

DESCRIPTION

CARBON DIOXIDE EMISSION REDUCTION METHOD AND CARBON DIOXIDE EMISSION REDUCTION SYSTEM

TECHNICAL FIELD

[0001]

The present invention relates to a carbon dioxide emission reduction method and a carbon dioxide emission reduction system, and more specifically to a carbon dioxide emission reduction method and a carbon dioxide emission reduction system capable of effectively reducing carbon dioxide contained in exhaust gas discharged from an internal combustion engine.

BACKGROUND ART

[0002]

In order to suppress global warming, reducing carbon dioxide (CO₂) emissions in construction work has become an important issue. Carbon dioxide emissions from internal combustion engines such as power generators and diesel engines used in constructions account for a relatively large proportion of carbon dioxide emissions in construction work. Therefore, it is important to reduce carbon dioxide contained in exhaust gas discharged from internal combustion engines in construction work.

[0003]

Heretofore, urea SCR systems have been used to purify exhaust gas from internal combustion engines of automobiles and ships. However, the urea SCR system is a system for purifying nitrogen oxides (NO_x) in exhaust gas and is not enabled to reduce carbon dioxide contained in exhaust gas (see, for example, Patent Document 1).

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0004]

Patent Document 1: Japanese patent application Kokai publication No. 2012-240446

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0005]

An object of the present invention is to provide a carbon dioxide emission reduction method and a carbon dioxide emission reduction system capable of effectively reducing carbon dioxide contained in exhaust gas discharged from an internal combustion engine.

MEANS FOR SOLVING THE PROBLEM

[0006]

In order to achieve the above object, a carbon dioxide emission reduction method of the present invention includes: reducing carbon dioxide contained in exhaust gas discharged from an internal combustion engine by injecting the exhaust gas into an alkaline solution stored in a storage tank, thereby bringing the alkaline solution and the exhaust gas into contact with each other inside the storage tank, and causing a neutralization reaction between the alkaline solution and carbon dioxide contained in the exhaust gas; and discharging the exhaust gas with the carbon dioxide reduced from an exhaust port of the storage tank.

[0007]

In order to achieve the above object, a carbon dioxide emission reduction system of the present invention includes: a storage tank configured to store an alkaline solution; and

an injection instrument configured to inject exhaust gas discharged from an internal combustion engine into the alkaline solution stored in the storage tank. The alkaline solution and the exhaust gas injected by the injection instrument are brought into contact with each other inside the storage tank to cause a neutralization reaction between the alkaline solution and carbon dioxide contained in the exhaust gas, thereby reducing the carbon dioxide contained in the exhaust gas. The exhaust gas with the carbon dioxide reduced is discharged from an exhaust port of the storage tank.

EFFECTS OF THE INVENTION

[0008]

According to the present invention, the carbon dioxide contained in the exhaust gas discharged from the internal combustion engine can be effectively reduced by injecting the exhaust gas discharged from the internal combustion engine into the alkaline solution stored in the storage tank and causing a neutralization reaction between the carbon dioxide contained in the exhaust and the alkaline solution inside the storage tank. Moreover, the alkaline solution used to reduce the carbon dioxide contained in the exhaust gas can be reduced in hydrogen ion concentration by causing the neutralization reaction with the carbon dioxide. Therefore, the alkaline solution can be also easily disposed of after use.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

[Fig. 1] Fig. 1 is an explanatory diagram schematically illustrating an embodiment of a carbon dioxide emission reduction system of the present invention.

[Fig. 2] Fig. 2 is an explanatory diagram schematically

illustrating a transverse cross-section of a storage tank in Fig. 1.

[Fig. 3] Fig. 3 is an explanatory diagram schematically illustrating multiple storage tanks connected in series and a notch tank, which are included in the carbon dioxide emission reduction system of the present invention.

[Fig. 4] Fig. 4 is an explanatory diagram schematically illustrating an exhaust supply line included in the carbon dioxide emission reduction system of the present invention.

[Fig. 5] Fig. 5 is an explanatory diagram schematically illustrating a solution supply line included in the carbon dioxide emission reduction system of the present invention.

[Fig. 6] Fig. 6 is a graph presenting an example of a transition in a hydrogen ion concentration in an alkaline solution and a transition in a cumulative absorption amount of carbon dioxide absorbed from exhaust gas in the carbon dioxide emission reduction system of the present invention.

[Fig. 7] Fig. 7 is an explanatory diagram schematically illustrating another embodiment of a carbon dioxide emission reduction system of the present invention.

[Fig. 8] Fig. 8 is an explanatory diagram schematically illustrating still another embodiment of a carbon dioxide emission reduction system of the present invention.

[Fig. 9] Fig. 9 is an explanatory diagram schematically illustrating a still further embodiment of a carbon dioxide emission reduction system of the present invention.

MODES FOR CARRYING OUT THE INVENTION

[0010]

Hereinafter, a carbon dioxide emission reduction method and a carbon dioxide emission reduction system of the present

invention will be described based on embodiments illustrated in the drawings.

[0011]

A carbon dioxide emission reduction method and a carbon dioxide emission reduction system 1 of the present invention illustrated in Figs. 1 to 5 reduce carbon dioxide (CO₂) contained in exhaust gas G discharged from an internal combustion engine 20. Examples of the internal combustion engine 20 include a power generator, a diesel engine, and so on. the carbon dioxide emission reduction system 1 of the present invention (hereinafter abbreviated as the reduction system 1) can be applied to the internal combustion engine 20 such as a power generator used in land-based construction work or a diesel engine equipped in construction machinery. This reduction system 1 can be also applied to the internal combustion engine 20 such as a power generator or a diesel engine equipped in a work vessel used in offshore construction work.

[0012]

As illustrated in Fig. 1, the reduction system 1 includes a storage tank 2 in which an alkaline solution A is stored, and an injection instrument 3 which injects exhaust gas G discharged from the internal combustion engine 20 into the alkaline solution A stored in the storage tank 2. This reduction system 1 is configured to reduce carbon dioxide contained in the exhaust gas G by bringing the alkaline solution A and the exhaust gas G injected by the injection instrument 3 into contact with each other inside the storage tank 2, thereby causing a neutralization reaction between the alkaline solution A and the carbon dioxide contained in the exhaust gas G. Then, the exhaust gas G with the carbon dioxide reduced is discharged from

an exhaust port 2c of the storage tank 2. In the drawings, flows of the exhaust gas G are schematically illustrated as open arrows and flows of the alkaline solution A are schematically illustrated as filled-in arrows.

[0013]

As the alkaline solution A, any of various solutions can be used as long as it is alkaline with a hydrogen ion concentration with a pH of higher than 7, and capable of undergoing a neutralization reaction with carbon dioxide. Specifically, for example, a calcium hydroxide solution, a sodium hydroxide solution, or the like can be used as the alkaline solution A. It is preferable to use an alkaline solution A having, for example, a hydrogen ion concentration with a pH of 8 or higher and 14 or lower, preferably a hydrogen ion concentration with a pH of 9 or higher and 14 or lower, and more preferably a hydrogen ion concentration with a pH of 10 or higher and 14 or lower. In this embodiment, an example is described in which the alkaline solution A (calcium hydroxide solution) is produced using recycled crushed stone R obtained by crushing concrete waste generated in demolition work or the like.

[0014]

As illustrated in Fig. 1, the storage tank 2 is an airtight, hollow container. The storage tank 2 in this embodiment includes a cylindrical portion having a circular cylindrical shape and extending in a vertical direction, and a diameter-reduced portion provided below the cylindrical portion and reduced in diameter toward the lower side in a tapered form. The shape of the storage tank 2 is not limited to the shape in this embodiment and, for example, a polygonal

cylindrical storage tank 2 may be used.

[0015]

An inflow port 2a through which the alkaline solution A flows is provided to a lower portion of the storage tank 2, and a connecting pipe 6 is connected to the inflow port 2a. A drain port 2d through which the alkaline solution A is discharged is provided to an upper portion of the storage tank 2, and a connecting pipe 6 is connected to the drain port 2d. The drain port 2d is located around a liquid level of the alkaline solution A stored in the storage tank 2. In this structure, the alkaline solution dA flows into the inside of the storage tank 2 from a solution supply line (to be described later) through the connecting pipe 6 connected to the inflow port 2a of the storage tank 2 (2X), and the alkaline solution A stored near the liquid level in the storage tank 2 flows out into the connecting pipe 6 connected to the drain port 2d.

[0016]

In this embodiment, as the injection instrument 3, an injection port 2b is provided at the lower portion of the storage tank 2, and a vent pipe 5 is inserted through the injection port 2b. An injector unit 4 is connected to a tip end of the vent pipe 5. The injector unit 4 is arranged at a lower portion inside the storage tank 2. An exhaust port 2c through which the exhaust gas G is discharged is provided at the upper portion of the storage tank 2, and a vent pipe 5 is connected to the exhaust port 2c. The exhaust port 2c is located above the liquid level of the alkaline solution A stored in the storage tank 2.

[0017]

In this structure, the exhaust gas G discharged from the internal combustion engine 20 is supplied to the injector unit

4 through an exhaust supply line (to be described later) and the vent pipe 5 inserted through the injection port 2b, and the supplied exhaust gas G is injected into the alkaline solution A by the injector unit 4. Then, the exhaust gas G injected from the injector unit 4 and passing through the alkaline solution A is discharged from the vent pipe 5 connected to the exhaust port 2c.

[0018]

As illustrated in Fig. 2, the injector unit 4 in this embodiment includes multiple ejection nozzles 4a and a branch pipe 4b. The branch pipe 4b is connected to the tip end of the vent pipe 5 inserted through the injection port 2b. The multiple ejection nozzles 4a are arranged on the branch pipe 4b. The exhaust gas G supplied from the vent pipe 5 to the branch pipe 4b is distributed by the branch pipe 4b to all the ejection nozzles 4a, and the exhaust gas G is ejected from all the ejection nozzles 4a. The injector unit 4 is configured to eject the exhaust gas G from all the ejection nozzles 4a, thereby generating swirling flows, in which numerous bubbles of the exhaust gas G spirally rise, in the alkaline solution A inside the storage tank 2. In Figs. 1 and 3, bubbles of the exhaust gas G ejected from one of the ejection nozzles 4a are schematically illustrated relatively large for illustrative purposes, but in reality, numerous fine bubbles of the exhaust gas G are ejected from all the ejection nozzles 4a, resulting in a state in which a very huge number of bubbles of the exhaust gas G are ejected into the alkaline solution A.

[0019]

More specifically, in the center in plan view, the branch pipe 4b in this embodiment includes a joint portion connected

to the tip end of the vent pipe 5. The branch pipe 4b further includes multiple distribution pipes radially branched out from the joint portion provided in the center, and an annular pipe which is located outside the distribution pipes and to which outer ends of the respective distribution pipes are connected. The multiple ejection nozzles 4a are arranged on the annular pipe at equal intervals in the circumferential direction. In this embodiment, each ejection nozzle 4a is installed in such an orientation as to eject the exhaust gas G in an obliquely-upward direction toward an inner surface of the storage tank 2. The number, layout, and ejection direction of the ejection nozzles 4a and the shape of the branch pipe 4b, which are included in the injector unit 4, are not limited to those in this embodiment and various other structures are possible.

[0020]

As illustrated in Fig. 1, a discharge pipe 11 from which a precipitate S generated by the neutralization reaction between the carbon dioxide contained in the exhaust gas G and the alkaline solution A is discharged is connected to the lower portion of the storage tank 2. The discharge pipe 11 is provided with an openable/closable discharge valve 12. In this embodiment, calcium carbonate generated by the neutralization reaction between the carbon dioxide contained in the exhaust gas G and the alkaline solution A (aqueous solution of calcium hydroxide) is precipitated as the precipitate S at the lower portion of the storage tank 2.

[0021]

The storage tank 2 is provided with a hydrogen ion concentration meter 13 configured to measure a hydrogen ion

concentration in the stored alkaline solution A, and a carbon dioxide concentration meter 14 configured to measure a carbon dioxide concentration in the exhaust gas G after the exhaust gas G passes through the alkaline solution A in the storage tank 2. In addition, the storage tank 2 is provided with a pressure meter 15 configured to measure a pressure of the exhaust gas G flowing in the vent pipe 5 connected to the exhaust port 2c of the storage tank 2. The hydrogen ion concentration meter 13, the carbon dioxide concentration meter 14, and the pressure meter 15 are each communicatively connected to a management apparatus 40 illustrated in Fig. 3. The management apparatus 40 is constituted by a computer. Measurement data measured by the hydrogen ion concentration meter 13, the carbon dioxide concentration meter 14, and the pressure meter 15 is transmitted to the management apparatus 40 as needed, and the transmitted measurement data is displayed on a monitor of the management apparatus 40.

[0022]

As illustrated in Fig. 3, in a structure of this embodiment, three storage tanks 2 (2X to 2Z) are connected in series via the vent pipes 5 through which the exhaust gas G flows and the connecting pipes 6 through which the alkaline solution A flows. The structures of the storage tanks 2X to 2Z and the structures of the injection instruments 3 provided in the respective storage tanks 2X to 2Z are the same. Each of the storage tanks 2X to 2Z is provided with the hydrogen ion concentration meter 13, the carbon dioxide concentration meter 14, and the pressure meter 15, which are each configured to transmit its measurement data to the management apparatus 40 as needed.

[0023]

A downstream end of the vent pipe 5 connected to the exhaust port 2c of the upstream storage tank 2X (on the internal combustion engine 20 side) is connected to the injector unit 4 provided in the downstream storage tank 2Y. A downstream end of the connecting pipe 6 connected to the drain port 2d of the upstream storage tank 2X is connected to the inflow port 2a of the downstream storage tank 2Y. A downstream end of the vent pipe 5 connected to the exhaust port 2c of the storage tank 2Y is connected to the injector unit 4 provided in the further downstream storage tank 2Z. A downstream end of the connecting pipe 6 connected to the drain port 2d of the storage tank 2Y is connected to the inflow port 2a of the downstream storage tank 2Z.

[0024]

An exhaust pipe 7 is connected to the exhaust port 2c of the most downstream storage tank 2Z. The exhaust gas G discharged from the exhaust port 2c of the storage tank 2Z is released, as treated exhaust gas GP with the carbon dioxide reduced, to the ambient atmosphere through the exhaust pipe 7. A connecting pipe 6 is connected to the drain port 2d of the most downstream storage tank 2Z, and a downstream end of that connecting pipe 6 is connected to an inflow port on an upstream side of a notch tank 17. The alkaline solution A that flows into the notch tank 17 is released as a neutralized treated solution AP from a drain pipe 9 connected to an outflow port on a downstream side of the notch tank 17.

[0025]

As illustrated in Fig. 4, in an exhaust supply line for supplying the exhaust gas G discharged from the internal combustion engines 20 to the injection instrument 3, a manifold

21 is connected to downstream sides of the internal combustion engines 20 via the vent pipes 5. The exhaust gas G discharged from the internal combustion engines 20 flows into the manifold 21 through the vent pipes 5. In a structure of this embodiment, multiple internal combustion engines 20 are connected to the manifold 21 via the respective vent pipes 5, and the exhaust gas G discharged from the multiple internal combustion engines 20 is collected in the manifold 21.

[0026]

A dust collecting device 22 is connected to a downstream side of the manifold 21 via a vent pipe 5. The dust collecting device 22 is a device for removing dust contained in the exhaust gas G. A pumping device 24 is connected to a downstream side of the dust collecting device 22 via a vent pipe 5. A heat removal tank 23 for removing heat from the exhaust gas G is provided between the dust collecting device 22 and the pumping device 24.

[0027]

The heat removal tank 23 stores cooling water CW, and a middle portion of the vent pipe 5 connecting the dust collecting device 22 and the pumping device 24 is submerged in the cooling water CW stored in the heat removal tank 23. A supply pipe for supplying new cooling water CW to the heat removal tank 23 and a drain pipe for discharging the cooling water CW stored in the heat removal tank 23 are connected to the heat removal tank 23. The heat removal tank 23 is configured to keep the temperature of the cooling water CW stored in the heat removal tank 23 at or below a predetermined temperature by being replenished with the cooling water CW.

[0028]

The exhaust gas G discharged from the dust collecting device 22 is subjected to heat removal in the heat removal tank 23, and then is sucked into the pumping device 24 through the vent pipe 5. The pumping device 24 is a device for pumping the exhaust gas G to the injection instrument 3, and includes a gas pump such as a vacuum pump. The injector unit 4 is connected to a downstream side of the pumping device 24 via the vent pipe 5. In this structure, the exhaust gas G pumped by the pumping device 24 is supplied to the injector unit 4.

[0029]

As illustrated in Fig. 5, an upstream side of the solution supply line for supplying the alkaline solution A to the storage tank 2 is provided with a solution production tank 30 which produces the alkaline solution A. In this embodiment, the solution production tank 30 is configured to be supplied with water W and receive recycled crushed stone R inputted at predetermined time intervals. The solution production tank 30 is provided with a stirrer 31. An upper portion of the solution production tank 30 is provided with an outflow port from which the produced alkaline solution A flows out. A lower portion of the solution production tank 30 is provided with a discharge port from which treated recycled crushed stone RP neutralized by use to produce the alkaline solution A is discharged.

[0030]

A raw water level adjustment tank 32 which temporarily stores the alkaline solution A produced in the solution production tank 30 is provided downstream of the solution production tank 30. The outflow port of the solution production tank 30 is connected to the raw water level adjustment tank 32 via a connecting pipe 6, and the alkaline solution A produced

in the solution production tank 30 flows into the raw water level adjustment tank 32 through the connecting pipe 6.

[0031]

The raw water level adjustment tank 32 is provided with a hydrogen ion concentration meter 13 and measurement data of a hydrogen ion concentration measured by the hydrogen ion concentration meter 13 is transmitted to the management apparatus 40 as needed. An upper portion of the raw water level adjustment tank 32 is provided with an outflow port from which the alkaline solution A flows out. The storage tank 2X is provided downstream of the raw water level adjustment tank 32, and the outflow port of the raw water level adjustment tank 32 and the inflow port 2a of the storage tank 2X are connected to each other via the connecting pipe 6. The outflow port of the raw water level adjustment tank 32 is arranged at a position higher than the inflow port 2a of the storage tank 2X.

[0032]

The liquid level of the alkaline solution A stored in the raw water level adjustment tank 32, the liquid levels of the alkaline solutions A stored in the respective storage tanks 2X to 2Z, and the liquid level of the alkaline solution A stored in the notch tank 17 are set to the same height.

[0033]

Next, a carbon dioxide emission reduction method using this reduction system 1 will be described.

[0034]

As illustrated in Fig. 5, in the solution supply line, the solution production tank 30 is supplied with the water W and receives the recycled crushed stone R inputted. The recycled crushed stone R is built up on the lower portion of

the solution production tank 30. As the water W supplied to the solution production tank 30, seawater, river water, groundwater, tap water, or the like at a construction site may be used. The stirrer 31 stirs the water W stored in the solution production tank 30, thereby dissolving calcium hydroxide contained in the recycled crushed stone R into the water W, and producing the alkaline solution A (calcium hydroxide solution). As a result of dissolution of the calcium hydroxide contained in the recycled crushed stone R into the water W, the recycled crushed stone R built up on the lower portion of the solution production tank 30 is neutralized. The treated recycled crushed stone RP neutralized by use to produce the alkaline solution A is released from the discharge port provided at the lower portion of the solution production tank 30 and then is collected.

[0035]

The alkaline solution A produced in the solution production tank 30 passes through the connecting pipe 6 connected to the outflow port of the solution production tank 30, flows into the raw water level adjustment tank 32, and is stored in the raw water level adjustment tank 32. In the raw water level adjustment tank 32, the hydrogen ion concentration meter 13 measures the hydrogen ion concentration in the stored alkaline solution A, and an input amount of recycled crushed stone R inputted to the solution production tank 30 is adjusted based on the measurement result. The input amount of recycled crushed stone R inputted to the solution production tank 30 may be adjusted so that the hydrogen ion concentration in the alkaline solution A stored in the raw water level adjustment tank 32 may have, for example, a pH of 8 or higher and 14 or

lower, preferably a pH of 9 or higher and 14 or lower, and more preferably a pH of 10 or higher and 14 or lower. The alkaline solution A stored in the raw water level adjustment tank 32 passes through the connecting pipe 6 connected to the outflow port of the raw water level adjustment tank 32, and flows into the storage tank 2X from the inflow port 2a of the storage tank 2X. In the solution production tank 30, a flow rate of the alkaline solution A supplied to the raw water level adjustment tank 32 is adjusted so that the liquid level position of the alkaline solution A stored in the raw water level adjustment tank 32 can be kept at a preset certain height.

[0036]

As illustrated in Fig. 4, in the exhaust supply line, when the target internal combustion engines 20 are operating, the exhaust gas G discharged from all the internal combustion engines 20 flows into the manifold 21 through the vent pipes 5. The exhaust gas G collected in the manifold 21 flows into the dust collecting device 22 through the vent pipe 5, and the dust collecting device 22 removes dust contained in the exhaust gas G.

[0037]

The exhaust gas G from which the dust is removed by the dust collecting device 22 is subjected to the heat removal by passing through the vent pipe 5 submerged in the cooling water CW stored in the heat removal tank 23, and the heat-removed exhaust gas G is sucked into the pumping device 24. As the cooling water CW for the heat removal tank 23, seawater, river water, groundwater, tap water, industrial water, or the like at a construction site may be used. The exhaust gas G sucked into the pumping device 24 is pumped by the pumping device 24

to the injection instrument 3 provided in the storage tank 2X.
[0038]

As illustrated in Figs. 1 to 3, in the storage tank 2X, the exhaust gas G pumped by the pumping device 24 is injected by the injection instrument 3 into the alkaline solution A stored in the storage tank 2X. In this embodiment, the exhaust gas G pumped by the pumping device 24 flows into the branch pipe 4b of the injector unit 4, and the exhaust gas G flowing in the branch pipe 4b is ejected from all the ejection nozzles 4a. As the exhaust gas G is ejected from all the ejection nozzles 4a, swirling flows in which numerous bubbles of the exhaust gas G spirally rise are generated in the alkaline solution A inside the storage tank 2X.

[0039]

While the bubbles of the exhaust gas G are spirally rising in the alkaline solution A, the alkaline solution A and the exhaust gas G come into contact with each other and cause a neutralization reaction between the alkaline solution A and the carbon dioxide contained in the exhaust gas G. Specifically, when a calcium hydroxide solution is used as the alkaline solution A, carbon dioxide (CO_2) contained in the exhaust gas G chemically reacts with water (H_2O) contained in the calcium hydroxide solution to generate carbonic acid (H_2CO_3) ($\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$). Then, the generated carbonic acid (H_2CO_3) chemically reacts with calcium hydroxide ($\text{Ca}(\text{OH})_2$) contained in the calcium hydroxide solution to generate calcium carbonate (CaCO_3) ($\text{Ca}(\text{OH})_2 + \text{H}_2\text{CO}_3 \rightarrow \text{CaCO}_3 + 2\text{H}_2\text{O}$).

[0040]

This neutralization reaction between the carbon dioxide contained in the exhaust gas G and the alkaline solution A

reduces the carbon dioxide contained in the exhaust gas G. The exhaust gas G with the carbon dioxide reduced by passing through the alkaline solution A accumulates in the upper portion of the inside of the storage tank 2X. As illustrated in Fig. 3, the exhaust gas G accumulated in the upper portion of the inside of the storage tank 2X is caused, as needed, to flow into the injection instrument 3 provided in the downstream storage tank 2Y through the vent pipe 5 connected to the exhaust port 2c of the storage tank 2X.

[0041]

As a new alkaline solution A is continuously supplied to the inflow port 2a of the storage tank 2X by the solution supply line, the alkaline solution A with the hydrogen ion concentration reduced by the neutralization reaction with the carbon dioxide contained in the exhaust gas G rises within the storage tank 2X together with the exhaust gas G. The alkaline solution A rising up to the upper portion of the storage tank 2X passes through the connecting pipe 6 connected to the drain port 2d and flows into the downstream storage tank 2Y from the inflow port 2a provided at the lower portion of the storage tank 2Y.

[0042]

The precipitate S (calcium carbonate) generated by the neutralization reaction is settled down at the lower portion of the storage tank 2X. As the discharge valve 12 of the discharge pipe 11 connected to the storage tank 2X is opened as needed, the precipitate S accumulated on the lower portion of the storage tank 2X is discharged to the outside of the storage tank 2X and then collected.

[0043]

The alkaline solution A with the hydrogen ion concentration reduced by the neutralization reaction in the upstream storage tank 2X flows into the downstream storage tank 2Y. The exhaust gas G discharged from the exhaust port 2c of the upstream storage tank 2X flows into the branch pipe 4b of the injector unit 4 provided in the downstream storage tank 2Y, and the exhaust gas G flowing in the branch pipe 4b is ejected from all the ejection nozzles 4a. As in the upstream storage tank 2X, the ejection of exhaust gas G from all the ejection nozzles 4a generates swirling flows, in which numerous bubbles of the exhaust gas G spirally rise, in the alkaline solution A inside the downstream storage tank 2Y.

[0044]

While the bubbles of the exhaust gas G are spirally rising in the alkaline solution A, the alkaline solution A and the exhaust gas G come into contact with each other and cause a neutralization reaction between the alkaline solution A and the carbon dioxide contained in the exhaust gas G. This neutralization reaction further reduces the carbon dioxide contained in the exhaust gas G and further reduces the hydrogen ion concentration in the alkaline solution A. The exhaust gas G with the carbon dioxide further reduced by passing through the alkaline solution A accumulates in the upper portion of the inside of the storage tank 2Y. The exhaust gas G accumulated in the upper portion of the inside of the storage tank 2Y is then caused, as needed, to flow into the injection instrument 3 provided in the further downstream storage tank 2Z through the vent pipe 5 connected to the exhaust port 2c of the storage tank 2Y.

[0045]

As the alkaline solution A continuously flows into the inflow port 2a of the storage tank 2Y, the alkaline solution A with the hydrogen ion concentration reduced by the neutralization reaction with the carbon dioxide contained in the exhaust gas G rises within the storage tank 2Y together with the exhaust gas G. The alkaline solution A rising up to the upper portion of the storage tank 2Y passes through the connecting pipe 6 connected to the drain port 2d and flows into the further downstream storage tank 2Z from the inflow port 2a provided at the lower portion of the storage tank 2Z.

[0046]

The precipitate S generated by the neutralization reaction is settled down at the lower portion of the storage tank 2Y. As the discharge valve 12 of the discharge pipe 11 connected to the storage tank 2Y is opened as needed, the precipitate S accumulated on the lower portion of the storage tank 2Y is discharged to the outside of the storage tank 2Y and then collected.

[0047]

The alkaline solution A with the hydrogen ion concentration further reduced due to the neutralization reaction in the storage tank 2Y flows into and is stored in the most downstream storage tank 2Z. The exhaust gas G discharged from the exhaust port 2c of the storage tank 2Y flows into the branch pipe 4b of the injector unit 4 provided in the storage tank 2Z, and the exhaust gas G flowing into the branch pipe 4b is ejected from the ejection nozzles 4a. As in the storage tank 2Y, inside the storage tank 2Z, swirling flows in which numerous bubbles of the exhaust gas G spirally rise are generated in the alkaline solution A, which causes a neutralization reaction

between the alkaline solution A and the carbon dioxide contained in the exhaust gas G.

[0048]

This neutralization reaction further reduces the carbon dioxide contained in the exhaust gas G and further reduces the hydrogen ion concentration in the alkaline solution A. The exhaust gas G with the carbon dioxide further reduced by passing through the alkaline solution A accumulates in the upper portion of the inside of the storage tank 2Z. The exhaust gas G accumulated in the upper portion of the inside of the storage tank 2Z is then discharged from the exhaust port 2c of the storage tank 2Z, and released as the treated exhaust gas GP with the carbon dioxide reduced into the ambient atmosphere through the exhaust pipe 7.

[0049]

As the alkaline solution A continuously flows into the inflow port 2a of the storage tank 2Z, the alkaline solution A with the hydrogen ion concentration reduced by the neutralization reaction with the carbon dioxide contained in the exhaust gas G rises within the storage tank 2Z together with the exhaust gas G. The alkaline solution A rising up to the upper portion of the storage tank 2Z passes through the connecting pipe 6 connected to the drain port 2d and flows into the notch tank 17. The alkaline solution A flowing into the notch tank 17 is subjected to removal of remaining precipitate in the notch tank 17 and then is discharged as a neutralized treated solution AP to a public water body, sewer, or the like.

[0050]

The precipitate S generated by the neutralization reaction is settled down at the lower portion of the storage

tank 2Z. As the discharge valve 12 of the discharge pipe 11 connected to the storage tank 2Z is opened as needed, the precipitate S accumulated on the lower portion of the storage tank 2Z is discharged to the outside of the storage tank 2Z and then collected.

[0051]

The measurement data measured by the hydrogen ion concentration meter 13, the carbon dioxide concentration meter 14, and the pressure meter 15 is transmitted to the management apparatus 40 as needed, and the transmitted measurement data is displayed on the monitor of the management apparatus 40. An administrator of the reduction system 1 can monitor the operating status of the reduction system 1 by checking the measurement data displayed on the monitor of the management apparatus 40.

[0052]

In a graph presented as an example in Fig. 6, a left vertical axis represents a hydrogen ion concentration (pH) of the alkaline solution A and a right vertical axis represents a cumulative absorption amount of carbon dioxide contained in the exhaust gas G. On a horizontal axis of the graph, M0 indicates the hydrogen ion concentration in the alkaline solution A stored in the raw water level adjustment tank 32. M1 indicates the hydrogen ion concentration in the alkaline solution A stored in the storage tank 2X and the cumulative absorption amount of carbon dioxide absorbed in the storage tank 2X. M2 indicates the hydrogen ion concentration in the alkaline solution A stored in the storage tank 2Y and the cumulative absorption amount of carbon dioxide absorbed in the storage tanks 2X and 2Y. M3 indicates the hydrogen ion concentration

in the alkaline solution A stored in the storage tank 2Z and the cumulative absorption amount of carbon dioxide absorbed in the storage tanks 2X to 2Z. In Fig. 6, a transition in the hydrogen ion concentration in the alkaline solution A is presented by a broken line and a transition in the cumulative absorption amount of carbon dioxide is presented by a solid line.

[0053]

As in the graph presented in Fig. 6, as the neutralization reaction between the alkaline solution A and the carbon dioxide contained in the exhaust gas G is caused in each of the storage tanks 2X to 2Z, the cumulative absorption amount of carbon dioxide contained in the exhaust gas G increases and the hydrogen ion concentration in the alkaline solution A reduces. In the upstream storage tank 2X, the hydrogen ion concentration in the alkaline solution A is relatively high and the proportion of carbon dioxide contained in the exhaust gas is also relatively high. For this reason, the neutralization reaction between the alkaline solution A and the carbon dioxide contained in the exhaust gas G proceeds relatively actively, resulting in a relatively large amount of carbon dioxide absorbed from the exhaust gas G. In addition, the hydrogen ion concentration in the alkaline solution A also reduces relatively significantly.

[0054]

In the downstream storage tanks 2Y and 2Z, since the proportion of carbon dioxide contained in the exhaust gas G and the hydrogen ion concentration in the alkaline solution A gradually reduce, the amount of carbon dioxide absorbed from the exhaust gas G gradually reduces compared to the upstream

storage tank 2X. Despite such reduction, at the stage where the exhaust gas G is finally released as the treated exhaust gas GP, most of the carbon dioxide contained in the exhaust gas G is already absorbed by the neutralization reaction. Also, at the stage where the alkaline solution A is finally disposed of as the treated solution AP, the neutralization process is completed and the hydrogen ion concentration is close to a neutral level.

[0055]

As described above, according to the present invention, the carbon dioxide contained in the exhaust gas G discharged from the internal combustion engines 20 can be effectively reduced by injecting the exhaust gas G discharged from the internal combustion engines 20 into the alkaline solution A stored in the storage tank 2 and causing a neutralization reaction between the carbon dioxide contained in the exhaust gas G and the alkaline solution A inside the storage tank 2. This contributes to reducing the emissions of carbon dioxide, which is a greenhouse gas acting as a factor for global warming. Moreover, the alkaline solution A used to reduce the carbon dioxide contained in the exhaust gas G is subjected to the neutralization reaction with the carbon dioxide, so that the hydrogen ion concentration is reduced. Therefore, the alkaline solution A can be also easily disposed of after use.

[0056]

Construction work generates a large amount of alkaline wastewater with a relatively high hydrogen ion concentration. For example, demolition work generates a large amount of concrete waste, and this concrete waste is crushed to obtain recycled crushed stone, which is also alkaline like concrete.

Therefore, a large amount of alkaline wastewater is generated in producing neutralized recycled crushed stone. In addition, in construction work, cleaning operations at manufacturing plants and transportation equipment for cement, mortar, and concrete also generate a large amount of alkaline wastewater (so-called cleaning water or washing water).

[0057]

When the alkaline wastewater generated during construction work is disposed of, it is necessary to perform a neutralization process to adjust the hydrogen ion concentration in the alkaline wastewater to a pH of 5.8 to 8.6 or less. In general, the neutralization process of alkaline wastewater is performed by adding an acidic neutralizing agent. By utilizing alkaline wastewater generated during construction work as the alkaline solution A, this reduction system 1 can perform the neutralization process of the alkaline wastewater concurrently with reducing the carbon dioxide contained in the exhaust gas G from the internal combustion engines 20.

[0058]

Carbon dioxide emissions from internal combustion engines 20 such as power generators and diesel engines account for a relatively large proportion of carbon dioxide emissions in construction work, and the construction work generates a large amount of alkaline wastewater. Therefore, the reduction system 1 of the present invention, which can effectively utilize the alkaline wastewater generated in construction work to reduce carbon dioxide emissions due to the exhaust gas G from the internal combustion engines 20, is extremely beneficial for those skilled in the art of construction work.

[0059]

In particular, the structure to generate the alkaline solution A using the recycled crushed stone R obtained by crushing concrete waste and store the produced alkaline solution A in the storage tank 2 as in this embodiment makes it possible to produce neutralized treated recycled crushed stone RP while effectively utilizing the alkaline recycled crushed stone R to generate the alkaline solution A. Applications of alkaline recycled crushed stone R are limited because the alkaline recycled crushed stone R used as it is as a paving material or the like may possibly increase the hydrogen ion concentration in surrounding soil. In contrast to this, the neutralized treated recycled crushed stone RP can be used in a wider range of applications. This enables more effective use of concrete waste. Furthermore, when the alkaline wastewater generated during the neutralization of the recycled crushed stone R is used as the alkaline solution A, it is possible to perform the neutralization process of the alkaline wastewater concurrently with reducing the carbon dioxide emissions due to the exhaust gas G from the internal combustion engines 20. This is therefore extremely beneficial for those skilled in the art of construction work.

[0060]

Also in the case where alkaline wastewater generated in cleaning operations or the like at manufacturing plants and transport facilities for cement, mortar, and concrete is used as the alkaline solution A, by effectively utilizing the alkaline wastewater as the alkaline solution A, it is possible to perform the neutralization process of the alkaline wastewater concurrently with reducing the carbon dioxide emissions due to the exhaust gas G from the internal combustion

engines 20. In the case where the alkaline wastewater generated in cleaning operations is used, it is preferable to perform a coagulation process by previously mixing and stirring a coagulant into the alkaline wastewater and removing coagulated solids, and then supply the alkaline wastewater after the coagulation process as the alkaline solution A to the raw water level adjustment tank 32 and the storage tanks 2.

[0061]

Construction sites often have excess cement and lime. Therefore, the reduction system 1 may be configured to use such excess cement and lime to produce the alkaline solution A. Alternatively, the reduction system 1 may be also configured to produce the alkaline solution A using slag generated during metal smelting.

[0062]

In this way, the reduction system 1 of the present invention not only reduces the carbon dioxide emissions due to the exhaust gas G from the internal combustion engines 20, but also functions as a system for performing a neutralization process on alkaline wastewater and alkaline waste materials generated in construction work. Therefore, this reduction system 1 is very beneficial for those skilled in the art of construction work.

[0063]

This embodiment employs the structure in which the multiple ejection nozzles 4a are installed in the lower portion of the inside of the storage tank 2, and the exhaust gas G is ejected from all the ejection nozzles 4a to generate the swirling flows in which numerous bubbles of the exhaust gas G rise spirally in the alkaline solution A. With this structure,

the movement distance and time required for the bubbles of the exhaust gas G to pass through the alkaline solution A can be secured longer than in the case where the bubbles of the exhaust gas G are caused to rise along a straight line in the alkaline solution A. Therefore, the more effective neutralization reaction between the carbon dioxide contained in the exhaust gas G and the alkaline solution A can be achieved in the storage tank 2.

[0064]

Meanwhile, the longer a vertical separation distance between the position where the exhaust gas G is ejected by the injection instrument 3 and the liquid level of the alkaline solution A stored in the storage tank 2, the longer the movement distance and the time required for the bubbles of the exhaust gas G to pass through the alkaline solution A can be secured, but, on the other hand, the higher the pumping pressure for injecting the exhaust gas G into the alkaline solution A is required. The pumping device 24 will consume more power as the pumping pressure for injecting the exhaust gas G becomes higher, resulting in more carbon dioxide emissions by the power generator or the like that supplies power to the pumping device 24.

[0065]

In this regard, the structure to generate the swirling flows in which numerous bubbles of the exhaust gas G spirally rise in the alkaline solution A, as in this embodiment, makes it possible to relatively shorten the vertical separation distance between the position where the exhaust gas G is ejected by the injection instrument 3 and the liquid level of the alkaline solution A, while securing a long movement distance

and a long time required for the bubbles of the exhaust gas G to pass through the alkaline solution A. Accordingly, it is possible to set a relatively low pumping pressure for injecting the exhaust gas G by the pumping device 24, which is also advantageous for reducing the power consumption of the pumping device 24. This is therefore more advantageous for reducing carbon dioxide emissions.

[0066]

As in this embodiment, the structure in which the multiple storage tanks 2 (2X to 2Z) are connected in series via the vent pipes 5 through which the exhaust gas G flows and the connecting pipes 6 through which the alkaline solution A flows makes it possible to cause the more effective neutralization reaction between the carbon dioxide contained in the exhaust gas G and the alkaline solution A by passing the exhaust gas G through the alkaline solution A stored in the multiple storage tanks 2. This is therefore more advantageous for reducing the carbon dioxide contained in the exhaust gas G discharged from the internal combustion engines 20. In addition, since the alkaline solution A is caused to flow together with the exhaust gas G from the upstream storage tank 2 to the downstream storage tank 2, the alkaline solution A can be utilized more effectively. Furthermore, causing the alkaline solution A to undergo the neutralization reaction with the carbon dioxide contained in the exhaust gas G in each of the storage tanks 2 is also advantageous for advancing the neutralization process of the alkaline solution A.

[0067]

As in this embodiment, the structure in which the liquid level positions of the alkaline solutions A stored in the raw

water level adjustment tank 32 and the storage tanks 2 (2X to 2Z) are set to the same height makes it possible to cause the alkaline solution A to naturally flow from the raw water level adjustment tank 32 to the most downstream storage tank 2Z by utilizing the siphon principle, without providing any power sources such as pumps to the connecting pipe 6 connecting the raw water level adjustment tank 32 and the storage tank 2 and to the connecting pipes 6 connecting the storage tanks 2 to each other. This is therefore even more advantageous for reducing carbon dioxide emissions. Furthermore, despite the simple structure, it is possible to maintain the constant amounts of the alkaline solutions A stored in the respective storage tanks 2X to 2Z.

[0068]

The reduction system 1 of the present invention may also be configured as illustrated in Fig. 7.

[0069]

In this embodiment, individual exhaust pipes 7 are connected to a midway point of the vent pipe 5 connecting the storage tank 2X and the storage tank 2Y, and to a midway point of the vent pipe 5 connecting the storage tank 2Y and the storage tank 2Z. Each of the exhaust pipes 7 is provided with an openable/closeable exhaust valve 8. In addition, individual drain pipes 9 are connected to a midway point of the connecting pipe 6 connecting the storage tank 2X and the storage tank 2Y, and to a midway point of the connecting pipe 6 connecting the storage tank 2Y and the storage tank 2Z. Each of the drain pipes 9 is provided with an openable/closeable drain valve 10. Moreover, each of the storage tanks 2X and 2Y is provided with a control device 16. The control device 16 is constituted by,

for example, a computer.

[0070]

The hydrogen ion concentration meter 13 and the carbon dioxide concentration meter 14 provided to the same storage tank 2 are both communicatively connected to the control device 16 provided to the same storage tank 2. With this structure, the measurement data measured by the hydrogen ion concentration meter 13 and the carbon dioxide concentration meter 14 are inputted to the control device 16 as needed. This embodiment employs the structure in which operations of opening and closing each of the exhaust valves 8 and the drain valves 10 are automatically controlled by the control device 16 provided in the storage tank 2 upstream of the valve concerned. The other structure is the same as the structure of the reduction system 1 in the embodiment illustrated in Figs. 1 to 5.

[0071]

In the structure of this embodiment, the hydrogen ion concentration in the alkaline solution A stored in each of the storage tanks 2 is measured by the hydrogen ion concentration meter 13, and the alkaline solution A whose hydrogen ion concentration is reduced to a preset threshold or lower is not allowed to flow into the downstream storage tank 2, but is disposed of as the treated solution AP. The aforementioned threshold for the hydrogen ion concentration in the alkaline solution A is set to, for example, about a pH of 7.0 to 8.6.

[0072]

Specifically, for example, when the hydrogen ion concentration in the alkaline solution A measured by the hydrogen ion concentration meter 13 provided in the storage tank 2X is higher than the preset threshold, the control device 16

provided in the storage tank 2X performs control to close the drain valve 10 provided between the storage tank 2X and the downstream storage tank 2Y. Thus, the alkaline solution A flowing into the connecting pipe 6 from the drain port 2d of the storage tank 2X flows straight into the downstream storage tank 2Y through the connecting pipe 6.

[0073]

On the other hand, when the hydrogen ion concentration in the alkaline solution A measured by the hydrogen ion concentration meter 13 provided in the storage tank 2X is equal to or lower than the preset threshold, the control device 16 provided in the storage tank 2X performs control to open the drain valve 10 provided between the storage tank 2X and the downstream storage tank 2Y. Thus, the alkaline solution A flowing into the connecting pipe 6 from the drain port 2d of the storage tank 2X flows into the drain pipe 9 from the midway point of the connecting pipe 6 and the alkaline solution A, which flows into the drain pipe 9 and which is neutralized so that the hydrogen ion concentration is equal to or lower than the threshold, is released to a sewer or the like as the treated solution AP.

[0074]

When the alkaline solution A is released from the drain pipe 9 with the drain valve 10 opened, the flow speed of the alkaline solution A stored in the storage tank 2 downstream of the drain pipe 9 temporarily decreases. However, as the alkaline solution A is continuously supplied from the solution production tank 30, the liquid level positions of the alkaline solutions A stored in the raw water level adjustment tank 32 and the storage tanks 2X to 2Z are maintained at the same height.

[0075]

With this structure, the alkaline solution A, whose hydrogen ion concentration is equal to or lower than the preset threshold and whose carbon dioxide absorption rate is reduced, is not allowed to flow into the downstream storage tank 2, but is disposed of as the treated solution AP. Therefore, even without finely adjusting the hydrogen ion concentration in the alkaline solution A generated in the solution production tank 30, it is possible to reduce variations in the hydrogen ion concentration in the alkaline solution A stored in each of the storage tanks 2, and also reduce variations in the amount of the carbon dioxide absorbed in each of the storage tanks 2. Despite the simple control, this is therefore more advantageous for stably reducing the carbon dioxide contained in the exhaust gas G.

[0076]

In the structure of this embodiment, the carbon dioxide concentration in the exhaust gas G after the exhaust gas G passes through the alkaline solution A in each of the storage tanks 2 is measured by the carbon dioxide concentration meter 14, and the exhaust gas G whose carbon dioxide concentration is equal to or lower than the preset reference value is not injected into the alkaline solution A stored in the downstream storage tank 2, but is disposed of as the treated exhaust gas GP. The aforementioned reference value for the carbon dioxide concentration in the exhaust gas G is set to, for example, about 5000 ppm.

[0077]

Specifically, for example, when the carbon dioxide concentration in the exhaust gas G measured by the carbon

dioxide concentration meter 14 provided in the storage tank 2X is higher than the preset reference value, the control device 16 provided in the storage tank 2X performs control to close the exhaust valve 8 provided between the storage tank 2X and the downstream storage tank 2Y. Thus, the exhaust gas G flowing into the vent pipe 5 from the exhaust port 2c of the storage tank 2X flows straight into the injection instrument 3 provided in the downstream storage tank 2Y through the vent pipe 5.

[0078]

On the other hand, when the carbon dioxide concentration in the exhaust gas G measured by the carbon dioxide concentration meter 14 provided in the storage tank 2X is equal to or lower than the preset reference value, the control device 16 provided in the storage tank 2X performs control to open the exhaust valve 8 provided between the storage tank 2X and the downstream storage tank 2Y. Thus, the exhaust gas G, which flows into the vent pipe 5 from the exhaust port 2c of the storage tank 2X and whose carbon dioxide concentration is equal to or lower than the preset reference value, flows into the exhaust pipe 7 from the midway point of the vent pipe 5 and is released as the treated exhaust gas GP to the ambient atmosphere.

[0079]

With this structure, the exhaust gas G which has a carbon dioxide concentration equal to or lower than the preset reference value and has almost no reactivity in neutralization with the alkaline solution A is not injected into the alkaline solution A stored in the downstream storage tank 2, but is disposed of as the treated exhaust gas GP. This makes it possible to reduce variations in the carbon dioxide concentration in the exhaust gas G injected into the alkaline

solution A stored in each of the storage tanks 2. This also makes it possible to reduce variations in the hydrogen ion concentration in the alkaline solution A stored in each of the storage tanks 2. Therefore, despite the simple control, this is more advantageous for stably reducing the carbon dioxide contained in the exhaust gas G and stably neutralizing the alkaline solution A.

[0080]

The reduction system 1 of the present invention may be configured as illustrated in Fig. 8.

[0081]

This embodiment employs a structure in which a protrusion 2e is provided on an inner surface of the storage tank 2, and the protrusion 2e lowers the rising speed of bubbles of the exhaust gas G rising in the alkaline solution A. In other words, as the protrusion 2e to act as an obstacle to rising bubbles of the exhaust gas G is provided on the inner surface of the storage tank 2, a time for which the bubbles of the exhaust gas G stay in the alkaline solution A is increased. In this embodiment, the protrusion 2e extending in a spiral shape is provided on the inner surface of the storage tank 2, and the protrusion 2e guides the swirling flows in which numerous bubbles of the exhaust gas G generated by the injection instrument 3 spirally rise.

[0082]

The other structure is the same as the structure of the reduction system 1 in the embodiment illustrated in Figs. 1 to 5. The protrusion 2e is not limited to the spiral structure as in this embodiment, but may have any of various other structures as long as the structure can lower the rising speed

of the bubbles of the exhaust gas G rising in the alkaline solution A.

[0083]

With the protrusion 2e provided on the inner surface of the storage tank 2 as described above, the time for which the bubbles of the exhaust gas G injected into the alkaline solution A from the injection instrument 3 are in contact with the alkaline solution A can be made longer, which makes it possible to cause the more effective neutralization reaction between the carbon dioxide contained in the exhaust gas G and the alkaline solution A in the storage tank 2. Therefore, despite the simple structure, this is even more advantageous for reducing the carbon dioxide contained in the exhaust gas G.

[0084]

As in this embodiment, when the protrusion 2e is configured to guide the swirling flows in which the numerous bubbles of the exhaust gas G generated by the injection instrument 3 spirally rise, the protrusion 2e makes the swirling flows more stable, which is more advantageous for securing a long distance and a long required time for the movement of the bubbles of the exhaust gas G passing through the alkaline solution A. This makes it possible to more effectively cause the neutralization reaction between the carbon dioxide contained in the exhaust gas G and the alkaline solution A in the storage tank 2, which is even more advantageous for reducing the carbon dioxide contained in the exhaust gas G.

[0085]

The reduction system 1 of the present invention may be configured as illustrated in Fig. 9.

[0086]

In this embodiment, a structure of the injection instrument 3 is different. The other structure is the same as the structure of the reduction system 1 in the embodiment illustrated in Figs. 1 to 5. In this embodiment, the injection instrument 3 includes multiple ejection nozzles 4a inserted through a side wall of the storage tank 2 in lateral directions. Four injection ports 2b are provided in the side wall of the storage tank 2 at equal intervals in the circumferential direction, and the ejection nozzles 4a are inserted through the respective injection ports 2b. In this structure, each of the ejection nozzles 4a ejects the exhaust gas G along the inner surface of the storage tank 2 in the lateral direction, thereby generating swirling flows in which numerous bubbles of the exhaust gas G rise spirally in the alkaline solution A inside the storage tank 2.

[0087]

Also in the case where the injection instrument 3 configured as in this embodiment is used, it is possible to achieve substantially the same effects as in the case where the injection instrument 3 in the embodiment illustrated in Figs. 1 to 5 is used. As described above, the structure of the injection instrument 3 to generate the swirling flows in which numerous bubbles of the exhaust gas G rise spirally in the alkaline solution A is not limited to the structure of the injection instrument 3 in the embodiment illustrated in Fig. 1 to 5 but may be any of various other structures. For example, the injection instrument 3 may be provided with a porous filter having numerous through-holes in the lower portion of the inside of the storage tank 2 and configured to generate numerous bubbles of the exhaust gas G in the alkaline solution A by causing

the exhaust gas G ejected from the ejection nozzles 4a to pass through the porous filter. The use of the porous filter enables efficient formation of numerous bubbles of the exhaust gas G. [0088]

The reduction system 1 of the present invention is not limited to the embodiments illustrated above, but may have any of various other structures. The manifold 21, the dust collecting device 22, and the heat removal tank 23 included in the exhaust supply line are not essential components and may be each optionally provided as needed. For example, for a reduction system 1 configured to reduce carbon dioxide in exhaust gas G from a single internal combustion engine 20, the exhaust supply line does not have to be provided with the manifold 21. For example, the exhaust supply line may be configured such that the exhaust port of the internal combustion engine 20 and the pumping device 24 are directly connected to each other with the vent pipe 5. Moreover, for example, the exhaust supply line may be configured such that a system for purifying the exhaust gas G from the internal combustion engine 20 (for example, a urea SCR system or the like) is provided between the exhaust port of the internal combustion engine 20 and the injection instrument 3.

[0089]

The solution production tank 30, the stirrer 31, and the raw water level adjustment tank 32 included in the solution supply line are not essential components and may be each optionally provided as needed. The solution supply line may have any structure as long as it can supply the alkaline solution A to the storage tanks 2, and may have any of various structures other than those illustrated above. For example, the solution

supply line may be configured such that alkaline wastewater generated during construction work or pre-produced alkaline solution A is directly introduced into the storage tank 2 (2X). Although the above description illustrates the case in which the three storage tanks 2X to 2Z are connected in series, the number of storage tanks 2 connected is not particularly limited. For example, a structure may be possible in which two storage tanks 2 are connected, or four or more storage tanks 2 are connected. Instead, the reduction system 1 of the present invention may also include only one storage tank 2.

EXPLANATION OF REFERENCE NUMERALS

[0090]

- 1 carbon dioxide emission reduction system
- 2, 2X to 2Z storage tank
 - 2a inflow port
 - 2b injection port
 - 2c exhaust port
 - 2d drain port
 - 2e protrusion
- 3 injection instrument
- 4 injector unit
 - 4a ejection nozzle
 - 4b branch pipe
- 5 vent pipe
- 6 connecting pipe
- 7 exhaust pipe
- 8 exhaust valve
- 9 drain pipe
- 10 drain valve
- 11 discharge pipe

12	discharge valve
13	hydrogen ion concentration meter
14	carbon dioxide concentration meter
15	pressure meter
16	control device
17	notch tank
20	internal combustion engine
21	manifold
22	dust collecting device
23	heat removal tank
24	pumping device
30	solution production tank
31	stirrer
32	raw water level adjustment tank
40	management apparatus
G	exhaust gas
GP	treated exhaust gas
A	alkaline solution
AP	treated solution
CW	cooling water
R	recycled crushed stone
RP	treated recycled crushed stone
S	precipitate
W	water

CLAIMS

[Claim 1]

A carbon dioxide emission reduction method comprising:
reducing carbon dioxide contained in exhaust gas discharged from an internal combustion engine by injecting the exhaust gas into an alkaline solution stored in a storage tank, thereby bringing the alkaline solution and the exhaust gas into contact with each other inside the storage tank, and causing a neutralization reaction between the alkaline solution and the carbon dioxide contained in the exhaust gas; and

discharging the exhaust gas with the carbon dioxide reduced from an exhaust port of the storage tank.

[Claim 2]

The carbon dioxide emission reduction method according to claim 1, wherein

a plurality of ejection nozzles configured to be supplied with the exhaust gas are provided at a lower portion inside the storage tank, and

the exhaust gas is ejected from each of the ejection nozzles, thereby generating a spiral flow in which numerous bubbles of the exhaust gas spirally rise in the alkaline solution inside the storage tank.

[Claim 3]

The carbon dioxide emission reduction method according to claim 1 or 2, comprising lowering a rising speed of bubbles of the exhaust gas rising in the alkaline solution with a protrusion provided on an inner surface of the storage tank.

[Claim 4]

The carbon dioxide emission reduction method according to any one of claims 1 to 3, comprising

producing the alkaline solution by using recycled crushed stone obtained by crushing concrete waste; and

storing the produced alkaline solution in the storage tank.

[Claim 5]

The carbon dioxide emission reduction method according to any one of claims 1 to 4, wherein

a plurality of the storage tanks are connected in series via a vent pipe through which the exhaust gas flows and a connecting pipe through which the alkaline solution flows,

the alkaline solution which is stored in the upstream storage tank and which has a hydrogen ion concentration reduced by the neutralization reaction with the carbon dioxide contained in the exhaust gas is discharged from a drain port of the upstream storage tank,

the alkaline solution discharged from the drain port flows into the downstream storage tank through the connecting pipe and is stored in the downstream storage tank and the exhaust gas discharged from the exhaust port of the upstream storage tank is injected through the vent pipe into the alkaline solution stored in the downstream storage tank, thereby bringing the alkaline solution and the exhaust gas into contact with each other inside the downstream storage tank to cause a neutralization reaction between the alkaline solution and the carbon dioxide contained in the exhaust gas, thereby further reducing the carbon dioxide contained in the exhaust gas and

further reducing the hydrogen ion concentration in the alkaline solution,

the exhaust gas with the carbon dioxide further reduced is discharged from the exhaust port of the downstream storage tank, and

the alkaline solution with the hydrogen ion concentration further reduced is discharged from the drain port of the downstream storage tank.

[Claim 6]

The carbon dioxide emission reduction method according to claim 5, wherein

a carbon dioxide concentration in the exhaust gas after the exhaust gas passes through the alkaline solution in each of the storage tanks is measured,

the exhaust gas whose carbon dioxide concentration is equal to or lower than a preset reference value is not injected into the alkaline solution stored in the downstream storage tank but is disposed of as treated exhaust gas.

[Claim 7]

The carbon dioxide emission reduction method according to claim 5 or 6, wherein

the hydrogen ion concentration in the alkaline solution stored in each of the storage tanks is measured,

the alkaline solution whose hydrogen ion concentration is equal to or lower than a preset threshold is not injected into the alkaline solution stored in the downstream storage tank but is disposed of as a treated solution.

[Claim 8]

The carbon dioxide emission reduction method according to any one of claims 1 to 7, comprising:

removing heat from the exhaust gas discharged from the internal combustion engine with a heat removal tank; and

injecting the exhaust gas after the heat removal into the alkaline solution stored in the storage tank.

[Claim 9]

The carbon dioxide emission reduction method according to any one of claims 1 to 8, comprising:

removing dust contained in the exhaust gas discharged from the internal combustion engine with a dust collecting device; and

injecting the exhaust gas after the dust removal into the alkaline solution stored in the storage tank.

[Claim 10]

The carbon dioxide emission reduction method according to any one of claims 1 to 9, wherein

in a state in which a raw water level adjustment tank configured to temporarily store the produced alkaline solution is connected to the storage tank by a connecting pipe, the alkaline solution stored in the raw water level adjustment tank is caused to flow into the storage tank, so that a liquid level position of the alkaline solution stored in the raw water level adjustment tank and a liquid level position of the alkaline solution stored in the storage tank are set to the same height.

[Claim 11]

The carbon dioxide emission reduction method according to claim 10, wherein

a flow rate of the alkaline solution supplied to the raw water level adjustment tank is adjusted so that the liquid level position of the alkaline solution stored in the raw water level adjustment tank is kept at a preset certain height.

[Claim 12]

A carbon dioxide emission reduction system comprising:
a storage tank configured to store an alkaline solution;
and

an injection instrument configured to inject exhaust gas discharged from an internal combustion engine into the alkaline solution stored in the storage tank, wherein

the alkaline solution and the exhaust gas injected by the injection instrument are brought into contact with each other inside the storage tank to cause a neutralization reaction between the alkaline solution and carbon dioxide contained in the exhaust gas, thereby reducing the carbon dioxide contained in the exhaust gas, and

the exhaust gas with the carbon dioxide reduced is discharged from an exhaust port of the storage tank.