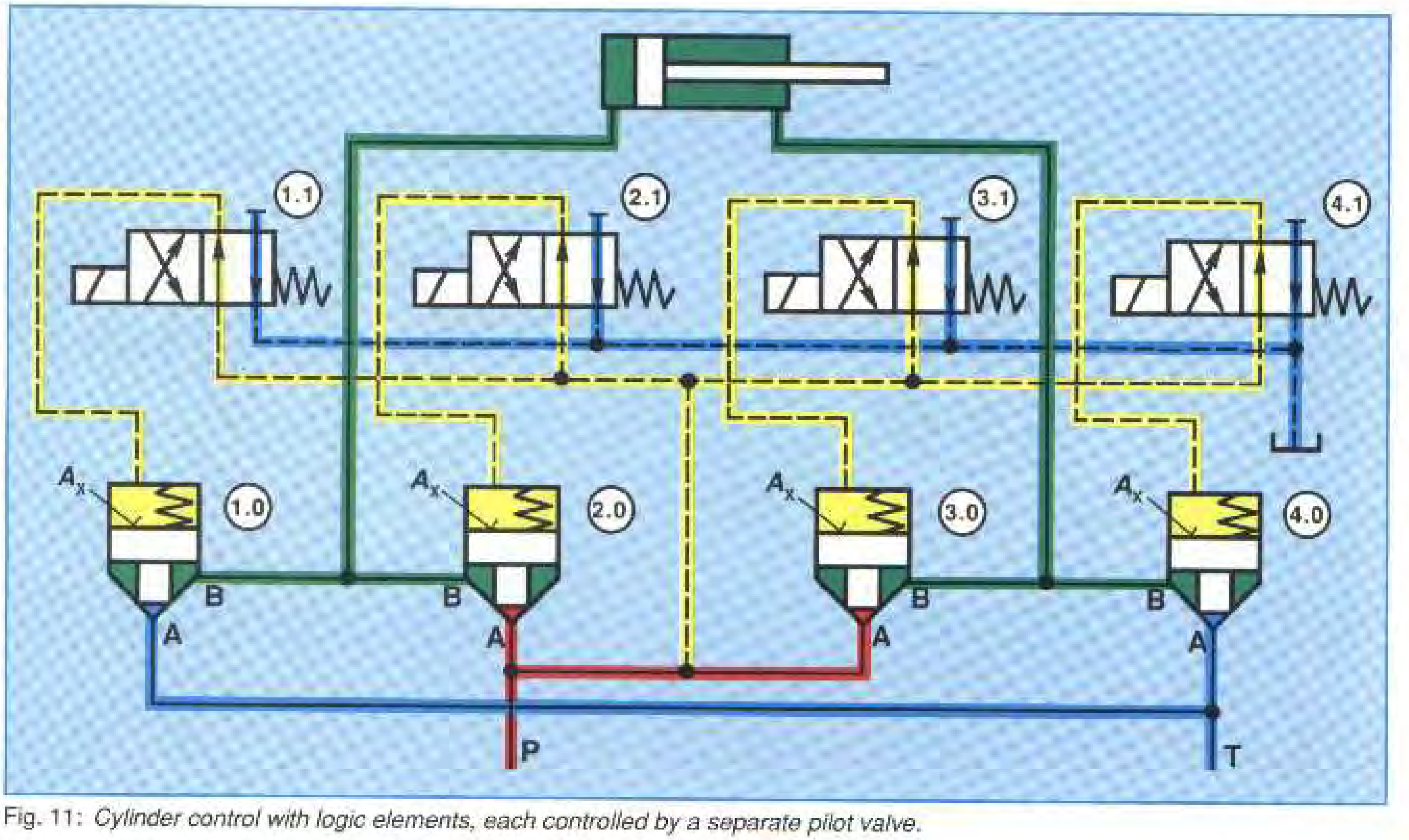


Fig. 11: *Cylinder control with logic elements, each controlled by a separate pilot valve.*

In order to be able to decide whether a logic element under fluid pressure would remain open or closed, we must always study the forces resulting from the pressures effecting the various areas.

Please study the following:

The opening and closing of a logic element is purely pressure dependent. To make this clear, we will consider a small section *(Fig.12)* of the whole circuit *(Fig.11)*.

Let us look at the forces affecting logic element 2.0, as shown in Fig.12, and ask ourselves whether these work in the opening or closing directions.

In an opening direction

$$\Uparrow F_{opening} = p_A \cdot A_A + p_B \cdot A_B$$

In closing direction

$$\Downarrow F_{closing} = p_A \cdot A_X + \text{spring force}$$

Numerical example

$p_A = 250$ bar

$p_B = 80$ bar

Logic element size 25 with a 4 bar spring and annular area 50% (= 3,45 bar cracking pressure A to B)
$p_X = p_A$

Spring force = required cracking pressure • effective area

$A_A\ (A_1) = 3.30\ cm^2$
$A_B\ (A_2) = 1.61\ cm^2$
$A_X\ (A_3) = 4.91\ cm^2$

$F_{Opening} = p_A \cdot A_A + p_B \cdot A_B$
$= 250 \cdot 3.3 + 80 \cdot 1.61$
$= \underline{953.8}$ daN

$F_{Closed} = p_A \cdot A_X + \text{spring force}$
$= 250 \cdot 4.91 + 3.45 \cdot 3.3$
$= \underline{1238.9}$ daN

From this it will be seen that the closing force is greater than the opening force.

The valves thus remains closed.

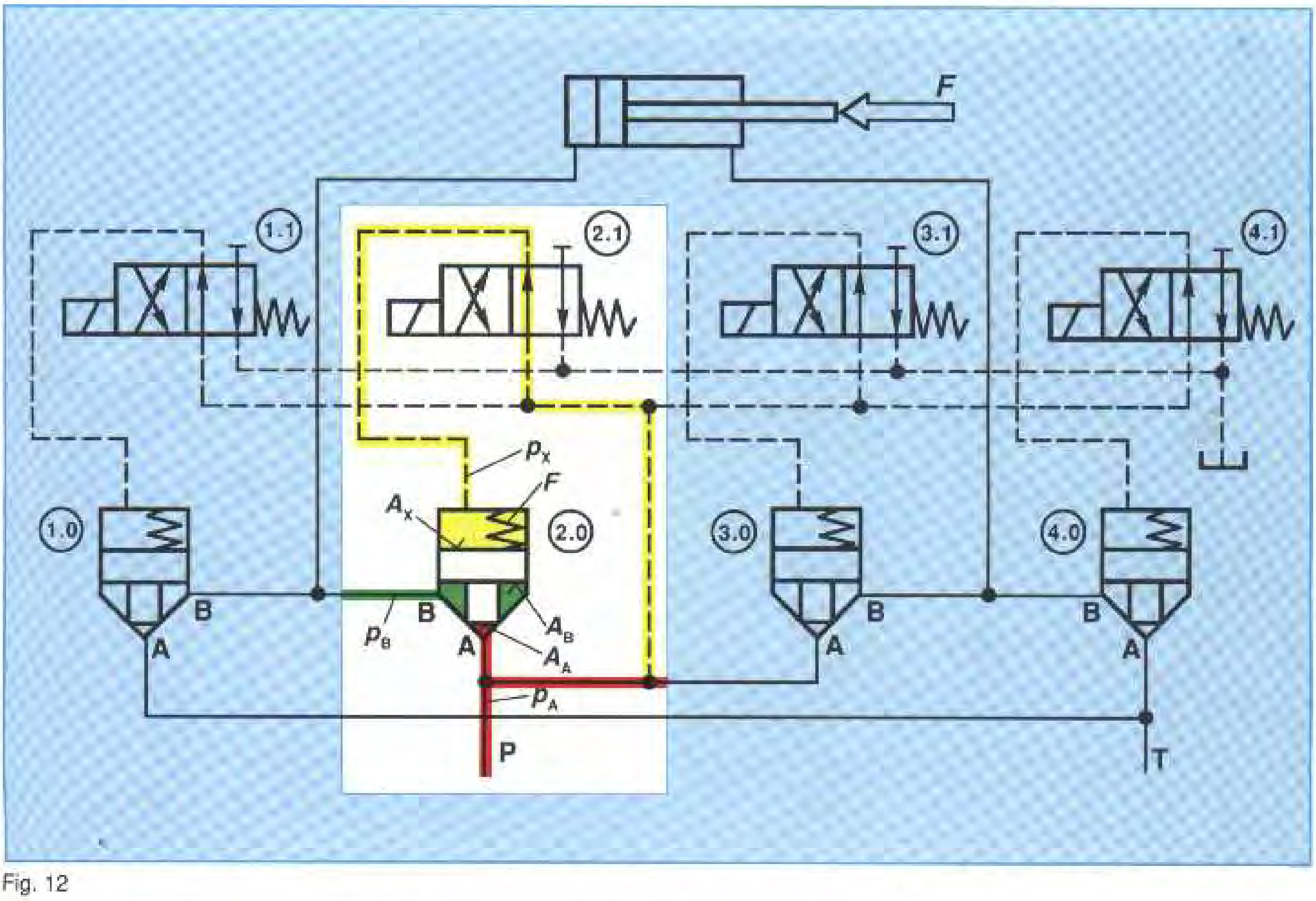


Fig. 12

Cylinder Extending

Pilot valves (1.1) and (3.1) remain in the start position. The pressure in the P-Line passes via the control line *(yellow)* and the pilot valves (1.1) and (3.1) onto the large control areas A_x of the logic elements (1.0) and (3.0). Both elements are therefore held closed and isolate the connection from B to A (1.0) and A to B (3.0).

Valves 2.1 and 4.1 are operated and move into the position indicated by the crossed arrows. The spring chambers of the logic elements (2.0) and (4.0) are thus unloaded. Logic element (2.0) is then opened by pressure on the are A_A. Fluid thus flows to the cylinder. Fluid from the rod end of the cylinder then flowing to logic element (4.0) opens this valve via area A_B against the spring, thus opening a connection to tank.

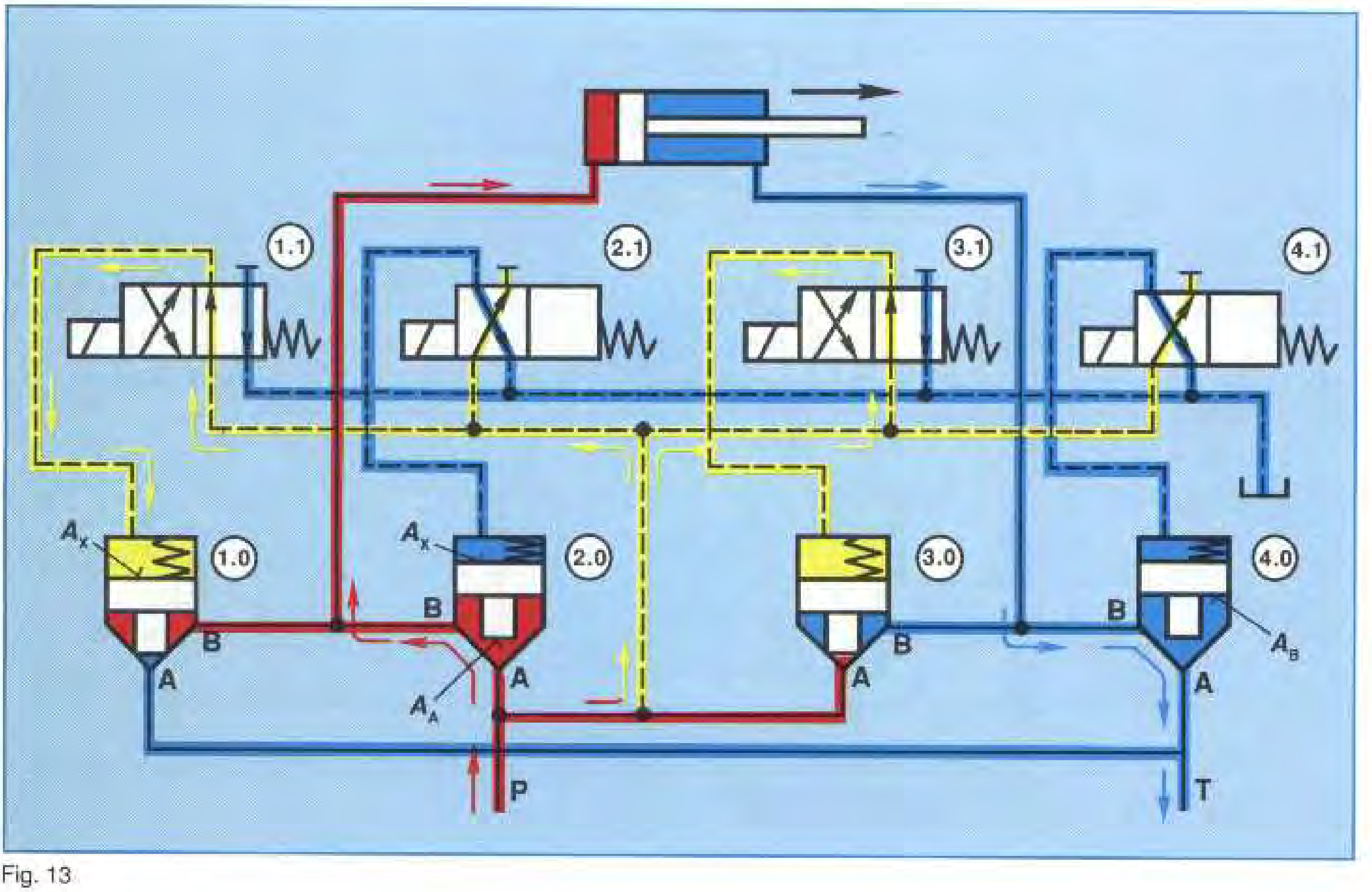


Fig. 13

Cylinder Retracting

In order to retract the cylinder, pilot valves (2.1) and (4.1) remain in the start position. Pressure from the the P-Line passes via the control lines into the spring chambers (Area A_X) of the valves (2.0) and (4.0) and holds these valves closed.

Valves (1.1) and (3.1) are energised, thus connecting the spring chambers of logic elements (1.0) and (3.0) to tank. Pressure in the P-Line can now open valve (3.0) via area A_A, lift the valve poppet and allow fluid to flow to the annulus side of the cylinder. The fluid ejected from the full bore side of the cylinder opens valves poppet (1.0) by means of area A_B against the spring and thus passes to tank.

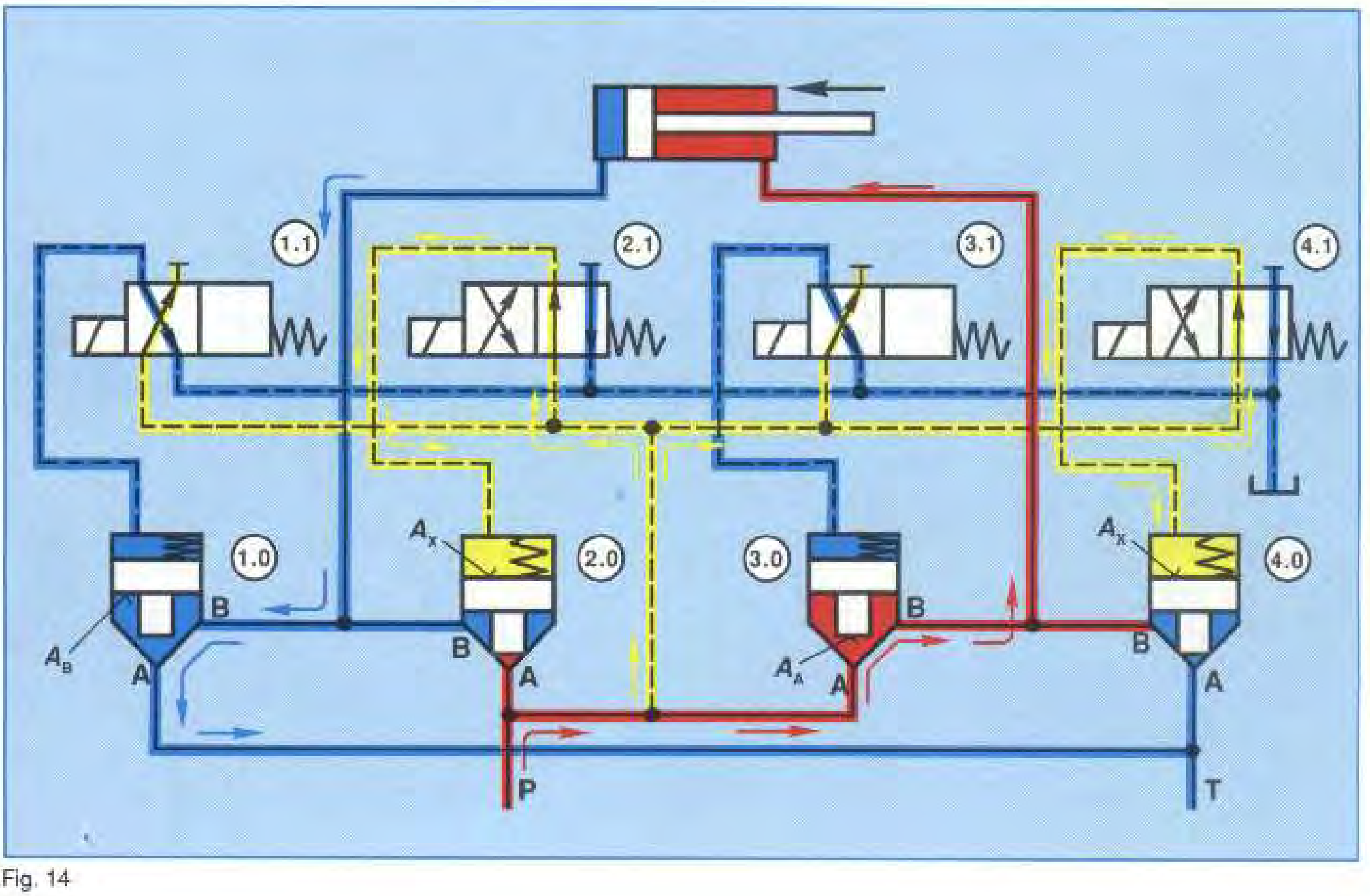


Fig. 14

The two following versions show that, in addition to the previously described functions obtained by operating the pilot valves, some other control variations are also possible.

As may be seen in *Fig. 15*, pilot valves (3.1) and (4.1) are in the rest position and pilot valves (1.1) and (2.1) are operated. Pressure in the P-Line holds logic elements (3.0) and (4.0) closed. On the other hand, logic element (2.0) is opened via area A_A (A_X being at zero pressure), allowing flow from A to B. Logic element (1.0) is opened via area A_B and allows fluid to flow from B to A and thus to tank. A low pressure by-pass is thus achieved.

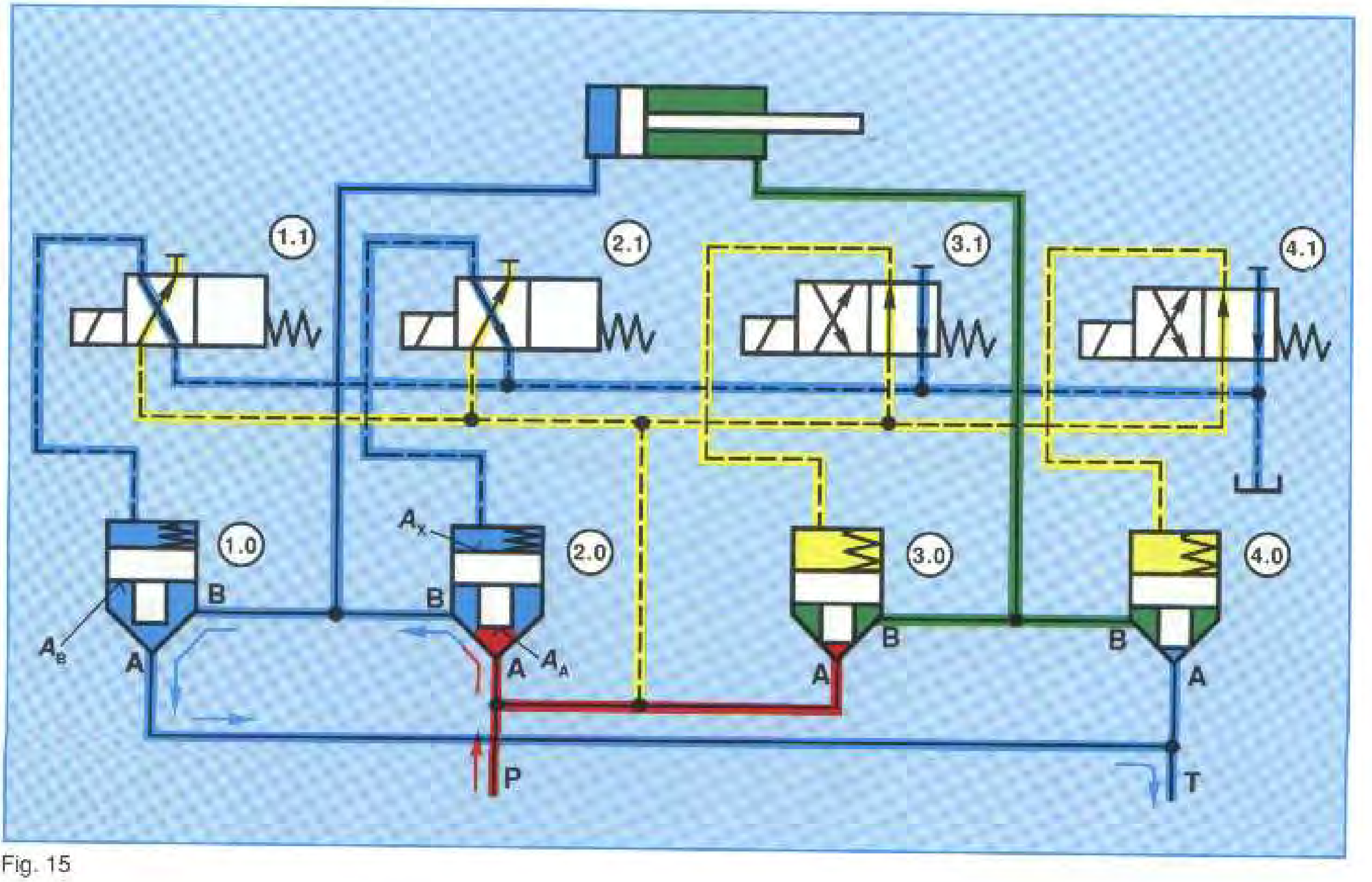


Fig. 15

Using the same valves in a different combination, a regenerative circuit may be achieved.

Logic elements (1.0) and (4.0) remain closed as valves (1.1) and (4.1) remain in the start position and the system pressure is effective on A_X.
It should also be noted, that valve 3.1 also remains in the start position.

As the large control area of logic element (2.0) is unloaded because directional valve (2.1) is operated, and can now be opened via area A_A, fluid can now flow from A to B via logic element (2.0) to the cylinder.

Fluid now flowing from the annulus area can now flow via logic element (3.0) from A to B, back into the pump line.

The following forces are effective on element (3.0):

In the closing direction

- pressure in the pump line • large control area
- spring force

In an opening direction

- pressure in the pump line • area A_A
- pressure from the annulus area • area A_B.

In a closing direction

$$\Downarrow F_{closing} = p_A \cdot A_X + \text{spring force}$$

In an opening direction

$$\Uparrow F_{opening} = p_A \cdot A_A + p_B \cdot A_B$$

With a 50 % area on the logic element poppet, the effective cracking pressure is double that for area A_A. However, sufficient pressure is generated on the area A_B to open the valve when the annulus is 50 % and effectively becomes the pressure drop from B to A.

Control valve (3.1) is not operated in order to avoid either pressure peaks or a collapse in pressure when the cylinder is changed from a regenerative control to "normal" extension mode.

The regenerative circuit is cancelled by operating pilot valve (4.1) thus releasing pressure from A_X of the valve (4.0) and allowing this valve to open providing a free flow path to tank from B to A. Valve (3.0) closes immediately as if it were a non return valve as the pressure p_B which provides the opening pressure supplied from port B of valve (4.0) falls below the level necessary to keep valve (3.0) open.

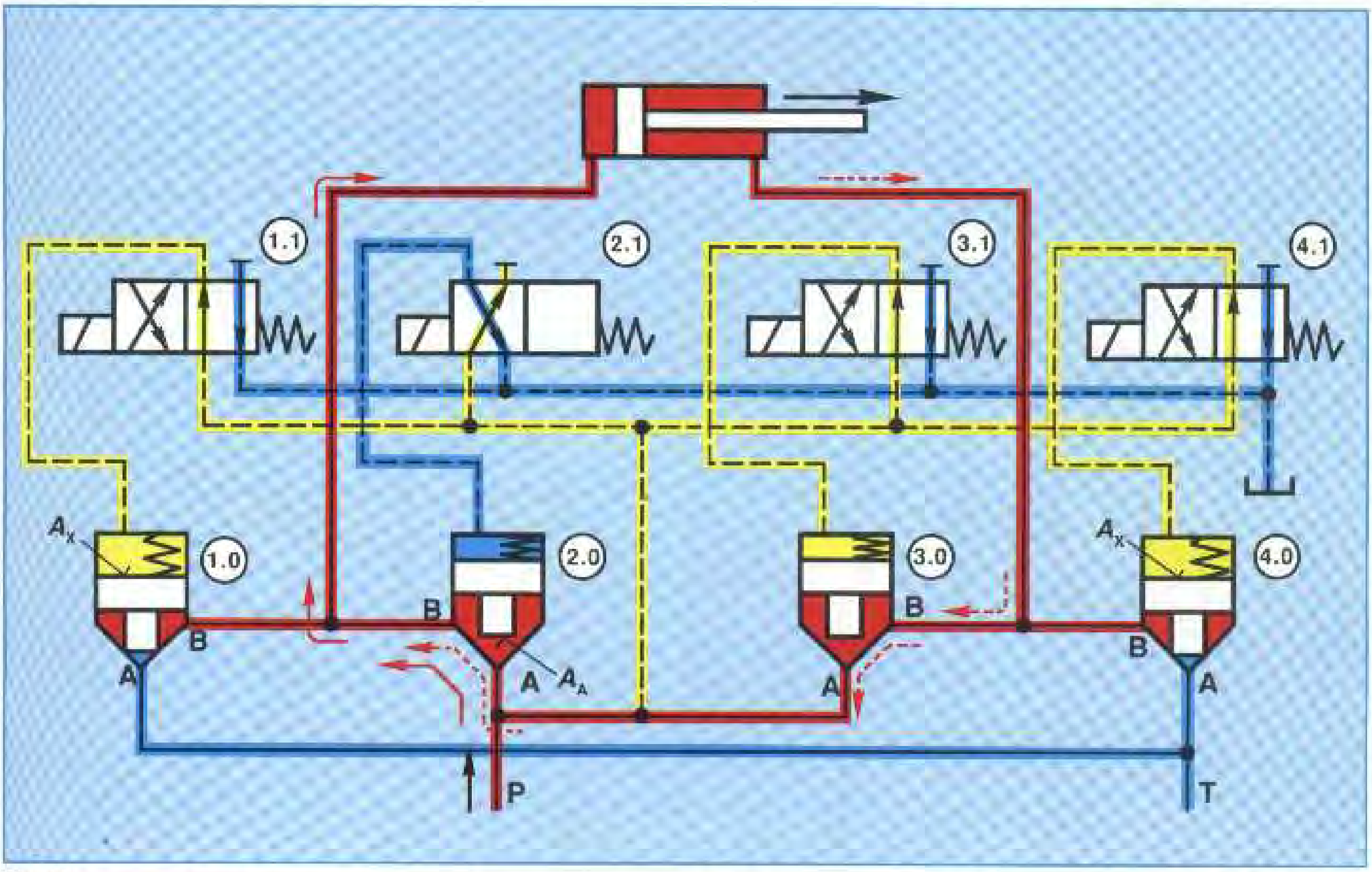


Fig. 16

5.2 Directional Valve Circuit

The control of 4 logic elements via a single pilot valve

In this example, the 4 logic elements are controlled by a **single** pilot valve.

This gives us a direct comparison with the cylinder control in *Fig.10* and also an insight into the function of the relevant control edges.

Before we examine the functions more closely, the following important points should be noted:

- the control of a number of logic elements by means of a single pilot valve appears much simpler as it contains fewer components, but a number hidden problems arise.
- this circuit will only operate in practice with orifices in the control lines in order to make the switching sequence rather more definite.
- optimising the circuit on site is therefore very time consuming.
- in addition, the operation of the circuit is heavily dependent upon viscosity.
- using a single control in this manner is therefore not recommended, but as mentioned above it uses far fewer components and is therefore used repeatedly.

Circuit Description.
Start Position *Fig.17.*

With pilot valve (5) in the start position shown, the pressure in the pump line *(red)* passes via the pilot valve and the control line *(yellow)* onto to the large control areas A_X of the logic elements (1) to (4) operating in a closing direction.

Pressure in the pump line is also simultaneously effective on the annular areas A_B of logic elements (2) and (3). These forces ($p_P \cdot A_B$) operate in an opening direction Annular areas A_B of valves (1) and (4) are connected to tank and are therefore at zero pressure.

If we then assume that the cylinder is not subject to load, then the larger forces on valve poppets (1) to (4) are in a closing direction.

Summarising the forces on the valve poppets of the logic elements makes this decision clear *(see page.24)*

Logic elements (2) and (3) prevent a connection from port B to A, and valves (1) and (4) prevent a connection from A to B. Thus the lines to the cylinder *(green)*, the pump *(red)* and the tank line *(blue)* are all isolated from each other. We have thus the same starting position as for the direction valve control shown in *fig.10*. If one compares this with the directional spool valve of the conventional circuit, then the blocked position between ports A and B of logic element (1) corresponds to the blocked condition between channels A and T in the directional spool valve *(sectional diagram)*. This comparison is also valid for the other paths within the valve P to A, P to B, and B to T.

We can thus see, that a logic element effectively replaces the function of an individual control edge within the directional spool valve.

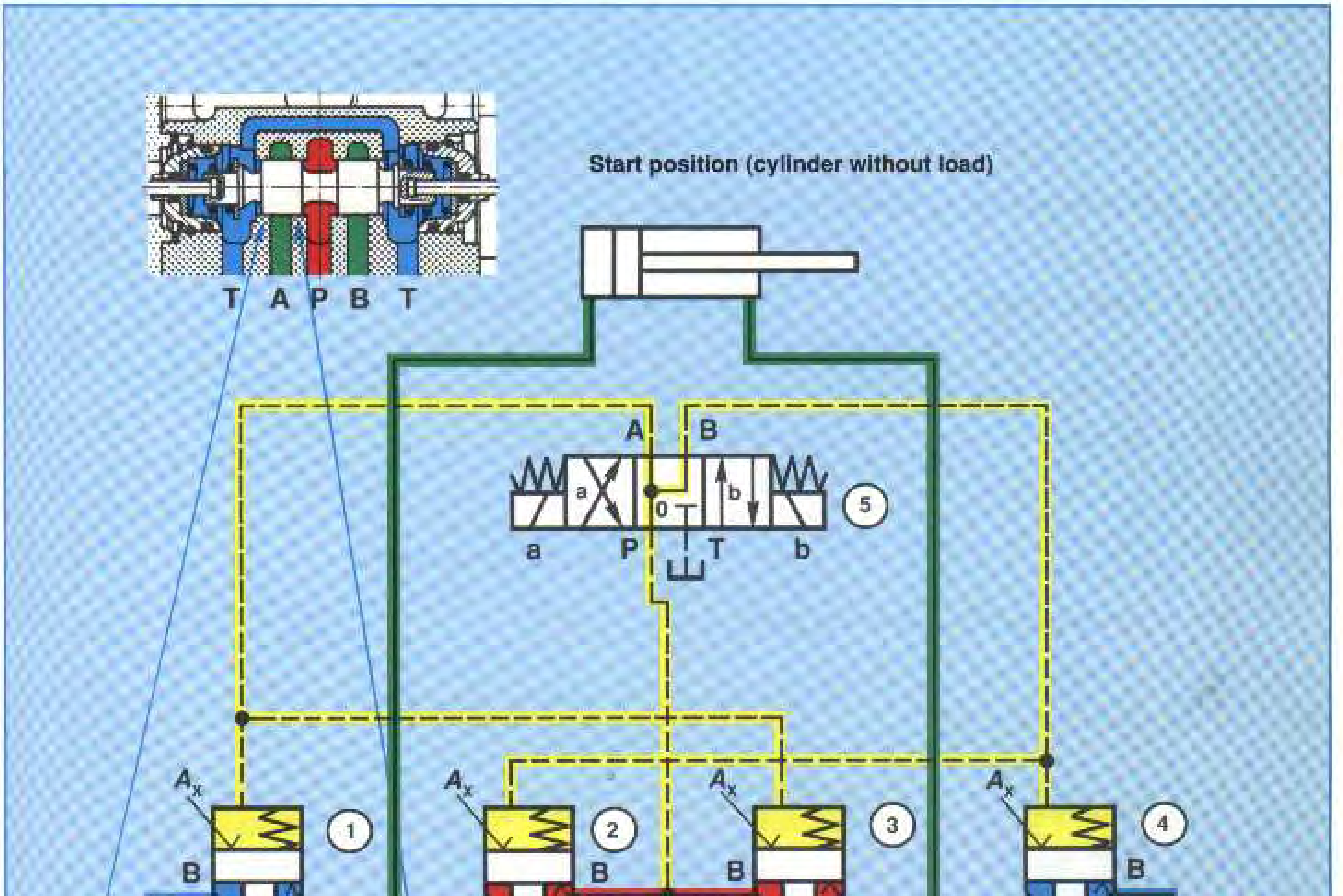

T A P B T
Start position (cylinder without load)
A B
a b
0
a P T b
5
Ax
1
B
AB
AA A
2
3
4
P
T

Fig. 17

The forces operating on the poppet of a logic element

(1) **In a closing direction**

⇓ $p_P \bullet A_X$

⇓ Spring

p_P = Pressure in pump line

In an opening direction

⇑ $p_K \bullet A_A$

⇑ $p_T \bullet A_B$

p_K = Pressure in cylinder line

p_T = Pressure in tank line
(both at almost zero pressure)

The forces in the closing direction predominate.

(2) **In a closing direction**

⇓ $p_P \bullet A_X$

⇓ Spring

p_P = Pressure in pump line

In an opening direction

⇑ $p_P \bullet A_B$

⇑ $p_K \bullet A_A$

p_K = at almost zero pressure

The forces in the closing direction predominate.

(3) **In a closing direction**

⇓ $p_P \bullet A_X$

⇓ Spring

In an opening direction

⇑ $p_P \bullet A_B$

⇑ $p_R \bullet A_A$

p_R = Pressure in annulus
(at almost zero pressure)

The forces in the closing direction predominate.

(4) **In a closing direction**

⇓ $p_P \bullet A_X$

⇓ Spring

In an opening direction

⇑ $p_R \bullet A_A$

⇑ $p_T \bullet A_B$

p_R = pressure in annulus

p_T = Pressure in tank line
(both at almost zero pressure)

The forces in the closing direction predominate.

Cylinder Extending

In *Fig. 18*, the pilot valve has been operated to position b. The pressure in the P line now passed via the pilot valve onto the control areas A_X *(yellow)* of the logic elements (1) and (3), which thus remain closed. The control areas of elements (2) and (4) are simultaneously connected to a tank via the pilot valve (5) and are therefore at zero pressure.

The pressure on the annulus A_B of element (2) moves the poppet upwards against spring C_2 and opens the flow path from B to A to the cylinder *(red)*. The cylinder extends and the fluid flowing from the cylinder annulus passes via logic element (4) by opening the valve via area A_A against spring C_4, to tank.

If one once again makes a comparison to the directional spool valve, then the opening of logic element (2) corresponds to the connection P to A in the directional spool valve caused by the control land opening.

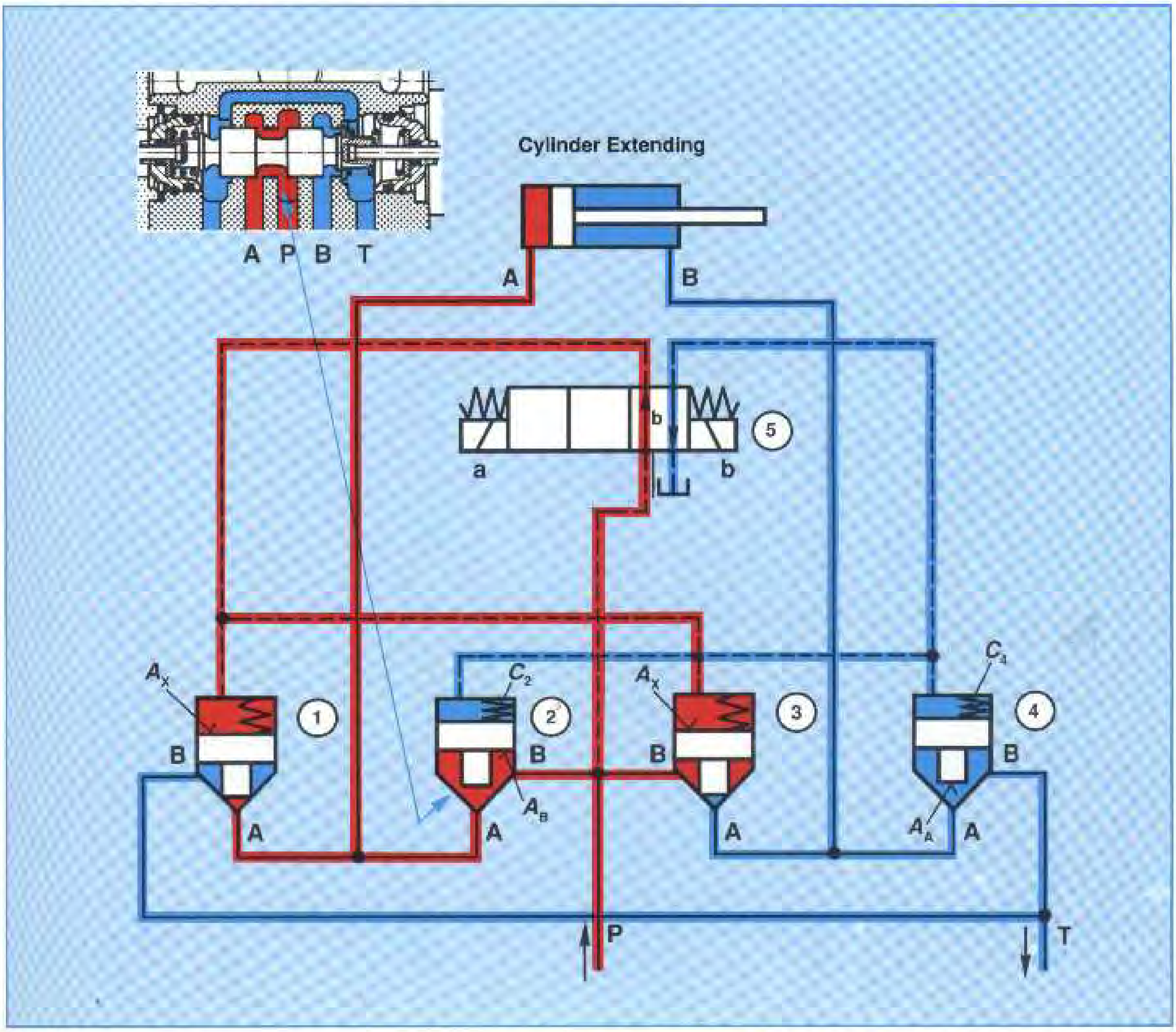


Fig. 18

Cylinder retracting

If the pilot valve is now moved to position a, logic elements (2) and (4) remain closed. Fluid flows from the pump via valve (3) (opened via area A_B against spring C_3) from B to A and to the annulus area of the cylinder. The cylinder retracts. The fluid flowing from the full bore side passes via valve (1) (opened via area A_A against spring C_3) from A to B and thus to tank.

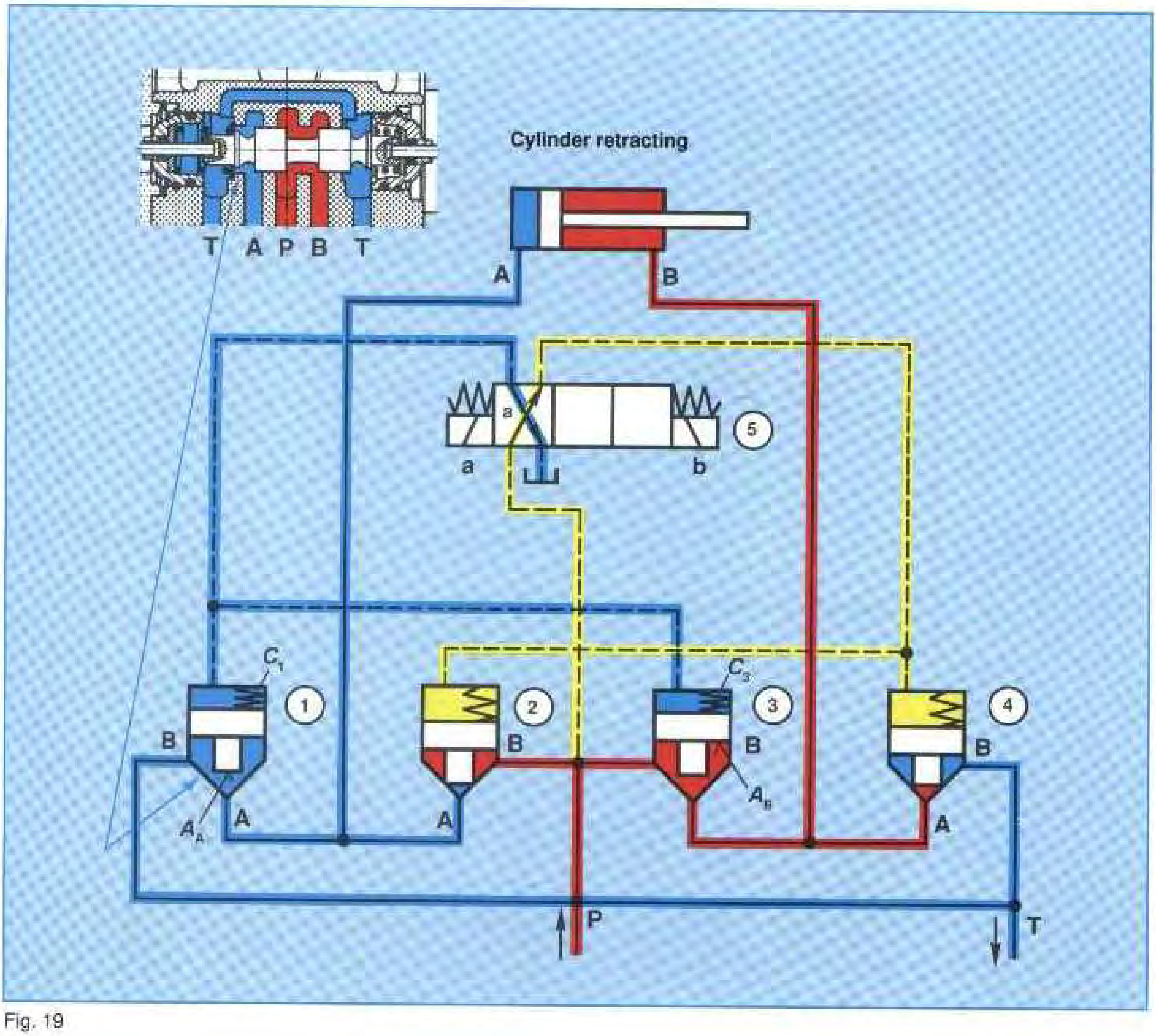


Fig. 19

Cylinder with a pulling load

The circuit in *Fig. 20.* is identical to that in *Fig.17.* The important difference is that here we have a cylinder under an extending load.

This will enable us to make clear once more the statement made on *page 11*:
"Logic elements always operate on a purely pressure dependent basis"

Whilst the control with a directional spool valve always operates purely on a signal dependent basis, the pressure operating on the various areas of logic elements must be considered.

If we assume in our example, that the pump is switched off and the cylinder is under a pulling load, pressure builds up on the annulus side *(green)*, and areas A_A of logic elements (3) and (4). As the control areas A_X are at this time at zero pressure, the valve poppets may be lifted against the spring force and fluid can flow to tank, for example. In addition, the full bore of the cylinder is subject to a negative pressure as no fluid can be sucked into this area.

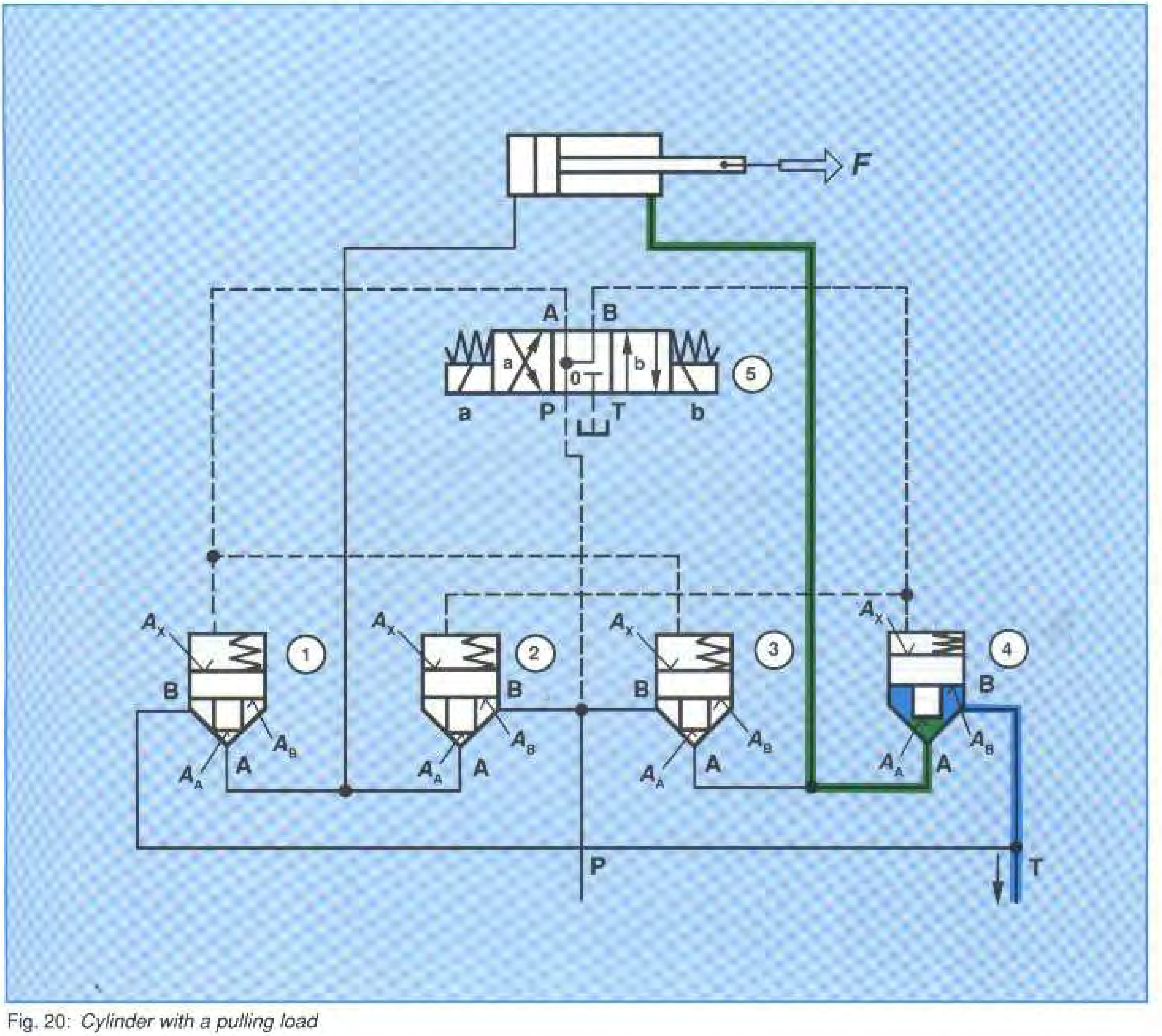


Fig. 20: *Cylinder with a pulling load*

In order to avoid these disadvantages in the circuit shown in *Fig. 20*, the valves required to remain closed must do so automatically utilising the pressure arising from the load itself. This is achieved by means of shuttle valve (6) in *Fig.21*. If now, for example a pulling load is present, the pressure builds up via shuttle valve (6) and pilot valve (5) (ports P, A and B) on the control areas *(light green)* of the logic elements (1) to (4) working with the spring in a closing direction.

In order to prevent pressure having any effect in the opposite direction via the pilot line, non return valve (7) is included in the circuit. Obviously, the low pressure is also effective simultaneously at port A (area A_A) of valves (3) and (4).

As the P and T lines in this example are at zero pressure, the logic elements remain closed.

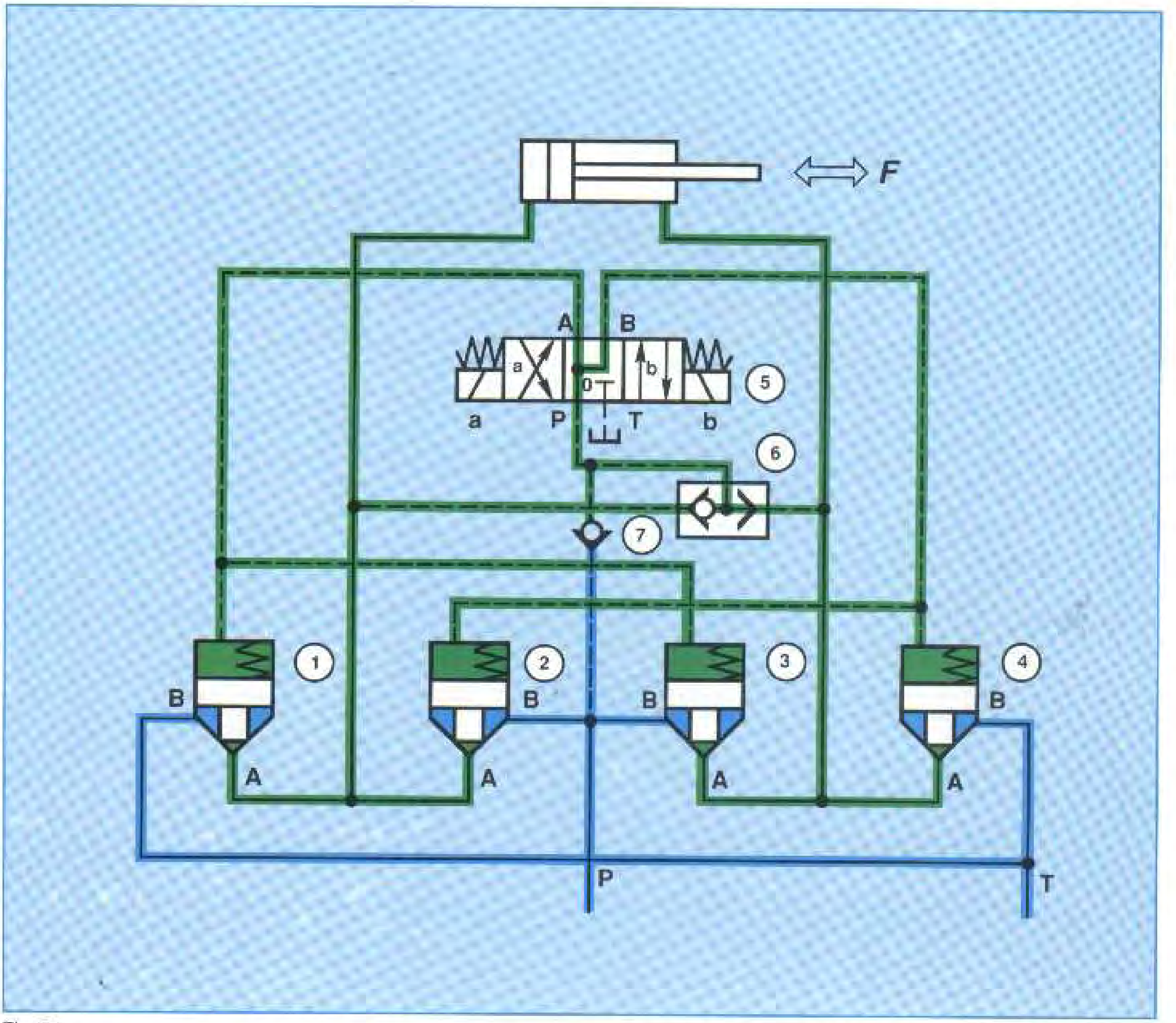


Fig. 21

We must also examine the circuit shown in *Fig. 21* and study the extension of the cylinder *(Fig. 22)* more closely.

Pilot valve (5) has been moved into position b. Pressure in the pump line *(red)* is now operative via pilot lines *(yellow)* and has the following effects:

1 on to shuttle valve (6), causing this to isolate the pump flow from the side of the cylinder at low pressure.

2 also via pilot valve via P to A onto the control areas of valves (1) and (3) to hold these closed.

Control areas of valves (2) and (4), on the other hand, are unloaded through the connection B toT at the pilot valve. The system pressure *(red)* can open logic element (2) via area A_B from port B. Valve 4 also opens, controlled via area A_A by the fluid flowing back from the cylinder, giving a connection A to B.

The cylinder thus extends.

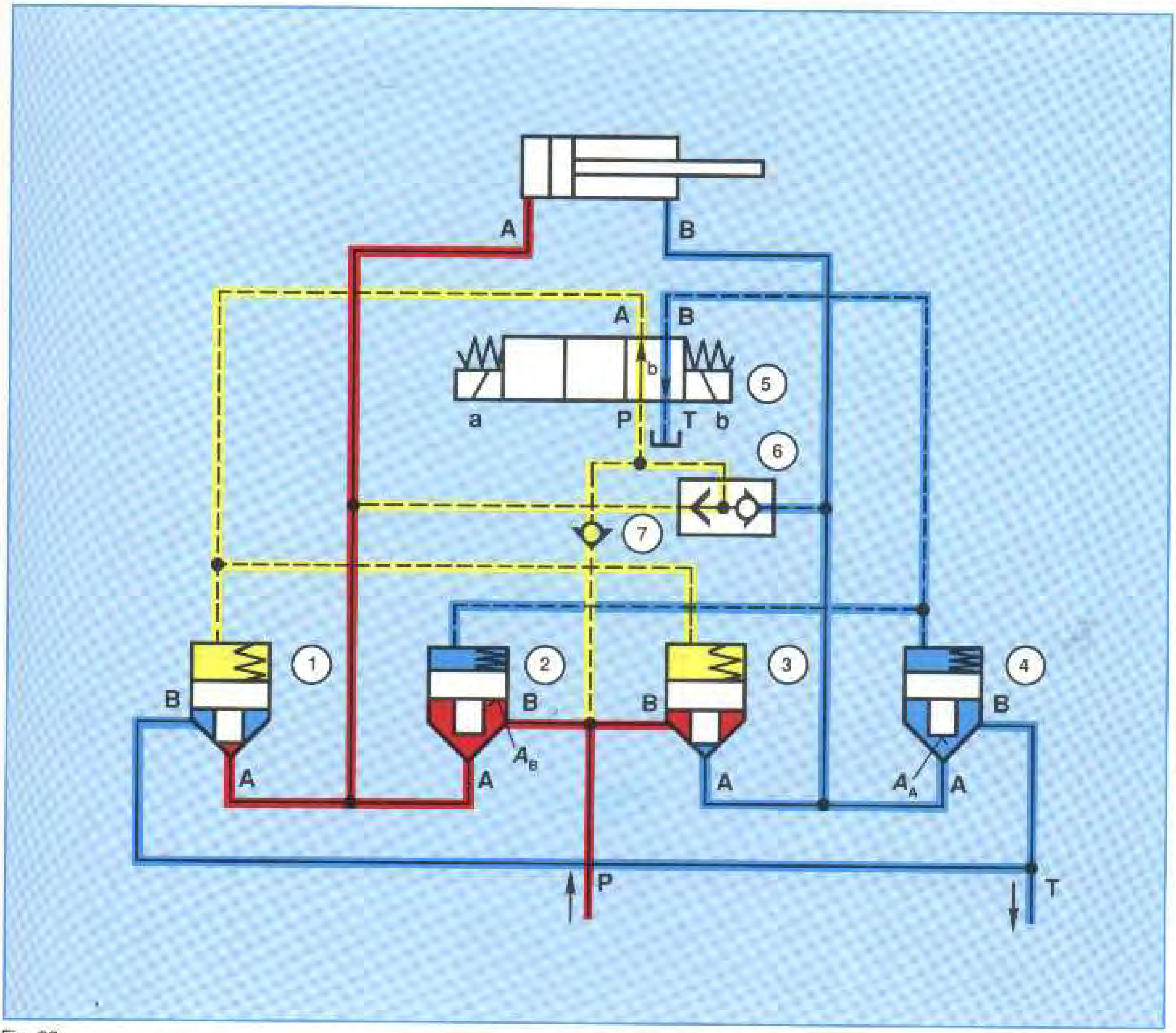


Fig. 22

Cylinder control
with coarse control of cylinder speed.

If one wishes to add a flow control function to the directional function of this circuit with logic elements, then the relevant valves are equipped with a stroke limiter *(for a more detailed explanation, see the chapter on flow control functions)*. For example, if it is required to control the speed as shown in *Fig.23*, two of the logic elements (1) and (4) are each equipped with stroke limiters (8) and (9).

As shown in *Fig. 23*, the fluid can flow freely to the cylinder, whilst the fluid returning to tank must pass via throttling points (10) or (11). In the circuit shown in *Fig.24*, fluid coming from the annulus of the cylinder is led via valve (4) to tank, and the flow influenced by the stroke limiter (9) controlling the stroke of the valve poppet.

In the same way, fluid on the full bore side of the cylinder is throttled in *Fig. 23* via the throttle/non return valve (10), and in *Fig. 24* via the stroke limiter (8) in logic element (1).

An example of this circuit from *Fig. 18*, makes it clear once more, that logic elements operate in a purely pressure dependent mode. Due to the throttling of the oil coming from the cylinder via valve (4) at the rod end of the cylinder *(green)* the pressure is intensified. Thus, logic element (3) would be opened via area A_A were it not for the shuttle valve (6).

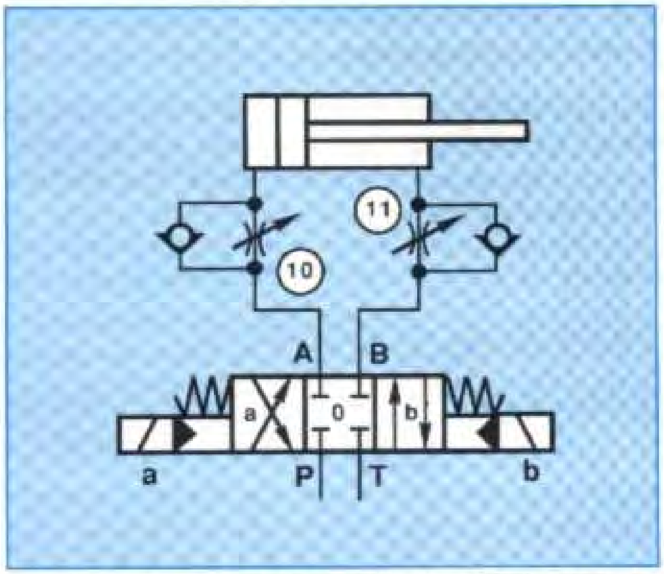


Fig. 23: *Example of cylinder control with a directional spool valve and throttle/ non return valves.*

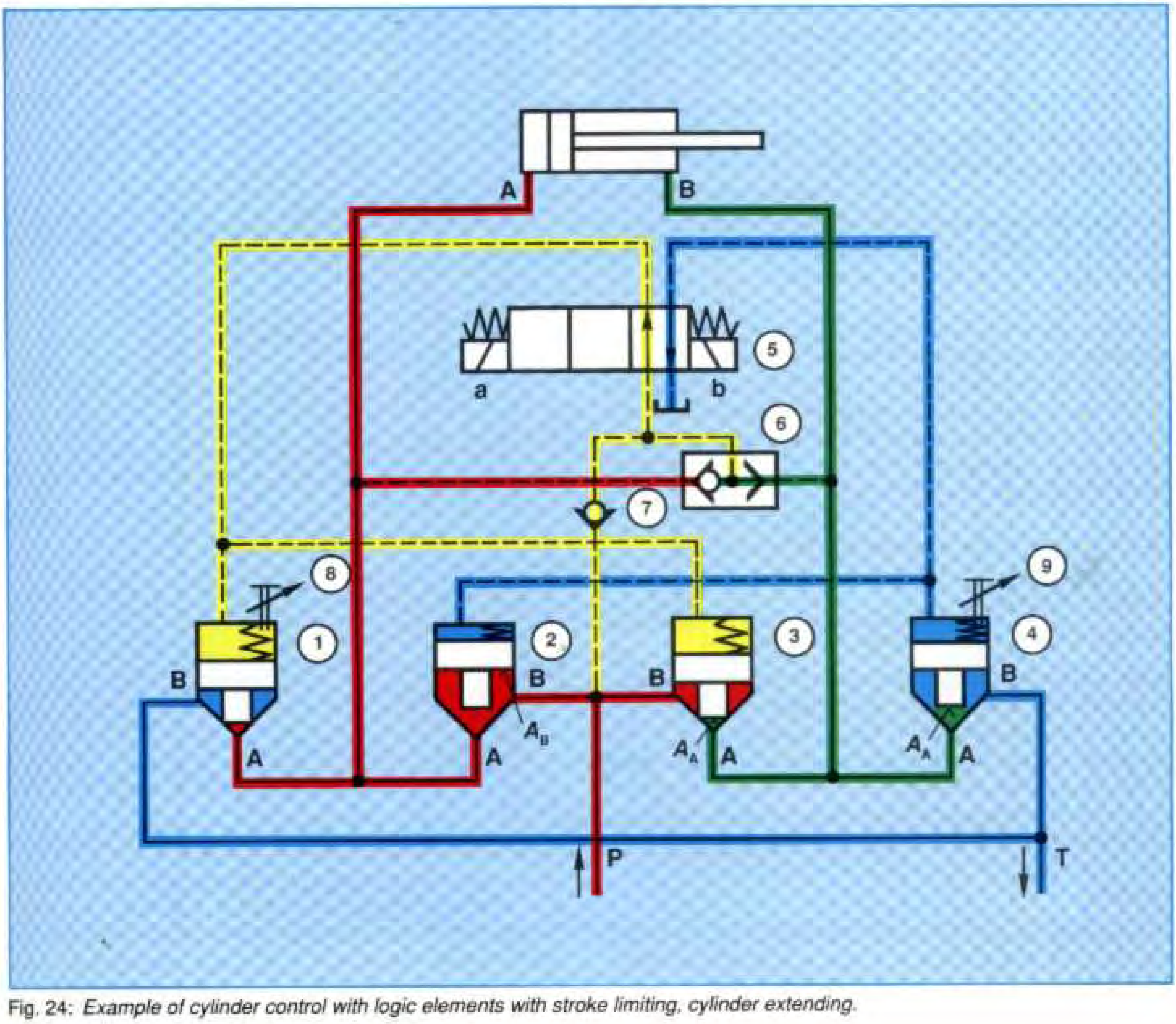


Fig. 24: *Example of cylinder control with logic elements with stroke limiting, cylinder extending.*

5.3 A sample application

Control of a lifting device.

The control in *Fig. 25* is the "old" model with conventional valves, i.e. directional spool valve, pilot operated check valves, pressure and flow control valves. This was built onto a manifold block.

The function is very simple to understand.

The pilot operated directional valve (1):

Spool position 0 — Leak free sealing of the cylinders via the pilot operated check valves (2) and (3).

Spool position a — Retraction of the cylinders with the setting of the lowering speed by means of the throttle/non return valve (5).

Spool position b — Extending the cylinders in regenerative mode with the setting of the lifting speed via the throttle/non return valve (4).

The pressure limiting within the cylinders via the pilot operated pressure relief valve (6).

The sizes of the necessary valves make it clear, that the manifold must also be very large. In fact, five size 52 valves and one size 32 valve were fitted.

In order to achieve a cost reduction, a control using logic elements was developed. From the functional point of view, this control has all the characteristics of the old circuit. However, it only requires two logic elements size 50, and one element size 32 built into the manifold block, and a single directional valve size 10 built onto the manifold as a pilot valve *(Fig. 26)*.

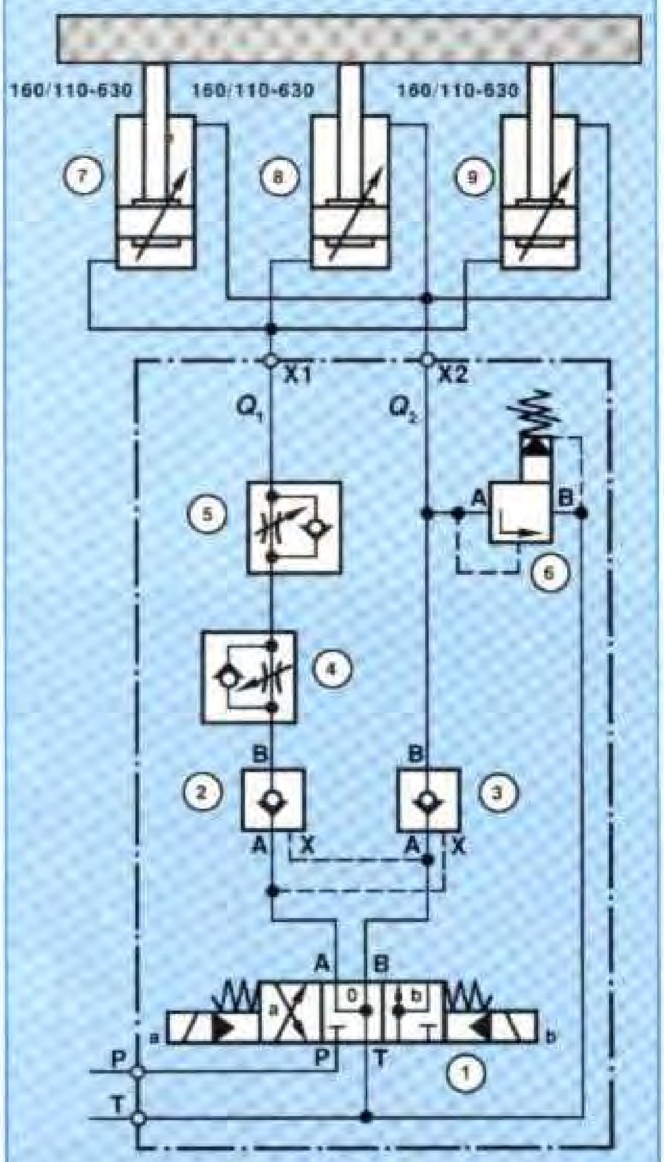
The individual functions were achieved as follows:

<u>Cylinder Extending</u>

Directional valve (13) with spool in position a.

In this condition, the pilot chambers of the logic elements (10) and (12) are pressurised and the pilot chamber (connection X) of logic element (11) is unloaded. Fluid from the pump line passes via element (11) from A to B to the full bore area of the cylinders. Fluid from the annulus area of the cylinders is present at port B of the valve (12) and opens the poppet via area A_B *(see also Fig. 4)* against the pump pressure due to pressure intensification in the cylinder.

Pilot oil from the pilot chamber is displaced via the pilot line, the pilot control valve (13) and the shuttle valve into the pump line. The fluid flowing from the annulus area now passes via valve (12) into the pump line and then to the cylinders. These then extend in regenerative control. The setting of the extension speed is achieved via the stroke limiter in element (11). Thus, no seperate flow control valve is required.



(1) to (5) size 52
(6) size 32
(1) solenoid a down
solenoid b up
Q_1 = 950 L/min
Q_2 = 470 L/min

Fig. 25

Cylinder retracting

Directional valve (13) with spool in position b.

With the pilot valve in position b, the pilot chambers of valves (10) and (12) are unloaded, and the fluid can pass from the pump line via valve (12) to the annular areas (valve(11) remains blocked). The displaced fluid can flow to tank throttled by the stroke limiter of the logic element (10).

Cylinder stopped.

Directional valve (13) in the neutral position.

In the centre position of the pilot valve, all three logic elements are held closed by the pump pressure acting on the large control areas A_X (port X).

A cost comparison of the two controls shows that the logic element circuit could be manufactured for approximately half of the price.

These last two examples of controls with logic elements should help to give an insight into the basic functioning of logic elements. At the same time, the sensible application and also the limitations and possibilities of logic elements should have become clear.

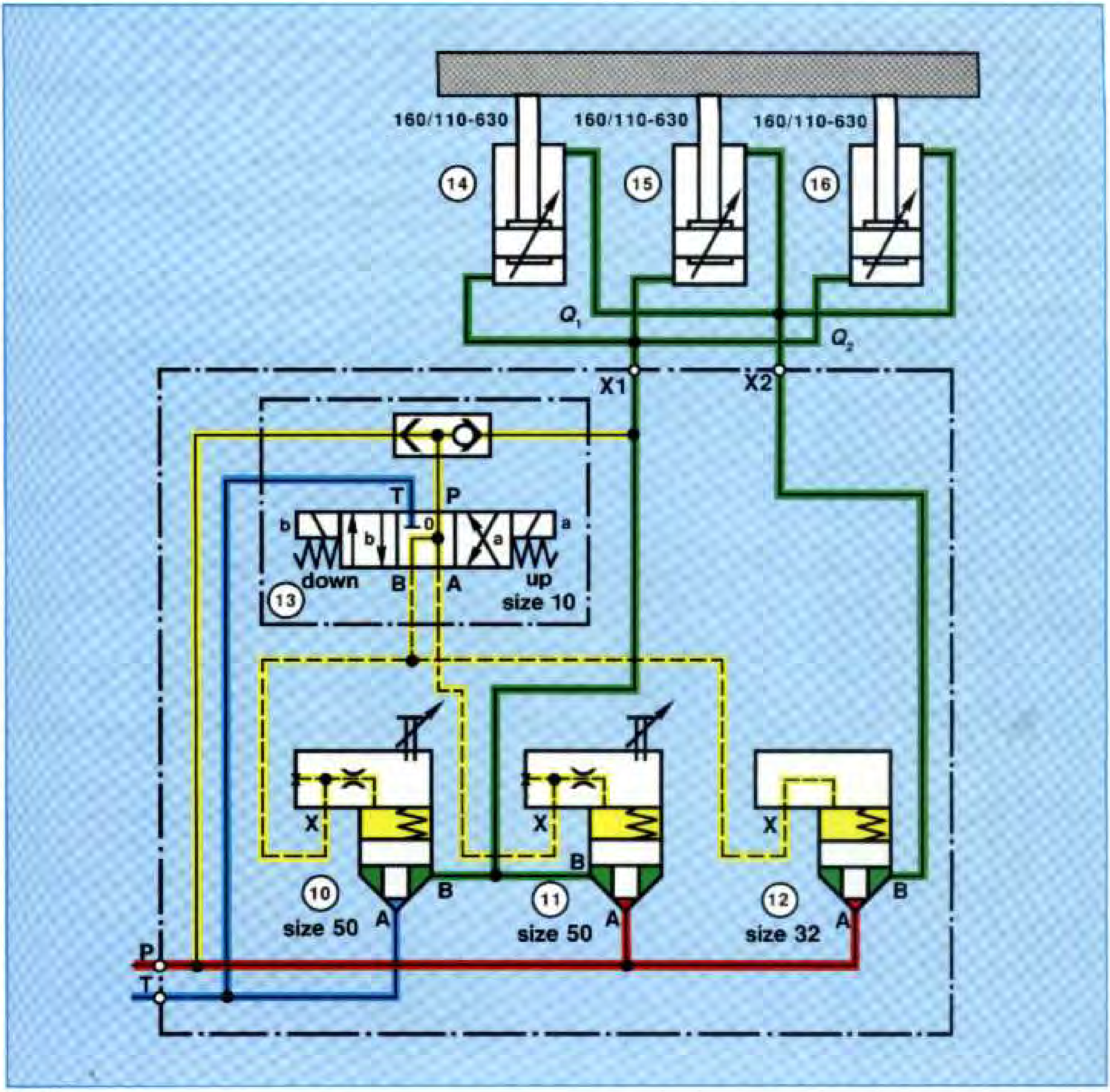


Fig. 26

6 The differences between directional spool valves and logic elements

Now that we have some insight into the basic operation of logic elements from the examples given, we should at this point summarise the characteristics (both advantages and disadvantages) of directional spool valves and logic elements:

Characteristics of directional spool valves.

- complete directional control is achieved by moving a single spool
- the spool passes through a number of positions within the housing, so that a number of functional spool patterns can be achieved.
- the arrangement of the lands and grooves on the spool within the housing can be almost infinitely varied giving rise to a manifold number of different spool symbols.
- in the operated condition, a complete static pressure balance is achieved at the spool.
- because of the pressure balance on the spool, a force balance in the axial direction is also assured.
- the sealing between the various chambers at varying pressure levels is achieved by spool clearance (giving leakage).
- the spool clearance can be sensitive to dirt and to the build up of off-setting pressure fields (spool clamping and holding time problems- silting).
- when changing the size of the spool valve, the dimensions change according to the third power, whilst the valve opening only changes as the square of the dimensions.

Characteristics of logic elements.

- space saving design.
- leakage free, dependent upon pilot control. (B to A, with poppet type pilot valves)
- optional individual control of each single flow path.
- multiple functions.
- very short operating times.
- the operating speed can be influenced in both the opening and the closing directions.
- high operational reliability.
- large flow range (practically no power limits for directional functions).
- low sensitivity to dirt.
- simplified stocking of spares.
- pressure peaks and switches shocks can be avoided relatively easily.
- various sizes corresponding to the various flows within a circuit possible.
- high permissible operating pressures.
- (for the uninitiated) an increased amount of planning work.
- increased time required for optimisation (only applies to standard manifold blocks or controls).
- due to installation within the manifold, greater difficulties are experienced by service personnel.
- "complex" method of operation, as the logic elements operate on a purely pressure dependent basis and require complete understanding from the designer.
- if errors occur, these can be more difficult to localise.
- as a directional valve, only one 2/2 way function within one element.
- in common with all directional poppet valves, static force balance at the switching element is not possible.

The following resumé can be made of the points so far covered

Controls incorporating logic elements only become sensible, if economic and/or technical advantages over conventional hydraulics present themselves.

Application of these elements over many years has shown that, it is not sensible to replace pure directional valve controls, at least in the smaller sizes (up to approximately size 32).

If, however, one can combine a number of functions, or the application involves large and widely varying oil flows, it pays in every case to consider the use of logic elements.

7 An over view of the basic elements, and the basic functions of logic elements

Dependent upon the function required and the characteristics to be expected from the control or logic element, there are a different basic elements as shown in *Fig. 27* for:

- directional functions
- pressure functions

Dependent upon the pilot control, simple opening or closing functions and purely hydraulically controllable non return valves, directional valves, pressure relief valves, pressure reducing valves or flow control valves may be achieved.

* By means of suitable pilot control, a pressure relief valve function can also be achieved with directional logic elements. For this, the model with 7 % annulus area (area A_B) is used (for further explanation, please see the chapter on pressure functions).

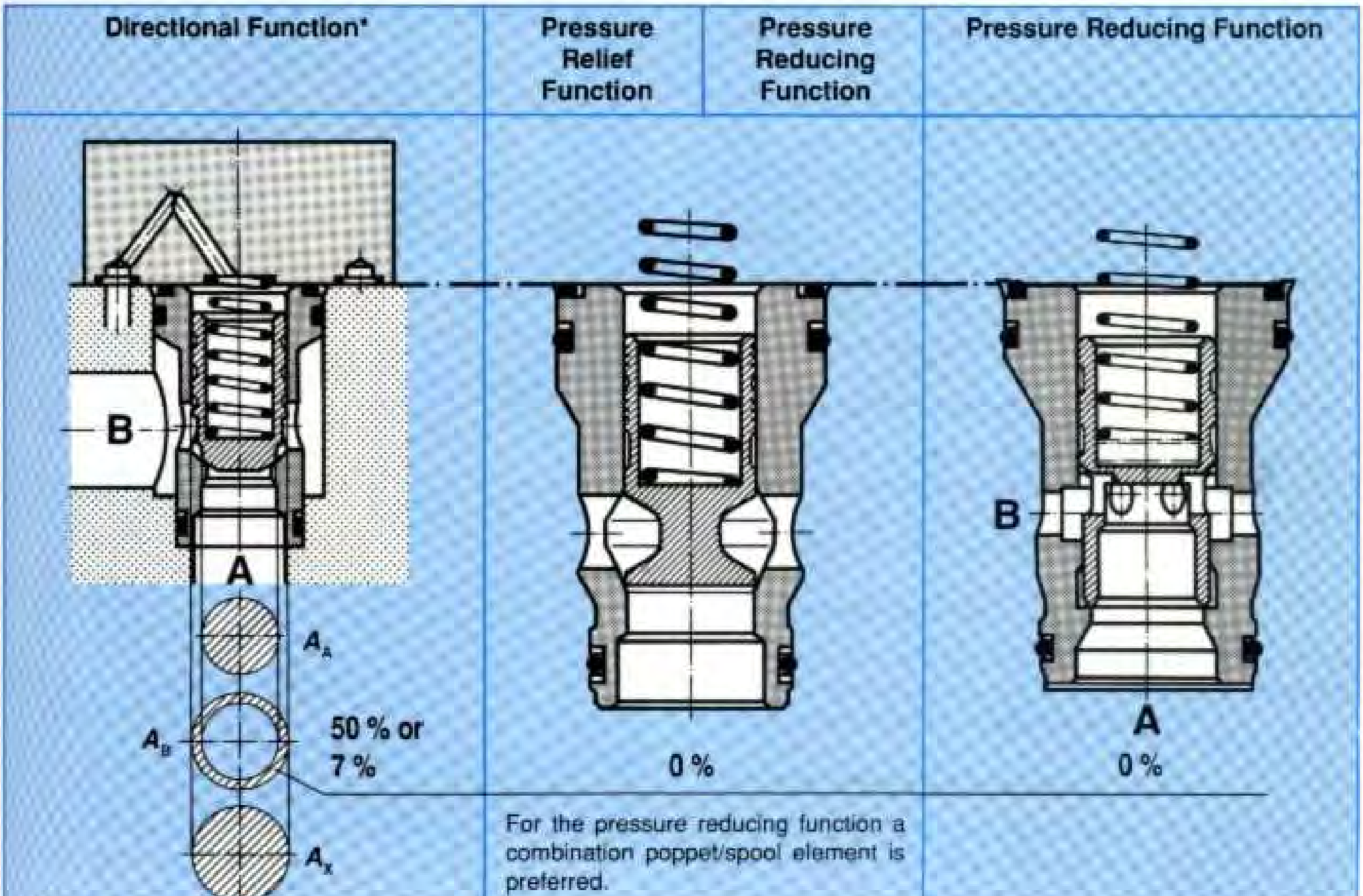


Fig. 27

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.

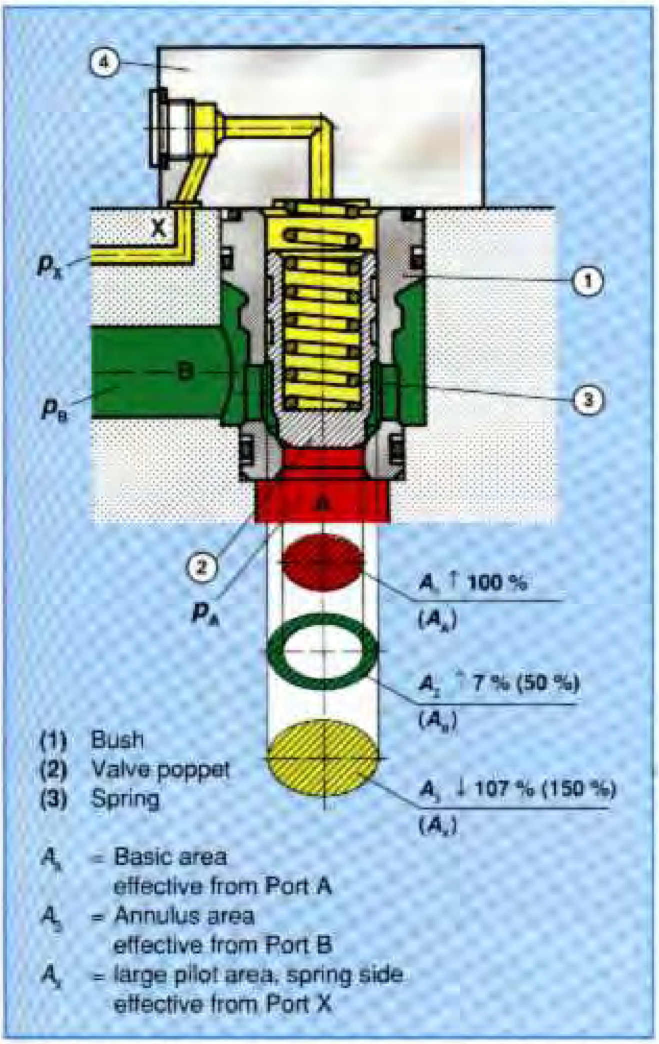


Fig. 28: *Basic logic element.*

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

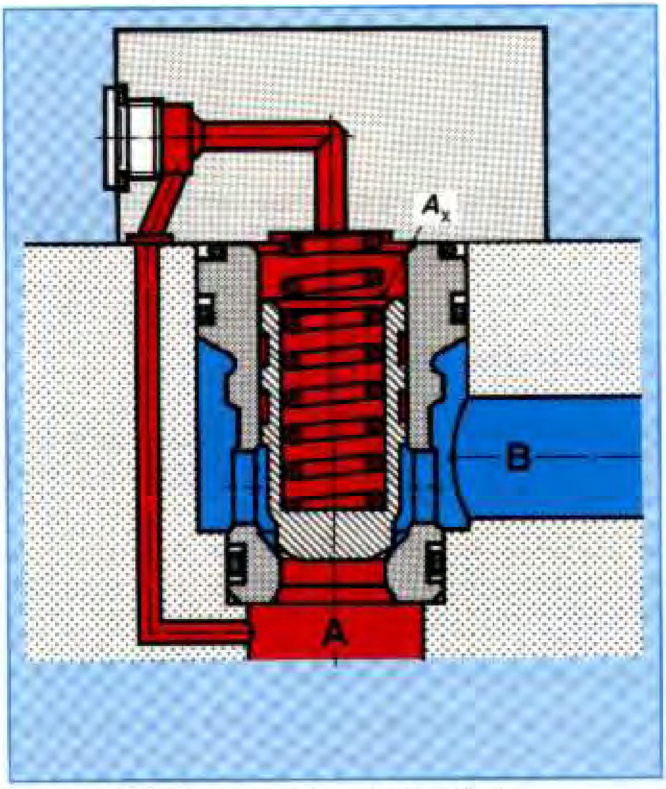


Fig. 29: *Logic element with control from side A.*

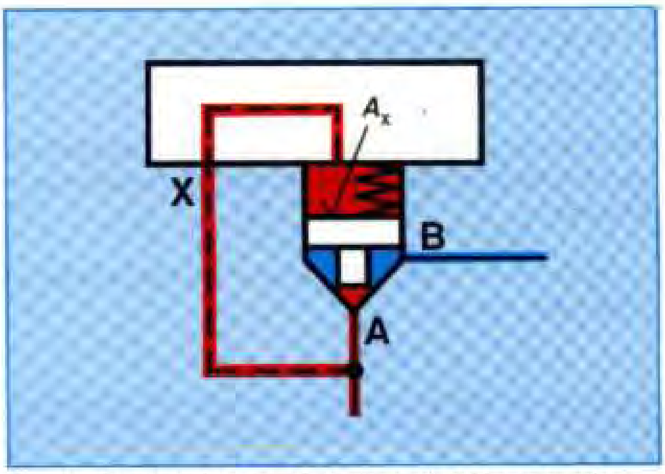


Fig. 30: *Symbol with schematic illustration of construction.*

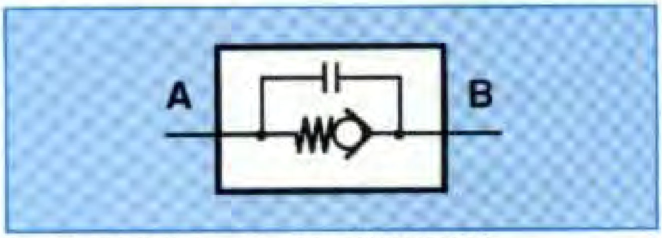


Fig. 31: *Symbol approximating DIN ISO 1219*

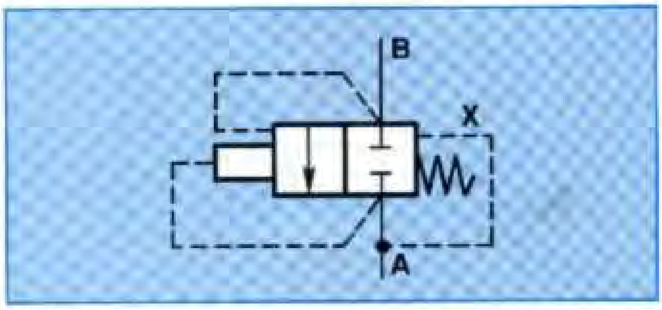


Fig. 32:
Symbol according to the illustration rules of DIN ISO 1219.

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.

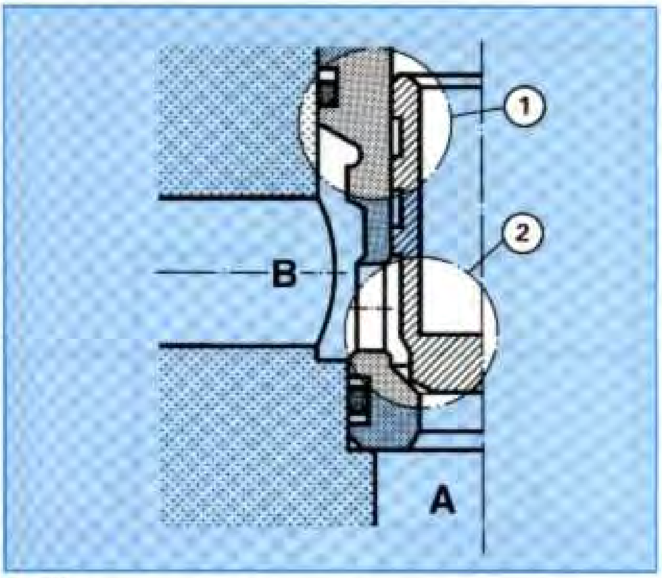


Fig. 33

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.

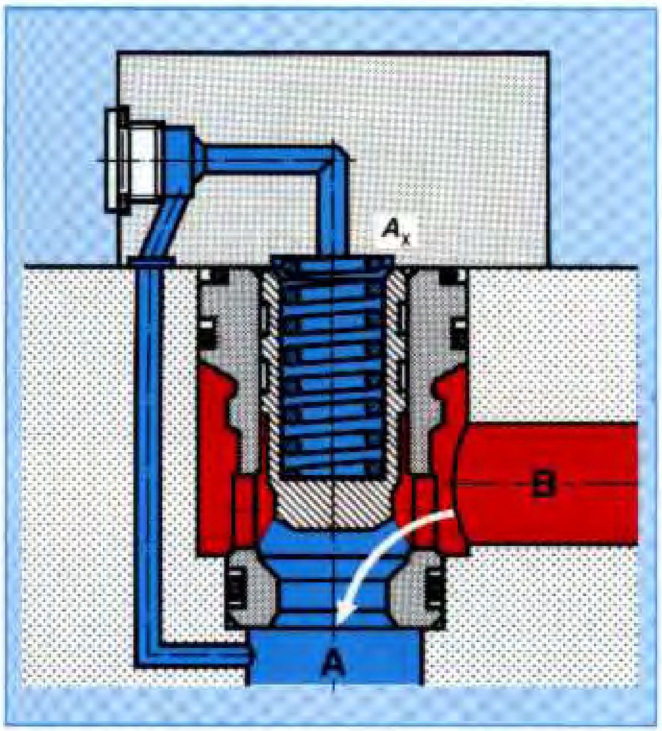


Fig. 34: *Illustration as Fig. 29, but with the valve poppet open (fluid flowing from B to A).*

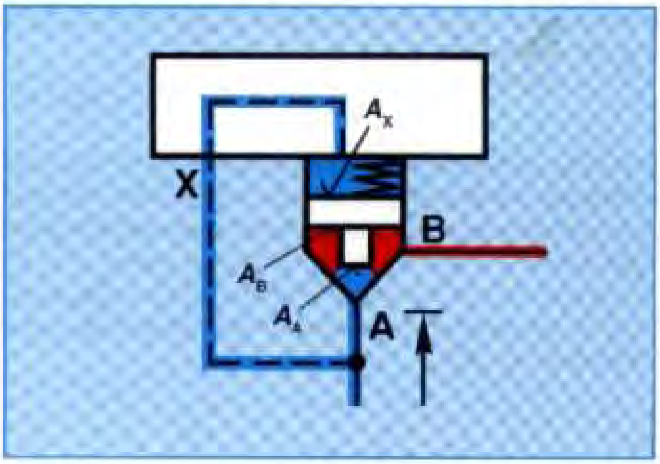


Fig. 35

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

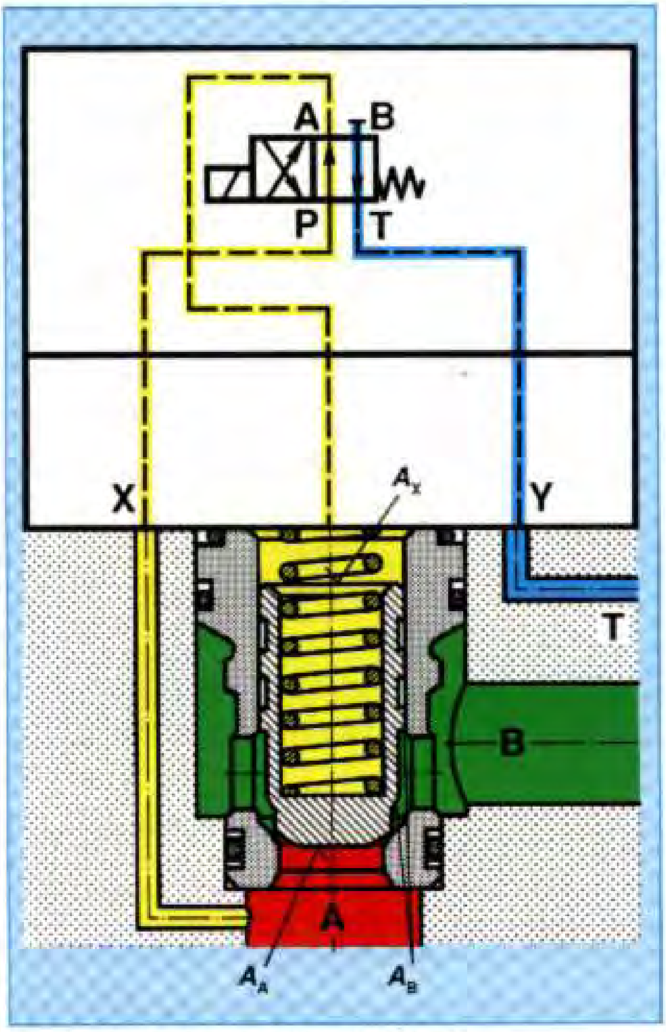


Fig. 36: *Logic element with control from A. Pilot valve in the control line.*

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)*.

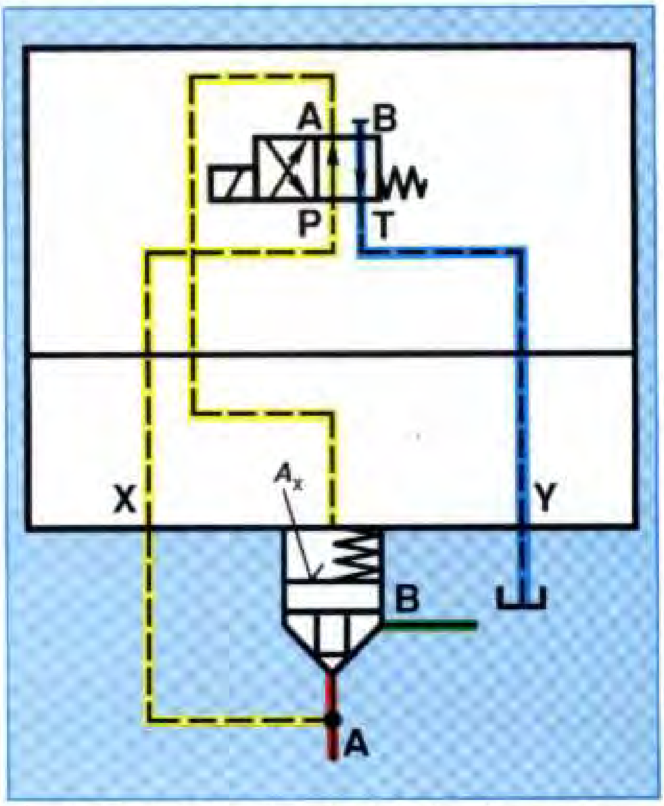


Fig. 37: *Symbol with schematic illustration of construction.*

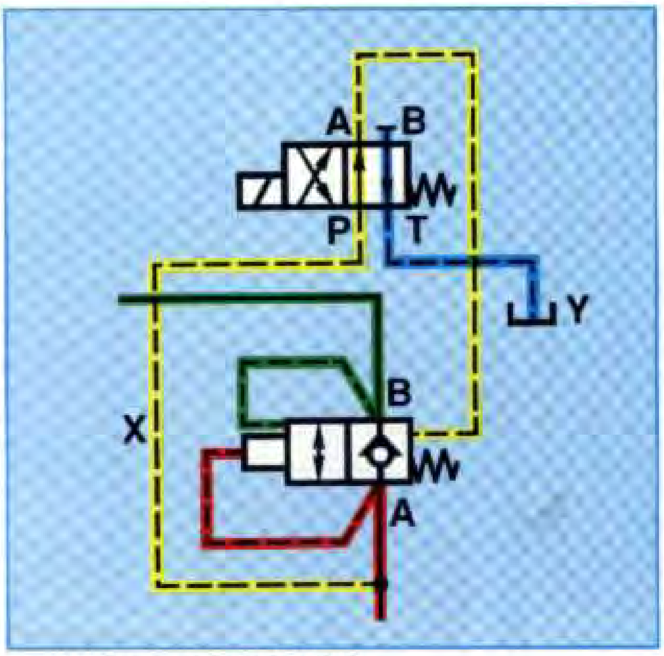


Fig. 38: *Symbol to DIN ISO 1219.*

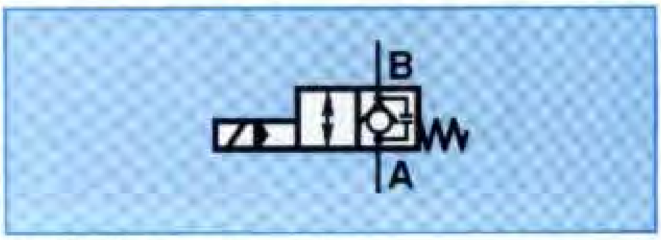


Fig. 39: *Replacement symbol.*

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 cm²
A_B (= A_2) = 2.74 cm²
A_X (= A_3) = 8.04 cm²

(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)

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

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

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

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

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.

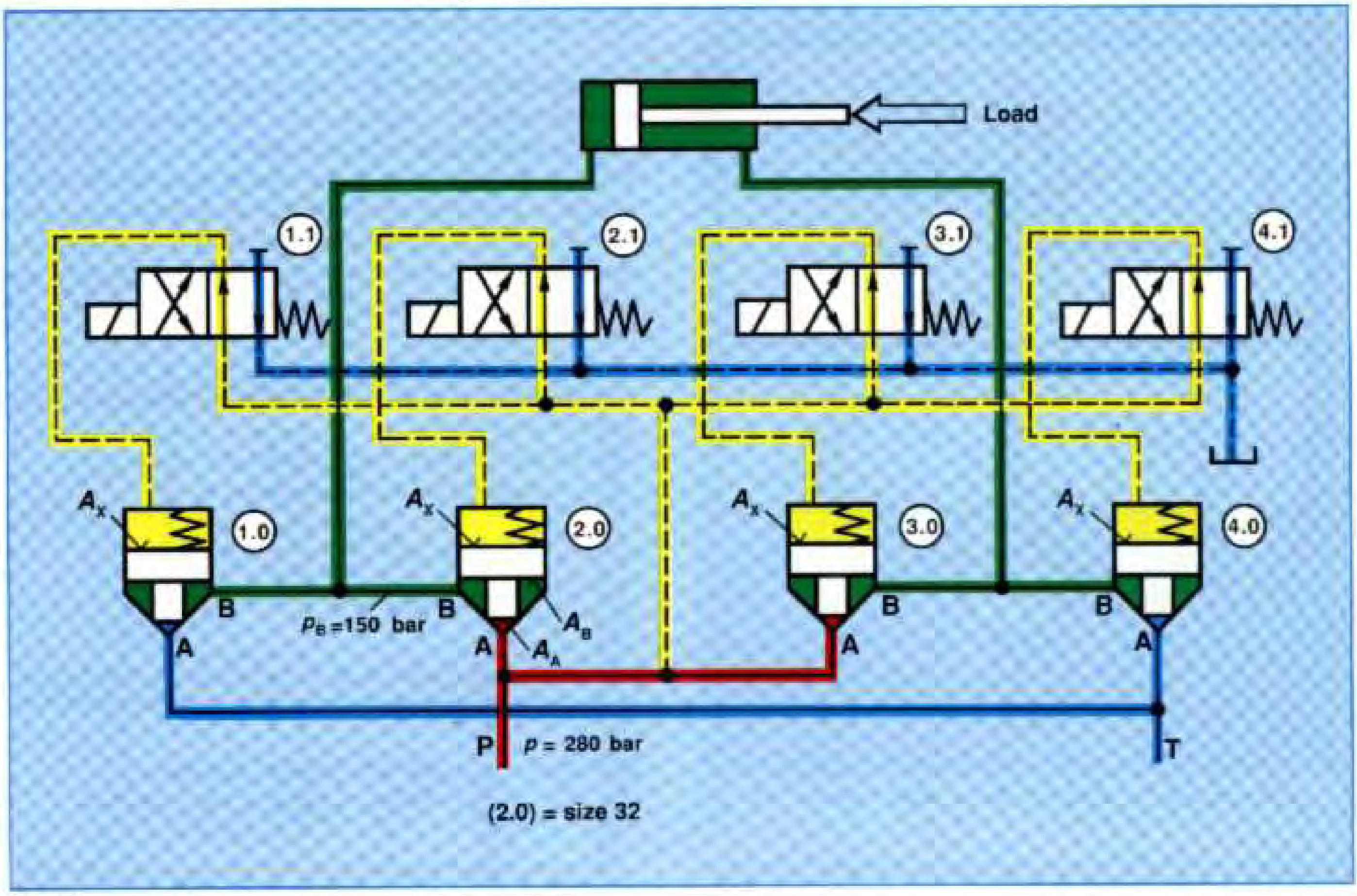


Fig. 40

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.

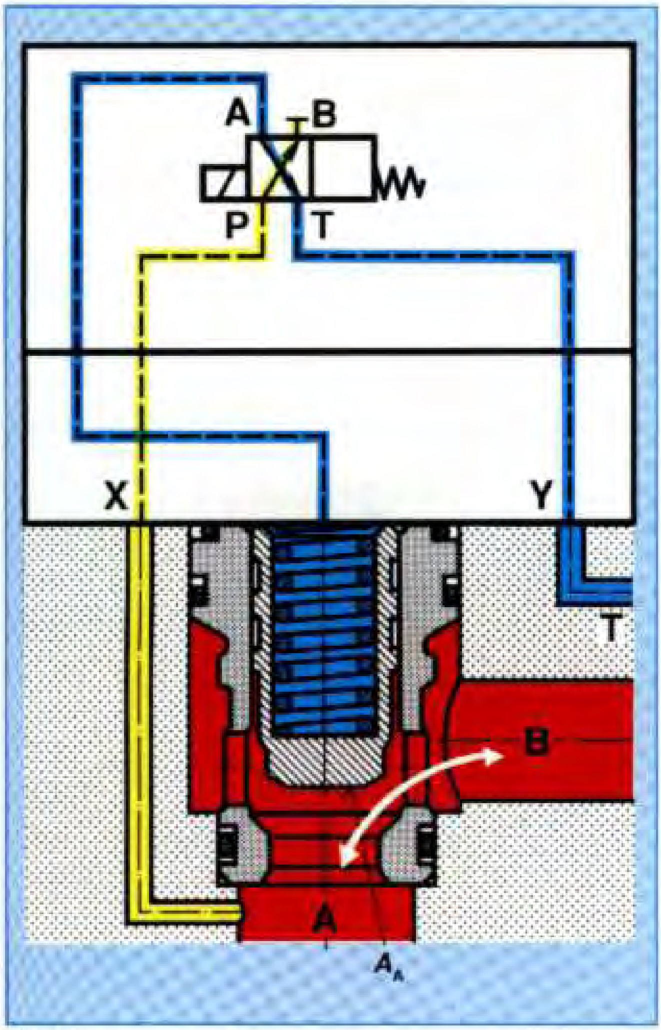


Fig. 41

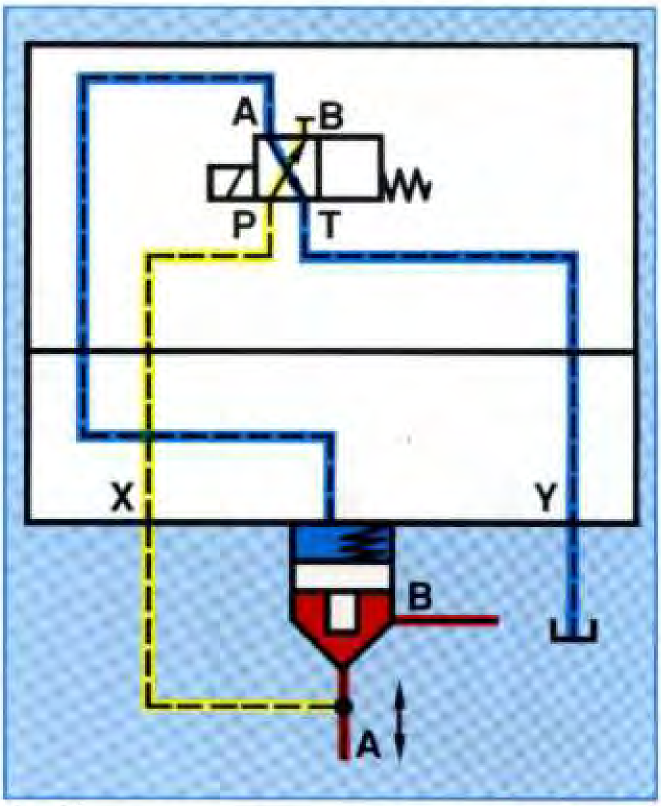


Fig. 42

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).

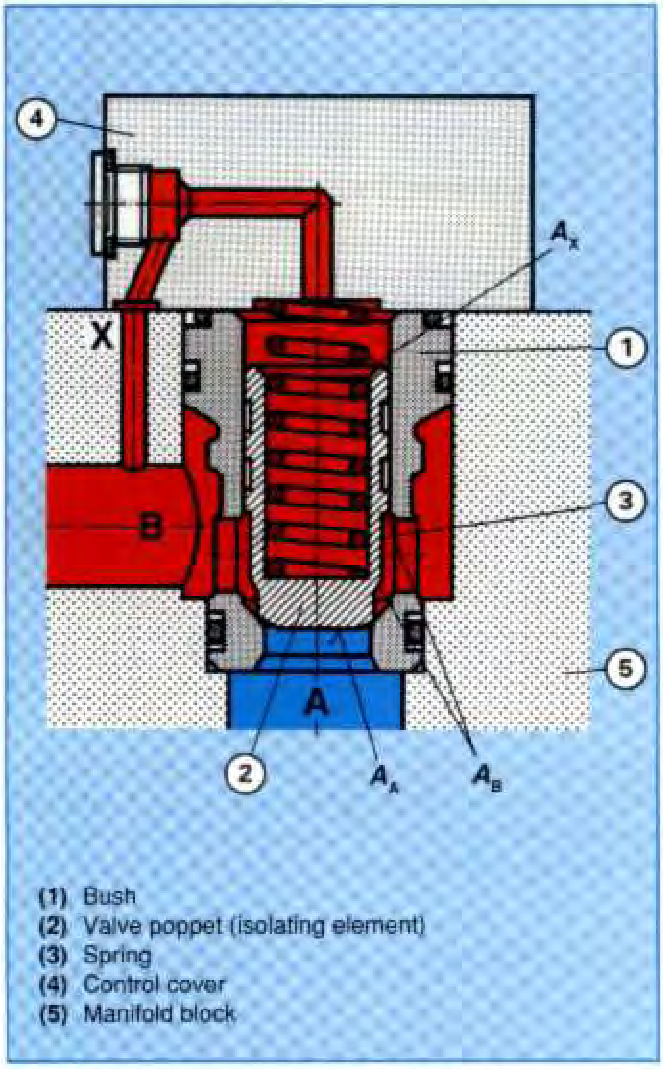


Fig. 43: *Logic element with control from Port B.*

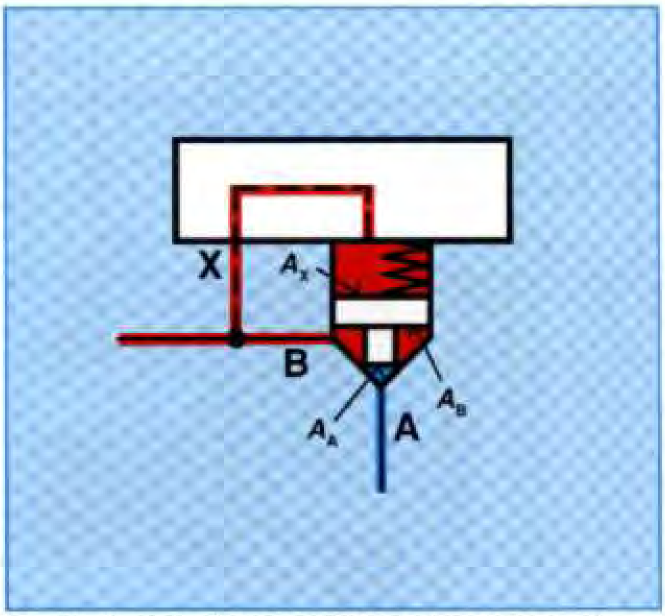


Fig. 44: *Symbol with schematic illustration of construction.*

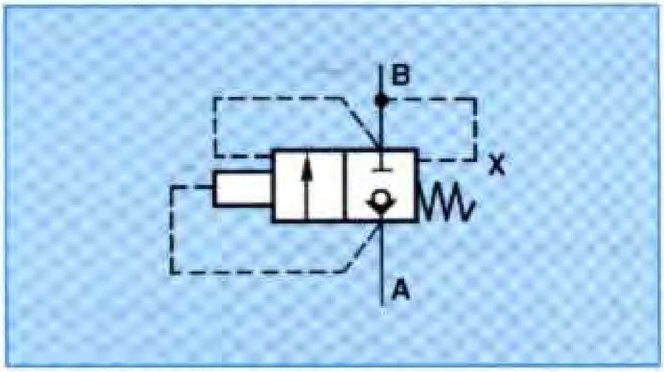


Fig. 45: *Symbol to DIN ISO 1219.*

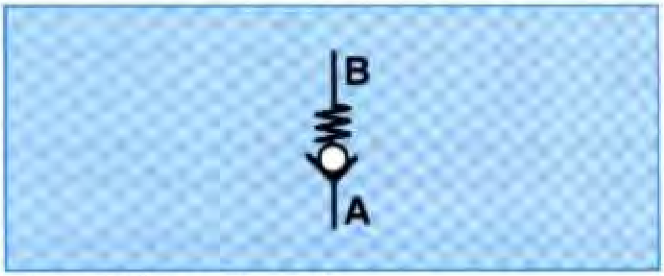


Fig. 46: *Replacement symbol.*

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.

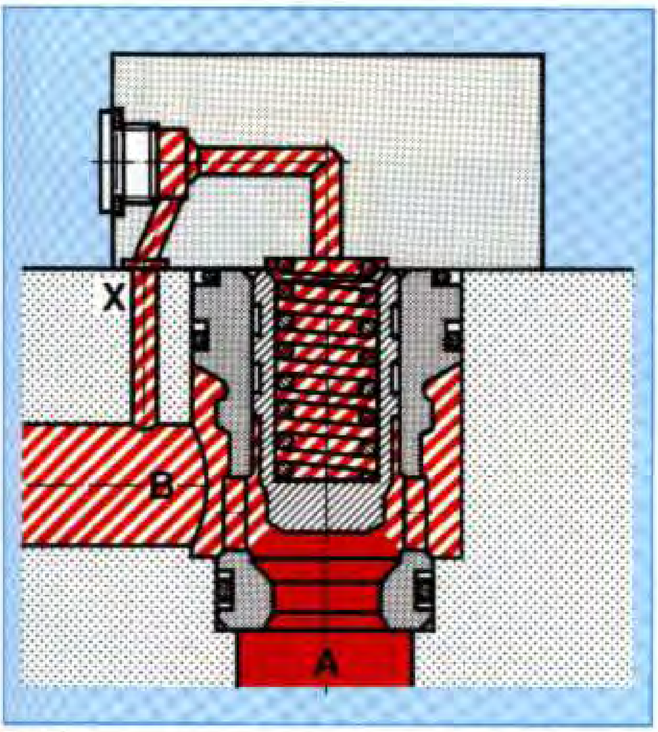


Fig. 47

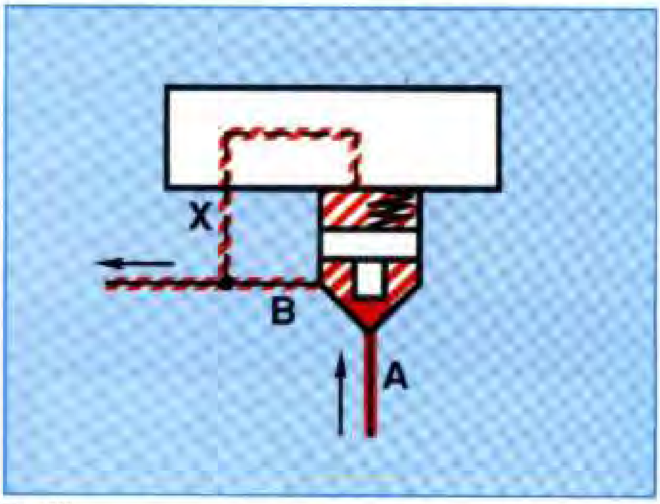


Fig. 48

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

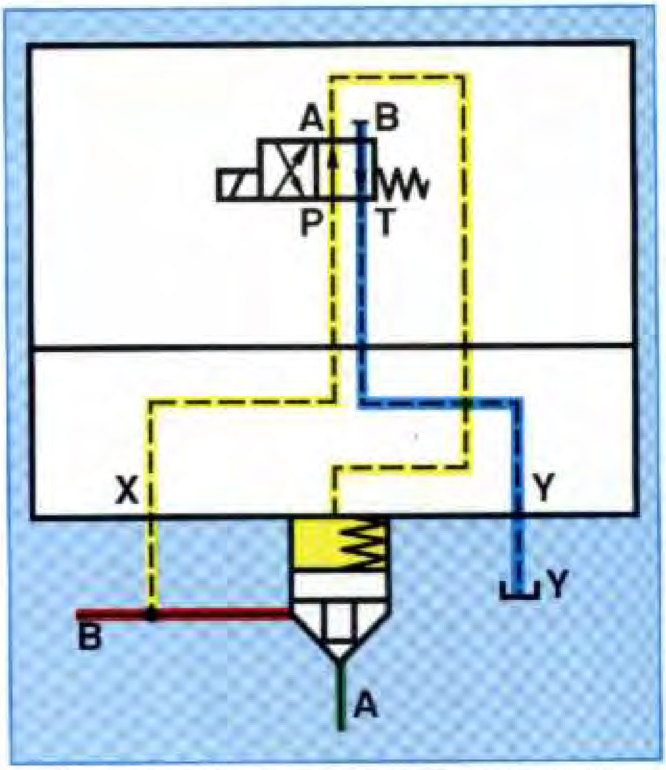
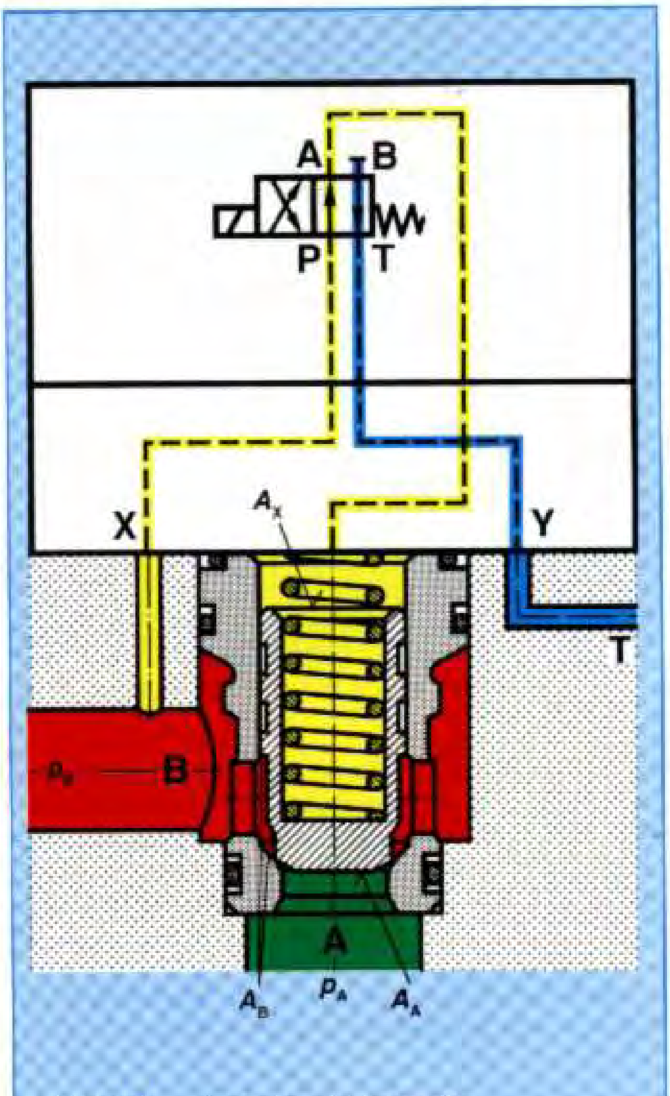


Fig. 50: *Symbol with schematic illustration of construction.*



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

Fig. 49

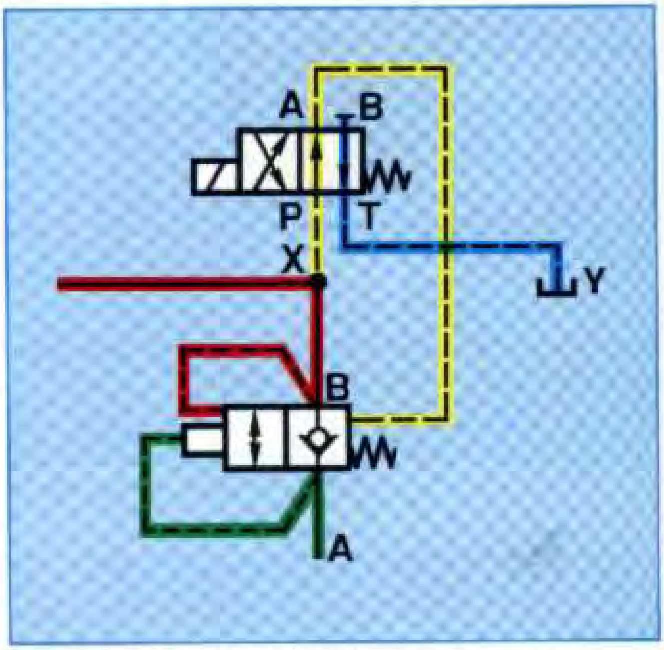


Fig. 51: *Symbol to DIN ISO 1219.*

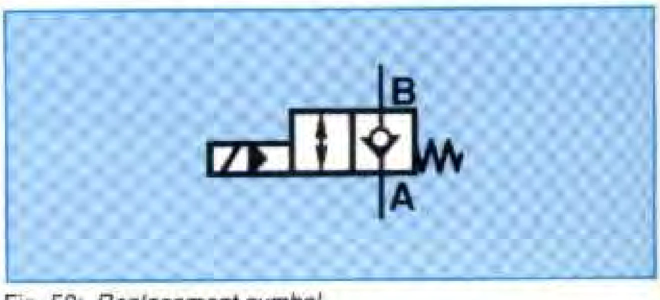


Fig. 52: *Replacement symbol.*

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.

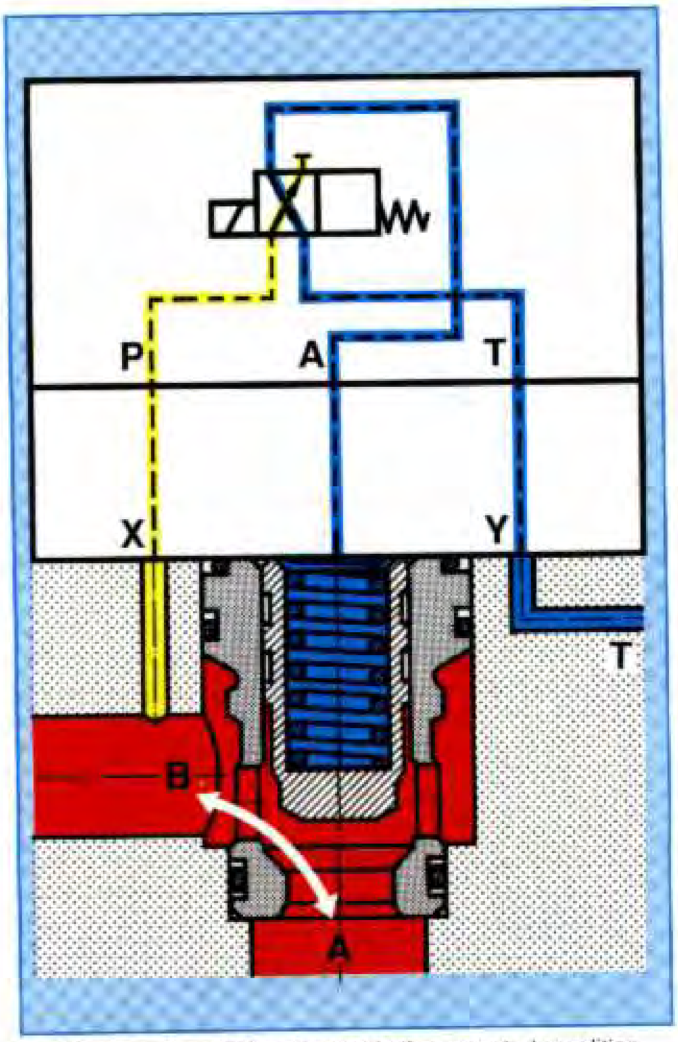


Fig. 53: *A section of the element in the operated condition.*

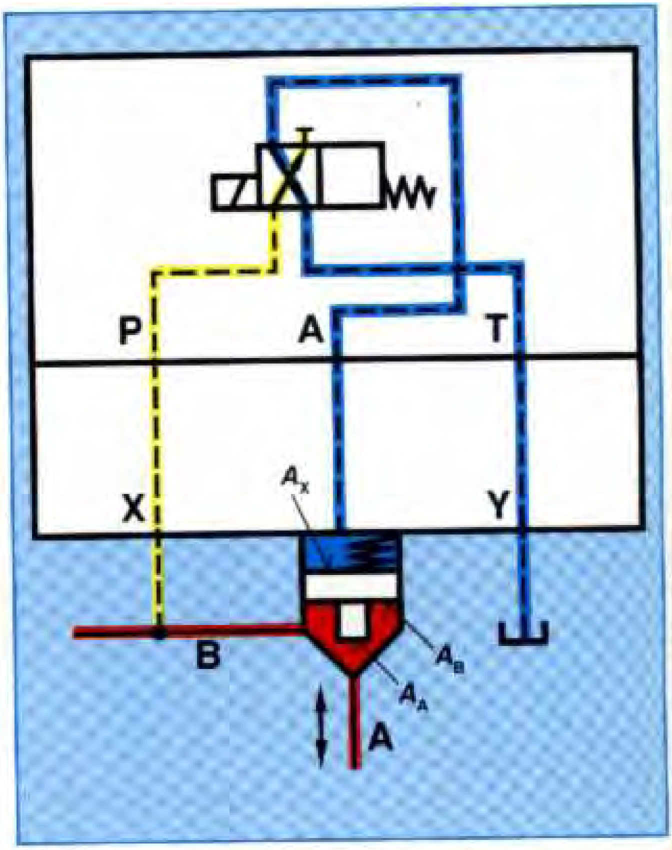


Fig. 54:
Schematic illustration of element in the operated condition.

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

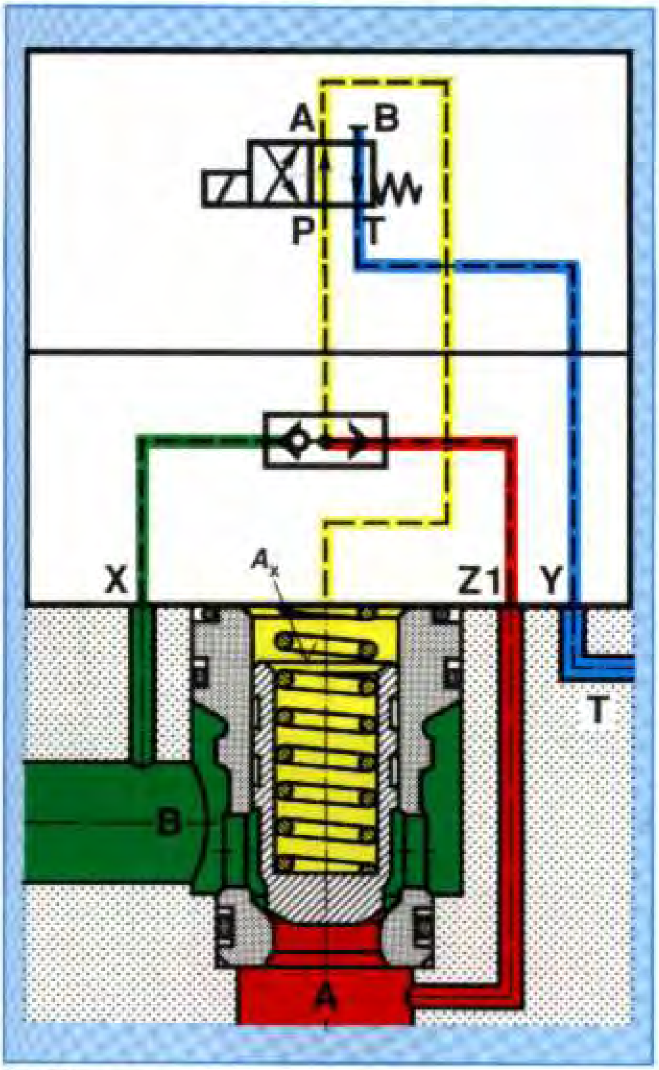


Fig. 55

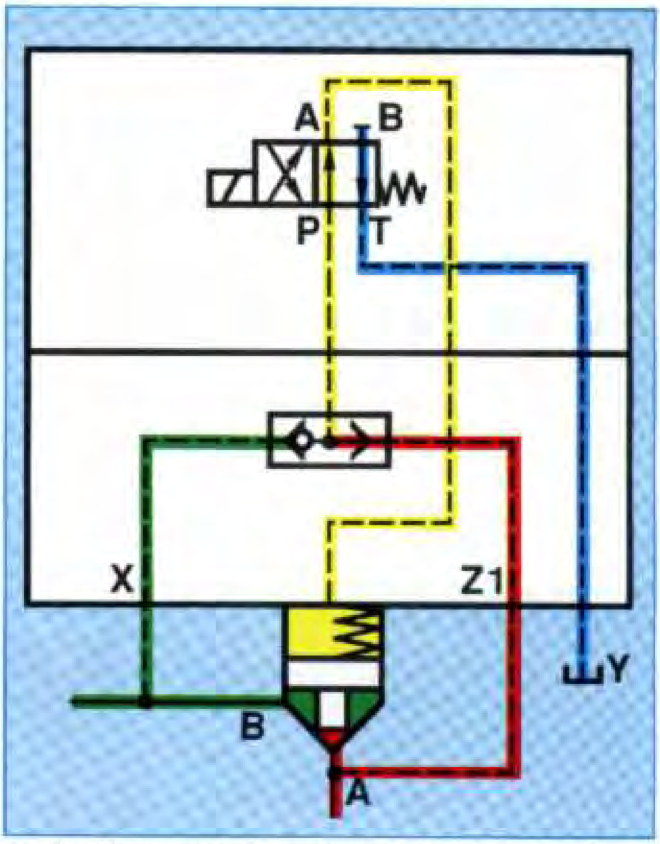


Fig. 56: *Symbol with schematic illustration of construction.*

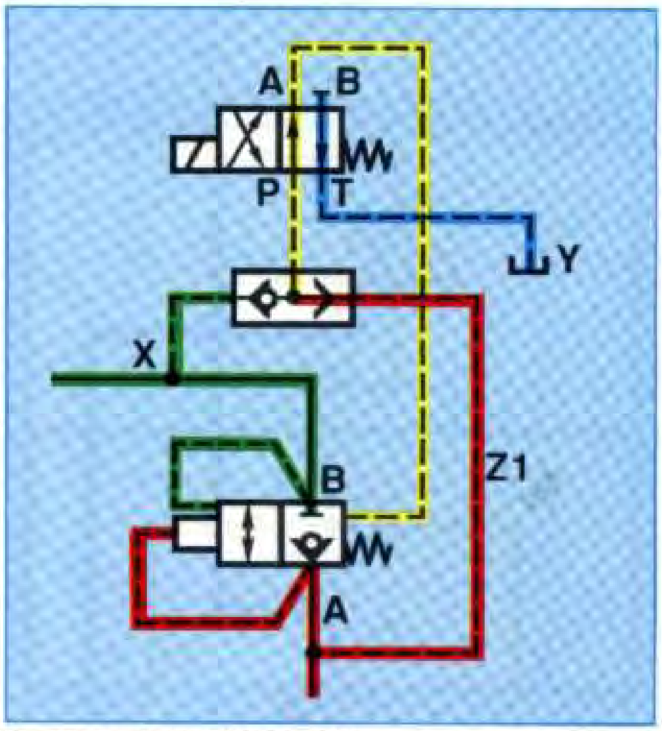


Fig. 57: *Symbol to DIN ISO 1219.*

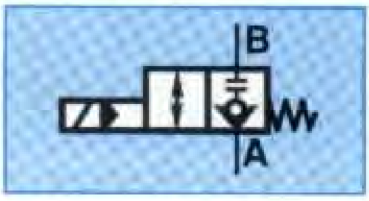


Fig. 58:
Replacement symbol.

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.

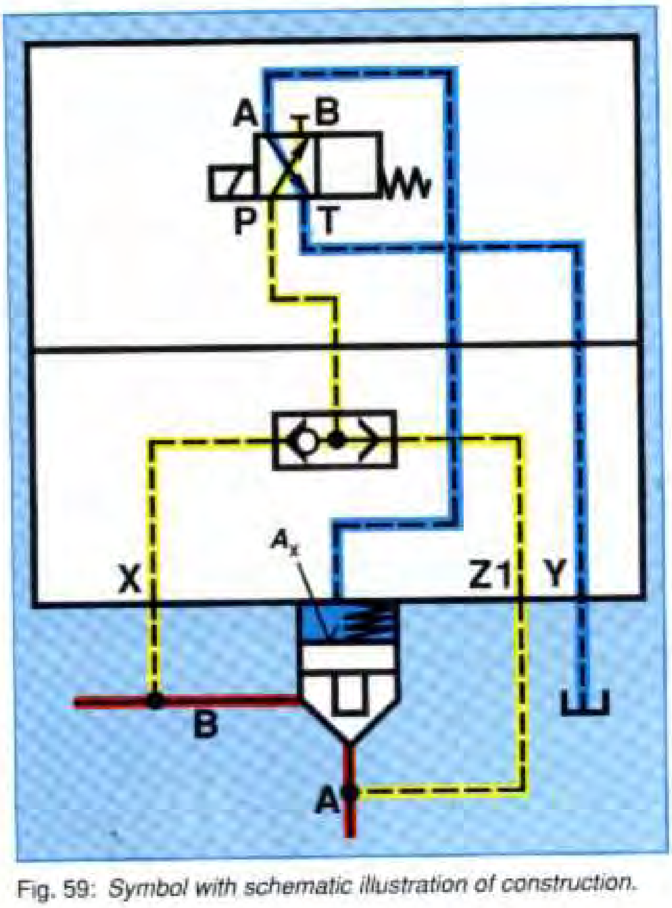


Fig. 59: *Symbol with schematic illustration of construction.*

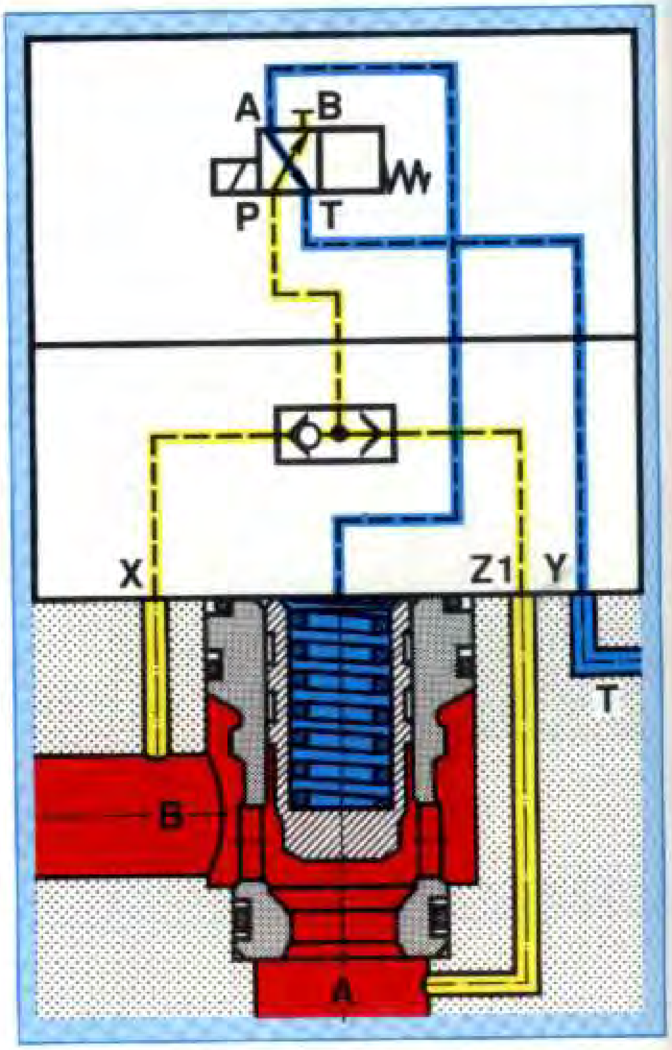
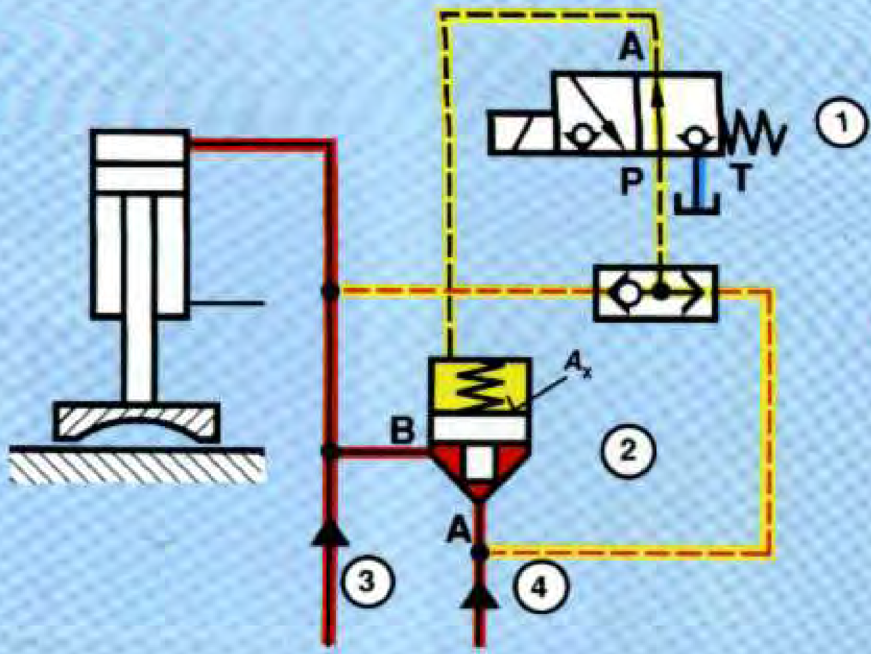


Fig. 60

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.

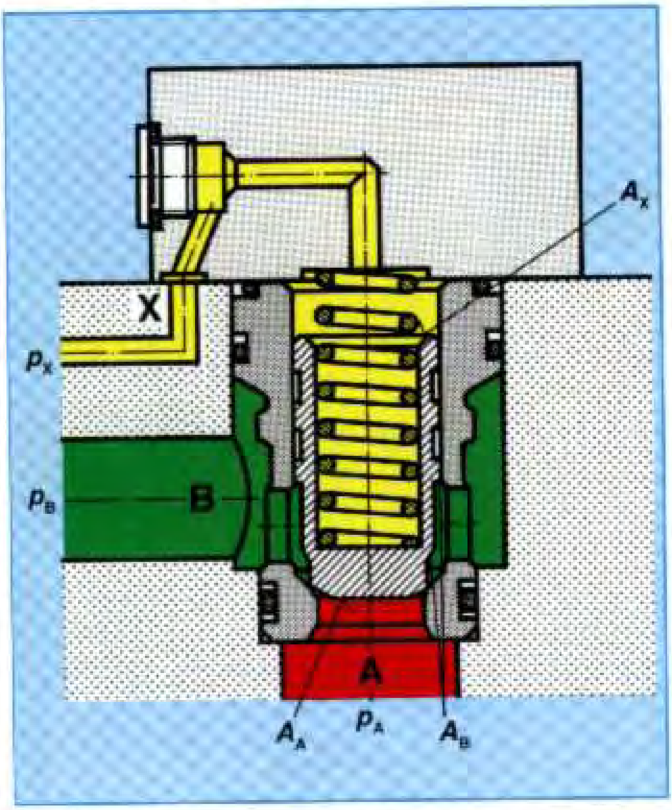


Fig. 62

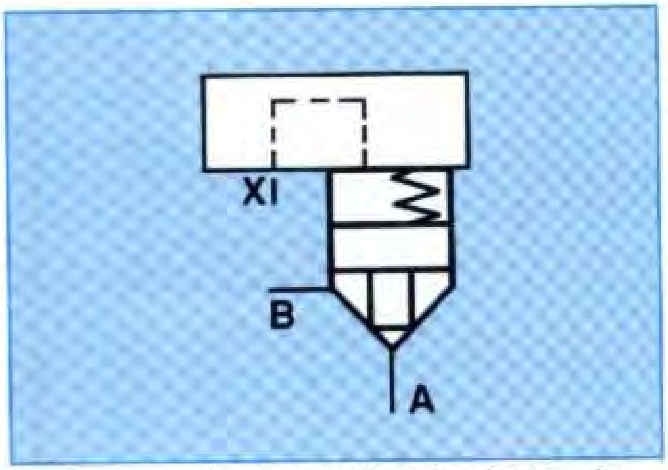


Fig. 63: *Symbol with schematic illustration of construction.*

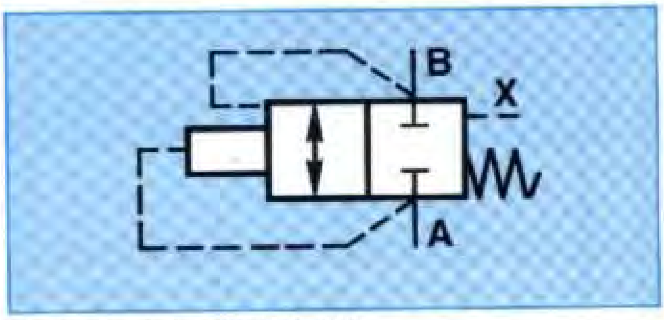


Fig. 64: *Symbol to DIN ISO 1219.*

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:

Forces in the opening direction

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

Forces in a closing direction

$F\downarrow = p_A \cdot A_X$ + 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".

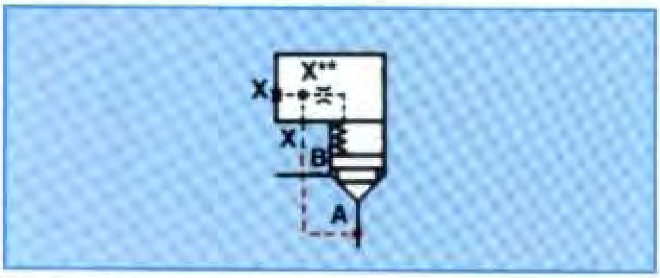


Fig. 65: *Control cover with remote control connections.*

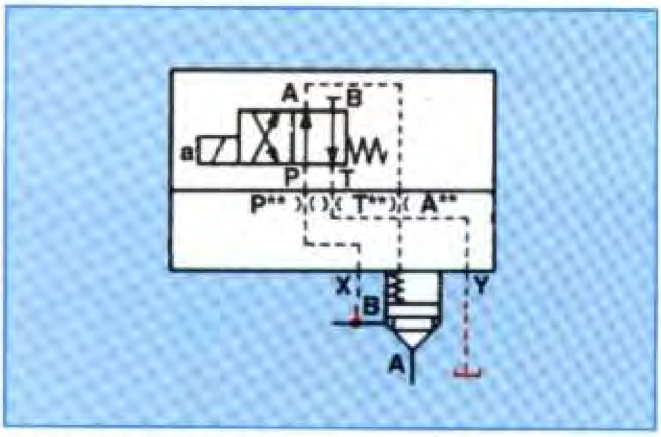


Fig. 66: *Control cover to accept a directional spool valve, or a directional poppet valve.*

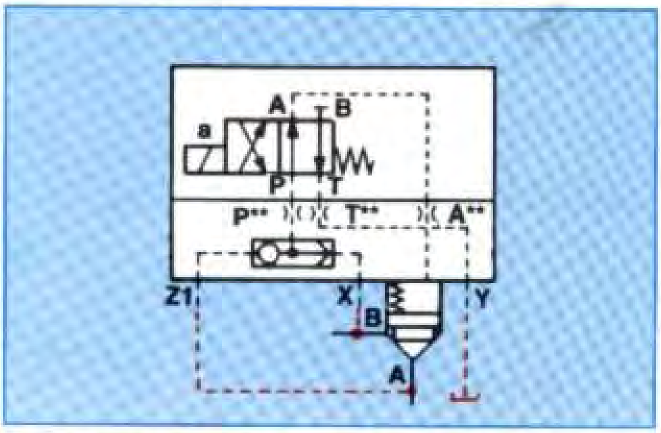


Fig. 67: *Control cover with built-in shuttle valve to accept a directional spool valve or a directional poppet valve.*

Directional Functions: Variations and Application Notes.

1 Area ratios on the valve poppet.

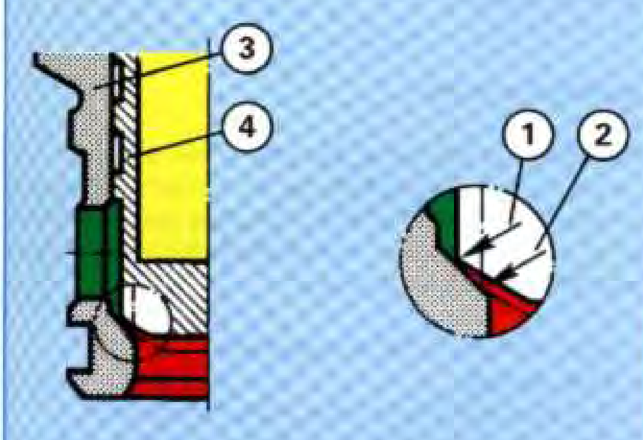
When studying the basic element, it becomes clear that three areas and the pressures working on these areas are important when considering the functioning of the element:

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.

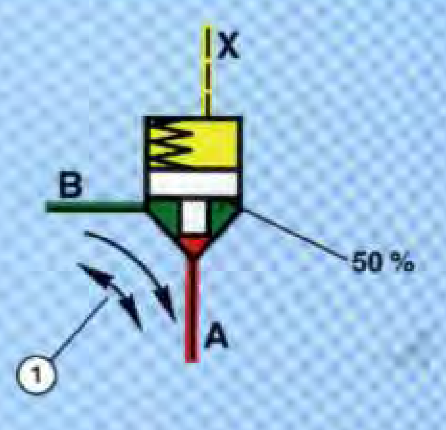
To take a numerical example:

Logic element size 25:

	annular area 50 %	annular area 7 %
Area A_X	4.91 cm²	4.91 cm²
Area A_A	3.30 cm²	4.60 cm²
Area A_B	1.61 cm²	0.31 cm²
Area ratio A_A: A_B	= 2:1	14.3:1

Table 1

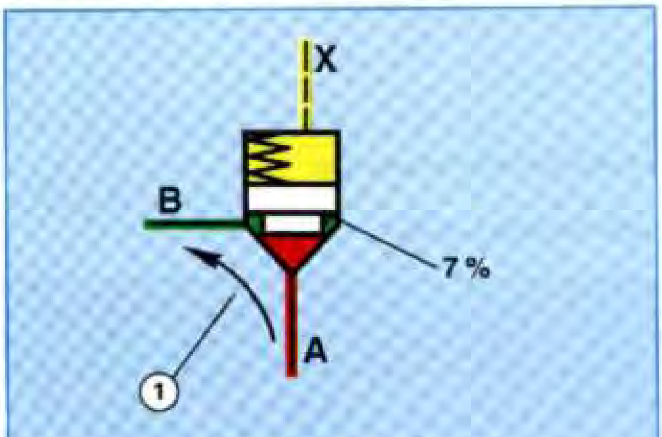
If the directional flow is to be exclusively from B to A then the model with A_B = 50% should preferably be employed *(Fig.69)*.



(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).



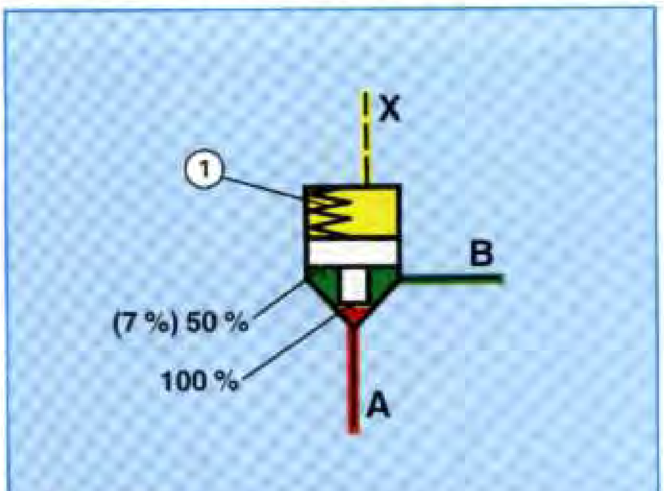
(1) Recommended direction of flow

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 A_B	Cracking pressure for flow direction 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)*.

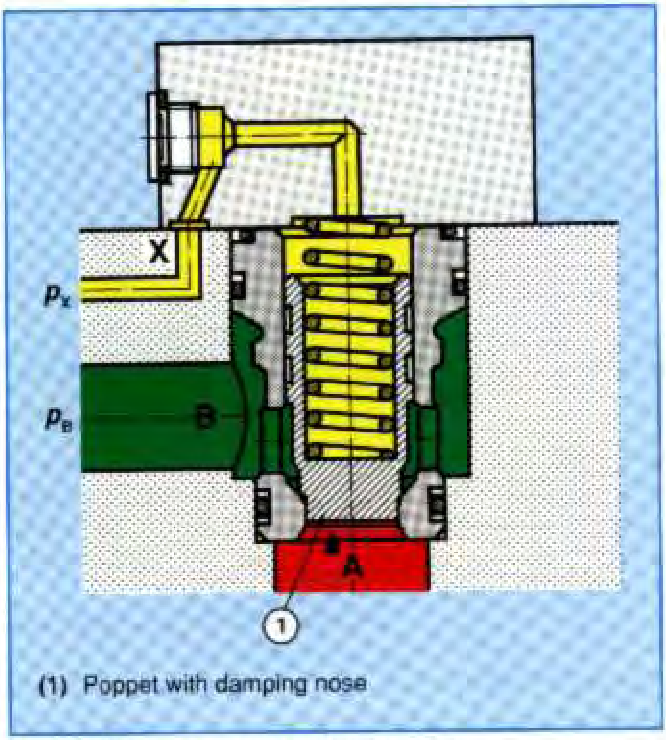


Fig. 72: *Logic element with damping nose.*

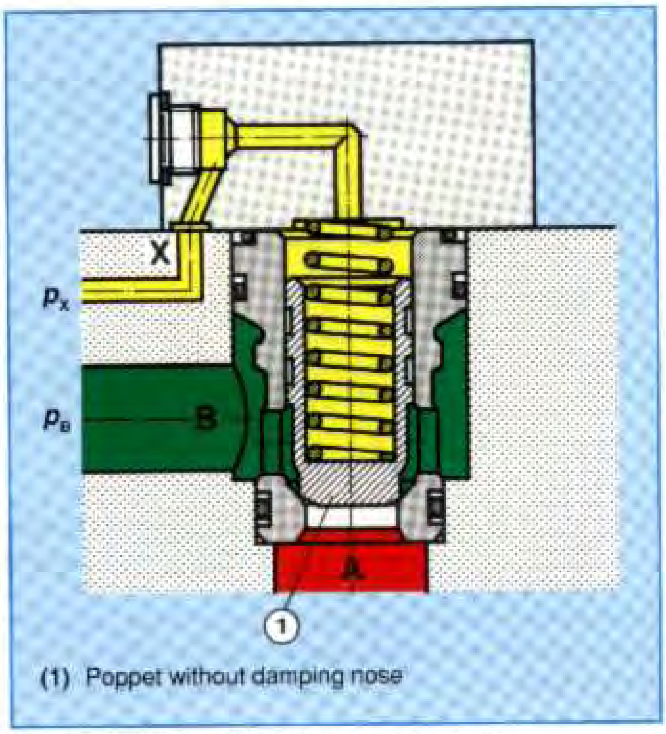


Fig. 75: *Logic element without damping nose.*

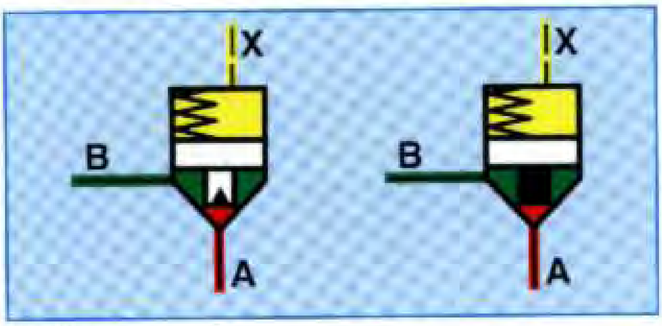


Fig. 73:
Schematic symbols of a logic element with a damping nose.

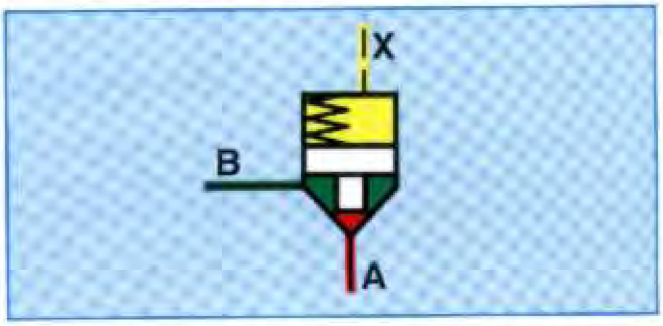


Fig. 76:
Schematic symbol of a logic element without a damping nose.

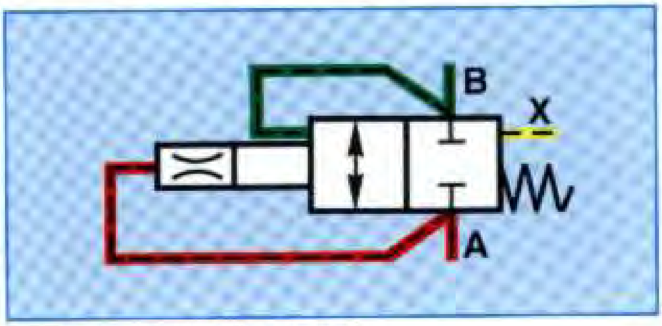


Fig. 74: *Symbol to DIN ISO 1219*

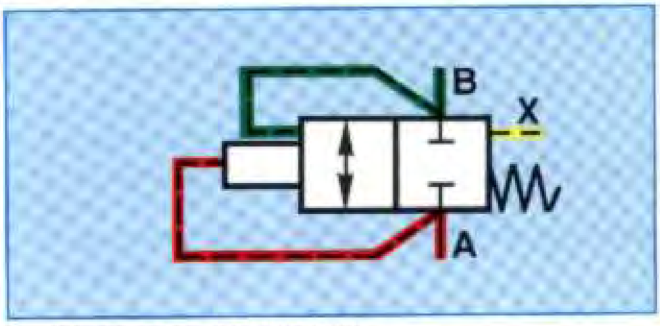


Fig. 77: *Symbol to DIN ISO 1219.*

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

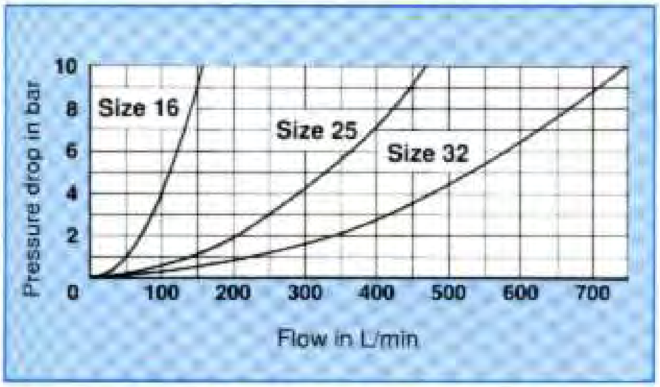


Diagram 1: *Pressure drop - flow curve for logic elements with damping nose.*

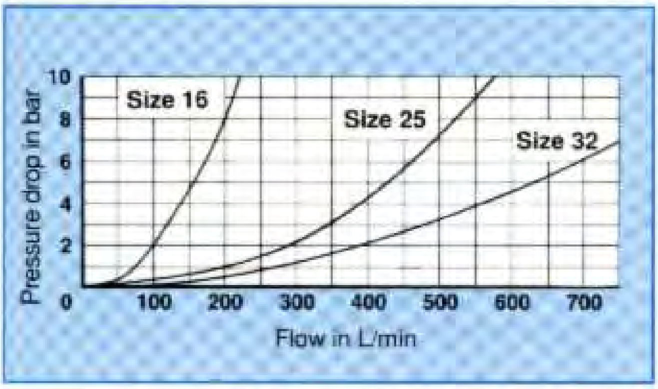


Diagram 2: *Pressure drop - flow curve for logic elements without damping nose.*

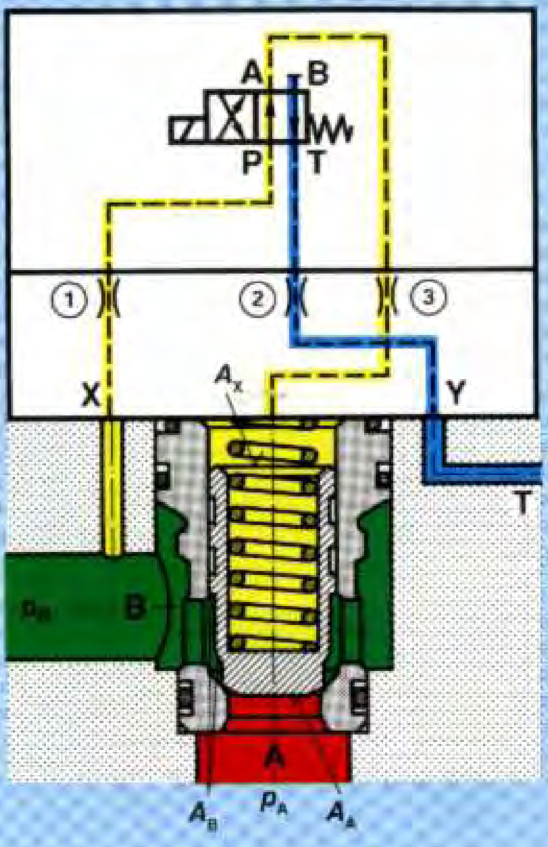
Typical examples of logic elements applied with a damping nose:

- 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 cm³

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

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

– 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

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

– 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 $\Delta p = 185$ 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

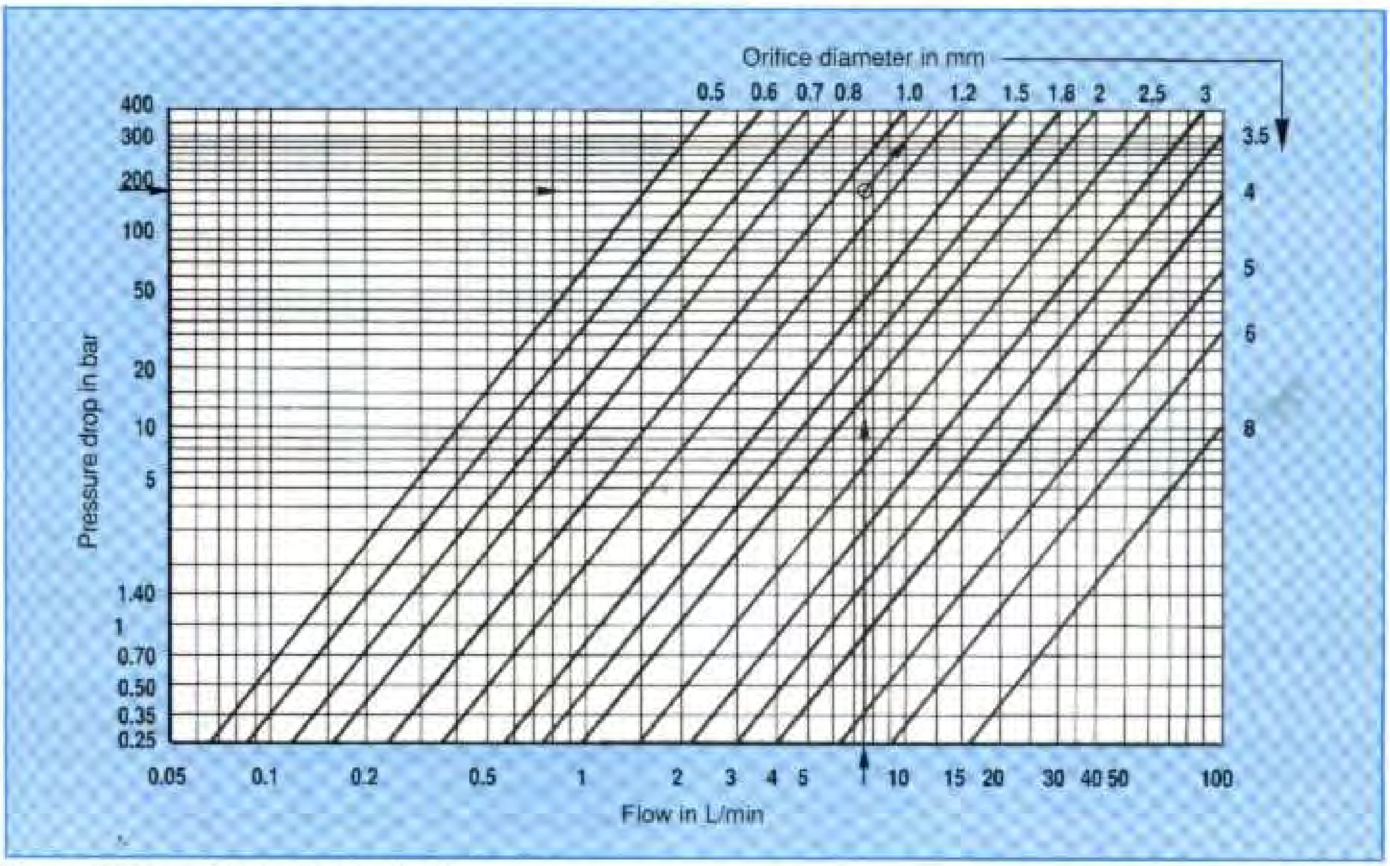


Diagram 3: *Curves for the selection of orifices*

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.

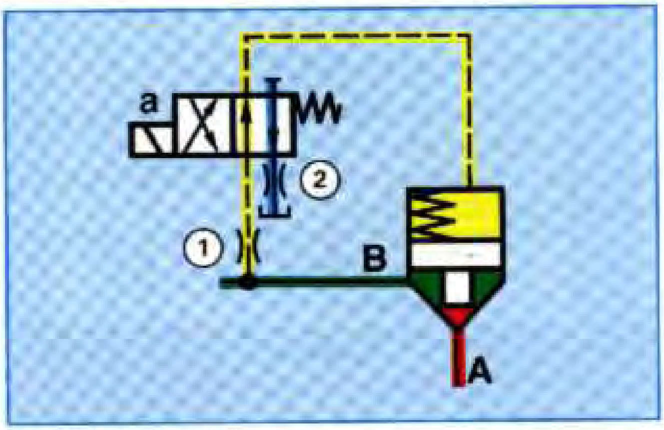


Fig. 79: Active control

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).*

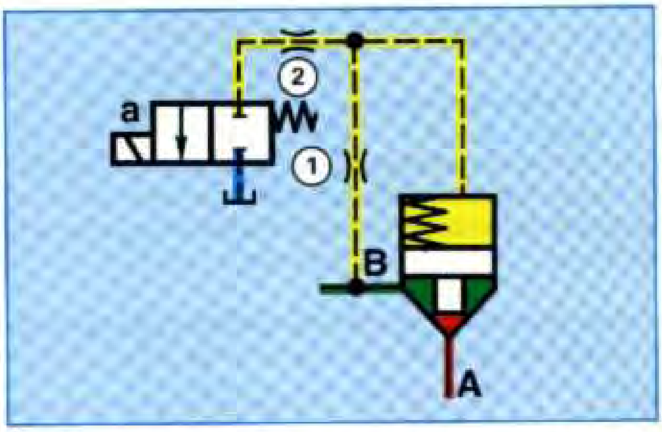


Fig. 80

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).

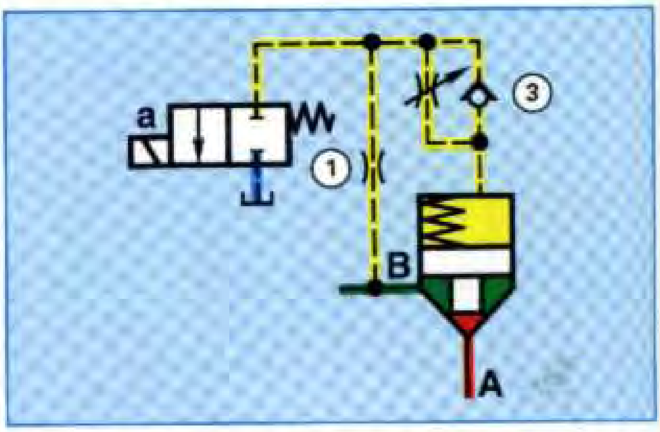


Fig. 81

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)*

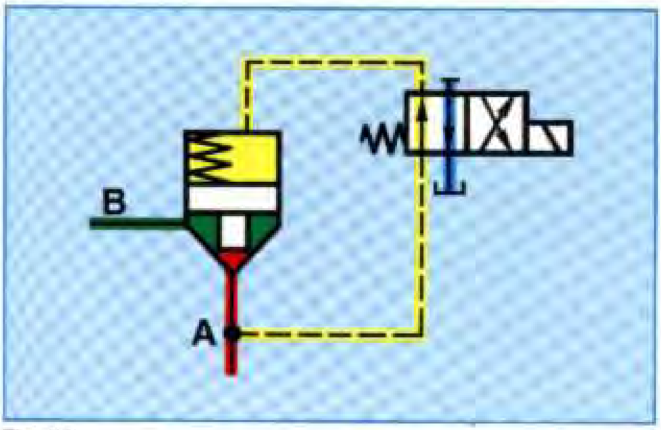


Fig. 82

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)*

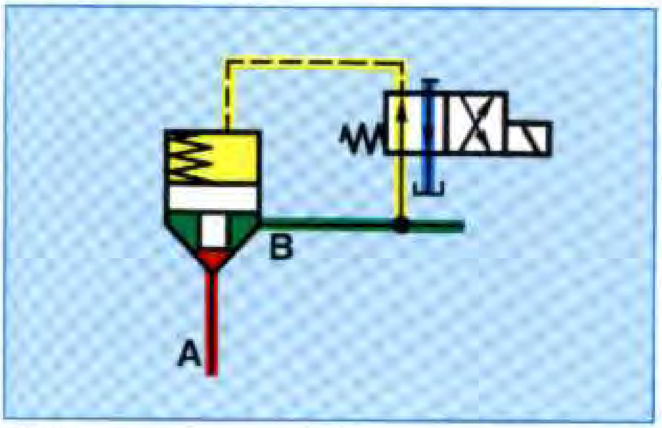


Fig. 83

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.

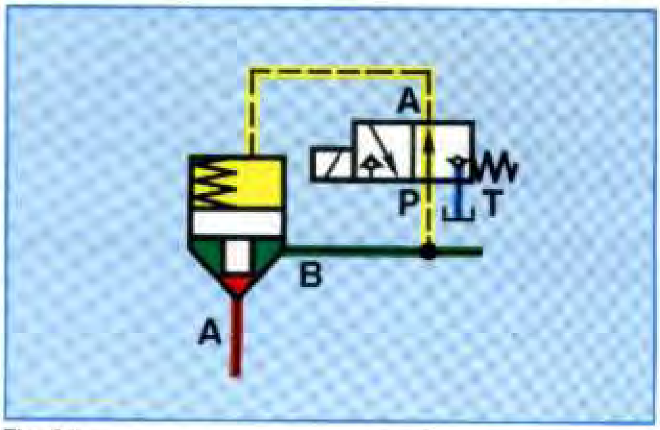


Fig. 84

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.

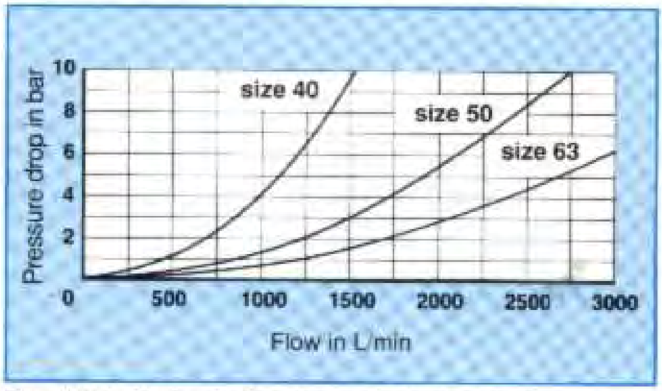


Diagram 4: *Pressure drop curves for logic element without damping nose.*

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.

Logic Elements, Pressure Control Functions

In the introduction to 2 way logic elements it was mentioned that these could also be used as pressure control elements. In this respect, they are effectively pilot operated pressure valves which are available in the following models:

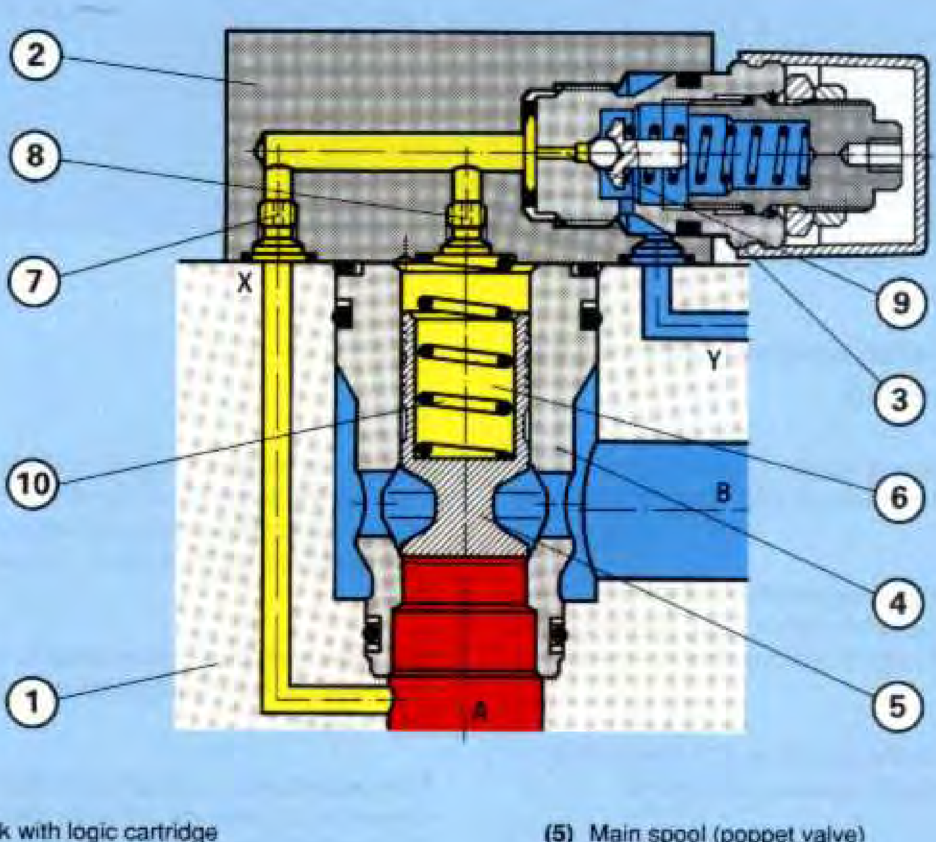
as pressure relief elements

as pressure reducing elements

as pressure sequence elements.

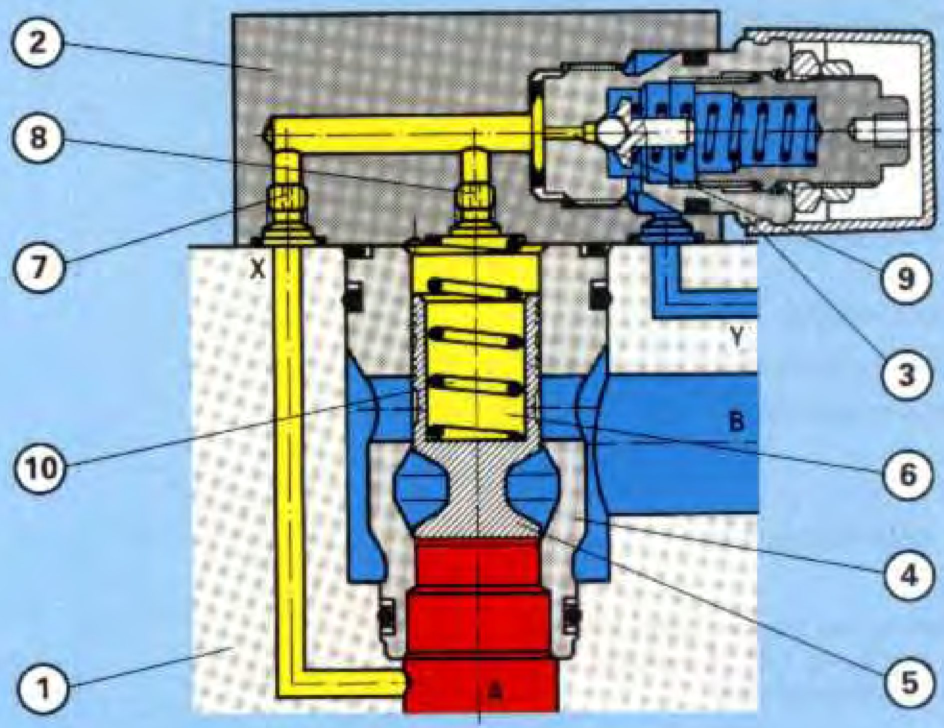
1 Pressure relief function

The cartridge element for the pressure relief function (bush (4), spool (5), and spring (10)) is available as a poppet valve or as a poppet/spool valve.



(1) Manifold block with logic cartridge (Bush, poppet valve and spring)
(2) Control cover
(3) Pilot valve (direct operated relief valve)
(4) Bush
(5) Main spool (poppet valve)
(6) Spring chamber
(7) and **(8)** Orifices in control line
(9) Control line
(10) Spring

Fig. 85: *Cartridge set with poppet element*



(1) Manifold block with logic cartridge (Bush, poppet valve and spring)
(2) Control cover
(3) Pilot valve (direct operated relief valve)
(4) Bush
(5) Main spool (poppet/spool valve)
(6) Spring chamber
(7) and (8) Orifices in control line
(9) Control line
(10) Spring

Fig.86: *Cartridge set with poppet/spool element*

1.1 Pressure relief function with manual pressure setting

At rest, the spool (poppet valve or poppet/spool valve) separates port A (the pressure port) from B (the tank port).

In contrast to a directional logic element, a pressure logic element for a pure pressure function, has no working area at port B. This means that the annulus area A_B is no longer present.

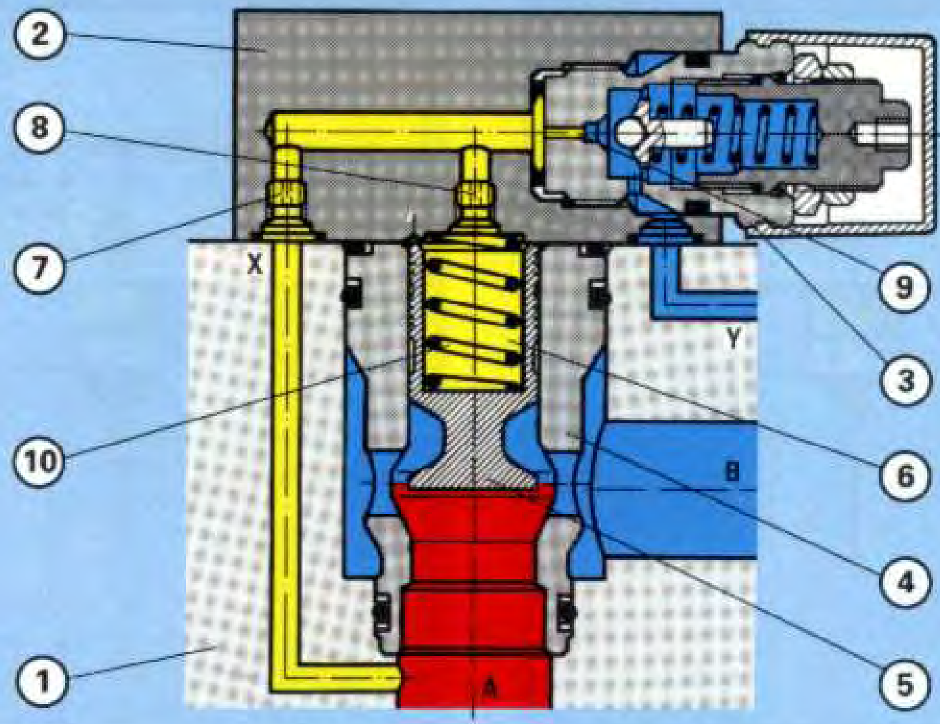
Pressure setting is via the pilot valve (3). The pilot valve itself is a direct operated pressure relief valve.

Function

Pressure present at port A passes to the pilot valve (3) via the control line *(yellow)*, orifice (7) and control line (9) and via the further orifice (8) to the spring loaded side of the main spool. At rest, i.e. when the pressure in the system is lower than the value set at the pilot valve, the same pressure is present on both ends of the spool. As the areas are the same, the forces are also equal. Spring (10) therefore holds the spool in the start position shown *(Figs. 85 and 86)* and ports A and B are separated from each other.

When the system pressure reaches the level set at the pilot valve (3), fluid flows via the orifices in the control line to tank via Y.

A pressure drop occurs across orifice (7) which causes a difference in pressure between the ends of the main spool. When the upward force produced by a product of the pressure drop and the spool area becomes greater than spring force 10, the spool moves upwards and excess fluid can flow from A to B and thus to tank. *(Fig.87)*. The pressure in port A is thus limited to the set value.



(1) Manifold block with logic cartridge (Bush, poppet/spool valve and spring)
(2) Control cover
(3) Pilot valve (direct operated relief valve)
(4) Bush
(5) Main spool (poppet/spool valve)
(6) Spring chamber
(7) and (8) Orifices in control line
(9) Control line
(10) Spring

Fig. 87

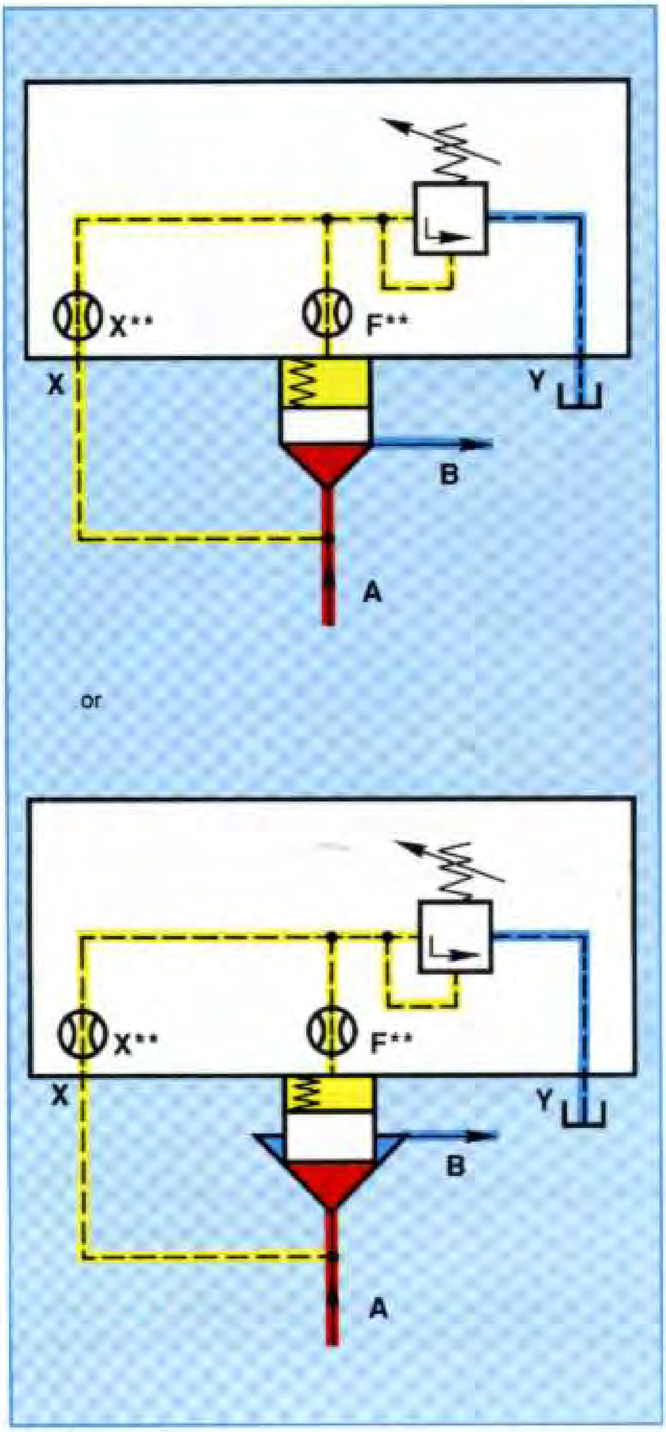


Fig. 88

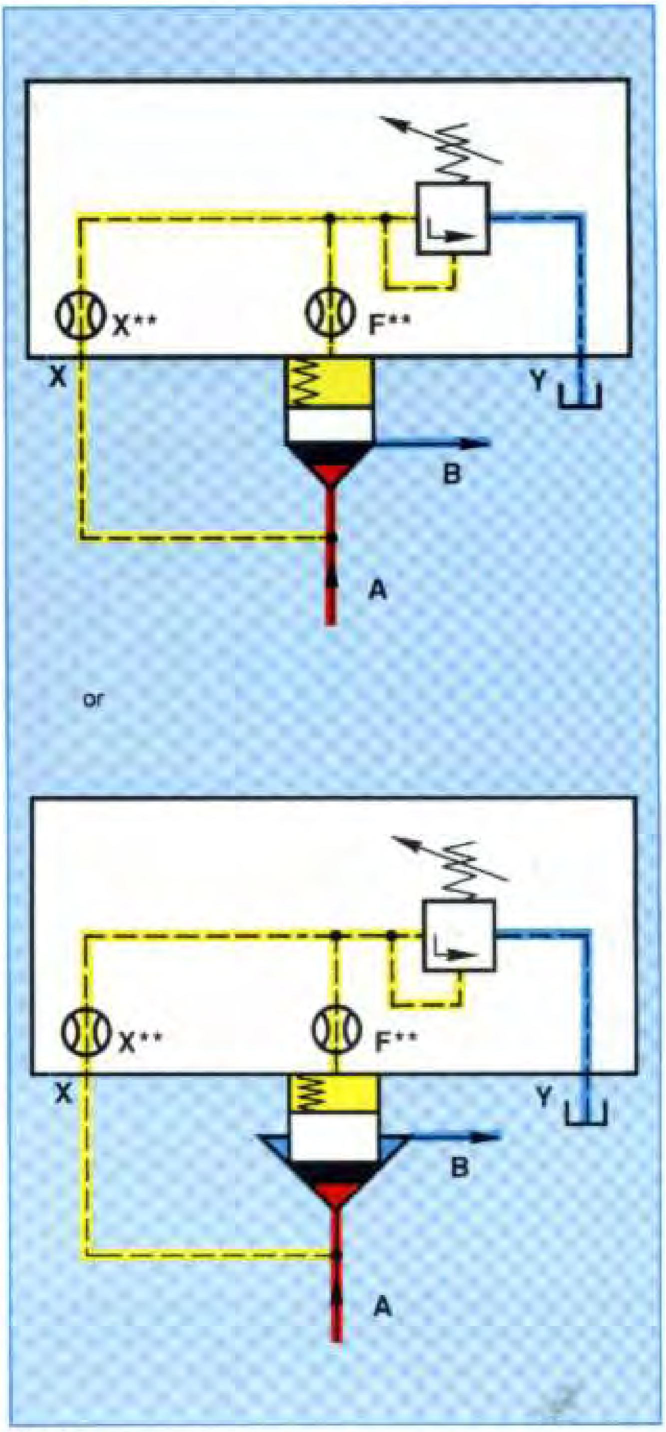


Fig. 89

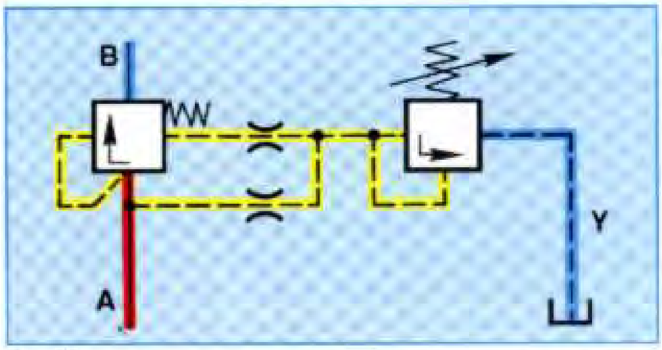


Fig. 90

Symbols for 2 way pressure logic elements with manual pressure setting

Fig. 88: *Symbol - schematic illustration - poppet valve*

Fig. 89: *Symbol - schematic illustration - poppet/spool valve*

Fig. 90: *Symbol - to DIN/ISO 1219 - poppet valve and poppet/spool valve.*

** = Orifice

What differences are felt in the system when using the poppet and poppet/spool valve configurations.?

Poppet valves

For low pressure by-pass situations, the poppet valve has a lower resistance to flow than the poppet/spool valve.

Poppet/spool valves

This design gives smoother operation i.e.a lower level of unloading shock when switching to low pressure by-pass.

The disadvantage is that the valve does not open immediately when the pressure rises rapidly and therefore pressure peaks must be expected .

Choice of springs

The preferred model has a spring corresponding to a cracking pressure of 2 bar at the main spool.

In addition to this, also as standards, variations are available without a spring or with a cracking pressure of 4 bar. Versions with cracking pressure of 5 or 8 bar are also possible. However, a special cover or a spacing piece is normally required for these in order to accommodate the larger spring.

Sizes and technical data

Pressure logic elements are available as pressure relief elements in sizes 16,25,32,40,50,63,80, and 100. These correspond to maximum flows between 250 and 7000 L/min.
As an example, *diagrams 5 and 6* show the curves for a size 16 element with manual pressure setting.

a) Model with poppet valve element.

The measurements were taken with no back pressure in the pilot line, i.e. with pilot port Y connected separately to tank. When Y and B are interconnected, the inlet pressure is raised by the pressure present in port B.

Diagrams 5 and 7 show the inlet pressure curves dependent on flow for the selected pressure settings.

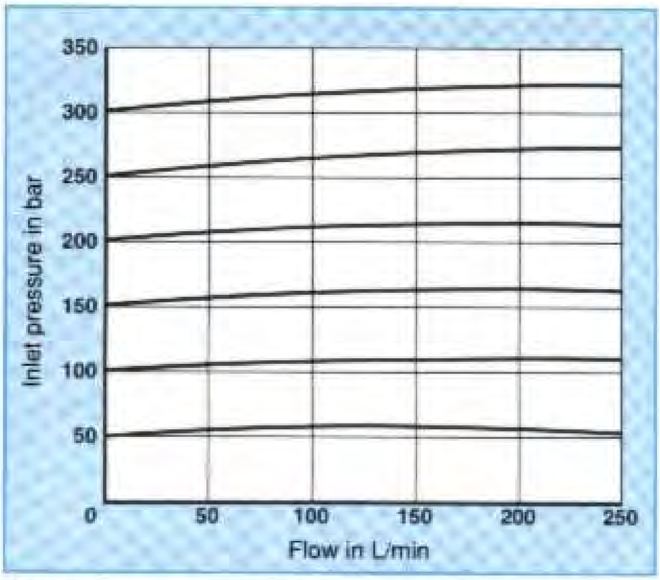


Diagram 5

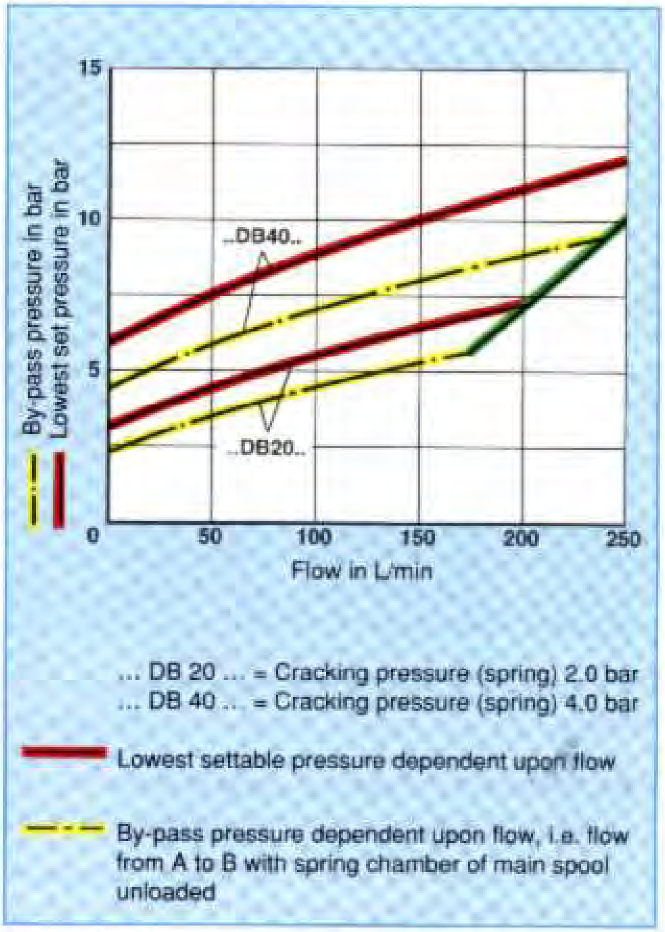


Diagram 6

b) Model with poppet/spool element

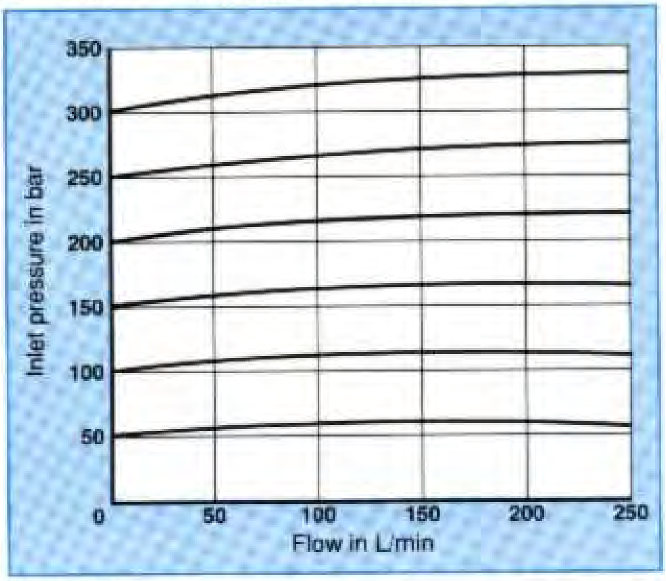


Diagram 7

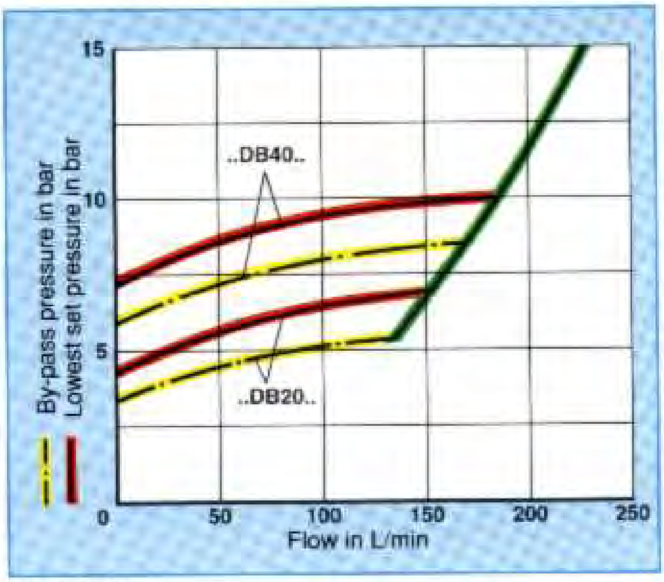


Diagram 8

If one compares the curve in *diagram 6* with that for a poppet/spool element *(diagram 8)*, the higher resistance to flow already mentioned is confirmed.

Orifices

The orifices shown in the control lines in the sectional diagrams and symbols are standard screw-in orifices. They are selected with relation to one another to suit the particular size of valve. The overview shown on this page shows an example of the orifice diameters in mm installed by Mannesmann Rexroth and also where they are placed within the control cover.

The flow pilot oil flow and with the valve operating characteristics are influenced by a single orifice, i.e. the opening and closing of the main spool are influenced by the arrangement of the damping orifices.

The orifices are arranged in the valve cover in 90 % of cases.

The advantages of this system are as follows:

- relatively easy access if they are blocked
- in certain cases the orifice size maybe changed in order to alter the characteristics of the valve, i.e. a change in pilot fluid flow.
- modifications on site are easily carried out.

In principle it is also possible fit the orifices in the main block or in the main spool.

As may be seen in *Fig. 4*, orifices X or D are selected according the size of the valve.

Size / Orifice	16	25	32	40	50	63	80	100
X **	0.8	0.8	—	—	—	—	3.0	3.0
F **	1.0	1.0	1.2	1.2	1.2	1.5	2.5	2.5
D **	—	—	0.8	1.0	1.2	1.5	—	—

Table 4

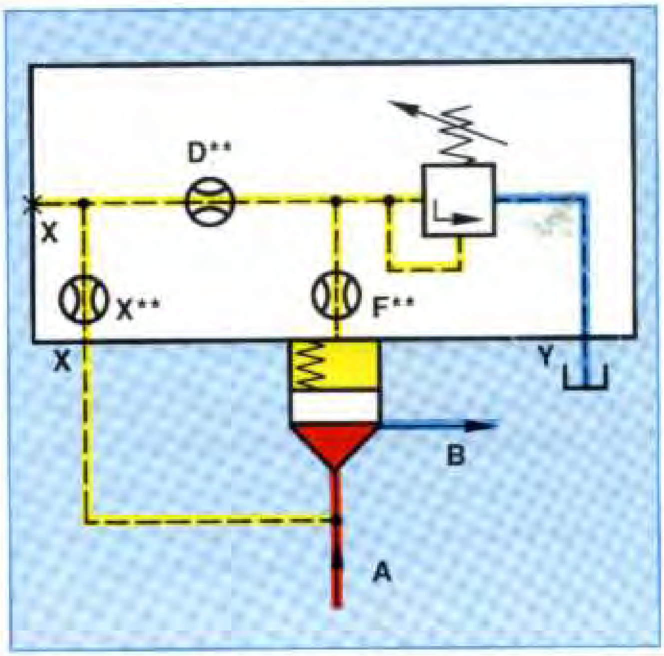


Fig. 91 ** = Orifice

In addition, there is a variant with an orifice in the main spool (usually drilled).

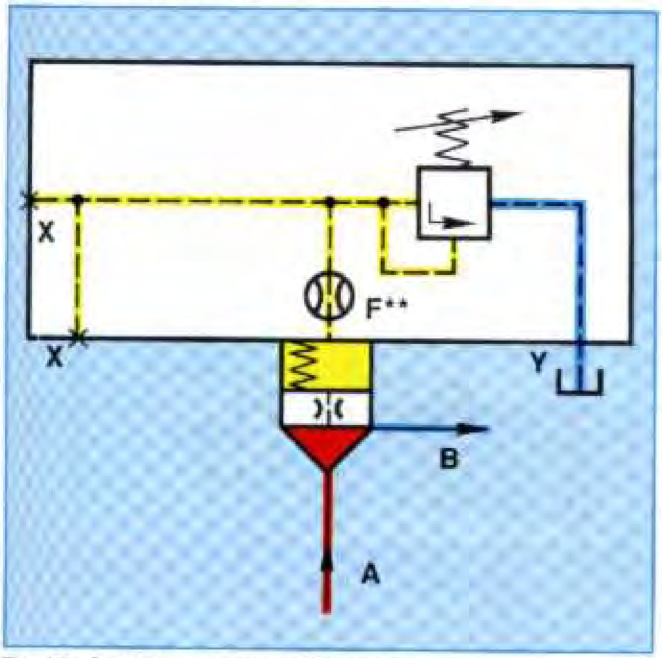


Fig. 92: Symbol - schematic illustration
** Orifice

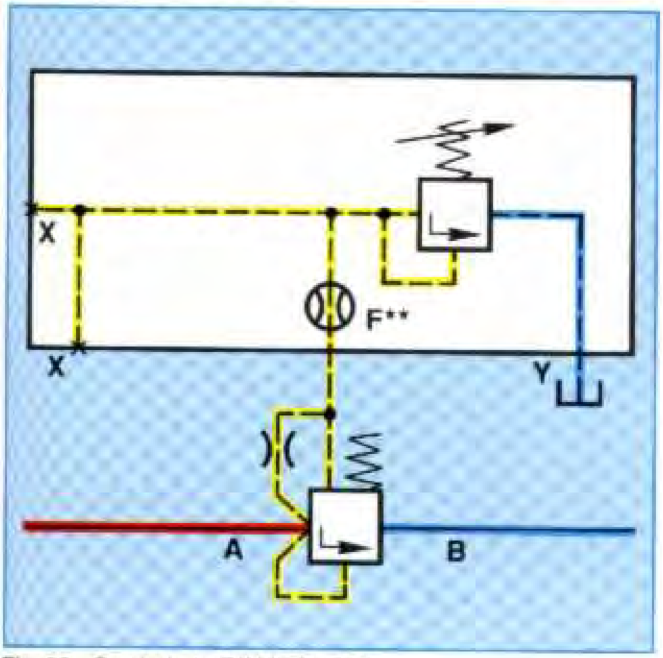


Fig. 93: *Symbol - to DIN/ISO 1219*
** Orifice

The advantages of this are:

- good bleeding irrespective installation position
- avoidance of oscillations due trapped air
- some saving of space as the X port is no longer required.

In principle, the orifice diameter is the same as X or D.

1.2 Pressure relief function with manual pressure setting and unloading via a directional valve.

Pressure relief function in the start position
(Figs. 94, 95 and 96).

If a directional valve (8) is installed correctly, it is possible to unload the spring chamber (6) of the main spool (5). In the start position, pressure at A is present via orifices X and D in the the pilot line (yellow) of the pilot valve (3) and at the same time via orifice F in spring chamber (6) of the main spool.

At the directional valve (8), port B is blocked (in the cover). We therefore have the pressure relief function. By operating the directional valve to position "a", spring chamber (6) is unloaded to port Y (tank) via orifices F, D and P. Only orifice P is effective when unloading.

As may be seen from *table 5*, orifice X is smaller than orifice P and the main spool can open fully (passive control). The "by-pass" pressure is mainly dependent upon spring (7), but the selection of the orifices is also important.

From *table 5* and also figures 94 to 101, it can be seen that dependent upon the size of the element and the pilot valve employed, different orifice sizes and arrangements and pilot drilling arrangements are used.

Orifice \ Size	16	25	32	40	50	63	80	100
X **	0.8	0.8	0.8	—	—	—	3.0	3.0
F **	1.0	1.0	1.2	1.2	1.2	1.5	2.5	2.5
D **	0.8	0.8	1.0	1.0	1.2	1.5	—	—
P **	1.0	1.0	1.0	1.2	1.5	1.8	3.5	3.5
A **	—	—	—	0.8	0.8	1.0	1.2	1.5
B **	—	—	—	—	—	—	3.0	3.0

Table 5 ** Orifice diameter in mm

With the pilot fluid arrangement shown in *Figs. 94 to 101* (which is employed for sizes 16,25 and 32) the arrangement is known as a "passive control". In this control, pilot fluid flows continuously when the valve is unloading.

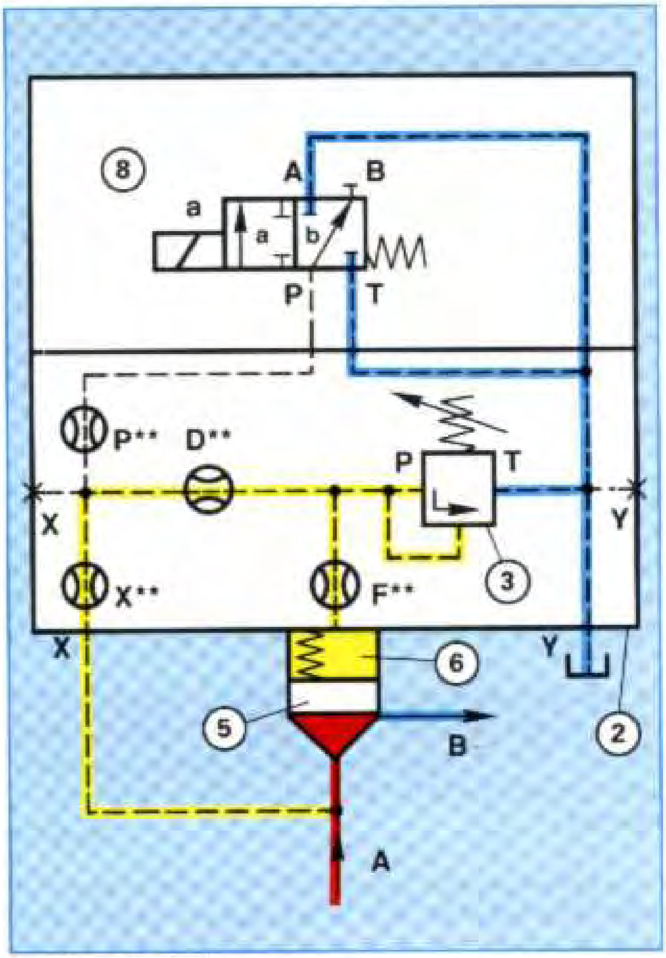


Fig. 94 ** = Orifice

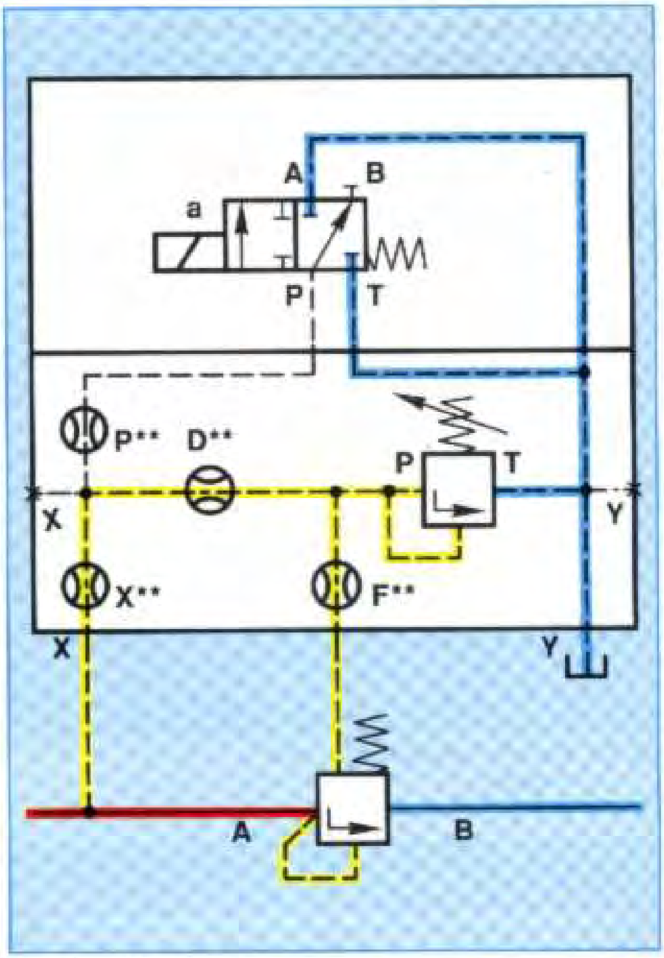
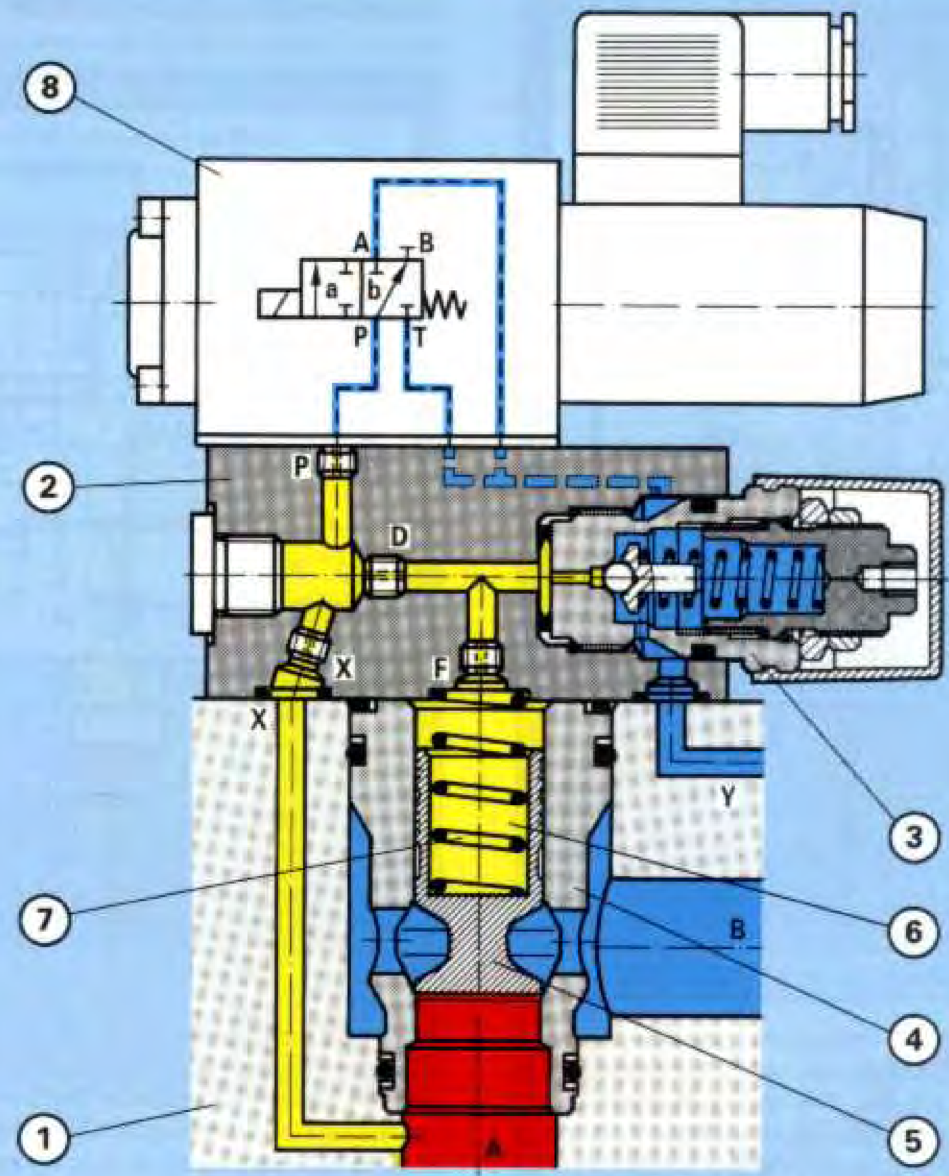


Fig. 95 ** = Orifice



(1) Manifold block
(2) Control cover with orifices X, D, F and P and also pilot valve
(3) Pilot valve
(4) Bush
(5) Main spool (in this case, a poppet valve)
(6) Spring chamber
(7) Spring
(8) Directional valve

Fig. 96

During the unloading operation (connection P to A in the directional valve) fluid also flows via orifice D from the spring chamber and via orifice X from the pressure side to orifice P. The small amount of fluid flowing from the spring chamber ((6) in *Fig. 96*) is increased by the flow of fluid from the feed orifice X.

More fluid is thus available to damp the unloading shock. Damping orifices (D and P) must not be made too small.

This is an advantage of "passive control" which is used up to size 32 *(compare Figs. 99 to 101)*.

Under "passive control", it is important that the pilot fluid drillings and the pilot valve permit more fluid to flow away than can flow into the system via orifice X.

Normally open - i.e. normally by-passing.

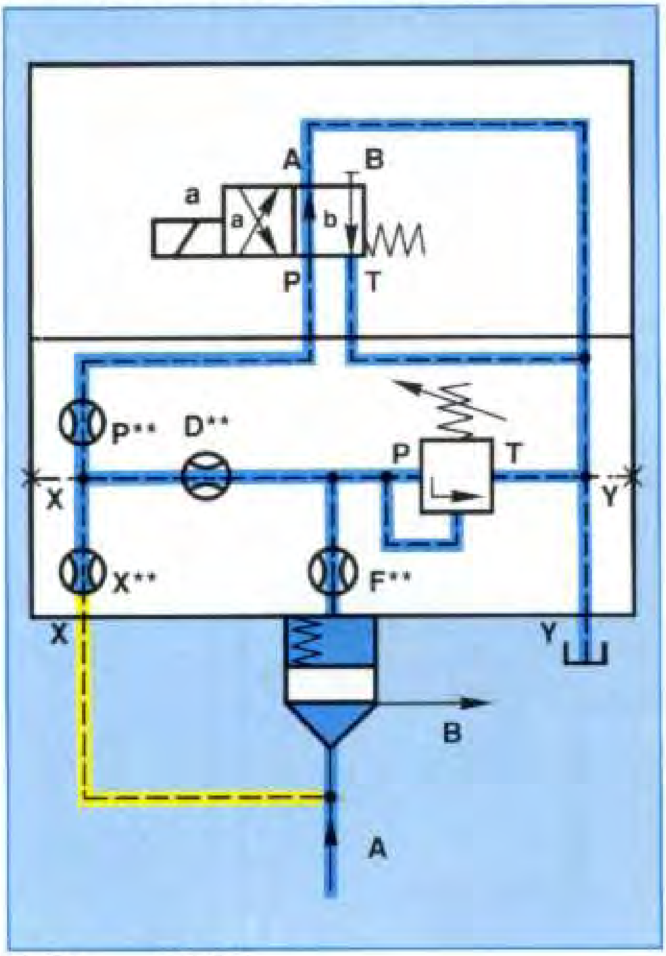


Fig. 97 ** Orifice

As illustrated in *Fig. 97*, dependent upon the choice of directional valve, it is possible to have a low pressure by-pass in the start condition. The spring chamber is unloaded to tank via the control line via orifices F, D and P and by the connection P to A in the directional valve.

When the directional valve is operated to position a, the connection between the control line and the tank is broken. (as port B of the directional valve is blocked). The valve now acts as a relief valve.

Pressure relief function with manual pressure setting and unloading via a directional poppet valve.

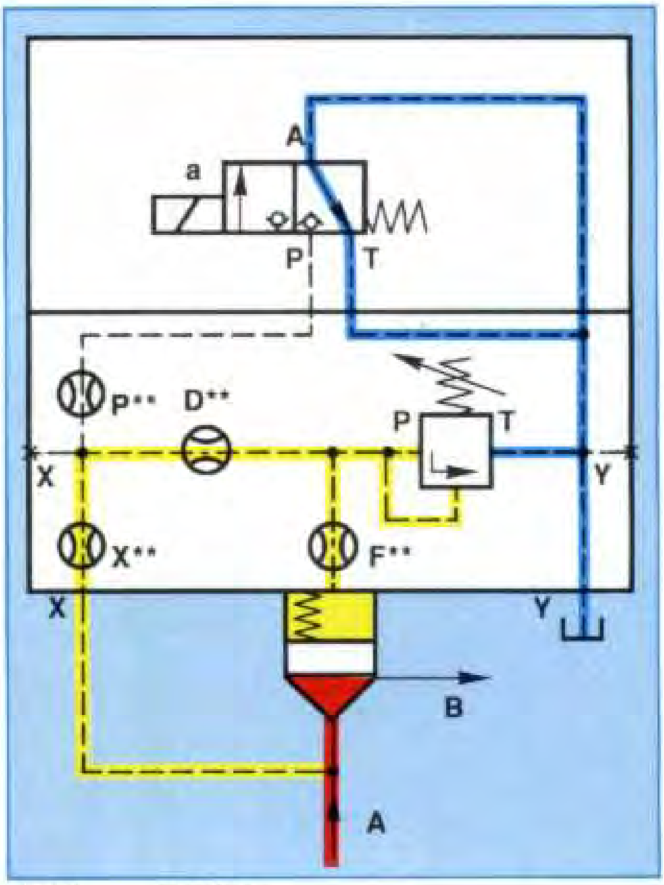


Fig. 98 ** Orifice

If a directional poppet valve is used instead of a directional spool valve, leakage via the pilot valve is avoided. In addition, dependent upon the pressure rating of the pilot valve, pressure ratings up to 420 bar (sizes 16,25 and 32) or up to 400 bar (sizes 40 to 100) are possible.

However, some leakage is still present at the main spool.

For larger sizes and with the larger flows involved, an "active control" can be employed *(Figs. 99, 100 and 101)*. In this case no additional pilot fluid flows when the valve is unloaded. Instead, only during the opening operation is fluid caused to flow directly to tank from the control chamber. The pilot line from X is blocked.

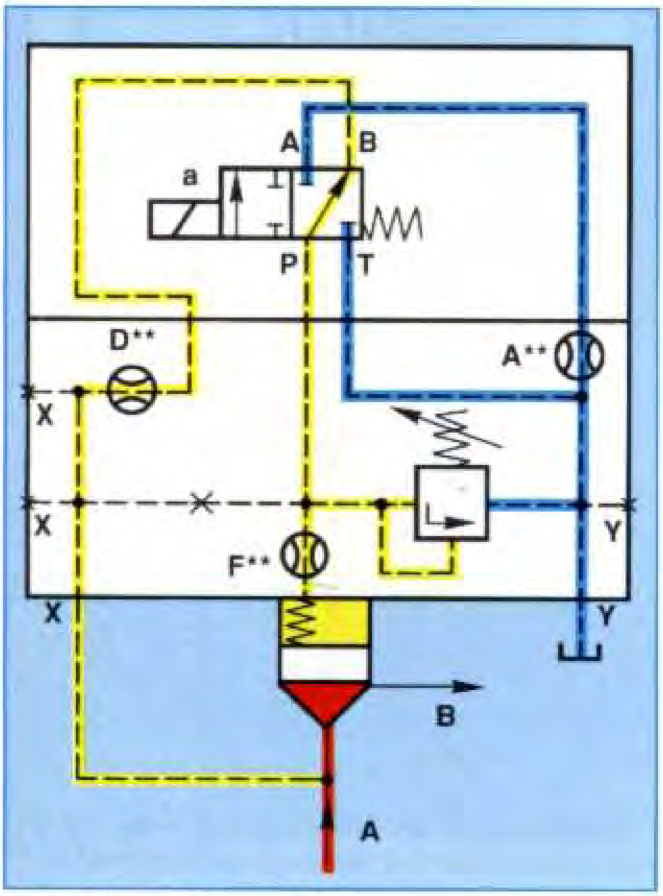


Fig. 99: *Sizes 40,50, and 63*
** = orifice

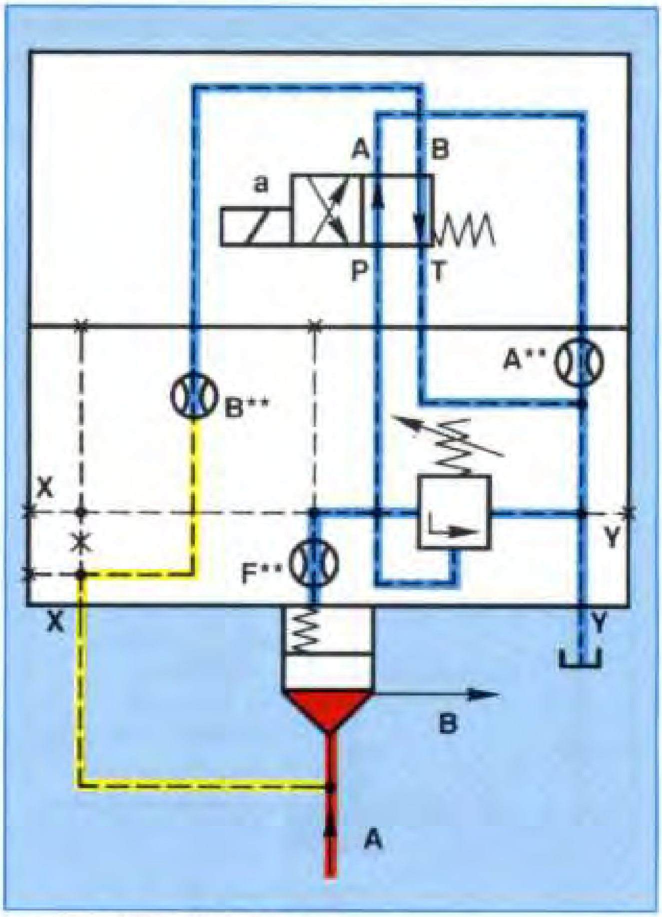


Fig. 100: *Sizes 80, and 100*
** = orifice

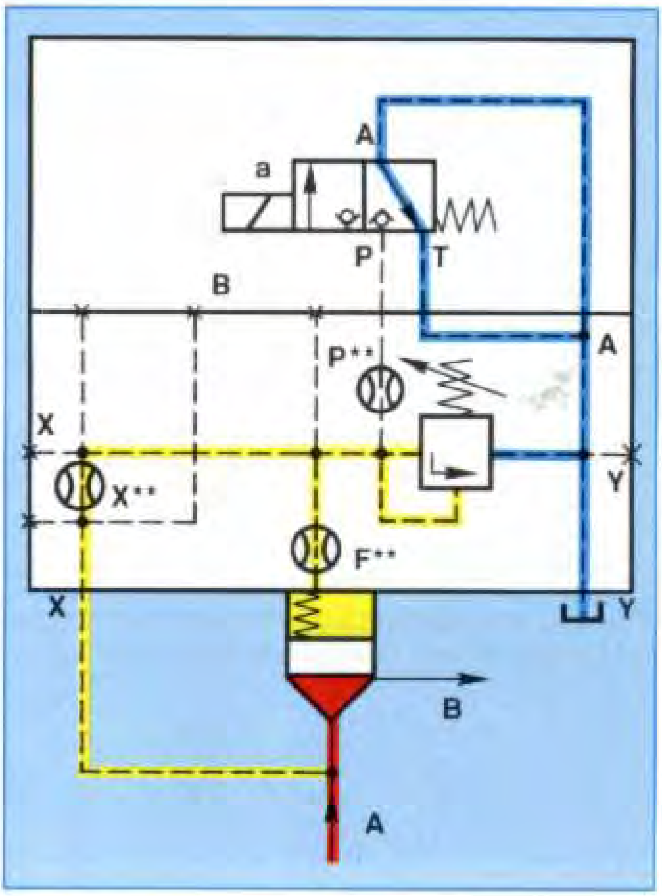


Fig. 101: *Sizes 80, and 100*
** = orifice

1.3 Pressure relief function with manual pressure setting and blocking function

Directional valve with a blocking function in the start position .

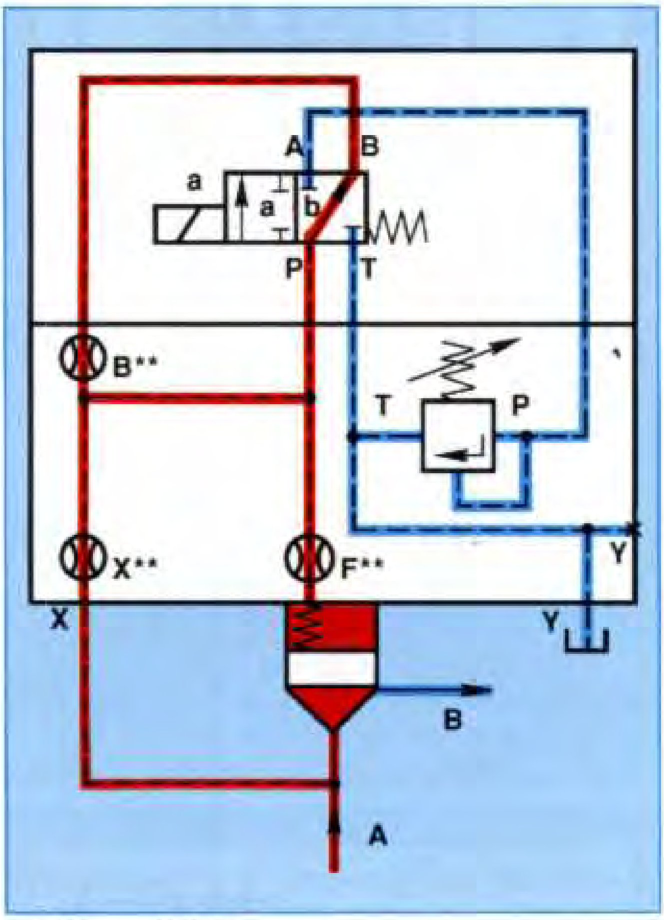


Fig. 102 ** Orifice

In the circuit shown in *Fig. 102*, a blocking function is obtained in addition to the relief function. In the start or rest position, pressure from port A of the logic element is also present on the spring loaded side of the main spool via control drilling *(port X, red)*. The direct operated pressure relief valve is isolated from the control line and is therefore inoperative.

The main valve is closed no matter what pressure is present at port A. When the directional valve is operated (solenoid a energised) the pilot line *(red)* is once more connected through the directional valve (P to A).

Pressure in the control line is now limited by the pilot valve and the logic element acts once more as a relief valve.

Directional valve in the start position: Pressure relief function

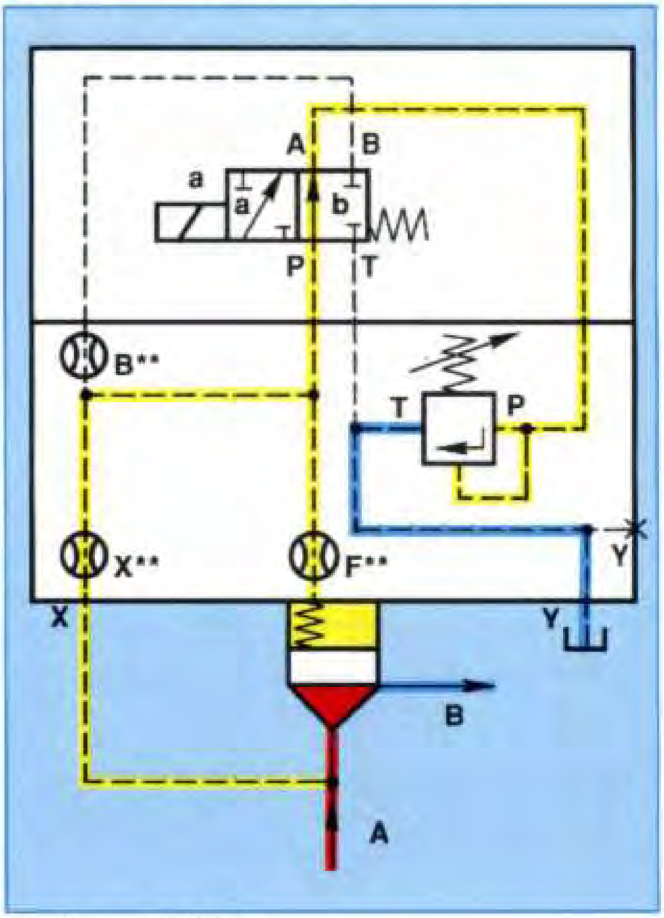


Fig. 103 ** Orifice

In comparison with the example shown in *Fig. 102*, the start position of the directional valve is now reversed.

The pressure relief function is obtained in the start position and the blocking function with the valve in position a.

Pressure relief, unloading and blocking

By utilising a 4/3 way valve as the pilot valve —with P, A and B connected in the neutral position— it is possible to achieve pressure relief, unloading and the blocking function.

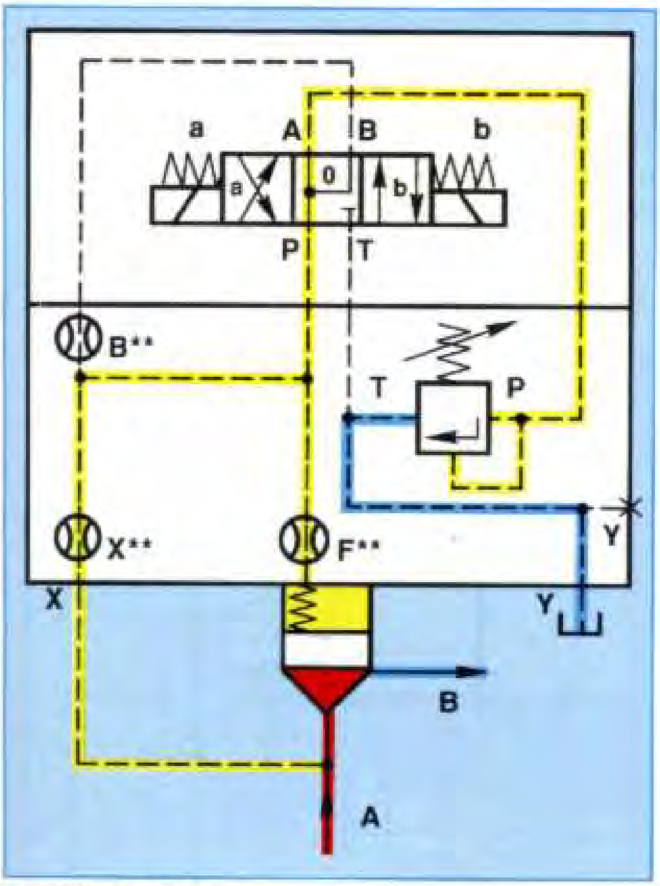


Fig. 104 ** = Orifice

Valve in neutral = Pressure relief function *(Fig. 104)*

With the directional valve in the neutral position, the logic element acts as a relief valve as a connection to the direct operated relief valve is established through orifices X and F and the control line.

Valve in position a = Blocking function *(Fig. 105)*

When the directional valve is in position a, (solenoid a energised), the pilot valve is isolated from the control line (red) and is connected to tank.
The same pressure is present at both sides of the main spool and port A is closed by the spring.

Valve in position b = Unloading function *(Fig. 106)*

When the directional valve is in position b, (solenoid b energised), both the pilot relief valve and the spring chamber of the main valve are connected to tank. Fluid may now flow at nominally zero pressure from A to B. The cracking pressure is dependent upon the the spring employed.

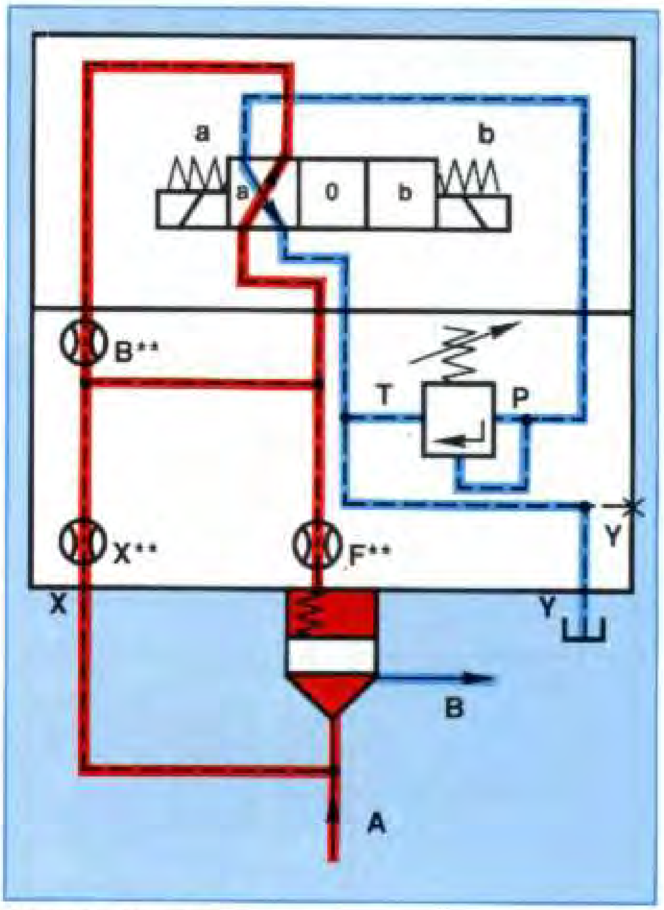


Fig. 105 ** = Orifice

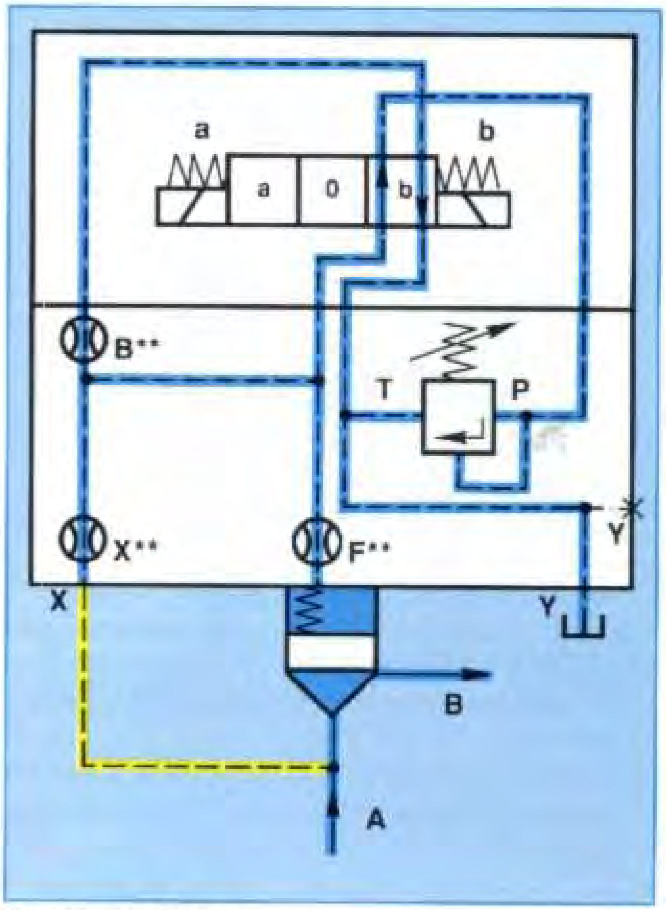


Fig. 106 ** = Orifice

1.4 Pressure relief function with two pressure settings

With this combination of components, it is possible to select two pre-set pressures, DB_1 and DB_{max} by means of a 4/2 way directional valve.

Directional valve in start position, pressure DB_1
(Figs. 107 and 108)

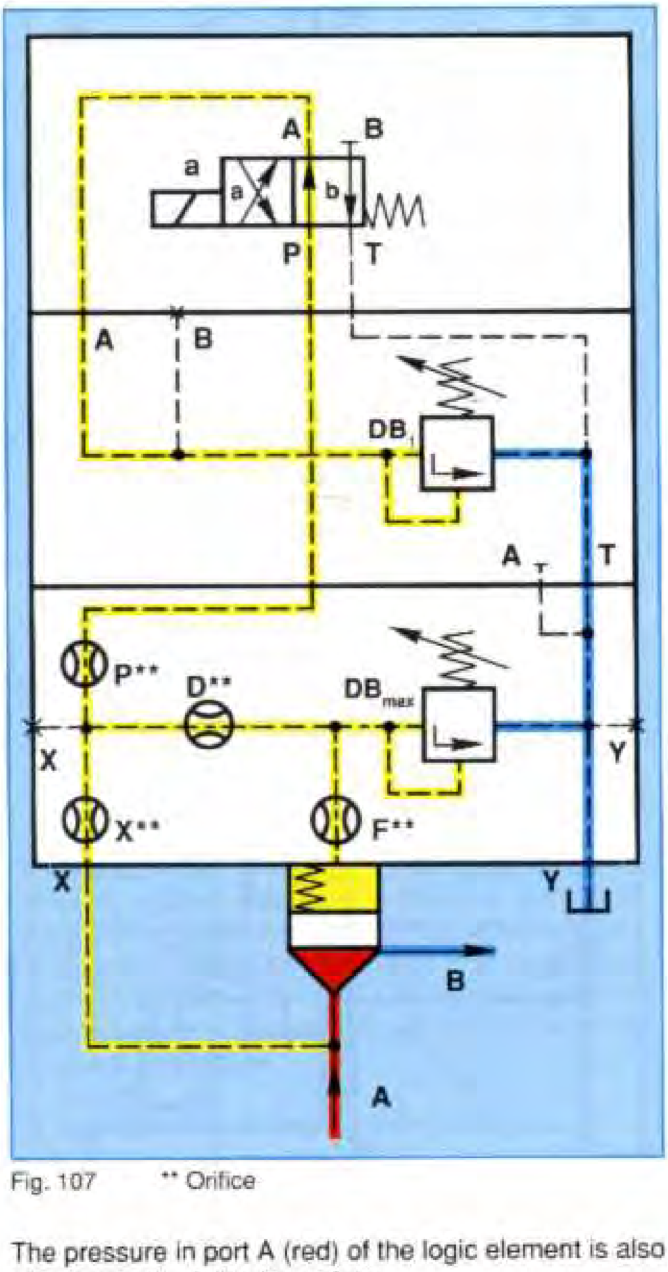


Fig. 107 ** Orifice

The pressure in port A (red) of the logic element is also effective at the following points:

- the control line (yellow) via orifices X and D at the pilot valve DB_{max}
- via orifice F in the spring chamber of the logic element
- via orifice P and the 4/2 way valve (P to A) at the pilot valve DB_1.

The maximum system pressure is set at pilot valve DB_{max} and the second pressure required is set at pilot valve DB_1.

The pressure set at valve DB_1 must be lower than that set at DB_{max}, as the latter always has a direct connection to the circuit.

In the start condition shown *(Figs. 107 and 109)*, the main spool reacts to the pressure set at DB_1.

With the directional valve in position a, the connection to pilot pressure relief valve DB_1 is interrupted. Thus only pilot pressure relief valve DB_{max} is operative. Maximum system pressure may then occur.

Directional valve in the start position, pressure DB_{max}. *(Fig. 108)*

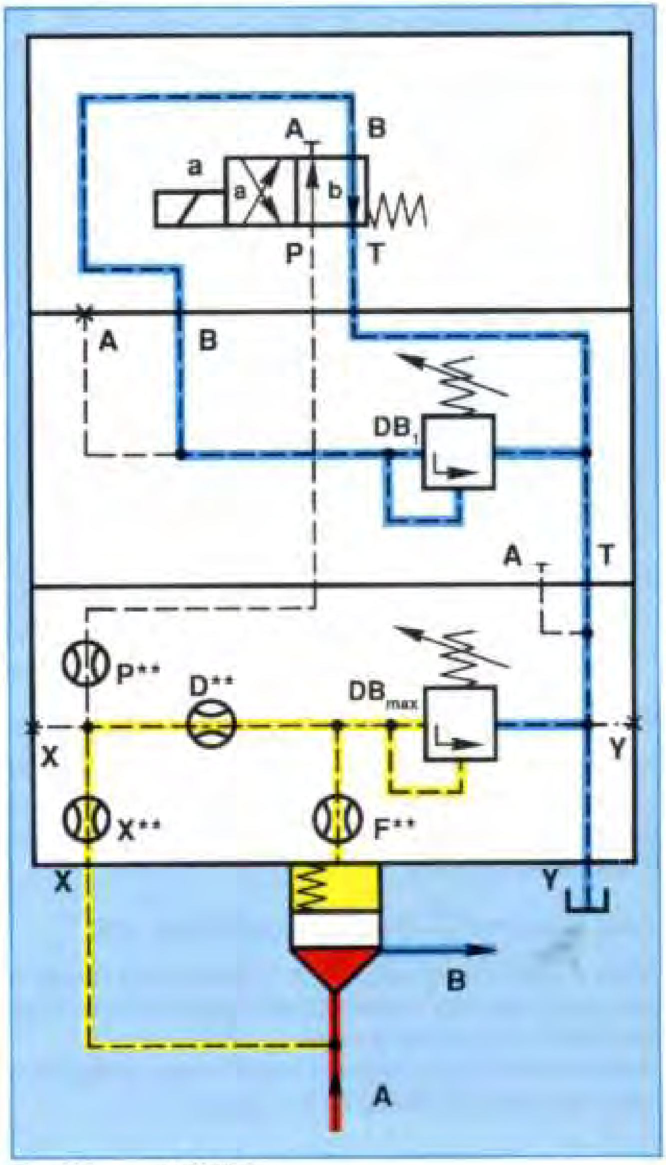


Fig. 108 ** Orifice

When port A of the 4/2 way directional valve is closed and port B is connected to the control line DB_1, then pressure DB_{max} is effective in the start position. When the directional valve is now moved to position a, DB_1 is connected is also connected to the control line *(yellow)* (via P to B). The pressure in the system is now limited to the setting of DB_1.

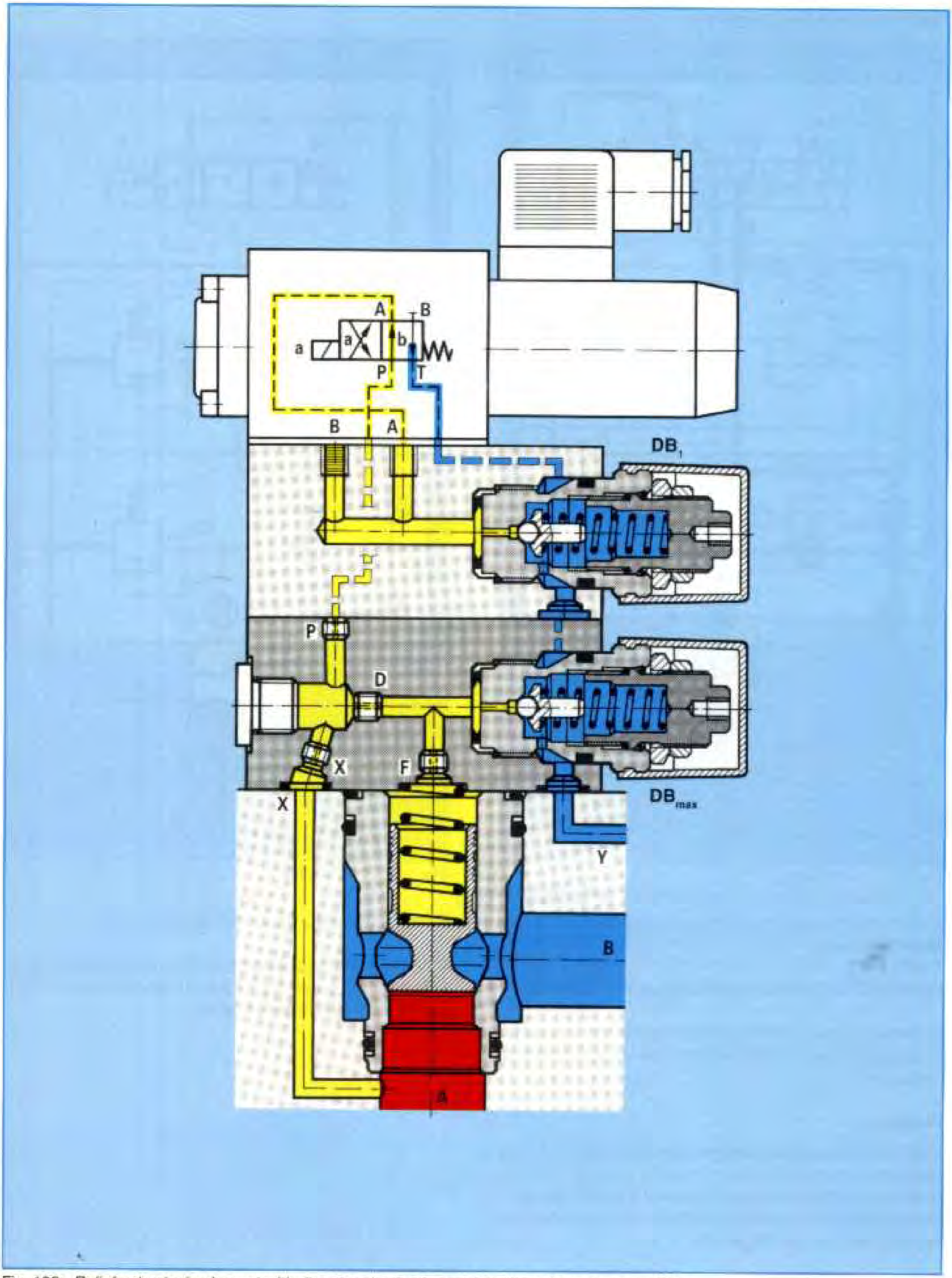


Fig. 109: *Relief valve logic element with directional valve in rest (start) position, pressure DB_1*

Two Pressures and Unloading

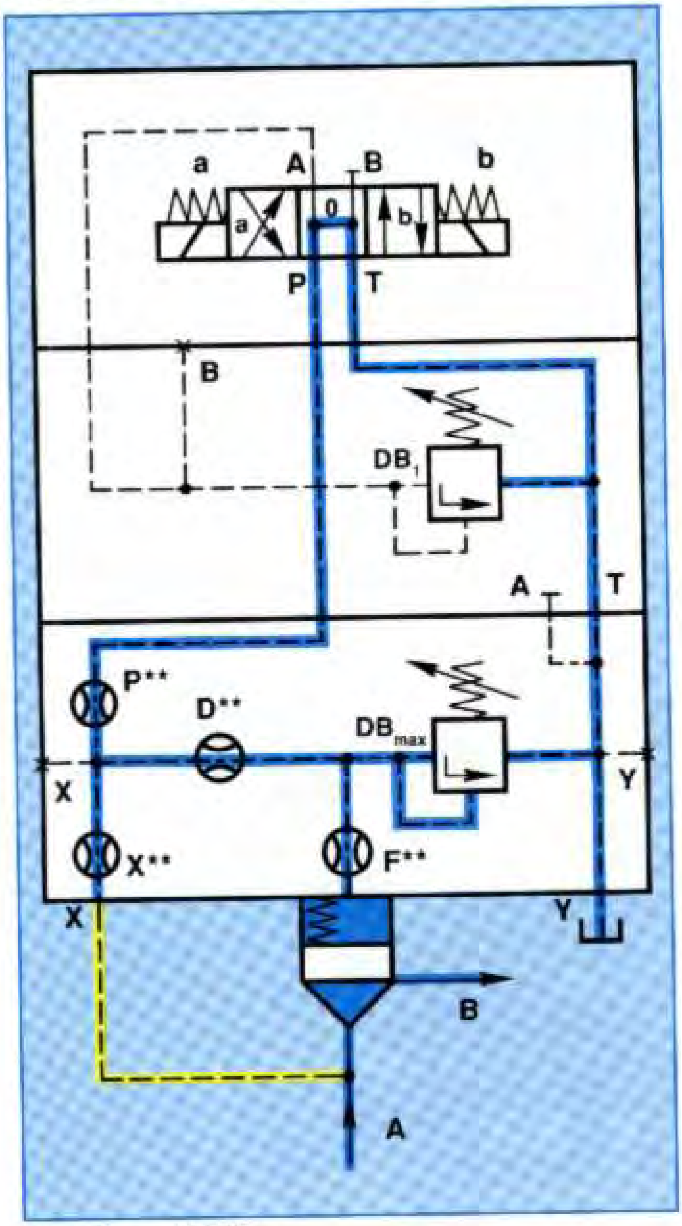


Fig. 110 ** Orifice

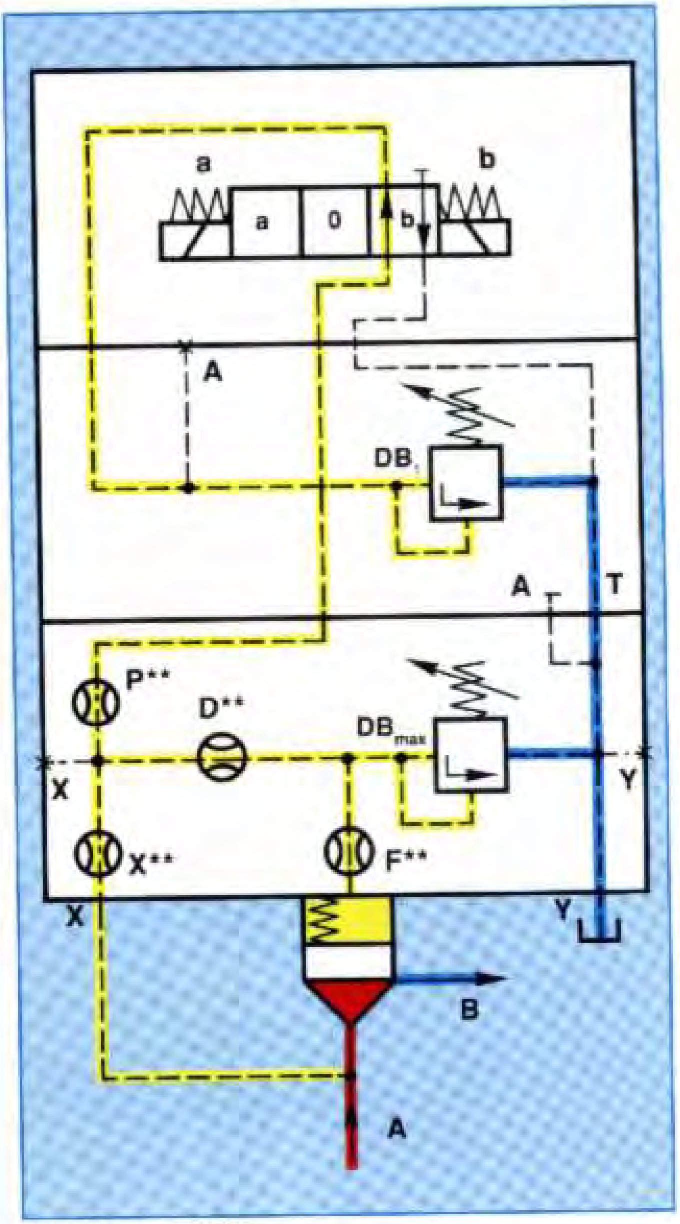


Fig. 111 ** Orifice

An extra function may be obtained by installing a 4/3 way directional valve.

Spool position 0 = low pressure by-pass (unloading)

As the control line and the spring chamber are connected to tank via P and T in the directional valve, the system is unloaded.

Warning

The circuit has a disadvantage when changing from one pressure setting to the other, in that it will drop momentarily to low pressure by-pass during the change-over. Under certain circumstances, this is not only be disturbing, but can also be dangerous.

Spool position b = Pressure DB_1 *(Fig. 111)*

With the spool in position b, both pressure relief valves DB1 and DB_{max} are connected to the main spool. Pressure DB_1 is therefore operative.

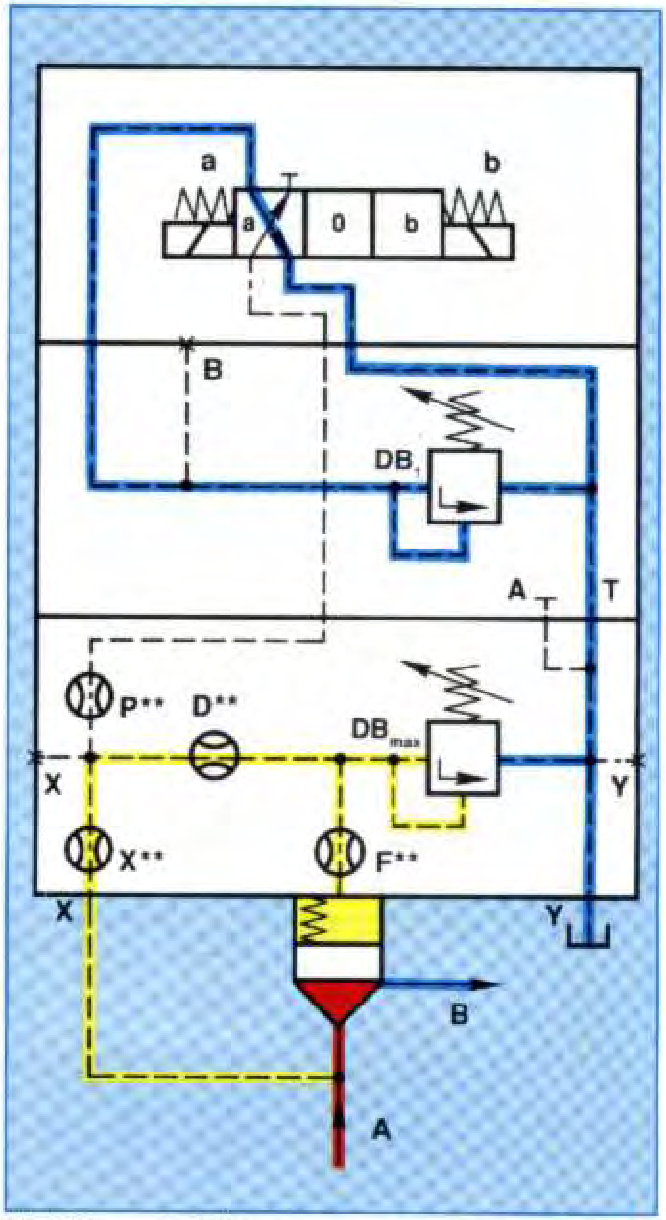


Fig. 112 ** Orifice

Spool position a= pressure DB_{max} *(Fig. 112)*.

Spool position a blocks the connection to pilot pressure relief valve DB_1. The pressure in A (red) can now reach the setting of DB_{max} and the maximum system pressure has now been selected.

1.5 Pressure relief function with 3 pressure settings - maximum pressure + two electrically selectable pressure settings.

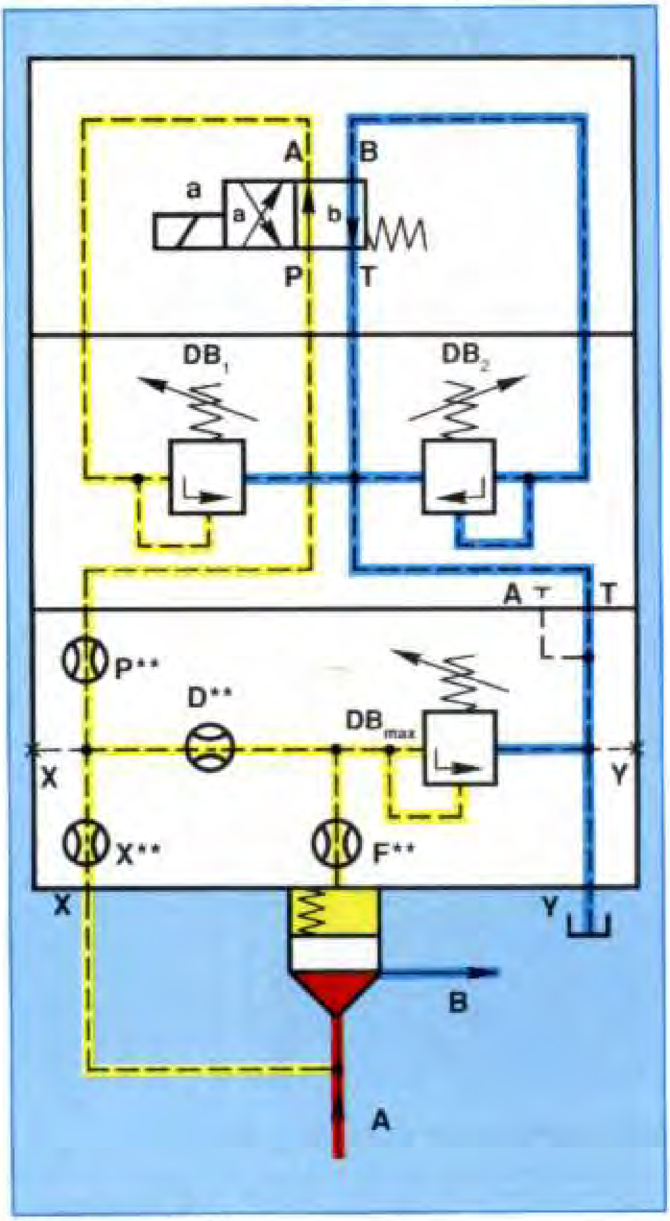


Fig. 113 ** Orifice

By selecting various directional valve configurations, a number of optional functions may be obtained.

The version shown in *Fig. 113* could be described as the "standard" version, in that it is most widely used. This system has two truly selectable pressure settings DB_1 and DB_2 whilst the 3rd. pressure is always present as a maximum pressure setting. In the start position, (directional valve position b) pressure DB_1 is operative. Pressure DB_2 is obtained with the directional valve in position a.

DB_{max} operates as a system safety valve (as it cannot be isolated from the circuit), for example if DB_1 or DB_2 does not operate correctly (if they are incorrectly set) a pressure peak occurs during the pressure change-over (e.g. if the directional spool sticks due to dirt, excess temperature, incorrect fixing or spool overlap).

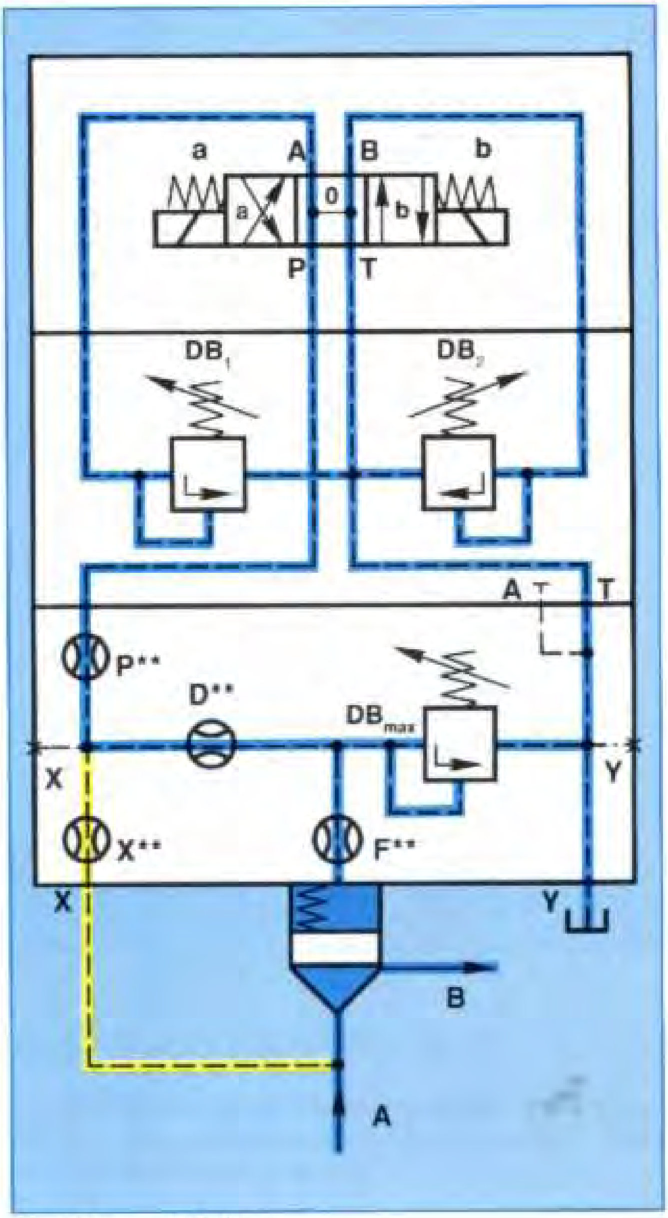


Fig. 114 ** Orifice

Spool position 0 = low pressure by-pass (unloading)

In addition to the functions shown in *Fig. 113*, a low pressure by-pass may be obtained with an open centre 4/3 way directional valve *(Fig. 114)*.

Figure 115 show the practical set-up. The 3 pressure relief valves are stacked relief valves and are connected to tank with the directional valve in the neutral position.

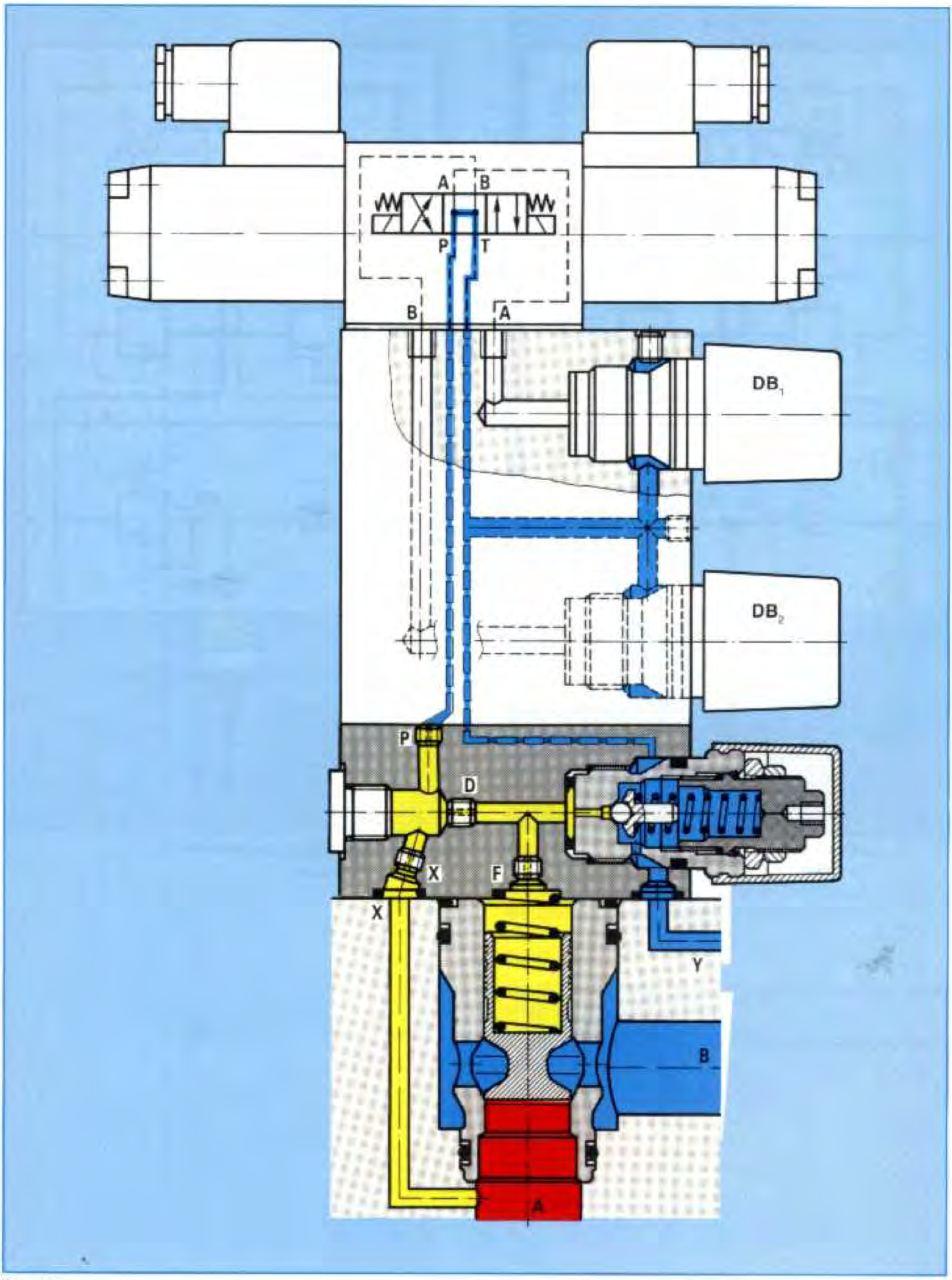


Fig. 115

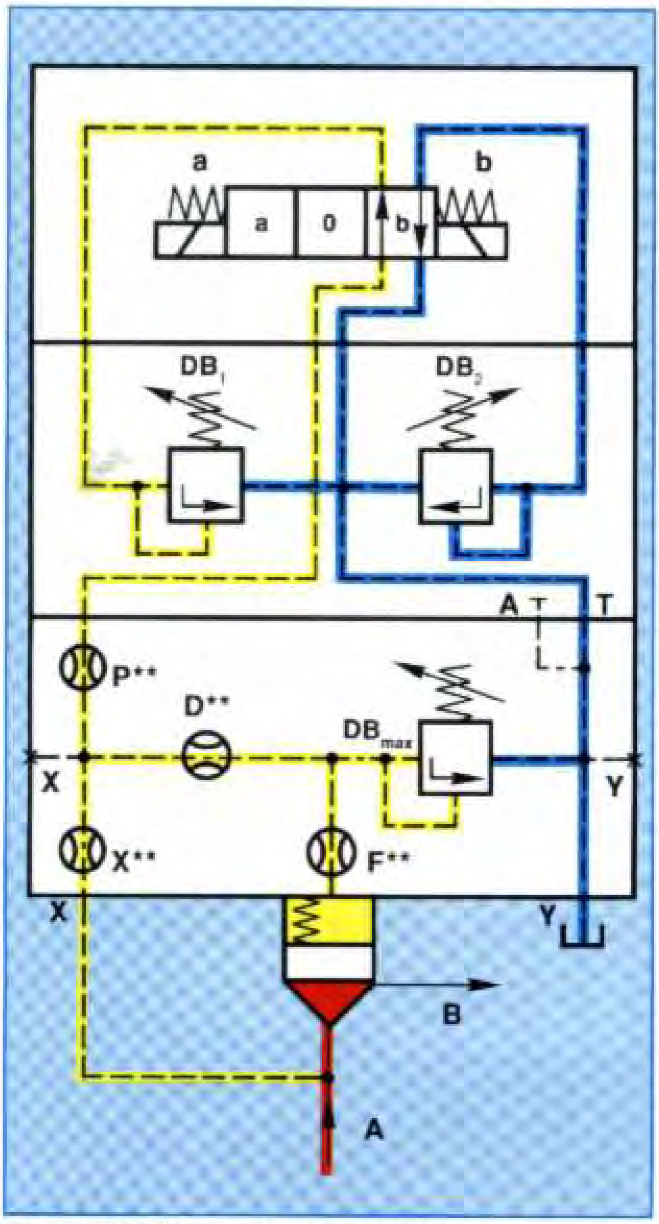


Fig. 116: *Spool position b = pressure DB_1*
** = Orifice

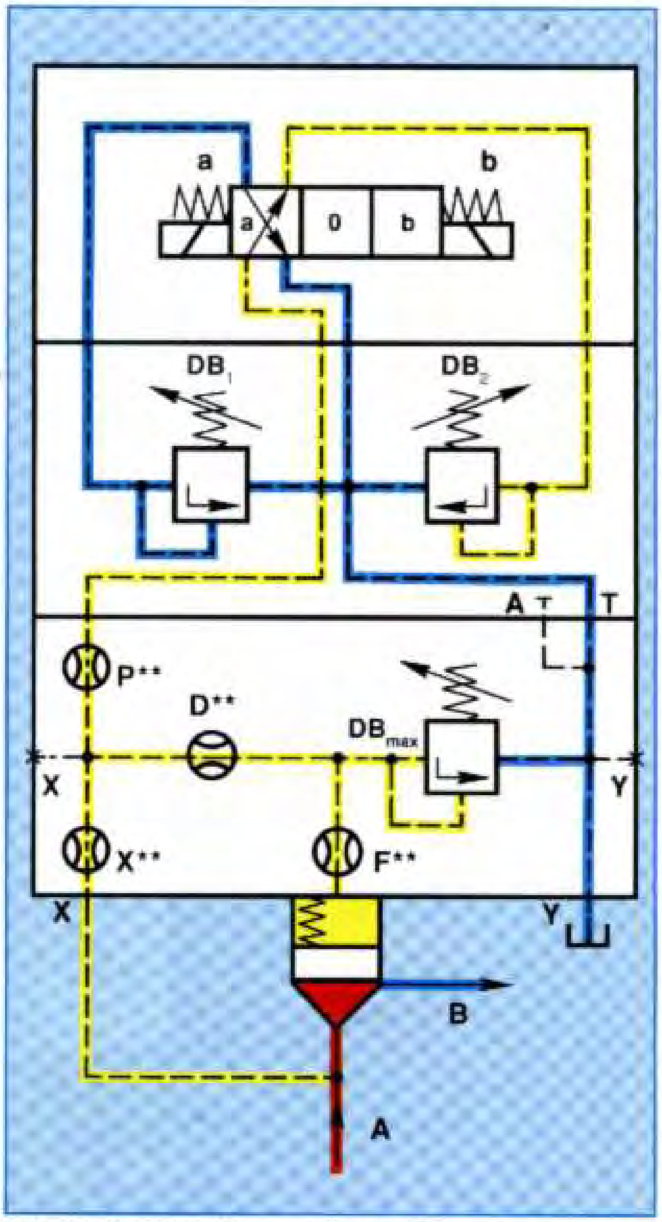


Bild 117: *Spool position a = pressure DB_2*
** = Orifice

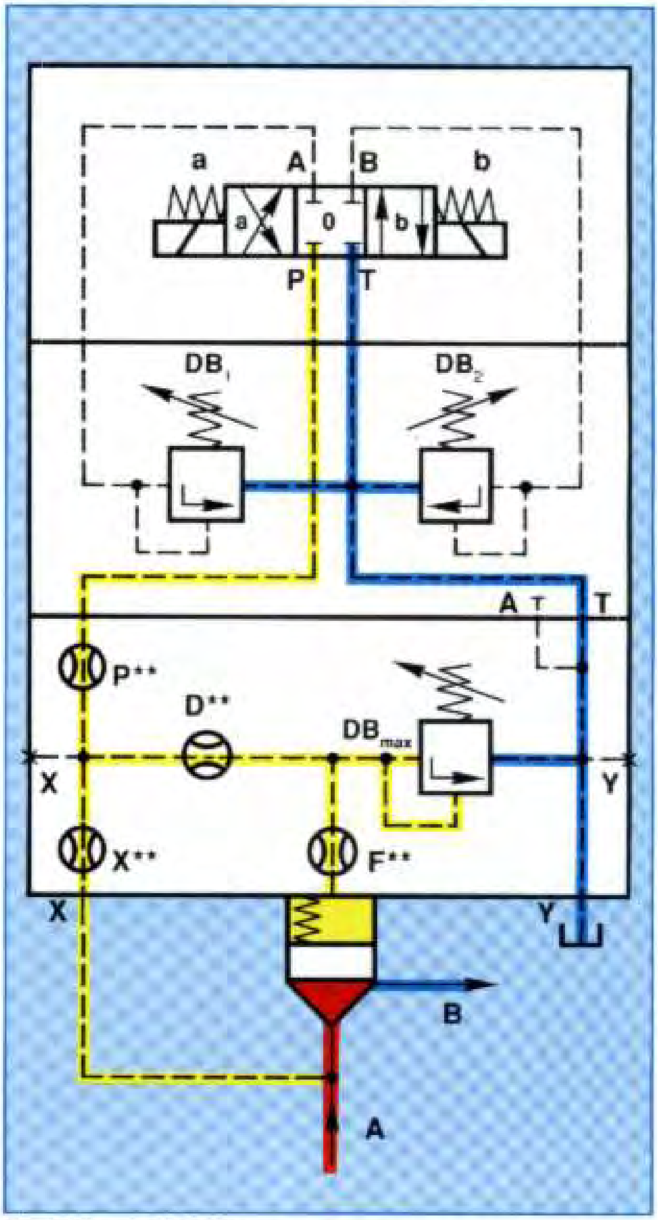


Fig. 118 ** Orifice

With the directional valve closed in the neutral position, 3 electrically selectable pressures are obtained.

Spool position 0 = DB_{max}

Spool position b = DB_1 and maximum pressure safety relief

Spool position a = DB_2 and maximum pressure safety relief.

1.6 Pressure relief function with proportional pressure setting

Without maximum pressure safety limitation

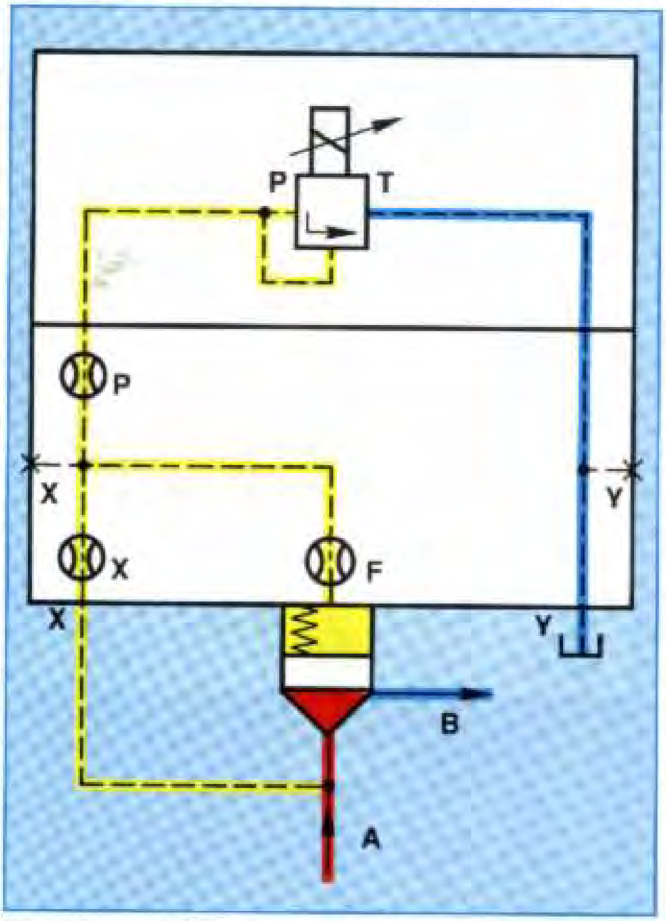


Fig. 119 ** Orifice

If a proportional pressure relief valve is used as the pilot valve, the maximum pressure in the system can be set steplessly via the amplifier card or set in fixed preset stages.

In this case, pressure can be varied with time (see also proportional information sheets).

For the valve to function correctly, the port Y of the pilot pressure relief valve should be connected separately to tank.

With maximum pressure safety limitation

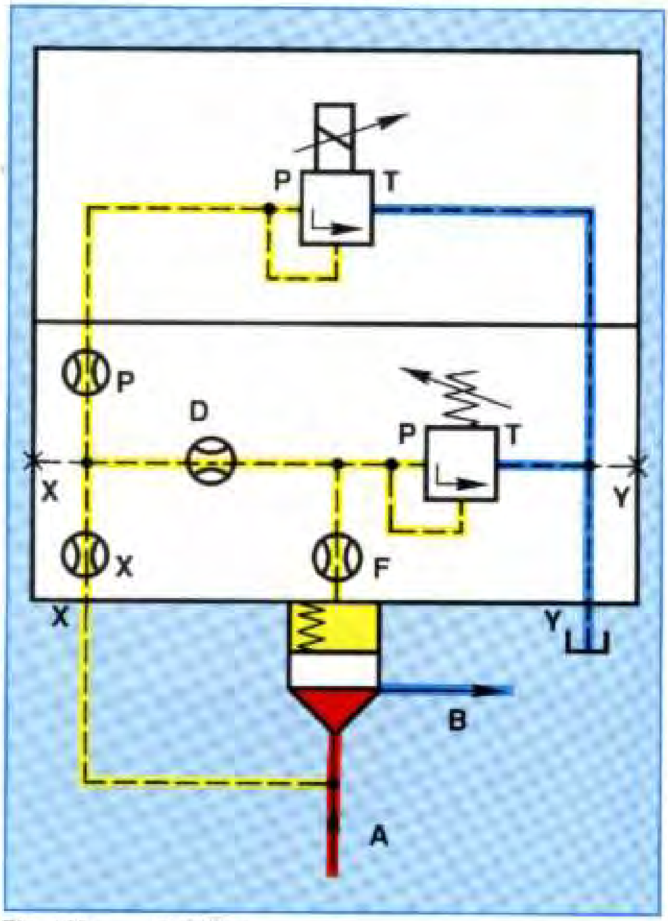


Fig. 120 ** Orifice

In order to protect the system against excessively high current in the proportional valve (and the unacceptably high pressures associated with them) an additional spring loaded standard relief valve is also installed as a maximum pressure safety relief valve.

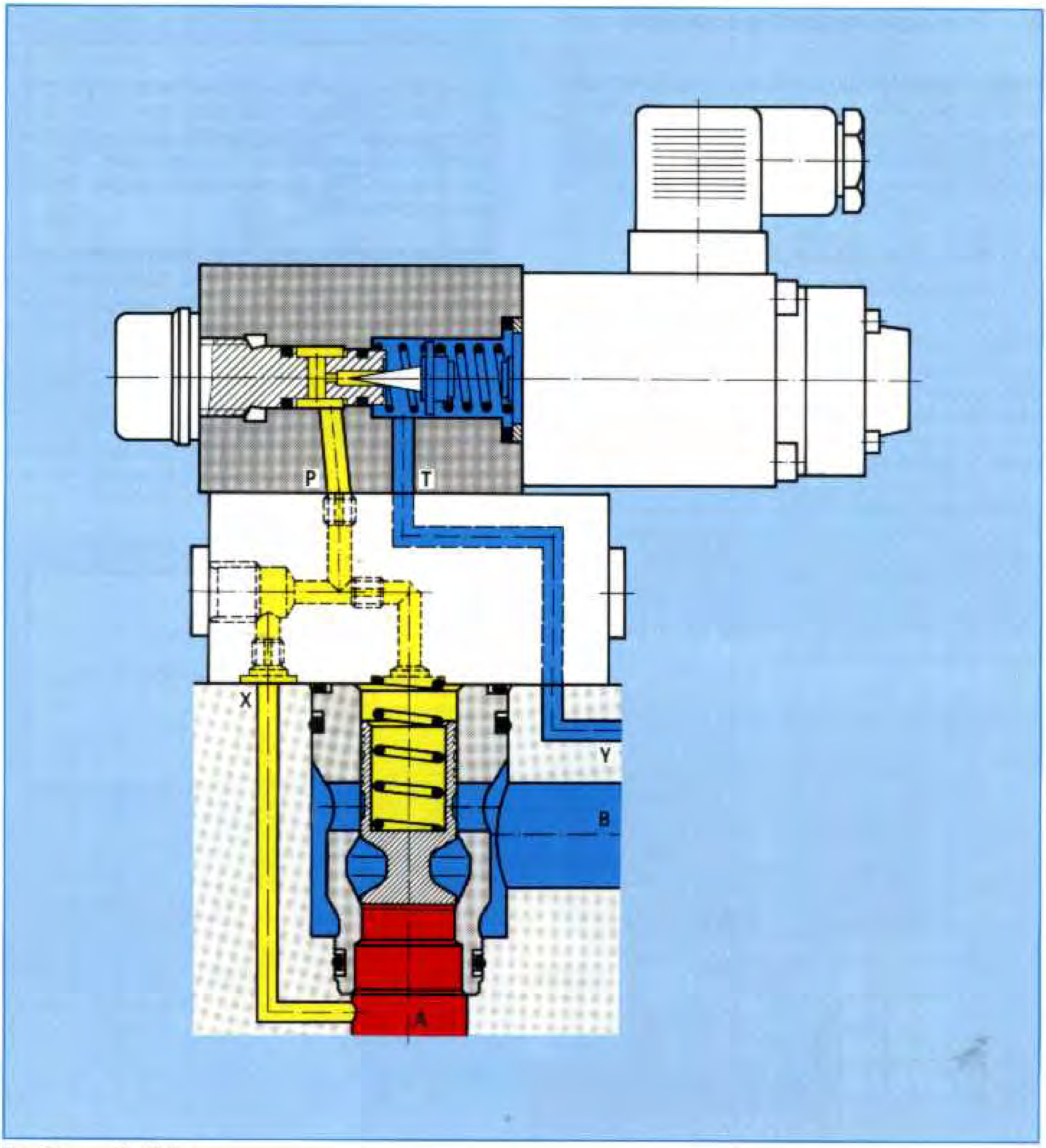


Fig. 121: ** = Orifice

2 Pressure reducing function

Pressure reducing valves may be constructed using either spool type or poppet /spool type logic elements. Dependent upon the design of the logic element and the pilot valve, the pressure reducing function can be obtained either a closed or an open in the start position.

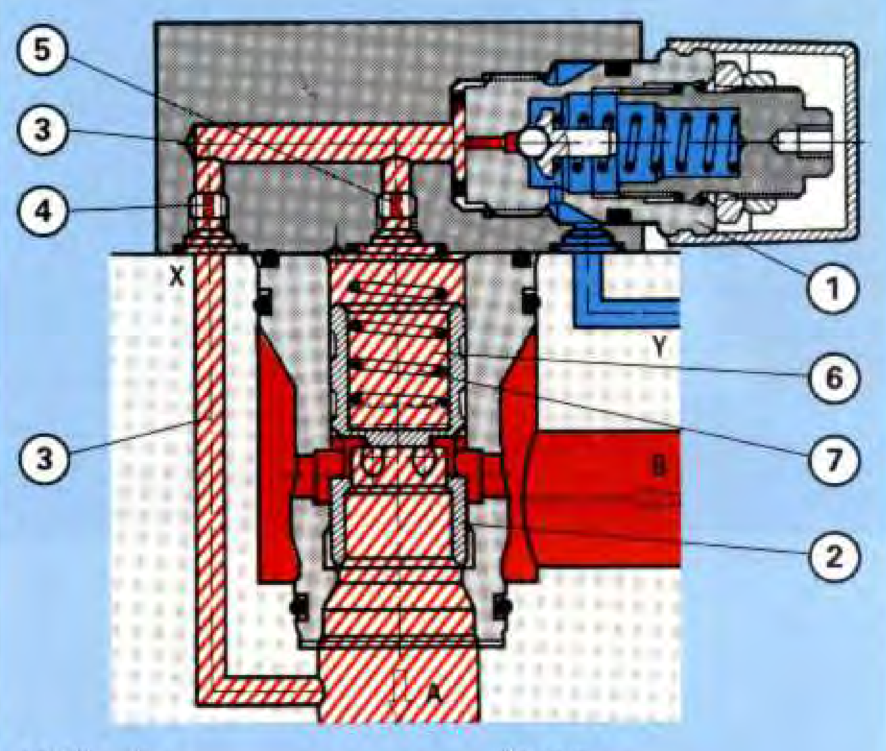
2.1 Pressure reducing valve, normally open

The pilot operated reducing valve shown in *Fig. 122* can be considered as the "standard" model. It consists of a logic element with spool type main valve (2) with no secondary effective area at B and a direct operated pressure relief valve as a pilot valve. It is thus identical with valves for the pressure relief function.

The direction of flow in the logic element is from B to A. In the start position, fluid may flow freely from B to A. The required secondary pressure is set at the pilot valve (1). Pressure in A acts on the underside of the main spool (2) and also passes through the control line (3) and orifice (4) to the pilot valve and also via orifice (5) to the spring loaded side of the main spool.

As long as the inlet pressure is less than the setting of the pilot valve (1) the main spool is held open by spring (7). When the pressure at A reaches the pressure set at pilot valve (1), control oil flows via this valve to tank. The pressure drop occurring across orifice (4) causes the main spool to start to close.

Fluid then continues to flow from port A of the main valve provided that the pressure setting is not exceeded. If no further flow is taken by the system, the main valve closes. During this time control oil passes continuously via the pilot valve to tank.



(1) Pilot valve
(2) Main spool
(3) Control line
(4) Orifice
(5) Orifice
(6) Spring loaded area
(7) Spring

Fig. 122

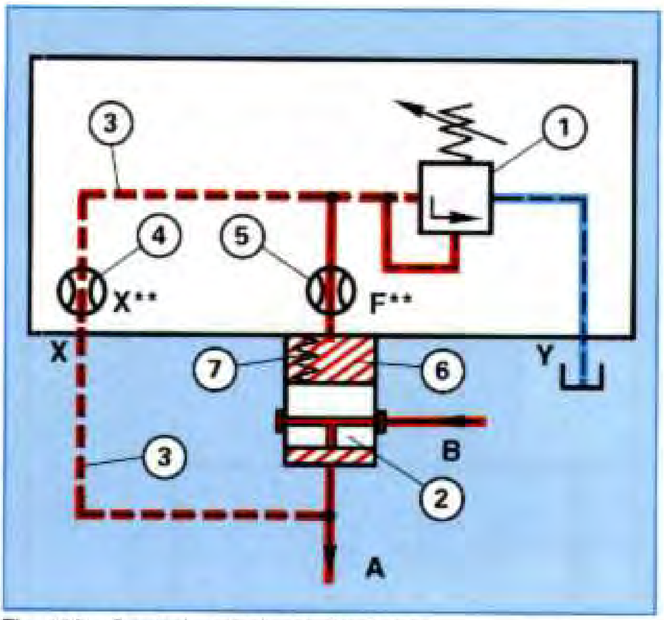


Fig. 123: *Symbol - schematic illustration*
** Orifice

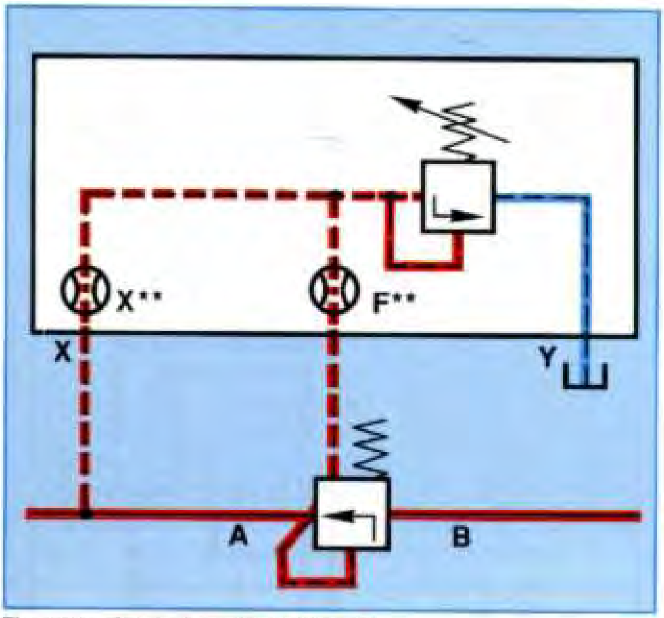


Fig. 124: *Symbol - to DIN ISO 1219*
** Orifice

Operating Curves/Power Limits

In the pressure reducing function, pilot control oil is taken immediately from the outlet of the logic element *(Fig. 123)*.

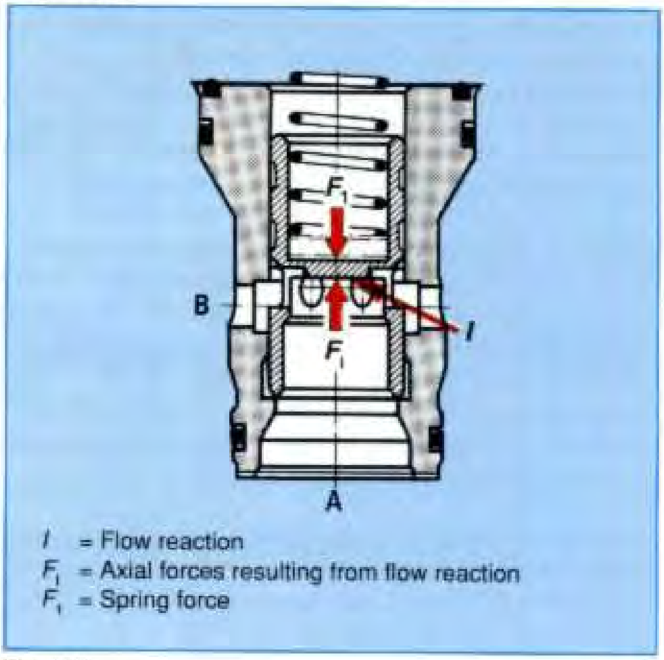


Fig. 125

The power limit is reached when the spring force is balanced by the reaction forces of the flow. The spool starts to close (moving upwards) when F_I is greater than F_1, e.g. the flow can no longer increase.

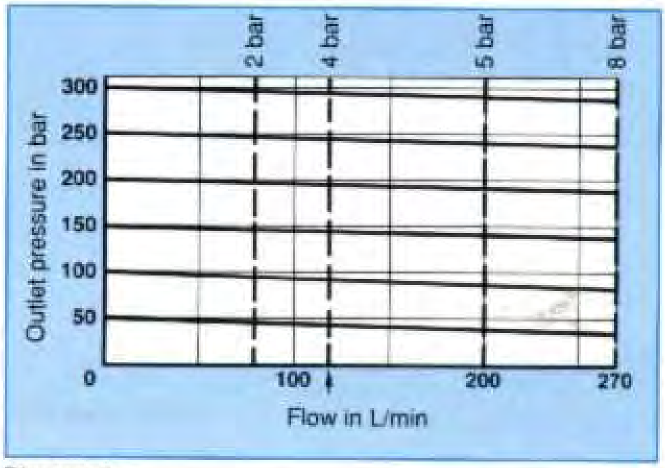


Diagram 9

The vertical dotted lines *(diagram 9)* indicate the limit of performance (flow limit).

e.g.
4 bar spring — $Q_{max.}$ = approx. 120 L/min.

2.2 Pressure reducing valve, normally closed with manual pressure setting.

With the arrangement shown in *Figs. 126 to 128*, the pressure reducing valve is closed in the start position. For this purpose, a pressure relief logic element (1) is used as the main valve and a pressure reducer valve (2) as the pilot valve. Pilot control oil is taken from the inlet side (port A) of the main valve via control line (3), orifice D and the open reducer valve (P to A) to the outlet side (port B).

Due the pressure drop between A and the spring chamber (5), the main spool opens allowing flow from A to B. Pressure at port B passes via the control line (6) at port A of the pressure reducing valve and via control line (7) to spool area (8) to work against spring (9). When the pressure at port B of the main spool reaches the pressure set at spring (9), spool (10) moves to the left and reduces (or closes) the opening P to A.

Pressure then rises in the control line *(yellow)* and in the spring chamber (5). Poppet/spool (4) starts to close and only permits sufficient fluid to flow from A to B so that the pressure set a spring (9) is not exceeded.

Any small pressure increase on the outlet side (port B) due to external forces at the actuator (cylinder or motor) are passed to tank via the third flow path in the pilot valve (A to T) For this to occur, pilot spool (10) moves slightly further to the left to permit the connection A to T.

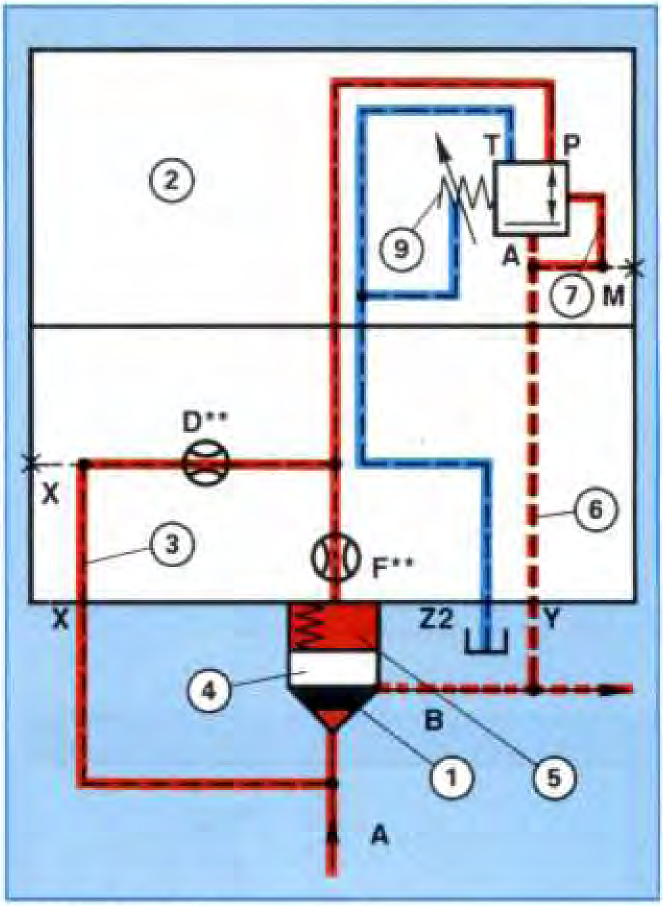


Fig. 126 ** = Orifice

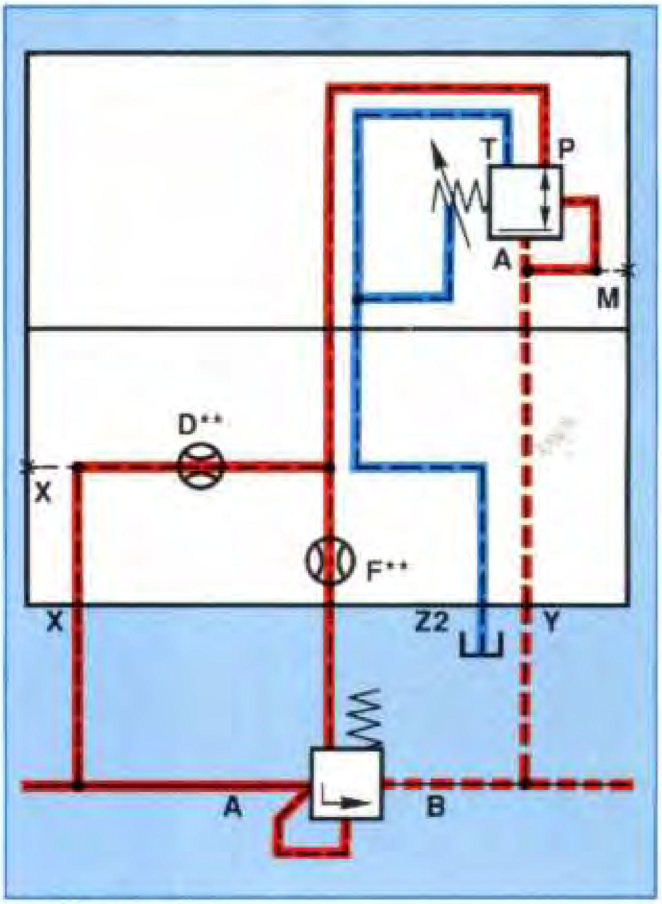
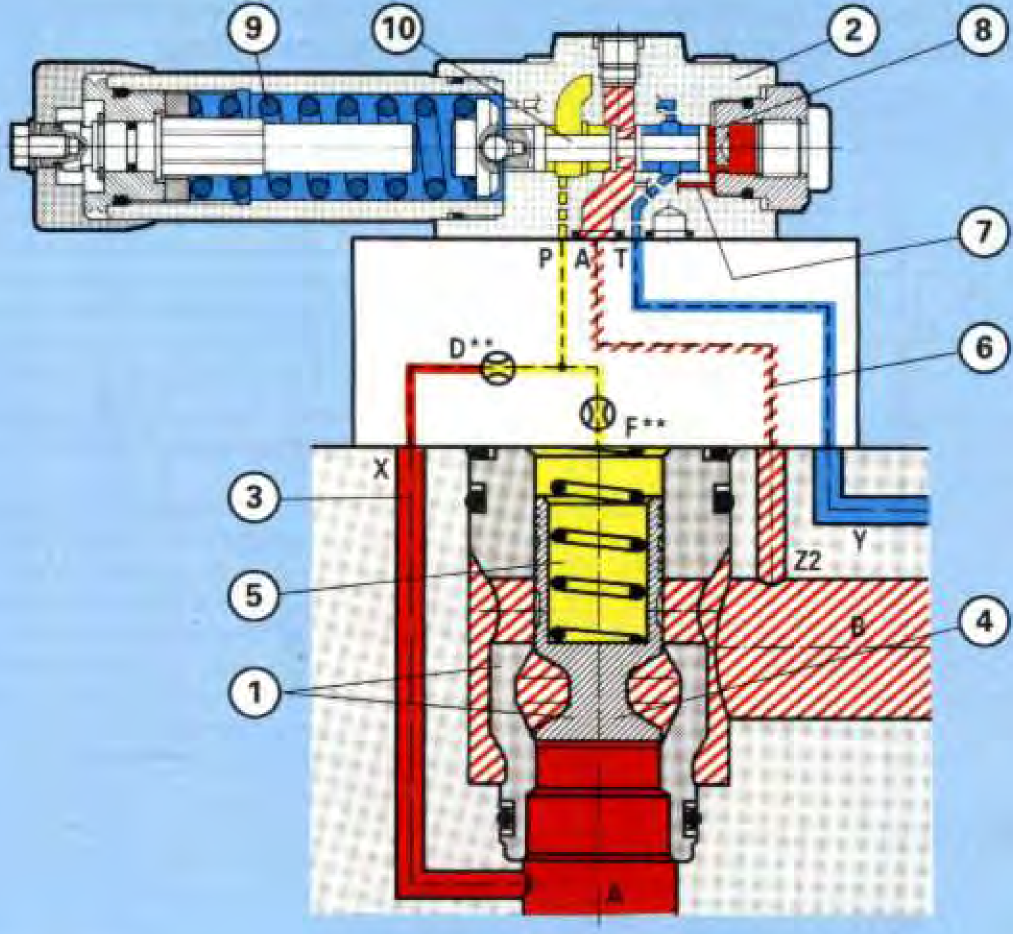


Fig. 127 ** = Orifice



(1) Pressure relief cartridge element
(2) Pressure reducing valve
(3) Control line
(4) Main spool (poppet valve)
(5) Spring chamber
(6) Control line
(7) Control line
(8) Spool control area
(9) Spring
(10) Pilot valve spool

Fig.128: *Pressure reducing function, normally closed*

2.3 A comparison between normally open and normally closed reducer functions

Normally open

- Flow from B to A
  (standard pressure reducing valve)
- Better control accuracy
  as the reaction forces on the spool are lower
- May also be used as a pressure compensator

Normally closed

- Flow from A to B
  (main valve is a pressure relief element)
- Higher power limit
- Soft starting of systems due to opening characteristics
- Quicker closing
- Possible blocking function *(see section 2.4)*
- Possible throttling function (with stroke limiter)

2.4 Pressure reducing function, normally closed at start with manual pressure setting and additional blocking function

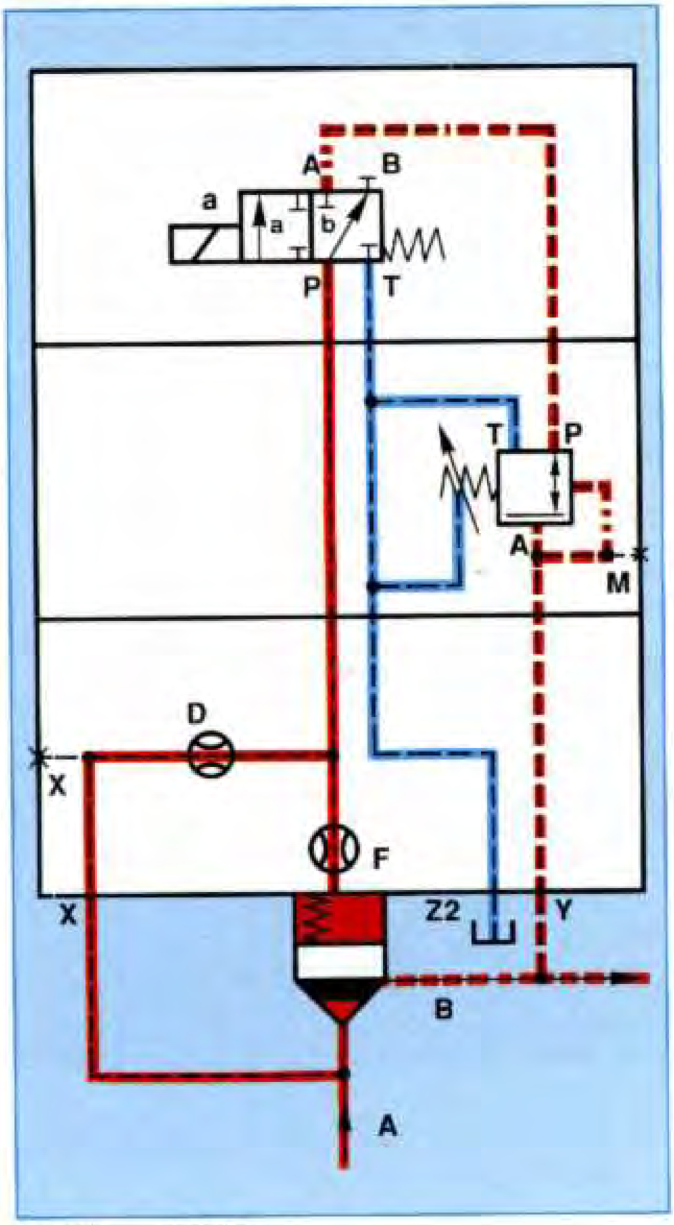


Fig. 130 ** Orifice

By installing a directional valve in the control line to port P of the pilot valve *(Fig. 129)*, an additional blocking function is achieved.

In the start position shown, the control line is closed at port B of the directional valve. The same pressure can thus build up in the spring chamber of the main spool as at port A. The logic element thus remains closed.

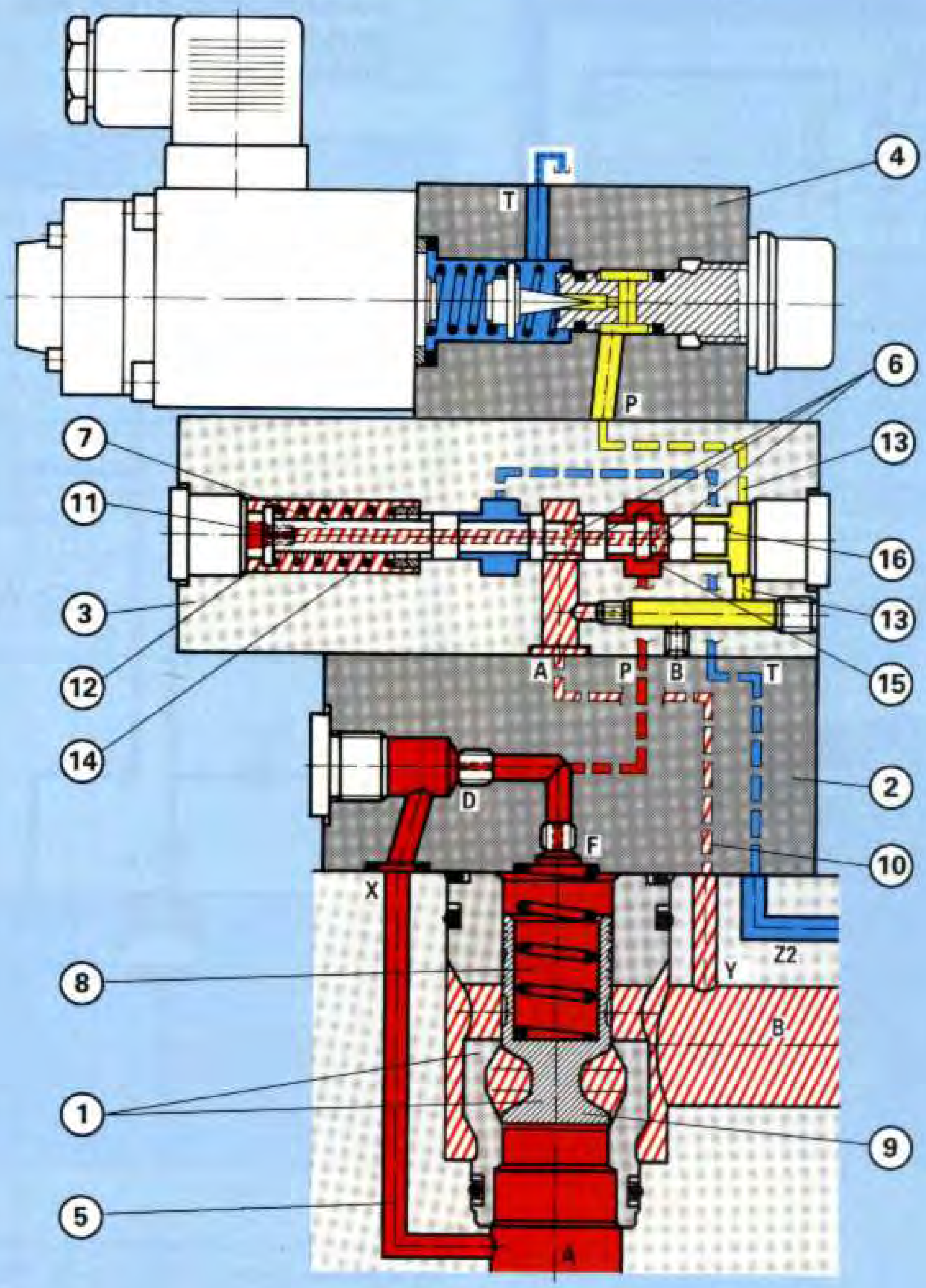
When the directional valve is moved to position a, the function described in section 2.2 *(Figs. 126 and 128)* is achieved.

2.5 Pressure reducing function, normally closed at start with electrically proportional pressure setting

In the variation shown in *Figs. 130 and 131*, the normally closed logic element permits the outlet (reduced pressure at port B of the main spool) to be set by means of an electro-hydraulic proportional valve. The main components of this assembly are the main valve (1) , the cover (2), the pressure compensator(3) and the direct operated proportional pressure relief valve(4). Pilot fluid passes from port A of the main valve(1) via the control line (5), orifice D, port P of the pressure compensator(3), drilling (6) in control spool (7) and port A of the pressure compensator to the outlet port (port B of the main spool(1)).

Due to the pressure drop between port A of the main valve (1) and spring chamber (8), the main spool(9) opens and allows flow from A to B. Pressure in port B passes via control line (10) at port A of the pressure compensator and via drilling (6) in spool (7) and orifice (11) to spool area (12). If control line (13) *(yellow)* to the proportional pressure relief valve is at zero pressure, spool (7) moves to the right when the pressure set by spring (14) is reached and reduces the opening at point (15) from P to A. The main valve poppet (9) closes sufficiently to maintain the pressure set in the outlet side (port B). This is then the minimum pressure setting of the valve and corresponds to the spring force (14).

Control spool thus only moves to the right (closing direction) when the pressure in port B has reached the pressure set by spring force (16) plus the pressure on the control area (14). The poppet spool (9) reacts accordingly to reduce the flow from A to b in order to maintain the set outlet pressure.



(1) Main valve
(2) Cover
(3) Pressure compensator
(4) Proportional pressure relief valve
(5) Control line
(6) Drilling
(7) Pilot valve spool
(8) Spring chamber
(9) Main spool
(10) Control line
(11) Orifice
(12) Control spool area
(13) Control line
(14) Spring
(15) Area open to flow at control land
(16) Control spool area

Fig.130: *Pressure reducing function, normally closed with electrically proportional pressure setting*

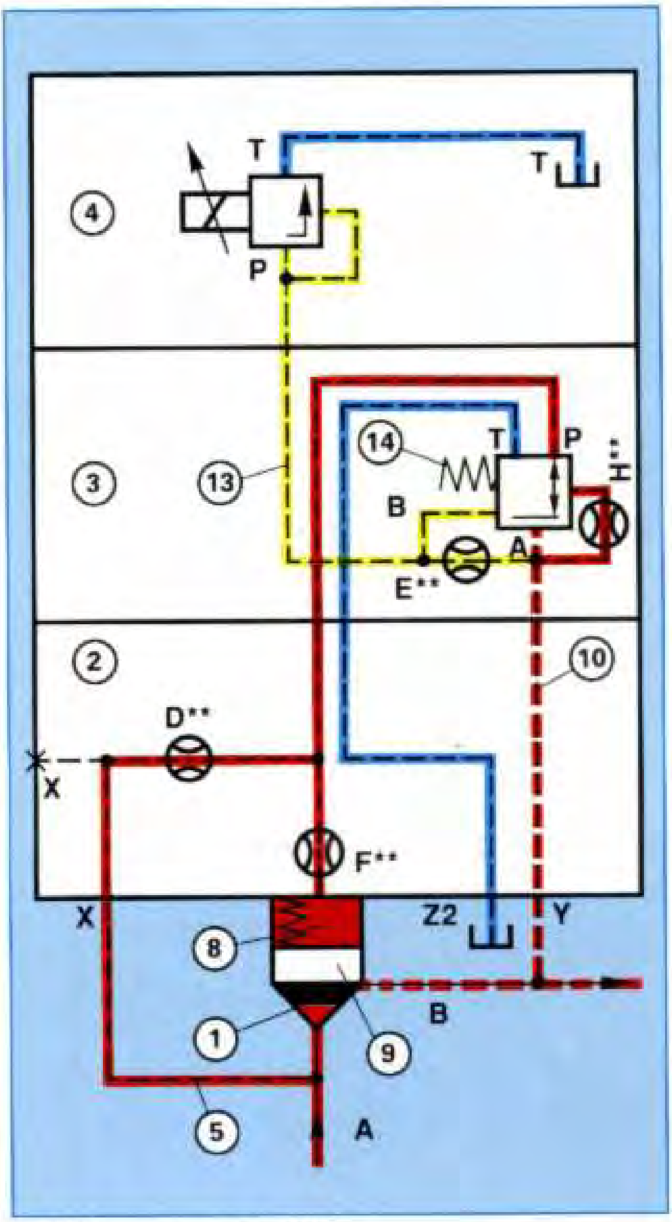


Fig. 131: ** = Orifice

2.6 Pressure reducing function, normally closed at start with electrically proportional pressure setting

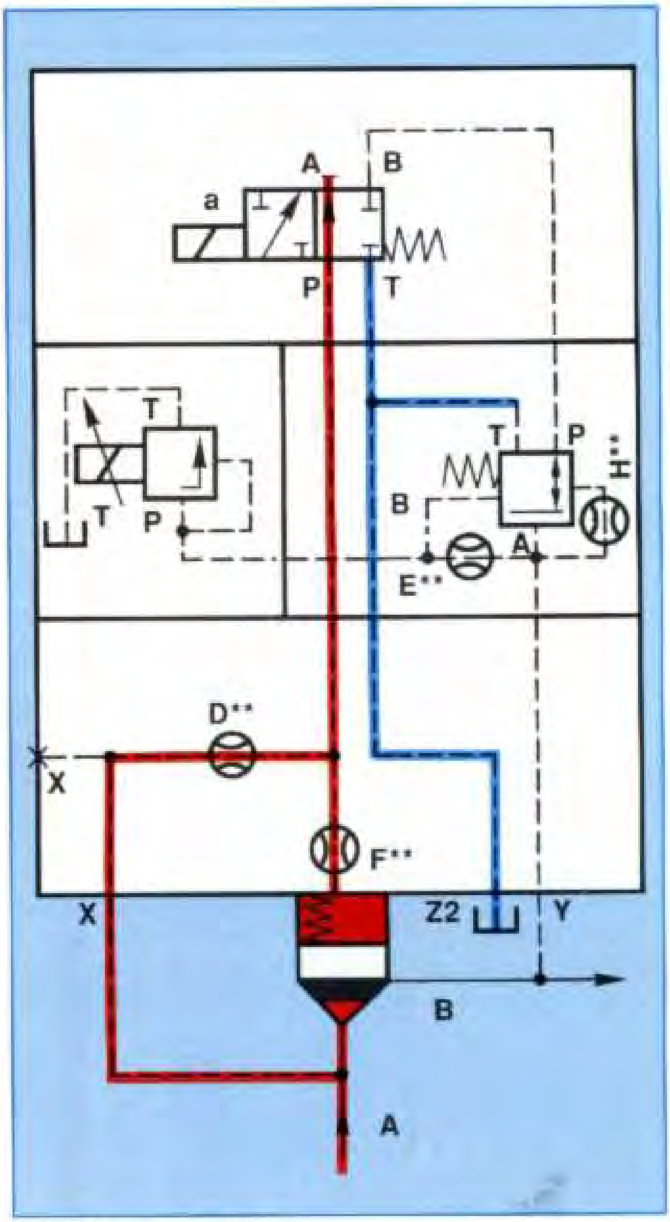


Fig. 132: ** = Orifice

If the version described in *section 2.5* is extended by adding a directional valve as shown in *Fig. 132*, a blocking function as described in *section 2.4* is obtained in addition to the electrically proportional pressure setting.

3 Pressure sequence function

The variation shown in *Fig. 133* permits a secondary circuit to be sequentially switched dependent on pressure.

The main element is a pressure relief valve element. A pressure reducing valve is used as a pilot valve.

The required sequencing pressure is set via the pilot valve built into the control cover.

The pilot oil supply can be derived either externally (pilot port X) or internally (from port A via control port X or Z2). The spring chamber of the pilot control valve is led directly to tank via ports Y or Z1.

When the pressure set at the pilot control valve spring is reached, the valve responds and unloads the spring chamber of the main valve to tank via port Z1. The main spool opens and permits flow from A to B.

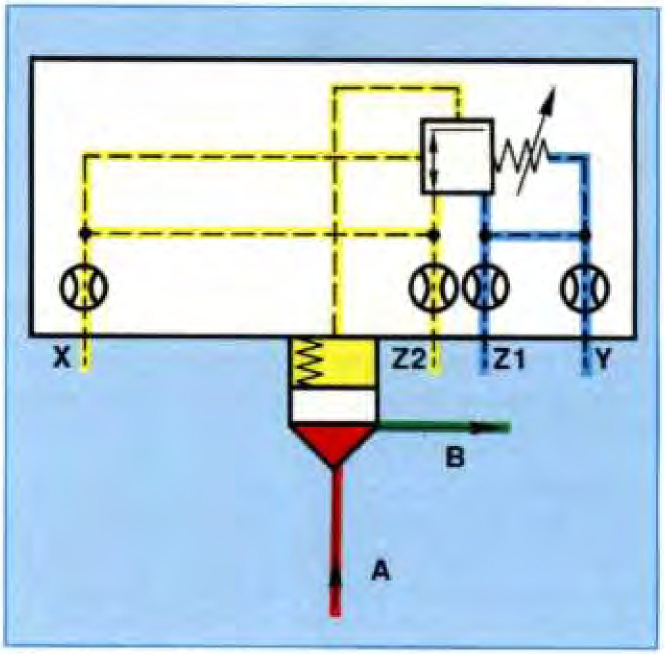


Fig. 133: *Symbol - schematic illustration*
** Orifice

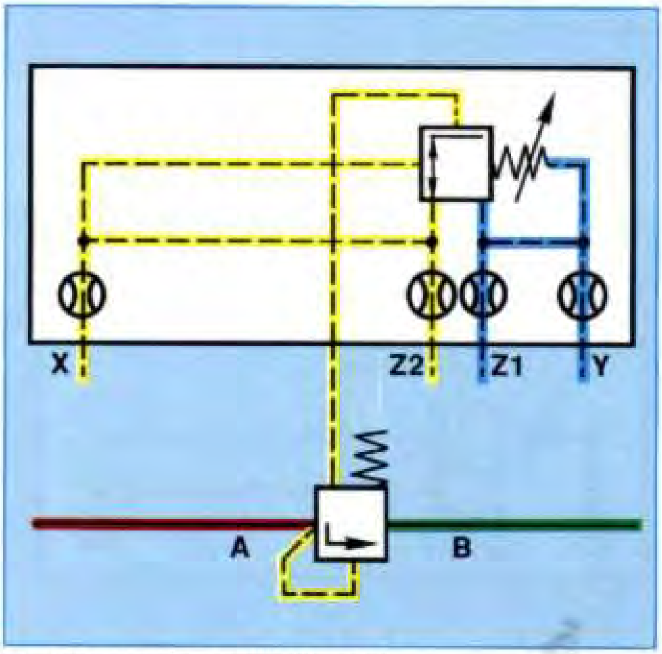


Fig. 134: *Symbol - to DIN/ISO 1219*
** Orifice

Typical Circuits

Example 1

In the circuits shown *(figs. 135 and 136)*, system p_s is fed by a high pressure and a low pressure pump.

Function

At the start, both pumps are engaged and supply fluid to the system. Logic element (1) is held closed by pressure from the low pressure pump via control line (2), port Z2 and the pressure reducing valve (3). Port A is isolated from port B.

System pressure in line (4) after the non return valve passes via control Line (5) and works against the spring of the pilot valve (3). When the pressure in the system exceeds the pressure setting of spring (6), the connection between the low pressure pump and the spring chamber 97) is broken and the latter is is unloaded via Z1 to tank. Logic element (1) opens and the low pressure pump is unloaded to tank. Non return valve RV prevents the high pressure pump also passing to tank via the low pressure circuit.

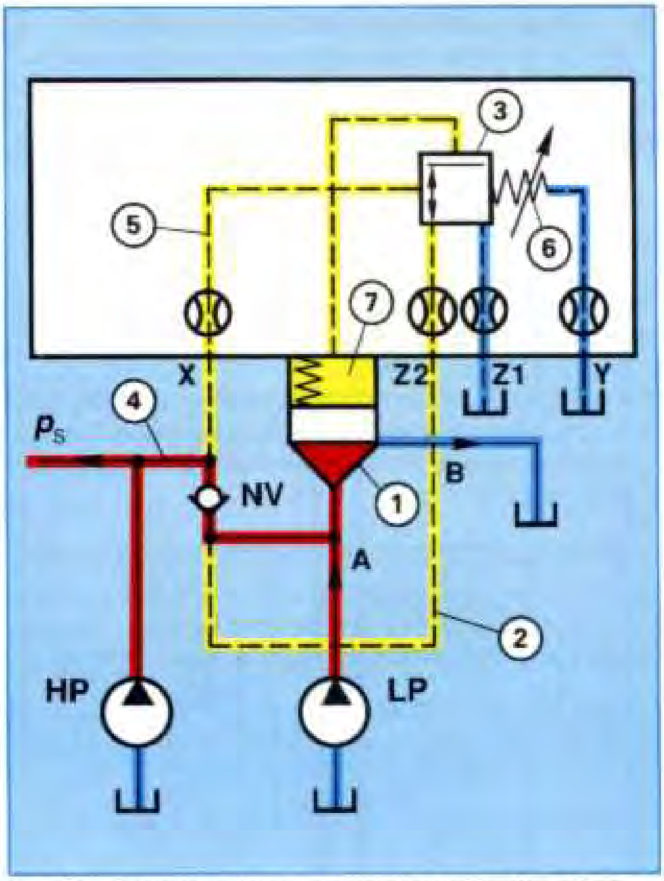


Fig.135: *Circuit for pressure dependent unloading of low pressure pump*

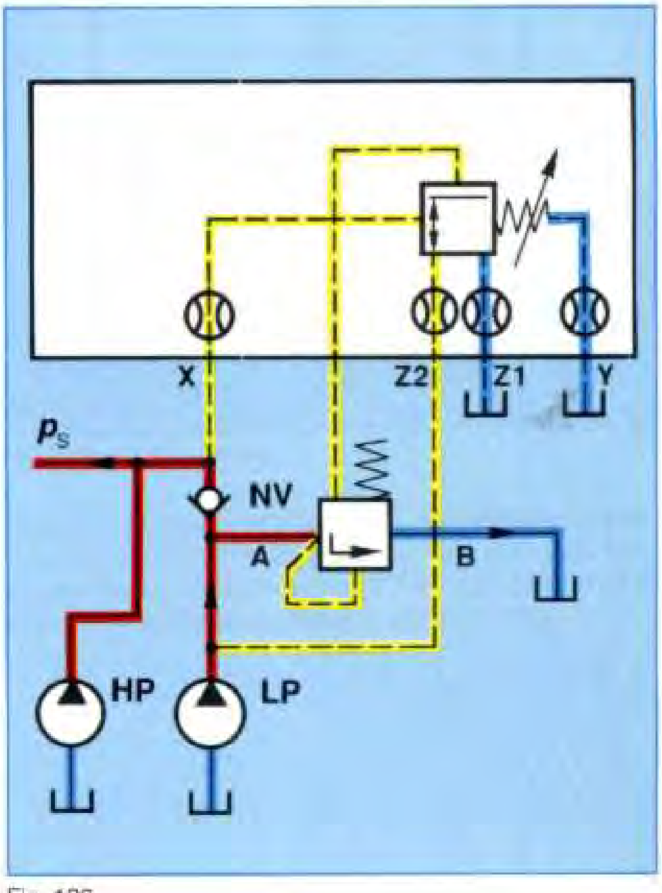


Fig. 136

Legend to Figs. 135 and 136

HP = High pressure
LP = Low pressure
NV = Non-return valve
p_s = System pressure

Example 2

With the circuit shown in *Fig. 137*, fluid is only permitted to flow into system 2 when the pressure in system 1 reaches the set level. Pilot oil flow is taken internally from port A of the main spool.

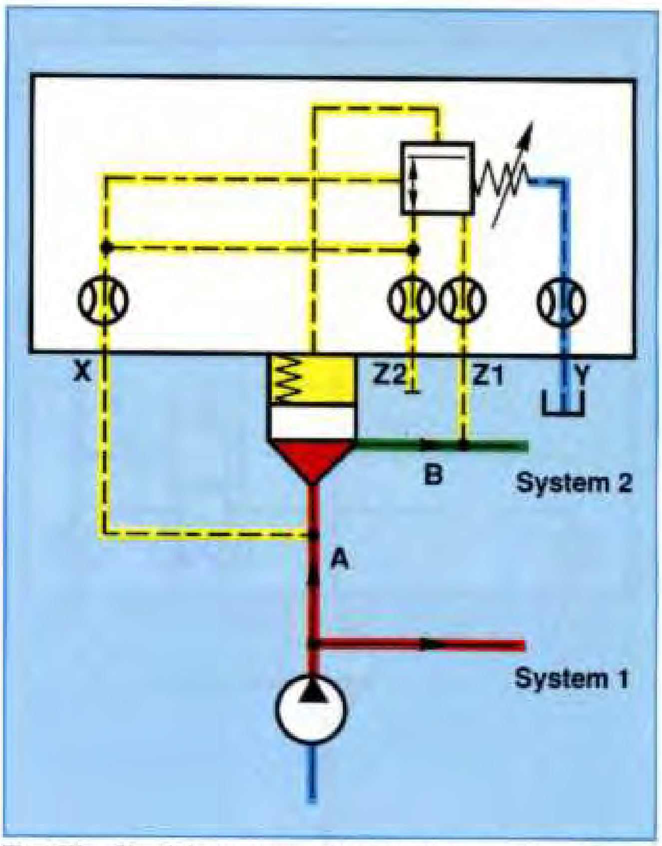


Fig.137: *Circuit for pressure dependent sequencing of a second circuit*

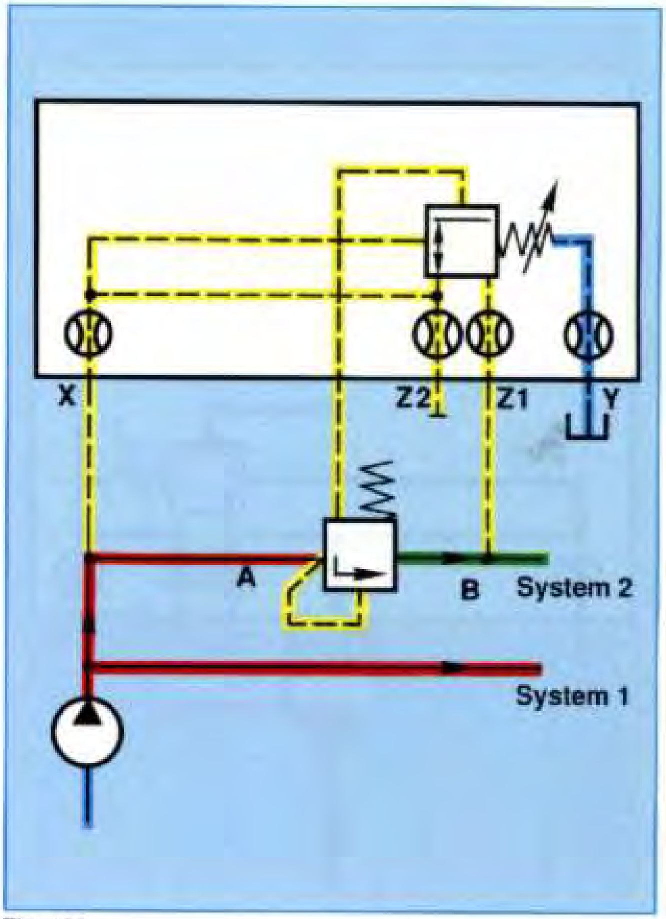


Fig. 138

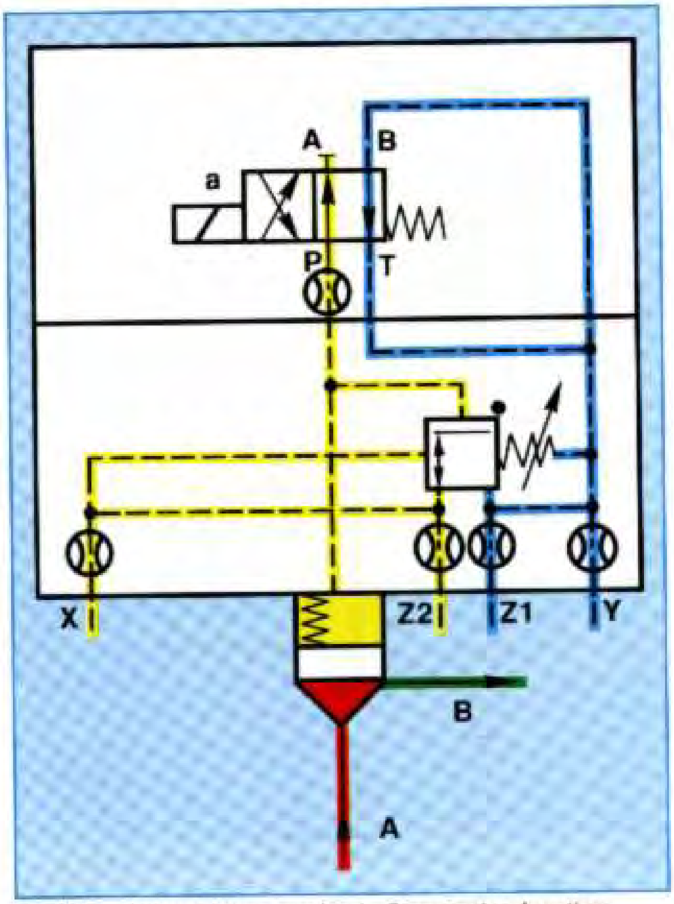


Fig.139: *Solenoid de-energised - Sequencing function*

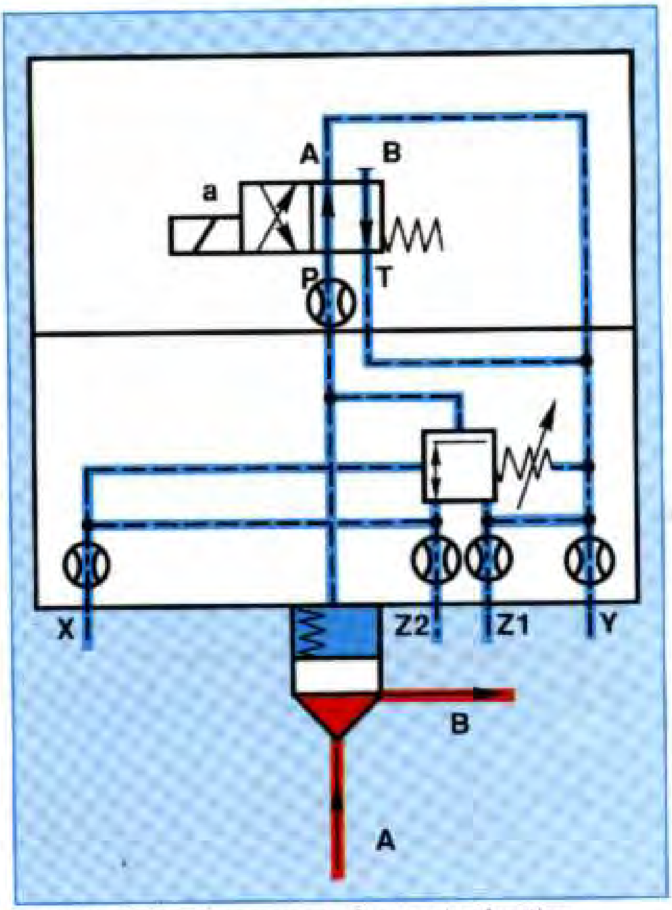


Fig.140: *Solenoid energised - Sequencing function*

By means of a built on directional valve *(Figs. 139 and 140)*, the secondary circuit can be sequenced either by the directional valve or by the pressure control valve.

Logic elements, flow control function

Various forms of flow control valves can be achieved using logic elements. These may include, for example,

- simple throttle valves
- proportional throttles

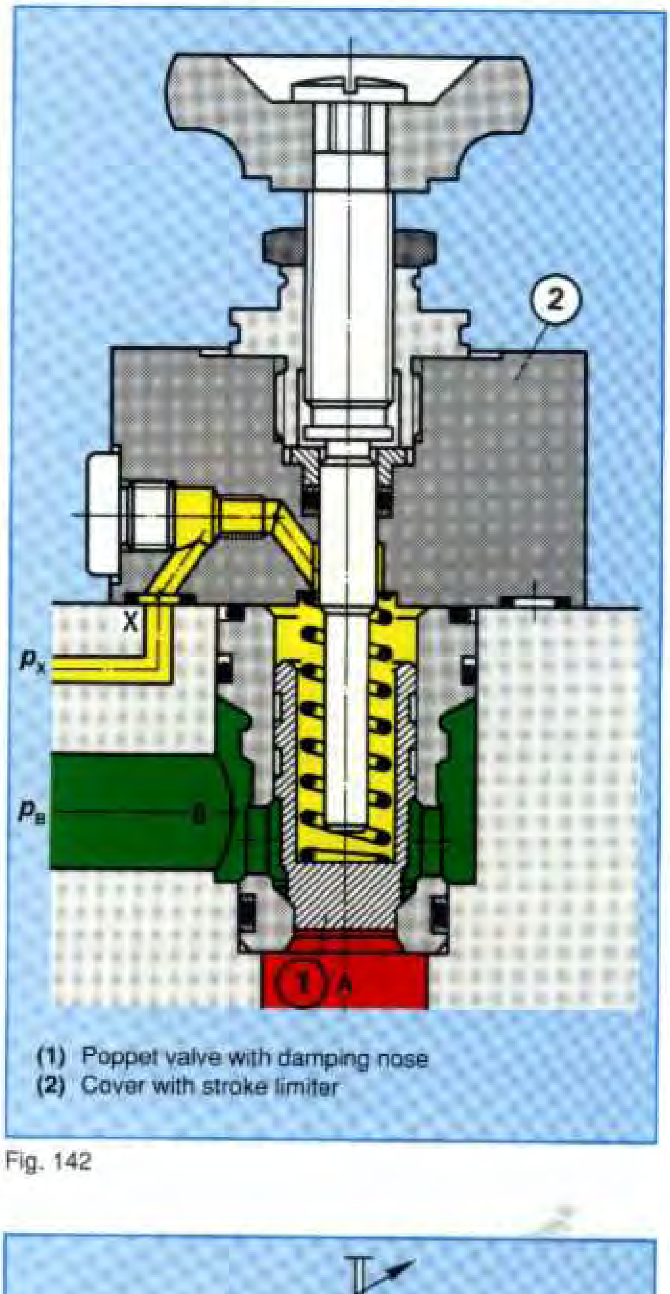
In conjunction with a second throttling element, for example a proportional directional valve, a logic element may be used as a pressure compensator. In this way, a fully pressure compensated flow control function can be achieved i.e. flow through the throttling point independent of load variations.

1 Simple Throttle Valve

A simple throttle consists of a simple directional logic element equipped with a cover incorporating a stroke limiter.

The stroke of the logic element poppet and with it the flow through the valve can be steplessly limited by setting the spindle via the hand wheel. The logic element itself is controlled according to the directional function required. Throttling takes place in both directions of flow.

The logic element illustrated in *Fig. 142* is equipped with a damping nose as this provides better control of the throttling action. In this way, the opening and closing actions of the logic element can be extended as described in the chapter *Directional Functions*. However, logic elements without damping noses are also to be found equipped with stroke limiters.



(1) Poppet valve with damping nose
(2) Cover with stroke limiter

Fig. 142

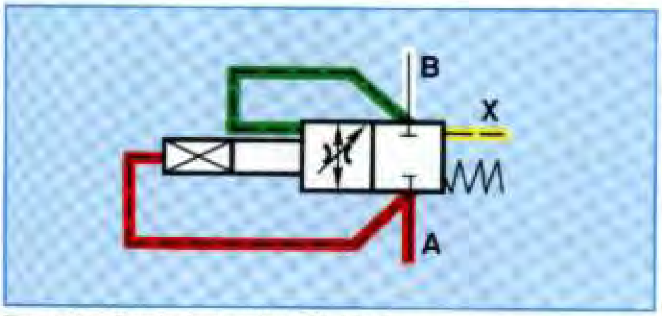


Fig. 141: *Symbol - to DIN ISO 1219*

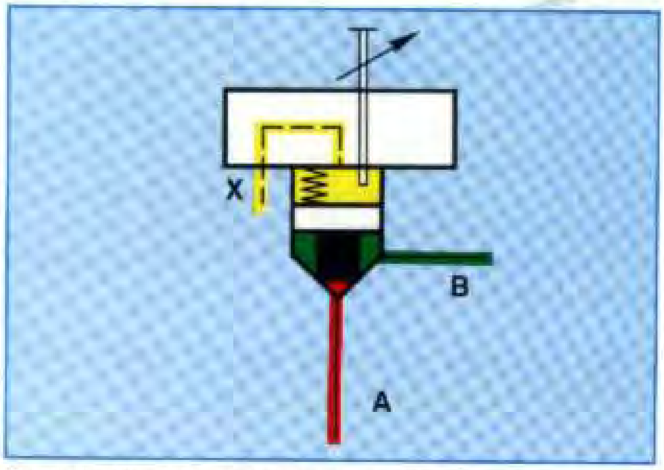


Fig. 143: *Symbol - schematic illustration*

2 2 way proportional throttle valves (Logic elements)

The combination of devices shown in *Fig. 145* is used either for simple throttle control of larger flows or in conjunction with a pressure compensator as a complete flow control system. Typical areas of application are in presses and plastic moulding machines. Two way throttle valves a simply variable orifices, the opening of which can be electrically preset.

The complete throttle element is supplied as a unit (dimensions to DIN 24 342) ready to install in a manifold block. Main bush (2) with its orifice spool (3) and feedback positional transducer (4) and also the pilot control section (5) with its proportional solenoid (6) are all screwed into the valve cover. Flow is from A to B. The pilot oil port X is connected to port A. The pilot oil drain port should be led to directly tank with a minimum pressure loss.

At a command value of zero (with the proportional valve de-energised, pressure in port A passes via control line X and control spool (10) to add to the force provided by spring in chamber (8) to keep the variable orifice (3) closed.

As soon a control signal is present, amplifier (7) compares the command signal with the actual value for spool position (the feedback signal from the positional transducer). The proportional solenoid (6) then receives an input current corresponding to the differential value between the two signals.

The solenoid moves spool (10) against spring (11). Due to the operation of the two throttling points (13 and 14), the pressure in the spring chamber is adjusted so that the spring loaded variable orifice spool (3) attains a position corresponding to the set input level and thus sets the valve opening.

Should the electrical current fail or a cable break, the orifice shuts automatically for complete safety. The components within the closed loop control circuit are carefully matched to each other so that the command value and the stroke of the orifice spool are directly proportional to each other. The result is that at a constant pressure drop, the flow from A to B is only dependent upon the spool stroke and the window geometry (9).

For a system requiring a linear relationship giving direct proportionality between command value and flow, model FE..C10/L should be used. If a quadratic (progressive) relationship between command value and flow is required, use model FE..C10/Q. (Both relationships considered at a constant pressure drop).

The curves shown in *diagrams 10 and 11* make this relationship clear.

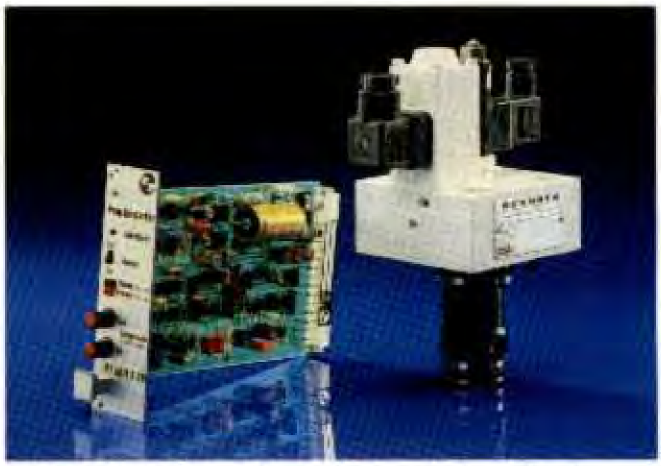


Fig. 144: *2 way proportional throttle valve,type FE...C...*

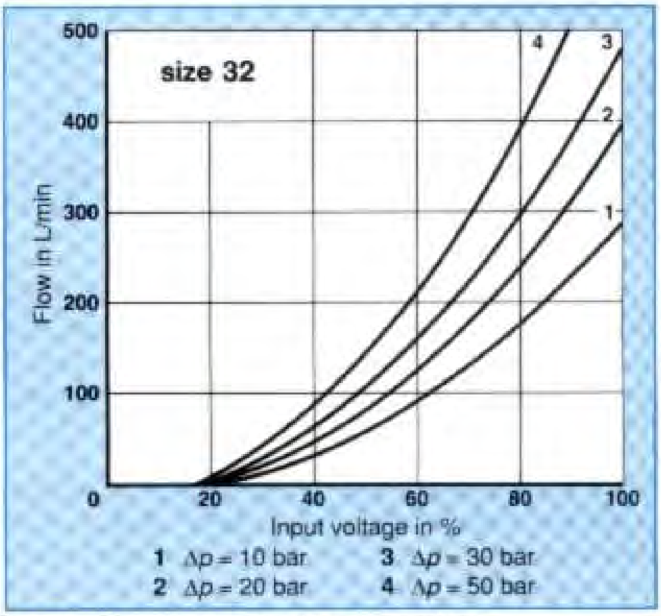


Diagram 10: *Progressive flow characteristic*

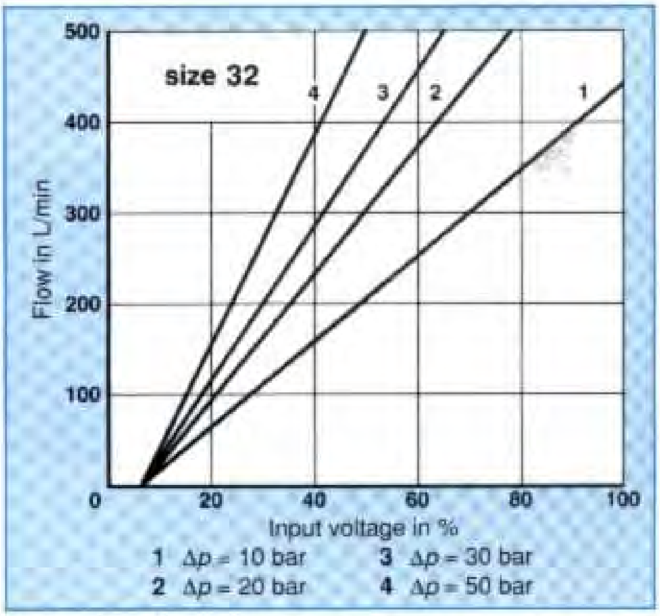


Diagram 11: *Linear flow characteristic*

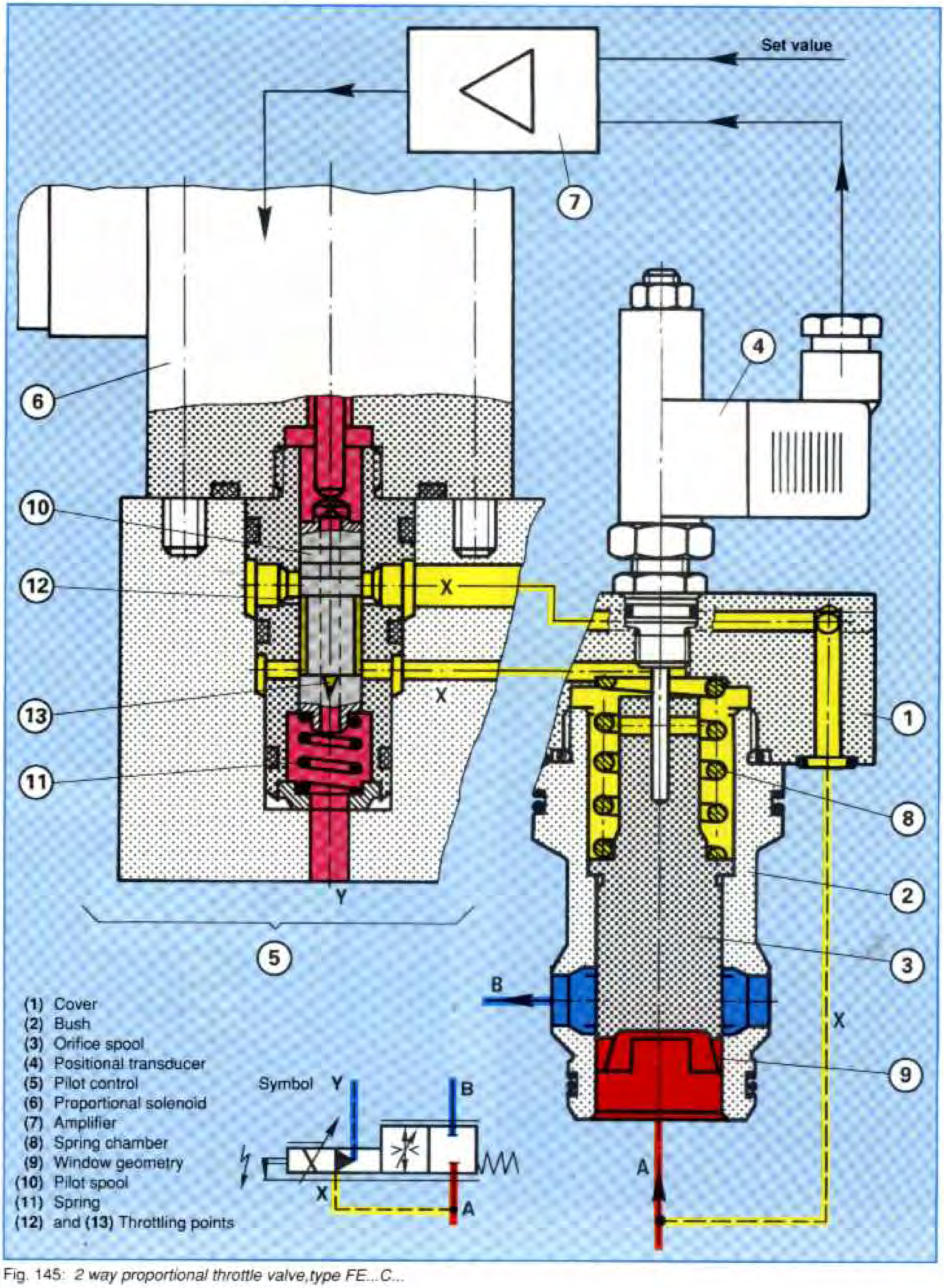


Fig. 145: *2 way proportional throttle valve,type FE...C...*

3 Two way flow control, normally open.

In order to achieve load compensation across a throttling point a pressure compensator must also be installed.

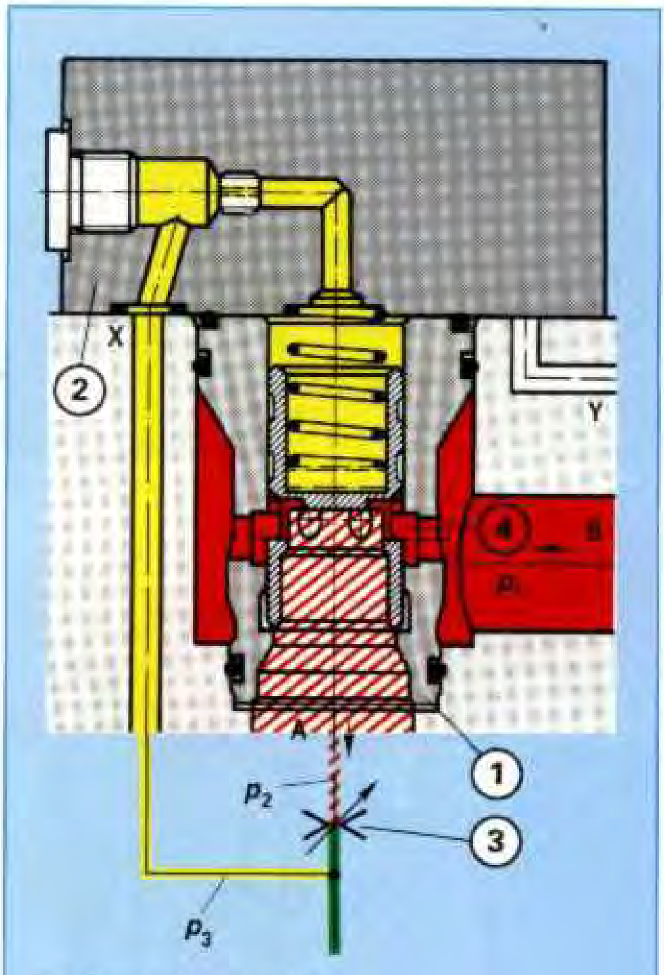
In this instance, the pressure compensator is formed by using a pressure reducing cartridge element. The pressure compensator is mounted upstream of the throttling valve. In the start position, the pressure compensator is open. Fluid can flow from B via the logic element (1) to A and then on to the throttling point (3) and from there to the working element (cylinder or motor). Pressure p_1 corresponds to the maximum system pressure. Pressure p_3 depends upon the load being applied. Pressure p_3 passes via port X and a damping orifice to the spring chamber of the logic element.

Pressure p_2 varies with the opening of the valve so that the pressure drop $(p_2 - p_3)$ remains constant. This pressure drop corresponds to the spring force on the spool.

3.1 Example

If pressure p_3 falls due to a change in load, the pressure in the spring chamber also falls. Flow tends to increase momentarily, but the spool moves upwards in the direction of the spring and thus reduces the valve opening (4). The flow then also falls at throttling point (3) and with it pressure p_2. This continues until a balance between p_3 and p_2 has once more been achieved. In this way, the pressure drop across the orifice is held constant.

Dependent upon the size of the logic element used, pressure compensators of this type are applied where it is required to control large flows.



(1) 2 way reducing cartridge
(2) Control cover
(3) Throttling point (e.g. proportional directional valve)
(4) Opening to flow in pressure compensator

Fig. 147

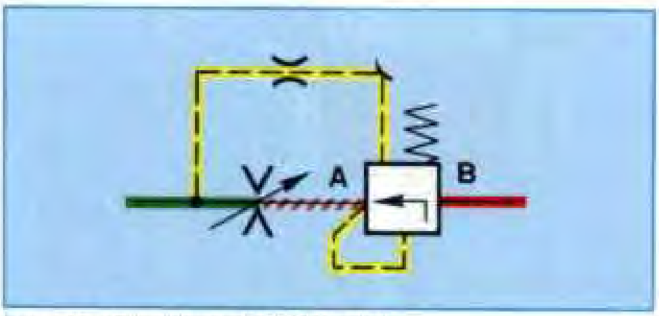


Fig. 146: *Symbol - to DIN ISO 1219*

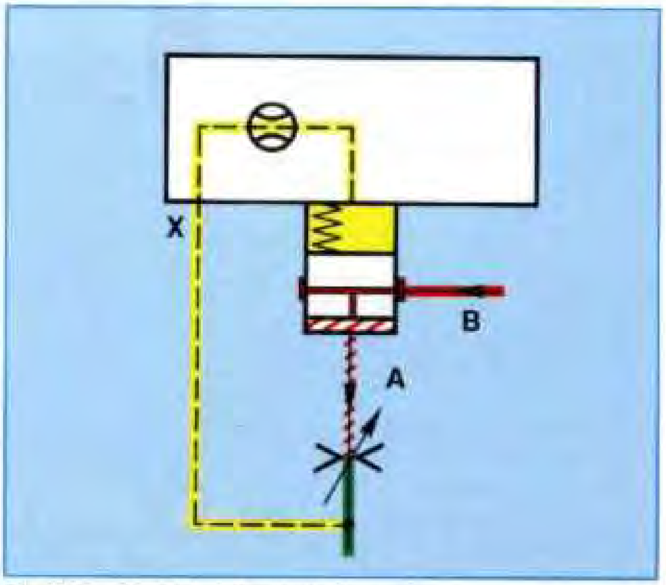


Fig. 148: *Symbol - schematic illustration*

3.2 Typical circuit

The typical circuit shown in *Fig. 149* shows a cylinder controlled by a proportional directional valve. In addition to acting as a directional valve, the valve also has a flow control function. In order to control the speed of the cylinder independently of load, a 2 way logic element is installed upstream of the proportional valve as a pressure compensator. In order to be able to receive a load pressure signal for both directions of cylinder travel, a shuttle valve is installed in the lines between the proportional valve and the cylinder.

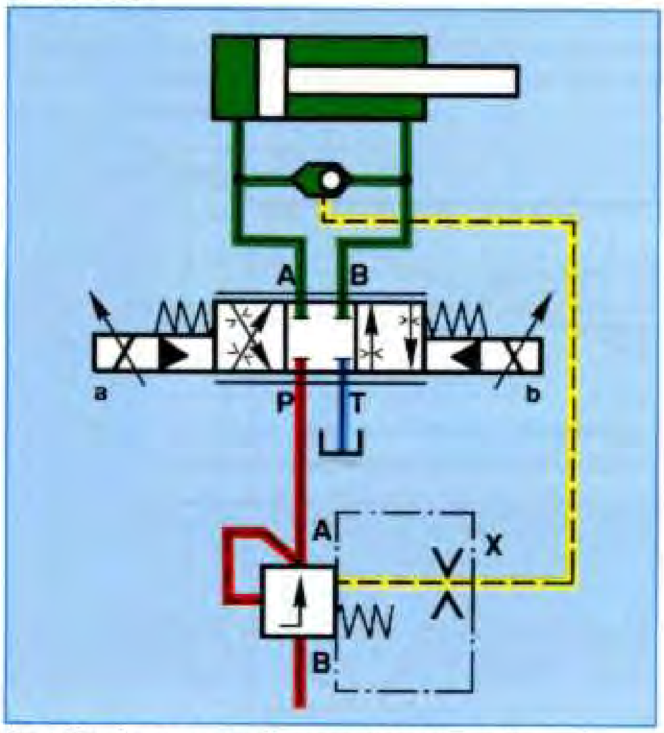


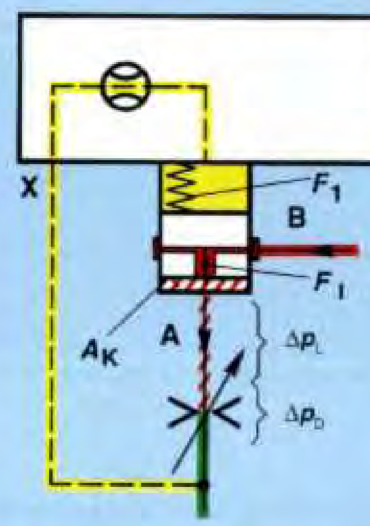
Fig.149: *2 way, meter- in pressure compensator*

3.3 The limit of performance of a pressure compensator.

When a 2 way pressure reducing logic element is used as a pressure compensator as shown in *Fig. 149*, particular attention must be paid to the limits of its performance. As spring chamber pressure is tapped off immediately after the throttling point, both the pressure drop along the line between A and the throttling (Δp_L) and the pressure drop across the throttle itself (Δp_D) must be taken into consideration.

The power limit is reached when the sum of the flow forces F_I *(see pressure reducing function)* arising from the pressure drop across the orifice and the pressure drop across the connecting line (referred to spool area A_K) balance the spring force F_1.

$$F_1 = F_I + \Delta p_L \cdot A_K + \Delta p_D \cdot A_K$$



F_1 = Spring force of 2 way valve in an opening direction

F_I = Sum of flow forces

Δp_L = Pressure drop resulting from pipe resistance between port A of the pressure compensator and the throttling point

Δp_D = Pressure drop at the throttling point

Fig. 150

Taking size 25 as an example, *diagram 12* shows the power limit for each type of spring which may be fitted. It is in fact reached when the spring curve intersects the valve flow curve (Δp – Q curve).

With the help of *diagram 12*, it is possible to determine the required pressure drop for the throttle and the connecting line ($\Delta p_L + \Delta p_D$) for a given flow rate.

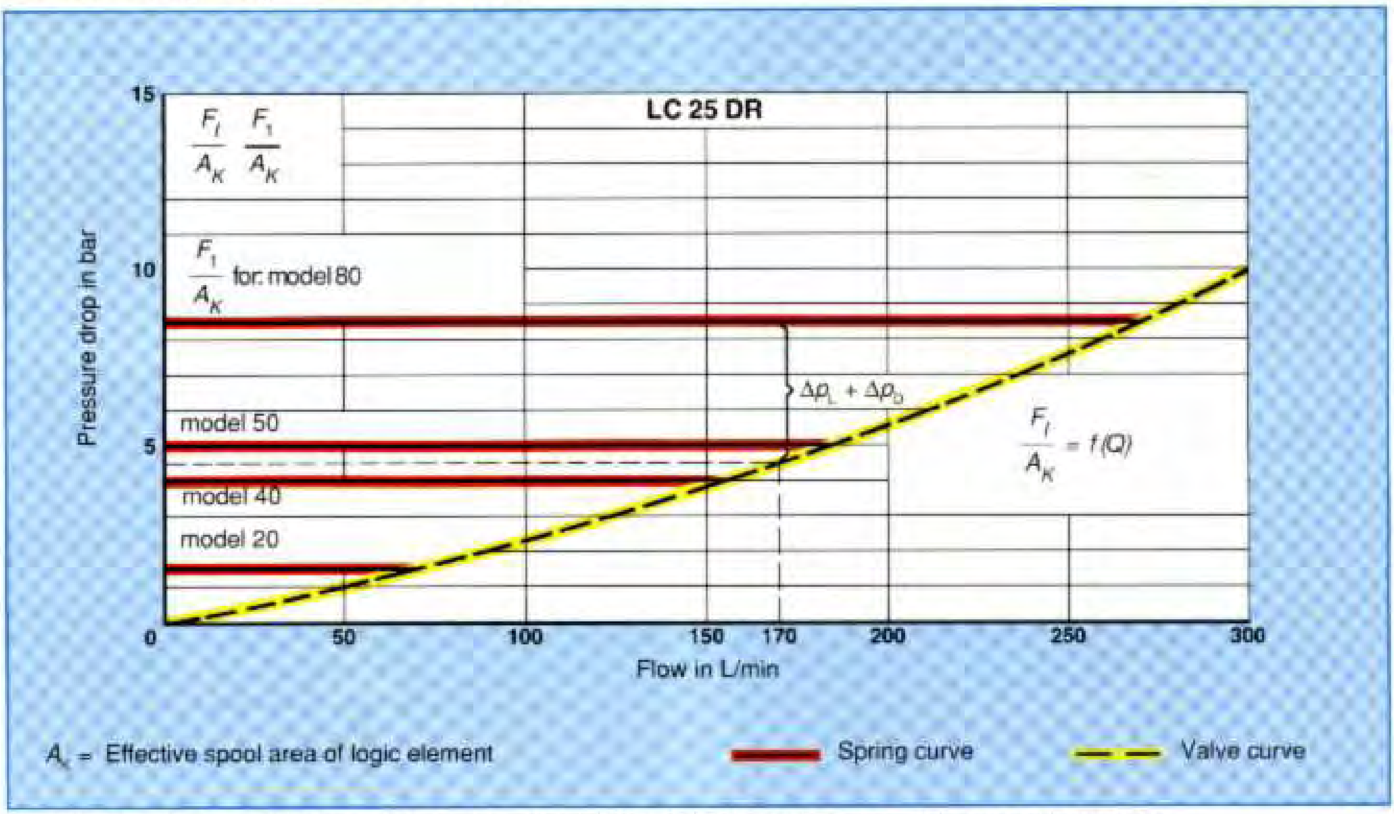


Diagram 12: *Performance limit/required pressure drop for a logic element used as a pressure compensator.*

Example

A size 25 cartridge reducer valve is to be installed as a pressure compensator for a flow of 170 L/min. Using model 80 (with an 8 bar spring) the throttling point must be selected so that the pressure drop ($\Delta p_L + \Delta p_D$) does not exceed 4 bar.

If this pressure drop is not available, the required flow rate cannot be achieved.

Or:

If a greater flow is required through a preset orifice and a certain size of pressure compensator, this can only be achieved by increasing the pressure drop i.e. increasing the spring force F_1.

If this cannot be achieved due to the space required for the installation of a heavier spring, the opening pressure at the logic element can be increased hydraulically.

For such a solution, see *Fig. 151*.

3.4 A pressure compensator with a settable pressure drop

If pressure losses occur in a system due to the situation of the valves e.g. due to pipe line losses (frequently not easy to foresee), these influence the pressure drop across the throttling point and the limit of performance. In order to be able to have some control over this factor, the pressure drop across the throttling point in *Fig. 151* can be set as required. In this circuit, a 2 way pressure reducing element is once more used, but in this case in conjunction with a cover incorporating a pilot pressure relief valve. Port X which is now used to supply the pilot valve with pressure is also connected to port B of the pressure compensator.

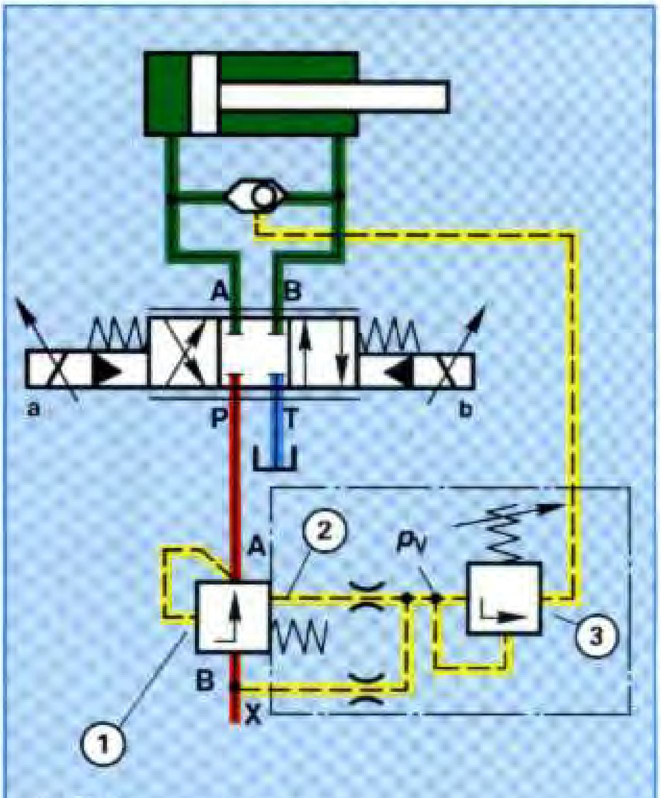
The pilot pressure relief valve (3) is now used to sense the load pressure.

The pressure drop which is held constant across the throttling point in the proportional directional valve is set at this valve.

The minimum pressure drop from P to A or B at the proportional valve is set by the spring force at the pressure compensator. The force resulting from the setting of the pressure relief valve must now be added to this spring force.

The load pressure which is felt at the outlet of the pressure relief valve (3) is effective over the seat area of this valve.

The pressure drop at the throttling point is now governed by the spring of the pressure compensator and the pressure p_V in the spring chamber.



(1) Pressure compensator
(2) Spring chamber of the pressure compensator
(3) Pressure relief valve
for setting the pressure drop across the orifice

Fig.151: *2 way, meter-in pressure compensator with adjustable pressure drop across metering orifice*

4 Typical Circuits

4.1 Load compensation with logic elements (pressure reducing elements) for both negative and positive load compensation in circuits for hydraulic motors and non-regenerative cylinder circuits.

Fluid flowing back from the cylinder must pass through the pressure reducing logic element from B_1 to A_1 (or B_2 to A_2) to the throttling point (the proportional directional valve). Pressure before the throttling point is felt at port A_1 (or A_2) and works against the spring to close the valve. Pressure at the outlet of the throttling point (T port) assists the spring to keep the valve open.

The pressure drop across the proportional valve is held constant.

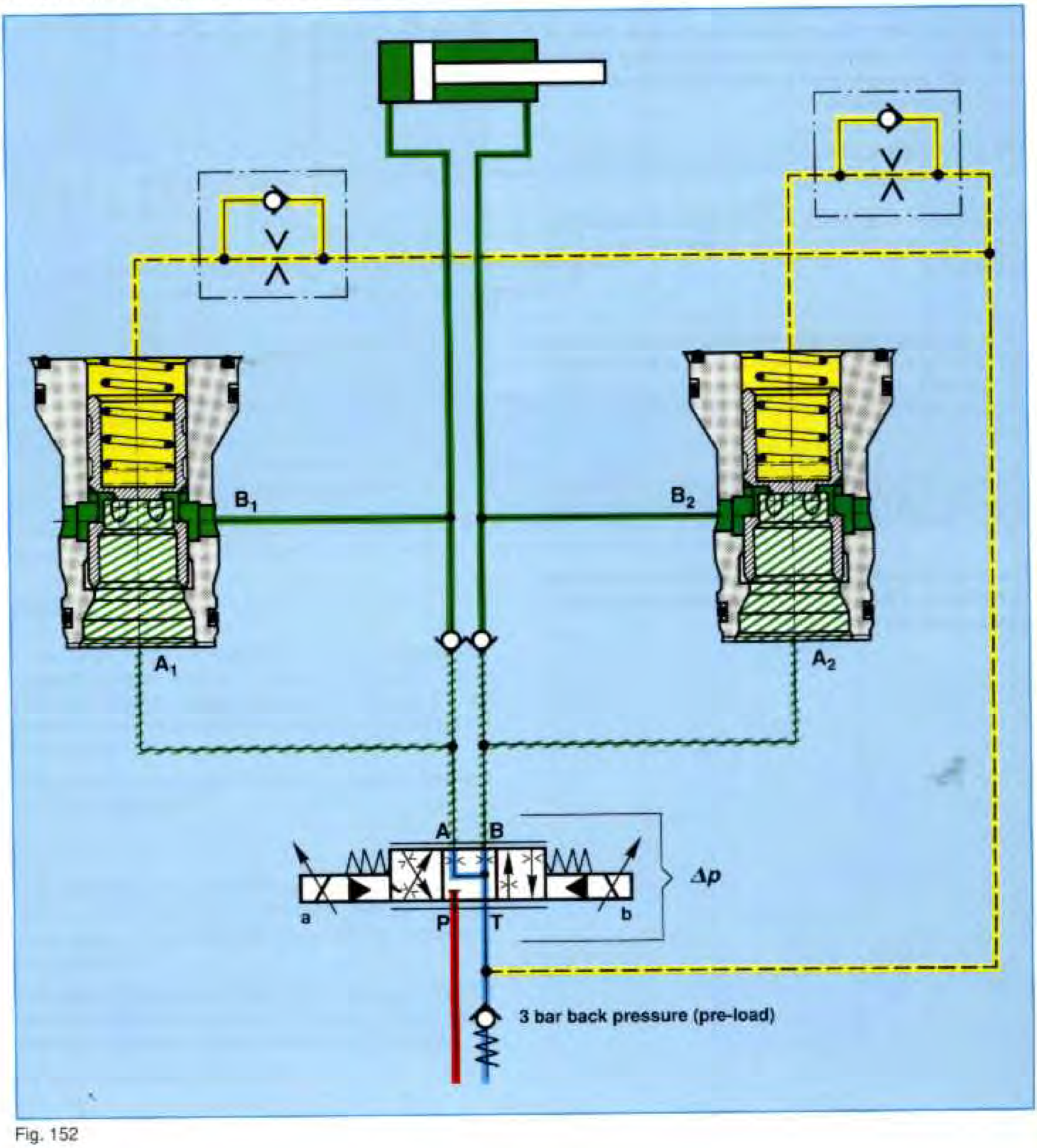


Fig. 152

4.2 Load compensation with logic elements (pressure reducing elements) for both negative and positive load compensation for cylinders with an area ratio of 2:1 and regenerative operation.

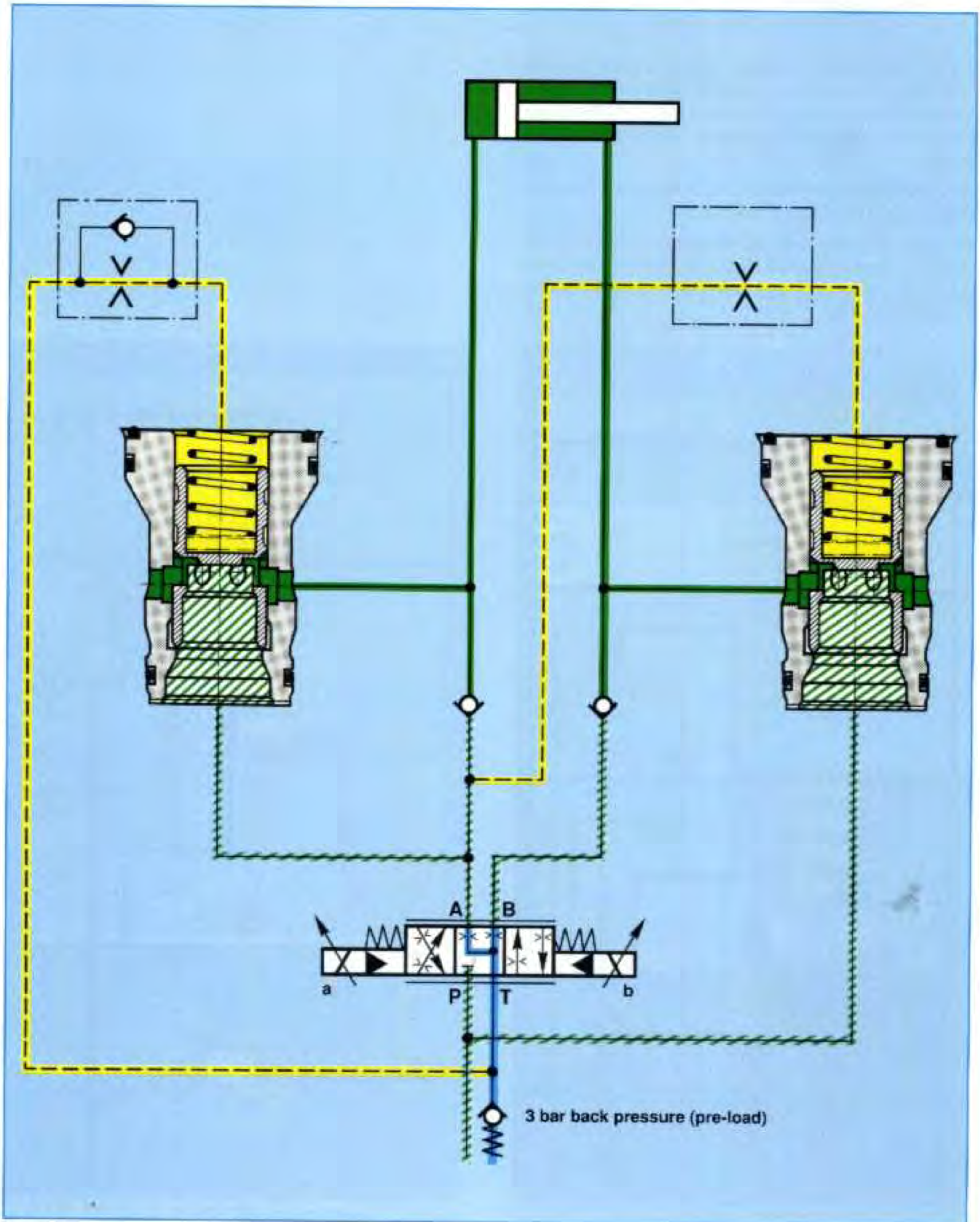


Fig. 153

5 2 way pressure compensated flow control with closed start position

If, as for the pressure reducing function, a pressure relief logic element is used in conjunction with a pressure reducing valve as pilot valve together with a throttling element, a normally closed pressure compensator is produced.

As in the case of the normally open pressure compensator, the same limiting criteria apply.

The pressure in the spring chamber of the pilot valve (2) can once more be varied by the proportional pressure relief valve. This in turn sets the pressure drop across the throttling point (3).

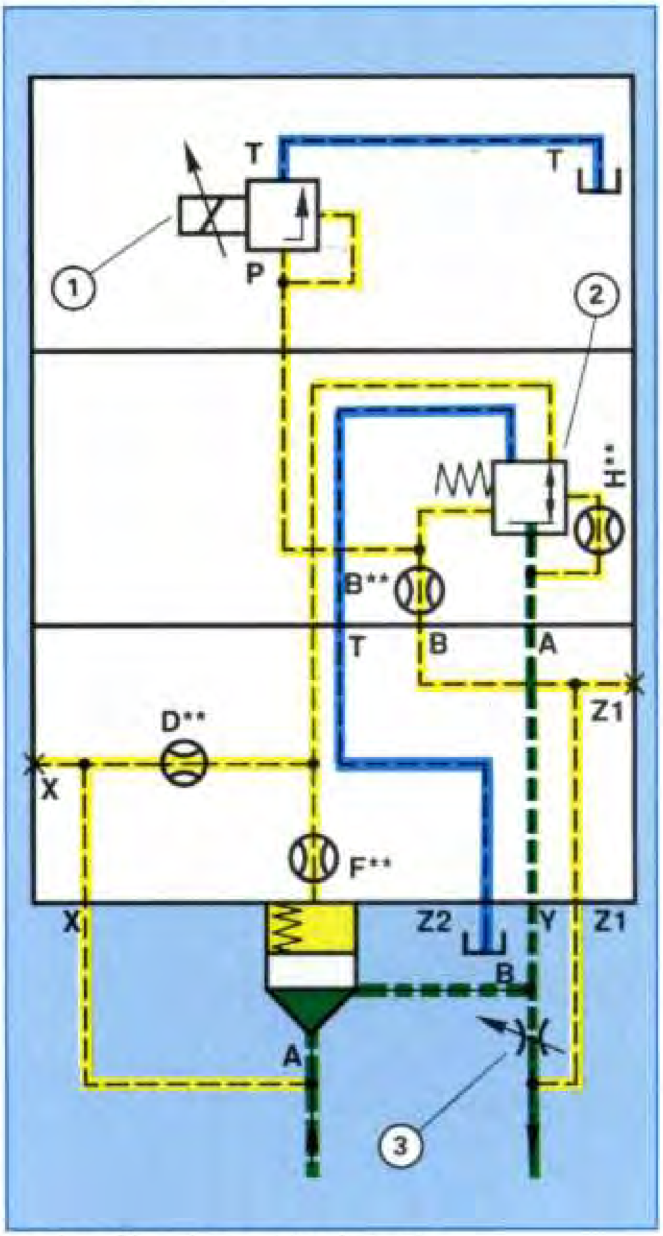


Fig. 154: *Symbol - schematic illustration*
**Orifice

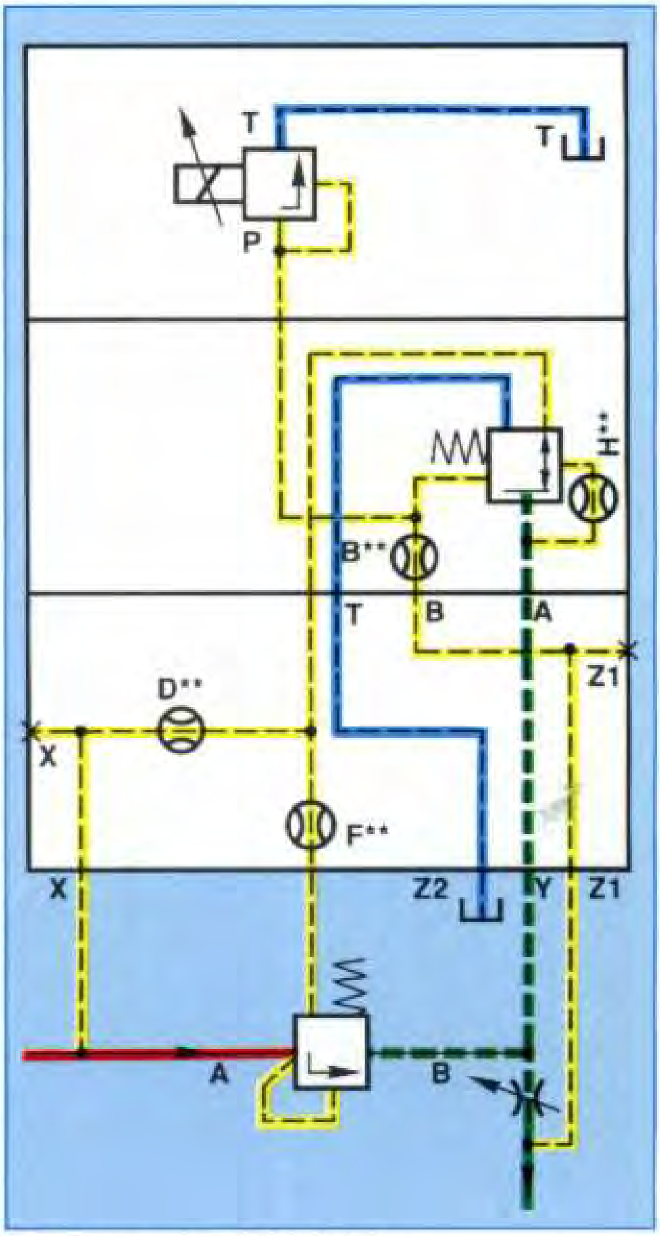
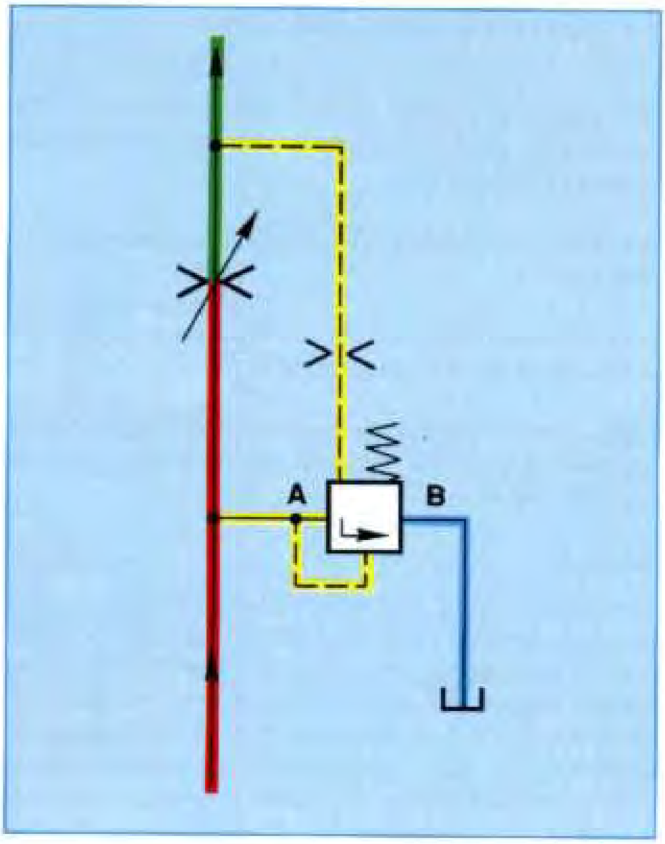
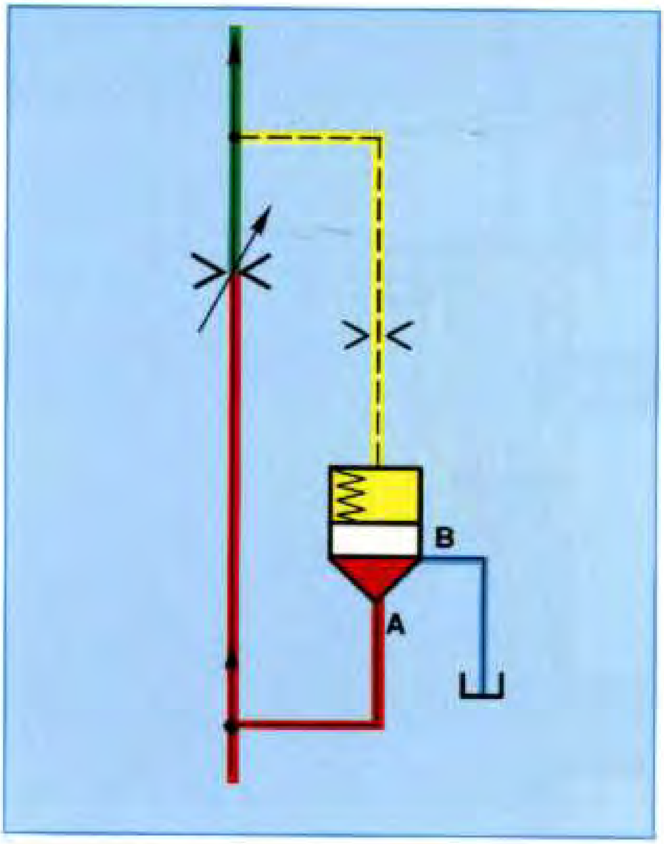
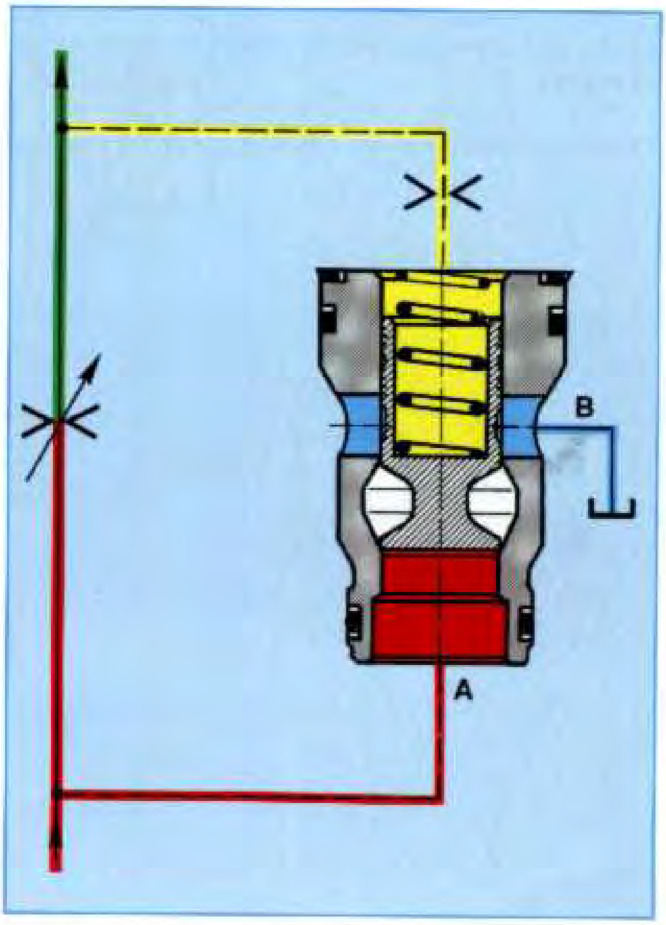


Fig. 155: *Symbol - to DIN ISO 1219*
** = Orifice


A
B


B
A


B
A

7 Servo Logic Cartridge

This unit is yet another form of flow control valve. It is suitable for controlling large flows with rapid and accurate changes in flow rates.

It is controlled by means of either a proportional or a servo pilot valve.

The main valve poppet(2) *(Fig. 161)* has been modified in order to fulfil the duty required of it.

The poppet is operated by means of suitable pilot valve (dependent upon the dynamic response required) via ports Z1 and Z2.

Function

The servo valve is controlled by means of a suitable electronic amplifier. If, for example, pressure is applied to port Z1 and pressure is removed from Z1,the poppet moves upwards a certain distance to provide the specified opening to flow from A to B. If Pressure is applied to Z2 and Z1 unloaded the poppet moves downwards to produce a smaller opening. Positional transducer (4) determines the movement of the poppet and feeds its position back to the electronic control. This actual position is then compared with the command position. As soon as the poppet has moved far enough to cause the the two signals to agree, the pilot valve moves into the neutral position and the poppet (2) remains in its set position.

It therefore operates under closed loop control.

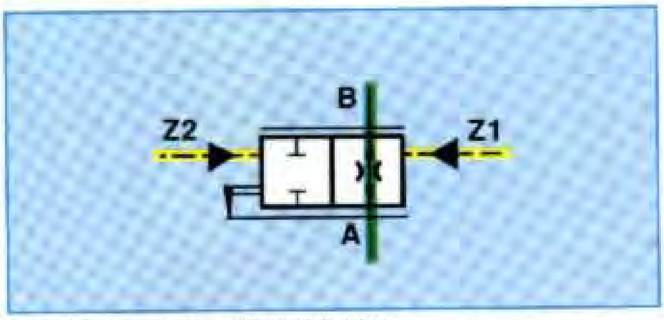
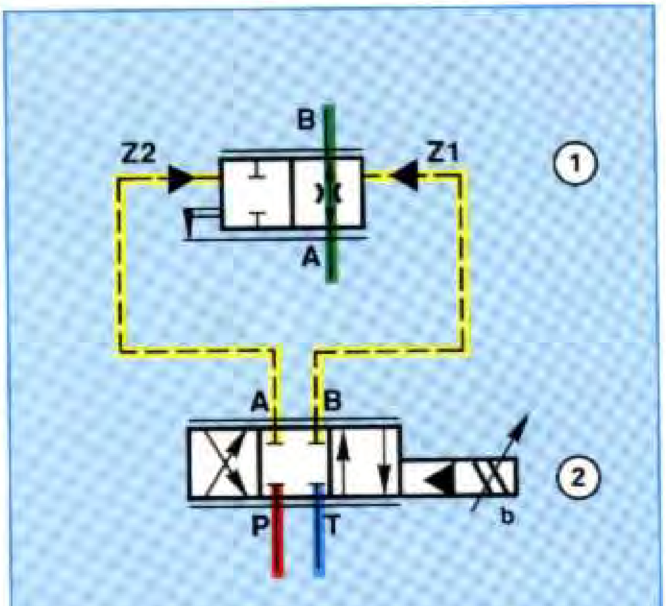
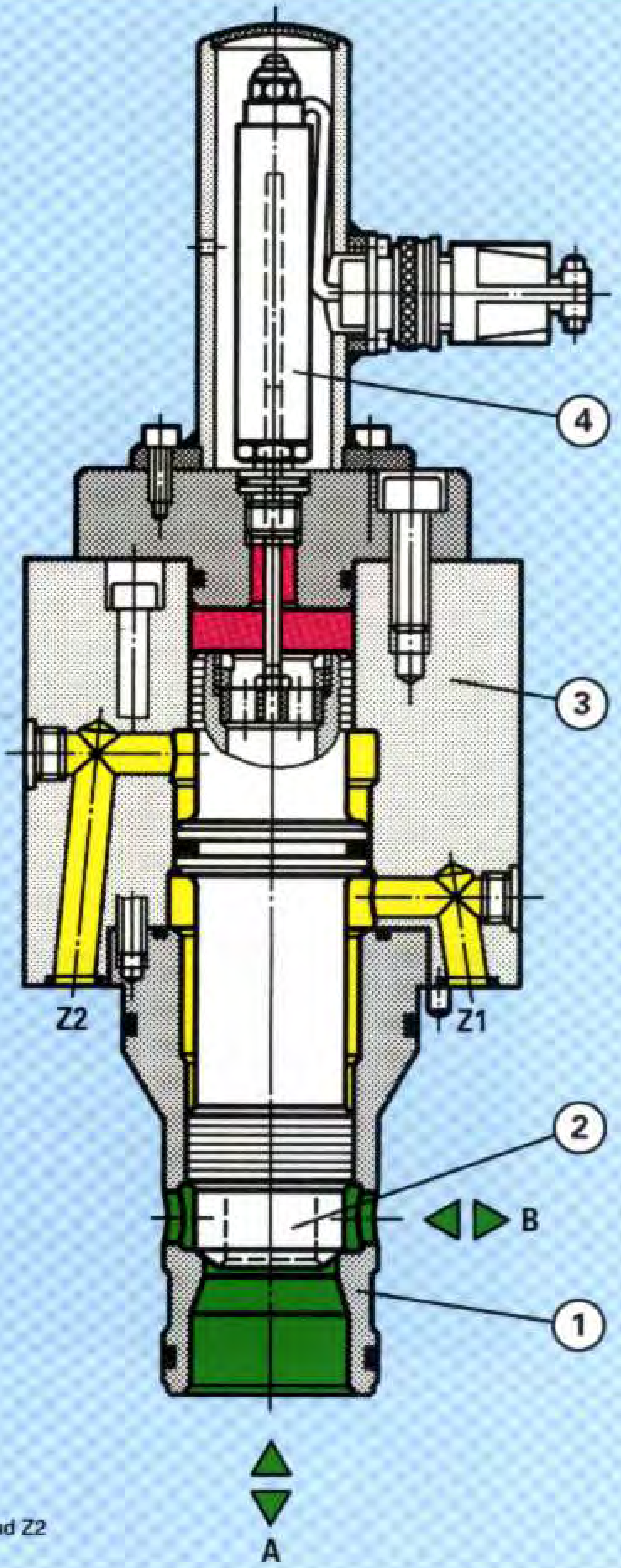


Fig. 159: *Symbol - to DIN/ISO 1219*



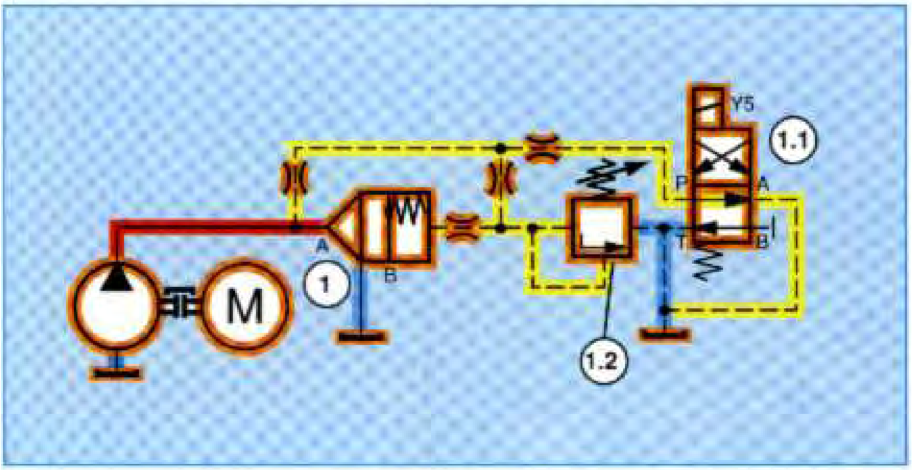
(1) Servo logic cartridge
(2) Pilot valve

Fig. 160: *Symbol - schematic illustration*



(1) Bush
(2) Poppet
(3) Cover
with control ports Z1 and Z2
(4) Positional transducer

Bild 161: *Servo logic cartridge*


Y5
1.1
P
A
T
B
1
A
B
M
1.2

Step Two

Retracting the cylinder (the return stroke) *Fig. 163*

Valve (2) is introduced into the circuit in order to retract the cylinder. Fluid can flow freely through this valve from A to B. When the system is at zero pressure and logic element (2) is held closed by the load pressure (the weight of the press tool) in the control line *(yellow)*. *(Also see the chapter on "Directional functions" 2.1, Fig. 29).*

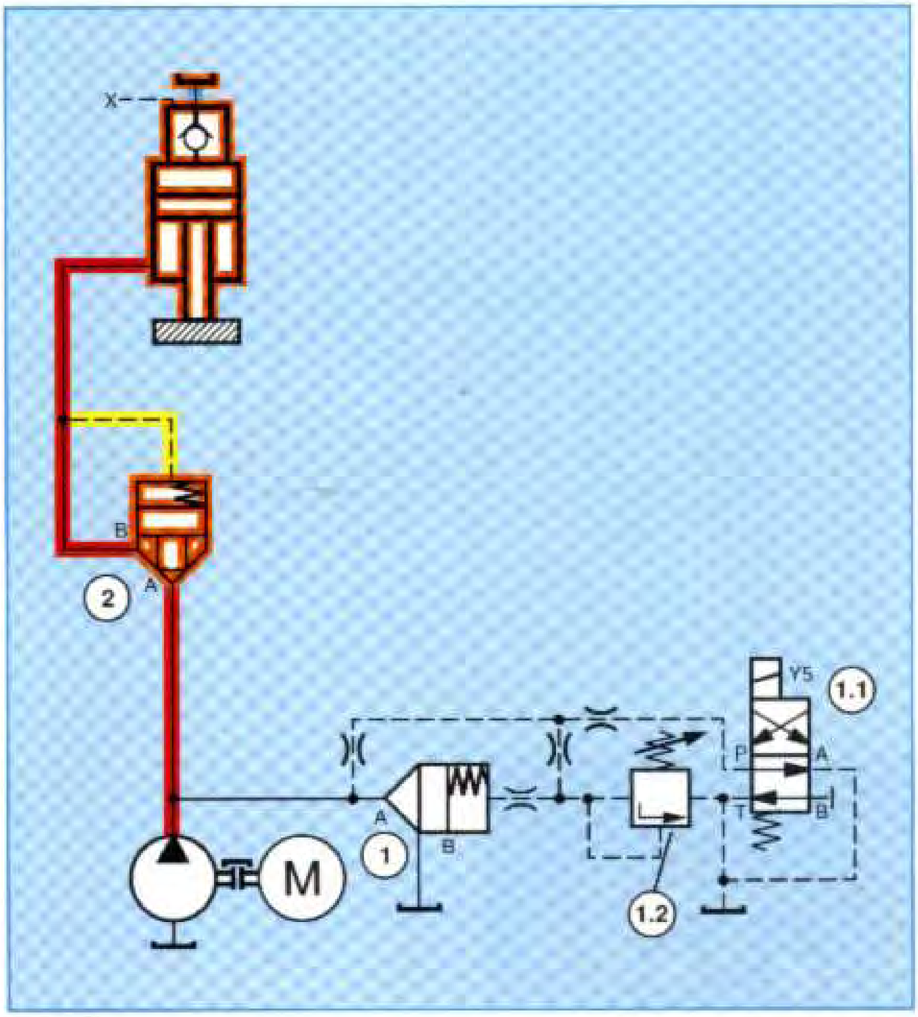


Fig. 163

Step Three

Decompression of the full bore of the cylinder before the return stroke

Before the cylinder can retract, the pressure present in the full bore of the cylinder resulting from the pressing operation must be dissipated in a controlled manner in order to prevent a decompression shock occurring. Logic element (3) with a damping nose and stroke limiter is used for this purpose.

In the starting condition shown in *Fig. 164*, logic element (3) is held closed by the 3/2 way directional valve. Operating solenoid Y2, releases pressure from the spring chamber of valve (3). Logic element(3) then opens under control from port A and unloads the cylinder. The orifice in the tank line of valve (3.1) influences the opening speed of the logic element.

The main volume of oil in the press cylinder can now be returned to tank via the prefill valve built on to the cylinder. Port X of the prefill valve is pressurised between 0,2 to 1 seconds later than the energisation of solenoid Y2.

Logic element (3) is equipped with a damping nose in order to extend the opening curve and enable the decompression to be more easily set. *(Also see the chapter "Directional Functions, Model variations; 3. Damping Noses")*. Stroke limiting is included if an extended decompression time (>1 sec) is required.

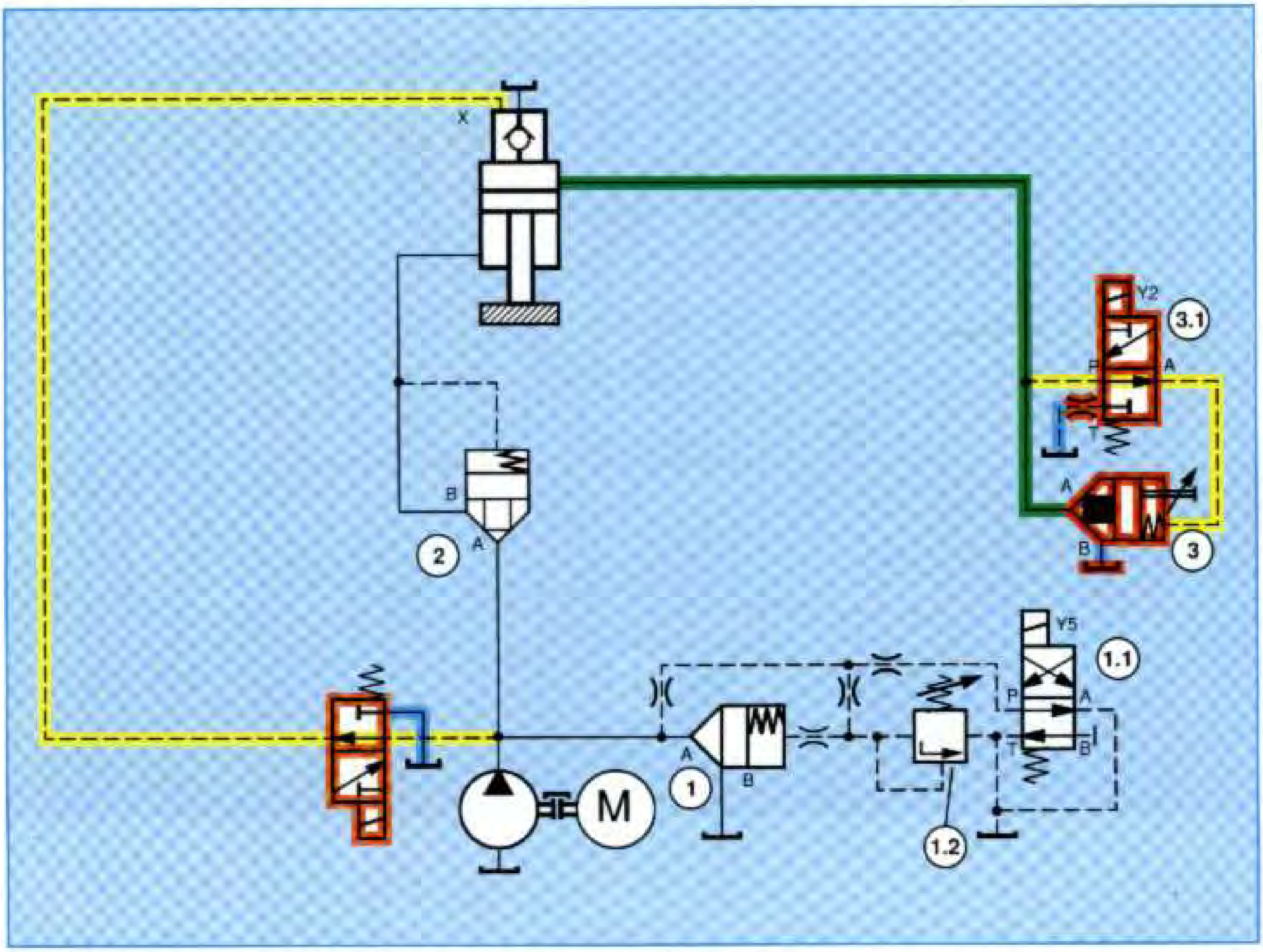
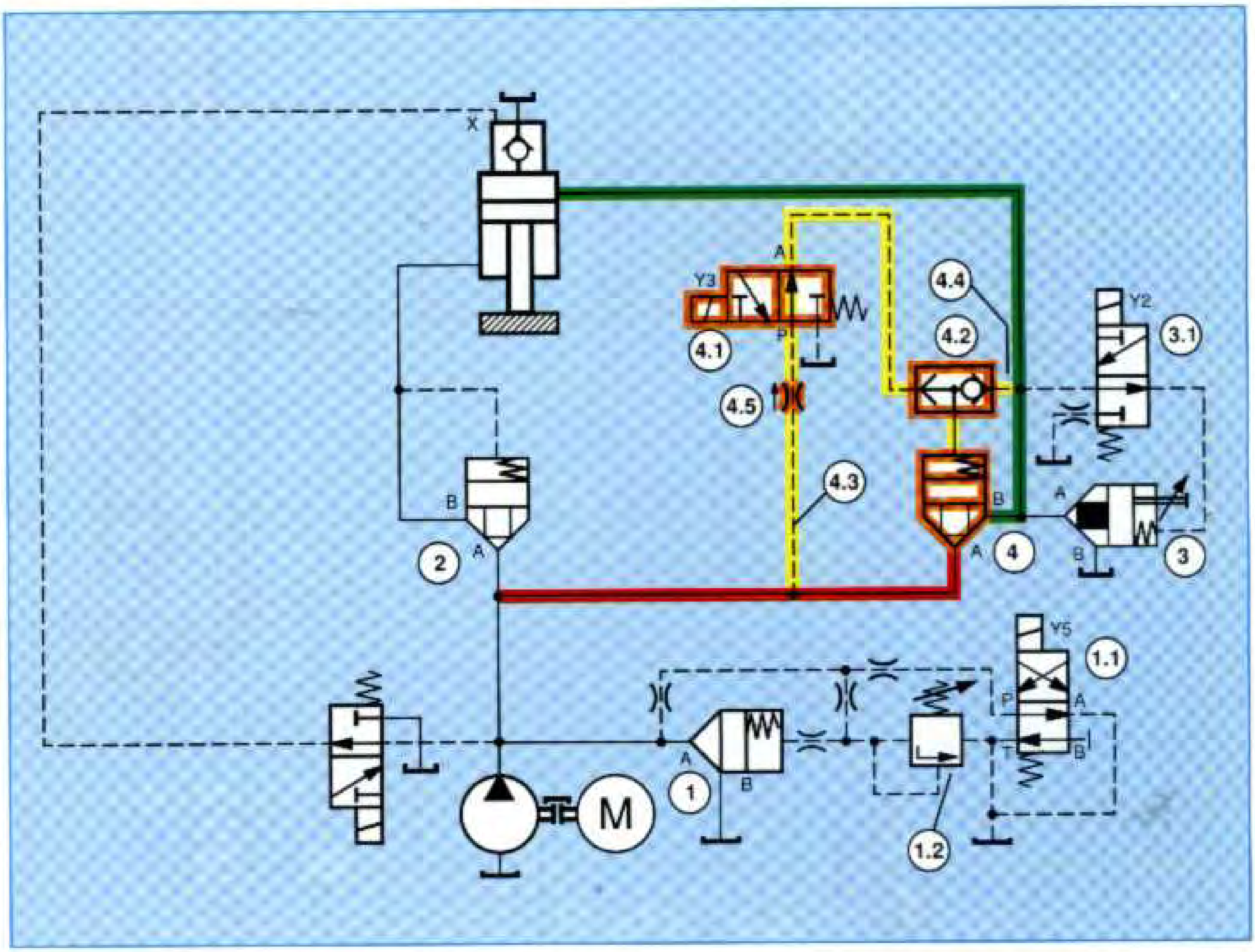
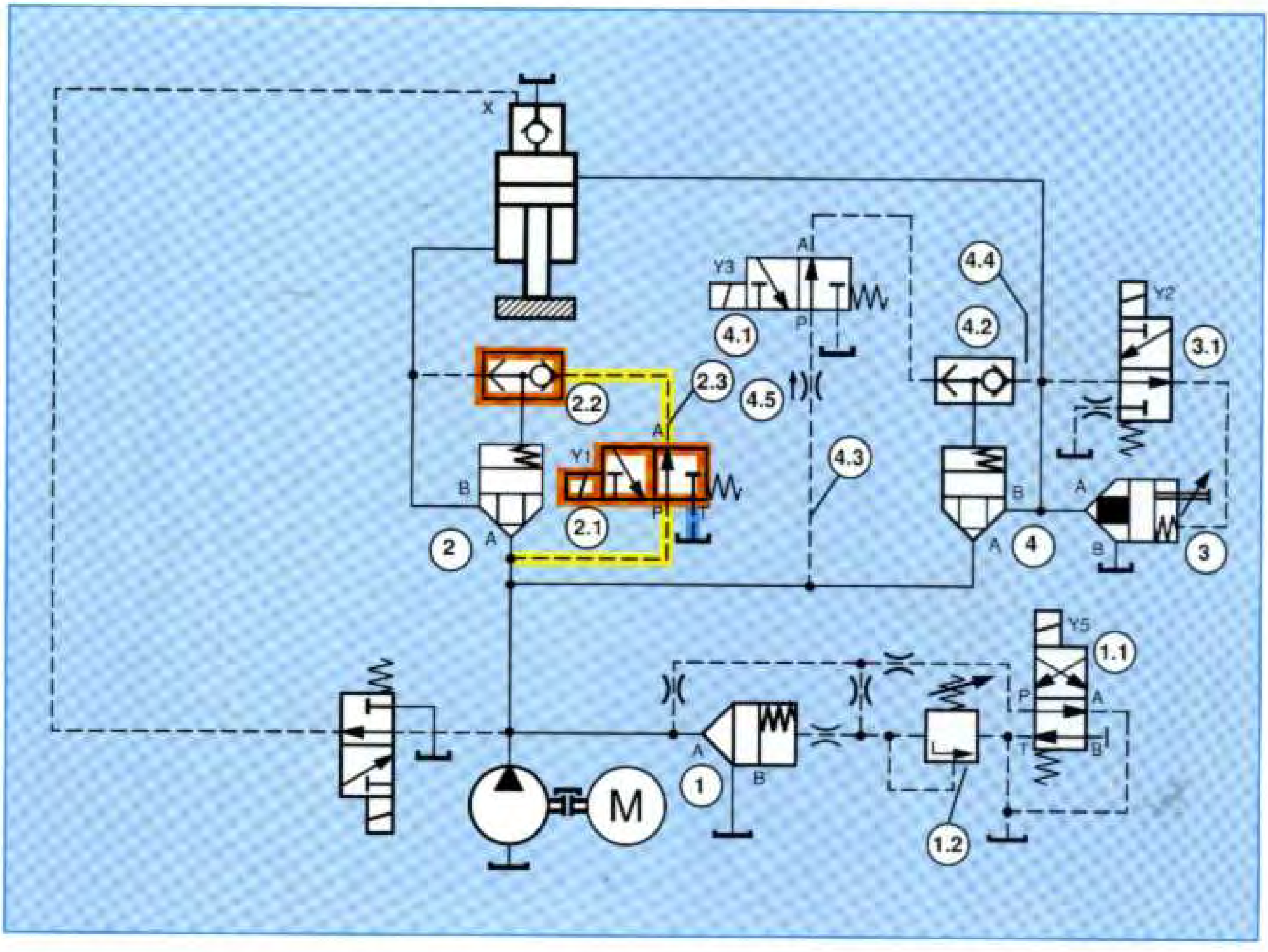


Fig. 164


X
A
Y3
P
4.1
4.5
4.4
4.2
4.3
Y2
3.1
B
A
2
A
4
3
Y5
1.1
P
A
T
B
A
1
B
M
1.2


X
Y3
A
P
4.1
4.4
4.2
Y2
3.1
2.2
2.3
4.5
Y1
2.1
4.3
B
A
2
4
3
Y5
1.1
P
A
T
B
M
1
1.2

Step Six

Lowering the cylinder (fast approach) *(Fig. 167)*
The connection of the pump to the full bore of the cylinder was explained in step four. In addition to this, fluid in the annulus of the cylinder must be able to flow to tank. At the same time, a back pressure must be held within the fluid flowing from the annulus area in order to produce a controlled descent of the cylinder i.e the flow must be throttled. This can be achieved by means of logic element (5). At first, this valve is held closed by directional valve (5.1). By energising (solenoid Y4, the spring chamber of valve (5) is de-pressurised and fluid can pass from A to B. The lowering speed (fast approach) can be set by the stroke limiter fitted to logic element (5).

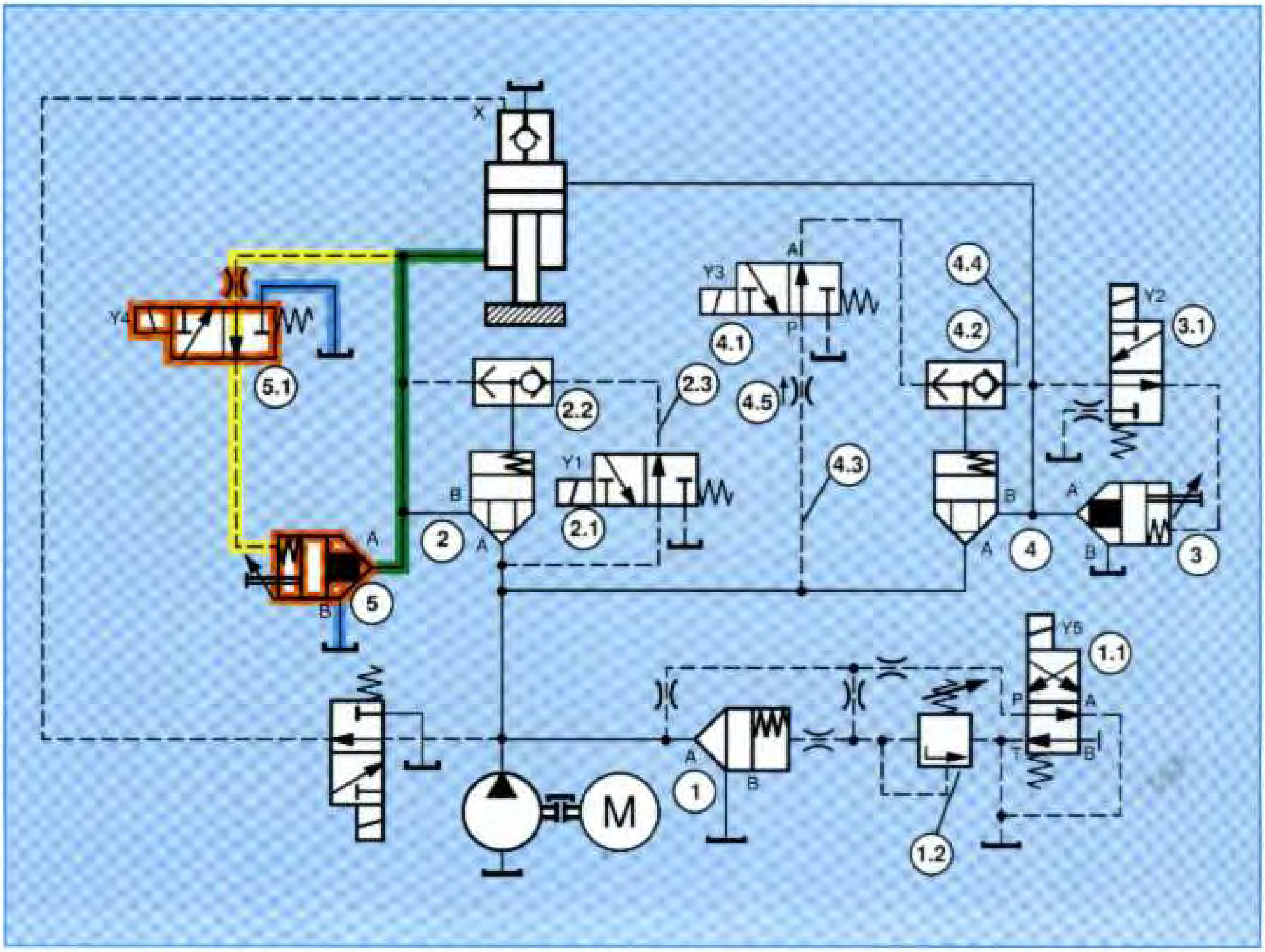


Fig. 167

Step Seven

Lowering the cylinder (slow speed), counterbalance and deceleration pressure *(Fig. 168)*

By operating directional valve (5.1) into the rest position, valve (5) starts to close. At the same time, logic element (6) (with damping nose (6.1)) starts to open). This occurs as the counterbalance pressure rises to the pressure set at pressure relief valve (6.2). The holding pressure set corresponds to the weight of the press head supported on the annulus of the press cylinder. This annulus pressure during the deceleration process cannot rise any higher than the pressure set at pressure relief valve (6.3). Deceleration pressure (valve 6.3) is set higher than the counterbalance pressure (valve 6.2). Dependent upon the deceleration pressure set, the following characteristics can be set:

p high → change-over from fast approach to slow speed (pressing speed) short

p low → change-over from fast approach to slow speed (pressing speed) long

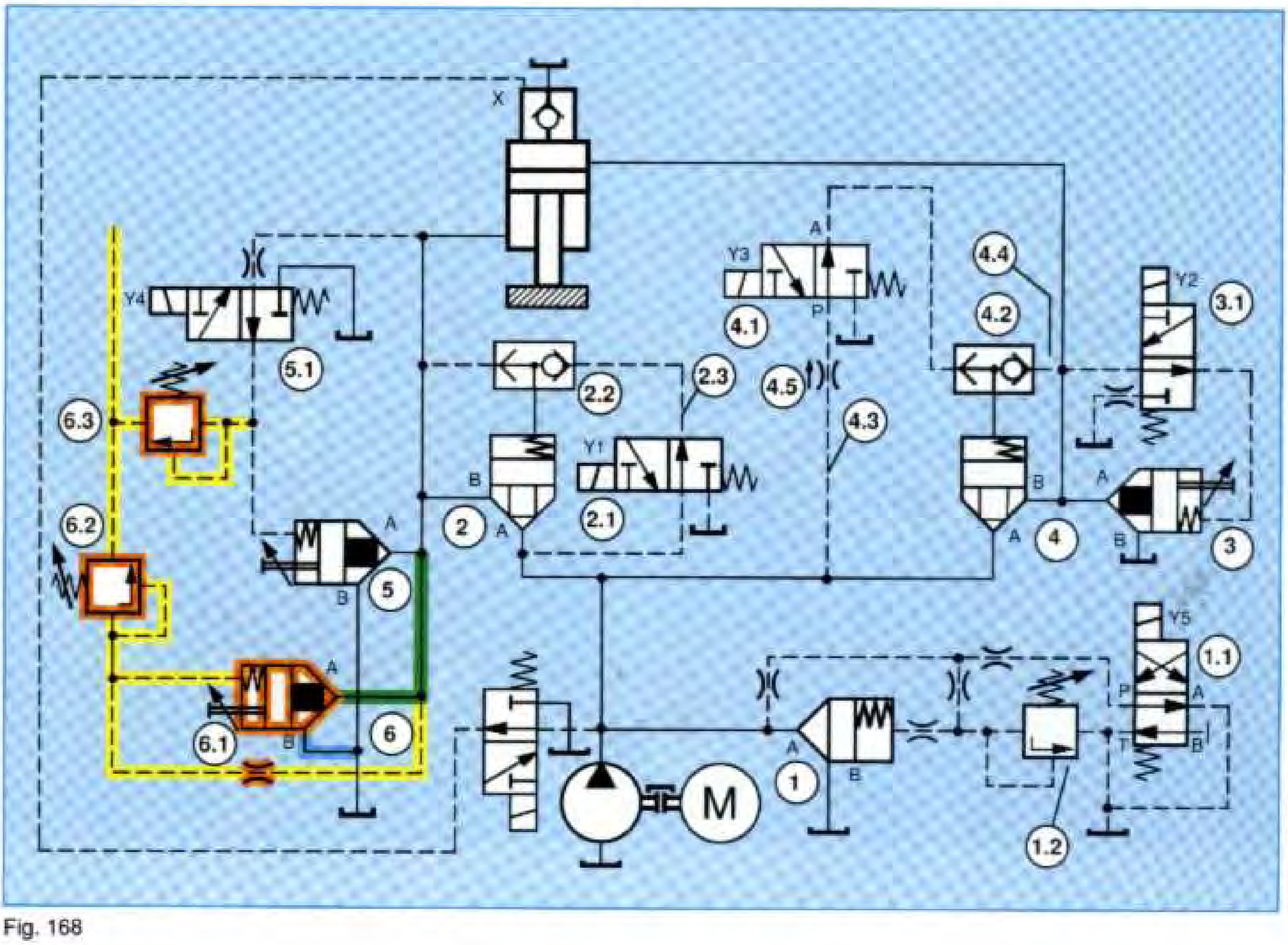
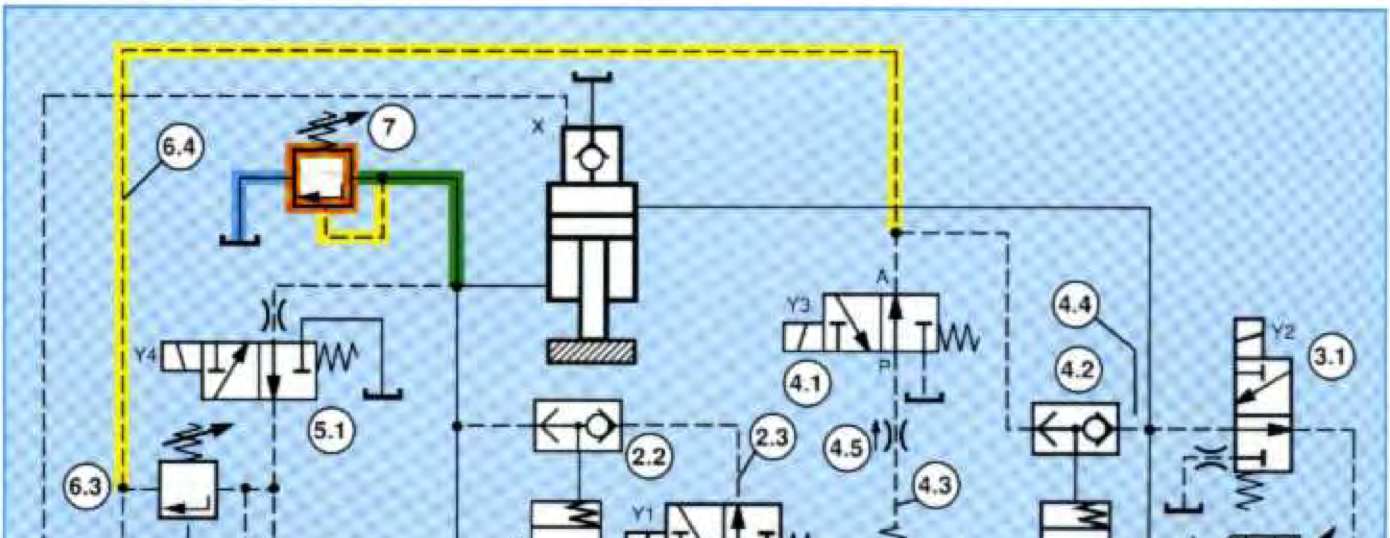


Fig. 168



X
7
6.4
A
Y3
P
4.1
4.4
Y2
3.1
4.2
Y4
5.1
2.2
2.3
4.5
4.3
6.3
Y1
B
2
A
2.1
8
B
A
4
A
3
B
6.2
A
5
B
Y5
1.1
A
P
A
6.1
B
6
A
1
B
T
B
M
1.2

1 Hydraulic Press Controls

Logic elements are being used more and more frequently in press controls, often grouped together into control modules.

In this sense, a module is either a closed or open loop control circuit incorporated into a manifold block. This can be extended or modified by the addition of a further module or extra hydraulic components.

A complete hydraulic control is produced by combining a number of modules. The functions of a basic module can be extended by the addition of other modules.

Logic elements covering directional and pressure functions built into modular units offer the following advantages over conventional piped systems:

- compactness
- individual elements may be matched to the flows required
- piping is very much reduced
- a number of circuit functions can be achieved with one arrangement of valves.

The function of logic elements in press circuits will be explained with the aid of the following hydraulic schematic diagram *(Figs. 170 to 174)* of a press module for a down stroking press. This press incorporates a prefill valve. Please not that this control does not comply with the safety regulations at present in force in the Federal Republic of Germany.

The control of this press module makes the following functions possible:

- Press stopped

  The press cylinder with its suspended mass remains in the position set. The pump flow is by-passed to tank.

- Fast approach

  The annulus of the press cylinder is connected to tank. The press cylinder and associated mass move downwards.

  The negative pressure created in the full bore of the cylinder opens the prefill valve and fluid is sucked from the header tank into the cylinder.

- Pressing

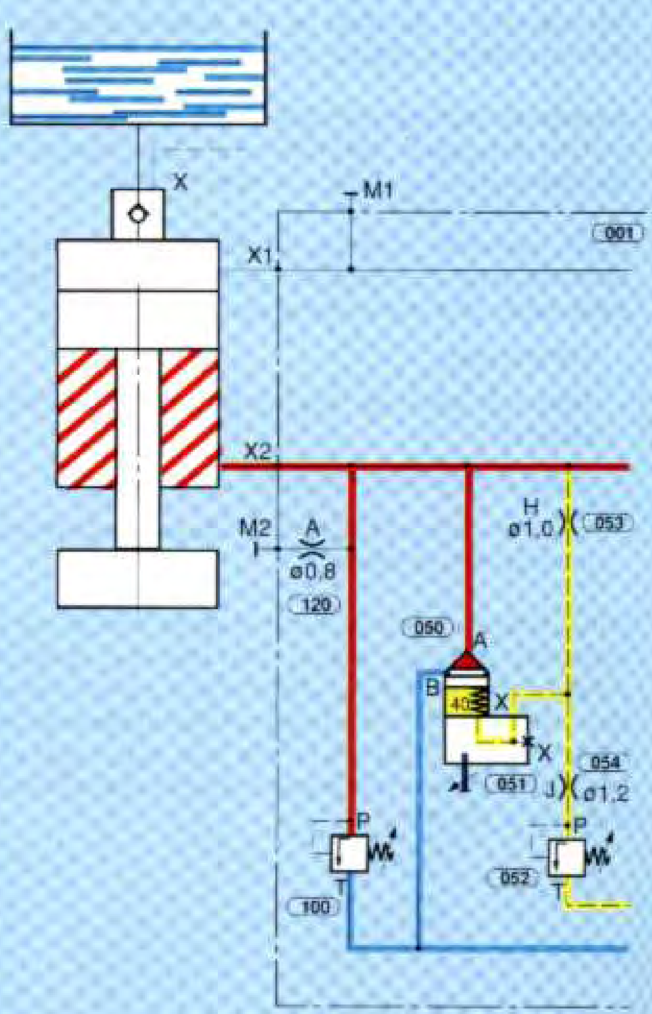
  As pressure in the full bore of the cylinder increases, the prefill valve closes and the full bore area of the cylinder is subject to pressure.

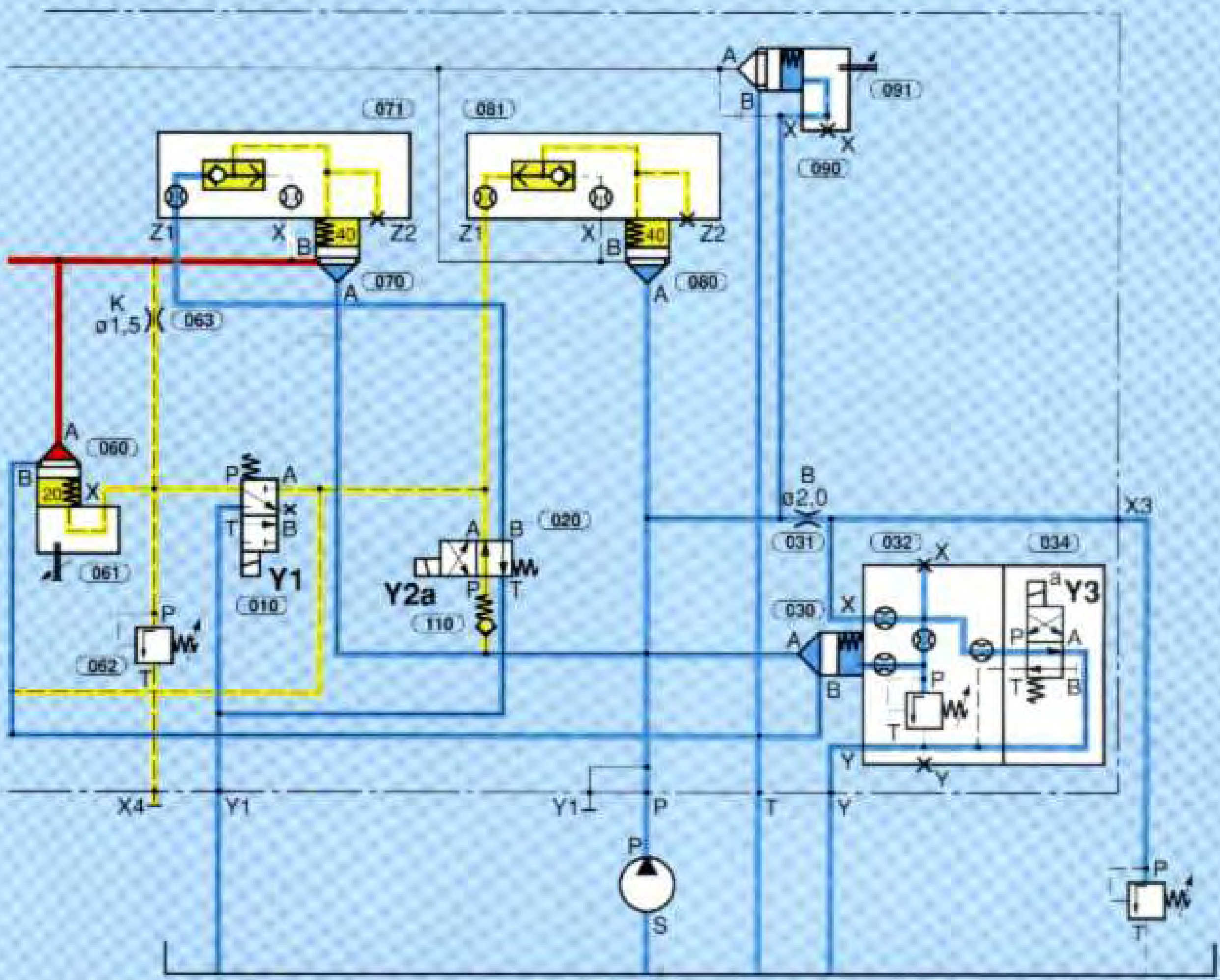
- Decompression

  By means of a decompression valve (which can be set as required), the compressed fluid is passed to tank in a controlled manner.

- Return

  The prefill valve is opened by means of pilot pressure and the pump flow is directed to the annulus side of the cylinder.


X
M1
001
X1
X2
M2
A
ø0,8
120
H
ø1,0
053
050
A
B
40
X
X
051
054
J
ø1,2
P
P
052
T
100
T


071
081
091
090
Z1
X
Z2
B
40
070
080
A
K
ø1,5
063
060
20
061
P
T
062
Y1
010
Y2a
110
020
ø2,0
031
032
034
030
Y3
X3
X4
Y
S

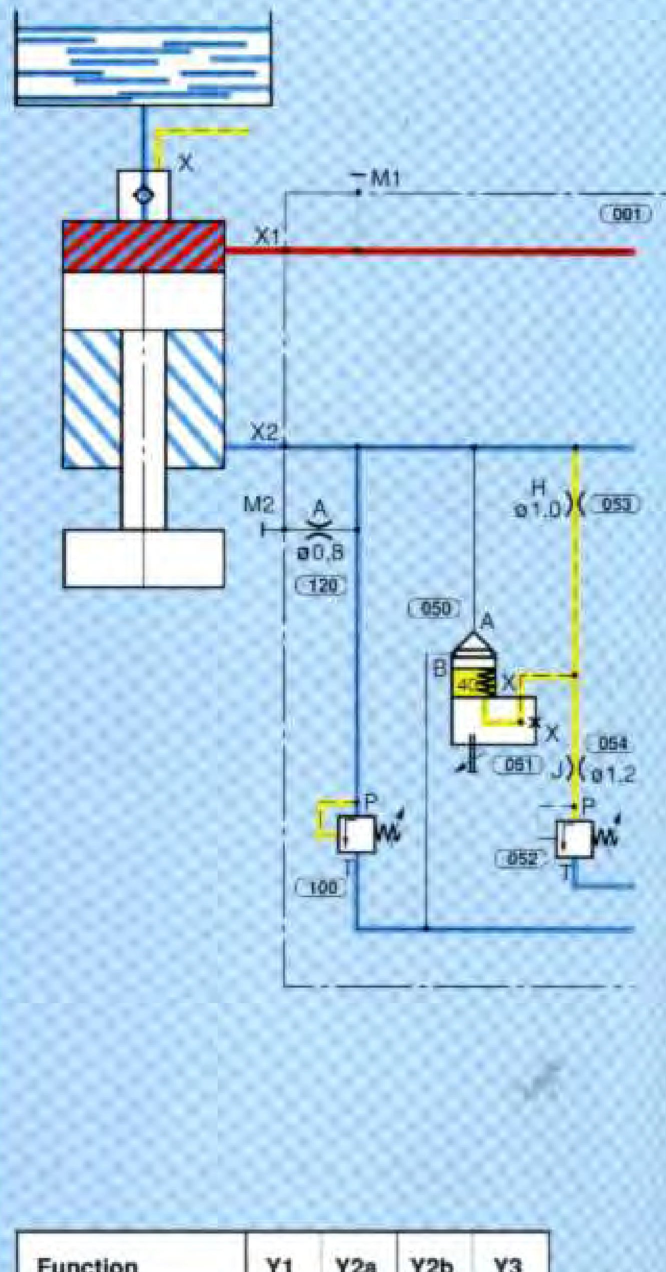
Fast approach

The fast approach operation permits the press to descend rapidly powered only by the weight of the weight of the piston, crosshead and press tools. At the start of the fast approach, pump flow is directed into the full bore of the cylinder. In this way, a delay in the change-over between fast approach to pressing speed is avoided. By operating pilot valve (item 034), pilot oil is passed to the control area of valve (item 030). Pilot oil pressure is therefore present at the P port of the pilot pressure relief valve (item 032). If the pilot pressure at this point rises above the pressure set at the pilot relief valve, oil flows along the control line to tank. This flow causes a pressure drop at orifice (item 031).

The pressure before the orifice is actually the pump pressure which is the same as the pressure at the base area A_A of valve (item 030). When pilot oil is flowing, the pressure at the control area A_X of valve (item 030) is the pump pressure minus the pressure drop across the orifice. As the pressure drop across the orifice (item 031) increases, the force balance across the control areas of the valve changes until the valve opens and operates as a pressure relief valve. The system pressure required can be set at the pilot valve (item 032).

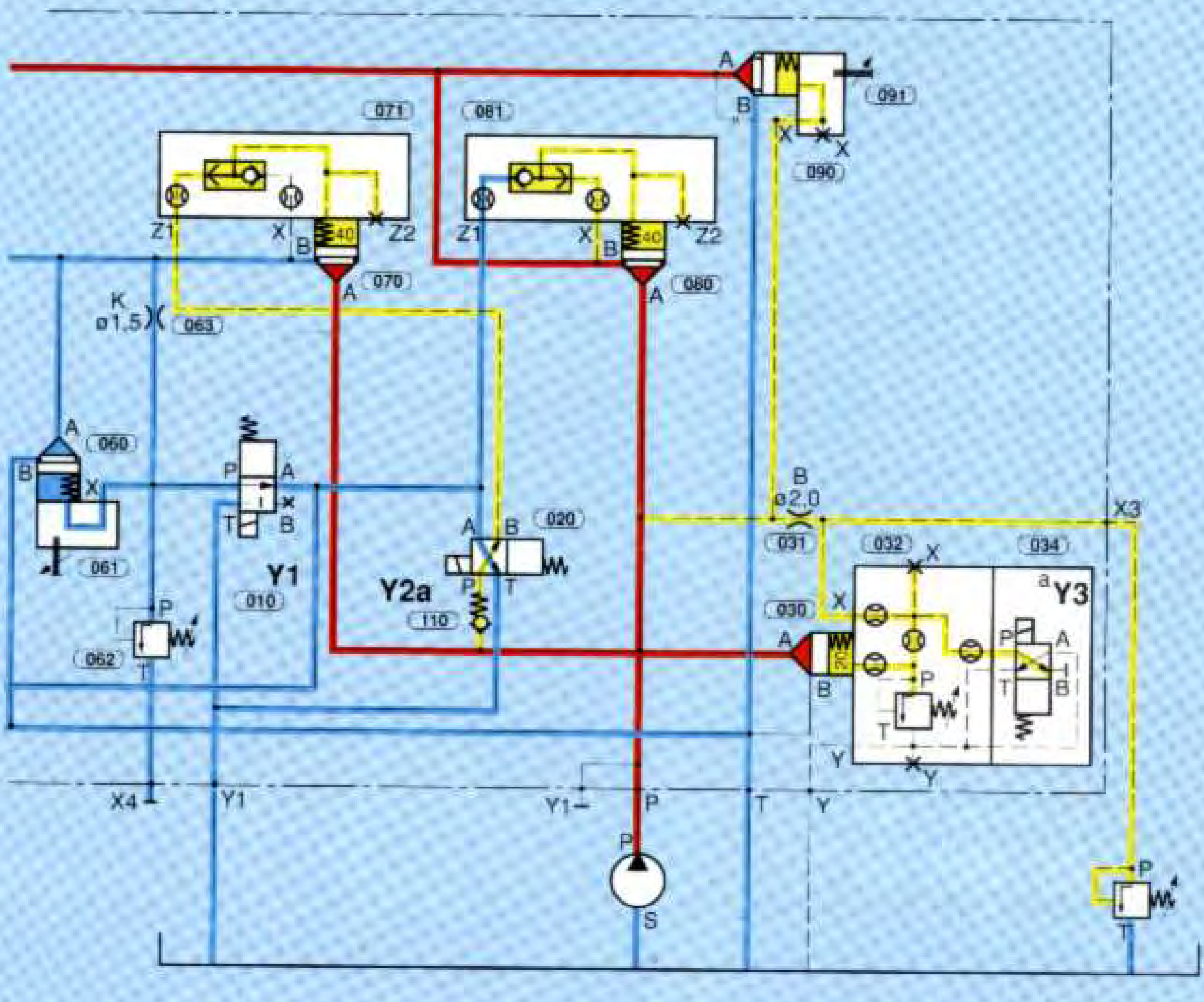
With pilot valves (items 010 and 020) operated, the control area of valve (item 060) is unloaded to tank and the annulus area of the cylinder is also connected to tank. Pump flow passes to the full bore of the cylinder via valve (item 080). The weight of the piston rod etc. causes the press to fall and expels the oil in the annulus side of the cylinder to tank. The lowering speed of the press is controlled by setting the stroke limiter of valve (item 060) which acts as a throttle valve.

With the press descending rapidly, the pump flow is insufficient to fill the full bore of the cylinder. A negative pressure is therefore created within the cylinder bore, the prefill valve opens and fluid flows from the header tank into the cylinder.



Function	Y1	Y2a	Y2b	Y3
Stationary				
Fast approach	●	●		●
Pressing		●		●
Decompression				
Return				●

Fig.171: *Press module - function: fast approach*



071
081
091
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Z1
X
B
40
Z2
070
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A
K
ø1,5
063
060
061
062
P
T
Y1
010
Y2a
110
020
ø2,0
031
032
034
030
X3
Y3
20
Y
X4
S

Pressing

Only solenoids Y2a and Y3 remain energised during the pressing cycle. Pressure peaks during the change-over from fast approach to pressing speed should be minimised in order to make the change-over as smooth as possible.

Pilot control valve (item 034) remains in the operated position in order to hold the decompression valve (item 090) and the by-pass valve (item 030) closed. Pump pressure is limited to the value set at valve (item 032).

Pilot control valve (item 020) also remains in the operated position. Pump flow can thus forced to pass via valve (item 080) to the full bore of the press cylinder.

When the cylinder reaches a predetermined point and a signal is given to indicate this, pilot valve (item 010) moves back to its rest position. The lowering valve thus closes and the annulus of the press cylinder is no longer connected to tank.

The annulus pressure rises and the holding pressure valve (item 050) opens as soon as the pressure exceeds the holding pressure.

The opening stroke of the pressure holding valve is limited by a stroke limiter to permit only the oil flowing at pressing sped to pass. Due to this small opening, the holding valve cannot pass sufficient flow at higher press speeds. The pressure in the annulus of the cylinder thus rises even further until the pressure at the control area of the lowering valve (item 060) is connected to tank via pilot control valve (item 062) (the combination thus acts as a pressure relief valve —as valve (item 030)). The deceleration process is complete when the annulus pressure is once more practically the same as the set holding pressure.

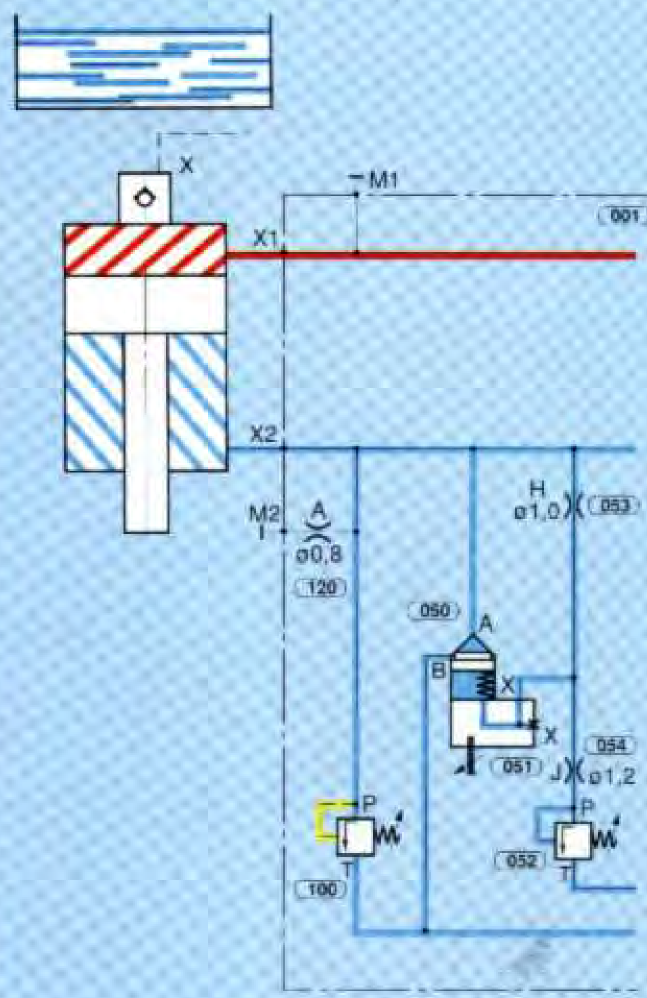
When the press head speed has been reduced to the pressing speed, the prefill valve closes due to the build up of pressure in the full bore of the press cylinder. The oil flowing from the annulus of the cylinder is expelled to tank via the holding valve. The change-over to pressing speed is therefore stepless.

The maximum possible pressing force at the presshead is therefore:

$$F_{press\ max.} = A_K \cdot p_a + F_G - A_R \cdot p_H$$

A_K = piston area of cylinder
A_R = annular area of cylinder
p_a = pressure set at valve item 032
p_H = holding (counterbalance pressure) set at valve item 052
F_G = Force due to weight of moving parts

Pilot control valve (item 034)also remains in the operated position during the pressing cycle in order to hold the decompression valve and the by-pass valves in the closed position.

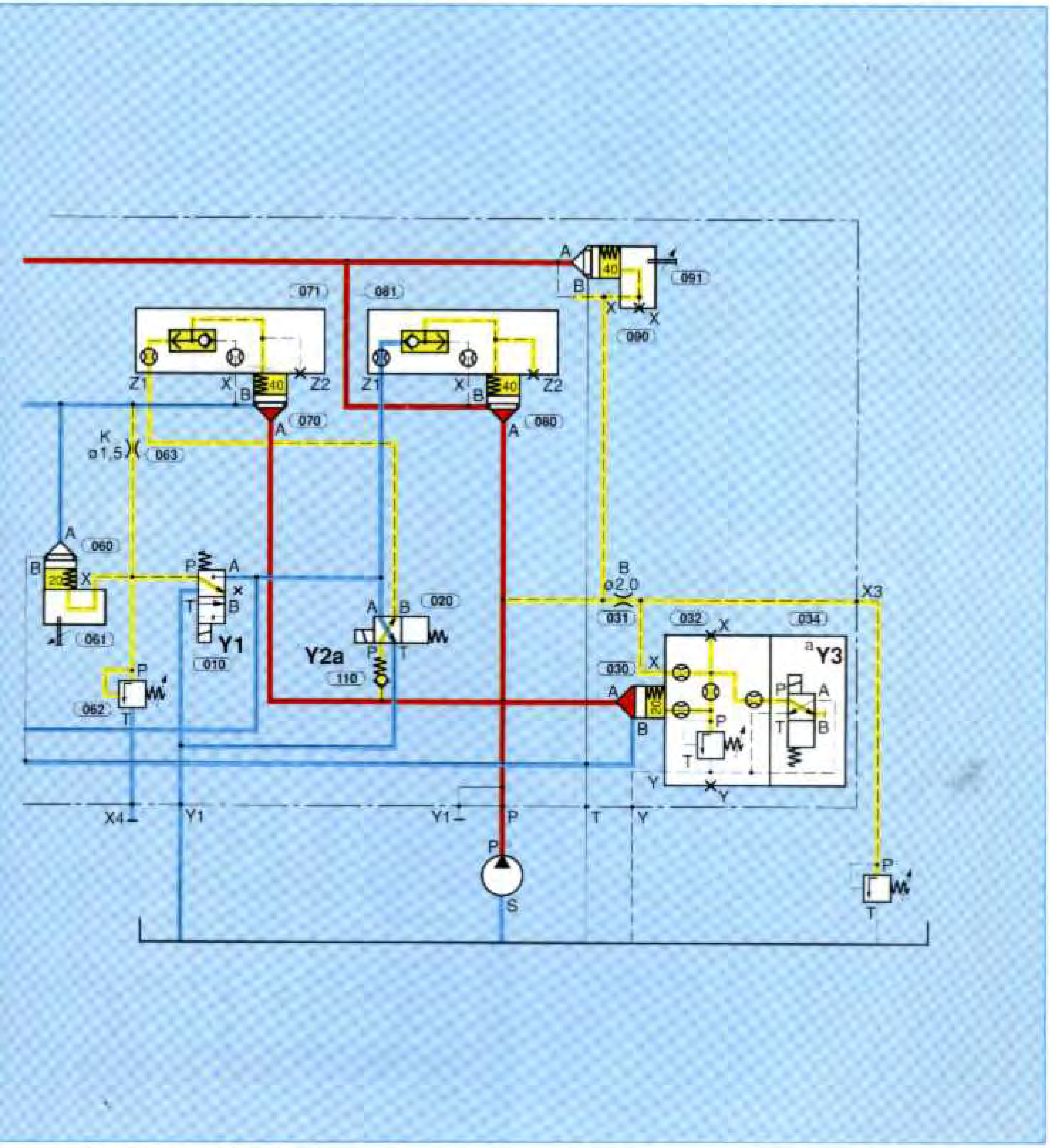


Function	Y1	Y2a	Y2b	Y3
Stationary				
Fast approach	●	●		●
Pressing		●		●
Decompression				
Return				●

Fig.172: *Press module - function: pressing*

The valves for the directional control of the press cylinder are separate switching elements which are controlled individually. For example, if the annulus area is blocked from the tank due to faulty operation of the valves while the full bore is still under pressure, pressure intensification occurs in the annulus of the cylinder (pressure ratio = 1/ area ratio).

In order to avoid damage due to faulty operation, the annulus area is protected by a direct operated relief valve (item 100).



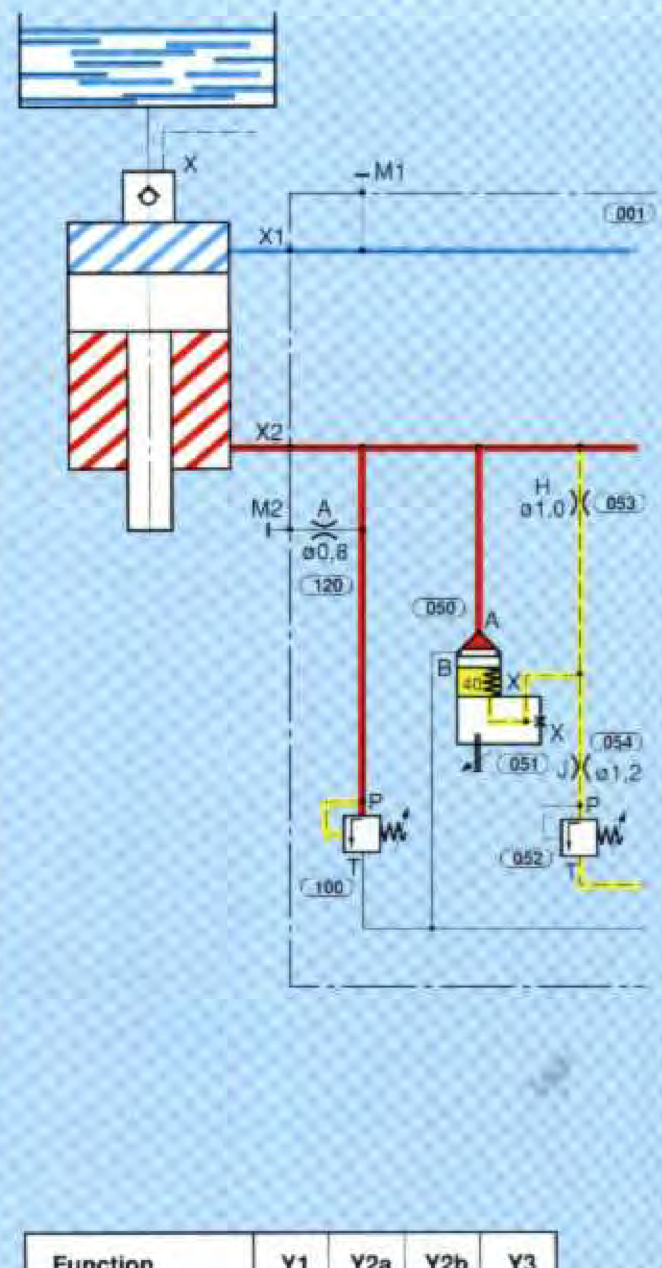
Decompression

When the pressing operation is finished, oil compressed within the cylinder and the pipework must be released smoothly, before the press is signalled to return, in order to prevent unnecessary loading on seals, valves and pipes due to decompression shocks in the system and in particularly in the tank line. At the same time, the pump flow is by-passed to tank during this operation.

When the press is stopped, all pilot valves are in the rest position.

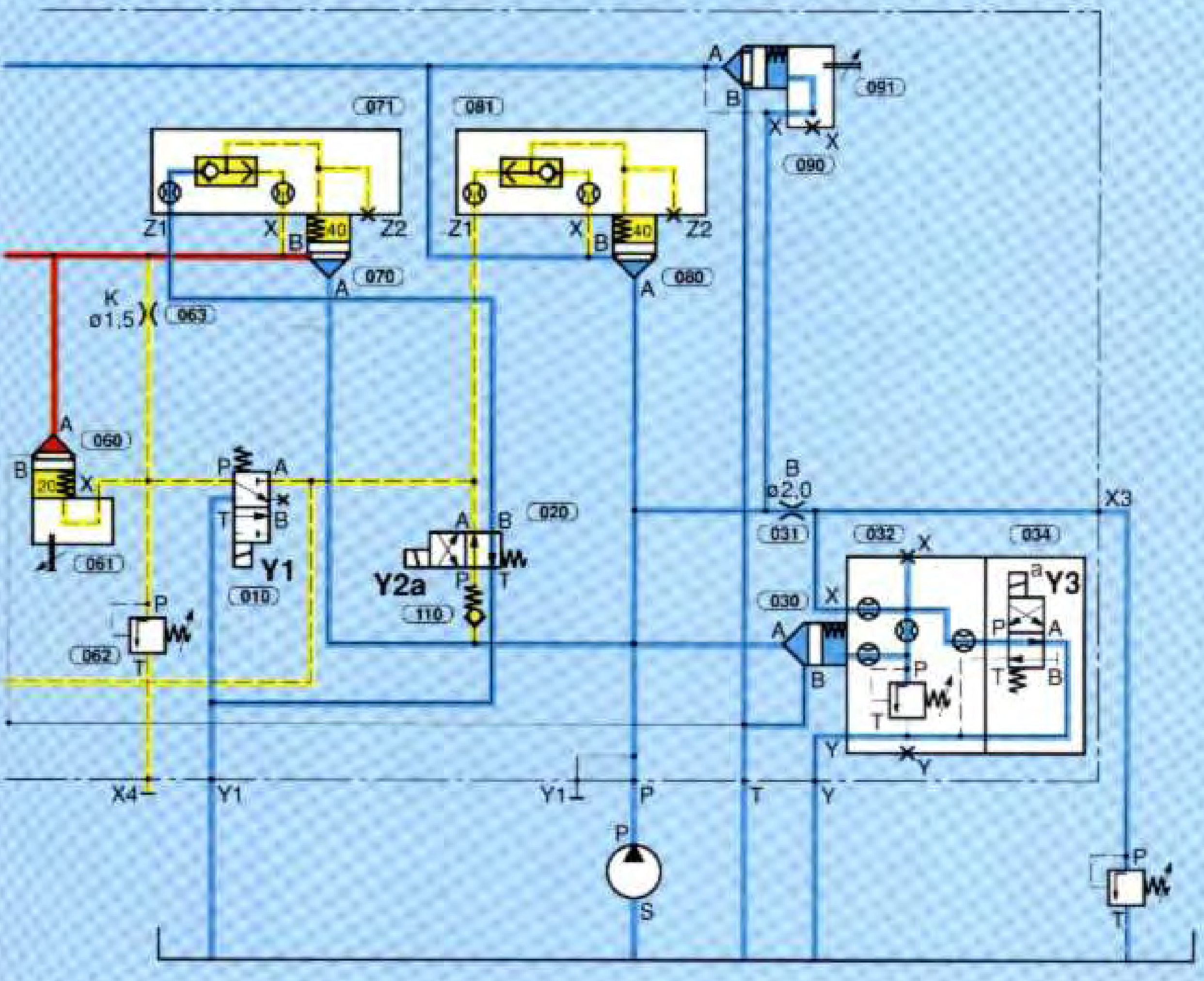
The valve poppet of the by-pass valve (item 030) opens as its control chamber is connected to tank via pilot control valve (item 034). When the pump is switched to by-pass, the control area of the decompression valve (item 090) is also connected to tank. The base area A_A of the decompression valve (item 090) is under pressing pressure at this time.

Pressing pressure opens the decompression valve (item 090). The compressed oil volume in the full bore of the press cylinder is decompressed. The rate of decompression and the decompression time can be set by the stroke limiter of the decompression valve to suit the particular press (cylinder size, pressing pressure etc.)



Function	Y1	Y2a	Y2b	Y3
Stationary				
Fast approach	●	●		●
Pressing		●		●
Decompression				
Return				●

Fig.173: *Press module - function: decompression*



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X
061
P
A
T
B
Y1
010
062
020
Y2a
110
ø2,0
031
032
034
030
Y3
X3
X4
Y1
P
T
Y
S

Return

The prefill valve is opened by means of an external prefill valve.

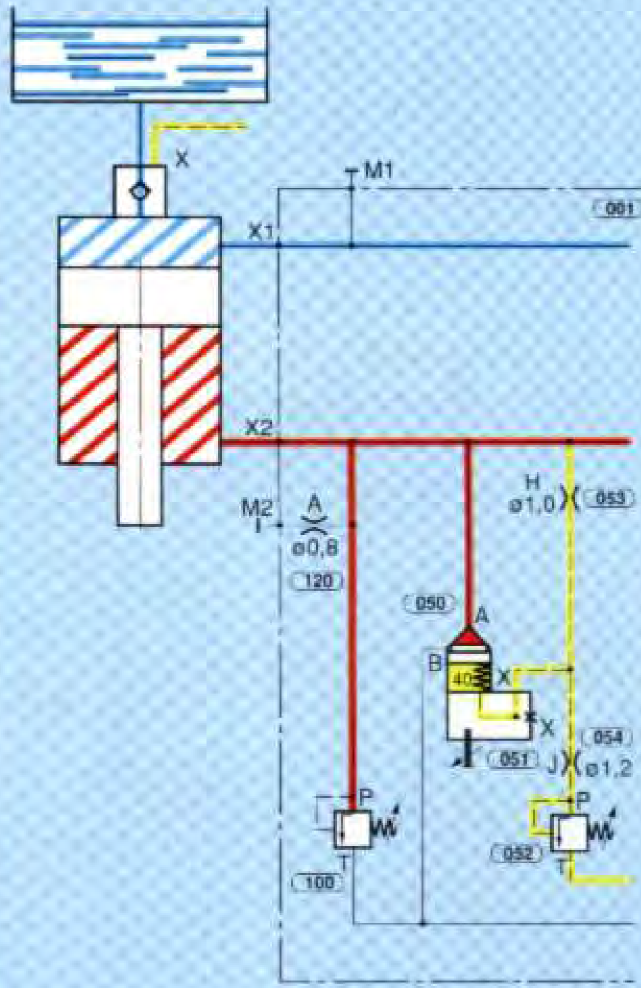
The press cylinder complete with hanging load is then returned to the upper start position.

The pump flow is fed directly into the annulus of the cylinder.

Pilot control valve (034) is operated and the by-pass valve (item 030) closes. Pump flow can no longer flow to tank. Fluid is then forced into the cylinder thus raising the press head.

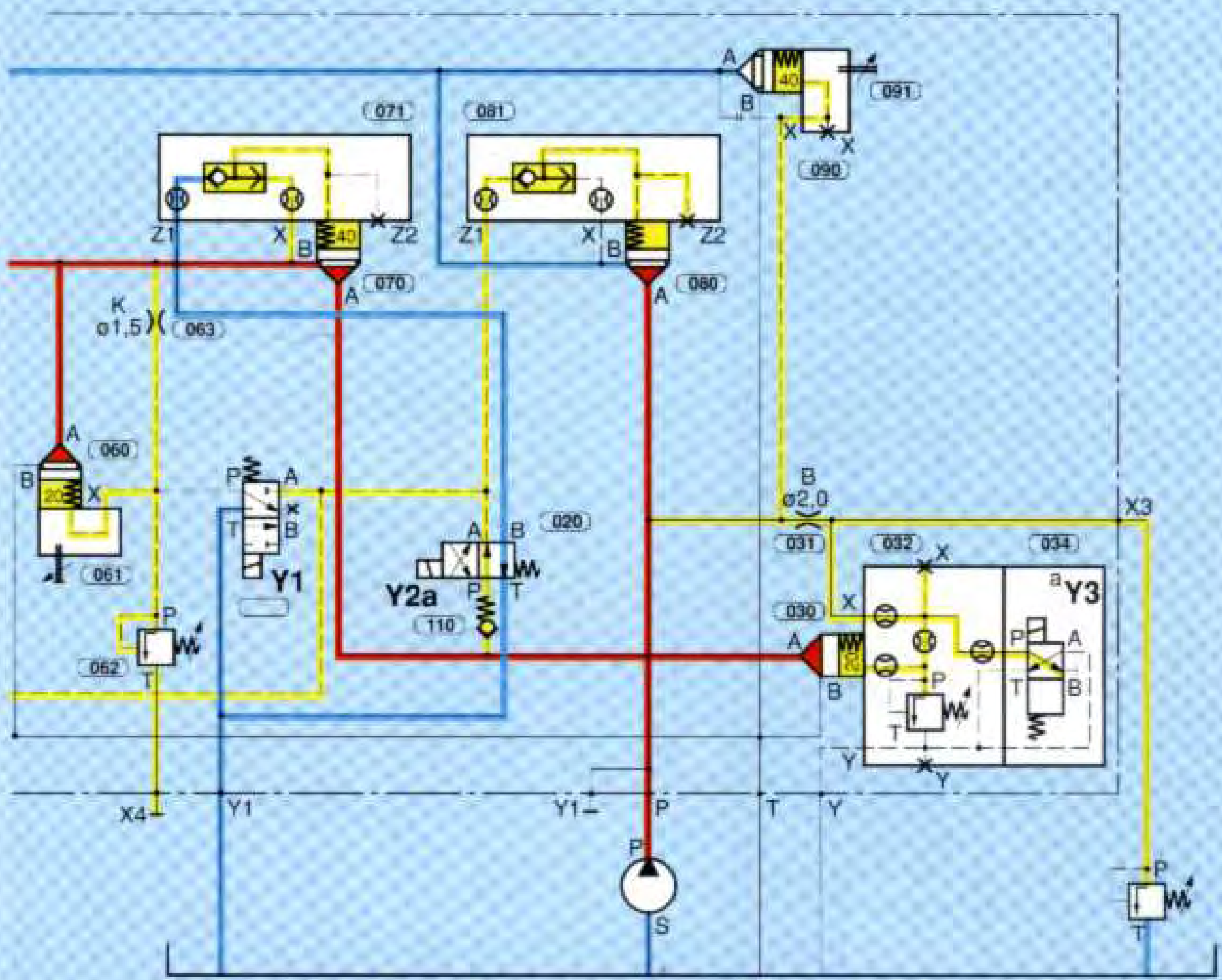
Pilot valves (items 020 and 010) are in the rest position. Logic elements (items 060 and 080) are therefore held closed.

Pump pressure is present at the base area A_A of valve (item 070) and pressure rises unit fluid on the control face of valve (item 070) is forced through to the annulus area of the cylinder via the shuttle valve Thus opening logic element (item 070) fully for pump flow to pass through to the cylinder. The piston then moves upwards. Logic elements (items 050 and 060) are held closed due the pressure in the cylinder annulus. Fluid from the full bore of the cylinder p[asses to tank vie the prefill valve. The return stroke is discontinued when the upper rest point is reached. Before a new press cycle is initiated, all the pilot valves are returned to the start (or rest) position.



Function	Y1	Y2a	Y2b	Y3
Stationary				
Fast approach	●	●		●
Pressing		●		●
Decompression				
Return				●

Fig.174: *Press module - function: return*



071
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032
034
Y1
Y2a
Y3
K
ø1,5
ø2,0
X3
X4
Z1
Z2

2 The control of a vertical external broaching machine

The circuit for this machine was designed as a manifold block with built-on valves.

The reason for the use of logic elements is the mixture of valve sizes necessary to cope with the widely varying requirements and speeds from machine to machine.

Flows lie in the range 50 L/min to 1900 L/min.

Function

Fluid is supplied to the system by a variable pump with electrical control of both pressure and flow.

At the start, none of the control elements are operated. When the pump is started, pressure builds up at port A of logic elements (1.0) and (3.0). At the same time, pressure passes through the control line *(yellow)*, non return valve (4) and pilot valve(1.1)on to port T of pressure relief valve (2.1) which is then held closed. Pressure also passes via valve (1.1)(P to B) into the spring chamber of valve (1.0) and also via valve (1.1) (P to A) and (3.1) into spring chamber (3.0). Both logic elements are thus blocked to flow from A to B. Pressure in the cylinder due to the weight of the piston and broaching tools holds the logic valve closed via control line (6).

At the start of the broaching operation, solenoids a on both valves (1.1) and (2.1) are energised and the required settings of pressure and flow are set at the pump. Pilot pressure passes via valve (1.1) (P to B) to port X of valve (1.0) which therefore remains closed. On the other hand, the spring chamber of logic element (3.0) and port T of valve (2.1) are both unloaded. Fluid passes from the pump to port A *(red)* and port (B) *(green)* to the rod end of the cylinder. This then moves downward in the broaching operation.

Fluid flowing from the full bore of the cylinder is expelled to tank via the logic element at the pressure set at pilot valve (2.1) (counterbalance pressure 24 bar).

On the return stroke, solenoid b of valve(1.1) and solenoid a of valve (3.1) are energised. Pressure relief valve (2.1) is blocked. At the same time, the spring chamber of valve (1.1) is unloaded.

Pump flow now passes from A to B and to the full bore side of the cylinder. Logic element (2.0) is closed. The cylinder extends giving the return stroke of the broaching tool. Fluid from the rod end of the cylinder passes against the spring through valve (3.0) from B to A back into the pump line. This is therefore a regenerative circuit.

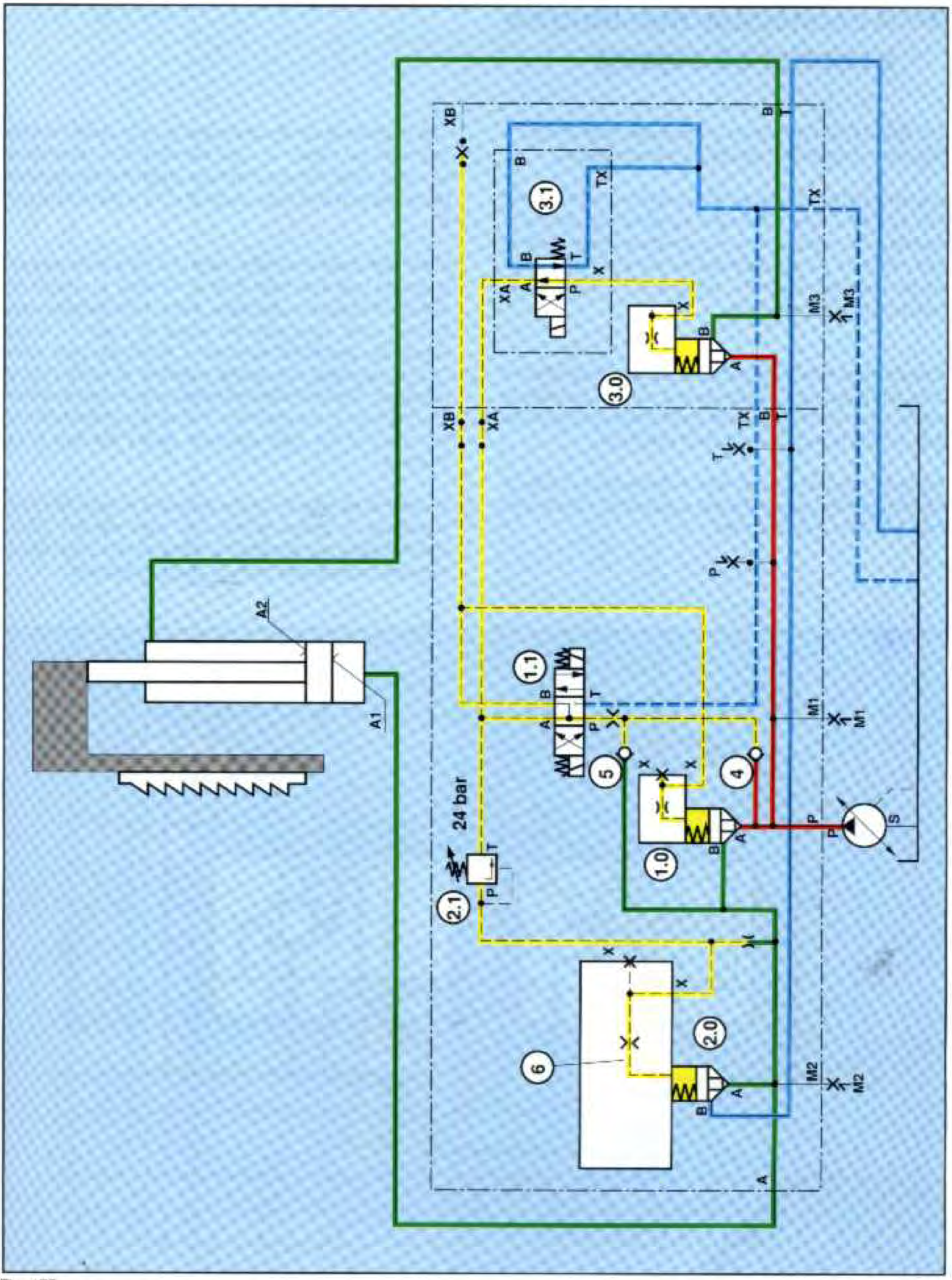

Fig. 175

3 A connection manifold for a central oil supply

The circuit *(Fig.176)* shows a connection manifold for a ring main installation, (usually on a machine tool).

In a central oil supply system (ring main) e.g. on a transfer line, a central power unit supplies pressurised oil to all of the machines instead of having individual power units on each machine. All the machines are therefore connected via the ring main lines (P = pump and T = tank) to the central hydraulic power unit.

As each of the individual machines all operate at different flows and pressures, and because it must be possible to isolate each machine, suitable control elements must be built into the branch lines to each machine.

In order to have a common form of connection in spite of the varying pressures and flows, a connection block with logic elements was designed.

The machine is either connected to or isolated from the ring main by means of logic element (1.0) (directional function). Flow from the ring main at port A of the manifold block and port B of logic element (1.0) is blocked at port B.

In the start position of pilot valve (1.1), the logic element is closed leak free from B to A. In order to ensure no leakage through the pilot valve, a directional poppet valve is used here. (see also the notes on *page 47*, Logic Elements, directional functions.) When the pilot valve (1.1) is operated, the spring chamber of valve (1.0) is unloaded. The logic element opens and permits flow from the ring main to the machine. The stroke limiter built into the cover of the logic elements allows the flow to be throttled.

In order to be able to set the pressure at each machine separately, a "pressure reducing" logic element (2.0)is installed *(also see section 2.2, pressure reducing valves, normally closed, with manual setting, page 92)*.

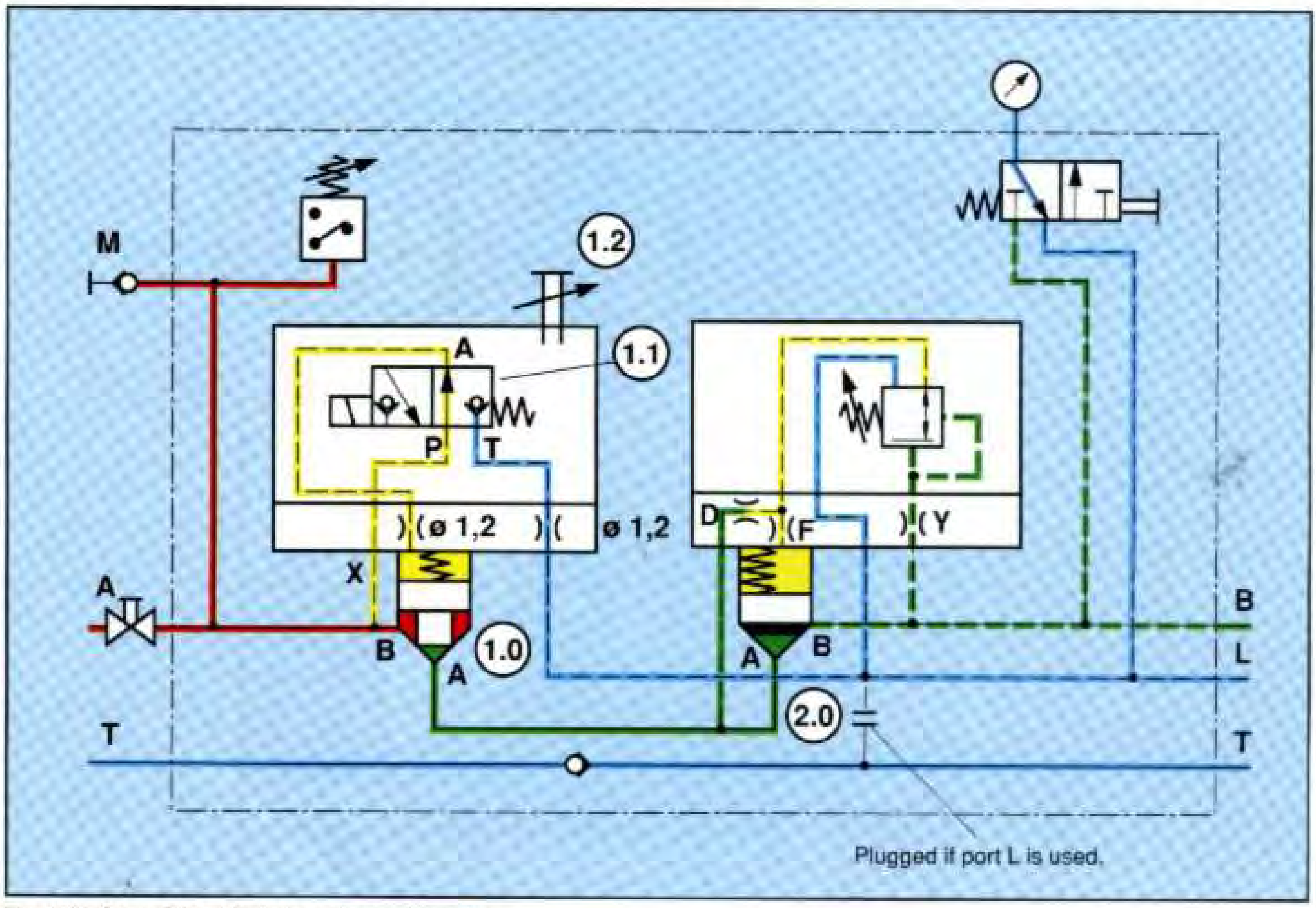

Fig. 176: *Connection block for a ring main system*