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[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR DEOXYGENATION

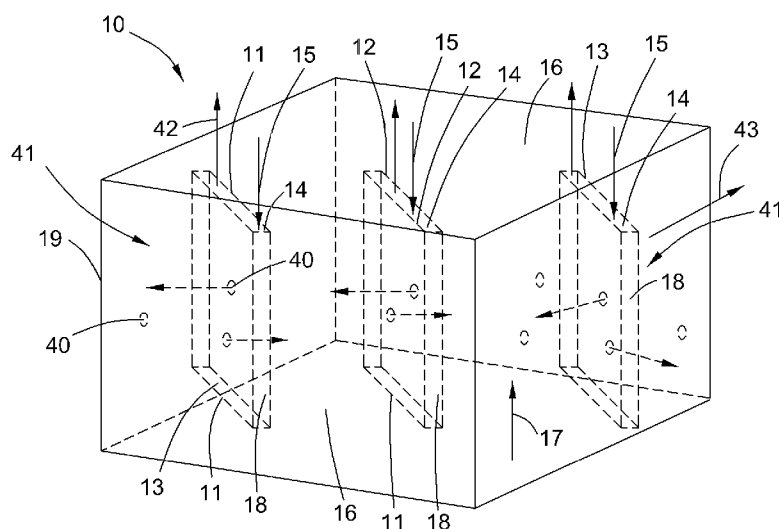


Fig. 1

(57) Abstract: The present disclosure relates to an apparatus for deoxygenation, comprising: a gas diffusion membrane comprising a first side and an opposite second side; a first compartment on the first side of the gas diffusion membrane for accommodating an aqueous stream comprising oxygen; and a second compartment on the second side of the gas diffusion membrane for accommodating a consuming liquid to consume the oxygen diffused from the first compartment. The present disclosure further relates to a corresponding method for deoxygenation.

**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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- *with international search report (Art. 21(3))*

APPARATUS AND METHOD FOR DEOXYGENATION

TECHNICAL FIELD

[0001] The present disclosure relates to an apparatus and a method for deoxygenation, and particularly to an apparatus and a method for removing oxygen from water.

BACKGROUND

[0002] Oxygen in water, such as dissolved oxygen which is dissolved in water, has to be removed from water before entering a vessel or a pipe, such as a boiler, a water pipe, etc, because it has a propensity to corrode the vessel for containing water or the pipe for delivering water, among other reasons.

[0003] The prior art apparatus and methods usually utilize vacuum pumping or gas purging or the like to remove oxygen from water. However, the deoxygenation effects of these apparatus and methods cannot meet various requirements all the time.

[0004] Therefore, there exists a need for a new apparatus and a new method for deoxygenation.

BRIEF DESCRIPTION

[0005] In one aspect, embodiments of the present invention relate to an apparatus for deoxygenation, comprising: a gas diffusion membrane comprising a first side and an opposite second side; a first compartment on the first side of the gas diffusion membrane for accommodating an aqueous stream comprising oxygen; and a second compartment on the second side of the gas diffusion membrane for accommodating a consuming liquid to consume the oxygen diffused from the first compartment.

[0006] In another aspect, embodiments of the present invention relate to a method for deoxygenation, comprising: inputting the aqueous stream comprising oxygen into the first compartment of the apparatus for deoxygenation according to the embodiments of the invention; and inputting the consuming liquid into the second compartment to consume the oxygen from the first compartment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The features, aspects and advantages of the present disclosure can be better

understood when the following detailed description is read with reference to the accompanying drawings, in which:

[0008] Figures 1, 2 and 3 illustrate schematic views of the apparatus according to the embodiments of the present invention.

DETAILED DESCRIPTION

[0009] Unless defined otherwise explicitly, the scientific and technical terms used in the present disclosure have the same meanings as commonly understood by one having ordinary skill in the art to which the present disclosure pertains. The terms “comprise”, “comprising”, “include”, “including” and the like used in the present disclosure mean that other items in addition to the items and the equivalents thereof following these words also fall in the scope.

[0010] Terms indicating approximation are used in the present disclosure to modify values, and mean that the disclosure is not limited to the specific values, but includes modifications that are close to the values, are acceptable and will not change the related basic functions. Accordingly, when a value is modified by “about”, “approximate”, “or so”, etc, it means that the disclosure is not limited to the precise value. In some embodiments, a term indicating approximation may correspond to the precision of an instrument used to measure the value. The numerical ranges in the present disclosure may be combined and/or interchanged. Unless otherwise specified explicitly, a numerical range includes all the numerical subranges covered by that numerical range.

[0011] In the specification and claims, unless otherwise indicated explicitly, all the items are by no means limited by singular or plural form. As used in the specification and claims of the present patent application for invention, “first”, “second” and similar terms do not suggest any sequential order, quantity or importance; instead, they are used merely to distinguish different elements, embodiments, etc.

[0012] Unless otherwise specified explicitly in the context, the terms “or” and “alternatively” are not exclusive, but include at least one of the items (such as component) mentioned, and include the case where a combination of the items mentioned may exist.

[0013] When “some embodiments” and the like are mentioned in the specification of the present application, it means that a particular element (for example, a feature, a structure and/or a characteristic) related with the present invention is included in at least one

embodiment described in the specification and may or may not appear in another embodiment. Additionally, it is to be appreciated that the elements of the present invention may be combined in any suitable way.

[0014] Hereinafter, the embodiments of the present invention will be illustrated with reference to the accompanying drawings, and the functions and structures known in the art will not be described in detail in order to avoid obscuring the present invention by unnecessary details.

[0015] FIGS. 1-3 are schematic views showing the apparatus 10, 20, 30 for deoxygenation according to some embodiments of the present invention. An apparatus 10, 20, 30 comprises: a gas diffusion membrane 11, 21, 31 comprising a first side 12, 22, 32 and an opposite second side 13, 23, 33; a first compartment 14, 24, 34 on the first side 12, 22, 32 of the gas diffusion membrane 11, 21, 31 for accommodating an aqueous stream 15, 25, 35 comprising oxygen 40, 50, 60; and a second compartment 16, 26, 36 on the second side 13, 23, 33 of the gas diffusion membrane 11, 21, 31 for accommodating a consuming liquid 17, 27, 37 to consume the oxygen 40, 50, 60 diffused from the first compartment 14, 24, 34.

[0016] The term “gas diffusion membrane” or the like mentioned in the present disclosure refers to a membrane through which a gas may diffuse from one side to the other but a liquid can't. In some embodiments, the gas diffusion membrane 11, 21, 31 is hydrophobic and porous. In some embodiments, the gas diffusion membrane 11, 21, 31 is a microfilter membrane. In some embodiments, the gas diffusion membrane 11, 21, 31 is an ultrafilter membrane. In some embodiments, the gas diffusion membrane 11, 21, 31 is made from polytetrafluoroethylene, polyvinylidene fluoride, polyethylene, polyvinyl chloride or the like.

[0017] The aqueous stream 15, 25, 35 accommodated in the first compartment 14, 24, 34 may be any aqueous stream comprising oxygen 40, 50, 60. In some embodiments, the aqueous stream 15, 25, 35 comprises other substances besides oxygen 40, 50, 60, for example, salts such as sodium chloride dissolved in water. In some embodiments, oxygen 40, 50, 60 dissolves in the aqueous stream 15, 25, 35.

[0018] In some embodiments, as shown in FIG. 1, the apparatus 10 comprises a support 18 for supporting a pair of the gas diffusion membranes 11. The gas diffusion membrane 11 is

a flat membrane and forms a membrane module 41 with the support 18. The first compartment 14 is located between the first sides 12 of the pair of gas diffusion membranes 11.

[0019] In some embodiments, a container 19 accommodates a plurality of supports 18 and corresponding gas diffusion membranes 11. The second compartment 16 is located inside the container 19 and outside the membrane module 14.

[0020] In some embodiments, as shown in FIG. 2, the apparatus 20 comprises a spacer 28 between a pair of the gas diffusion membranes 21. In some embodiments, the spacer 28 and the gas diffusion membranes 21 wind around a pivot 29 to form a membrane module 51. In some embodiments, the gas diffusion membrane 21 is a flat membrane. The first compartment 24 is located between the first sides 22 of the gas diffusion membranes 21, and the second compartment 26 is located between the second sides 23.

[0021] In some embodiments, as shown in FIG. 3, the gas diffusion membrane 31 is a hollow fiber membrane which forms a membrane module 61 by itself. In some embodiments, the first side 32 is the inner side, and the gas diffusion membrane 31 defines the first compartment 34 therein. In some embodiments that are not shown, the second side is the inner side, and the hollow fiber membrane defines the second compartment therein.

[0022] In some embodiments, a container 39 accommodates a plurality of the gas diffusion membranes 31 and defines the second compartment 36 therein. The second side 33 is the outer side of the gas diffusion membrane 31, and the second compartment 36 is located outside the gas diffusion membrane 31. In some embodiments that are not shown, the container accommodates hollow fiber membranes and defines the first compartment therein. The first side is the outer side of the gas diffusion membrane, and the first compartment is located outside the gas diffusion membrane.

[0023] The container, support, pivot and spacer may be chosen in light of the specific application environments, such as various aqueous streams 15, 25, 35, consuming liquids 17, 27, 37, gas diffusion membranes 11, 21, 31, or deoxygenation requirements, etc. In some embodiments, the container 19, 39 is manufactured from glass, plastic (e.g. fiber-reinforced plastic) or alloy (e.g. stainless steel), etc. In some embodiments, the container is configured as a cylinder, cuboid or cube, etc. In some embodiments, the support 18 is manufactured from

glass, plastic (e.g. fiber-reinforced plastic) or alloy (e.g. stainless steel), etc. In some embodiments, the support 18 is configured as a rectangular frame. In some embodiments, the pivot and spacer are manufactured from plastic.

[0024] The aqueous stream 15, 25, 35 comprising oxygen 40, 50, 60 is fed into the first compartment 14, 24, 34. The consuming liquid 17, 27, 37 is fed into the second compartment 16, 26, 36 to consume the oxygen 40, 50, 60 from the first compartment 14, 24, 34. The first compartment 14, 24, 34 and the second compartment 16, 26, 36 are located on the two contiguous sides of the gas diffusion membrane 11, 21, 31 respectively.

[0025] The oxygen 40, 50, 60 in the first compartment 14, 24, 34 diffuses to the second compartment 16, 26, 36 where it is consumed by the consuming liquid 17, 27, 37, so that the oxygen 40, 50, 60 in the aqueous stream 15, 25, 35 is removed. As a result, the oxygen concentration of the aqueous stream 42, 52, 62 exiting the first compartment 14, 24, 34 is lower than the concentration of the oxygen 40, 50, 60 in the aqueous stream 15, 25, 35 entering the first compartment 14, 24, 34.

[0026] In some embodiments, the consuming liquid 17, 27, 37 reacts with the oxygen 40, 50, 60 to consume the oxygen 40, 50, 60. In some embodiments, the consuming liquid 17, 27, 37 is a reducing solution. In some embodiments, the consuming liquid 17, 27, 37 comprises sodium sulfite. In some embodiments, the sodium sulfite concentration of the consuming liquid 43, 53, 63 exiting the apparatus 10, 20, 30 is lower than that of the consuming liquid 17, 27, 37 entering the apparatus 10, 20, 30.

[0028] In some embodiments, the aqueous stream 15, 25, 35 flows through the first compartment 14, 24, 34 in a once-through operation mode. In some embodiments, the aqueous stream 15, 25, 35 flows through the first compartment 14, 24, 34 in a circular operation mode. In some embodiments, the consuming liquid 17, 27, 37 flows through the second compartment 16, 26, 36 in a once-through operation mode. In some embodiments, the consuming liquid 17, 27, 37 flows through the second compartment 16, 26, 36 in a circular operation mode.

[0029] In light of the requirements for deoxygenation effect and the specific composition of the aqueous stream, one may adjust the components and the concentrations thereof in the consuming liquid 17, 27, 37, adjust the ratio of the flow rate of the consuming liquid 17, 27,

37 to the flow rate of the aqueous stream 15, 25, 35, use a suitable circulation process, or choose the type or design parameters of the gas diffusion membrane 11, 21, 31.

[0030] The apparatus and method for deoxygenation according to the embodiments of the present invention are completely different from the conventional apparatus and methods, and exhibit low cost, high efficiency, superior deoxygenation effect, and small floor space.

EXAMPLES

[0031] The following examples may provide guidance to one having ordinary skill in the art in practicing the present invention. These examples do not limit the scope of the claims.

[0032] Example 1

[0033] A hydrophobic polytetrafluoroethylene membrane having a pore diameter of 0.22 μm was used as a gas diffusion membrane. A membrane module having a thickness of 5 mm, a length of 200 mm and a width of 150 mm was formed using two gas diffusion membranes and a stainless steel support, wherein the volume of the membrane module for accommodating water was 150 mL, and the membrane area was 480 cm^2 . The membrane module was placed in a glass container. Deionized water was fed into the first compartment between the first sides of the two gas diffusion membranes in the membrane module, allowing it to flow at a rate of 60 mL/min. A 500 mL 1 mol/L sodium sulfite solution was infused into the second compartment outside the membrane module in the container as a consuming liquid. A Mettler Toledo dissolved oxygen meter was used to measure the oxygen concentration of the deionized water flowing out of the membrane module. Table 1 below shows the oxygen concentration measured as a function of test time.

[0034] Table 1

Test Time (s)	Oxygen Concentration (ppm)
0	7.46
30	4.33
60	1.12

90	0.96
120	0.34
150	0.12
180	0.02
210	0.01
240	0.01
270	0.01
300	0.01

[0035] As can be seen from the data in Table 1, the oxygen concentration of the deionized water was 7.46 ppm at the beginning of the experiment, and the oxygen concentration of the deionized water decreased to about 0.01 ppm in the following 210 seconds or so. As thus can be seen, the apparatus and method removed the oxygen from the deionized water effectively by decreasing the oxygen concentration to a very low level.

[0036] Example 2

[0037] Example 1 was repeated except that the initial concentration of the oxygen in the deionized water was 10 ppm. The deionized water stream was infused into the first compartment between the first sides of the two gas diffusion membranes in the membrane module at 60 mL/min, 90 mL/min, 120 mL/min, 250 mL/min and 270 mL/min respectively, and the consuming liquid in the second compartment outside the membrane module in the container was a sodium sulfite solution having a concentration of 2.46 mol/L. The retention time of the water in the membrane module was recorded. The oxygen concentrations of the deionized water flowing out of the membrane module at different rates were measured and designated as the final concentrations. The flow rate of the water stream was divided by the membrane area to give an amount of water treated by a unit area of membrane in a unit time, designated as the treatment capacity of the membrane. The difference between the initial oxygen concentration and the final oxygen concentration when the stream flew out of the

membrane module was divided by the initial concentration to give a percentage which was designated as the oxygen removal rate. The foregoing data are listed in Table 2 below.

[0038] Table 2

Water Flow Rate (mL/min)	Final Oxygen Concentration (ppm)	Retention Time (s)	Treatment Capacity of Membrane (L/min·m ²)	Oxygen Removal Rate
60	0.01	150	1.25	99.9%
90	0.01	100	1.88	99.9%
120	0.01	75	2.50	99.9%
250	0.01	36	5.21	99.9%
270	0.03	33	5.63	99.7%

[0039] As can be seen from the data in Table 2, the oxygen removal rate of the apparatus and method was higher than 99.5% when the flow rate was 60 mL/min to 270 mL/min. Moreover, when the flow rate was up to 250 mL/min, the oxygen concentration may be decreased to 10 ppb (0.01 ppm), so that the treatment capacity of the membrane was relatively high. As compared with the prior art, the oxygen removal rate was increased, and the amount of water treated by a unit area of membrane in a unit time was increased as well. Hence, in the case where the amount of water keeps the same, the amount of membrane used may be reduced. Furthermore, the consuming liquid was cheap, and thus the cost may be decreased.

[0040] The present invention has been demonstrated in view of particular examples. Nonetheless, one having ordinary skill in the art may understand that a number of modifications and variations may be made to the present invention. Therefore, it is to be appreciated that the claims intend to cover all such modifications and variations in the genuine concept and range of the present invention.

CLAIMS

What we claim is:

1. An apparatus for deoxygenation, comprising:
a gas diffusion membrane comprising a first side and an opposite second side;
a first compartment on the first side of the gas diffusion membrane for accommodating an aqueous stream comprising oxygen; and
a second compartment on the second side of the gas diffusion membrane for accommodating a consuming liquid to consume the oxygen diffused from the first compartment.
2. The apparatus of claim 1, further comprising a support for supporting a pair of the gas diffusion membranes, wherein the first compartment is located between the first sides of the pair of the gas diffusion membranes.
3. The apparatus of claim 2, further comprising a container accommodating a plurality of supports and corresponding gas diffusion membranes.
4. The apparatus of claim 1, further comprising a spacer between a pair of the gas diffusion membranes.
5. The apparatus of claim 4, further comprising a pivot, wherein the spacer and the gas diffusion membranes wind around the pivot.
6. The apparatus of claim 1, wherein the gas diffusion membrane is a hollow fiber membrane defining the first compartment therein.
7. The apparatus of claim 6, further comprising a container accommodating a plurality of the gas diffusion membranes and defining the second compartment therein.
8. The apparatus of claim 1, wherein the gas diffusion membrane is hydrophobic and porous.
9. A method for deoxygenation, comprising:
inputting the aqueous stream comprising oxygen into the first compartment of the apparatus of any of claims 1-8; and

inputting the consuming liquid into the second compartment to consume the oxygen from the first compartment.

10. The method of claim 9, wherein the consuming liquid reacts with the oxygen.
11. The method of claim 9, wherein the consuming liquid comprises sodium sulfite.

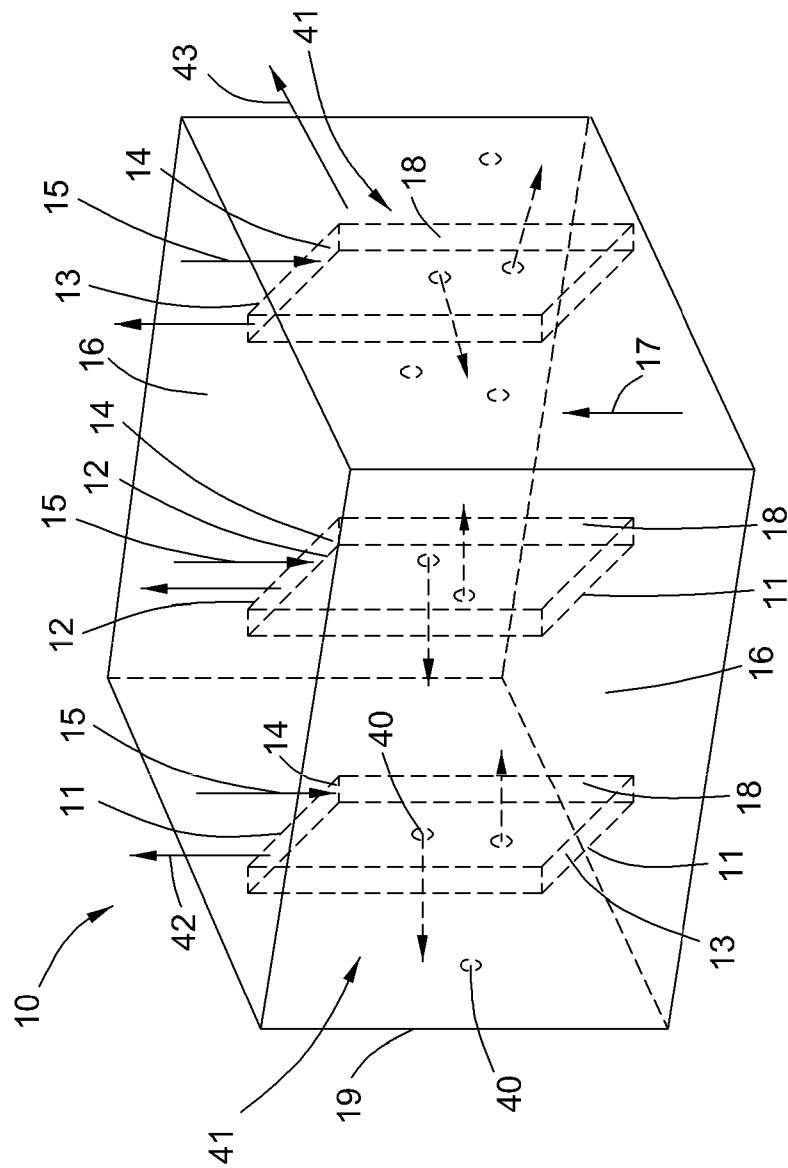


Fig. 1

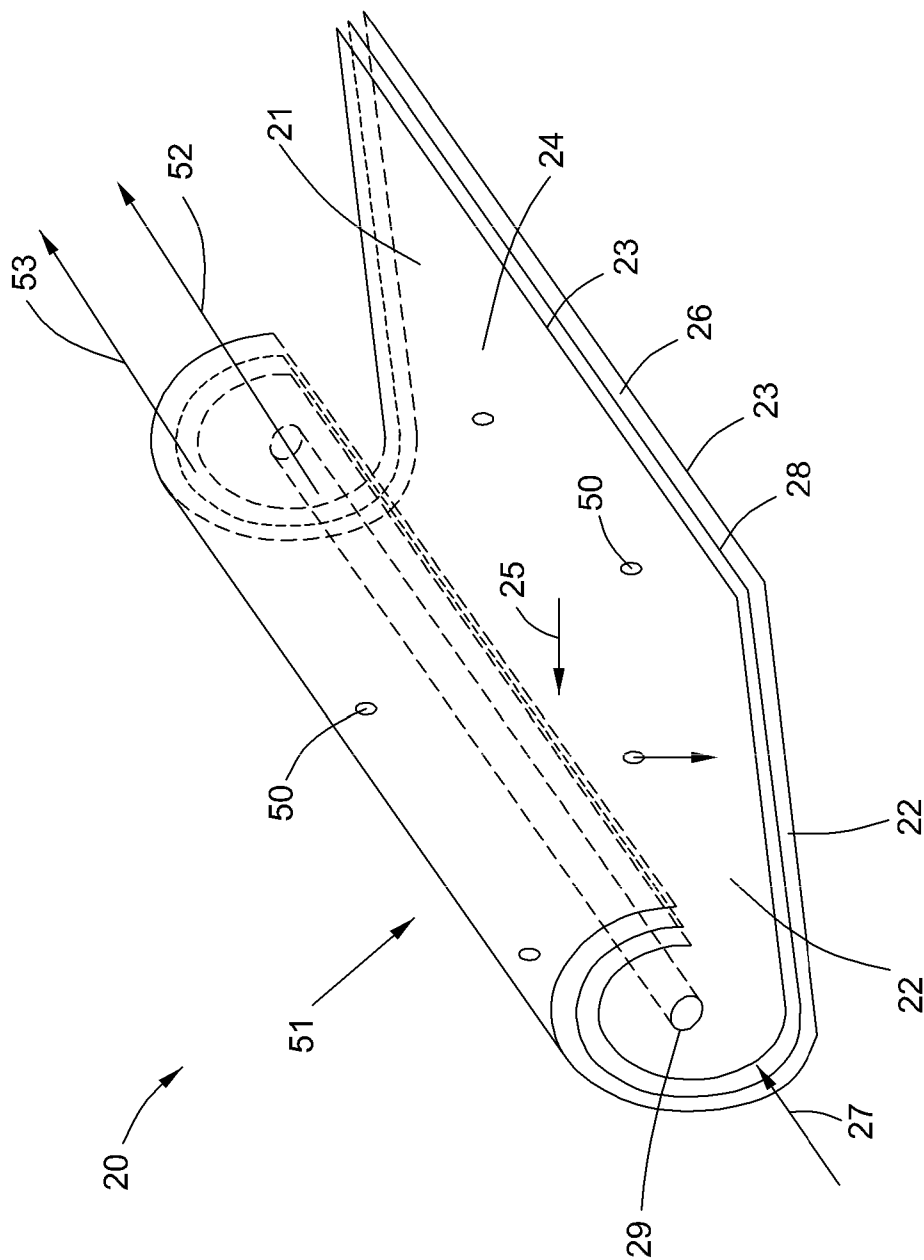


Fig. 2

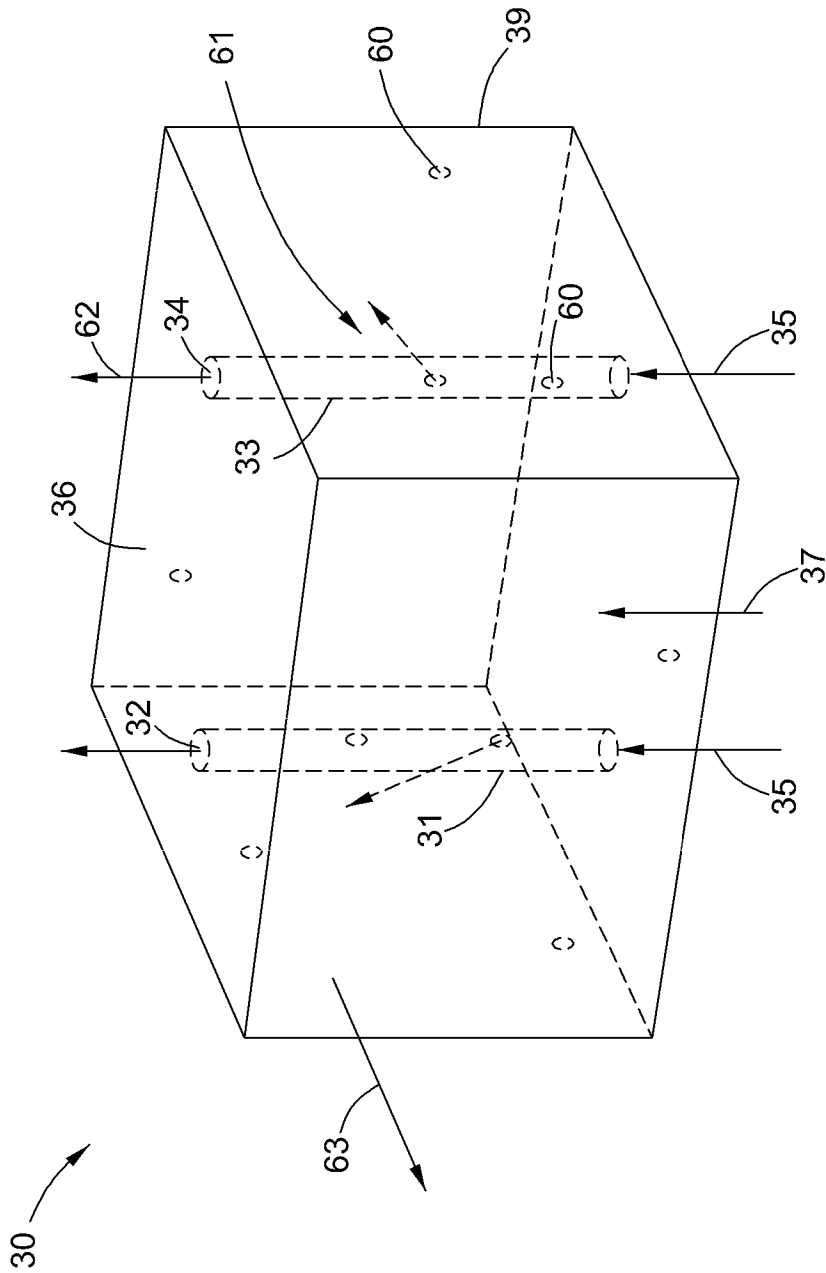


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/023152

A. CLASSIFICATION OF SUBJECT MATTER

INV. B01D19/00 B01D53/22 B01D61/24 C12M1/00 C12M1/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B01D C12M C02F B01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 94/16800 A1 (TYGOLA PTY LTD [AU]; JOHNSON ROBERT ARTHUR [AU]) 4 August 1994 (1994-08-04) fig.1, page 3 line 25 - page 4 line 16 -----	1-11
X	US 5 902 747 A (NEMSER STUART MARSHALL [US] ET AL) 11 May 1999 (1999-05-11) fig.2, column 7 line 29-37 -----	1-8
X	US 5 639 375 A (HIROSHI NOMURA [US]) 17 June 1997 (1997-06-17) fig.1, column 3 line 51 - column 4 line 22 -----	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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27/05/2016

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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