

METHOD AND APPARATUS FOR REMOVING CARBON DIOXIDE FROM FLUE GAS

Field

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The present invention relates to a method and apparatus for removing carbon dioxide from flue gas. In particular the present invention relates to a method and apparatus for removing carbon dioxide from flue gas using saline water.

10 Background

Flue gas from power plants, industrial plants, refineries and so forth are a major source of greenhouse gases, in particular carbon dioxide. There are several chemical processes and scrubbers which are routinely used to treat flue gas to remove
15 pollutants such as particulates, heavy metal compounds, nitrogen oxides and sulphur oxides to comply with regulations for environmental emissions control. However, there is an ongoing need for technologies directed to methods and systems for capture and storage of carbon dioxide that are economically viable.

20 One commercially proven process for the recovery of carbon dioxide from flue gas uses commercial absorbents comprising monoethanolamine (MEA) and other primary amines. These absorbents are capable of recovering 85-95% of the carbon dioxide in flue gas and produce a 99.95+% pure carbon dioxide product when regenerated. However, these absorbents require regular regeneration which has an energy cost
25 associated therewith, and the absorbents are subject to corrosion and solvent degradation problems over time.

There is therefore a need for alternative or improved methods and systems for removing carbon dioxide from flue gas.

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Summary

According to a first aspect, there is provided a method of removing carbon dioxide from a flue gas, the method comprising:

- 35
- a) mixing the flue gas with ammonia; and,
 - b) contacting the gas mixture with saline water to produce bicarbonate precipitates and an ammonium chloride solution.

In one embodiment, the method may further comprise the step of recovering the bicarbonate precipitates by separating the bicarbonate precipitates from the ammonium chloride solution.

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According to a second aspect, there is provided an apparatus for removing carbon dioxide from a flue gas, the apparatus comprising:

a reaction vessel having an inlet to receive saline water and an inlet to receive a gas mixture of flue gas and ammonia;

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a gas-liquid contactor configured to diffuse said gas mixture into the saline water;

the reaction vessel being provided with an impellor configured to circulate the diffused gas mixture in the saline water for a period of time sufficient to produce bicarbonate precipitates.

15 Brief Description of the Drawings

Notwithstanding any other forms which may fall within the scope of the method and apparatus as set forth in the Summary, specific embodiments will now be described, by way of example only, with reference to the accompanying drawings in which:

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Figure 1 is a schematic representation of an apparatus for removing carbon dioxide from flue gas; and,

Figure 2 is a schematic representation of a plant for removing carbon dioxide
25 from flue gas using the apparatus shown in Figure 1.

Detailed Description

In one aspect, the present application relates to a method of removing carbon dioxide
30 from flue gas.

Flue gas

The term 'flue gas' is used broadly to refer to any gas exiting to the atmosphere via a flue, which is a pipe or channel for conveying exhaust gases produced by industrial or
35 combustion processes. Generally, flue gas refers to the combustion exhaust gas produced at power plants fuelled by fossil fuels, such as coal, oil and gas. However, it will be appreciated that the term flue gas may refer to exhaust gases containing carbon

dioxide produced by other industrial processes such as cement and lime production, steel production, incinerators, and the process furnaces in large refineries, petrochemical and chemical plants; and also to exhaust gases from various types of engines including, but not limited to, diesel engines, combustion engines, and gas-turbine engines.

The composition of flue gas depends on the combustion fuel or the type of industrial process which generates the flue gas. Flue gas may comprise nitrogen, carbon dioxide, carbon monoxide, water vapour, oxygen, hydrocarbons, and pollutants, such as particulate matter, nitrogen oxides (NO_x) and sulphur oxides (SO_x).

Removing carbon dioxide

The method of removing carbon dioxide from flue gas comprises:

- a) mixing the flue gas with ammonia; and,
- b) contacting the gas mixture with saline water to produce a bicarbonate precipitate and an ammonium chloride solution.

Mixing the flue gas with ammonia

The temperature of the flue gas exiting from a flue may be in the range of about 300 °C to about 800 °C, depending on the process by which the flue gas is produced, the length of the flue, and other factors as will be understood by those skilled in the art. Prior to mixing the flue gas with ammonia, the flue gas may be cooled to less than 35 °C.

Cooling the flue gas may be achieved by passing the flue gas through a heat exchanger, preferably an air-cooled heat exchanger.

Additionally, or alternatively, cooling the flue gas may be achieved by mixing the flue gas with a lower temperature gas, in particular ammonia gas. Advantageously, the ammonia in the resulting flue gas-ammonia mixture will be absorbed and solubilised in the saline water when the flue gas-ammonia mixture is passed through the gas-liquid contactor, as described below.

Mixing the flue gas with ammonia may comprise introducing a flow of ammonia into a flow of flue gas. Preferably, ammonia is mixed with the flue gas just prior to the gas mixture being contacted with the saline water.

Ammonia may comprise from about 20 %v/v to about 40 % v/v of the flue gas-ammonia mixture.

- 5 The flue gas may be also compressed to a pressure of at least 10 psi, preferably to a pressure between 10 psi and about 15 psi.

Saline water

10 The term 'saline water' broadly refers to any aqueous solution that contains a significant concentration of dissolved salts (mainly NaCl). The concentration of dissolved salts is usually expressed in parts per million (ppm) or grams per litre. The salinity of the saline water may be greater than about 20 grams of salt per litre. The aqueous solution may be water, deionised water, ultrapure water, distilled water, municipal water, groundwater, produced water, process water, brine, hypersaline
15 water, or seawater. Where the salinity of the aqueous solution is less than about 20 grams of salt per litre (e.g. deionised water, ultrapure water, distilled water, municipal water, produced water, process water), it will be appreciated that additional salt may be added thereto to meet the desired salinity concentration.

- 20 The pH of the saline water is in a range of about 7 to about 10, preferably in the range of about 7.5 to about 8.4. Suitable buffers, as will be well known to those skilled in the art, may be used to maintain the pH of the saline water in this particular range, although it is anticipated that in most cases the volume of ammonia in the flue gas-ammonia mixture will be sufficient to maintain the pH of the saline water in the desired
25 pH range.

The saline water is maintained at a low temperature of less than 35 °C, preferably from about 10 °C to about 25 °C. The saline water is kept at low temperature to increase the capacity of the saline water to absorb carbon dioxide from the flue gas-ammonia
30 gas mixture and to maintain the carbon dioxide in solution as bicarbonate/carbonate anions, as will be described later. Keeping the saline water at low temperature also lowers the partial pressure of ammonia in the headspace above the reaction mixture.

Contacting the gas mixture with the saline water

- 35 Contacting the gas mixture with the saline water may comprise passing the flue gas-ammonia mixture through a gas-liquid contactor. The gas-liquid contactor is

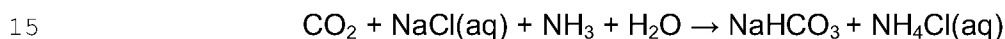
- 5 -

configured to diffuse bubbles of said gas mixture into the saline water.

It will be appreciated that contacting the flue gas-ammonia mixture with the saline water facilitates absorption of carbon dioxide and ammonia (and SO_x and NO_x gases) in the saline water. Absorption may be by physical absorption or chemisorption processes.

In physical absorption processes, carbon dioxide and ammonia dissolve in the saline water. The solubility of the dissolved carbon dioxide gas will be dependent, at least in part, on the temperature, pressure and pH of the saline water.

The primary chemisorption process relating to absorption of carbon dioxide and ammonia in the saline water can be described as follows:



The gas-liquid contactor may be configured to produce a gas bubble having a mean size selected to ensure a desired degree of gas mass transfer to achieve absorption of carbon dioxide and ammonia in the saline water and effective gas scrubbing.

Similarly, the pressure and the flow rate of the gas mixture through the gas-liquid contactor may be selected to produce a gas bubble having a size selected to ensure a desired degree of gas mass transfer to achieve absorption of carbon dioxide and ammonia in the saline water and effective gas scrubbing.

The bubbles of flue gas-ammonia gas mixture are entrained in circulatory currents in the saline water established therein by a rotating mixing device in the form of an impellor. In this way, said bubbles are dispersed throughout the saline water.

The gas mixture may be continually, or intermittently, introduced into the saline water until the saline water reaches saturation and bicarbonate precipitates begin to form. It will be appreciated by persons skilled in the art that the bicarbonate precipitates will generally take the form of sodium bicarbonate salts, although other alkali metal or alkaline earth metal bicarbonate salts may also precipitate concurrently or independently of sodium bicarbonate salts, depending on the concentration thereof in the reaction mixture.

The reaction mixture may be allowed to age to increase the particle size of the bicarbonate precipitates and aid separation thereof. Aging may take place *in situ*. Alternatively, the reaction mixture may be transferred to a separate vessel for aging and/or settling of the bicarbonate precipitates.

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Alternatively, in a continuous process, the reaction mixture may pass through a series of reaction vessels having reaction mixtures with increasing concentration of reagents and products.

10 *Recovering the bicarbonate precipitates*

The step of recovering the bicarbonate precipitates may be achieved by separating the bicarbonate precipitates from the ammonium chloride solution. Any suitable separating technique, as will be well known to those skilled in the art, may be employed including, 15 but not limited to, gravity separation, filtration, centrifugation, and so forth.

The separated ammonium chloride solution may be subsequently reacted with lime (i.e. CaO) to form calcium chloride and regenerate ammonia gas. The regenerated ammonia gas is recirculated and recycled in the process for step a). The calcium 20 chloride is separated as a byproduct.

The remaining filtrate may be transferred to evaporation ponds, whereby resulting salts are harvested. Alternatively, the remaining filtrate may be returned to the ocean.

25 *Apparatus for removing carbon dioxide from flue gas*

The apparatus for removing carbon dioxide from a flue gas comprises:

a reaction vessel having an inlet to receive saline water and an inlet to receive a gas mixture of flue gas and ammonia;

a gas-liquid contactor configured to diffuse said gas mixture into the saline water;

30 the reaction vessel being provided with an impellor configured to circulate the diffused gas mixture in the saline water for a period of time sufficient to produce bicarbonate precipitates.

The apparatus may further comprise a separator for separating the resulting 35 bicarbonate precipitates. The separator may be any separator suitable for separating bicarbonate precipitates from the saline water, as will be understood by the person skilled in the art. Examples of suitable separators include, but are not limited to,

cyclones, filters such as filter press arrangements, filter-cloth separators, gravity separators, and so forth.

5 It will be appreciated that a flow path of the flue gas will be configured to convey the flue gas to the gas-liquid contactor. The flow path may be adapted to introduce a flow of ammonia gas into the flue gas and thereby convey a mixture of flue gas and ammonia to the gas-liquid contactor.

10 The apparatus may further comprise an ammonia recovery system in fluid communication with the reaction vessel and configured to receive and recover ammonia from off-gases in the headspace of the reaction vessel.

Reaction vessel to produce bicarbonate precipitates

15 The reaction vessel may be any vessel suitable for contacting the flue gas-ammonia gas mixture with saline water to produce bicarbonate precipitates and an ammonium chloride solution.

20 The reaction vessel has an inlet to receive saline water and an inlet to receive the flue gas-ammonia gas mixture. The reaction vessel may optionally be provided with an outlet for withdrawing a mixture of bicarbonate precipitates and the ammonium chloride solution which can be subsequently separated in the separator.

25 The reaction vessel may be covered to prevent loss of emissions therefrom. In particular, ammonia gas entering the head space in the reaction vessel may be captured and recycled back to the flow path of the flue gas entering the reaction vessel.

30 It will be appreciated that the apparatus may comprise more than one reaction vessel arranged in series, each subsequent vessel being configured to receive overflow of reactants and products from an adjacent preceding reaction vessel in said series.

Gas-liquid contactor

35 The gas-liquid contactor may be configured to diffuse said gas mixture into the saline water. In one embodiment of the invention, the gas-liquid contactor takes the form of a hollow perforated annulus that is arranged in fluid communication with the flow path to

convey the mixture of flue gas and ammonia thereto.

The perforations of the gas-liquid contactor may be configured and sized to produce a gas bubble having a mean size selected to ensure a desired degree of gas mass
5 transfer to achieve absorption of carbon dioxide and ammonia in the saline water and effective gas scrubbing.

The reaction vessel may be provided with an impellor configured to circulate the diffused gas mixture in the saline water for a period of time sufficient to produce
10 bicarbonate precipitates.

The impellor establishes a circulatory flow of gas mixture in the saline water to facilitate the physical absorption or chemisorption processes described above to produce bicarbonate precipitates and ammonium chloride solution.

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Cooling means

The apparatus may further comprise a cooling means located upstream of the reaction vessel for cooling the flue gas. The cooling means may take the form of a heat exchanger or an expander.

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The heat exchanger may be any suitable heat exchanger, such as a shell and tube heat exchanger, plate heat exchanger, plate and shell heat exchanger, plate fin heat exchanger, and so forth. The heat exchanger may be air-cooled. Alternatively, the heat exchanger may employ an alternative gas or liquid coolant, such as a refrigerant,
25 which is circulated through a refrigeration circuit and the heat exchanger by one or more pumps.

The expander may be any suitable device configured to expand the flue gas, thereby lowering its pressure and temperature. Examples of suitable expanders include, but
30 are not limited to, venturi tubes, turbo expanders, pressure reducing valves, and so forth.

The reaction vessel may also be provided with a cooling means for maintaining the saline water at a temperature less than 35 °C. Suitable cooling means include a
35 refrigerated jacket associated with said reaction vessel.

Referring to Figures 1 and 2, where like reference numerals are used to denote similar or like parts throughout, one embodiment of the method and apparatus 10 for removing carbon dioxide from flue gas will now be described.

5 Flue gas is emitted from an emissions source (e.g. power station, not shown) via a flue 12. The flue 12 may be configured in fluid communication with respective inlets 14 of a pair of reaction vessels 16a, 16b arranged in series. The inlets 14 are configured with additional inlets 14a, 14b to receive ammonia gas from an ammonia absorption chiller 50 and thereby introduce a gas mixture containing flue gas and ammonia into the
10 reaction vessels 16a, 16b.

It will be appreciated that prior to mixing with ammonia, the flue gas may have been cooled to less than 35 °C in an air-cooled heat exchanger 17 or manifold. The reaction vessels 16a, 16b may also be provided with external cooling jackets 19 wherein the
15 coolant is an ammonia coolant from the ammonia absorption chiller 50. In this way, the contents of reaction vessels 16a, 16b may be controlled within a desired temperature range, preferably less than 35 °C, even more preferably less than 30 °C.

The reaction vessels 16a, 16b are generally cylindrical with a downwardly tapering
20 lower portion 18 terminating in an outlet 20 in the form of a drain for withdrawing the liquid contents of the reaction vessels 16a, 16b. The reaction vessels 16a, 16b are provided with respective lids 22 to contain off-gases (e.g. ammonia) from the liquid contents of the reactions vessels 16a, 16b in the headspace thereof. Conduits 21 are provided to direct and recycle such off-gases to an ammonia recovery system 23
25 where the ammonia is recovered and, optionally, recirculated to the inlets 14 of the reaction vessels 16a, 16b. Withdrawal of off-gases may be achieved by means of applying negative pressure to the headspace of the reaction vessels 16a, 16b with a vacuum pump (not shown).

30 Reaction vessel 16a is provided with an inlet 24 to receive saline water therein. Reaction vessel 16a is also provided with an overflow pipe 26 in fluid communication with reaction vessel 16b to convey excess saline water from reaction vessel 16a to adjacent reaction vessel 16b. Similarly, reaction vessel 16b may be provided with an overflow pipe 26' arranged in fluid configuration with a settling tank (not shown) or a
35 separator.

Each reaction vessel 16a, 16b is provided with a draft tube 28, in the form of a hollow

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cylinder, concentrically aligned along a central longitudinal axis of the reaction vessel 16a, 16b. The draft tube 28 is supported within the reaction vessel 16 by supporting brackets 30 laterally extending from side walls of the reaction vessel 16.

- 5 The inlets 14 are integral with a gas-liquid contactor 32 which is disposed in an upper portion of the draft tube 28. In this particular embodiment, the gas-liquid contactor 32 comprises a hollow perforated annulus. The gas-liquid contactor 32 is arranged, in use, to be submerged below the surface of the saline water in the reaction vessel 16 concentrically within the draft tube 28. The gas-liquid contactor 32 may be provided
10 with a hoist means 34 to raise or lower the gas-liquid contactor 32 within the reaction vessel 16.

The diameter of the hollow perforated annulus 32 is selected such that an outer diameter of the hollow perforated annulus 32 is spaced apart from side walls of the
15 draft tube 28. Preferably, the perforations in the hollow annulus 32 are disposed on an underside thereof so that, in use, a flow of bubbles of flue gas-ammonia gas mixture descends through the draft tube 28.

The reaction vessel 16 is also provided with an impellor 36 mounted on a shaft
20 disposed in longitudinal alignment with the central longitudinal axis of the reaction vessel 16. The impellor 36 is driven by a motor 40 and associated top drive mounted on the lid 22 of the reaction vessel 16. In use, the impellor 36 creates a down draft which draws the flow of gas bubbles downward through the draft tube 28 and along a circulatory path 38 to disperse the gas bubbles through the saline water held in the
25 reaction vessel 16.

Figure 2 shows the apparatus 10 of the present invention in fluid communication with a reservoir 40 for supply of saline water to reaction vessel 16a, and a series of precipitation tanks 42 for receiving and aging mixtures of bicarbonate precipitates and
30 ammonium chlorides produced in said reaction vessels 16a, 16b. The precipitation tanks 42 may be provided with respective draft tubes 28 and impellors 36 to agitate the contents therein. The precipitation tanks 42 may be arranged in fluid communication with a settling tank 46 and a separator 44 in the form of a filtration press to separate bicarbonate precipitates from the ammonium chloride solution.

35 In use, flue gas from an emissions source is cooled to less than 35 °C and directed via a flue 12 to an inlet 14 of a reaction vessel 16 whereupon it is mixed with ammonia gas

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prior to injecting said gas mixture into a body of saline water held in the reaction vessel 16. Said gas mixture is injected into the body of saline water through a gas-liquid contactor configured to diffuse bubbles of the gas mixture in the saline water. A rotating impellor 36 generates a circulatory flow path for the bubbles within the reaction vessel 16 to enhance gas-liquid mass transfer and associated chemisorption and physical absorption processes associated with the conversion of CO₂ into bicarbonate.

When the saline water in reaction vessel 16 reaches its absorptive capacity with respect to carbon dioxide, it may be directed to precipitation tanks 42 and subsequently the settling tank 46 and separator 44 for recovery of bicarbonate precipitates. The resulting filtrate containing ammonium chloride may then be mixed with calcium oxide to produce calcium chloride and gaseous ammonia may be regenerated from the remaining solution and recycled back to the reaction vessel 16.

As will be evident from the foregoing description, the process of the present invention facilitates a reduction of greenhouse gas emissions (i.e. carbon dioxide) in comparison with conventional technologies for treating flue gas.

A financial instrument tradable under a greenhouse gas Emissions Trading Scheme (ETS) may be created by juxtaposing an apparatus as described herein and a flue gas emissions source, such as an industrial power plant, in a manner whereby the processes of the present invention may be readily employed. The instrument may be, for example, one of either a carbon credit, carbon offset or renewable energy certificate. Generally, such instruments are tradable on a market that is arranged to discourage greenhouse gas emission through a cap and trade approach, in which total emissions are 'capped', permits are allocated up to the cap, and trading is allowed to let the market find the cheapest way to meet any necessary emission reductions. The Kyoto Protocol and the European Union ETS are both based on this approach.

One example of how credits may be generated by using the fertilizer plant as follows. A person in an industrialised country wishes to get credits from a Clean Development Mechanism (CDM) project, under the European ETS. The person contributes to the establishment of a fertilizer plant employing the processes of the present invention in proximal vicinity to a source of flue gas emissions. Credits (or Certified Emission Reduction Units where each unit is equivalent to the reduction of one metric tonne of CO₂ or its equivalent) may then be issued to the person. The number of CERs issued is based on the monitored difference between the baseline and the actual emissions.

It is expected by the applicant that offsets or credits of a similar nature to CERs will be soon available to persons investing in low carbon emission energy generation in industrialised nations, and these could be similarly generated.

- 5 It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

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It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

- 15 In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the
20 invention.

CLAIMS:

1. A method of removing carbon dioxide from a flue gas, the method comprising:
 - a) mixing the flue gas with ammonia; and,
 - b) contacting the gas mixture with saline water to produce a bicarbonate precipitate and an ammonium chloride solution.
2. The method according to claim 1 further comprising the step of recovering the bicarbonate precipitate by separating the bicarbonate precipitate from the ammonium chloride solution.
3. The method according to claim 1 or claim 2, wherein the saline water has a dissolved salts concentration of at least 20 grams per litre.
4. The method according to any one of the preceding claims, wherein the pH of the saline water is in the range of about 7 to about 10.
5. The method according to claim 4, wherein the pH of the saline water is in the range of 7.5 to 8.4.
6. The method according to any one of the preceding claims, wherein the temperature of the saline water is less than about 30 °C.
7. The method according to claim 6, wherein the temperature of the saline water is from about 10 °C to about 25 °C.
8. The method according to any one of the preceding claims, wherein ammonia comprises from about 20 % v/v to about 40 % v/v of the flue gas-ammonia mixture.
9. The method according to any one of the preceding claims, wherein the flue gas is compressed to a pressure in a range of between about 10 psi to about 15 psi.
10. An apparatus for removing carbon dioxide from a flue gas, the apparatus comprising:
 - a reaction vessel having an inlet to receive saline water and an inlet to receive a gas mixture of flue gas and ammonia;
 - a gas-liquid contactor configured to diffuse said gas mixture into the saline water;

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the reaction vessel being provided with an impellor configured to circulate the diffused gas mixture in the saline water for a period of time sufficient to produce bicarbonate solids.

11. The apparatus according to claim 10, wherein the apparatus further comprises a separator for separating the bicarbonate precipitates.
12. The apparatus according to claim 10 or claim 11, wherein the apparatus comprises a cooling means for cooling the flue gas prior to contacting the flue gas with ammonia.
13. The apparatus according to claim 12, wherein the cooling means comprises a heat exchanger disposed upstream of the gas mixture inlet of the reaction vessel.
14. The apparatus according to any one of claims 10 to 13, wherein the gas-liquid contactor comprises a perforated annulus concentrically disposed about a central longitudinal axis of the reaction vessel.
15. The apparatus according to claim 14, wherein the perforated annulus and the impellor are concentrically disposed within a draft tube, the arrangement being such that, in use, the impellor generates a circulatory flow path for bubbles of the gas mixture disposed about side walls of the draft tube.
16. The apparatus according to any one of claims 10 to 15, further comprising an ammonia recovery system in fluid communication with the reaction vessel and configured to receive and recover ammonia from off-gases in the headspace of the reaction vessel.
17. A method of creating a financial instrument tradable under a greenhouse gas Emissions Trading Scheme (ETS), the method comprising the step of exploiting a method for removing carbon dioxide from flue gas defined by any one of claims 1 to 9 or an apparatus defined by any one of claims 10 to 16.
18. The method according to claim 17, wherein the financial instrument comprises one of either a carbon credit, carbon offset or renewable energy certificate.

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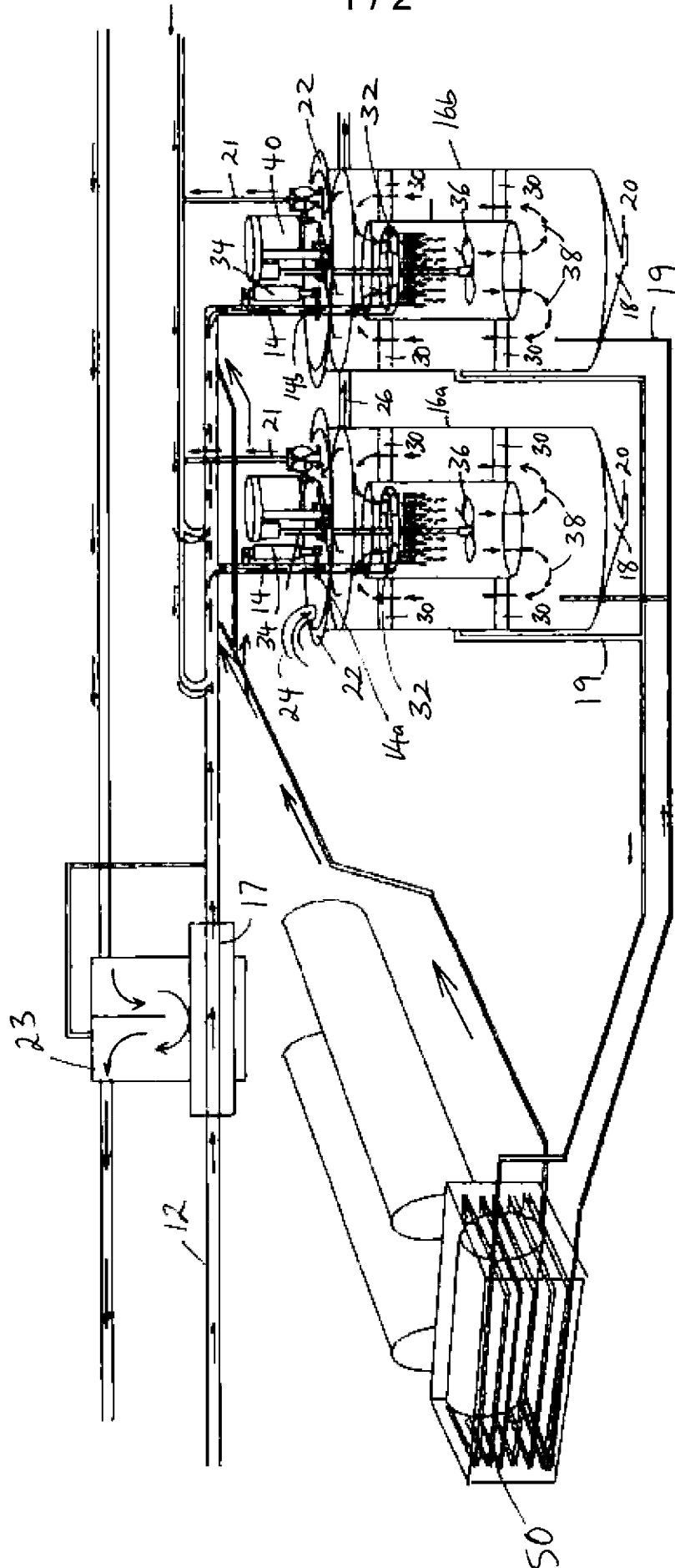


Figure 1

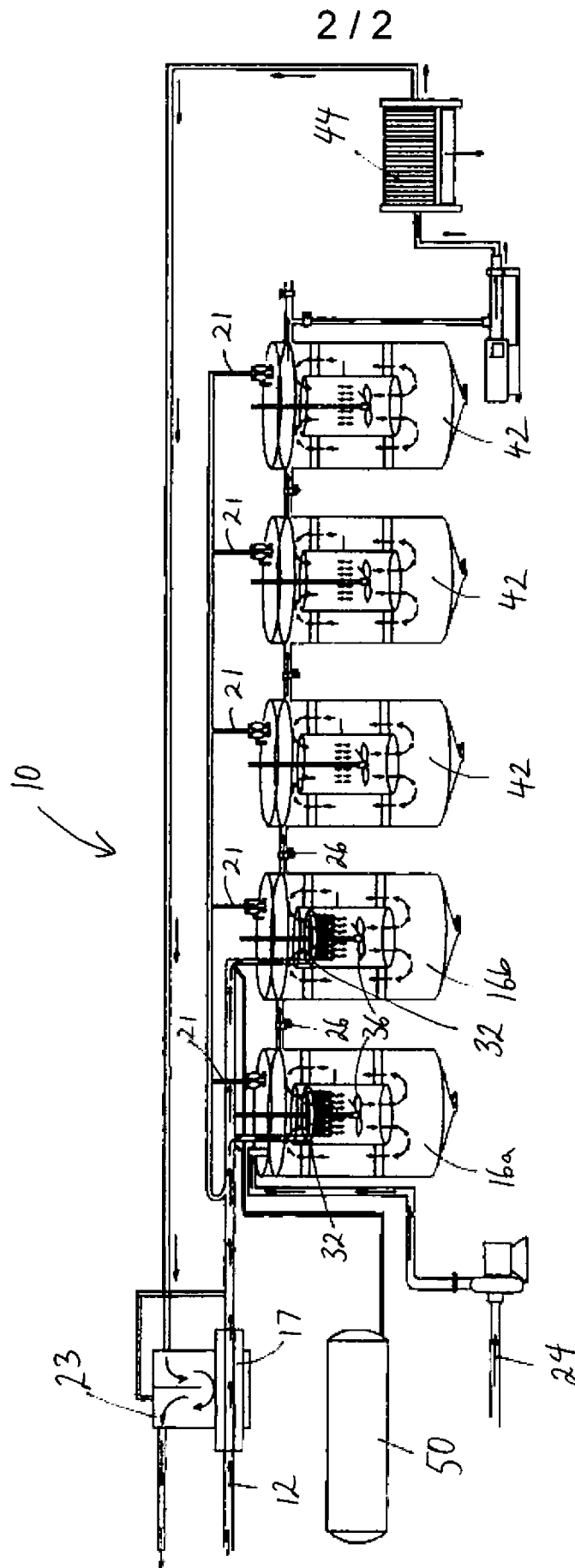


Figure 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2014/001119

A. CLASSIFICATION OF SUBJECT MATTER

B01D 53/62 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

EPOQUE – X-Full: \$Patent: TXTAU1, TXTCA1, TXTEP1, TXTGB1, TXTSG1, TXTUS0, TXTUS1, TXTUS2, TXTUS3, TXTUS4, TXTUS5, TXTWO1, WPI, EPODOC; IPC/CPC: B01D53/-, B01D2252/102, B01D2257/504, B01D2258/0283, C01B31/20, C01B31/24, Y02C10/06, Y02C10/04 & Keywords (carbon dioxide, CO₂, ammonia, flue, waste, combustion, stack, exhaust, gas, air, NH₃, mix, blend, combine, add, saline, brine, brackish, salt, sea, water, sodium chloride, NaCl, bicarbonate, sodium bicarbonate, NaHCO₃ and similar terms);

Espacenet & Google Patents: keywords (carbon dioxide, CO₂, ammonia, flue, waste, combustion, stack, exhaust, gas, air, NH₃, mix, blend, combine, add, saline, brine, brackish, salt, sea, water, sodium chloride, NaCl, bicarbonate, sodium bicarbonate, NaHCO₃)

Applicant search is done on "REID SYSTEMS" and inventor search is done on "REID TERRENCE" through Espacenet and AusPat.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
2 March 2015

Date of mailing of the international search report
02 March 2015

Name and mailing address of the ISA/AU

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INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2014/001119
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/0268633 A1 (ZOU) 03 November 2011 abstract; para 0002; para 0008-0028; para 0040-0054; figs. 1-2	1-18
X	US 5275794 A (LUNA) 04 January 1994 abstract; col 1, lines 6-11; col 2, line 64 to col 11, line 25; col 13, line 64 to col 15, line 27; figs. 1-4	1-2, 10-11, 16
X	US 3449067 A (KARL OTTO SCHMITT et al.) 10 June 1969 col 1, line 16 to col 3, line 5; example	1-2, 6-7, 10-11, 16

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2014/001119	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
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		JP S4829720 B1	12 Sep 1973
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			