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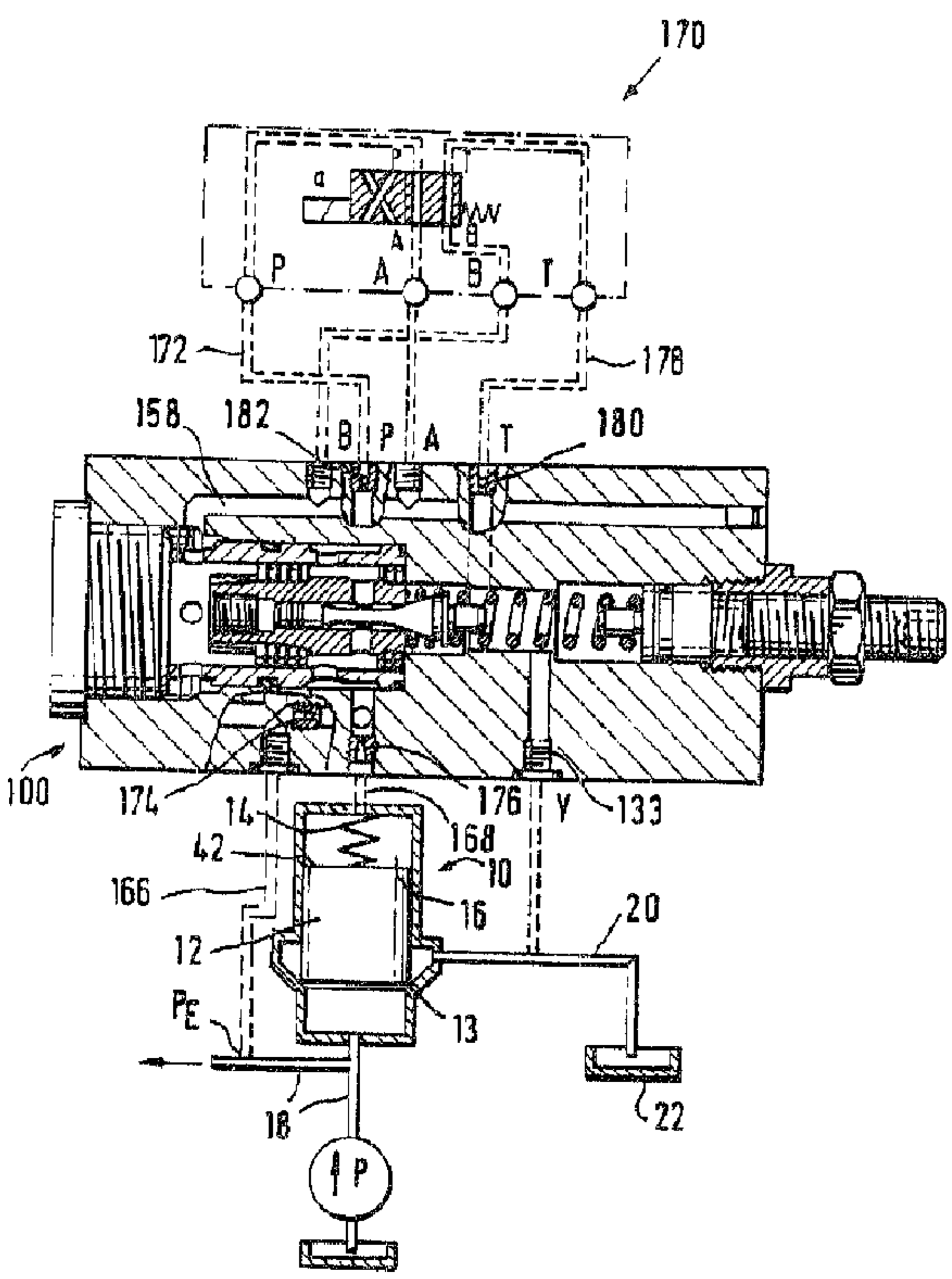

(57) Abrégé/Abstract:
A pilot stage for pressure control valves comprises an axially displaceable valve piston (110) which bounds a valve chamber (141) axially on one side and includes a valve seat (140) for a closure cone (104) therein. Valve piston (110) has an actuating surface in a pressure chamber (164) that is substantially larger than the free cross-section of the valve seat (140). By pressurization of this pressure chamber (164), a large hydrostatic force is exerted on the valve piston (110) which opposes the closing force of the pressure-setting spring (106). A housing stop (130) fixes a first axial end position of the valve piston (110) in the direction of this hydrostatic force. The pilot control stage has improved properties both in manually adjustable pressure control valves and in proportional pressure control valves.

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ABSTRACT

A pilot stage for pressure control valves comprises an axially displaceable valve piston (110) which bounds a valve chamber (141) axially on one side and includes a valve seat (140) for a closure cone (104) therein. Valve piston (110) has an actuating surface in a pressure chamber (164) that is substantially larger than the free cross-section of the valve seat (140). By pressurization of this pressure chamber (164), a large hydrostatic force is exerted on the valve piston (110) which opposes the closing force of the pressure-setting spring (106). A housing stop (130) fixes a first axial end position of the valve piston (110) in the direction of this hydrostatic force. The pilot control stage has improved properties both in manually adjustable pressure control valves and in proportional pressure control valves.

(FIGURE 4)

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Pilot stage for pressure control valves

The invention relates to a pilot stage for pressure control valves.

It relates more particularly to a pilot stage for pressure control valves comprising a valve chamber connected to a first control channel, a closure element axially displaceable in the valve chamber and engaging therein a valve seat and a pressure-setting spring associated with the closure element so as to exert thereon a closing force in the direction of the valve seat.

The function of pressure control valves in hydraulic systems is to limit the system pressure to a specific pre-set pressure level. If this pre-set value is achieved, then the pressure control valve responds and returns the surplus volume flow (i.e. the difference between the pump flow rate and the load flow rate) to the tank. In the case of a relatively large flow rate, the pressure control valves are provided with pilot stages.

Pilot stages, as described hereinbefore, may include manual adjusting means for the pressure-setting spring. If such pilot stages are combined with a controllable directional valve, it is possible to change over from the pressure control function to pressureless circulation. This change-over is effected by hydraulic short-circuiting of the pilot stage by way of the directional valve. Too rapid a response of the main stage to this short-circuiting can, however, be associated with undesirable pressure peaks in the hydraulic system.

Pilot stages, as described above, may also include proportional actuating coils for adjusting the pressure. Because of the limited actuation force of the actuating coil, the free cross-section of the valve seat must be smaller in proportional pilot stages, than in manually adjustable pilot stages. A relatively small valve seat cross-section causes however a undesirable pressure increase in the hydraulic system with an increasing flow rate through the main stage.

Proportional pressure control valves most often include an additional spring-loaded manually adjustable pressure release valve. The object of such an additional pressure release valve is to safeguard the hydraulic system from high control currents at the proportional actuating coil, which would inevitably cause excessive pressures in the hydraulic system. This additional pressure release valve involves however additional costs and requires additional space.

The object of the invention is to provide a pilot stage which has improved properties both in manually adjustable pilot-controlled pressure control valves and in pilot-controlled proportional pressure control valves.

According to the invention this problem is solved by a pilot stage as described in the preamble, which is characterized by the following features:

an axially displaceable valve piston which bounds said valve chamber axially on one side and forms said valve seat therein, said valve seat having a free cross-section,

a connection channel through said valve piston connecting said free cross-section of said valve seat to a second control channel,

a pressure chamber connected to a third control channel, said valve piston having an actuating surface in said pressure chamber that is substantially larger than said free cross-section of said valve seat, wherein by pressurization of said pressure chamber a hydrostatic force is exerted on said valve piston which opposes the closing force of said pressure-setting spring, and

a housing stop for said valve piston fixing a first axial end position of said valve piston in the direction of said hydrostatic force.

In the pilot stage according to the invention the pre-loading of the pressure-setting spring can be continuously varied between a minimum value and a maximum value by adjusting the pressure in said pressure chamber. The maximum pre-loading of the pressure-setting spring is obtained when the valve piston is in its first axial end position against the housing stop. Even when the pressure in the pressure chamber is excessively high, this maximum pressure-setting cannot be exceeded.

In a pilot stage according to the invention, the free cross-section of the valve seat can be the same size as in manually adjustable pilot stages. Indeed, the marked difference in size between the actuating surface of the valve piston in the pressure chamber on one hand and the free cross-section of the valve seat on the other hand results in following advantages:

(a) a low pressure in the pressure chamber produces a significant force for increasing the pre-loading of the pressure-setting spring,

(b) a high control pressure in the connection channel to the valve seat produces a low pressure increase in the pressure chamber for emptying the latter through the third control channel, and results therefore in a highly effective damping of the valve piston.

Consequently, the free cross-section of the valve seat may be sized larger without functional disadvantages both in manually adjustable pilot-controlled pressure control valves and in pilot-controlled proportional pressure control valves.

The closure element is preferably a closure cone rigidly connected to a damping piston, which is guided axially in a guide bore of the valve piston. Thus a perfect axial guidance of the closure cone is guaranteed, and an additional damping of the opening and closing movements of the closure cone is achieved.

In a preferred embodiment of the invention the valve piston has a first and second cross-sectional region which are both axially sealed in a guide bore for the valve piston. These cross-sectional regions delimit within the guide bore an inner annular chamber, into which the connection channel to the valve seat opens. This inner annular chamber is connected to the second control channel.

The pilot stage according to the invention can be an independent valve, e.g. a plate-valve, to be mounted on the housing of the main stage or can be integrated directly into a common housing with the main stage.

The present invention also provides a pilot-controlled, manually adjustable pressure control valve, which can be switched to pressure-relief, e.g. by means of a control signal, without causing pressure peaks in the hydraulic system.

This pilot-controlled, manually adjustable pressure control valve comprises:

a main stage having a first and second main flow port and a control chamber, said first main flow port being connected to a hydraulic system and said second main flow port being connected by way of a relief channel to a tank,

a pilot stage according to the invention as described above, said pilot stage having a manual adjusting means for said pressure-setting spring, said first control channel being connected to said tank and said second control channel being connected to said hydraulic system and to said control chamber of said main stage, and

a directional valve connected to said third control channel, said directional valve having a first and a second position, wherein in said first position said pressure chamber of said pilot valve is pressurizable with the pressure in said hydraulic system through a control pressure channel, and wherein in said second position said pressure chamber of said pilot valve is connected to said tank through a control tank channel.

With this pressure control valve, a slow response of the main stage to the control signal for pressure relief can be guaranteed, so that no disturbing pressure peaks occur as the hydraulic system is relieved of pressure.

Advantageously, a discharge throttle is inserted in the control tank channel in order to further control the time response of the main stage to the control signal for pressure relief. It will be appreciated that with a pilot stage according to the invention, the pressure-relief phase in the hydraulic system can be adjusted, without having to choose a throttle with an unreasonably small free cross-section.

An inlet throttle is advantageously inserted in the control pressure channel. By means of this inlet throttle, the pressure build-up phase in the hydraulic system can be adjusted independently of the pressure relief phase.

The present invention also provides a pilot-controlled proportional pressure control valve, which has an excellent valve behavior and an integrated mechanical safeguard against maximum pressure being exceeded.

This pilot-controlled proportional pressure control valve comprises:

a main stage having a first and second main flow port and a control chamber, said first main flow port being connected to a hydraulic system and said second main flow port being connected by way of a relief channel to a tank,

a pilot stage according to the invention as described above, having a manual adjusting means for said pressure-setting spring, said first control channel being connected to said tank and said second control channel being connected to said hydraulic system and to said control chamber of said main stage, and

a proportional pressure-regulating valve having a (P)-port, (T)-port and (B)-port, said (P)-port being connected to said hydraulic system by means of a control pressure channel, said (T)-port being connected to said tank by means of a control tank channel, and said (B)-port being connected to said third control channel of said pilot stage,

wherein said proportional pressure-regulating valve pressurizes said pressure chamber of said pilot stage to a control input signal.

Because of the relatively large free cross-section of the valve seat in the pilot stage according to the invention, the control pressure established in the connection channel to the valve seat is relatively independent of the flow rate through this pilot stage. It follows that the pressure in the hydraulic system also gets more independent of the flow through the main stage.

If it is desirable to achieve a very accurate pressure adjustment of the pilot-controlled proportional pressure control valve, the pilot stage according to the invention is advantageously equipped with a displacement sensor for sensing the position of the valve piston. This position of the valve piston is adjusted in a closed loop position-control circuit, proportionally to a pre-set value signal. Consequently, the pre-loading of the pressure-setting spring is controlled with very high accuracy.

Further advantages and features of the invention are apparent from the following description referring to the accompanying drawings. This description includes an detailed description of a preferred embodiment of a pilot stage according to the invention, several examples of application of such a pilot stage in pressure control valves and a comparative description of the state of the art.

Figure 1 shows the hydraulic layout of a prior-art pilot-controlled pressure control valve with a manual adjustment means for the opening pressure and a facility to change over to pressureless circulation;

Figure 2 shows the hydraulic layout of a prior-art proportional pressure control valve with an additional safeguard against the maximum pressure being exceeded;

Figure 3 shows a section through an embodiment of the pilot stage according to the invention;

Figure 4 shows an enlarged detail view from Figure 3;

Figure 5 shows the pilot stage according to the invention as shown in Figure 3 and 4 in a pressure control valve with a manual adjustment means for the opening pressure and a facility for relieving pressure and building up pressure respectively in response to a control signal;

Figure 6 shows the pilot stage according to the invention as shown in Figure 3 and 4 in a proportional pressure control valve with an integrated safeguard against maximum pressure being exceeded;

Figure 7 shows the pilot stage according to the invention as shown in Figure 3 and 4 in a proportional pressure control valve with integrated safeguard against maximum pressure being exceeded and a closed loop position-control circuit.

Referring first to Figures 1 and 2, the disadvantages and problems of prior-art pilot-controlled pressure control valves will be briefly explained. In both figures, a pressure control valve 10 is shown. This valve 10 comprises a main piston 12, a main valve seat 13, a main piston spring 14 and a main control chamber 16. The object of the pressure control valve 10 is to protect a hydraulic system 18 against inadmissible high pressures and/or to keep an adjusted pre-set pressure constant. To that end, the hydraulic system 18 is connected through the pressure control valve 10 to a pressureless tank 22 by means of a relief channel 20.

The reference number 24 indicates a pilot valve with manual pressure adjustment. The valve has a valve seat 26 and a closure cone 28. The latter is axially displaceable in a valve chamber 30 and can sealingly engage the valve seat 26. A manually adjustable pressure-setting spring 32 is associated with the closure cone 28 so that it exerts thereon a closing force in the direction of the valve seat 26. The valve chamber 30 is connected to the tank 22 by way of a first control channel 34. A second control channel 36 opens at one end into the valve seat 26. At its other end it is hydraulically connected by way of a third control channel 38 to the main control chamber 16 and by way of a fourth control channel 40 to the hydraulic system 18.

If the system pressure p_E in the hydraulic system 18 is lower than the opening pressure set at the pressure-setting spring 32, then the pilot valve 24 is closed and the main control chamber 16 is pressurized with the system pressure p_E. Since the main piston 12 has in the main control chamber 16 a main control surface or pilot area 42 which corresponds approximately to the free cross-section of its valve seat 13, the main piston 12 is then in hydrostatic equilibrium and is pressed by way of the main piston spring 14 into its valve seat 13 to form a seal. The connection between the hydraulic system 18 and the tank 22 through the relief channel 20 is consequently closed.

If the system pressure p_E in the hydraulic system 18 exceeds the opening pressure set at the pressure-setting spring 32, the closure cone 28 opens against the pressure-setting spring 32 and enables pilot oil to be discharged through the valve chamber 30 and the first control channel 34 to the tank 22. Admission of pilot oil through the fourth control channel 40 from the hydraulic system 18 is limited by a first throttle 44. A relatively constant control pressure is established in the second control channel 36 and the main control chamber 16. If the system pressure p_E continues to rise, then ultimately the main piston 12 opens and the hydraulic system 18 is connected through the relief channel 20 to the tank 22, as a result of which the system pressure is limited.

In Figure 1 the hydraulic system 18 can be depressurized according to demand by a control signal to an electromagnetically operated directional valve 46 (e.g. a 2/2-way valve with spring return). This directional valve 46 is connected hydraulically in parallel with the pilot valve 24. When the directional valve 46 is opened electromagnetically, the main control chamber 16 is relieved to tank 22. In other words, by by-passing the pilot valve 24, the pressure adjustment function thereof becomes ineffective. The main control piston 12 opens, because its main control surface 42 is now relieved of pressure, and the flow in the hydraulic system 18 is deviated to the relief channel 20. The system pressure that establishes in the hydraulic system 18 is dependent on the counter-force of the main piston spring 14 and the throttles 44, 48, 50 arranged in the pilot system.

The prior art depressurization of the hydraulic system 18 of Figure 1 provides an unsatisfactory result. The main piston 12 responds too abruptly to the short-circuiting of the pilot valve 24 and opens within a few milliseconds, so that a relief shock occurs, corresponding to a rapid flow rate increase in relief channel 20. In addition to causing noise, such relief shocks can lead to disturbances in the system, such as damage to filters, coolers, seals and fixing elements, for example, or to undesirable vibrations in the machines connected to the system. Even throttle 48 inserted in the outlet of the main control chamber 16, and throttle 50 inserted in the tank channel of the pilot valve 24, provide in many cases only an inadequate slowing down of the opening movement of the main piston 12. In fact, the throttles 48, 50 must have a minimum free cross-section so that dirt particles are prevented from blocking them.

The prior art valve 10 in Figure 2 is used as a pilot-controlled proportional pressure control valve having an independent mechanical pressure relief. The reference number 52 indicates a pilot valve which, like the pilot valve 24, comprises a valve seat 54 and a closure cone 56. This closure cone 56 is axially displaceable in a valve chamber 58 and sealingly engages in the valve seat 54. In replacement of the manually adjustable pressure-setting spring 32 in the pilot valve 24, the pilot valve 52 has an electrically controllable proportional actuating coil 60 generating the closing force of the closure cone 56 in proportion to an electric control current 62. Since the closure force acting on the closure cone 56 determines the opening pressure of the pilot valve 52 and consequently the pressure in the main control chamber 16 of the pressure control valve 10, the pressure p_E in the hydraulic system 18 is continuously variable proportionally to the electrical control current 62. In an alternative embodiment, the proportional actuating coil 60 acts on a pressure spring (not shown) which exerts on the closure cone 56 a closing force in the direction of the valve seat 54 and controls the bias thereof, and thus the pressure p_E in the hydraulic system 18, continuously. Both embodiments have the disadvantage that the free cross-section of the valve seat 54 has to be designed relatively small, because of the limited actuating force of the proportional actuating coil 60 (generally about 60N to 100N). The free cross-section of the valve seat 54 is normally about seven to ten times smaller than the free cross-section of the valve seat 26 in the manually adjustable pilot valve 24. This considerably reduced flow cross-section of the valve seat 54 leads to parasitic pressure losses in the pilot valve 52. It follows that the pressure in the main control chamber 16 is far more dependent on fluctuations in the flow in control channel 40. Fluctuations in the flow in the control channel 40 can be explained, for example, in that a flow increase through pressure control valve 10 results in higher flow forces acting on the main piston 12 in the closing direction. The pressure p_E in the hydraulic system increases, which in turn causes an increased flow rate in control channel 40. The outcome is a rise of the system pressure p_E with an increasing flow rate Q through the pressure control valve 10. The larger the pressure loss in pilot control valve 52, the steeper the rise in the characteristic curve (Q; p_E) of the pilot-controlled pressure control valve 10. It is therefore regrettable that pilot stages actuated by proportional actuating coils generally have a smaller free cross-section of their valve seat than manually adjustable pilot valves.

In Figure 2 a manually adjustable pilot valve 24' is arranged in parallel with the pilot valve 52. the object of pilot valve 24' is to protect the hydraulic system 18 against pressures that are too high. Such high pressures which may for example be caused by a defective control of proportional actuating coil 60 (e.g. excessive control current 62). With its valve seat 26', its closure cone 28', its valve chamber 30' and its pressure-setting spring 32', this pilot valve 24' corresponds in function and construction with the pilot valve 24 of Figure 1. Incorporating such a second valve 24' into the pilot part of the pressure control valve 10 entails additional expense and requires additional space.

A preferred embodiment of a pilot valve according to the invention is described with reference to Figures 3 and 4. The valve 100 comprises the following main elements: a valve housing 102, a closure element, such as a closure cone 104, a pressure-setting spring 106, an adjusting means 108 for the pressure-setting spring 106, a valve piston 110, and a valve sleeve 112 for the valve piston 110.

The valve sleeve 112 is inserted in a sealed manner in a first stepped bore 116 of the valve housing 102. A closure stopper 114 seals this first stepped bore 116 axially and at the same time fixes the valve sleeve 112 therein. A second stepped bore 118 extends the stepped bore 116 axially through the valve housing 102 and has smaller cross-sections than the first stepped bore 116. This second stepped bore 118 is sealed axially by the adjusting means 108, for example, a conventional manually operated adjusting mechanism with a screw spindle. The pressure-setting spring 106 bears at a first end against a spring plate 120 of adjusting means 108 and at its second end against a shoulder surface 122 of closure cone 104, and accordingly exerts on the closure cone 104 a resilient force in the direction of the first stepped bore 116. This force is manually adjustable through adjusting means 108.

The inner left-hand part of the pilot valve 100, including in particular the valve sleeve 112, the valve piston 110 and the closure cone 104, is described in detail with reference to Figure 4. The valve piston 110 is axially displaceable within a guide bore 124 of the valve sleeve 112, namely, between a first axial end position, in which it lies with its first end surface 126 against an annular shoulder surface 130 in the valve housing 102, and a second axial end position, in which it lies with its second end surface 128 against the closure stopper 114. A valve chamber 132 in axial continuation of the guide bore 124 has a smaller cross-section than the latter, thus forming shoulder surface 130. In Figure 4, the valve piston is located in its first axial end position. A first control channel 133 opens into the valve chamber 132.

The closure cone 104 is advantageously rigidly connected to a damping piston 134. This piston 134 is advantageously guided axially by means of a guide extension 136 at its free end in a guide bore 138 in the valve piston 110. This damping piston 134 has to displace the hydraulic fluid, for example by way of a flattened surface (not shown) on the guide extension 136, so that a damping force opposing the respective direction of movement of the closure cone 104 is created. The first end of the guide bore 138 (or rather its axial continuation) opens axially at one end into the second end surface 126 of the valve piston 110 and forms therein the free cross-section of a valve seat 140 in which the closure cone 104 engages positively. A spherical or plate-shaped valve seat with a suitably adapted valve seat could, of course, also be provided in replacement of closure cone 104. An opening spring 141 is advantageously provided between closure cone 104 and the second end surface 126 of the valve piston 110.

At its opposite end, the guide bore 138 is sealed axially. A connection channel 142 of annular cross-section leading to the valve seat 140 is defined between the damping piston 134 and the guide bore 138, since the damping piston 134 has, between its guide extension 136 and the closure cone 104, a substantially smaller cross-section than the guide bore 138. A transverse bore 144 in the valve piston 110 connects the connection channel 142 with an inner annular chamber 146. The latter is bounded axially in a sealed manner within the guide bore 124 between a first and second cross-sectional region 148 and 150 of the valve piston 110. Through corresponding connecting openings 152 in the valve sleeve 112, the inner annular chamber 146 is connected through an outer annular chamber 154, which is arranged between the valve sleeve 112 and the first stepped bore 116, with a second control channel 156.

A third control channel 158 is connected by way of a further outer annular chamber 160 and a further connecting opening 162 in the valve sleeve 112 to a pressure chamber 164. This pressure chamber 164 is bounded within the guide bore 124 of the valve sleeve 112 on the one hand by the closure stopper 114 and on the other hand by the second end surface 128 of the valve piston 110. The valve piston thus has in this pressure chamber 164 a pressure-actuating surface, the area of which corresponds to the cross-section of the guide bore 124. This area is more than ten times larger than the free cross-section of the valve seat 140.

The above-described construction could, of course, be structurally altered without departing from the basic concept of the invention. Thus, for example, the damping piston 134 could be omitted and be replaced by a guidance of the closure cone 104 outside the valve piston 110. The valve sleeve 112 could also be omitted. Alternative solutions relating to the construction of the two end stops for the valve piston 110 are also obvious to the expert.

The mode of operation and essential advantages of the pilot valve 100 shown in Figures 3 and 4 are described with reference to Figures 5, 6 and 7, showing three different valve embodiments.

In the valve embodiments of Figures 5, 6 and 7, the pilot valve 100 according to the invention is used in each case with a pressure control valve 10 as the main stage. For the purpose of describing the main stage, reference is made to Figures 1 and 2. Identical elements have been provided with the same reference numbers. Note that the reference numbers that relate to parts of the pilot valve 100 are shown in Figures 3 and 4. To avoid congestion in the Figures, these reference numbers have not been incorporated in Figures 5, 6 and 7. Figures 3 and 4 should accordingly also be consulted for better understanding of the following description.

In Figure 5, the pilot valve 100 forms with the main stage valve 10 a pilot-controlled pressure control valve in which the opening pressure is adjusted manually. By way of the adjusting means 108, the closing force acting on the closure cone 104 is accordingly set by pre-loading the pressure-setting spring 106. The first control channel 133 of the pilot valve 100 is connected to the tank 22. The second control channel 156 of the pilot valve 100 is connected through a pilot oil pressure port 166 to the hydraulic system 18, so that the closure cone 104 is pressurized in its valve seat 140 with the system pressure p_E. By way of a main control chamber port 168, the second control channel 156 is likewise connected to the main control chamber 16. Provided that the system pressure p_E is lower than the opening pressure set at the adjusting means 108, the main control chamber 16 is pressurized through the pilot oil pressure port 166 and the main control chamber port 168 with the system pressure p_E. If the areas of the main control surface 42 and the cross-section of the main valve seat 13 are equal, the main piston 12 is in hydrostatic equilibrium and is pressed by the piston spring 14 onto the main valve seat 13 to form a seal.

The reference number 170 indicates a 4/2-way valve (represented by its graphic symbol according to ISO 1219), which is actuated electromagnetically and has four ports (A), (B), (P) and (T), two control positions and a basic position defined by spring force. In one of the two control positions of the directional valve 170, the pressure chamber 164 of the pilot valve 100 is connected through the directional valve 170 and a control pressure channel 172 through the valve housing 102 to the pilot oil pressure port 166 (only part of the control pressure channel 172 is illustrated in the valve housing 102). The valve piston 110 of the pilot valve 100 is accordingly pressed with great force against the shoulder surface 130.

If the system pressure p_E in the hydraulic system 18 exceeds the set opening pressure, the closure cone 104 lifts away from the valve seat 140. A flow of pilot oil limited by an inlet throttle 174 in the pilot oil pressure port 166 flows through the valve seat 140 and the first control channel 133 to the tank 22. In the connection channel 142 to the valve seat 140 the control pressure is accordingly largely constant. This control pressure p_C acts through the main control chamber connection 168 on the main control surface 42 of the main control piston 12. If the system pressure continues to rise, then the hydrostatic force acting on the main piston in the opening direction ultimately becomes greater than the spring force of the main piston spring 14 acting in the closing direction. The main piston 12 then lifts away from its valve seat 13 and the flow is deviated through the relief channel 20 to the tank 22. Pressure control has thus taken effect. A damping throttle 176 in the main control chamber connection 168 damps the movements of the main piston 12. The pressure difference between the system pressure and the control pressure determined by the main piston spring 14, determines in combination with the flow cross-section of the inlet throttle 174, the flow of pilot oil through the pilot valve 100. The inlet throttle 174 and the damping throttle 176 should, of course be matched to one another in an optimum manner so as to obtain a stable operational behavior without pressure fluctuations, and a characteristic curve $(Q;P_E)$ with little rise in the system pressure P_E as the flow through the main valve 10 increases.

So far, the mode of operation of the pilot valve 100 is not markedly different from the pilot valve 24 of Figure 1. Major differences are found, however, in the electrically operated pressure relief of the hydraulic system 18 through the pressure control valve 10 and the relief channel 20 to the tank 22.

The 4/2-way valve 170 is connected by way of its two working ports (A) and (B) to the third control channel 158. If depressurization is to be effected when the directional valve 170 is without current, the connection with the working port (A) is closed by a stopper, as shown in Figure 5. If, however, depressurization is to be effected with the directional valve 170 actuated, the connection with the working port (B) is closed by a stopper (not shown). In both cases, when switching to depressurization of the hydraulic system 18, the pressure chamber 164 of the pilot valve 100 is depressurized by the directional valve 170 through a control tank channel 178 to the tank 22. The tank channel 178 may, for example, as shown in Figure 5, open into the valve chamber 132 of the pilot valve 100, which is connected through the first control channel 133 to the tank 22. In place of a 4/2-way valve, a 3/2-way valve could, of course, be used.

A force F acts on the valve piston 110 in the direction of the closure stopper 114. The modulus of this force is $F = p_C x A_S$, where P_C is the opening pressure pre-set by the pressure-setting spring 106 (or rather the control pressure that becomes established) and A_S is the free cross-section of the valve seat 140. This force is available, on switching to depressurization, to displace the valve piston 110 in the direction of the closure stopper 114. The pilot oil from the pressure chamber 164 is pressed through the third control channel 158, the directional valve 170 and the control tank channel 178 into the tank 22. The movement of the valve piston 110 is here very slow, since the available force F causes in the pressure chamber 164 a pressure which is smaller by the factor $k=A_S/A_D$ $(k<1)$ than the pressure p_C, where A_D is the cross-sectional area of the guide bore 124 in the valve sleeve 112. The speed of movement of the valve piston 110 can be made yet slower by a discharge throttle 180 installed in the control tank channel 178.

The pressure-setting spring 106 relaxes proportionally to the distance that the valve piston 110 covers in the direction of the closure stopper 114. The set opening pressure, and thus the control pressure in the main control chamber 16 of the pressure control valve 10, therefore decreases. The latter opens to the relief channel 20, but always remains under the control of the pilot valve 100.

The opening spring 141 in the pilot valve 100 guarantees that the closure cone 104 lifts away from the valve seat 140 properly and enables the discharge of pilot oil in the tank 22 for complete reduction of the control pressure in the control chamber 16. In this manner, proper lifting of the closure cone 104 from the valve seat 140 is guaranteed even with high flow forces, which act in known manner in the closing direction on the closure cone 104.

The progress of depressurization can be intentionally influenced by the pilot control valve 100 according to the invention, that is to say, can be slowed down. In the embodiment shown in Figure 5, the reduction factor k is, in fact, about equal to 1:15. That means that the pressure available in the pressure chamber 164 is fifteen times smaller than the control pressure p_C. It is therefore possible to adjust, with throttle diameters larger than 0.6 to 1 mm, such slow depressurization times that no depressurization shock occurs. Depressurization is achieved by time-controlled relaxation of the pressure-setting spring 106, that is to say, by time-controlled reduction of the pre-set desired pressure value, without having to intervene in the pressure-regulating function of the main piston 12 of the main stage.

With the prior art valves of Figure 1, this is not the case. During depressurization of the main control chamber 16, which is under high pressure, the pilot valve 24 is short-circuited by way of the directional valve 46, as described. Due to the high pressure difference at the throttle 50 in the control tank channel, the opening movement of the main piston 12 can be slowed only to a very limited extent.

With pilot valve 100 it is also possible to influence the pressure build-up phase by means of an inlet throttle 182 incorporated in the pressure channel 173. The free cross-section of the throttle 182 determines the rate of movement of the valve piston 110 in the direction of its first axial end position and thus the pressure build-up time. Depressurization and pressure build-up phase can therefore be influenced independently of one another, by way of the discharge throttle 180 and the inlet throttle 182 respectively.

In the arrangement shown in Figure 6, the 4/2-way valve 170 of Figure 5 is replaced by a proportional pressure-regulating valve 184 having three ports (B), (P) and (T), a proportional actuating coil. A basic position of the valve is defined by spring force. The (B)-port is connected to the third control channel 158; the (P)-port is connected to the control pressure channel 172; and the (T)-port is connected to the control tank channel 178. The pressure in the (B)-port is controlled proportionally to a control current in a low-pressure range (i.e. 0 to 12 bars). The pressure chamber 164 in the pilot valve 100 is pressurized with this proportionally controlled low pressure. An area ratio of about 15:1 between the guide bore 124 and the free cross-section of valve seat 140, guarantees that the pre-controlled low pressure in the pressure chamber 164 is sufficient to pre-load the pressure-setting spring 106 by displacement of the valve piston 110. Accordingly, a control pressure is controlled by the pressure-setting spring 106 proportionally to control current 162, and the system pressure p_E in the hydraulic system 18 is controlled proportionally to this control pressure as described above.

The maximum system pressure can be set manually at adjusting means 108. This setting is independent of the control electronics of the pressure-regulating valve 184. When an error in these control electronics occurs, the control pressure cannot exceed the maximum pressure set manually at the adjusting means 108. Indeed, the valve piston 110 can advance only as far as the end stop against the shoulder surface 122, even with excessive actuating pressure in pressure chamber 164. An additional, manually adjustable, pilot valve, as in the diagram of Figure 2, is therefore superfluous, since this function is already a basic function of the pilot valve 100 according to the invention.

Using the pilot valve 100 according to the invention it is possible to achieve an improved valve characteristic (Q, p_E) with a substantially flatter rise of the system pressure p_E as the valve flow-through Q increases, in comparison with the prior art valve arrangement shown in Figure 2. This advantage can be attributed to the approximately 10-times larger free cross-section of the valve seat 140 of the pilot valve 100 compared with prior art pilot valves having proportional actuating coils.

Figure 7 shows a further application of the pilot valve 100 in a pilot-controlled proportional pressure control valve. The closure stopper 114 of the pilot valve 100 is replaced by a displacement sensor 188 which detects the exact position of the valve piston 110 and generates an output signal proportionally to this position. The displacement sensor can be, for example, a pressure-tight inductive displacement sensor, which is mechanically connected by way of a screw stopper 190 to the valve piston 110.

A proportional displacement valve 192 with a proportional actuating coil is connected by an (A)-port to the second control channel 156, by a (T)-port to the control tank channel 178 and by a (P)-port to the control channel 172 of the pilot valve 100. The position of valve piston 110 is then controlled in a closed loop position-controlling circuit. For that purpose, the output signal of displacement sensor 188 is compared with a desired value, and the proportional pressure-regulating valve 192 is correspondingly adjusted. The pre-loading of the pressure-setting spring 106 is consequently continuously variable with high precision in accordance with the pre-set desired value and, as described above, regulates the corresponding system pressure p_E in the hydraulic system 18. The pilot valve 100 is a simple means to build an electrically controlled proportional pressure-control valve of high adjustment accuracy.

CLAIMS

1. A pilot stage for a pressure control valve comprising:

a housing having therein a valve piston guide bore, a valve chamber, a pressure chamber, and first, second, and third control channels, said valve piston guide bore having a piston stop, said valve chamber being fluidically coupled to said first control channel, and said pressure chamber being fluidically coupled to said third control channel;

a valve piston slidably mounted in said valve piston guide bore for axial movement therein through a range of motion bounded at one end by a first axial end position in which said valve piston is engaged with said piston stop, said valve piston axially bounding said valve chamber at one end thereof, and said valve piston having:

a valve seat formed therein having a free cross section;

a connection channel therethrough fluidically coupling said second control channel with said valve seat; and

an actuating surface disposed in said pressure chamber and having a cross-sectional area substantially larger than said free cross section of said valve seat;

a closure element disposed in said valve chamber for axial displacement therein and being operably engageable with said valve seat;

a pressure-setting spring coupled to said closure element to bias said closure element with a closing force into engagement with said valve seat and thereby urging said valve piston away from said first axial position;

whereby pressurization of said pressure chamber produces a hydrostatic force on said valve piston opposing said closing force of said pressure-setting spring and urging said piston toward said first axial end position.

2. The pilot stage of claim 1, wherein:

said valve piston includes a damping piston guide bore therein; and said closure element includes:

a damping piston disposed in said damping piston guide bore for axial movement therein; and

a closure cone fixed to said damping piston.

3. The pilot stage of claim 1:

wherein said valve piston further includes first and second axially-spaced cross sectional regions sealingly fitted in said valve piston guide bore and defining therebetween in said valve piston guide bore an inner annular chamber, said connection channel being fluidically coupled with said inner annular chamber; and

further comprising means for connecting said inner annular chamber to said second control channel.

4. The pilot stage of claim 3, further comprising:

a valve sleeve fitted in said housing and having said guide bore formed therein;

an outer annular chamber surrounding said valve sleeve and being fluidically coupled to said second control channel; and a connecting opening through said valve sleeve fluidically coupling said inner annular chamber to said outer annular chamber.

5. A pilot controlled, manually adjustable pressure control valve for selectively relieving a pressurized hydraulic system to an unpressurized tank, the tank having a relief channel coupled thereto, said control valve comprising:

a main stage having:

a control chamber;

a first main flow port fluidically coupled to the hydraulic system; and

a second main flow port fluidically coupled to the relief channel;

a pilot valve having:

a housing having therein a valve piston guide bore, a valve chamber, a pressure chamber, and first, second, and third control channels, said valve piston guide bore having a piston stop, said valve chamber being fluidically coupled to said first control channel, and said pressure chamber being fluidically coupled to said third control channel, said first control channel being fluidically coupled to the tank and said second control channel being fluidically coupled to the hydraulic system and to said main stage control chamber;

a valve piston slidably mounted in said valve piston guide bore for axial movement therein through a range of motion bounded at one end by a first axial end position in which said valve piston is engaged with said piston stop, said valve piston axially bounding said valve chamber at one end thereof, said valve piston having:

a valve seat formed therein with a free cross section;

a connection channel therethrough fluidically coupling said second control channel with said valve seat; and

an actuating surface disposed in said pressure chamber and having a cross-sectional area substantially larger than said free cross section of said valve seat;

a closure element disposed in said valve chamber for axial displacement therein and being operably engageable with said valve seat;

a pressure-setting spring coupled to said closure element to bias said closure element with a closing force into engagement with said valve seat and thereby urging said valve piston away from said first axial position; and

means for manually adjusting said pressure-setting spring;

whereby pressurization of said pressure chamber produces a hydrostatic force on said valve piston opposing said closing force of said pressure-setting spring and urging said piston toward said first axial end position; and a directional valve fluidically coupled via said third control channel with said pressure chamber, said directional valve having first and second operative positions and including:

a control pressure channel fluidically coupling said pilot valve pressure chamber to the hydraulic system in said first position; and

a control tank channel fluidically coupling said pressure chamber to the tank in said second position.

6. The valve of claim 5, further comprising a discharge throttle disposed in said control tank channel.

7. The valve of claim 5, further comprising an inlet throttle disposed in said control pressure channel.

8. A pilot-controlled proportional pressure control valve for selectively relieving a pressurized hydraulic system to an unpressurized tank, the tank having a relief channel coupled thereto, said control valve comprising:

a main stage having:

a control chamber;

a first main flow port fluidically coupled to the hydraulic system; and

a second main flow port fluidically coupled to the relief channel;

a pilot valve having:

a housing having therein a valve piston guide bore, a valve chamber, a pressure chamber, and first, second, and third control channels, said valve piston guide bore having a piston stop, said valve chamber being fluidically coupled to said first control channel, and said pressure chamber being fluidically coupled to said third control channel, said first control channel being fluidically coupled to the tank and said second control channel being fluidically coupled to the hydraulic system and to said main stage control chamber;

a valve piston slidably mounted in said guide bore for axial movement therein through a range of motion bounded at one end by a first axial end position in which said valve piston is engaged with said piston stop, said valve piston axially bounding said valve chamber at one end thereof, said valve piston

having:

a valve seat formed therein with a free cross section;

a connection channel therethrough fluidically coupling said second control channel with said valve seat; and

an actuating surface disposed in said pressure chamber and having a cross-sectional area substantially larger than said free cross section of said valve seat;

a closure element disposed in said valve chamber for axial displacement therein and being operably engageable with said valve seat;

a pressure-setting spring coupled to said closure element to bias said closure element with a closing force into engagement with said valve seat and thereby urging said valve piston away from said first axial position; and whereby pressurization of said pressure chamber produces a hydrostatic force on said valve piston opposing said closing force of said pressure-setting spring and urging said piston toward said first axial end position; and

a proportional pressure-regulating valve responsive to a control input signal, comprising:

a P-port and a T-port;

a control pressure channel connecting said P-port to the hydraulic system;

a control tank channel connecting said T-port to the tank; a B-port connected to said third control channel of said pilot stage;

said proportional pressure-regulating valve pressurizing said pressure chamber of said pilot valve through said third control channel proportionally to the control input signal.

9. The valve of claim 8, further comprising:

a displacement sensor disposed to sense the position of said valve piston, and

means for controlling the position of said valve piston proportionally to a pre-set desired value signal, thereby controlling the pre-loading of said pressure-setting spring in a closed-loop.

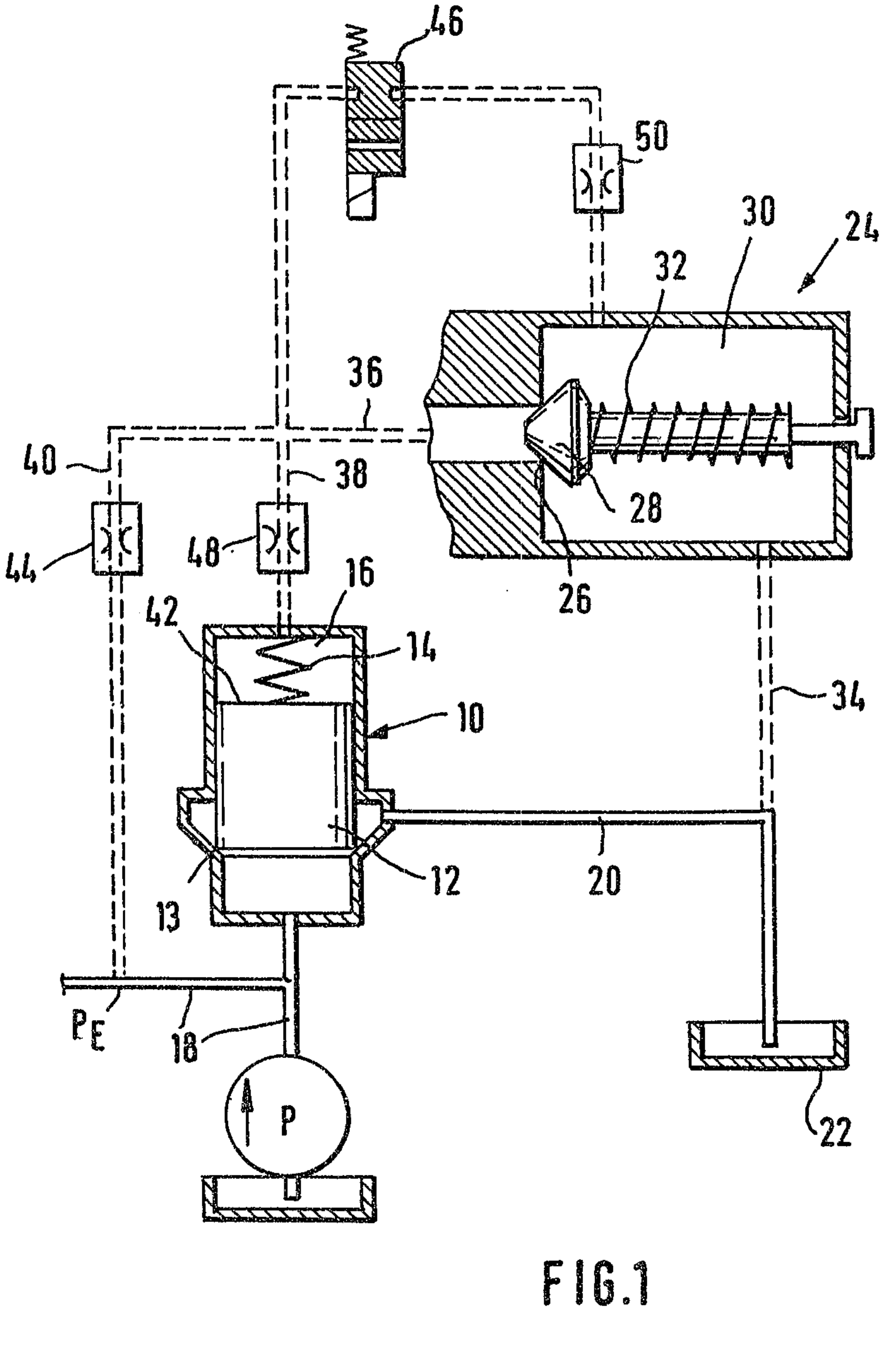
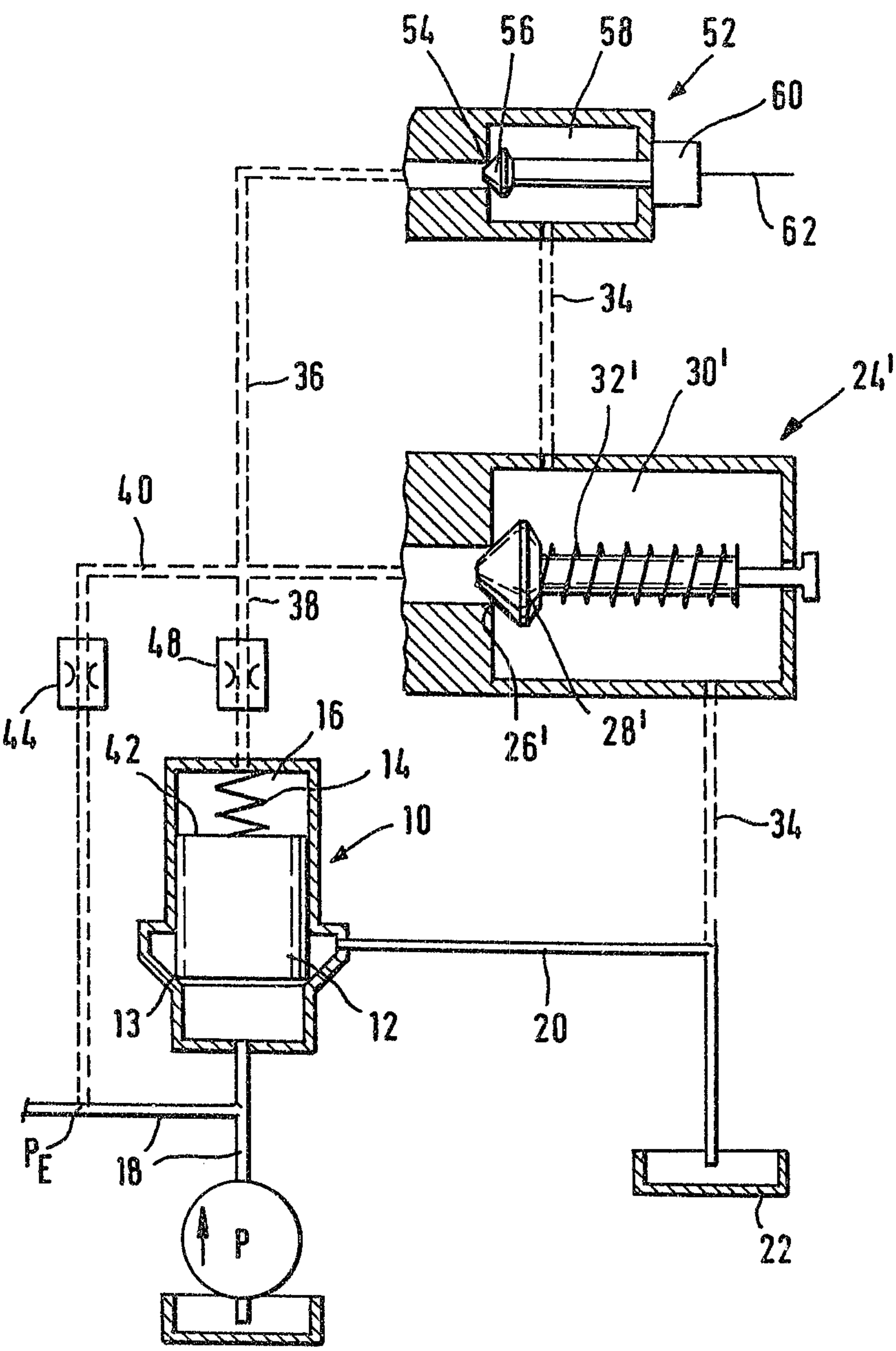


FIG.1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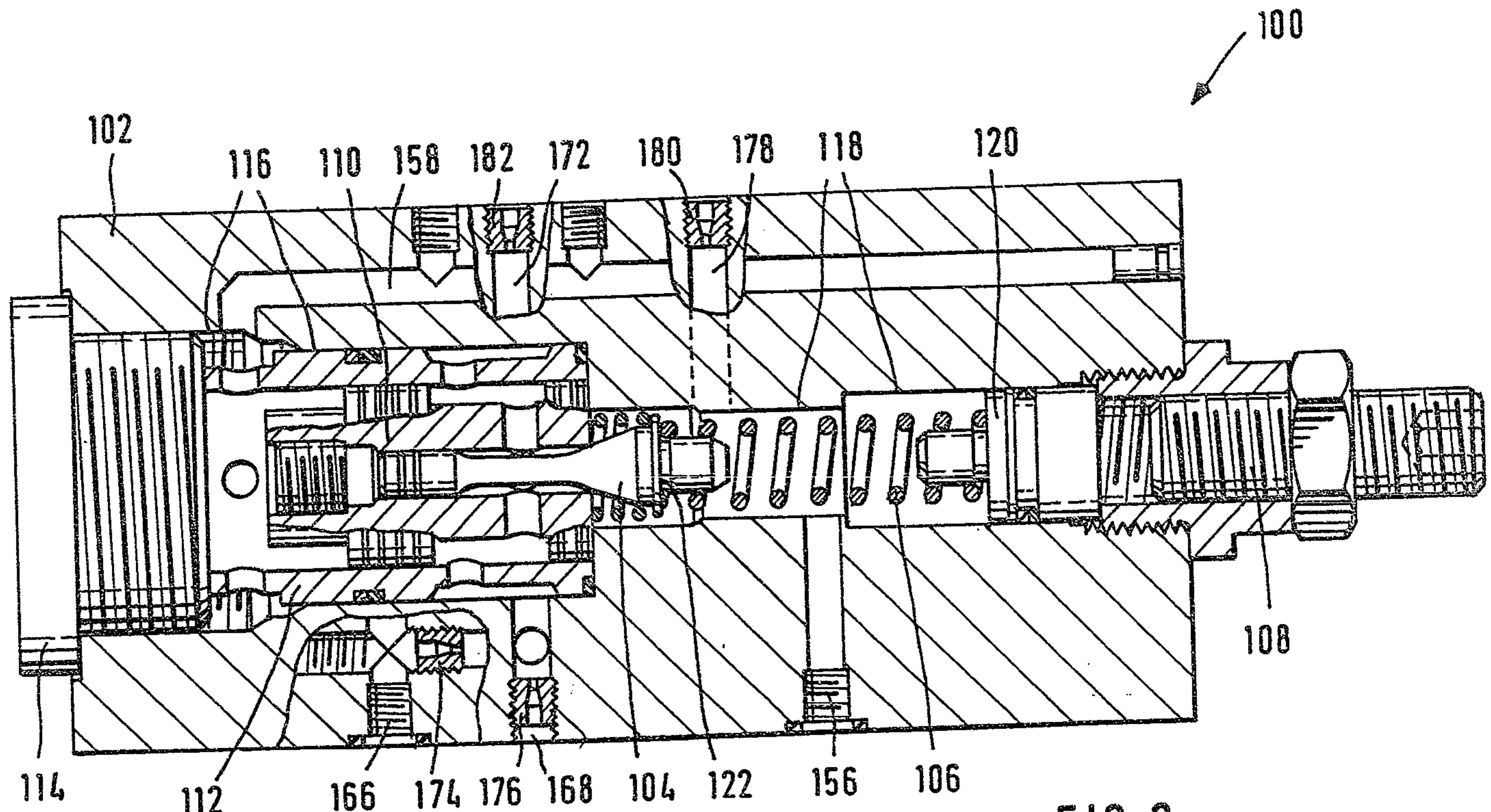
60
62
34
36
32'
30'
24'
40
38
48
44
16
42
14
10
34
13
12
20
P_E
18
P
22

FIG. 2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102
116
110
158
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172
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122
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106

FIG. 3

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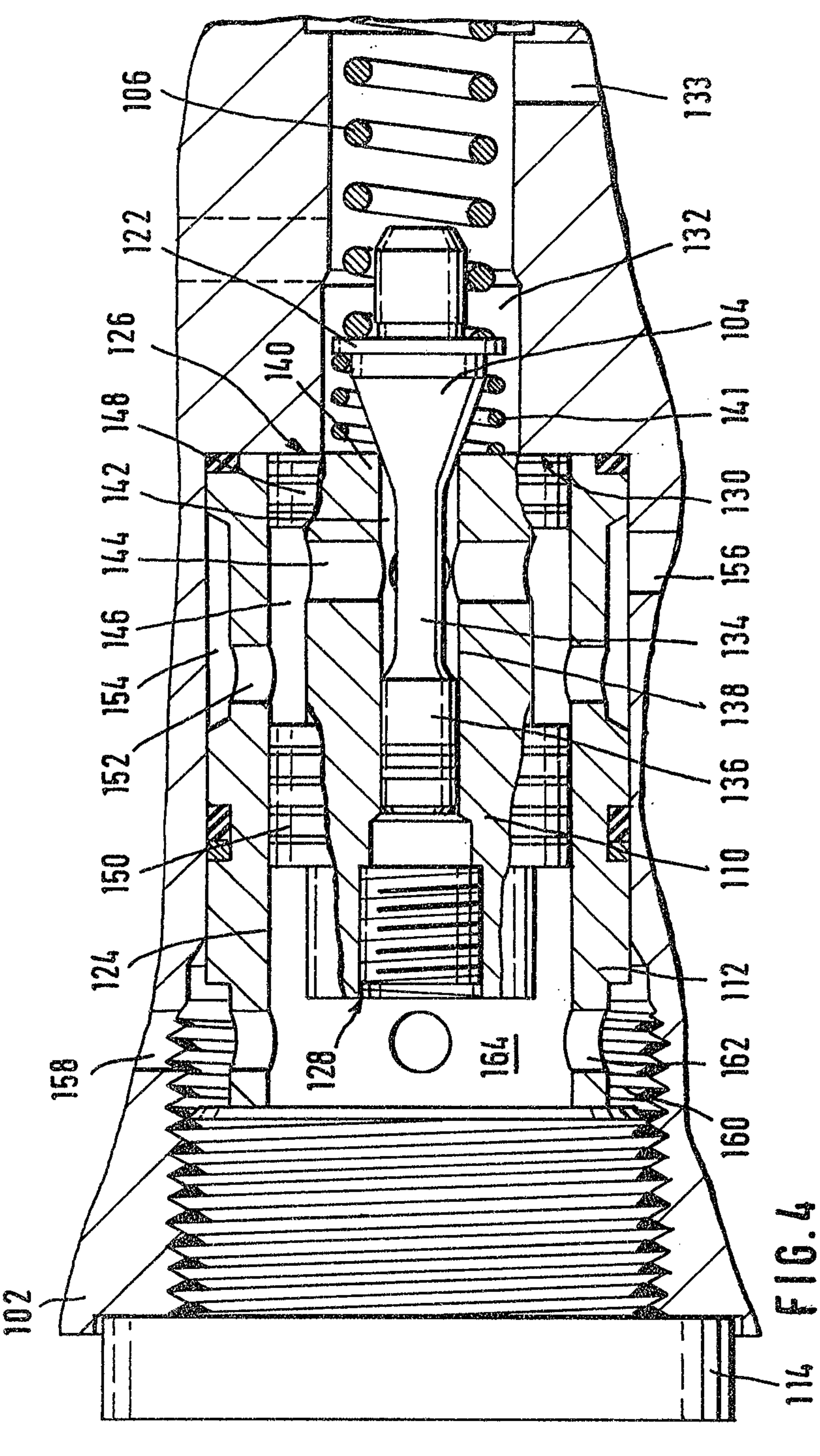


FIG. 4

2138053

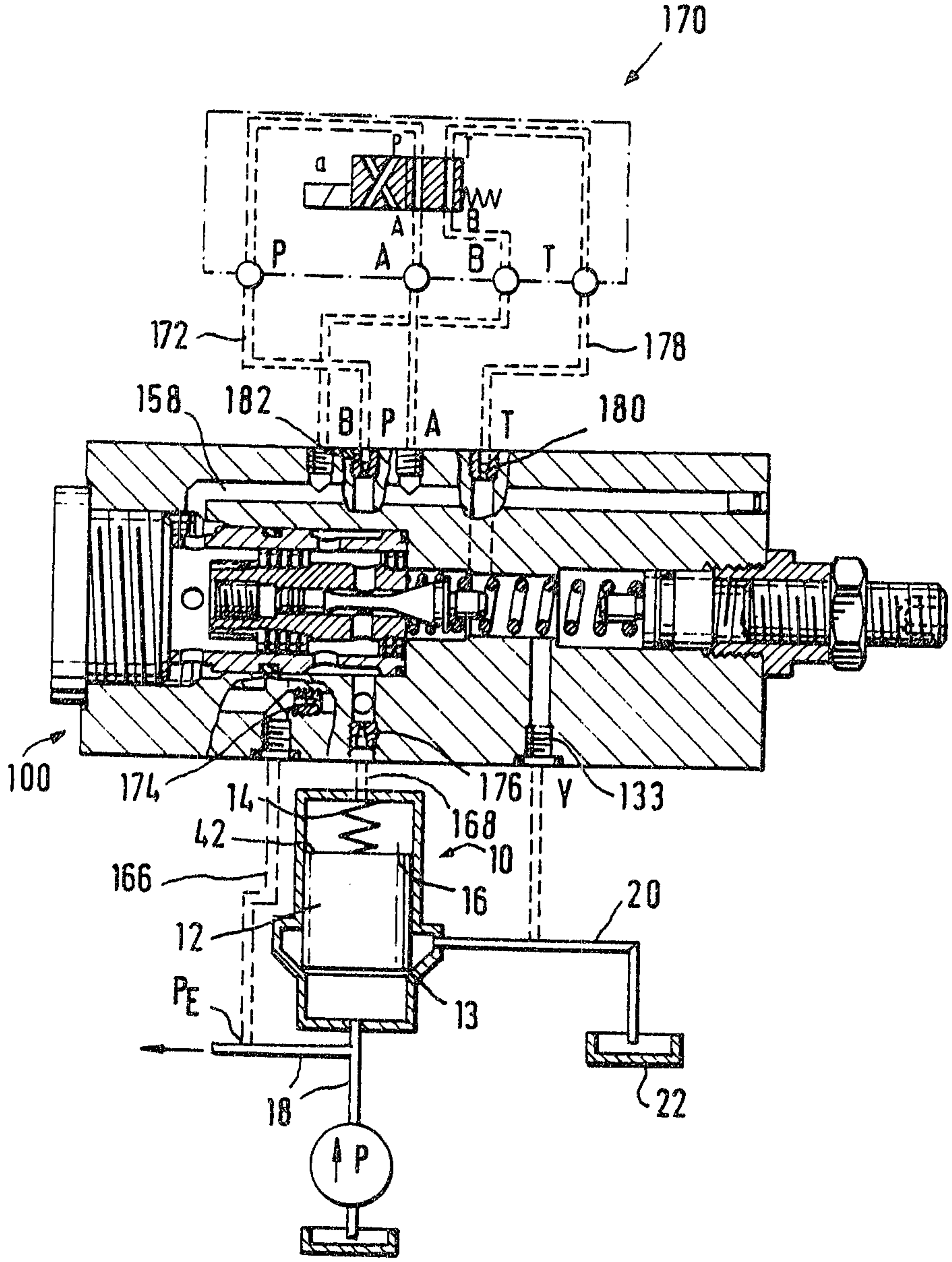
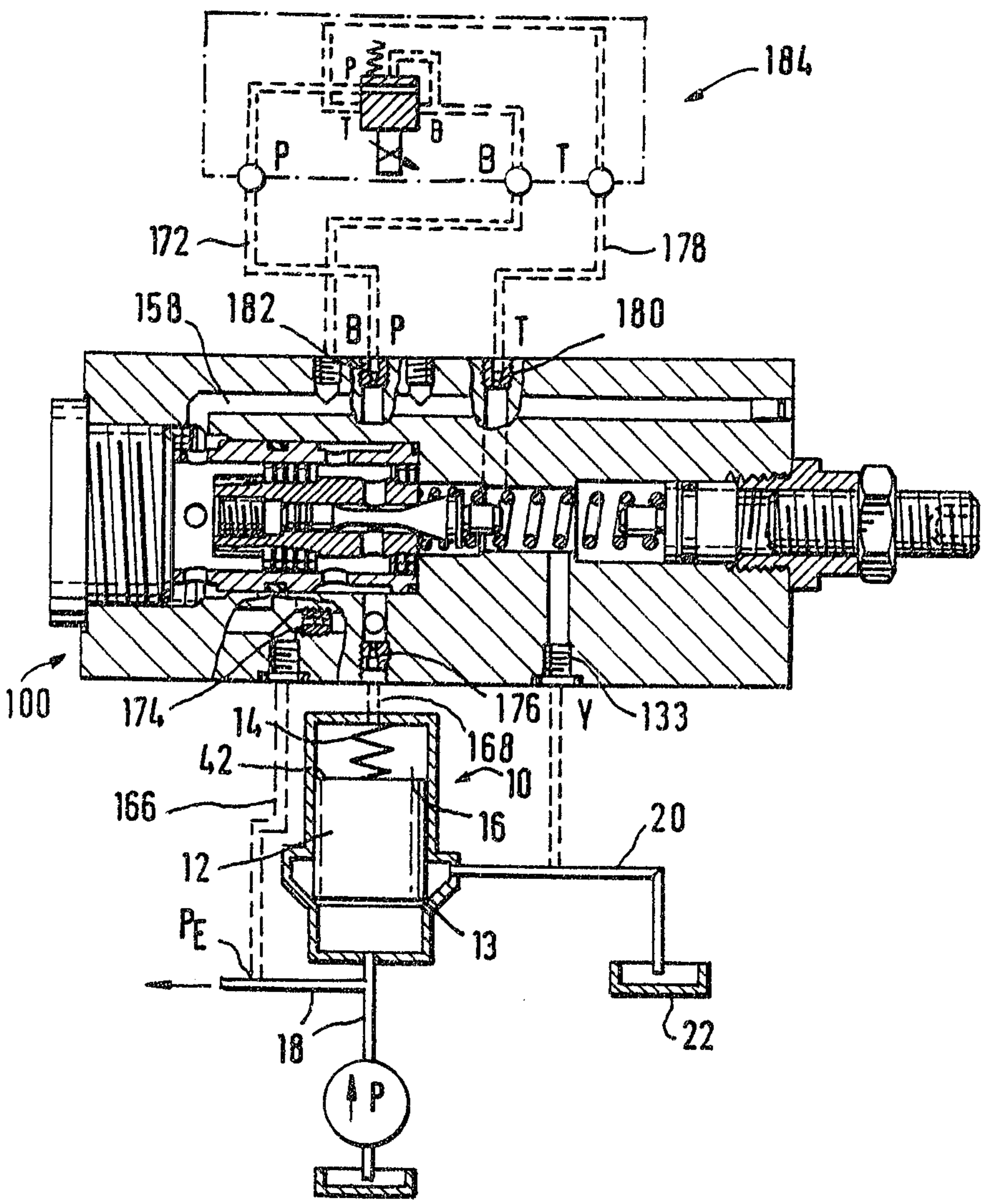
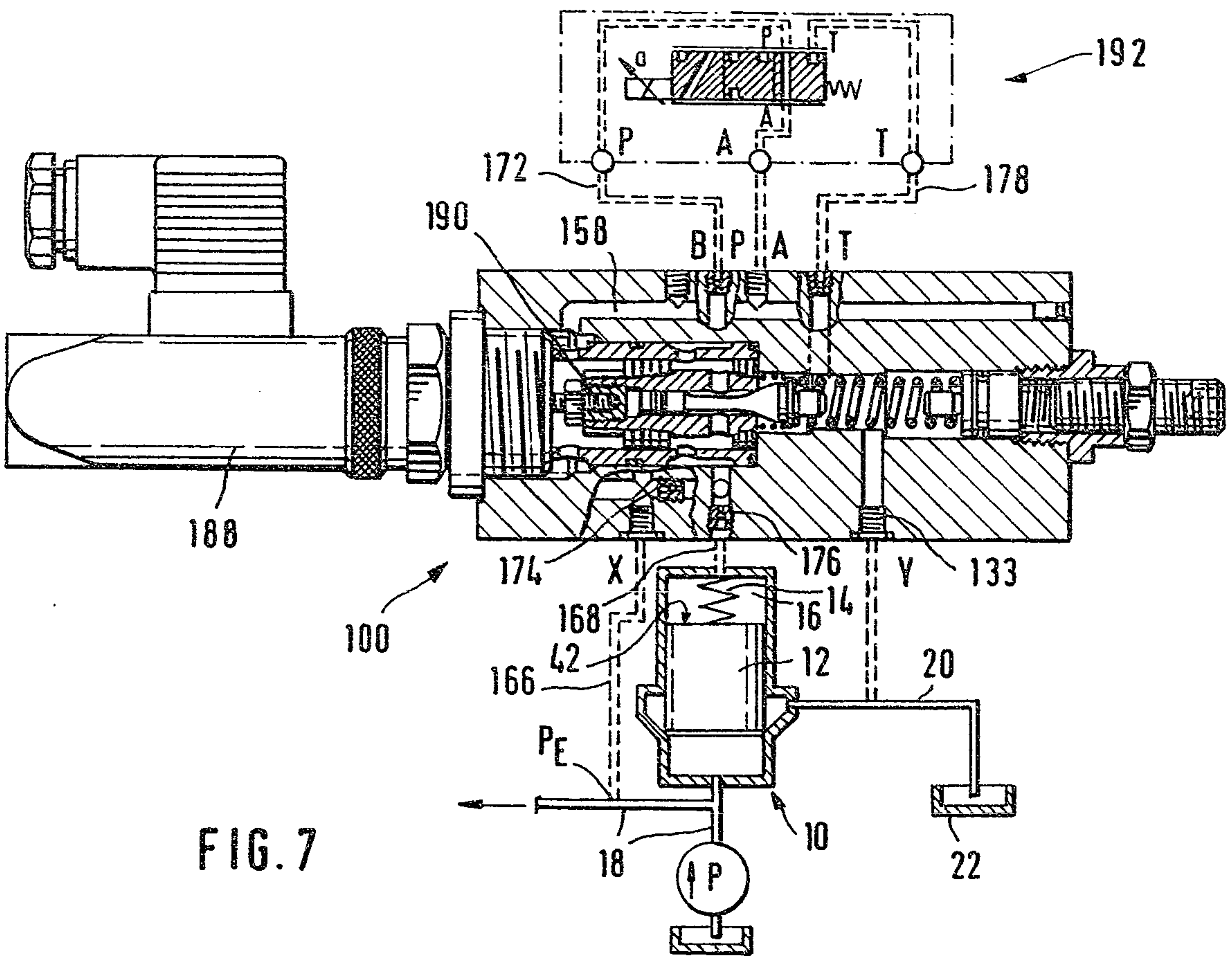


FIG.5



184
P
T
B
P
B
T
172
178
158
182
B
P
T
180
100
174
176
Y
133
14
168
42
10
166
16
20
12
13
P_E
18
22
P

FIG. 6



192
172
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190
158
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P_E
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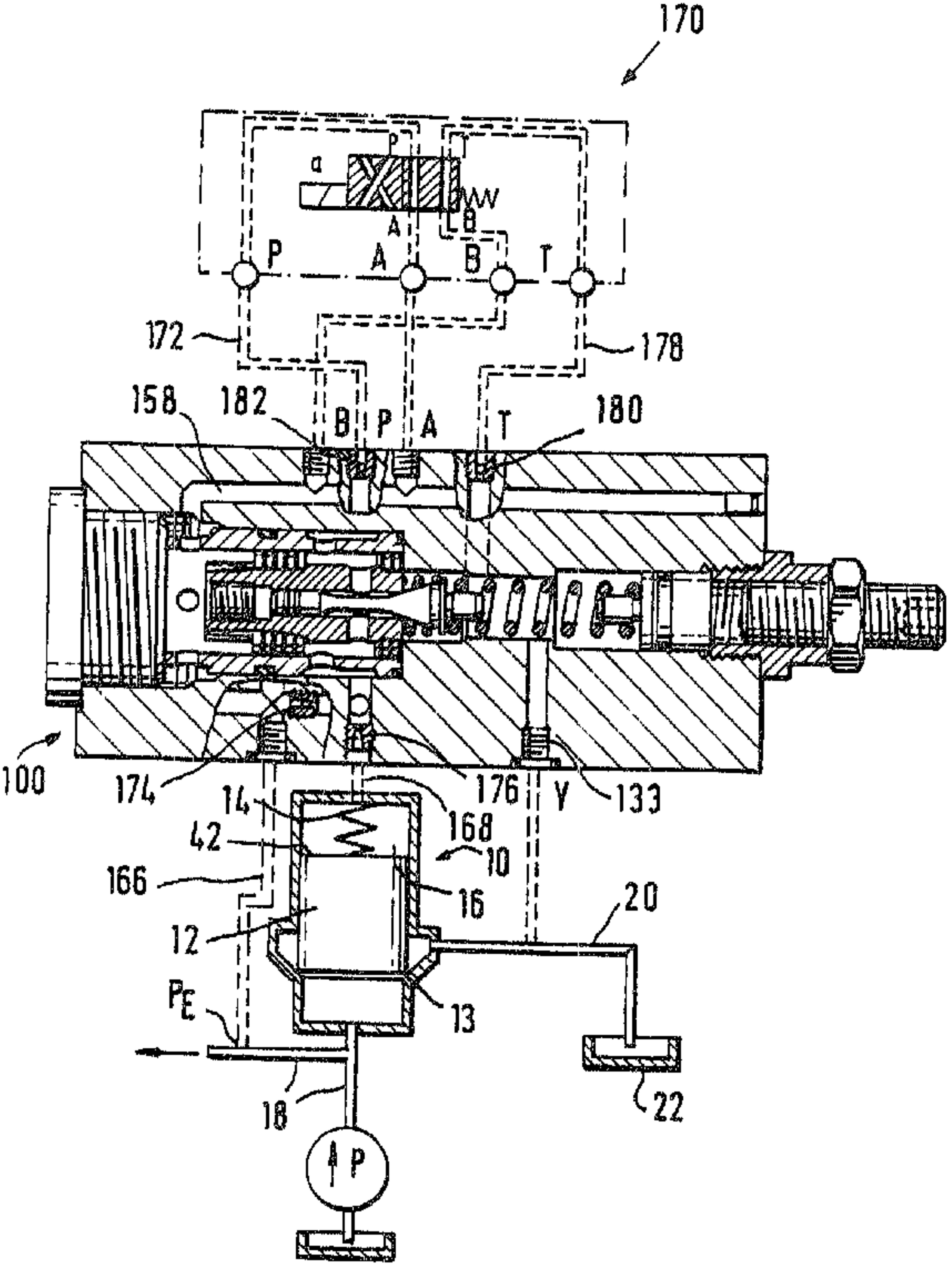
FIG. 7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