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(54) CRYOGENIC PUMP

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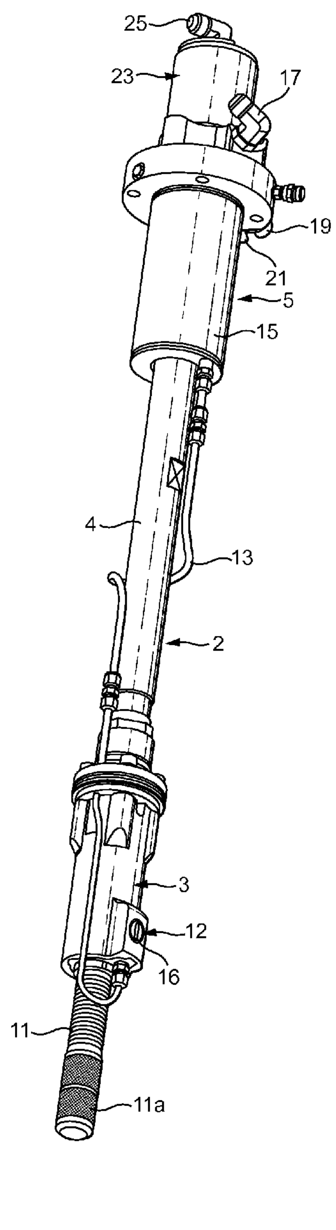
(57) **ABSTRACT**

A cryogenic pump is typically used to supply high pressure natural gas to an engine. The pump has a piston operable to discharge cryogenic liquid from a pumping chamber within a pump housing. The cryogenic liquid exits the chamber through an outlet port in which a check valve is positioned. The check valve has a valve member which is loaded by a spring and is retained by a retaining member accessible from outside the housing. The check valve has an inlet which is axial with the valve member and an outlet which is transverse to the axis of the valve member.



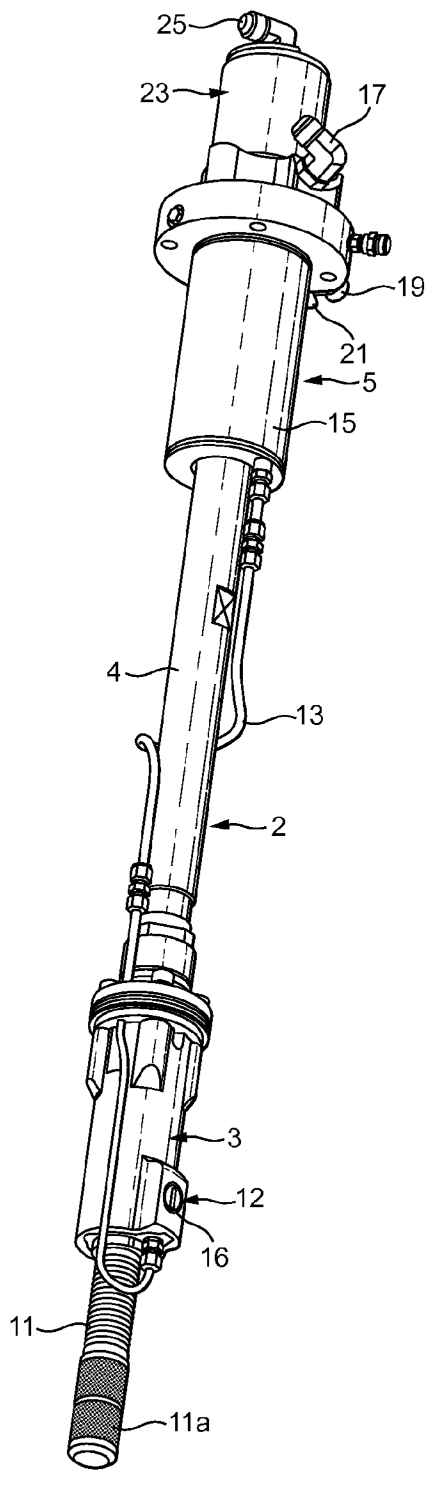


FIG. 1

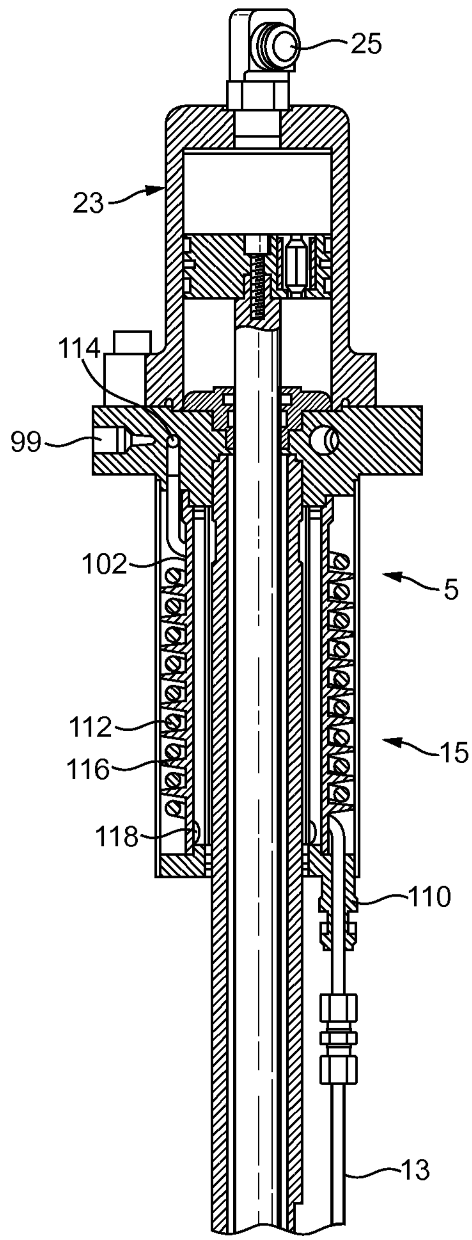


FIG. 2

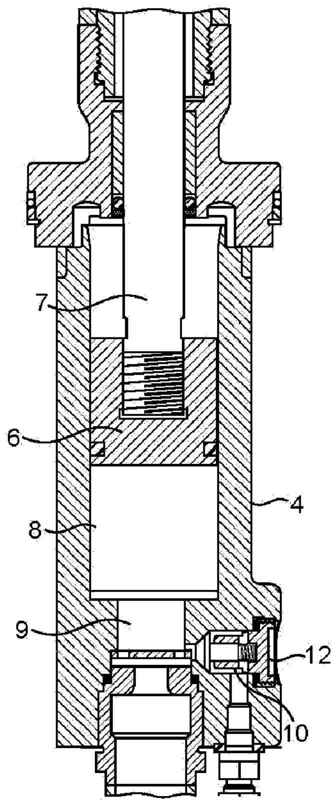


FIG. 3

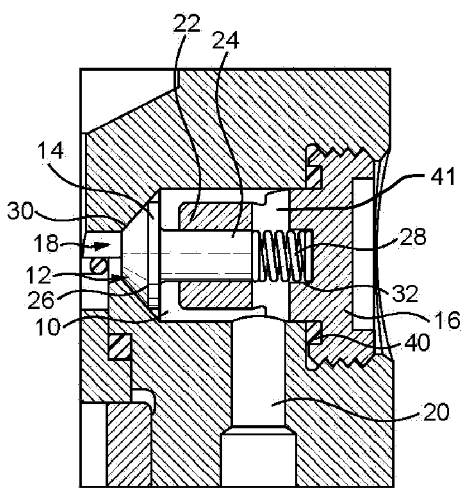


FIG. 4

CRYOGENIC PUMP

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of International Application No. PCT/CA2012/050416 having an international filing date of Jun. 22, 2012 entitled “Cryogenic Pump”. The ’416 international application claimed priority benefits, in turn, from European Patent Application No. 11352008.4 filed on Jun. 29, 2011. The ’416 international application is hereby incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to a cryogenic pump and particularly to a check valve for a cryogenic piston pump

BACKGROUND OF THE INVENTION

[0003] A cryogenic pump that utilizes a piston as the pumping member has a pumping chamber with an outlet port from the pumping chamber communicating with a conduit for the pumped liquid. Typically, a check valve is located in the conduit to prevent backflow of liquid from the conduit to the pumping chamber. A check valve typically has its inlet and outlet in axial alignment with one another.

[0004] Cryogenic pumps are typically used in industrial plants for example, in plant for the separation or liquefaction of industrial gases. Cryogenic liquefied gases are becoming increasingly widely used. For example, liquefied natural gas (LNG) is now being used as an automotive fuel, particularly for heavy goods vehicles (HGVs). Piston pumps have been developed in order to transfer the LNG from a storage vessel on board the vehicle to the vehicle’s engine. Such a pump needs to be quite compact and easy to maintain. The pump typically has a vaporizer associated with it.

[0005] An example of a cryogenic pump suitable for use with LNG on an HGV is given in U.S. Pat. No. 7,293,418.

SUMMARY OF THE INVENTION

[0006] A cryogenic pump for pumping liquid natural gas comprises:

- **[0007]** (a) a piston operable to discharge cryogenic liquid from a pumping chamber within a pump housing;
- **[0008]** (b) an outlet port from the pumping chamber, the outlet port disposed in the pump housing; and
- **[0009]** (c) a check valve in the outlet port, the check valve comprising:
  - **[0010]** (i) a valve member;
  - **[0011]** (ii) a demountable retaining member accessible from the exterior of the pump housing;
  - **[0012]** (iii) an inlet axial with the valve member and transverse to the axis of the pumping chamber of the cryogenic pump; and
  - **[0013]** (iv) an outlet transverse to the axis of the valve member and parallel to the axis of the pumping chamber of the cryogenic pump.

[0014] In one embodiment, the retaining member comprises a sleeve for guiding the valve member. The sleeve is preferably formed integrally with the retaining member.

[0015] In another embodiment, the valve member is spring-loaded. The valve member preferably comprises a cylindrical body and a frustoconical head, which, when the check valve is in its closed position, sealingly engages, under bias of the spring, a complementary valve seat formed in the pump housing. The head is preferably formed from plastic material or polytetrafluoroethylene (PTFE). The valve seat is preferably formed from metal such as stainless steel).

[0016] In another embodiment, the spring is a compression spring. The compression spring is preferably seated in a detent formed in the retaining member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] A cryogenic pump according to the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

[0018] FIG. **1** is a schematic perspective view of the pump;

[0019] FIG. **2** is a sectional side elevation of the warm end of the pump shown in FIG. **1**;

[0020] FIG. **3** is a sectional elevation of the pumping chamber of the pump shown in FIG. **1**; and

[0021] FIG. **4** is an enlarged sectional elevation of part of the pumping chamber shown in FIG. **3** illustrating the check valve in the outlet part of the pumping chamber.

[0022] The drawings are not to scale.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT(S)

[0023] Referring to the drawings, there is shown generally a cryogenic pump **2** of the kind having a cold end **3** adapted to be immersed in a volume of cryogenic liquid, not shown, to be supplied to, for example, a combustion engine. Pump **2** is generally of the same kind as that disclosed in U.S. Pat. No. 7,293,418, save that it does not include an accumulator. Instead, pump **2** has a pumping chamber communicating directly with a vaporizer or like heater. The disclosure of U.S. Pat. No. 7,293,418 is hereby incorporated by reference herein in its entirety. Cryogenic pump **2** has a warm end **5** opposite cold end **3**. Warm end **5** is not intended for immersion in the cryogenic liquid. Pump **2** has a housing **4** of generally elongate configuration with an axial piston **6** and piston shaft **7**. Piston **6** is able, in operation, to draw cryogenic liquid into, and force cryogenic liquid out of, a pumping chamber **8** defined within housing **4**. Pumping chamber **8** has an inlet **9** for cryogenic liquid communicating with a hollow cylindrical cryogenic liquid intake member **11** typically fitted with a filter **11***a* effective to prevent small solid particles from entering the pump.

[0024] Pumping chamber **8** has an outlet port **10** for the discharge of cryogenic liquid. With particular reference to FIGS. **3** and **4**, outlet port **10** houses a check valve **12**. Outlet port **10** is connected to a relatively small diameter conduit **13** which extends from cold end **3** to warm end **5** of pump **2**. Conduit **13** terminates in an annular heat exchange device **15**, in which the cryogenic liquid is vaporized by indirect heat exchange with a relatively high temperature heat exchange fluid. (If, for example, the cryogenic liquid is LNG, and pump **2** is intended to supply the natural gas to an engine (not shown), the heat exchange fluid can be the aqueous liquid that is used to cool the engine.) The heat exchange device **15** is provided with an outlet **99** (see FIG. **2**) for vaporized natural gas and an inlet **19** and outlet **21** for the heat exchange fluid. Typically, there is within the heat exchange device a passage (not shown) for the cryogenic liquid in heat exchange relationship with another passage (not shown) for the heat exchange fluid. Flow of the cryogenic liquid through its passage causes it to vaporize.

[0025] At warm end **5** of pump **2** there is provided a drive chamber **23** for piston **6**. Typically, a hydraulic drive is employed, there being an inlet port **25** and an outlet port **17** for hydraulic liquid, but an electrical, pneumatic or mechanical drive could alternatively be used. The drive arrangements may in general be similar to those disclosed in U.S. Pat. No. 7,293,418 for the pump described and shown therein. Piston **6** has two strokes. In its upward stroke (that is in its stroke away from cold end **3**, a flow of cryogenic liquid through inlet **9** is induced. In its downward stroke (that is in its stroke away from warm end **5**) a flow of cryogenic liquid through outlet port **10** is provided. Pump **2** is capable of generating a high delivery pressure, typically in the order of 300 bar, or higher.

[0026] Check valve **12** is best viewed in FIG. **4**. Check valve **12** is located in pump housing **4** at outlet port **10**. Check valve **12** has a spring-loaded valve member **14** which is retained within housing **4** by a demountable retaining member **16** accessible from the exterior of pump housing **4**. Retaining member **16** may make a screw-threaded engagement with pump housing **4** and may have a configuration such that access can be gained to valve member **14** from outside housing **4** by means of a specific tool (not shown) to dismantle the part, in association with a standard wrench. In its normal position retaining member **16** comprises a resilient O-ring seal **40** to prevent leakage of fluid out of pump **16** via the screw-threads of retaining member **16**. Retaining member **16** has a sleeve **22** for guiding valve member **14**. Sleeve **22** is typically formed integrally with retaining member **16**.

[0027] Valve member **14** has a cylindrical body **24** and a frustoconical head **26**. During the delivery stroke check valve **12** remains open but it closes for the intake stroke of piston **6**. If the pump is idle, check valve **12** remains closed. When check valve **12** is in its closed position, head **26** makes a sealing engagement, under the bias of a compression spring **28** and any fluid pressure in outlet **20**, with a complementary valve seat **30** formed in pump housing **4**. Typically, head **26** and the rest of valve member **14** are formed of a plastics material which is able to be used at cryogenic temperatures. PTFE is one such plastics material.

[0028] Similarly, housing **4** and, in particular, valve seat **30** is made of a material that in addition to being a metallic engineering material is suitable for use at cryogenic temperatures. Stainless steel is one such material. Compression spring **28** is seated in a detent **32** in retaining member **16**. The bias of compression spring **28** acts in a valve-closing direction. Thus, when there is no cryogenic liquid pressure acting in the opposite direction, valve **12** remains in a closed position preventing back flow of fluid from conduit **13** into pumping chamber **8**. Moreover, the basis of the spring is effective to keep check valve **12** closed when there is no cryogenic liquid pressure acting on valve member **14** irrespective of the attitude of cryogenic pump **2**. (In practice, the cryogenic pump is typically positioned with its axis at angle to the vertical.)

[0029] Valve **12** has an inlet **18** which is axial with valve member **14** and a radial outlet **20** which is transverse to the axis of valve member **14**. Check valve **12**, when open, permits cryogenic liquid to flow from inlet **18** to outlet **20**. The flow path has an axial element being defined between sleeve **22** and a complementary portion of housing **4** and a transverse radial element through outlet **20**, there being a transverse radial passage **41** through sleeve **22** of retaining member **16** to aid flow of the cryogenic liquid.

[0030] The position of check valve **12** in housing **4** of cryogenic pump **2** keeps down the dead volume between piston **6** at the end of the downward stroke, namely, the stroke away from warm end **5**, and the sealing area of check valve **12**, and thereby avoids loss of pump efficiency.

[0031] Typically, valve member **14** undergoes wear in use, so is exchanged for an identical such member after a chosen period of time. In order to exchange valve member **14**, pump **2** is withdrawn from the tank (not shown) containing cryogenic liquid in which it is typically located, pump **2** allowed to return to ambient temperature, and retaining member **16** removed.

[0032] While particular elements, embodiments and applications of the present invention have been shown and described, it will be understood, that the invention is not limited thereto since modifications can be made by those skilled in the art without departing from the scope of the present disclosure, particularly in light of the foregoing teachings.

What is claimed is:

1. A cryogenic pump for pumping liquid natural gas comprising:
(a) a piston operable to discharge cryogenic liquid from a pumping chamber within a pump housing;
(b) an outlet port from said pumping chamber, said outlet port disposed in said pump housing; and
(c) a check valve in said outlet port, said check valve comprising:
(i) a valve member;
(ii) a demountable retaining member accessible from the exterior of said pump housing;
(iii) an inlet axial with said valve member and transverse to the axis of said pumping chamber of said cryogenic pump; and
(iv) an outlet transverse to the axis of said valve member and parallel to the axis of said pumping chamber of said cryogenic pump.

2. The cryogenic pump of claim **1**, wherein said retaining member comprises a sleeve for guiding said valve member.

3. The cryogenic pump of claim **2**, wherein said sleeve is integral with said retaining member.

4. The cryogenic pump of claim **1**, wherein said valve member is spring-loaded.

5. The cryogenic pump of claim **4**, wherein said valve member comprises a cylindrical body and a frustoconical head, which, when said check valve is in its closed position, sealingly engages, under bias of said spring, a complementary valve seat formed in said pump housing.

6. The cryogenic pump of claim **5**, wherein said head is formed from plastic material.

7. The cryogenic pump of claim **5**, wherein said head is formed from polytetrafluoroethylene.

8. The cryogenic pump of claim **5**, wherein said valve seat is formed from metal.

9. The cryogenic pump of claim **8**, wherein said valve seat is formed from stainless steel.

10. The cryogenic pump of claim **4**, wherein said spring is a compression spring.

11. The cryogenic pump of claim **10**, wherein said compression spring is seated in a detent formed in said retaining member.

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