(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 January 2013 (17.01.2013)

(10) International Publication Number
WO 2013/008070 A1

(51) International Patent Classification:
B01J 7/00 (2006.01) ***C06D 5/10*** (2006.01)
C01B 31/20 (2006.01) ***B01J 7/02*** (2006.01)

(21) International Application Number:
PCT/IB2012/001326

(22) International Filing Date:
6 July 2012 (06.07.2012)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
UD2011A000105 8 July 2011 (08.07.2011) IT

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title**: PORTABLE AND COMPACT DEVICE TO GENERATE AND DELIVER CO2 IN A CONTROLLED MANNER, METHOD AND USE

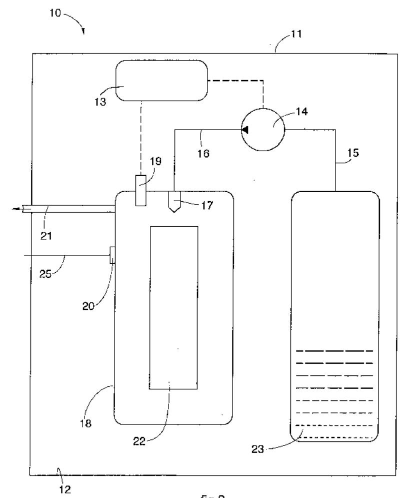

fig.2

(57) **Abstract**: A device (10) to generate and deliver gaseous CO2 under controlled pressure toward a desired user apparatus (50) of gaseous CO2, comprises a container (1 1) having a housing compartment (12) inside, which comprises a reaction chamber (18), which can be selectively closed hermetically and is provided with containing means (22) comprising solid forms consisting of a mix of solid powders of bicarbonate of alkaline earth metal and at least a solid acid. The solid forms are able to be solubilized in water and determine the reaction of the bicarbonate and solid acid in an aqueous environment for the chemical production of gaseous CO2. Exit means (21) are provided to transfer the gaseous CO2 produced toward the outside. The device (10) also comprises a tank (23) for the water involved in said reaction, pumping means (14) able at least to determine a flow of water from said tank (23) toward said containing means (22), pressure sensor means (19) associated to said reaction chamber (18) and configured to supply a signal correlated to the pressure value inside the reaction chamber (18) and electronic control means (13) to selectively command at least said pumping means (14), on the basis of said signal coming from said pressure sensor means (19), so as to control the generation and delivery of gaseous CO2 substantially automatically on the basis of desired gaseous CO2 generation parameters required by the user apparatus (50).

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PORTABLE AND COMPACT DEVICE TO GENERATE AND DELIVER CO2 IN A CONTROLLED MANNER, METHOD AND USE

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FIELD OF THE INVENTION

The present invention concerns a portable and compact device and a method to generate and deliver gaseous CO2 in a controlled manner, as well as the corresponding use in different fields of the state of the art.

In particular, the present invention is applied to incubators for cell cultures and to apparatuses for the controlled delivery of CO2 in the industrial, chemical, biological, food, aesthetic, medical-surgical fields, in research laboratories or hospitals and in similar or comparable applicative contexts.

BACKGROUND OF THE INVENTION

It is known that, in autonomous incubators of biological material, it is necessary to feed gaseous CO2, usually obtained with pressurized metal cylinders, containing gaseous CO2 compressed at about 60 bar, to keep a predetermined concentration of CO2 in at least an internal chamber of the incubator because, for most human or animal cells or tissues, a concentration of CO2 of about 5% is physiological.

If the biological material is exposed to an atmosphere enriched with CO2, the cell functions which are necessary for the survival of the biological material may be seriously damaged.

The cylinders are connected to a pressure reducer, which takes the gaseous CO2 to about 9-10 bar, which is then fed to the incubator by means of suitable members to connect and intercept the fluid, generally an adjustment valve downstream of the pressure reducer.

Known incubators are provided with control systems which, as the concentration of CO2 inside them varies, command the cylinders to feed the CO2. This can happen, for example, every time the operator opens and closes the incubator to work on the content, which causes unbalances in the CO2 concentration and activates the adjustment systems mentioned above.

One disadvantage of cylinders with pressurized CO2 is that the delivery of pressurized gas upon request, in the cases given as examples above, determines pressure peaks in the gaseous CO2, which can frequently be repeated with a pulsating effect, particularly when the adjustment valve downstream of the pressure reducer is opened every time that the adjustment system detects a deviation from the set CO2 concentration. For this reason it may damage particular human/vegetable cells and cultures of micro-organisms.

Furthermore, cylinders of pressurized CO2 are intrinsically dangerous, so much so that recent legislative developments will oblige laboratories not to keep pressurized cylinders inside them, since they are heavy, bulky, difficult to transport, not easy to refill and have a great environmental impact due to the emission of CO2 into the ecosystem during disposal or refilling.

The international application WO-A-2005093038 describes an autonomous incubator for biological material that is able to create and maintain a predetermined concentration of CO2 in an internal chamber. In particular, the autonomous incubator provides, integrated inside it, a generator controlled by a sensor, able to produce CO2 by means of bicarbonate which reacts in an acid solution contained in a tank. The generator is activated if the concentration of CO2 diminishes in the internal chamber of the incubator by more than a predetermined value, keeping the gaseous CO2 at a constant pressure in the incubator.

US-A-3,660,242 describes a compact incubator that comprises an insulated chamber in which the culture means are heated by means of conduction in a controlled manner, and the CO2 is generated by means of water-soluble tablets consisting of bicarbonate which are dissolved in an acid solution.

One disadvantage of these solutions, apart from the fact that they are not usable with other apparatuses that use CO2 except for the incubator in which it is integrated, is that they are dangerous for the operator when he is handling the tank with the acid solution and in general the acid in a liquid solution during topping up, replenishment, maintenance and cleaning.

WO-A-2007/145629 describes a system for producing a constant flow of CO2, used to attract insects into a trap. This known system includes a phial closed by an upper lid. The upper lid comprises a bag containing a liquid, for example water, to deliver drops of liquid slowly, from the top and by gravity, onto a mixed composition from a source of carbonates and weak acids contained in a loose and free form inside the phial closed by the lid, and then to produce gaseous CO2 chemically following the chemical reaction between liquid and composition which occurs in the phial itself. The lid can provide a connection to an external source of liquid, or the bag can be filled when necessary. In any case, the bag containing the liquid allows the latter to pass slowly, it falls due to gravity onto the composition without any possibility of controlling or adjusting the flow rate of the liquid. The phial or the lid can be equipped with an element to regulate the exit flow of gaseous CO2 produced. This known solution, due to its specific application to traps for insects, is intrinsically lacking in internal controls for the production of gaseous CO2, the pressure reached and safety systems in the event of malfunctions or unforeseen problems: it is therefore totally unsuitable for a production of gaseous CO2 that is reliable, safe and which satisfies production needs, for example for incubators of biological material. Nor can this known solution provide, suggest or need internal controls and safety measures, directed as it is for a mass-consumption product and common for the production of CO2 for insect traps.

WO-A-96/30563 describes a device for the controlled electro-chemical generation of a gas at flow rates provided by an electro-chemical cell with an anode and a cathode which can include a DC electric energy source, a switch, a possible resistor to regulate the flow rate of gas produced. In this known solution, the electro-chemical decomposition of metal carbonates or bicarbonates is made. In order to control the increase or reduction in the exit flow rate of the gas produced, this known device may comprise a controller to regulate the resistance of the possible resistor, or may provide an adjustable DC electric energy source. Consequently, due to the specific electro-chemical technology employed, this known solution also lacks internal controls for the production of gas, the pressure reached and safety systems in the event of malfunctions or unforeseen problems, and is therefore not usable for a production of gaseous CO2 that is reliable and safe, nor can it provide, suggest or need additional internal controls and safety measures which would not be justified by the electro-chemical technology adopted.

WO-A-97/02849 describes an apparatus for the controlled delivery of a liquid that includes an infusion device divided into two compartments, of which a first is to deliver the liquid and the second is to generate a gas, separated by a flexible membrane. The first compartment includes a flexible membrane that delimits an expansion tank for the gas and a tank for liquid associated to a Luer valve. The second compartment includes liquid and solid chemical reagents which are combined to produce the gas and create a pressure to move the liquid from the first compartment. The chemical reagents are separated by a barrier that is broken from the outside when necessary. The gas produced flows into the gas expansion tank and the pressure which it exerts is transmitted, thanks to the flexible membrane, to the liquid present in the liquid tank which can therefore flow toward the outside, since the valve is open. A safety valve may be provided in the event of excess pressure in the infusion device, which is set at a predefined threshold pressure, preventing any overpressure when the valve is closed and keeping the pressure in the device to a pre-set value. In any case, the internal pressure of the gas produced in this known apparatus is not adjustable, and only a point-by-point control of the set-point is possible. Furthermore, the known apparatus may not be very safe, because once the barrier between the chemical reagents is broken, there is no way to stop the production of gas in the infusion device and therefore no way to control and regulate the pressure that it exerts on the liquid and, unless there is a simple on/off control, closing the non-return valve, there is no way to regulate the flow of fluid toward the outside.

None of the documents described above provides, in particular, a portable and compact device to generate and deliver CO2 in a controlled manner, in terms of pressure, flow or flow rate, able to be connected with any external user device for any application in the industrial, foodstuff, aesthetic or medical field.

One purpose of the present invention is to obtain a device to generate and deliver gaseous CO2 with a minimum bulk so that it can easily be positioned and transported in any environment where it can be used, also, possibly, in a sterile environment.

Another purpose of the present invention is to obtain a device to generate and deliver gaseous CO2 at a pressure that is absolutely not dangerous for animal and vegetable cell cultures and micro-organisms.

Another purpose of the present invention is to obtain a device to generate and deliver gaseous CO2 which is compact, therefore easy to handle and to position in any environment.

Another purpose of the present invention is to obtain a device to generate and deliver gaseous CO2 that can be refilled by the operator easily and safely, without having to handle dangerous substances, economically, quickly and with low environmental impact.

Another purpose of the present invention is to obtain a device to generate and deliver gaseous CO2 which can possibly be connected to an incubator but also to any other type of apparatus usable in all those technical applications where it is necessary to deliver controlled quantities of CO2 at a predetermined pressure and not harmful for the organism.

Another purpose of the present invention is to obtain a device to generate and deliver gaseous CO2 which can be sterilized in advance so that it can be used in sterile environments and in any case in all those applications where it is necessary to control the bacterial load present in the environment.

The Applicant has devised, tested and embodied the present invention to overcome the shortcomings of the state of the art and to obtain these and other purposes and advantages.

SUMMARY OF THE INVENTION

The present invention is set forth and characterized in the independent claims, while the dependent claims describe other characteristics of the invention or variants to the main inventive idea.

In accordance with the above purposes, a device according to the present invention can be used to generate and deliver gaseous CO2 under controlled pressure toward a desired user apparatus of gaseous CO2.

According to the present invention, the device comprises a container having a housing compartment inside which comprises:

- a reaction chamber, which can be selectively closed hermetically and provided with containing means comprising solid forms consisting of a mix of solid powders from a carbonate source, such as carbonate or bicarbonate of alkaline-earth metal and at least a solid acid, said solid forms being able to solubilize in water and determine the reaction of the bicarbonate and solid acid in an aqueous environment for the chemical production of gaseous CO2, and with exit means to transfer the gaseous CO2 produced toward the outside, in which the containing means are configured to contain the solid forms in an orderly and delimited manner;

- a tank to contain the water involved in the reaction, outside the reaction chamber and connected to it by means of fluidic connection means;
- suction pumping means disposed downstream of the tank and able at least to determine a flow of water from the tank toward the containing means included in the reaction chamber toward the fluidic connection means;
- pressure sensor means configured to supply a signal correlated to the pressure value of the gaseous CO2 produced;
- electronic control means to selectively command at least the suction pumping means, on the basis of the signal coming from the pressure sensor means, so as to control, at least in terms of pressure and flow, the generation and delivery of gaseous CO2 substantially automatically on the basis of desired gaseous CO2 generation parameters required by the user apparatus.

Advantageously, the device of the present invention produces gaseous CO2 by chemical means, therefore with a purity close to 100%, with the exception of modest quantities of aqueous vapor which can be removed with hygroscopic filters for example. The device of the present invention also produces gaseous CO2 according to needs thanks to the electronic control means provided and to the generation mode itself and when it is not in use it is not under pressure.

With the present invention, an autonomous generator and dispenser of gaseous CO2 is obtained, which can be selectively associated to any apparatus that uses gaseous CO2, which has a minimum bulk, which produces gaseous CO2 only when it is needed and in the required quantity, and therefore does not operate at high pressures, reaching at most a little more than 1 bar.

Advantageously, thanks to the pressure control, the electronic control means can signal in advance that the CO2 is finished. In this case, the operator can re-start the generator by himself, simply by replacing or integrating the reaction material, thus saving time and costs. Moreover, the device does not emit dangerous waste.

In some forms of embodiment, it is possible to use monovalent, bivalent or trivalent solid acids.

If a monovalent acid is used, the stoichiometric ratio between bicarbonate and acid is 1:1 M.

If a bivalent acid is used, the stoichiometric ratio between bicarbonate and acid is 2:1 M.

If a trivalent acid is used, the stoichiometric ratio between bicarbonate and acid is 3:1 M.

In some forms of embodiment, the solid acid used is selected from tartaric acid and citric acid or a mixture thereof.

In some variants, the suction pumping means are located downstream of the tank and upstream of the reaction chamber, with respect to the flow of water during normal use.

In some variants the suction pumping means are located downstream of the tank and also downstream of the reaction chamber.

In some variants the present invention comprises one-directional fluid interception means, configured to selectively prevent an unwanted reflux of fluid from the reaction chamber toward the tank.

In some variants, the pressure sensor means are associated to the reaction chamber in order to supply a signal correlated to the pressure value of the gaseous CO2 produced inside the reaction chamber.

In some forms of embodiment, the reaction chamber comprises at least a delivery member connected fluidically to the tank in order to deliver a desired and controllable quantity of water toward the containing means.

According to some variants, the electronic control means integrate a PID controller.

In some forms of embodiment, the container is made at least externally of plastic material or fiberglass suitable to be sterilized.

In some forms of embodiment, the containing means comprise a cartridge that can be refilled with the solid forms, or disposable type cartridge.

In some forms of embodiment, the exit means are associated to an accumulation tank for the gaseous CO2 produced.

In some variants, the pressure sensor means are associated to the accumulation tank.

The present invention also concerns a device as set forth above, for use as an autonomous generator of CO2 which can be connected to an incubator for animal/vegetable cells or to another device used in the foodstuff, health or aesthetic field and in any case in all fields where the generation and subsequent delivery of gaseous CO2 under controlled pressure is required.

The present invention also concerns a method to generate and deliver gaseous CO2 under controlled pressure toward a desired user apparatus of gaseous CO2. The method provides to make available, in a reaction chamber which can be selectively closed hermetically, solid forms consisting of a mix of solid powders from a carbonate source, such as carbonate or bicarbonate of an alkaline-earth metal and at least a solid acid, to determine a flow of water toward the solid forms contained in the reaction chamber in order to solubilize in water at least part of the solid forms, and to determine the reaction of bicarbonate and solid acid in an aqueous environment to produce gaseous CO2, to detect a signal correlated to the pressure value of the gaseous CO2 produced inside the reaction chamber and to selectively command, on the basis of the signal, the flow of water, in order to control, at least in terms of pressure and flow, the generation and delivery of gaseous CO2 substantially automatically on the basis of desired gaseous CO2 generation parameters required by the user apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other characteristics of the present invention will become apparent from the following description of a preferential form of embodiment, given as a non-restrictive example with reference to the attached drawings wherein:

- fig. 1 is a schematic representation of a compact portable device to generate and deliver gaseous CO2 in a controlled manner according to the present invention, associated to an apparatus that uses CO2;
- fig. 2 is a schematic representation of one form of embodiment of the device in fig. 1;
- fig. 3 is a schematic representation of another form of embodiment of the device in fig. 1;

To facilitate comprehension, the same reference numbers have been used, where possible, to identify identical common elements in the drawings. It is understood that elements and characteristics of one form of embodiment can conveniently be incorporated into other forms of embodiment without further clarifications.

DETAILED DESCRIPTION OF SOME PREFERENTIAL FORMS OF EMBODIMENT

With reference to the attached drawings, a device 10 according to the present invention can be used to generate and deliver gaseous CO2 under controlled pressure, by means of an exit pipe 21 of which more will be said hereafter, toward a desired user apparatus 50 of gaseous CO2, which can be, for example but not only, an incubator for cell cultures, and which can be connected in any known and desired way to the device 10.

The device 10 comprises a portable and compact container 11, which in some solutions is made of plastic material or fiberglass so as to be anti-corrosive and suitable to be subjected to sterilization, advantageous if used in sterile environments such as for example operating theaters in human and animal surgery. The plastic material or fiberglass makes the container 11 light and therefore the device 10 can be easily transportable.

The container 11 has a housing chamber 12 inside, accessible through a door or window which can be selectively opened and is not shown in the drawings.

In the housing compartment 12 a reaction chamber 18 is located, which can be selectively closed hermetically, in which the chemical production of gaseous CO2 occurs according to the known reaction between a bicarbonate of alkaline-earth metal (for example, bicarbonate of sodium, potassium or calcium) in a solid form in a defined molar stoichiometric ratio, with an acid in solid form (for example hydrochloric, sulphuric, tartaric or citric acid) capable to dissolve in water, thus causing the reaction with the bicarbonate present therein in order to generate CO2 in the gaseous state according to the following chemical reaction:

$$R'HCO3 + HR'' \rightarrow R'R'' + H20 + CO2$$

in which, for example, R' represents an alkaline-earth metal and R'' represents chloride, sulfate, tartrate or citrate.

The reaction chamber 18 also comprises containing means, in this case conformed as a cartridge 22, for example, conformed as a plastic tube of suitable size, to contain in an orderly and delimited way the above-mentioned bicarbonate salts and acids, both in solid powder form, preferably mixed and compacted into tablets or similar solid forms. Advantageously, at the lower end of the cartridge 22 a filter can be provided, to prevent the powder material from escaping. Moreover the cartridge 22 has ends with suitable apertures, slits or passages to allow the gaseous CO2 produced to emerge.

The housing compartment 12 comprises a tank 23 for the water involved in the reaction, which is outside the reaction chamber 18 and is connected to it by means of fluidic connection 15, 16 (fig. 2) or fluidic connection means 27 (fig. 3).

A nozzle, or similar delivery member 17, fluidically connected to the water tank 23, is mounted on the reaction chamber 18 and through this the desired quantity of water is delivered which dissolves the bicarbonate and the acid to start off the reaction.

A suction pump 14 is provided downstream of the tank 23, to transfer the water from the tank 23 toward the reaction chamber 18. For example a micro-pump is used which functions at 12V with a low flow.

The pump 14 is able to deliver a measured quantity of water toward the bicarbonate salts with acids contained in the cartridge 22.

Inside the housing compartment 12 there is a control card 13 of the electronic type which in a preferential solution integrates a PID (Proportional Integral Derivative) controller. The control card 13 is configured to command and control the generation and delivery of CO2 substantially automatically once the operator has set the CO2 generation modes, generally the pressure, required by the user apparatus.

The control card 13 is connected to the pump 14 in order to control the functioning thereof, in particular with regards to the quantity and delivery time of the water.

Advantageously, the control card 13 can be set with a "set-point" value of gaseous CO2 pressure inside the reaction chamber 18, which can be selected by the operator, for example by means of an external user interface, depending on the needs of the user apparatus 50 connected downstream of the device 10.

Advantageously a pressure switch 19 is mounted on the reaction chamber 18 and is connected to the control card 13. The pressure switch 19 is able to detect the internal pressure of the reaction chamber 18, which will vary depending on the gaseous CO2 produced by the chemical reaction described above, and transmit a corresponding signal to the control card 13. The latter will therefore be able to command the pump 14 in a controlled manner, depending on the pressure inside the reaction chamber 18, for example starting or stopping, increasing or reducing, the amount of water which is delivered, to obtain or keep the desired pressure value of the gaseous CO2 according to the needs of the user apparatus 50 downstream.

When the pressure inside the reaction chamber 18, detected by the pressure switch 19, is equal to atmospheric pressure, the pressure switch 19 exercises a relay associated to the control card 13 which drives the pump 14, which delivers water into the cartridge 22, starting the chemical reaction in order to produce gaseous CO2. In this way, the pressure inside the reaction chamber 18 increases and, once the pre-set value has been reached, for example a little higher than atmospheric pressure, such as 1.3 – 1.5 bar, the pressure switch 19 supplies a correlated signal which is used by the control card 13 to interrupt the functioning of the pump 14 and therefore to stop the flow of water and prevent the further development of the reaction. The form of embodiment of the control card 13 with a PID controller makes this control efficient, robust and responsive.

The reaction chamber 18 finally comprises the exit pipe 21 by means of which the gaseous CO2 produced is transferred and made available, at a desired pressure, toward the outside, for use by the user apparatus 50.

In a known way, the reaction chamber 18 comprises a safety valve 20 pre-set to vent, by means of a venting pipe 25 toward the outside of the container 11, once the pressure in the reaction chamber 18 reaches a determinate threshold safety value. Moreover, a pressure gauge, not shown, can be provided on the external part of the container 11 which, connected to the reaction chamber 18, is able to display its internal pressure.

According to an advantageous form of embodiment, the nozzle 17 comprises a precision micro-valve able to deliver desired micro-voluminal amounts of water. In sophisticated forms of embodiment, for the purposes of precision, the micro-dispensing of the nozzle 17 can be controlled with precision by means of a photometer which, in substance, counts the drops of water actually delivered in correlation to the commands receiver from the control card 13.

According to the present invention, the bicarbonate and the acid for the reaction are supplied in a mixture of solid powders, in the form of tablets contained in the cartridge 22, and therefore easy to manage and without risks for the operator. Once the mixture in the cartridge 22 is finished, as the reaction progresses, it will easily be possible to integrate or renew the content of the cartridge 22 simply by adding the material in tablet form. Similarly, the amount of water in the tank 23 can be easily integrated or topped up by the operator.

The amount of mixture of bicarbonate and solid acids and water will be variable depending on the size of the device 10, which can be sized according to the needs of the user apparatus 50.

According to the present invention, it is possible to use mono, bi or trivalent acids, in the first case the stoichiometric ratio of bicarbonate to acid is equal to 1:1 M, in the second case 2:1 M and in the third case 3:1 M.

According to one form of embodiment, the solid acid used is selected from tartaric acid and citric acid or a mixture thereof, with the advantage that these solid acids are not dangerous for the operators.

In fig. 2 one form of embodiment of the device 10 is shown, in which the pump 14 is located downstream of the tank 23 and upstream of the reaction chamber 18. In this solution, suction pipes 15 and delivery pipes 16 are provided, to connect the pump 14 respectively to the tank 23 on one side and to the reaction chamber 18 on the other side. In this solution the delivery pipe 16 is connected directly to the nozzle 17 entering the reaction chamber 18. This solution can be advantageous in applications where a greater overpressure of the gaseous CO2 is required, in the delivery of CO2 in applications of carboxy therapy for example for aesthetic or cosmetic purposes.

In fig. 3 another form of embodiment of the device 10 is shown, in which the pump 14 is located downstream of the reaction chamber 18. In this solution a connection pipe 27 is provided between the tank 23 and the reaction chamber 18 for the passage of the water. The connection pipe 27 is associated to the nozzle 17, in the same way as the delivery pipe 16 in fig. 2. Moreover the connection between the reaction chamber 18 and the pump 14 downstream is made by a suction pipe 29, the same as the suction pipe 15 in fig. 2. The delivery of the pump 14 in this case is made by the same exit pipe 21 as discussed above.

In this form of embodiment, the pump 14 puts the reaction chamber 18 in a depression; the reaction chamber 18, in its turn, is fluidically connected to the tank 23 which is therefore also put in a depression, causing the water to rise, which, passing through the connection pipe 27, will be delivered by the nozzle 17 into the cartridge 22, thus causing the desired reaction of chemical production of CO2.

This solution is advantageous in that it facilitates the exit of the gaseous CO2 toward the exit pipe 21, since operating with the reaction chamber 18 under depression the steam tension thereof is reduced. Moreover, if there is a blockage or malfunction of the pump there is no risk of an undesired feeding of water to the reaction chamber 18. Finally, since the reaction chamber 18, in order to be able to operate, must be in a condition of hermetic watertight seal so as to guarantee the necessary pressure, this solution is advantageous if such conditions are accidentally not guaranteed, for example, in cases of re-starting following interventions of an operator on the reaction chamber 18. Indeed, if we were to suppose that, for example to replenish the quantity of reaction tablets in the cartridge 22, the operator closes the reaction chamber 18 incorrectly, this cannot be put in a depression by the pump 14, and therefore, there will be no suction of water toward the cartridge and consequently no, or in any case very little, production of gaseous CO2, thus giving an advantageous functioning safety.

The connection pipe 27 can include, in some variant embodiments, one-directional fluid interception means 28 configured to selectively prevent a flow of fluid toward the tank 23, such as a non-return valve, or an electro-valve commanded by a switch-off signal from the pump 14.

In the second form of embodiment in fig. 3, if the pump 14 were to stop for any reason, also unexpectedly, the water would continue to be sucked in for a certain period into the reaction chamber 18 through the connection pipe 27. Consequently, the reaction to produce gaseous CO2 would continue, making the pressure rise in the reaction chamber 18 which, if there were no one-directional fluid interception means 28 provided between the reaction chamber 18 and the tank 23, would cause the return of gaseous CO2 into the tank 23.

Moreover, in some variant embodiments of both the first and the second forms of embodiment, downstream of the pump 14, an accumulation tank 31 can be provided for the gaseous CO2 generated, associated to the exit pipe 21, in this case in line downstream of the reaction chamber 18, or of the pump 14, advantageous to accumulate the gaseous CO2 generated and to make the exit of gaseous CO2 homogenous and uniform, both in terms of pressure and possibly in terms of flow. In this case, the pressure switch 19, in addition to or in replacement of its position mounted on the reaction chamber 18, could be installed on the accumulation tank 31, as shown by a dotted line in fig. 3.

It is clear that modifications and/or additions of parts may be made to the device to generate and deliver CO2 as described heretofore, without departing from the field and scope of the present invention.

CLAIMS

1. Device to generate and deliver gaseous CO2 under controlled pressure toward a desired user apparatus (50) of gaseous CO2, **characterized in that** it comprises a container (11) having a housing compartment (12) inside, said housing compartment (12) comprising:

- a reaction chamber (18), which can be selectively closed hermetically and is provided with containing means (22) comprising solid forms composed of a mix of solid powders from a carbonate source, such as carbonate or bicarbonate of an alkaline-earth metal and at least a solid acid, said solid forms being able to solubilize in water and determine the reaction of the bicarbonate and solid acid in an aqueous environment for the chemical production of gaseous CO2, and with exit means (21) to transfer the gaseous CO2 produced toward the outside, said containing means (22) being configured to contain said solid forms in an orderly and delimited manner;
- a tank (23) to contain the water involved in said reaction, outside said reaction chamber (28) and connected to it by means of fluidic connection means (15, 16; 27);
- suction pumping means (14) disposed downstream of the tank (23) and able at least to determine, in a controlled and adjustable manner, a flow of water from said tank (23) toward said containing means (22) included in said reaction chamber (18) through said fluidic connection means (15, 16; 27);
- pressure sensor means (19) configured to supply a signal correlated to the pressure value of the gaseous CO2 produced;
- electronic control means (13) to selectively command at least said suction pumping means (14), on the basis of said signal coming from said pressure sensor means (19), so as to control, at least in terms of pressure and flow, the generation and delivery of gaseous CO2 substantially automatically on the basis of desired parameters for the generation of pressure and flow of gaseous CO2 required by the user apparatus (50).

2. Device as in claim 1, **characterized in that** the solid acid is selected from monovalent, bivalent or trivalent acids, in which, if a monovalent acid is used, the stoichiometric ratio between bicarbonate and acid is 1:1 M, if a bivalent acid is used the stoichiometric ratio between bicarbonate and acid is 2:1 M and if a trivalent acid

is used, the stoichiometric ratio between bicarbonate and acid is 3:1 M.

3. Device as in claim 1 or 2, **characterized in that** the solid acid used is selected from tartaric acid and citric acid or a mixture thereof.

4. Device as in claim 1, 2 or 3, **characterized in that** the suction pumping means (14) are located upstream of the reaction chamber (18).

5. Device as in claim 1, 2 or 3, **characterized in that** the suction pumping means (14) are located downstream of the reaction chamber (18).

6. Device as in claim 5, **characterized in that** it comprises one-directional fluid interception means (28) configured to selectively prevent a flow of fluid from the reaction chamber (18) toward the tank (23).

7. Device as in claim any claim hereinbefore, **characterized in that** said pressure sensor means (19) are associated to said reaction chamber (18) in order to supply a signal correlated to the pressure value of the gaseous CO2 produced inside the reaction chamber (18).

8. Device as in claim any claim hereinbefore, **characterized in that** said reaction chamber (18) comprises at least a delivery member (17) connected fluidically to said tank (23) in order to deliver a desired and controllable quantity of water toward said containing means (22).

9. Device as in any claim hereinbefore, **characterized in that** said electronic control means (13) integrate a PID controller.

10. Device as in any claim hereinbefore, **characterized in that** said container (11) is made at least externally of plastic material or fiberglass, suitable to be sterilized.

11. Device as in any claim hereinbefore, **characterized in that** said containing means comprise a cartridge (22) of the re-chargeable or disposable type.

12. Device as in claim any claim hereinbefore, **characterized in that** said exit means (21) are associated to an accumulation tank (31) for the gaseous CO2 produced.

13. Device as in claim 12, **characterized in that** said pressure sensor means (19) are associated to said accumulation tank (31).

14. Device as in any claim hereinbefore, for use as an autonomous generator of CO2 which can be connected to an incubator for animal/vegetable cells or to another device used in the foodstuff, health or aesthetic field and in any case in all fields where the generation and subsequent delivery of gaseous CO2 under

controlled pressure is required.

15. Method to generate and deliver gaseous CO2 under controlled pressure toward a desired user apparatus (50) of gaseous CO2 by means of a device as in any claim hereinbefore, **characterized in that** it provides to make available, in a reaction chamber (18) which can be selectively closed hermetically, solid forms composed of a mix of solid powders from a carbonate source, such as carbonate or bicarbonate of alkaline-earth metals and at least a solid acid, to determine a flow of water toward said solid forms contained in said reaction chamber (18) in order to solubilize in water at least part of said solid forms and determine the reaction of bicarbonate and solid acid in an aqueous environment to produce gaseous CO2, to detect a signal correlated to the pressure value of the gaseous CO2 produced and to selectively command said flow of water, on the basis of said signal, in order to control, at least in terms of pressure and flow, the generation and delivery of gaseous CO2 substantially automatically on the basis of desired parameters for the generation of pressure and flow of gaseous CO2 required by the user apparatus (50).

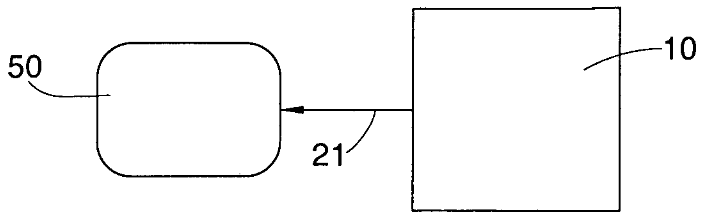

fig.1

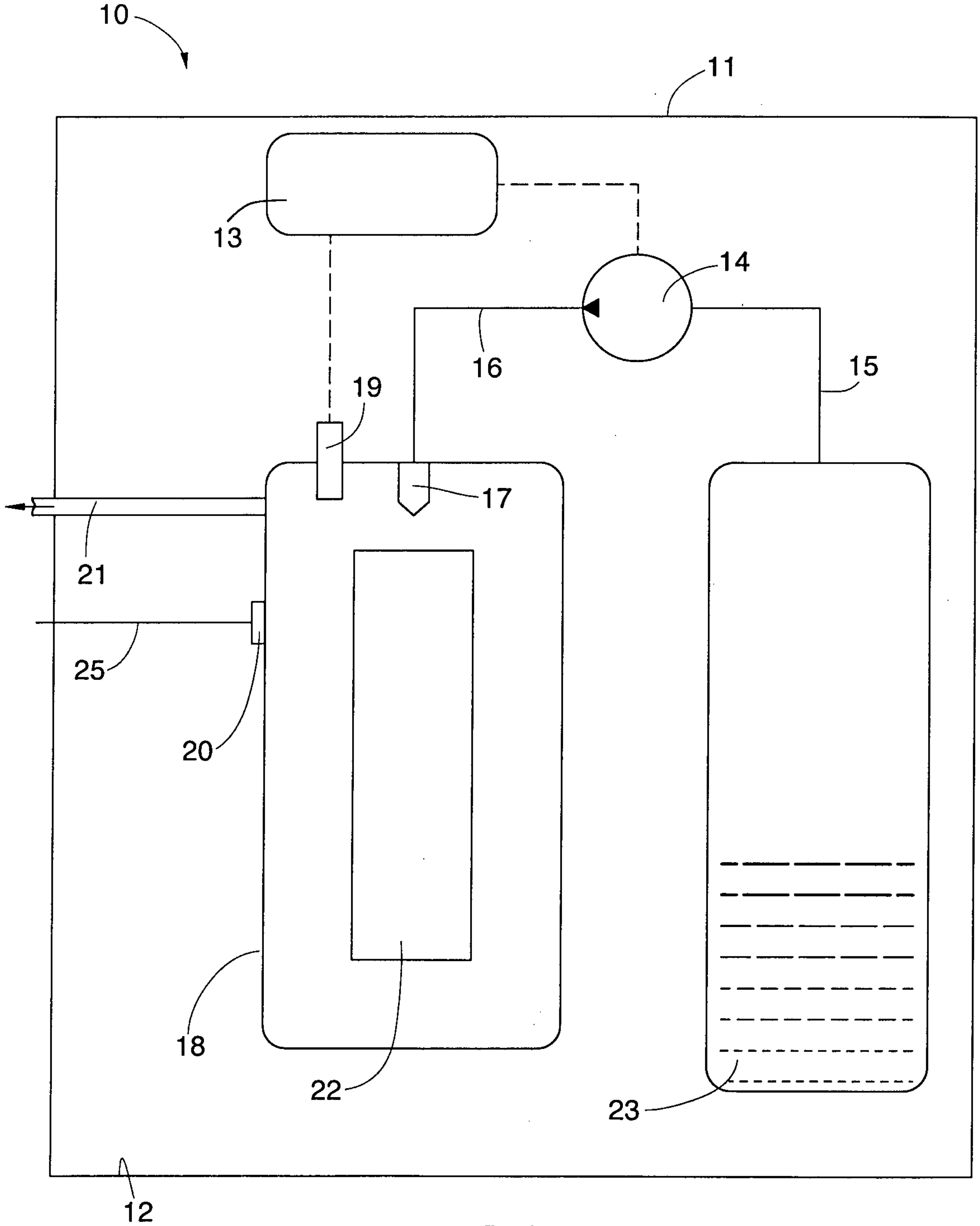

fig.2

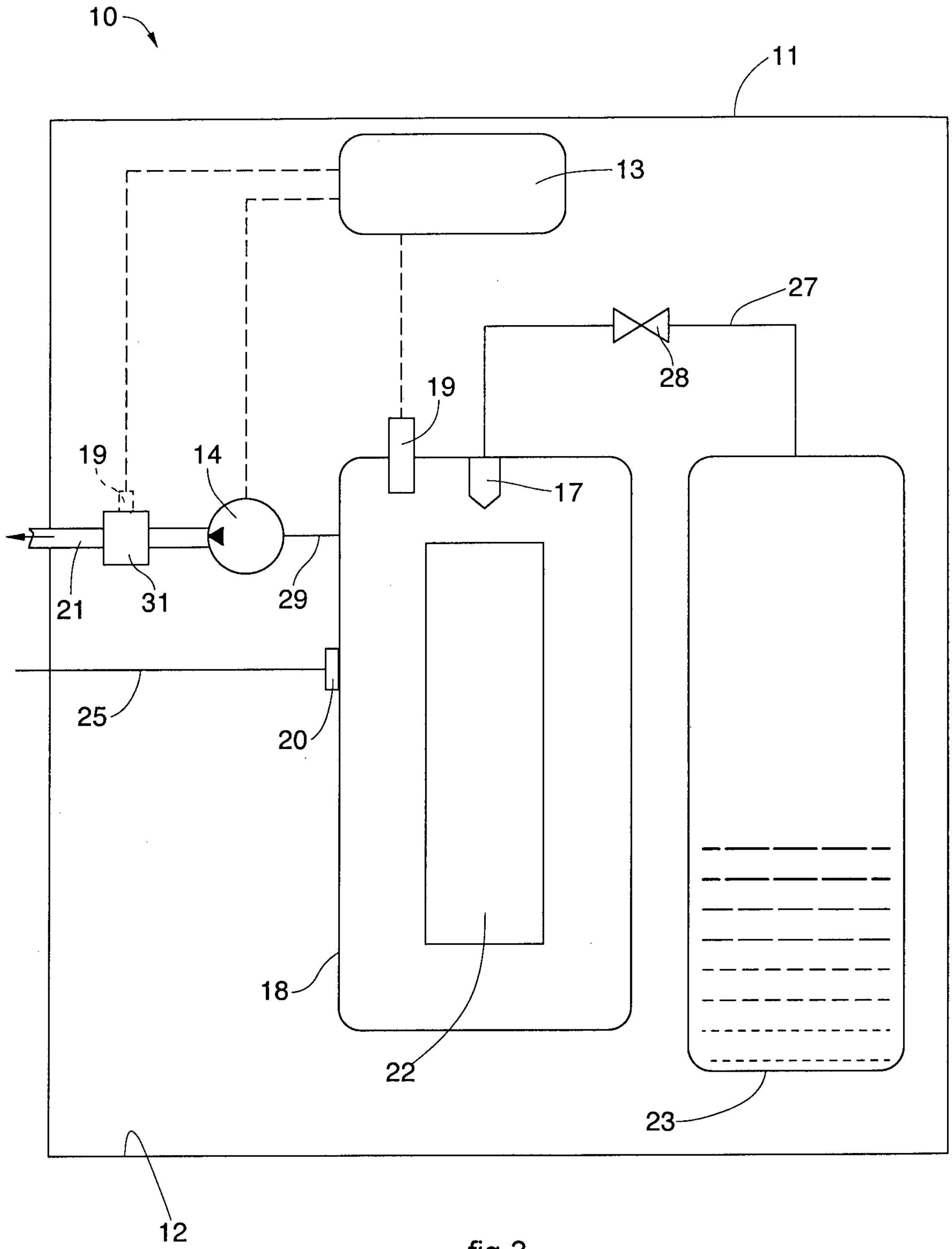

fig.3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/001326

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01J7/00 C01B31/20 C06D5/10 B01J7/02
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)
B01J C01B C06D C12M

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)

EPO-Internal, WPI Data, BIOSIS, EMBASE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2007/145629 A1 (UNIV NEW YORK STATE RES FOUND [US]; WEBSTER FRANCIS X [US]; SACK CHRIS) 21 December 2007 (2007-12-21) paragraph [0002] claims 1-5	1-15
Y	WO 96/30563 A1 (CERAMATEC INC [US]) 3 October 1996 (1996-10-03) claim 1 page 11, line 19 - line 25	1-15
Y	WO 97/02849 A1 (RIVER MEDICAL INC [US]) 30 January 1997 (1997-01-30) claim 1 figure 1	1-15

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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	Date of mailing of the international search report
28 August 2012	05/09/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Jones, Laura

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/001326

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 040 342 A (AUSTIN ROBERT ROY ET AL) 9 August 1977 (1977-08-09) claim 1 figure 1 -----	1-15
A	WO 98/53866 A1 (APEX MEDICAL TECH [US]; MCGLOTHLIN MARK W [US]; DEPAUL ALICE A [US]; S) 3 December 1998 (1998-12-03) claim 1 figure 1 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/001326

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 2007145629	A1	21-12-2007	CA	2654569	A1	21-12-2007
			EP	2041063	A1	01-04-2009
			US	2007292335	A1	20-12-2007
			WO	2007145629	A1	21-12-2007
WO 9630563	A1	03-10-1996	JP	H11502900	A	09-03-1999
			US	5593552	A	14-01-1997
			WO	9630563	A1	03-10-1996
WO 9702849	A1	30-01-1997	AU	6458296	A	10-02-1997
			EP	0837703	A1	29-04-1998
			US	5700245	A	23-12-1997
			WO	9702849	A1	30-01-1997
US 4040342	A	09-08-1977	NONE			
WO 9853866	A1	03-12-1998	AU	7484498	A	30-12-1998
			EP	0999863	A1	17-05-2000
			US	5992700	A	30-11-1999
			WO	9853866	A1	03-12-1998