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(54) APPARATUS AND METHOD FOR COMPRESSING A CRYOGENIC MEDIA

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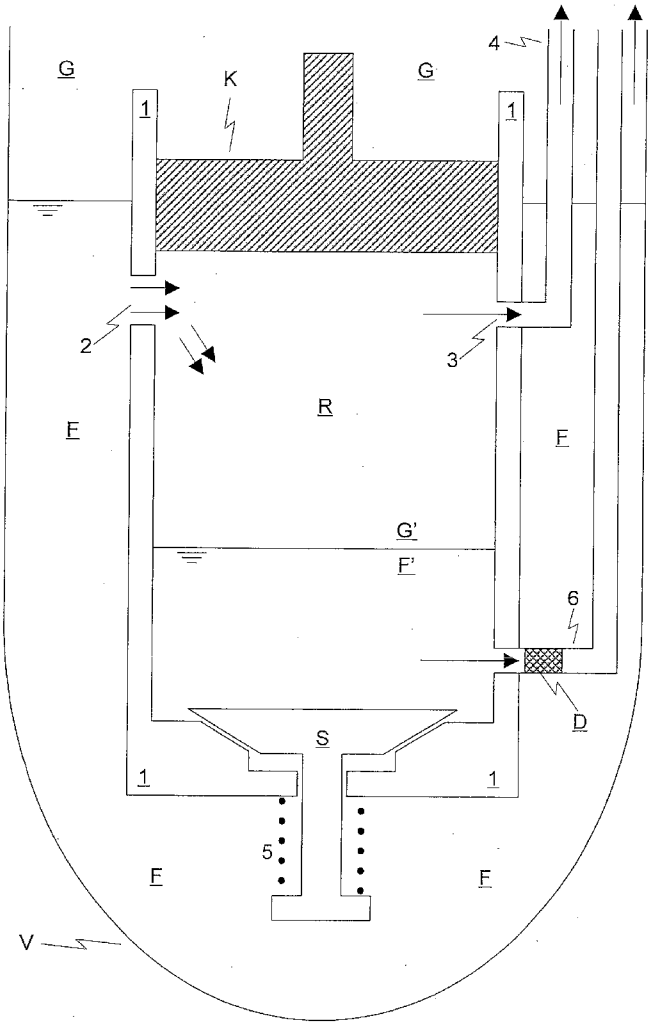
(57) **ABSTRACT**

An apparatus and method for compressing a cryogenic media is disclosed. A compressor includes a compressor chamber surrounded by a cylinder wall in which a compressor piston is moved in a linear manner, a suction valve and a pressure valve, which are arranged in the region of the lower end position of the compressor piston, and a liquid chamber which at least partially surrounds the compressor chamber. The cylinder wall defines at least one opening, which corresponds to the liquid chamber, and at least one opening, via which the gaseous medium can be extracted from the compressor chamber, where the openings are located at points on the cylinder wall that are passed by the compressor piston.



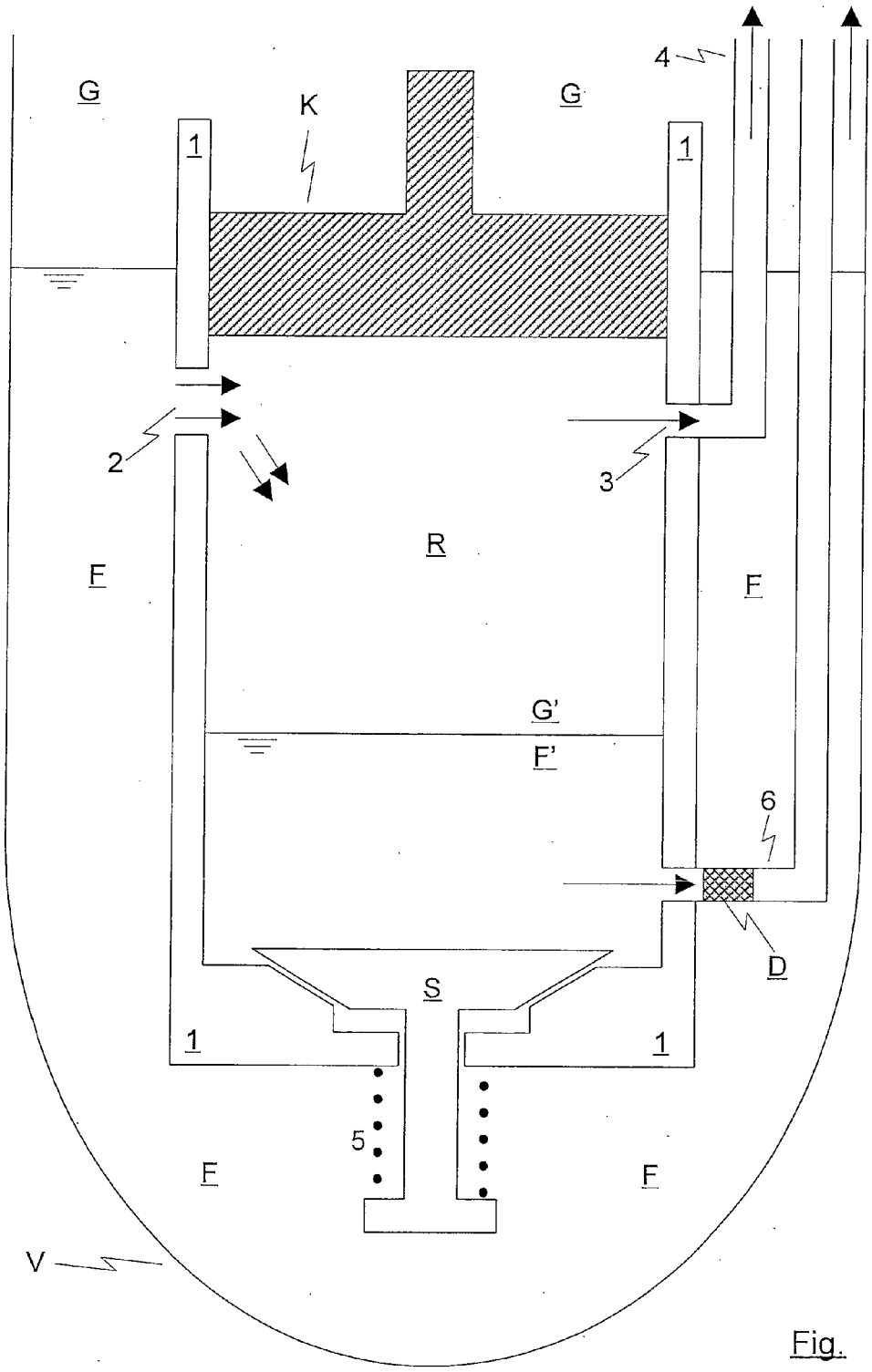


Fig.

APPARATUS AND METHOD FOR COMPRESSING A CRYOGENIC MEDIA

[0001] This application claims the priority of International Application No. PCT/EP2006/005241, filed Jun. 1, 2006, and German Patent Document No. 10 2005 028 200.8, filed Jun. 17, 2005, the disclosures of which are expressly incorporated by reference herein.

BACKGROUND AND SUMMARY OF THE INVENTION

[0002] The invention relates to a compressor, in particular a compressor for cryogenic media, preferably for liquid hydrogen, comprising a compressor chamber surrounded by a cylinder wall in which a compressor piston is moved in a linear manner, a suction valve and a pressure valve, which are arranged in the region of the lower end position of the compressor piston, and a liquid chamber which at least partially surrounds the compressor chamber.

[0003] The term "cryogenic media" is understood in the following to refer to so-called deep cold fluids, in particular liquid hydrogen, liquefied natural gas, liquid nitrogen, liquid oxygen and other liquefied gases.

[0004] Compressors of this type are sufficiently well known from the state of the art. They all have in common the fact that the medium to be compressed is fed through a spring-loaded suction valve into a compressor chamber, where it is compressed and then removed from the compressor chamber via a spring-loaded pressure valve.

[0005] The elastic force of the spring used for closing a suction valve (in this case, we are dealing preferably with helical springs) is selected, as a rule, so that a defined closing of the suction valve is achieved; the suction valve is therefore pressed into its valve seat and thereby sealed.

[0006] During the suction stroke of the compressor (in the process, the compressor piston moves from the lower to the upper end position), the elastic force and, depending upon the arrangement of the suction valve (at least partially), its weight must be overcome by the medium flowing into the compressor chamber.

[0007] Particularly, when a cryogenic medium like liquid hydrogen, for example, is suctioned, considerable losses with regard to conveying capacity occur due to the suction valve designs that have been used until now, because the medium that is entering the compressor chamber via the suction valve is at least partially vaporized when overcoming the aforementioned forces of the suction valve.

[0008] The result of this is that the liquid portion of the medium that is to be compressed is reduced, which results in a reduction in the conveying capacity and an increase in the specific compressor output.

[0009] The objective of the present invention is disclosing a generic compressor, in particular a generic compressor for cryogenic media, in which the aforementioned disadvantages can be avoided.

[0010] To attain this objective, a generic compressor is proposed, which is characterized in that the cylinder wall comprises at least one opening that corresponds to the liquid chamber, and at least one opening, via which the gaseous medium can be extracted from the compressor chamber, wherein the openings are located at points on the cylinder wall that are passed by the compressor piston.

[0011] Additional advantageous embodiments of the compressor in accordance with the invention are characterized in that:

- **[0012]** the openings are embodied in the form of one and/or more slots,
- **[0013]** the opening(s) via which the gaseous medium can be extracted from the compressor chamber is/are effectively connected with a gas extraction line,
- **[0014]** the openings are located at points on the cylinder wall that are not released by the compressor piston until the compressor piston is directly in front of its upper end position or has arrived at its upper end position,
- **[0015]** the suction valve has at least one indentation on its surface facing the compressor piston, wherein the indentation is embodied in such a manner that a vacuum forms between the suction valve and the compressor piston.

[0016] The compressor in accordance with the invention comprising a high-pressure phase separator and additional embodiments of the compressor, are explained in more detail on the basis of the exemplary embodiment depicted in the FIGURE.

BRIEF DESCRIPTION OF THE DRAWING

[0017] The FIGURE shows a lateral schematic sectional representation through a possible embodiment of the inventive compressor with a high-pressure phase separator.

DETAILED DESCRIPTION OF THE DRAWING

[0018] A compressor chamber R surrounded by a cylinder wall **1** is provided within a compressor housing V: A compressor piston K is moved linearly back and forth and/or up and down within the compressor chamber. The two reversing points of the compressor piston K are referred to in the following as the upper and lower end positions of the compressor piston K.

[0019] Arranged on the base of the compressor chamber R is a suction valve S which is spring **5** loaded and a spring-loaded pressure valve D (only depicted schematically). Both valves are pressed into their valve seats and thereby sealed via the forces generated by means of the springs. The compressor chamber R and/or the cylinder wall **1** are at least partially surrounded by a liquid chamber F, which is formed by the liquid medium that is to be compressed. A gas volume and/or gas chamber G is embodied above this liquid chamber F.

[0020] The openings **2** and **3** depicted in the FIGURE do not show compressor designs that are included in the state of the art. During the suction stroke (in the process, the compressor piston K moves from the lower to the upper end position), liquid medium flows via the suction valve S from the liquid chamber F into the compressor chamber R, whereby, as already explained, the liquid medium at least partially vaporizes.

[0021] According to the invention, at least two openings **2** and **3** are henceforth provided. In this case, one of the openings **2** corresponds to the liquid chamber, while a gaseous medium can be extracted from the compressor chamber R via the other opening **3**. In the exemplary embodiment of the inventive compressor depicted in the FIGURE, this extraction of the gaseous medium from the compressor chamber R is accomplished via a gas extraction line **4**. The gas generated by the suction process via opening **2** can now exit the compressor chamber R via the opening **3** and be replaced by the liquid

medium flowing in after it. This results in an increase in the conveying capacity and a reduction in the specific compression work.

[0022] The gas compressed by means of the piston K exits the compressor chamber R when pressure valve D is opened via the gas extraction line **6** and is then fed via a high-pressure line to a consumer.

[0023] The two openings **2** and **3** are embodied in accordance with an advantageous embodiment of the inventive compressor preferably in the form of one and/or more slots.

[0024] The openings **2** and **3** are preferably located at points on the cylinder wall **1**, which are not passed by the compressor piston K until the compressor piston is directly in front of its upper end position or has arrived at its upper end position.

[0025] The FIGURE depicts the compressor piston K in its upper end position. The two openings **2** and **3** are henceforth released so that the liquid medium that is to be compressed can flow via the opening **2** from the liquid chamber F into the compressor chamber R (shown by the two parallel arrows). This inflowing liquid medium supplements the liquid quantity F' already located in the compressor chamber R, which results from the liquid medium flowing in during the suction stroke via the suction valve S.

[0026] The gaseous medium G' formed during the suction stroke can escape from the compressor chamber R via opening **3** and/or the gas extraction line **4**. This escape of the gaseous medium is supported by the liquid medium flowing in via opening **2** since the gaseous medium G' located in the compressor chamber R is displaced from the compressor chamber R by the inflowing liquid medium.

[0027] In contrast to hitherto known compressor designs, the inevitably forming gas portion G' of the medium to be compressed is henceforth no longer compressed since it can be extracted from the compressor chamber R before compression. By providing the opening **2**, which corresponds to the liquid chamber F, it is henceforth assured that the compressor chamber R is completely filled with liquid medium F' before compression.

[0028] Not shown in the FIGURE is another advantageous inventive embodiment of the compressor, according to which the suction valve S has at least one indentation on its surface facing the compressor piston K; the indentation is embodied in this case such that a vacuum forms between the suction valve S and the compressor piston K.

[0029] If the compressor piston K now moves upward during the suction stroke, the suction valve S is moved and/or lifted by it because of the vacuum formed between the valve and the compressor piston K.

[0030] In principle, the shape of the indentation(s) to be provided on the surface of the suction valve S facing the compressor piston K can be selected at will; crucial is ultimately only that a vacuum be formed between suction valve S and the compressor piston K. In addition, one or even several indentations can be provided.

[0031] The invention described in the foregoing makes it possible to achieve an increase in the amount of liquid in the compressor chamber, which results in a greater conveying capacity of the inventive compressor. Therefore, it is possible to achieve a reduction in the specific compressor output based on the quantity of medium compressed and/or conveyed.

[0032] The advantages associated with the inventive compressor are achieved by a compressor design that is slightly more complex as compared with the state of the art, but the resulting increase in cost is more than compensated for by the advantages achieved with this design.

1-4. (canceled)

5. A compressor for cryogenic media, comprising a compressor chamber surrounded by a cylinder wall in which a compressor piston is moved in a linear manner, a suction valve and a pressure valve, which are arranged in a region of a lower end position of the compressor piston, and a liquid chamber which at least partially surrounds the compressor chamber, wherein the cylinder wall defines a first opening, which corresponds to the liquid chamber, and a second opening, via which a gaseous medium is extractable from the compressor chamber, and wherein the first and second openings are located at points on the cylinder wall that are passed by the compressor piston, and wherein the second opening via which the gaseous medium is extractable from the compressor chamber is effectively connected with a gas extraction line.

6. The compressor according to claim **5**, wherein the first and second openings are embodied in a form of a slot.

7. The compressor according to claim **5**, wherein the first and second openings are located at points on the cylinder wall, which are not released by the compressor piston until the compressor piston is directly in front of an upper end position or has arrived at the upper end position.

8. The compressor according to claim **5**, wherein the suction valve has an indentation on a surface facing the compressor piston, wherein the indentation is embodied in such a manner that a vacuum forms between the suction valve and the compressor piston.

9. A compressor for compressing a cryogenic media, comprising:

a compressor chamber defined by a cylinder wall, wherein the cylinder wall defines a first opening and a second opening at an upper end of the compressor chamber;

a compressor piston moveable linearly within the compressor chamber;

a suction valve and a pressure valve disposed within the cylinder wall at a lower end of the compressor chamber; and

a liquid chamber which at least partially surrounds the compressor chamber and contains the cryogenic media in a liquid form;

wherein when the compressor piston is at the upper end of the compressor chamber, the cryogenic media in the liquid form enters the compressor chamber through the first opening and the cryogenic media in a gaseous form is extracted from the compressor chamber through the second opening and a gas extraction line coupled to the second opening.

10. The compressor according to claim **9**, wherein the suction valve has an indentation on a surface facing the compressor piston.

11. The compressor according to claim **9**, wherein a second gas extraction line is coupled to the pressure valve.

12. The compressor according to claim **11**, wherein the cryogenic media in the gaseous form is extracted from the compressor chamber through the pressure valve and the second gas extraction line coupled to the pressure valve when the compressor piston is at the lower end of the compressor chamber.

13. A method for compressing a cryogenic media in a compressor, wherein the compressor includes:

a compressor chamber defined by a cylinder wall, wherein the cylinder wall defines a first opening and a second opening at an upper end of the compressor chamber;

a compressor piston moveable linearly within the compressor chamber;

a suction valve and a pressure valve disposed within the cylinder wall at a lower end of the compressor chamber; and

a liquid chamber which at least partially surrounds the compressor chamber and contains the cryogenic media in a liquid form;

and comprising the steps of:

adding the cryogenic media in the liquid form to the compressor chamber through the first opening from the liquid chamber when the compressor piston is at the upper end of the compressor chamber; and

extracting the cryogenic media in a gaseous form from the compressor chamber through the second opening and a gas extraction line coupled to the second opening when the compressor piston is at the upper end of the compressor chamber.

14. The method according to claim **13**, further comprising the step of extracting the cryogenic media in the gaseous form from the compressor chamber through the pressure valve and a second gas extraction line coupled to the pressure valve when the compressor piston is at the lower end of the compressor chamber.

15. The method according to claim **13**, further comprising the step of creating a vacuum between an indentation on a surface of the suction valve facing the compressor piston and the compressor piston.

16. The method according to claim **13**, wherein an entire quantity of the cryogenic media in the gaseous form is extracted from the compressor chamber through the second opening and the gas extraction line coupled to the second opening before the compressor piston begins a compression stroke.

17. The method according to claim **16**, wherein the compressor chamber is completely filled with the cryogenic media in the liquid form below the compressor piston before the compressor piston begins the compression stroke.

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