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(54) **Method for cooling an article using a cryocooler and a cryocooler**

Verfahren zum Kühlen eines Artikels mittels eines Kryokühlers und Kryokühler

Méthode de réfrigération d' un article au moyen d' un cryoréfrigérateur et cryoréfrigérateur

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- **PATENT ABSTRACTS OF JAPAN vol. 014, no. 177 (M-0960), 9 April 1990 (1990-04-09) -& JP 02 029556 A (FUJI ELECTRIC CO LTD), 31 January 1990 (1990-01-31)**

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EP 1 503 155 B1

Description

Field of the Invention

[0001] This invention relates to a method for cooling an article using a cryocooler and the cryocooler.

Description of the related art

[0002] In a superconducting filter of IT communication field, a superconducting MRI of medical field, or in fundamental scientific field, it is required to cool a high precise electron microscope or a high performance precise instrument such as a high sensitivity submillimeter wave detector or an infrared ray detector to eliminate thermal disturbances therefrom. In cooling such a high performance precise instrument as mentioned above, as of now, a liquefied gas or a cryocooler is employed. Recently, the cooling temperature range of the cryocooler is improved down to 4K, which can be easily operated by pushing a button and in the past, can be realized only by using an extremely low temperature cryogen.

[0003] Fig. 1 is a structural view schematically illustrating a conventional GM (Gifford McMahon) type cryocooler. The cryocooler 10 illustrated in Fig. 1 includes a compressor 11 and a cryocooler cold head 12. In the cryocooler cold head 12 are provided a regenerator 13 and a displacer 14, and at the bottom in the cryocooler cold head 12 is provided a cold end 16. The combination of the regenerator 13 and the displacer 14 is called as a cooling cylinder. A high pressure gas and a low pressure gas are supplied to the cryocooler cold head 12 from the compressor 11 through the flexible hoses 15 and via the switching valve 17, compressed and expanded at the cryocooler cold head 12.

[0004] At the displacer 14, cooling power is created through the expansion of the gas to be synchronized with the expansion of the gas at the next stage by operating the motor 18. The coolant is repeatedly created through a plurality of expansions of the gas, and the thus obtained cooling power is are stored in the regenerator 13. As a result, the cold end 16 is cooled down to an extremely low temperature. An article is contacted with the cold end 16 to be cooled.

[0005] Fig. 2 is a structural view schematically illustrating a pulse tube type cryocooler. The cryocooler illustrated in Fig. 2 includes a compressor 21 and a cryocooler cold head 22. In the cryocooler cold head 22 are provided a regenerator 23 and a pulse tube 24, and at the bottom in the cryocooler cold head 22 is provided a cold end 26. The combination of the regenerator 23 and the pulse tube 24 is called as a cooling cylinder. A high pressure gas and a low pressure gas are supplied to the cryocooler cold head 22 from the compressor 21 through the flexible hoses 25 and via the switching valve 27, compressed and expanded at the cryocooler cold head 22.

[0006] At the pulse tube 24, cooling power is created through the expansion of the gas to be synchronized with the expansion of the gas at the next stage by operating the switching valve. The gas expansion is carried out by controlling the introduction timing of the gas into a buffer tank 28, which is successive to the pulse tube 24, via an orifice 29. The cooling power is repeatedly created through a plurality of expansions of the gas, and the thus obtained cooling power is stored in the regenerator 23. As a result, the cold end 26 is cooled down to an extremely low temperature. An article is contacted with the cold end 26 to be cooled.

[0007] In both of the GM type cryocooler and the pulse tube type cryocooler, since the high pressure gas and the low pressure gas, which are supplied from the compressors 11 and 21, are circulated in the cryocooler cold heads 12 and 22, the cold ends 16 and 26 are vibrated inevitably by an amplitude of about 10 μm in the axial directions thereof. The allowable limit in vibration of the high performance precise instrument is within a range of submicro-meter, so that if a relatively large vibration is applied to the precise instrument, the inner structure and the controllability of the precise instrument may be destroyed, so that the precise instrument may malfunction.

[0008] US 2002/0134089 relates to a refrigerator, in particular for glass door merchandiser or other types of vending machines. Cooling of the refrigerator space is performed by four Stirling units each having a cold end. The Stirling units are arranged in pairs at different height levels, and the cold ends are connected by a cold end heating exchanger. The Stirling units on opposite diagonals are operated in opposite phases so that the vibrations transferred from the heat exchanger to the glass door merchandiser as a whole largely cancel out.

[0009] US-A-4,375,749 discloses a multi-phase Stirling-cycle refrigeration apparatus suitable for cooling articles down to cryogenic temperatures. The piston cylinders of the cryocooler are operated 180° out of phase, two of which form a first refrigerating system and the other two of which form a second refrigerating system.

[0010] US-A-5,056,317 relates to a cryogenic refrigerator in which the transmission of vibrations is minimized by mounting the article to be cooled on a raised rim of an end cap.

[0011] DE-A-38 36 959 relates to a vibration free gas refrigerating machine of the stirling type comprising four coaxially arranged pistons divided into two pairs. The two pairs are operated with 180° phase difference so that the vibrations caused by each pair of pistons cancel. The refrigerating machine has two cold ends which are located and spaced apart in an axial end portion of the refrigerating machine.

FR-A-2 750 481 relates to a cryogenic cooler for cooling miniature elements. It comprises two heat exchangers each of which has a cold point being connected via regenerators to gas pressure pulse generators which are operated in mutual antiphase. The warm end of each heat exchanger is connected to a reservoir. The regenerators are thermally coupled.

SUMMARY OF THE INVENTION

[0012] It is an object of the present invention to cool an article such as a high performance precise instrument up to an extremely low temperature without the application of vibration to the article.

[0013] In order to achieve the above object, this invention relates to a method according to claim 1 for cooling an article using a cryocooler , and a cryocooler according to claim 5.

[0014] The inventors had intensely studied to achieve the above-mentioned object. As a result, they found out the following fact.

[0015] The cold end is formed in circular shape, and two pairs of cooling cylinders are arranged on the main surface of the cold end so that the diagonal line connecting one pair of cooling cylinders is orthogonal to the diagonal line connecting the other pair of cooling cylinders. Then, a high pressure gas is supplied to the one pair of cooling cylinders, and a low pressure gas is supplied to the other pair of cooling cylinders. In this case, the shape of the cold end is deformed as shown in Fig. 3. As is apparent from Fig. 3, although the shape of the cold end is changed with time, the portion substantially near and along the diameter of the cold end, particularly the almost center portion of the cold end is not deformed and remain stationary.

[0016] Therefore, if a stationary point is set onto the stationary area of the cold end, and a given article is cooled by utilizing the stationary point, the article can be cooled up to an extremely low temperature with isolation of vibration to the article.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] For better understanding of the present invention, reference is made to the attached drawings, wherein

Fig. 1 is a structural view schematically illustrating a conventional GM (Gifford McMahon) type cryocooler,

Fig. 2 is a structural view schematically illustrating a conventional pulse tube type cryocooler,

Fig. 3 relates to imaging views illustrating the deformation of the cold end of the cryocooler of the present invention,

Fig. 4 is a structural view illustrating a cold end of a cryocooler according to the present invention, and

Fig. 5 is a structural view illustrating the connection of the cooling cylinder of the cryocooler illustrated in Fig. 4 to the cold end thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] This invention will be described in detail with reference to the accompanying drawings. Fig. 4 is a structural view illustrating a cold end of a cryocooler according to the present invention, and Fig. 5 is a structural view illustrating the connection of the cooling cylinder of the cryocooler illustrated in Fig. 4 to the cold end thereof. In Fig. 4, a compressor is omitted and only the cryocooler cold head is drawn.

[0019] The cryocooler cold head 30 illustrated in Fig. 4 includes two pairs of cooling cylinders 31, 32 and a cold end 36 which is provided at the bottoms of the cooling cylinders 31 and 32 so as to be connected with the cooling cylinders 31 and 32.

[0020] As illustrated in Fig. 5, the cooling cylinders 31 and 32 are connected with the cold end 36 so that the diagonal line X connecting the cooling cylinders 31 is orthogonal to the diagonal line Y connecting the cooling cylinders 32.

A high pressure gas is supplied to the cooling cylinders 31, and a low pressure gas is supplied to the cooling cylinders 32. In this case, the portion of the cold end 36 to which the high pressure gas is applied is deformed downward, and the portion of the cold end 36 to which the low pressure gas is applied is deformed upward.

[0021] However, the area near and along the diameter Z between the upward and the downward deformed portions of the cold end 36 is not almost deformed, and particularly, the center O of the cold end 36 is not almost deformed. Therefore, a stationary point can be set onto the area near and along the diameter Z.

In the cryocooler 30 illustrated in Fig. 4, a mounting slot 39 is formed at the center O of the cold end 36 as the stationary point. Therefore, if a given article is mounted on the mounting slot 39, the article can be cooled almost with isolation of vibration to the article.

[0022] If the gas supply cycle to the cooling cylinders 31 is shifted from the gas supply cycle of the cooling cylinders 32 by a phase shift of 180 degrees and the cold end 36 is made by thick and rigid material such as tungsten carbide, the cold end 36 itself can not be vibrated. In this case, the stationary point can be set onto any portion of the cold end 36.

[0023] Although the present invention was described in detail with reference to the above examples, this invention is not limited to the above disclosure and every kind of variation and modification may be made without departing from the scope of the present invention.

[0024] According to the present invention can be cooled an article such as a high performance precise instrument up to an extremely low temperature with isolation of vibration to the article.

Claims

1. A method for cryocooling a vibration-sensitive article using a regenerative cryocooler (30), **characterized by** the steps of:

providing a regenerative cryocooler (30) having at least two pairs of cooling cylinders (31, 32) being arranged on and connected to a single

main surface of a cold end (36) of said cryocooler (30), said two pairs of cooling cylinders being arranged such that a diagonal line connecting one pair of cooling cylinders (31) is orthogonal to another diagonal line connecting the other pair of cooling cylinders (32),
said cryocooler cyclically supplying a high pressure gas to said one pair of cooling cylinders (31) and a low pressure gas to said other pair of cooling cylinders (32), said two pairs of cooling cylinders presenting a pressure phase-shift with respect to one another, thus establishing a vibration-free portion on said main surface of said cold end (36) of said cryocooler (30), and
mounting said vibration-sensitive article onto said vibration-free portion of said cold end (36).

2. The cryocooling method as defined in claim 1, wherein said main surface of said cold end (36) is formed in circular shape, and said vibration-free portion is established in an area substantially near and along a diameter of said main surface of said cold end (36).

3. The cryocooling method as defined in claim 2, wherein said vibration-free portion is established at the center of said main surface of said cold end (36).

4. The cryocooling method as defined in claim 1, further comprising the steps of shifting a supply cycle of said high pressure gas from another supply cycle of said low pressure gas by a phase shift of 180 degrees and making said cold end of rigid material, whereby said cold end (36) does not vibrate and said vibration-free portion is established over said main surface of said cold end (36).

5. A regenerative cryocooler (30) comprising:

at least two pairs of cooling cylinders (31, 32) being arranged on and connected to a single main surface of a cold end (36) of said cryocooler (30) such that a diagonal line connecting one pair of cooling cylinders (31) is orthogonal to another diagonal line connecting the other pair of cooling cylinders (32),

wherein in use a high pressure gas is to be cyclically supplied to said one pair of cooling cylinders (31) and a low pressure gas is to be cyclically supplied to said other pair of cooling cylinders (32), and wherein said two pairs of cooling cylinders present a pressure phase-shift with respect to one another, thus establishing a vibration-free portion on said main surface of said cold end (36).

6. The cryocooler as defined in claim 5, wherein said main surface of said cold end (36) is formed in circular shape and said vibration-free portion is established in an area substantially near and along a diameter of said main surface of said cold end (36).

7. The cryocooler as defined in claim 6, wherein said vibration-free portion is established at the center of said main surface of said cold end (36).

8. The cryocooler as defined in claim 7, wherein said cold end is made of rigid material, and a supply cycle of said high pressure gas is shifted from another supply cycle of said low pressure gas by a phase shift of 180 degrees so that said vibration-free portion is established over said main surface of said cold end (36).

Patentansprüche

1. Ein Verfahren zum Kryokühlen eines vibrationsempfindlichen Gegenstands unter Verwendung eines regenerativen Kryokühlers (30), **gekennzeichnet durch** die Schritte von:

Bereitstellen eines regenerativen Kryokühlers (30), der wenigstens zwei Paare von Kühlzylindern (31, 32) hat, die an einer einzelnen Hauptfläche eines kalten Endes (36) des Kryokühlers (30) angeordnet und hiermit verbunden sind, wobei besagte zwei Paare von Kühlzylindern derart angeordnet sind, dass eine ein Paar von Kühlzylindern (31) verbindenden Diagonallinie senkrecht zu einer anderen Diagonallinie ist, die das andere Paar von Kühlzylindern (32) verbindet,

wobei der Kryokühler zyklisch ein Hochdruckgas zu dem einen Paar von Kühlzylindern (31) und ein Niederdruckgas zu dem anderen Paar von Kühlzylindern (32) führt, wobei die beiden Paare von Kühlzylindern eine Druck-Phasenverschiebung zueinander zeigen, so dass ein vibrationsfreier Abschnitt an der Hauptfläche des kalten Endes (36) des Kryokühlers (30) gebildet wird, und
Anordnen des vibrationsempfindlichen Gegenstands an dem vibrationsfreien Abschnitt des kalten Endes (36):

2. Das Kryokühlverfahren nach Anspruch 1, bei dem die Hauptfläche des kalten Endes (36) in Kreisform ausgebildet ist und der vibrationsfreie Abschnitt in einem Bereich im Wesentlichen nahe an und entlang eines Durchmessers der Hauptfläche des kalten Endes (36) gebildet wird.

3. Das Kryokühlverfahren nach Anspruch 2, bei dem der vibrationsfreie Abschnitt in der Mitte der Hauptfläche des kalten Endes gebildet wird.

4. Das Kryokühlverfahren nach Anspruch 1, weiterhin aufweisend die Schritte des Verschiebens eines Zufuhrzyklus des Hochdruckgases gegenüber einem anderen Zufuhrzyklus des Niederdruckgases um eine Phasenverschiebung von 180° und des Ausbildens des kalten Endes aus steifem Material, wodurch das kalte Ende (26) nicht vibriert und der vibrationsfreie Abschnitt über die Hauptfläche des kalten Endes (36) hinweg gebildet wird.

5. Ein regenerativer Kryokühler, aufweisend:

wenigstens zwei Paare von Kühlzylindern (31, 32), die an einer einzelnen Hauptfläche eines kalten Endes (36) des Kryokühlers (30) angeordnet und hiermit verbunden sind, so dass eine ein Paar von Kühlzylindern (31) verbindende Diagonallinie senkrecht zu einer anderen Diagonallinie ist, die das andere Paar von Kühlzylindern (32) verbindet,

wobei im Gebrauch ein Hochdruckgas zyklisch zu dem einen Paar von Kühlzylindern (31) und ein Niederdruckgas zyklisch zu dem anderen Paar von Kühlzylindern (32) geführt wird, und wobei die beiden Paare von Kühlzylindern eine Druck-Phasenverschiebung zueinander zeigen, so dass ein vibrationsfreier Abschnitt an der Hauptfläche des kalten Endes (36) gebildet wird.

6. Der Kryokühler nach Anspruch 5, bei dem die Hauptfläche des kalten Endes (36) in Kreisform ausgebildet ist und der vibrationsfreie Abschnitt in einem Bereich im Wesentlichen nahe an und entlang eines Durchmessers der Hauptfläche des kalten Endes (36) gebildet ist.

7. Der Kryokühler nach Anspruch 6, bei dem der vibrationsfreie Abschnitt in der Mitte der Hauptfläche des kalten Endes gebildet ist.

8. Der Kryokühler nach Anspruch 7, bei dem das kalte Ende aus steifem Material gebildet ist, und ein Zufuhrzyklus des Hochdruckgases gegenüber einem anderen Zufuhrzyklus des Niederdruckgases um eine Phasenverschiebung von 180° verschoben ist, so dass der vibrationsfreie Abschnitt über die Hauptfläche des kalten Endes (36) hinweg gebildet ist.

Revendications

1. Procédé pour le cryorefroidissement d'un article sensible aux vibrations utilisant un cryorefroidisseur (30) régénératif, **caractérisé par** les étapes consistant à :

fournir un cryorefroidisseur (30) régénératif ayant au moins deux paires de cylindres (31, 32) refroidisseurs étant disposées sur et connectés à une seule surface principale d'une extrémité froide (36) dudit cryorefroidisseur (30), lesdites deux paires de cylindres refroidisseurs étant disposées de manière telle qu'une ligne diagonale connectant une paire de cylindres (31) refroidisseurs soit orthogonale à une autre ligne diagonale connectant l'autre paire de cylindres (32) refroidisseurs,
ledit cryorefroidisseur fournissant de manière cyclique un gaz à haute pression à ladite une paire de cylindres (31) refroidisseurs et un gaz à basse pression à ladite autre paire de cylindres (32) refroidisseurs, lesdites deux paires de cylindres refroidisseurs présentant un décalage de phase de pression en fonction de l'une de l'autre, établissant ainsi une partie sans vibration sur ladite surface principale de ladite extrémité (36) froide dudit cryorefroidisseur (30), et
monter ledit article sensible aux vibrations sur ladite partie sans vibration de ladite extrémité (36) froide.

2. Procédé de cryorefroidissement selon la revendication 1, dans lequel ladite surface principale de ladite extrémité (36) froide présente une forme circulaire, et ladite partie sans vibration est établie dans une région sensiblement proche et le long d'un diamètre de ladite surface principale de ladite extrémité (36) froide.

3. Procédé de cryorefroidissement selon la revendication 2, dans lequel ladite partie sans vibration est établie au centre de ladite surface principale de ladite extrémité (36) froide.

4. Procédé de cryorefroidissement selon la revendication 1, comprenant en outre les étapes consistant à décaler un cycle d'alimentation dudit gaz à haute pression par rapport à un autre cycle d'alimentation dudit gaz à basse pression par un décalage de phase de 180 degrés et consistant à fabriquer ladite extrémité froide dans un matériau rigide, d'où il résulte que ladite extrémité (36) froide ne vibre pas et ladite partie sans vibration est établie sur ladite surface principale de ladite extrémité (36) froide.

5. Cryorefroidisseur (30) régénératif comprenant :

au moins deux paires de cylindres (31, 32) refroidisseurs étant disposées sur et
connectées à une seule surface principale d'une extrémité (36) froide dudit cryorefroidisseur (30) de manière telle qu'une ligne diagonale connectant une paire de cylindres (31) refroidisseurs soit orthogonale à une autre ligne diagonale connectant l'autre paire de cylindres (32) refroi-

disseurs,

dans lequel, au cours de l'utilisation, un gaz à haute pression doit être fourni de manière cyclique à ladite une paire de cylindres (31) refroidisseurs et un gaz à basse pression doit être fourni de manière cyclique à ladite autre paire de cylindres (32) refroidisseurs, et dans lequel lesdites deux paires de cylindres refroidisseurs présentent un décalage de phase de pression en fonction de l'une de l'autre, établissant ainsi une partie sans vibration sur ladite surface principale de ladite extrémité (36) froide.

6. Cryorefroidisseur selon la revendication 5, dans lequel ladite surface principale de ladite extrémité (36) froide présente une forme circulaire et ladite partie sans vibration est établie dans une région sensiblement proche et le long d'un diamètre de ladite surface principale de ladite extrémité (36) froide.

7. Cryorefroidisseur selon la revendication 6, dans lequel ladite partie sans vibration est établie au centre de ladite surface principale de ladite extrémité (36) froide.

8. Cryorefroidisseur selon la revendication 7, dans lequel ladite extrémité froide est fabriquée dans un matériau rigide, et un cycle d'alimentation dudit gaz à haute pression est décalé par rapport à l'autre cycle d'alimentation dudit gaz à basse pression par un décalage de phase de 180 degrés de sorte que ladite partie sans vibration soit établie sur ladite surface principale de ladite extrémité (36) froide.

FIG. 1

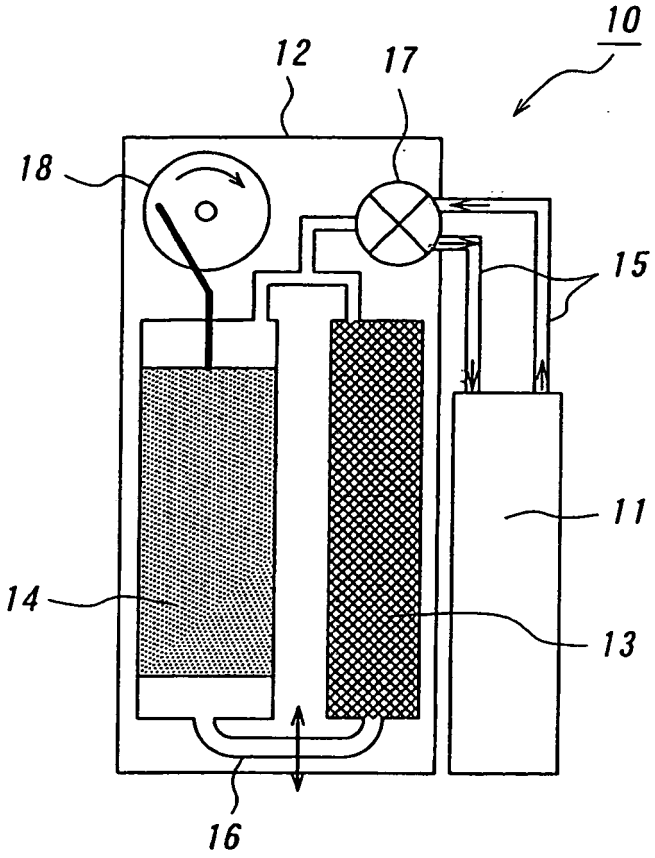


FIG. 2

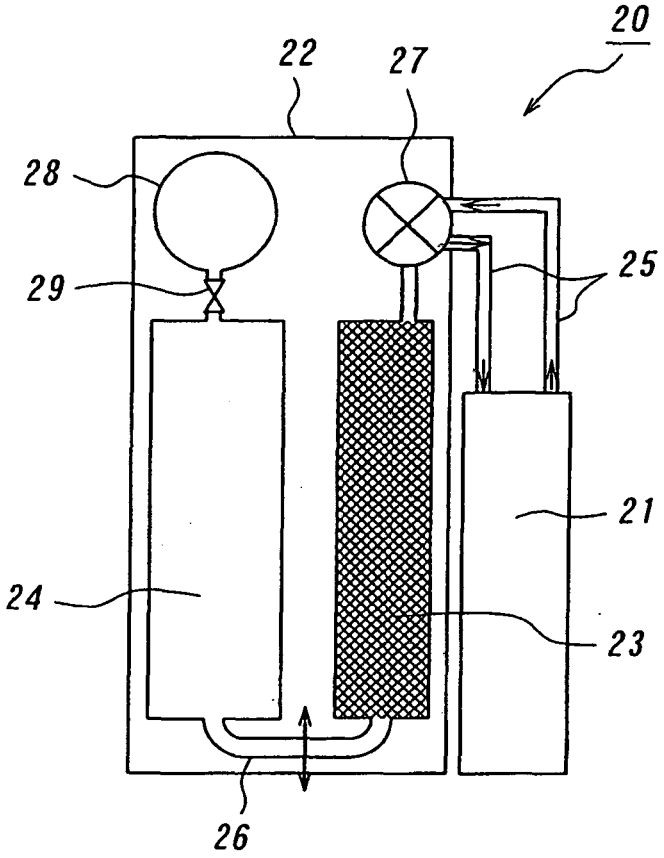


FIG. 3

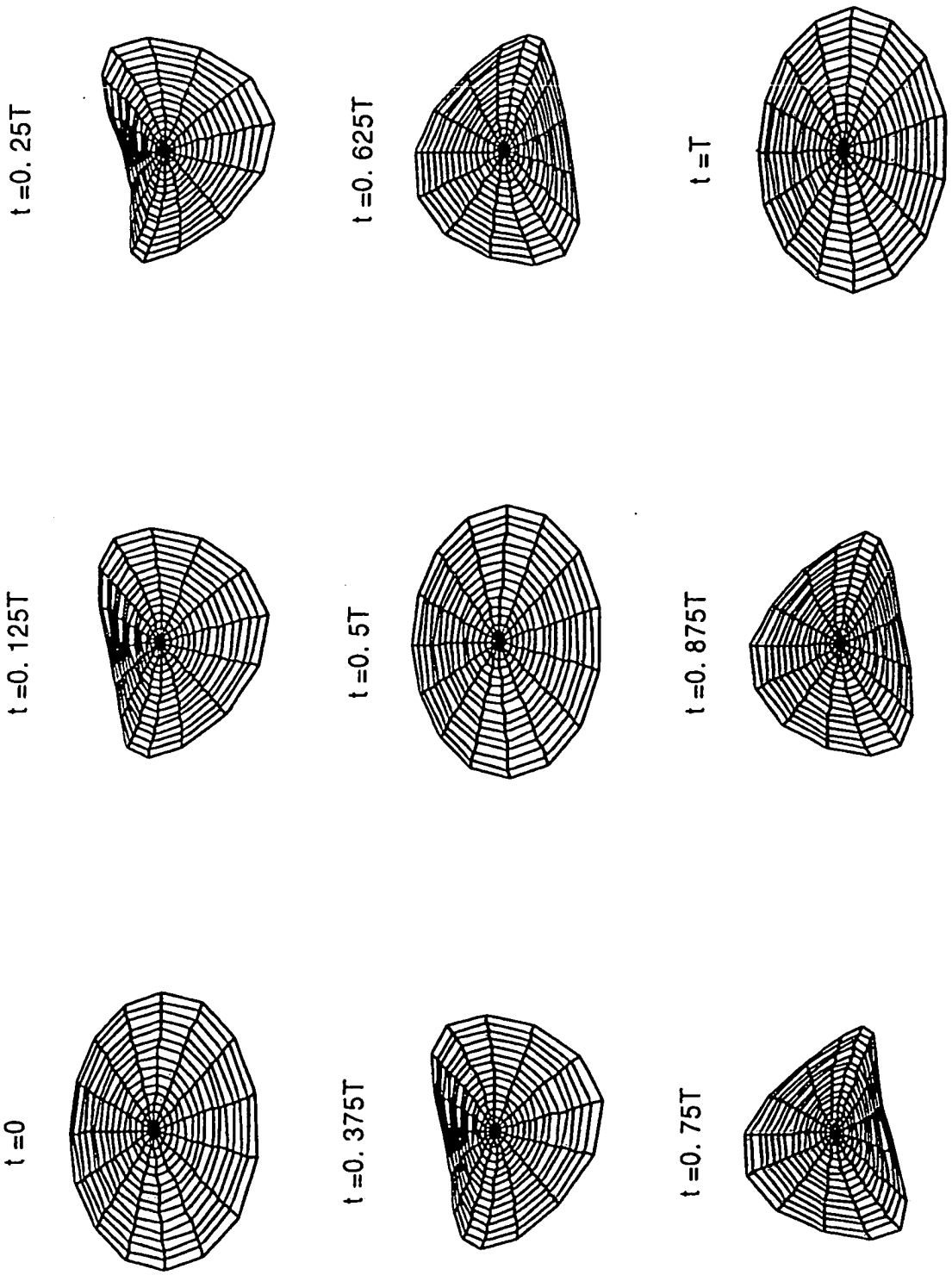


FIG. 4

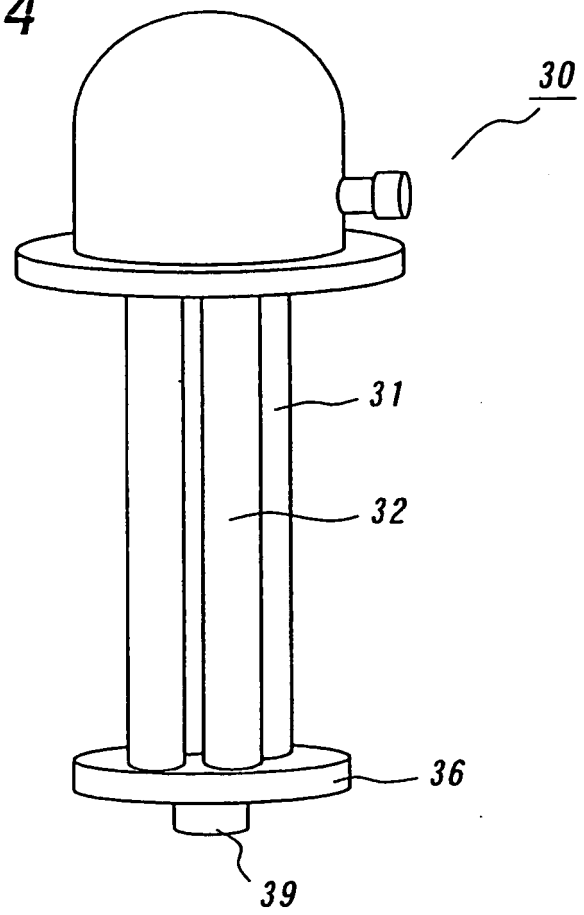
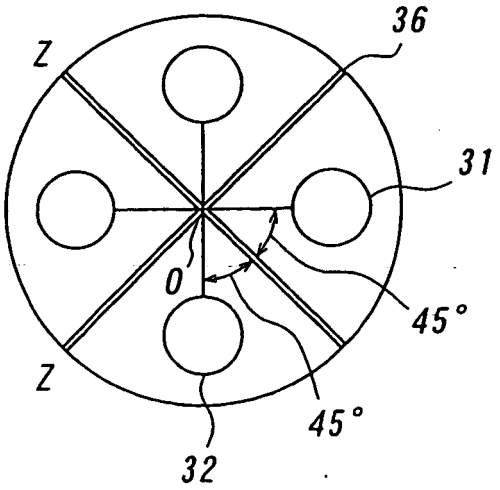


FIG. 5



REFERENCES CITED IN THE DESCRIPTION

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