

SYSTEMS AND METHODS FOR REMOVING CARBON DIOXIDE FROM A COMBUSTION FLUE GAS AND/OR AIR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 63/232,843, filed August 13, 2021, and U.S. Provisional Application No. 63/219,189, filed July 7, 2021, which are incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] The systems and methods disclosed herein generally relate to removing carbon dioxide (CO₂) from a combustion flue gas and/or air. More particularly, the disclosed systems and methods use a high-pressure aqueous ammonia (NH₃) solvent and a plurality of liquid driven ejectors to absorb and remove CO₂ for carbon capture utilization or storage (CCUS). The NH₃ solvent is regenerated at a high pressure to save potential compression energy required for the absorption and removal of CO₂.

BACKGROUND

[0003] Environmental concerns regarding the release of flue gas contaminants into the atmosphere from combustion plants have led to strict limits on emissions from power plants, refineries, and other industrial processes. Numerous systems and methods have been developed in response to the desire to achieve a near zero emission of contaminants such as CO₂. NH₃, for example, has been used to efficiently remove CO₂, as well as other contaminants, from a flue gas.

[0004] In one system referred to as a chilled ammonia process, the flue gas is treated with NH₃ at a low temperature (e.g., between 0°-20°C) to absorb and remove CO₂. A special refrigeration system is thus, required to effectively remove CO₂ from the flue gas. A fan/blower

is also required to move the flue gas from the power plant (or combustion system stack) to and through the CO₂ absorber. Because the chilled ammonia process generates a slurry (solid/liquid mixture), it requires special piping and pumping equipment to avoid the solids dropping out of the solution.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The detailed description is described below with reference to the accompanying drawings, in which like elements are referenced with like reference numbers, in which:

[0006] **FIG. 1** is a schematic diagram illustrating an exemplary absorption and water wash section of a new system for removing CO₂ from a combustion flue gas.

[0007] **FIG. 2** is a schematic diagram illustrating an exemplary solvent regeneration section of the new system for removing CO₂ from a combustion flue gas.

[0008] **FIG. 3** is a schematic diagram illustrating an exemplary solvent recovery section of the new system for removing CO₂ from a combustion flue gas.

DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

[0009] The subject matter of the present disclosure is described with specificity, however, the description itself is not intended to limit the scope of the disclosure. The subject matter described herein thus, might also be embodied in other ways, to include different structures, steps and/or combinations similar to and/or fewer than those described herein, in conjunction with other present or future technologies. Although the term “step” may be used herein to describe different elements of methods employed, the term should not be interpreted as implying any particular order among or between various steps herein disclosed unless otherwise expressly limited by the description to a particular order. Other features and advantages of the disclosed embodiments will be or will become apparent to one of ordinary skill in the art upon

examination of the following figures and detailed description. It is intended that all such additional features and advantages be included within the scope of the disclosed embodiments. Further, the illustrated figures are only exemplary and are not intended to assert or imply any limitation with regard to the environment, architecture, design, or process in which different embodiments may be implemented. To the extent that temperatures and pressures are referenced in the following description, those conditions are merely illustrative and are not meant to limit the disclosure.

[0010] The systems and methods disclosed herein enhance the removal of CO₂ from a combustion flue gas by using a high-pressure NH₃ solvent and a plurality of liquid driven ejectors to absorb and remove CO₂. Because the absorption operating temperature is about 90°F-120°F, a regular water-cooling system may be used instead of the special refrigeration system used in a conventional chilled ammonia process. Moreover, the fan/blower and special piping/pumping equipment required in a conventional chilled ammonia process are not required because the NH₃ solvent is regenerated at a high pressure. The high-pressure regenerated NH₃ solvent thus, provides power to the liquid driven ejectors that discharge the flue gas at a higher pressure than a fan/blower and only require regular liquid handling piping/pumping equipment.

[0011] In one embodiment, the present disclosure includes a system for removing carbon dioxide from a combustion flue gas or air, comprising: i) a first ejector having a suction port, a motive port and an outlet; ii) an ammonia solvent liquid stream in fluid communication with the first ejector motive port; iii) a mixed feed gas stream with carbon dioxide or an air stream with carbon dioxide in fluid communication with the first ejector suction port, the mixed feed gas stream comprising a combustion flue gas stream and a flash gas stream; iv) a first two-phase fluid stream in fluid communication with the first ejector outlet and a first separator; v) a second

ejector having a suction port, a motive port and an outlet; vi) a first water wash stream in fluid communication with the second ejector motive port; vii) a first gas stream connected to the first separator and the second ejector suction port, the first gas stream comprising less carbon dioxide than the mixed feed gas stream or the air stream and a residual amount of ammonia solvent from the ammonia solvent liquid stream; viii) a first liquid stream connected to the first separator, the first liquid stream comprising a portion of the ammonia solvent liquid stream and absorbed carbon dioxide; ix) a second two-phase fluid stream in fluid communication with the second ejector outlet and a second separator; x) an absorber connected to the first water wash stream; xi) a second gas stream connected to the second separator and the absorber, the second gas stream comprising less carbon dioxide and ammonia solvent than the first gas stream; xii) a second liquid stream connected to the second separator, the second liquid stream comprising another portion of the ammonia solvent liquid stream, absorbed carbon dioxide and a portion of the first water wash stream; and xiii) a treated gas stream connected to the absorber the treated gas stream comprising less carbon dioxide than the second gas stream.

[0012] In another embodiment, the present disclosure includes a method for removing carbon dioxide from a combustion flue gas or air, comprising: i) routing an ammonia solvent liquid stream through a first ejector motive port; ii) drawing a mixed feed gas stream with carbon dioxide or an air stream with carbon dioxide through a first ejector suction port, the mixed feed gas stream comprising a combustion flue gas stream and a flash gas stream; iii) discharging a first two-phase fluid stream through a first ejector outlet, the first two-phase fluid stream comprising a mixture of the ammonia solvent liquid stream and one of the mixed feed gas stream and the air stream; iv) separating the first two-phase fluid stream into a first gas stream and a first liquid stream, the first gas stream comprising less carbon dioxide than the mixed feed gas stream

or the air stream and a residual amount of ammonia solvent from the ammonia solvent liquid stream and the first liquid stream comprising a portion of the ammonia solvent liquid stream and absorbed carbon dioxide; v) routing a first water wash stream through a second ejector motive port; vi) drawing the first gas stream through a second ejector suction port; vii) discharging a second two-phase fluid stream through a second ejector outlet, the second two-phase fluid stream comprising a mixture of the first water wash stream and the first gas stream; viii) separating the second two-phase fluid stream in to a second gas stream and a second liquid stream, the second gas stream comprising less carbon dioxide and ammonia solvent than the first gas stream and the second liquid stream comprising another portion of the ammonia solvent liquid stream, absorbed carbon dioxide and a portion of the first water wash stream; ix) routing the first water wash stream and the second gas stream to an absorber; and x) processing the first water wash stream and the second gas stream in the absorber to produce a treated gas stream comprising less carbon dioxide than the second gas stream.

CO₂ ABSORPTION

[0013] Referring now to **FIG. 1**, a schematic diagram illustrates an exemplary absorption and water wash section **100** of a new system for removing CO₂ from a combustion flue gas. Flash gas **102** comprising the nitrogen, oxygen, and feed contaminants that were co-absorbed in the solvent absorption section **100** along with a small amount of unreacted CO₂ and residual water vapor from a solvent regeneration section **200** of the system is mixed with a combustion flue gas **104** containing CO₂ to form a mixed feed gas at about 0 PSIG (atmospheric pressure). A high pressure aqueous NH₃ solvent **106** from the solvent regeneration section **200** is routed at high speed through a motive port of a first ejector **108**, which draws the mixed feed gas through a suction port of the first ejector **108**. The mixed feed gas and NH₃ solvent **106** are mixed in the

first ejector **108** at a pressure of about 0 to about 500 PSIG and discharged through an outlet as a two-phase fluid. By raising the pressure of the mixed feed gas from 0 PSIG to about 15 PSIG in the first ejector **108** using the high pressure NH₃ solvent **106**, absorption and reaction of CO₂ from the mixed feed gas into the NH₃ solvent **106** is enhanced.

[0014] The two-phase fluid is discharged from the first ejector **108** to a first heat exchanger **110** where heat from the two-phase fluid is transferred to cooling water passing through the first heat exchanger **110** to form a cooled two-phase fluid at about 90° to 120° F. At or about this temperature, absorption and reaction of CO₂ from the mixed feed gas into the NH₃ solvent **106** is further enhanced. The cooled two-phase fluid is routed to a first separator **112** where it is separated into a gas stream comprising the mixed feed gas with less CO₂ and some residual NH₃ solvent **106** and a liquid stream **114** comprising the NH₃ solvent **106** and absorbed CO₂.

[0015] The liquid stream **114** is routed to the solvent regeneration section **200**. The high pressure aqueous NH₃ solvent **106** from the solvent regeneration section **200** is routed at high speed through a motive port of a second ejector **116**, which draws the gas stream from the first separator **112** through a suction port of the second ejector **116**. The gas stream and NH₃ solvent **106** are mixed in the second ejector **116** and discharged through an outlet as a two-phase fluid. By raising the pressure of the gas stream from 15 PSIG to about 30 PSIG in the second ejector **116** using the high pressure NH₃ solvent **106**, absorption of CO₂ from the gas stream into the NH₃ solvent **106** is enhanced.

[0016] The two-phase fluid is discharged from the second ejector **116** to a second heat exchanger **118** where heat from the two-phase fluid is transferred to cooling water passing through the second heat exchanger **118** to form a cooled two-phase fluid at about 90°-120° F. At

or about this temperature, absorption and reaction of CO₂ from the gas stream into the NH₃ solvent **106** is further enhanced. The cooled two-phase fluid is routed to a second separator **120** where it is further separated into a gas stream comprising the gas stream from the first separator **112** with less CO₂ and some residual NH₃ solvent **106** and a liquid stream **114** comprising the NH₃ solvent **106** and absorbed CO₂.

[0017] The liquid stream **114** is routed to the solvent regeneration section **200**. The high pressure aqueous NH₃ solvent **106** from the solvent regeneration section **200** is routed at high speed through a motive port of a third ejector **122**, which draws the gas stream from the second separator **120** through a suction port of the third ejector **122**. The gas stream and NH₃ solvent **106** are mixed in the third ejector **122** and discharged through an outlet as a two-phase fluid. By raising the pressure of the gas stream from 30 PSIG to about 45 PSIG in the third ejector **122** using the high pressure NH₃ solvent **106**, absorption of CO₂ from the gas stream into the NH₃ solvent **106** is enhanced.

[0018] The two-phase fluid is discharged from the third ejector **122** to a third heat exchanger **124** where heat from the two-phase fluid is transferred to cooling water passing through the third heat exchanger **124** to form a cooled two-phase fluid at about 90°-120° F. At or about this temperature, absorption and reaction of CO₂ from the gas stream into the NH₃ solvent **106** is further enhanced. The cooled two-phase fluid is routed to a third separator **126** where it is further separated into a gas stream comprising the gas stream from the second separator **120** with less CO₂ and NH₃ solvent **106** and a liquid stream **114** comprising the NH₃ solvent **106** and absorbed CO₂.

[0019] Although three liquid driven ejectors are described herein for enhancing CO₂ absorption by the NH₃ solvent **106**, a different number may be used, instead, depending on

different constraints (e.g., cost, space, environmental). One or more liquid driven ejectors, for example, may provide sufficient CO₂ absorption based on the relevant constraints. Likewise, a different number of heat exchangers may be used to further enhance CO₂ absorption depending on the same constraints.

[0020] The liquid stream **114** is routed to the solvent regeneration section **200**. A medium-pressure water wash **128** from a solvent recovery section **300** is routed at high speed through a motive port of a fourth ejector **130**, which draws the gas stream from the third separator **126** through a suction port of the fourth ejector **130**. The gas stream and water wash **128** are mixed in the fourth ejector **130** and discharged through an outlet as a two-phase fluid. By raising the pressure of the gas stream from 45 PSIG to about 55 PSIG in the fourth ejector **130** using the medium-pressure water wash **128**, absorption of CO₂ and NH₃ solvent **106** from the gas stream into the water wash **128** is enhanced.

[0021] The two-phase fluid is discharged from the fourth ejector **130** to a fourth separator **132** where it is further separated into a gas stream comprising the gas stream from the third separator **126** with trace amounts of CO₂ and NH₃ solvent **106** and a liquid stream **114** comprising the water wash, NH₃ solvent **106** and CO₂.

[0022] The liquid stream **114** is routed to the solvent regeneration section **200** and the gas stream from the fourth separator **132** is routed to a lower section of an absorber **134**. The absorber **134** may include trays and/or packing, which separate the trace amounts of CO₂ and NH₃ solvent **106** from the fourth separator **132** gas stream and produce the liquid stream **114** comprising the water wash, NH₃ solvent **106** and CO₂. The absorber **134** also produces a treated gas **136**, which is vented to the atmosphere and comprises the nitrogen, oxygen, and feed

contaminants that were co-absorbed in the solvent absorption section **100** along with a trace amount of unreacted CO₂, unreacted solvent, and residual water vapor.

SOLVENT REGENERATION

[0023] Referring now to **FIG. 2**, a schematic diagram illustrates an exemplary solvent regeneration section **200** of the new system for removing CO₂ from a combustion flue gas. The liquid stream **114** from the absorption and water wash section **100** is mixed with NH₃ **202** recovered from the solvent recovery section **300** to produce a mixed liquid feed. The mixed liquid feed is fed to a fourth heat exchanger **204** where heat from the mixed liquid feed is transferred to cooling water passing through the fourth heat exchanger **204** to form a cooled two-phase fluid. The cooled two-phase fluid passes through the fourth heat exchanger **204** to a fifth separator **206** where it is separated into the flash gas **102** and a liquid stream comprising water wash, NH₃ solvent **106** and CO₂.

[0024] A pump **208** is used to transfer the liquid stream from the fifth separator **206** at a high pressure of about 625 PSIG to an upper section of a regenerator **210**. A portion of the liquid stream pumped from the fifth separator **206** may be heated by routing it through a fifth heat exchanger **212** where heat from the NH₃ solvent **106** (from the bottom of the regenerator **210**) passing through the fifth heat exchanger **212** is transferred to the liquid stream. The liquid stream from the fifth separator **206** may be pumped directly to the regenerator **210** and/or through the fifth heat exchanger **212** to the regenerator **210** by controlling valves **214** and **216**. In this manner, a temperature profile for the liquid stream pumped from the fifth separator **206** to the regenerator **210** can be controlled. A water wash **218** is controllably released from the solvent recovery section **300** to an upper section of the regenerator **210** by valve **219**. By controlling the temperature profile of the liquid stream pumped from the fifth separator **206** and using the water

wash **218**, the liquid stream pumped from the fifth separator **206** is separated into a gas stream comprising CO₂ and a liquid stream comprising the NH₃ solvent **106** and the water wash **218**. A reboiler **220** is used to heat the solvent and break the NH₃-CO₂ bond, generate steam, and then the steam will strip the released CO₂ out of the solvent.

[0025] The liquid stream from the regenerator **210** may be routed as NH₃ solvent **222** to the solvent recovery section **300** and/or as NH₃ solvent **106** to the absorption and water wash section **100** by controlling valve **224**. The liquid stream routed as NH₃ solvent **106** to the absorption and water wash section **100** passes through the fifth heat exchanger **212** where it is cooled and a sixth heat exchanger **226** where it is further cooled by cooling water passing through the sixth heat exchanger **226** to form the NH₃ solvent **106** routed to the absorption and water wash section **100**.

[0026] The gas stream from the regenerator **210** flows through a seventh heat exchanger **228** where heat from the gas stream is transferred to cooling water passing through the seventh heat exchanger **228** to form a cooled two-phase fluid comprising water and CO₂. The cooled two-phase fluid is routed to a sixth separator **230** where it is separated into a gas stream **232** comprising CO₂ at a high pressure of about 400-550 PSIG and a liquid stream **234** comprising water. The gas stream **232** may be controllably released to the system battery limits for CCUS by a valve **236** and the liquid stream **234** may be sent to recycle outside the system battery limits. By producing the CO₂ at a high-pressure for CCUS, multiple stages of CO₂ compression are eliminated when compared to an amine system, which produces the CO₂ at 10-20 PSIG.

SOLVENT RECOVERY

[0027] Referring now to **FIG. 3**, a schematic diagram illustrates an exemplary solvent recovery section **300** of the new system for removing CO₂ from a combustion flue gas. NH₃

solvent **222** from the solvent regeneration section **200** is fed through an eighth heat exchanger **302**, where it is heated, to a distillation column **304**. The distillation column **304** includes a trayed or packed vertical vessel, which separates the NH₃ solvent **222** into a gas stream and a liquid stream. The gas stream from the distillation column **304** comprises the recovered NH₃ stream **202** and the non-condensable component stream **318**. The liquid stream comprises the water wash streams **128** and **218** and the excess water stream **322**. A reboiler **306** is used to heat the solution and separate the NH₃ and water and to then strip the released NH₃ out of the solution.

[0028] The gas stream from the distillation column **304** flows through a ninth heat exchanger **308** where heat from the gas stream is transferred to cooling water passing through the ninth heat exchanger **308** to form a cooled two-phase fluid comprising the recovered NH₃ **202** and residual reflux. The cooled two-phase fluid is routed to a seventh separator **310** where it is separated into a gas stream comprising the NH₃ solvent and a liquid stream comprising water that is pumped back to the distillation column **304** using a pump **312**.

[0029] The gas stream from the seventh separator **310** is sent to a tenth heat exchanger **314** where heat from the gas stream is transferred to cooling water passing through the tenth heat exchanger **314** to form a cooled two-phase fluid comprising NH₃ and non-condensable components that may have accumulated in the NH₃ solvent. The cooled two-phase fluid is routed to an eighth separator **316** where it is separated into a gas stream comprising any non-condensable components **318** and a liquid stream comprising the recovered NH₃ **202**. The gas stream **318** from the eighth separator **316** is controllably vented to the atmosphere by valve **320** and the recovered NH₃ liquid stream **202** is routed to the solvent regeneration section **200**.

[0030] The liquid stream from the distillation column **304** flows through the eighth heat exchanger **302** where it is cooled. The cooled liquid stream comprising water may be routed to the absorption and water wash section **100**, the solvent regeneration section **200** and/or outside the system battery limits as excess water **322** to recycle. The cooled liquid stream may be further cooled before it is routed to the absorption and water wash section **100** as water wash **128** by sending it through an eleventh heat exchanger **324** where heat from the cooled liquid stream is transferred to cooling water passing through each heat exchanger. The cooled liquid stream may be further cooled before it is routed to the solvent regeneration section **200** as water wash **218** by sending it through a thirteenth heat exchanger **328** where heat from the cooled liquid stream is transferred to cooling water passing through the thirteenth heat exchanger **328**. A pump **330** may be used to facilitate routing the cooled liquid stream as water wash **218** to the solvent regeneration section **200**.

[0031] A simulation of the system was developed using a ProMax Simulation program. The simulation confirms the feasibility of the system and the quality of the products produced by the methods. The simulation also provides energy and utility requirement information. The simulation used a combustion flue gas that contained approximately 71.9 vol% nitrogen, 6.6 vol% oxygen, 6.9 vol% carbon dioxide and 14.5 vol% water vapor with trace quantities of 0.2 PPMV sulfur dioxide, 0.001 PPMV sulfur trioxide, and 25 PPMV carbon monoxide. The carbon dioxide recovery calculated by the simulation indicated over 99% carbon dioxide recovery with a product that is over 99% carbon dioxide at 500 PSIG and 100°F.

[0032] The simulation indicates that the electric power required for the pumps is less than 75 kW-h of electric power per ton of carbon dioxide recovered. The system does require a heating media for the two reboilers and cooling water for the various cooling requirements. The

heating media required for the reboilers will need to boil the solvent at approximately 400°F and 360°F and the total heating requirement is about 30 MMBTU/Ton of carbon dioxide recovered. The cooling water required is expected to cool and condense the various process streams to about 100°F and will be about 33 MMBTU/Ton of carbon dioxide recovered.

[0033] While the present disclosure has been described in connection with presently preferred embodiments, it will be understood by those skilled in the art that it is not intended to limit the disclosure of those embodiments. For example, the systems and methods may be applied to remove CO₂ from air in the atmosphere. It is therefore, contemplated that various alternative embodiments and modifications may be made to the disclosed embodiments without departing from the spirit and scope of the disclosure defined by the appended claims and equivalents thereof.

CLAIMS

1. A system for removing carbon dioxide from a combustion flue gas or air, comprising:
 - a first ejector having a suction port, a motive port and an outlet;
 - an ammonia solvent liquid stream in fluid communication with the first ejector motive port;
 - a mixed feed gas stream with carbon dioxide or an air stream with carbon dioxide in fluid communication with the first ejector suction port, the mixed feed gas stream comprising a combustion flue gas stream and a flash gas stream;
 - a first two-phase fluid stream in fluid communication with the first ejector outlet and a first separator;
 - a second ejector having a suction port, a motive port and an outlet;
 - a first water wash stream in fluid communication with the second ejector motive port;
 - a first gas stream connected to the first separator and the second ejector suction port, the first gas stream comprising less carbon dioxide than the mixed feed gas stream or the air stream and a residual amount of ammonia solvent from the ammonia solvent liquid stream;
 - a first liquid stream connected to the first separator, the first liquid stream comprising a portion of the ammonia solvent liquid stream and absorbed carbon dioxide;
 - a second two-phase fluid stream in fluid communication with the second ejector outlet and a second separator;
 - an absorber connected to the first water wash stream;
 - a second gas stream connected to the second separator and the absorber, the second gas stream comprising less carbon dioxide and ammonia solvent than the first gas stream;

a second liquid stream connected to the second separator, the second liquid stream comprising another portion of the ammonia solvent liquid stream, absorbed carbon dioxide and a portion of the first water wash stream; and

a treated gas stream connected to the absorber the treated gas stream comprising less carbon dioxide than the second gas stream.

2. The system of claim 1, further comprising a first heat exchanger positioned between the first ejector and the first separator and enclosing a portion of the first two-phase fluid stream and a first portion of a cooled water stream.

3. The system of claim 2, further comprising a second heat exchanger enclosing a portion of a mixed liquid feed stream comprising the first liquid stream, the second liquid stream and a recovered ammonia stream and a second portion of the cooled water stream.

4. The system of claim 3, further comprising a third separator in fluid communication with the mixed liquid feed stream and connected to the flash gas stream and a third liquid stream comprising ammonia solvent in the ammonia solvent liquid stream and carbon dioxide.

5. The system of claim 4, further comprising a regenerator in fluid communication with the third liquid stream and connected to a third gas stream comprising carbon dioxide and a fourth liquid stream comprising the ammonia solvent in the ammonia solvent liquid stream and water in the first water wash stream and a second water wash stream.

6. The system of claim 5, wherein the second water wash stream is connected to an upper section of the regenerator.

7. The system of claim 6, further comprising a third heat exchanger enclosing a portion of the third liquid stream and a portion of the fourth liquid stream.

8. The system of claim 7, further comprising a fourth heat exchanger enclosing a portion of the fourth liquid stream and a portion of a fifth liquid stream comprising the first water wash stream, the second water wash stream and a third water wash stream.
9. The system of claim 8, further comprising a distillation column connected to the fourth liquid stream, the fifth liquid stream and a fourth gas stream comprising the recovered ammonia stream and a non-condensable component stream.
10. The system of claim 9, further comprising a fourth separator in fluid communication with the fourth gas stream and connected to the recovered ammonia stream and the non-condensable component stream.
11. A method for removing carbon dioxide from a combustion flue gas or air, comprising:
- routing an ammonia solvent liquid stream through a first ejector motive port;
 - drawing a mixed feed gas stream with carbon dioxide or an air stream with carbon dioxide through a first ejector suction port, the mixed feed gas stream comprising a combustion flue gas stream and a flash gas stream;
 - discharging a first two-phase fluid stream through a first ejector outlet, the first two-phase fluid stream comprising a mixture of the ammonia solvent liquid stream and one of the mixed feed gas stream and the air stream;
 - separating the first two-phase fluid stream into a first gas stream and a first liquid stream, the first gas stream comprising less carbon dioxide than the mixed feed gas stream or the air stream and a residual amount of ammonia solvent from the ammonia solvent liquid stream and the first liquid stream comprising a portion of the ammonia solvent liquid stream and absorbed carbon dioxide;
 - routing a first water wash stream through a second ejector motive port;

drawing the first gas stream through a second ejector suction port;

discharging a second two-phase fluid stream through a second ejector outlet, the second two-phase fluid stream comprising a mixture of the first water wash stream and the first gas stream;

separating the second two-phase fluid stream into a second gas stream and a second liquid stream, the second gas stream comprising less carbon dioxide and ammonia solvent than the first gas stream and the second liquid stream comprising another portion of the ammonia solvent liquid stream, absorbed carbon dioxide and a portion of the first water wash stream;

routing the first water wash stream and the second gas stream to an absorber; and

processing the first water wash stream and the second gas stream in the absorber to produce a treated gas stream comprising less carbon dioxide than the second gas stream.

12. The method of claim 11, further comprising cooling the first two-phase fluid stream.

13. The method of claim 12, further comprising cooling a mixed liquid feed stream comprising the first liquid stream, the second liquid stream and a recovered ammonia stream.

14. The method of claim 13, further comprising separating the mixed liquid feed stream into the flash gas stream and a third liquid stream comprising ammonia solvent in the ammonia solvent liquid stream and carbon dioxide.

15. The method of claim 14, further comprising separating the third liquid stream into a third gas stream comprising carbon dioxide and a fourth liquid stream comprising the ammonia solvent in the ammonia solvent liquid stream and water in the first water wash stream and a second water wash stream.

16. The method of claim 15, further comprising cooling the fourth liquid stream using the third liquid stream.

17. The method of claim 16, further comprising heating the fourth liquid stream using a fifth liquid stream comprising the first water wash stream, the second water wash stream and a third water wash stream.
18. The method of claim 17, further comprising separating the fourth liquid stream into the fifth liquid stream and a fourth gas stream comprising the recovered ammonia stream and a non-condensable component stream.
19. The method of claim 18, further comprising separating the fourth gas stream into the recovered ammonia stream and the non-condensable component stream.
20. The method of claim 11, wherein a pressure of the mixed feed gas stream or the air stream is increased from about 0 PSIG to about 15 PSIG after it is drawn through the first ejector suction port.