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(71) Applicant *(for all designated States except US)*: **KATHOLIEKE UNIVERSITEIT LEUVEN** [BE/BE]; K.U.Leuven R&D, Waaistraat 6 - Box 5105, B-3000 Leuven (BE).

(71) Applicant *(for US only)*: **M4E N.V.** [BE/BE]; Teerlingstraat 14, B-9190 Stekene (BE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **DERDELINCKX Guy** [BE/BE]; Rue du paradis 34, B-1400 Nivelles (BE). **MARTENS Johan** [BE/BE]; Borheidestraat 25, 3040 Huldenberg (BE). **RONGÉ Jan** [BE/BE]; Uilenstraat 58, B-1150 Sint-Pieters-Woluwe (BE). **VELGHE Firmin** [BE/BE]; Teerlingstraat 14, B-91 90 Stekene (BE).

(74) Agent: **ROELANTS, Ivo**; Katholieke Universiteit Leuven, K.U.Leuven R&D, Waaistraat6-bus5105, B-3000 Leuven (BE).

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(54) **Title**: $C0_2$ DISSOLUTION

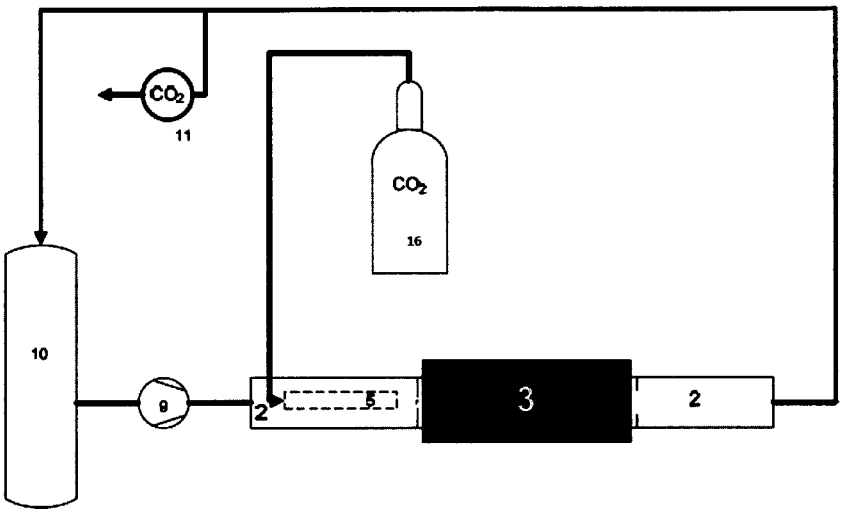


Fig. 15

(57) **Abstract**: The present invention relates generally to an apparatus and method for enhanced dissolving or dissolving with an with increased saturation efficiency of carbon dioxide ($C0_2$) into an aqueous liquid, more particularly to a system and method for enhanced $C0_2$ in water dissolution from $C0_2$ gas. The present invention relates in particular to an apparatus and method for in-line carbonation of aqueous liquids with increased dissolving with increased saturation efficiency of $C0_2$ from a $C0_2$ gas or from gas whereof an essential part is $C0_2$ by flowing a mixture of gas and liquid through a zone surrounded by a permanent magnet (3) or an assembly of permanent magnets.

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CO_2 DISSOLUTION

BACKGROUND AND SUMMARY

Background of the invention

A. Field of the Invention

The present invention relates generally to an apparatus and method for enhanced dissolving or dissolving with an increased saturation efficiency of carbon dioxide (CO_2) into an aqueous liquid, more particularly to a system and method for enhanced CO2 in water dissolution from CO_2 gas. The present invention relates in particular to an apparatus and method for in-line carbonation of aqueous liquids with increased dissolving with increased saturation efficiency of CO_2 from a CO_2 gas or from gas whereof an essential part is CO2.

Several documents are cited throughout the text of this specification. Each of the documents herein (including any manufacturer's specifications, instructions etc.) are hereby incorporated by reference; however, there is no admission that any document cited is indeed prior art of the present invention.

B. Description of the Related Art

There are several means in the art to carbonate an aqueous solution or to dissolve carbon dioxide in an aqueous solution.

One method for carbonating aqueous liquids involves using yeast. In this method, some yeast is added to a sweet sugar-based liquid. The yeast bacteria consume the sugars and produce carbon dioxide as a by-product. This carbon dioxide production continues for a number of days in a warm environment after which it is to be kept refrigerated. This ferment carbonation can result in a CO_2 content of about 3 g/l or a bit more depending on the height of the fermentation tank. But additional carbonation by additional or other means is still necessary, in particular for two reasons. Firstly the natural carbonation process during fermentation is not sufficiently reliable or controllable to

steer it to a desired and/or predictable end concentration of solved CO_2. Secondly a desired end concentration of 5 g/l - 7 g/l of dissolved CO_2 cannot be reached by this natural fermentation derived carbonation process.

A possible physical process of producing carbonated water (water containing carbon dioxide) or other carbonated aqueous liquids can be by passing carbon dioxide under pressure through such water or other aqueous liquid. Thus the process usually involves high pressures of carbon dioxide at a relatively high especially when the system is susceptible to pressure drops, whereby carbon dioxide used for carbonation is compressed carbon dioxide. The solubility of CO_2 in water varies according to the temperature of the water and the pressure of the gas. It decreases with increased temperature and increases with increased pressure. At 15.5°C and a pressure of 1 atm (15 psi), water will absorb its own volume of carbon dioxide. Raising the pressure to 10 atm (150 psi) will bring about an increase in the gas solubility to around 9.5 volumes. Since it is easy it is simpler to carbonate if the product temperature is low early carbonators used refrigeration to carbonate at ca. 4◦C. For instance the product is spread over chilled plates, such that the product runs down the plates as a thin film. This is carried out in a constant pressure carbon dioxide atmosphere. The product being chilled as a film maximises the surface area available to the carbon dioxide thus promoting effective carbonation. This energy usage of this process is however high.

Other basic methods use the injection and dispersion of carbon dioxide into the liquid to be carbonated, and the fine spraying of the product into a carbon dioxide atmosphere. For batch production it has been found by experience that the most effective method is to spray the water into a carbon dioxide atmosphere within a pressurised vessel. The rate of flow and the pressure of the carbon dioxide are critical to ensure that the correct carbonation. The greater the liquid surface area exposed to the carbon dioxide the higher the rate of absorption of the carbon dioxide by the liquid. For instance injection of compressed carbon dioxide into the container or recipient with a watery fluid is described in U.S. Pat. No. 6,036,054 or US7296508 B2). The Japanese patent application JP2003112796 A describes such for carbonation of a beverage.

Recently, many methods for producing carbonated spring by using a membrane have been proposed such as Japanese Patent No. 2, 810,694 which describes the use of a hollow yarn membrane module incorporating plural porous hollow yarn membranes whose both ends are open and further the Japanese Patent Nos. 3,048,499 and the 3,048,501, Japanese Patent Application Laid-Open No.2001-293344 and the like which propose methods of using a nonporous hollow yarn membrane as a hollow yarn membrane. In these systems carbonated water is produced using a membrane, a so-called one-pass type in which carbonated water is produced by passing raw water through a carbon dioxide gas dissolver having a membrane module. The Japanese Patent JP2006020985 describes the use of micropore systems in an apparatus for diffusing carbon dioxide in a water volume.

Another method for carbonating liquids includes using dry ice as a source of carbon dioxide. In this method, carbon dioxide is in a solid state, and is placed into the liquid to be carbonated. The carbon dioxide sublimates from a solid to gaseous state, and carbonates the liquid.

Carbonation is particular critical for some beer, for instance the Belgian beer, since for consumer acceptance a reasonable foam head in proper dimensions is required. This is obtainable by the proper concentration of CO_2 is said beer. Such beer foam further comprises polypeptides of different groups with different relative hydrophobicity. As the hydrophobicity of the polypeptide groups increases, so does the stability of the foam.

In general the presence of carbon dioxide does make aerated waters and soft drinks both more palatable and visually attractive. The final product sparkles and foams. It gives the 'fizz' to carbonated drinks, the cork pop and bubbles in champagne and the head to beer. Consumers tend to place a lot of importance on beer heads: too much of a head is undesirable because it detracts from the mass of the drink (similar to carbonated soda drinks), but on the other hand, a beer drink is viewed as incomplete unless it has a head, and the specific form of head expected for the type of beer.

Moreover the dissolved CO_2 is responsible for the flavour. If a beer is not properly saturated with carbonic acid then beer's characteristics of full taste is lacking or a

feeling of full taste is not observed by a significant portion of consumers, representatives in a taste panel or beer sommeliers. Moreover above a certain level of carbonation carbon dioxide has a preserving property, having an effective antimicrobial effect against moulds and yeasts.

Methods in practice of beer carbonation are beside the CO_2 production and dissolution by the fermentation itself, sparging the CO_2 in beer that flows through a guidance pipe. Hereafter the beer/CO_2 mixture flow to a series of static mixers to enhance the CO_2 dissolution into the liquid. Another common method concerns carbonation of the beer in a closed pressurized container whereby the carbon dioxide is sparged into the liquid the beer mass through a carbonation stone.

The methods of the art have several drawbacks. There is a need in the art for carbonators that remain clean-in-place (CIP) and which do not leaf remains or waste in said system after operation. This is particularly a problem if the same system has to be used for carbonation of another aqueous fluid. Some of the carbonators are susceptible to considerable pressure drops is smaller than for delivery of CO_2 gas in large volumes of liquids and they need powerful pumps high energy consuming pumps. Some of the carbonators or carbonation systems occupy too much space in an industrial environment in particular the inline systems operate with too long aqueous fluid pipelines. . In general there is a need for carbonators that operate with increase carbonation efficiency.

Thus, there is a need in the art for improving the current carbonation methods by enhanced dissolving of gases in liquid fluids and in particular for more efficient and cost effective dissolving carbon dioxide in watery or aqueous bodies.

Present invention provides a solution for enhanced dissolving of CO_2 gas into an aqueous liquid. The system of invention provides improvements on above mentioned drawbacks.

SUMMARY OF THE INVENTION

The present invention solves the problems of the related art by provided a system that allows a selective increase of the dissolution efficiency of some gas compounds versus other gas compounds out of a gas mixture.

In accordance with the purpose of the invention, as embodied and broadly described herein, the invention is broadly drawn to a flow through and eventually recirculation method of CO_2 has and a flow through or flow through recirculation apparatus for enriching an aqueous liquid fluid with CO_2 compounds of the flow through CO_2 gas. The method and apparatus can be used CO_2 dissolution in small volume reservoirs (for instance bottles) or in large liquid bodies (for instance in industrial reactors). The present invention relates generally to an apparatus and method for increased dissolving with increased saturation efficiency of CO_2 into an aqueous liquid from a CO_2 gas or from gas whereof an essential part is CO2. In a certain embodiment present invention concerns enhancing dissolution of CO_2 molecules in an aqueous liquid from a CO_2 gas stream. These dissolving of CO_2 gas in aqueous liquids can by operation of the device of present invention

In accordance with various embodiments, the CO_2 gas fluid and aqueous liquid fluid are combined in a line or fluid conduit (e.g. tube or pipe) and flow through a zone of reduced pressure under a permanent field which is generated by a surrounding permanent magnet or assembly of permanent magnets. The apparatus can be further foreseen further downstream with a fluid reservoir in a closed container (e.g. closed drum) to with a valve outlet to tap volumes of said carbonated aqueous liquid.

Via an inlet port the CO_2 gas fluid is aspirated in the confined environment of the flow through (eventually recirculation) system. The CO_2 gas can be released from a pressurized CO_2 gas storage container or carbon dioxide storage systems or it can be sucked through the inlet port into a zone of the liquid fluid line or fluid conduit (e.g. tube or pipe) which has a narrower inner diameter than upstream or downstream of the narrower passage so that if operational the motile liquid in this constricted section of the liquid fluid line or fluid conduit (e.g. tube or pipe) will induce a pressure drop in the zones compared to directly upstream or downstream or even near vacuum creation that is compensated by aspiration of the CO_2 gas fluid through a gas inlet port. Alternatively

the CO_2 gas is released through a porous device as vapour bubbles locoregional or adjacent before , neighboring before or in front near or abut the zone of the liquid fluid line or fluid conduit (e.g. tube or pipe) which has a narrower inner diameter than upstream or downstream of the narrower passage or alternatively locoregional or adjacent before , neighboring before or in front near or abut the zone in the liquid fluid line or fluid conduit (e.g. tube or pipe) which is separated by an in line entrance shield or wall and an outlet shield or wall which comprises openings that are smaller than the inner diameter of the liquid fluid line or fluid conduit (e.g. tube or pipe). The CO_2 gas fluid and liquid fluid is mixed under a magnetic field, preferably a permanent magnetic field, while passing through a section of the conduit that is surrounded a permanent magnet or permanent magnet assembly or an electro conductive coil. This section can be with narrower inner diameter than upstream or downstream or can be shielded or formed by the in line transversal wall with openings smaller than the inner diameter of said the liquid fluid line or fluid conduit (e.g. tube or pipe).

Since the strength of each commercially available magnet is usually limited to about 10,000 gauss, a means to increase the effective magnetic field is to flow the aqueous liquid through a number of magnets arranged in series (especially for limiting or prolonging the duration of treatment) and/or to re-circulate the aqueous liquid several times, i.e. preferably at least 10 times, more preferably at least 40 times, through the same magnetic field. Preferably the strength of each said magnetic field used for carrying out the method of the invention is at least about 0.2 Telsa (2,000 gauss) or at least 0,2 Telsa (2,000 gauss) at the active region thereof and preferably in at a value from the range of 0,20 to 2 Tesla, more preferably of 0,50 to 1,5 Tesla, yet more preferably of 0,60 to 1,20 Tesla and yet more preferably of 0.65 to 1 Tesla, yet more preferably of 0,70 to 0,80 Tesla and most preferably of 0,75 Tesla or about 0,75 Tesla and the flow rate through each said magnetic field of the aqueous liquid to be carbonated is at a value from the range of 0,1 to 5 l/s, more preferably 0,15 to 0,3 and yet more preferably 0,2 to 2,5 l/s. In yet another embodiment magnetic field used for carrying out the method of the invention is at least about 0.2 Telsa (2,000 gauss) or at least 0,2 Telsa (2,000 gauss) at the active region thereof and preferably in at a value from the range of 0,20 to 2 Tesla, more preferably of 0,50 to 1,5 Tesla, yet more preferably of 0,60 to 1,20 Tesla and yet more preferably of 0.65 to 1 Tesla, yet more

preferably of 0,70 to 0,80 Tesla and most preferably of 0,75 Tesla or about 0,75 Tesla and the linear flow rate of said aqueous fluid flowing through each said magnetic field is between 0.25 and 25 m/s.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

Detailed Description

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

The following detailed description of the invention refers to the accompanying drawings. The same reference numbers in different drawings identify the same or similar elements. Also, the following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims and equivalents thereof.

Several documents are cited throughout the text of this specification. Each of the documents herein (including any manufacturer's specifications, instructions etc.) are hereby incorporated by reference; however, there is no admission that any document cited is indeed prior art of the present invention.

The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn to scale

for illustrative purposes. The dimensions and the relative dimensions do not correspond to actual reductions to practice of the invention.

Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

Moreover, the terms top, bottom, over, under and the like in the description and the claims are used for descriptive purposes and not necessarily for describing relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other orientations than described or illustrated herein.

It is to be noticed that the term "comprising", used in the claims, should not be interpreted as being restricted to the means listed thereafter; it does not exclude other elements or steps. It is thus to be interpreted as specifying the presence of the stated features, integers, steps or components as referred to, but does not preclude the presence or addition of one or more other features, integers, steps or components, or groups thereof. Thus, the scope of the expression "a device comprising means A and B" should not be limited to the devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or

characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

Similarly it should be appreciated that in the description of exemplary embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims following the detailed description are hereby expressly incorporated into this detailed description, with each claim standing on its own as a separate embodiment of this invention.

Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only. Each and every claim is incorporated into the specification as an embodiment of the present invention. Thus, the claims are part of the description and are a further description and are in addition to the preferred embodiments of the present invention. Each of the

claims set out a particular embodiment of the invention. The following terms are provided solely to aid in the understanding of the invention.

Definitions

For the purpose of describing the present invention, the following terms have these meanings:

"Metal" means a metal or an alloy of one or more metals.

"Microbubble" means a bubble with a diameter less than 50 microns.

"Nanobubble" means a bubble with a diameter less than that necessary to break the surface tension of water. Nanobubbles remain suspended in the water, giving the water an opalescent or milky appearance.

A nanobubble under the critical diameter is a nanobubble with a diameter under 110 nm, preferably under 100 nm and yet more preferably under 90 nm . In present invention such CO_2 nanobubbles under the critical diameter are generated by a nonobubbles generator to achieve an effect of increased CO_2 when forced through the magnet mixer of present invention. At higher that pressure than atmospheric pressure such nanobubble under the critical diameter are yet smaller.

"Supersaturated" means CO_2 at a higher concentration than normal calculated CO_2 solubility at a particular temperature and pressure.

"Supercarbonated water" means water with an CO_2 content at least 120% of that calculated to be saturated at a temperature.

An "aqueous medium" can be water but it can for instance also comprise a beverage or a beverage concentrate for instance a beverages such as coffee, coffee-flavoured milk, black tea, tea with milk, soybean milk, nutrition-supplement drink, vegetable drink, vinegar drink, juice, cola, mineral water, sport drink, and the like; alcohol drinks such as

beer, wine, cocktail, sour, and the like; milk and dairy products such as milk, yogurt, cheese, and the like; and others.

"Water" means a fluid wherein the main chemical substance is with the chemical formula H_2O. Concerned the present invention water can have different origins or uses it can be one or more of the following groundwater, meltwater, meteoric water, fresh water, surface water, mineral water, brackish water, seawater, tap water, bottled water, drinking water or potable water, purified water, laboratory-grade, analytical-grade or reagent-grade water or highly purified often broadly classified as Type I, Type II, or Type III in this category including but is not limited to distilled water, double distilled water or deionized water, soft water , hard water; distilled water, double distilled water, deionized water, drinking water, wastewater and/or surface water. Water, as the main component of a soft drink, usually accounts for between 85 and 95% of the product and acts as a carrier for the other ingredients.

"Carbonation "usually refers to the dissolving of carbon dioxide in an aqueous solution and carbonation occurs when carbon dioxide is dissolved in water or an aqueous solution. This process is generally represented a reaction, where water and gaseous carbon dioxide react to form a dilute solution of carbonic acid. For a given volume, the amount of carbon dioxide which a solution can maintain depends on the temperature and pressure. The higher the temperature the greater the pressure required to maintain the carbon dioxide in solution. Conversely, the lower the temperature the greater the amount of carbon dioxide that is retained in Solution. Any decrease in pressure, or increase in temperature, will render the mixture metastable, that is, supersaturated, such that the temperature/pressure combination is insufficient to keep the carbon dioxide in solution. 'The volume of an ideal gas at constant pressure is directly proportional to the absolute temperature'. These two laws can be combined to form the universal ideal gas law: $p \cdot V = n \cdot R \cdot T$ (Henry's law), here p is the absolute pressure, V is the volume, n is the number of moles of gas, R is the gas constant (for that particular ideal gas) and T is absolute temperature. For carbon dioxide the molecular weight is 44.01 and R is 0.18892 J/mol K.

"Carbonated beverages" are typically formulated to be in the range of 2–3 volumes dissolved gas. The effect of dissolution is to form carbonic acid (H_2CO_3), and this in turn dissociates partly to form bicarbonate and carbonate ions.

"Dissolved carbon dioxide" can be measured and expressed. The unit of measurement of dissolved carbon dioxide is volumes of the gas corrected to normal temperature and pressure (i.e. NTP = 0°C and 760 mmHg), per volume of the liquid. More recently, it has been expressed as grams per litre. (Note: 1 l CO_2 at NTP weighs 1.97 g.)

"Carbon dioxide storage systems" are available in the art. They are normally sited outside with suitable weather protection for the associated electrical equipment or when situated inside a building then adequate ventilation is provided. Basic requirement of such tank is to maintain a constant tank temperature independent of the environment and the withdrawal rate of the CO_2 gas. The tank is normally insulated with at least 10 cm thick urethane. This is normally covered with a pre-painted aluminium jacket. The actual tank is usually constructed in fine-grain carbon steel. It is normal practice for a bulk vessel to have at least two suitably sized relief valves, connected to the vessel via a changeover valve. This allows one valve to be maintained whilst the other is in operation. A normal storage pressure is in the region of 20.5 bar at −17◦C. This has been found to be the most practical operating level and has been adopted as the worldwide standard by most carbon dioxide suppliers.

The solubility of gases is generally defined by Henry's law is used to quantify the solubility of gases in solvents. The solubility of a gas in a solvent is directly proportional to the partial pressure of that gas above the solvent. This relationship is written as: where kH is a temperature-dependent constant, p is the partial pressure (atm), and c is the concentration of the dissolved gas in the liquid (mol/L). The solubility of gases is sometimes also quantified using Bunsen solubility coefficient. In the presence of small bubbles, the solubility of the gas does not depend on the bubble radius in any other way than through the effect of the radius on pressure (i.e., the solubility of gas in the liquid in contact with small bubbles is increased due to pressure increase by $\Delta p = 2\gamma/r$;

By an IUPAC definition, solvation is defined as an interaction of a solute with the solvent, which leads to stabilization of the solute species in the solution. One may also refer to the solvated state, whereby an ion in a solution is complexed by solvent molecules. The concept of the solvation interaction can also be applied to an insoluble material, for example, solvation of functional groups on a surface of ion-exchange resin. Solvation is, in concept, distinct from dissolution and solubility.

Dissolution is a kinetic process, and is quantified by its rate. Solubility quantifies the dynamic equilibrium state achieved when the rate of dissolution equals the rate of precipitation. The consideration of the units makes the distinction clearer. Complexation can be described by coordination number and the complex stability constants. The typical unit for dissolution rate is mol/s. The unit for solubility can be mol/kg.

The device of present invention concerns to increase the dissolution, solubility or solvation of CO_2 compounds in a watery fluid by dissolving such under reduced pressure and under magnetization or by releasing microbubbles of such CO_2 gas in watery fluid under reduced pressure and under magnetization comprises use of magnets electromagnets or preferably permanent magnets. A permanent magnet is an object made from a material that is magnetized and creates its own persistent magnetic field. Materials that can be magnetized, which are also the ones that are strongly attracted to a magnet, are called ferromagnetic (or ferromagnetic). These include iron, nickel, cobalt, some alloys of rare earth metals, and some naturally occurring minerals such as lodestone. Ferromagnetic materials can be divided into magnetically "soft" materials like annealed iron which can be magnetized but don't tend to stay magnetized and magnetically "hard" materials, which do. Permanent magnets are made from "hard" ferromagnetic materials which are subjected to special processing in a powerful magnetic field during manufacture, to align their internal microcrystalline structure, making them very hard to demagnetize. Different types of permanent magnets are suitable for present invention for instance permanent magnets comprising magnetic metallic elements, composite permanent magnets, injection molded permanent magnets, flexible permanent magnets, rare earth magnets, single-molecule magnets (SMMs) and single-chain magnets (SCMs° or nano-structured magnets. Magnetic metallic elements concerns magnets that are composed of or that comprise paramagnetic materials which

have unpaired electron spins, for instance such paramagnetic materials such as iron ore (magnetite or lodestone), cobalt and nickel, as well the rare earth metals gadolinium and dysprosium (when at a very low temperature). Composite permanent magnets comprise materials such as Ceramic or ferrite, Alnico (magnets are made by casting or sintering a combination of aluminium, nickel and cobalt with iron and small amounts of other elements added to enhance the properties of the magnet) or Ticonal (an alloy of titanium, cobalt, nickel, and aluminium, with iron and small amounts of other elements). The injection molded magnets are a composite of various types of resin and magnetic powders, allowing parts of complex shapes to be manufactured by injection molding. The physical and magnetic properties of the product depend on the raw materials. Flexible magnets are similar to injection molded magnets, using a flexible resin or binder such as vinyl, and produced in flat strips, shapes or sheets. These magnets are lower in magnetic strength but can be very flexible, depending on the binder used. Rare earth (lanthanoid) elements have a partially occupied f electron shell (which can accommodate up to 14 electrons.) The spin of these electrons can be aligned, resulting in very strong magnetic fields, and therefore these elements are used in compact high-strength magnets where their higher price is not a concern. The most common types of rare earth magnets are samarium-cobalt and neodymium-iron-boron (NIB) magnets. The Single-molecule magnets (SMMs) and single-chain magnets (SCMs) are very different from conventional magnets that store information at a magnetic domain level and theoretically could provide a far denser storage medium than conventional magnets. The two main attributes of an SMM are: a large ground state spin value (S), which is provided by ferromagnetic or ferromagnetic coupling between the paramagnetic metal centres and a negative value of the anisotropy of the zero field splitting (D) Most SMMs contain manganese, but can also be found with vanadium, iron, nickel and cobalt clusters. Some chain systems can also display a magnetization which persists for long times at higher temperatures. These systems have been called single-chain magnets. Nano-structured magnets comprise nano-structured materials which exhibit energy waves called magnons. An electromagnet is a type of magnet whose magnetic field is produced by the flow of electric current. The magnetic field disappears when the current ceases. A possible set up for present invention is simple electromagnet consisting of a coil of insulated wire wrapped around the metal liquid fluid line or fluid conduit (e.g.

tube or pipe) forming the magnetic zone for enhanced CO_2 gas dissolution. The strength of magnetic field generated is proportional to the amount of current.

Particular and preferred aspects of the invention are set out in the accompanying independent and dependent claims. Features from the dependent claims may be combined with features of the independent claims and with features of other dependent claims as appropriate and not merely as explicitly set out in the claims.

Thus, the claims following the detailed description are hereby expressly incorporated into this detailed description, with each claim standing on its own as a separate embodiment of this invention.

EXAMPLES

Example 1: Carbonation using the magnet technology, Materials and Methods

A rotary vane pump with a period of 28s recirculated water was pumped through a liquid guidance pipe in a recirculation system which comprised liquid guidance lines, the pump, a water sampling unit, a CO_2 gas guidance connected to the liquid guidance line with its input port connected to porous device, sintered porous metal length 195 mm, inner diameter 16 mm and pores of 25 µm (Cegelec/M4E) in the gas guidance line to introduce carbon dioxide inline in the liquid guidance line through the porous device, a gas debit meter (Cegelec/M4E) to sense and control the CO_2 flow into the liquid guidance line, and further comprising a container or closed reservoir (e.g. drum or tank) which was almost completely filled with water and which could be air tight locked to isolate it from the outer atmosphere (container of 120 liter which was at operation filled with 74 liter of water). Solved CO_2 was measured online by a CO_2-sensor (Hach Ultra™ Orbisphere 3658) for selective in situ CO_2 measurement.The solved CO_2 concentration was also measured by a GC analysis (HP 6890 chromatograph with TCD detector). We used a mol sieve type column to have strong adsorption of the water and fast elution of the gas phase. Samples of 4 µl (1:15 split ration) were injected and helium was the drive gas. The device of the present invention was allowed to take in CO_2 gas to solve this CO_2 in a line or fluid conduit (e.g. tube or pipe) that recirculated water back towards the

closed container (e.g. drum or closed reservoir)... Each such experiment was operated with two experimental conditions: 1) whereby the device of present invention was operated *without magnet* and 2) the condition whereby the device of present invention was operated *with magnet (Cegelec/M4E)*. The water temperature was 15-20 °C. The magnet induced a magnetic field of 0.75 Tesla.

Carbon dioxide from a carbon dioxide tank or carbon dioxide storage systems was guided through a gas guidance pipe towards a beer guidance tube and the carbon dioxide was introduced in line of the beer guidance tube through porous device (a sintered porous metal). A permanent magnet (Cegelec/M4E) is placed surrounding the liquid guidance conduit (tube, pipeline or duct) next after the sintered porous metal. The zone in the liquid guidance tube on which the surrounding magnet can be mounted is separated at the proximal and at the distal end inline septum, wall or partition wherein there is a at least one opening which opening(s) have a surface that is smaller than the inner diameter of the liquid guidance conduit (tube, pipeline or duct) Cegelec/M4E). This forms the magnet zone when the magnet is mounted. When operational an interesting phenomenon was observed CO_2 vapor bubbles released from the porous device into the beer guidance tube are under the magnetic field burst into smaller vapor bubbles. By preferential adsorption of anions at the vapor bubble surface these vapor bubbles are negatively loaded. Under the Lorentz force of the magnetic field the loaded vapor bubbles, deviate from their orbit normally imposed by the liquid flow and are pushed against the guidance wall where these bubbles are submitted to shear stress and ruptured in further bubbles segments. This process is controllable by the flow speed of the beer, the injection speed of the CO_2 gas and the magnetic flux density. Increased levels of CO_2 dissolution was obtainable without the static mixers which are used in carbonation processes of the art. The installation of present invention is for this reason reach efficient carbonation with a much more compact carbonation system than the carbonators of the art.

Example 2: Evaluation of the system. Pressure and temperature effects

Since the solubility of CO_2 in water varies according to the temperature of the water and the pressure and since between the different experiments a temperature difference up

to 5°C was possible the concentration of dissolved CO_2 was expressed as % of saturation. Figure 1 displays that at higher pressure higher concentrations of dissolved CO_2 could be reached. In this experimental set up at t = 0 the pressure was 1 bar and the CO_2 flow into the liquid guidance was activated. The dot lines demonstrate when the gas flow was stopped. For the higher pressure this was later in time since the pressure had to build up.

Example 3 : Results – Influence of the magnet at various pressures

Experimental set up I:

In a first phase we operated the system of present invention (Example 1) under atmospheric pressure (water reservoir open – water in contact with air) and CO_2 gas was introduced inline according to the protocol of example 1. In a second phase the system was closed (confined water reservoir) and the pressure was increased up to 1,5 bar and CO_2 gas was introduced inline according to the protocol of example 1. When the magnet was mounted on the recirculation system a considerable increase of CO_2 solution was obtained. The water temperature was 15-20 °C.

At atmosphere pressure (Fig. 2) CO_2 gas dissolved in the water as long it was introduced inline. When the magnets were mounted on the system dissolved CO_2 augmented to a maximal level and consequently declined. Without magnets the dissolved CO_2 concentration was rising until the CO_2 supply was ceased. Apparent CO_2 oversaturation is due to a temporarily increase in pressure in the liquid guidance line. When the CO_2 gas supply was stopped, this pressure decreased to 1 bar and the dissolved CO_2 remained constant at 100%. When the magnet was mounted thus when mixing the CO_2 gas vapor bubbles in water under the magnetic field the concentration of dissolved CO_2 increased with 4,2 % /s and reached a maximum at after 30 s or in about one period (cycle). Without magnet the concentration at dissolved CO_2 increased at a speed of 2,4 %/s only whereby a maximum was reached after 50 s (1,8 periods of recycling)

With a pressure increase to 0,5 bar (fig. 3). The concentration of dissolved CO_2 increased for the condition without magnet at equal speed as for the condition without magnet. But for the condition without magnet the onset of the increase in dissolved CO_2

concentration was delayed with 20 seconds. With the magnet the concentration of dissolved CO_2 increased with a concentration of 2,7 %/s and this lasted for 20s (0.7 period) to reach the maximum. Without magnet this was 3 %/s lasting for 40s (1,4 period).

Experimental set up II :

In a first phase we operated the system of present invention (Example 1) under atmospheric pressure (water reservoir open – water in contact with air) and CO_2 gas was introduced inline according to the protocol of example 1. In a second phase the system was closed (confined water reservoir) and the pressure was increased up to 2,5 bar. When the magnet was mounted on the recirculation system a considerable increase of CO_2 solution was obtained; The water temperature was 15-20 °C.

Figure 4 provides a graphic display of dissolved CO_2 in the experiment at 2,5 bar In both cases (with or without magnets) the retardation or phase lag was 20 s. this can be explained because in this experimental set up the dissolved CO_2 concentration was measured after the sintered metal and in its direct proximity instead of after the sintered metal two meters further in the water guidance pipeline. With the magnet the concentration of dissolved CO_2 increased with 2,8 %/s whereby a maximal level was reached after 60 s (2,1 period of recirculation). Without magnet the concentration of dissolved CO_2 increased with 1,6 %/s whereby a maximal level was reached after 100 s (3,6 periods of recirculation).

Example 4: Results – Effect of the magnet system

Figure 11: is a graphic display of the dissolved CO_2 concentration for mixing of CO_2 vapor nanobubbles in water under a magnetic field or without magnetic field the speed of CO_2 solving and the yield is displayed. The magnetic field induces a faster solution of the CO_2 gas that was introduced inline as vapor bubbles in motile or flowing water and mixed with the liquid phase under a magnetic field. The CO_2 gas dissolution is faster and its yield is higher (expressed as % of introduced CO_2 gas that is dissolved). Figure 11 displays the average time to reach the maximal levels and the maximal reached yield per experiment per experiment. The maximal yield of 42% was reached faster under a

magnetic field (when the magnet was mounted and surrounded the CO_2/water mixing zone) and this yield was 14 % higher than the condition of no magnet or induced magnetic field.

Example 5: Results – Effect of the venturi

Figure 1_2 provides a graphic display on the dissolved CO_2-concentration with and without venturi mixing at 1 bar in the water guidance line after the venture system (as displayed in a graphic scheme in Fig. 19 A). . The gas was introduced between t = 10s and t = 40s. In this experimental set up we investigated the effect of the replacement of the sintered metal for introduction of the CO_2 gas in the watery liquid as vapour bubbles (Fig 19 B) by a venturi mixture (Fig. 19 A) . Surprisingly under this condition of CO_2 delivery in a separate venture (Fig 19 A) there was no effect if the magnet was absent or present. When the CO_2 gas was introduced via de venture system instead of via the sintered metal the CO_2 gas dissolution was slower and a lower maximal concentration of dissolved CO_2 was reached.

Generally we observed two systems with enhanced CO_2 gas dissolution after inline introduction in water. The first system of fig 19 B whereby CO_2 gas is passed through a nanobubble generator for generation generation CO_2 gas nanobubbles or CO_2 gas micro/nanobubbles (comprising nanoscale-sized CO_2 bubbles) for instance by pushing it under pressure or by a gas pump through a microporous devices to release nanobubbles. The proximal part (where it joined in the liquid fluid guidance conduit (pipeline, tube or duct) near the magnetic mixer) of the CO_2 inlet port comprises a nanobubble creation means for instance microporous means to inflow in the aqueous fluid CO_2 gas in the form of vapour bubbles with a critical diameter under 110 nm, preferably under 100 nm and most preferably under 90 nm. Small CO_2 vapour bubbles under a critical diameter of under 110 nm, preferably under 100 nm and most preferably under 90 nm result in an increased efficiency of increased CO_2 dissolution even at a shorter zone of the magnetic field or even when only one magnet or magnet assembly is used or even when the magnetic zone is created is only one and it is no repetitions of magnetic fields generated by separate magnets or magnet assemblies along the axis of the aqueous fluid guidance.

The microporous means can be in the form of a plate but it can be formed in various geometrical forms. It further may comprise or consist of various materials such a ceramic in case it comprises a micro-porous ceramic filter. In present experiments the sintered metal device of Cegelec/M4E (Fig 16 see element (5)). These vapor nanobubbles with critical diameter are released near or abut the entrance of a magnet venture mix for instance they are released near or abut the septum , wall or partition ((7) in fig 19 B) with entrance opening or openings (which is or are together narrower than inner transverse section of the liquid guidance conduit (pipeline, tube or duct)) into the magnetic zone in the liquid guidance conduit (pipeline, tube or duct). A second system for efficient carbonation of aqueous fluids that we observed is displayed in the graphic scheme of fig. C. The CO_2 gas is introduced near or abut or in the magnetic zone directly in the zone of reduced pressure of a magnet venture. For instance it is injected after the septum , wall or partition with entrance opening or openings ((7) in fig 19 C) (which is or are together narrower than inner transverse section of the liquid guidance conduit (pipeline, tube or duct)) into the magnetic zone in the liquid guidance conduit (pipeline, tube or duct) and well before the near or abut the septum , wall or partition with liquid output opening or openings ((6) in fig 19 C) (which is or are together narrower than inner transverse section of the liquid guidance conduit (pipeline, tube or duct)). In this design the CO_2 is introduced in zone of the liquid guidance conduit (pipeline, tube or duct)) that is under reduced pressure and a magnetic field.

Example 6: Results – Gas and water flow rate

Figure 13 provides a graphic display on the dissolved CO_2-concentration for a CO_2 gas that was introduced into the water stream under a pressure of 1 bar. For the different levels of gas flows and for the different levels of water flow. CO_2 gas was introduced in the water between t = 10s and t = 40s, 60s, 70s. This study on the flow levels of CO_2 gas and water provided the following observations. Two parameters influenced the size of the CO2 vapor bubbles: gas flow and water flow. The experiments were carried out at a water flow speed of 2,5 l/s and a CO2 gas introduction at a low gas flow of 2,5 g/s and at a high gas flow of 7 g/s. In principles such flow are sufficient to reach 150% saturation (2,8 g/l dissolved CO_2) after on recirculation period in reality the yields are lower. On could expect that by less CO_2 gas supply and introduction into the water one can

improve the dissolution and thus the efficiency. However, results of three experiments with magnet and thus CO_2 water mixing under a magnetic field as displayed in figure 13 demonstrate. Figure 13 for the liquid flow of 2,5 l/s condition at the low CO_2 gas inflow (low gas flow of 2,5 g/s) the dissolved CO_2 concentration will increase at less than halve of the normal speed : 1,6 %/s versus 4,2 %/s (-at a high gas flow of 7 g/s) and this under a condition whereby the CO_2 gas inflow has been halved and we thus expected an increase of 2,1 %/s. If the CO_2 gas (2,5 g/s) inflow and the water flow (1,5 l/s) was decreased then the increase at dissolved CO_2 was 1,2 %/s and oversaturation could not be reached. This concentration could be caused by lower pressure in the fluid guidance line and a too low turbulence for efficient mixing in the zone of the magnetic field

Example 7 : *Disinfection of the aqueous fluids in the magnet system*

We used artificial urine with the same components as human urine, which has proven to be a good culture medium for common gram-negative bacteria (*Brooks T, Keevil CW. A simple artificial urine for the growth of urinary pathogens. Lett Appl Microbiol 1997; 24(3):203-206*) The urine flowed at room temperature through permanent magnetic device and was collected magnetic device in a closed-flowing set up. The permanent magnetic device provided strength of about 10,000 gauss. We colonized the artificial urine with *E. coli* at an initial concentration of 10^2 colonies. A pump maintained the urinary flow at 5 ml/min. We took samples at 4 and at 8 hrs before and after passing the magnetic device. The samples were spread in blood-agar plates and then were incubated at 37°C in a bacteriology laboratory. After one day the results were expressed in total number of colonies per plate. The control group consisted of the same set up with the same amount of *E. coli* passing through demagnetized control device (CD). Results were compared with a student t-test for dependent samples. The table shows a statistically significant reduction in the number of colonies in the infected urine after passing through the permanent magnetic device at 4 hrs and at 8hrs. In the control group there were no statistical changes.

Conclusions

Our initials results show a promising use of permanent magnetic device as a therapeutic alternative to reduce *E.coli* growth in urine of patients with permanent indwelling catheters and urinary tract infections.

Table 1: Effect on the bacterial load of flowing artificial urine through a magnetic fluid treatment device

	Mean Number of Colonies	Std. Dev.	N	p-value
4 hrs before MFD 4 hrs after MFD	39,88889 19,33333	11,1405$_2$ 10,40433	9	0,000$_2$56
8 hrs before MFD 8 hrs after MFD	$_2$10,4444 147,1111	88,0$_2$998 54,04730	9	0,038108
4 hrs before CD 4 hrs after CD	34,6667 3$_2$,6667	10,85664 1$_2$,53$_2$6$_2$	6	0,3$_2$3$_2$60
8 hrs before CD 8 hrs after CD	$_2$47,5000 $_2$39,1667	45,0$_2$777 55,083$_2$7	6	0,174688

Example 8 :

Preferably the method according to the invention involves re-circulating (e.g. in a closed circuit) two or more times a CO2 gas fluid / aqueous liquid fluid mixture through a magnetic field(s) preferably of 0.20 to 2 Tesla, more preferably of 0.50 to 1.5 Tesla, yet more preferably of 0.60 to 1.20 Tesla and yet more preferably of 0.65 to 1 Tesla, yet more preferably of 0.70 to 0.80 Tesla and most preferably of 0.75 Tesla or about 0.75 Tesla. The magnetic field in a specific zone of the liquid guidance conduit (pipeline, tube, duct) can for instance be created by a permanent magnet or by an electromagnet. The number of re-circulation times may be easily adapted to the specific average size targeted for the specific bioactive compound involved in a certain application. It is important that the CO_2 gas fluid / aqueous liquid fluid mixture is flowed or circulated through the magnetic field(s) at a speed which allows the magnetic treatment to effectively perform a size reduction of the vapour bubbles to a significant extent. Preferably, the linear flow rate of said fluid through each said magnetic field is between about 0.25 and 25 m/s. In view of the length of the magnetic field, it may be calculated that the residence time of said fluid through each said magnetic field is preferably between about 60 microseconds and 10 seconds, depending upon the number or re-circulation times.

It was observed that the magnetic treatment of the invention resulted in a size reduction of the CO_2 vapour bubbles in the liquid fluid of a gas that was infused in said the liquid

fluid under reduced pressure directly in said the magnet venture or if the CO_2 was released a vapour bubbles with a size under a critical size of less than 100 nm in nearby in front of the magnet venturi. The bubble size distributions in the gas-liquid flow is altered and the vapour bubbles reduce and CO_2 gas is dissolved when the aqueous liquid is not yet supersaturated or not yet supercarbonated water. Depending upon the population of vapour bubbles and the extent to which such size reduction occurs, and how it affects the appearance of the fluids by reduction or increase of the vapour bubbles can be measured in tubes and vessels by methods of three-dimensional still pictures and optical particle sizing techniques such as holography, particle imaging velocimetriy and sizing, laser light sheet and particle light scattering techniques. These techniques of sensing are most suitable for droplet well known in the art. Furthermore there are sensors in the art to directly measure the level of CO_2 gas solutions in a liquid. Therefore of the magnet field a directly been characterized, as will be described in the following other embodiments of this invention.

Example 9 : Scale up test

EXPERIMENTAL DATA

Evolution of dissolved gas concentration in the beer flow

1. Industrial condition

Gas pressure at beer pipe injection (CO2): 6.5 bar

CO2-gas flow at beer pipe injection : 2.6 KG/min

Beer pipe section : 125 mm

Characteristics of the beer BEFORE carbonation :

Temperature : 14°C; dissolved CO2 content : 2.4 G/L.

Dissolved CO2 is measured in line by specific ORBISPHERE electrodes located five meters after gas injection

2. Results *(these results are the mean of 25 tests over 5 weeks ; s: +/- 0.02*

Table 1

Dissolved carbonic acid (gazeous CO2) in G/L

Time (min)	without device	**with magnet**	**with static mixer**
0,00	2,20	2,20	2,20
0,25	2,80	4,80	4,80

0,50	2,85	4,80	4,80
1	2,85	4,80	4,80
5	2,85	4,80	4,80
15	2,85	4,80	4,80
30	2,85	4,80	4,80
60	2,85	4,80	4,80
120	2,85	4,80	4,80
180	2,85	4,80	4,80
240	2,85	4,80	4,80
300	2,85	4,80	4,80

Drawing Description

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Fig. 1 is a graphic display of dissolved CO_2 concentration when CO_2 was introduced in the system of example 1 at different pressure. The CO_2 gas was introduced inline in water flowing through the liquid guidance tube at t = 0s (1 bar) and t = 25s (1,5 bar) and t = 70s (2,5 bar).

Fig. 2 is a graphic display of dissolved CO_2 concentration when CO_2 was introduced in the system of example 1 at atmospheric pressure. The CO_2 gas was introduced between t=10s and t= 40S.

Fig. 3:. is a graphic display of dissolved CO_2 concentration when CO_2 was introduced in the system of example 1 at a pressure of 1,5 bar. The CO_2 gas was introduced between t=0 s and t= 25 s.

Fig. 4: is a graphic display of dissolved CO_2 concentration when CO_2 was introduced in the system of example 1 at a pressure of 2,5 bar. The CO_2 gas was introduced between t = 0s en t = 50s (with magnet) of t = 70s (without magnet)

Fig 5 shows a member 1 is a transverse section of the liquid fluid line or liquid fluid conduit (e.g. tube or pipe) and 2 is a transverse section of the permanent magnet (Fig. 5A) or of an assembly of permanent magnets (Fig. 5B). Figure 5 provides a picture of a transverse section through the liquid fluid line or liquid fluid conduit (e.g. tube or pipe) and magnet or magnet assembly. The set of permanent magnets can comprise different members of permanent magnets that are adjacent to each other's aligned around the liquid fluid line or liquid fluid conduit (e.g. tube or pipe) whereby the different permanent magnet members are aligned radial around the liquid fluid line or liquid fluid conduit (e.g. tube or pipe (as demonstrated in the transfer section on fig. 5 B). The set or assembly permanent magnet is preferably demountable.

Fig 6 provides a schematic overview of the CO_2 gas fluid in liquid fluid enrichment system (11). This enrichment system comprises a closed container or closed reservoir (6) (e.g. drum or tank) which when operational in comprises a passage liquid. The container or closed reservoir (6) has an inlet port and an outlet port. The outlet port can be connected with a recirculation system (10). The recirculation system can comprises a liquid fluid line or liquid fluid conduit (e.g. tube or pipe) (3) which comprises a (recirculation) pump (5) and the CO_2 gas injector (1) and magnetic CO_2 gas solubilisation system of present invention (4) as described in the figures 5 – 6 or in figure 18. The examples provide different experimental condition whereby water was recirculated through the system (9) sampled and analysed. The container or closed reservoir (6) (e.g. drum or tank) can comprise a second inlet port (7) and a second outlet port (8) to tap liquid fluid or to provide the container or closed reservoir (6) with new liquid fluid. The examples provide different experimental conditions whereby water was recirculated through the system (9) sampled and analysed.

Fig. 7: is a graphic display of the dissolved CO_2 concentration for CO_2 water mixing under a magnetic field or without magnetic field. The speed of CO2 solving and the yield are displayed.

Fig. 8 : is a graphic display of the dissolved CO2-concentration with and without venture at 1 bar pressure. CO_2 was introduced between t = 10s en t = 40s

Fig. 9: is a graphic display of the dissolved CO_2-concentration at a pressure of 1 bar, for different CO_2 gas- en water flows. CO_2 gas was introduced t = 10s en t = 40s, 60s, 70s

Fig. 10 displays a specific embodiment of entrance device of the zone in the pipeline, tube or duct of the aqueous liquid guidance that can be surrounded by a magnet or magnet assembly. The entrance device is provides with a shield (8) and therein one or more entrance ports (9) and (10). The one or more entrance ports result in the aqueous liquid being forced through a narrower opening than the inner diameter of the pipeline, tube or duct of the aqueous liquid guidance. Specific forms of said the entrance port(s) can induce a turbulence in the magnetic zone for optimal mixing of said the CO_2 gas, in particular the gas bubbles, with the aqueous liquid under the magnetic field.

Fig 11 displays an embodiment of an output device that can be mounted between aqueous liquid guidance conduits (pipeline, tube or duct) after the magnetic zone (This zone in the pipeline, tube or duct of the aqueous liquid guidance that is designed to be surrounded by a magnet or magnet assembly). This output device has a shield (6) and therein at least one opening or port that is smaller than the inner diameter of the liquid guidance conduits (pipeline, tube or duct); in a preferred embodiment the surface of the opening or port or the multiple openings or ports is smaller than the surface of the opening or port or the multiple openings or ports in the entrance device of the magnetic zone (Figure 10)

Figure 12 and 13 displays the proximal end of the sintered metal device which is mounted at the inlet port of the CO_2 gas guidance conduct (tube, pipeline or duct) which is aqueous liquid guidance conduits (pipeline, tube or duct) (2) before the magnetic zone (This zone in the pipeline, tube or duct of the aqueous liquid guidance that is designed to be surrounded by a magnet or magnet assembly). The sintered metal device is in the form of a tube, pipeline or duct with a microporous wall where trough when operational CO_2 vapour bubbles escape.

Fig 14 is a graphic display of an embodiment of present invention. Element 3 represent a magnet or a magnet assembly surrounding a particular zone (the magnetic zone) in the

liquid guidance conduit (2) (tube, pipeline or duct) which magnetic zone is preceded by a shield with entrance port or ports (e.g. 7) and an end shield with output port or ports (6). A CO_2 guidance conduit (pipeline, tube or duct) (1) enters in the liquid guidance conduit (2) in a zone preceding and neighbouring the magnetic zone at the proximal end of as CO_2 guidance conduit (pipeline, tube or duct) (1); the sintered metal device (5) is mounted that if operational releases CO_2 as vapour bubbles through its porous wall.

Figure 15 is a graphic scheme of a system whereby the CO_2 gas is introduced in the liquid guidance conduit abut to entrance of the magnetic mixer through a nanobubble generator (5) which in the examples is a sintered porous metal tube. Such CO_2 gas can be from a carbon dioxide storage systems (16) for instance a CO_2 gas container for instance a cylinder. A drive pump (9) can drive aqueous liquid through a liquid guidance conduit (duct, tube or pipeline) and consequently through the magnet mixer which comprises a 1) liquid guidance conduit (duct, tube or pipeline) ($_2$) with upstream the nanobubble generator (5) and gas fluid outlet and 2) a magnetic zone that is formed by two partitions ((8) or (6)) opposed to the flow direction or positioned transverse in the liquid passage conduit and which partitions have each at least one aperture (7, 9 or 10) so that the aperture area in each partition is smaller or narrower than the internal cross sectional area narrower than respective cross sectional areas of the conduit (directly) upstream and downstream of such partition and whereby 4) a permanent magnet is or an assembly of permanent magnets (3) is mountable adjacent to said zone for instance radially surrounding said conduit of said zone and 4) a gas conduit with an outer input port coupled with a (inject - outlet) port to the liquid conduit in a position to deliver or introduce a gas into the nanobubble generator (5).

Figure 16 is a graphic scheme of a magnetic mixer (15) of present invention for CO_2 dissolution or carbonation of aqueous fluids bodies while bathing in said the aqueous fluids bodies. Such magnetic mixer of present invention is when operational engaged with a CO_2 gas delivery conduit. Instead of bathing in the aqueous fluid body such CO_2 dissolution magnetic mixer can be engaged with an aqueous liquid conduit for in line carbonation. Element 3 is a magnet for instance an electromagnet, a permanent magnet or a permanent magnet assembly. (9 and/or 10) is an aperture in a transverse partition

in the liquid conduit of said the magnet mixture (15) and (7) is an aperture in a transverse partition in the liquid conduit of said the magnet mixture (15) downstream in the liquid flow. Element 9 is a drive pump.

The method, system and apparatus of invention can be used for in line or batch carbonation of water, aqueous liquids and vegetable, root or fruit juices. It can for instance be used for integration in the brewery process to carbonate beers before storage in a confined environment for instance before bottling. The methods, systems or installations of present invention can be used to carbonate an aqueous liquid to react the dissolved CO_2 with substances in the liquid for instance to react the dissolved CO_2 with calcium to calcium carbonate. A particular use is dissolving CO_2 in a juice to precipitate impurities for instance to precipitate impurities in beetroot juices by reacting the dissolved CO_2 with calcium to calcium carbonate.

The difference between water and a beverage such as beer is too limited to experience large influences on the solubility of CO_2 [American society of brewing chemists. Methods of analysis. 5th edition, 1949 OR Wilhelm, E. et al. (1977). Low-pressure solubility of gases in liquid water. Chem. rev. 77, 219-262.]. The above mentioned methods and devices are suitable for carbonation of aqueous liquids and in particular those aqueous liquids that after treatment by the method of present invention or in the apparatus of present invention result in beer, carbonated water, champagne, cola, diet coke, carbonated yogurt snack or sparkling yogurt (i.e. Fizzix), sparkling wine, soft drink or tonic water.

A particular embodiment of present invention is introducing CO_2 gas and in particular CO_2 gas inline in a beer stream and mixing such under a magnetic field and a beer temperature at a value of the range of 1 to 10 °C, preferably 1 to 5 °C, more preferably 1,5 to 3 °C, yet more preferably 1,7 to 2,5°C, yet more preferably 1,8 to 2,2 °C and most preferably 2°C or about 2°C. The pressure in the beer guidance line is hereby at a value of the range of 1 to 3 bar, preferably 1,2 to 2,5 bar, yet more preferably 1,4 to 2,2 bar, yet more preferably 1,5 to 2 bar, yet more preferably 1,6 to 1,8 bar, yet more preferably 1,65 to 1,75 bar and most preferably 1,7 bar or 1,8 bar. At such condition a concentration of dissolved CO_2 of 4 - 6 g/l, for instance 5 g/l or about 5 g/l can be

reached in particularly since the conditions of CO_2 input flow and of liquid flow are controllable and adjustable.

The CO_2 can be introduced in the beer guidance conduit (tube, pipeline or duct) as nanobubbles under a critical size of less than 100 nm diameter near or abut the entrance of the magnetic zone in said the beer guidance conduit (tube, pipeline or duct). In magnetic zone or the internal diameter of tube, pipeline or duct is smaller than that of the tube, pipeline or duct directly before or after the magnetic zone or at some distance before or after the magnetic zone. Alternatively the magnetic zone is separated from the other parts of the tube , pipeline or duct by a septum, wall or partition distal and proximal of the magnetic zone which septum, wall or partition has an entrance or an outlet opening which is smaller than the inner diameter of the beer guidance conduit(tube , pipeline or duct) or each such septum, wall or partition has several openings of which the surface is smaller than the surface of the inner transverse section of the beer guidance conduit(tube , pipeline or duct). Alternatively the CO_2 gas is injected directly into the upstream part of the magnetic zone under a reduced pressure when operational.

In a particular embodiment this method further involves the use of at least one in situ CO_2 sensor for monitoring dissolved CO_2 and to produce a signal indicative for the dissolved CO_2 at the end of the line or inline. Such at least one sensor can be connected to an electronic controller to process the sensor signals into a signal that activates a programmable actuator for modulating CO_2 gas flow or a that activates a programmable actuator for modulating the beer liquid flow. In a particular embodiment two in situ CO_2 sensors are used, so that one sensor is checked against the other. The actuator can for instance be a pump or valve actuator.

The CO_2 gas is preferably introduced in the liquid guidance conduit (pipeline, tube or duct) through a porous tube with micropores of a size of a value between 5 to 50 μm, preferably between 10 to 40 μm, more preferably between 15 to 30 μm, yet more preferably 20 to 28 μm, yet more preferably 22 to 27 μm, yet more preferably 24 to 26 μm and most preferably 25 μm or about 25 μm. The microporous device can for instance be comprise a sintered metal for instance with a length of a value from arrange of 50 to

250 mm, preferably 100 to 230 mm, yet more preferably from 150 to 220 mm, yet more preferably 180 to 210 mm , yet more preferably 190 to 200 mm and most preferably 195 mm or about 195 mm and an inner diameter of a value of the range 8 to 24 mm, preferably the range of 10 to 20 mm, yet more preferably from 12 to 18 mm, yet more preferably the range from 14 to 17 mm and most preferably 16 mm or about 16 mm. The men skilled in the art when informed about these values will understand that the carbonator can be upscalled so that these dimensions of tubes or pipelines will enlarge.

The same of a similar method is suitable for carbonation of other aqueous liquids for instance such that after carbonation it is one of the following: carbonated water, champagne, cola, diet coke, carbonated yogurt snack or sparkling yogurt (i.e. Fizzix), sparkling wine, soft drink or tonic water.

Particular advantages at the system of present invention and the way the magnet or the magnet assembly is mounted on the liquid guidance pipe is that these remain clean-in-place (CIP). The system can be cleaned while it is integrated in the liquid fluid line. If static mixers are used instead there is a risk of remains that have to be removed for a next run or operation. This is particularly a problem if the same system has to be used for carbonation of another aqueous fluid.

An advantage of CO_2 gas in line delivery is that the pressure drop is smaller than for delivery of CO_2 gas in large volumes of liquids. By consequence our systems requires less powerful pumps and less energy is consumed for carbonation of aqueous liquids, in particular with the increase carbonation efficiency in the magnetic field zone.

Furthermore the carbonator of present invention or this carbonator integrated in an inline aqueous fluid flow pipeline, tube or duct system will occupy less space. It can be build compact because the magnet or magnet assembly will result in a condition that the length of the fluid flow pipeline, tube or duct can be reduced for solving the CO_2 gas.

For infusion of a CO_2 gas directly into the magnetized zone of the liquid fluid line (guidance, duct or passage), the system of present invention comprises a CO_2 gas fluid port a) locoregional before the magnetized flow zone of the liquid fluid guidance, duct or

passage (the part of the liquid fluid guidance, duct or passage that is surrounded by permanent magnets, by an assembly of permanent magnets or by an array of permanent magnets eventually as an annular ring around said this guidance, duct or passage part) or b) adjacent to the magnetized flow zone of the liquid fluid guidance, duct or passage or c) directly associated with the magnetized flow zone of a liquid fluid guidance, duct or passage. This port can collect the CO_2 gas fluid from an open or a closed environment. The port is preferably through the CO_2 gas fluid guidance, duct or passage (e.g. tube) engaged with such environment to suck or aspirate said CO_2 gas fluid into the magnetized zone of the liquid fluid guidance, duct or passage so that when operational the CO_2 gas fluid and the fluid liquid mix in the chamber or the guidance, duct or passage zone that is under a permanent magnetic field. Such CO_2 gas fluid guidance, duct or passage (e.g. tube) can be bound or coupled to the magnetized liquid fluid guidance, duct or passage so that can flow gas that it leads to the magnetized liquid fluid guidance, duct or passage through the aperture of the liquid fluid guidance, duct or passage inject port directly so that CO_2 gas fluid is directly disposed into the enclosure or confined environment of the magnetized zone of the liquid fluid guidance, duct or passage or directly in front abut to the magnetized zone of the liquid fluid guidance, duct or passage or (locoregional) juxtaposed (according to the flow stream direction) positioned in front of the magnetized zone of the liquid fluid guidance, duct or passage so that CO_2 gas fluid / liquid fluid mixing can occur in the magnetized low pressure environment. A specific embodied feature of present invention has a technical advantage that CO_2 gas fluid can be infused from a non-pressurized environment by the flow of the motive liquid fluid in the liquid fluid guidance, duct or passage so that without a separate CO_2 gas fluid drive such as gas pump or without high-pressure gas as the working CO_2 gas fluid the gas is infused into the magnetized zone of the liquid fluid guidance, duct or passage. When operational the pressure energy of a motive fluid to velocity energy creates a low pressure zone that draws in and entrains a suction CO_2 gas fluid from the injection pore. The low pressure in the magnetic zone receives CO_2 gas fluid through the inject port as a suction fluid into the and the second technical advantage that higher gas in a liquid fluid with increased saturation efficiency and to enhanced gas dissolution is achieved than for a gas that has been introduced on a place that is remote from the magnetized zone of the liquid fluid guidance, duct or passage.

CO_2 gas fluid / liquid fluid mixing under reduced pressure and permanent magnetic field provided, for instance in a taper of the liquid fluid guidance, duct or passage surrounded by permanent magnets, drastically increased gas dissolution versus gas injected into the water flowing in a tube at another given point. The efficiency of gas dissolving depends on presence of the magnetic field, the reduced pressure drop and mixing time in the magnetized low pressure zone.

Another advantage of present invention is that the moving water has significantly reduced bacterial load, in particular of waterborne pathogens if it is recirculated over this system. This recirculation process allows to slow microbial growth in aquatic systems and in particularly recirculating aquatic systems with an organic load. This effect is still enhanced if the inlet CO_2 gas fluid comprised a steam. The efficiency of low heat pasteurization depends on presence of the magnetic field, the reduced pressure drop and mixing time in the magnetized low pressure zone.

In an embodiment the method of present and use of apparatus of present invention solve the technical problem of selective solving of gas molecules of a CO_2 gas fluid in order to achieve a drain of liquid fluid that is selectively enriched with the dissolved CO_2 The method of present invention concerns aspiration in zone of reduced pressure and permanent magnetization for instance in the narrower or slimmer diameter of a liquid guidance pipe or the tapered zone of a liquid guidance with motive liquid which is surrounded by a permanent magnet or an assembly or array of magnets that surround said narrower or tapered part of the liquid conduit or that are combined with, connected to or associated with the conduit in a position at its narrower or slimmer diameter of a liquid guidance pipe or the tapered zone. The magnets can be positioned radial around said this narrower diameter zone of the liquid conduit.

A particular embodiment of present invention is a magnetic carbonation system that increases the dissolution of CO_2 molecules from CO_2 gas which is aspirated in a defined position of the system so that CO_2 gas nanobubbles are mixed with a watery fluid under a permanent magnetization and decreased pressure. The CO_2 enriched motive watery fluid can be further transported by a conduit to a reactor that needs CO_2 enriched watery fluid for instance an anaerobic bioreactors or an algae farming tank. For

biotreatment purposes, for instance of organic loaded wastewater streams, anaerobic organisms are most commonly employed because for instance in biogas fermenters. It will be appreciated that CO_2 must be supplied to such processes in order to maintain a high contaminant destruction rate. Typically the denitrification process and an algae culture process benefits input of CO_2.

Present invention in a certain embodiment concerns an apparatus and a method for creating the fluid/CO_2 gas mixing directly in an environment, chamber or tube under permanent magnetic field under a reduced pressure and gradually increasing the pressure as the after the magnetic field as the fluid moves further in tube. The method of selectively solving of CO_2 molecules of a gas mixture concerns establishing a pressure drop in a flow of an aqueous liquid through a conduit or pipe and aspiration of the gas mixture into the pressure drop zone and mixing said fluid and gas under reduced pressure or near to vacuum under a permanent magnetic field and gradually increasing the pressure to a value of the range between 2 to 7 bar, preferably between 2,5 to 6 bar, yet more preferably between 3 and 6 bar and most preferably between 3.5 and 5 bar after the magnetization as the fluid moves further through the part of the conduit or pipe that is not surrounded by magnets. The apparatus can further be foreseen of an open container for resting and release of the not dissolved CO_2 gas elements for instance in a case these need to be recycled and re aspirated back into the magnet venture.. The liquid enriched with the dissolved CO_2 flow will be flow through a line or conduit to a mechanical reactor, biochemical, bioreactor or another destination and unsolved CO_2 gas elements are remove from the mixture or combination, isolated and set apart in or guided to another unit eventually for recirculation or other uses.

The apparatus of present invention can concerns an aqueous liquid fluid source in which CO_2 gas is introduced via a gas dissolution means or the apparatus can simple bath into the liquid fluid source (Fig. 20) whereby an inlet port of the CO_2 gas fluid conduit baths in to a CO_2 gas atmosphere for instance in a CO_2 storage container.

For the various embodiments whereby CO_2 is aspirated in a zoned of reduced pressure a regulating means (e.g. valve) before the injection port can operate to infuse or aspirate

the CO_2 gas fluid at selected range and grade into the reduced pressure or near vacuum magnetized zone of a motile water body or watery fluid body.

In a particular embodiment of present strength of each said magnetic field in the carbonator is at least 0,2 Tesla (2,000 gauss) and the linear flow rate of said fluid through each said magnetic field is preferably between 0.25 and 25 m/s.

It should also be understood that the effect of the method of CO_2 gas in liquid dissolution is more important when the strength of the magnetic field is higher and/or the number of flows through the magnetic field is higher. Since the strength of each commercially available magnet is usually limited to about 1 Tesla (10,000 gauss), a means to increase the effective magnetic field is to carry out the fluid and CO_2 gas mixing through a number of magnets arranged in series (especially for limiting the duration of treatment) in a zone of reduced pressure and/or to re-circulate the suspension several times through the same zone and to adjust the CO_2 gas aspiration by a valve in front of the CO_2 gas inlet port into the magnetized and reduced pressure for instance near vacuum zone. Whatever the fluid, flowing said fluid through the magnetic field(s) is preferably effected at a temperature below the Curie temperature of the magnetic material used for generating said magnetic field(s), e.g. below about 400°C for a magnetic device of the Al-Ni-Co type. The motile liquid flowing through said magnetic field(s) is preferably effected at a temperature between the freezing temperature and 50°C while flowing said fluid through said magnetic field(s). For instance when said fluid is water under atmospheric pressure, flowing said liquid through said magnetic field(s) is preferably effected at a temperature between about 2°C and 50°C.

Preferably the method for disinfection, pasteurization or disinfecting according to the invention involves re-circulating (e.g. in a closed circuit) two or more times the fluid. The magnetic field, and may be easily adapted to the microbial load for specific pathogens in a certain industrial application.

Preferably the method for selective dissolution of CO_2 gas according to the invention involves re-circulating (e.g. in a closed circuit) two or more times the fluid wherein amounts CO_2 gas are aspirated in the magnetic field/reduced pressure zone.

It is important that the aqueous liquid flows through the magnetic field(s) at reduced pressure wherein the CO_2 gas is aspirated while mixed is at a speed which allows the magnetic treatment and mixing to effectively perform the dissolution of certain gas elements to a significant extent. Or it is important the aqueous liquid wherein CO_2 nanobubbles of preferably less than 100 nm size are introduced flows through the magnetic field(s) at reduced pressure wherein the CO_2 gas and aqueous fluid mixed is at a speed which allows the magnetic treatment and mixing to effectively perform the dissolution of certain gas elements to a significant extent. The linear flow rate of said fluid through each said magnetic field is between 0.25 and 25 m/s. In view of the length of the magnetic field, it may be calculated that the residence time of said fluid through each said magnetic field is preferably between 60 microseconds and 10 seconds, depending upon the number or re-circulation times.

A post-processing step may be reinstallation of a pressure increase in the confined environment of the liquid conduit, flowing the mixture to a unit for separation where the un dissolved gas elements are separated for instance by into a recirculation gas conduit to present this CO_2 back to the dissolution device.

CO_2 DISSOLUTION

Claims

What is claimed is:

1. A CO_2 dissolution apparatus or watery fluid carbonation apparatus , whereby the apparatus comprises **1)** a liquid passage duct [2] with at least one zone that is separated from the other parts of the liquid passage duct by two partitions [8 and 6] opposed to the flow direction or positioned transverse in the liquid passage duct and which partitions have each at least one aperture [12, 13 and/or 7] so that the aperture area in each partition is smaller or narrower than the internal cross sectional area narrower than respective cross sectional areas of the duct (directly) upstream and downstream of such partition and 2) a permanent magnet or an assembly of permanent magnets adjacent to said zone [14] between two partitions [8 and 6] and 3) a gas duct [1] with its outer input port coupled with a port to the liquid duct in a position to deliver or introduce CO_2 through a nanobubble generating device [4 or 5] or a CO_2 nano bubbles escape [4 or 5] near or abut the partition [8] at the entrance of the magnetic zone or near or abut the upstream partition [8] of the magnetic zone.
2. The apparatus according to any one of the previous claims, whereby the permanent magnet [3] generates or the assembly of permament magnets [3] generate an uniform magnetic body force.
3. The apparatus according to any one of the previous claims, whereby the diameter section of the liquid passage duct is the same before and between the two partitions that separate the magnetic zone.
4. The apparatus according to any one of the previous claims 1 to 3, whereby the nanobubble generating device is a porous nanobubble generating device.
5. The apparatus according to any one of the previous claims 1 to 3, whereby the CO_2 nano bubbles escape is a sintered metal device.
6. The apparatus according to any one of the previous claims 1 to 3, whereby CO_2 nano bubbles escape is in the form of a tube, pipeline or duct with a microporous wall (e.g. sintered metal).

7. The apparatus according to any one of the previous claims, adapted to have the liquid flows through a conduit and the CO_2/liquid mixing under the uniform magnetic field of the permanent magnet or magnets in that particular internal section of the conduit which is separated in the liquid guidance conduit by an entrance or front wall with at least one inlet hole and back wall with at least one outlet hole which separates the magnetic zone from the zone where CO_2 nanobubbles are delivered.
8. The apparatus according to any one of the previous claims 1 to 8, whereby the in CO_2 nanobubble generator is in a liquid guidance conduit upstream before the magnetic zone.
9. The apparatus according to any one of the previous claims 1 to 8, whereby the CO_2 nanobubble generator as nanobubbles in a liquid guidance conduit upstream near or about the magnetic zone.
10. The apparatus according to any one of the previous claims 1 to 9, whereby the permanent magnets comprises different members of permanent magnets that are adjacent to each other aligned around the liquid passage tube
11. The apparatus according to any one of the previous claims 1 to 9, whereby the permanent magnets comprises different members of permanent magnets that are aligned radial around the passage tube .
12. The apparatus according to any one of the previous claims 1 to 9, whereby the permanent magnets comprises different members of permanent magnets that are adjacent to each other aligned around the liquid passage tube
13. The apparatus according to any one of the previous claims 1 to 9, whereby the permanent magnets comprises different members of permanent magnets that are aligned radial around the passage tube
14. The apparatus according to any one of the previous claims 1 to 9, whereby the permanent magnets comprises different members of permanent magnets that are aligned radial around the passage tube and are organized to have their S- and N-poles thereof in the same position.
15. The apparatus according to any one of the previous claims 1 to 14, whereby the liquid body or part thereof is by recirculation subjected again to the process until its relative dissolved CO_2 gas composition is a liquid end product that substantially CO_2 enriched in a CO_2 gram/ liter range.

16. The apparatus according to any one of the previous claims 1 to 14, whereby the liquid body or part thereof is by recirculation subjected again to the process until its relative dissolved CO_2 gas composition is a liquid end product that substantially CO_2 enriched so that it is CO_2 oversaturated when brought at atmospheric pressure.
17. The apparatus according to any one of the previous claims 1 to 14, whereby the liquid flow and/or the CO_2 flow is under a controller not to have supersaturation in the pressured liquid guidance conduit immediately after the magnetized mixing zone.
18. A CO_2 dissolution apparatus according to any of the previous claims 1 to 17, further comprising a liquid driving means to pass liquid through the liquid passage duct
19. A CO_2 dissolution apparatus according to any of the previous claims 1 to 17, whereby the duct is a conduit, is a tube or a pipe.
20. A CO_2 dissolution apparatus according to claim 18, whereby the liquid driving means is positioned upstream from said zone.
21. A CO_2 dissolution apparatus according to claim 18, whereby the liquid driving means is positioned downstream from said zone.
22. A CO_2 dissolution apparatus according to claim 18, whereby the liquid driving means is a pump
23. A CO2 dissolution apparatus according to any of the previous claims, whereby when operational the liquid driving means forced a liquid through the liquid conduit so it creates a pressure drop in the zone and CO_2 in contact with the gas tube inlet is sucked or aspirated and released in the zone so that liquid and CO_2 gas mix under reduced pressure under a permanent magnetic field.
24. A CO_2 dissolution apparatus according to any of the previous claims, whereby when operational the CO_2 gas and liquid mix under a non pressurized condition
25. A CO2 dissolution apparatus according to any of the previous claims, whereby when operational the CO_2 gas and liquid mix under a near vacuum condition.
26. A CO_2 dissolution apparatus according to any of the previous claims, whereby when operational the infused CO_2 gas fluid (B) and the passing liquid (A) is under a non pressurized condition or a condition of a substantial pressure drop during passage while being subjected to the magnet field of the permanent magnet (or magnet

assembly) to increase saturation efficiency and/or increased dissolving of selected CO_2 gas elements.

27. A CO_2 dissolution apparatus according to any of the previous claims, whereby the permanent magnet or magnet assembly is demountable

28. A method of dissolution of CO_2 molecules from a CO_2 gas into an aqueous liquid whereby the dissolution efficiency of the CO_2 molecules is favorably enhanced versus the normal dissolution efficiency of said the CO_2 molecules by in line mixing of said CO_2 gas in a motile aqueous liquid or an aqueous liquid stream flows through a liquid guidance conduit for instance a tube, duct or pipeline with motile aqueous liquid or an aqueous liquid stream characterised in that the CO_2 enters before the magnetic field via a CO_2 vapour bubbles escape adapted to generate nanobubbes at the the proximal end of CO_2 gas guidance conduct (tube, pipeline or duct) before entering a zone that is surrounded by at a permanent magnet or an assembly of permament magnets

29. The CO_2 dissolution method according to claim 28, whereby the liquid flows through a conduit and the CO_2/liquid mixing under a magnetic happens in that particular internal section of the conduit which is separated in the liquid guidance conduit by an entrance or front wall with at least one inlet hole and back wall with at least one outlet hole which separates the magnetic zone from the zone where CO_2 nanobubbles are delivered.

30. The CO2 dissolution method according to any one of the claims 28 or 29, whereby the motile aqueous liquid or an aqueous liquid stream flows through a liquid guidance conduit for instance a tube, duct or pipeline. permanent magnet or an assembly of permament magnets generate an uniform magnetic field

31. The CO2 dissolution method according to any of the previous claims 28 to 30, whereby the CO2 gas is introduced in line via a nanobubble generator as nanobubbles in a liquid guidance conduit upstream before the magnetic zone.

32. The CO2 dissolution method according to any of the previous claims 28 to 30, the CO2 gas is introduced in line via a nanobubble generator as nanobubbles in a liquid guidance conduit upstream near or about the magnetic zone.

33. The CO2 dissolution method according to any of the previous claims 28 to 32, whereby the nanobubbles have a critical size of less than 100 nm.

34. The CO2 dissolution method according to any of the previous claims 28 to 33, whereby the CO_2 gas is essentially pure.
35. The CO2 dissolution method according to any of the previous claims 28 to 33, whereby CO2 gas comprises at least 98% CO2 molecules
36. The CO2 dissolution method according to any of the previous claims 28 to 33, whereby the CO2 gas is essentially free of O_2
37. The CO2 dissolution method according to any of the previous claims 28 to 33, whereby the CO2 gas comprises less than 0.1% O_2 molecules
38. The CO2 dissolution method according to any of the previous claims 28 to 33, using the apparatus according to any one of the previous claims 1 to 27.
39. The CO2 dissolution method according to any one of the previous claims 28 to 38, whereby the liquid body or part thereof is by recirculation subjected again to the process until its relative dissolved CO2 gas composition is a liquid end product that substantially CO2 enriched in a CO2 gram/ liter range.
40. The CO2 dissolution method according to any one of the previous claims 27 to 38, whereby the liquid body or part thereof is by recirculation subjected again to the process until its relative dissolved CO2 gas composition is a liquid end product that substantially CO2 enriched so that it is CO2 oversaturated when brought at atmospheric pressure.
41. The CO2 dissolution method according to any one of the previous claims 28 to 38, whereby the liquid flow and/or the CO2 gas flow is regulated not to have supersaturation in the pressured liquid guidance conduit immediately after the magnetized mixing zone.
42. The CO2 dissolution method according to any one of the previous claims 28 to 41, whereby the solved CO2/L in beer at 16°C is at least -4.8 gram.
43. The use of the apparatus according to any one of the previous claims 1 to 27, according to a method any of the previous claims 28 to 42, while magnetically disinfecting the liquid and/or CO2 gas streams in the tube zone of reduced pressure and magnetization

Figures

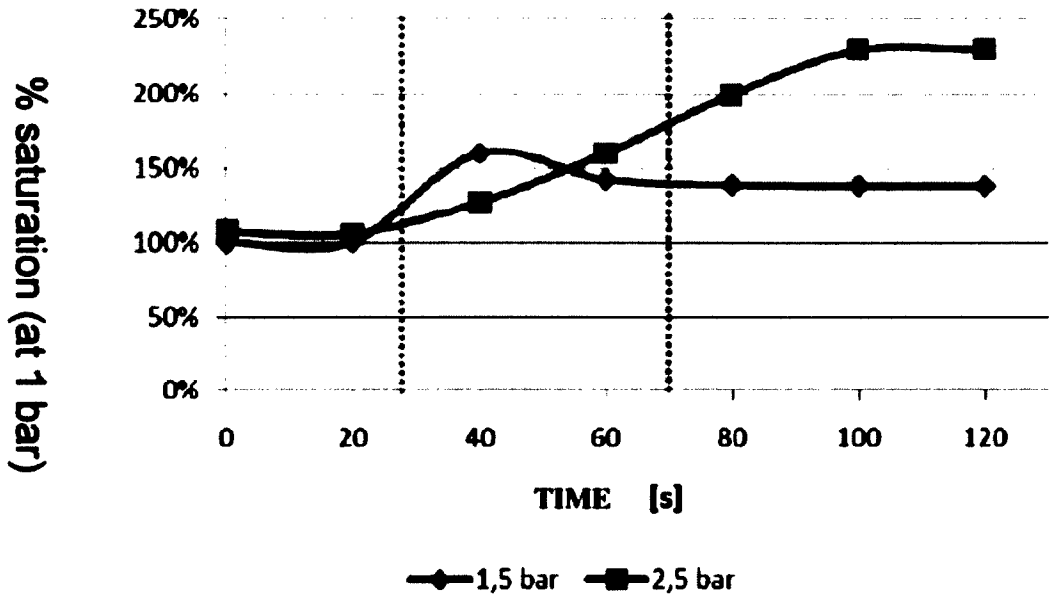


Fig. 1

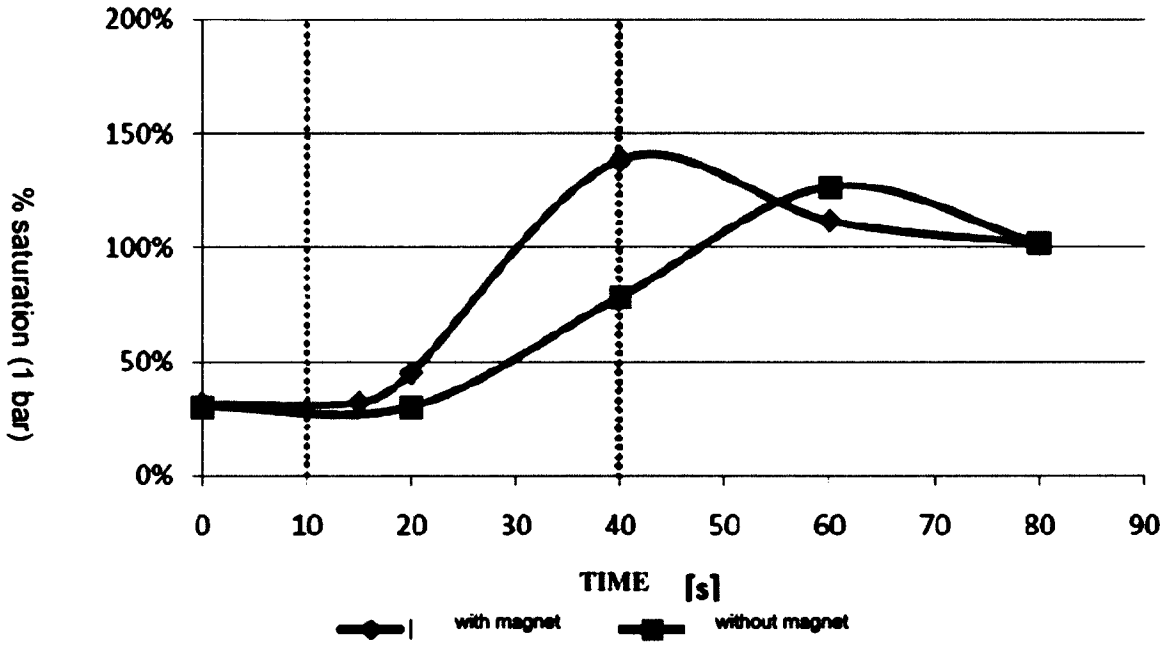


Fig. 2

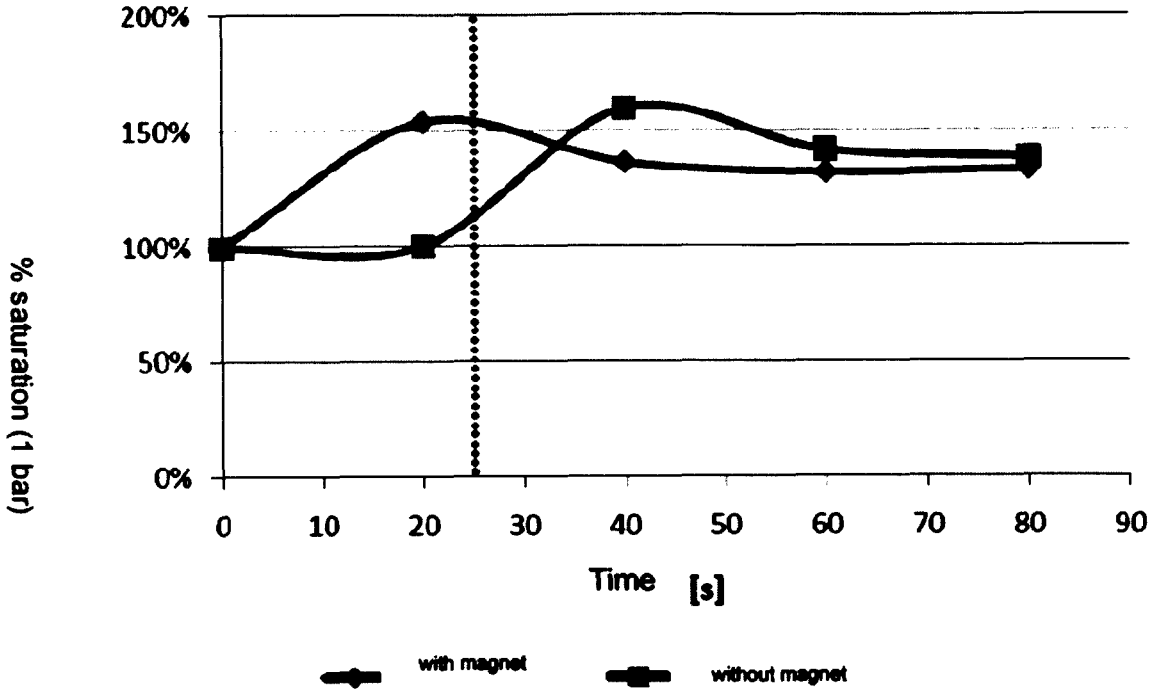

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80
90
Time [s]
with magnet
without magnet

Fig. 3

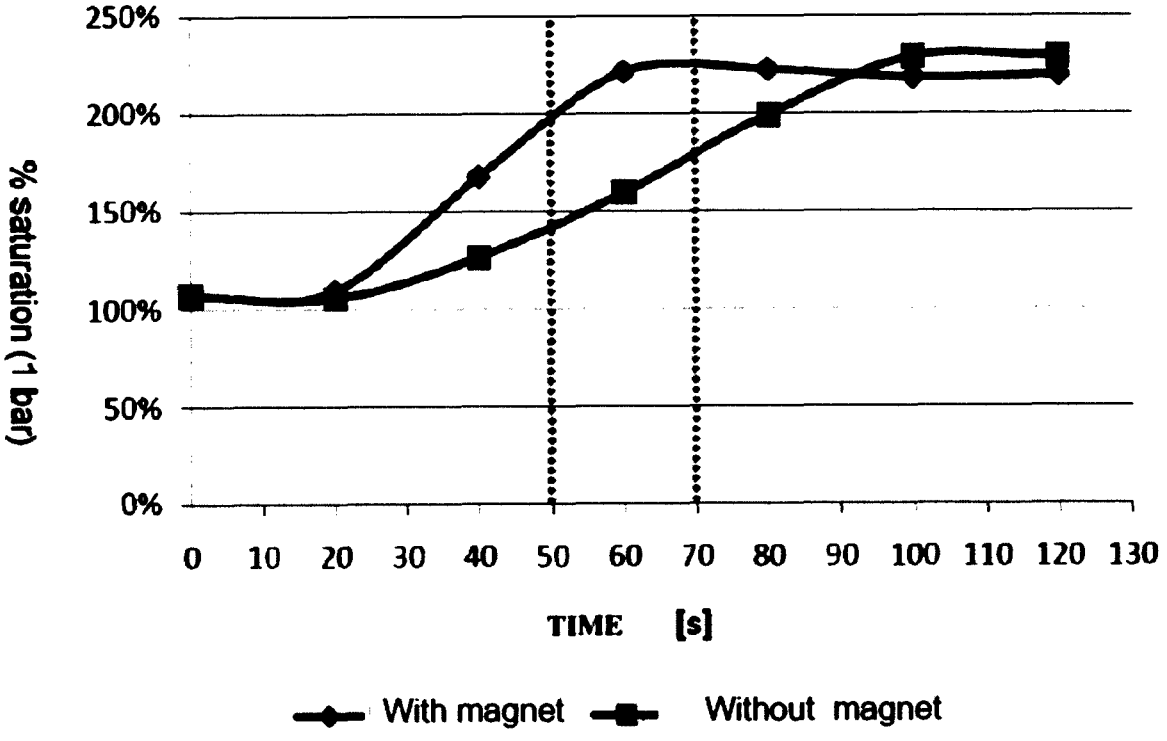

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TIME [s]
With magnet
Without magnet

Fig. 4

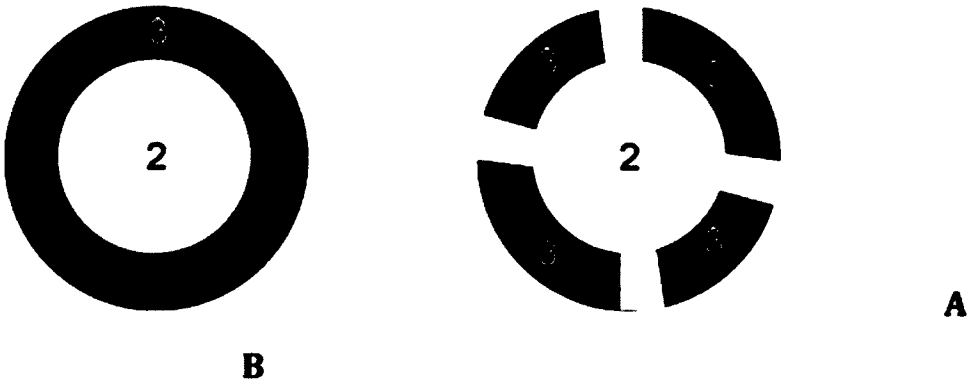


Fig. 5 A & B

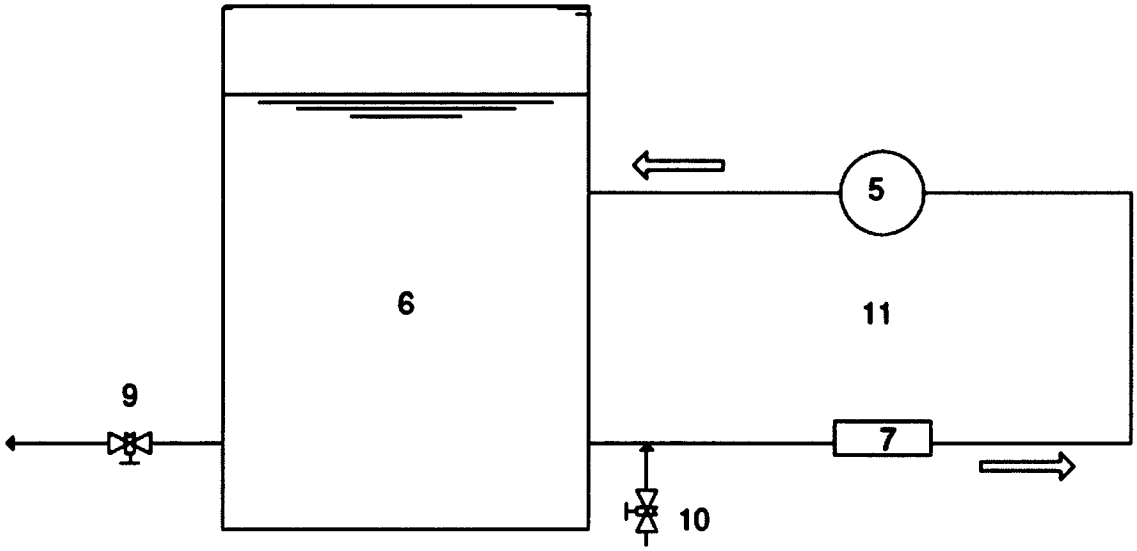


Fig 6

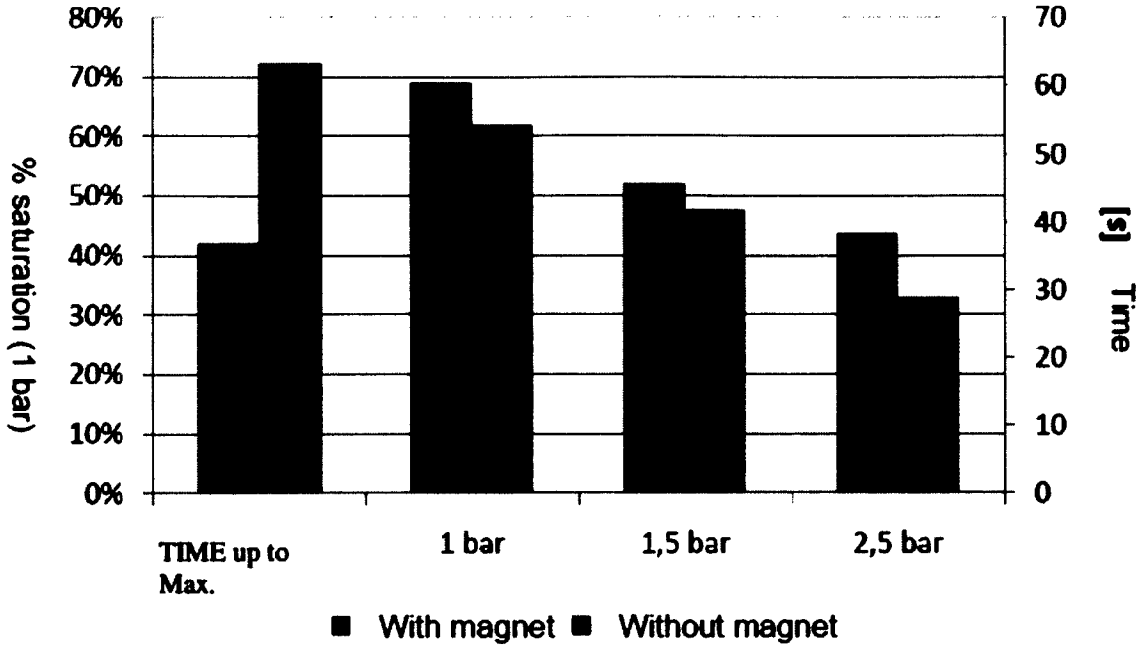

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TIME up to Max.
1 bar
1,5 bar
2,5 bar
With magnet
Without magnet

Fig. 7

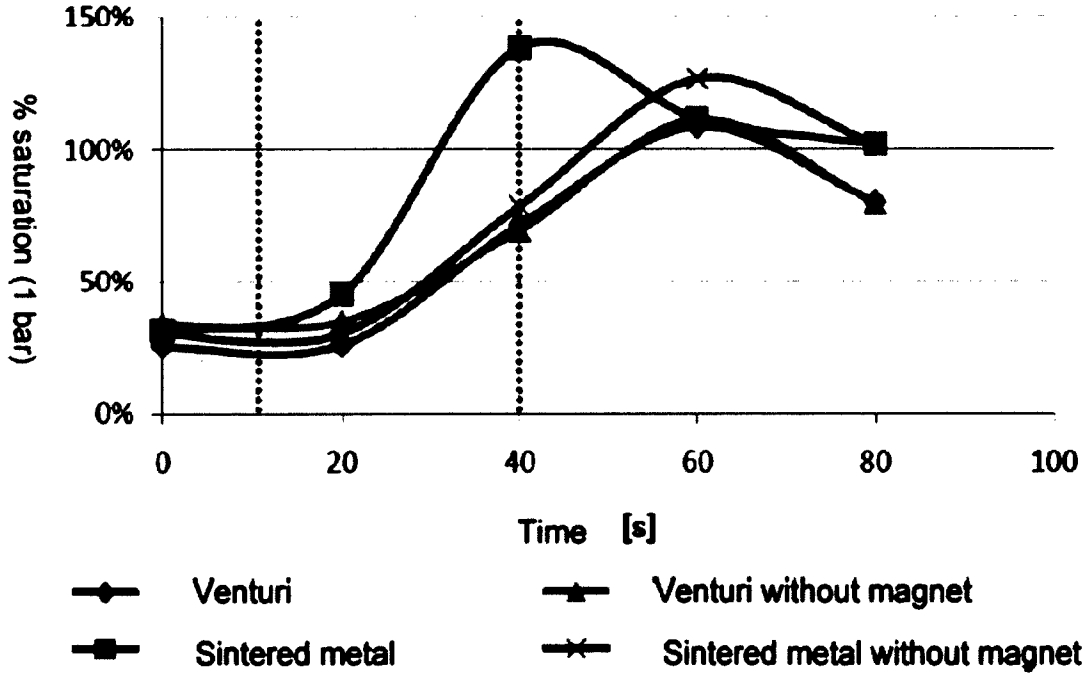

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Time [s]
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Venturi without magnet
Sintered metal
Sintered metal without magnet

Fig. 8

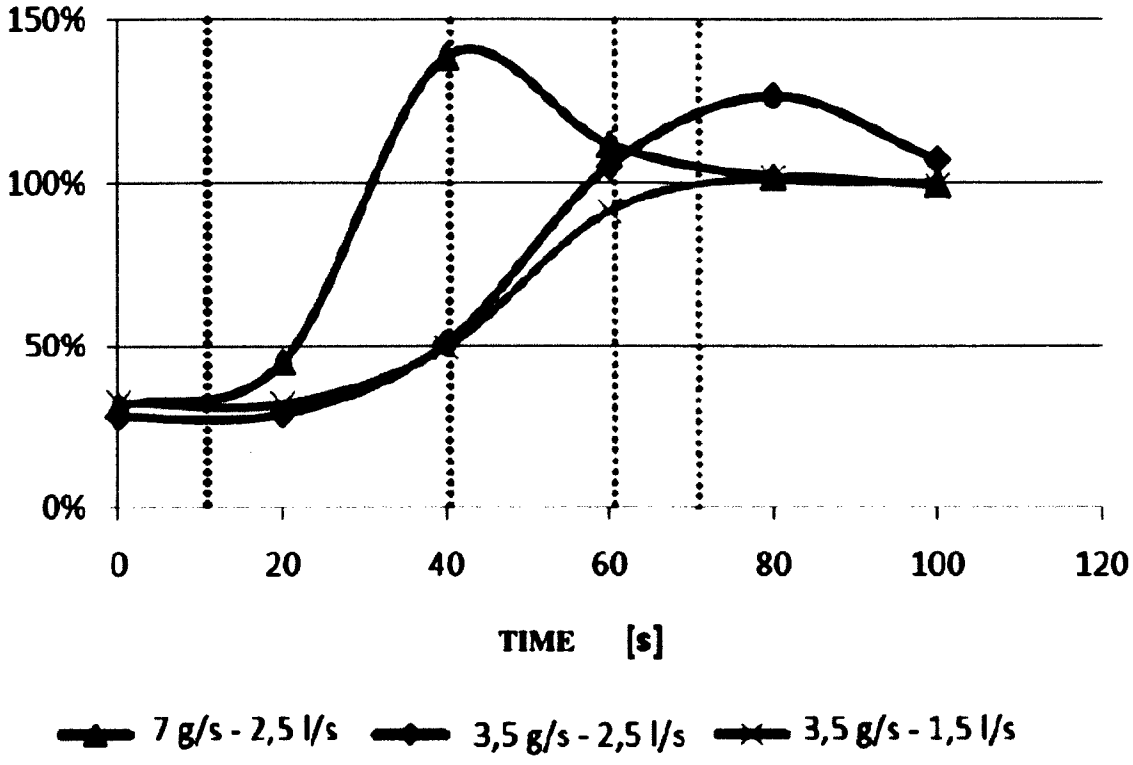

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80
100
120
TIME [s]
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3,5 g/s - 2,5 l/s
3,5 g/s - 1,5 l/s

Fig. 9



Fig. 10

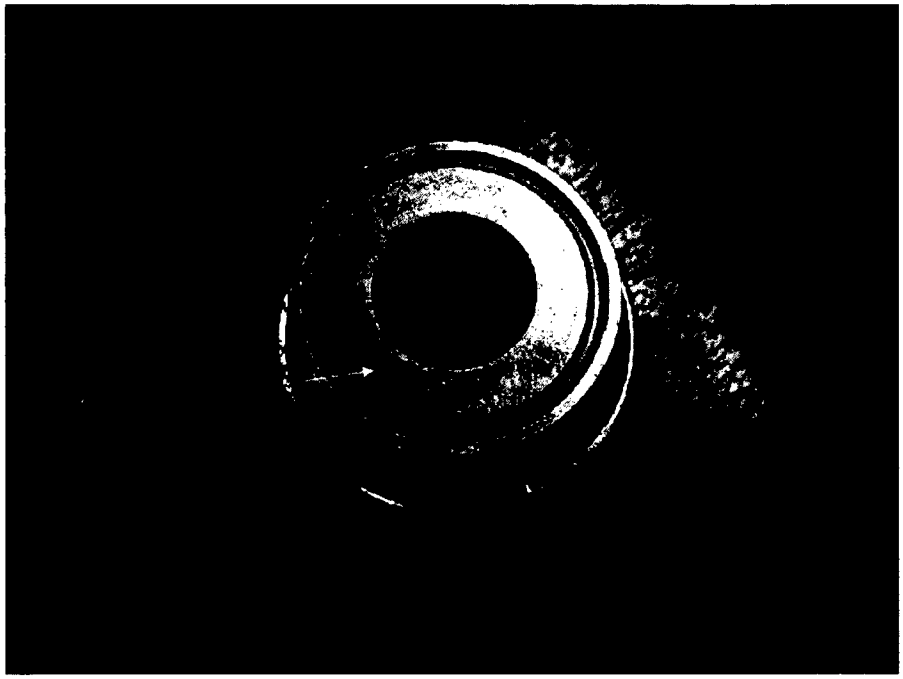


Fig. 11

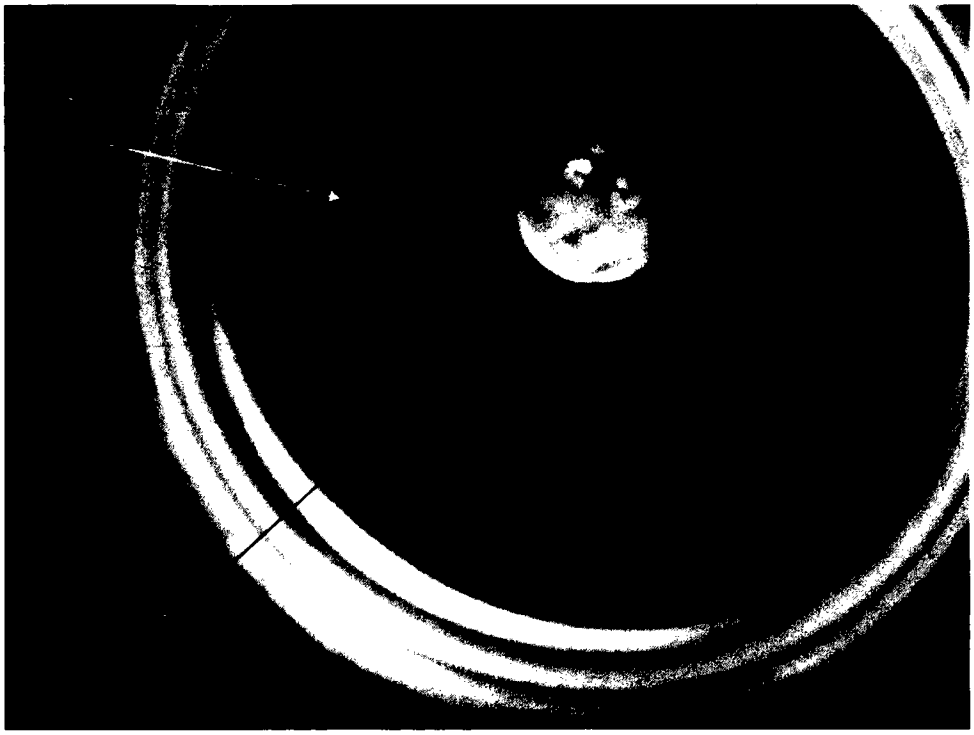


Fig. 12

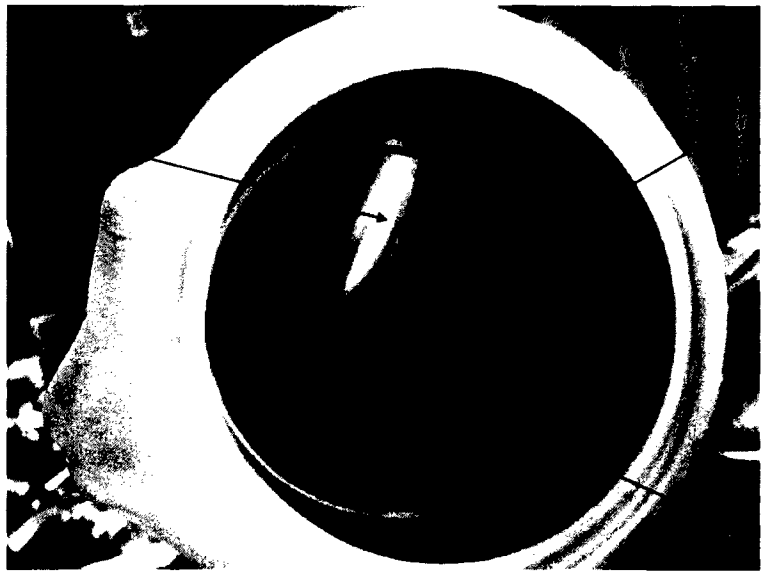


Fig. 13

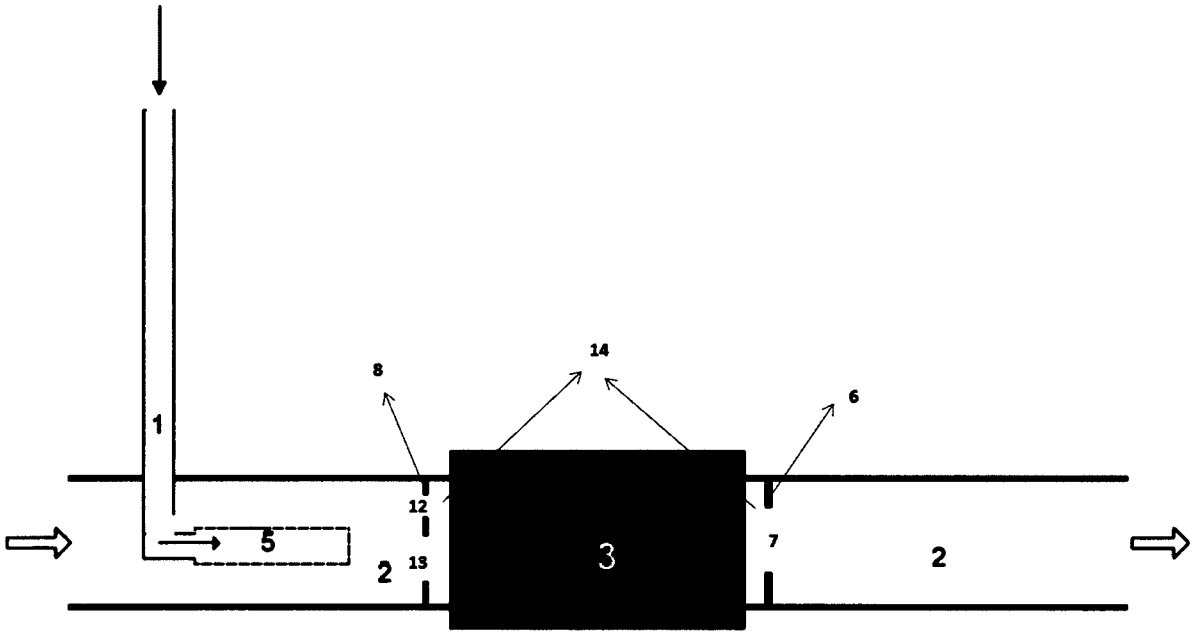


Fig. 15

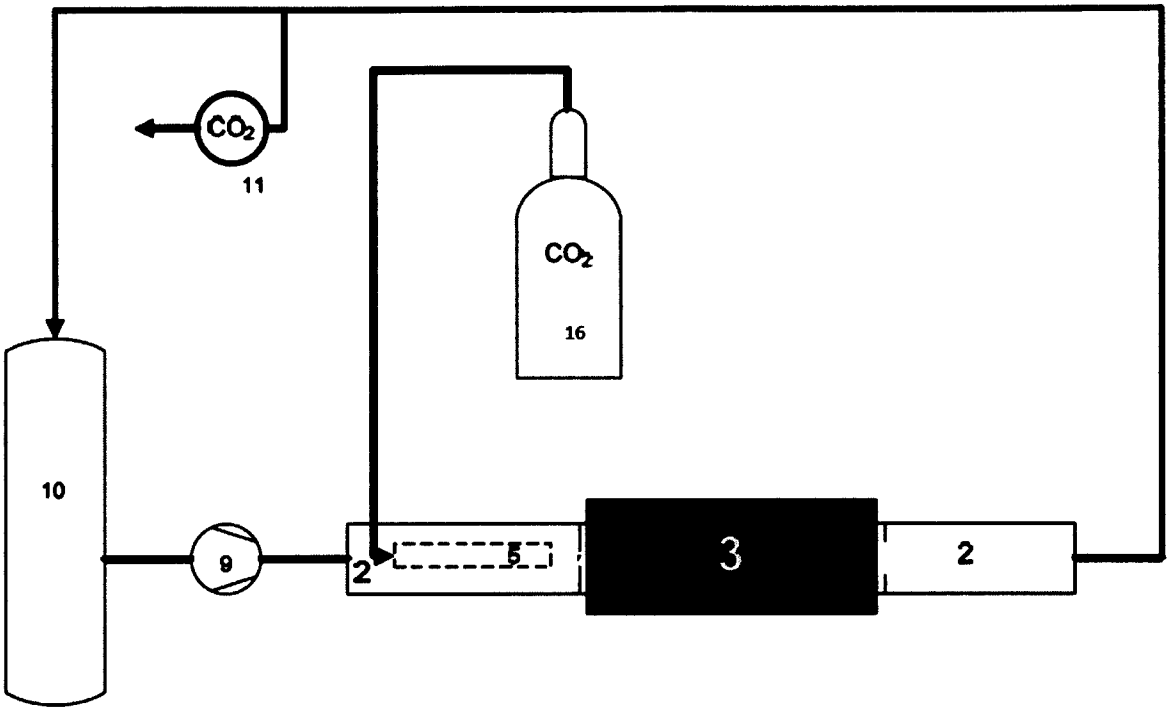


Fig. 15

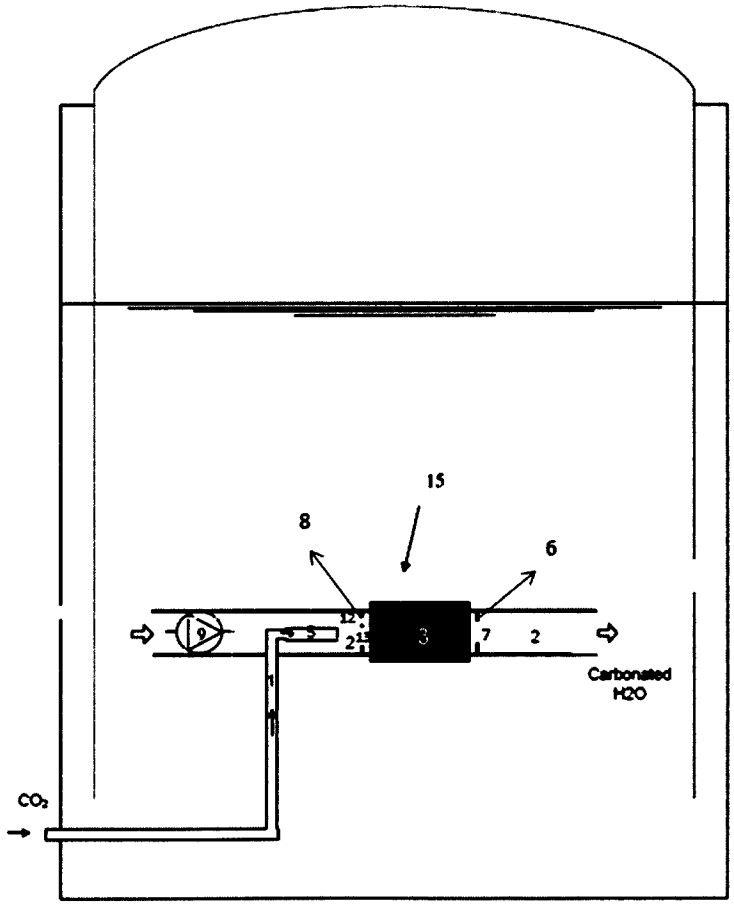


Fig. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/BE2012/000003

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01F3/04 B01F5/04 B01F5/06 B01F5/10 B01F13/00
C12C11/11
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)
B01F C12C C02F

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/095626 A1 (KOIDE TOSHIKAZU [JP]; SEO MIKYOUG [JP]) 26 August 2010 (2010-08-26)	1,2,7-9, 18-22,27
A	abstract figures	3-6, 10-17, 23-26, 28-43

X	US 2010/147690 A1 (AUDUNSON TORE [NO] ET AL) 17 June 2010 (2010-06-17)	28,30-38
Y	paragraph [0002] - paragraph [0004] paragraph [0028] - paragraph [0032] figures 1,3-5	1,2, 4-20,22, 23,26, 27,29, 39-41
A		3,21,24, 25,42,43

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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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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
9 July 2012	18/07/2012

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	Real Cabrera, Rafael

INTERNATIONAL SEARCH REPORT

International application No
PCT/BE2012/000003

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2 060 318 A1 (YARA INT ASA [NO]) 20 May 2009 (2009-05-20)	1,2, 4-14, 18-20, 22,26, 27,29
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