



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication: **07.03.2012 Bulletin 2012/10** (51) Int Cl.: **F25D 19/00** ^(2006.01) **F25B 9/10** ^(2006.01)

(21) Application number: **11176360.3**

(22) Date of filing: **02.08.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **03.08.2010 JP 2010174082**

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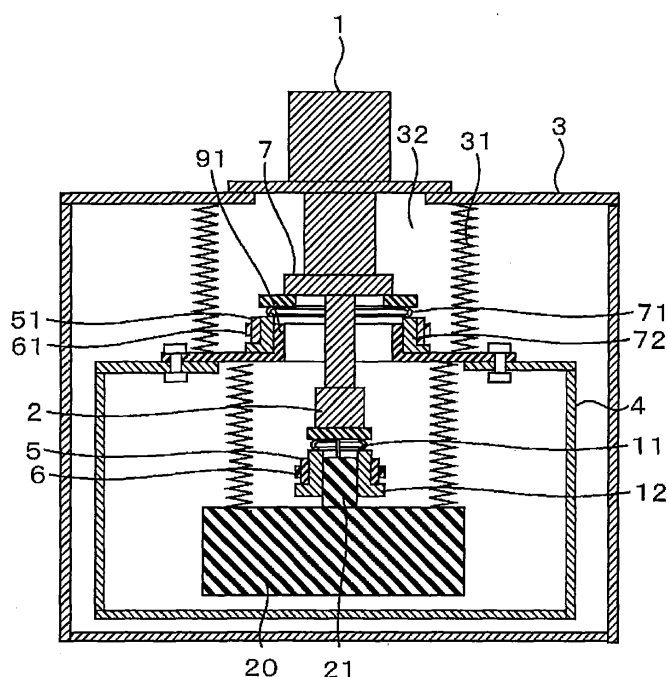
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(54) **Cryogenic refrigerator coupling structure**

(57) For providing a refrigerator coupling structure for enabling attaching/detaching and re-cooling of the refrigerator in a short time-period, by suppressing a heat movement from the refrigerator at the room temperature to an object to be cooled, which is cooled down to cryogenic temperature when attaching a cryogenic refrigerator thereon, while suppressing a volume of heat invasion

into the object to be cooled, it has a heat contact portion (12,72) having a flexible portion (11) at least in a part thereof, which is coupled with a cold stage of the cryogenic refrigerator (1), wherein on an outer peripheral portion of this heat contact portion is provided a heat contracting ring (5), which has a heat contraction rate larger than that of the heat contact portion.

FIG. 1



Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an apparatus for using a cryogenic refrigerator, and it relates to a refrigerator coupling structure for enabling attaching/detaching of a refrigerator under a condition of cooling an object to be cooled down to the cryogenic temperature, in particular, in a cryo-cooled superconducting magnet.

[0002] The cryo-cooled superconducting magnet for cooling the superconducting magnet by the cryogenic refrigerator has a remarkable characteristic that there is no necessity of liquid helium. Because of no necessity of the liquid helium, there is no need of energy consumption in a process for producing the liquid helium, and this enables an advancement of energy saving. Such cryo-cooled superconducting magnet, because it can achieve a cryogenic environment, easily, by only pushing down one (1) piece of button, but without supplying the liquid helium thereto, is expected to be applied into various technical fields, for example, a magnetic levitation train, measurement of physical properties under circumstances of strong magnetic field, magnetization and magnetic separation, etc.

[0003] The cryogenic refrigerator for achieving the cryogenic environment without using the liquid helium therein must be conducted with maintenances thereon, periodically, because of the structural problems, which will be mentioned hereinafter. Thus, it is said that, on a Gifford-McMahon (GM) type refrigerator, which is applied, in general, in the cryo-cooled superconducting magnet, the maintenances must be conducted, for example, one (1) time per a year or every 15,000 hours. This is caused due to friction accompanying the reciprocal movement of a displacer, which executes compression/expansion and heat-exchange within the cryogenic refrigerator, and the parts rubbed must be exchanged. Because of gradual deterioration of purity of helium gas, which is filled up within the cryogenic refrigerator, it is also necessary to replace the helium gas.

[0004] For executing maintenance of the cryogenic refrigerator, it is necessary to increase temperature of that cryogenic refrigerator up to the room temperature, once. The time-duration for increasing temperature can be shortened through heating by a heater; however, there is a problem that it also increases temperature the object to be cooled, which is unified with the cryogenic refrigerator in one body. Also, heat capacity of the object to be cooled, which is coupled with a cold stage of the cryogenic refrigerator, is larger than the heat capacity of the cryogenic refrigerator itself, and there is a problem that the time-duration for increasing the temperature when the cryogenic refrigerator and the object to be cooled are unified in one body. Further, since cooling must rely on only the cooling capacity of the cryogenic refrigerator, there is also other problem that, for the system having the longer time-duration for increasing temperature, the

cooling time thereof is longer.

[0005] Within the cryo-cooled superconducting magnet for cooling the object to be cooled by only the cryogenic refrigerator, because of a possibility that temperature of the object to be cooled increases when executing maintenance on the cryogenic refrigerator, and that it is not in the condition of superconducting, there is necessity of demagnetizing the magnetic field, which is generated by the superconducting magnet. Accordingly, during the maintenance, it cannot show or exhibit the function as the magnet. For achieving re-magnetization thereof as early as possible, it is necessary to bring the increase of temperature of the superconducting magnet to be small, and also to cool it, again, down to the excitable temperature thereof in a short time-period.

[0006] The cooling structure of the refrigerator, according to the conventional cryogenic refrigerator, is shown in Fig. 7. The cryogenic refrigerator 1 is attached on a vacuum container 3, wherein the object 20 to be cooled and a heat shield 4 are cooled by a second cold stage 2 and a first cold stage 7. Peripheries of the object 20 to be cooled and the heat shield 4 are in the vacuum condition, so as to suppress an amount of movement of heats from the vacuum container 3 of the room temperature.

[0007] When conducting the maintenance on the cryogenic refrigerator 1, it must be separated from, upon contacting surfaces between the second cold stage 2 of the cryogenic refrigerator 1 and the object to be cooled, and between the first cold stage 7 and the heat shield 4. For bringing the peripheries of the cryogenic refrigerator 1 into the atmospheric pressure in that instance, a vacuumwall 31 is provided surrounding the cryogenic refrigerator 1. Parts of the object 20 to be cooled and the heat shield 4 are also utilized as a part of the vacuum container 3.

[0008] The maintenance methods for dissolving such problems can be divided into two (2), roughly.

[0009] A first method is that of separating the cryogenic refrigerator from the object to be cooled, physically. In the Patent Publication 1, the cryogenic refrigerator is in contact with the object to be cooled, thermally, in the form of suppressing it on that object, wherein the cryogenic refrigerator and the object to be cooled can be separated from each other, through loosening or releasing screws of a portion of room temperature. Also, in the Patent Publication 2, by loosening or releasing the screws, coupling the cryogenic refrigerator and the object to be cooled, from the portion of room temperature, the cryogenic refrigerator can be separated from the object to be cooled. Further, in the Patent Publication 3, a spring configuration is applied to coupling portions between the cryogenic refrigerator and the object to be cooled. In any one of those methods, it is characterized that the cryogenic refrigerator and the object to be cooled are separated while maintaining the object to be cooled in the cryogenic temperature condition, as it is.

[0010] As a second method can be considered a method of increasing temperature of only the cryogenic refrigerator

erator under the condition the cryogenic refrigerator and the object to be cooled are coupled with each other. Thus, the cryogenic refrigerator and the object to be cooled are separated, thermally, with applying a so-called a thermal switch therein, and the temperature of only the cryogenic refrigerator is increased. Since the displacer and so on are exchanged within the cryogenic refrigerator after an increase of the temperature, there is no necessity of replacing the main body of the refrigerator.

[0011] In the Patent Document 2, as a heat transfer medium, helium gas is filled up between the cryogenic refrigerator and the object to be cooled, and it is used as the thermal switch. By discharging the helium gas, the thermal coupling (or, heat connection) is extinguished between the cryogenic refrigerator and the object to be cooled, and then only the temperature of the cryogenic refrigerator can be increased.

<Prior Art Documents>

<Patent Documents>

[0012]

[Patent Document 1] Japanese Patent Laying-Open No. Hei 9-287838 (1997);

[Patent Document 2] Japanese Patent Laying-Open No. 2004-294041 (2004);

[Patent Document 3] Japanese Patent Laying-Open No. Hei 1-196479 (1989); and

[Patent Document 4] Japanese Patent Laying-Open No. 2002-252111 (2002).

BRIEF SUMMARY OF THE INVENTION

[0013] Although various patents are already proposed, in relation to the maintenances of the refrigerator, however each one of them has a problem(s) to be dissolved, respectively.

[0014] In the Patent Document 1 mentioned above is disclosed that the rotation speed of the cooling fan is controlled by the inverter, however no disclosure is made in relation to the control when an inverter trip is generated.

[0015] With the technology described in the Patent Document 1, since the object to be cooled is in contact with, applying pressure on the surface thereof, it must have the structure for enduring such surface pressure thereon, i.e., increasing the cross-section area of a supporting portion, there is a problem that an amount of heats invading into the object to be cooled comes to be large. With the technology described in the Patent Document 2, it is necessary to bring the cold stage of the cryogenic refrigerator and the object to be cooled to be in contact with each other, thermally, before cooling the cryogenic refrigerator, and there is a problem that the temperature of the

object to be cooled increases due to the heat capacity of the refrigerator. With the technology described in the Patent Document 3, the refrigerator of the room temperature and the object to be cooled, which is cooled down to the cryogenic temperature, are in the form of being thermally in contact with each other, there is a problem that the temperature of the object to be cooled increases due to the heat capacity of the refrigerator. With the technology described in the Patent Document 4, because of necessity of the time-period for increasing the temperature of the cryogenic refrigerator up to the room temperature, there is a problem that a long time-period is necessary for executing the maintenance on the refrigerator.

[0016] An object, according to the present invention, is to provide a refrigerator coupling structure for enabling detaching and re-cooling of a refrigerator in a short time-period, by suppressing an increase of temperature of a superconducting magnet, and also by suppressing the movement of heats from the refrigerator of the room temperature to the object to be cooled, which is cooled down to the cryogenic temperature, when attaching the cryogenic refrigerator, for shortening the time-period necessary for the maintenance and the re-cooling, in the cryo-cooled superconducting magnet.

[0017] For accomplishing the object mentioned above is applied such structures as is described in the claims, which will be mentioned later, for example. According to the present invention, there are included plural numbers of means for dissolving the problems mentioned above, and if listing up an example thereof, for dissolving the problem(s) mentioned above, a first feature of the coupling structure for a cryogenic refrigerator, according to the present invention, lies in that it has a heat contact portion being coupled with a cold stage of the cryogenic refrigerator, and that a heat contracting ring having a heat contraction rate larger than that of the heat contact portion is provided on an outer peripheral portion of this heat contact portion. With this, the contracting ring having a large volume of heat contraction fastens an inside of the heat contact portion, and thereby obtaining preferable heat contact with the coupling portion between the heat contact portion and a cooling object.

[0018] Also, a second feature of the present invention lies in that, the heat contact portion is in contact with a flexible portion. With provision of the flexible portion, it is easy for the heat contact portion to change a position or an angle thereof, and thereby obtaining preferable heat contact between the heat contact portion and the coupling portion of the cooling object.

[0019] Also, a third feature of the present invention lies in that, the heat contact portion is divided in a peripheral direction thereof. The heat contact portion is divided, and the heat contracting ring provided on an outer periphery of the heat contact portion is cooled down, thereby to contract; thereby fastening the heat contact portion. With this, it is possible to obtain the preferable heat contact between the heat contact portion and the coupling portion of the cooling object.

[0020] Also, a fourth feature of the present invention lies in that, the heat contact portion, being in contact with the cold stage of the cryogenic refrigerator, thermally, produces a clearance between the heat contact portion and the cooling target, when the cold stage of the cryogenic refrigerator is at the room temperature. No heat contact is established between the cryogenic refrigerator at the room temperature and the cooling object under the condition of cryogenic temperature, and this prevents a heat capacity of the cryogenic refrigerator at the room temperature from moving into the cooling object under the condition of cryogenic temperature.

[0021] Also, a fifth feature of the present invention lies in that, the heat contact portion and the heat contracting ring, being thermally coupled with the cold stage of the cryogenic refrigerator, are cooled down, by starting the cryogenic refrigerator after maintenance; thereby, the heat contracting ring 5 shrinks due to the thermal contraction, and then the coupling portion and the coupling portion of the cooling object are automatically in contact with each other, thermally. With this, under the condition that the temperature of the cold stage of the cryogenic refrigerator is high, the heat contact portion, being thermally coupled with the cold stage of the cryogenic refrigerator, and the coupling portion of the cooling object are in the non-contact condition; thereby, it is possible to suppress a heat invasion from the cold stage having high temperature into the coupling portion of the cooling object, and also to suppress an increase of temperature of the cooling object down to the lowest limit. Accompanying with lowering of temperature of the cold stage of the cryogenic refrigerator, the heat contracting ring, being coupled with the heat contact portion, thermally contracts, gradually, and therefore the heat contact portion and the coupling portion of the cooling object are automatically in contact with each other, thermally.

[0022] With provision of the coupling structure of the cryogenic refrigerator according to the present invention, the movement of heats from the cryogenic refrigerator, being in the condition of the room temperature when maintenance is carried out thereon, to the cooling object, and the temperature of the cooling object is kept at the cryogenic temperature.

[0023] In the process of cooling the cryogenic refrigerator, the heat transfer means, being in contact with the cryogenic refrigerator, thermally, due to heat contraction of the heat contracting ring, and the cooling object automatically come into contact with each other, thermally. With such thermal contact between the heat transfer means and the cooling object under the condition where the heat transfer means is cooled by the cryogenic refrigerator, it is possible to suppress an increase of temperature of the cooling object down to the lowest limit.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0024] Those and other objects, features and advan-

tages of the present invention will become more readily apparent from the following detailed description when taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a cross-section view of a coupling portion of a cryogenic refrigerator, for showing a first embodiment of the present invention;

Fig. 2 is a detailed cross-section view of the coupling structure of the cryogenic refrigerator on a second cold stage, according to the first embodiment;

Figs. 3A and 3B are cross-section views when seeing the coupling structure of the cryogenic refrigerator, according to the first embodiment;

Fig. 4 is a detailed cross-section view of the coupling structure of the cryogenic refrigerator on the second cold stage, according to a second embodiment of the present invention;

Fig. 5 is a detailed cross-section view of the coupling structure of the cryogenic refrigerator on a first cold stage, according to a third embodiment of the present invention;

Fig. 6 is a detailed cross-section view of the coupling structure of the cryogenic refrigerator on the first cold stage, according to a fourth embodiment of the present invention;

Fig. 7 is a cross-section view for showing the conventional coupling structure of the refrigerator; and

Fig. 8 is a view for showing an example of a thermal contraction rate of main constituent materials (edited by Hiroyasu HAGIWARA, "An Outline of Low Temperature Engineering", Tokyo Denki University Publishing Office, published July, 1999, P292).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Hereinafter, embodiments according to the present invention will be fully explained by referring to the attached drawings.

<Embodiment 1>

[0026] Fig. 1 is a cross-section view of a coupling portion of cryogenic refrigerator, for showing a first embodiment of the present invention.

[0027] A cryogenic refrigerator 1 is attached on a vacuum container 3, and has such a structure that an object 20 to be cooled (hereinafter, "a cooling object 20") and a heat shield 4 are cooled by a second cold stage 2 and a first cold stage 7. Peripheries of the cooling object 20

and the heat shield 4 are brought in the vacuum condition, so as to suppress an amount of heats transferring from the vacuum container 3, which has the room temperature, to be small. When maintaining the cryogenic refrigerator 1, it is necessary to separate the second cold stage 2 of the cryogenic refrigerator 1 and the cooling object 20, from the contact surface thereof, and the first cold stage 7 and the heat shield 4 from the contact surface thereof, respectively. In that instance, since the periphery of the cryogenic refrigerator 1 is changed from the vacuum condition to the atmospheric pressure, a vacuum wall 31 is provided surrounding the cryogenic refrigerator 1. Parts of the cooling object 20 and the heat shield 4 are also utilized as a part of the vacuum container 3.

[0028] The cryogenic refrigerator 1 is, for example, the GM type refrigerator, and has the first cold stage 7 and the second cold stage 2 for generating cold. The first cold stage 7 is cooled down between 30K and 80K. Also, the second cold stage 2 is cooled down to 30K, or lower than that.

[0029] The cooling object, which is cooled on the first cold stage 7 of the cryogenic refrigerator 1 is mainly the heat shield 4. This heat shield 4 receives radiation from the vacuum container 3 at the room temperature. For reducing an amount of radiation received by the heat shield 4, a heat insulating material, such as, so-called a laminated heat insulating material, not shown in the figure, is provided between the heat shield 4 and the vacuum container 3. The heat shield 4 is utilized, for example, as a thermal anchor for a current reed, not shown in the figure, and is also applied for suppressing the heat transfer to be small, transferring from the current reed to the cooling object.

[0030] On the second cold stage 2 of the cryogenic refrigerator 1, cooling is made on the cooling object 20, which operates under the cryogenic temperature environment. The cooling object 20 is, for example, a superconducting magnet or equipment applying SQID therein. This can be also applied other equipments utilizing the cryogenic temperature environment.

[0031] The cooling object 20, which is cooled on the second cold stage of the cryogenic refrigerator 1, has a coupling portion 21, and cools the cooling object 20 down to the cryogenic temperature through cooling the coupling portion 21 on the second cold stage 2 of the cryogenic refrigerator 1.

[0032] The heat shield 4, which is cooled on the first cold stage 7 of the cryogenic refrigerator 1, has a coupling portion 72, and is able to cool the heat shield 4 down to the cryogenic temperature through cooling the coupling portion 72 on the first cold stage 7 of the cryogenic refrigerator 1.

[0033] The cryogenic refrigerator 1 is fixed on the vacuum container 3. The vacuum container 3 is able to bring an inside thereof into a vacuum condition, i.e., an air inside is discharged to vacuum by a vacuum pump not shown in the figure. The surrounding of the cryogenic refrigerator 1 defines an enclosed space 32, different

from a vacuum tank surrounding the cooling object 20, by a vacuum wall 31 functioning as a partition. When removing, the cryogenic refrigerator 1 is removed while bringing the enclosed space 32 into the atmospheric pressure. In this instance, the enclosed space 32 is filled up with the helium gas, and thereby preventing it from condensation/forming dew within the cryogenic temperature portion.

[0034] On the second cold stage 2 are coupled, thermally, at least a flexible portion 11 at one (1) place and a thermal or heat contact portion 12 with the cooling object. In the similar manner, on the first cold stage are coupled, thermally, at least a flexible portion 71 at one (1) place and a coupling portion 72, being the heat contact portion with the cooling object. The flexible portions 11 and 71 are made from a material having high thermal conductivity, such as, oxygen free copper or high purity aluminum, etc., for example. The flexible portions 11 and 71 are made up, by combining or bundling stranded wires of oxygen free copper or high purity aluminum, for example, and has high thermal conductivity, as well as, high flexibility.

[0035] The heat contact portion 12 and the heat contact portion 72 are manufactured from copper or aluminum, having high thermal conductivity. The heat contact portion 12 and the flexible portion 72 are coupled with, thermally. In the similar manner, the heat contact portion 72 and the flexible portion 71 are coupled with, thermally.

[0036] On outer periphery of the heat contact portion 12 is provided a heat contracting ring 5. Also, on outer periphery of the heat contact portion 72 is provided a heat contracting ring 51. Both the heat contracting rings 5 and the heat contact portion 72 are manufacture from fluoro-resin, such as, Teflon (®), etc., or a high molecular compound (a high-polymer), such as, nylon (®), etc., for example. And, on the heat contracting rings 5 and 51 are provided heaters 6 and 61, respectively, neighboring therewith. By means of the heat contracting ring 51, the heat contact portion 72 and a coupling portion 91 are fasten tightly.

[0037] By referring to Fig. 2, explanation will be made on the function of each element when attaching the refrigerator, about the second cold stage of the cryogenic refrigerator 1. Fig. 2 is a detailed cross-section view of the coupling structure of the cryogenic refrigerator on the second cold stage, according to the first embodiment.

[0038] The second cold stage 2 is thermally coupled with the heat contact portion 12, through at least a part of the flexible portion 11. The heat contact portion 12 has the structure of being divided in the peripheral direction thereof, and each of the heat contact portions divided has the structure of being movable in a radial direction thereof. On outer periphery of the heat contact portion 12 are provided the heat contracting ring 5 and the heater 6. The heat contact portion 12 and the heat contracting ring 5 are so shaped that they are coupled with, thermally, at least in a part of the heat contact portions, which are divided in the peripheral direction.

[0039] Such designing is made that a certain clearance can be produced between the heat contact portion 12, which is thermally coupled with the second cold stage 2 through the flexible portion 11, and the coupling portion 21, when the heat contact portion 12 is in the condition of the room temperature. Accordingly, under the condition that the cryogenic refrigerator 1 at the room temperature is attached thereon, the heat contact portion 12 on the second cold stage and the coupling portion 21 are in the condition of non-contact with, and therefore no movement of heats is generated directing from the cold stage 2 at the room temperature to the coupling portion 21.

[0040] After attaching the cryogenic refrigerator 1 thereon, if lowering the temperature of the second cold stage 2, gradually, by operating the cryogenic refrigerator 1, the temperature of the heat contact portion 12, which is thermally coupled with the second cold stage 2, is also lowered down, gradually. And also, the temperature of the heat contracting ring 5, which is attached on the outer periphery of the heat contact portion 12, is lowered down.

[0041] The heat contracting ring 5 is larger in the thermal contraction rate than the heat contact portion 12 of the second cold stage, in particular, when it is cooled down to the cryogenic temperature. Fig. 8 is a view for showing a relationship between volumes of thermal contraction rates of main constituent materials (extraction from "An Outline of Low Temperature Engineering" edited by Hiroyasu HAGIWARA, Tokyo Denki University Publishing Office, published July, 1999, P292).

[0042] For example, in case where the heat contact portion is made of copper, it contracts by 0.3% under the condition of being cooled down to about 50K, comparing to that when it is at the room temperature; but on the contrary, where the heat contracting ring 5 or 51 is made of nylon, it contracts by 1.4% under the condition of being cooled down to 50K, comparing to that at the room temperature, and where it is made of Teflon (®), it contracts by 2.0% under the condition of being cooled down to 50K, comparing to that at the room temperature.

[0043] Although the heat contact portion 12 thermally contracts accompanying with lowering down of the temperature thereof, but since the volume of the heat contraction of the heat contracting ring 5 is larger than that of the heat contact portion 12, the heat contracting ring 5 fastens the heat contact portion 12 tight, gradually. Accompanying with this heat contact, the movement of heats is produced, directing from the cryogenic refrigerator 1 to the cooling object 20, if the temperature of the cryogenic refrigerator 1 is high; however, since the cryogenic refrigerator 1 is in contact with, thermally, under the condition of being fully cooled down, the volume of the heat movement is small, and it is possible to suppress an increase of temperature of the cooling object 20 to be small.

[0044] Next, by referring to Figs. 1 and 2, explanation will be given on a process for removing or detaching the refrigerator.

[0045] For separating the coupling portion 21 under

the cryogenic temperature condition from the second cold stage 2 of the cryogenic refrigerator 1, the heater 6 attached on the outer periphery of the heat contracting ring 5 is heated up. Because of an increase of temperature of the heat contracting ring 5, the volume of heat contraction of the heat contracting ring 5 comes to be small, and therefore a clearance is generated between the heat contact portion 12 and the coupling portion 21, which are fastened tight by the heat contracting ring 5. In the similar manner, for separating the coupling portion 91 under the cryogenic temperature condition from the first cold stage 7 of the cryogenic refrigerator 1, the heater 61 attached on the outer periphery of the heat contracting ring 51 is heated up. Because of an increase of temperature of the heat contracting ring 51, the volume of heat contraction of the heat contracting ring 51 comes to be small, and therefore a clearance is generated between the heat contact portion 72 and the coupling portion 91, which are fastened tight by the heat contracting ring 51.

[0046] At the time-point when the clearances are generated on both the first cold stage 7 and the second cold stage 2 of the cryogenic refrigerator 1, the cryogenic refrigerator 1 can be removed from.

[0047] Figs. 3A and 3B are cross-section views when seeing a heat transfer means on the second cold stage 2, i.e., the heat contact portion 12 and the heat contracting ring 5, from the above. The heat contact portion 12 is divided in the peripheral direction thereof. The heat contact portion 12 is in contact with the coupling portion 21 locating at a center thereof. On the outer periphery of the heat contact portion 12 are provided the heat contracting ring 5 and the heater 6.

[0048] Fig. 3A shows the positional relationship between the heat contact portion 12 and the coupling portion 21 of the cooling object before cooling the cold stages of the cryogenic refrigerator, i.e., under the condition of the room temperature. Under the condition of the room temperature, there is the clearance between the heat contact portion 12 and the coupling portion 21, and therefore no movement of heats is produced from the heat contact portion 12 at the room temperature to the coupling portion 21 under the condition of cryogenic temperature. Due to this, it is possible to suppress an increase of temperature of the cooling object when coupling the refrigerator.

[0049] Fig. 3B shows the positional relationship between the heat contact portion 12 and the coupling portion 21 after cooling the cold stages of the cryogenic refrigerator. By means of the second cold stage 2 of the cryogenic refrigerator, the heat contact portion 12, the heat contracting ring 5 and the heater 6 are cooled down to the cryogenic temperature. The heat contracting ring 5 contracts, thermally, due to the fact of being cooled down to the cryogenic temperature. The heat contracting ring 5 shortens a peripheral length through the thermal contraction thereof, and it shrinks in the radial direction. For example, in case of a ring made of Teflon (®) having an inner diameter of 50 mm, the peripheral length is short-

en by 2% through the thermal contraction down to 50K. This means that the diameter come to be small, 4.9 mm. Because of shrinkage of the heat contracting ring 5 on the diameter thereof, the heat contracting ring 5 is in the form of fastening the heat contact portion 12, and thereby the heat contact portion 12 and the coupling portion 21 are in contact with each other, thermally.

<Embodiment 2>

[0050] Fig. 4 is the detailed cross-section view of the coupling structure of the cryogenic refrigerator on the second cold stage, according to a second embodiment of the present invention. Explanation will be given only on a part(s) differing from the first embodiment mentioned above.

[0051] A heat transfer means 122 has such structure that it supports the heat contracting ring 5 on both surfaces, e.g., from an inner side and an outer side thereof. A sticking or closely contacting condition is established between the heat transfer means 122 and the heat contracting ring 5, and when the temperature of the second cold stage 2 of the cryogenic refrigerator 1 increases, there can be produced an effect that the outer periphery of the heat contracting ring 5 separates the heat contact portion.

<Embodiment 3>

[0052] Fig. 5 is the detailed cross-section view of the coupling structure of the cryogenic refrigerator on the first cold stage, according to a third embodiment of the present invention. By referring to Fig. 5, explanation will be given on the coupling structure of the cryogenic refrigerator on the first cold stage 7 of the cryogenic refrigerator 1.

[0053] The first cold stage 7 is coupled with, thermally, at least the heat contact portion 72 through a part of the flexible portion 71. The heat contact portion 72 has the structure of being divided in the peripheral direction thereof, and each of the heat contact portions divided has the structure of being movable in a radial direction. On the outer periphery are provided the heat contracting ring 51 and the heater 61. The heat contact portion 72 and the heat contracting portion 51 are in such form that they are coupled with, thermally, at least a part of the heat contact portions, which are divided in the peripheral direction.

[0054] Such designing is made that a certain clearance can be produced between the heat contact portion 72, which is thermally coupled with the first cold stage 7 through the flexible part 71, and the coupling portion 91, when the heat contact portion 72 is in the condition of the room temperature. Accordingly, under the condition that the cryogenic refrigerator 1 at the room temperature is attached thereon, the heat contact portion 72 on the first cold stage and the coupling portion 91 are in the condition of non-contact with, and therefore no move-

ment of heats is generated directing from the cryogenic refrigerator 1 at the room temperature to the coupling portion 91.

[0055] After attaching the cryogenic refrigerator 1 thereon, if lowering the temperature of the first cold stage 7, gradually, by operating the cryogenic refrigerator 1, the temperature of the heat contact portion 72, which is thermally coupled with the first cold stage 2, is also lowered down, gradually. And also, the temperature of the heat contracting ring 51, which is attached on the outer periphery of the heat contact portion 72, is lowered down.

[0056] The heat contracting ring 51 is larger in the thermal contraction rate than the heat contact portion 72 of the first cold stage, in particular, when it is cooled down to the cryogenic temperature. Although the heat contact portion 72 thermally contracts accompanying with lowering down of the temperature thereof, but since the volume of the heat contraction of the heat contracting ring 51 is larger than that of the heat contact portion 72, the heat contracting ring 51 fastens the heat contact portion 72 tight, gradually. Accompanying with this heat contact, the movement of heats is produced, directing from the cryogenic refrigerator 1 to the heat shield 4, if the temperature of the cryogenic refrigerator 1 is high; however, since the cryogenic refrigerator 1 is in contact with, thermally, under the condition of being fully cooled down, the volume of the heat movement is small, and it is possible to suppress an increase of temperature of the heat shield to be small.

[0057] Next, similarly, by referring to Fig. 5, explanation will be given on a process for removing or detaching the refrigerator.

[0058] For separating the coupling portion 71 under the cryogenic temperature condition from the first cold stage 7 of the cryogenic refrigerator 1, the heater 61 attached on the outer periphery of the heat contracting ring 51 is heated up. Because of an increase of temperature of the heat contracting ring 51, the volume of heat contraction of the heat contracting ring 51 comes to be small, and therefore a clearance is generated between the heat contact portion 72 and the coupling portion 91, which are fastened tight by the heat contracting ring 51. In the similar manner, for separating the coupling portion 91 under the cryogenic temperature condition from the first cold stage 7 of the cryogenic refrigerator 1, the heater 61 attached on the outer periphery of the heat contracting ring 51 is heated up. Because of an increase of temperature of the heat contracting ring 51, the volume of heat contraction of the heat contracting ring 51 comes to be small, and therefore a clearance is generated between the heat contact portion 72 and the coupling portion 91, which are fastened tight by the heat contracting ring 51. At the time-point when the clearances are generated on both the first cold stage and the second cold stage of the cryogenic refrigerator, the cryogenic refrigerator 1 can be removed from.

<Embodiment 4>

[0059] Fig. 6 is the detailed cross-section view of the coupling structure of the cryogenic refrigerator on the first cold stage 7, according to a fourth embodiment of the present invention.

[0060] A heat transfer means 78 has such structure that it supports the heat contracting ring 51 on both surfaces, e.g., from an inner side and an outer side thereof. A sticking or closely adhering condition can be established between the heat transfer means 78 and the heat contracting ring 51, and when the temperature of the first cold stage 7 of the cryogenic refrigerator 1 increases, there can be produced an effect that the outer periphery of the heat contracting ring 51 separates the heat contact portion 78.

[0061] However, the present invention should not be restricted to the embodiments mentioned above, but may include various modifications. For example, the embodiments mentioned above are explained in details thereof for the purpose of easy understanding of the present invention, but should not be limited, necessarily, to that having all the constituent elements explained in the above. Also, it is possible to replace a part (s) of the constituent elements of a certain embodiment by the constituent elements of other embodiment, or to add the constituent elements of other embodiment to the constituent elements of a certain embodiment. And, it is also possible to add/delete/replace other constituent element (s), with respect to a part of the constituent elements of each embodiment.

[0062] Also, with each structure, function, processing portion, processing means, etc., which are mentioned above, a part or all of those may be achieved by, for example, hardware, through designing an integrated circuit, or so on. Or, each structure or function mentioned above may be achieved by software, through interpreting a program for achieving the respective functions by a processor, for example. Information of the program, a table (s) or a file (s), etc., for achieving each function, may be disposed in a recording device, such as, a memory, a hard disk, or a SSD (Solid State Drive), or on a recording medium, such as, an IC card, a SD card, a DVD, etc.

[0063] The present invention may be embodied in other specific forms without departing from the spirit or essential feature or characteristics thereof. The present embodiment(s) is/are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the forgoing description and range of equivalency of the claims are therefore to be embraced therein.

Claims

1. A coupling structure for a cryogenic refrigerator (1) in a cryogenic storage container, comprising:

a vacuum container (3), which stores a cooling object (20) in an inside thereof;
a heat shield (4), which is provided between said cooling object (20) and said vacuum container (3);
a cold stage, which is configured to cool said cooling object (20) and said heat shield (4) down to cryogenic temperature; and
a cryogenic refrigerator (1), which is coupled with said vacuum container (3) through a coupling structure, further having in said coupling structure:

a heat contact portion, which is coupled with said cold stage; and
a heat contracting ring, which is provided on an outer peripheral portion of said heat contact portion and also has a thermal contraction rate larger than that of said heat contact portion.

2. The coupling structure in the cryogenic storage container, as described in the claim 1, wherein said cold stage has a first cold stage (7) and a second cold stage (2), and further having:

a coupling portion between said heat shield (4) and the first cold stage (7) of said cryogenic refrigerator (1), and a coupling portion between said cooling object (20) and the second cold stage (2) of said cryogenic refrigerator (1), and further having, in said two (2) coupling portions; and
heat contact portions (12, 72) coupled with the first cold stage (7) of said cryogenic refrigerator (1) and the second cold stage (2) of said cryogenic refrigerator (1), respectively, wherein the heat contracting ring (5, 51) having the thermal contraction rate larger than that of said heat contact portion is provided on the outer peripheral portion of said heat contact portion (12, 72).

3. The coupling structure in the cryogenic storage container, as described in the claim 1 or 2, wherein said heat contact portion has a flexible portion (11, 71) at least a part thereof.
4. The coupling structure in the cryogenic storage container, as described in any of claims 1 to 3, wherein said heat contact portion is divided in peripheral direction thereof.
5. The coupling structure in the cryogenic storage container, as described in any one of claims 1 to 4, wherein
a clearance is produced between the first cold stage (7) of said cryogenic refrigerator (1) and said heat shield (4) when the cryogenic refrigerator (1) is at

room temperature, and the heat contracting ring (51) contracts, thermally, in a process where the first cold stage (7) of the cryogenic refrigerator (1) reaches to a condition of the cryogenic temperature, whereby the heat contact portion (72) and the heat shield (4) are in thermal contact with each other, automatically. 5

6. The coupling structure in the cryogenic storage container, as described in any one of claims 1 to 5, wherein 10
a clearance is produced between the second cold stage (2) of said cryogenic refrigerator (1) and said cooling object (20) when the cryogenic refrigerator (1) is at room temperature, and the heat contracting ring (5) contracts, thermally, in a process where the 15
second cold stage (2) of the cryogenic refrigerator (1) reaches to a condition of the cryogenic temperature, whereby the heat contact portion (12) and the cooling object (20) are in thermal contact with each other, automatically. 20

7. A cryogenic storage container having the coupling structure of the cryogenic storage container, as described in any one of claims 1 to 6. 25

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FIG. 1

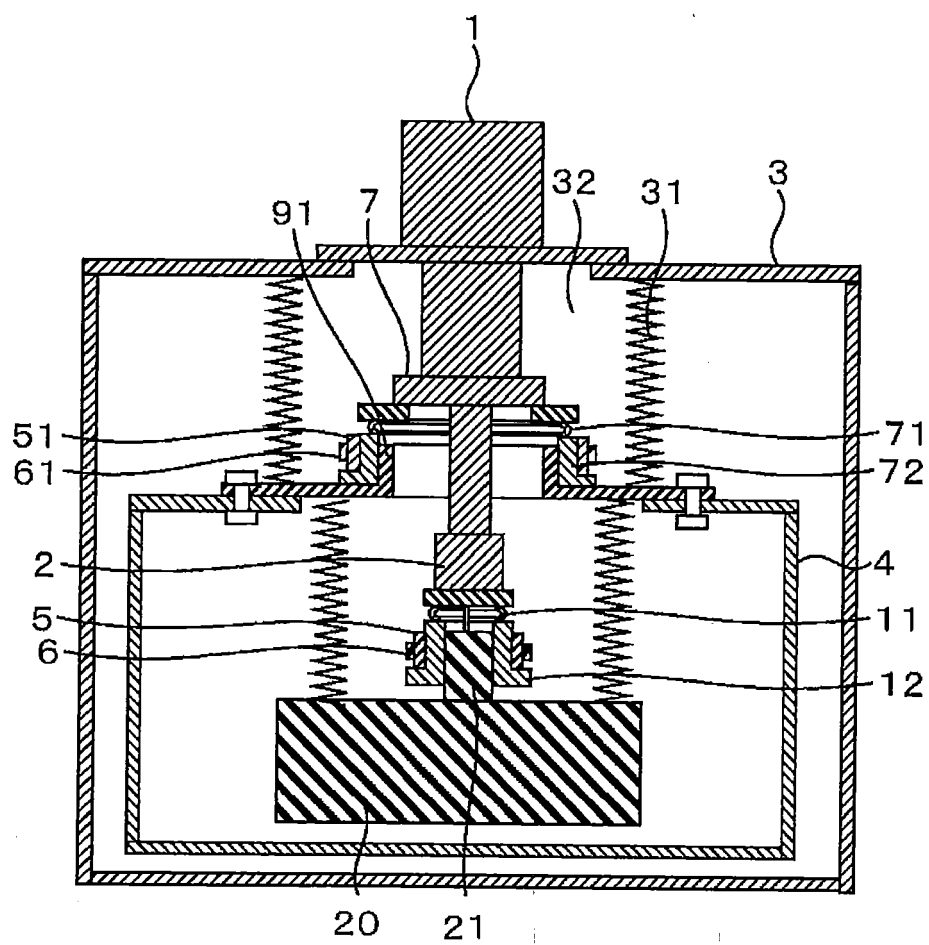


FIG. 2

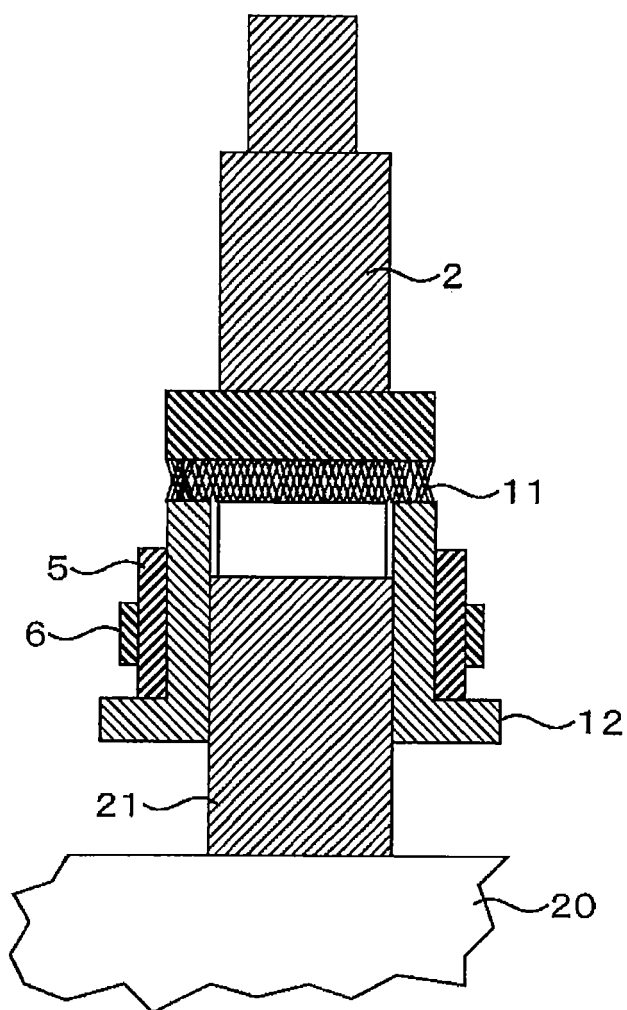
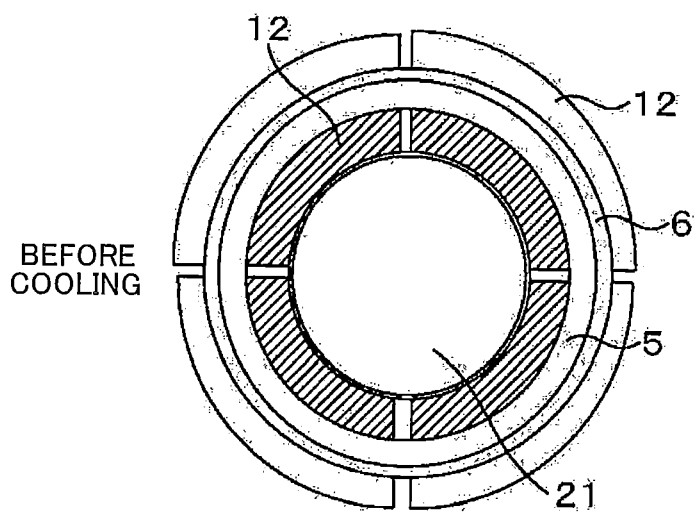


FIG. 3A



COOLING

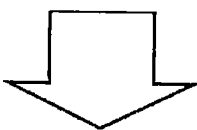


FIG. 3B

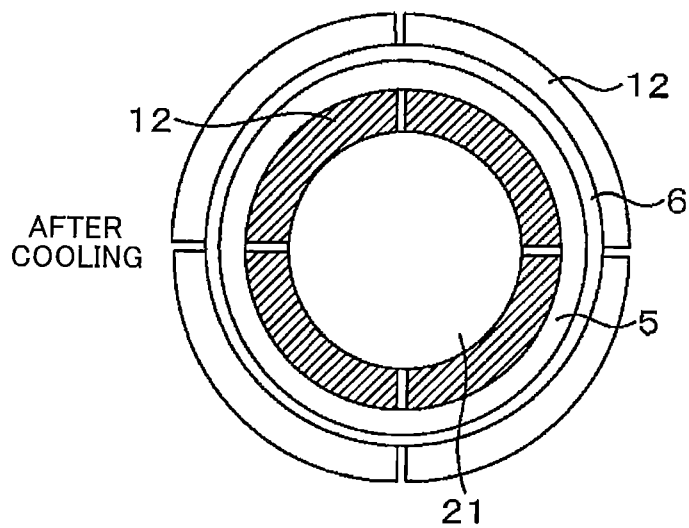


FIG. 4

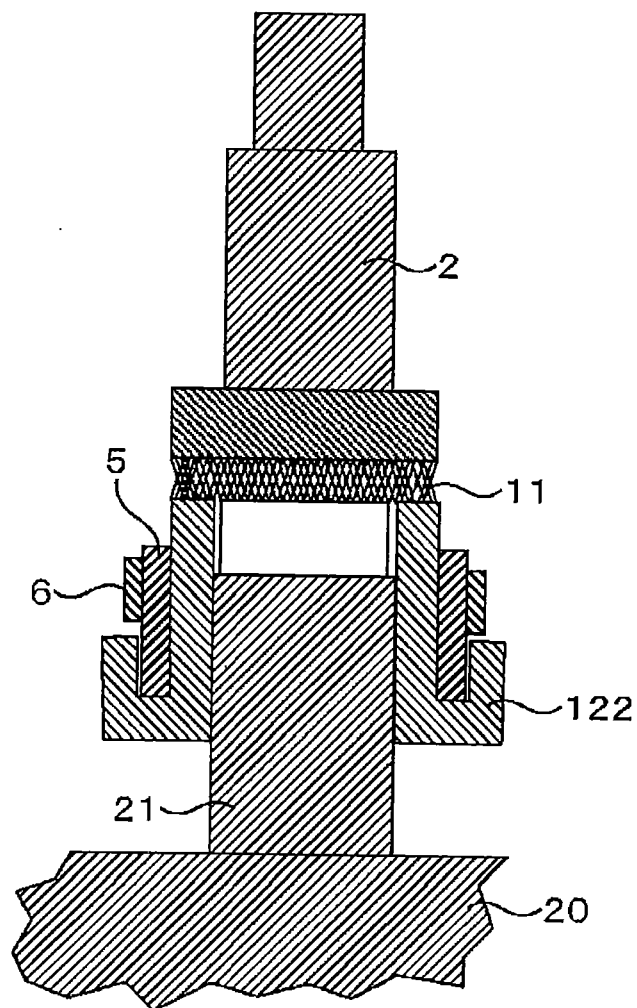


FIG. 5

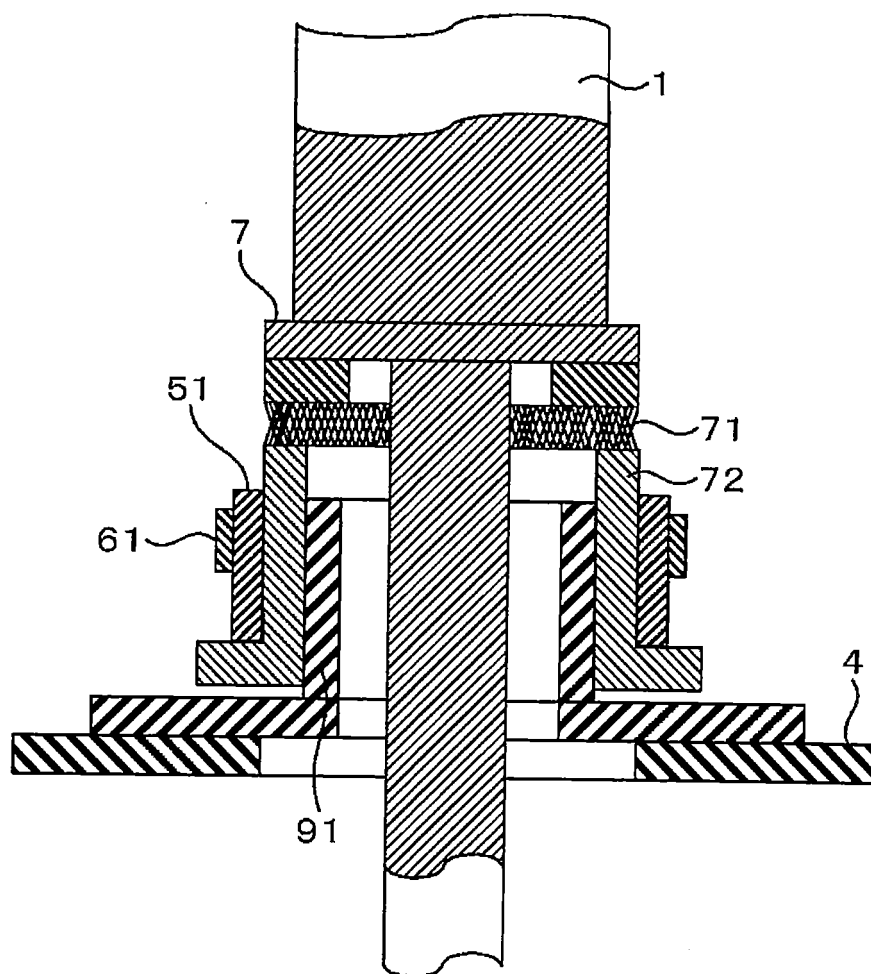


FIG. 6

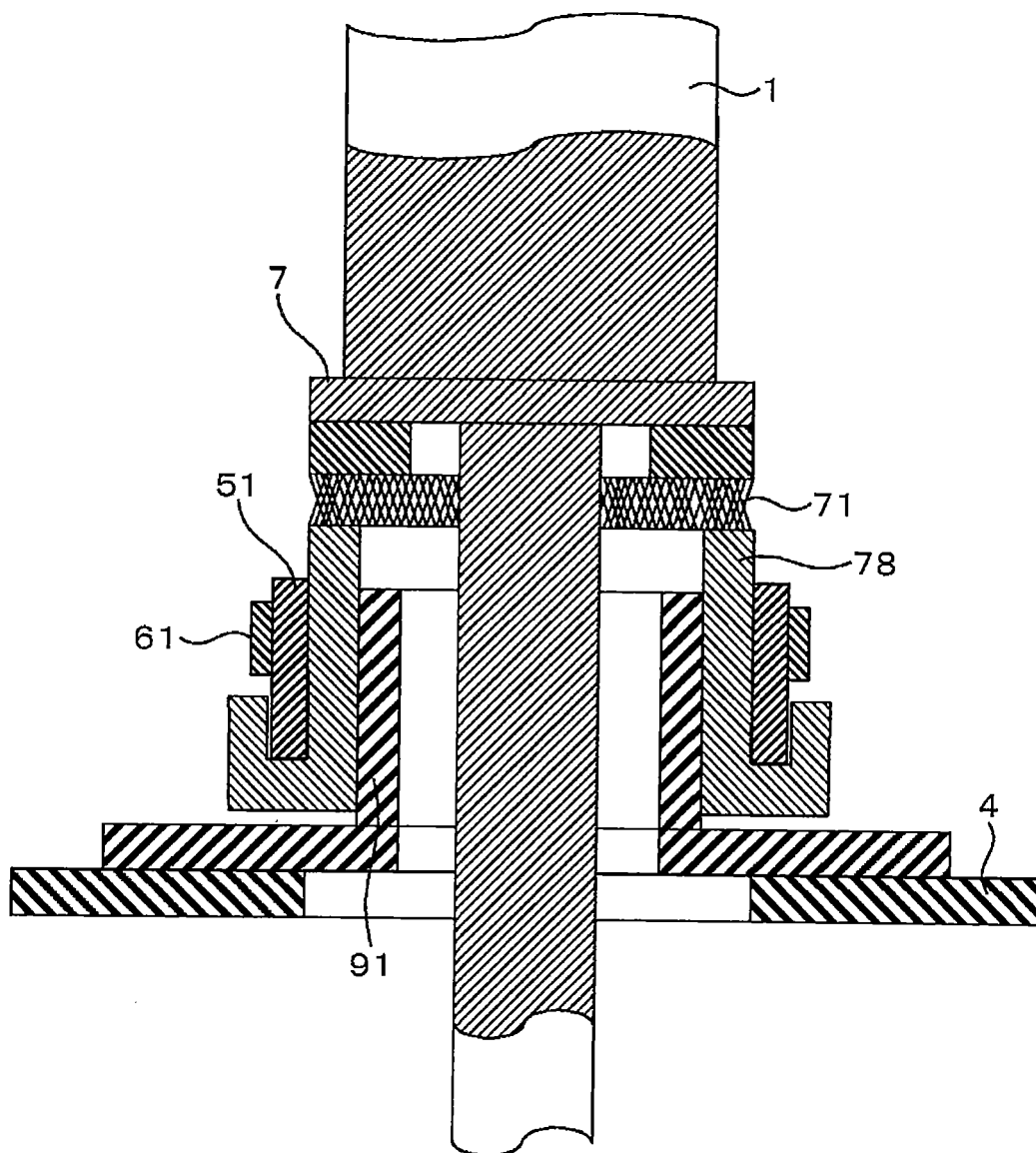


FIG. 7
PRIOR ART

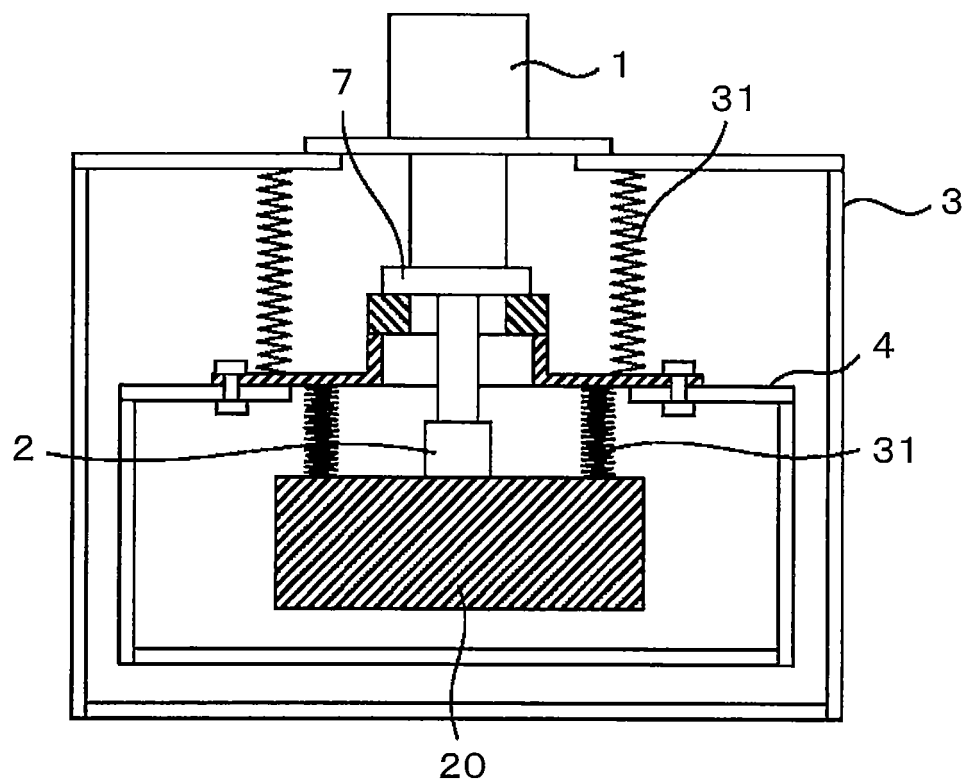
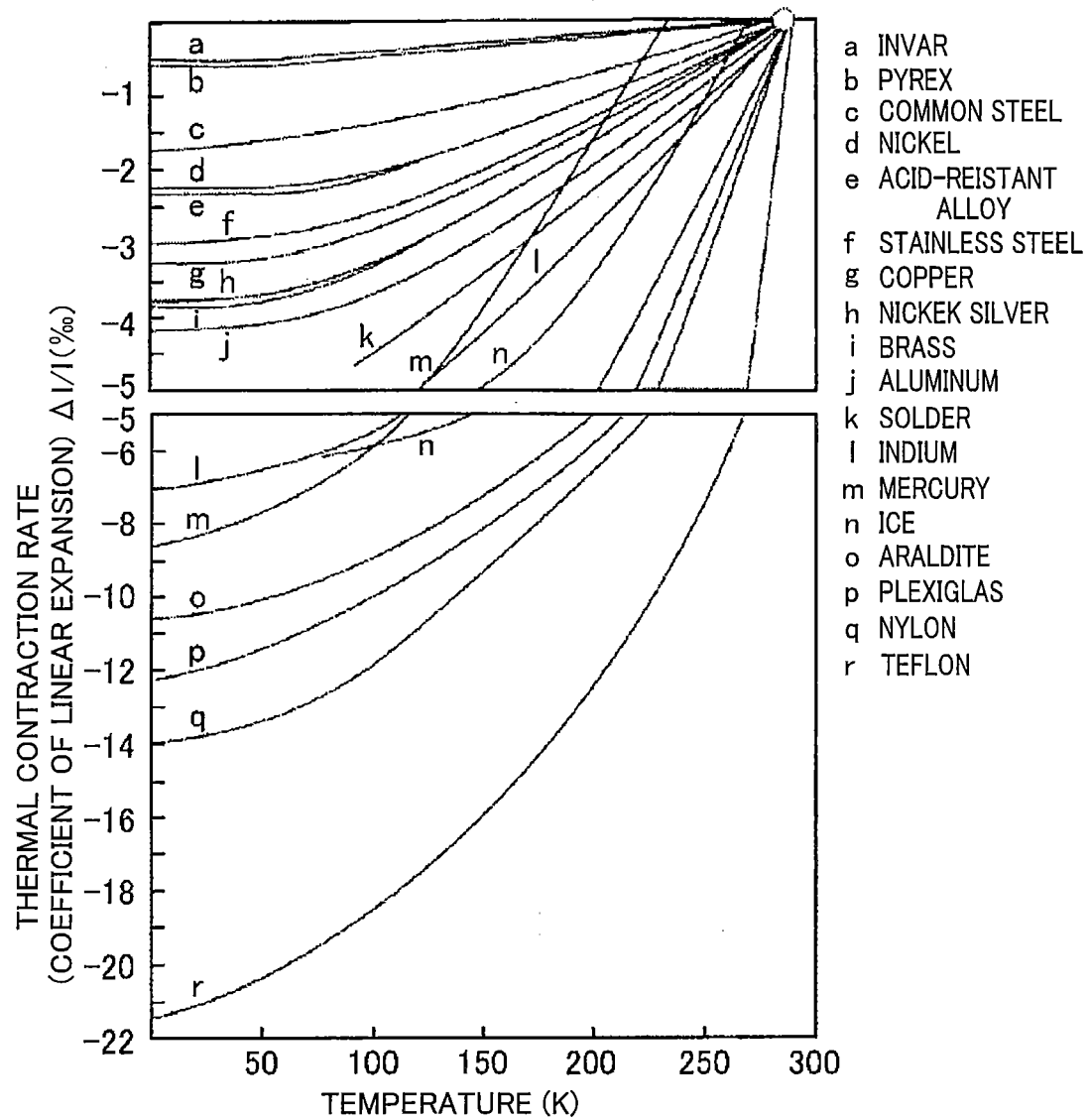


FIG. 8
PRIOR ART



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP HEI9287838 B [0012]
- JP 2004294041 A [0012]
- JP HEI1196479 B [0012]
- JP 2002252111 A [0012]

Non-patent literature cited in the description

- An Outline of Low Temperature Engineering. Tokyo
DenkiUniversity Publishing Office, July 1999, 292
[0024]
- An Outline of Low Temperature Engineering. Tokyo
Denki University Publishing Office, July 1999, 292
[0041]