Oct. 11, 1966 L. TYREE, JR., ET AL 3,277,797

PUMP WITH TEMPERATURE RESPONSIVE SEAL

Filed March 26, 1964

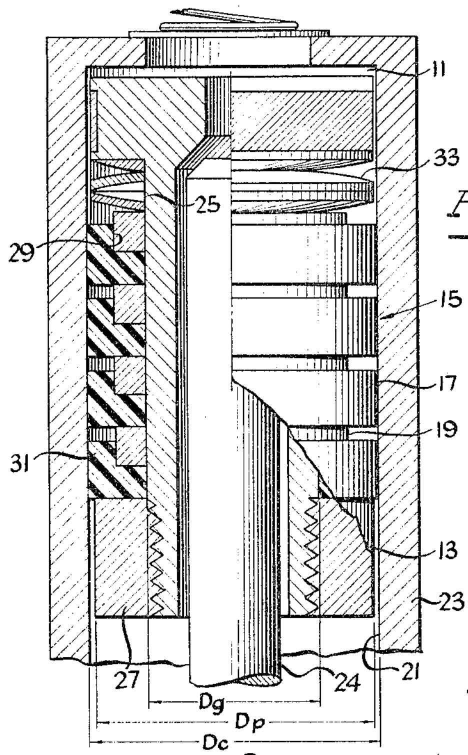

Fig 1

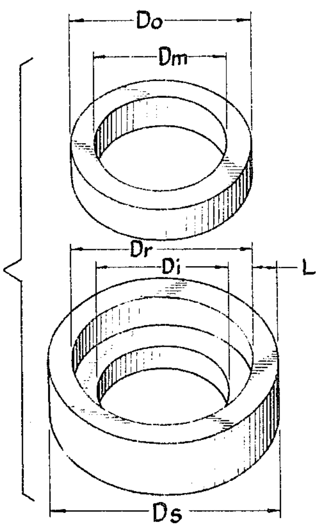

Fig 3

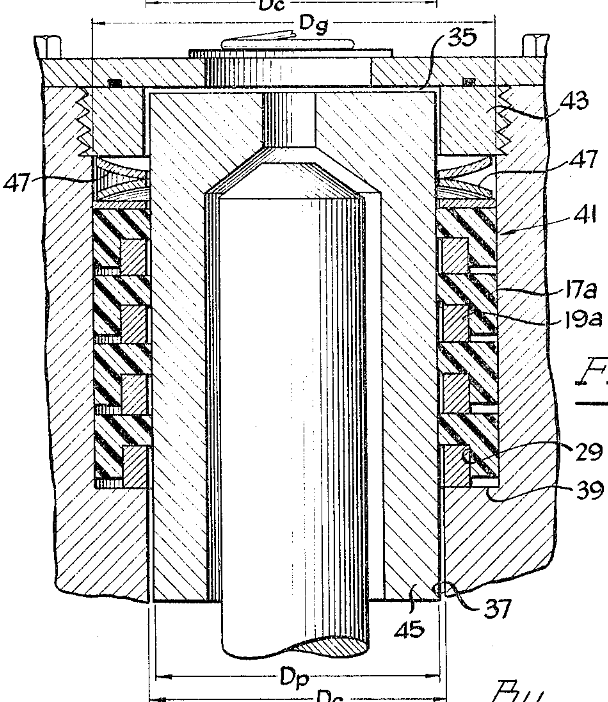

Fig 2

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3,277,797

PUMP WITH TEMPERATURE RESPONSIVE SEAL

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Filed Mar. 26, 1964, Ser. No. 354,967
12 Claims. (Cl. 92—194)

This invention relates to seals for reciprocating pumps. More particularly, it relates to seals for reciprocating pumps which are adapted to transfer high-pressure cryogenic liquids.

Pumps utilized in the transfer of cryogenic liquids such as, for example, liquid oxygen or liquid nitrogen, are generally of the positive displacement type and comprise a piston reciprocating within a stationary cylinder. Such pumps conventionally include a seal between the cylinder wall and the piston to prevent the pumped liquid from by-passing the piston. This seal may be located on or within the piston, in which case the arrangement is referred to as a piston-type pump, or may be affixed to the stationary cylinder wall, in which case the arrangement is referred to as a plunger-type pump.

The provision of a satisfactory sealing arrangement between the cylinder wall and piston presents numerous problems in pumps intended for the transfer of cryogenic liquids, i.e., liquids at a temperature of below −70° F., which are not encountered in pumps utilized for the transfer of other liquids. For example, many such liquids have extremely low viscosities and, consequently, are capable of passing through very small clearances between the seal and the piston or between the seal and the cylinder wall. The extremely high pressures under which the pumps operate serve to intensify this problem by increasing the tendency for the liquid to flow through such clearances, and by rendering certain sealing materials unsuitable for this application.

Additionally, cryogenic liquids are generally pumped at a temperature which is not appreciably below their boiling point and the addition of even a small amount of heat to the system at any given point may be sufficient to cause flashing of liquid in the vicinity of the point. This vaporization of the liquid, of course, seriously impairs the operation of the entire system. In this regard, the frictional forces associated with pressure loaded sealing devices, i.e., devices in which the seal is maintained in sliding engagement with the surface of either the piston or cylinder wall by the pressure of the liquid being pumped, thus exerting radial pressure against that surface, have been found to produce the small amount of heat capable of causing the flashing, thus rendering the use of such friction seals unsatisfactory.

Attempts have been made to compensate for this heat of friction by operating the pumps at temperatures substantially below the boiling point of the liquid and/or by positioning the seals at a substantial distance from the pumping chamber to minimize the heat transfer to the liquid being pumped. Both methods have, however, had undesirable effects. When the pump is operated at a much lower temperature than the system ordinarily requires, the efficiency of the system is reduced. On the other hand, when the seals are spaced substantially from the pumping chamber, the clearance volume of the pump is increased to an undesirable level.

It is the principal object of the present invention to provide an improved sealing arrangement for a reciprocating cryogenic liquid transfer pump.

A further object of the invention is to provide such a seal which is effective to prevent a cryogenic liquid from by-passing the piston during the operation of the pump.

A still further object of the present invention is to provide a ring-type non-pressure loaded seal for a reciprocating cryogenic liquid transfer pump which is maintained in sliding contact with a surface of the cylinder or piston.

Another object of the present invention is to provide such a ring-type seal which is maintained in close gripping contact with one of the piston or cylinder wall while being in sliding contact with the other of the piston or cylinder wall.

Still another object of the present invention is to provide a ring-type seal for a reciprocating cryogenic liquid transfer pump which is adapted to compensate for wear of the seal incident to the operation of the pump.

Further objects and advantages of the invention will become apparent with reference to the following description and the accompanying drawing.

In the drawing:

FIGURE 1 is a fragmentary elevational view, partially in section, showing various of the features of the invention;

FIGURE 2 is a fragmentary elevational sectional view of an alternate application of the invention as illustrated in FIGURE 1; and

FIGURE 3 is a perspective exploded view of two elements forming a portion of the structure as shown in FIGURE 1.

Very generally, a principal embodiment of a pump showing various of the features of the present invention is illustrated in FIGURE 1 and comprises means defining a cylindrical pump chamber **11** having a piston **13** positioned therein and adapted for reciprocal movement longitudinally thereof. A plurality of seal assemblies **15** surround the piston, each comprising an annular non-metallic ring **17** which is adapted to shrink when the pump is cooled to provide a compressive static seal between the ring and piston at cryogenic temperatures, and an inner metallic ring **19** positioned partially within the non-metallic ring so as to limit the shrinkage of the non-metallic ring and maintain the outer surface thereof in a size-on-size sliding sealing engagement with the surface of the cylinder wall without pressure loading, i.e., without utilizing the pressure of the pumped liquid.

Referring now to FIGURE 1, the pump chamber **11** is defined by a cylindrical surface **21** of a wall **23** forming a portion of a cylinder block, a cylinder liner, or the like formed of a metal such as stainless steel. The surface **21** is preferably machined to a very smooth finish and in a manner which provides the chamber **11** with a close tolerance diameter, designated D_c in the drawing.

The piston **13** of the illustrated embodiment is of a hollow construction similar to that shown in U.S. Patent No. 3,023,710 to enable it to receive an inner piston member **24**, as fully described in said patent. It is preferably formed of the same material as the wall **23** defining the chamber **11** or of a material having properties of thermal expansion and contraction similar to those of the material of the wall **13**. The outer diameter of the piston, designated D_p in FIGURE 1 of the drawing, is slightly less than the diameter D_c of the pump chamber **11** to provide an annular space between the walls of the piston and the cylindrical surface **21** of the chamber **11** sufficient to permit reciprocal movement of the piston within the chamber **11** without contact between the walls of the piston and the surface **21**.

To enable the piston **13** to accommodate the seal assemblies **15**, it is provided with an encircling groove or relieved portion **25** having a diameter designated D_g which is somewhat less than the outer diameter D_p of the piston. Preferably, an end of the groove, hereinafter referred to as the upper end, is defined by a downwardly facing shoulder of the upper portion or head of the piston, while the lower end of the groove is defined by the upper surface of a ring or nut **27** threaded onto the piston body. Accordingly, when the nut **27** is removed from the piston, the sealing assemblies may be slipped over the lower end of the piston into the groove **25** and maintained therein when the nut is replaced.

Referring now to the seal assemblies **15**, the non-metallic ring **17** is formed of a rigid material having a low coefficient of friction and having a greater coefficient of thermal contraction than the material of the wall **23** of the pump chamber **11** and the material of which piston **13** is formed. Also, the material should have the ability to cold flow under pressure at ambient temperatures, for reasons which will be explained in greater detail shortly. Two materials which have been found to be particularly suitable in this regard are Teflon, a tetrafluoroethylene polymer product of E. I. du Pont de Nemours & Co., and Kel-F, a trifluorochloroethylene polymer product of the Minnesota Mining & Mfg. Co. A glass-filled Teflon is quite desirable because of its increased strength and decreased thermal contraction.

As can be seen most clearly in FIGURE 3, the ring **17** is of a generally flat configuration having an outer diameter (designated D_s) which is slightly greater at the time of assembly of the pump than the inner diameter D_c of the pump chamber **11**. Thus, when the piston and seal assemblies are initially placed within the chamber **11**, the non-metallic ring **17** is placed in compression by virtue of the size differential of the diameters D_c and D_s. However, as previously stated, the material of the non-metallic ring **17** is such that it undergoes cold flow when under pressure at ambient temperatures and, consequently, after a short period of time, the ring assumes a size-on-size fit with the cylindrical surface **21** of the pump chamber wall **23** and the pressure between the surface **21** and the ring **17** is relieved. When the size-on-size fit has been achieved, the clearance between the ring **17** and surface **21** is no greater than one ten-thousands of an inch. Furthermore, there is no pressure-loading of the ring due to the pressure of the liquid within the chamber, thus eliminating the heat of friction which such pressure-loading would create.

The internal diameter of the non-metallic ring, designated D_i (FIGURE 3), is appropriately sized to allow a slip fit of the rings into the groove **25** of the piston at ambient temperatures. Accordingly, this dimension of the ring is slightly greater than the diameter D_g of the piston groove. Further, the internal diameter D_i is such that when the pump is cooled to cryogenic temperatures, the differential of the coefficients of thermal contraction between the material of the non-metallic ring **17** and that of the piston **13** will cause the ring **17** to contract into compressive engagement with the cylindrical walls of the groove **25** of the piston, thus providing a static seal at this interface between the ring **17** and piston **13** and preventing passage of the pumped cryogenic liquid therebetween.

It has been previously pointed out that the piston **13** and chamber wall **23** have similar coefficients of thermal contraction, and that the coefficient of thermal contraction of the ring **17** is greater than that of the piston or chamber wall. Accordingly, the ring shrinks onto the piston at cryogenic temperatures to provide the static seal described above. It should be apparent, however, that at cryogenic temperatures there is also a tendency for the outer cylindrical surface of the ring to shrink away from the cylindrical surface **21** with which it is in size-on-size fit at ambient temperatures. To maintain this size-on-size fit between the ring **17** and surface **21** at cryogenic temperatures, the ring **19** is provided, as hereinafter described.

More specifically, and as seen best in FIGURE 3, the flat non-metallic ring **17** is provided with a centrally located recess **29** to receive the metallic ring **19**. The recess is concentric with the outer periphery of the ring **17** and of a diameter D_r equal to approximately the average of the outer and inner diameters D_s and D_i of the ring **17**. The recess **29** thus provides the ring with a cylindrical lip **31** extending therearound having a thickness, indicated at L in FIGURE 3, which is equal to one-half the difference between the outer diameter D_s of the ring **17** and the diameter D_r of the recess **29**.

The inner-metallic ring **19** is formed of metal such as stainless steel which has a coefficient of thermal contraction less than the coefficient of thermal contraction of the material of each the chamber wall **23** and piston **13**. The ring is of flat configuration and has a thickness greater than the depth of the recess so that, when disposed within the recess, its upper portion will project outwardly and be engaged by a surface of an overlying ring **17** of a stack of the assemblies **15**. The inner diameter D_m (FIGURE 3) of the ring **19** is such as to allow the ring to be slipped easily into the groove **25** and is therefore somewhat greater than the diameter D_g of the piston at the groove. The outer diameter D_o of the metallic ring **19** is sized slightly larger than the diameter D_r of the recess **29** of the ring **17**, creating a force fit when the ring **19** is placed into the recess **29**.

The exact size of the outer diameter D_o of the metallic ring **19** is determined from a consideration of the relative coefficients of thermal contraction of the materials of which the chamber wall **23**, piston **13**, and rings **17** and **19** are formed so that, at a given cryogenic temperature level, the metallic ring will maintain the lip portion of the non-metallic ring **17** in size-on-size sealing engagement with the cylinder wall. More specifically, the components are dimensioned such that the diametrical contraction of the ring **19** plus twice the contraction of the lip **31** of the ring **17** equals or is slightly less than the diametrical contraction of the surface **21** of the chamber **11**. In the latter case, the lip **31** may be under slight compression. Any tendency of the outer diameter of the ring **17** in the vicinity of the lip **31** to contract by an amount greater than the diameter D_c of the surface **21** is resisted by the ring **19**. Hence, the size-on-size fit providing a clearance of not greater than one ten-thousandth of an inch at ambient temperatures is maintained at cryogenic temperatures.

Accordingly, a static compressive seal is provided between the non-metallic ring **17** and the cylindrical wall of the piston groove **25**, and a size-on-size sliding seal is provided between the outer surface of the non-metallic ring and the surface **21** of the chamber **11**. The effectiveness of the seal is further improved by the provision of a plurality of the seal assemblies **15** arranged in stacked relation, as seen in FIGURE 1.

It will be appreciated that continued reciprocal movement of the piston within the pump chamber **11** will produce wear of the outer surface of the non-metallic ring **17**. In order to compensate for such wear, a biasing spring **33** in the form of a group of Belleville washers is provided to place the seal assemblies **15** under a compressive load which, at ambient temperatures, as when the pump is not in use, will cause cold flow of the rings **17** in an outward radial direction to compensate for the wear. When the pump is cooled to cryogenic temperatures, the cold flow properties of the non-metallic ring are substantially reduced and the compressive force of the spring is ineffective to cause radial forces to be imparted to the cylinder wall by the non-metallic ring.

The sealing arrangement of the present invention may also be employed in reciprocating cryogenic transfer pumps of plunger-type construction such as is shown in FIGURE 2. In such a construction, a pump chamber **35** is provided having a cylindrical surface **37** of a diameter D_c recessed to provide a cylindrical groove **39** of a diameter D_g in which sealing assemblies **41** are carried. The cylinder may include a threaded cap **43** to permit insertion of the seal assemblies **41** into the groove **39**.

The pumping chamber **35** receives a reciprocating piston **45** which is of a diameter D_p somewhat less than the diameter D_c of the chamber **35**. The piston is provided with side wall surfaces which are machined to provide a smooth finish. As in the embodiment of FIGURE 1, the piston and chamber defining means are preferably formed of like metals.

The seal assemblies **41** are identical in construction to the seal assemblies **15** of the embodiment of FIGURE 1, but are dimensioned somewhat differently relative to the piston and to the cylindrical surface. The seal assemblies are shown in a position inverted relative to their position in FIGURE 1, but they might be utilized as well in the FIGURE 1 orientation. In like manner, the seal assemblies **15** of FIGURE 1 might be utilized in the orientation shown in FIGURE 2.

Referring now more specifically to the seal assemblies **41**, each includes a non-metallic flat ring **17*a*** having an outer diameter D_s slightly greater than the diameter D_g of the groove **39** so as to require a forced insertion of the ring into the groove at ambient temperatures. Accordingly, at cryogenic temperatures the shrinkage of the ring **17*a***, as limited by the ring **19*a*** will be such that the cylindrical surface **41** will shrink around the ring, thereby effecting a compressive static seal between the ring **17*a*** and the surface **41**. The ring has an inner diameter D_i sufficiently greater than the diameter D_p of the piston so that, at cryogenic temperatures, the shrinkage of the ring **17*a***, as limited by the ring **19*a***, will provide a size-on-size fit between the inner cylindrical surface of the ring and the wall of the piston **45**. These dimensions are computed based upon the coefficients of contraction of the various materials used.

The ring **17*a***, like the ring **17**, is provided with a recess **29** of a diameter D_r to receive the metallic ring **19*a*** and so as to provide the ring with a lip **31**. The metalic ring **19*a*** has an outer dimeter D_o slightly greater than the diameter D_r of the recess so as to be forced therein at ambient temperatures and has an inner diameter D_m sufficiently greater than the diameter D_p of the piston **45** to permit freedom of movement of the piston therein.

The seal assemblies are again placed under a longitudinal compressive loading by spring washers **47** to produce cold flow at ambient temperatures and compensate for any wear which might occur during operation at cryogenic temperatures.

Example I

A cryogenic pump of the piston type (FIGURE 1) is provided which includes a pumping chamber defined by a steel cylinder having an inner diameter D_c of 2.000 inches and a surface finish of 2 to 4 micro-inches. The coefficient of thermal contraction of the cylinder is 2.9×10^{-3} inches/inch under standard conditions (68° F. to −300° F). A piston carried within the pumping chamber is formed of steel also having a coefficient of thermal contraction of 2.9×10^{-3} inches/inch under standard conditions. The outer diameter D_p of the piston is 1.960 inches, and a groove provided in a side wall of the piston has a diameter D_g of 1.500 inches.

Four glass-filled Teflon rings having outer diameters D_s of 2.002 inches, inner diameters D_i of 1.500 inches, and recess diameters D_r of 1.873 inches are carried within the grove of the piston. The coefficient of thermal contraction of the rings is 8.0×10^{-3} inches/inch under standard conditions. Four metallic rings formed of AISI 410 stainless steel having a coefficient of thermal contraction of 1.7×10^{-3} inches/inch under standard conditions are carried within the recesses of the Teflon rings and have outer diameters D_o of 1.8750 inches and an inner diameter D_m of 1.501 inches.

The pump is assembled at ambient temperatures and the thickness of the lip portions of the non-metallic rings, as determined by the radial distance between the cylinder wall diameter D_c and the outer diameter of the metallic rings D_o, is therefore .0625 inch. When the pump is cooled down to a cryogenic temperature of −300° F., the cylinder wall diameter D_c is reduced to 1.9942 inches and the outer diameter of the metallic rings is reduced to 1.8718 inches, providing a radial differential of .0612 inch. At the cryogenic temperature, the lip thickness of .0625 inch contracts less than $\frac{1}{10,000}$ inch, thus still insuring a size-on-size engagement with the cylinder inner diameter.

At a cryogenic temperature of −300° F., the outer diameter D_g of the relieved portion of the piston is reduced to 1.4957 inches and the inner diameter of the non-metallic rings D_i is theoretically reduced to 1.4880 inches, thus providing for a compressive static seal therebetween.

Example II

A cryogenic pump of the plunger type (FIGURE 2) is provided which includes a pumping chamber defined by a steel cylinder having an inner diameter D_c of 2.02 inches. The coefficient of thermal contraction of the cylinder is 2.9×10^{-3} inches/inch. A groove is provided in the cylinder wall which has a diameter D_g of 2.500 inches.

A piston carried within the pumping chamber is formed of steel also having a coefficient of thermal contraction of 2.9×10^{-3} inches/inch, and a surface finish of 2 to 4 micro-inches. The outer diameter D_p of the piston is 2.000.

Four glass-filled Teflon rings having outer diameters D_s of 2.500 inches, inner diameters D_i of 2.000 inches and recess diameters D_r of 2.250 inches are positioned within the groove of the piston. The coefficient of thermal contraction of the rings is 8.0×10^{-3} inches/inch. Four metallic rings formed of AISI 410 stainless steel having a coefficient of thermal contraction of 1.7×10^{-3} inches/inch are carried within the recesses of the Teflon rings and have outer diameters D_o of 2.250 inches and inner diameters D_m of 2.020 inches.

The pump is assembled at ambient temperatures and the thickness of the lip portions of the non-metallic rings, as determined by the radial distance between the cylinder wall groove diameter D_g and the outer diameter of the metallic rings D_o is therefore .125 inch. When the pump is cooled down to a cryogenic temperature of −300° F., the groove diameter is reduced to 2.4927 inches and the outer diameter of the metallic rings is reduced to 2.2462 inches, producing a radial differential of .1232 inch. The thickness of the lip portions of the non-metallic rings, however, is theoretically only reduced to .1240 inch, thus providing for a compressive static seal between the lip portion outer diameter D_s and the cylinder groove diameter D_g.

At a cryogenic temperature of −300° F., the piston outer diameter is reduced to 1.9942 inches. The inner diameters D_i of the non-metallic rings are theoretically reduced to 1.984 inches providing a size-on-size engagement with the piston outer diameter.

As can be seen and appreciated, a sealing arrangement for a reciprocating cryogenic liquid transfer pump has been provided which is adapted to provide a compressive engagement static seal between a pump component supporting the seal and the seal, and to provide a size-on-size sliding seal between the sealing member and a relatively moving component of the pump. The sealing arrangement is further adapted to compensate for any wear of the relatively moving parts to maintain the size-on-size engagement of the seal surfaces at cryogenic temperatures for an extended service life.

What is claimed is:

1. A pump construction comprising means having a generally cylindrical surface defining an elongated pumping chamber, a piston carried within said pumping chamber for a reciprocal movement, said piston and said chamber being proportioned relative to one another so as to provide an annular space between the side wall of said piston and the said cylindrical surface of said chamber, and a rigid annular sealing member positioned within said annular space, said sealing member being dimensioned such that when said pump is at ambient temperature a surface of said member and one of said chamber and piston are in non-pressure loaded engagement with a clearance therebetween of not greater than one ten-thousandth of an inch, said sealing member being formed of a material having a coefficient of contraction greater than that of said one of said chamber-defining means and piston so as to have a tendency to alter the dimensional relationship between the said surface of said sealing member and the adjacent surface of said one of said chamber and piston at cryogenic temperatures, and means for maintaining at cryogenic temperatures the ambient temperature relationship between said surface of said member and said surface of one of said cylinder and piston.

2. A pump construction comprising means having a generally cylindrical surface defining an elongated pumping chamber, a piston carried within said pumping chamber for reciprocal movement, said piston and said chamber being proportioned relative to one another so as to provide an annular space between the side wall of said piston and the said cylindrical surface of said chamber, and a rigid annular sealing member positioned within said annular space and secured to said piston, said sealing member having an outer surface dimensioned such that when said pump is at ambient temperature said surface is in a non-pressure loaded engagement with the cylindrical surface of said pumping chamber with a clearance therebetween of less than one ten-thousandth of an inch, said sealing member being formed of a material having a coefficient of contraction greater than that of said cylindrical surface-defining means so as to have a tendency to shrink away from the cylindrical surface when the pump is cooled to below ambient temperatures, and means for maintaining said surface of said sealing member in contact with said cylindrical surface at temperatures below ambient.

3. A pump construction comprising means having a generally cylindrical surface defining an elongated pumping chamber, a piston carried within said pumping chamber for reciprocal movement, said piston and said chamber being proportioned relative to one another so as to provide an annular space between the side wall of said piston and the said cylindrical surface of said chamber, and a rigid sealing member positioned within said annular space in encircling relation to said piston and maintained stationary relative thereto, said sealing member being in the form of a flat annular ring recessed centrally and concentrically on one face to provide an annular lip disposed generally parallel to said cylindrical surface of said pumping chamber, said sealing member having an outer surface dimensioned such that when said pump is at ambient temperature said surface is in a non-pressure loaded engagement with the cylindrical surface of said cylinder with a clearance therebetween of less than one ten-thousandth of an inch, said sealing member having a coefficient of contraction greater than that of said cylindrical surface-defining means so as to have a tendency to shrink away from the cylindrical surface when the pump is cooled, and a metallic ring within said recess of said sealing member engageable with the inner cylindrical surface of said lip, said ring having a coefficient of contraction less than that of said cylindrical surface-defining means and said sealing member so as to limit diametrical shrinkage of said lip and maintain said surface in the ambient temperature relationship with said cylindrical surface at temperatures below ambient.

4. A pump intended to be operated at temperatures substantially below ambient, said pump construction comprising means having a generally cylindrical surface defining an elongated pumping chamber, a piston carried within said pumping chamber for reciprocal movement, said piston and said chamber being proportioned relative to one another so as to provide an annular space between the side wall of said piston and the said cylindrical surface of said chamber, and a rigid sealing member positioned within said annular space, said member being formed of a material capable of cold flow at ambient temperature under a given pressure to an extent equal to the normal wear encountered by said member during operation of the pump, said member being maintained in a stationary position with respect to the surface of one of said chamber and piston wall and having a surface in sliding non-pressure loaded contact with the surface of the other of said chamber and piston wall, the dimensions of said member being such that the clearance between the said surface of said member and the surface of the other of said chamber and piston is no greater than one ten-thousandth of an inch during operation of said pump, and biasing means placing said sealing member under said given pressure at ambient temperature so as to cause cold flow sufficient to compensate for the wear incurred by said member during operation of said pump.

5. A sealing unit for use with a positive displacement pump including a generally cylindrical surface defining an elongated pumping chamber and a piston carried within said chamber for reciprocal movement, said sealing unit comprising a rigid non-metallic sealing member in the form of a flat annular ring recessed centrally and concentrically on one surface to provide an annular lip on said ring, said sealing member being formed of a material having a coefficient of contraction greater than that of said cylindrical surface-defining means and that of said piston and being capable of cold flow under pressure at ambient temperatures, and a metallic ring adapted to fit within said recess and having an outer diameter closely approximating the diameter of said recess, said metallic ring being formed of a material having a coefficient of contraction less than that of said sealing member, said cylinder-defining means, and said piston.

6. A pump intended to be operated at a temperature substantially below ambient, said pump comprising means having a generally cylindrical surface defining an elongated pumping chamber, a cylindrical piston carried within said chamber for reciprocal movement, said piston having a diameter less than that of said cylindrical surface, the outer surface of said piston being provided with a generally cylindrical groove, a seal for said piston comprising an annular non-metallic sealing member carried within said groove of said piston, said sealing member being in the form of a flat ring having an outer diameter providing a clearance between said cylindrical surface and said sealing member of not more than one ten-thousandth of an inch, said sealing member being recessed centrally and concentrically to provide a cylindrical lip, said sealing member being formed of a material capable of cold flow at ambient temperatures and having a coefficient of contraction greater than that of said piston and cylinder-defining means, a metallic ring carried within said groove of said piston within the said recess of said sealing member, said metallic ring having a coefficient of contraction less than that of said sealing member, said piston, and said cylinder-defining means and biasing means within said groove of said piston adapted to exert sufficient pressure on said sealing member at ambient temperatures to cause sufficient cold flow thereof to compensate for wear of said member during operation of said pump.

7. A pump intended to be operated at a temperature substantially below ambient, said pump comprising means defining a generally cylindrical surface defining an elongated pumping chamber, said surface being provided with a generally cylindrical groove, a cylindrical piston carried within said chamber for reciprocal movement, said piston having a diameter less than that of said cylindrical surface, a seal for said pump comprising an annular nonmetallic sealing member carried within said groove of said cylindrical surface, said sealing member having an inner diameter providing a clearance between the outer wall of said piston and the inner surface of said sealing member of not more than one ten-thousandth of an inch, said sealing member being recessed concentrically and internally to provide a cylindrical lip, said sealing member being formed of a material capable of cold flow at ambient temperatures and having a coefficient of contraction greater than that of said piston and cylinder-defining means, a metallic ring carried within said groove of said piston and within the said recess of said sealing member, said metallic ring having a coefficient of contraction less than that of said sealing member, piston and cylinder-defining means, and biasing means within said groove of said piston adapted to exert sufficient pressure on said sealing member at ambient temperatures to cause sufficient cold flow thereof to compensate for wear of said member during operation of said pump.

8. A pump intended to be assembled at ambient temperature and to be operated at a substantially different temperature, said pump comprising means defining an elongated pumping chamber including a generally cylindrical surface, a piston carried within said pumping chamber for reciprocal movement, said piston defining an outer generally cylindrical surface parallel to but spaced from the cylindrical surface of said chamber-defining means so as to provide a space of annular transverse cross-section between said surfaces, a rigid annular sealing member disposed within said space, said sealing member including a first generally cylindrical surface parallel to the generally cylindrical surfaces of said chamber-defining means and said piston, said first generally cylindrical surface being disposed in close proximity to the generally cylindrical surface of one of said chamber defining means and piston at ambient temperature and being adapted to be disposed in a predetermined sealing engagement with the said generally cylindrical surface of said one of said chamber-defining means and piston at the operating temperature, said sealing member also including a second generally cylindrical surface defining a shoulder parallel to and in transverse alignment with at least a portion of said first surface, and a retainer defining a generally cylindrical surface in face-to-face engagement with said shoulder of said sealing member, said pump being constructed with said one of said chamber-defining means and piston formed of a material having a given coefficient of contraction, with said sealing member being formed of a material having a coefficient of contraction greater than said given coefficient of contraction, and with the said retainer being formed of a material having a coefficient of contraction less than said given coefficient of contraction so that when the temperature of the pump is changed from ambient temperature to operating said retainer is effective to limit the change in the diameter of said first surface of said sealing member so as to effect said predetermined sealing engagement between said first surface of said sealing member and said generally cylindrical surface of said one of said chamber-defining means and piston.

9. A pump in accordance with claim 8 particularly adapted to operate at temperatures appreciably below ambient, wherein said sealing member defines a third generally cylindrical surface parallel to said first generally cylindrical surface, said third generally cylindrical surface having a diameter at ambient temperature such that upon the reduction of the temperature of the pump from ambient to operating temperature, said third generally cylindrical surface contracts into a predetermined sealing engagement with the generally cylindrical surface of the other of said chamber-defining means and piston.

10. A pump in accordance with claim 9 wherein said annular sealing member is so dimensioned at ambient temperature that one of said first and third generally cylindrical surfaces thereof effects a dynamic seal with the generally cylindrical surface of one of said chamber-defining means and said piston at operating temperature and the other of said first and third generally cylindrical surfaces effects a static seal with the generally cylindrical surface of the other of said chamber-defining means and piston at the operating temperature.

11. A pump in accordance with claim 8 wherein said annular sealing member is maintained in a stationary relation to said chamber-defining means, wherein said first surface of said annular sealing member constitutes the outer surface thereof and is proportioned so as to be in close fitting relation to said generally cylindrical surface of said chamber-defining means at ambient temperature, and wherein said retainer is effective to limit the diametrical contraction of said first surface of said annular sealing member to an amount not greater than the diametrical contraction of said generally cylindrical surface of said chamber-defining means so as to effect a static seal between said surfaces at a given temperature appreciably below ambient.

12. A pump in accordance with claim 8 wherein said chamber-defining means and piston are formed of carbon steel, wherein said retainer is formed of stainless steel, and wherein said sealing member is formed of a fluorinated hydrocarbon polymer.

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