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**Zschieschang**

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(54) **CAMSHAFT ADJUSTER HAVING A CHAMBER SHORT-CIRCUITING, PRESSURE-CONTROLLED CONTROL UNIT**

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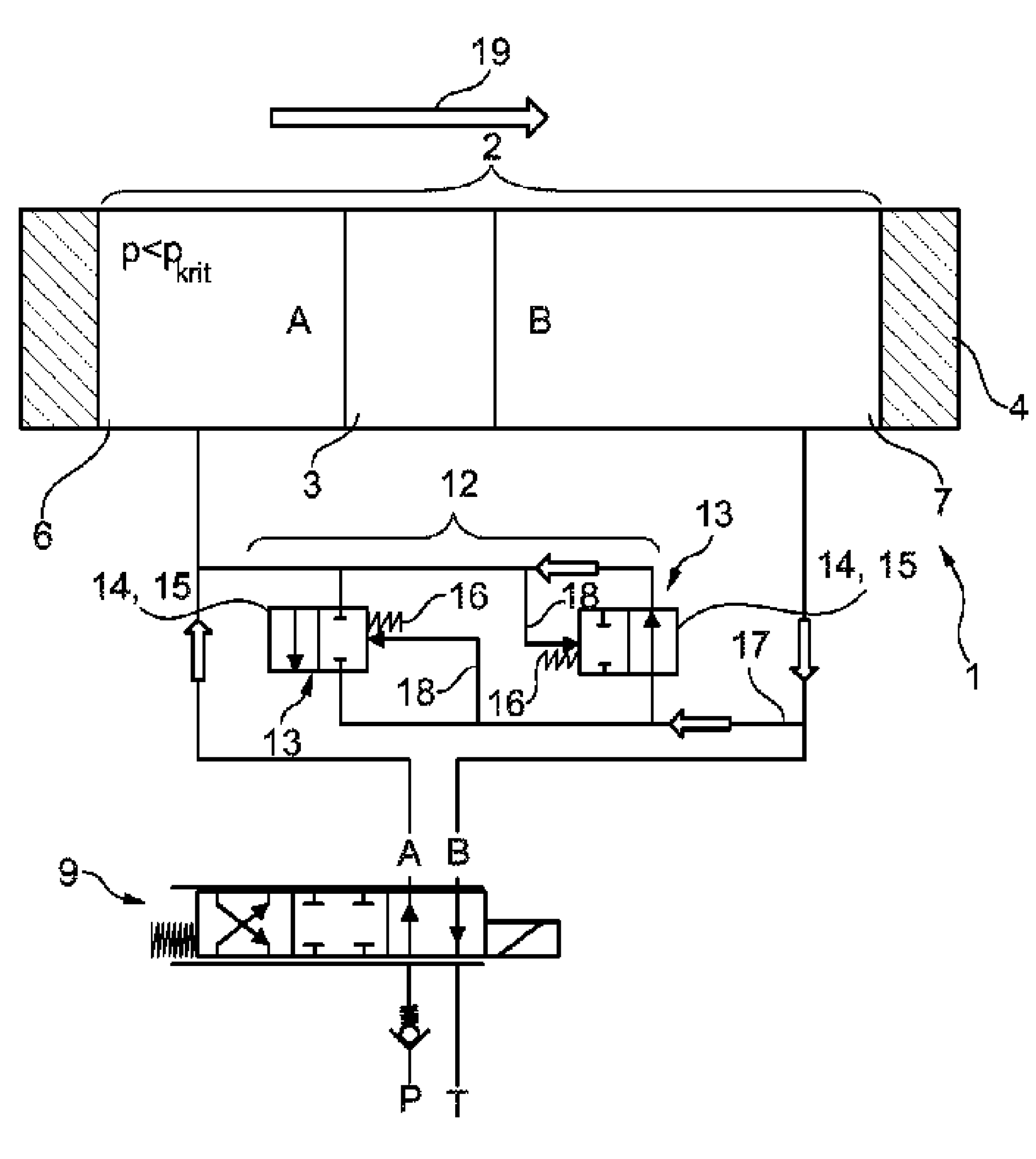
(74) *Attorney, Agent, or Firm* — Davidson, Davidson & Kappel, LLC

(57) **ABSTRACT**

A vane-type camshaft adjuster (**1**) including a rotor (**2**) which has radially projecting vanes (**3**) and forms vane cells (**5**) along with a stator (**4**) rotatably accommodating the rotor (**2**), each vane cell (**5**) being subdividable by a vane (**3**) into two adjustable chambers provided for holding hydraulic fluid; a hydraulic fluid-controlling device (**12**) for conducting hydraulic fluid is disposed and/or connected between the chambers (**6**, **7**) in such a way that a drop in pressure in the chambers (**6**, **7**) caused or reinforced by camshaft switching moments occurring during operation is used to open the hydraulic fluid-controlling device (**12**) such that fluid flows therethrough.

**16 Claims, 7 Drawing Sheets**



(58) **Field of Classification Search**
USPC .......................................................... 123/90.15
See application file for complete search history.

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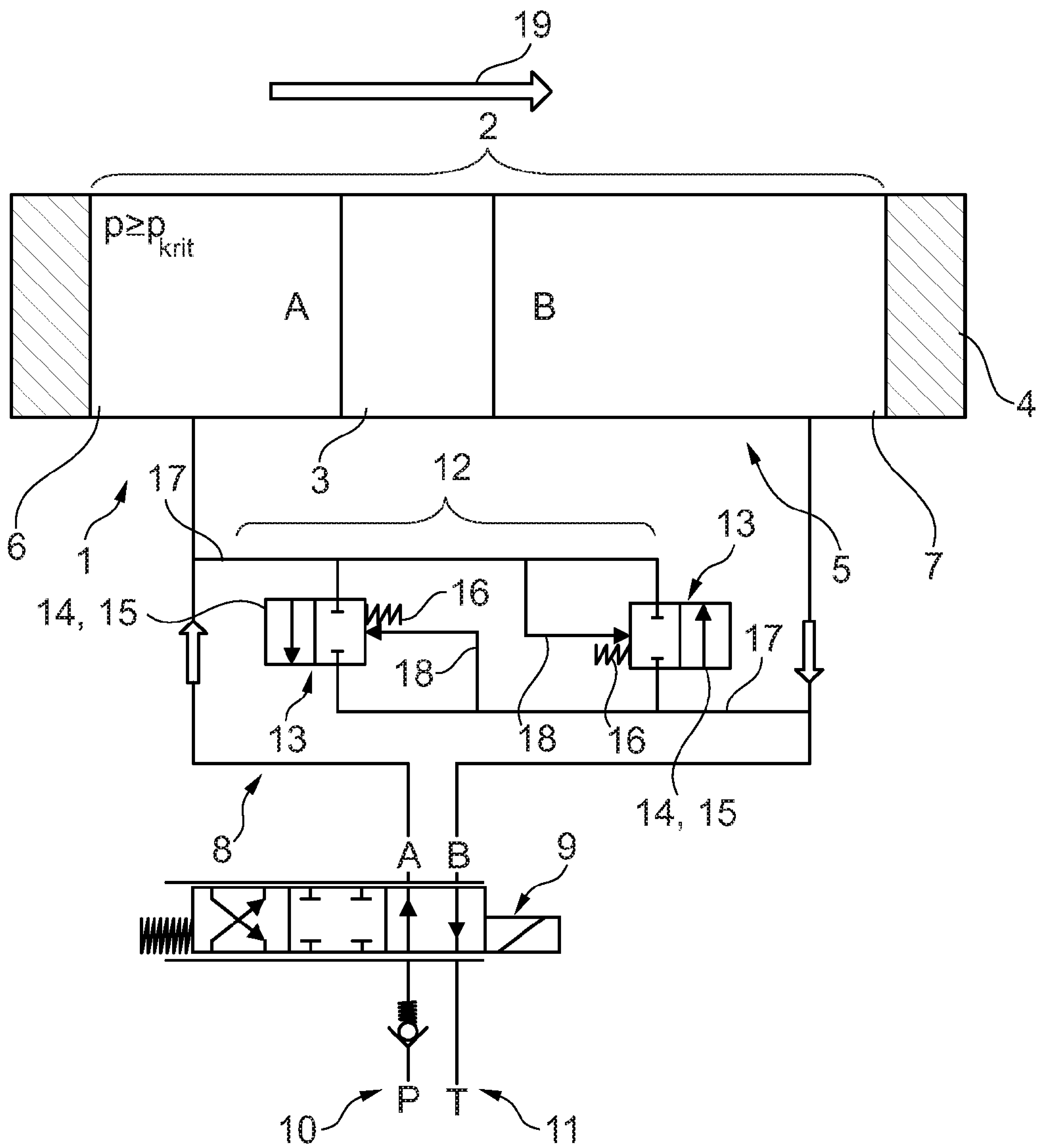
19
2
p≥p krit
A
B
4
6
3
5
7
1
17
12
13
14, 15
16
18
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17
13
18
16
14, 15
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A B
9
P T
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11

Fig. 1

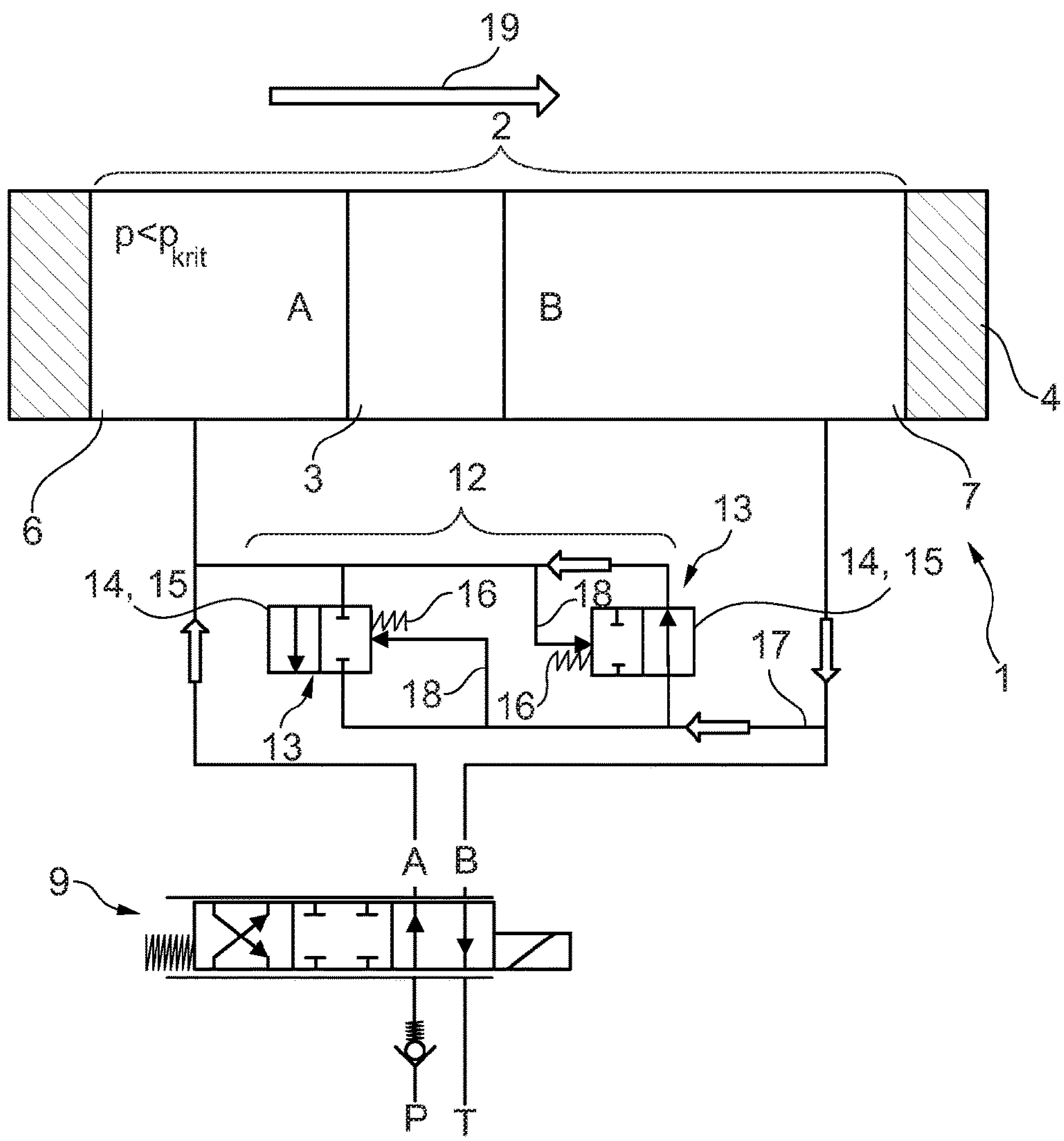



Fig. 2

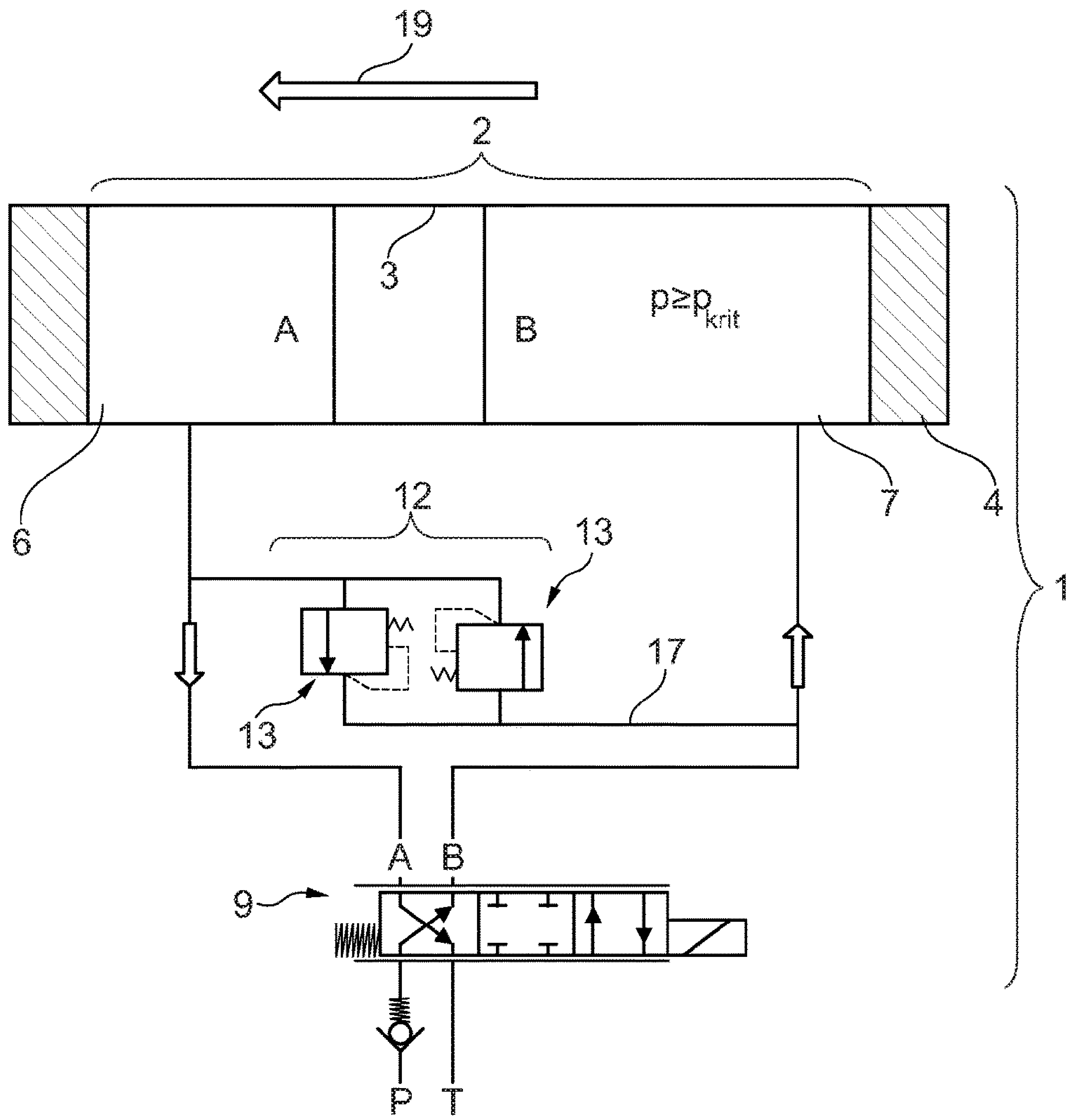



Fig. 3

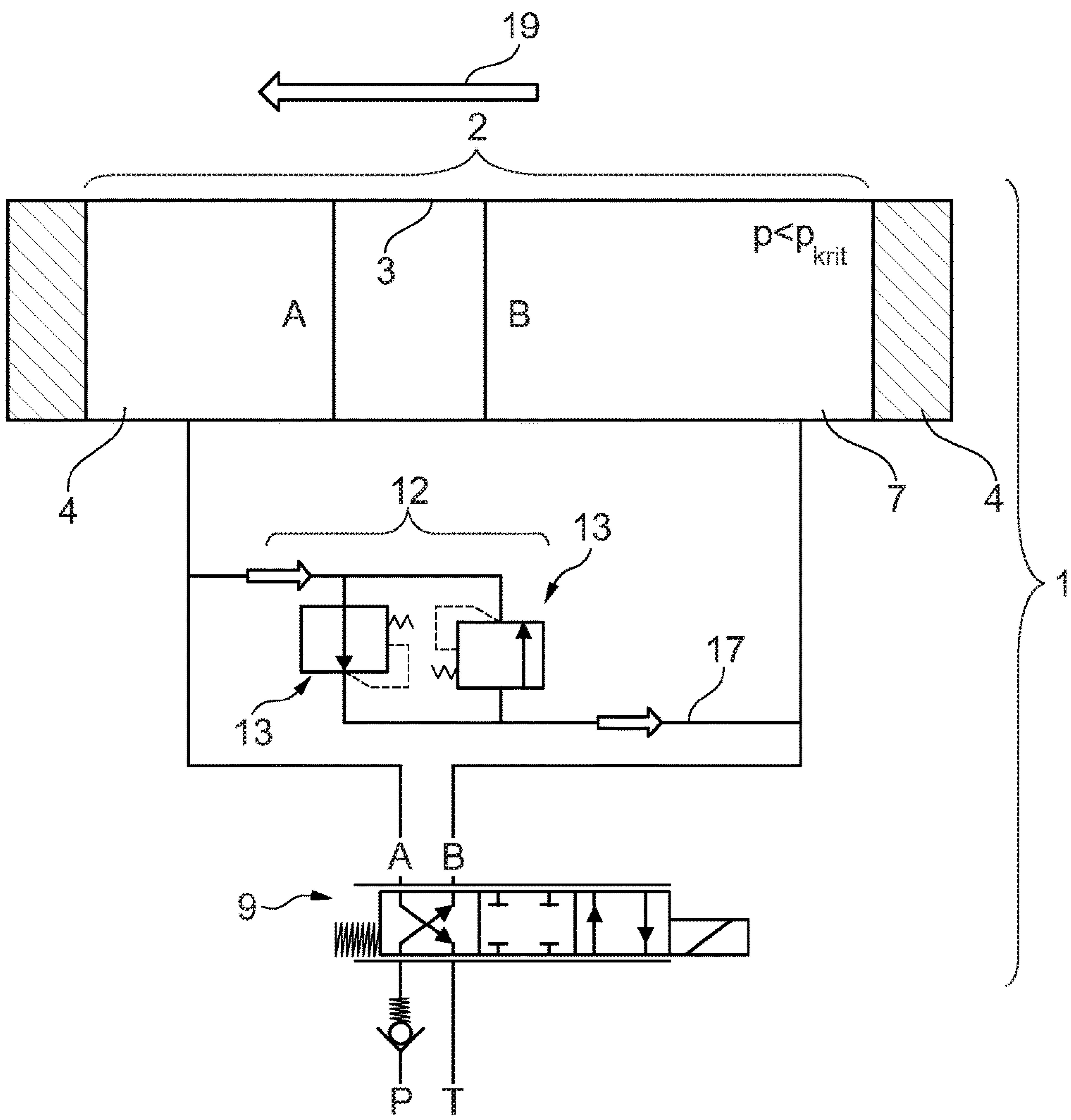



Fig. 4

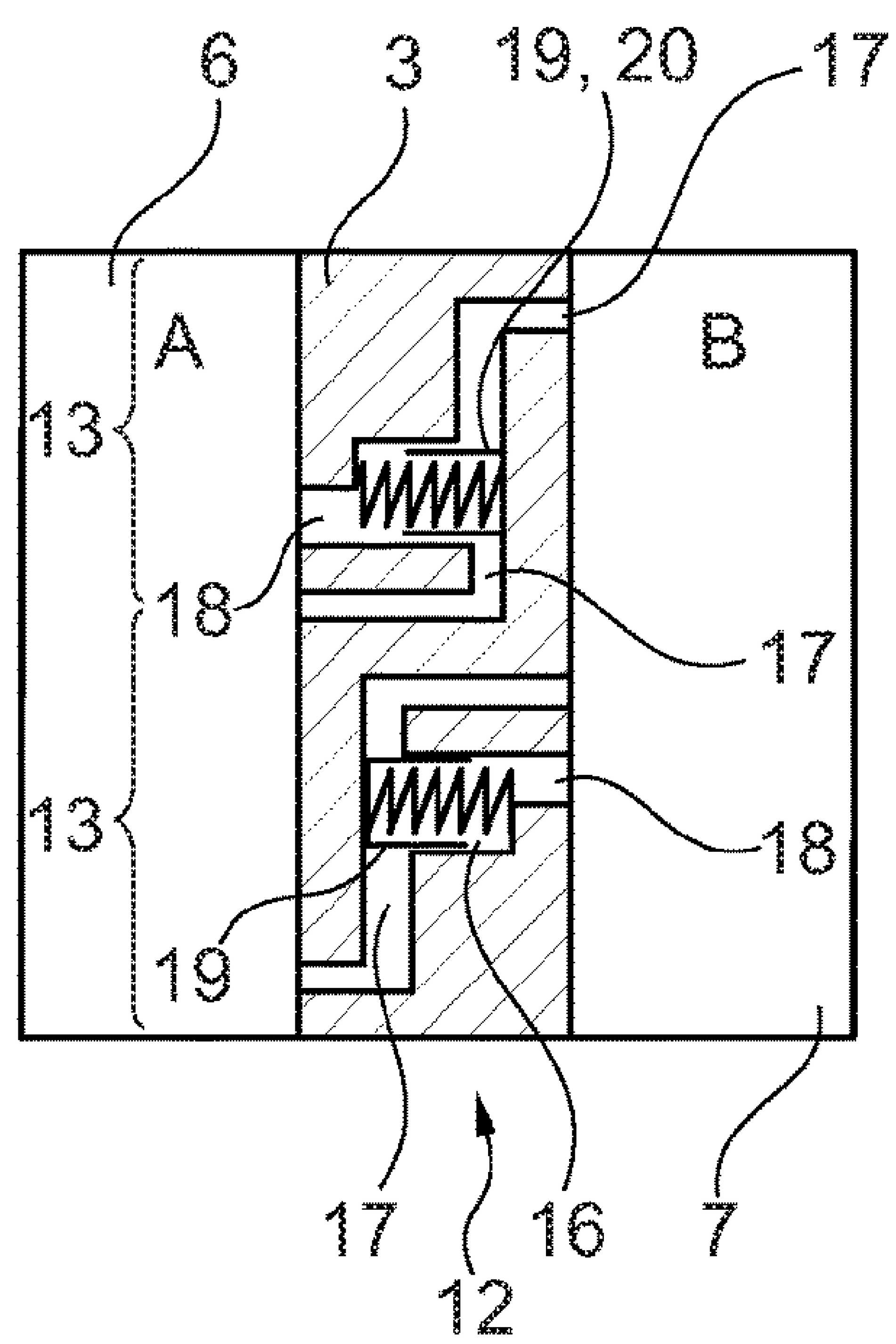
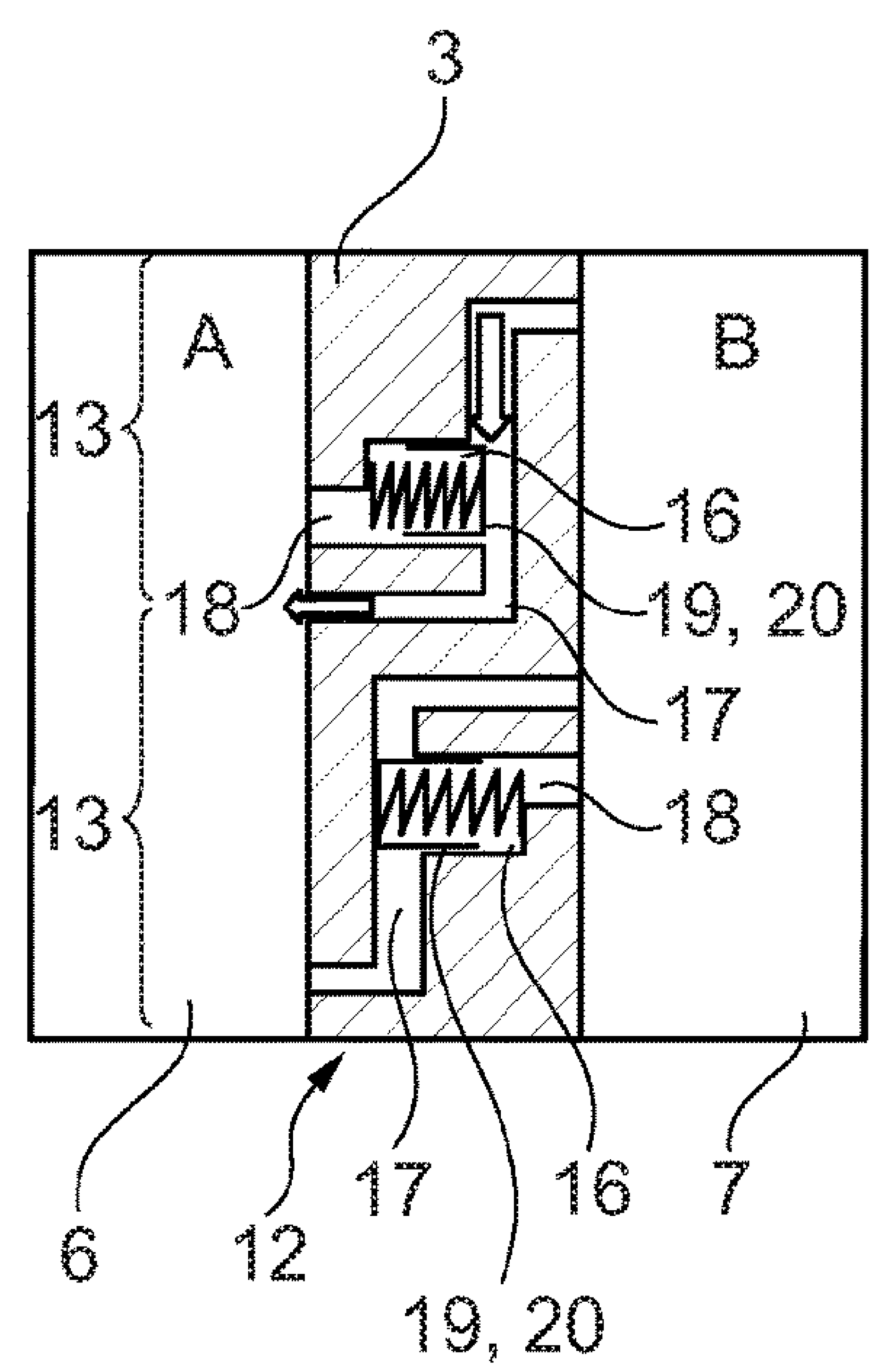

6
3
19, 20
17
A
B
13
18
17
13
18
19
17
16
12
7

Fig. 5


3
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16
7
19, 20

Fig. 6

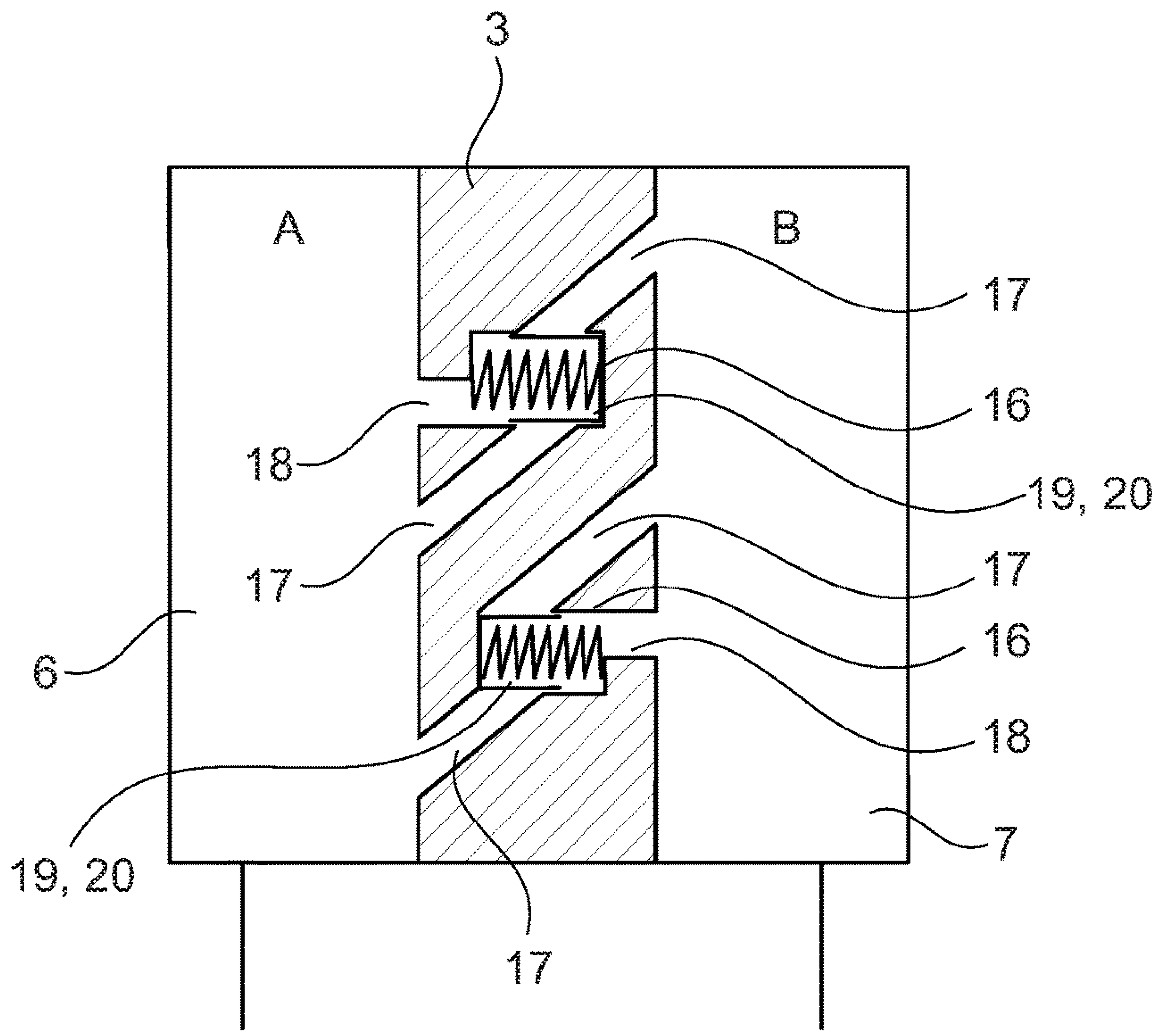


Fig. 7

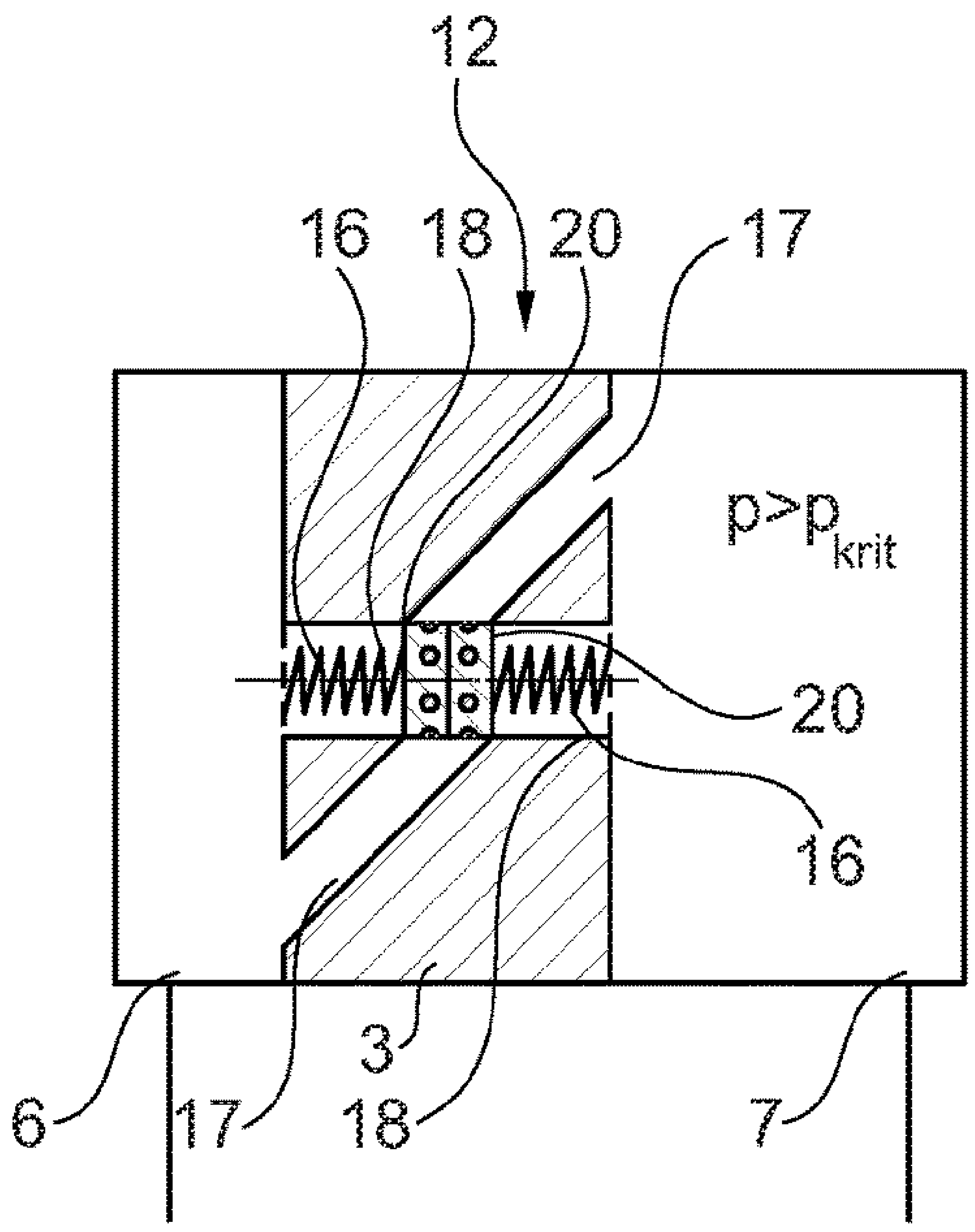
12
16
18
20
17
p>p_krit
20
16
6
17
3
18
7

Fig. 8

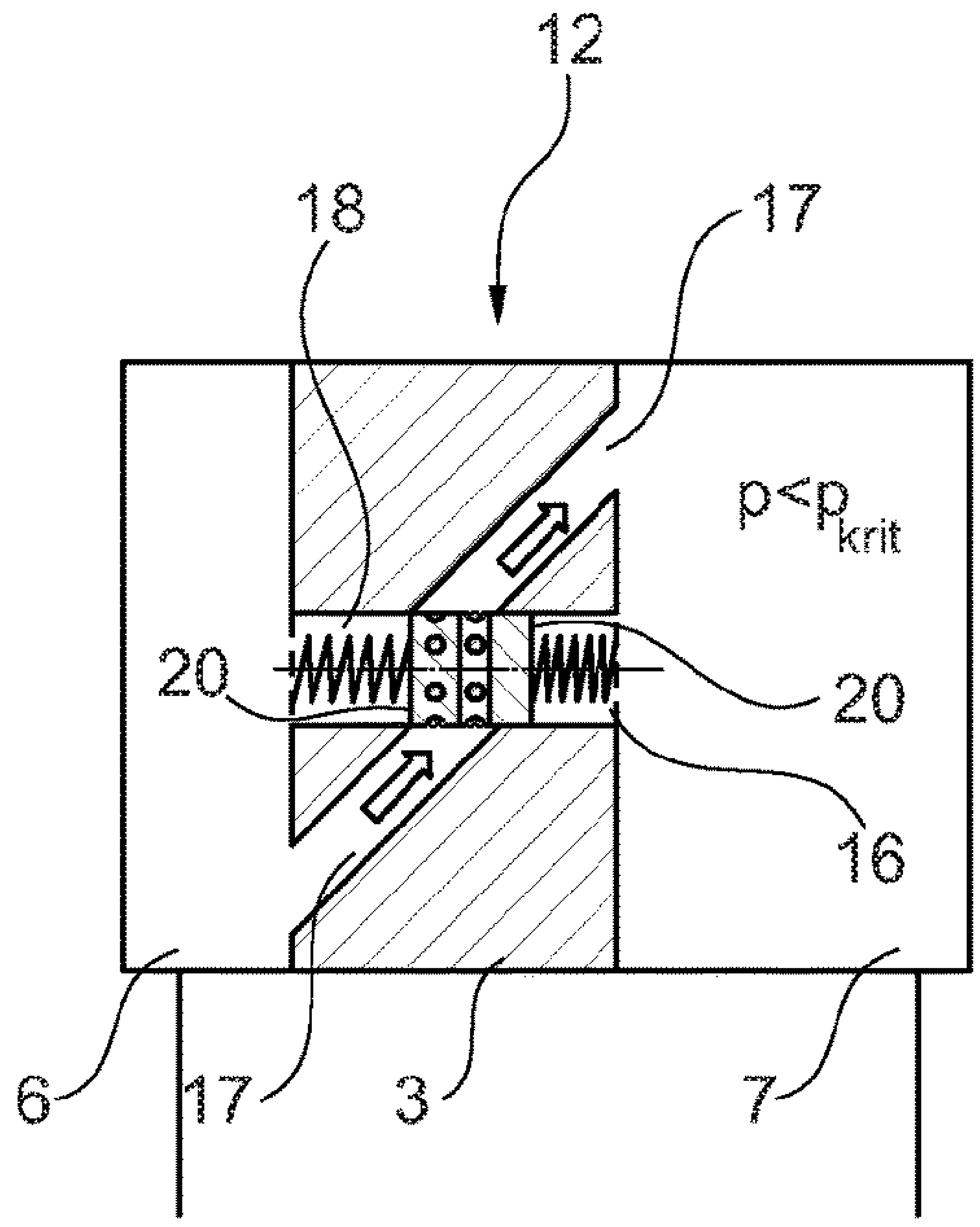
12
18
17
p<p_krit
20
20
16
6
17
3
7

Fig. 9

# CAMSHAFT ADJUSTER HAVING A CHAMBER SHORT-CIRCUITING, PRESSURE-CONTROLLED CONTROL UNIT

The present invention relates to a vane-type camshaft adjuster, including a rotor, which has radially projecting vanes, the rotor, together with a stator rotatably accommodating the rotor, forming vane cells, each of which is divided by a vane into two adjustable chambers provided for accommodating hydraulic fluid.

## BACKGROUND

Camshaft adjusters of this type are used in valve train assemblies of internal combustion engines, as known, for example, from DE 102 39 748 A1. Camshaft adjusters as valve timing control units are also known from the prior art, for example US 2008/0173267 A1 or U.S. Pat. No. 7,182,052 B2 or DE 10 2008 000 083 A1. In these publications, a valve timing control unit controls a valve timing of an inlet/outlet valve of an internal combustion engine. The device includes a housing which is rotated with the aid of a drive shaft. The housing has a chamber space which accommodates a vane rotor, which is rotatable toward a retard and an advance side relative to the housing with the aid of a driven shaft, in that a hydraulic pressure is applied thereto in a retard and advance chamber in the chamber space. A filter is provided in a fluid channel for removing foreign substances, which extends from a sliding section between the driven shaft and a bearing to both the housing and the vane rotor through a connected section between the driven shaft and the vane rotor. The filter is provided on the side of both the housing and the vane rotor with respect to the sliding section.

Camshaft adjusters are furthermore known from the publications U.S. Pat. No. 7,245,077 B2, U.S. Pat. No. 7,318,401 B2 and U.S. Pat. No. 7,000,580 B1. Slide valve devices for a camshaft adjuster including integrated check valves are described therein.

The present invention is in the field of accumulators and additional control functions in the switching valve. It therefore relates to pressure-driven adjusters, which are also known as oil pressure-activated (OPA) adjusters.

## SUMMARY OF THE INVENTION

At excessively high torsional moments, an underpressure currently occurs periodically on the pump side in a camshaft adjuster. This results in dynamic problems and in additional air intake due to suction from leakage gaps and/or a degassing of a hydraulic fluid, such as a hydraulic liquid, e.g., oil, such as pressure oil/motor oil.

An object of the present invention is to avoid these disadvantages, to provide a particularly dynamically optimized camshaft adjuster and to eliminate or at least mitigate the disadvantages known from the prior art.

The present invention provides that a hydraulic fluid control device/hydraulic fluid regulating device is situated and/or connected between the chambers for conducting hydraulic fluid in such a way that a pressure drop, preferably below a predetermined limit pressure in the chambers, caused or amplified by camshaft alternating torques occurring during operation, is used to open the hydraulic fluid control device so that fluid flows therethrough.

The pressure at which the system begins to suck in air, or at which oil begins to degas, may be understood to be the critical pressure, in certain situations equal to a limit pressure. A limit pressure is understood to be the pressure which is the pressure set via the spring pretension and piston active surface.



It is advantageous if the hydraulic fluid control device includes at least one bypass line closing device or preferably two bypass line closing devices. In this way, hydraulic fluid may be transported both from the one chamber into the other chamber during a pressure drop and from the other chamber into the one chamber. An optimization in both adjusting directions of the camshaft adjuster is then achievable.

If the two bypass line closing devices are situated in parallel to each other in a fluid conducting manner, the reaction times may be minimized.

A particularly efficient camshaft adjuster optimization is achieved if the bypass line closing device includes a valve, such as a 2/2-way valve, and a spring acting thereupon, such as a pressure or tension spring. In this case, two open/close valves may be situated on/in the camshaft adjuster, which are actuated when the pressure in the first chamber falls. The actuated valve then opens a channel to allow oil to flow from the other chamber to the first chamber.

If the spring pretensions the valve into a position in which the hydraulic fluid flow is prevented, simple means may be used to facilitate a complex actuation.

A hydraulic fluid control unit is thus proposed, which connects chambers A and B, i.e., a first chamber and a second chamber, only when the pressure in one chamber falls below the pressure ($p_{krit}$) set via a controller/switch. A pressure compensation between the chambers may then take place. In this process, the pressure gradient between the chambers is utilized, which is induced in any case by the (camshaft) alternating torques.

As long as the pressure in the relevant chamber is above the critical pressure (limit pressure), the relevant controller/switch ensures a blocking of the short-circuit between the chambers. Each path A or B having the particular connected chambers requires a separate control unit, which varies the pressure in the corresponding path or opens the bypass to the other chamber if the pressure falls below the critical pressure in the one chamber. The pressure difference between the chambers is not an issue. It is additionally possible that a bypass/bypass line is opened when the pressure falls below a level set via the control unit (limit pressure). An overflow through this bypass line then occurs. The pressure level is not "equalized," but instead the camshaft adjuster takes in the additional oil available to it (i.e., the oil "that it can get") and thus increases the speed of its adjusting movement.

It is desirable if the bypass line closing device is preset in such a way that, when the pressure in a first of the chambers falls below a limit pressure ($p_{krit}$), a switching position of the bypass line closing device is forced, in which the hydraulic fluid enters the one, first chamber from the other, second chamber through a bypass line.

It is advantageous if the spring is adapted to the limit pressure/the pressure ($p_{krit}$) set via the controller. This precise limit pressure is set with the aid of the spring, the area ratios and/or the active surfaces on the piston.

It is also advantageous if the hydraulic fluid conducting device is integrated or built into a vane. In this way, a very compact camshaft adjuster may be achieved.

It is advantageous if the bypass line closing device includes a pilot line, which establishes a pressure-transmitting connection between the first chamber and a closing element, the spring, in its basic position, forcing the closing element into the bypass line connecting the two chambers in a hydraulic fluid-suppressing manner and, in an activating position, opening the bypass line, when the pressure in the first chamber reaches and/or falls below the limit pressure.

One advantageous exemplary embodiment is also characterized in that two pistons, which are movable toward and away from each other, are situated in a channel, the pistons being situated in such a way that they are activated only by the pilot line assigned to them. The two pistons are thus hydraulically controllable separately from each other. A pressure-impermeable separation is thus to be maintained in the channel, which may be designed in the manner of a bore. In this way, a specific embodiment in a vane may be used as an insertion element which includes two separate chambers and pistons/cups. The insertion element may be provided with two sections having bores in a sleeve. Internally, the spring-loaded pistons or cups close the bores in a basic position, the pressure in both chambers being above the critical pressure. If the pressure in one of the two chambers falls below the critical pressure, the piston located on this chamber side moves, whereby the piston exposes a bore, and an overflow into the chamber having the lower pressure from the other chamber occurs via the bypass line.

A camshaft adjuster of this type may also be refined in that the switching area is the area of the shared pilot line which ensures a hydraulic fluid-permeable connection between the two bypass lines in a pressure difference-/pressure drop-dependent displacement of one of the pistons.

It should be noted that it is possible to provide the springs on the two slide valves with tensile or pressure pretensioning or to eliminate them altogether, depending on how the critical pressure level is to be set, at which the slide valve is to be deflected out of its initial position (closed without pressure). For example, no spring is necessary if the slide valve is to open upon falling below 0 bar, the underpressure in the chamber connected to the corresponding port “pulling open” the slide valve.

A spring having pressure pretensioning is sensible if the slide valve is to be moved only starting at a certain underpressure, e.g., at a pilot pressure of −0.1 bar. A tensile pretensioning is theoretically also conceivable if the slide valve is to open the bypass upon falling below a certain positive pressure, such as above 0 bar. A pilot pressure would then be detectable, e.g., at 0.1 bar. However, this design is risky, because both slide valves are set to “through-flow” upon the startup of the internal combustion engine, i.e., they are open without pressure, and are thus able to generate an undesirable short circuit via the two slide valves. One may try to compensate for this state with the aid of additional switching elements. This design is still technically very critical, since there is the risk of the bypass unintentionally opening or being open in the first place with each torque zero crossing/alternating torque, causing a back-flow of the fluid. The variant without a spring is also critical, since the indifferent position of the cups/pistons/slide valves may also cause the wrong bypass to open unintentionally. From a technical perspective, therefore, the variant with spring pretensioning is sensible and preferred, because it permits a defined basic position of the valve, and a secure sealing against chamber pressures may thus occur.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is explained in greater detail below with the aid of drawings in which four exemplary embodiments are illustrated.

FIG. **1** shows a circuit diagram for a first specific embodiment of a camshaft adjuster according to the present invention, a first chamber A being supplied with hydraulic fluid via a pump, the pressure in first chamber A being above the critical pressure, the torsional moments being uncritical, the system functioning as an OPA system, and a short circuit A-B being closed at a main valve;

FIG. **2** shows the camshaft adjuster from FIG. **1** in the situation in which the pressure in first chamber A falls below critical pressure $p_{krit}$, i.e. a suction phase is present, the torsional moments dominating the behavior of the camshaft adjuster in a driving manner, the pressure supply from the pump furthermore no longer being sufficient, a hydraulic fluid control device/pressure regulating unit releasing a short-circuit via a bypass line from second chamber B to first chamber A as long as the system ensures that the pressure rises again above the critical pressure in the first chamber by compensating the pressure and resupplying hydraulic fluid from the second chamber to the first chamber;

FIG. **3** shows another type of representation of the camshaft adjuster from FIGS. **1** and **2**, second chamber B being supplied with hydraulic fluid by the pump, the pressure in chamber B being above the critical pressure, the torsional moments being uncritical, the adjusting direction of the camshaft adjuster being opposite the adjusting direction of the specific embodiment in FIGS. **1** and **2**, and short circuit A-B also being closed;

FIG. **4** shows the situation in the adjusting direction as shown in FIG. **3**, however the pressure in second chamber B falling below the critical pressure (suction phase), the torsional moments dominating the behavior of the camshaft adjuster in a driving manner, the pressure regulating unit/hydraulic fluid control device releasing the short circuit/bypass line from chamber A to chamber B, the system continuing to compensate the pressure and resupply the hydraulic fluid from chamber A to chamber B until the pressure in chamber B is again above the critical pressure;

FIG. **5** shows another exemplary embodiment, in which two valves are integrated into a rotor vane and spring-loaded cups/pistons are used;

FIG. **6** shows the exemplary embodiment from FIG. **5** but in an open switching position of the bypass line;

FIG. **7** shows another specific embodiment for positioning the valves in the vane, where the pilot bore may also be provided centrically with respect to the piston or cup axis, so that the bypass line does not have to be offset but may also be drilled in a single pass, if the piston or the cup sufficiently blocks the opposite chamber in a blocking position and sufficiently releases the channel for the through flow in an open position;

FIG. **8** shows another specific embodiment in the closed position of the bypass line; and

FIG. **9** shows the exemplary embodiment from FIG. **8** in the open position of the bypass line.

The figures are only of a schematic nature and are used only for the sake of understanding the present invention. Identical elements are provided with identical reference numerals.

Features of the individual exemplary embodiments are also interchangeable with each other.

## DETAILED DESCRIPTION

A first specific embodiment of a camshaft adjuster **1** according to the present invention is illustrated in FIG. **1**. This camshaft adjuster **1** is provided for use in a valve train assembly on an internal combustion engine. This camshaft adjuster **1** includes a rotor **2**, which has radially projecting vanes **3**. Three or more vanes **3** are usually used. Four vanes **3** are particularly preferred.

Rotor **2** is rotatably situated in a stator **4**, which may be connected to an endless traction mechanism, such as a chain, e.g. via a gear wheel. Rotor **2** and stator **4** form vane cells **5**, which are each divided into a first chamber **6** and a second chamber **7** by a vane **3**. The first chamber may also be referred to as chamber A, and the second chamber may also be referred to as chamber B, and vice versa. A main shutoff/switchover valve **9** is provided in a line system **8**. This main shutoff/switchover valve **9** is situated between a pump (P) **10** and a tank (T) **11**. A hydraulic fluid control device **12** is additionally provided.

Hydraulic fluid control device **12** preferably includes two bypass line closing devices **13**. The two bypass line closing devices **13** include a valve **14**, such as a 2/2-way valve **15**. This valve **14**, which may also be referred to as a slide valve, is pretensioned with the aid of a spring **16**.

Bypass line closing devices **13** are each situated in one bypass line **17** or situated in a shared bypass line **17**. There is also a pilot line **18** for each bypass line closing device **13**. Upon falling below limit pressure/critical pressure $p_{krit}$ in first chamber **6**, an opening action is ultimately applied to one of the two 2/2-way valves **15** via pilot line **18**, so that, as illustrated in FIG. **2**, e.g. hydraulic fluid, such as oil, enters first chamber **6** from second chamber **7** via bypass line **17**. Bypass line **17** remains open, due to valve **14** on the left in the figure, until pressure P in first chamber **6** is increased to critical pressure $p_{krit}$.

The adjusting direction of rotor **2** relative to stator **4** is symbolized by arrow **19**.

FIGS. **3** and **4** show a modified type of representation in opposite adjusting direction **19** of rotor **2** relative to stator **4**.

However, a variant of the specific embodiments illustrated in FIGS. **1** through **4** is shown in FIGS. **5** and **6**. In FIG. **5**, both a first bypass line **17** and a second bypass line **17** are closed, whereas a bypass line **17** is opened based on the pressure transmission from first chamber **6** due to a closing element **20** pretensioned by spring **16**, so that hydraulic fluid is able to enter first chamber **6** from second chamber **7**.

The two bypass line closing devices **13**, which are separated from each other, are mounted alternatingly in vane **3**. Each bypass line closing device **13** includes a pilot line **18** to particular assigned first or second chamber **6** or **7**, which facilitates an opening and closing of particular assigned bypass/bypass line **17** in coordination with active spring **16**. Pilot line **18** may also be referred to as a pilot channel.

The arrangement is selected in such a way that the first and second chambers are hydraulically separated from each other in a valve basic position, i.e. when the pilot pressure is above the critical pressure. Neither the (over)pressure in first chamber **6** nor the pressure in second chamber **7** may cause closing element **12** to open in the manner of a piston or a cup, nor cause a pressure gradient between the two chambers **6** and **7**.

A suitable recess in the sense of an indentation for the end-face accommodation of closing element **20** may support the secure closing of the closing element/valve body/cup/piston.

The pressure in both chambers is above the critical pressure, as shown in FIG. **5**. The valves are in their basic positions, whereby bypass/bypass line **17** is closed.

In FIG. **6**, on the other hand, the pressure in first chamber **6** has fallen below the critical pressure. However, the torsional moments carry along camshaft adjuster **1**, in particular rotor **2**. The supply of volume flow through pump **10** is then no longer sufficiently ensured. As a result, a pressure which falls below the critical pressure sets in chamber A, i.e. in first chamber **6**. Closing element **20** is now pulled out of its seat or recess against illustrated spring **16** due to this "underpressure" in first chamber **6**. The short circuit from second chamber **7** to first chamber **6** is thus opened. This opening is also hydraulically supported by the chamber pressure in second chamber **7**, which acts upon the now exposed end face of closing element **20**.

If a pressure compensation occurs between the two chambers **6** and **7**, valve/closing element **20** returns to its seat and closes bypass/bypass line **17**. A slight recess for accommodating closing element **20** ensures a secure sealing against a laterally acting pressure from chambers **6** and **7**.

The system operates like a traditional adjuster in pure OPA mode until the pressure in one chamber **6** or **7** falls as a result of the present alternating torques and critical pressure $p_{krit}$ set via spring **16** and an active surface of the closing element interior or the piston surface. Up to this point, the system is operated by oil pressure control and is not dependent on "repumping" between the chambers, which has an advantageous effect on the adjusting speed or the adjusting behavior at low torsional moments.

As the moments increase, the adjustment is then additionally supported by the repumping between the chambers, in the sense of a CTA adjustment, i.e. a cam torque actuation. The pressure gradient between chambers **6** and **7** additionally helps achieve higher adjusting speeds. The potential for air intake or outgassing from the oil is minimized. Of course, this also depends on the set pilot pressure.

FIG. **7** shows another specific embodiment, pilot lines **18** being present, which extend (orthogonally) from the two chambers **6** and **7** and which act upon adjusting devices **19**/closing elements **20** which are in an operative relationship with springs **16**. Closing elements **20** close sloping bypass lines **17**.

FIGS. **8** and **9** show two closing elements **20**, which are movable independently of each other, in a bore, which connects the two chambers **6** and **7** orthogonally to the surface of vane **3**. If the pressure drops below the limit pressure in second chamber **7**, for example closing element **20** which is closer to second chamber **7**, i.e. the corresponding piston, is sucked/displaced in the direction of second chamber **7**. A passage for oil from the one section of bypass line **17** to the other section of bypass line **17** is facilitated thereby, so that hydraulic fluid is transported from first chamber **6** to second chamber **7** according to the arrow direction shown in bypass line **17** in FIG. **9**.

LIST OF REFERENCE NUMERALS

**1** camshaft adjuster
**2** rotor
**3** vane
**4** stator
**5** vane cell
**6** first chamber
**7** second chamber
**8** line system
**9** main shutoff/switchover valve
**10** pump
**11** tank
**12** hydraulic fluid control device
**13** bypass line closing device
**14** valve
**15** 2/2-way valve
**16** spring
**17** bypass line
**18** pilot line
**19** adjusting direction
**20** closing element

What is claimed is:

1. A vane-type camshaft adjuster comprising:

a rotor having radially projecting vanes, the rotor, together with a stator rotatably accommodating the rotor, forming vane cells, each vane cell divided by one of the vanes into a first adjustable chamber and a second adjustable chamber provided for accommodating hydraulic fluid,

a hydraulic fluid control device entirely inside one of the vanes for conducting the hydraulic fluid between the first and second adjustable chambers being situated in such a way that a pressure drop in each of the first and second chambers is induced or amplified by camshaft alternating torques occurring during operation and is used to open the hydraulic fluid control device so that the hydraulic fluid flows therethrough,

wherein the hydraulic fluid control device is configured such that the hydraulic fluid flows from the second chamber through the hydraulic fluid control device to the first chamber when a pressure in the first chamber falls below a limit pressure,

wherein the limit pressure is a critical pressure at which air is sucked into the hydraulic fluid or at which the hydraulic fluid begins to degas.

2. The camshaft adjuster as recited in claim **1** wherein the hydraulic fluid control device includes at least one bypass line closing device.

3. The camshaft adjuster as recited in claim **2** wherein the at least one bypass line closing device includes a valve and a spring acting thereupon.

4. The camshaft adjuster as recited in claim **3** wherein the spring pretensions the valve into a position in which the hydraulic fluid flow is prevented.

5. The camshaft adjuster as recited in claim **2** wherein the at least one bypass line closing device is preset in such a way that, when a pressure in the first chamber falls below the limit pressure, a switching position of the at least one bypass line closing device is forced, the hydraulic fluid entering the first chamber from the second chamber through a bypass line in the switching position.

6. The camshaft adjuster as recited in claim **5** wherein the at least one bypass line closing device includes a valve and a spring acting thereupon, the spring configured such that the valve opens when the pressure falls below the limit pressure.

7. The camshaft adjuster as recited in claim **6** wherein the at least one bypass line closing device includes a pilot line establishing a pressure-transmitting connection between the first chamber and a closing element, the spring, in a basic position, forcing the closing element into the bypass line connecting the two chambers in a hydraulic fluid-suppressing manner, and the bypass line being open in an activating position, when the pressure in the first chamber reaches or falls below the limit pressure.

8. The camshaft adjuster as recited in claim **1** wherein the hydraulic fluid control device includes two bypass line closing devices.

9. The camshaft adjuster as recited in claim **8** wherein the two bypass line closing devices are situated in parallel to each other in a fluid-conductible manner.

10. The camshaft adjuster as recited in claim **1** wherein two pistons movable toward and away from each other are situated in a channel or bore connecting the first and second chambers, the two pistons being situated in such a way that the two pistons are activated only by a pilot line assigned to the two pistons.

11. The camshaft adjuster as recited in claim **1** wherein the hydraulic fluid control device is configured such that the hydraulic fluid flows from the first chamber through the hydraulic fluid control device to the second chamber when a pressure in the second chamber falls below the limit pressure.

12. The camshaft adjuster as recited in claim **1** wherein the hydraulic fluid control device includes a first spring configured to move to allow the hydraulic fluid to flow through a first bypass line from the first chamber to the second chamber when the pressure in the second chamber falls below the limit pressure; and a second spring configured to move to allow the hydraulic fluid to flow through a second bypass line from the second chamber to the first chamber when the pressure in the first chamber falls below the limit pressure.

13. A vane-type camshaft adjuster comprising:

a rotor having radially projecting vanes, the rotor, together with a stator rotatably accommodating the rotor, forming vane cells, each vane cell divided by one of the vanes into a first adjustable chamber and a second adjustable chamber provided for accommodating hydraulic fluid,

a hydraulic fluid control device inside one of the vanes for conducting the hydraulic fluid between the first and second adjustable chambers being situated in such a way that a pressure drop in each of the first and second chambers is induced or amplified by camshaft alternating torques occurring during operation and is used to open the hydraulic fluid control device so that the hydraulic fluid flows therethrough,

the hydraulic fluid control device being configured such that the hydraulic fluid flows from the first chamber through the hydraulic fluid control device to the second chamber when a pressure in the second chamber falls below a limit pressure,

the hydraulic fluid control device being configured such that the hydraulic fluid flows from the second chamber through the hydraulic fluid control device to the first chamber when a pressure in the first chamber falls below the limit pressure,

wherein the limit pressure is a critical pressure at which air is sucked into the hydraulic fluid or at which the hydraulic fluid begins to degas.

14. The camshaft adjuster as recited in claim **13** wherein the hydraulic fluid control device includes a first spring is configured to move to allow the hydraulic fluid to flow through a first bypass line from the first chamber to the second chamber when the pressure in the second chamber falls below the limit pressure.

15. The camshaft adjuster as recited in claim **13** wherein the hydraulic fluid control device includes a second spring is configured to move to allow the hydraulic fluid to flow through a second bypass line from the second chamber to the first chamber when the pressure in the first chamber falls below the limit pressure.

16. A vane-type camshaft adjuster comprising:

a rotor having radially projecting vanes, the rotor, together with a stator rotatably accommodating the rotor, forming vane cells, each vane cell divided by a vane into two adjustable chambers provided for accommodating hydraulic fluid,

a hydraulic fluid control device for conducting the hydraulic fluid between the two chambers being situated in such a way that a pressure drop in the two chambers is induced or amplified by camshaft alternating torques occurring during operation and is used to open the hydraulic fluid control device so that the hydraulic fluid flows therethrough, and wherein two pistons movable toward and way from each other are situated in a channel or bore connecting the two chambers, the two pistons being situated in such a way that the two pistons are activated only by a pilot line assigned to each of the two pistons.

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