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(54) **Title**: CRYOGENIC PUMPS

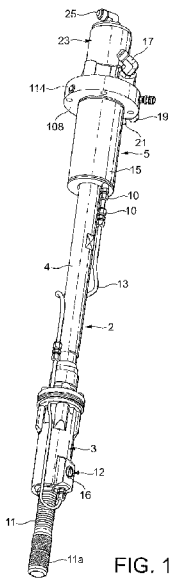


FIG. 1

(57) **Abstract**: A cryogenic pump (2) for a cryogenic liquid has associated therewith a heater (15) for vaporising the cryogenic liquid. The heater (15) comprises a chamber (100) (bounded by an inner sleeve (102) and an outer sleeve (104)), a helical heating coil (112) having a plurality of turns disposed within the chamber (100), an inlet (110) for cryogenic liquid communicating with the heat exchange coil (112) and an outlet (99) for resulting heated fluid communicating with the heat exchange coil (112). An inlet (19), and an outlet (18) from the water chamber (100) for heat exchange fluid are provided. The heater chamber (100) has a helical baffle (116) having a plurality of turns for guiding the heat exchange fluid over the turns of the heat exchange coil (12). The turns of the baffle (116) are interspaced with the turns of coil (112).

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# ***CRYOGENIC PUMPS***

This invention relates to a cryogenic pump and particularly to a heater for use with a cryogenic piston pump.

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 pumps need to be quite compact, easy to maintain and to produce vaporised LNG at a high pressure (typically 300 bar).

An example of a cryogenic pump suitable for use with LNG on an HGV is given in US 7 293 418 B2,

According to the present invention there is provided a cryogenic pump for pumping a cryogenic liquid that is LNG, the cryogenic pump having associated therewith a heater for vaporising the cryogenic liquid, the heater comprising a chamber bounded by an inner sleeve and outer sleeve, a helical heat exchange coil having a plurality of turns disposed within the heater chamber, an inlet for cryogenic liquid communicating with the heat exchange coil, an outlet for resulting vaporised fluid communicating with the heat exchange coil, an inlet to the heater chamber for a heat exchange fluid, and an outlet from the chamber for the heat exchange fluid, wherein the heater chamber has a helical baffle having a plurality of turns for guiding the heat exchange fluid of the turns over the heat exchange coil, the turns of the helical baffle being interspaced with the turns of the helical coil.

The terms "vaporised", "vaporisation" and "vaporise" all refer to the heating of a cryogenic liquid from below to above its critical temperature. In operation of a cryogenic pump according to the invention, a pumping chamber receives a cryogenic liquid and pumps it typically at a pressure above its critical pressure to a vaporiser. The cryogenic liquid typically enters the vaporiser at a pressure above its critical pressure, is heated in the vaporiser from a temperature below its critical temperature to above its critical temperature, and leaves the vaporiser as a supercritical fluid.

The arrangement of the baffle facilitates heat exchange between the cryogenic liquid and the heat exchange fluid.

The baffle may be integral with the inner or outer sleeve.

The cryogenic pump typically has a piston operable to discharge cryogenic liquid from a pumping chamber within a pump housing. The pump housing is conveniently of generally elongate, cylindrical configuration. The heater chamber is conveniently disposed about the pump housing.

The pumping chamber typically has an outlet port communicating with one end of the conduit for conducting the cryogenic liquid to the heat exchange coil of the heater, the other end of the conduit communicating with the inlet to the heat exchange coil.

The outlet from the chamber for the heat exchange fluid is typically formed in the inner sleeve. Used heat exchange fluid may be withdrawn from a space defined inwardly of the inner sleeve.

The coil may be provided with internal or external ribs or fins or the like so as to facilitate heat exchange.

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

Figure 1 is a schematic perspective view of the pump;

Figure 2 is a sectional side elevation of the warm end of the pump shown in Figure 1;

Figure 3 is a sectional elevation of the pumping chamber of the pump shown in Figure 1;

Figure 4 is a schematic perspective view of the arrangement of the inner sleeve, heat exchange coil and baffle of the heater of the cryogenic pump shown in Figure 1; and

Figure 5 is a schematic sectional elevation of a central portion of the heater shown in Figures 1, 2 and 4, but with all items internal to the housing of the pump being omitted for purposes of clarify of illustration.

The drawings are not to scale.

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. The pump 2 is generally of the same kind as that disclosed in US 7 293 418 B2, save that it does not include an accumulator. Instead the pump 2 has a pumping chamber communicating directly with a vaporiser or like heater. The disclosure of US 7 293 418 B2 is incorporated herein by way of reference.

The cryogenic pump has a warm end 5 opposite the cold end 3. The warm end 5 is not intended for immersion in the cryogenic liquid. The pump 2 has a housing 4 of generally elongate configuration with an axial piston 6 and piston shaft 7. The piston 6 is able, in operation, to draw cryogenic liquid into, and force cryogenic liquid out of, a pumping chamber 8 defined within the housing 4. The 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 11a effective to prevent small solid particles from entering the pump.

The outlet port 10 houses a check valve 12. The outlet port 10 is connected to a relatively small diameter conduit 13 which extends from the cold end 3 to the warm end 5 of the pump. The conduit 13 terminates in an annular heater or heat exchange device 15, in which the cryogenic liquid is vaporised by indirect heat exchange with a relatively high temperature heat exchange fluid. If, for example, the cryogenic liquid is LNG and the pump 2 is intended to supply the natural gas to an engine (not shown) the heat exchange, the heat exchange fluid can be an aqueous fluid that is used to cool the engine. Typically, the cryogenic pump 2 raises the pressure of the cryogenic liquid to above its critical pressure, so that strictly speaking it becomes a supercritical fluid rather than a liquid in the heater 15. The heater 15 is provided with an outlet 99 (see Figure 2) for vaporised natural gas and with an inlet 19 and outlet 21 for the heat exchange fluid. As will be

described with reference to Figures 2, 4 and 5 below, there is within the heater 15 a passage for the cold supercritical fluid in heat exchange relationship with another passage for heat exchange fluid. Flow of the cold supercritical fluid through its passage causes its temperature to rise typically to above minus 20°C..

At the warm end 5 of the pump 2, there is provided a drive chamber 23 for the piston 6. Typically, a hydraulic drive is employed with there being an inlet port 25 and an outlet port 17 for hydraulic fluid, but an electrical, pneumatic, or mechanical drive could alternatively be used. The drive arrangements may in general be similar to those disclosed in US 7 293 418 B2 for the pump described and shown therein. The piston 6 has two strokes. In its upward stroke (that is in its stroke away from the cold end 3, a flow of cryogenic liquid through the inlet 9 is induced. In its downward stroke (that is its stroke away from the warm end 5) a flow of cryogenic liquid through the outlet port is provided. The pump 2 is capable of generating a high delivery pressure typically in the order of 300 bar or higher. In one example, the pump 2 delivers cryogenic liquid at a pressure of 320 bar and a temperature of -162$^{o}$C, the cryogenic liquid being LNG.

The configuration of the heater 15 is shown in more detail in Figures 2, 4 and 5. The heat exchange chamber 100 is bounded by an inner sleeve 102, an outer sleeve 104, a first flange 106, and a second flange 108. The conduit 13 terminates in an inlet port 110 formed in the first flange 106. The inlet port 110 is connected to a helical heating or heat exchange coil 112 located in the heat exchange chamber 100. In operation, cryogenic supercritical fluid (typically supercritical natural gas) enters the helical coil 112 from the port 110 and is progressively warmed as it flows around the turns of the coil 112. The end of coil 112 remote from the port 110 communicates with the outlet port 99 (shown in Figure 2). Natural gas typically leaves the port 99 at a temperature of minus 20$^{o}$C and a pressure of above 300 bar. The

heat exchange coil 112 may be provided with internal or external fins or ribs (not shown) so as to facilitate heat exchange.

The heater 15 is provided with a distribution chamber 114, bounded in part by the second flange 108, for a heating fluid, typically an aqueous liquid employed in the cooling of an internal combustion engine to which the natural gas is supplied as a fuel. The distribution chamber 114 has an inlet port 19 (see Figure 1) for the heating liquid. The inner sleeve 102 is provided with an integral helical baffle 116. The turns of the baffle 116 are interspaced with the turns of the coil 112. The turns of the baffle 116 engage the inner surface of the outer sleeve 104. Accordingly, heating liquid admitted to the chamber 100 is caused to flow along a helical path over the turns of the coil 112, flowing counter-currently to the supercritical fluid admitted to the heating coil 112. The arrangement of the baffle 116 thus enhances heat exchange between the heating liquid and the high pressure fluid flowing through the coil 112. In the example of the vaporisation of the LNG at a pressure of 300 bar or higher, with the heating fluid being an aqueous coolant from an engine to which the natural gas is supplied as fuel, it is possible to achieve a gas discharge temperature in the range of 25 - 75 $^{o}$C when the inlet temperature of the heating liquid is 100 $^{o}$C and the engine is performing from 800 – 1600rpm.

The heating liquid is discharged from the chamber 100 through apertures 118 into an annular space 121 defined between the inner sleeve 102. The heating liquid can be withdrawn from this space via the port 21 with the assistance of a water pump (not shown) which is associated with the engine (not shown) to which the natural gas is supplied as fuel.

CLAIMS

1. A cryogenic pump (2) for pumping a cryogenic liquid that is LNG, the cryogenic pump (2) having associated therewith a heater (15) for vaporising the cryogenic liquid, the heater (15) comprising a chamber (100) bounded by an inner sleeve (102) and an outer sleeve (104), a helical heat exchange coil (112) having a plurality of turns disposed within the heater chamber (100), an inlet (110) with cryogenic liquid communicating with the heat exchange coil (112), an outlet (99) for resulting vaporised fluid communicating with the heat exchange coil (110), an inlet (19) to the heater chamber (100) for a heat exchange fluid and an outlet (118) from the heater chamber (100) for the heat exchange fluid wherein the heater chamber (100) has a helical baffle (116) having a plurality of turns for guiding the heat exchange fluid over the turns of the heat exchange coil (112), the turns of the baffle (116) being interspaced with the turns of the heat exchange coil (112).

2. A cryogenic pump (2) according to claim 1, wherein the baffle (116) is integral with the inner sleeve (102) or the outer sleeve (104).

3. A cryogenic pump (2) according to claim 1 or claim 2, having a piston (6) operable to discharge cryogenic liquid from a pumping chamber (8) within a pump housing (4)..

4. A cryogenic pump (2) according to claim 3, wherein the pump housing (4) is of generally elongate, cylindrical configuration.

5. A cryogenic pump (2) according to claim 4, wherein the chamber (100) is disposed about the pump housing (4).

6. A cryogenic pump (2) according to any one of claims 3 to 5, wherein the pumping chamber (8) has an outlet port (10) communicating with one end of the conduit (13) for conducting the cryogenic liquid to the heat exchange coil (112), the other end of the conduit (13) communicating with the inlet (110) to the heat exchange coil (112).

7. A cryogenic pump (2) according to any one of the preceding claims, wherein the heat exchange coil is provided with external or internal ribs or fins to facilitate heat exchange.

8. A cryogenic pump (2) according to any one of the preceding claims, wherein the outlet (118) from the heater chamber (100) for the heat exchange fluid is formed in the inner sleeve (102).

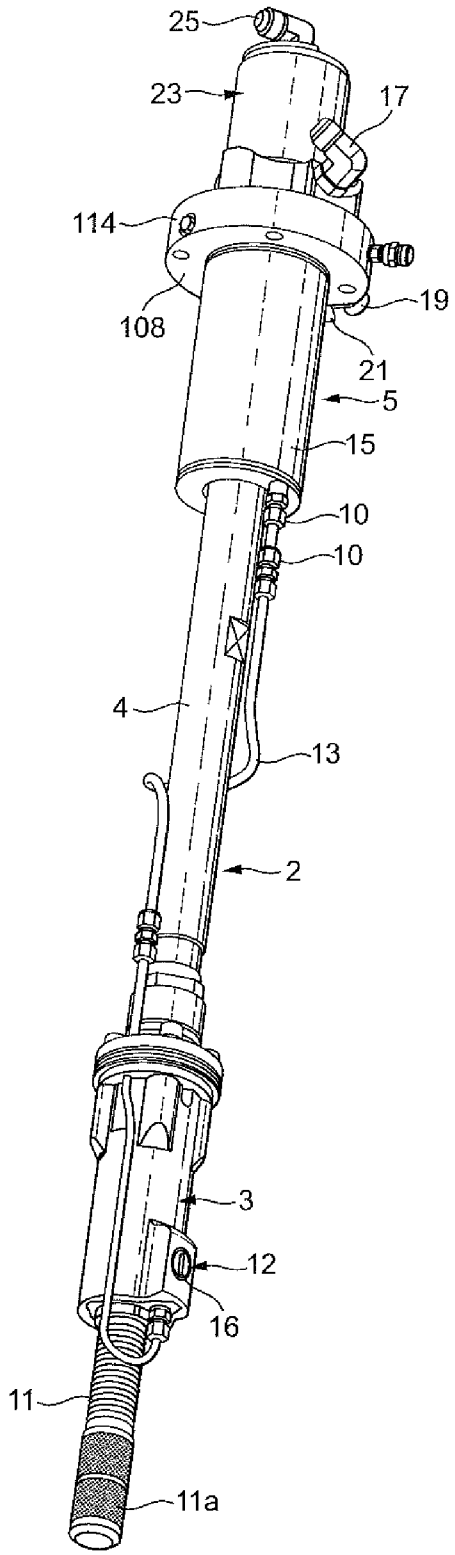


FIG. 1

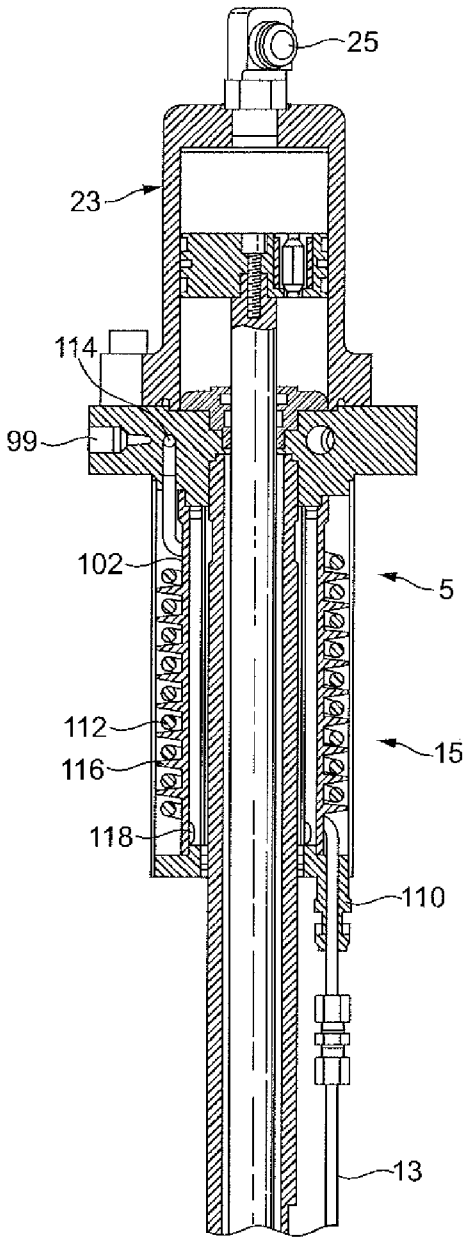


FIG. 2

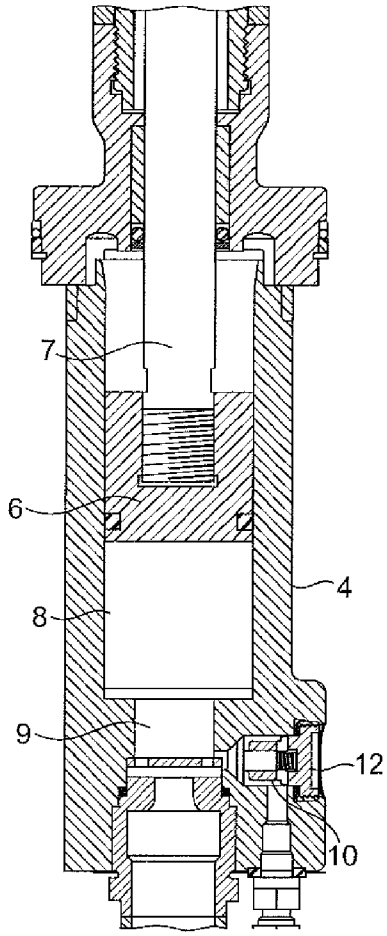


FIG. 3

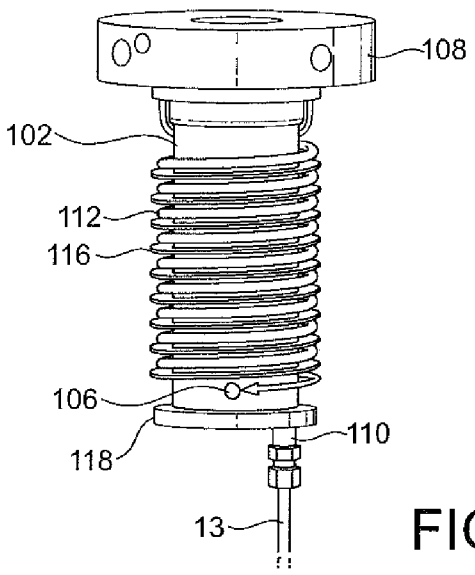


FIG. 4

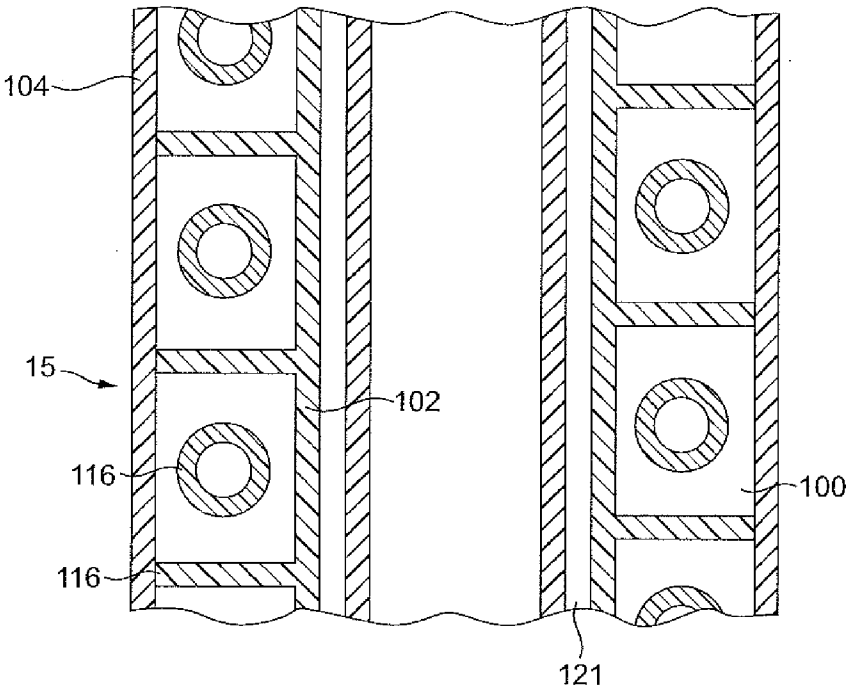


FIG. 5

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/CA2012/050415

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***F04B 19/00*** (2006.01) , ***F04B 15/00*** (2006.01) , ***F04B 53/08*** (2006.01) , ***F04B 9/08*** (2006.01)
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(2006.01): F04B 19/00, F04B 15/00, F04B 53/08, F04B 9/08, F04B15/08, F04B15/06, F17C9/02

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Databases: Canadian Patent Database (CPD), EPOQUE (X-Full, Epodoc)
Keywords: cryogenic, LNG, liquefied, natural, gas, heater, coil, helical

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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| A | US5819544A (ANDONIAN, M. D.) 13 October 1998 (13-10-1998)<br>*the whole document* | 1 - 8 |
| A | US5884488A (GRAM, A. et al.) 23 March 1999 (23-03-1999)<br>*the whole document* | 1 - 8 |
| A | US5971727A (HORAN, G. P.) 26 October 1999 (26-10-1999)<br>*the whole document* | 1 - 8 |

[ ] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 30 July 2012 (30- 07-2012) | 01 August 2012 (01-08-2012) |

| Name and mailing address of the ISA/CA | Authorized officer |
|---|---|
| Canadian Intellectual Property Office<br>Place du Portage I, C114 - 1st Floor, Box PCT<br>50 Victoria Street<br>Gatineau, Quebec K1A 0C9<br>Facsimile No.: 001-819-953-2476 | Adeeb Zarifa (819) 934-2692 |

**INTERNATIONAL SEARCH REPORT**
Information on patent family members

International application No.
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