(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 October 2003 (09.10.2003)

PCT

(10) International Publication Number
WO 03/083301 A1

(51) International Patent Classification[7]: F04B 39/00, 53/14

(21) International Application Number: PCT/CA03/00440

(22) International Filing Date: 26 March 2003 (26.03.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2,379,447 28 March 2002 (28.03.2002) CA

(71) Applicant *(for all designated States except US)*: **WESTPORT RESEARCH INC.** [CA/CA]; 1700 West 75th Avenue, Vancouver, British Columbia V6P 6G2 (CA).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **GRAM, Anker** [CA/CA]; 1280 Arbutus Street, Vancouver, British Columbia V6J 3W6 (CA).

(74) Agents: **OYEN, Gerald, O., S.** et al.; Oyen Wiggs Green & Mutala, #480 - The Station, 601 West Cordova Street, Vancouver, British Columbia V6B 1G1 (CA).

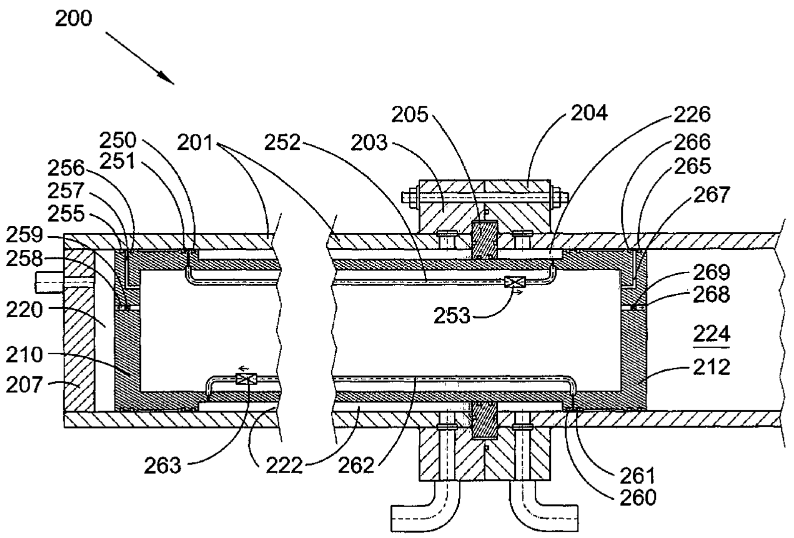
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: LEAK OIL RECOVERY IN A DOUBLE ACTING FREE PISTON ASSEMBLY



(57) Abstract: A double-acting free-floating piston apparatus comprises two chambers wherein a fluid is introducable and removable. The free floating piston assembly comprises two pistons, each one defining a dynamic boundary to a respective one of the first and second chambers, and an elongated body disposed between and attached to each of the two pistons. A fluid recovery system comprises a first pair of ring seals spaced apart from each other and disposed around the circumference of the first piston, a one-way fluid conduit through which fluid is flowable from a space between the first pair of ring seals to the second chamber, a second pair of ring seals spaced apart from each other and disposed around the circumference of the second piston, and a one-way fluid conduit through which fluid is flowable from a space between the second pair of ring seals to the first chamber. A method is provided for capturing fluid that leaks from a first chamber, directing the fluid through the body of a reciprocating piston assembly and recovering the fluid in a second chamber.

WO 03/083301 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

LEAK OIL RECOVERY IN A DOUBLE ACTING FREE PISTON ASSEMBLY

Field of the Invention

The present invention relates to a method and apparatus for improving a double acting reciprocating piston assembly. More particularly, the reciprocating piston is a free-floating piston assembly and the method and apparatus can be employed to recover fluid that leaks by the piston ring seals.

Background of the Invention

A reciprocating piston assembly that is a free-floating piston divides a cylinder into a drive chamber and a compression chamber. Fluid pressure in the drive chamber is controlled to provide a differential pressure between the drive chamber and the compression chamber to cause reciprocating movement of the piston assembly. That is, to cause a compression stroke, fluid pressure within the drive chamber is higher than the fluid pressure in the compression chamber. To reverse the direction of piston movement, fluid pressure within the drive chamber is reduced so that fluid pressure within the compression chamber is higher than fluid pressure within the drive chamber.

An apparatus comprising a double acting free-floating piston assembly can be employed to compress a gas or to pump a liquid. The drive fluid can be a gas or a liquid. By way of example, an apparatus that employs an oil as the drive fluid is commonly referred to as being hydraulically driven, whereas an assembly that employs pressurized air as the drive fluid is commonly referred to as being pneumatically driven.

In an apparatus comprising a double-acting reciprocating piston assembly, there are at least two compression chambers and fluid is compressed when the piston moves in both directions. When a free-floating piston is employed, there are two drive chambers with one drive chamber powering the compression stroke in one compression chamber and the other drive chamber powering the compression stroke in the other compression chamber. The apparatus operates by alternating between compression and intake strokes for each compression chamber with the operation of one compression chamber offset from the other compression chamber by 180 degrees.

In FIG. 1 conventional apparatus 100 employs a double acting free-floating piston assembly. Cylinders 101 and 102 are welded to central flange 105 to define a hollow cylindrical body. End plates 107 and 108 are screwed into and seal respective ends of cylinders 101 and 102. A free-floating piston assembly comprises two pistons 110 and 112, which are connected to each other by solid rod 114. Defined within cylinder 101 are first compression chamber 120 between piston 110 and end plate 107, and first drive chamber 122 between piston 110 and central flange 105. Defined within cylinder 102 are second compression chamber 124 between piston 112 and end plate 108 and second drive chamber 126 between piston 112 and central flange 105.

Fluid flows into first and second compression chambers 120 and 124 through respective one-way valves 132 and 136 and out of the same compression chambers 120 and 124 through respective one-way valves 134 and 138. Drive fluid flows into and out of first and second drive chambers 122 and 126 through respective fluid passages 140 and 142.

Double acting reciprocating piston apparatus 100 operates as described in the following paragraphs.

When the free-floating piston assembly moves to the left in FIG. 1, piston 110 is in the midst of a compression stroke. Fluid within first compression chamber 120 is compressed and expelled therefrom through one-way valve 134 when pressure within first compression chamber 120 is greater than the pressure within the pipe connected to one-way valve 134. Drive fluid is directed to first drive chamber 122 through fluid passage 140 to propel first piston 110 towards end plate 107. Simultaneously, piston 112 is in the midst of an intake stroke, as drive fluid flows out from second drive chamber 126 through fluid passage 142, and new fluid fills expanding second compression chamber 124 through one-way valve 136.

When piston 110 completes its compression stroke, the free-floating piston assembly reverses direction, and piston 110 begins an intake stroke and piston 112 begins a compression stroke. That is, with reference to FIG. 1, the free-floating piston assembly begins to move to the right, when drive fluid is directed to second drive chamber 126 and flows out from first drive chamber 122. Fluid within second compression chamber 124 is compressed and eventually expelled therefrom through one-way valve 138 when pressure within second compression chamber 124 is higher than pressure within the pipe connected to one-way valve 138. Meanwhile, fluid flowing through one-way valve 132 fills expanding first compression chamber 120.

Dynamic seals are employed to guard against fluid leakage between the compression and drive chambers around the moving components of the free-floating piston assembly. For example, pistons 110 and 112 have respective ring seals 150 and 160 and seals 170 are provided within central flange 105 around rod 114 to guard against leakage between the drive chambers.

A problem with a conventional apparatus such as the one shown in FIG. 1 is that a dynamic seal has not yet been developed that can guarantee completely effective sealing. Over the course of time, a ring seal can wear out and allow some fluid to leak by it. A ring seal can also have manufacturing or material defects that can also result in leakage. Accordingly, there is a need for a method and apparatus for recovering fluid that leaks by dynamic seals between compression and drive chambers, and guarding against contamination of one fluid with the other fluid.

Summary of the Invention

A double-acting free-floating piston apparatus comprises:

(a) a first chamber wherein a first fluid is introducable and removable;

(b) a second chamber wherein the first fluid is introducable and removable;

(c) a free floating piston assembly comprising:

a first piston defining a dynamic boundary to the first chamber;

a second piston defining a dynamic boundary to the second chamber; and

an elongated body disposed between and attached to each one of the first and second pistons; and

(d) a fluid recovery system comprising:

a first pair of ring seals spaced apart from each other and disposed around the circumference of the first piston;

a first one-way fluid conduit through which fluid is flowable from a space between the first pair of ring seals to the second chamber;

a second pair of ring seals spaced apart from each other and disposed around the circumference of the second piston; and

a second one-way fluid conduit through which fluid is flowable from a space between the second pair of ring seals to the first chamber.

In a preferred embodiment, the double-acting free-floating piston apparatus comprises:

(a) a free-floating piston assembly that comprises:

a first piston having a first diameter;

a second piston having a second diameter;

an elongated body disposed between and attached to each one of the first and second pistons, the body having a longitunal portion with a length that is at least as long as a full piston stroke, the longitudinal portion having a third diameter that is less than the first and second diameters;

(b) a cylinder comprising a bore within which the free-floating piston assembly is reciprocable, wherein the bore comprises:

a first section with a diameter that is a matched fit with the first diameter;

a second section that is a matched fit with the second diameter; and

a divider section that is disposed between the first and second sections that is a matched fit with the third diameter; and

(c) a fluid recovery system that comprises:

a first pair of ring seals spaced apart from each other and disposed around the circumference of the first piston;

a second pair of ring seals spaced apart from each other and disposed around the circumference of the second piston;

a first one-way fluid conduit disposed within the free-floating piston through which a fluid can flow from a space between the first pair of ring seals to a second chamber defined by a space between the divider section and the second piston; and

a second one-way fluid conduit disposed within the free-floating piston through which the fluid can flow from a space between the second pair of ring seals to a first chamber defined by a space between the divider section and the first piston.

In another preferred embodiment of the apparatus comprises a free-floating double acting piston that is reciprocable within a cylinder and a fluid recovery system that comprises:

(a) a first pair of ring seals spaced apart from each other and disposed around the circumference of a first piston;

(b) a second pair of ring seals spaced apart from each other and disposed around the circumference of a second piston;

(c) a first one-way fluid conduit disposed within the free-floating piston assembly through which the fluid can flow from a space between the first pair of ring seals to a chamber defined by a space between the second piston and an end that seals the portion of the cylinder within which the second piston reciprocates; and

(d) a second one-way fluid conduit disposed within the free-floating piston assembly through which the fluid can flow from a space between the second pair of ring seals to a chamber defined by a space between the first piston and an end plate that seals the portion of the cylinder within which the first piston reciprocates.

The first and second one-way fluid conduits can be formed by boring into the solid body of the free-floating piston assembly. However, in preferred embodiments, the elongated body is hollow, and the fluid conduits are formed, at least in part, by pipes disposed within the hollow interior of the elongated body. Such pipes preferably each comprise an inlet end that is connected to a fluid passage that passes through one of the first and second cylinder heads. The fluid passage communicates with a space between a respective one of the spaced ring seals. The pipe further comprises an outlet end that is connected to a port opening into a respective one of the first and second chambers, as described above.

The first and second one-way fluid conduits extend substantially from one end of the elongated body associated with the first piston to an opposite end of the elongated body associated with the second piston. In preferred embodiments, during operation of the apparatus, the outlet end of the pipe is always in communication with the chamber with which it is associated, regardless of the position of the free-floating piston assembly.

Each one of the one-way fluid conduits preferably comprises a check valve for controlling the direction of flow to allow flow only in the desired direction. The check valves are located proximate to respective outlet ends of the fluid conduits to prevent a significant amount of fluid from filling the conduit between the outlet and the check valve when the associated chamber is undergoing a compression stroke.

The apparatus is suitable for recovering a gas or a liquid, although, as described herein, when the fluid is a gas, piping may not be required, and the hollow interior of the elongated body can be employed to convey the recovered gas.

Typically the first and second pistons have equal diameters, but the apparatus can also be employed with two pistons that have different diameters.

A method is provided for recovering a fluid that leaks within an apparatus comprising a reciprocable double-acting free-floating piston assembly. The method comprises:

defining a dynamic boundary to a first chamber with a first piston of the piston assembly;

defining a dynamic boundary to a second chamber with a second piston of the piston assembly;

capturing the fluid in a first recovery space between a first pair of spaced ring seals that are disposed around the circumference of the first piston, when the fluid leaks from the first chamber;

directing the fluid from the first recovery space through a first fluid conduit disposed within the free-floating piston assembly to the second chamber;

capturing the fluid in a second recovery space between a second pair of spaced ring seals that are disposed around the circumference of the second piston, when the fluid leaks from the second chamber; and

directing the drive fluid from the second recovery space through a fluid conduit disposed within the free-floating piston assembly to the first drive chamber.

The method can further comprise:

defining a dynamic boundary to a third chamber with the first piston;

defining a dynamic boundary to a fourth chamber with the second piston;

capturing a second fluid, which leaks from the third chamber, in a third recovery space between a third pair of spaced ring seals that are disposed around the circumference of the first piston;

directing the second fluid from the third recovery space through a fluid conduit disposed within the free-floating piston to the fourth chamber;

capturing the second fluid, which leaks from a fourth chamber, in a fourth recovery space between a fourth pair of spaced ring seals that are disposed around the circumference of the second piston; and directing the second fluid from the fourth recovery space through a fluid conduit disposed within the free-floating piston assembly to the third chamber.

In preferred methods, the first fluid is a liquid and the second fluid is a gas.

Brief Description of the Drawings

FIG. 1 is a section view of a prior art double acting reciprocating piston apparatus with a free-floating piston;

FIG. 2 is a section view of an embodiment of an improved double acting reciprocating piston apparatus with a free-floating piston assembly. In this embodiment, the apparatus comprises features for recovering fluid that leaks by the piston ring seals. More specifically, the apparatus comprises fluid passages provided within the body of the piston assembly for recovering fluid that leaks from two of the fluid chambers within the apparatus;

FIG. 3 is an enlarged partial section view of the embodiment of FIG. 2 showing details of the fluid recovery features; and

FIG. 4 is a partial section view of another embodiment of a double-acting free-floating piston assembly that comprises fluid passages provided within the body of the piston assembly for recovering fluid that leaks from the outer fluid chambers that are between the pistons and respective end flanges.

While FIGS. 2 through 4 illustrates specific embodiments of the invention, it should not be considered as restricting the spirit or scope of the invention in any way.

Detailed Description of Preferred Embodiment(s)

With reference to FIG. 2 (and FIG.3 which is an enlarged view of portions of the apparatus of FIG. 2), apparatus 200 comprises a double-acting free-floating piston assembly that is reciprocable within a hollow cylindrical body. The hollow cylindrical body is defined by coaxial cylinders 201 and 202 which each have respective open flanged ends 203 and 204, and closed ends covered by respective end plates 207 and 208. Flanges 203 and 204 are employed to join and align the open ends of cylinders 201 and 202.

The free-floating piston assembly comprises pistons 210 and 212 and elongated body 214. Elongated body 214 is disposed between and attached to each one of pistons 210 and 212. Elongated body 214 has a diameter that is less than the diameters of pistons 210 and 212. The length of elongated body 214 is at least as long as a full stroke of the piston assembly.

Piston 210 is reciprocable within a bore of cylinder 201 and piston 212 is reciprocable within a bore of cylinder 202. The longitudinal axis of cylinders 201 and 202 and their respective bores are aligned with each other in addition to being aligned with the longitudinal axis of the free-floating piston assembly.

Apparatus 200 comprises a pair of drive chambers and a pair of compression chambers. One pair of chambers is outer chambers 220 and 224 defined by spaces within respective cylinders 201 and 202 between respective pistons 210 and 212 and respective end plates 207 and 208. The other pair of chambers is inner chambers 222 and 226 defined by the respective annular spaces between elongated body 214 and respective cylinders 201 and 202, between divider 205 and the back sides of respective pistons 210 and 212. The pair of chambers that act as drive chambers depends upon the function of the apparatus.

In the example illustrated by FIGS. 2 and 3, inner chambers 222 and 226 are preferably filled with liquid and outer chambers 220 and 224 are filled with a gas. If this apparatus is employed to pump a liquid using gas pressure directed to outer chambers 220 and 224, then these outer chambers act as the drive chambers. For other applications, the apparatus can be configured to compress a gas in outer chambers 220 and 224, in which case inner chambers 222 and 226 would act as the drive chambers. Apparatus 200 is operable as a pump or compressor in a manner similar to known apparatuses with double-acting free-floating piston assemblies.

A sealing arrangement within apparatus 200 provides a method and apparatus for recovering fluid that leaks by a piston ring seal, and returning the recovered fluid to an appropriate chamber within the apparatus. That is, the fluids from the drive and compression chambers are kept apart and recovered liquid is returned to a liquid-filled chamber while recovered gas is returned to a gas-filled chamber.

A pair of ring seals disposed around the circumference of piston 210 provides a dynamic seal for containing fluid within inner chamber 222. Ring seal 250 is spaced apart from ring seal 251. During operation, fluid that leaks by ring seal 250 is captured in the space between ring seals 250 and 251. Fluid conduit 252 fluidly connects the space between rings seals 250 and 251 with inner chamber 226. A one-way flow controller, such as check valve 253 allows fluid to flow through conduit 252 only in the direction of inner chamber 226. Fluid conduit 252 and check valve 253 are disposed within the body of the free-floating piston assembly.

A similar arrangement is provided for recovering fluid that leaks from inner chamber 226. A pair of ring seals disposed around the circumference of piston 212 provides a dynamic seal for containing fluid within inner chamber 226. Ring seal 260 is spaced apart from ring seal 261. During operation, fluid that leaks by ring seal 260 is captured in the space between ring seals 260 and 261. Fluid conduit 262 fluidly connects the space between rings seals 260 and 261 with inner chamber 222. A one-way flow controller, such as check valve 263 allows fluid to flow through conduit 262 only in the direction of inner chamber 222.

Pressure alternates between inner chambers 222 and 226. When the pressure within inner chamber 222 is higher than the pressure within inner chamber 226, the pressure of the fluid within conduit 252 is higher than the pressure of the fluid within inner chamber 226, and the fluid that leaked from inner chamber 222 is recovered within inner chamber 226. Similarly, when the pressure within inner chamber 226 is higher than the pressure within inner chamber 222, the pressure of the fluid within conduit 262 is higher than the pressure of the fluid within inner chamber 222, and the fluid that leaked from inner chamber 226 is recovered within inner chamber 222.

In the illustrated embodiments, elongated body 214 is hollow, reducing weight and material costs, while also providing a convenient space for conduits 252 and 262.

An additional feature shown in the embodiment of FIGS. 2 and 3 is a sealing arrangement for recovering gas that leaks from outer chambers 220 and 224. A pair of ring seals disposed around the circumference of piston 210 provides a dynamic seal for containing the gas within outer chamber 220. Ring seal 255 is spaced apart from ring seal 256. During operation, fluid that leaks by ring seal 255 is caught in the space between ring seals 255 and 256. Fluid conduit 257 fluidly connects the space between rings seals 255 and 256 with the hollow interior of elongated body 214. Another pair of ring seals disposed around the circumference of piston 212 provides a dynamic seal for containing the gas within outer chamber 224. Ring seal 265 is spaced apart from ring seal 266. During operation, fluid that leaks by ring seal 265 is caught in the space between ring seals 265 and 266. Fluid conduit 267 fluidly connects the space between rings seals 265 and 266 with the hollow interior of elongated body 214.

One-way fluid passage 258 allows gas to flow from the interior of elongated body 214 into outer chamber 220. One-way fluid passage 258 preferably comprises check valve 259 disposed within the piston head of piston 210. One-way fluid passage 268 allows gas to flow from the interior of elongated body 214 into outer chamber 224. One-way fluid passage 268 preferably comprises check valve 269 disposed within the piston head of piston 212. Accordingly, gas that leaks from outer chambers 220 and 224 collects within the interior of elongated body 214 until the gas pressure therein is higher than the gas pressure within one of outer chambers 220 and 224, at which point the gas is recovered within the outer chamber with the lower pressure. This normally occurs when one of outer chambers 220 and 224 is undergoing a suction stroke, or when the apparatus is shut down.

With reference to FIG. 4, many of the component parts of apparatus 400 are substantially the same as the components of apparatus 200 and like components with like functions will not be described again.

The embodiment of FIG. 4 is suitable for an apparatus that fills outer chambers 420 and 424 with a liquid, and inner chamber 422 and 426 with a gas. An example of an apparatus that employs this configuration would be a gas intensifier. A gas intensifier is employed to raise the pressure of a gas to a very high pressure, and so apparatus 400 utilizes the piston surface area differential in favor of the drive fluid. That is, by applying hydraulic fluid pressure to the side of the piston with the larger surface area, the gas can be compressed to higher pressures without raising the pressure of the hydraulic fluid to the same high pressure.

Apparatus 400 operates on the same principal as apparatus 200, except that instead of connecting inner chambers 422 and 426, the fluid recovery systems connect outer chambers 420 and 424. Ring seals 455 and 456 are spaced apart from each other and provide dynamic seal between piston 410 and cylinder 401 to contain a fluid within outer chamber 420. During operation, fluid that leaks from outer chamber 420 by ring seal 455 is caught in the space between ring seals 455 and 456. Fluid conduit 457 fluidly connects the space between rings seals 455 and 456 with outer chamber 424. A one-way flow controller, such as check valve 458 allows fluid to flow through conduit 457 only in the direction of outer chamber 424. Fluid conduit 457 and check valve 458 are disposed within the body of the free-floating piston assembly. Ring seals 465 and 466, fluid conduit 467, and check valve 468 function in the same manner, but to capture fluid that leaks from outer chamber 424 and direct it to outer chamber 420. Check valves 458 and 468 are preferably disposed within the piston heads of respective pistons 412 and 410.

Illustrated apparatus 400 is suitable for filling inner chambers 422 and 426 with a gas. Gas that leaks from inner chamber 422 by ring seal 450 is captured between ring seal 450 and 451 and then directed to the interior of the free-floating piston assembly. Similarly, gas that leaks from inner chamber 426 by ring seal 460 is captured between ring seal 460 and 461 and then directed to the interior of the free-floating piston assembly. When gas pressure within the interior of the free-floating piston assembly is greater than the gas pressure within one of inner chambers 422 and 426, gas is returned to the inner chambers through respective one-way fluid passages 463 or 453.

In another embodiment (not shown), an apparatus can incorporate both fluid passages 252 and 262 of FIGS. 2 and 3, and fluid passages 257 and 267 of FIG. 4. Such an arrangement can be employed, for example, when the apparatus is a hydraulically driven liquid pump, and such an arrangement would allow recovery of drive fluid and the pumped liquid, without filling the hollow piston assembly with liquid.

An advantage of the disclosed fluid recovery arrangement is that leaked fluid is continuously and immediately recoverable within the apparatus because of the pressure differential between the source chamber and the recovery chamber.

As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

What is claimed is:

1. A double-acting free-floating piston apparatus comprising:

(a) a hollow body;

(b) a first chamber defined within said hollow body wherein a first fluid is introducable and removable;

(c) a second chamber defined within said hollow body wherein said first fluid is introducable and removable and said second chamber is fluidly separated from said first chamber;

(d) a free-floating piston assembly reciprocable along a longitudinal axis within said hollow body, said free-floating piston assembly comprising:

a first piston comprising a surface transverse to said longitudinal axis and facing said first chamber and thereby defining a dynamic boundary to said first chamber;

a second piston comprising a surface transverse to said longitudinal axis and facing said second chamber and thereby defining a dynamic boundary to said second chamber; and

an elongated body disposed between and attached to each one of said first and second pistons; and

(e) a fluid recovery system comprising:

a first pair of ring seals spaced apart from each other and disposed around the circumference of said first piston;

a first one-way fluid conduit disposed within said free-floating piston assembly through which fluid is flowable from a space between said first pair of ring seals to said second chamber;

a second pair of ring seals spaced apart from each other and disposed around the circumference of said second piston; and a second one-way fluid conduit disposed within said free-floating piston assembly through which fluid is flowable from a space between said second pair of ring seals to said first chamber; and

(f) a plurality of fluid passages for alternating between introducing or draining fluid from said first and second chambers.

2. A double-acting free-floating piston apparatus comprising:

(a) a free-floating piston assembly that comprises:

a first piston having a first diameter;

a second piston having a second diameter;

an elongated body disposed between and attached to each one of said first and second pistons, said elongated body having a longitunal portion with a length that is at least as long as a full piston stroke, said longitudinal portion having a third diameter that is less than said first and second diameters;

(b) a cylinder comprising a bore within which said free-floating piston assembly is reciprocable, wherein said bore comprises:

a first section with a diameter that is a matched fit with said first diameter, wherein said first piston is disposed and reciprocable within said first section;

a second section that is a matched fit with said second diameter, wherein said second piston is disposed and reciprocable within said second section; and

a divider section that is disposed between said first and second sections that is a matched fit with said third diameter, wherein said elongated body extends through said divider section; and

(c) a fluid recovery system that comprises:

a first pair of ring seals spaced apart from each other and disposed around the circumference of said first piston;

a second pair of ring seals spaced apart from each other and disposed around the circumference of said second piston;

a first one-way fluid conduit disposed within said free-floating piston through which a fluid can flow from a space between said first pair of ring seals to a second chamber defined by a space between said divider section and said second piston; and

a second one-way fluid conduit disposed within said free-floating piston through which said fluid can flow from a space between said second pair of ring seals to a first chamber defined by a space between said divider section and said first piston; and

(d) a plurality of fluid passages for alternating between introducing or draining fluid from said first and second chambers.

3. A double-acting free-floating piston apparatus comprising:

(a) a free-floating piston assembly that comprises:

a first piston having a first diameter;

a second piston having a second diameter;

an elongated body disposed between and attached to each one of said first and second pistons, said elongated body having a longitunal portion with a length that is at least as long as a full piston stroke, said longitudinal portion having a third diameter that is less than said first and second diameters;

(b) a cylinder comprising a bore within which said free-floating piston is reciprocable, wherein said bore comprises:

a first section with a diameter that is a matched fit with said first diameter, wherein said first piston is disposed and reciprocable within said first section, said first section associated with a first end of said cylinder;

a second section that is a matched fit with said second diameter, wherein said second piston is disposed and reciprocable within said second section, said second section associated with a second end of said cylinder;

a divider section that is disposed between said first and second sections that is a matched fit with said third diameter, wherein said elongated body extends through said divider section;

a first end plate that seals said first end of said cylinder;

a second end plate that seals said second end of said cylinder; and

(c) a fluid recovery system that comprises:

a first pair of ring seals spaced apart from each other and disposed around the circumference of said first piston;

a second pair of ring seals spaced apart from each other and disposed around the circumference of said second piston;

a first one-way fluid conduit disposed within said free-floating piston through which said fluid can flow from a space between said first pair of ring seals to a second chamber defined by a space between said second piston and said second end plate; and

a second one-way fluid conduit disposed within said free-floating piston through which said fluid can flow from a space between said second pair of ring seals to a first chamber defined by a space between said first piston and said first end plate; and

(d) a plurality of fluid passages for alternating between introducing or draining fluid from said first and second chambers.

4. The apparatus according to claims 1, 2 or 3 wherein said elongated body is hollow.

5. The apparatus according to claim 4 wherein said first and second one-way fluid conduits each comprise a pipe disposed within the hollow interior of said elongated body.

6. The apparatus according to claim 5 wherein each one of said pipes comprises:

an inlet end that is connected to a fluid passage that passes through one of said first and second cylinder heads, said fluid passage communicating with a space between a respective one of said spaced ring seals; and

an outlet end that is connected to a port opening into a respective one of said first and second chambers.

7. The apparatus according to claim 6 wherein each one of said one-way fluid conduits further comprises a check valve for controlling the direction of flow through respective ones of said fluid conduits.

8. The apparatus according to claim 7 wherein said check valves are located proximate to respective outlet ends of said fluid conduits.

9. The apparatus according to claims 1, 2 or 3 wherein said fluid is a liquid.

10. The apparatus according to claims 2 or 3 wherein said first and second diameters are equal.

11. The apparatus according to claim 2 further comprising two chambers defined by spaces between head surfaces of said first and second piston and respective opposing cylinder end plates wherein a gas is introducable into and removable from said two chambers.

12. The apparatus according to claim 11 wherein said free-floating piston comprises a hollow interior between said first and second pistons, said apparatus further comprising:

a third pair of ring seals spaced apart from each other and disposed around the circumference of said first piston, said third pair of ring seals being spaced from said first pair of ring seals and closer than said first pair of ring seals to said head surface of said first piston;

a fourth pair of ring seals spaced apart from each other and disposed around the circumference of said second piston, said fourth pair of ring seals being spaced from said second pair of ring seals and closer than said second pair of ring seals to said head surface of said second piston;

a fluid passage connecting a space between said third pair of ring seals to said hollow interior;

a fluid passage connecting a space between said fourth pair of ring seals to said hollow interior;

a third one-way conduit passage with an outlet disposed within an end face of said first piston, through which said gas can flow from said hollow interior;

a fourth one-way fluid conduit with an outlet disposed within an end face of said second piston, through which said gas can flow from said hollow interior.

13. The apparatus according to claim 11 further comprising:

a third pair of ring seals spaced apart from each other and disposed around the circumference of said first piston, said third pair of ring seals being spaced from said first pair of ring seals and closer than said first pair of ring seals to said head surface of said first piston;

a fourth pair of ring seals spaced apart from each other and disposed around the circumference of said second piston, said fourth pair of ring seals being spaced from said second pair of ring seals and closer than said second pair of ring seals to said head surface of said second piston;

a third one-way fluid conduit disposed within said free-floating piston through which said gas is flowable from a space between said third pair of ring seals to a cylinder chamber defined by a space between said second piston and a respective one of said end plates;

a fourth one-way fluid conduit disposed within said free-floating piston through which said gas is flowable from a space between said fourth pair of ring seals to a cylinder chamber defined by a space between said first piston and a respective one of said end plates.

14. The apparatus according to claims 1, 2 or 3 wherein said first and second one-way fluid conduits extend substantially from one end of said elongated body associated with said first piston to an opposite end of said elongated body associated with said second piston.

15. A method of recovering a fluid that leaks within an apparatus comprising a reciprocable double-acting free-floating piston assembly, said method comprising:

within a hollow body, reciprocating said double-acting free-floating piston assembly, which comprises a first piston and a second piston;

defining a dynamic boundary to a first chamber with a head surface of said first piston;

defining a dynamic boundary to a second chamber with a head surface of said second piston;

providing a pressure differential between said first and second chambers that alternates with reciprocation of said double-acting free-floating piston assembly;

switching between introducing or draining said fluid from said first and second chambers when said double-acting free-floating piston assembly reverses direction;

capturing said fluid in a first recovery space between a first pair of spaced ring seals that are disposed around the circumference of said first piston, when said fluid leaks from said first chamber;

directing said fluid from said first recovery space through a first one-way fluid conduit disposed within said free-floating piston assembly to said second chamber;

capturing said fluid in a second recovery space between a second pair of spaced ring seals that are disposed around the circumference of said second piston, when said fluid leaks from said second chamber; and

directing said fluid from said second recovery space through a second one-way fluid conduit disposed within said free-floating piston assembly to said first chamber.

16. The method according to claim 15 wherein said fluid is a liquid.

17. The method according to claim 15 further comprising:

defining a dynamic boundary to a third chamber with a piston surface of said first piston that is opposite to said head surface;

defining a dynamic boundary to a fourth chamber with a piston surface of said second piston that is opposite to said head surface;

providing a pressure differential between said third and fourth chambers that alternates with reciprocation of said double-acting free-floating piston assembly;

switching between introducing or draining a second fluid from said third and fourth chambers when said double-acting free-floating piston assembly reverses direction;

capturing said second fluid, which leaks from said third chamber, in a third recovery space between a third pair of spaced ring seals that are disposed around the circumference of said first piston;

directing said second fluid from said third recovery space through a one-way fluid conduit disposed within said free-floating piston to said fourth chamber;

capturing said second fluid, which leaks from a fourth chamber, in a fourth recovery space between a fourth pair of spaced ring seals that are disposed around the circumference of said second piston; and

directing said second fluid from said fourth recovery space through a one-way fluid conduit disposed within said free-floating piston assembly to said third chamber.

18. The method according to claim 17 wherein said second fluid is a gas.

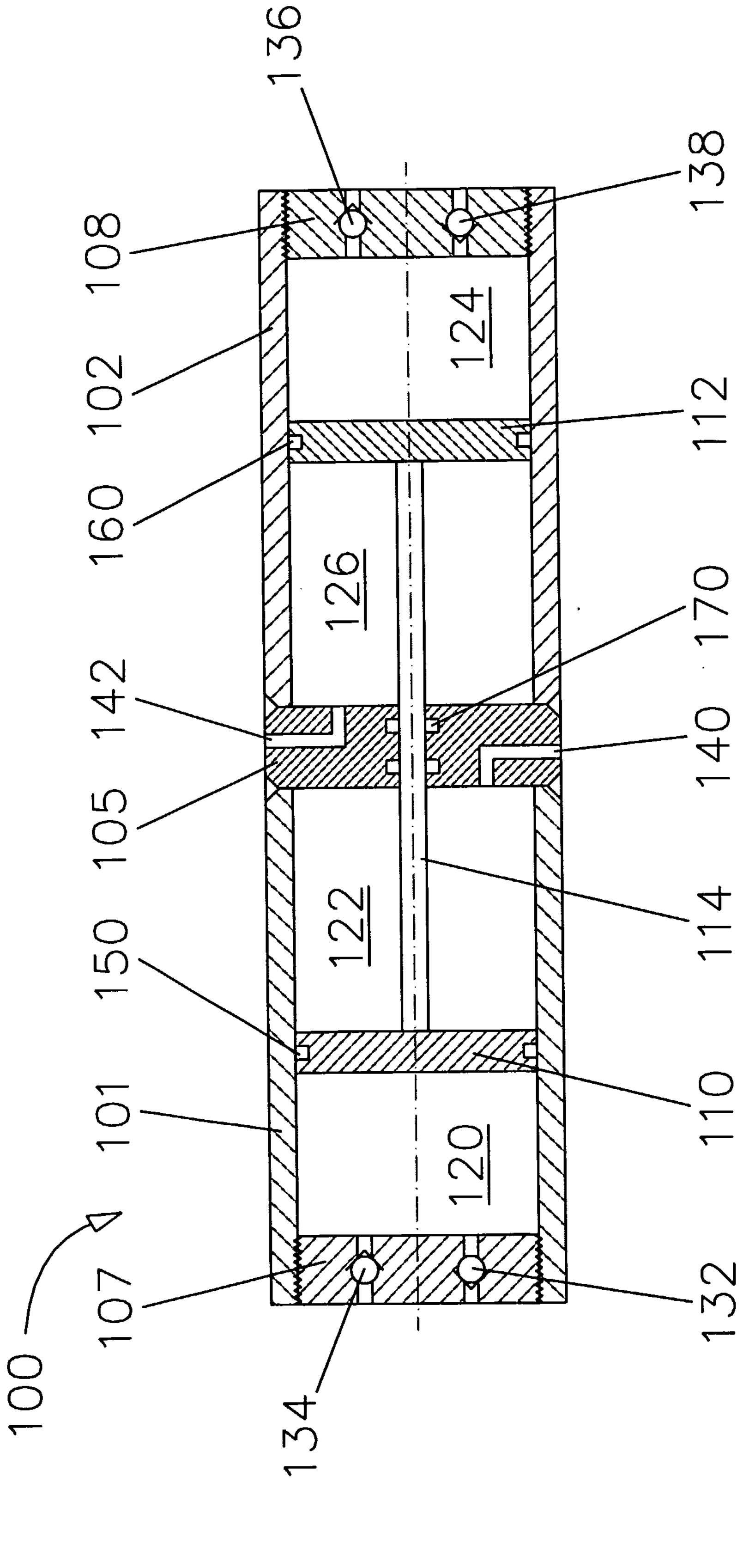


FIGURE 1 (PRIOR ART)

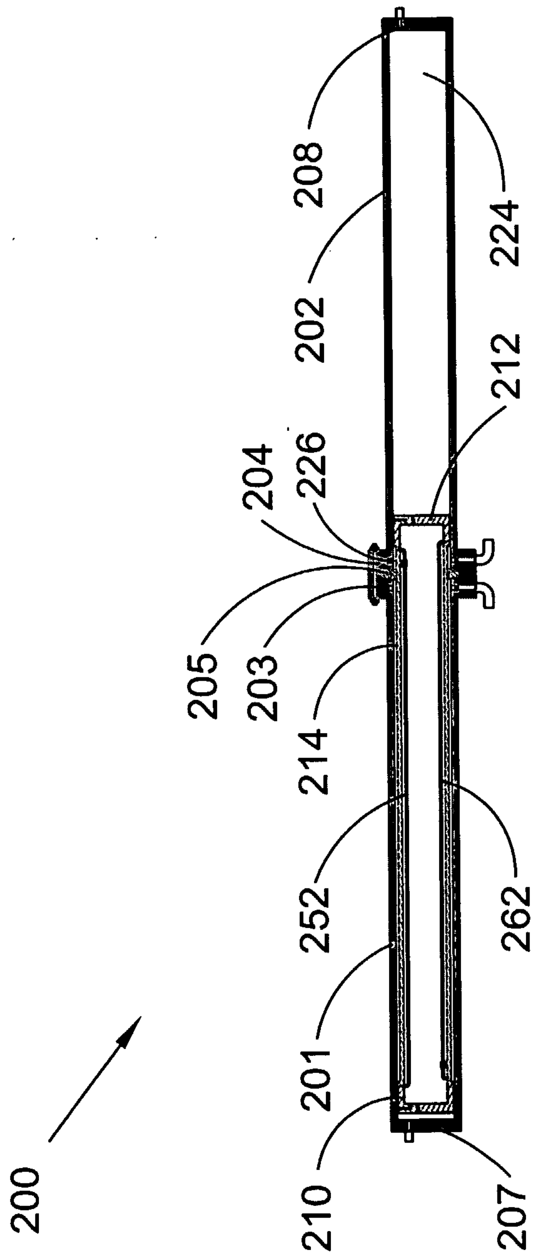


FIG. 2

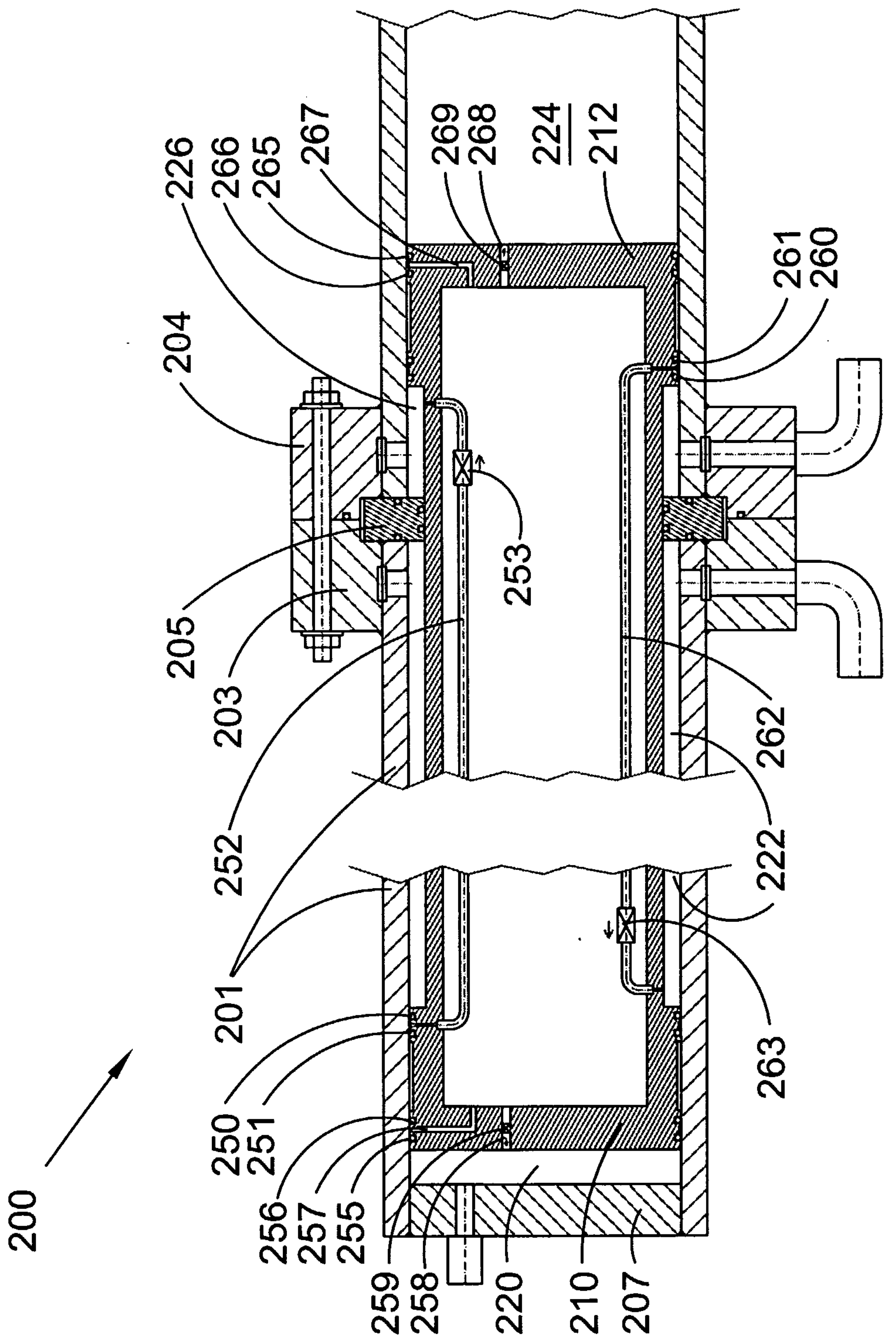

200
201
203
204
205
207
210
212
220
222
224
226
250
251
252
253
255
256
257
258
259
260
261
262
263
265
266
267
268
269

FIG. 3

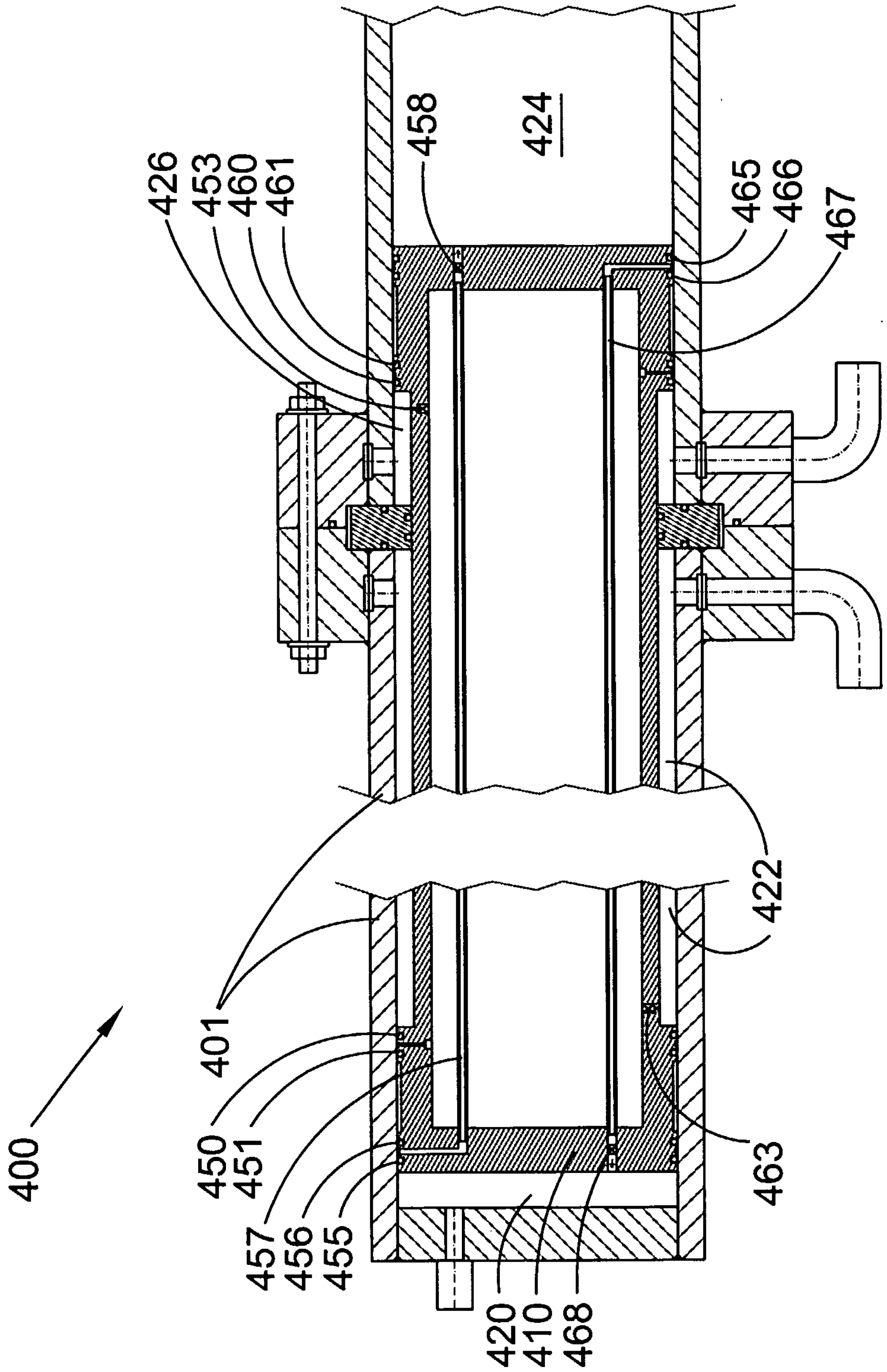

400
401
410
420
422
424
426
450
451
453
455
456
457
458
460
461
463
465
466
467
468

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 03/00440

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F04B39/00 F04B53/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 390 322 A (BUDZICH TADEUSZ) 28 June 1983 (1983-06-28) column 13, line 18 -column 13, line 54	1-3,15
A	DE 34 39 458 A (STILL CARL GMBH CO KG) 8 August 1985 (1985-08-08) page 9, paragraph 2	1-3,15
A	US 5 993 170 A (ALVAREZ DAVID ET AL) 30 November 1999 (1999-11-30) abstract	1-3,15

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 June 2003	27/06/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Toffolo, O

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 03/00440

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4390322 A	28-06-1983	US 4383804 A	17-05-1983
DE 3439458 A	08-08-1985	DE 3439458 A1	08-08-1985
		EP 0150819 A2	07-08-1985
		US 4690160 A	01-09-1987
US 5993170 A	30-11-1999	NONE	