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RECIPROCATING CRYOGENIC PUMP

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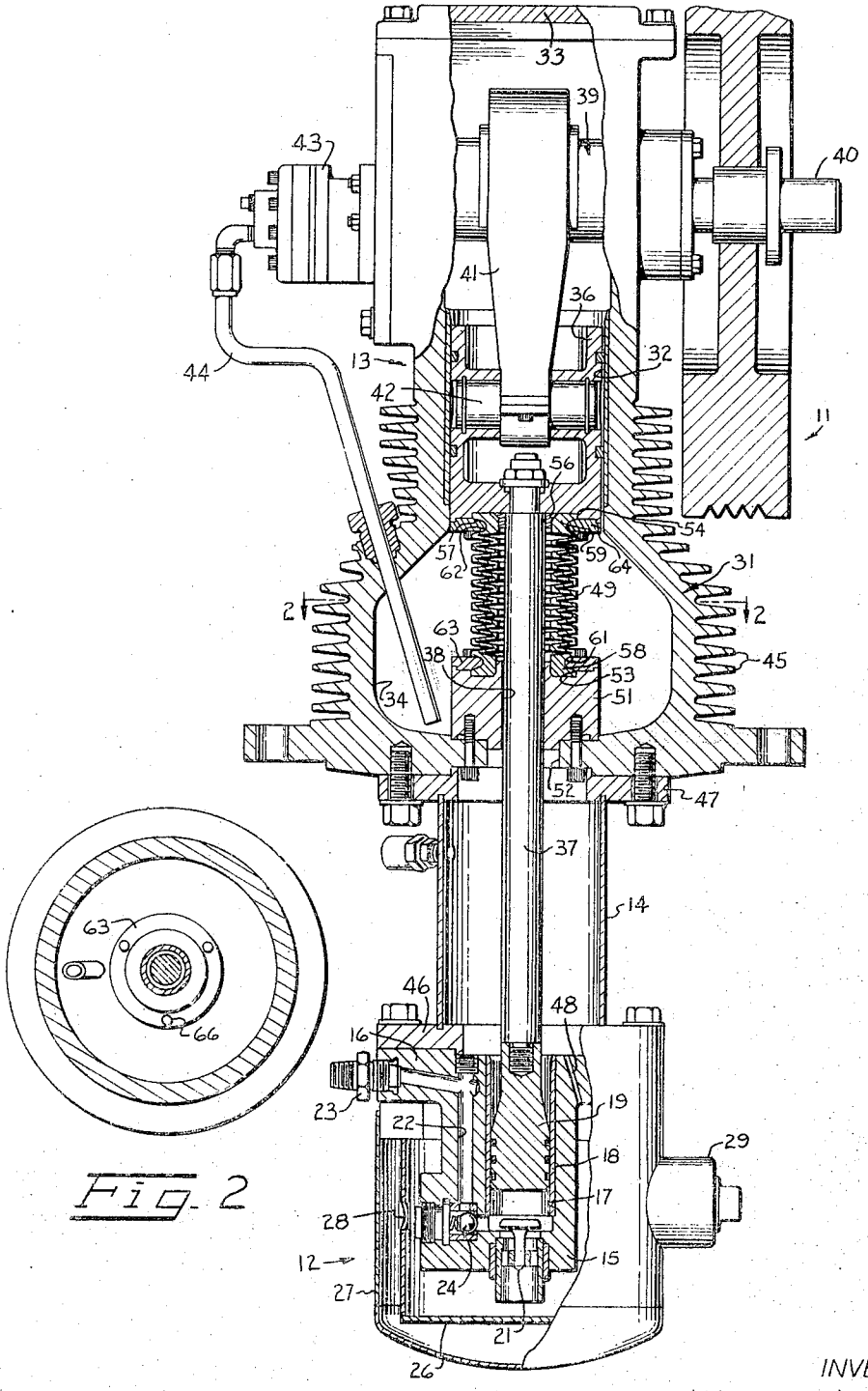


Fig. 2

Fig. 1

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RECIPROCATING CRYOGENIC PUMP

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The present invention relates to reciprocating cryogenic pumps of the type employed in the pumping of liquid oxygen, nitrogen, and other liquefied gases. The invention is more particularly directed to a reciprocating pump of this type which is arranged to completely and positively prevent the transfer of lubricating oil from the driving section of the pump into the pumping section thereof and the transfer of liquefied gas from the pumping section into the driving section.

Reciprocating pumps are extensively employed in the pumping of various liquefied gases, such as oxygen, nitrogen, and the like, from a main supply into transportable storage containers. These pumps generally include a pumping section having a head in which a bore is provided, and a pumping piston mounted for reciprocation within the bore to define a pumping chamber therewith. The piston operates to deliver liquefied gas from an inlet to the chamber to an outlet therefrom. It is desirable to insulate the head against excessive heat leak, and therefore it is the usual practice to provide a cooling chamber about the head and circulate the liquefied gas through the cooling chamber en route to the pumping chamber inlet. Alternatively, in some instances the head may be submerged directly into the liquefied gas to be pumped. In either case, the head is encompassed by liquefied gas which thermally isolates the head from the ambient surroundings.

To reciprocate the pumping piston, it is connected by an elongated piston rod to the driving section of the pump, more particularly to a drive piston thereof which is reciprocated within a cylinder bore of a driving section body by appropriate motivating means. The cylinder bore is communicated with a lubricating system arranged to circulate lubricating oil or the like between the cylinder wall and drive piston for purposes of minimizing friction. Typically, the driving and pumping sections are interconnected by a spacer sleeve secured therebetween concentrically about the piston rod. The sleeve is secured to an end of the driving section body having a rod accommodating bore traversed by the piston rod, and to the pumping section head about the pumping chamber bore into which the pumping piston extends. With this arrangement it will be appreciated that lubricating oil from within the pumping section body can flow through the clearance between the piston rod and rod accommodating bore into the interior of the spacer sleeve. The oil can then be sucked from the interior of the spacer sleeve into the pumping chamber through the clearance between the pumping piston and pumping chamber bore. This of course results in undesirable oil contamination of the liquefied gas pumped through the pumping section of the pump. Conversely, liquefied gas may flow through the clearance between the pumping piston and pumping chamber bore into the interior of the spacer sleeve. This gas may in turn be sucked into the interior of the driving section body, including the cylinder bore, through the clearance between the piston rod and rod accommodating bore. By virtue of the very low temperature of the liquefied gas, the driving section may "freeze up" or be otherwise adversely effected.

Heretofore, attempts have been made to overcome the foregoing problem by providing seals between the piston rod and rod accommodating bore and between the pumping piston and pumping chamber bore. Although, these seals minimize the undesirable transfer of oil and liquefied

gas between the respective sections of the pump, intolerable amounts of these materials are still transferred.

It is therefore an object of the present invention to provide a reciprocating cryogenic pump wherein interior portions of the driving section and pumping section are entirely separated and isolated from each other to positively block communication therebetween and thereby prevent the transfer of oil to the pumping section and the transfer of liquefied gas to the driving section of the pump.

Another object of the invention is the provision of an improved reciprocating cryogenic pump of the class described wherein a flexible impervious wall is provided in association with the reciprocating piston assemby thereof in such a manner as to positively block communication between interior portions of the driving section of the pump and of the spacer sleeve thereof through the clearance between the rod and rod accommodating bore in the driving section.

It is a further object of the invention to provide an improved reciprocating cryogenic pump of the character outlined above wherein the flexible impervious wall is provided by a bellows concentrically disposed about the piston rod and sealably secured at its opposite ends to the end face of the drive piston and to an interior wall portion of the body of the driving section circumscribing the rod accommodating bore.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of the preferred form of the invention which is illustrated in the drawing accompanying and forming part of the specification. It is to be understood, however, that variations in the showing made by the said drawing and description may be adapted within the scope of the invention as set forth in the claims.

FIGURE 1 is an elevational view with portions broken away of an improved reciprocating cryogenic pump in accordance with the invention.

FIGURE 2 is a sectional view taken at line 2—2 of FIGURE 1.

Referring now to the drawing, a reciprocating cryogenic pump **11** in accordance with the present invention will be seen to include a pumping section **12** and a driving section **13** spaced therefrom as by means of a spacer sleeve **14** secured therebetween. In basic respects the pump is conventional.

The pumping section **12** includes a generally cylindrical head **15** having an outwardly flared annular flange **16** at one end. An axial bore **17** extends through the head and the end of the bore adjacent the flange is preferably sleeved, as indicated at **18**, to receive a pumping piston **19**. The opposite end of the bore is fitted with a check valve **21** which serves as a cyclically opening and closing inlet to a high pressure pumping chamber defined by the bore wall, piston, and valve. A passage **22** extends transversely into the head from a point adjacent the valved end of the bore, then longitudinally and outwardly to terminate in an outlet fitting **23** extending radially into the flange **16**. A ball check valve **24**, or equivalent means, is provided in passage **22** to cyclically open and close same in opposition to the operation of the inlet check valve **21**. More particularly, the piston **19** is reciprocated in the bore by means subsequently described, and during a compression stroke thereof the valve **21** is closed and the valve **24** is open. Conversely, during an expansion stroke of the piston, the valve **21** is open and the valve **24** is closed. Thus liquefied gas, or the like, may be sucked into the pumping chamber through valve **21** during each expansion stroke of the piston, and this liquefied gas is delivered through the valve **24** to outlet **23** during each compression stroke.

The head **15** is commonly enclosed within a cooling chamber which serves to thermally insulate the head from

the ambient surroundings and to thereby minimize heat leak which would tend to vaporize the liquefied gas. In this regard, axially and radially spaced nested cylindrical cupped jacket members **26**, **27** are coaxially secured to the head flange **16**, with the inner member **26** being axially and radially spaced from the head. An aperture **28** is provided through the side wall of the inner member **26** and an inlet fitting **29** adapted for connection to a source of liquefied gas extends radially through the side walls of both members **26**, **27**. The cooling chamber thus includes an inner portion surrounding the head, and an outer portion between the members **26**, **27** surrounding the inner portion. Liquefied gas supplied through the inlet fitting **29** enters the inner portion of the cooling chamber and a portion of the gas passes through aperture **28** to fill the outer portion of the chamber. The liquefied gas in the cooling chamber, being at very low temperature, serves to cool the head, and therefore the pumping chamber. Since the inlet valve **21** is communicated with the inner portion of the cooling chamber, it is from this region that the liquefied gas is introduced to the pumping chamber. In various alternative arrangements the cooling jacket members **26**, **27** may be dispensed with and the pumping head **15** directly submerged in a supply of liquefied gas to produce equivalent results.

Considering now the driving section **13** in detail, same will be seen to include a generally cylindrical body **31** having a cylinder bore **32** axially thereof communicating at one end with the interior of a crank case **33** and at the opposite end with a lubricant cooling chamber **34**. A drive piston **36** is mounted for reciprocation in the cylinder bore **32**, and an elongated piston rod **37** is centrally secured to the end of the drive piston to extend coaxially therefrom through a rod accommodating bore **38** in the end of the body **31**. The pumping piston **19** is coaxially secured to the free end of the piston rod such that the drive piston, piston rod, and pumping piston reciprocate as a unit. Such reciprocation is effected as by means of a crank shaft **39** journalled for rotation within the crank case **33** transverse to the cylinder bore **32**. An end of the shaft **39** projects from the crank case, as indicated at **40**, to facilitate connection thereof to a motor or the like. The shaft is coupled to the drive piston by means of a connecting rod **41** and wrist pin **42** whereby the piston is reciprocated in response to rotation of the shaft. An oil pump **43** is mounted on the exterior of the body adjacent the crank case and the crank shaft is coupled in driving relation thereto. An oil line **44** extends from the oil pump, through the body, and into the lubricant cooling chamber **34** to a point adjacent the end thereof. With this arrangement oil or other lubricant is circulated from the cooling chamber **34** to the crank case **33** wherefrom the oil is returned through the space between the drive piston and wall of the cylinder bore to the cooling chamber. The oil, of course, serves to minimize friction between the drive piston and cylinder wall. However, there is still sufficient friction that substantial heat is generated during reciprocation of the piston. Accordingly, the exterior of the body **31** is conventionally provided with fins **45** in the region thereof containing the cylinder bore and lubricant cooling chamber. Such fins serve to dissipate heat transferred to the body from the relatively hot oil delivered to the cooling chamber such that relatively cool oil is delivered to the crank case.

It will be appreciated that the spacer sleeve **14** coaxially secured between the pumping section head **15** and the driving section body **31** concentrically about the piston rod **37** would normally provide a path of communication between interior portions of the body and head. More particularly, the sleeve is typically provided with flanges **46**, **47** at its opposite ends which are respectively attached to the head **15** in outwardly spaced concentric relation to the bore **17** and to the body **31** in outwardly spaced concentric relation to the rod accommodating bore **38**. There

is of course some clearance between the piston rod **37** and bore **38**, and between the pumping piston **19** and bore **17**. Thus oil from interior portions of the driving section body, namely the lubricant cooling chamber **34**, is normally transmitted into the interior of the spacer sleeve **14** through the clearance between the rod **37** and bore **38**. Liquefied gas from interior portions of the pumping section head, namely the pumping chamber, is normally transmitted into the interior of the spacer sleeve through the clearance between the pumping piston **19** and bore **17**. In this latter regard, a pressure equalizer vent **48** is typically provided through the head flange **16** to communicate the interior of the sleeve with the head cooling chamber and to provide for the return of gas therebetween. Oil in the sleeve interior would normally be transmitted into the pumping chamber through the clearance between the pumping piston **19** and bore **17**, as well as into the head cooling chamber through the vent **48**. This transfer of oil would normally result in contamination of the liquefied gas pumped through the pumping section. Conversely, liquefied or vaporized gas in the sleeve interior would normally be transmitted into the interior portions of the pumping section through the clearance between the rod **37** and rod accommodating bore **38**. Inasmuch as the liquefied gas, and even the vaporized gas, are at very low temperatures, freezing of components of the driving section would result or the driving section would otherwise be detrimentally affected.

It is possible to minimize the foregoing detrimental transfer of oil and liquefied gas between the driving and pumping sections of the pump by providing seal rings, or the like, between the rod **37** and bore **38** and between the pumping piston **19** and bore **17**. In fact, previous approaches to solving the problem have been generally along these lines. However, these seals are incapable of completely blocking communication between the respective sections of the pump and are pervious to some extent to the passage of oil and liquefied gas therethrough. In practice absolutely no transfer of oil and gas between the respective sections of the pump can be tolerated in many applications. Therefore, the provision of seals in the foregoing manner does not provide a solution to the problem. It is only where the interior portions of the pumping and driving sections are sectionalized into two isolated entirely separate non-communicating chambers that no transfer of oil and gas can occur therebetween.

In accordance with the improvement of the present invention the interior portions of the pumping and driving sections are separated into two such completely separated non-communicating chambers to thereby positively eliminate transfer of oil and gas therebetween. An impervious wall is provided which separates the interior portions of the pumping and driving sections into non-communicating chambers and which is yet traversed by the piston rod **37**. In this regard the impervious wall in general respects is sealably secured between the assembly of the pumping piston **19**, drive piston **36**, and piston rod **37** and a wall portion of the overall passage which extends between the interior portions of the pumping and driving sections of the pump through the interior of sleeve **14**. The impervious wall is flexible to permit reciprocation of the piston assembly and secured to the wall of the passage at one end thereof, or at a position intermediate the ends. Communication between the pumping and driving sections through the passage is thus completely and positively blocked by the flexible impervious wall. The flexible impervious wall may be variously provided as a diaphragm, or the like, and secured to the passage wall and to the piston assembly at any of a variety of positions, as previously noted. However, in a preferred arrangement of the invention the flexible impervious wall is defined by a bellows **49** which, in effect, is sealably secured between the drive piston **36** and the end of the passage extending into the interior portions of the driving section of the pump. More

particularly, the bellows is concentrically disposed about the piston rod **37** and coaxially sealably secured at its opposite ends to the end face of the drive piston **36** and an interior surface portion of the body **31** which circumscribes the rod accommodating bore **38**. In this regard a cylindrical adapter block **51** is best coaxially attached to the interior end surface of the body in circumscribing relation to an aperture **52** normally provided therethrough to project coaxially into the lubricant cooling chamber **34**. The block is provided with an axial bore, in the present instance comprising the accommodating bore **38** through which the piston rod **37** extends. The exposed end face of the block is formed with an annular groove **53** concentrically outward from the bore **38**. The end face of drive piston **36** is provided with an annular recess **54** and an annular guide **56** is concentrically disposed about the piston rod within the recess. An annular groove **57** is defined between the periphery of the guide and peripheral wall of the recess. The annular grooves **53, 57** serve to receive annular flanged end portions **58, 59** of the bellows **49**. These end portions are formed with peripheral grooves **61, 62** for receiving retaining rings **63, 64**. With the flanged end portions of the bellows recessed in the grooves **53, 57**, the retaining rings **63, 64** are respectively secured to the end face of block **51** and to the end face of the drive piston **36**, as by means of cap screws **66** or equivalent fasteners, to thereby provide sealed connections therebetween.

With the bellows **49** thus mounted between the drive piston **36** and block **51** it will be appreciated that the piston may still be reciprocated, the bellows being alternately expanded and compressed to permit such reciprocation. The interior of the sleeve **14** communicates through the space between the piston rod **37** and bore **38** with the interior of the bellows **49**. The bellows, however, provides an impervious wall which blocks communication between its interior and the lubricant cooling chamber **34**. The bellows thus sectionalizes the pump interior into two separate non-communicating chambers, one of which includes the lubricant cooling chamber **34** and other internal portions of the driving section, and the second of which includes the interior portions of the pumping section and interior of the spacer sleeve. Oil from the first sectionalized chamber cannot flow into the second and gas from the second cannot flow into the first. Contamination of the liquefied gas pumped through the pumping section by oil from the driving section and freeze up of the driving section by liquefied gas from the pumping section are consequently prevented.

What is claimed is:

1. An improved reciprocating cryogenic pump comprising a pumping section including a head with a bore extending thereinto and a pumping piston mounted for reciprocation in said bore and defining therewith a pumping chamber for liquefied gas, a driving section including a body with a cylinder bore having a drive piston mounted for reciprocation therein and a lubricating system communicated therewith, said body having a rod accommodating bore in an end thereof coaxial with respect to said cylinder bore, a piston rod coaxially secured at its opposite ends to said drive piston and said pumping piston and extending through said rod accommodating bore, said drive piston and pumping piston and piston rod forming an integral reciprocal piston assembly, a spacer sleeve disposed in concentric outwardly spaced relation to said rod and secured at its opposite ends to said body and said head, the interior of said sleeve and clearances between said pumping piston and head bore and between said piston rod and rod accommodating bore defining a passage between interior portions of said pumping section head and driving section body, and a flexible impervious wall

sealably secured between said piston assembly and a wall portion of said passage.

2. A pump according to claim **1**, further defined by said flexible impervious wall comprising a bellows concentrically disposed about said piston rod and having its opposite ends sealably secured to said piston and to an interior wall surface of said body circumscribing said rod accommodating bore.

3. A reciprocating cryogenic pump comprising a cylindrical head having an outwardly flared annular flange at one end, said head having an axial bore extending therethrough, said head having a passage extending exteriorly from said bore adjacent the opposite end thereof from said flange and terminating in an outlet, a check valve disposed in the opposite end of said bore from said flange, a second check valve disposed in said passage, at least one cylindrical cupped jacket secured to said flange in radially and axially spaced relation to said head to define a head cooling chamber thereabout, means defining an inlet to said head cooling chamber for admission of liquefied gas, a pumping piston mounted for reciprocation in said bore, a generally cylindrical body coaxially spaced from said head, said body having a cylinder bore therein communicated at its opposite ends with a crank case and a lubricant cooling chamber, said body having a rod accommodating bore therethrough in communication with said lubricant cooling chamber, a drive piston mounted for reciprocation in said cylinder bore, a crank shaft journalled for rotation in said crank case, a connecting rod coupling said crankshaft to said drive piston, a lubricant pump mounted upon said body and coupled in driven relation to said crankshaft, a lubricant line extending from said lubricant pump into said lubricant cooling chamber, a piston rod coaxially connected at its opposite ends to said drive piston and said pumping piston, said piston rod extending through said rod accommodating bore and into the head bore at the flanged end of said head, a cylindrical spacer sleeve concentrically disposed about said piston rod and coaxially secured at its opposite ends to said body and the flange of said head, said head flange having a vent therethrough communicating said head cooling chamber with the interior of said cooling jacket, and a bellows concentrically disposed about said piston rod and secured at its opposite ends to said drive piston and an interior surface of said body adjacent said lubricant cooling chamber and circumscribing said rod accommodating bore.

4. A pump according to claim **3**, further defined by said drive piston having an annular groove defined in an end thereof concentrically outwardly disposed about said piston rod, said interior surface of said body having an annular groove defined therein concentrically about said rod accommodating bore, said bellows having annular flanges at its opposite ends with peripheral grooves therein, said annular flanges of said bellows received in said annular grooves, and by a pair of retaining rings engaging said peripheral grooves and secured to said end of said drive piston and to said interior surface of said body.

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