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

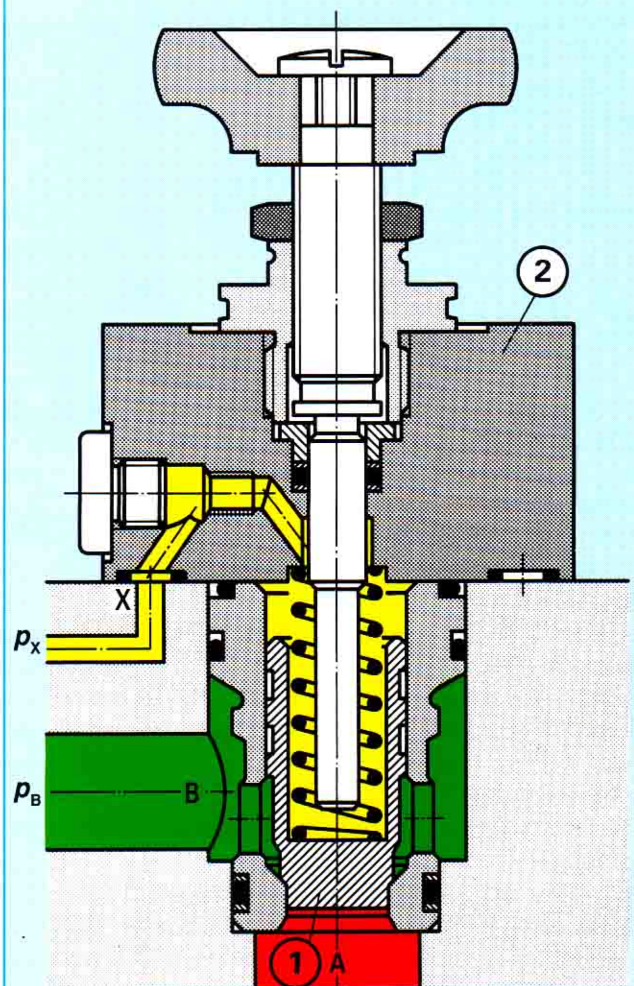
In conjunction with a second throttling element, for example a proportional directional valve, a logic element may be used as a pressure compensator. In this way, a fully pressure compensated flow control function can be achieved i.e. flow through the throttling point independent of load variations.

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

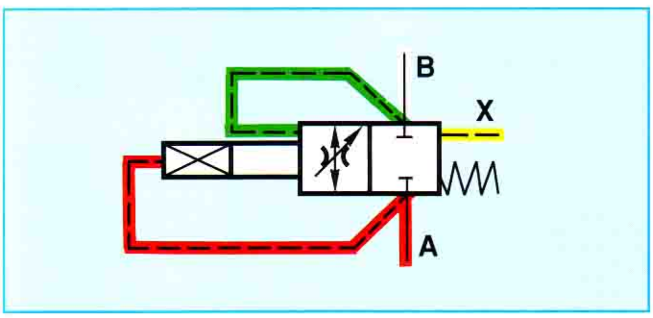


Fig. 141: *Symbol - to DIN ISO 1219*

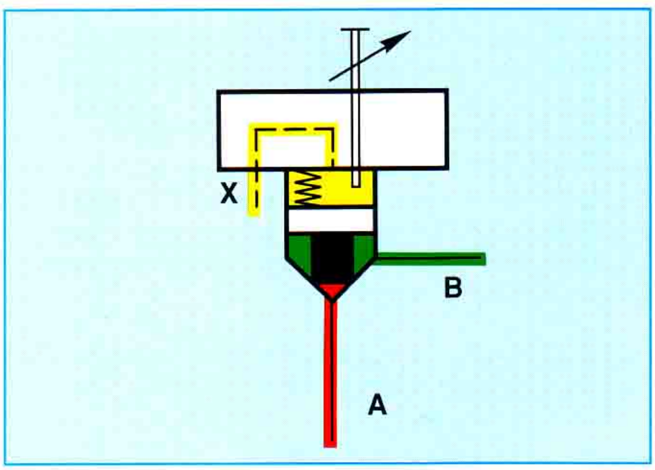


Fig. 143: *Symbol - schematic illustration*

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.

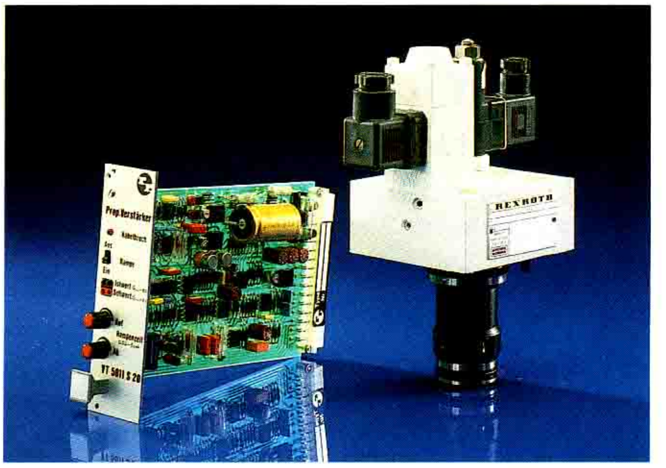


Fig. 144: *2 way proportional throttle valve,type FE...C...*

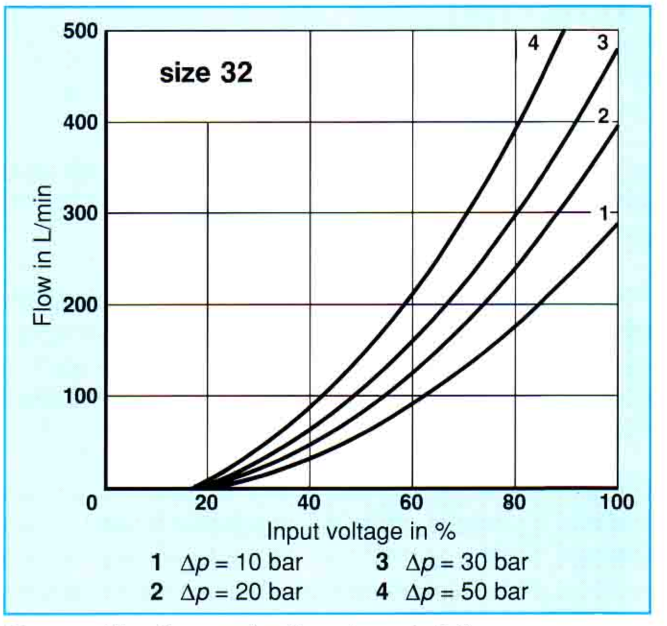


Diagram 10: *Progressive flow characteristic*

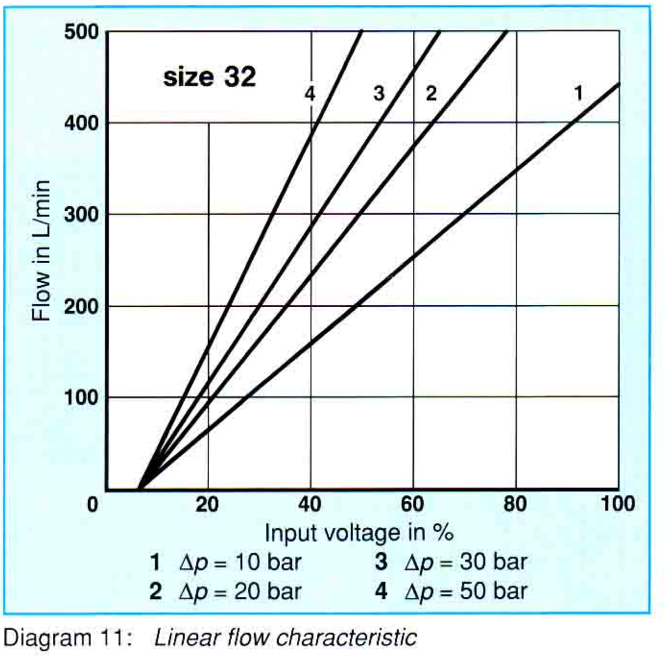
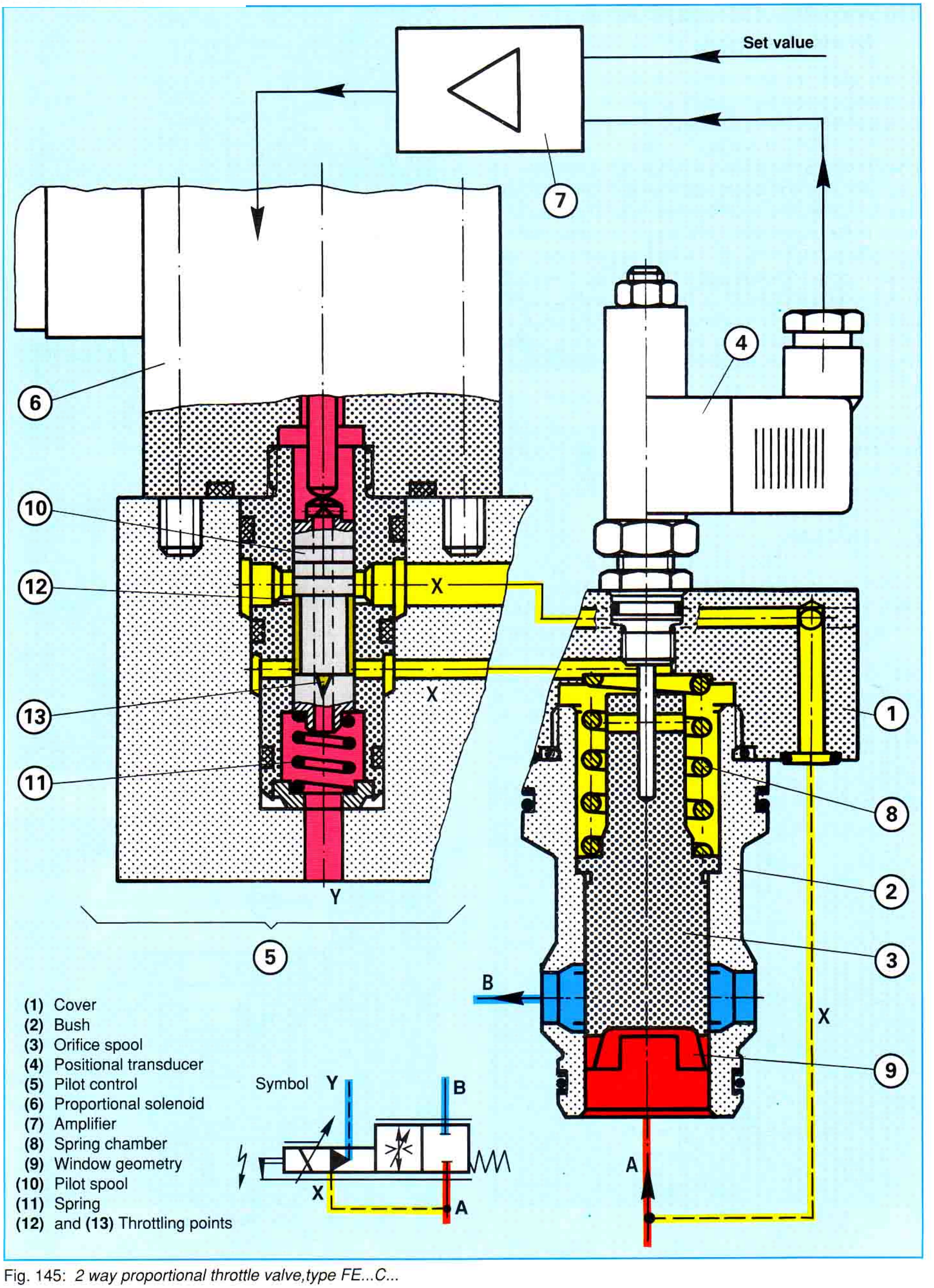


Diagram 11: *Linear flow characteristic*



(1) Cover
(2) Bush
(3) Orifice spool
(4) Positional transducer
(5) Pilot control
(6) Proportional solenoid
(7) Amplifier
(8) Spring chamber
(9) Window geometry
(10) Pilot spool
(11) Spring
(12) and (13) Throttling points

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.

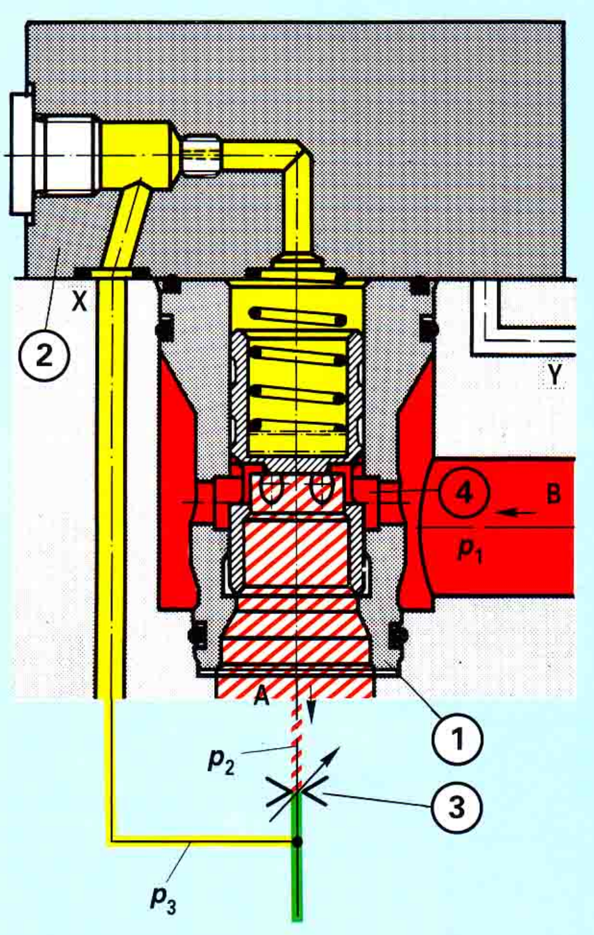
In this instance, the pressure compensator is formed by using a pressure reducing cartridge element. The pressure compensator is mounted upstream of the throttling valve. In the start position, the pressure compensator is open. Fluid can flow from B via the logic element (1) to A and then on to the throttling 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

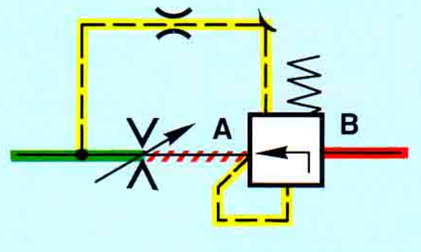


Fig. 146: *Symbol - to DIN ISO 1219*

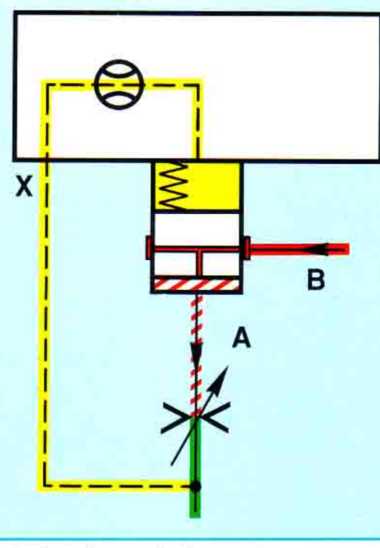


Fig. 148: *Symbol - schematic illustration*

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.

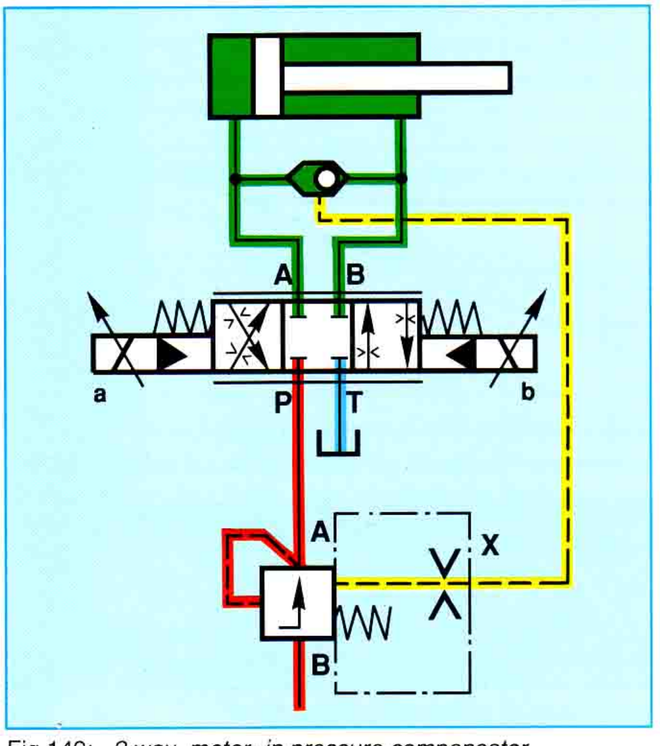


Fig.149: *2 way, meter- in pressure compensator*

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.

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

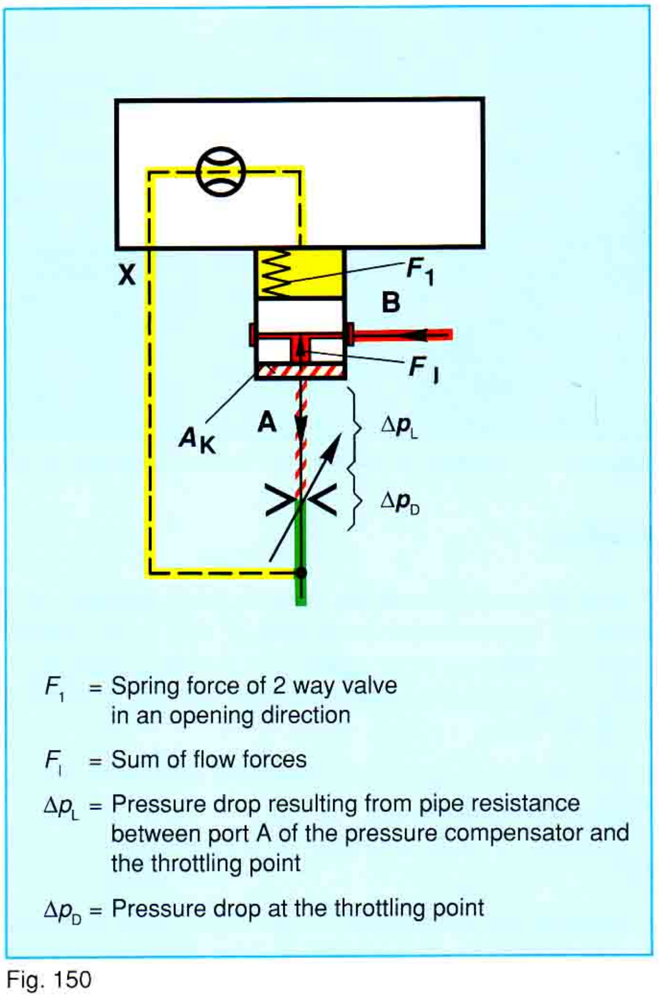


Fig. 150

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.

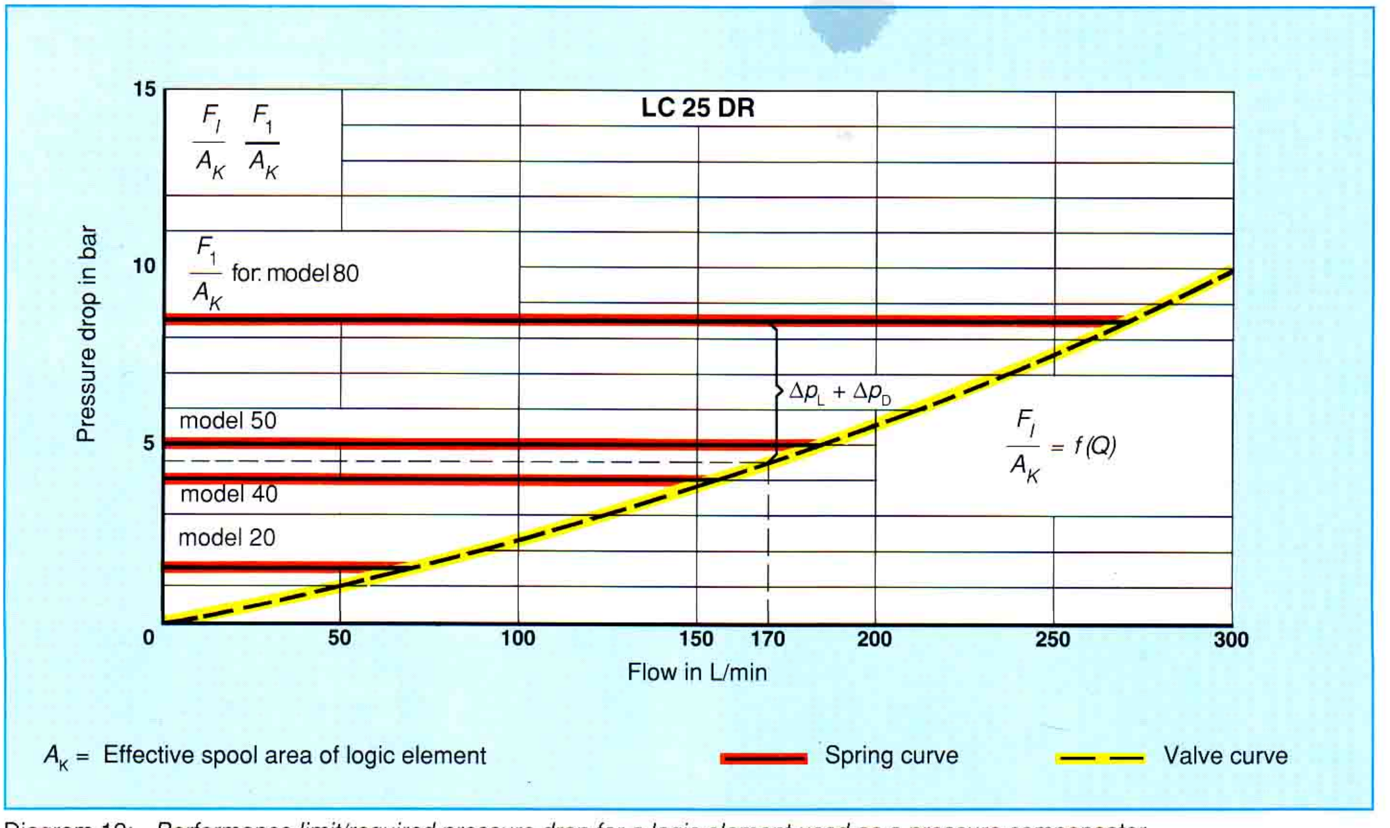


Diagram 12: *Performance limit/required pressure drop for a logic element used as a pressure compensator.*

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.

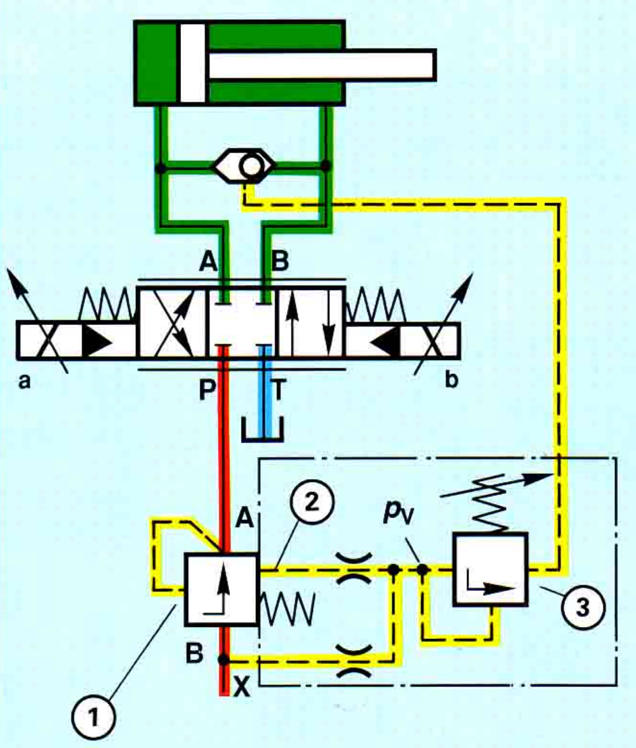
The pilot pressure relief valve (3) is now used to sense the load pressure.

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.

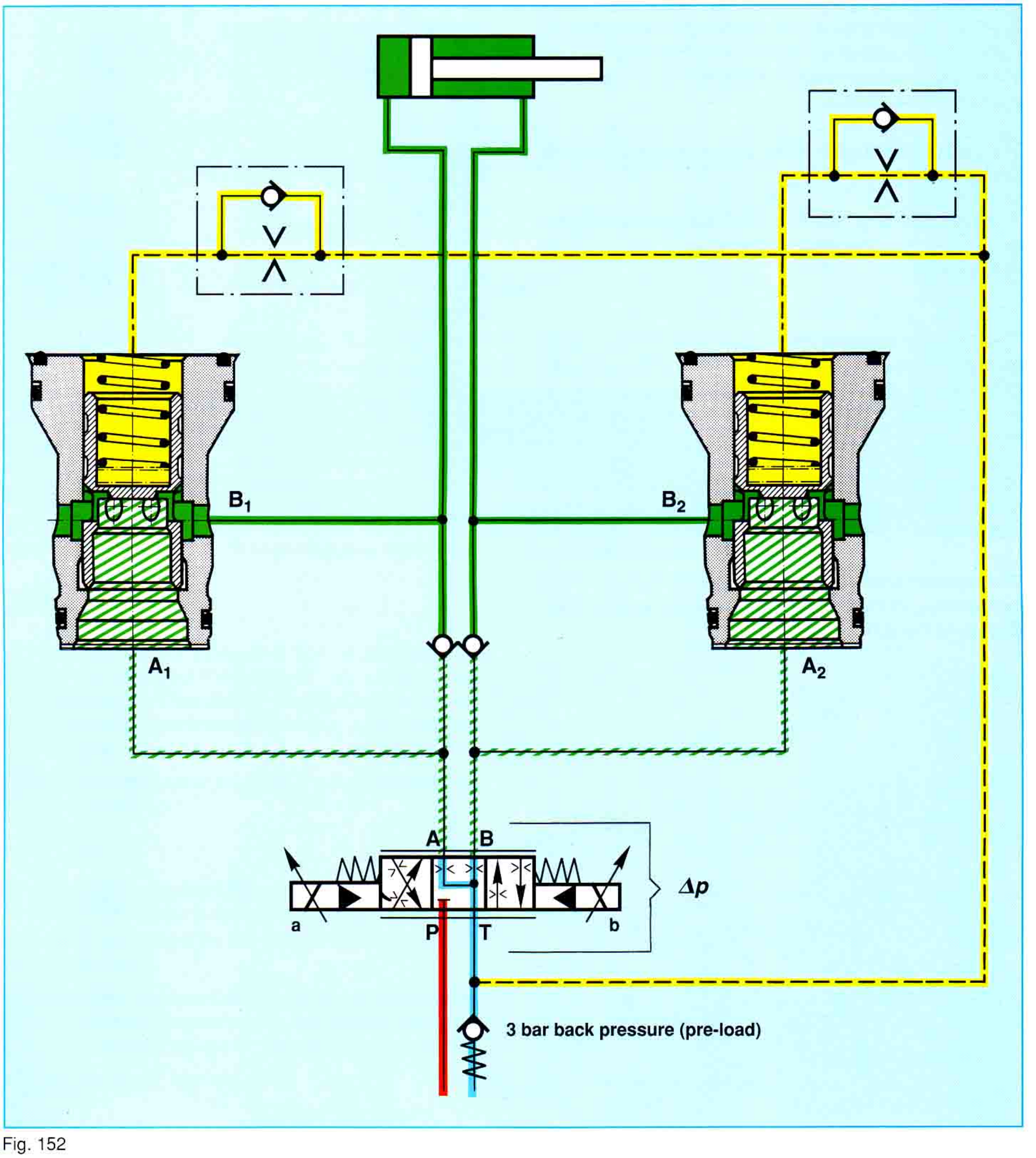


Fig. 152

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.

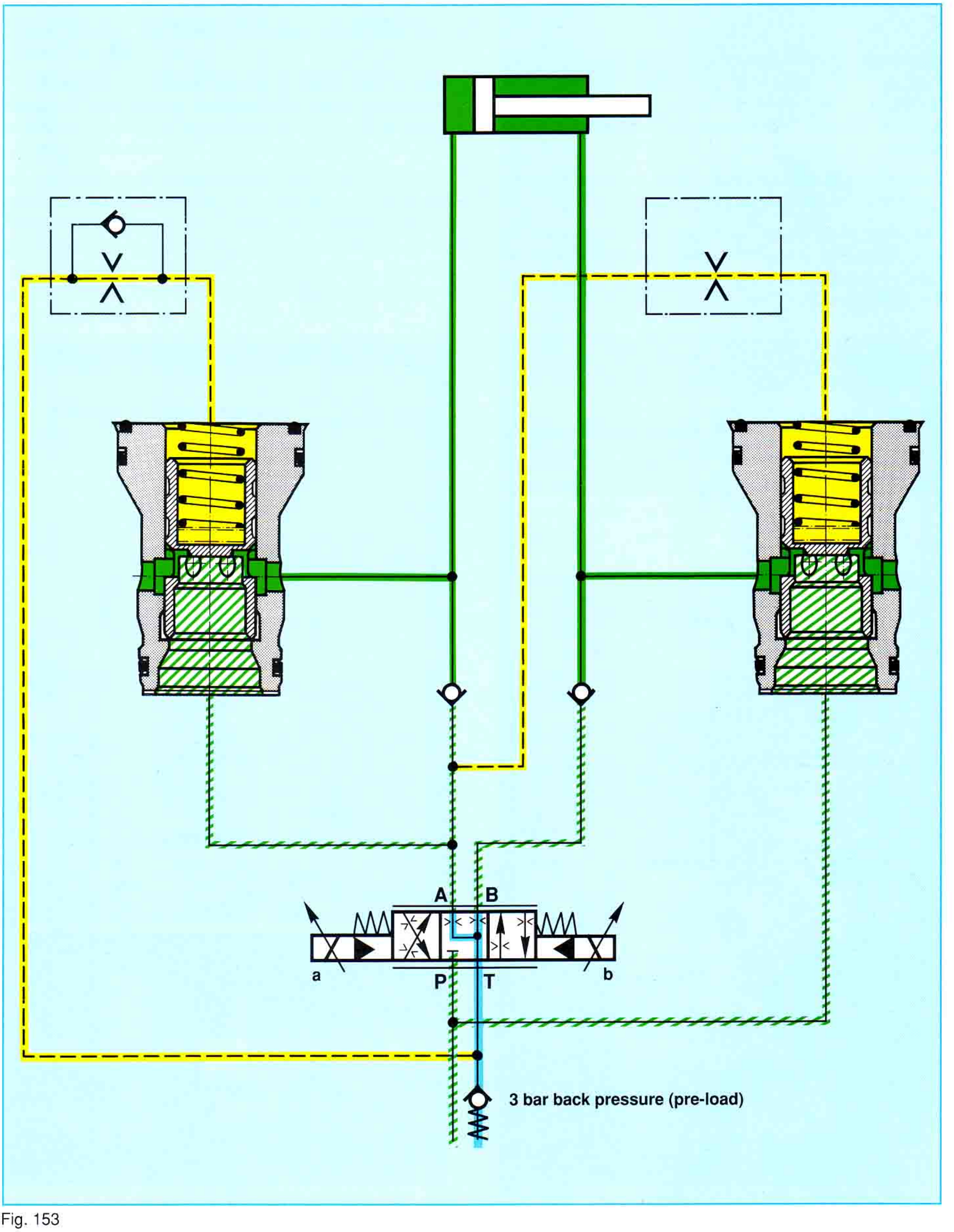


Fig. 153

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).

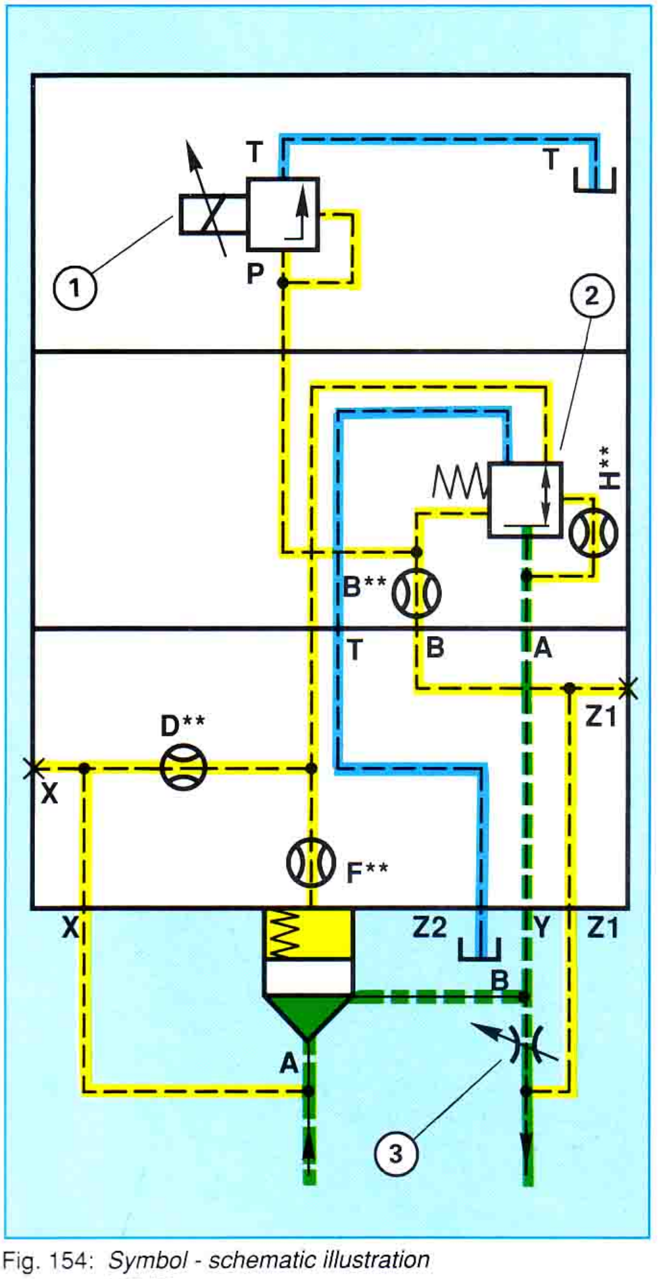


Fig. 154: *Symbol - schematic illustration*
**Orifice

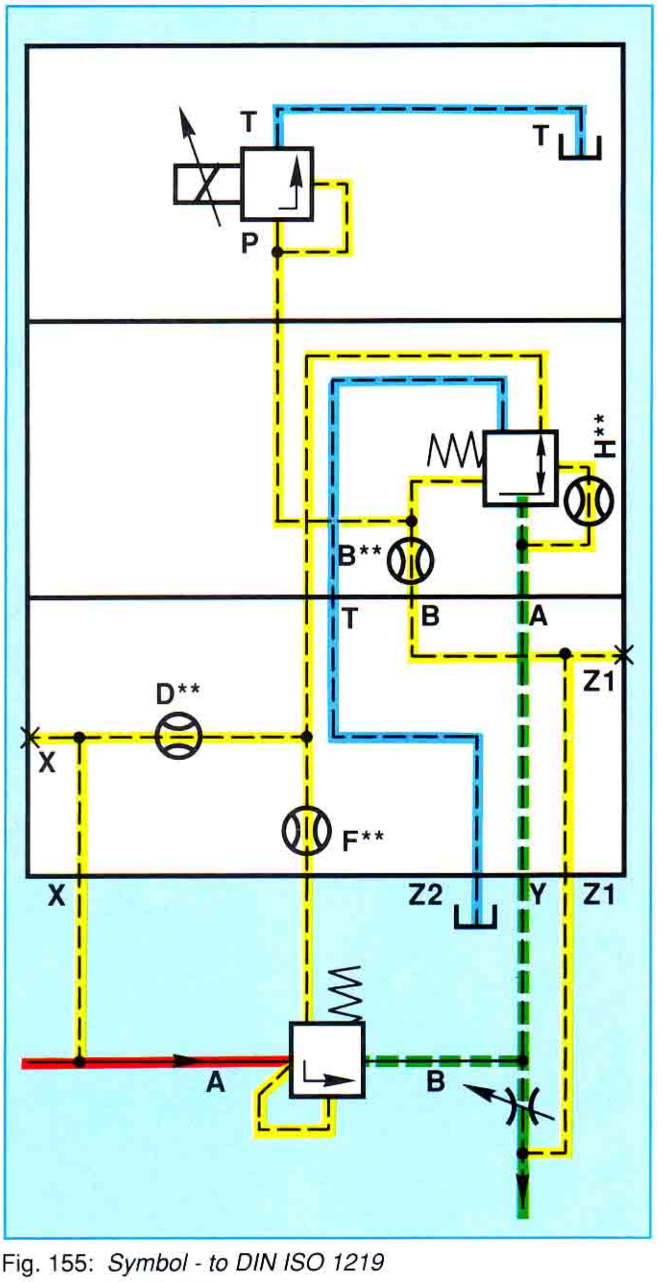


Fig. 155: *Symbol - to DIN ISO 1219*
** = Orifice

6 3 way pressure compensated flow control

To produce a 3 way flow control, a pressure relief logic element is used.

In a 2 way flow control set up, the throttling point and the pressure compensator are installed in series, whereas in a 3 way flow control, the pressure compensator is installed in a branch line.

Pressure upstream of the orifice is felt at port A of the logic element tending to open the valve. Pressure downstream of the orifice (the load pressure) works together with the spring to close the valve. As soon as the pressure drop at the orifice exceeds the sum of these forces, the logic element opens to permit the excess flow to pass from A to B and to tank.

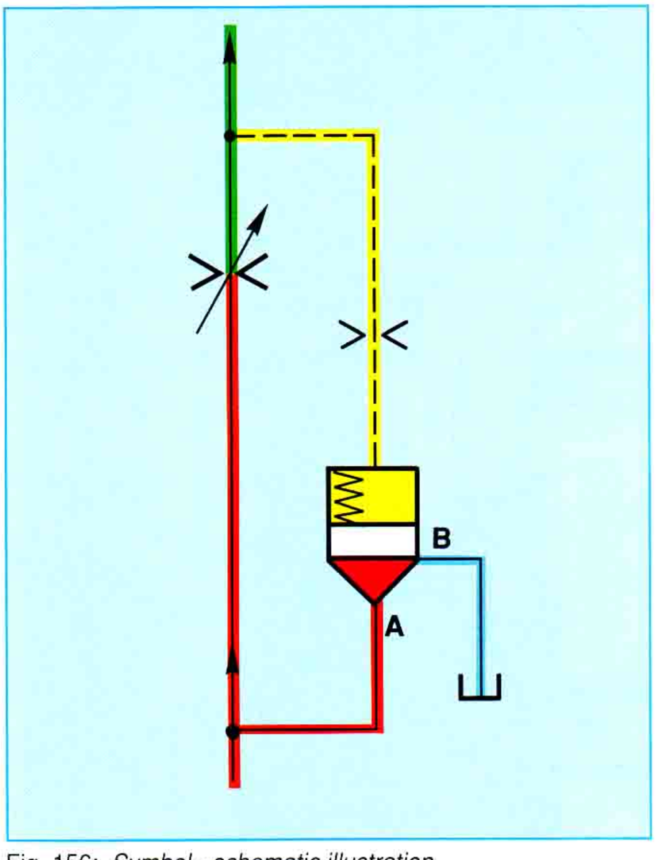


Fig. 156: *Symbol - schematic illustration*

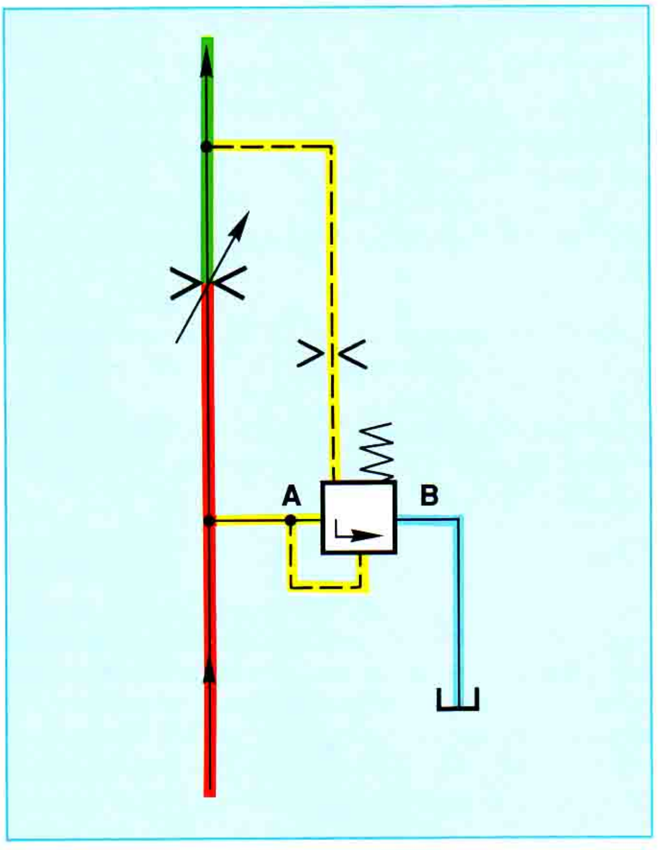


Fig. 157: *Symbol - to DIN/ISO 1219*

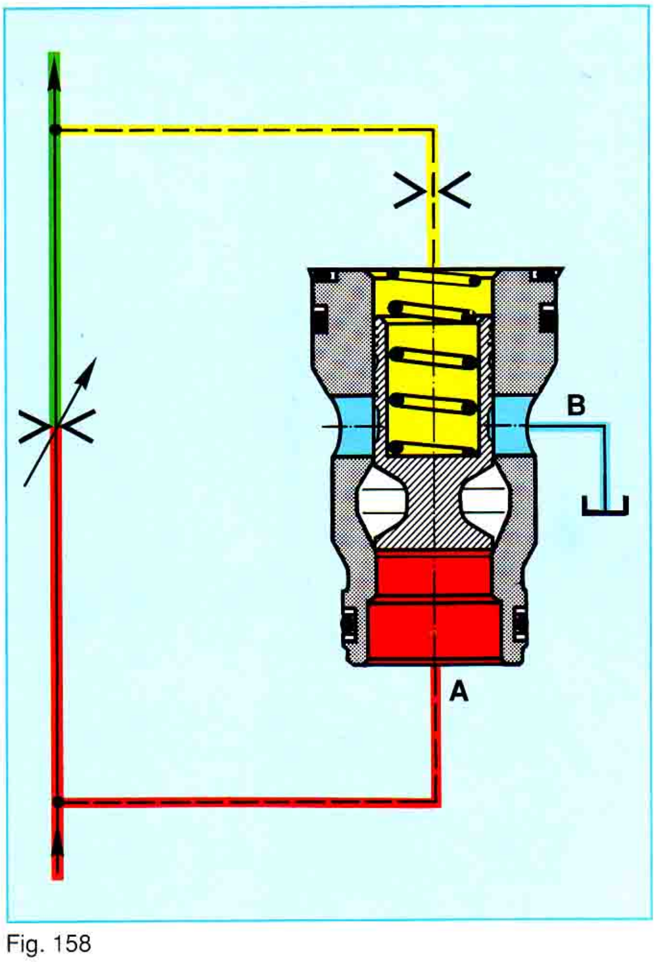


Fig. 158

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.

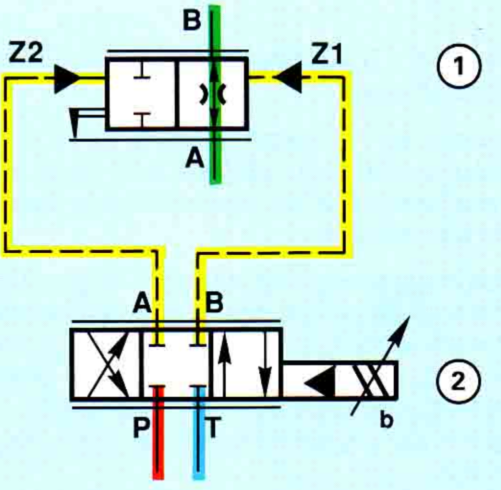
The main valve poppet(2) *(Fig. 161)* has been modified in order to fulfil the duty required of it.

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.



(1) Servo logic cartridge
(2) Pilot valve

Fig. 160: *Symbol - schematic illustration*

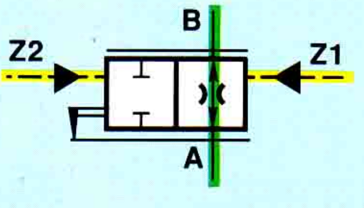
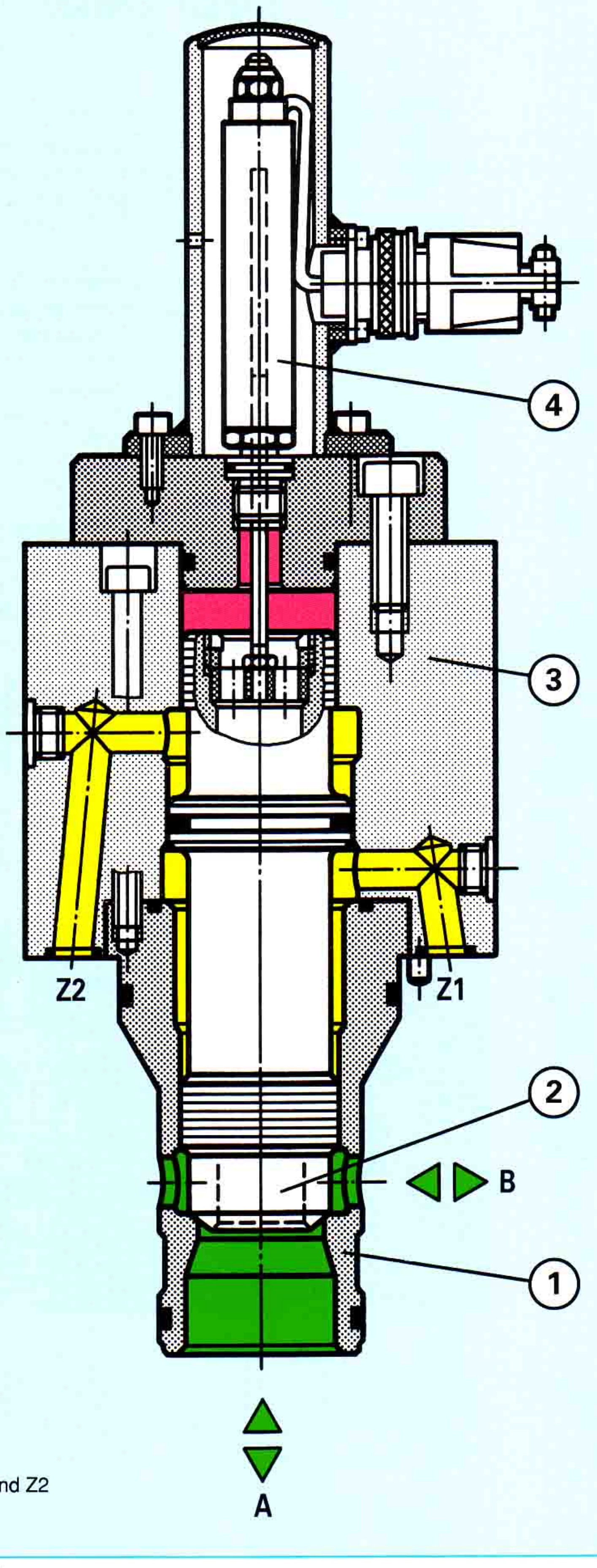


Fig. 159: *Symbol - to DIN/ISO 1219*



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

Bild 161: *Servo logic cartridge*