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(54) **Liquid helium recondensation device and transfer line used therefor**

Vorrichtung zur Rekondensation von flüssigem Helium und dafür verwendete Transportleitung

Appareil permettant de recondenser de l'helium liquide et conduite de transfert utilisee a cet effet

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(73) Proprietor: **Japan Science and Technology Agency**
Kawaguchi-shi,
Saitama 332-0012 (JP)

(72) Inventor: **Takeda, Tsunehiro**
Tokyo 135-0044 (JP)

(74) Representative: **Jackson, Robert Patrick**
Dehns
St Bride's House
10 Salisbury Square
London
EC4Y 8JD (GB)

(56) References cited:
US-A- 3 882 687 **US-A- 3 892 106**
US-A- 4 432 216 **US-A- 4 790 147**
US-A- 4 796 433

- **PATENT ABSTRACTS OF JAPAN vol. 015, no. 232 (M-1124), 13 June 1991 (1991-06-13) -& JP 03 070960 A (HITACHI LTD), 26 March 1991 (1991-03-26)**

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Description

[0001] This invention relates to liquid helium circulation systems and transfer lines used with the said systems. To be more specific, it relates to the liquid helium circulation system used as part of a brain magnetism measurement system that liquefies helium gas evaporating from its liquid helium reservoir, where an encephalomagnetometer is disposed in an extreme low temperature environment, and to the transfer line used with the system that sends the liquefied helium back to the liquid helium reservoir. Besides brain magnetism measurement systems, the said liquid helium circulation systems and transfer lines are also usable with magnetocardiographs and magnetic resonance imaging (MRI) systems, and in studying and evaluating the properties of a variety of materials at extreme low temperatures.

[0002] Brain magnetism measurement systems to detect magnetic fields generated by human brains are under development These systems use super-conducting quantum interference devices (SQUIDs) capable of measuring brain activities with a high space-time resolution and without harming the organs. The SQUID is used in the refrigerated state, dipped in the liquid helium filled in an insulated reservoir.

[0003] With most conventional liquid helium reservoirs in those systems, the helium gas evaporating from the reservoir is released into the air. This waste of helium in large quantity makes the systems economically disadvantageous when helium is as expensive as ¥1,200 per liter. Moreover, as the liquid helium in the reservoir is consumed, it has to be replenished with fresh liquid helium from a commercial cylinder. The replenishment however presents problems such that the process is extremely troublesome, or that outsourcing costs are substantial.

[0004] Against the background as above-mentioned, there are recent moves to develop liquid helium circulation systems, which may recover, recondense and liquefy the helium gas evaporating from the reservoir in its entirety and send it back to the reservoir.

[0005] Referring to Fig.4, briefly shown below, is the schematic configuration of a type of such liquid helium circulation system. 101 stands for a liquid helium reservoir, wherein an encephalomagnetometer is disposed; 102 a drive pump that recovers the helium gas vaporized inside reservoir 101; 103 a dryer that dehydrates the helium gas recovered; 104 a flow regulating valve; 105 a purifier; 106 an auxiliary refrigerator; 107 a heat exchanger No.1 for auxiliary refrigerator 106; 108 a condensing refrigerator and 109 a condensing heat exchanger of condensing refrigerator 108. The helium gas boiling off from liquid helium reservoir 101 and whose temperature is raised to about 300° Kelvin (K) is suctioned with drive pump 102, and sent through dryer 103 and purifier 105 to auxiliary refrigerator 106, where it is cooled down to about 40° K and liquefied. The liquid helium is sent to condensing refrigerator 108, where it is further cooled down to about 4° K as it passes condensing heat exchanger 109. Finally the extreme low temperature liquid helium is supplied to liquid helium reservoir 101 through transfer line 110.

[0006] This prototype helium circulation system is basically a system to recover and recycle entirely the helium gas evaporating from the liquid helium reservoir. Compared with conventional similar systems, whose vaporized helium is released into the air or recovered in a gas bag or the like for reprocessing, it consumes a remarkably smaller quantity of helium, promising benefits of economy and efficiency which has been spurring recent efforts to put to practical use. In addition, the added feature of the new system demanding little trouble to refill fresh liquid helium would make maintenance of the measurement system easier as a whole.

[0007] Nevertheless, the new circulation system as above-mentioned cannot be free from necessary improvements as follows:

[0008] While liquid helium is an indispensable medium to keep a SQUID in the refrigerated state, a huge amount of electric energy has to be consumed to run the refrigerator to liquefy helium gas. In addition, a large volume of water is required to cool the compression pump of the refrigerator. Furthermore, as the liquefied helium is transferred from the refrigerator to the liquid helium reservoir through the transfer line, it is difficult to isolate it completely from high-temperature parts, causing a large portion of it to become vaporized, resulting in a poor transfer rate. Such being the case, the running cost as well as insulation measures amount to a huge sum comparable to that in the case of allowing the gas to escape into the air. An economical version of liquid circulation system overcoming such problems needs to be developed.

[0009] JP03-070960 which shows the features of the preamble of claim 1, describes a transfer line having a liquid helium pipe and helium gas return pipes disposed in a common vacuum layer in the transfer line.

[0010] US 3,882,687 describes a transfer line having a central liquid cryogen pipe surrounded by (in increasing size) a first coaxial pipe containing a two-phase mixture, a second coaxial pipe which is evacuated, a third coaxial pipe containing gas and a fourth coaxial pipe which is evacuated.

[0011] With the above-mentioned considerations in the background, the inventor has developed the idea of this invention from the phenomena that the quantity of heat (sensible heat) required to raise the temperature of helium gas from about 4° K to about 300° K is much higher than that (vaporization heat) required for the phase change from liquid to gas of helium at about 4° K, and that while the energy required to cool down high-temperature helium to low-temperature helium is moderate, substantial energy is required to liquefy low-temperature helium gas.

[0012] Namely, this invention offers a new type of liquid helium circulation system as a solution to the problems conventional circulation systems have had as above-mentioned. With this invention, high-temperature helium gas as high as 300° K boiling off from the liquid helium reservoir is recovered, cooled down to about 40° K, a temperature within the easy reach of a refrigerator, and supplied to the upper part in said reservoir. Also, low-temperature helium gas, say about 10° K, near the surface of liquid helium inside said reservoir is recovered and liquefied at about 4° K and supplied back to said reservoir. In this manner, the inventory of liquid helium inside said reservoir is easily replenished by as much as is lost by evaporation.

[0013] The present invention provides a transfer line comprising a first line supplying liquid helium, a second line supplying low-temperature helium gas and a third line supplying refrigerated helium gas whose temperature is higher than that of said low-temperature helium gas, characterised in that the first line comprises a pipe surrounded by a first vacuum layer and the second line comprises a pipe surrounded by a second vacuum layer and the third line comprises a pipe surrounded by a third vacuum layer and in that the first, second and third lines are disposed in a pipe surrounded by an outer vacuum layer which surrounds all three lines.

[0014] In a preferred embodiment, the invention provides a transfer line characteristic of its construction consisting of a line that supplies liquid helium, a line that supplies low-temperature helium gas, and a line that supplies refrigerated helium gas of a temperature higher than that of said low-temperature helium, with each line surrounded by a vacuum layer and all lines disposed inside a same conduit whose outer surface is insulated with a vacuum layer.

[0015] With the liquid helium circulation system described herein, it is possible to minimize liquid helium boil-off from the liquid helium reservoir because therein the sensible heat of refrigerated helium gas removes a large quantity of heat. Also, cooling helium gas from about 300° K down to about 40° K requires an amount of energy much less compared with that when producing liquid helium of about 4° K by liquefying helium gas of about 40° K. Therefore, compared with conventional systems liquefying the entire volume of helium gas recovered, this system offers outstanding economic benefit by lowering remarkably the amount of energy consumed in liquefying helium gas by shortening the running time of the refrigerator, etc.

[0016] Also, this system recovers and liquefies low-temperature helium gas in the vicinity of the surface of liquid helium in the liquid helium reservoir, which greatly helps save the amount of energy needed in the process of liquefying helium gas, leading to a large reduction in running cost.

[0017] An alternative arrangement which does not form part of the claimed invention provides a transfer line characteristic of its triple-pipe design consisting of a line that supplies liquid helium at the center, an intermediate line that supplies low temperature helium gas, and an outermost line that supplies refrigerated helium gas of a temperature higher than that of said low-temperature helium gas, with each line surrounded by a vacuum layer.

[0018] This system adapts a method for refrigerated helium gas or low-temperature helium gas to flow around the line supplying liquid helium liquefied by the refrigerator. This feature is to isolate the line from surrounding high-temperature parts and protect the liquid helium from evaporating as it flows though the line, which minimizes the loss of energy in a helium gas liquefying process and makes this system a more efficient liquid helium circulation system.

[0019] Preferred embodiments of the invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

> Fig. 1 is a schematic representation of the multi-circulation type liquid helium circulation system suitable for use with this invention. Fig. 2 shows an enlarged side view with a broken section of a transfer line according to an embodiment of this invention. Fig. 3(a) shows a cross-sectional drawing of an embodiment of transfer lines according to the invention. Fig. 3(b) shows an alternative arrangement not forming part of the invention. Fig. 4 shows the schematic configuration of a conventional circulation type liquid helium circulation system.

[0020] Referring to Fig. 1 showing a schematic construction of the multi-circulation type liquid helium circulation system for use with this invention, the description is given of the system as follows:

[0021] Number 1 stands for a liquid helium reservoir (FRP cryostat) that is disposed inside a magnetic-shield room and wherein a SQUID is placed. 1a a gas-liquid separator disposed in said reservoir; 1b a level gauge measuring the liquid level of liquid helium 13; 1c a pipe for recovery gas line 12 recovering high-temperature helium gas heated up to about 300° K inside said reservoir. Number 2 stands for a flow regulating pump that supplies high-temperature helium gas recovered to a small capacity refrigerator via pipe 1c. 4 a flow regulating valve. 5 a 4 KGM small capacity refrigerator known for its remarkable progress of late. 6 and 7 heat exchangers No. 1 and No.2 of said refrigerator. 6a and 7a No.3 and No. 4 heat exchangers, which liquefy high-temperature helium gas recovered from the reservoir, or fresh helium supplied from a helium cylinder 10 as it is supplied through line 20 in the event the inventory of liquid helium falls short inside said reservoir. 8 a 6.5KW helium compressor. 9 a transfer line with combined three lines - 9a that supplies liquid helium liquefied with refrigerator 5 to liquid helium reservoir 1; 9b that recovers low-temperature helium gas from inside said reservoir 1 and 9c that supplies helium gas cooled down to about 40° K with refrigerator 5 to liquid helium reservoir 1. 10 a helium cylinder that supplements a fresh batch of helium in an emergency. 11 an insert pipe, which is connected with transfer line 11 and disposed in liquid helium reservoir 1. Above-mentioned component units are interconnected with each other ensuring fluids to flow in the directions as indicated by arrows. In addition, 14 forms the magnetic-shield room of FPR cryostat 1.

[0022] Referring to Figs. 2 and 3, the constructions of two different types of transfer lines, among others, are described as follows. Fig.2 is a side view with a broken section of a transfer line. Fig.3 (a) is the section A-A of the transfer line in Fig.2 and Fig.3(b) shows a section of a transfer line of different construction not belonging to the present invention.

[0023] The example of transfer line given in Fig.3 (a) has pipe 9a disposed at the center of a surrounding vacuum layer 9d for flowing liquid helium of about 4° K, pipe 9b disposed at the center of a surrounding vacuum layer 9d for flowing low-temperature helium gas of about 10° K recovered from inside the reservoir and pipe 9c disposed at the center of a surrounding vacuum layer 9d for flowing refrigerated helium gas cooled down to about 40° K with the refrigerator. These pipes 9a, 9b and 9c are lined up in parallel with one another and housed in a large pipe 9A with a surrounding vacuum layer 9d for insulation and an insulation material 13 installed in its inside.

[0024] The transfer line according to Fig. 3(b) is a triple-pipe version of transfer line 9, consisting of a large pipe 9'c surrounded with a vacuum layer 9d at the outermost, a medium size pipe 9'b surrounded with a vacuum layer 9d set at the center of pipe 9'c and a small pipe 9'a surrounded with a vacuum layer set at the center of pipe 9'b. This triple-pipe construction is designed to allow the flow of refrigerated helium gas of about 40° K along the outer surface of medium size pipe 9'b, low-temperature helium gas of about 10° K along the outer surface of small size pipe 9'a and liquid helium of about 4° K through the inside of small size pipe 9'a.

[0025] In the case of example (a) of transfer line, three pipes can be bound together, offering an advantage of smaller outer diameter compared with the triple-pipe construction shown in Fig. 3(b).

[0026] In each case of transfer line 9, the reservoir-side end of the transfer line is connected with an insert pipe 11 disposed in liquid helium reservoir 1, and a gas-liquid separator 1a is installed at the end of insert pipe 11. While this gas-liquid separator does not constitute an essential part of this invention, it is desirable to install it where it is necessary to prevent the disturbance of temperature equilibrium in the reservoir due to a paucity of helium gas generating from liquid helium in transit. Of three pipes placed inside transfer line 9, an end of pipe 9a that supplies the liquid helium liquefied with the refrigerator to liquid helium reservoir 1 is connected with gas-liquid separator 1a, an end of pipe 9b that recovers low-temperature helium gas from inside reservoir 1 and supplies it to the refrigerator is located close to the gas-liquid separator 1a of insert pipe 11 or in the vicinity of the surface of liquid helium inside reservoir 1 so that low-temperature helium gas can be collected from an area of the lowest available temperature (close to 4° K) inside reservoir 1, and an end of pipe 9c that supplies refrigerated helium gas, cooled down to 40° K with the refrigerator, to reservoir 1 is opened over insert pipe 11 (the inner upper part of reservoir 1).

[0027] The function of the liquid helium circulation system with a construction as above-mentioned is as follow:

[0028] The liquid helium pooled inside liquid helium reservoir 1 starts to gasify at a temperature of about 4° K inside said reservoir and keeps refrigerating the inner space of said refrigerator until its temperature rises to a room temperature of about 300° K by sensible heat. The high-temperature helium gas of about 300° K is suctioned out with flow-regulating pump 2 via helium gas recovery pipe 1c installed at the upper part of reservoir 1. The entire helium gas recovered is sent to heat exchanger No. 6 of small-capacity refrigerator 5, where the helium gas is cooled down to about 40° K The refrigerated helium is supplied via pipe 9c disposed inside the transfer line to the upper part inside reservoir 1 and cools down efficiently the inner space of reservoir 1 by sensible heat until its temperature rises to 300° K While the lower space inside reservoir 1 is kept at constant 4° K as the liquid helium inside reservoir 1 evaporates, the evaporation is slowed down because the shrouding helium gas of about 40° K as above-mentioned inhibits heat infiltration from above to the liquid helium. Meanwhile, although, in order to raise the cooling performance of reservoir 1, it is desirable to supply refrigerated helium gas cooled down as low as possible below about 40° K to the reservoir, it is economically unfavorable since it demands a system with a much higher refrigeration capacity.

[0029] Also, pipe 9c with its opening close to the surface of liquid helium inside reservoir 1 recovers low-temperature helium gas of about 40° K, which is liquefied with the heat exchanger 7 of small capacity refrigerator 5. The liquefied helium is returned to reservoir 1 via pipe 9a inside transfer line 9, and via gas-liquid separator 1a if necessary. This method of liquefying low-temperature helium gas of about 10° K using a small capacity refrigerator is instrumental in replenishing constantly the reducing inventory of liquid helium due to evaporation inside said reservoir at a lower energy cost. Moreover, liquefied helium flowing inside transfer line 9 is protected with refrigerated helium gas or low-temperature helium gas flowing also inside said transfer line against high-temperature parts, which helps restrict the liquid helium in transit from evaporating. Meanwhile, liquefying helium gas of the lowest available temperature drawn out from inside reservoir 1 helps raise the liquefying efficiency of refrigerator used, making it possible to use a small capacity refrigerator with an ensuing reduction in running cost.

[0030] Described above is a transfer line that consists of pipe 9c that supplies refrigerated helium gas, cooled down to about 40° K, to reservoir 1, pipe 9b that transports low-temperature helium gas of about 10° K recovered from reservoir 1 and pipe 9a that transports liquefied helium. Unlike this design, it is possible to design pipe 9c that supplies refrigerated helium gas to reservoir 1 as an insulated pipe independent from the transfer line.

[0031] Aforementioned is an operational system where the entire volume of high-temperature helium gas of about 300° K recovered from reservoir 1 is cooled down to about 40° K, and the refrigerated helium gas is sent to the inner upper part of said reservoir. It is also possible, by operating flow-regulating valve 4, to supply part of high-temperature helium gas through the line indicated as 20 in the drawing to the heat exchangers No. 1 6a and No.2 7a (different from those aforementioned) of refrigerator 5 for liquefying and to return the liquefied helium to reservoir 1 via aforementioned pipe 9a.

[0032] As above-mentioned, this liquid helium circulation system is designed to perform as follows:

[0033] First, the helium gas whose temperature is about 300° K from inside the liquid helium reservoir, and the recovered helium gas is cooled down to about 40° K in its entirety taking advantage of the first-stage refrigeration cycle of the refrigerator and the refrigerated helium gas is sent back to the liquid helium reservoir Second, low-temperature helium gas of about 40° K is recovered through a pipe with its opening close to the surface of liquid helium inside the reservoir. The recovered low-temperature helium gas is supplied to the heat exchangers No. 2 7 of the small capacity refrigerator where the helium gas is liquefied, and the liquefied helium is returned to the reservoir to add to the reducing inventory of liquid helium. Owing to these design features, the helium gas of 40° K can cool the liquid helium reservoir because a large quantity of heat is removed as the helium gas is heated up to about 300° K, and the lower space inside the reservoir is kept at about 4° K, which makes the system comparable with conventional systems in terms of cooling effect. Also, the inventory of liquid helium inside the reservoir is reduced as it evaporates. The design feature to recover and liquefy low-temperature helium gas in the vicinity of the surface of liquid helium inside the reservoir and return the liquefied helium into the reservoir helps minimize energy loss in producing liquid helium, paving the way for designing a liquid helium circulation system with high efficiency at a low cost.

[0034] Also, the design feature to have helium gas cooled down with the refrigerator or low-temperature helium gas recovered from the reservoir protects the liquid helium liquefied with said refrigerator in transit greatly helping to reduce the volume of the liquid helium lost by evaporation.

[0035] Also, while condensing helium gas of about 40° K to produce liquid helium of about 4° K demands a huge amount of energy the design feature of this invention to condense helium gas of about 10° K helps minimize the liquefying energy, making it possible to use a small capacity refrigerator.

[0036] Meanwhile, it goes without saying that another type of refrigerator can replace the refrigerator described above. Using a multi-stage refrigerator would make it possible to have helium gas of different temperatures flow at one time. Also, in designing, a controller, though it is not shown in the drawing, that is activated with signals from a sensor such as level gauge disposed inside the liquid helium reservoir can be included to control the flow-regulating valve used in replenishing the inventory of liquid helium. Also, optional component units, materials etc. are selectable to suit the purpose of the system.

[0037] While the system described above uses one unit of small capacity refrigerator for producing liquid helium and refrigerated helium gas, instead, it is possible to use two or more units of smaller capacity refrigerators, each one assigned with a specific function. Furthermore, while the temperature of helium gas supplied to the refrigerator of the system described above for refrigeration is about 40° K, this temperature is not binding and helium gas at a variety of temperatures may be used depending upon the purpose of the work.

[0038] Because of its design feature of recovering low-temperature helium (about 10° K) by means of a pipe with its opening close to the liquid helium inside the reservoir, liquefying the recovered gas with a small capacity refrigerator and returning the liquefied helium to said reservoir to replenish the inventory of liquid helium, the loss of energy in producing liquid helium can be minimized, paving the way for designing highly efficient liquid helium circulation systems operating at a low running cost.

[0039] Its design feature ensuring the effective use of a large quantity of sensible heat required while helium gas of about 40° K is raised to 300° K for cooling the liquid helium circulation system dismisses the conventional need of liquefying the entire volume of helium gas with ensuing benefits of saving measurable energy and running cost.

[0040] Its design feature to recover and recycle helium in its entirety dismisses the conventional method of troublesome helium replenishment and reduces largely the cost involving liquid helium.

[0041] Its feature to transport the liquid helium liquefied with the refrigerator without allowing it to contact high-temperature parts prevents it from evaporating while in transit and ensures its stabilized return to the reservoir.

Claims

1. A transfer line comprising a first line (9a) for supplying liquid helium, a second line (9b) for supplying low-temperature helium gas and a third line (9c) for supplying refrigerated helium gas whose temperature is higher than that of said low-temperature helium gas, **characterised in that** the first line comprises a pipe (9a) surrounded by a first vacuum layer (9d) and the second line comprises a pipe (9b) surrounded by a second vacuum layer (9d) and the third line comprises a pipe (9c) surrounded by a third vacuum layer (9d) and **in that** the first, second and third lines are disposed in a pipe surrounded by an outer vacuum layer (9d).

2. A transfer line as claimed in claim 1, wherein the first, second and third lines (9a, 9b, 9c) are disposed in parallel.

3. A transfer line as claimed in claim 1 or 2, wherein the first, second and third lines (9a, 9b, 9c) are disposed in an insulating material (13) and the outer vacuum layer (9d) surrounds the insulating material (13).

Patentansprüche

1. Übertragungsleitung umfassend eine erste Leitung (9a) zum Zuleiten flüssigen Heliums, eine zweite Leitung (9b) zum Zuleiten von Heliumgas tiefer Temperatur und eine dritte Leitung (9c) zum Zuleiten gekühlten Heliumgases, dessen Temperatur höher ist als diejenige des Heliumgases niedriger Temperatur, **dadurch gekennzeichnet, dass** die erste Leitung ein Rohr (9a) umfasst, welches von einer ersten Vakuumschicht (9d) umgeben ist, und dass die zweite Leitung ein Rohr (9b) umfasst, welches von einer zweiten Vakuumschicht (9d) umgeben ist, und dass die dritte Leitung ein Rohr (9c) umfasst, welches von einer dritten Vakuumschicht (9d) umgeben ist, und dass die erste, zweite und dritte Leitung in einem Rohr angeordnet sind, welches von einer äußeren Vakuumschicht (9d) umgeben ist.

2. Übertragungsleitung gemäß Anspruch 1, wobei die erste, zweite und dritte Leitung (9a, 9b, 9c) parallel angeordnet sind.

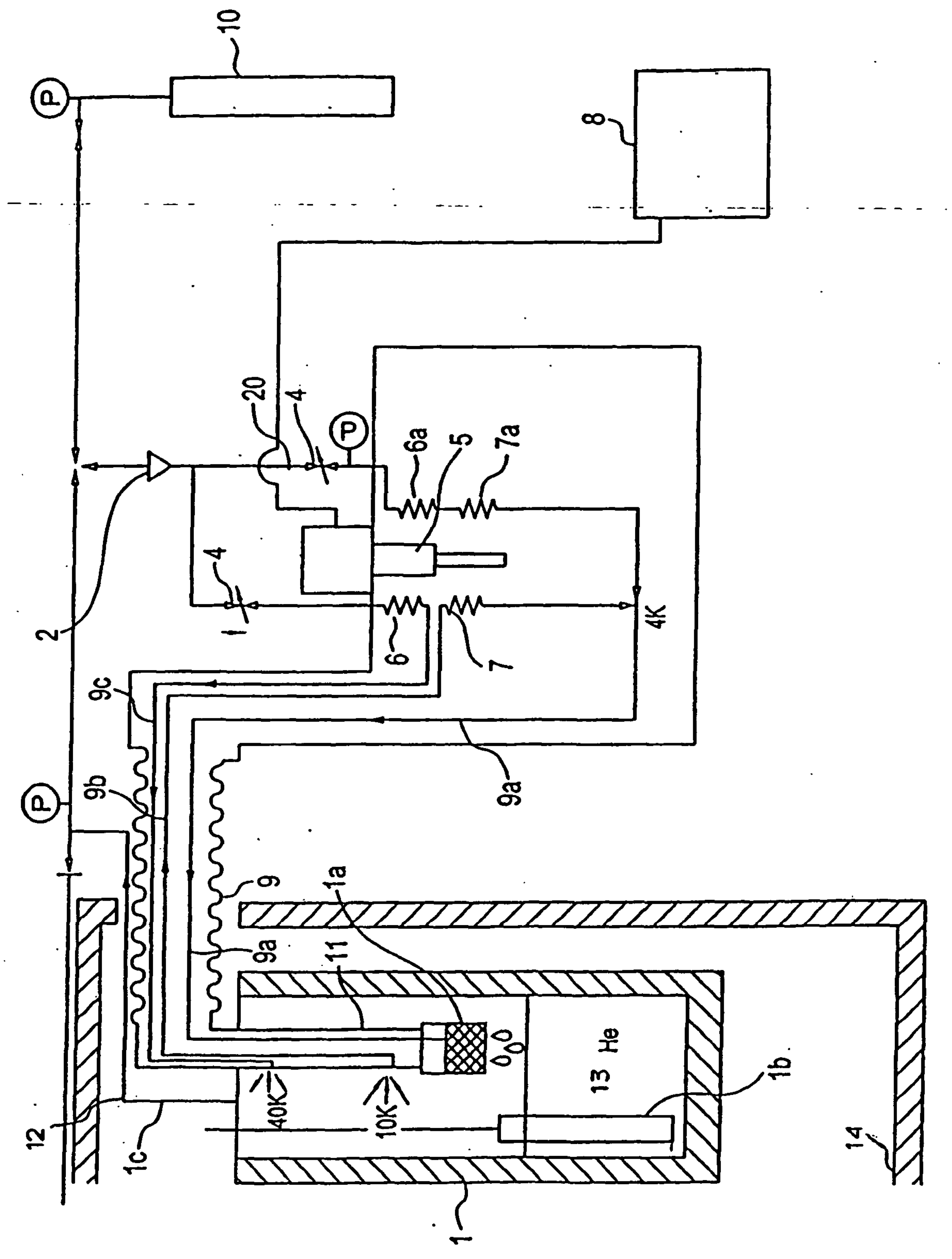
3. Übertragungsleitung gemäß Anspruch 1 oder 2, wobei die erste, zweite und dritte Leitung (9a, 9b, 9c) in einem Isoliermaterial (13) angeordnet sind, und die äußere Vakuumschicht (9d) das Isoliermaterial (13) umgibt.

Revendications

1. Conduite de transfert comprenant une première conduite (9a) pour fournir de l'hélium liquide, une deuxième conduite (9b) pour fournir de l'hélium gazeux à basse température et une troisième conduite (9c) pour fournir de l'hélium gazeux réfrigéré dont la température est supérieure à celle dudit hélium gazeux à basse température, **caractérisée en ce que** la première conduite comprend un tube (9a) entouré d'une première couche sous vide (9d) et la deuxième conduite comprend un tube (9b) entouré d'une deuxième couche sous vide (9d) et la troisième conduite comprend un tube (9c) entouré d'une troisième couche sous vide (9d) et **en ce que** les première, deuxième et troisième conduites sont disposées dans un tube entouré d'une couche sous vide externe (9d).

2. Conduite de transfert selon la revendication 1, dans laquelle les première, deuxième et troisième conduites (9a, 9b, 9c) sont disposées parallèlement.

3. Conduite de transfert selon la revendication 1 ou 2, dans laquelle les première, deuxième et troisième conduites (9a, 9b, 9c) sont disposées dans un matériau isolant (13) et la couche sous vide externe (9d) entoure le matériau isolant (13).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6
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4K
9c
9b
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1a
11
9a
12
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10K
13 He
1b
14
1

Fig. 1

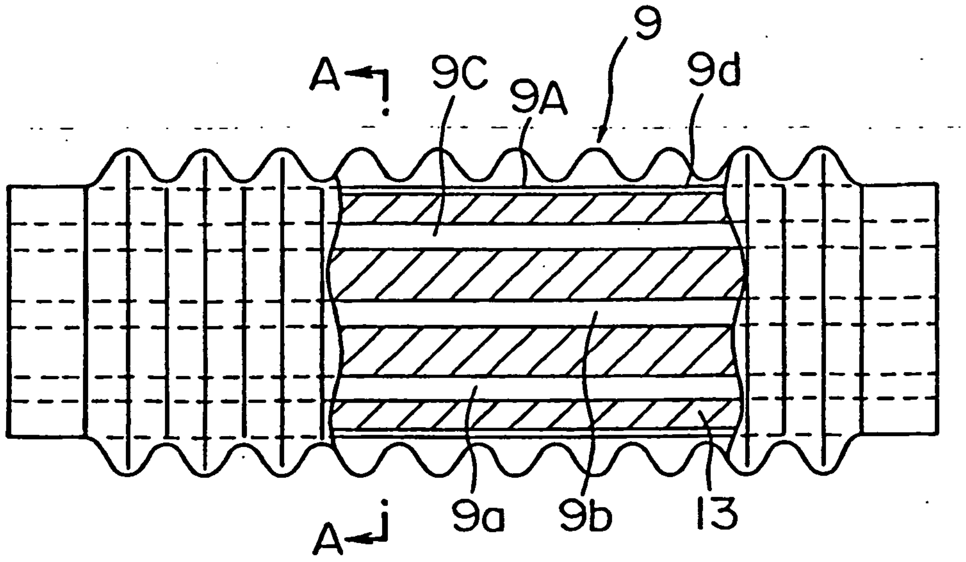
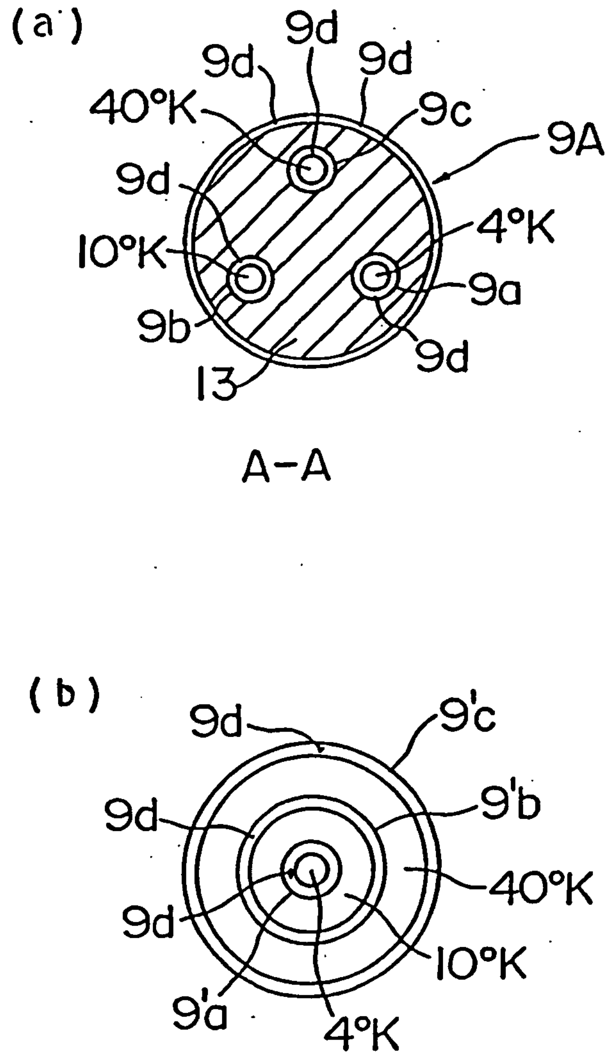


Fig. 2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9d
9d
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9c
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9d
4°K
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9a
9b
9d
13
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(b)
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9'c
9d
9'b
40°K
9d
10°K
9'a
4°K

Fig. 3

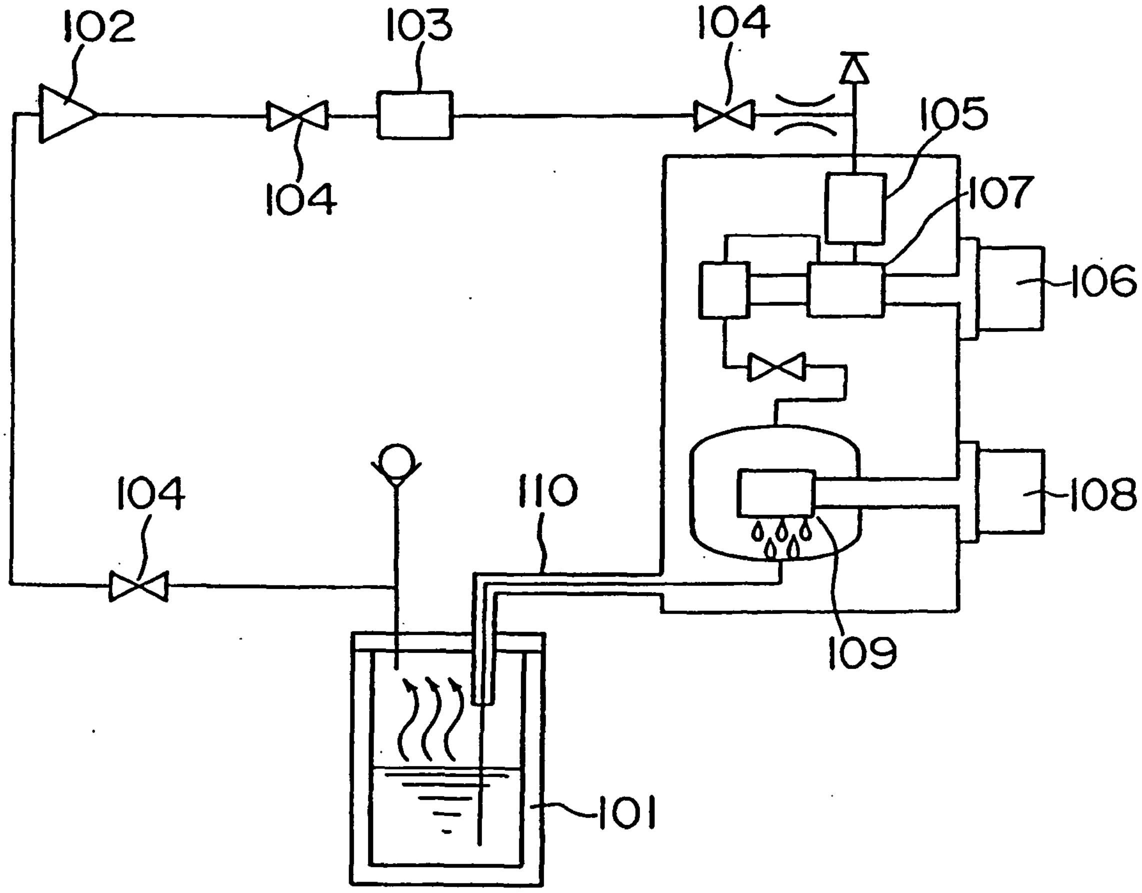

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3070960 A **[0009]**
- US 3882687 A **[0010]**