

SPECIFICATION

GAS DISSOLUTION APPARATUS

BACKGROUND

Technical Field

[0001]

The present invention relates to a gas dissolving apparatus that can produce a liquid that contains a dissolved gas (referred to as "gas-dissolved liquid" hereinafter) by causing gas to be dissolved into a liquid in the effective manner.

Background

[0002]

A gas may be dissolved into a liquid in various applications and various purposes. For example, there is a system that produces drinking water that contains lots of dissolved oxygen, by causing a particular gas, such as ozone gas, that is used to desalinate sea water to be dissolved into the sea water in the effective and efficient manner. There is also a system in which the ozone gas is used, for example, for the purpose of cleaning the waters, such as the industrial waste water, the water in the polluted rivers and lakes, the rain water and the like, and those waters can be cleaned by taking advantage of the sterilizing, deodorizing and decolorizing effects of the ozone gas. For such systems, however, it is desired that the gas can be left dissolved effectively in the liquid and can also remain dissolved in the liquid consistently and with high stability for a long time.

[0003]

In the conventional art, various methods for mixing gases into liquids are known. For example, the bubbling method is proposed as disclosed in Japanese patent publication of unexamined application Heisei11(1999) -

188255. One example is shown in Fig. 9. As shown in Fig. 9, a liquid 32 may be delivered by a liquid delivery pipe 31 into a gas and liquid mixing casing 30 having a cylindrical shape, and a gas bubble generator 34, which is linked to a gas delivery pipe 33, is provided inside of the gas and liquid mixing casing 30 and on the lower side thereof. Gas bubbles 35 may be produced by the gas bubble generator 34 as the gas enters the gas bubble generator 34 through the gas delivery pipe 33. Those gas bubbles 35 may be mixed into the liquid 32, some of which may be mixed with and dissolved into the gas, and the rest of which may be removed out of the gas and liquid mixing casing 30 through a gas outlet pipe 36. In this way, the mixture that is composed of the liquid and dissolved gas may be obtained.

[0004]

There is another method which is called as “the filled-layer dissolving method”. As shown in Fig. 10, in this method, a gas and liquid mixing casing 40 having the cylindrical shape has a filled layer 42 therein that is filled with a filler material 41, above which a shower head 44, which is linked to a liquid delivery pipe 43, is arranged. A gas delivery pipe 45 is connected to the gas and liquid mixing casing 40 on the lower portion thereof, and a gas delivery pipe 46 is connected to the gas and liquid mixing casing 40 on the upper portion thereof. In addition, a gas and liquid mixture delivery pipe 47 is connected to the gas and liquid mixing casing 40 on the lower portion thereof. In this method, the liquid that is delivered from the liquid delivery pipe 43 to the shower head 44 may be supplied in the form of a shower from the shower head 44 into the filled layer 42 through which the liquid may travel downwardly through the filled layer 42, while the gas that is delivered through the gas delivery pipe 45 into the gas and liquid mixing casing 40 may travel upwardly through the filled layer 42, going out of the gas and liquid mixing casing 40 through a gas outlet pipe 46. Through the filled layer 42, the gas and the liquid may travel in opposite directions, while contacting each

other. In this way, the gas may be dissolved into and mixed with the liquid. The gas and liquid mixture that contains the dissolved gas thus obtained may be removed out of the gas and liquid mixing casing 40 through the gas and liquid mixture outlet pipe 47.

There are other gas and liquid mixing methods. One example is the method using the ejector (Japanese patent publication of unexamined application No.Heisei10 (1998) - 290928, for example), and another example is the method using the vortex flow pump (Japanese patent publication of unexamined application No. 2000-161278, for example).

SUMMARY OF THE INVENTION

Problem to be solved by the invention

[0005]

However, the conventional gas and liquid mixing methods and apparatuses that have been mentioned above are intended for dissolving and mixing a gas into a liquid and transferring the resulting mixture containing the dissolved gas and liquid, and, for most cases, are not intended for allowing the gas to remain dissolved into the liquid with stability. In any of the conventional apparatuses, therefore, the problem is that the gas cannot be dissolved efficiently, and it might take a long time until the gas has been dissolved completely. Thus, the gas dissolving process cannot be performed efficiently. Furthermore, the gas that has been dissolved into the liquid may be separated easily from the liquid (degassing), and the gas cannot remain dissolved stably in the liquid. It may be appreciated from the above description that the conventional methods or apparatuses cannot meet the needs of dissolving the gas into the liquid effectively and efficiently, and then allowing such dissolved gas to remain dissolved in the liquid consistently and stably.

[0006]

The present invention has been made by considering the above described problems of the prior art, and it is therefore an object of the present invention to eliminate those problems of the prior art, and provide a gas dissolving apparatus that can produce a gas and liquid mixture that contains lots of the dissolved gas, by permitting the gas to be dissolved into the liquid effectively, and then allowing such dissolved gas to remain dissolved in the liquid consistently and stably for a long time.

Means for solving problem

[0007]

In order to solve the problems described above, a first aspect of the present invention as defined in Claim 1 is to provide the gas dissolving apparatus that includes a gas dissolving device for causing an turbulent flow to be produced in a mixture composed of gas and liquid (referred to as the “gas and liquid mixture” hereinafter) while the gas and liquid mixture is being introduced into the gas dissolving device, thereby enhancing the dissolubility of the gas into the liquid and providing the liquid containing such dissolved gas (referred to as the “gas-dissolved liquid” hereinafter), an injection outlet connected to the gas dissolving device for injecting the gas-dissolved liquid, and a pressure tank in which the gas-dissolved liquid injected through the injection outlet into the pressure tank can be stored, and from which the gas-dissolved liquid can be taken out.

[0008]

A second aspect of the present invention as defined in Claim 2 is to provide the gas dissolving apparatus that includes a gas dissolving device for causing an turbulent flow to be produced in a mixture composed of gas and liquid (referred to as the “gas and liquid mixture” hereinafter) while the gas and liquid mixture is being introduced into the gas dissolving device, thereby enhancing the dissolubility of the gas into the liquid and providing the liquid

containing the dissolved gas (referred to as the “gas-dissolved liquid” hereinafter), an injection outlet connected to the gas dissolving device for injecting the gas-dissolved liquid, and a pressure tank in which the gas-dissolved liquid injected into the space inside the pressure tank through the injection outlet into the pressure tank can be stored, and from which the gas-dissolved liquid can be taken out.

[0009]

A third aspect of the present invention as defined in Claim 3 is to provide a variation of the gas dissolving apparatus according to Claim 1 or 2, wherein the gas dissolving device includes an injection pipe through which the gas and liquid mixture introduced into the gas dissolving device is to be injected in the form of a jet stream, and a baffler for producing a turbulent flow in the jet stream when the jet stream strikes against the baffler.

[0010]

A fourth aspect of the present invention as defined in Claim 4 is to provide a variation of the gas dissolving apparatus according to Claim 3, wherein the gas dissolving device further includes a flat base space portion provided as said baffler and having two opposite walls facing opposite each other and each having a passage hole through which a liquid passes, and a circumferential wall surrounding the space between the two opposite walls, wherein the flat base space portion is provided such that the locations of the passage hole in the opposite wall on the downstream side are out of line with the locations of the passage hole in the opposite wall on the upstream side and that the jet stream of the liquid that has passed through the passage hole in the opposite wall on the upstream side may strike against the opposite wall on the downstream side within the flat base space portion, producing a violent turbulent flow in the stream of the liquid.

[0011]

A fifth aspect of the present invention as defined in Claim 5 is to

provide a variation of the gas dissolving apparatus according to Claim 4, wherein at least one of the two opposite walls within the flat base space portion has a plurality of passage holes, and a plurality of reduced-diameter injection pipes connected in parallel are linked to the respective ones of the passage holes.

[0012]

A sixth aspect of the present invention as defined in Claim 6 is to provide a variation of the gas dissolving apparatus according to Claim 4 or 5, wherein the opposite wall on the downstream side includes a protruding portion formed in the position opposite the passage hole in the opposite wall on the upstream side, and a passage hole on the outer side of the protruding portion.

[0013]

A seventh aspect of the present invention as defined in Claim 7 is to provide a variation of the gas dissolving apparatus according to Claim 1 or 2, wherein including a gas and liquid mixing portion on the upstream side thereof, for mixing the gas and liquid together.

[0014]

An eighth aspect of the present invention as defined in Claim 8 is to provide a variation of the gas dissolving apparatus according to Claim 7, wherein the gas and liquid mixing portion is a gas and liquid mixer pump.

[0015]

An ninth aspect of the present invention as defined in Claim 9 is to provide a variation of the gas dissolving apparatus according to Claim 2, wherein the injection outlet for the gas-dissolved liquid is arranged such that the gas-dissolved liquid can be injected through the injection outlet toward the surface of the gas-dissolved liquid existing in the pressure tank, and can be directed in the direction substantially along the direction in which the gas-dissolved liquid is caused to revolve within the pressure tank.

[0016]

A tenth aspect of the present invention as defined in Claim 10 is to provide a variation of the gas dissolving apparatus according to Claim 1 or 2, wherein the pressure tank includes a pressure adjusting valve for adjusting the internal pressure within the tank to any desired pressure value.

[0017]

A eleventh aspect of the present invention as defined in Claim 11 is to provide a variation of the gas dissolving apparatus according to Claim 10, wherein the pressure adjusting valve is provided for setting the internal pressure within the pressure tank to any value between above the atmospheric pressure and the atmospheric pressures of + 0.6 MPa.

[0018]

An twelfth aspect of the present invention as defined in Claim 12 is to provide a variation of the gas dissolving apparatus according to Claim 1 or 2, wherein it further includes a return pipe for returning the gas-dissolved liquid within the pressure tank toward the upstream side of the gas dissolving device, thereby allowing the gas-dissolved liquid to circulate between the gas dissolving device and the pressure tank.

[0019]

In accordance with the present invention, when the gas and liquid mixture is delivered into the gas dissolving device, it can produce a turbulent flow in the mixture while it is flowing through the gas dissolving device, thereby atomizing the gas into smaller particles within the liquid and thus increasing the dissolubility of the gas into the liquid. The resulting gas-dissolved liquid may be injected through the gas-dissolved liquid injection outlet into the pressure tank, in order to ensure that the dissolved gas can remain as dissolved stably within the liquid. In addition, when the gas-dissolved liquid is injected into the space within the pressure tank, it can draw the gas that exists in the space of the tank into the gas-dissolved liquid,

thereby increasing the amount of the gas that can remain as dissolved in the liquid. In particular, the gas-dissolved liquid injection outlet may be arranged such that it can inject the gas-dissolved liquid toward the surface of the gas-dissolved liquid existing in the pressure tank and in the direction substantially along the direction in which the flow of the gas-dissolved liquid is caused to revolve within the pressure tank. In this way, when the gas-dissolved liquid is injected through its injection output, it may produce a jet stream that causes the gas-dissolved liquid existing in the pressure tank to have the revolving flow. As a result, the dissolved gas can be distributed uniformly and evenly in the liquid, and can remain as dissolved consistently and stably within the liquid.

[0020]

Note that the gas-dissolved liquid injection outlet may be provided as part of the gas dissolving device, or may be connected to the gas dissolving device by way of its delivery pipe. Preferably, the injection outlet should be provided on or near the gas dissolving device in order to ensure that the dissolved gas can be injected into the pressure tank as quickly as possible, so that it can remain as dissolved in the liquid. One or more gas-dissolved liquid injection outlets may be provided, and may be arranged such that each of those outlets can inject the gas-dissolved liquid in the direction substantially along the direction in which the gas-dissolved liquid can have the revolving flow within the pressure tank.

[0021]

The gas-dissolved liquid may be obtained by the gas and liquid mixing portion which may be provided on the upstream side of the gas dissolving device. This gas and liquid mixing portion may be implemented by using various mechanical means or processes, such as by using the known ejector or bubbling method. Preferably, the gas and liquid mixer pump may be used as the gas and liquid mixing portion. When the gas and liquid mixer pump is

used, for example, the gas may be introduced under the applied pressure into the gas dissolving device, so that the gas can be dissolved acceleratingly. In addition, when the gas-dissolved liquid is injected into the pressure tank, the pressure tank can always be kept under the applied pressure. This can eliminate the need of using any other means, such as an air pressure pump, to place the pressure tank under the applied pressure.

[0022]

The gas dissolving device according to the present invention is only intended for producing a turbulent flow in the gas and liquid mixture introduced into the gas dissolving device, thereby increasing the dissolubility of the gas into the liquid and then delivering the gas-dissolved liquid more easily or quickly. Desirably, the turbulent flow should be produced both violently and effectively. For example, this violent turbulent flow may be produced by causing the gas and liquid mixture to strike against the baffler in the gas dissolving device when it is flowing through its injection pipe. The baffler may have any form, and may be arranged in any position, without departing from the spirit and scope of the present invention. Rather, the baffler may be implemented by a flat base space portion that will be described later.

[0023]

The baffler may be provided in the form of a flat base space portion that includes two opposite walls facing opposite each other, each having a passage hole through the liquid passes, and a circumferential wall surrounding the space between the opposite walls. Within the flat base space portion, the opposite walls may be provided such that the locations of the passage hole in the opposite wall on the upstream side is out of line with the locations of the passage hole in the opposite wall on the downstream side, in the direction in which the two opposite walls face each other. In this way, the jet stream of the liquid that has passed through the passage holes in the

opposite wall on the upstream side can strike against the opposite wall on the downstream side, producing the violent turbulent flow.

[0023]

On each of the two opposite walls, two or more passage holes may be provided, and reduced-diameter injection pipes may be connected to the respective passage holes. This may produce the turbulent flow with the increased efficiency. Note that the total bore cross-sectional area of those reduced-diameter injection pipes should be smaller than the bore cross-sectional area of the main injection pipe provided on the upstream side. In this way, the flow rate of the injected stream can be increased, thereby producing the turbulent flow more violently.

[0025]

The gas-dissolved liquid that has been injected into the pressure tank from the gas-dissolved liquid injection outlet port may be stored in the pressure tank, from which the gas-dissolved liquid may be taken out as required. Although the pressure tank may be placed under the higher pressure by delivering the gas under the pressure by way of the pressure pump, it is desirable that the pressure within the pressure tank should be provided by the gas and liquid mixture delivered from the gas and liquid mixer pump, as described earlier. Note that the internal pressure of the pressure tank may be adjusted to any appropriate value by using the pressure adjusting valve that may be provided within the pressure tank. For example, this internal pressure may be adjusted to any value between above the atmospheric pressure and the atmospheric pressure of +0.6 MPa. As it is referred to here, the atmospheric pressure corresponds to the prevailing pressure in the environment in which the pressure tank is located.

[0026]

It should be noted that the gases that may be dissolved into the liquid in accordance with the present invention are not limited to any particular

type, and any of the gases such as ozone, oxygen, nitrogen and the like may be chosen as appropriate. It should also be noted that the liquids into which the gases may be dissolved are not limited to any particular type, and liquids such as the utility service water, sea water, polluted water and the like may be used as appropriate. It should be noted that the applications in which the gas dissolving apparatus of the present invention may be used are not limited to any particular application, and the gas dissolving apparatus may be used in any of the applications in which the liquids containing the dissolved gases are utilized.

Effect of the invention

[0027]

It may be appreciated from the foregoing description that the gas dissolving apparatus according to the present invention includes the gas dissolving injector that may produce a turbulent flow in the gas and liquid mixture while it is being introduced into the injector, thereby increasing the dissolubility of the gas into the gas and liquid mixture so that the gas-dissolved liquid can be injected to the outside, and the pressure tank in which the gas-dissolved liquid injected from the injector into the pressure tank or into the space within the pressure tank can be stored, and from which the gas-dissolved liquid may be delivered to the outside, whereby the gas can be absorbed into the liquid more efficiently, the gas can be dissolved in a short time (for example, through one pass) until it becomes saturated, and the gas can remain as dissolved for an extended time of period. Note that the apparatus can have a reduced-size construction, and may be manufactured at reduced costs.

BRIEF DESCRIPTION OF DRAWINGS

[0028]

Fig. 1 is a schematic diagram illustrating the general arrangement of

the gas dissolving apparatus in accordance with one embodiment of the present invention;

Fig. 2 shows the neighborhood of the pressure tank in the gas dissolving apparatus of Fig. 1, in which (a) is a perspective view and (b) is a cross-sectional plan view;

Fig. 3 is a partial cross-sectional view illustrating the gas dissolving apparatus of Fig. 1;

Fig. 4 is a perspective view illustrating the gas dissolving apparatus of Fig. 1;

Fig. 5 is an exploded view illustrating the flat base space portion in the gas dissolving apparatus of Fig. 1;

Fig. 6 is a perspective view illustrating the components of the gas dissolving apparatus of Fig. 1 being assembled together;

Fig. 7 is a schematic diagram illustrating part of the gas dissolving apparatus in accordance with another embodiment of the present invention;

Fig. 8 represents two graphs (a) and (b) showing the test results for the purpose of comparing the embodiments of the present invention with those of the prior art;

Fig. 9 is a diagram illustrating one example of the gas and liquid mixture according to the prior art; and

Fig. 10 is a diagram illustrating another example of the gas and liquid mixture according to the prior art.

Explanation of numerals

[0029]

1 gas dissolving apparatus

2 liquid storage container

3 liquid delivery pipe

4 gas delivery pipe

6 gas and liquid mixer pump
8 gas dissolving device
9 gas dissolving devices
81,83,85,87 flat base space portion
89 injection outlet for injecting the gas-dissolved liquid
814 protruding portion
10 gas-dissolved liquid
11 pressure tank
14 pressure adjusting valve
15 liquid outlet pipe
20 return pipe
21 gas-dissolved liquid injection pipe
21a outlet

BEST MODE OF EMBODYING THE INVENTION

[0030]

(Embodiment 1)

A first embodiment of the present invention is now described by referring to Figs. 1 through 6.

Referring to Fig. 1, the gas dissolving apparatus 1 according to the present embodiment is shown, which includes a liquid storage container 2 for storing a liquid 10a (such as water) into which any suitable gas such as ozone gas is to be dissolved. A liquid delivery pipe 3 is connected to the liquid storage container 2, and a gas delivery pipe 4 is connected in parallel to the liquid delivery pipe 3 on its intermediate way, on the downstream of which a gas and liquid mixer pump 6 is provided. When air is delivered through the gas delivery pipe 4, for example, the pipe 4 may have its end open to the atmosphere. When any suitable gas such as ozone gas is delivered, for example, the gas delivery pipe 4 may be connected to the gas supply source.

A vortex flow pump may be used as the gas and liquid mixer pump 6. The liquid delivery pipe 3 has switch valves 5a, 5b that may be operated to open or close, each of which is located near each of the upstream and downstream sides of the gas and liquid mixer pump 6, respectively. The liquid delivery pipe 3 also has a pressure gauge 7a and a flow meter 7b located on the downstream side of the gas and liquid mixer pump 6. On its downstream side, furthermore, the liquid delivery pipe 3 has two branches extending into the pressure tank 11. Note that there are switch valves 12a, 12b, each of which is provided on each of the branches.

[0031]

In the pressure tank 11, there are two gas dissolving devices 8, 9, for example, each of which is connected to the forward end of each of the two branches of the liquid delivery pipe 3, as shown in Figs. 1 and 2. Each of the gas dissolving devices 8, 9 is provided symmetrically of the center axis of the pressure tank 11 so that it is directed downwardly and inclined with respect to the cylindrical pressure tank 11. Each of the gas dissolving devices 8, 9 has an injection outlet on its forward end, through which the gas-dissolved liquid may be injected. Specifically, the gas dissolving devices 8, 9 are arranged so that the gas-dissolved liquid for each can be injected in the direction substantially along the direction in which the gas-dissolved liquid is caused to revolve within the pressure tank 11. The construction of the gas dissolving devices will be described in detail later.

In the present embodiment, the two gas dissolving devices are provided as shown and described above, but any number of the gas dissolving devices may be provided without limitation.

[0032]

In the pressure tank 11, a pressure gauge 13 and a pressure adjusting valve 14 are provided. The pressure gauge 13 may be used to monitor the internal pressure within the pressure tank 11, and the pressure adjusting

valve 14 may be used to adjust the internal pressure of the pressure tank 11 to the predetermined pressure level. Desirably, the initial pressure level that has been preset should be varied to any desired pressure level at any time.

On the lower portion of the pressure tank 11, there is a liquid outlet pipe 15 that is connected to the pressure tank 11 by way of a switch valve 17, through which the gas-dissolved liquid 10 stored in the pressure tank 11 can be taken out of the pressure tank. The liquid outlet pipe 15 has a liquid delivery output 16 on its forward end through a filter 18 and an ultraviolet sterilizing device 19 that are provided on its intermediate way.

[0033]

Now, the details of the gas dissolving device will be described by referring to Figs. 3 through Fig. 6. In this embodiment, two gas dissolving devices 8, 9 are provided, for example, and have the identical structure. Thus, the gas dissolving device 8 is described below, while the gas dissolving device 9 is not described. Note, however, that the description of the gas dissolving device 8 may be applied to the gas dissolving device 9.

The gas dissolving device 8 includes an injection pipe 80 on the inlet side that is connected to the liquid delivery pipe 3. On the downstream side of the injection pipe 80, there are flat base space portions 81, 83, 85, 87 arranged in that order and each acting as a baffler, respectively. The flat base space portions 81, 83 are interlinked by way of a set of six reduced-diameter pipes 82-82, the flat base space portions 83, 85 are interlinked by way of a set of six reduced-diameter pipes 84-84, and the flat base space portions 85, 87 are interlinked by way of a set of six reduced-diameter pipes 86-86. Each of the reduced-diameter pipes in all sets has a bore of the same cross-section and the total cross-sectional area of the bores in all of the six reduced-diameter pipes in each set is set to be smaller than the cross-sectional area of the bore in the injection pipe 80.

[0034]

As its details are shown in Fig. 5, the flat base space portion 81 described above includes a base space member 800 and a base space member 810. The base space member 800, on one hand, includes an opposite wall 801 having a round plate form, and a peripheral wall 803 adjoining the circumferential edge of the opposite wall 801, the opposite wall 801 having a passage hole 802 on the center to which the main injection pipe may be connected. The base space member 810, on the other hand, includes an opposite wall 811 having a round plate form, and a peripheral wall 813 adjoining the circumferential edge of the opposite wall 811, the opposite wall 811 having six passage holes 812· 812 arranged at angular intervals of 60 degrees in the circumferential direction. The opposite wall 811 further includes a cylindrical protruding portion 814 on the center that is formed to a thickness equal to the width of the peripheral wall 813. As shown in Figs. 3 and 4, in the flat base space portion 81, the base space members 800, 810 are joined together such that the respective opposite walls 801, 811 can be placed to face opposite each other, with the respective peripheral walls 803, 813 being joined closely without any gap therebetween.

[0035]

As its details are shown in Fig. 5, the flat base space portion 83 includes base space members 810, 810, in which the base space members 810, 810 are joined together such that the respective opposite walls 811, 811 can be placed to face opposite each other, with the locations of the passage holes 812, 812 in one opposite wall 811 being out of line by an angle of 30 degrees with the locations of the passage holes 812, 812 in the other opposite wall 811 and with the respective peripheral walls 813, 813 being joined closely without any gap therebetween. In this case, the cylindrical protruding portions 814 on the upstream and downstream sides have their respective forward ends brought into intimate contact with each other, forming a ring-like space around the circumference.

The other ends of the reduced-diameter injection pipes 82-82 connected to the respective passage holes 811, 811 in the flat base space portion 81 are connected to the corresponding passage holes 811 on the upstream side of the flat base space portion 83, and the passage holes 811, 811 on the downstream side of the flat base space portion 83 are connected to the reduced-diameter injection pipes 84, 84, respectively.

[0036]

Similarly, the flat base space portion 85 includes base space members 810, 810, in which the base space members 810, 810 are joined together such that the respective opposite walls 811, 811 can be placed to face opposite each other, with the locations of the passage holes 812, 812 in one opposite wall 811 being out of line by an angle of 30 degrees with the locations of the passage holes 812, 812 in the other opposite wall 811 and with the respective peripheral walls 813, 813 being joined closely without any gap therebetween. In this case, the cylindrical protruding portions 814 on the upstream and downstream sides have their respective forward ends brought into intimate contact with each other, forming a ring-like space around the circumference.

The other ends of the reduced-diameter injection pipes 84-84 connected to the respective passage holes 811 on the downstream side of the flat base space portion 83 are connected to the corresponding passage holes 811 on the upstream side of the flat base space portion 85, and the passage holes 811 on the downstream side of the flat base space portion 83 are connected to the reduced-diameter injection pipes 86- 86, respectively.

[0037]

Next, the flat base space portion 87 includes base space members 810, 800, in which the base space members 810, 800 are joined together such that the respective opposite walls 811, 801 can be placed to face opposite each other, with the respective peripheral walls 813,803 being joined closely with any gap therebetween.

The other ends of the reduced-diameter injection pipes 86-86 connected to the respective passage holes 811 on the downstream side of the flat base space portion 85 are connected to the corresponding passage holes 811 in the flat base space portion 87. To the passage hole 801 on the downstream side of the flat base space portion 87 is connected the injection pipe 88 on the downstream side, and the forward end of the injection pipe 88 provides an injection output port through which the gas-dissolved liquid may be injected.

[0038]

Now, the operation of the gas dissolving apparatus 1 that has been described so far is described below. In the following description, an ozone gas, for example, is used so that it can be dissolved into the water, such as the sea water, for example.

Initially, the internal pressure within the pressure tank 11 may be set to the predetermined pressure level by means of the pressure adjusting valve 14, and the sea water may previously be placed as liquid 10a in the liquid storage container 2. The switch valves 5a, 5b, 12a, 12b may then be opened while the switch valve 17 is closed, and the gas and liquid mixer pump 6 may be operated so that the ozone gas can be introduced into the gas and liquid mixer pump 6 through the gas delivery pipe 4.

The ozone gas that has been introduced into the gas and liquid mixer pump 6 may then be mixed with the sea water within the gas and liquid mixer pump 6. As the ozone gas is being dissolved into the sea water, the resulting gas and liquid mixture may be delivered to the downstream side of the gas and liquid mixer pump 6 through the liquid delivery pipe 3. While the gas and liquid mixture is being delivered, its pressure may be measured by the pressure gauge 7a, and its flow rate may be measured by the flow meter 7b.

[0039]

As it is delivered through the liquid delivery pipe 3, the gas and liquid mixture may then go to the gas dissolving devices 8, 9. As the gas dissolving

devices 8, 9 may be operated in the same manner, the operation for the gas dissolving device 8 will be described below, and the operation for the gas dissolving device 9 will be not be described.

The gas and liquid mixture that has been introduced into the injection pipe 80 on its inlet side may then be introduced into the internal space inside the flat base space portion 81 through its passage hole 802. Upon entering the flat base space portion 81, the gas and liquid mixture may be led toward the protruding portion 814 and hit to the protruding portion 814.

Afterward the gas and liquid mixture may flow to the outer peripheral side of the protruding portion 814, and may then be delivered into the reduced-diameter pipes 82-82 through the passage hole 812 while it is striking against the opposite wall 811. During this process, the gas and liquid mixture may produce a turbulent flow while striking against the protruding portion 814 and the opposite wall 811, and the turbulent flow may atomize the bubbles of ozone gas into much more smaller particles, which can then be dissolved into the sea water. The gas-dissolved liquid mixture may be obtained in this way.

[0040]

As it is delivered through the reduced-diameter pipes 82-82, the gas-dissolved liquid can be flowing with its increasing speed, and may then be introduced into the ring-like space through the passage holes 812, 812 on the upstream side of the flat base space portion 83. By providing the ring-like space within the flat base space portion, the gas and liquid mixture can be drawn into the space by keeping the decrease in its flow rate as small as possible. After it is drawn into the space, the gas and liquid mixture may then flow toward the downstream side, where it may strike against the opposite wall 811, producing a violent turbulent flow and then going out into the reduced-diameter pipe 84 through the passage holes 812-812 on the downstream side. As the passage holes on the upstream side and the passage

holes on the downstream side are provided such that the locations for the passage holes on the downstream side are out of line sufficiently and effectively with regard to the locations for the passage holes on the upstream side, the gas-dissolved liquid that has been injected through the passage holes on the upstream side can surely strike against the opposite wall 811 on the downstream side, producing a turbulent flow effectively which further increases the dissolubility of the ozone gas into the liquid. Then, the gas-dissolved liquid may be introduced into the reduced-diameter pipes 84, through which it can be flowing with its increasing speed, going into the flat base space portion 85 where it can produce a violent flow in the same manner as for the flat base space portion 83, enabling the ozone gas to be dissolved into the sea water effectively. The gas-dissolved liquid within the flat base space portion 85 may then be delivered into the flat base space portion 87 through the reduced-diameter pipes 86, 86. The gas-dissolved liquid within the flat base space portion 87 may go from the circumference of the protruding portion 814 toward the downstream side, where it can strike against the opposite wall 801, going through the passage hole 802 into the injection pipe 88. When the gas-dissolved liquid strikes against the opposite wall 801, it can also produce a turbulent flow that will increase the dissolubility of the ozone gas into the liquid.

[0041]

The gas-dissolved liquid that has been delivered into the injection pipe 88 on the downstream side may be injected from the injection outlet for injecting the gas-dissolved liquid 89 at the forward end of the injection pipe 88 into the space within the pressure tank 11. With the gas-dissolved liquid 10 being stored in the pressure tank 11, the gas-dissolved liquid that is subsequently injected from the two gas dissolving devices 8, 9 may provide its injecting force that places the gas-dissolved liquid 10 existing in the pressure tank 11 under the rotational action so that the liquid 10 can flow while

revolving within the pressure tank 11, and thus can be distributed uniformly. This also avoids that the excess part of ozone gas that may remain dissolved locally will be dissipated from the liquid so that the ozone gas can remain dissolved consistently and with high stability.

[0042]

The part of ozone gas that is not dissolved within the pressure tank 11 or the oxygen derived from the ozone gas may place the pressure tank 11 under the compressed pressure. When this occurs, the internal pressure can be adjusted to the predetermined pressure level by means of the pressure adjusting valve 14.

When the gas-dissolved liquid 10 that has thus been stored in the pressure tank 11 is to be taken out from the pressure tank 11, the switch valve 17 may be opened so that the liquid 10 can be removed from the pressure tank 11 through the liquid outlet pipe 15. When the gas-dissolved liquid 10 contains any foreign matter, it may be removed through the filter 18 or the gas-dissolved liquid 10 may be sterilized by using the ultra-violet sterilizer 19. After the gas-dissolved liquid 10 is cleaned in this way, it may be delivered through its outlet port 16. Such gas-dissolved liquid 10 contains lots of dissolved oxygen and useful minerals contained in the fresh water, and therefore may be used as the drinking water after it is passed through the subsequent water cleaning process.

A return pipe 20 may be connected between the pressure tank 11 and the storage container 2 for the gas-dissolved liquid so that the gas-dissolved liquid stored in the pressure tank 11 can be returned to the storage container 2 through the return pipe 20, although this has not been described so far in this embodiment. By circulating the gas-dissolved liquid between the pressure tank 11 and storage container 2 through the return pipe 20, it is ensured that the gas-dissolved liquid can contain lots of the dissolved gas.

[0043]

(Embodiment 2)

In the preceding embodiment 1, the gas dissolving device 8 is provided in the upper space within the pressure tank 11 so that it can inject the gas-dissolved liquid from its injection outlet toward the gas-dissolved liquid existing in the pressure tank 11 through the upper space. In the embodiment 2 that corresponds to a variation of the embodiment 1, as shown in Fig. 7, the gas dissolving device 8 may be provided outside the pressure tank 11, and the gas-dissolved liquid injection pipe 21 is connected to the lower side of the pressure tank 11, so the outlet 21a which is the forward end of the liquid injection pipe 21 can be directed into the gas-dissolved liquid existing in the pressure tank 11. Note that the upstream side of the gas dissolving device 8 may be similar to that in the preceding embodiment.

[0044]

Although the present invention has been described with particular reference to the embodiments 1 and 2, it should be understood that the present invention is not limited to those embodiments, but other structures and features may be implemented without departing from the spirit and scope of the present invention.

(Examples)

[0045]

The present invention is described by showing specific examples of the present invention and prior art and comparing those respective examples.

Oxygen is used as the gas to be dissolved, and utility service water is used as the liquid into which the oxygen is to be dissolved.

In the first example of the present invention, the gas dissolving apparatus described in the embodiment 1 is used, and is operated to cause the oxygen to be dissolved into the utility service water by drawing the atmospheric air into the apparatus. In the second example of the present invention, the gas dissolving apparatus described in the embodiment 2 is

placed outside the pressure tank, and a utility service water supply device is provided for delivering the water into the gas-dissolved liquid stored in the pressure tank. Then, the gas-dissolved liquid is removed from the pressure tank through the output port provided on the lower side of the pressure tank. The internal pressure in the pressure tanks are set to the atmospheric pressure of +0.2 MPa.

In the examples of the prior art that are provided for comparing with the examples of the present invention, the gas and liquid mixer pump is used to mix the gas and liquid together.

In the respective examples of the present invention and prior art, the gas is dissolved into the water or is mixed with the water, respectively, and the respective amounts of the oxygen that remains as dissolved in the water are measured at regular time intervals as expressed in terms of minutes by using the oxygen meter based on the diaphragm galvanic cell technique (Model DO-24P manufactured by Towa DKK company). At the end of the predetermined time, the gas dissolving operation or gas and liquid mixing operation is stopped and then resumed, and the respective amounts of the oxygen that remains as dissolved in the water are measured again at regular time intervals as expressed in terms of minutes.

The variation of the respective amounts of the dissolved oxygen that have been measured over the time are presented in Table 1 and Fig. 8 (a), and variations in the respective amounts of the dissolved oxygen that have been measured after the operation is stopped and then resumed are presented in Table 2 and Fig. 8 (b).

It may be seen from Tables 1, 2 and Figs. 8 (a), (b) that the amount of the dissolved oxygen can be increased and can be maintained consistently and stably for a long time, by using the gas dissolving apparatus of the present invention. In particular, in the example 1 in which the gas dissolving device has its outlet directed toward the surface of the liquid existing within the

pressure tank, the amount of the dissolved oxygen can be increased remarkably.

[0046]

[mg/L]

Target Machine	Time [min]											
	0	1	2	3	4	5	10	15	20	30	40	50
Example 1	9.2	12.3	15.4	19.0	22.1	26.7	40.1	49.5	56.1	63.0	62.8	64.2
Example 2	9.3	11.8	14.8	17.2	20.3	24.1	33.2	37.0	42.1	43.1	44.9	45.2
Prior Art	8.9	9.5	13.13	15.0	15.8	16.7	19.3	19.9	20.2	19.9	20.2	20.1

[0047]

[mg/L]

Target Machine	Time [day]											
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day
Example 1	65	50.1	46.2	44.6	43	42.3	38	36.7	36	35.4	35.2	34.7
Example 2	45.1	33.9	32.4	29.1	27.5	25.2	23.9	23.0	22.1	21.6	21.2	20.7
Prior Art	20.2	16.0	15.3	14.9	13.5	12.8	11.8	11.2	10.6	10	9.5	9.2

[0048]

The gas dissolving apparatus according to the present invention may be used in conjunction with the system in which the sea water is desalinated, for example, wherein the apparatus allows the ozone gas, for example, to be mixed with (dissolved into) the sea water effectively, thereby producing the drinking water containing lots of dissolved oxygen. The apparatus may also be used in conjunction with the system in which the industrial waste water, the water in the polluted rivers, lakes or marshes or the rain water are treated by using the ozone gas, for example, wherein the apparatus allows those waters to be cleaned by taking advantage of the sterilizing, decolorizing and deodorizing effects of the ozone gas.

CLAIMS

What is claimed is:

1. A gas dissolving apparatus including:

a gas dissolving device for causing an turbulent flow to be produced in a mixture composed of gas and liquid (referred to as a gas and liquid mixture) while the gas and liquid mixture is being introduced into said gas dissolving device, thereby enhancing the dissolubility of the gas into the liquid and providing the liquid containing the dissolved gas (referred to as a gas-dissolved liquid);

an injection outlet connected to said gas dissolving device for injecting the gas-dissolved liquid; and

a pressure tank in which the gas-dissolved liquid injected through said injection outlet can be stored and from which the gas-dissolved liquid can be taken out.

2. A gas dissolving apparatus including:

a gas dissolving device for causing an turbulent flow to be produced in a mixture composed of gas and liquid (referred to as a gas and liquid mixture) while the gas and liquid mixture is being introduced into said gas dissolving device, thereby enhancing the dissolution of the gas into the liquid and providing the liquid containing the dissolved gas (referred to as a gas-dissolved liquid);

an injection outlet connected to said gas dissolving device for injecting the gas-dissolved liquid; and

a pressure tank in which the gas-dissolved liquid injected into the space inside said pressure tank through said injection outlet can be stored and from which the gas-dissolved liquid can be taken out.

3. The gas dissolving apparatus as defined in Claim 1 or 2, wherein said gas dissolving device includes an injector pipe through which the gas and liquid mixture introduced into said gas dissolving device is to be injected in

the form of a jet stream, and a baffler for producing a turbulent flow in said jet stream when said jet stream strikes against said baffler.

4. The gas dissolving apparatus as defined in Claim 3, wherein said gas dissolving device further includes a flat base space portion provided in the form of the baffler and having two opposite walls facing opposite each other and each having a passage hole through which a liquid passes, and a circumferential wall surrounding the space between said two opposite walls, wherein said flat base space portion is provided such that the locations of the passage hole in the opposite wall on the downstream side are out of line with regard to the locations of the passage hole in the opposite wall on the upstream side and that the jet stream of the liquid that has passed through the passage hole in the opposite wall on the upstream side can strike against the opposite wall on the downstream side within said flat base space portion, producing a violent turbulent flow in the stream of the liquid.

5. The gas dissolving apparatus as defined in Claim 4, wherein at least one of said two opposite walls within said flat base space portion has a plurality of passage holes, and a plurality of reduced-diameter injection pipes connected in parallel are linked to the respective ones of said passage holes.

6. The gas dissolving apparatus as defined in Claim 4 or 5, wherein said opposite wall on the downstream side includes a protruding portion formed in the position opposite the passage hole in said opposite wall on the upstream side, and a passage hole on the outer side of said protruding portion.

7. The gas dissolving apparatus as defined in any one of Claim 1 or 2, including a gas and liquid mixing portion on the upstream side of said gas dissolving device, for mixing the gas and liquid together.

8. The gas dissolving apparatus as defined in Claim 7, wherein said gas and liquid mixing portion is a gas and liquid mixer pump.

9. The gas dissolving apparatus as defined in any one of Claim 2, wherein said injection outlet for the gas-dissolved liquid is arranged such that

the gas-dissolved liquid can be injected through said injection outlet toward the surface of the gas-dissolved liquid existing in said pressure tank, and can be directed in the direction substantially along the direction in which the flow of the gas-dissolved liquid is caused to revolve within the pressure tank.

10. The gas dissolving apparatus as defined in Claim 1 or 2, wherein said pressure tank includes a pressure adjusting valve for adjusting the internal pressure within the pressure tank to any desired pressure level.

11. The gas dissolving apparatus as defined in Claim 10, wherein said pressure adjusting valve is provided for setting the internal pressure within the pressure tank to any value between above the atmospheric pressure and the atmospheric pressures of + 0.6 MPa.

12. The gas dissolving apparatus as defined in any one of Claim 1 or 2, further including a return pipe for returning the gas-dissolved liquid within the pressure tank toward the upstream side of said gas dissolving device, thereby allowing the gas-dissolved liquid to circulate between the gas dissolving device and the pressure tank.