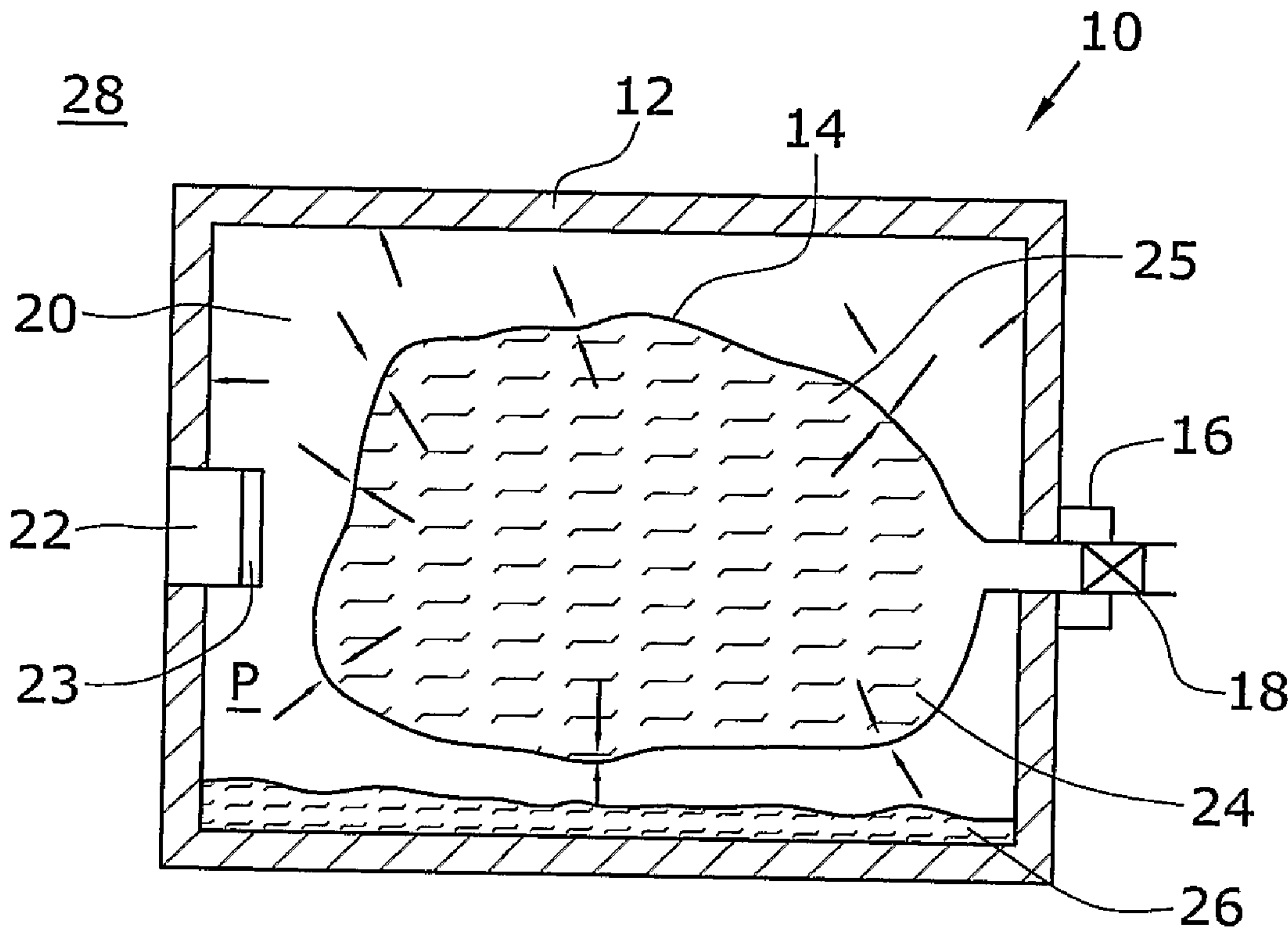




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 (72) Inventeurs/Inventors:  
 ADAMS, PAUL, US;  
 CURELLO, ANDREW J., US;  
 FAIRBANKS, FLOYD, US;  
 STEPAN, CONSTANCE R., US  
 (73) Propriétaire/Owner:  
 SOCIETE BIC, FR  
 (74) Agent: METHOD LAW PROFESSIONAL  
 CORPORATION

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(57) **Abrégé/Abstract:**

A fuel supply (10) connectable to a fuel cell is disclosed. The fuel supply comprises an outer casing (12) and a fuel liner (14) and an effective amount of fuel (26) in the space (20) between the outer casing and the fuel liner to control the pressure inside the fuel liner. In one example, the fuel inside the fuel liner is methanol, and the fuel between the outer casing and the fuel liner is methanol or methanol gel.

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(71) Applicant (for all designated States except US): **SOCIETE BIC** [FR/FR]; 14 Rue Jeanne D'asnieres, F-92611 Clichy Cedex (FR).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **ADAMS, Paul** [US/US]; 21 Perry Drive, Monroe, CT 06468 (US). **CURELLO, Andrew, J.** [US/US]; 15 Eramo Terrace, Hamden, CT 06518 (US). **FAIRBANKS, Floyd** [US/US]; 103 Birch Lane, Naugatuck, CT 06770 (US). **STEPAN, Constance, R.** [US/US]; 16 Krystalle Lane, Oxford, CT 06478 (US).

(74) Agent: **THAN, H., T.**; THE H.T. THAN LAW GROUP, 1010 WISCONSIN AVENUE, N.W., Suite 560, Washington, DC 20007 (US).

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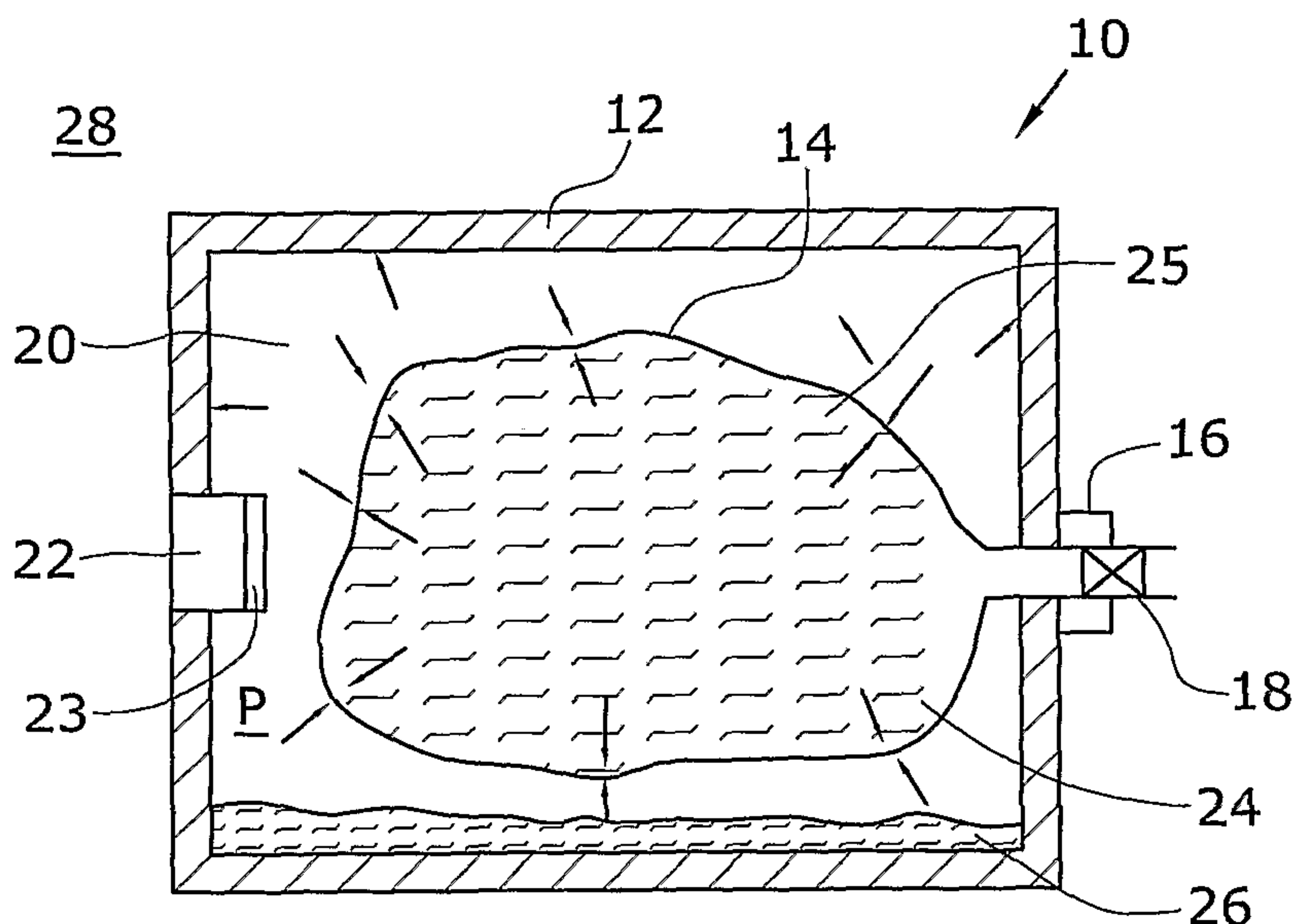
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(54) Title: FUEL CARTRIDGE OF A FUEL CELL WITH FUEL STORED OUTSIDE FUEL LINER



(57) Abstract: A fuel supply (10) connectable to a fuel cell is disclosed. The fuel supply comprises an outer casing (12) and a fuel liner (14) and an effective amount of fuel (26) in the space (20) between the outer casing and the fuel liner to control the pressure inside the fuel liner. In one example, the fuel inside the fuel liner is methanol, and the fuel between the outer casing and the fuel liner is methanol or methanol gel.

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**FUEL CARTRIDGE OF A FUEL CELL WITH FUEL  
STORED OUTSIDE FUEL LINER**

**FIELD OF THE INVENTION**

5           This invention generally relates to fuel cartridges for fuel cells, and more particularly this invention relates to fuel supplies having an outer casing and an inner fuel container, wherein a fuel is stored between the casing and the fuel container.

**BACKGROUND OF THE INVENTION**

10           Fuel cells are devices that directly convert chemical energy of reactants, *i.e.*, fuel and oxidant, into direct current (DC) electricity. For a number of applications, fuel cells can be more efficient than conventional power generation, such as combustion of fossil fuel, and more efficient than portable power storage, such as lithium-ion batteries.

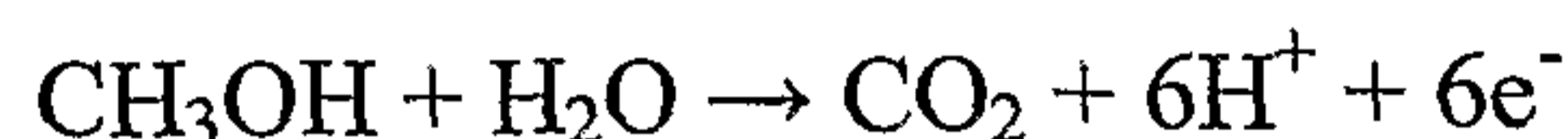
          In general, fuel cell technologies include a variety of different fuel cells, such as alkali  
15 fuel cells, polymer electrolyte fuel cells, phosphoric acid fuel cells, molten carbonate fuel cells, solid oxide fuel cells and enzyme fuel cells. Today's more important fuel cells can be divided into several general categories, namely (i) fuel cells utilizing compressed hydrogen (H<sub>2</sub>) as fuel; (ii) proton exchange membrane (PEM) fuel cells that use alcohols, *e.g.*, methanol (CH<sub>3</sub>OH), metal hydrides, *e.g.*, sodium borohydride (NaBH<sub>4</sub>), hydrocarbons, or other fuels  
20 reformed into hydrogen fuel; (iii) PEM fuel cells that can consume non-hydrogen fuel directly or direct oxidation fuel cells; and (iv) solid oxide fuel cells (SOFC) that directly convert hydrocarbon fuels to electricity at high temperature.

          Compressed hydrogen is generally kept under high pressure and is therefore difficult to handle. Furthermore, large storage tanks are typically required and cannot be made sufficiently  
25 small for consumer electronic devices. Conventional reformat fuel cells require reformers and other vaporization and auxiliary systems to convert fuels to hydrogen to react with oxidant in the fuel cell. Recent advances make reformer or reformat fuel cells promising for consumer electronic devices. The most common direct oxidation fuel cells are direct methanol fuel cells or DMFC. Other direct oxidation fuel cells include direct ethanol fuel cells and direct  
30 tetramethyl orthocarbonate fuel cells. Solid oxide fuel cells (SOFC) convert hydrocarbon fuels,

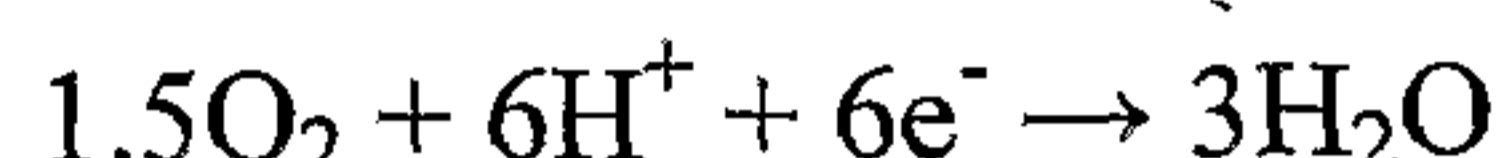
such as butane, at high heat to produce electricity. SOFC requires relatively high temperature in the range of 1000°C for the fuel cell reaction to occur.

The chemical reactions that produce electricity are different for each type of fuel cell. For DMFC, the chemical-electrical reaction at each electrode and the overall reaction for a  
5 direct methanol fuel cell are described as follows:

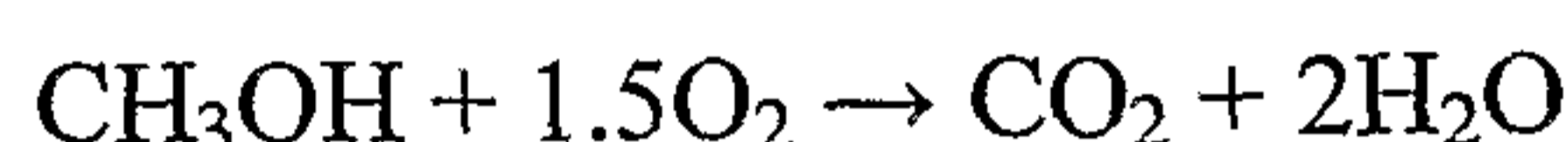
Half-reaction at the anode:



Half-reaction at the cathode:



10 The overall fuel cell reaction:



Due to the migration of the hydrogen ions ( $\text{H}^+$ ) through the PEM from the anode to the cathode and due to the inability of the free electrons ( $\text{e}^-$ ) to pass through the PEM, the electrons  
15 flow through an external circuit, thereby producing an electrical current through the external circuit. The external circuit may be used to power many useful consumer electronic devices, such as mobile or cell phones, calculators, personal digital assistants, laptop computers, and power tools, among others.

DMFC is discussed in United States patent nos. 5,992,008 and 5,945,231, which are incorporated herein by reference in their entireties. Generally, the PEM is made from a  
20 polymer, such as Nafion® available from DuPont, which is a perfluorinated sulfonic acid polymer having a thickness in the range of about 0.05 mm to about 0.50 mm, or other suitable membranes. The anode is typically made from a Teflonized carbon paper support with a thin layer of catalyst, such as platinum-ruthenium, deposited thereon. The cathode is typically a gas diffusion electrode in which platinum particles are bonded to one side of the membrane.

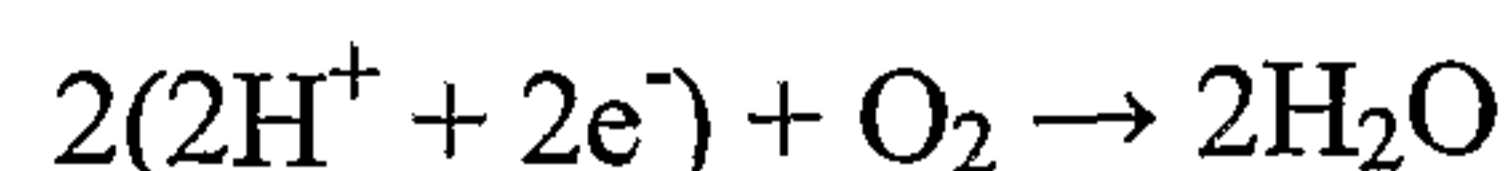
25 Another fuel cell reaction for a metal hydride, such as sodium borohydride, reformer fuel cell is as follows:



Half-reaction at the anode:



30 Half-reaction at the cathode:



Suitable catalysts for this reaction include platinum and ruthenium, and other metals. The hydrogen fuel produced from reforming sodium borohydride is reacted in the fuel cell with an oxidant, such as O<sub>2</sub>, to create electricity (or a flow of electrons) and water byproduct. Sodium borate (NaBO<sub>2</sub>) byproduct is also produced by the reforming process. A sodium borohydride fuel cell is discussed in United States patent no. 4,261,956, which is incorporated herein by reference.

One of the important features for fuel cell application is fuel storage. The fuel supply should also be easily inserted into the fuel cell or the electronic device that the fuel cell powers. Additionally, the fuel supply should also be easily replaceable or refillable. When a liquid fuel such as methanol is stored in the fuel supply or in a fuel liner within the fuel supply, pressure builds within. There remains a need for a fuel supply where the pressure on the fuel liner is equalized to reduce the stress placed on the fuel liner.

### **SUMMARY OF THE INVENTION**

The invention is directed to a fuel supply connectable to a fuel cell comprising at least an outer casing and an inner fuel container storing fuel for the fuel cell. An amount of fuel is added between the outer casing and the inner fuel container to control the pressure inside the fuel supply. The fuel supply can further comprise a check valve disposed on the outer casing that can regulate the pressure in the space between the outer casing and the inner fuel container. The fuel between the outer casing and the inner fuel container serves as a barrier or buffer zone to minimize the permeation of fuel from the inner fuel container to the atmosphere. This fuel also vaporizes at substantially the same rate as the fuel inside the inner fuel container, so that the fuel vapor pressure inside the inner fuel container is substantially the same as the fuel vapor pressure in the space between the outer casing and the inner fuel container.

In one preferred embodiment, the outer casing is more rigid than the inner fuel container and provides structure to the fuel supply. Preferably, the inner fuel container is flexible or deformable. The fuel contained between the outer casing and the inner fuel container is preferably chemically similar to the fuel inside the inner fuel container and, more preferably, substantially the same. In one example, the fuel inside the fuel container is methanol and the fuel between the outer casing and inner fuel container is methanol or a fuel

similar to methanol, such as ethanol, propanol and other alcohols, in liquid, gaseous or gel form.

The fuel supply may further comprise an outer fuel container encasing the inner fuel container, and the space between the outer fuel container and inner fuel container may be filled  
5 with another fuel similar to the fuel contained inside the inner fuel container. The outer fuel container can be relatively rigid or flexible.

In a different embodiment, the invention is directed to a method of controlling the pressure inside a fuel cartridge, comprising the steps of (a) providing a fuel cartridge comprising an outer casing and an inner fuel container, (b) filling the inner fuel container with  
10 a first fuel, and (c) filling the space between the outer casing and the fuel container with a second fuel to control the pressure inside the fuel supply. The method may further comprise the steps of (d) providing a check valve on the outer casing and/or (e) providing an outer fuel container encasing the inner fuel container and filling the space between the outer and inner fuel containers with a third fuel.

15 Other methods of controlling the permeation rate to and from the fuel supply are also disclosed.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1A is a cross-sectional view of a fuel cartridge having fuel outside of the fuel liner,  
20 when the fuel liner is relatively full of fuel;

FIG. 1B shows the fuel cartridge of FIG.1A when the fuel liner contains a relatively small amount of fuel;

FIG. 1C shows another embodiment of FIG. 1A with cushions holding the fuel outside of the fuel liner;

25 FIG. 2 is a longitudinal cross-sectional view of a fuel cartridge having a gel containing fuel outside of the fuel liner;

FIG. 3 is a longitudinal cross-sectional view of a fuel cartridge having an outer liner containing methanol, and an inner liner as fuel liner;

FIG. 4A is a perspective view of another embodiment of the present invention; and

30 FIG. 4B is a cross-sectional view of the fuel cartridge of FIG. 4A.

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**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

As illustrated in the accompanying drawings and discussed in detail below, the present invention is directed to a fuel supply, which stores fuel cell fuels such as methanol and water, methanol/water mixture, methanol/water mixtures of varying concentrations or pure methanol. Methanol is usable in many types of fuel cells, *e.g.*, DMFC, enzyme fuel cells and reformat fuel cells, among others. The fuel supply may contain other types of fuel cell fuels, such as ethanol or alcohols, metal hydrides, such as sodium borohydrides, other chemicals that can be reformatted into hydrogen, or other chemicals that may improve the performance or efficiency of fuel cells. Fuels also include potassium hydroxide (KOH) electrolyte, which is usable with metal fuel cells or alkali fuel cells, and can be stored in fuel supplies. For metal fuel cells, fuel is in the form of fluid-borne zinc particles immersed in a KOH electrolytic reaction solution, and the anodes within the cell cavities are particulate anodes formed of the zinc particles. KOH electrolytic solution is disclosed in United States published patent application no. 2003/0077493, entitled "Method of Using Fuel Cell System Configured to Provide Power to One or more Loads," published on April 24, 2003. Fuels also include a mixture of methanol, hydrogen peroxide and sulfuric acid, which flows past a catalyst formed on silicon chips to create a fuel cell reaction. Fuels also include a blend or mixture of methanol, sodium borohydride, an electrolyte and other compounds, such as those described in United States patent numbers 6,554,877; 6,562,497 and 6,758,871. Fuels also include those that are partially dissolved in solvent and partially suspended in solvent, described in United States patent number 6,773,470 and those that include both liquid fuel and solid fuels, described in United States published patent application number 2002/076602.

Fuels also include a metal hydride such as sodium borohydride ( $\text{NaBH}_4$ ) and water, discussed above, and the low pressure, low temperature produced by such reaction. Fuels further include hydrocarbon fuels, which include, but are not limited to, butane, kerosene, alcohol and natural gas, disclosed in United States published patent application no. 2003/0096150, entitled "Liquid Hetero-Interface Fuel Cell Device," published on May 22, 2003. Fuels also include liquid oxidants that react with fuels. The present invention is, therefore, not limited to any type of

fuels, electrolytic solutions, oxidant solutions or liquids or solids contained in the supply or otherwise used by the fuel cell system. The term "fuel" as used herein includes all fuels that can be reacted in fuel cells or in the fuel supply, and includes, but is not limited to, all of the above suitable fuels, electrolytic solutions, oxidant solutions, gaseous, liquids, solids and/or  
5 chemicals and mixtures thereof.

As used herein, the term "fuel supply" includes, but is not limited to, disposable cartridges, refillable/reusable cartridges, containers, cartridges that reside inside the electronic device, removable cartridges, cartridges that are outside of the electronic device, fuel tanks, fuel refilling tanks, other containers that store fuel and the tubings connected to the fuel tanks  
10 and containers. While a cartridge is described below in conjunction with the exemplary embodiments of the present invention, it is noted that these embodiments are also applicable to other fuel supplies and the present invention is not limited to any particular type of fuel supplies.

The fuel supply of the present invention can also be used to store fuels that are not used  
15 in fuel cells. These applications include, but are not limited to, storing hydrocarbons and hydrogen fuels for micro gas-turbine engine built on silicon chips, discussed in "Here Come the Microengines," published in The Industrial Physicist (Dec. 2001/Jan. 2002), at pp. 20-25. As used in the present application, the term "fuel cell" also includes microengines. Other applications include storing traditional fuels for internal combustion engines, and  
20 hydrocarbons, such as butane for pocket and utility lighters and liquid propane.

When a liquid fuel, such as methanol, is stored in a fuel container, pressure builds within the container over time. The internal pressure can be caused by a number of factors including partial vapor pressure from the fuel in the gaseous state.

Referring to FIGS. 1A and 1B, fuel cartridge 10 comprises an outer casing 12 and a fuel  
25 liner 14 disposed within outer casing 12. Fuel cartridge 10 further comprises a nozzle 16 that houses a shut-off valve 18, which fluidly connects fuel liner 14 to a fuel cell (not shown). A space 20 is defined to be the space between outer casing 12 and fuel liner 14. Fuel cartridge 10 further comprises a check valve 22 which is adapted to open when internal pressure inside space 20 reaches a high threshold or a low threshold. Fuel liner 14 contains a fuel 24, such as  
30 methanol, and a head space 25 above the liquid fuel, shown most clearly in FIG. 1B. Head space 25 may be present after fuel liner 14 is filled with fuel or may develop after fuel is

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transported out of fuel liner 14. Head space 25 is typically formed when part of the fuel vaporizes. Between outer casing 12 and fuel liner 14, an amount of fuel 26 is positioned to control the pressure in space 20. Fuel 26 can be introduced before, during or after the process of scaling the outer casing 12. Alternatively, fuel 26 can be added or removed through check  
5 valve 22. Fuel 26 also vaporizes or contributes to the vapor pressure in space 20. Fuel 26 can be deposited directly in space 20, or fuel 26 can be stored at least partially in an absorbent member, such as a foam, a filler material or other porous materials.

Outer casing 12 is preferably rigid, but can also be sufficiently flexible to be compressed along with inner liner 14, as fuel is transported from the cartridge. A rigid outer  
10 casing can provide structural support to fuel liner 14. Outer casing 12 is preferably made from metals, such as stainless steel and cold rolled steel, or polymers, such as polyacetal resin or polyphenylene sulfide, which can be injection molded or extruded.

Fuel liner 14 is preferably flexible and deformable, such that the volume inside fuel liner 14 decreases when fuel is being transported to the fuel cell. More preferably, fuel liner 14  
15 is thin and made from a durable and flexible material so that it efficiently collapses or reduces its volume as fuel is withdrawn. Examples of materials for the fuel liner 14 include natural rubber, polyethylene (including low density to high density PE), ethylene propylene (EP), EPDM and other thin polymeric films. Preferably the polyethylene is fluorine based and substantially free of metal ions to ensure low permeation. The polyethylene can be laminated  
20 with a vapor barrier layer, such as aluminum foil or fluorine treated plastics, to reduce methanol permeation. Preferably, fuel liner 14 is made from a low density polyethylene and is blow-molded to form a thin-wall bladder. Such a fuel liner and outer casing are fully disclosed in commonly owned, U.S. patent no. 7,172,825 entitled "Fuel Cartridge with Flexible Liner,".

Nozzle 16 and shut-off valve 18 are adapted to be connected to a fuel cell (not shown)  
25 or to a refilling fuel container/cartridge/supply. Shut-off valves are fully discussed in commonly owned, issued U.S. patent no. 7,537,024 entitled "Fuel Cartridge with Connecting Valve,". Shut-off valve 18 can also be replaced by a porous material capable of transporting fuel through capillary or wicking action.

Check valve 22 is preferably a unidirectional relief valve commonly known as a poppet  
30 valve or poppet-type valve. Suitable check valves are disclosed in the '004 patent application. Check valve 22 allows air to enter space 20 intermittently to prevent buildup of a partial

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vacuum inside the fuel cartridge 10, as fuel is withdrawn from the cartridge. Alternatively, check valve 22 may be configured in an opposite direction to allow pressure within space 20 to be vented to the atmosphere. Additionally, check valve 22 also may be adapted to allow methanol to be added to or removed from the cartridge.

5            Preferably, check valve 22 is used in conjunction with optional membrane 23, which is adapted to allow only air or other gases to enter or leave the cartridge and keep liquid from entering or leaving the cartridge. Such a gas permeable, liquid impermeable membrane is disclosed in commonly owned, co-pending patent application serial no. 10/356,793, entitled  
10            "Fuel Cartridge for Fuel Cells," filed on January 31, 2003; in United States patent no. 3,508,708, entitled "Electric Cell with Gas Permeable Vent Stopper," issued on April 21, 1970; and in United States patent no. 4,562,123, entitled "Liquid Fuel Cell," issued on December 31, 1985. Such membranes can be made from polytetrafluoroethylene (PTFE), nylon, polyamides, polyvinylidene, polypropylene, polyethylene or other polymeric membrane. A commercially available hydrophobic PTFE microporous membrane can be obtained from W.L.  
15            Gore Associates, Inc. Gore-Tex® is a suitable membrane. Gore-Tex® is a microporous membrane containing pores that are too small for liquid to pass through, but are large enough to let gas through.

             Membrane 23 can be replaced by filler materials, such as those disclosed in the '793 patent application. As used herein, filler materials include foam and similarly absorbent  
20            materials. Filler materials retain liquids and allow gases to pass through. A suitable filler material is the absorbent material used in diapers. Preferably, these filler materials also swell when absorbing liquid, and become less permeable to liquid. Membrane or filler 23 can also be positioned proximate to nozzle 16 or valve 18 or other orifices to retain fuel 26 within casing  
12.

25

Cartridge 10 may also have one or more cushions 27, which can be porous or which can have methanol or fuel retaining mechanism contained therein, that line the interior surface of outer casing 12, as shown in FIG. 1C. Cushions 27 may include springs. Cushions 27 are adapted to cushion fuel liner 14 from impacts. Cushions 27 can be elastic or deformable. In one embodiment, cushion 27 can be porous and adapted to hold fuel 26 therewithin.

The ideal gas laws generally govern the pressure buildup inside fuel liner 14. Boyle's law states that at constant temperature, the volume of a gas varies inversely with the pressure. Charles' law states that at constant pressure, the volume of a gas varies directly with the absolute temperature and that at constant volume, the pressure of a gas varies directly with the absolute temperature. Dalton's law states that the total pressure of a mixture of gases is equal to the sum of the partial pressures due to each type of gas. Without being limited to any theory, Dalton's law will be used to describe the invention.

When fuel liner 14 is relatively full of fuel as shown in FIG. 1A, the total pressure ( $P_{\text{total-25-A}}$ ) of head space 25 is equal to the sum of the partial pressure of methanol gas ( $P_{\text{methanol-25-A}}$ ) from fuel 24 and the partial pressure of the other gases, including air ( $P_{\text{gas-25-A}}$ ).

$$P_{\text{total-25-A}} = P_{\text{methanol-25-A}} + P_{\text{gas-25-A}}$$

Also, when the fuel liner is relatively full of fuel, the total pressure ( $P_{\text{total-20-A}}$ ) of the space 20 is equal to the sum of the partial pressure of methanol gas ( $P_{\text{methanol-20-A}}$ ) from the small amount of fuel 26 in space 20 and the partial pressure of the other gases, including air ( $P_{\text{air-20-A}}$ ):

$$P_{\text{total-20-A}} = P_{\text{methanol-20-A}} + P_{\text{air-20-A}}$$

When fuel liner 14 is partially empty as shown in FIG. 1B, fuel liner 14 is in a partially collapsed stage. Under some circumstances, *e.g.*, when the partially empty fuel liner is left unused for a long period of time, the vapor pressure in head space 25 can build up. As such, the total pressure ( $P_{\text{total-25-B}}$ ) of head space 25 is equal to the sum of the partial pressure of methanol ( $P_{\text{methanol-25-B}}$ ) and the partial pressure of other gases ( $P_{\text{gas-25-B}}$ ).

$$P_{\text{total-25-B}} = P_{\text{methanol-25-B}} + P_{\text{gas-25-B}}$$

Also, when fuel liner 14 is partially empty, the total pressure ( $P_{\text{total-20-B}}$ ) of space 20 is equal to the sum of the partial pressure of methanol ( $P_{\text{methanol-20-B}}$ ) and the partial pressure of the air or other gases ( $P_{\text{air-20-B}}$ ):

$$P_{\text{total-20-B}} = P_{\text{methanol-20-B}} + P_{\text{air-20-B}}$$

At any given time, the total pressure of space 20 is equal to the total pressure of head space 25, because space 20 and head space 25 are at substantially the same temperature. Space 20 and head space 25 are also at substantially the same pressure, because they are separated only by flexible liner 14. Therefore:

$$\begin{array}{l}
 5 \quad P_{\text{total-25-A}} \quad = \quad P_{\text{total-20-A}}, \quad \text{and} \\
 \quad P_{\text{total-25-B}} \quad = \quad P_{\text{total-20-B}}
 \end{array}$$

According to another aspect of the present invention, the amount of methanol 26 placed in space 20 should be sufficient so that at least a portion of methanol 26 remains in the liquid phase. This is to ensure that as the volume of methanol 24 inside fuel liner 14 decreases, sufficient gas can evaporate from methanol 26 to replace the lost volume. Hence, the placement of methanol in space 20 and the subsequent vaporization of this fuel create a pressure in space 20 that is substantially similar to the vapor pressure inside fuel liner 14 in head space 25. Hence, the pressure inside cartridge 10 is in equilibrium, and any internal pressure build-up inside fuel liner 14 is counteracted by substantially the same pressure in space 20. If the amount of methanol 26 is not sufficient to maintain some of the methanol 26 in the liquid phase, then the pressure in fuel liner 24 may be higher than the pressure in space 20.

In accordance with another aspect of the present invention, the presence of methanol vapors in space 20 serves as a buffer zone that minimizes methanol 24 from leaving fuel liner 14. One of the reasons that methanol 24 inside fuel liner 14 migrates outside of the fuel liner is that a methanol gradient exists from the relatively high methanol vapor concentration within fuel liner 14 to the relatively low methanol vapor concentration in the atmosphere outside of cartridge 10, labeled as 28. By having a methanol concentration in space 20, the migration of methanol now includes the migration from space 20 to atmosphere 28 and from head space 25 to space 20, thereby reducing the migration rate from head space 25 to atmosphere 28. Additionally, the walls of outer casing 12 can be made from a low permeation material, such as metal, for example stainless steel, cold rolled steel or aluminum, or polyacetal, for example, Delrin®. These walls can also be made thicker and/or be coated, lined or wrapped with low permeation materials. Such coatings and wraps are fully disclosed in commonly owned, co-pending application serial no. 10/913,715, entitled "Fuel Supplies for Fuel Cells," filed on August 6, 2004. This application is incorporated herein by reference in its entirety. In essence, the methanol vapors in space 20 serve as a barrier that can reduce the permeation effects.

Furthermore, the invention allows for the regulation of pressure when temperature of fuel cartridge 10 varies from hot to cold. While an increase in the temperature increases the partial pressures of gases in space 20, the temperature increase also increases the partial pressure in head space 25 to maintain pressure equilibrium inside fuel cartridge 10.

5 Referring to FIG. 2, a fuel cartridge 30 comprises, among other components, a methanol gel 32 used in space 20 between an outer casing 12 and a fuel liner 14. Otherwise, the components of fuel cartridge 30 are similar to those described in FIGS. 1A and 1B.

Methanol gel is available from a variety of sources, such as from widely available food warming products. Methanol gel can be formulated from denatured methanol, water and gel.  
10 Methanol gel is normally used as a source of methanol inside small burners to keep coffee urns and food containers warm in restaurants and banquet halls. Because methanol gel burns smoothly and safely, it is a convenient source of fuel in the restaurant industry. An effective amount of methanol gel 32 can be placed inside outer casing 12 to generate an effective amount of partial pressure of methanol to counteract the pressure buildup inside the fuel liner 14.

15 Referring to FIG. 3, a fuel cartridge 40 comprises an outer fuel liner 60 and an inner fuel liner 44 containing a fuel 54. An outer fuel liner 60 encases inner fuel liner 44. In space 63 between outer fuel liner 60 and inner fuel liner 44, there is an effective amount of methanol 62 to control the pressure inside inner fuel liner 44, which does so in a manner similar to the embodiment described above with respect to FIGS. 1A-C. This embodiment is otherwise  
20 substantially similar to the embodiment described above with respect to FIGS. 1A-C. Fuel cartridge 40 further comprises an optional nozzle 64 that houses an optional check valve 66, which is in fluid communication with space 63 between outer fuel liner 60 and inner fuel liner 44. An additional amount of methanol can also be positioned in space 50 between an outer casing 12 and outer fuel liner 60 to provide an additional buffer, similar to the buffer described  
25 above with respect to FIGS. 1A-C.

It will be noted that while methanol (24, 26, 54, 62) is used herein to describe the present invention, this invention is not so limited. The present invention is suited for use with any fuel that may develop partial vapor pressure inside the fuel supply, *e.g.*, methanol, ethanol, propanol, hydrocarbons (butane, propane, etc.). Additionally, fuel 24, 54 inside fuel liner 14,  
30 44 can be different from fuel 26, 62 inside space 20, 50, 63, so long as the vapors created by the fuels have reduced partial pressure profiles between the two chambers. For example, if fuel

24, 54 is methanol then the fuel positioned inside space 20, 50, 63 can be methanol, ethanol, propanol or other alcohols. If fuel 24, 54 is a hydrocarbon, then fuel 26, 62 inside space 20, 50, 63 should be the same hydrocarbon or another hydrocarbon.

In accordance with another aspect of the present invention, fuel 26, 62 in space 20, 50, 63 can be replaced by any substance that can provide positive vapor pressure at the temperature and pressure within which cartridge 10, 30, 40 operates. In other words, fuel 26, 62 can be replaced by any substance that is capable of providing a "positive" pressure in space 20, 50, 63 that is higher than the pressure provided by ambient air that occupies space 20, 50, 63 after fuel cartridge 10, 30, 40 is manufactured. This residual air cannot sufficiently expand to occupy the space of the fuel withdrawn from fuel liner 14, 44 during use. Such substance includes liquids and solids that change to gases (sublimation) or change to liquids and then gases. Exemplary subliming solids include, but are not limited to, dry ice (CO<sub>2</sub>), iodine crystals and naphthalene (moth balls), among others. Suitable liquids include, but are not limited to, water, methane and hydrocarbons. Gels, such as methanol gels discussed above, can also be used.

In accordance with another aspect of the present invention, another fuel 26, 62 is placed in space 20, 50, 63 to pressurize cartridge 10, 30, 40. Suitable fuels include, but are not limited to, hydrocarbons in liquid and gaseous phases, such as n-butane, iso-butane and propane. The inventors of the present invention have discovered that so long as some portion of fuel 26, 62, albeit very small, remains in the liquid phase, then the pressure in space 20, 50, 63 is steady at about 30 psi at room temperature. This provides a convenient way to maintain positive pressure on fuel liner 14, 44.

Another advantage of the present invention is that once fuel liner 14, 44 is substantially emptied, the residual fuel 24, 54 therein would not re-inflate fuel liner 14, 44 to the equalizing pressure in space 20, 50, 63.

In another embodiment of the present invention, outer casing 12 is made from a metal such as stainless steel, aluminum, tin or any metals that can be made into a can or made from any known polymers, as shown in FIG. 4A. The inside surface of outer casing 12 is preferably smooth with a smoothness similar to that of polished sheet metals. The outer surface of liner 14 is similarly smooth. When the two smooth surfaces come into contact with each other as illustrated in FIG. 4B, it was observed that the two contacting smooth surfaces reduce the permeation rate of gas into and out of liner 14. Preferably, the volume of liner 14 when fully

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filled is slightly larger than the volume of outer casing 12 to encourage contact between the smooth outer surface of the liner and the smooth inner surface of the casing. Even when the fuel in liner 14 is partially depleted, the permeated air and/or fuel vapors occupy the volume of the used fuel to inflate fuel liner 14 into contact with the smooth inside surface of outer casing 12 to halt or reduce further permeation.

The shape of casing 12 and liner 14 is preferably round, *i.e.*, without sharp corners, such as oval or circular prisms or cylinders. In one embodiment as illustrated in FIGS. 4A and 4B, casing 12 is a cylindrical can with raised protruding lip 70 on at least the top end. Height "A" of raised protruding lip 70 is preferably greater than the height of conventional cans, *e.g.*, cans containing food, so that conventional can openers would not be able to open casing 12. In one example, height "A" is at least about 0.5 cm. Casing 12 may also have protruding bead 72 around the outside of lip 70 as shown. Protruding bead 72 makes more difficult for conventional can openers to wrap around lip 70. Protruding bead 72 can also be located inside lip 70, and can be used in conjunction with a lip with conventional height. Furthermore, casing 12 may also have upstanding protrusion 74 on the top end thereof. Protrusion 74 can block some conventional from grapping on to the lip of casing 12 and makes more difficult for conventional can openers to open casing 12. Upstanding protrusion 74 may be a single distinct upstanding member as shown in FIG. 4B, or may comprise multiple upstanding members, or be a continuous upstanding member located concentric to lip 70.

Alternatively, both ends of casing 12 have no protruding members to render more difficult the removal of the ends by conventional can openers.

From the above detailed description of the invention, the operation and construction of same should be apparent. While there are herein shown and described preferred embodiments of the invention, it is nevertheless understood that various changes may be made with respect thereto without departing from the principle and scope of the invention as measured by the claims appended hereto.

**CLAIMS**

We claim:

1. A fuel cartridge comprising:  
an outer casing;  
a flexible fuel container comprising a first fuel for a fuel cell and a first head space, wherein the first head space comprises an amount of the first fuel in a first vapor state with a first vapor pressure and the first head space has a total pressure  $P_1$ ; and  
a second space, between the outer casing and the fuel container, comprising a non-gaseous material, wherein the second space comprises an amount of the non-gaseous material in a second vapor state with a second vapor pressure and the second space has a total pressure  $P_2$ , wherein  $P_1$  and  $P_2$  are substantially the same as the first fuel is transported from the fuel container.
2. The fuel cartridge of claim 1, wherein the non-gaseous material comprises a second fuel.
3. The fuel cartridge of claim 2, wherein the first fuel is different from the second fuel.
4. The fuel cartridge of claim 3, wherein the first fuel is methanol.
5. The fuel cartridge of claim 2, wherein the first fuel and the second fuel are substantially similar.
6. The fuel cartridge of claim 5, wherein the first and second fuels comprise methanol.
7. The fuel cartridge of claim 1, wherein at least a portion of the non-gaseous material is contained within an absorbent member.
8. The fuel cartridge of claim 7, wherein the absorbent member comprises a porous material.
9. The fuel cartridge of claim 7, wherein the absorbent member comprises a filler material.
10. The fuel cartridge of claim 7, wherein the absorbent member comprises a foam.
11. The fuel cartridge of claim 1, wherein the outer casing comprises a check valve.

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12. The fuel cartridge of claim 11, wherein the outer casing further comprises a liquid impermeable membrane cooperating with the check valve.
13. The fuel cartridge of claim 11, wherein the outer casing further comprises a liquid retainer cooperating with the check valve.
14. The fuel cartridge of claim 1, wherein the non-gaseous material comprises a gel.
15. The fuel cartridge of claim 14, wherein the gel comprises a methanol gel.
16. The fuel cartridge of claim 1, wherein the non-gaseous material comprises a solid.
17. The fuel cartridge of claim 16, wherein the solid comprises a subliming solid.
18. The fuel cartridge of claim 17, wherein the subliming solid comprises iodine or naphthalene.
19. The fuel cartridge of claim 1, wherein the non-gaseous material comprises a liquid.
20. The fuel cartridge of claim 19, wherein the liquid comprises water, hydrocarbon or methanol.
21. The fuel cartridge of claim 19, wherein at least a portion of the non-gaseous material remains in the liquid phase until substantially all the first fuel has been transported from the fuel container.
22. The fuel cartridge of claim 19, wherein the liquid non-gaseous material comprises a hydrocarbon.
23. The fuel cartridge of claim 22, wherein the hydrocarbon comprises n-butane, iso-butane or propane.
24. The fuel cartridge of claim 1, wherein the outer casing is substantially rigid.
25. The fuel cartridge of claim 1, wherein the fuel container is elastic.
26. The fuel cartridge of claim 1, wherein the fuel container is encased within an outer fuel container.
27. The fuel cartridge of claim 26, wherein a second vapor pressure material is contained in the space between the outer fuel container and the fuel container.

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28. The fuel cartridge of claim 27, wherein said first fuel is different from said second vapor pressure material.
29. The fuel cartridge of claim 27, wherein said first fuel is substantially similar to said second vapor pressure material.
30. The fuel cartridge of claim 27, wherein the outer fuel container is flexible.
31. The fuel cartridge of claim 1 further comprising a cushion adapted to soften impacts on the fuel container.
32. The fuel cartridge of claim 31, wherein the cushion comprises a porous medium.
33. The fuel cartridge of claim 32, wherein at least some of the non-gaseous material is contained within the cushion.
34. A fuel cartridge, comprising:  
an outer casing; and  
a flexible fuel container containing a first fuel for a fuel cell and having a first concentration of fuel, wherein a buffer zone is disposed in a space between the outer casing and the fuel container, wherein the buffer zone comprises a second concentration of a second fuel for the fuel cell that reduces the fuel concentration gradient from inside the fuel container to the atmosphere outside the outer casing.
35. The fuel cartridge of claim 34, wherein the at least a portion of the second fuel is in a vapor state.
36. The fuel cartridge of claim 35, wherein the first fuel is substantially similar to the second fuel.
37. The fuel cartridge of claim 35, wherein the first fuel is different than the second fuel.
38. The fuel cartridge of claim 34, wherein the first fuel comprises methanol.

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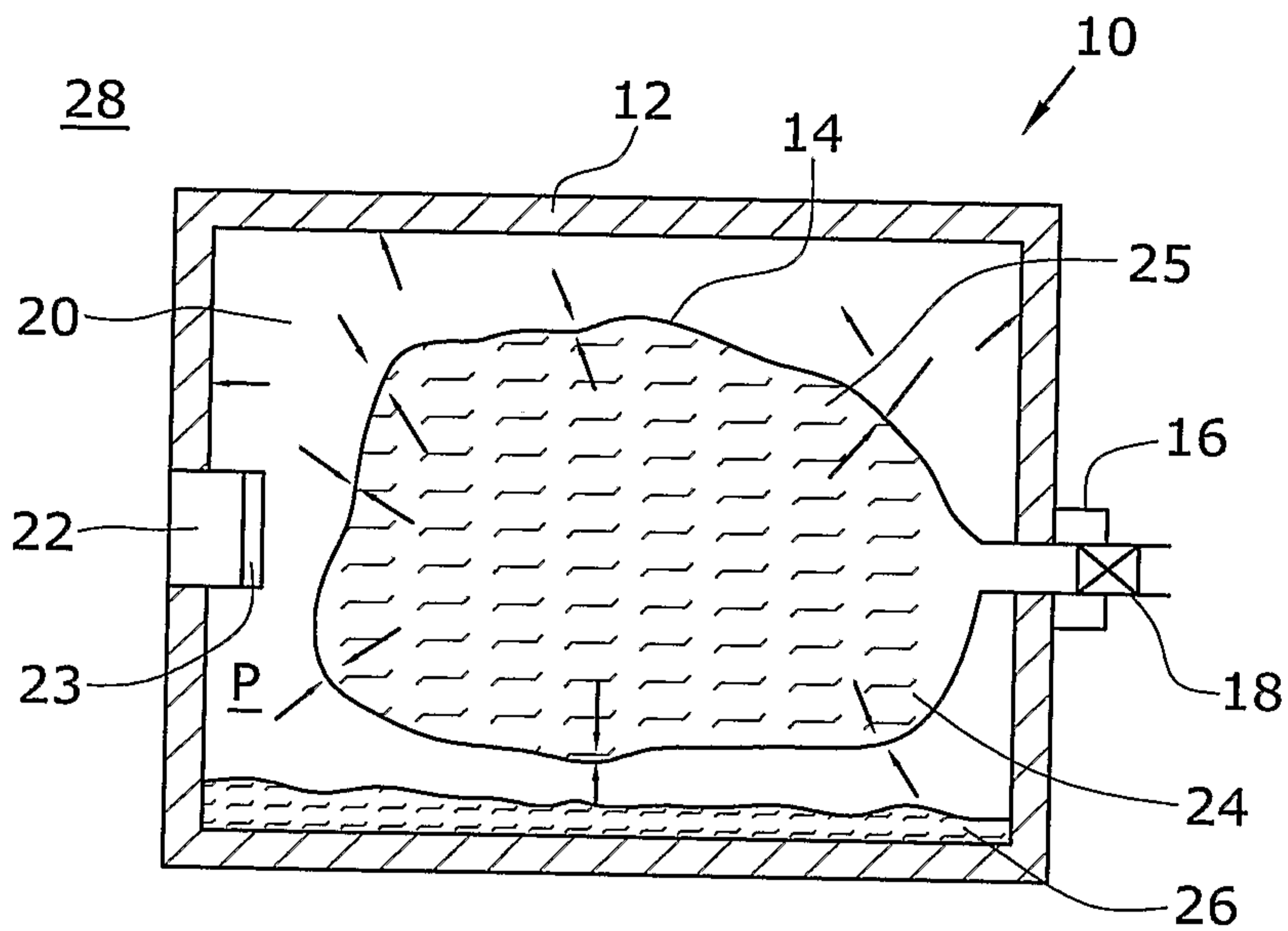


Fig. 1A

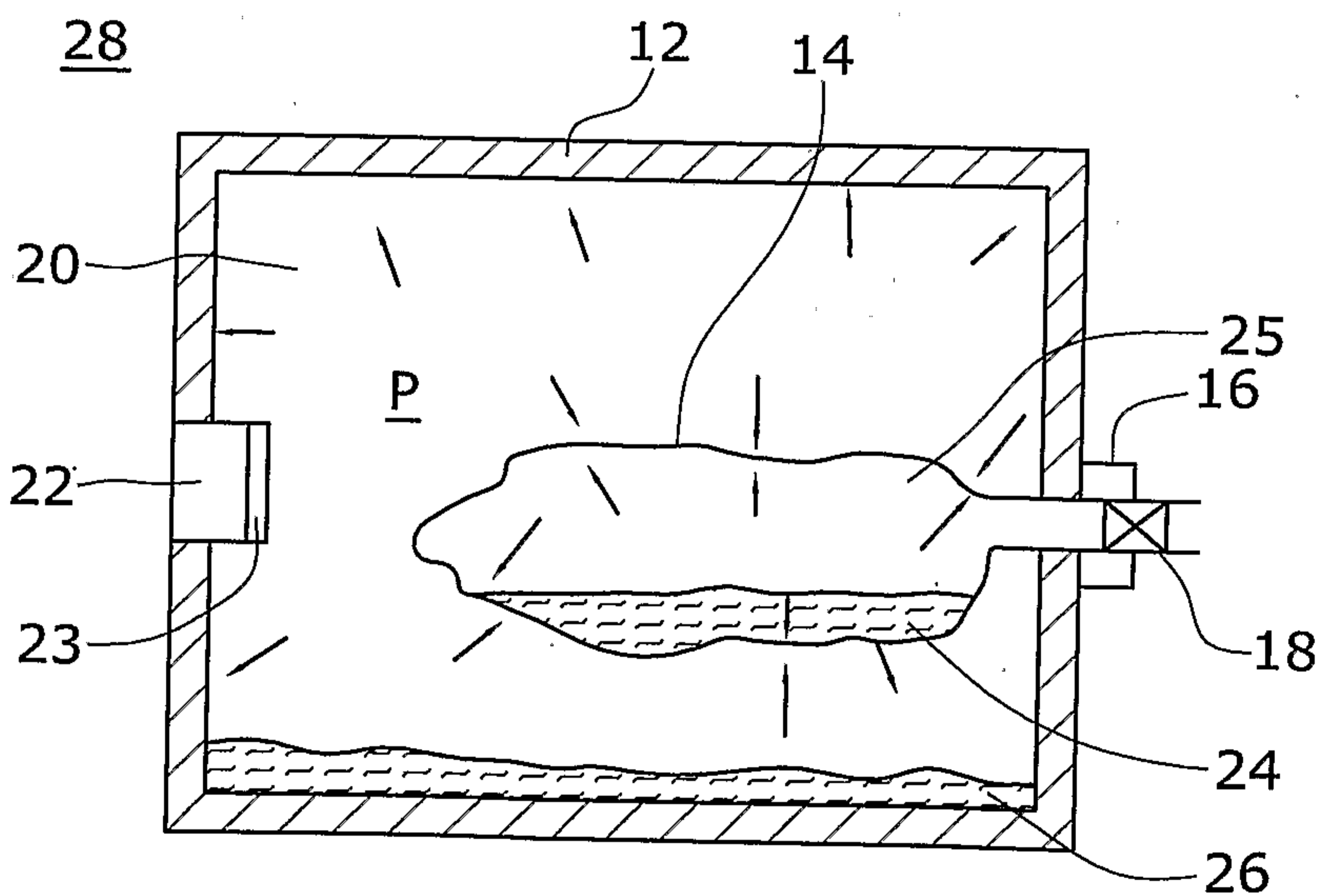


Fig. 1B

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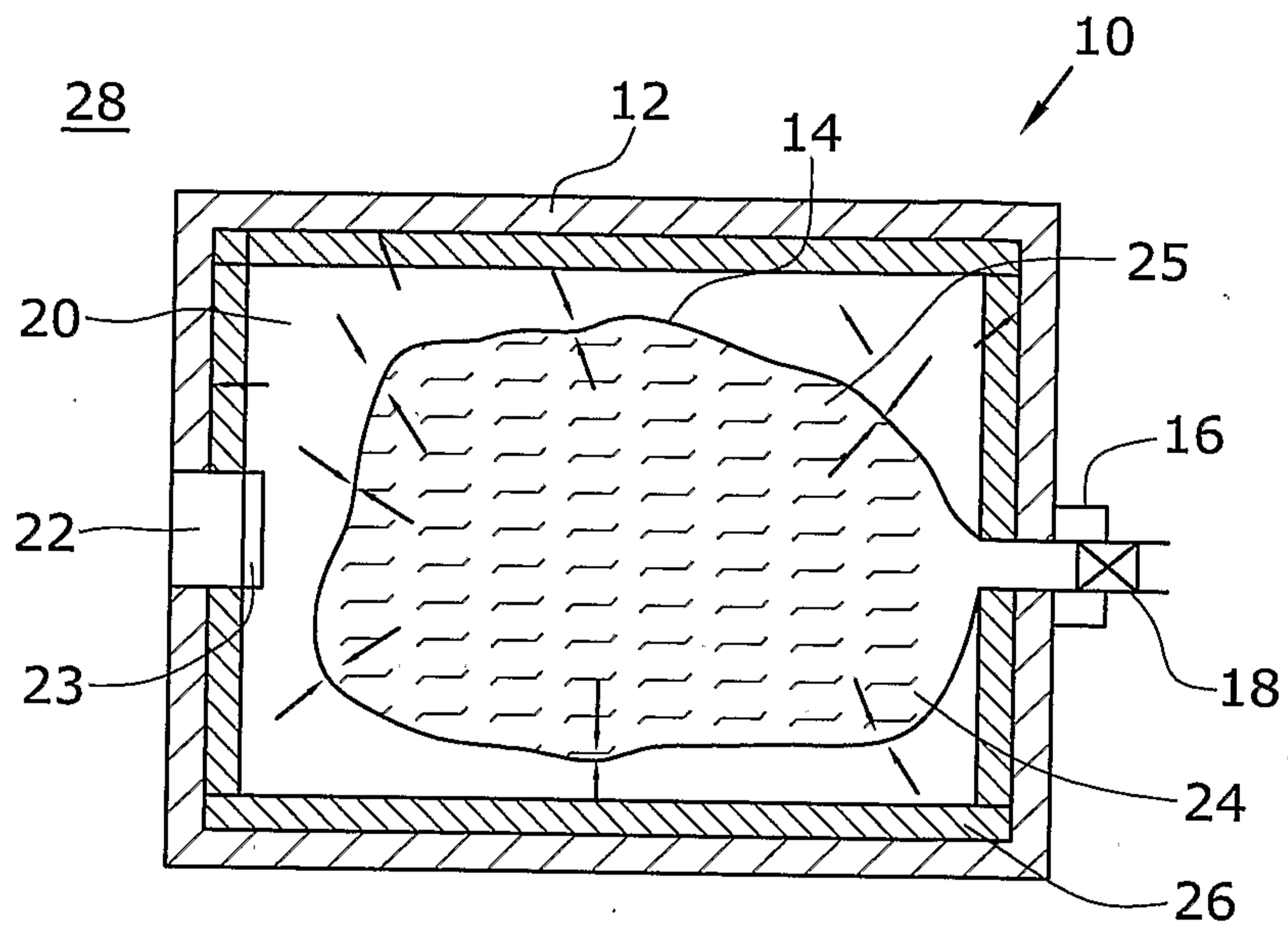


Fig. 1C

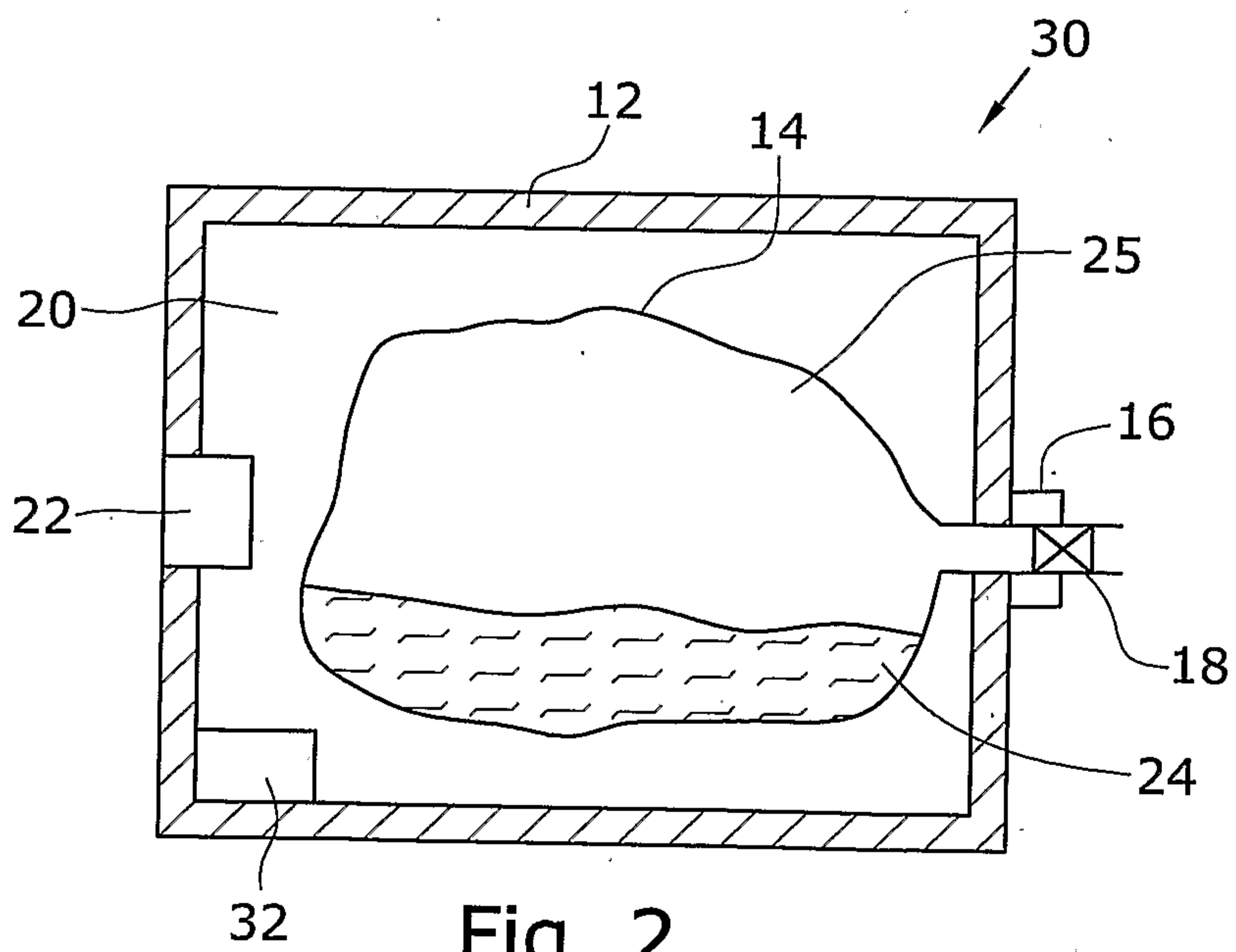


Fig. 2

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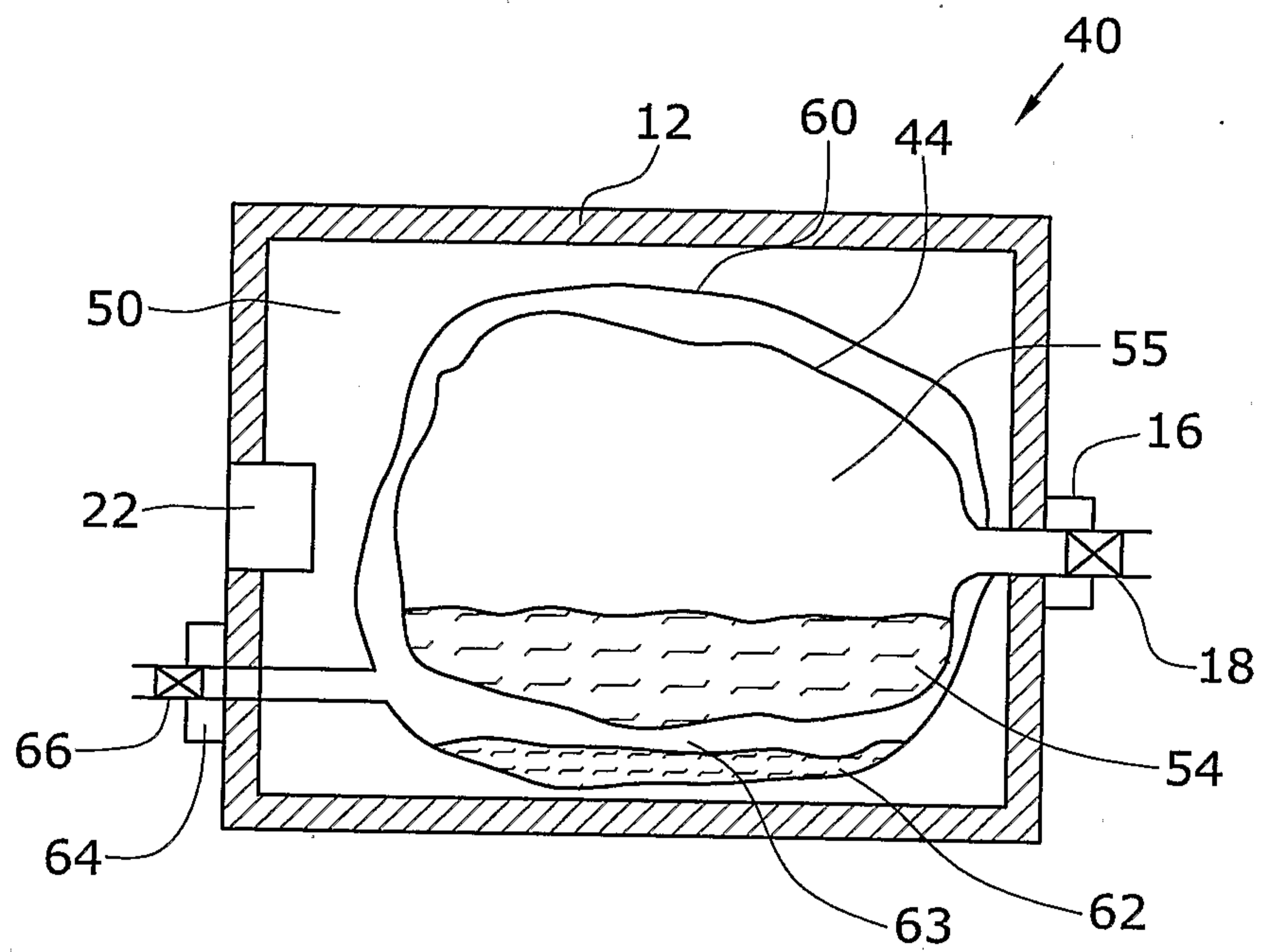


Fig. 3

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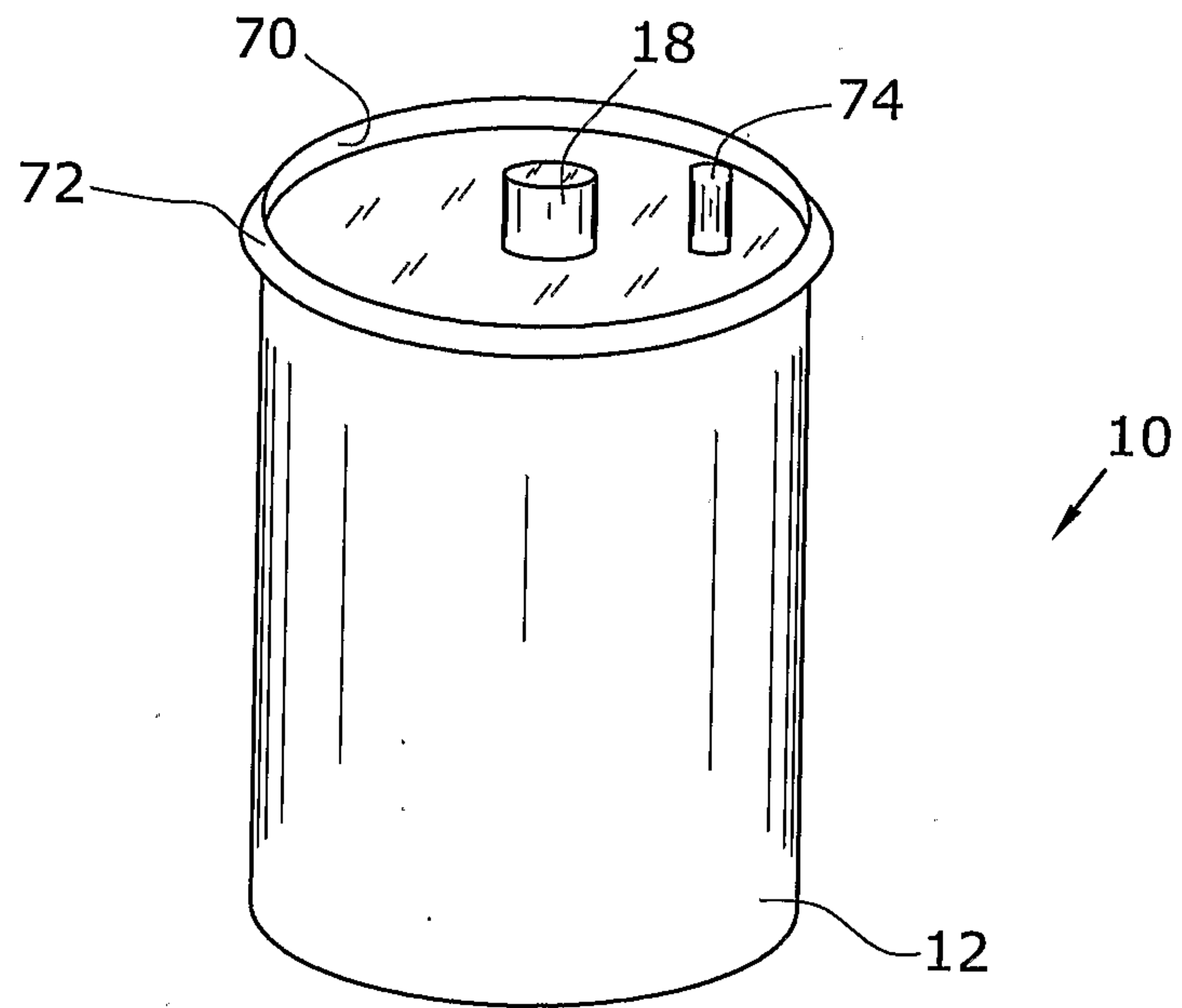


Fig. 4A

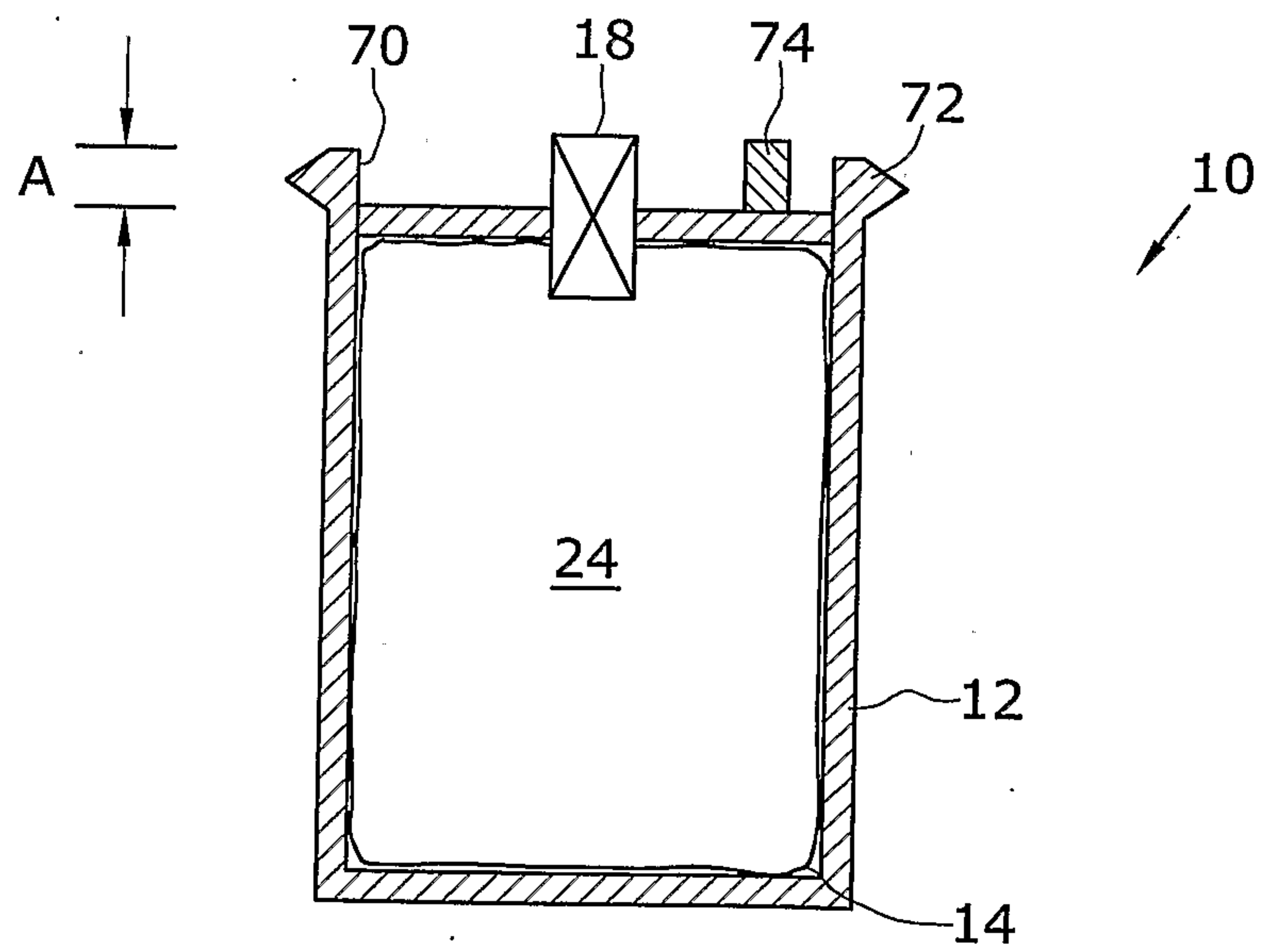


Fig. 4B

