

Cold head for cryogenic refrigerating machine

The invention relates to a cold head for a cryogenic refrigerating machine.

WO 94/29653 describes a cold head for a cryogenic refrigerating machine, which is operated with helium as the working gas and is connected to a high-pressure source and a low-pressure source. The cold head includes a multi-channel control valve that controls the respective connection of a high-pressure inlet and a low-pressure inlet to a piston-cylinder unit and to a working chamber of the cold finger on the warm side. At one of its ends, the displacer which may include a regenerator, delimits a warm-side working chamber and at the opposite end it delimits a cold-side working chamber. While the displacer is periodically reciprocated by the piston-cylinder unit, heat is constantly drawn from the housing of the cold head. With a cold head having a single-stage displacer, temperatures down to about 30 K can be generated. With two- or three-stage displacers, temperatures below 1 K can be generated. A thermodynamic cycle process (a Stirling process or a Gifford-McMahon process) is performed in the cold head using process gas, generally helium, the process gas being guided in a closed circuit. As a consequence, heat is drawn from one end region of the housing enclosing the displacer.

The cold head is connected to a compressor. Since the circuit is a closed circuit, both the high-pressure connection and the low-pressure connection of the cold head are connected to the compressor. Such compressors typically include an overflow valve. The same is arranged in a return flow conduit arranged between the high-pressure side and the low-pressure side. Typically, overflow valves are spring-loaded check valves generally designed for a differential pressure between the high and low pressures of the compressor of 18 bar, for example. When a cold head, whose resistance is very high, is connected to the compressor the working pressure increases excessively on the high-pressure side at the compressor. For discharging this excess energy, the overflow valve opens so that the refrigerant, in particular helium, flows to the low-pressure side of the compressor via the return flow conduit. Due to the cyclic process of the cold head, a pulsed gas supply from the compressor to the cold head is realized. Here, gas oscillations may occur. In particular over a longer period, this may cause a frequent

opening and closing of the overflow valve. Thereby, the overflow valve is subjected to significant overload. This may lead to damage to the valve seat of the overflow valve or even to the destruction of the same. Further, this causes the generation of significant noise and losses in performance. When an overflow valve is damaged, it may happen that oil gets into the refrigeration circuit. Another disadvantage is that performance losses occur due to the existing hysteresis of the overflow valve between the opening pressure and the closing pressure.

It is an object of the invention to reduce the load on the overflow valve.

According to the invention, this object is solved with a cold head as defined in claim 1.

The cold head for a cryogenic refrigerating machine of the present invention has a working chamber in a housing, possibly a multi-part housing. A single- or multi-stage displacer is arranged in the working chamber. The cold head further comprises a high-pressure connection for supplying highly compressed refrigerant to the working chamber and a low-pressure connection for discharging expanded or low pressure refrigerant. Further, a control valve device is provided. The control valve device serves to control the supply and discharge of refrigerant into and from the working chamber. Here, the control device may comprise a plurality of valves, for example an inlet valve and an outlet valve. It is preferred that the control valve device has a multi-channel control valve which controls the connection between the high-pressure connection, the low-pressure connection and the working chamber. According to the invention the cold head has a bypass channel arranged between the high-pressure connection and the low-pressure connection and connecting the two connections. If needed, excess refrigerant can flow through said channel directly from the high-pressure connection to the low-pressure connection without flowing through the cold head. Such occurring surplus energy can thus be discharged via the bypass. As a result, the overflow valve integrated in the compressor is relieved. Possibly, the overflow valve may be omitted altogether from the compressor or it may be provided merely as a safety device. As a consequence, it is possible at least to use a significantly less costly overflow valve.

In a particularly preferred development of the invention a throughflow regulation device is arranged in the bypass channel. This may for example be a nozzle and/or a valve. The throughflow regulation device may be adjustable. In this context it is possible that a fixed setting is made prior to operation, so that the valve opens for example when a pressure difference is exceeded. Further, it is possible to allow for an adjustment of the throughflow regulation device from outside, i.e. from outside the cold head. As such, it may possibly be allowed to make corresponding adjustments also during operation.

Since the present invention provides a bypass in the cold head, which preferably includes a pressure regulation device, it is possible to achieve a significant reduction of costs for the compressors used. Further, the operating safety of the compressors can be enhanced and the compressor performance can be increased. The risk of an oil breakthrough caused by a damaged overflow valve in the compressor is also reduced. Further, service life is extended and a constant noise behavior can be achieved.

In a preferred development of the invention the cold head has a movement device for moving the displacer. The movement device may be a motor. By means of the motor, which may be an electric motor, for example, the displacer can be moved using a slotted guide. This may be effected e.g. through an eccentric so that the rotational movement of the motor is converted into a longitudinal movement of the displacer in a simple manner. As an alternative, a piston/cylinder unit may be provided for moving the displacer. The piston-cylinder unit may for example be driven via a separate hydraulic system. However, for the purpose of movement, it is preferred to connect the piston-cylinder unit to the high-pressure connection and the low-pressure connection. In a preferred embodiment, the actuation of the piston-cylinder unit and thus the movement of the displacer are realized by means of the refrigerant.

It is further preferred that the cold head has a distributor body in which at least a first connecting channel is provided. The first connecting channel serves to connect the high-pressure connection to the working chamber. Preferably, this connection is made via the control valve device so that the first connecting channel is arranged between the control valve device and the working chamber. Pref-

erably, the distributor body additionally has a second connecting channel arranged between the control valve device and the low-pressure connection.

In a particularly preferred embodiment the valve body is designed such that it also comprises a control channel. The control channel serves to supply and discharge control medium to the movement device, i.e. in particular to the piston-cylinder unit. The control medium preferably is the refrigerant.

The invention will be explained in detail hereinafter with reference to a preferred embodiment and to the accompanying drawings.

In the Figures:

Figure 1 is a schematic illustration of a cryogenic refrigeration machine of the prior art,

Figure 2 is a schematic illustration of a cryogenic refrigeration machine of the present invention and

Figure 3 is a schematic sectional view of an embodiment of a cold head according to the present invention.

A cryogenic refrigeration machine of the prior art (Figure 1) comprises a compressor 10 which compresses a refrigerant such as helium. On the high-pressure side, the compressor 10 is connected to a high-pressure connection 14 of a cold head 16 via a conduit 12. A low-pressure connection 18 of the cold head 16 is connected to the low-pressure side of the compressor 10 via a conduit 20. To avoid an overload on the compressor 10 a check valve 24 is arranged in a return flow conduit 22 that connects the high-pressure side of the compressor 10 to the low-pressure side of the compressor 10.

Inside the cold head 16 a working chamber 26 is provided in which a displacer piston is arranged that is not illustrated in Figure 1. An inlet valve 28 is connected to the high-pressure connection 14 so that compressed refrigerant flows into

the working chamber 26 when the inlet valve 28 is open. Expanded refrigerant may be guided to the low-pressure connection 18 via an outlet valve 30.

In the basic configuration of a system of the present invention illustrated in Figure 2, similar and identical components are identified by the same reference numerals.

According to the invention schematically illustrated a bypass channel 32 is provided between the inlet valve 28 of the cold head 16 and the outlet valve 30 of the cold head 16, in which bypass channel a throughflow regulation device may possibly be arranged. As shown in broken lines in Figure 2, providing the bypass channel 32 of the present invention makes it possible to omit the return flow conduit 22 and the overflow valve 24.

A preferred embodiment of the cold head 16 is illustrated in a schematic sectional view in Figure 3.

The cold head 16 has a housing formed by the two housing parts 34 and 36. In the housing part 34 two cylindrical cold-side working chambers 38 and 40 are provided for the two displacer stages 42 and 44.

The upper displacer stage 42 delimits a warm-side working chamber 46 and is provided with a drive piston 48 arranged in a cylinder 50 of a distributor body 52. Thus, the displacer 42, 44 is arranged in a working chamber 38, 40, 46 formed by a plurality of partial chambers.

The distributor body 52 delimits the warm-side working space 46. It is provided with bores that form a control channel 54, a first connecting channel 56, as well as a second connecting channel 57. The first connecting channel 56 opens into the working chamber 46 and serves to supply working gas to this chamber. All three channels are controlled by the control valve 58. The first connecting channel 56 connects the control valve 58 to the warm-side working chamber 46, the control channel 54 connects the valve 58 to the cylinder 50 and the second 57 connects the valve 58 to a low-pressure connection 60. The control valve 58 is further connected to a chamber 62 that is in communication with a high-pressure

connection 64. The high-pressure connection 64 supplies helium gas at a pressure of ca. 20 bar, while helium at a pressure of about 5 bar prevails at the low-pressure connection 18. Both pressures are supplied to corresponding connections (not illustrated) of the control valve 58 via the chamber 62 and the second connecting channel 57, respectively. All conduits lead into the upper side of the distributor body 52 and from there to the valve 58.

The housing part 36 accommodates a motor 66 that drives the control valve 58 via a shaft 68. The valve is acted upon by a compression spring 70.

In the embodiment illustrated the process gas subjected to the thermodynamic cycle process and the drive gas for the piston-cylinder unit 48, 50 are identical. Suitably, helium is used. It is possible to use a different gas than the process gas as the drive gas.

Instead of the piston-cylinder unit 48, 50 provided in the embodiment illustrated for moving the displacers 72, 76, the displacers 72, 76 may also be moved by a motor, e.g. using an electric motor. For this purpose, the electric motor may be provided with an eccentric and a slotted guide so that the rotation of the eccentric is converted into a linear movement.

In the cylindrical working chamber 46, the displacer stage 42 has a tubular displacer 72 filled with a thermal regenerator 74 that is permeable to gas. The regenerator 74 serves to store cold and to give off stored cold to the inflowing warm gas.

Similarly, the displacer stage 44 that has a smaller diameter than the displacer stage 42, includes a tubular displacer 76 shiftable in the axial direction in the cylindrical working chamber 40, said displacer being connected to the displacer 72 and also being filled with a gas-permeable regenerator 78.

In operation of the cold finger, the working chamber 46 on the warm side is first connected to the high-pressure connection 64 via the first connecting channel 56 and the control valve 58. At the same time, high pressure is introduced into the cylinder 50 through the control channel 54. The displacers 72 and 76 are shifted

towards the cold side (downward). The gas under high pressure flows through the regenerators 74 and 78 to the cold side as well. In doing so it expands while cooling, with further expansion being effected by heat exchange with the regenerators.

In the second phase the control channel 54 is connected to the low-pressure connection. Under the effect of the high pressure, the displacers 72, 76 are shifted towards the warm side so that the working chamber 46 on the warm side becomes smaller and gas flows into the working chamber 40 on the cold side through the regenerators 74 and 78.

In the third phase the control valve 58 causes the connection of the working chamber 40 to the low-pressure connection 60 via the conduit 56. Thereby, the gas in all working chambers of the cold head expands while cooling.

Thereafter the displacers 72 and 76 are moved to the cold side, whereby the volume of the cold-side working chamber 40 shrinks so as to be prepared for the next cycle. In this phase the cold gas flows from the working chamber 40 into the regenerators 74 and 78 which are thereby cooled further.

The frequency of the working cycle described is about 2 Hz.

Further, in the embodiment illustrated, a bypass channel 80 according to the invention is provided in the distributor body 52. The bypass channel 80 connects the second control channel 57 to the chamber 62. The bypass channel 80 thus connects the high-pressure connection 64 to the low-pressure connection 60. As schematically illustrated, a throughflow regulation device, such as a valve 82, is arranged in the bypass channel 80. In case of an undesired high pressure increase in the chamber 62, a part of the refrigerant thus flows directly through the bypass channel 80 back into the channel 57 connected to the low-pressure connection 60.

Claims

1. Cold head for cryogenic refrigeration machines, comprising

a displacer (72, 76) mounted in a working chamber (38, 40, 46) of a housing (34, 36),

a high-pressure connection (64) for supplying highly compressed refrigerant into the working chamber (38, 40, 46),

a low-pressure connection (60) for discharging expanded refrigerant from the working chamber (38, 40, 46), and

a control valve device (28, 30; 58) for controlling the supply and discharge of refrigerant into and from the working chamber (38, 40, 46),

characterized by

a bypass channel (80) connecting the high-pressure connection (64) to the low-pressure connection (60).
2. Cold head for cryogenic refrigeration machines of claim 1, characterized in that a throughflow regulation device (82) is arranged in the bypass channel (80).
3. Cold head for cryogenic refrigeration machines of claim 2, characterized in that the throughflow regulation device (82) is adjustable in particular during operation.
4. Cold head for cryogenic refrigeration machines of one of claims 1 -3, characterized by a movement device (48, 50) for moving the displacer (72, 76).
5. Cold head for cryogenic refrigeration machines of claim 4, characterized in that the movement device is configured as a piston-cylinder unit (48, 50)

which, for actuation, is preferably connected to the high-pressure connection (64) and the low-pressure connection (60).

6. Cold head for cryogenic refrigeration machines of claim 4, characterized in that the movement device has a motor, in particular an electric motor.
7. Cold head for cryogenic refrigeration machines of claim 6, characterized in that the electric motor drives an eccentric that acts on a slotted guide to cause a linear movement of the displacer (72, 76).
8. Cold head for cryogenic refrigeration machines of one of claims 1 - 7, characterized in that the control valve device (28, 30; 58) has a cyclically operating, multi-channel control valve (58) that controls the connection of a working chamber (38, 40, 46) to a high-pressure connection (64) and to a low-pressure connection (60).
9. Cold head for cryogenic refrigeration machines of claim 8, characterized in that the control valve (58) controls the connection of the piston-cylinder unit (48, 50).
10. Cold head for cryogenic refrigeration machines of one of claims 1 - 9, characterized by a distributor body (52) in which at least a first connecting channel (56) is provided for connecting the high-pressure connection (64) to the working chamber (38, 40, 46).
11. Cold head for cryogenic refrigeration machines of claim 10, characterized in that the first connecting channel (56) is arranged between the control valve (58) and the working chamber (38, 40, 46).
12. Cold head for cryogenic refrigeration machines of claim 8 or 9, characterized in that the distributor body (52) has a second connecting channel (57) between the control valve (58) and the low-pressure connection (60).
13. Cold head for cryogenic refrigeration machines of one of claims 10 - 12, characterized in that the distributor body (52) has a control channel (54)

for supplying and/or discharging a control medium, in particular a refrigerant, to and/or from the piston-cylinder unit (48, 50).