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Description

Technical Field of the Invention

[0001] The present invention relates to a vaporiser for liquefied gas. The invention also relates to the use of such a vaporiser for vaporising liquid carbon dioxide.

Background to the Invention

[0002] Carbon dioxide gas has a wide variety of applications. It is used in the food and beverage, oil and chemical industries and in many consumer products that require pressurized gas.

[0003] Carbon dioxide can be liquefied at ambient temperatures when compressed to around 60 bar. As such carbon dioxide is usually supplied in pressurised vessels, in which it exists as a liquid. As the pressure under which liquid carbon dioxide is stored is reduced, for example as carbon dioxide gas is released from a pressurised vessel containing liquefied carbon dioxide, it can no longer remain in a liquid form and in the absence of sufficient energy to allow a change of state to a gas it forms a solid which, as energy becomes available, sublimes.

[0004] These physical properties of carbon dioxide complicate its handling. If an attempt is made to draw off carbon dioxide gas from a pressurised container of liquefied carbon dioxide at a rate which requires more energy to be supplied to the liquid than can be absorbed from the environment surrounding the container the liquid can solidify. This dramatically reduces the flow of gas which may be obtained from the container and can give the mistaken impression that the container is empty. If liquefied carbon dioxide is drawn from a container and allowed to expand downstream in pipe work for conducting the liquid it can solidify in and block the pipe work. This can prevent flow of gas, and can also lead to a build up of pressure behind solid carbon dioxide blocking the pipe work to the point where the solid is ejected by the build up of pressure potentially forming a dangerous projectile.

[0005] In view of these difficulties it is conventional to vaporise liquid carbon dioxide using a heater to maintain the temperature of the liquid as pressure is released in order to prevent the carbon dioxide solidifying. In beverage dispense and other relatively small applications it is common for vaporisers employing electrically powered heaters to be used. In larger 'bulk supplies' when liquid carbon dioxide is stored in a refrigerated condition steam is often used.

[0006] Use of a heater, and hence an energy supply, is undesirable in view of the cost and also the effect on the environment, depending on the energy source employed.

[0007] Embodiments of the present invention have been made in consideration of these problems, and seek to enable liquid carbon dioxide to be vaporised safely, but without the use of a heater.

[0008] DE 932222 discloses a vaporiser for liquefied gas, in particular liquid oxygen. It comprises an upright annular chamber. An inlet tube extends to the bottom of the chamber and an outlet is provided at the top of the chamber. The inlet tube has a smaller cross-section than that of the chamber.

Summary of the Invention

[0009] According to an aspect the present invention there is provided a vaporiser suitable for vaporising liquefied carbon dioxide gas, the vaporiser comprising an inlet for liquefied gas leading into a chamber having a base and an outlet for vaporised gas leading from the chamber, the inlet having a cross-sectional area smaller than that of the chamber and the vaporiser being arranged so that it may be oriented in use so that the inlet is spaced above the base of the chamber and the outlet is spaced above the inlet, so that any solid carbon dioxide which is formed in the chamber may fall to the base of the chamber away from the inlet and the outlet.

[0010] According to another aspect of the present invention there is provided a method of vaporising liquid carbon dioxide comprising the steps of: providing apparatus according to the invention and introducing liquid carbon dioxide into the chamber through the inlet.

[0011] As liquefied carbon dioxide passes through the inlet into the chamber the increase in cross-sectional area and hence volume allows the liquid to expand to form a gas. Any solid carbon dioxide which results will fall to the base of the chamber, away from the outlet allowing gas to flow unimpeded by solid through the outlet. Solid carbon dioxide at the base of the chamber can gradually absorb energy from the environment and as it sublimes the resulting gas will also flow through the outlet. Thus, liquefied carbon dioxide may be vaporised using energy absorbed from the ambient environment, avoiding the need to use a heater, but without the usual risks and impediments to flow associated with formation of solid carbon dioxide.

[0012] The ratio of the cross-sectional area of the inlet to that of the chamber is preferably less than 1:1000 and more preferably less than 0.5:1000. The outlet may be formed in a top of the chamber. The inlet may be configured to create a rotating gas flow inside the chamber. The chamber may have a substantially circular internal sidewall and may be be generally cylindrical in shape. The inlet may comprise a passageway leading to an opening in the internal sidewall of the chamber. The passageway may extend towards the opening in a direction generally tangential to the sidewall of the chamber. Alternatively, the inlet may comprise a pipe. The pipe may extend along a substantially helical path within the chamber, terminating with a free end. A flow control means may be provided to control the rate of flow of liquid gas into the chamber. The flow control means may be adjustable. The flow control means may comprise a liquid gas flow regulator and / or a needle valve or some other form

of variable orifice. The outside surface of the chamber may include formations, for example fins, arranged to increase the rate at which heat may be absorbed by the container from the environment surrounding the container. The chamber may be associated with a heat exchanger. The chamber may provide a heat sink for a refrigeration system. The inlet may include a fitting suitable for connection to a supply of liquefied gas. The outlet may be connected to a valve and/or pressure regulator.

Detailed Description of the Invention

[0013] In order that the invention may be more clearly understood an embodiment thereof will now be described, by way of example only, with reference to the accompanying drawings, of which:

Figure 1 shows a liquefied carbon dioxide cylinder connected to a vaporiser according to the invention;

Figure 2 shows a horizontal cross-section along the line II-II through the vaporiser of figure 1;

Figure 3 shows a longitudinal cross-section through the flow control fitting of the vaporiser of figure 1; and

Figure 4 shows an enlarged vertical cross-section through part of the vaporiser of figure 1.

[0014] In the following description the terms upper, lower, top, bottom and like terms are used to refer to the apparatus in the orientation it is depicted in the drawings, which is the orientation in which it is intended to be used, and should not be taken as otherwise limiting. Hidden detail is shown by broken lines.

[0015] Referring to the drawings, a vaporiser is formed from stainless steel, although any other suitable metal, other material or combination of materials could be used.

[0016] The vaporiser comprises an upright, elongate generally cylindrical chamber 1 with a substantially circular cross-section. A plurality of fins 3 are mounted to the outside of the chamber. The fins 3 extend generally radially from the chamber. The base of the chamber is closed and the top is open, forming an outlet. The internal cross-sectional area of the outlet is smaller than that of the chamber. The outside of the chamber adjacent the outlet is threaded. The chamber is made with sufficient strength to enable it to contain liquefied carbon dioxide when placed in normal ambient conditions.

[0017] The chamber is formed from three sections, a lower section 5, an intermediate inlet section 4, and an upper section 6. The three sections are connected together by threaded connections, but could be connected by any other suitable means. The inlet section comprises a body which defines an internally threaded bore 7 which extends radially relative to the chamber, for receiving a flow control fitting 8 and leads to a narrow inlet passageway 2 which extends towards an inlet in the wall of the chamber in a direction generally tangential to the internal wall of the chamber. The cross-sectional area of the opening into the chamber is much smaller than that of the chamber (in a horizontal cross-section).

[0018] In an alternative embodiment the inlet comprises a pipe of narrow cross-section which extends info the chamber in a substantially helical fashion adjacent the internal wall of the chamber and terminates in a free end below the point of entry to the chamber after passing around the inside of the wall of the chamber about three times.

[0019] A flow control fitting 8 is screwed into the threaded bore 7 of the body of the inlet section of the chamber. The flow control fitting 8 is threaded at opposite ends respectively, and a bore extends from one end to the fitting to the other. At one end a sintered brass filter 9 is disposed in the bore. At the other end the bore is internally threaded and the threaded portion leads to a valve seat 10 formed by a narrowing in the bore. A grub screw 11 with a cone shaped end is screwed into the internal bore so that that cone shaped end faces the valve seat. The opposite end of the grub screw 11 is shaped to receive an Alan key or some other driver. The grub screw forms a needle valve with the remainder of the fitting and can be tightened against the valve seat to restrict the flow of fluid through the fitting. Depending on application, channels could be formed in the threaded bore in the flow control fitting 8 to allow a greater volume of fluid to flow past the grub screw 11.

[0020] In assembly of the vaporiser for use the grub screw 11 is fully tightened against the valve seat then slackened off a desired amount, to achieve a desired restriction to flow through the fitting. The fitting is then screwed into the threaded bore 7 of the inlet body, with the end of the fitting housing the grub screw being inserted into the inlet body.

[0021] A liquid gas flow control regulator 12 is then coupled to the opposite end of the flow control fitting 8. The liquid flow control regulator is of a conventional type. In this embodiment it is capable of regulating a supply of liquid under pressure of about 55bar inlet to produce an output at a pressure of around 10bar. The specification may, however, be varied depending on the size of the vaporiser, the nature of liquid gas supply and ambient conditions.

[0022] In use, liquid carbon dioxide is supplied to the regulator 12 of the vaporiser. In the arrangement illustrated in figure 1 the liquid is supplied via a hose 13 from a pressurised container 14, typically referred to as a cylinder owing to its shape. The cylinder 14 contains liquid carbon dioxide 15 and comprises a dip tube 16 which extends from a valve 17 on the top of the cylinder towards the bottom of the cylinder so as to pick up liquid carbon dioxide which will be forced out of the cylinder owing to the build up of pressure of carbon dioxide gas above the liquid sufficient to keep the remainder of the carbon di-

oxide in a liquid state. Other arrangements for the supply of liquid carbon dioxide are of course possible. The hose 13 could be replaced with rigid pipework. The regulator 12 of the vaporiser could be connected directly to a liquid carbon dioxide storage vessel.

[0023] The regulator 12 on the vaporiser is set as desired and the valve 17 on the pressurised container 14 is opened. Provided that the outlet 6 of the vaporiser is at a pressure lower than the gas above the liquefied carbon dioxide 15 in the pressurised container 14 liquid carbon dioxide will be forced out of the container 14, through the hose 13 to the flow regulator 12 and from the flow regulator through the sintered filter 9, needle valve and inlet passage into the chamber. As the liquid carbon dioxide flows through the regulator and flow control fitting 8 and enters the chamber the reduction in pressure allows the liquid to evaporate, absorbing heat energy from the chamber and its surroundings, and to the extent that insufficient energy is available to completely evaporate the liquid some of the liquid will form a solid. Any solid carbon dioxide which forms will fall, under gravity, to the bottom of the chamber away from the inlet and outlet reducing the risk of either becoming blocked with solid. The generally tangential direction of the inlet passage as it approaches the chamber will cause liquid, gas and any solid entering the chamber to flow in a generally circular or helical path creating a rotating gas flow within the chamber which aids separation of any solid carbon dioxide from the gas by way of vortex separation. The chamber thus acts as a cyclone.

[0024] Carbon dioxide gas flows toward and out of the outlet of the chamber. A pressure regulating valve 18 may be fitted to the outlet by means of a threaded connection with the thread formed on the outside of the vaporiser, although any other suitable connection could be used. This valve may be used to control the output of gas from the vaporiser and may in turn be connected to a hose or other supply pipe. Alternatively the outlet of the vaporiser may be connected directly to a pipe or hose to deliver the gas the where it is required and gas flow may be controlled down stream.

[0025] As carbon dioxide vaporises in the chamber it draws heat from the walls of the chamber, primarily in the upper part of the chamber extending from the inlet to the outlet. This cools the chamber walls which, in turn, absorb heat from the surroundings. The fins 3 mounted to the outside of the chamber will enhance the absorption of heat from the environment surrounding the chamber by providing an increased surface area through which heat can be absorbed. Any solid carbon dioxide which builds up at the bottom of the chamber will absorb heat from the ambient surroundings of the chamber through the walls of the lower part of the chamber causing it to sublime and the resulting carbon dioxide gas will also flow from the chamber through the outlet. Accumulation of some solid in the lower part of the chamber during use serves as a useful reservoir, and sublimation of the solid can help meet temporary increases in the demand for flow of gas which would otherwise exceed the amount of liquid gas being supplied through the inlet.

[0026] In an alternative arrangement all or part of the outside of the chamber could be associated with a heat exchanger forming part of a refrigeration or other cooling system and provide a heat sink for that system. Thus, where there is a refrigeration requirement at the same site where it is necessary to vaporise carbon dioxide the need for refrigeration apparatus can be reduced or eliminated, leading to a further energy saving.

[0027] The size of the inlet passageway of the vaporiser is selected and the valve in the flow control fitting and the flow control regulator are set to limit the maximum flow of liquid carbon dioxide into the vaporiser to that which can be vaporised in the chamber through absorption of heat from the environment around the chamber thus preventing flooding of the chamber with liquid carbon dioxide. The flow control regulator 12 and valve in the flow control fitting 8 may be adjusted to accommodate different environmental conditions whilst obtaining maximum gas flow. These flow controls are positioned close to the point at which the inlet opens out into the chamber to prevent it becoming blocked by formation of solid carbon dioxide.

[0028] When the inlet flow controls have been set the flow of gas from the vaporiser can be controlled by valves or other controls at the outlet or downstream of the outlet. In the current example, if the outlet 6 were open to the atmosphere then the inlet flow controls 8, 12 would provide the only limitation on the flow of liquid carbon dioxide into the vaporiser. If the flow of carbon dioxide gas out of the vaporiser is restricted, either by regulator 18 or a downstream application then the gas pressure inside the vaporiser will increase, also serving to restrict the flow of liquid into the chamber. If the flow of gas out of the vaporiser is stopped entirely then the gas pressure in the chamber will build up until it is equal to that in the cylinder and liquid will then not flow from the cylinder into the vaporiser.

[0029] In the current example the internal diameter of the chamber is about 25mm. The lower part of the chamber is about 300mm in length, which is suitable for most applications. The height of the upper part of the chamber can be varied dependent upon the flow rate of gas required and thus surface area of the chamber necessary to absorb sufficient heat from its surroundings. A height of about 2500mm is sufficient to provide a rate of evaporation similar to that of a 1 kW electrically heated evaporator when the apparatus is used an environment at about 10 degrees Centrigrade. The chamber should extend above the inlet a height greater than the height to which particles of solid CO2 may rise during operation. Beyond that though, the chamber may turn through 180 degrees to provide for a more compact unit. Of course other dimensions are possible and the capacity of the apparatus could be changed by scaling its size. In a particular installation additional capacity could be provided by providing multiple units of the apparatus.

[0030] The described embodiment enables liquid carbon dioxide to be vaporised by absorption of heat from the surrounding environment, avoiding the need to use a heater whilst reducing or avoiding the risk that solid carbon dioxide will block the flow of gas by providing for the separation of solid and gas phase carbon dioxide within the chamber.

[0031] The above embodiment is described by way of example only. Many variations are possible without departing from the scope of the invention as defined by the following claims.

Claims

1. A vaporiser suitable for vaporising liquefied carbon dioxide gas, the vaporiser comprising an inlet (2) for liquefied gas leading into a chamber (4,5,6) having a base (5) and an outlet for vaporised gas leading from the chamber, the inlet having a cross-sectional area smaller than that of the chamber and the vaporiser being arranged so that in use the inlet is spaced above the base of the chamber and the outlet is spaced above the inlet, so that any solid carbon dioxide which is formed in the chamber may fall to the base of the chamber away from the inlet and the outlet.

2. A vaporiser as claimed in claim 1 wherein the ratio of the cross-sectional area of the inlet to that of the chamber is less than 1:1000.

3. A vaporiser as claimed in claim 2 wherein the ratio of the cross-sectional area of the inlet to that of the chamber is less than 0.5:1000.

4. A vaporiser as claimed in any preceding claim wherein the inlet is configured to create a rotating gas flow inside the chamber.

5. A vaporiser as claimed in any preceding clam wherein the chamber has a substantially circular internal sidewall.

6. A vaporiser as claimed in claim 5 wherein the inlet comprises a passageway (2) leading to an opening in the substantially circular internal sidewall of the chamber, the passageway extending towards the opening in a direction generally tangential to the sidewall.

7. A vaporiser as claimed in any preceding claim comprising flow control means (8,12) to control the rate of flow of liquid gas into the chamber.

8. A vaporiser as claimed in claim 7 wherein the flow control means comprises a liquid gas flow regulator (12).

9. A vaporiser as claimed in claim 7 or 8 wherein the flow control means comprises a needle valve (8).

10. A vaporiser as claimed in any preceding claim wherein an outside surface of the chamber includes formations (3) arranged to increase the rate at which heat may be absorbed by the chamber from its surrounding environment.

11. A vaporiser as claimed in an preceding claim wherein the chamber is associated with a heat exchanger.

12. A vaporiser as claimed in any preceding claim wherein the outlet is connected to a pressure regulator (18).

13. A method of vaporising liquid carbon dioxide comprising the steps of: providing a vaporiser as claimed in any preceding claim and introducing liquid carbon dioxide into the chamber through the inlet.

Patentansprüche

1. Verdampfer, geeignet um verflüssigtes Kohlenstoffdioxidgas zu verdampfen, mit einem Einlass (2) für verflüssigtes Gas, der in eine Kammer (4,5,6) hineinführt, wobei die Kammer einen Boden (5) und einen Auslass für verdampftes Gas, der aus der Kammer herausführt, aufweist, wobei der Einlass eine Querschnittsfläche kleiner derjenigen der Kammer aufweist und der Verdampfer derart angeordnet ist, dass im Betrieb der Einlass beabstandet oberhalb des Bodens der Kammer angeordnet ist und dass der Auslass beabstandet oberhalb des Einlasses angeordnet ist, sodass jegliches festes Kohlenstoffdioxid, das in der Kammer gebildet wird, zum Boden der Kammer, weg vom Einlass und Auslass, fallen kann.

2. Verdampfer nach Anspruch 1, bei dem das Verhältnis der Querschnittsfläche des Einlasses zu derjenigen der Kammer weniger als 1 : 1000 beträgt.

3. Verdampfer nach Anspruch 2, bei dem das Verhältnis der Querschnittsfläche des Einlasses zu derjenigen der Kammer weniger als 0,5 : 1000 beträgt.

4. Verdampfer nach einem der vorangehenden Ansprüche, bei dem der Einlass zur Erzeugung eines rotierenden Gasstroms innerhalb der Kammer ausgebildet ist.

5. Verdampfer nach einem der vorangehenden Ansprüche, bei dem die Kammer eine im Wesentlichen kreisrunde innere Seitenwand aufweist.

6. Verdampfer nach Anspruch 5, bei dem der Einlass

einen Durchgang (2) aufweist, der zu einer Öffnung in der im Wesentlichen kreisrunden inneren Seitenwand der Kammer führt, wobei der Durchgang sich zur Öffnung hin in einer Richtung erstreckt, die in etwa tangential zur Seitenwand verläuft.

7. Verdampfer nach einem der vorangehenden Ansprüche, mit einem Mittel (8,12) zur Durchflusssteuerung, um die Durchflussrate von Flüssiggas in die Kammer hinein zu steuern.

8. Verdampfer nach Anspruch 7, bei dem das Mittel zur Durchflusssteuerung einen Durchflussregler (12) für Flüssiggas aufweist.

9. Verdampfer nach Anspruch 7 oder 8, bei dem das Mittel zur Durchflusssteuerung ein Nadelventil (8) aufweist.

10. Verdampfer nach einem der vorangehenden Ansprüche, bei dem eine äußere Oberfläche der Kammer Strukturen (3) aufweist, die dazu dienen, die Rate zu erhöhen, mit welcher Wärme von der Kammer aus der Umgebung aufgenommen werden kann.

11. Verdampfer nach einem der vorangehenden Ansprüche, bei dem die Kammer mit einem Wärmeübertrager verbunden ist.

12. Verdampfer nach einem der vorangehenden Ansprüche, bei dem der Auslass mit einem Druckregler (18) verbunden ist.

13. Verfahren zum Verdampfen von flüssigem Kohlenstoffdioxid, mit folgenden Schritten: Bereitstellen eines Verdampfers nach einem der vorangehenden Ansprüche, und Einleiten flüssigen Kohlenstoffdioxids in die Kammer durch den Einlass.

Revendications

1. Vaporisateur approprié pour la vaporisation de dioxyde de carbone gazeux comprenant un orifice d'entrée (2) pour du gaz liquéfié, aboutissant dans une chambre (4,5,6) comportant une base (5) et un orifice de sortie pour du gaz vaporisé à partir de la chambre, l'orifice d'entrée ayant une section transversale inférieure à celle de la chambre et le vaporisateur étant agencé de façon que, en utilisation, l'orifice d'entrée soit disposé au-dessus de la base de la chambre et que l'orifice de sortie soit disposé au-dessus de l'orifice d'entrée, de telle sorte que tout dioxyde de carbone solide qui se forme dans la chambre puisse tomber à la base de la chambre au delà des orifices d'entrée et de sortie.

2. Vaporisateur selon la revendication 1, dans lequel le rapport entre la surface de la section de l'orifice d'entrée et celle de la chambre est inférieur à 1 :1000.

3. Vaporisateur selon la revendication 2, dans lequel le rapport entre la surface de la section de l'orifice d'entrée et celle de la chambre est inférieur à 0,5 :1000.

4. Vaporisateur selon l'une quelconque des revendications précédentes, dans lequel l'orifice d'entrée est configuré de façon à créer un flux de gaz rotatif à l'intérieur de la chambre

5. Vaporisateur selon l'une quelconque des revendications précédentes, dans lequel la chambre a une paroi interne sensiblement circulaire.

6. Vaporisateur selon la revendication 5, dans lequel l'orifice d'entrée comporte un passage(2) aboutissant à une ouverture dans la paroi sensiblement circulaire de la chambre, le passage s'étendant vers l'ouverture dans une direction généralement tangentielle à la paroi.

7. Vaporisateur selon l'une quelconque des revendications précédentes comportant des moyens de contrôle de débit (8,12) pour contrôler le débit de gaz liquide dans la chambre.

8. Vaporisateur selon la revendication 7, dans lequel les moyens de contrôle de débit comportent un régulateur (12) de débit de gaz liquide.

9. Vaporisateur selon la revendication 7 ou 8, dans lequel les moyens de contrôle de débit comportent une valve pointeau (8).

10. Vaporisateur selon l'une quelconque des revendications précédentes, dans lequel la surface extérieure de la chambre comporte des dispositions(3) ménagées de façon à augmenter le taux auquel la chaleur de son environnement peut être absorbée par la chambre.

11. Vaporisateur selon une revendication précédente, dans lequel la chambre est associée à un échangeur de chaleur.

12. Vaporisateur selon l'une quelconque des revendications précédentes, dans lequel l'orifice de sortie est relié à un régulateur de pression (18).

13. Procédé de vaporisation de dioxyde de carbone comprenant les étapes de : disposer un vaporisateur selon l'une quelconque des revendications précédentes et d'introduire du dioxyde de carbone liquide dans la chambre par l'orifice d'entrée.

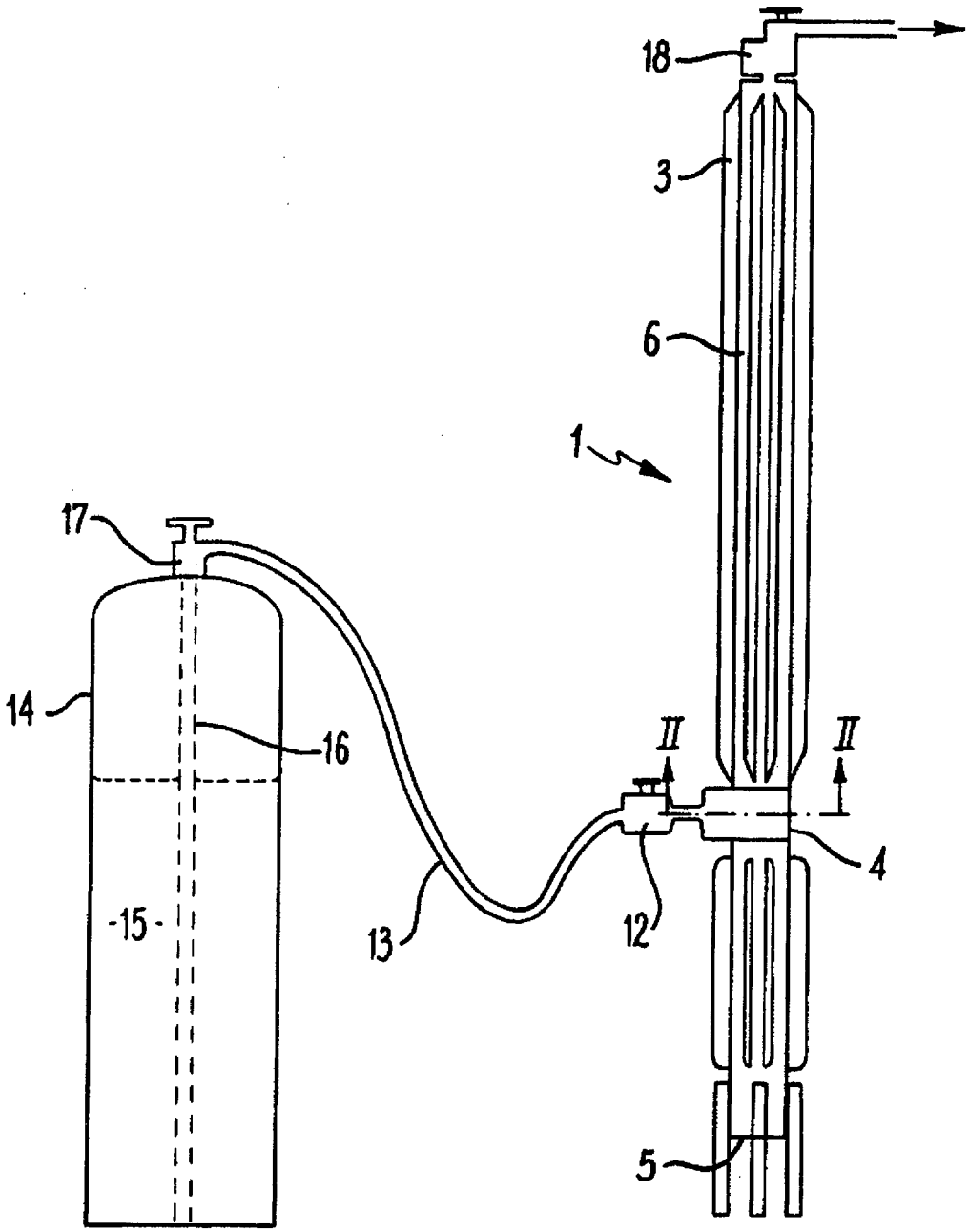


FIG. 1

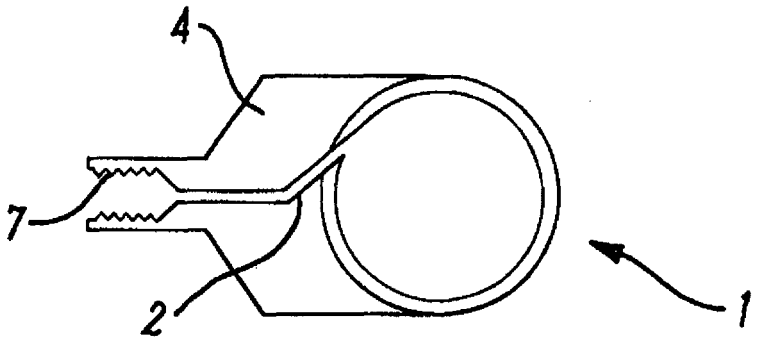


FIG. 2

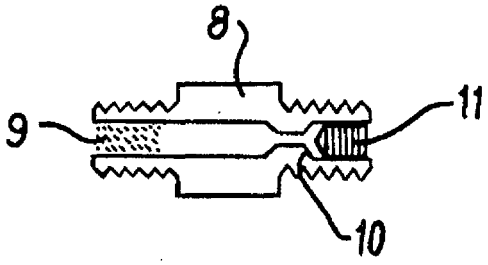


FIG. 3

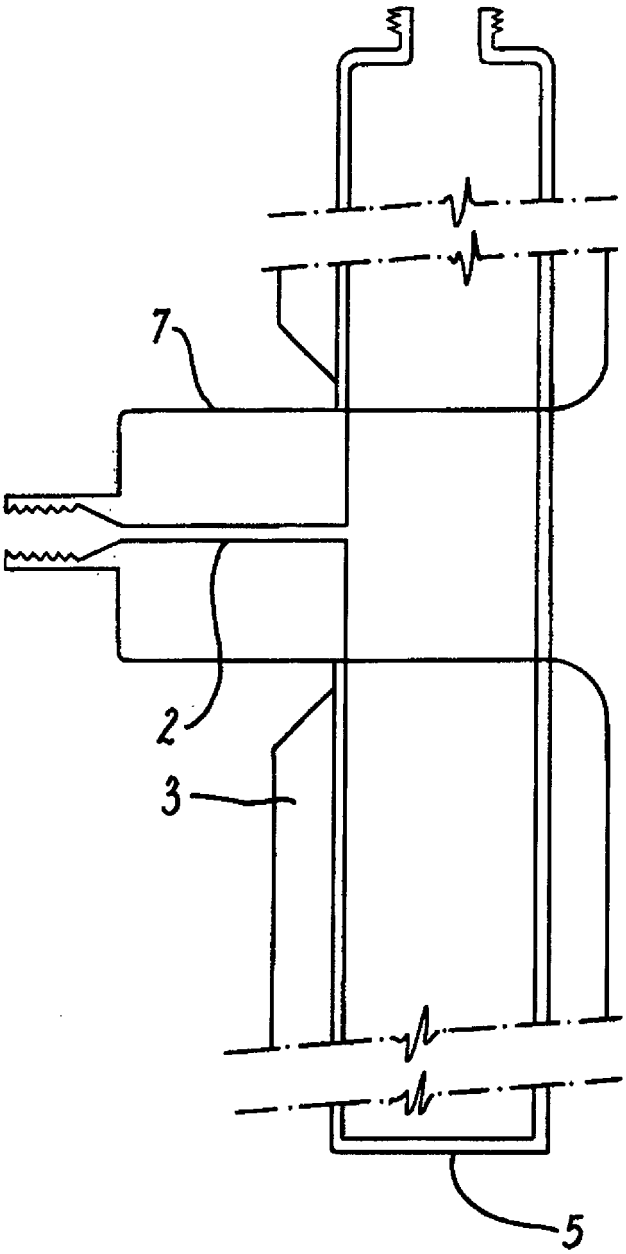


Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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