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STEPPED PISTON ELEMENT**(30) **Foreign Application Priority Data**

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(76) Inventors: **Norbert Alaze**, Markgroeningen
(DE); **Wolfgang Schuller**,
Cleebronn (DE); **Thomas Michl**,
Stuttgart (DE); **Frank Benkert**,
Tamm (DE); **Andreas Karl**,
Marbach/Neckar (DE); **Goekham**
Oezkan, Freiberg Am Neckar (DE);
Berthod Kaferstein, Mockmuhl
(DE)

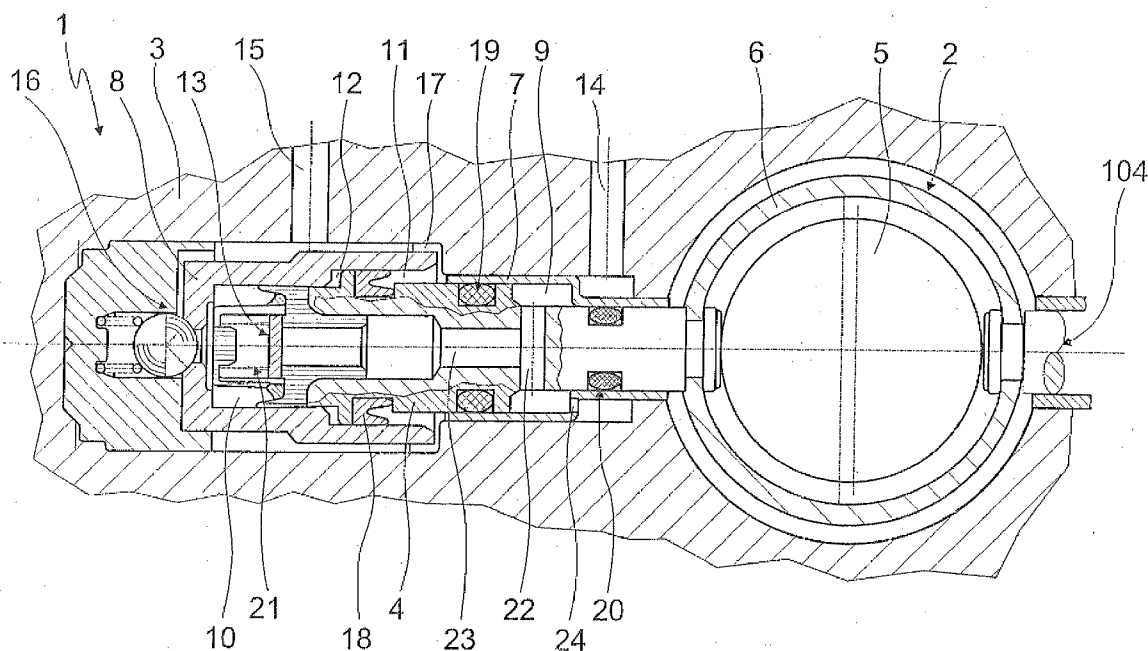
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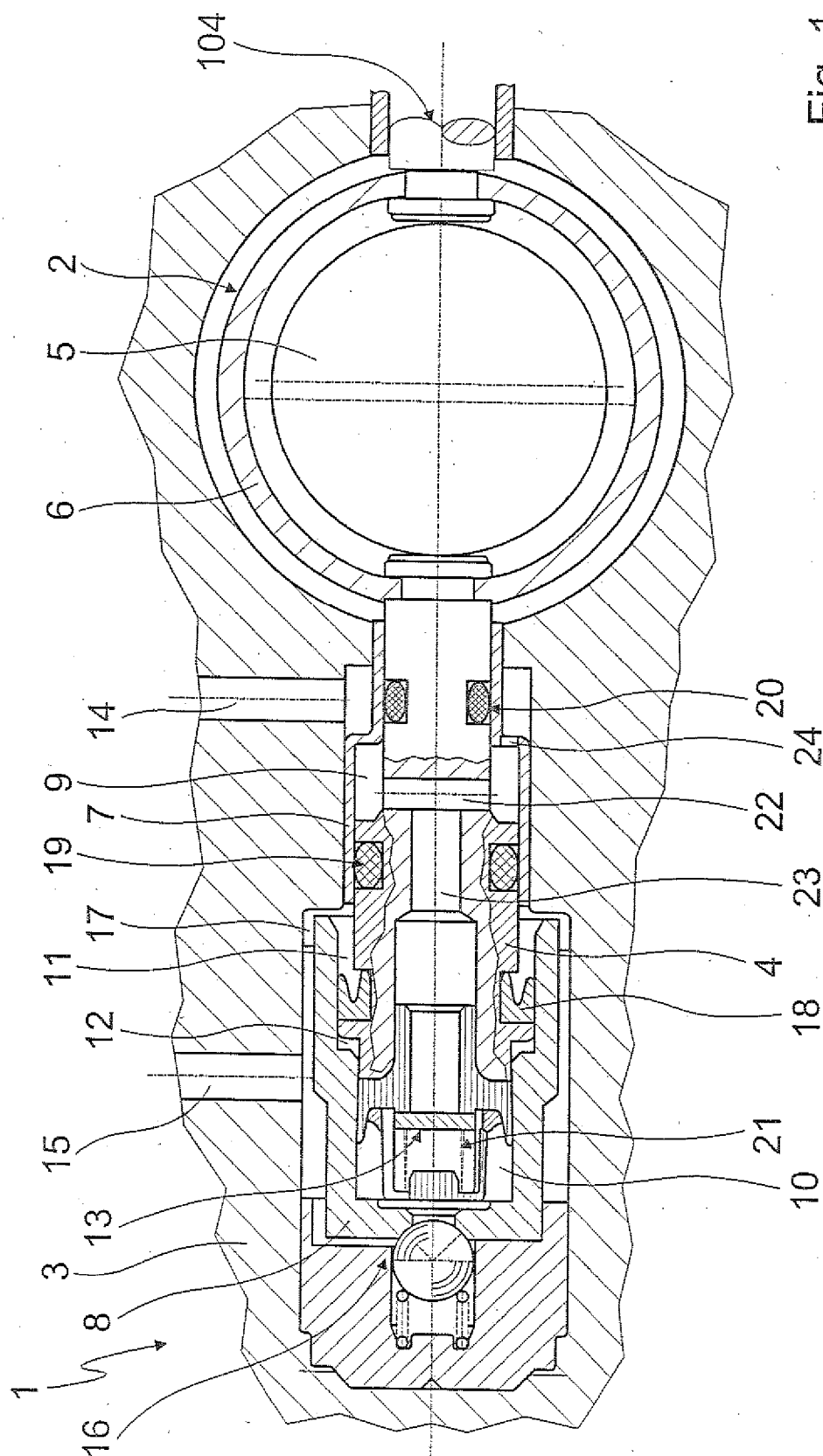
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(57) **ABSTRACT**

A piston pump with at least one driven stepped piston element disposed longitudinally movably in a housing is disclosed. The piston element and housing define a plurality of pressure chambers whose volumes vary as a function of the motion of the stepped piston. A volume of the first pressure chamber is decreased during an intake stroke of the piston that increases the volume of the second pressure chamber. A volume of a third pressure chamber, communicating with the pumping side and defined by the stepped piston element and the housing, is increased by a defined volumetric value during the compression stroke and decreased by the during the intake stroke; the defined volumetric value is less than the change in volume of the second pressure chamber during the compression stroke of the stepped piston element.

Correspondence Address:

RONALD E. GREIGG**GREIGG & GREIGG P.L.L.C.****1423 POWHATAN STREET, UNIT ONE
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PISTON PUMP WITH AT LEAST ONE STEPPED PISTON ELEMENT

PRIOR ART

[0001] The invention relates to a piston pump with at least one stepped piston element that can be driven via an eccentric device and is disposed longitudinally in a housing, as generically defined further by the preamble to claim 1.

[0002] From German Patent Disclosure DE 199 28 913 A1, a piston pump with a pump housing that has a pump bore and with a piston, disposed in the pump bore and drivable in the axial direction, is known. The piston is embodied as a stepped piston, and together with the pump housing it defines pressure chambers, which can be made to communicate via an inlet valve device for carrying fluid from a first pressure chamber, communicating with an intake region, into a second pressure chamber, and whose volumes vary as a function of a motion of the piston element. A volume of the first pressure chamber is decreased during an intake stroke of the piston that increases the volume of the second pressure chamber, while the volume of the first pressure chamber is increased during a compression stroke of the piston that decreases the volume of the second pressure chamber. During the compression stroke, the second pressure chamber communicates with a pumping side and is disconnected by the inlet valve device from the intake region or intake side of the piston pump.

[0003] The stepped embodiment of the piston on the intake side has the effect that the volumetric flow in the intake line is split with regard to the motion of the piston in the compression stroke, or during the compression stroke and during the intake stroke, and as a result the friction losses of the fluid in the outlet region of the piston pump are reduced, and better intake performance of the piston pump is achieved.

[0004] However, it is disadvantageous that fluid compressed by the piston pump only during the pressure stroke or the compression stroke of the piston is pumped out of the second pressure chamber to the pumping side of the piston pump, which because of the uneven pressure pulsation leads to unwanted noise production.

ADVANTAGES OF THE INVENTION

[0005] The piston pump of the invention is embodied with at least one stepped piston element that can be driven via a drive mechanism and is disposed longitudinally movably in a housing. The stepped piston element is operatively connected to the drive mechanism in such a way that via the operative connection, both tensile and compressive forces can be transmitted. The piston pump is furthermore embodied with two pressure chambers, each defined by the stepped piston element and the housing, which can be made to communicate via an inlet valve device for carrying fluid from a first pressure chamber, communicating with an intake region, into a second pressure chamber. In addition, the volumes of the two pressure chambers vary as a function of a motion of the piston element, and a volume of the first pressure chamber is decreased during an intake stroke of the stepped piston element that increases the volume of the second pressure chamber, and the volume of the first pressure chamber is decreased during a compression stroke of the stepped piston element that increases the volume of the second pressure chamber. The second pressure chamber can be made to communicate with a pumping side of the piston pump via an outlet valve device.

[0006] In addition, a volume of a third pressure chamber, communicating with the pumping side and defined at least by the stepped piston element and the housing, is increased by a defined volumetric value during the compression stroke of the stepped piston element and is decreased by the defined volumetric value during the intake stroke of the stepped piston element; the defined volumetric value is less in amount than the change in volume of the second pressure chamber during the compression stroke of the stepped piston element.

[0007] This leads according to the invention to a distribution of the volumetric fluid flow, pumped by the piston pump to the pumping side of the piston pump, to the intake stroke phase and the compression stroke phase of the stepped piston element. The distribution on the pumping side of the volumetric fluid flow causes a reduction in friction losses of the fluid in the lines on the pumping side of the piston pump, and as a result better pumping performance of the piston pump is attained, with less operating noise compared to conventional piston pumps.

[0008] In principle, with the design according to the invention of the piston pump, a volumetric flow on the pumping side of the piston pump can be attained that is more uniform over an operating cycle of the piston pump, with accordingly little operating noise, and using the piston pump of the invention in a vehicle brake system, such as an ESP system, EHB system, or the like, advantageously leads to an improvement in driving comfort.

[0009] Further advantages and advantageous features of the subject of the invention can be learned from the description, drawing and claims.

DRAWING

[0010] In the drawing, a preferred exemplary embodiment of a piston pump embodied according to the invention, which is described in further detail in the ensuing description, is shown in schematically simplified form.

[0011] The sole FIGURE of the drawing shows a piston pump of the invention in a schematic longitudinal sectional view.

DESCRIPTION OF THE EXEMPLARY EMBODIMENT

[0012] In the drawing, a piston pump **1**, with a stepped piston element **4** that can be driven via a drive mechanism **2** and is disposed longitudinally movably in a housing **3**, is shown in a fragmentary longitudinal section. In the present instance, the drive mechanism **2** is embodied as an eccentric device, so that the stepped piston element **4** is adjusted in the axial direction between two terminal positions, that is, top dead center and bottom dead center, as a function of a rotary motion of an eccentric shaft **5**, preferably driven by an electric motor, not shown further.

[0013] By one end, the end oriented toward the drive mechanism **2**, the stepped piston element **4** is connected to an eccentric ring **6**, so that the stepped piston element **4** is operatively connected to the drive mechanism **2** in such a way that via the operative connection, both tensile and compressive forces can be transmitted. The region of the stepped piston element **4** that the eccentric ring **6** extends through is embodied with a reduced outer diameter, both relative to the region of the stepped piston element **4** that is disposed on the side of the eccentric ring **6** remote from the eccentric shaft **5**, and relative to the region of the stepped piston element **4** that is

disposed on the side of the eccentric ring 6 oriented toward the eccentric shaft 5. The operative connection is thus established by positive engagement between the stepped piston element 4 and the eccentric ring 6.

[0014] With respect to the stepped piston element 4, a further stepped piston element 104 of a further piston pump, which in principle has the same construction as the piston pump 1 and is intended to supply a further pressure circuit of a vehicle brake system as needed, is located on the opposite side of the eccentric shaft 5, and this further piston element is connected to the drive mechanism 2 in the same manner as the stepped piston element 4 and is phase-offset by 180° from the piston element 4 of the drive mechanism 2.

[0015] Furthermore, jointly with a guide sleeve 7 structurally connected to the housing and an insert element 8 fixed to the housing, the housing 3 and the stepped piston element 4 define a plurality of pressure chambers 9 through 12. A first pressure chamber 9, operatively connected to an intake region 14 of the piston pump 1, can be made to communicate with a second pressure chamber 10 via an inlet valve device 13 in order to deliver the hydraulic fluid, aspirated from the intake region 14 of the piston pump, to a pumping side 15 of the piston pump 1, for instance to a pressure circuit of a vehicle brake system.

[0016] The volumes of the pressure chambers 9 through 12 each vary as a function of the motion of the stepped piston element 4; a volume of the first pressure chamber 9 is decreased during an intake stroke of the stepped piston element 4 that increases the volume of the second pressure chamber 10, and is decreased during a compression stroke of the stepped piston element 4 that increases the volume of the second pressure chamber.

[0017] To make the pressure buildup required for the functioning of the piston pump possible in the second pressure chamber 10, the inlet valve device 13 is closed during the compression stroke of the stepped piston element 4. Once a predefined pressure value in the second pressure chamber 10 is reached, an outlet valve device 16, which in the closed state disconnects the second pressure chamber 10 from the pumping side 15 of the piston pump, is opened, and the fluid, compressed during the compression stroke of the piston element 4 from its bottom dead center in the direction of its top dead center, is pumped out of the second pressure chamber 10 in the direction of the pumping side 15 of the piston pump 1.

[0018] A third pressure chamber 11 is furthermore defined by the stepped piston element 4, the insert element 8, and the housing 3; it communicates permanently with the pumping side 15 via slits 17 in the guide sleeve 7.

[0019] In addition, between the insert element 8 and the stepped piston element 4, a fourth pressure chamber 12 is provided, which is sealed off from the third pressure chamber 11 by means of a so-called overflow cuff 18. The third pressure chamber 11 is in turn sealed off from the first pressure chamber 9, in the region between the guide sleeve 7 and the stepped piston element 4, via a sealing device 19 and, between the housing 3 and the guide sleeve 7, via a sealing partial press fit between the guide sleeve 7 and the housing 3. The first pressure chamber 9 and the intake region 14 of the piston pump 1 are furthermore sealed off from the drive mechanism 2 via a sealing device 20, disposed between the stepped piston element 4 and the guide sleeve 7, and a press fit between the guide sleeve 7 and the housing 3.

[0020] The advantageous mode of operation of the embodiment of the piston pump 1 of the invention will now be described in further detail in the following description:

[0021] If the stepped piston element 4, beginning at its bottom dead center, in which the first pressure chamber 9, which in the present instance is embodied as an annular chamber defined by the guide sleeve 7 and the stepped piston element 4, has its most-minimal volume, moves in the direction of its top dead center in which the first pressure chamber 9 has its maximum volume, the volume of the second pressure chamber 10 is decreased increasingly. The pressure in the second pressure chamber 10 rises in the process. During this phase, the inlet valve device 13 is closed, because of the spring force of a spring device 21 and because of the positive pressure drop between the second pressure chamber 10 and the first pressure chamber 9, which communicate when the inlet valve device 13 is open via a transverse bore 22 and a longitudinal bore 23 of the stepped piston element 4.

[0022] This means that during a compression stroke of the stepped piston element 4, the volume of the second pressure chamber 10 is decreased, and the volume of the first pressure chamber 9, which communicates with the intake region 14 of the piston pump 1 via at least one bore 24 of the guide sleeve 7, is increased. The area ratios of the piston steps of the stepped piston element 4 are dimensioned such that the change in volume of the first pressure chamber 9 corresponds to approximately half the change in volume of the second pressure chamber 10 during a compression stroke of an intake stroke of the stepped piston element 4.

[0023] As a result, it is attained that both during a compression stroke and during an intake stroke of the stepped piston element 4, half the stroke volume of the piston pump 1 is carried from the intake side in the direction of the second pressure chamber 10. During the intake stroke of the stepped piston element 4, the other half of the stroke volume from the first pressure chamber 9 that is to be carried in the direction of the second pressure chamber 10 is used for completely filling the second pressure chamber 10.

[0024] Simultaneously, the volume of the third pressure chamber 11, communicating with the pumping side 15 of the piston pump 1, varies during the compression stroke or the intake stroke of the stepped piston element 4 by approximately half the stroke volume of the piston pump 1 or of the change in volume of the second pressure chamber 10. The volume of the third pressure chamber 11 is increased by half the stroke volume of the second pressure chamber 10 during the compression stroke of the piston element 4 and decreased by half the stroke volume of the second pressure chamber 10 during an intake stroke of the stepped piston element 4.

[0025] As a consequence, during the intake stroke of the stepped piston element 4, during which the outlet valve device 16 is closed, no fluid from the second pressure chamber 10 is carried in the direction of the pumping side 15 of the piston pump 1, and the volume of the third pressure chamber 11 is decreased, despite the fact that pumping of hydraulic fluid to consumers communicating with the pumping side 15 of the piston pump 1 takes place.

[0026] Because of the disposition of the third pressure chamber 11, it is additionally accomplished that during the compression stroke of the stepped piston element 4, in which the full stroke volume of the second pressure chamber 10 is carried via the opened outlet valve device 16 in the direction of the pumping side 15, only half the stroke volume of the second pressure chamber 10 is pumped to the consumers that

communicate with the pumping side 15. This is due to the fact that the other half of the stroke volume of the second pressure chamber 10 that is pumped is received in the third pressure chamber 11, which is increased at the end of the compression stroke of the stepped piston element 4 by half the stroke volume of the second pressure chamber 10, and is temporarily stored during the intake stroke of the piston element 4 for the above-described pumping, on the pumping side of the piston pump, of hydraulic fluid.

[0027] As a function of the motion of the stepped piston element 4, an underpressure or a slight overpressure builds up in the fourth pressure chamber 12, depending on the motion of the stepped piston element 4. If the fourth pressure chamber 12, during the operation of the piston pump, is filled with fluid—brake fluid, when the piston pump is used in the brake system—by way of the sealing leakage originating in the second pressure chamber 10, then the possibly excess volume in the fourth pressure chamber 12 is rescinded via the overflow cuff 18 in the direction of the third pressure chamber 11.

1-12. (canceled)

13. In a piston pump having at least one stepped piston element, drivable via a drive mechanism and disposed longitudinally movably in a housing, which element is operatively connected to the drive mechanism in such a way that via the operative connection, both tensile and compressive forces can be transmitted, and having at least two pressure chambers each, which can be made to communicate via an inlet valve device for carrying fluid out of the first pressure chamber, connected to an intake region, into the second pressure chamber and whose volumes vary as a function of a motion of the stepped piston element, and a volume of the first pressure chamber is decreased during an intake stroke of the stepped piston element that increases the volume of the second pressure chamber the volume of the first pressure chamber being decreased during a compression stroke of the stepped piston element that increases the volume of the second pressure chamber, and the second pressure chamber can be made to communicate with a pumping side via an outlet valve device, the improvement wherein a volume of a third pressure chamber, communicating with the pumping side and defined at least by the stepped piston element and the housing, is increased by a defined volumetric value during the compression stroke of the stepped piston element and is decreased by the defined volumetric value during the intake stroke of the stepped piston element, and where the defined volumetric value is less in amount than the change in volume of the second pressure chamber during the compression stroke of the stepped piston element.

14. The piston pump as defined by claim 13, further comprising a stepped guide sleeve between the stepped piston element and the housing, which stepped guide at least partly represents a boundary of the first pressure chamber relative to the intake region.

15. The piston pump as defined by claim 14, further comprising a bore in the guide sleeve providing communication between the first pressure chamber and the intake region.

16. The piston pump as defined by claim 14, wherein the guide sleeve at least partly represents a boundary of the third pressure chamber relative to the pumping side.

17. The piston pump as defined by claim 15, wherein the guide sleeve at least partly represents a boundary of the third pressure chamber relative to the pumping side.

18. The piston pump as defined by claim 14, further comprising at least one slit in the guide sleeve, third pressure chamber communicating with the pumping side via the at least one slit.

19. The piston pump as defined by claim 15, further comprising at least one slit in the guide sleeve, third pressure chamber communicating with the pumping side via the at least one slit.

20. The piston pump as defined by claim 16, further comprising at least one slit in the guide sleeve, third pressure chamber communicating with the pumping side via the at least one slit.

21. The piston pump as defined by claim 13, further comprising an insert element fixed relative to the housing and the stepped piston element and defining the second pressure chamber.

22. The piston pump as defined by claim 14, further comprising an insert element fixed relative to the housing and the stepped piston element and defining the second pressure chamber.

23. The piston pump as defined by claim 18, further comprising an insert element fixed relative to the housing and the stepped piston element and defining the second pressure chamber.

24. The piston pump as defined by claim 23, wherein the third pressure chamber is defined by the stepped piston element, the guide sleeve, and the insert element.

25. The piston pump as defined by claim 14, wherein the guide sleeve is fixed via a partial press fit in the housing that seals off the intake region from the pumping side.

26. The piston pump as defined by claim 21, further comprising a fourth pressure chamber is defined by the stepped piston element and the insert element, and an overflow cuff sealing off the fourth pressure chamber from the third pressure chamber, and wherein the volume of the fourth chamber varies as a function of the motion of the stepped piston element.

27. The piston pump as defined by claim 24, further comprising a fourth pressure chamber is defined by the stepped piston element and the insert element, and an overflow cuff sealing off the fourth pressure chamber from the third pressure chamber, and wherein the volume of the fourth chamber varies as a function of the motion of the stepped piston element.

28. The piston pump as defined by claim 26, wherein the overflow cuff is embodied with a sealing function such that a positive pressure drop between the fourth pressure chamber and the third pressure chamber can be rescinded via the overflow cuff in the direction of the third pressure chamber.

29. The piston pump as defined by claim 13, wherein the defined volumetric value by which the volume of the third pressure chamber varies as a function of the motion of the stepped piston element corresponds at least approximately to half the amount of the change in volume of the second pressure chamber.

30. The piston pump as defined by claim 14, wherein the defined volumetric value by which the volume of the third pressure chamber varies as a function of the motion of the stepped piston element corresponds at least approximately to half the amount of the change in volume of the second pressure chamber.

31. The piston pump as defined by claim 13, wherein the area ratios of the operative end faces of the stepped piston element are provided such that the volume of the first pressure

chamber that is established as a function of the motion of the stepped piston element varies at least approximately by half the amount of the change in volume of the second pressure chamber.

32. The piston pump as defined by claim **14**, wherein the area ratios of the operative end faces of the stepped piston

element are provided such that the volume of the first pressure chamber that is established as a function of the motion of the stepped piston element varies at least approximately by half the amount of the change in volume of the second pressure chamber.

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