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(54) **Piston compressor for compressing gas**

(57) A horizontal piston compressor having at least one first cylinder end (3), a piston (10), a piston rod passage (7) and a piston rod (30) being connected to a reciprocating piston (10) and extending through the piston rod passage (7), a stuffing box (50) arranged at the first cylinder end (3) that the piston rod (30) extends there through and that comprise one or more packing rings (51) engaging the piston rod (30) and providing a seal therewith, a piston rod external surface liquid cooling system with a piston rod cooling unit (60) arranged adjacent to a side of the one or more packing rings (51). Cooling

liquid passes through a cooling liquid supply channel to an annular space (77) between the ring member (75) and the piston rod (30). Buffer gas seals (105) being provided in the piston rod cooling unit (60) delimiting an annular buffer gas space (104) at each axial end of the annular space (77). The cooling unit (60) is provided with one or more buffer gas supply channels (102) to supply a buffer gas thereto, the cooling system comprising a source (100) of pressurized buffer gas for establishing a buffer gas pressure in each buffer gas space (104).

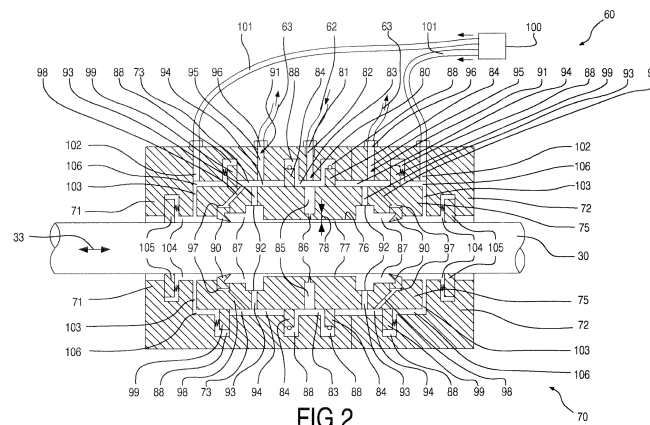


FIG.2

Description

[0001] The invention pertains to a piston compressor for compressing gas, in particular to a piston compressor in which the cylinder that comprises the compression chamber is arranged substantially horizontally.

[0002] In piston compressors, the piston rod extends from the compression chamber through a piston rod passage the cylinder end. Generally, a stuffing box with packing rings is provided to reduce the leakage of high pressure gas from the compression chamber via the piston rod passage in the cylinder end. The packing rings have to provide this reduction of leakage under difficult circumstances: the pressure difference between the compression chamber and the environment outside the cylinder generally is high and the piston rod reciprocates through the packing rings, generally at a high speed.

[0003] In order to obtain a good seal, the packing rings have to be in contact with the piston rod. In many cases, a force is applied to the packing rings, which force pushes the packing rings tightly against the piston rod. Such a force can for example be applied by circular springs or by means of a gas pressure. With such a design, higher pressure differences between the compression chamber and the environment outside the cylinder can be handled by the packing rings.

[0004] The downside of this design is that the harder the packing rings are pushed against the piston rod, the more friction occurs between the packing rings and the piston rod. This friction makes that the piston rod is heated up and that the piston rod and the packing rings suffer from an increase in wear. In piston gas compressors in which the piston rod is arranged substantially horizontal, the problem of friction between the packing rings and the piston rod is even larger than in piston compressors with a vertical piston rod, because the horizontal piston rod bends under the influence of gravity. Furthermore, in particular when the rider rings of the piston wear, a slight tilting of the piston rod occurs, leading to increased friction on one side of the piston rod.

[0005] It has been proposed to lubricate the piston rod in the vicinity of the packing rods to reduce the friction. For many applications this however does not provide an acceptable solution because some of the lubricant will adhere to the piston rod. The piston rod will therewith introduce lubricant into the compression chamber. This is not always acceptable, for example when the compressor is used for compressing a dry gas and/or in cases where a non-lubricated piston compressor, such as a floating piston compressor of the type described in EP0839280, is applied.

[0006] US 3,194,568 discloses the cooling of a piston rod inside the stuffing box. The stuffing box comprises a channel that brings water to an annular space in the stuffing box that is present around the piston rod. Seals are provided on both axial ends of this annular space to keep most of the water in the annular space. Some water will adhere to the piston rod and slip through the seals. Ac-

cording to the disclosure of US 3,194,568, this water will evaporate due to the elevated temperature of the piston rod and then disappear through venting holes that are provided in the stuffing box.

[0007] Practice has shown that the cooling capacity of such a design is limited and that it can only be used in combination with a limited number of types of cooling liquid.

[0008] The invention aims to provide a piston compressor with a piston rod external surface cooling system.

[0009] According to the invention, a horizontal piston compressor for compressing gas in accordance with claims 1 and 18 is provided.

[0010] In the horizontal piston compressor according to the invention, a piston rod external surface cooling system is provided that comprises a piston rod cooling unit that is arranged adjacent the side of the set of one or more packing rings remote from the first compression chamber and a cooling liquid source that is adapted to provide a flow of cooling liquid to the cooling unit. The piston rod extends through the piston rod cooling unit.

[0011] The piston rod cooling unit has a housing and a ring member. The ring member has a bore through which the piston rod extends. The diameter of said bore is larger than the diameter of the piston rod, such that an annular space is present between the piston rod and the ring member. The ring member is arranged in the housing.

[0012] In a possible embodiment, the diameter of the bore is about 0,2 to 0,5 mm larger than the diameter of the piston rod. In a possible embodiment, the diameter of the bore is about 0,3 mm larger than the diameter of the piston rod.

[0013] The ring member is movably supported relative to the housing in a manner that allows for motions of the ring member in radial directions that follow and/or compensate for piston rod motions and deflections in radial directions in order to maintain the annular space between the piston rod and the ring member. This allows to maintain an annular region of flowing cooling liquid about the piston rod at the location of the ring member and prevents undesirable contact between the ring member and the piston rod.

[0014] The piston rod cooling unit further comprises a cooling liquid supply channel, which extends from an inlet thereof to one or more supply ports in communication with the bore. The cooling liquid supply channel is adapted to pass the cooling liquid to the annular space between the ring member and the piston rod, thereby allowing to establish a flow of cooling liquid in contact with the external surface of the piston rod and through said annular space causing the removal of heat from the external surface of the piston rod. The flowing cooling liquid cools the surface of the piston rod.

[0015] When operated in a suitable manner the cooling liquid in the annular space between the piston rod and the ring member can be seen to exert a hydrostatic pressure between the piston rod and the ring member. This

hydrostatic pressure helps to center the ring member around the piston rod, resulting in the size of the annular space between the piston rod and the ring member being at least substantially constant around the circumference of the piston rod.

[0016] In an alternative, less preferred, embodiment, it is envisaged to use a cooling gas instead of a cooling liquid. Such a cooling gas can also be used to center the ring member around the piston rod. The cooling gas can be a gas flow that is diverted from the main gas flow through the compressor, or it can come from a separate source.

[0017] In a possible embodiment, the cooling unit is provided with axially spaced apart cooling liquid seals that sealingly engage on the piston rod. It is advantageous if these cooling liquid seals also have a scraper function, to scrape cooling liquid from the piston rod that reciprocates relative to these seals. The cooling liquid seals can be provided in the ring member or in a separate ring. The cooling liquid is introduced into the annular space in between the cooling liquid seals. In this embodiment, the cooling unit further comprises at least one cooling liquid discharge channel, which extends from one or more discharge ports in communication with the bore to an outlet so as to discharge said cooling liquid from the annular space between the piston rod and the ring member. In this embodiment, the flow rate can be controlled more accurately. The liquid discharge channel or channels can be arranged in the ring member and the housing, or in a separate ring. This separate ring can be the same ring that holds a cooling liquid sealing ring, or it can be an entirely separate ring.

[0018] In a variant of this embodiment, each cooling liquid seal is a sealing ring that is received in a corresponding groove in the ring member or in a separate ring. Preferably, this sealing ring is received in the groove with radial play. This allows relative radial motion of the ring member with respect to the sealing ring. Preferably the ring member or the separate ring that holds the cooling liquid sealing ring is provided with a duct connecting the radial play region to the cooling liquid discharge channel. This prevents the build up of a pressure by cooling liquid in the groove which the seal is arranged.

[0019] In a further variant, the cooling unit is provided - near a or each cooling liquid seal - with one or more respective buffer gas seals that delimit an annular buffer gas space at each axial end of the annular space between the piston rod and the ring member through which the cooling liquid is made to flow. To this end, the cooling unit is provided with one or more buffer gas supply channels, which extend from a buffer gas inlet to each annular buffer gas space to supply a buffer gas thereto. The cooling unit further comprises a source for pressurized buffer gas that is adapted to establish a buffer gas pressure in each buffer gas space.

[0020] The buffer gas space acts to counter the entraining of cooling liquid on the external surface from the piston rod to outside the cooling unit. This is for example

achieved by providing the buffer gas in the buffer gas space with a pressure that is higher than the pressure of the cooling liquid in the annular space between the piston rod and the ring member. The higher pressure of the buffer gas in the buffer gas space will prevent cooling liquid to flow from the annular space between the piston rod and the ring member to the buffer gas space. Preferably, on each axial end of the annular space between the piston rod and the ring member, a buffer gas space is present. This way, leakage of cooling liquid via the cooling liquid seal or the piston rod is reduced or even prevented.

[0021] In a possible embodiment, the cooling unit housing is a tubular housing, and wherein the ring member is arranged within a portion of said housing having an inner diameter that is greater than the outer diameter of the ring member such that an annulus is present between the ring member and the housing. This annulus can be used to make that the ring member of the cooling unit can be moved relative to the housing. The annulus can for example be filled with an elastic material, or it can be used to accommodate spring member in. It is also possible to fill it with a fluid. In this embodiment preferably, the housing of the cooling unit comprises spaced apart end portions between which the ring member is retained in axial direction.

[0022] In a variant of this embodiment, spaced apart seal members are present in said annulus between the housing and the ring member. Those seal members form at least one of a cooling liquid supply space and a cooling liquid discharge space in said annulus. In this variant, at least one of the inlet and the outlet for cooling liquid is provided in the housing of the cooling unit. The cooling liquid supply channel is partly formed by said cooling liquid supply space and/or the cooling liquid discharge channel is partly formed by the cooling liquid discharge space. In this embodiment, the annulus is filled with cooling liquid. The cooling liquid in the annulus allows the ring member to move relative to the housing and helps to center the ring member in the housing.

[0023] In a possible embodiment, the one or more supply ports of the cooling liquid supply channel that open out into the bore are arranged in the ring member, located centrally between the axial ends of the ring member. In this embodiment, discharge ports are arranged in the ring member at spaced apart locations at opposite sides from the one or more centrally arranged supply ports. This allows that annular flow of cooling liquid generally in opposed axial directions is caused in the annular cooling liquid space. In this embodiment, the liquid is in contact with the piston rod over a relatively short distance. This has the effect that the temperature difference between the cooling liquid and the piston rod remains larger, so a higher level of cooling of the piston rod can be obtained.

[0024] In a variant to this embodiment, the bore of the ring member has a central portion of a smallest diameter and the one or more supply ports are located in said central portion. Furthermore, the bore of the ring member

has at either axial end of said central portion a discharge portion of a greater diameter and the one or more discharge ports are located in said discharge portions. This allows an advantageous flow profile to be obtained for the cooling liquid.

[0025] In a possible embodiment, a supply port is formed by an orifice opening forming a flow restriction for the cooling liquid through the cooling liquid supply channel. This allows a good control of the flow of cooling liquid into the cooling unit and contributes to an advantageous flow profile.

[0026] In a possible embodiment, the cooling system further comprises a closed cooling liquid circulation system including a pump for providing flow of the cooling liquid and a heat exchanger adapted to cool the cooling liquid. The pump can also be used to obtain a desired cooling liquid pressure in the annular space between the piston rod and the ring member. This is particularly useful when the pressure of the cooling liquid is used for centering the ring member around the piston rod.

[0027] In the piston compressor according to claim 18, the cooling unit is provided with axially spaced apart cooling liquid seals that sealingly engage on the piston rod. It is advantageous if these cooling liquid seals also have a scraper function, to scrape cooling liquid from the piston rod that reciprocates relative to these seals. The cooling liquid seals can be arranged in the ring member or in a separate ring. The cooling liquid is introduced into the annular space in between said cooling liquid seals. The cooling unit further comprises at least one cooling liquid discharge channel, which extends from one or more discharge ports in communication with the bore to an outlet so as to discharge said cooling liquid from the annular space between the piston rod and the ring member. The cooling unit is further provided - near a or each cooling liquid seal - with one or more respective buffer gas seals that delimit an annular buffer gas space at each axial end of the annular space wherein the cooling liquid is made to flow. The cooling unit is further provided with one or more buffer gas supply channels, which extend from a buffer gas inlet to each annular buffer gas space to supply a buffer gas thereto. The cooling system also comprises a source for pressurized buffer gas that is adapted to establish a buffer gas pressure in each buffer gas space, said buffer gas space acting to counter the entraining of cooling liquid on the external surface from the piston rod to outside the cooling unit.

[0028] The piston compressor according to claim 18 can be used with a ring member that is movably supported relative to the housing such as to allow for motions of the ring member in radial directions that follow and/or compensate for piston rod motions and deflections in radial directions in order to maintain the annular space, but it can also be used with an other type of ring member, for example a ring member which is fixed and stationary mounted in the housing.

[0029] In a possible embodiment, the compressor has a floating piston, preferably as described in EP0839280.

Preferably at least one rider ring element is fitted around at least the bottom of the piston body and projects beyond the periphery of the piston body, the rider ring element being made of a material suitable for direct frictional contact with the cylinder. The piston compressor comprises a source which continuously delivers a gas under pressure, e.g. via one or more valves passing pressurized gas into a chamber inside the piston. Conduit means are provided that are connected to the source and open out at at least one outflow opening provided in the rider ring element for supplying the gas coming from the source to a position between the rider ring element and the cylinder, the position of the at least one outflow opening and the pressure of the gas supplied from the source being such that gas supplied to a position between the rider ring element and the cylinder constantly exerts an upward force on the piston.

[0030] The invention will be explained in more detail under referral to the drawing, in which non-limiting embodiments of the invention are shown. The drawing shows in:

Fig. 1: a horizontal piston compressor,

Fig. 2: an embodiment of a cooling unit in accordance with the invention,

Fig. 3: a second embodiment of a cooling unit in accordance with the invention,

Fig. 4: an embodiment of a cooling system according to the invention,

Fig. 5: different ways of mounting the cooling unit onto the piston rod.

[0031] Fig. 1 shows a side view of a horizontal piston compressor. The compressor comprises a frame 1, in or to which other parts of the compressor are mounted.

[0032] The piston comprises a cylinder 2. The cylinder 2 has a first cylinder end 3 and a second cylinder end 4. The first cylinder end 3 and the second cylinder end 4 are each arranged at an axial end of the cylinder 2. The first cylinder end 3 comprises a piston rod passage 7.

[0033] The cylinder 2 further has a cylinder wall 5 and a longitudinal axis 6.

[0034] In the cylinder 2, a piston 10 is arranged. The piston 10 is reciprocable in the cylinder 2, which means that it can move back and forth inside the cylinder 2 along the longitudinal axis 6 of the cylinder 2.

[0035] In traditional piston compressors, the piston is lubricated by a liquid lubricant (e.g. oil) such that metal-to-metal contact between the piston and the cylinder wall is prevented. In a more modern design, no oil lubrication is necessary between the piston and the cylinder wall. Such piston compressors, in which there is no oil lubrication between the piston and the cylinder wall are referred to as non-lubricated compressors. Such compressors however could comprise parts, for example rider rings that extend around the piston, that contain a solid lubricant such as molybdenum disulfide. A special kind of non-lubricated compressors are the so called "floating

piston compressors". In such compressors, a gas film between the piston and the cylinder wall is present to prevent metal-to-metal contact between the piston and the cylinder wall. Examples of a floating piston compressor are described in EP0839280.

[0036] At least one compression chamber is present in the cylinder 2. Each compression chamber is delimited on one axial end by the piston and on the opposite axial end by a cylinder end. In the embodiment of fig. 1, the piston compressor comprises two compression chambers 11, 21.

[0037] Each compression chamber has an inlet port 12, 22 and an outlet port 13, 23. In each compression chamber inlet port 12, 22, an inlet valve 14, 24 is arranged. In each compression chamber outlet port 13, 23, an outlet valve 15, 25 is arranged. The valves 14, 24, 15, 25 are controlled in such a way that when the inlet valve 14, 24 of a compression chamber 11, 21 is open, the outlet valve 15, 25 of that same compression chamber is closed, and that when the outlet valve 15, 25 of a compression chamber 11, 21 is open, the inlet valve 14, 24 of that same compression chamber is closed.

[0038] The piston 10 is mounted on piston rod 30. The piston rod has a first end 31 and a second end 32. In the embodiment shown in fig. 1, the piston 10 is connected to the first end 31 of the piston rod 30. In an alternative embodiment (not shown), the piston rod can extend beyond the piston 10 into pressure chamber 11 and through a passage in the second cylinder end 4.

[0039] In the embodiment of fig. 1, the piston rod 30 extends through a distance piece 35 in the frame 1 to the drive assembly 40. In this embodiment, the second end 32 of the piston rod 30 is connected to crosshead 41. In use, the crosshead reciprocates inside the distance piece 35 of frame 1.

[0040] The crosshead 41 is driven by connecting rod 42. The connecting rod 42 has a first end 43 and a second end 44. The first end 43 of the connecting rod 42 is connected to the crosshead 41, while the second end 44 of the connecting rod 42 is connected to crank shaft 45. In use, the crank shaft 45 rotates. The connection rod 42 transforms this rotation into a translation, and therewith drives the reciprocating movement of the crosshead 41.

[0041] Where the piston rod 30 leaves the cylinder 2 via piston rod passage 7 in the cylinder cover 3, a good seal is important to prevent the escape of gas from the pressure chamber 21 via the piston rod passage 7. This seal is provided by stuffing box 50, which is only schematically shown in fig. 1. Piston rod 30 extends through stuffing box 50.

[0042] In the stuffing box 50, packing rings 51 are present for the actual sealing. The packing rings 51 reduce or even prevent leakage of gas from the compression chamber 21 over the surface of the piston rod. For an effective seal, the packing rings 51 have to fit tightly around the piston rod 30. This causes friction between the packing rings 51 and the piston rod 30, and therewith heating of the piston rod.

[0043] In the embodiment shown in fig. 1, two sets of multiple packing rings are present in the stuffing box. As the skilled person will understand, any other number of packing rings is possible.

5 **[0044]** In the embodiment of fig. 1, the piston rod 30 extends through just one of the cylinder ends. In an alternative embodiment, where the piston rod extends through both cylinder ends, there are two stuffing boxes present, each for sealing one piston rod passage.

10 **[0045]** The horizontal piston compressor of fig. 1 is provided with a piston rod external surface cooling system for cooling the surface of the piston rod. This piston rod external surface cooling system comprises a piston rod cooling unit 60. In the embodiment shown in fig. 1, the cooling unit 60 is arranged outside the stuffing box 50 that contains the packing rings, and not connected to the stuffing box 50. In alternative embodiments (not shown), the cooling unit can be connected to the outside of the stuffing box or arranged inside the stuffing box.

20 **[0046]** The piston rod cooling unit 60 is preferably arranged adjacent the packing ring or packing rings, because that is where the piston rod is heated up, due to the friction between the packing rings and the piston rod.

25 **[0047]** The piston rod external surface cooling system further comprises a cooling liquid source 61. The cooling liquid source 61 is connected to the piston rod cooling unit 60 by at least one cooling liquid flow line 62. This first cooling liquid flow line 62 takes cooling liquid from the cooling liquid source 61 to the piston rod cooling unit 60. Preferably, also a second cooling liquid flow line 63 is present, which takes cooling liquid from the piston rod cooling unit 60 back to the cooling liquid source 61.

30 **[0048]** Fig. 2 shows an embodiment of a piston rod cooling unit 60 according to the invention. Piston rod 30 extends through the piston rod cooling unit 60, so that the cooling unit can act directly on the surface of the piston rod 30. It is quite common to make piston rods out of stainless steel. Stainless steel is not such a good heat conductor, so a significant portion of the heat that is created at the surface of the piston rod, remains present at the surface of the piston rod instead of dissipating to the core of the piston rod.

35 **[0049]** The piston rod 30 reciprocates through the piston rod cooling unit 60 in accordance with arrow 33.

40 **[0050]** The piston rod cooling unit 60 comprises a housing 70, which in the embodiment of fig. 2 is made up of a first housing ring 71 and a second housing ring 72. Using two or more housing rings that together form the housing 70 allows an easy mounting of the cooling unit onto the piston rod. Inside the housing 70, a ring member 75 is present. For easy mounting, the ring member 75 and the housing rings 71, 72 are made up out of two or more ring segments. The housing rings 71, 72 are mounted in such a way that they cannot move relative to each other.

50 **[0051]** In the embodiment shown in fig. 2, the outer diameter of the ring member is smaller than the inner diameter of the housing rings 71, 72 where the housing

rings 71, 72 extend over the ring member 75. This creates an annulus 73 between the outer diameter of the ring member 75 and the inner diameter of the housing rings 71, 72 at the part where they extend over the ring member 75. This annulus 73 makes relative movement in radial directions of the ring member 75 with respect to the tubular housing 70 possible.

[0052] The ring member 75 comprises a bore 76. When the piston rod cooling unit 60 is mounted to the piston rod of a piston compressor, the piston rod 30 extends through this bore 76.

[0053] The diameter of the bore 76 is larger than the outside diameter of the piston rod 30, or at least larger than the outside diameter of the part of the piston rod 30 that reciprocates through the piston rod cooling unit 60. The difference between the diameter of the bore and the diameter of the piston rod makes that an annular space 77 is present between the ring member 75 and the piston rod 30. If the piston rod 30 is perfectly centered in the bore 77, the distance 78 between the piston rod 30 and the surface of the bore 76 is the same over the entire circumference of the bore.

[0054] The diameter of the bore 76 can vary over the length of the bore, e.g. in the form of a stepwise variation, but the diameter can also be constant over the length of the bore.

[0055] In a possible embodiment, the difference between the diameter of the bore 76 and the diameter of the piston rod 30 is between 0,1 mm and 0,6 mm at the portion of the bore 76 that has the smallest diameter. In an alternative embodiment, the difference between the diameter of the bore 76 and the diameter of the piston rod 30 is between 0,2 mm and 0,4 mm at the portion of the bore 76 that has the smallest diameter. In a further alternative embodiment, the difference between the diameter of the bore 76 and the diameter of the piston rod 30 is about 0,3 mm at the portion of the bore 76 that has the smallest diameter.

[0056] The piston rod cooling unit 60 further comprises a cooling liquid supply channel 80. This cooling liquid supply channel has an inlet 81, which receives cooling liquid from the cooling liquid source via cooling liquid flow line 62.

[0057] Channel 82 allows the cooling liquid to flow through the housing ring 71. From channel 82, the cooling liquid comes into cooling liquid supply space 83, between the housing ring 71 and the ring member 75. The cooling liquid supply space 83 forms part of the annulus 73 between the ring member 75 and the housing rings 71, 72. In use, the annulus can be empty, or filled with cooling liquid, or partly filled with cooling liquid, entirely or partly filled with a buffer gas or any other type of gas, or it can accommodate elastic members and/or seals.

[0058] The cooling liquid supply space 83 is sealed on its two axial ends by seals 84. The seals 84 make that the cooling liquid flows from the cooling liquid supply space 83 to channel 85 in the ring member 75, and does not escape before having reached the annular space 77

between the ring member 75 and the piston rod 30.

[0059] Channel 85 in the ring member 75 allows the cooling liquid to flow from the cooling liquid supply space 83 to supply port 86, which is in fluid communication with the bore 76 of the ring member 75. From the supply port 86, the cooling liquid enters the annular space 77 between the ring member 75 and the piston rod 30. The supply port 86 preferably has a smaller diameter than the channel 85 such that it forms an orifice. This creates a better flow profile in flow of the cooling liquid.

[0060] In the annular space 77, the cooling liquid is in direct contact with the piston rod's outer surface, so that it can cool the surface of the piston rod 30.

[0061] It is possible that the ring member 75 is provided with more than one channel 85 with a supply port 86. This provides a better distribution of cooling liquid from the cavity 83 to the annular space 77 between the ring member and the piston rod. Alternatively, there is a single channel 85 with supply port 86.

[0062] From the supply port 86, the cooling liquid flows through the annular space 77 to cooling liquid collection chambers 87. The flow of cooling liquid through the annular space 77 cools the external surface of the piston rod 30.

[0063] In the embodiment of fig. 2, two cooling liquid collection chambers 87 are provided. It is however also possible that just a single collection chamber 87 is present.

[0064] In the embodiment of fig. 2, the piston rod cooling unit 60 further comprises two cooling liquid seals 90. They can be any type of suitable seals; in fig. 2 scraper rings are applied. They have the additional benefit of -apart from sealing- scraping cooling liquid from the surface of the reciprocating piston rod.

[0065] The cooling liquid seals 90 delimit the annular space between the ring member 75 and the piston rod 30 in axial direction. The cooling liquid collection chambers 87 are widened portions of this annular space, formed by parts of the bore that have a larger diameter than the central portion of the bore. The central portion of the bore has the smallest diameter, and therewith forms the part of the annular space 77 that has the smallest distance 78 between the ring member 75 and piston rod 30.

[0066] From the cooling liquid collection chambers 87, the cooling liquid is discharged. For the discharge, in this example multiple discharge channels 91 are provided. As an alternative, a single discharge channel can be present.

[0067] The cooling liquid enters the discharge channel via discharge port 92. This discharge port 92 is in fluid communication with the bore 76 and therewith with the annular space 77 between the ring member 75 and the piston rod 30.

[0068] From the discharge port 92, the cooling liquid comes into channel 93 in the ring member 75, and from there in the cooling liquid discharge space 94, which is part of the annulus 73 between the ring member 75 and

the housing 70. Seals 99 seal outer axial ends of the cooling liquid discharge spaces 94. The inner axial ends of the cooling liquid discharge spaces 94 are sealed by seals 84. Seals 84 prevent the flow of cooling liquid from cooling liquid supply space 83 to a cooling liquid discharge space 94. Seals 99 prevent the escape of cooling liquid from cooling liquid discharge spaces 94 to at their respective outer axial end.

[0069] The seals 99 and 84 are arranged in grooves 88 of the housing rings 71, 72. The grooves 88 are dimensioned in such a way that the seals 99,84 can move relative to the housing ring 71,72, thereby allowing relative movement of the ring member relative to the housing 70.

[0070] The cooling liquid in the cooling liquid supply space 83 and cooling liquid discharge spaces 94 acts as a combination of a spring and a dampener for the relative movement of the ring member 75 and the housing 70.

[0071] The cooling liquid seals are arranged in grooves 97 in the ring member 75. The grooves 97 have a larger radial dimension than the outer diameter of the cooling liquid seal 90, so that in radial direction there is space between the outer diameter of the cooling liquid seal and the wall of the respective groove 97.

[0072] The grooves 97 are in fluid communication with the cooling liquid discharge channel via duct 98. If any cooling liquid slips past the seal 90 into groove 97, it flows out of groove 97 again via duct 98. Ducts 98 therewith prevent the build-up of cooling liquid in grooves 97.

[0073] In the embodiment of fig. 2, the cooling unit 60 is further provided with a buffer gas system.

[0074] The buffer gas system comprises a buffer gas source 100 for the supply of pressurized buffer gas. Via buffer gas supply lines 101, the buffer gas source 100 supplies a buffer gas under pressure to buffer gas supply channels 102. Each housing ring 71, 72 has been provided with a buffer gas supply channel 102.

[0075] The buffer gas can be an inert gas, such as nitrogen. The buffer gas can be the same type of gas as the gas that is compressed by the piston compressor. The buffer gas source can receive the gas that will function as buffer gas from the same source as from which the compressor receives the gas to be compressed. The buffer gas source could also be a separate container which contains gas under pressure.

[0076] The housing rings 71, 72 have a part with a large internal diameter. This part extends over the ring member 75. The housing rings 71, 72 also have a part with a smaller internal diameter. This part is located next to an axial end of the ring member 75.

[0077] When a buffer gas system is present, preferably there is some distance between the axial ends of the ring member and the adjacent housing ring, such that a space 103 is present between the axial end of the ring member and the adjacent housing ring. Buffer gas can then enter this space from the buffer gas supply channel 102. From this space 103, the buffer gas can reach annular buffer gas space 104. Alternatively, buffer gas channel 102 can

be extended such that it supplies the buffer gas directly to the associated buffer gas space 104.

[0078] The buffer gas spaces 104 are delimited on one axial end by a buffer gas seal 105 and on the opposite axial end by a cooling liquid seal 90.

[0079] The gas in the buffer gas spaces is kept under pressure by the buffer gas source 100. The pressure of the buffer gas in the buffer gas spaces 104 acts to counter the entraining of cooling liquid on the external surface of the piston rod to the outside of the cooling unit.

[0080] Keeping the buffer gas pressure above the pressure of the cooling liquid in the collection chambers 87 reduces or even prevents the leakage of cooling liquid over the cooling liquid seals 90 of the cooling unit.

[0081] In an advantageous embodiment, as is shown in fig. 2, the buffer gas can also enter space 106 between the outer diameter of the ring member 75 and the inner diameter of the housing ring 71, 72. This way, the buffer gas pressure also acts on the seals 99, helping to reduce or even prevent the leakage of cooling liquid over these seals.

[0082] Fig. 3 shows a second embodiment of a cooling unit in accordance with the invention.

[0083] In the cooling unit 200 of fig. 3, a ring member 205 is present. The ring member has a bore 206, which bore has a diameter that is larger than the diameter of the piston rod 30, or at least larger than the outside diameter of the part of the piston rod 30 that reciprocates through the piston rod cooling unit 200. The piston rod 30 extends through the bore 206 of the ring member 205. In use, an annular space 207 is present between the surface of the bore 206 of the ring member 205 and the outer surface of the piston rod 30.

[0084] The ring member 205 is arranged in a housing, which housing comprises housing ring 210. In the embodiment shown in fig. 3, the outer diameter of the ring member 205 is smaller than the inner diameter of the housing ring 210 where the housing ring 210 extends over the ring member 205. This creates an annulus 215 between the outer diameter of the ring member 205 and the inner diameter of the housing ring 210 at the part where it extends over the ring member 205. This annulus 215 makes relative movement in radial directions of the ring member 205 with respect to the housing ring 210 possible.

[0085] In a possible embodiment, the difference between the diameter of the bore 206 and the diameter of the piston rod 30 is between 0,1 mm and 0,6 mm. In an alternative embodiment, the difference between the diameter of the bore 206 and the diameter of the piston rod 30 is between 0,2 mm and 0,4 mm. In a further alternative embodiment, the difference between the diameter of the bore 206 and the diameter of the piston rod 30 is about 0,3 mm.

[0086] The piston rod cooling unit 200 further comprises a cooling liquid supply channel 220. This cooling liquid supply channel has an inlet 221, which receives cooling liquid from the cooling liquid source via a cooling liquid

flow line 62.

[0087] Channel 222 allows the cooling liquid to flow through the housing ring 210. From channel 222 the cooling liquid comes into cooling liquid supply space 223, between the housing ring 210 and the ring member 205. The cooling liquid supply space 223 forms part of the annulus 215 between the ring member 205 and the housing ring 210. In use, the annulus can be empty, or filled with cooling liquid, or partly filled with cooling liquid, entirely or partly filled with a buffer gas or any other type of gas, or it can accommodate elastic members and/or seals.

[0088] The cooling liquid supply space 223 is sealed on its two axial ends by seals 224. The seals 224 make that the cooling liquid flows from the cooling liquid supply space 223 to channel 225 in the ring member 205, and does not escape before having reached the annular space 207 between the ring member 205 and the piston rod 30.

[0089] Channel 225 in the ring member 205 allows the cooling liquid to flow from the cooling liquid supply space 223 to supply port 226, which is in fluid communication with the bore 206 of the ring member 205. From the supply port 226, the cooling liquid enters the annular space 207 between the ring member 205 and the piston rod 30. The supply port 226 preferably has a smaller diameter than the channel 225 such that it forms an orifice. This creates a better flow profile in flow of the cooling liquid.

[0090] In the annular space 207, the cooling liquid is in direct contact with the piston rod's outer surface, so that it can cool the surface of the piston rod 30.

[0091] It is possible that the ring member 205 is provided with more than one channel 225 with a supply port 226. This provides a better distribution of cooling liquid from the cavity 223 to the annular space 207 between the ring member and the piston rod. Alternatively, there is a single channel 225 with supply port 226.

[0092] From the supply port 226, the cooling liquid flows through the annular space 207 to primary cooling liquid collection chambers 227. The flow of cooling liquid through the annular space 207 cools the external surface of the piston rod 30.

[0093] The primary cooling liquid collection chambers 227 are arranged on both axial ends of the annular space 207 between the piston rod 30 and the ring member 205. They receive cooling liquid from the annular space 207. Instead of two primary cooling liquid collection chambers 227, it is possible to have a single primary cooling liquid collection chamber 227. In that case, it is advantageous to arrange the supply port 226 on one axial end of the annular space 207 and the primary cooling liquid collection chamber 227 on the other axial end of the annular space 207.

[0094] Each primary cooling liquid collection chamber 227 is formed in a discharge ring 240. Each discharge ring 240 is arranged on an axial end of housing ring 210. Each discharge ring 240 is provided with a bore 241. The diameter of the bore 241 of each discharge ring is pref-

erably larger than the diameter of the bore 206 of the ring member 205.

[0095] From the primary cooling liquid collection chambers 227, the cooling liquid is discharged. For the discharge, one or more discharge channels 242 are provided in each discharge ring 240. Each discharge ring has a discharge port 243 and an outlet 244. The cooling liquid that flows out of the liquid discharge channels 242 is collected in one or more secondary cooling liquid collection chambers 245.

[0096] In the embodiment of fig. 3, two secondary cooling liquid collection chambers 245 are present, each associated with a discharge ring 240. In the example of fig. 3, the secondary cooling liquid collection chambers 245 extend over the circumference of the discharge rings 240, and are formed by a ring 246 having a recess 247 therein. The recess 247 preferably extends around the entire inner circumference of the ring 246.

[0097] Preferably, cooling liquid that is collected in a secondary cooling liquid collection chamber 245 flows from that secondary cooling liquid collection chamber 245 back to the cooling liquid source via cooling liquid flow line 63.

[0098] On the axial end opposite to the axial end facing the ring member 205, each primary cooling liquid collection chamber 227 is delimited by a cooling liquid seal 230. The cooling liquid seals 230 can be any type of suitable seals; in fig. 3 scraper rings are applied. They have the additional benefit of -apart from sealing- scraping cooling liquid from the surface of the reciprocating piston rod.

[0099] Each cooling liquid seal 230 is arranged in a groove 231 in the discharge ring 240. Both grooves 231 have a larger radial dimension than the outer diameter of the cooling liquid seal 230, so that in radial direction there is space between the outer diameter of the cooling liquid seal 230 and the wall of the respective groove 231 in which it is arranged.

[0100] The grooves 231 are in fluid communication with the secondary cooling liquid collection chamber 245 via duct 233. If any cooling liquid slips past the seal 230 into groove 231, it flows out of groove 231 again via duct 233. Ducts 233 therewith prevent the build-up of cooling liquid in grooves 231.

[0101] In the embodiment of fig. 3, further two back up rings 270 are present. Each back up ring 270 is arranged adjacent a discharge ring 240, on the side opposite to the side facing the ring member 205. The back up ring 270 has a bore 272 which is preferably smaller than the outer diameter of the cooling liquid seal 230, so that it can provide axial support for the cooling liquid sealing ring 230. The piston rod 30 extends through this bore 272.

[0102] The back up rings are provided with one or more channels 271, which are in fluid communication with a secondary cooling liquid collection chamber 245. This way, any cooling liquid that slips through past the cooling liquid seals 230 via the surface of the piston rod 30 can flow to the secondary cooling liquid collection chamber

245, and from there back to the cooling liquid source via a cooling liquid flow line 63.

[0103] In the embodiment of fig. 3, the cooling unit 200 is further provided with a buffer gas system.

[0104] The buffer gas system comprises a buffer gas source 250 for the supply of pressurized buffer gas. Via buffer gas supply lines 251, the buffer gas source 250 supplies a buffer gas under pressure to buffer gas supply channels 252. In the embodiment of fig. 3, separate buffer gas rings 255 have been provided. Each buffer gas ring 255 is provided with one or more buffer gas channels 252.

[0105] The buffer gas can be an inert gas, such as nitrogen. The buffer gas can be the same type of gas as the gas that is compressed by the piston compressor. The buffer gas source can receive the gas that will function as buffer gas from the same source as from which the compressor receives the gas to be compressed. The buffer gas source could also be a separate container which contains gas under pressure.

[0106] Each buffer gas ring 255 has been provided with bore 256, such that a buffer gas space 260 is created. The buffer gas spaces 260 are delimited on both axial ends by a buffer gas seal 261 a,b. The buffer gas seals 261a on the inner axial end of a buffer gas space 260 press against a surface of a back up ring 270, while the buffer gas seals 261 b on the outer axial end of a buffer gas space 260 press against the surface of an end ring 275.

[0107] The gas in the buffer gas spaces is kept under pressure by the buffer gas source 250. The pressure of the buffer gas in the buffer gas spaces 260 acts to counter the entraining of cooling liquid on the external surface of the piston rod to the outside of the cooling unit.

[0108] Keeping the buffer gas pressure above the pressure of the cooling liquid in the primary cooling liquid collection chambers 227 reduces or even prevents the leakage of cooling liquid over the cooling liquid seals 230 of the cooling unit.

[0109] In the embodiment of fig. 3, the discharge rings 240, the back up rings 270, the buffer gas rings 255 and the end rings 275 all are separate rings. It is however also possible to combine two or three adjacent rings into a single ring. For example, a discharge ring and a back up ring, or a backup ring, a buffer gas ring and an end ring can be combined into a single ring.

[0110] In a possible embodiment, the rings of a cooling unit such as shown in fig.2 or fig. 3 are held together in axial direction by clamping them between two flanges, by arranging them in a cooling unit housing or in the housing of the stuffing box, or by clamping them between a flange and the housing of the stuffing box.

[0111] Fig. 4 shows an embodiment of a piston rod external surface cooling system according to the invention.

[0112] The system of fig. 4 comprises a cooling unit 60, which is mounted in the piston compressor in such a way that the piston rod 30 extends through the cooling unit 60. The cooling unit can be the embodiment as

shown in fig. 2 or any other embodiment according to the invention. In the example of fig. 4, the cooling unit is mounted to the outside of the stuffing box.

[0113] The piston rod external surface cooling system of fig. 4 further comprises a cooling liquid source 61 in the form of a reservoir containing cooling liquid. First cooling liquid flow line 67 connects the cooling liquid source to a pump 65. Pump 65 provides the flow of cooling liquid through the cooling system.

[0114] Second cooling liquid flow line 62 takes the cooling liquid to the cooling unit. Third cooling liquid flow line 63 receives the cooling liquid from the cooling unit 60 again. The cooling liquid has now been heated up by the piston rod.

[0115] Third cooling liquid flow line 63 brings the heated up cooling liquid to heat exchanger 66, where the cooling liquid is cooled again. The heat exchanger can be any suitable kind of heat exchanger, e.g. a countercurrent flow heat exchanger, a heat exchanger with atmospheric air as a cooling medium.

[0116] Fourth cooling liquid flow line 68 takes the cooled cooling liquid back to the cooling liquid source 61, the reservoir, again.

[0117] Preferably, the cooling liquid source 61, the pump 65 and the heat exchanger 66 are mounted in a housing 64 together.

[0118] Fig. 5 shows different ways of mounting the cooling unit 60 onto the piston rod 30.

[0119] In fig. 5A, the housing of the cooling unit 60 is provided with a flange 69. By means of this flange 69, the cooling unit is attached to the stuffing box 50 using bolts.

[0120] In fig. 5B, the cooling unit is not attached to the stuffing box 50, but to the frame 1. The connection with the frame 1 makes that the cooling unit 60 remains in place despite the reciprocating action of the piston rod 30. Optionally, hinges 79 are provided in the connection between the cooling unit 60 and the frame 1. This way, the cooling unit can cope with tilting of the piston rod relative to the frame, as e.g. occurs due to bending of the piston rod.

[0121] Fig. 5C shows a stuffing box 50 which is enlarged, so the cooling unit 60 can be placed within the stuffing box 50.

Claims

1. A horizontal piston compressor for compressing gas, said compressor comprising:

a frame;
at least one cylinder having a cylinder wall, a first cylinder end, a second cylinder end and a longitudinal axis, wherein the first cylinder end is provided with a piston rod passage;
wherein the cylinder is mounted in the frame such that the longitudinal axis of the cylinder ex-

tends in a substantially horizontal direction;
 a piston reciprocable inside the cylinder, the piston delimiting at least a first compression chamber in the cylinder, the cylinder including at least one inlet port to the first compression chamber and with at least one outlet port from the first compression chamber;
 a piston rod having a first end and a second end, the piston rod extending through the piston rod passage in the first cylinder end, the piston rod connected to the piston;
 a drive assembly for driving the piston rod and the piston in reciprocating manner, the drive assembly connected to the second end of the piston rod;
 a stuffing box arranged at the first cylinder end, the piston rod extending through the stuffing box, the stuffing box comprising one or more packing rings that engage the piston rod and provide a seal therewith;
 a piston rod external surface liquid cooling system for cooling the piston rod external surface with a cooling liquid, the cooling system comprising:

a piston rod cooling unit arranged adjacent to a side of the one or more packing rings that is remote from the first compression chamber;
 a cooling liquid source for providing a flow of cooling liquid to the cooling unit;

wherein the piston rod cooling unit comprises:

a ring member having a bore through which the piston rod extends, the diameter of said bore being larger than the diameter of the piston rod such that an annular space is present between the piston rod and the ring member;
 a cooling liquid supply channel extending from an inlet thereof to one or more supply ports in communication with the bore so as to pass the cooling liquid to the annular space between the ring member and the piston rod, thereby allowing a flow of cooling liquid in contact with the external surface of the piston rod and through said annular space for removing heat from the external surface of the piston rod;
 wherein the piston rod cooling unit includes axially spaced apart cooling liquid seals that sealingly engage the piston rod, and wherein the cooling liquid is introduced into the annular space in between said cooling liquid seals;
 wherein the piston rod cooling unit further comprises at least one cooling liquid dis-

charge channel which extends from one or more discharge ports in communication with the bore to an outlet to discharge said cooling liquid from the annular space between the piston rod and the ring member; wherein the piston rod cooling unit is provided with one or more respective buffer gas seals that delimit an annular buffer gas space at each axial end of the annular space wherein the cooling liquid is made to flow; and
 wherein the cooling unit is provided with one or more buffer gas supply channels which extend from a buffer gas inlet to each annular buffer gas space to supply a buffer gas thereto, and wherein the cooling system comprises a source of pressurized buffer gas for establishing a buffer gas pressure in each buffer gas space, each said buffer gas space acting to counter the entraining of cooling liquid on the external surface from the piston rod to outside the cooling unit.

2. The compressor of claim 1, wherein the compressor has a floating piston.
3. The compressor of claim 1, wherein the piston is a non-lubricated piston.
4. The compressor of claim 1, wherein the one or more buffer gas seals are provided near each cooling liquid seal.
5. The compressor of claim 4, wherein the one or more buffer gas seals prevent leakage of cooling liquid over the cooling liquid seals.
6. The compressor of claim 1, wherein the source of pressurized buffer gas is maintained at a pressure above the pressure of the cooling liquid in the cooling unit.
7. The compressor of claim 1, wherein the buffer gas space is formed between an end ring and a back-up ring of the cooling unit.
8. The compressor of claim 1, wherein the buffer gas space is delimited on both axial ends by respective buffer gas seals.
9. A piston rod external surface cooling system for cooling the piston rod external surface of a piston compressor according to claim 1 with a cooling liquid, the system comprising:

a piston rod cooling unit, that is arranged adjacent the side of the one or more packing rings remote from the first compression chamber;

a cooling liquid source that is adapted to provide a flow of cooling liquid to the cooling unit; wherein the cooling unit comprises:

a housing, 5
 a ring member having a bore through which in use the piston rod extends, the diameter of said bore being larger than the diameter of the piston rod, such that an annular space is present between the piston rod and the ring member; 10
 a cooling liquid supply channel, which extends from an inlet thereof to one or more supply ports in communication with the bore so as to pass the cooling liquid to the annular space between the ring member and the piston rod, thereby allowing to establish a flow of cooling liquid in contact with the external surface of the piston rod and through said annular space causing the removal of heat from the external surface of the piston rod; 20
 wherein the cooling unit is provided with axially spaced apart cooling liquid seals that sealingly engage on the piston rod, and wherein said cooling liquid is introduced into the annular space in between said cooling liquid seals; 25
 and wherein the cooling unit further comprises at least one cooling liquid discharge channel, which extends from one or more discharge ports in communication with the bore to an outlet so as to discharge said cooling liquid from the annular space between the piston rod and the ring member; 30
 and, 35
 wherein the cooling unit is provided - near a or each cooling liquid seal - with one or more respective buffer gas seals that delimit an annular buffer gas space at each axial end of the annular space wherein the cooling liquid is made to flow; and, 40
 wherein the cooling unit is provided with one or more buffer gas supply channels, which extend from a buffer gas inlet to each annular buffer gas space to supply a buffer gas thereto, and wherein the cooling system comprises a source for pressurized buffer gas that is adapted to establish a buffer pressure in each buffer gas space, and buffer gas space acting to counter the entraining of cooling liquid on the external surface from the piston rod to outside the cooling unit. 50

10. A method for compressing gas using the horizontal piston compressor according to claim 1. 55

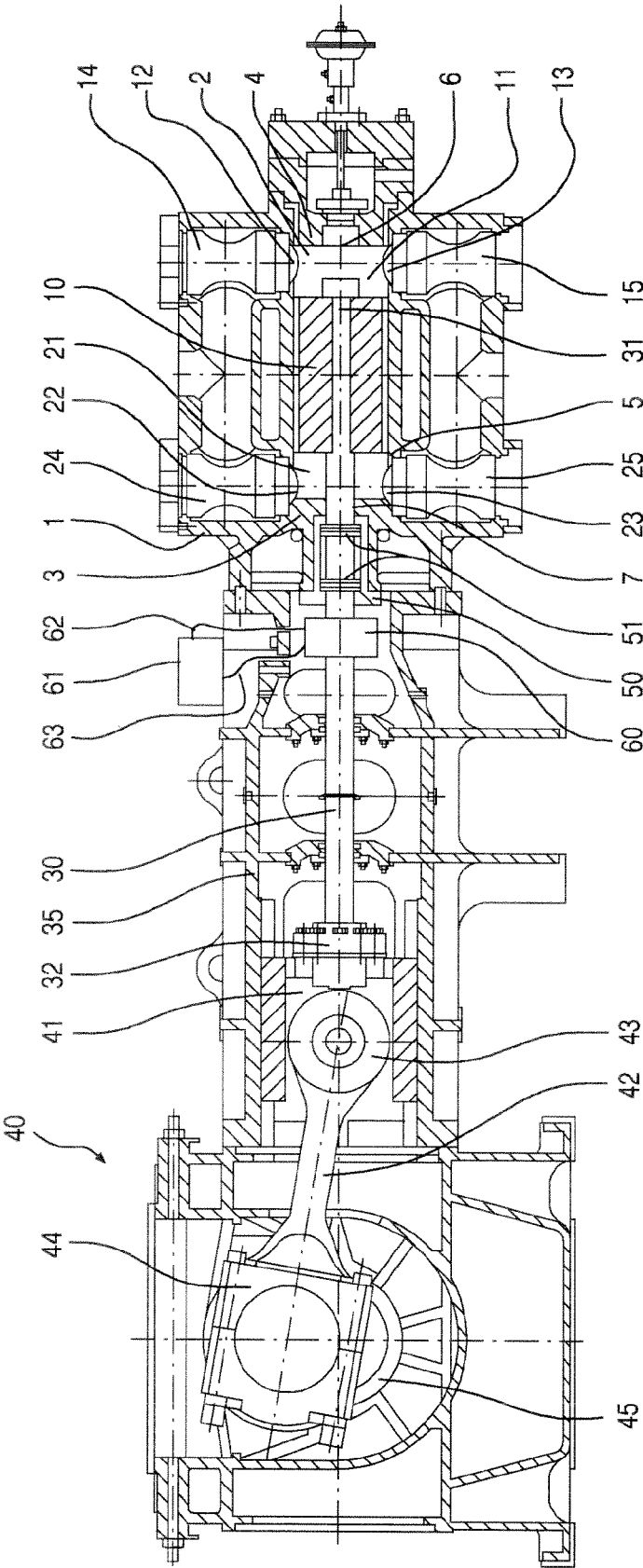


FIG.1

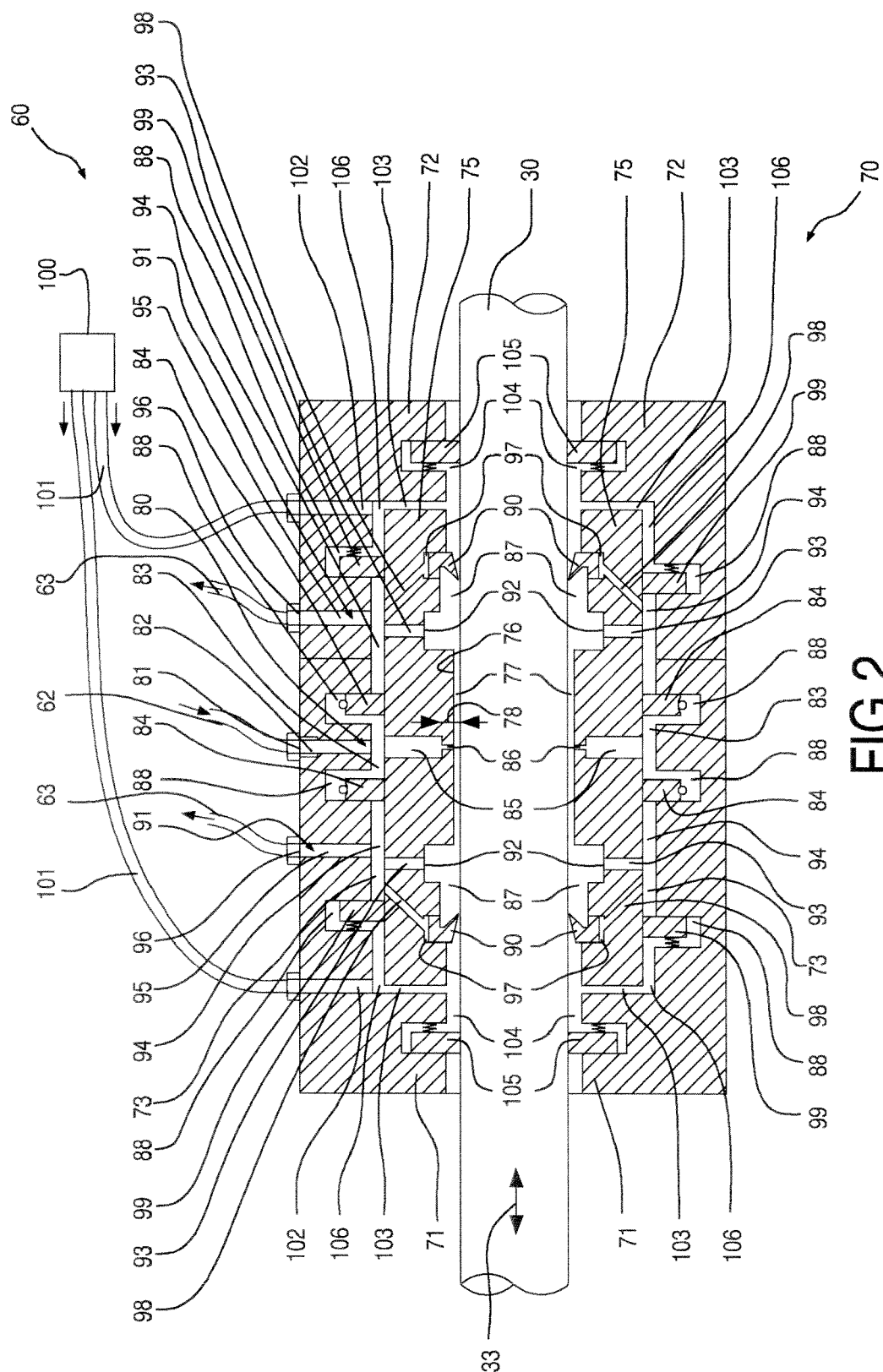


FIG. 2

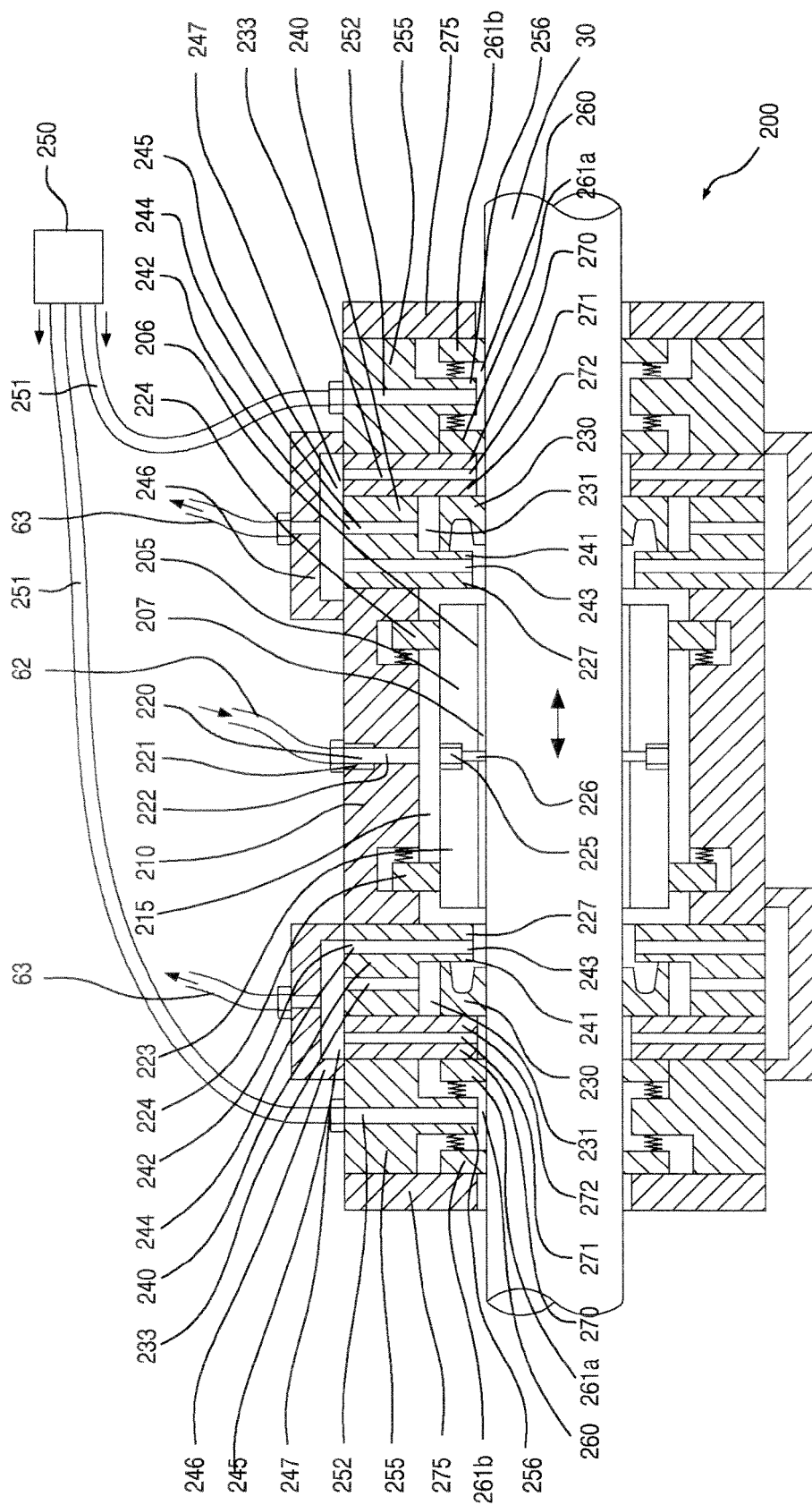


FIG.3

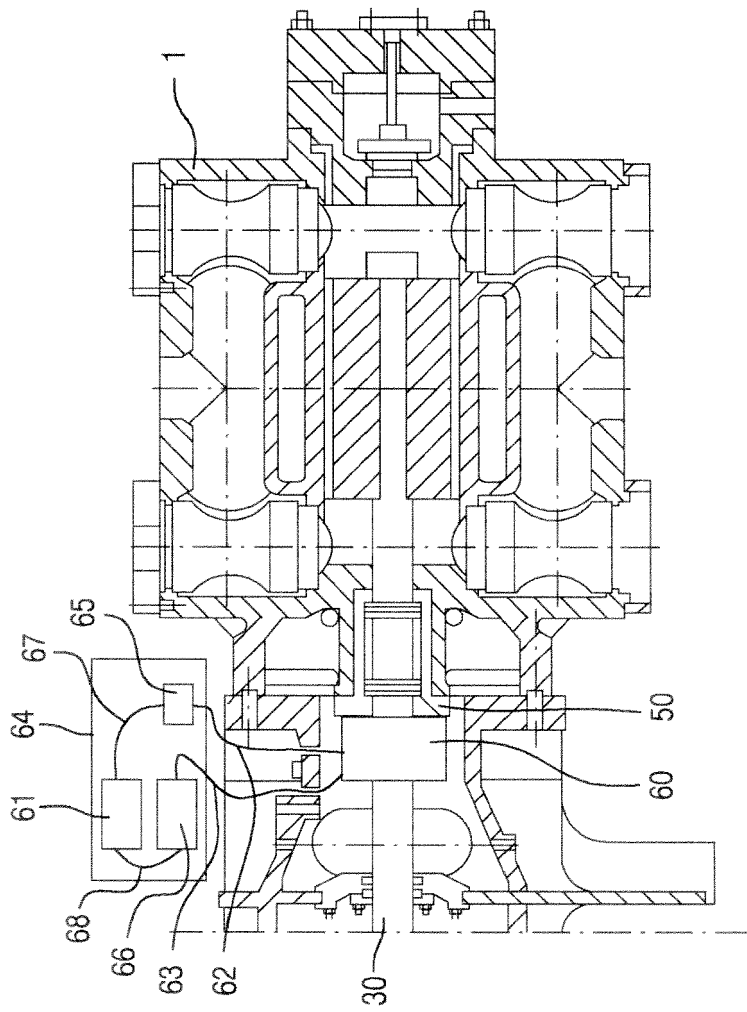


FIG.4

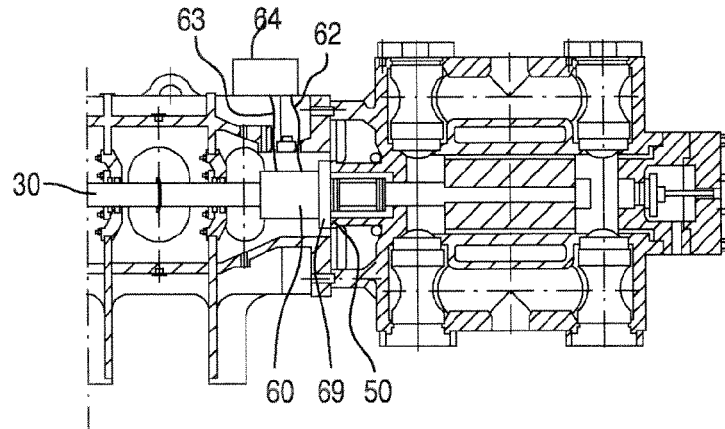


FIG.5A

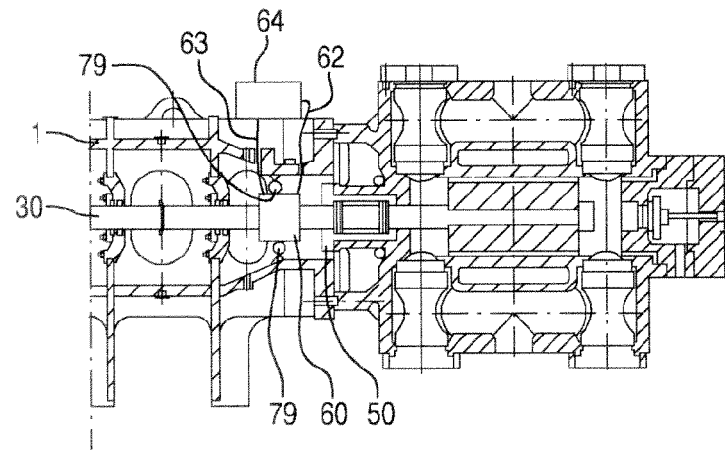


FIG.5B

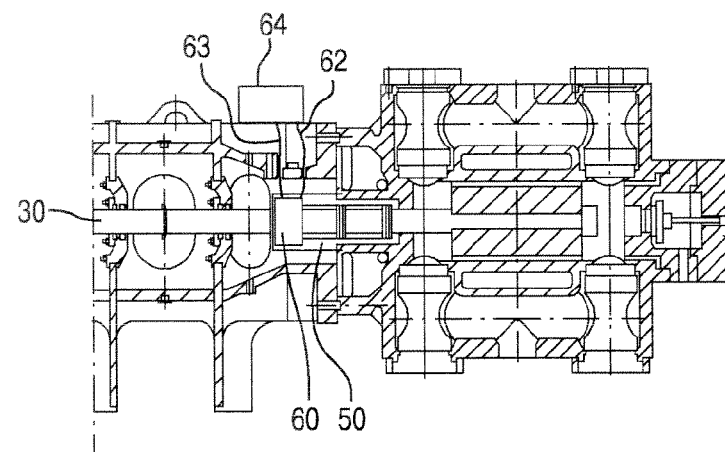


FIG.5C



EUROPEAN SEARCH REPORT

Application Number
EP 14 19 8860

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	US 3 544 118 A (KLEIN DONALD E) 1 December 1970 (1970-12-01) * column 3, line 3 - line 24 * * column 3, line 53 - column 4, line 15 * * figures 1-4 *	1	
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 15 June 2015	Examiner Lange, Christian
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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