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(54) COMPRESSION APPARATUS AND FILLING STATION COMPRISING SUCH AN APPARATUS

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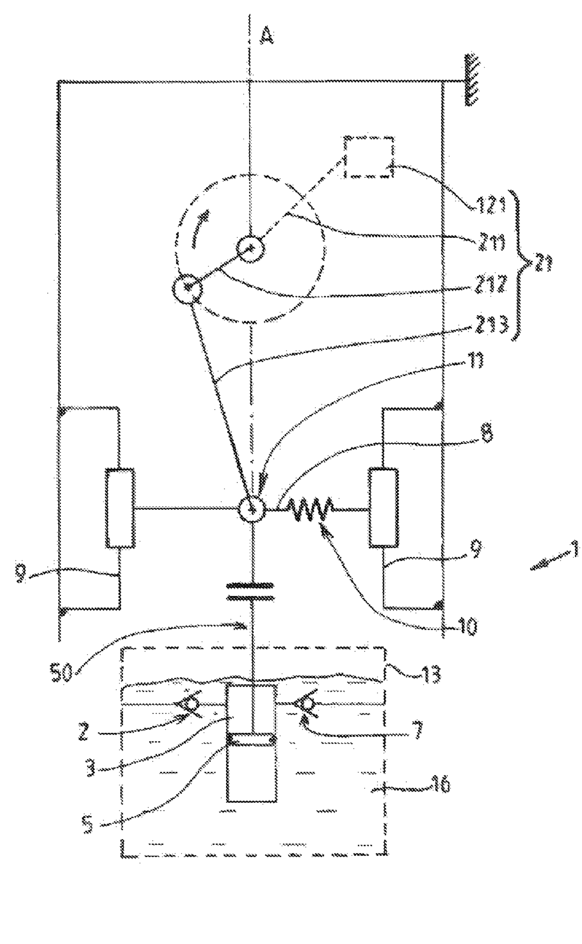
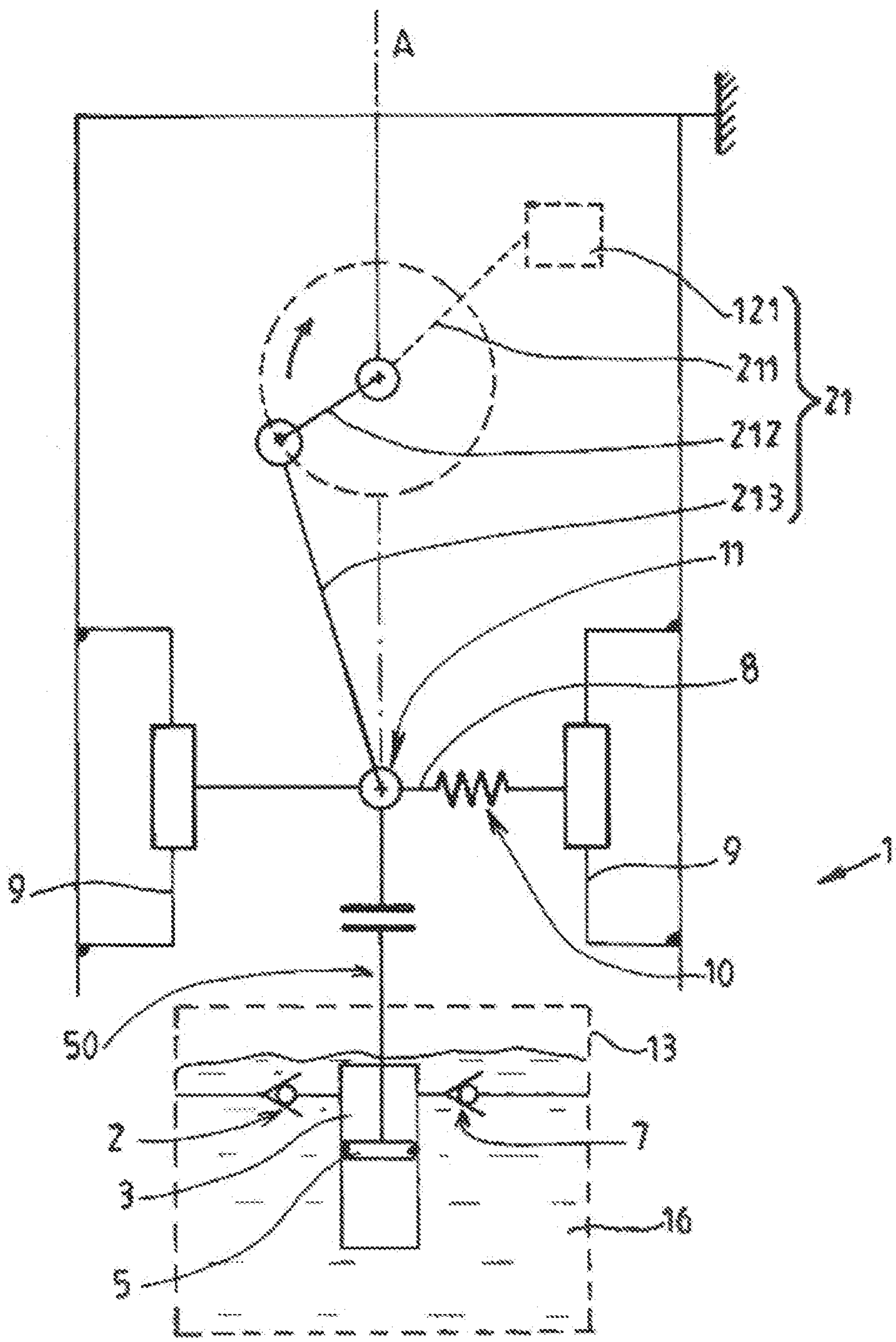
(57) **ABSTRACT**

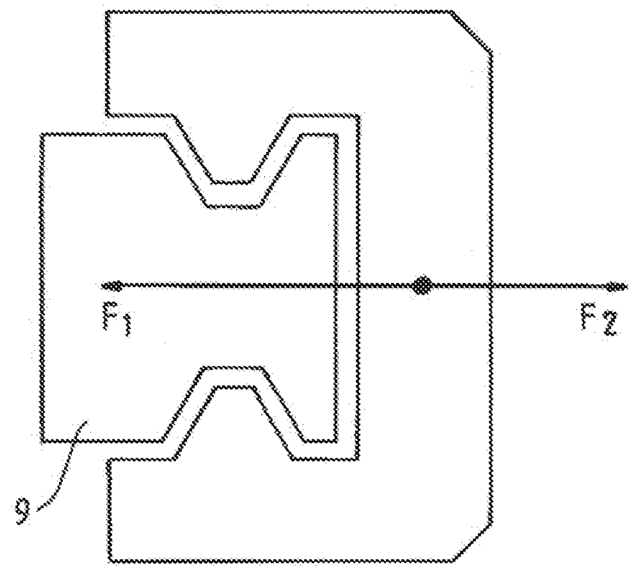
The invention relates to an apparatus for compressing cryogenic fluid, comprising a sealed enclosure intended to contain a bath of cryogenic fluid, a compression chamber communicating with the bath, an intake system communicating with the compression chamber and configured to allow the inlet of fluid to be compressed into the compression chamber, and a mobile piston for compressing the fluid in the compression chamber, the apparatus also comprising an evacuation system communicating with the compression chamber and configured to allow the outlet of compressed fluid, the piston being mounted at a first end of a rod, the apparatus comprising a mechanism for driving the rod in a back and forth movement along a longitudinal direction, the drive mechanism comprising a motor provided with a rotating shaft and a mechanical system converting the rotary movement of the rotating shaft into a movement in translation of a head sliding along the longitudinal direction and to which a second end of the rod is connected, characterized in that the head is mounted so as to slide and to be guided by two fixed guide rails situated on either side of the head, and in that the head and/or one rail comprises a resilient portion, the resilient portion being configured to generate, on the rail or rails, a force transverse to the longitudinal direction.



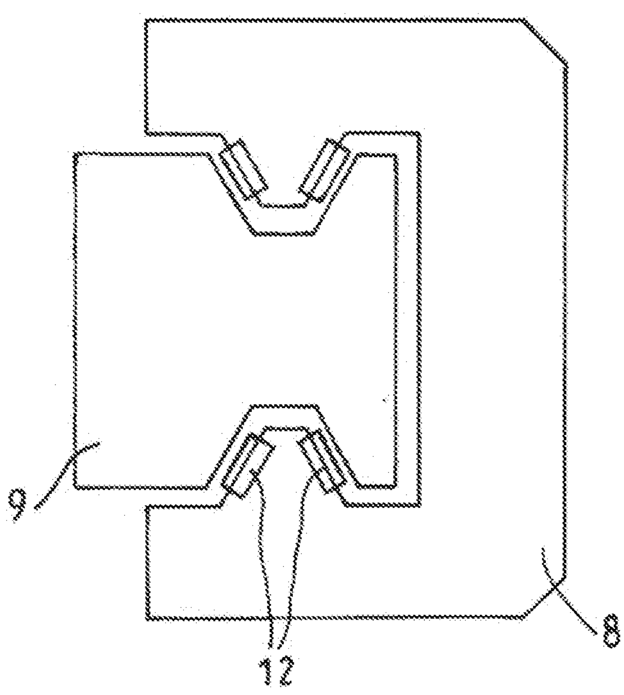
[Fig. 1]



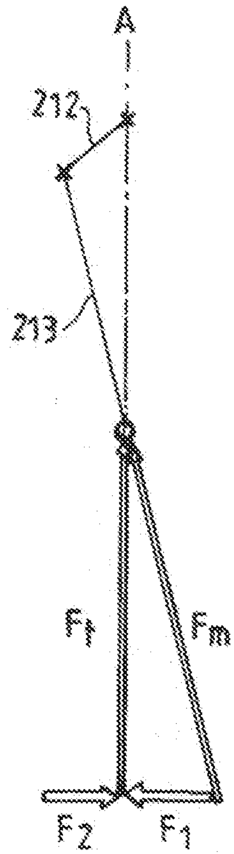
[Fig. 2]



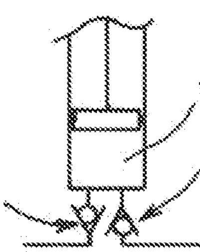
[Fig. 3]



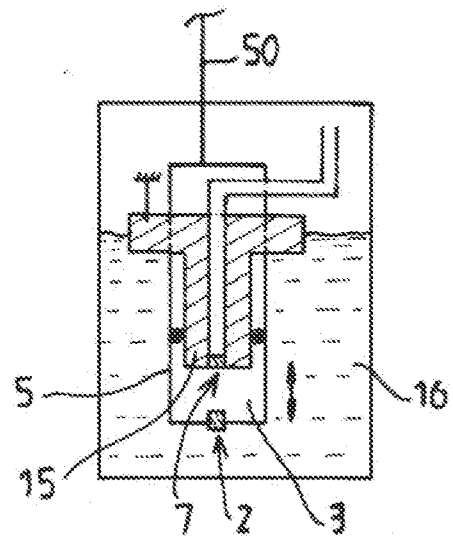
[Fig. 4]



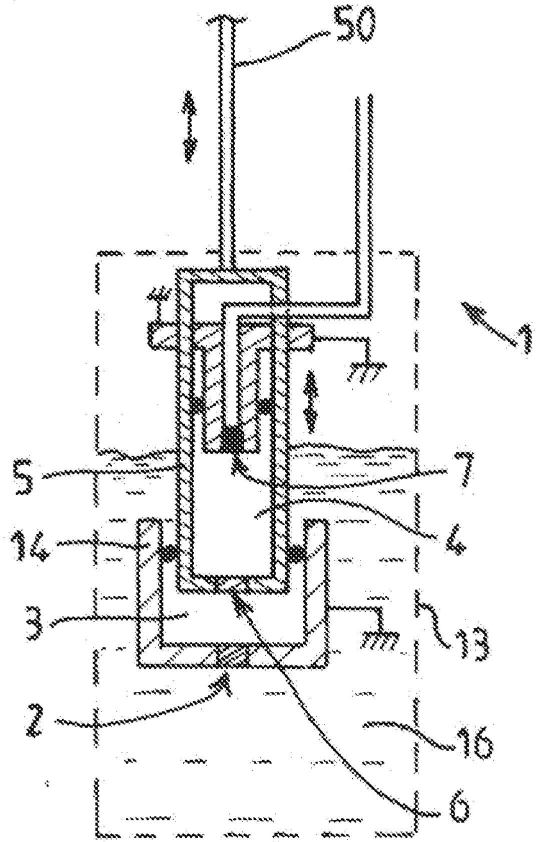
[Fig. 5]



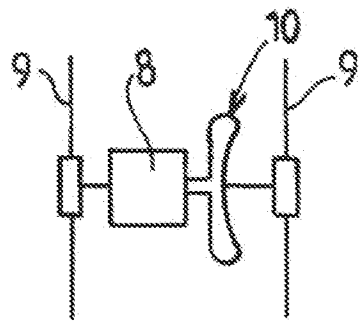
[Fig. 6]



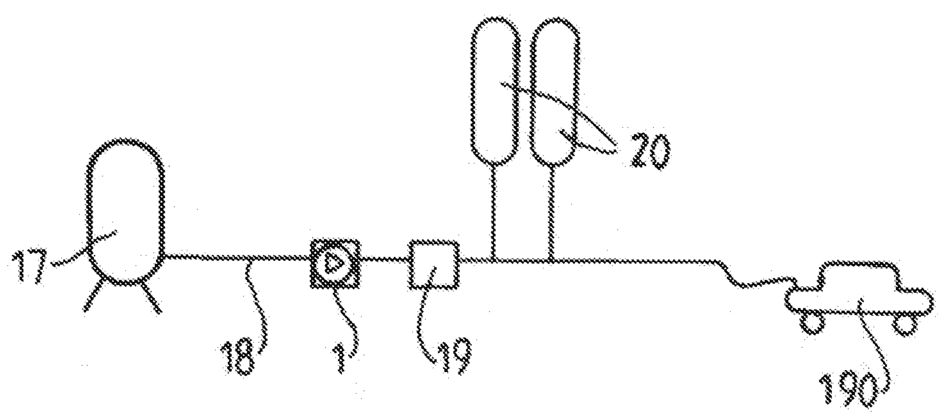
[Fig. 7]



[Fig. 8]



[Fig. 9]



COMPRESSION APPARATUS AND FILLING STATION COMPRISING SUCH AN APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a § 371 of International PCT Application PCT/EP2022/061961, filed May 4, 2022, which claims the benefit of FR2105323, filed May 21, 2021, both of which are herein incorporated by reference in their entireties.

FIELD OF THE INVENTION

[0002] The invention relates to a compression apparatus and a filling station comprising such an apparatus. Such an apparatus is for example a cryogenic pump, in particular for pumping liquefied hydrogen.

BACKGROUND OF THE INVENTION

[0003] Drive by a connecting rod-crank mechanism is a known actuation solution for cryogenic piston pumps. Most of these pumps operate with oil splash lubrication to guide the piston rod. This architecture is well suited to horizontal piston rod configurations because oil leaks are very limited. The piston rod can be guided by plain bearings or antifriction strips (for example bronze plates).

[0004] For a vertically configured cryogenic pump, it is very difficult to perform such splash lubrication for the movement converting mechanism. Specifically, the cold end of the pump is placed in a tank (generally called a sump) and the articulated mechanism must be placed vertically on top of it. Oil leaks occur along the piston rod owing to the linear reciprocating movement. The fall of oil drops onto the cryogenic part is not allowed for safety reasons.

[0005] One solution is to use a leak collection and recirculation system (with pump, filter, etc.). This solution is not satisfactory.

[0006] One solution is to use a linear guide mechanism (for example roller carriages, ball bearing sleeves, etc.) without oil, mounted on the side receiving the transverse force generated. This architecture is subject to significant forces which limit the service life and require frequent maintenance. This solution can also cause a high temperature increase requiring the installation to be shut down. In addition, the piston stroke is relatively short compared with the load (forces). The sliding head size is close to the stroke size. In addition, the forces are poorly distributed owing to the asymmetry of the mechanism. To take up the forces, a plurality of sliding heads can be provided or a plurality of guides can be used on the side receiving the forces with additional mechanical couplings (ball joint to allow assembly). However, this does not completely solve the problems.

SUMMARY OF THE INVENTION

[0007] In certain embodiments, the invention relates more particularly to an apparatus for compressing cryogenic fluid comprising a sealed enclosure intended to contain a bath of cryogenic fluid, a compression chamber communicating with the bath, an intake system communicating with the compression chamber configured to allow the entry of fluid to be compressed into the compression chamber, a movable piston to ensure the compression of the fluid in the compression chamber, the apparatus further comprising an evacuation system communicating with the compression chamber and configured to allow the exit of compressed fluid, the piston being mounted at a first end of a rod, the apparatus comprising a mechanism for driving the rod in a back and forth movement in a longitudinal direction, the drive mechanism comprising a motor provided with a rotating shaft and a mechanical system converting the rotational movement of the rotating shaft into a translational movement of a head sliding in the longitudinal direction and to which a second end of the rod is connected.

[0008] An aim of the present invention is to overcome all or some of the drawbacks of the prior art outlined above.

[0009] To this end, the compression apparatus according to certain embodiments of the invention, moreover conforming to the generic definition given in the preamble above, can include a head that is slidably mounted and guided by two fixed guide rails located on either side of the head, and in that the head and/or a rail comprises an elastic portion, said elastic portion being configured to generate on the rail or rails a force transverse to the longitudinal direction.

[0010] Furthermore, embodiments of the invention may comprise one or more of the following features:

- **[0011]** the compression of the fluid in the compression chamber is obtained by traction or compression of the rod, said traction or compression generating a transverse thrust of the head on one of the rails in a direction transverse to the longitudinal direction, the force generated by the elastic portion being in the opposite direction to this thrust,
- **[0012]** the elastic portion is configured to generate on the rail or rails a transverse force having, in absolute value, an intensity less than, equal to or greater than the maximum intensity of the thrust force,
- **[0013]** the elastic portion is located between a central zone of the head and one of the two rails,
- **[0014]** the elastic portion is located between one of the two rails and the fixed support of said rail,
- **[0015]** the elastic portion comprises a spring or a deformable zone and is prestressed,
- **[0016]** in the operating configuration, the rod is movable with a back and forth movement in a vertical longitudinal direction,
- **[0017]** the mechanical system converting the rotational movement of the rotating shaft into a translational movement of the carriage is of the connecting rod and crank type,
- **[0018]** the mechanical system converting the rotational movement of the rotating shaft into a translational movement of the head is connected to a central zone of the head via a ball joint or pivot connection, said connection being located on a longitudinal straight line passing through the axis of translation of the rod, said straight line also being secant to the straight line passing through the rotating shaft of the motor,
- **[0019]** the head is slidably mounted in the guide rails via a guide system with or without rolling element(s), for example a system with rollers, and/or balls and/or sliding rollers or a precision rail(s) type system,
- **[0020]** the apparatus is of the type with one compression stage, that is to say that the fluid is compressed only once between the intake system and the evacuation system,
- **[0021]** the apparatus is of the type with two compression stages, that is to say that the fluid is compressed

twice between the intake system and the evacuation system, the apparatus comprising two compression chambers, the intake system communicating with a first compression chamber, a transfer system communicating with the first and the second compression chamber and configured to allow the transfer of fluid compressed in the first compression chamber to the second compression chamber, the movable piston alternately compressing the fluid in the first and second compression chambers in its direction of movement, the evacuation system communicating with the second compression chamber, and

[0022] the second compression chamber is delimited by a portion of the body of the piston and a fixed wall of the apparatus.

[0023] Certain embodiments of the invention also relate to a station for filling tanks or pipes with pressurized gas, comprising a source of liquefied gas, in particular liquefied hydrogen, a withdrawal circuit having a first end connected to the source and at least one second end intended to be connected to a tank to be filled, the withdrawal circuit comprising a compression apparatus conforming to any one of the features above or below.

[0024] Embodiments of the invention may also relate to any alternative device or method comprising any combination of the features above or below within the scope of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The invention will be understood better from reading the following description and from studying the accompanying figures. These figures are given only by way of illustration and do not in any way limit the invention.

[0026] FIG. **1** represents a schematic and partial vertical sectional view illustrating an example of the structure and operation of a compression apparatus according to the invention,

[0027] FIG. **2** represents a schematic and partial horizontal sectional view of a detail of the aforementioned apparatus at the level of the arrangement of one end of a sliding head and its vertical guide rail,

[0028] FIG. **3** represents another schematic and partial horizontal sectional view of a detail of the aforementioned apparatus at the level of the arrangement of one end of the sliding head and its vertical guide rail and illustrating rolling members,

[0029] FIG. **4** schematically and partially represents an example of distributions of forces at one end of the sliding head and its guide rail of the apparatus in a traction configuration,

[0030] FIG. **5** represents a schematic and partial sectional view illustrating a detail of a possible variant embodiment of the compression chamber of such a compression apparatus,

[0031] FIG. **6** represents a schematic and partial sectional view illustrating a detail of a second possible variant embodiment of the compression chamber of such a compression apparatus,

[0032] FIG. **7** represents a schematic and partial sectional view illustrating a detail of a third possible variant embodiment of the compression chamber of such a compression apparatus,

[0033] FIG. **8** represents a schematic and partial view illustrating a detail of the apparatus illustrating a possible exemplary embodiment of the structure of the elastic portion,

[0034] FIG. **9** represents a schematic and partial view illustrating an example of a filling station using such a compression apparatus.

DETAILED DESCRIPTION OF THE INVENTION

[0035] The apparatus **1** for compressing cryogenic fluid represented schematically comprises a sealed enclosure **13** intended to contain a bath **16** of cryogenic fluid (typically a liquid phase in the lower part and a gaseous phase in the upper part). The apparatus **1** has at least one compression chamber **3** communicating with the liquid bath (in particular the compression chamber **3** is preferably immersed in the bath).

[0036] The apparatus **1** comprises an intake system **2** communicating with the compression chamber **3** and configured to allow the entry of fluid to be compressed into the compression chamber **3** (typically comprising a system of valve(s) and/or orifice(s)).

[0037] The apparatus **1** further comprises a movable piston **5** to ensure the compression of the fluid in the compression chamber **3** and an evacuation system **7** communicating with the compression chamber **3** configured to allow the exit of compressed fluid (typically comprising a set of valve(s) and communicating with an evacuation pipe).

[0038] The piston **5** is mounted at a first end of a rod **50**. The apparatus **1** comprises a mechanism **21** for driving the rod **50** in an alternating back and forth movement in a longitudinal direction A. The drive mechanism **21** conventionally comprises a motor **121** provided with a rotating shaft **211** and a mechanical system **212**, **213** converting the rotational movement of the rotating shaft **211** into a translational movement of a head **8** sliding in the longitudinal direction A. A second end of the rod **50** is connected to the head to receive its actuation.

[0039] The head **8** can be made up of one or more assembled parts. This head **8** can also be designated in the literature by the terms "crossmember", "crossbeam" or "crosshead".

[0040] For example, the piston rod **50** can be connected to one end of the head **8** via a coupling part, such as a rigid connection (for example of the bolted flange type) or a flexible connection (of the ball joint or pivot type, for example).

[0041] The head **8** is slidably mounted and guided by two fixed guide rails **9**. The two rails **9** are located on either side of the head **8** (on either side in a direction perpendicular to the longitudinal direction A). The head **8** is guided in translation by the rails **9** and receives the traction and thrust forces via one end of the mechanism **21**, for example a connecting rod **213** is connected to the head **8** at a ball joint or pivot connection **11**.

[0042] As illustrated, the mechanical system converting the rotational movement of the rotating shaft **211** into a translational movement of the head **8** can be connected to a central zone of the head **8** via a connection **11** located on a longitudinal straight line A passing through the axis of translation of the rod **50**. Moreover, this straight line can also be secant to the straight line passing through the rotating shaft **211** of the motor **210**.

[0043] As illustrated in section in [FIG. **2**] and [FIG. **3**], each end of the head **8** can be slidably mounted on a rail **9**. As seen in [FIG. **3**], the head **8** can be slidably mounted on the guide rail **9** via a set **12** of rollers and/or balls. The sliding system can also be of the precision rails type or any other suitable guide system (preferably not using oil in the case where the axis of the rod is vertical in the use position).

[0044] For example, carriages (with rollers or balls) are screwed onto the head **8** and move with it. The rails **9** themselves are, for example, fixed to the frame of the apparatus. For lubrication, a passive (or active) cartridge can nevertheless be mounted on each of the carriages.

[0045] The head **8** comprises an elastic portion **10** which is configured to generate on the rail or rails **9** a force transverse to the longitudinal direction A.

[0046] That is to say that the elastic portion **10** generates a permanent transverse force on the rail(s) **9**.

[0047] The movement of compression of the fluid in the compression chamber **3** generates significant forces in the mechanism (the compression of the fluid is obtained during traction of the rod in the representation of [FIG. **1**]). Owing to the asymmetry of the mechanism (mechanism of the eccentric type), during this compression, the lateral forces at the rails **9** are not symmetrical. In particular, one rail **9** can be loaded transversely more than the other (left rail in this nonlimiting example shown).

[0048] The aforementioned arrangement makes it possible to at least partially rebalance these transverse forces in the apparatus **1**.

[0049] Specifically, as schematically illustrated in [FIG. **4**], the force Fm exerted by the movement conversion mechanism **21** induces a traction component Ft on the rod **50** and a transverse thrust component F**1** toward one of the rails **9**. The elastic portion **10** is configured to generate on this same rail **9** a continuous force F**2** in the opposite direction to this thrust F**1** and which at least partially compensates for it (for example the force F**2** is sized to halve the thrust force F**1**). It should be noted that a force F**2** can also be generated on the other rail **9**; this has no particular influence on the proper functioning of the device.

[0050] It should be noted that the intensity of this force F**2** generated by the elastic portion is preferably constant, whereas the thrust F**1** has an intensity which varies cyclically during the movements. The value of F**2** can be chosen to partially compensate for the maximum intensity of F**1** during the cycle.

[0051] The maximum thrust force (when operating at low load, the spring force will be greater than the thrust force.

[0052] That is to say that the elastic portion **10** permanently realizes a "transverse compensating load". The final force resulting in the mechanism is thus limited and makes it possible to limit the stresses in the operating phase generating the most forces. A better balancing or clipping of the transverse forces is obtained.

[0053] Thus, instead of using a single guide rail on one side of the head **8** (on the side receiving the forces), this solution provides a second guide rail which, together with the elastic member **10**, makes it possible to reduce the lateral forces.

[0054] It should be noted that this arrangement also makes it possible to deal with the possible problems of alignment and spacing between the two rails **9** to ensure that the assembly is assembled correctly (assembly tolerances). As shown schematically, the elastic portion **10** can be located between the central zone of the head **8** and one of the two rails **9**. This elastic portion **10** may comprise a prestressed spring or a prestressed deformable zone or any other member generating an appropriate force. As schematically illustrated in [FIG. **8**], this elastic portion may comprise a spring formed by a loop-shaped portion (for example with two lobes) of a part of the body of the head **8**.

[0055] It should be noted that the elastic portion **10** can be integrated into (or constituted by) the head **8**. The elements **8** and **10** may be separate parts or one and the same part.

[0056] In the example of [FIG. **1**] as well as in the example of [FIG. **6**], the fluid compression force is obtained by traction (raising) of the rod **50**.

[0057] Of course, this is in no way limiting. Thus, and as illustrated in [FIG. **5**], the fluid compression force can be obtained by a thrust (lowering) of the rod **50**. In this case, the lateral forces are reversed with respect to the description above. In this case, the force F**2** of the elastic portion **10** can also simply be reversed (either by moving this elastic portion on the other side of the head or by modifying the structure of the elastic portion **10** so that its force is oriented to oppose the excessive force on the side concerned).

[0058] It should be noted that in the embodiment of [FIG. **6**], the piston **5** comprises a tubular portion mounted around a fixed central guide **15**. A terminal end of the central guide **15** forming the fixed wall delimiting a part of the compression chamber **3** with the tubular portion of the piston **5**.

[0059] In the aforementioned examples, the apparatus **1** is of the type with one compression stage (fluid compressed only once). Of course, the invention also applies in the same way to a compression apparatus with two compression stages (fluid undergoing two compressions in series). [FIG. **7**] illustrates an example of a compression structure with two compression stages. Thus, the apparatus **1** may comprise a tubular piston **5** cooperating with a tubular cavity **14** or fixed chamber which is closed at its lower end to delimit two compression chambers **3**, **4**. The intake system **2** communicates with a first compression chamber **3**. The architecture comprises a transfer system **6** (valve or the like) communicating with the first **3** and the second **4** compression chamber and configured to allow the transfer of fluid compressed in the first compression chamber **3** to the second compression chamber **4**. The movable piston **5** alternately compressing the fluid in the first **3** (towards the second chamber **4**) and in the second **4** compression chamber in its direction of movement. The evacuation system **7** communicates with the second compression chamber **4**.

[0060] The apparatus **1** can have the following operating characteristics: piston stroke of between 40 and 160 mm, a motor rotation speed of the order of 80 rpm to 500 rpm (corresponding to a frequency of between 1.3 Hz and 8.5 Hz for the piston **5**). For a traction force Ft, the thrust force F**1** can be of the order of 10-20% of Ft while the opposite force generated by the elastic member **10** can be of the order of 5-10% of Ft.

[0061] The aforementioned solution has many advantages.

[0062] It makes it possible to limit the maximum load peak in the mechanism. This makes it possible to increase the service life of the guide system subjected to these forces.

[0063] The architecture eliminates the need for an oil bath lubrication system that would seep on the cryogenic part. The architecture avoids having to manage an oil bath during maintenance operations. Only any lubricators which provide passive self-lubrication in operation of certain elements of the mechanism must be recharged. The solution is compact and lightweight and can be applied to any type of piston pump and any type of crank(s) drive mechanism.

[0064] While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations as fall within the spirit and broad scope of the appended claims. The present invention may suitably comprise, consist or consist essentially of the elements disclosed and may be practiced in the absence of an element not disclosed. Furthermore, if there is language referring to order, such as first and second, it should be understood in an exemplary sense and not in a limiting sense. For example, it can be recognized by those skilled in the art that certain steps can be combined into a single step.

[0065] The singular forms "a", "an" and "the" include plural referents, unless the context clearly dictates otherwise.

[0066] "Comprising" in a claim is an open transitional term which means the subsequently identified claim elements are a nonexclusive listing (i.e., anything else may be additionally included and remain within the scope of "comprising"). "Comprising" as used herein may be replaced by the more limited transitional terms "consisting essentially of" and "consisting of" unless otherwise indicated herein.

[0067] "Providing" in a claim is defined to mean furnishing, supplying, making available, or preparing something. The step may be performed by any actor in the absence of express language in the claim to the contrary.

[0068] Optional or optionally means that the subsequently described event or circumstances may or may not occur. The description includes instances where the event or circumstance occurs and instances where it does not occur.

[0069] Ranges may be expressed herein as from about one particular value, and/or to about another particular value. When such a range is expressed, it is to be understood that another embodiment is from the one particular value and/or to the other particular value, along with all combinations within said range.

[0070] All references identified herein are each hereby incorporated by reference into this application in their entireties, as well as for the specific information for which each is cited.

1-13. (canceled)

14. An apparatus for compressing cryogenic fluid comprising:

a sealed enclosure configured to contain a bath of cryogenic fluid;

a compression chamber in fluid communication with the bath of cryogenic fluid;

an intake system in fluid communication with the compression chamber configured to allow the entry of fluid to be compressed into the compression chamber;

a movable piston configured to ensure the compression of the fluid in the compression chamber;

an evacuation system in fluid communication with the compression chamber and configured to allow the exit of compressed fluid, the movable piston being mounted at a first end of a rod; and

a mechanism for driving the rod in a back and forth movement in a longitudinal direction, the drive mechanism comprising a motor provided with a rotating shaft and a mechanical system converting the rotational movement of the rotating shaft into a translational movement of a head sliding in the longitudinal direction and to which a second end of the rod is connected,

wherein the head is slidably mounted and guided by two fixed guide rails located on either side of the head, and in that the head and/or a rail comprises an elastic portion, said elastic portion being configured to generate on the rail or rails a force transverse to the longitudinal direction, and in that the elastic portion comprises a spring or a deformable zone and is prestressed.

15. The apparatus as claimed in claim **14**, wherein the compression of the fluid in the compression chamber is obtained by traction or compression of the rod, said traction or compression generating a transverse thrust of the head on one of the rails in a direction transverse to the longitudinal direction, and in that the force generated by the elastic portion is in the opposite direction to this thrust.

16. The apparatus as claimed in claim **15**, wherein the elastic portion is configured to generate on the rail or rails a transverse force having, in absolute value, an intensity less than or equal to the maximum intensity of the thrust force.

17. The apparatus as claimed in claim **14**, wherein the elastic portion is located between a central zone of the head and one of the two rails.

18. The apparatus as claimed in claim **14**, wherein the elastic portion is located between one of the two rails and a fixed support of said rail.

19. The apparatus as claimed in claim **14**, wherein, in the operating configuration, the rod is movable with a back and forth movement in a vertical longitudinal direction.

20. The apparatus as claimed in claim **14**, wherein the mechanical system converting the rotational movement of the rotating shaft into a translational movement of the carriage is of the connecting rod and crank type.

21. The apparatus as claimed in claim **14**, wherein the mechanical system converting the rotational movement of the rotating shaft into a translational movement of the head is connected to a central zone of the head via a ball joint or pivot connection, said connection being located on a longitudinal straight line passing through the axis of translation of the rod, said straight line being further secant to the straight line passing through the rotating shaft of the motor.

22. The apparatus as claimed in claim **14**, wherein the head is slidably mounted in the guide rails via a guide system with rolling element(s), for example a roller system, and/or balls and/or sliding rollers or a precision rail(s) type system.

23. The apparatus as claimed in claim **14**, wherein it is of the type with one compression stage, that is to say that the fluid is compressed only once between the intake system and the evacuation system.

24. The apparatus as claimed in claim **14**, wherein it is of the type with two compression stages, that is to say that the fluid is compressed twice between the intake system and the evacuation system, the apparatus comprising two compression chambers, the intake system communicating with a first compression chamber, a transfer system communicating with the first and the second compression chamber and configured to allow the transfer of fluid compressed in the first compression chamber to the second compression chamber, the movable piston alternately compressing the fluid in the first and second compression chambers in its direction of movement, the evacuation system communicating with the second compression chamber.

25. The apparatus as claimed in claim **24**, wherein the second compression chamber is delimited by a portion of the body of the movable piston and a fixed wall of the apparatus.

26. A station for filling tanks or pipes with pressurized gas, comprising a source of liquefied gas, in particular liquefied hydrogen, a withdrawal circuit having a first end connected to the source and at least one second end intended to be connected to a tank to be filled, the withdrawal circuit comprising a compression apparatus as claimed in claim **14**.

* * * * *