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.*

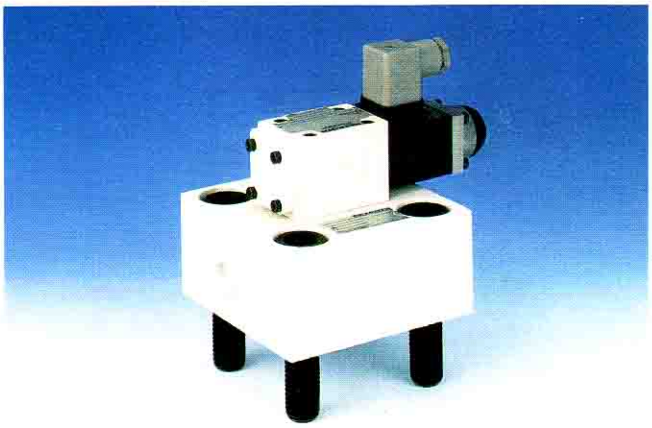
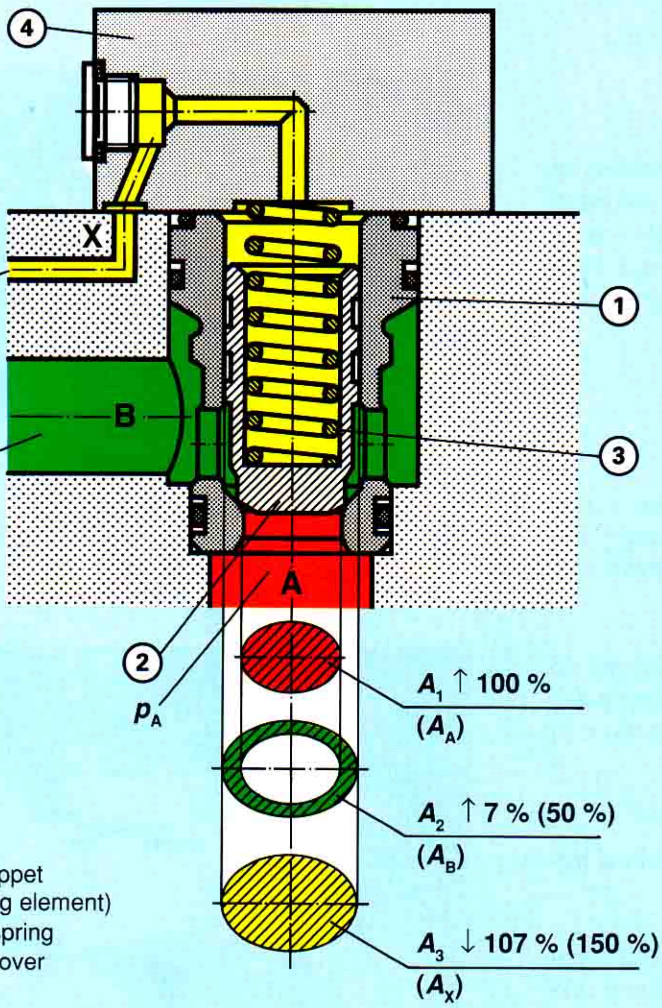


Fig. 3: *Control cover with built on directional spool valve.*

2 The basic element and its function

First of all a look at the basic element.



(1) Bush
(2) Valve poppet (Switching element)
(3) Closing spring
(4) Control cover

Fig. 4: *Basic Element*

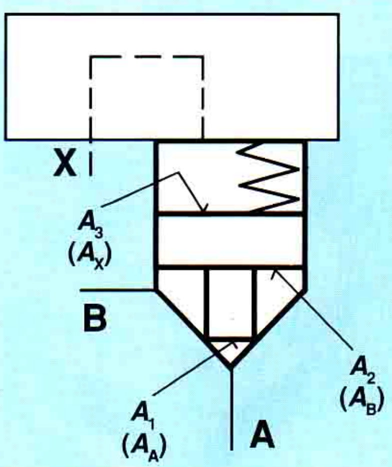


Fig. 5: *A frequently used symbol which appears in DIN 24342, appendix 1 as the schematic symbol for these units.*

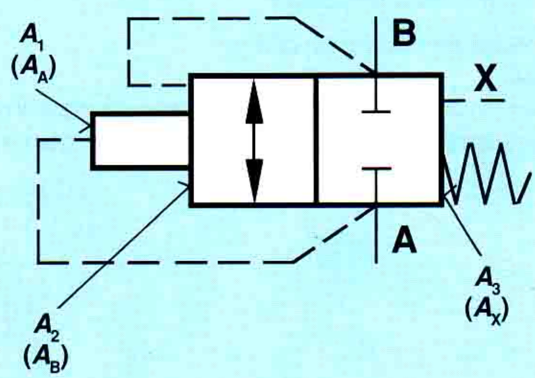


Fig. 6: *The symbol as it appears under the illustration rules for DIN ISO 1219.*

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

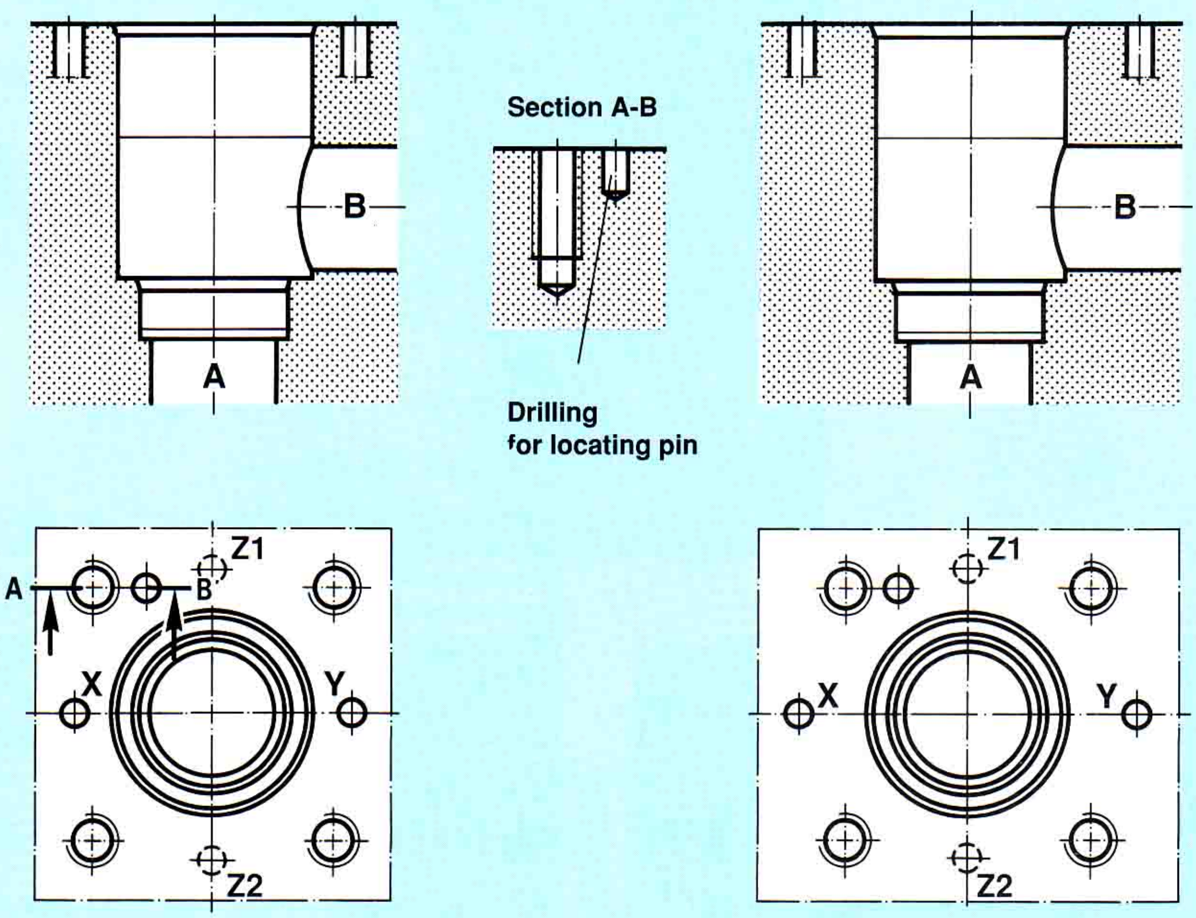
Cavity to DIN 24342

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.

Form A
A flange pattern for square cover

Form B
Flange pattern for rectangular cover
(other dimensions as form A)

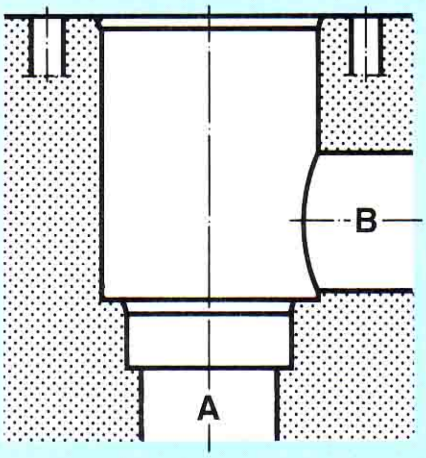


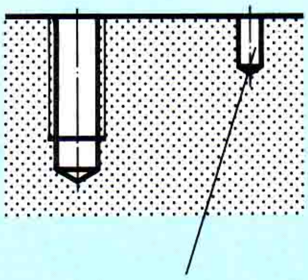
A, B Service ports
X Pilot feed connection
Y Pilot drain connection
Z1, Z2 Additional pilot connection
Z1 Preferred feed connection
Z2 Preferred drain connection

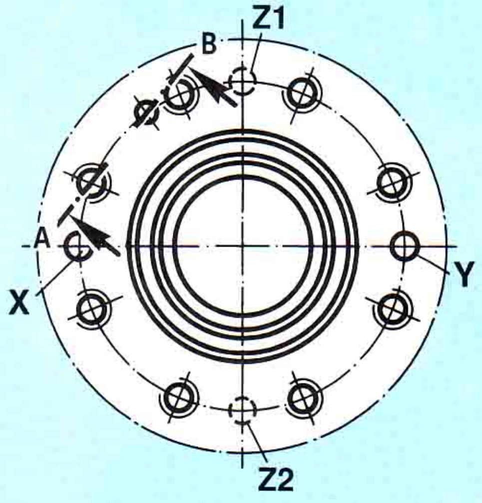
Fig. 7: *Bore dimensions for logic elements sizes 16,25,32,40,50 and 63 (four hole flange).*

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.*

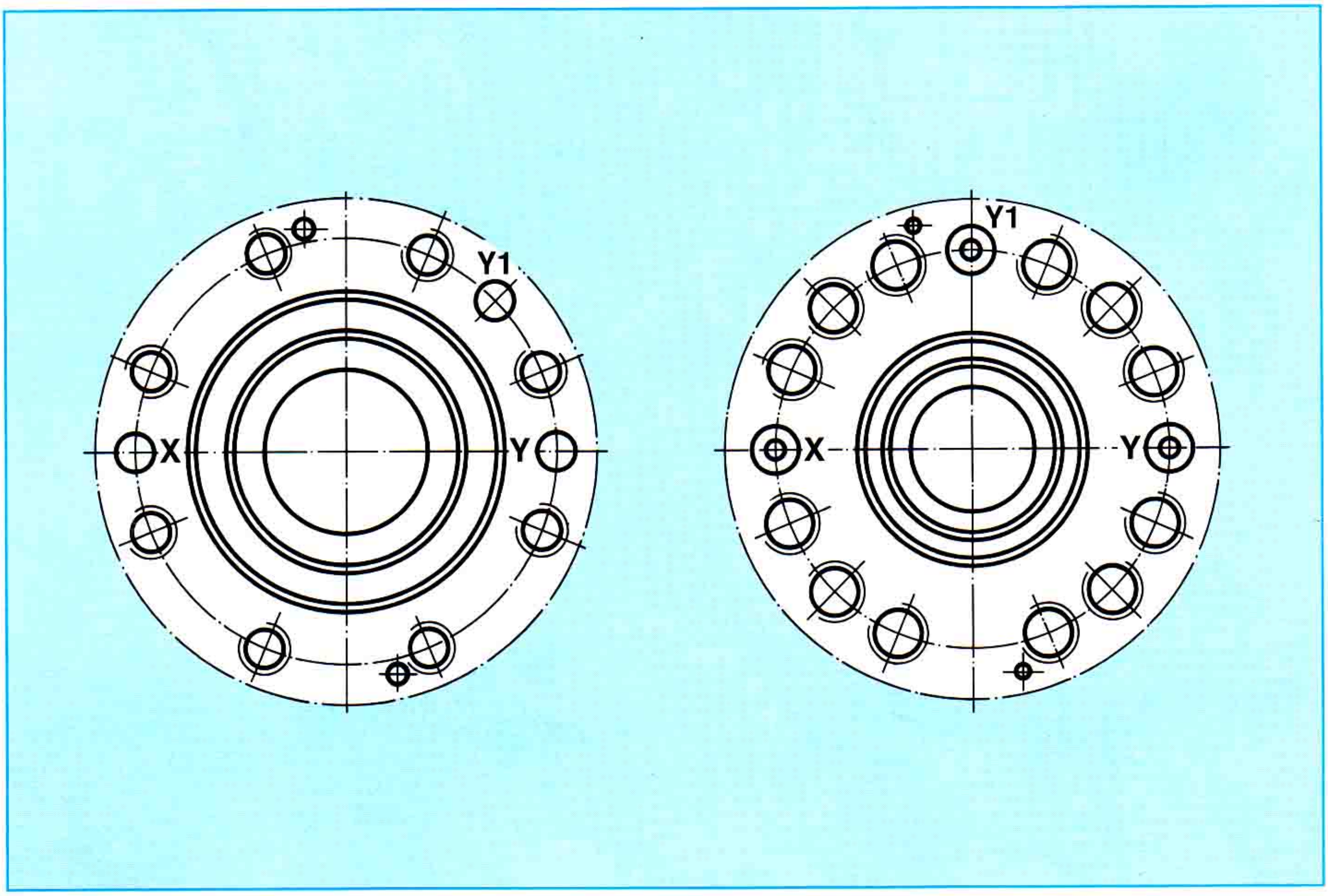


Fig. 9: *Bore dimensions for logic elements size 125 and 160.*

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 you.

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.

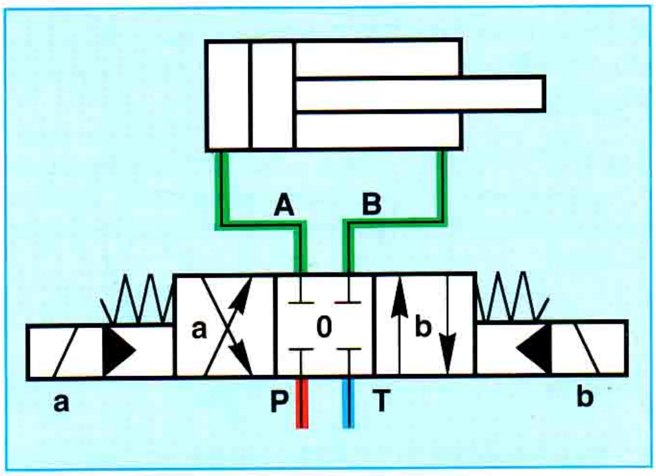


Fig. 10: *Circuit with 4/3 way directional valve.*

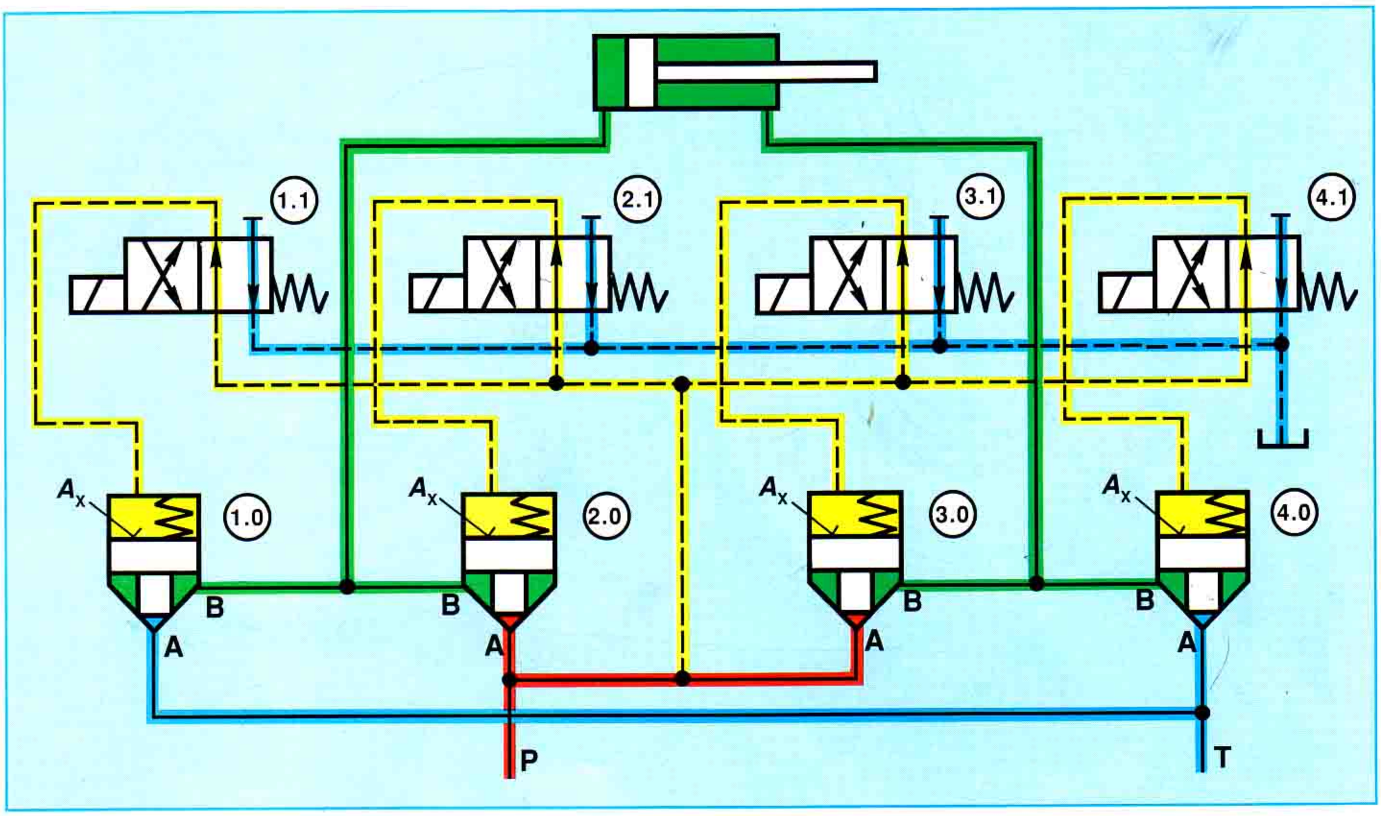


Fig. 11: *Cylinder control with logic elements, each controlled by a separate pilot valve.*

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 cm²
A_B (A_2) = 1.61 cm²
A_X (A_3) = 4.91 cm²

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

$F_{Closed} = p_A \cdot A_X$ + 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.

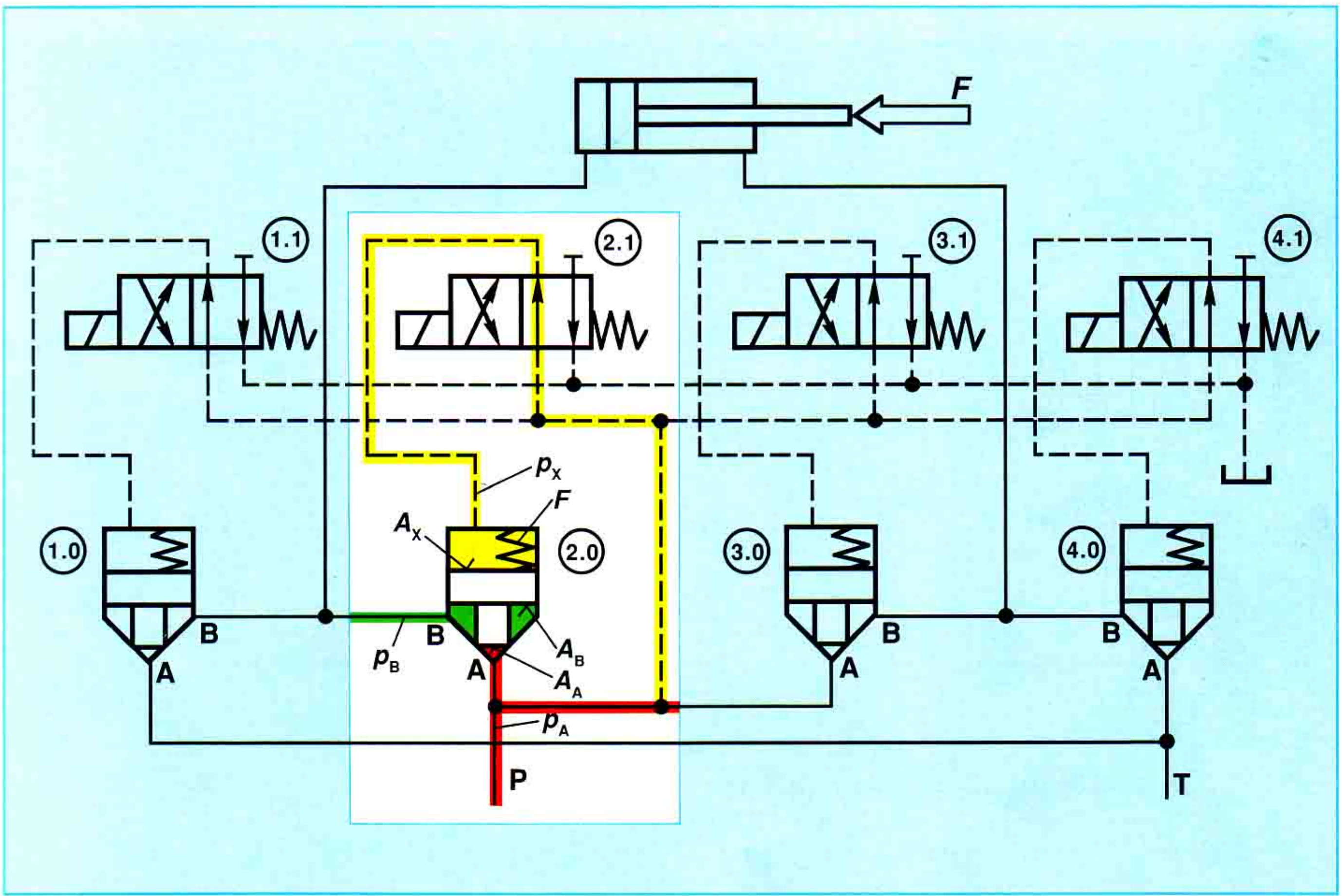


Fig. 12

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.

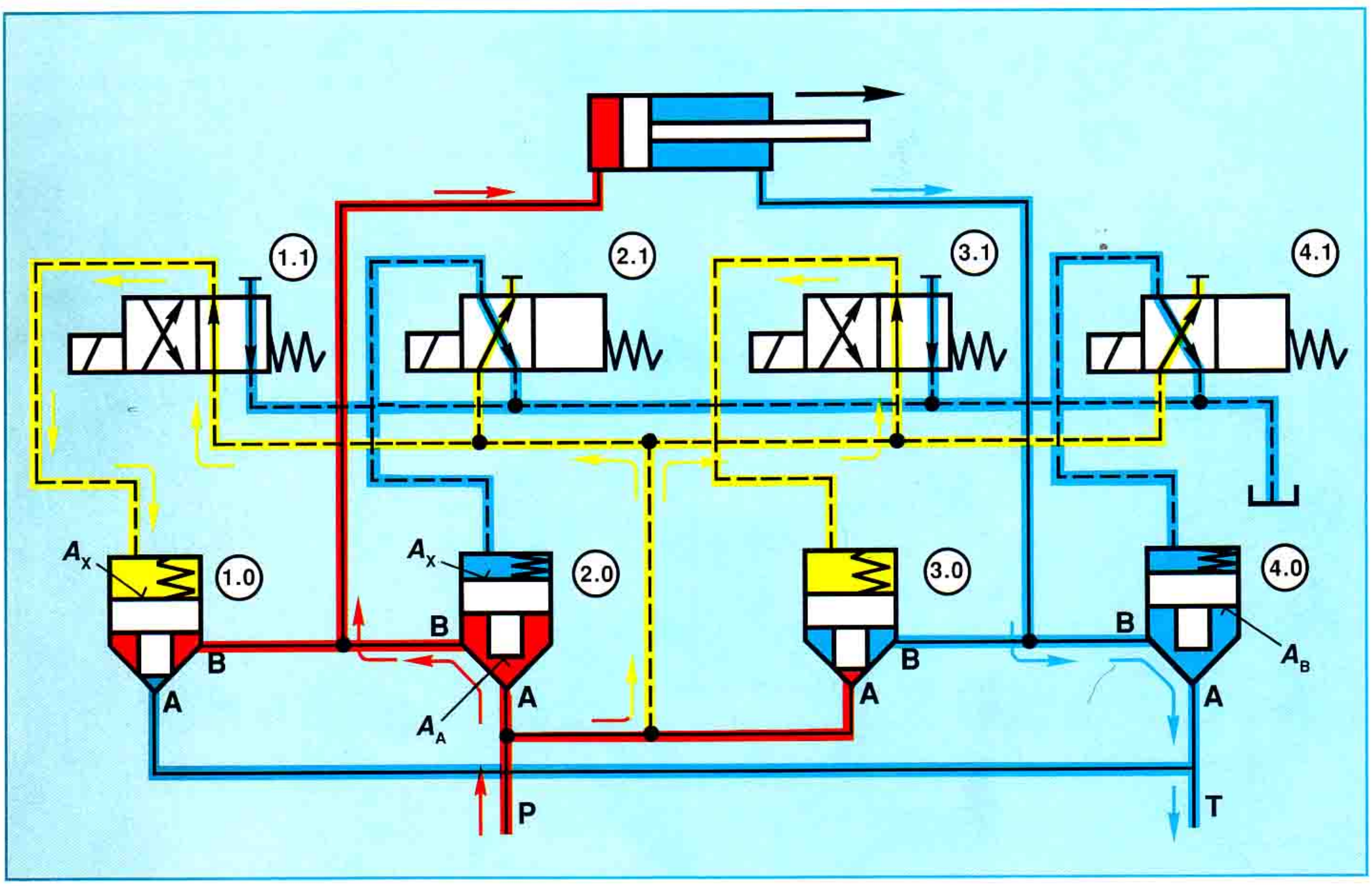


Fig. 13

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.

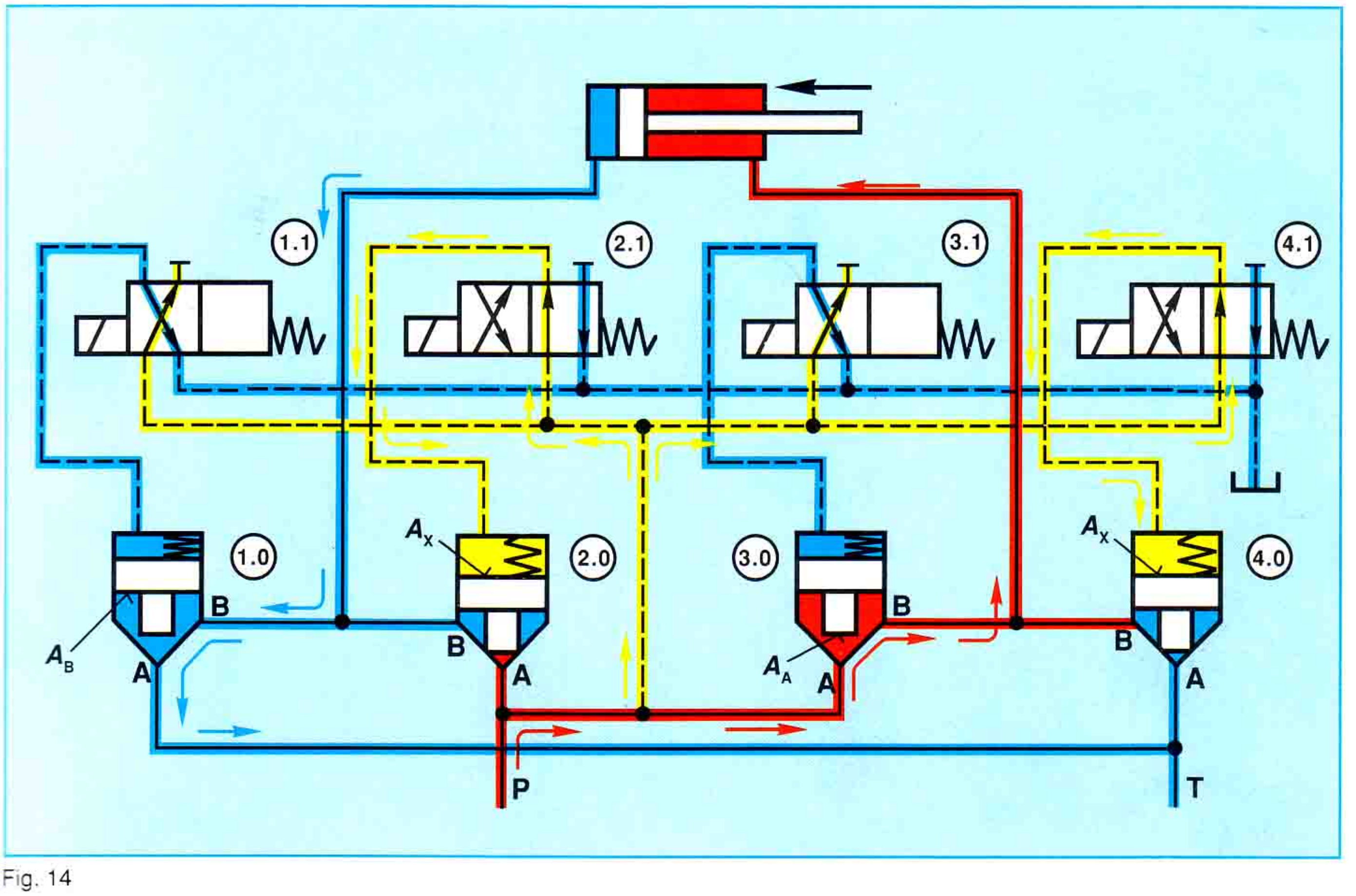


Fig. 14

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.

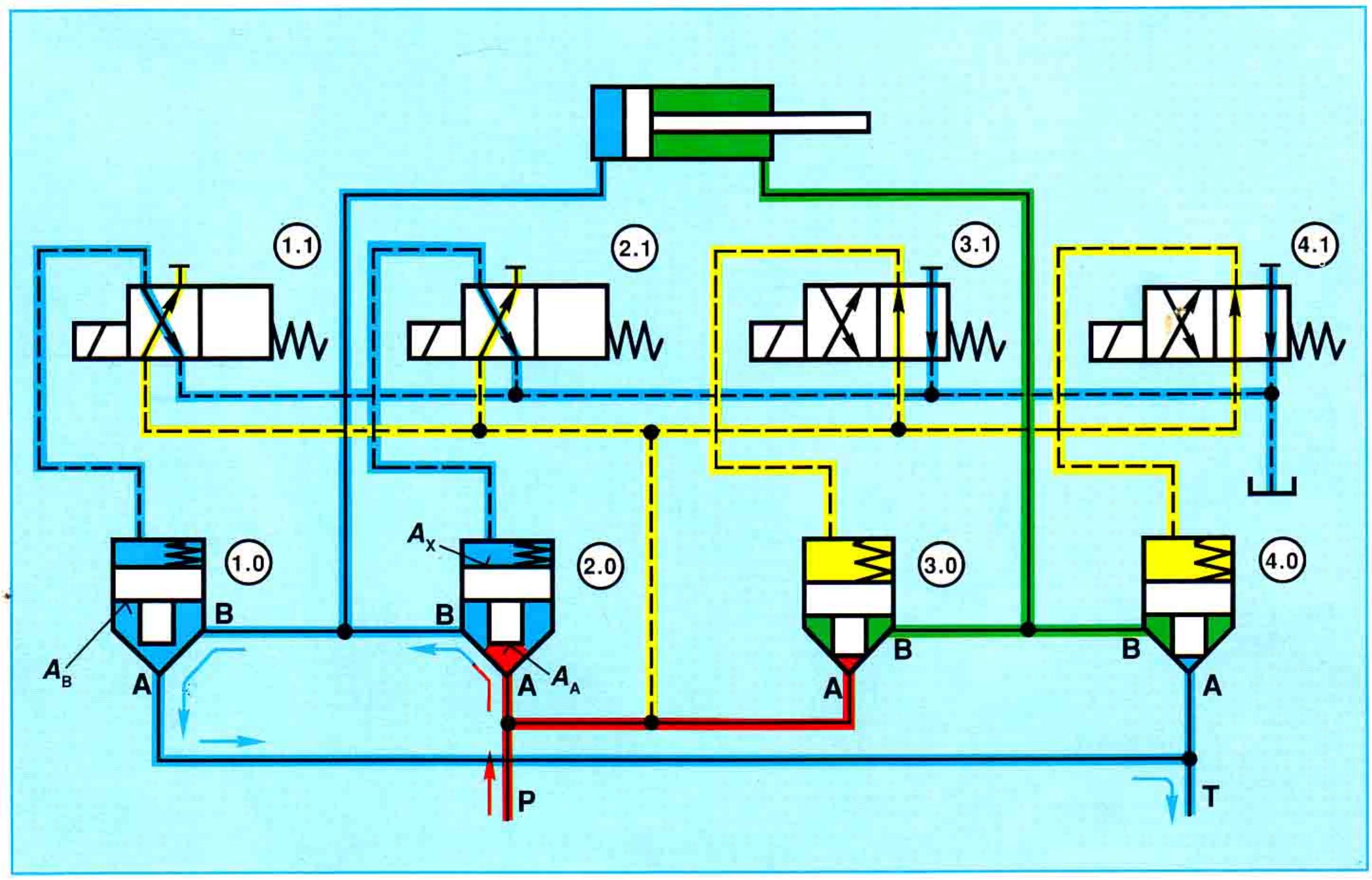


Fig. 15

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.

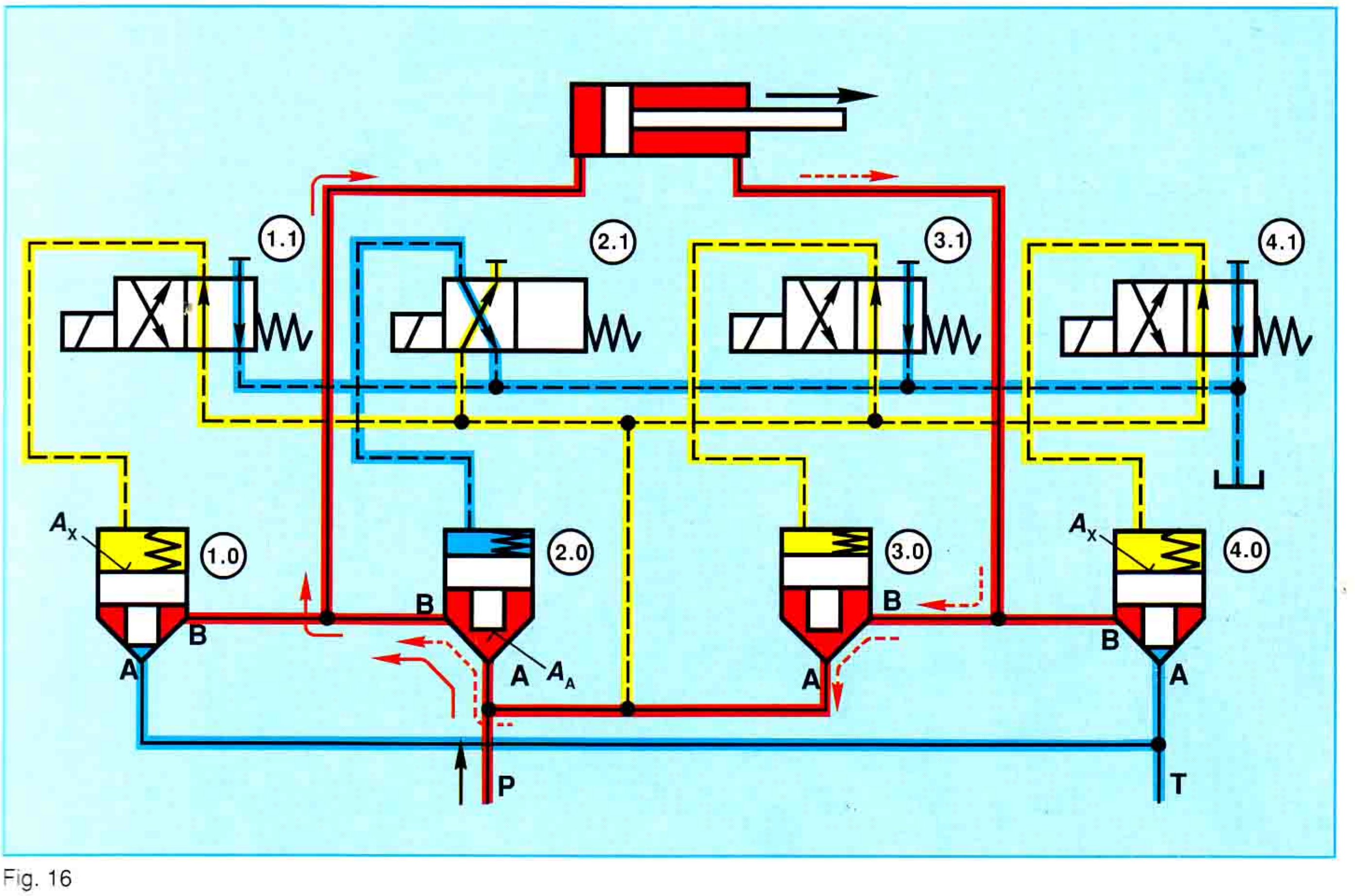


Fig. 16

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.

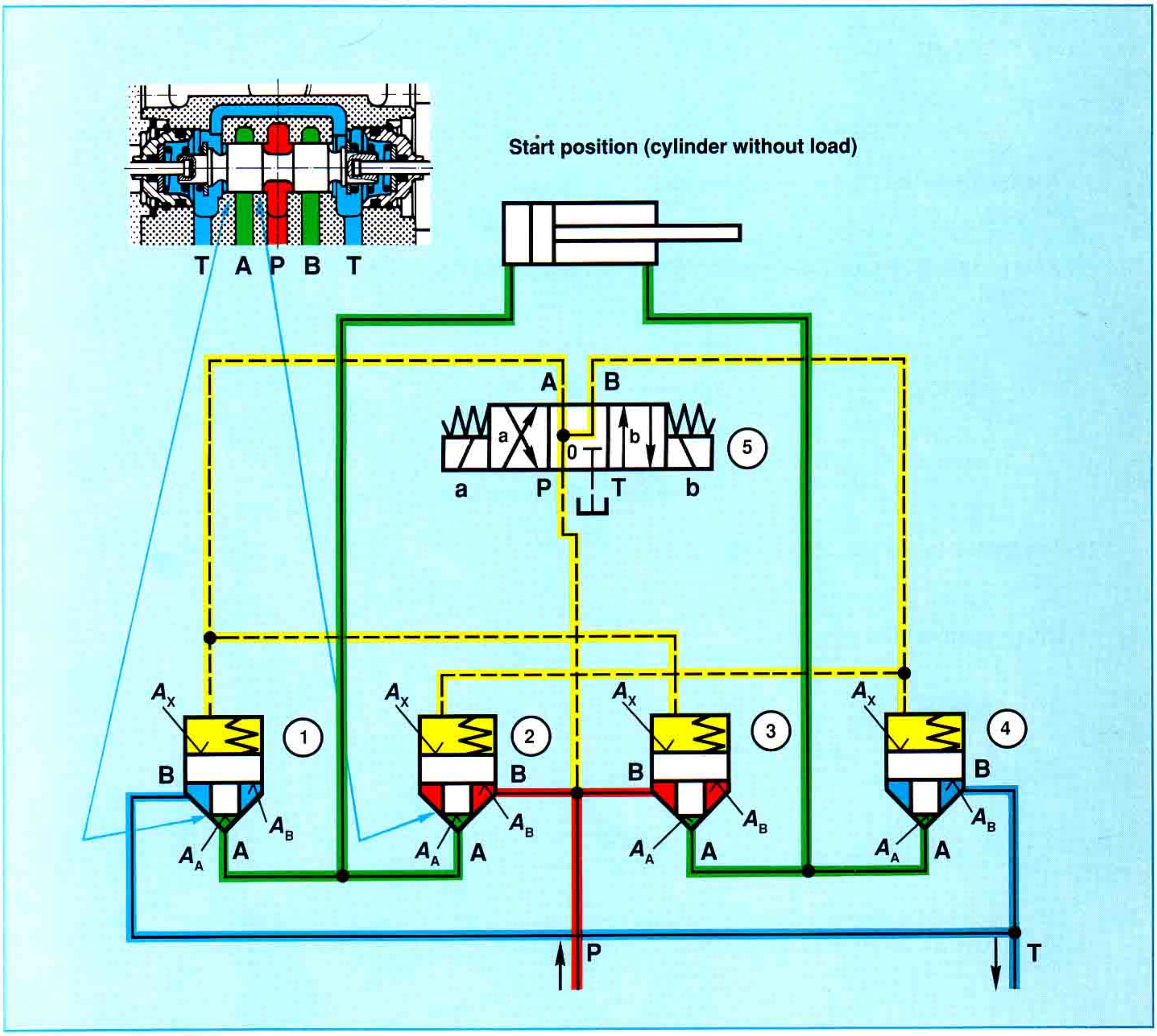

T A P B T
Start position (cylinder without load)
A
B
a
0
b
5
a
P
T
b
A_X
1
B
A_B
A_A
A
A_X
2
B
A_B
A_A
A
A_X
3
B
A_B
A_A
A
A_X
4
B
A_B
A_A
A
P
T

Fig. 17

The forces operating on the poppet of a logic element

(1) In a closing direction | **In an opening direction**

In a closing direction	In an opening direction
⇓ $p_P \bullet A_X$	⇑ $p_K \bullet A_A$
⇓ Spring	⇑ $p_T \bullet A_B$

p_P = Pressure in pump line

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 | **In an opening direction**

In a closing direction	In an opening direction
⇓ $p_P \bullet A_X$	⇑ $p_P \bullet A_B$
⇓ Spring	⇑ $p_K \bullet A_A$

p_P = Pressure in pump line

p_K = at almost zero pressure

The forces in the closing direction predominate.

(3) In a closing direction | **In an opening direction**

In a closing direction	In an opening direction
⇓ $p_P \bullet A_X$	⇑ $p_P \bullet A_B$
⇓ Spring	⇑ $p_R \bullet A_A$

p_R = Pressure in annulus
(at almost zero pressure)

The forces in the closing direction predominate.

(4) In a closing direction | **In an opening direction**

In a closing direction	In an opening direction
⇓ $p_P \bullet A_X$	⇑ $p_R \bullet A_A$
⇓ Spring	⇑ $p_T \bullet A_B$

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.

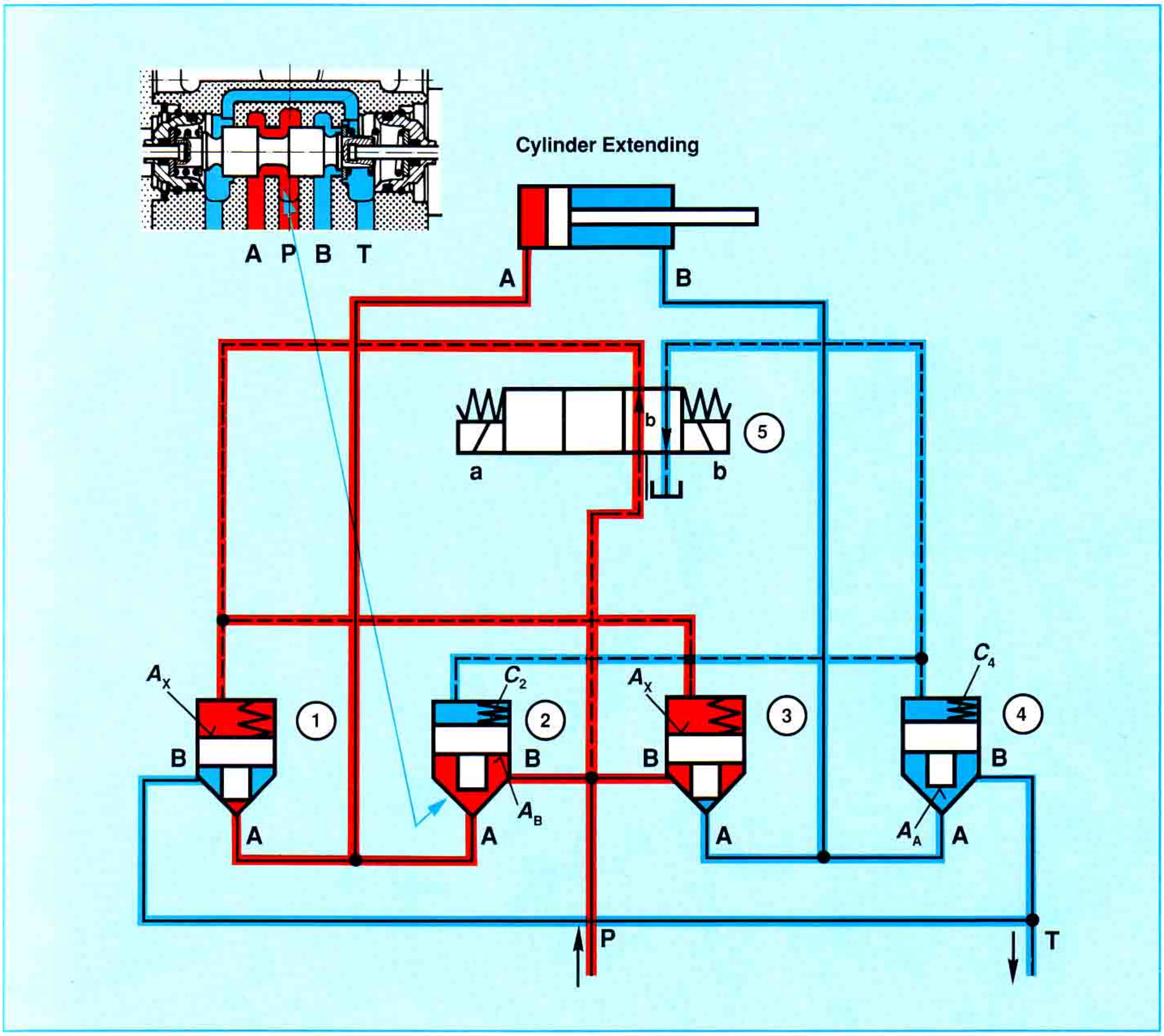


Fig. 18

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.

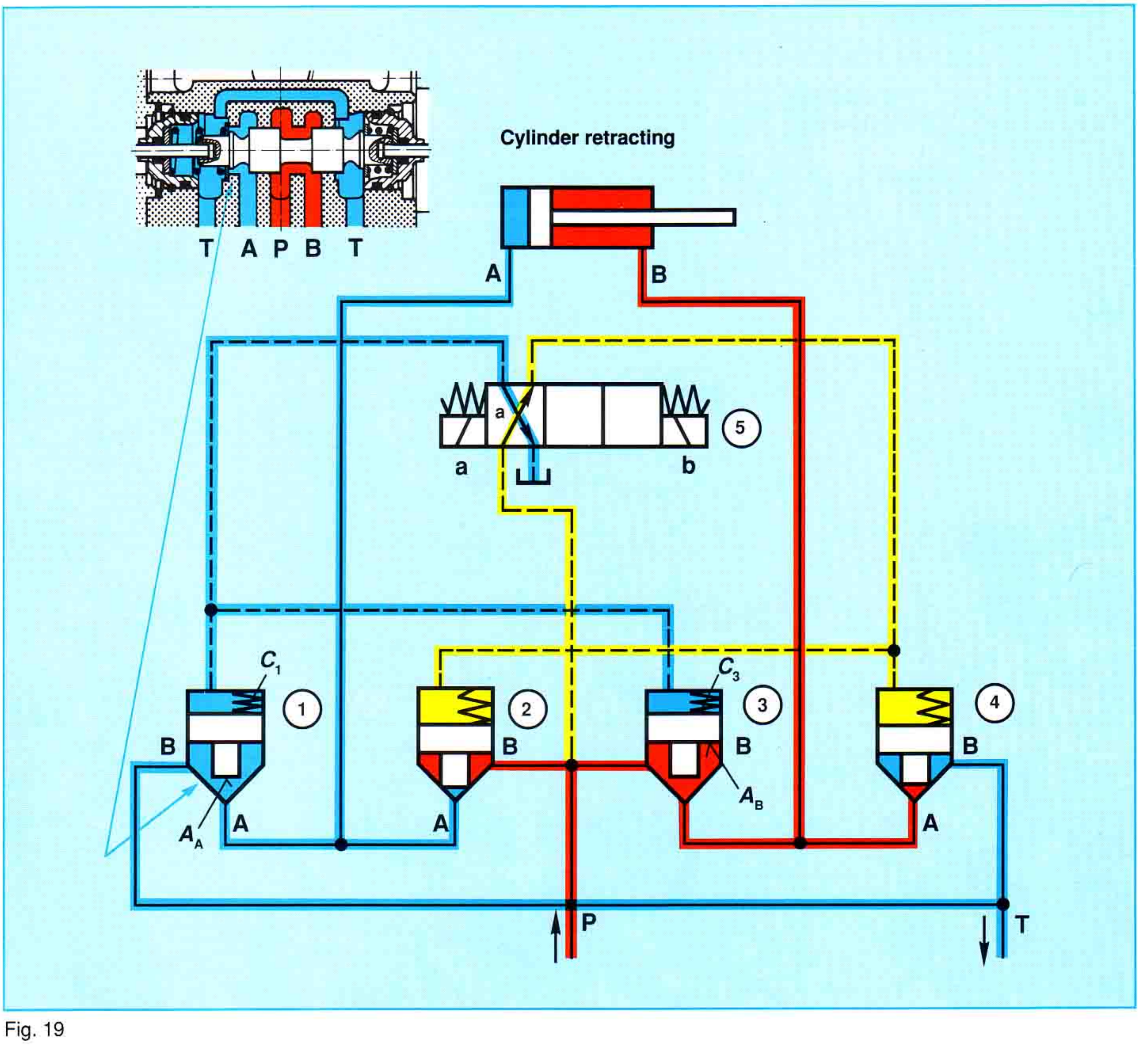


Fig. 19

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.

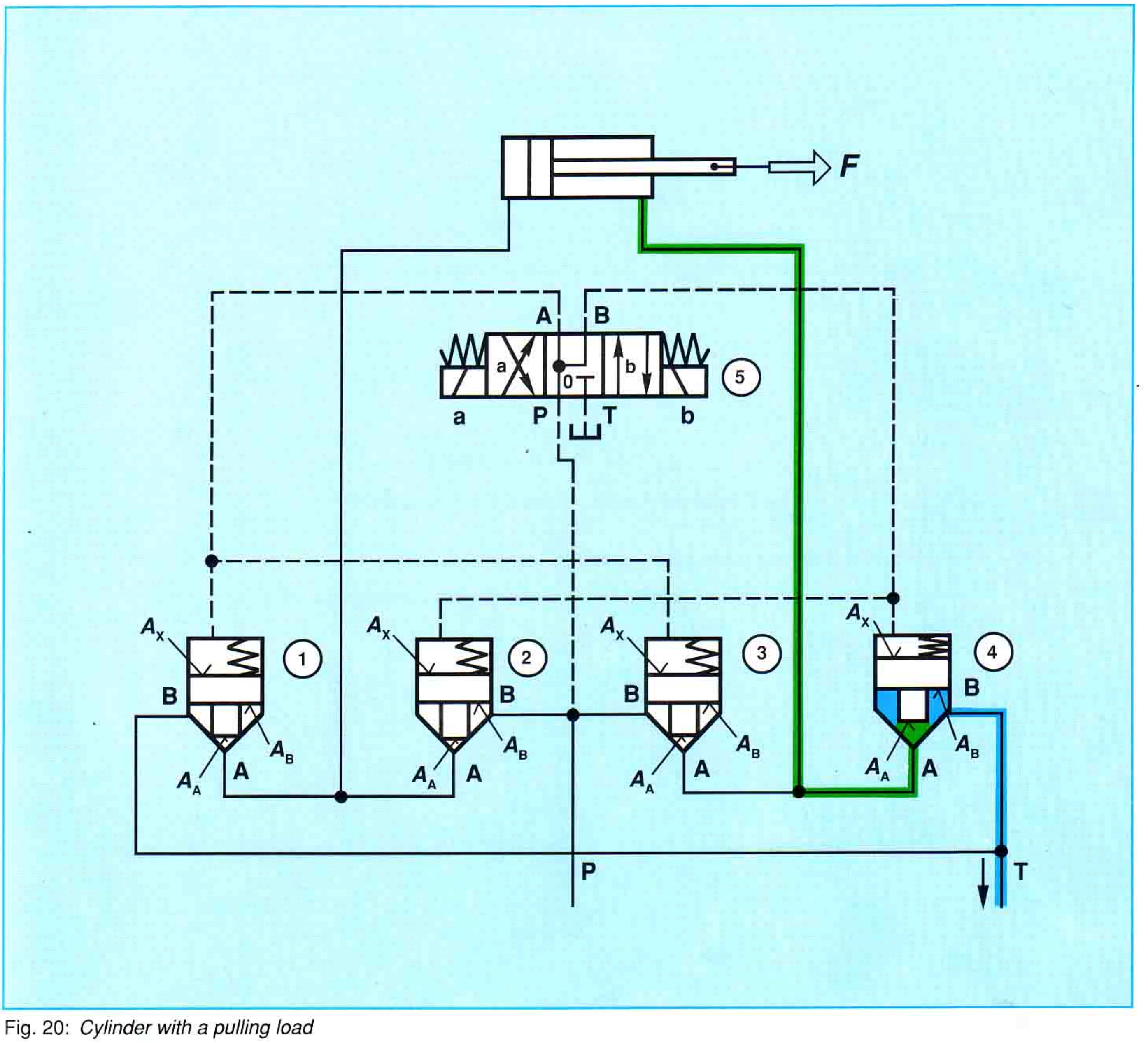


Fig. 20: *Cylinder with a pulling load*

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.

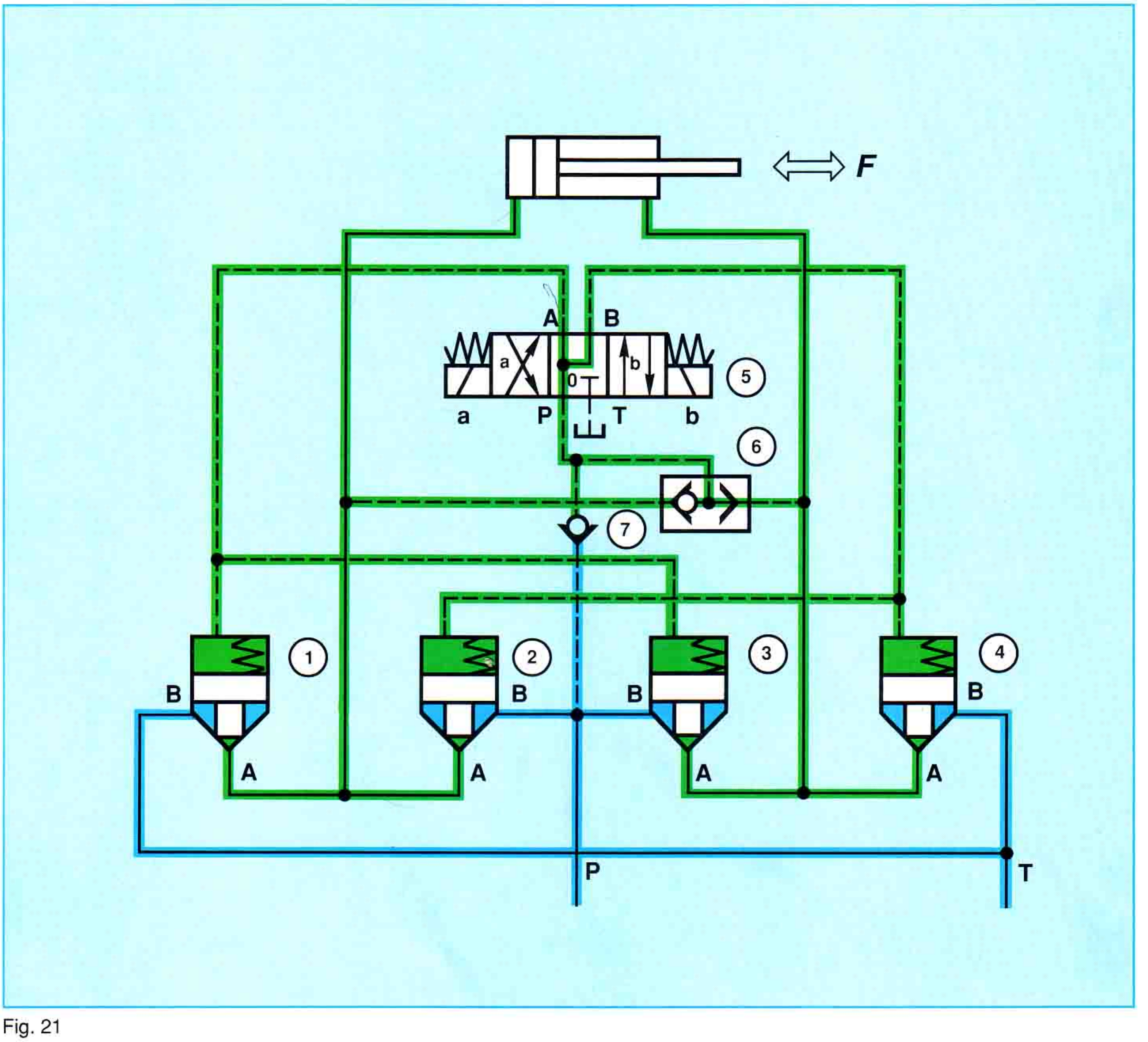


Fig. 21

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.

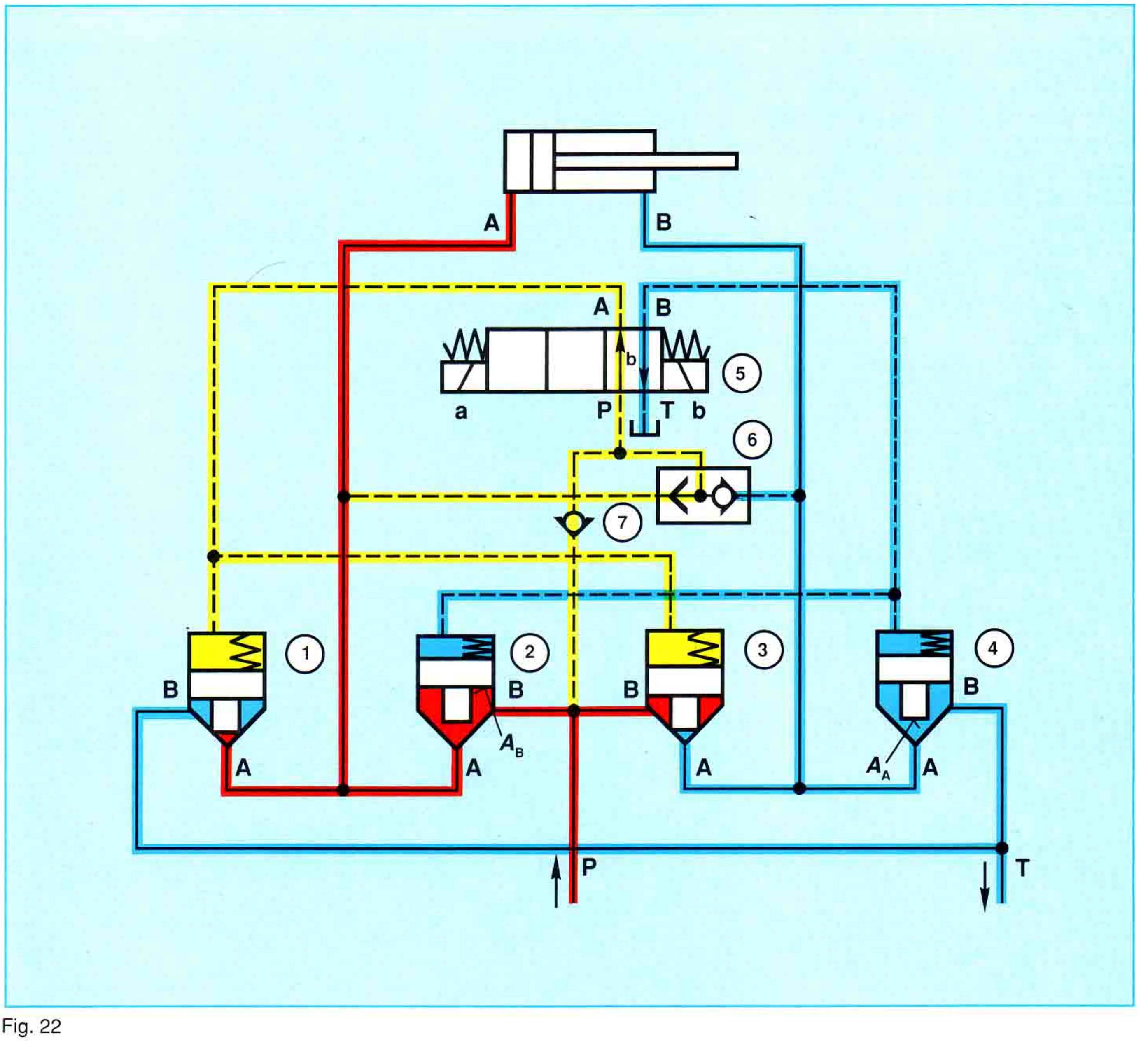


Fig. 22

**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).

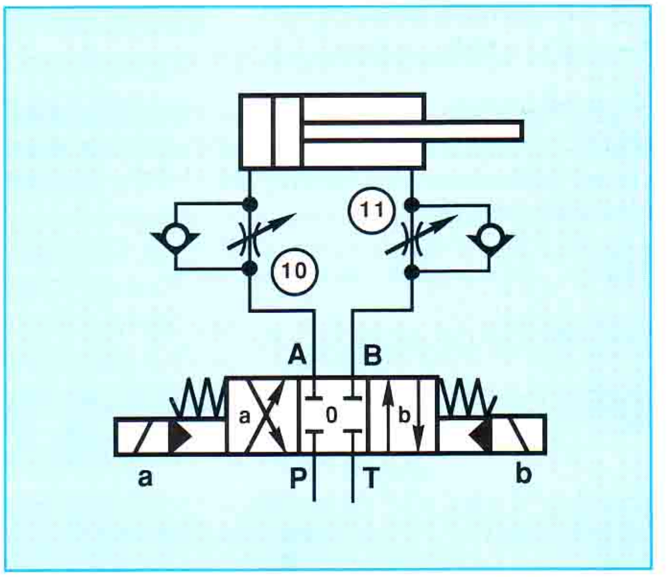


Fig. 23: *Example of cylinder control with a directional spool valve and throttle/ non return valves.*

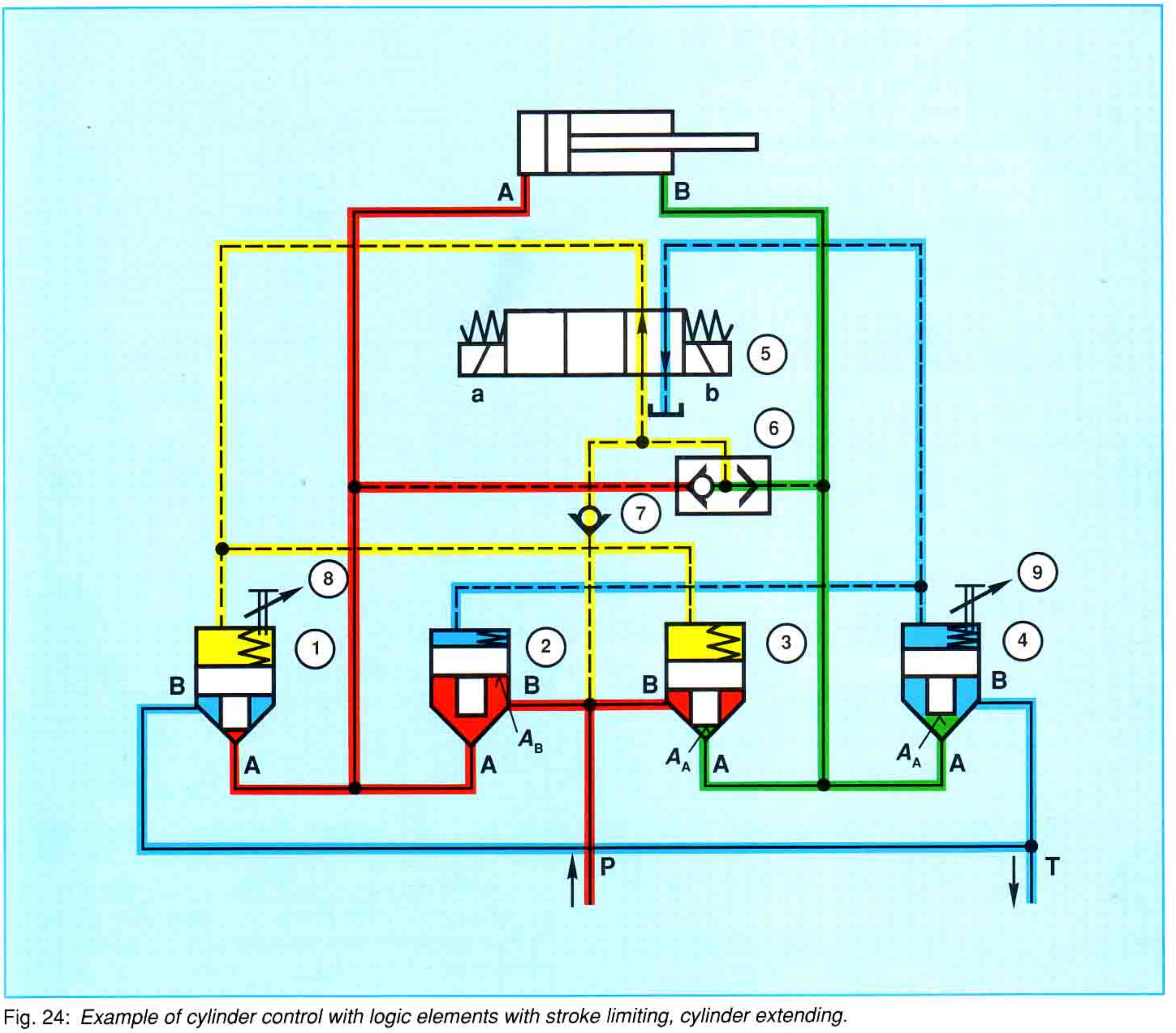


Fig. 24: *Example of cylinder control with logic elements with stroke limiting, cylinder extending.*

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)*.

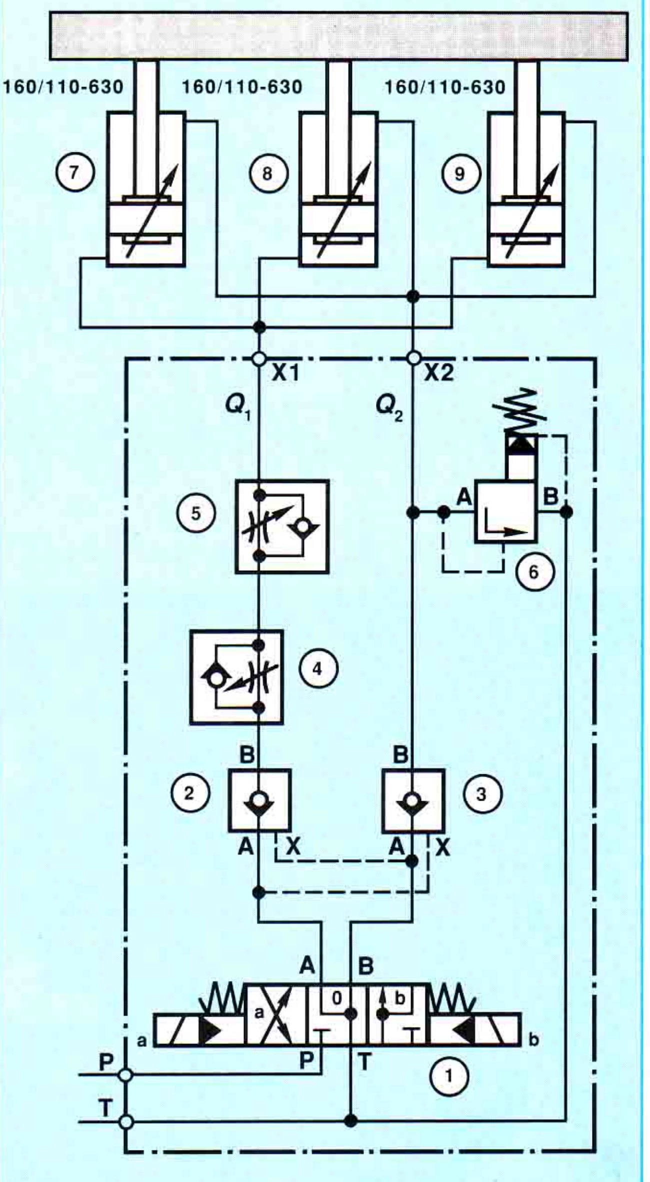
The individual functions were achieved as follows:

Cylinder Extending

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



(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

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.

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.

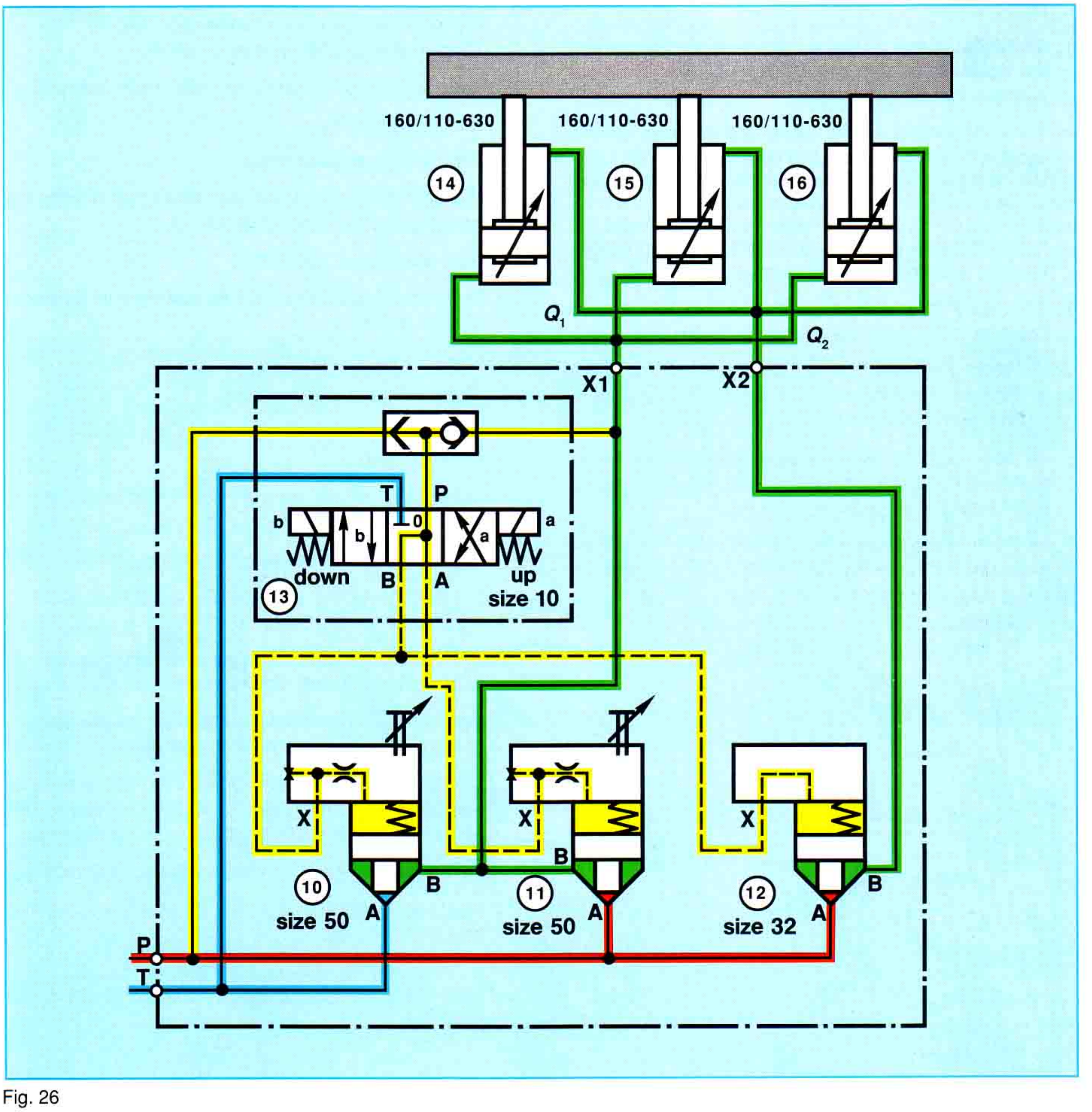


Fig. 26

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).

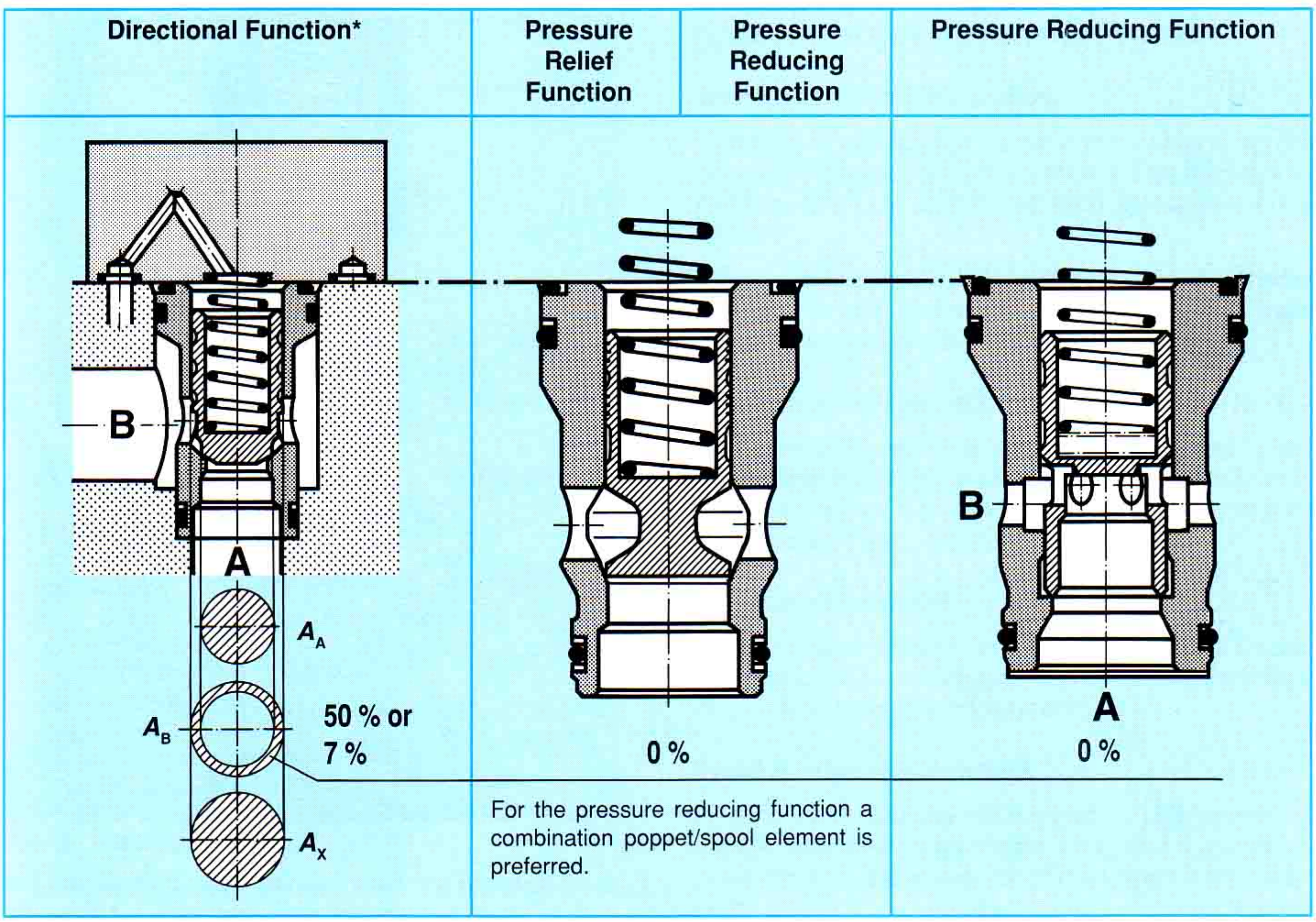


Fig. 27