



(19) **United States**

(12) **Patent Application Publication**
Guidati et al.

(10) **Pub. No.: US 2012/0227440 A1**

(43) **Pub. Date: Sep. 13, 2012**

(54) **SYSTEM AND PROCESS FOR THE PHYSICAL ABSORPTION OF CARBON DIOXIDE FROM A FLUE GAS STREAM**

Publication Classification

(51) **Int. Cl.**
F25J 3/08 (2006.01)

(52) **U.S. Cl.** **62/617**

(75) **Inventors:** **Gianfranco L. Guidati**, Zurich (CH); **Jean-Marc G. Amann**, Vaxjo (SE); **Viktoria Von Zedtwitz-Nikulshyna**, Zurich (CH); **Andre Burdet**, Savigny (CH)

(57) **ABSTRACT**

Disclosed herein is a system comprising a first heat exchanger; the first heat exchanger being operative to reduce a temperature of a carbon dioxide rich flue gas stream to about -100 to about -60 C; an absorber; the absorber being located downstream of the first heat exchanger; wherein the absorber facilitates contact between the flue gas stream and a solvent to form a carbon dioxide rich solvent stream; the solvent being operative to selectively absorb carbon dioxide over other gases present in the flue gas stream; and a valve; the valve being located downstream of the absorber; the valve being operative to reduce a pressure on the carbon dioxide rich solvent stream to produce carbon dioxide and a lean carbon dioxide solvent stream.

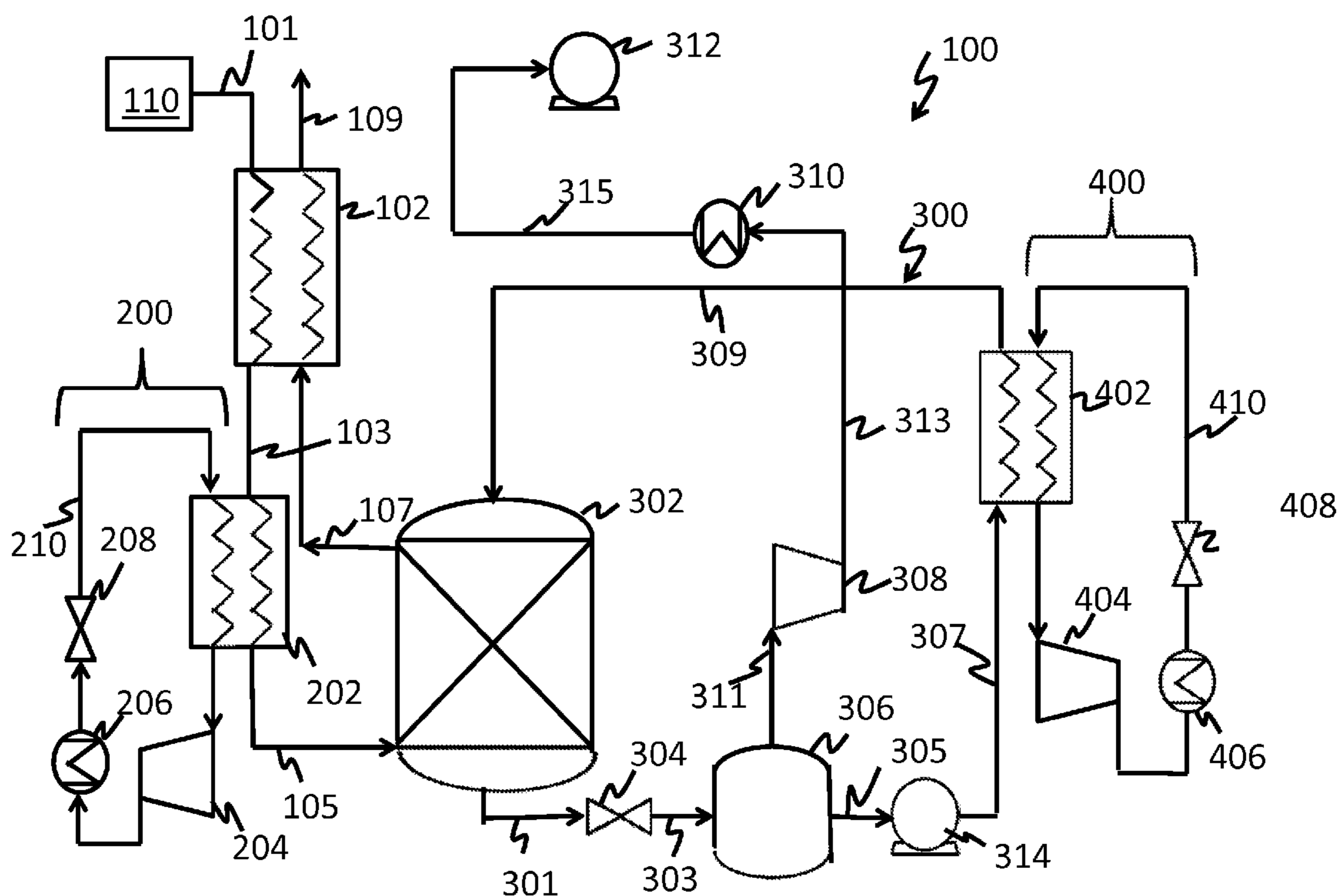
(73) **Assignee:** **ALSTOM TECHNOLOGY LTD.**, Baden (CH)

(21) **Appl. No.:** **13/414,132**

(22) **Filed:** **Mar. 7, 2012**

Related U.S. Application Data

(60) Provisional application No. 61/451,278, filed on Mar. 10, 2011.



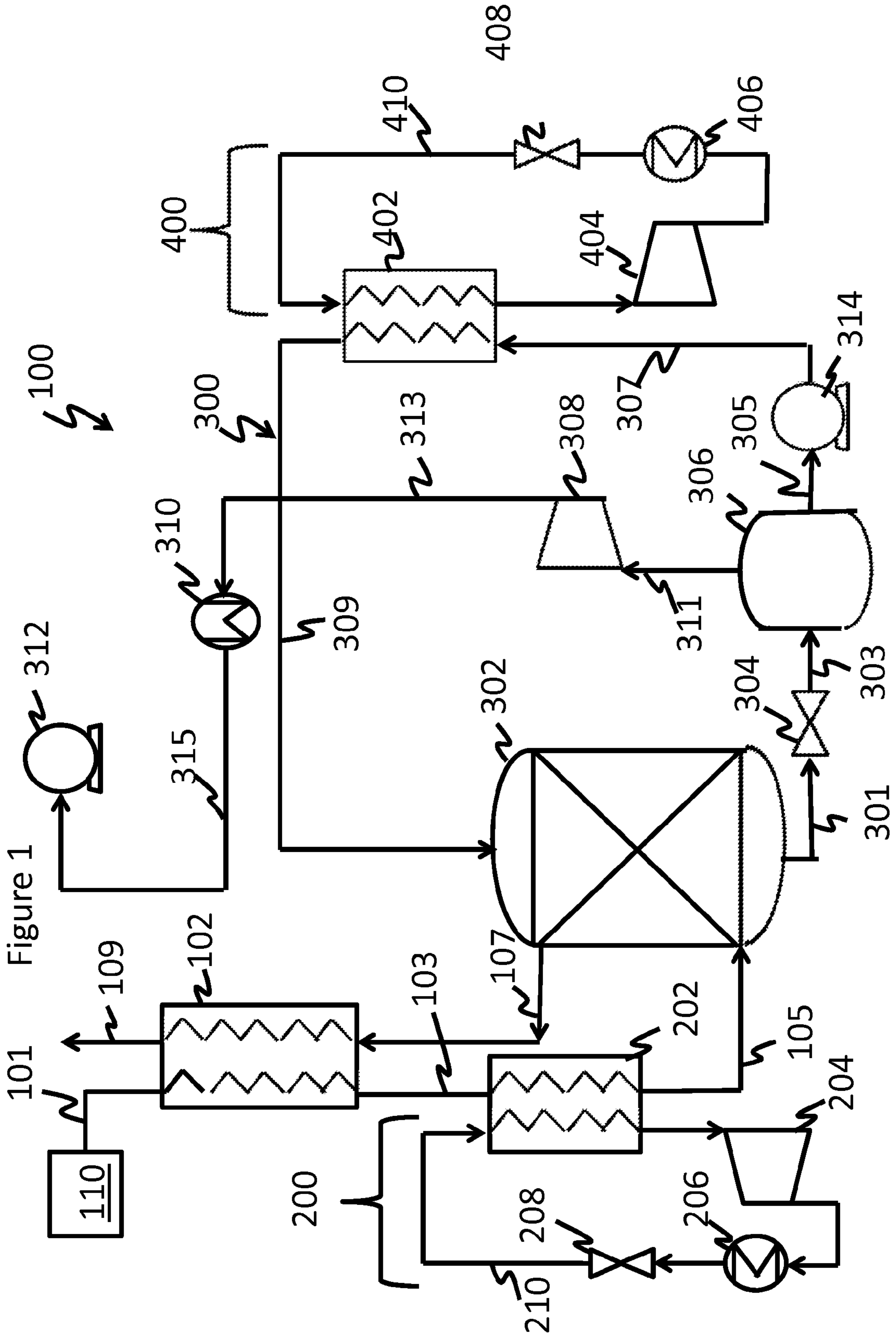
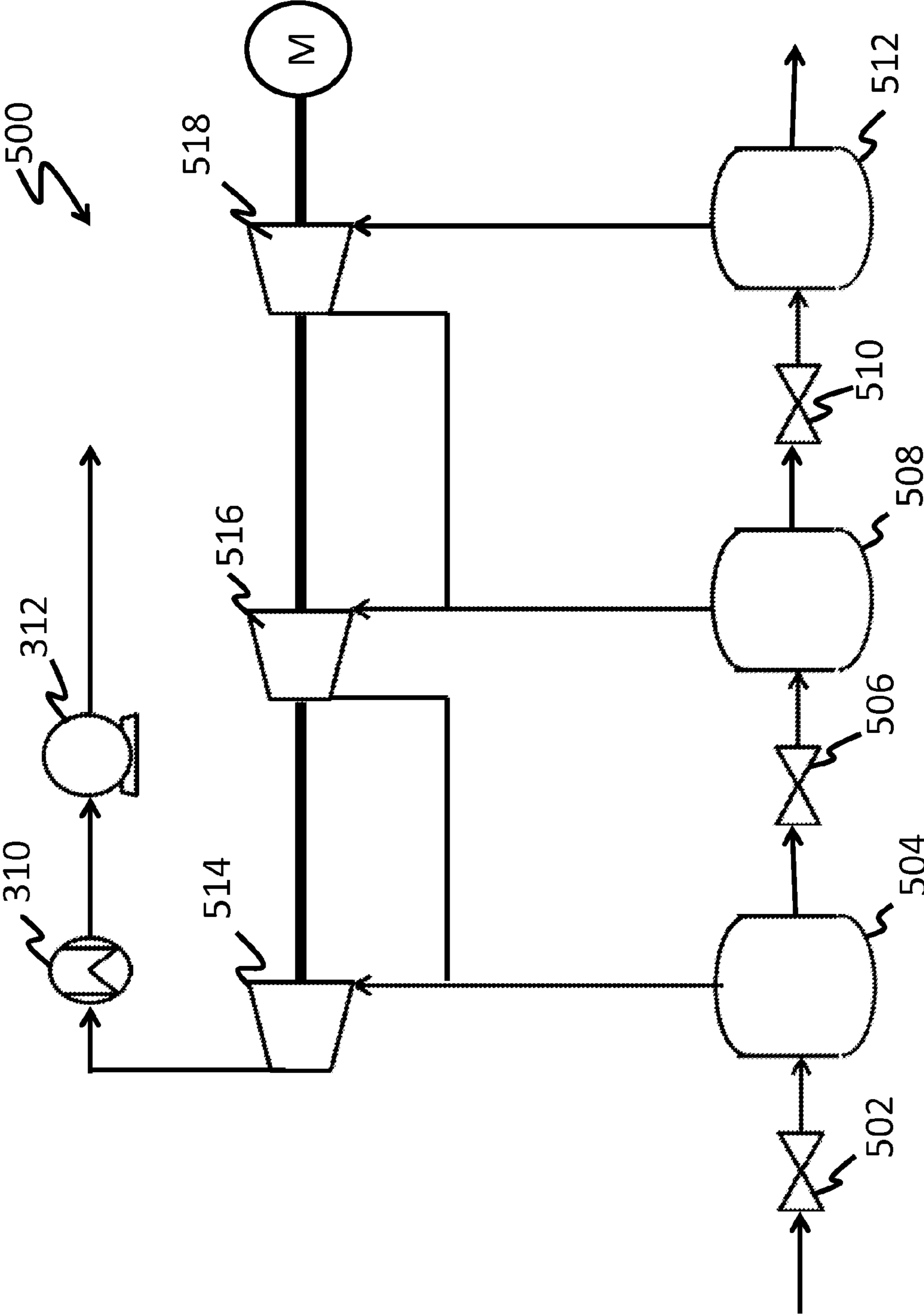


Figure 2



**SYSTEM AND PROCESS FOR THE
PHYSICAL ABSORPTION OF CARBON
DIOXIDE FROM A FLUE GAS STREAM**

CROSS REFERENCE TO RELATED
APPLICATION

[0001] This reference claims priority to U.S. Provisional Application No. 61/451,278 filed on Mar. 10, 2011, the entire contents of which are hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] This disclosure relates to a system and to a process for the physical absorption of carbon dioxide from a flue gas stream. In particular, this disclosure relates to a method and system for the physical absorption of carbon dioxide (CO₂) from a process gas stream using a solvent.

BACKGROUND

[0003] In the combustion of a fuel (e.g., coal, oil, peat, waste, biofuel, natural gas, or the like) in combustion plants used for the generation of power or for the production of materials such as cement, steel or glass, or the like, a stream of hot flue gas (also sometimes known as process gas) is generated. Such a hot flue gas contains, among other components, carbon dioxide (CO₂). The negative environmental effects of releasing carbon dioxide to the atmosphere have been widely recognized, and have resulted in the development of processes adapted for removing carbon dioxide from the hot flue gas using a liquid solvent to absorb the carbon dioxide from the gas.

[0004] While such processes are believed to be effective, there remains a need to reduce the power utilized to operate the system (so called ‘parasitic power’), and to reduce the expense and environmental impact of the solvent caused by solvent loss.

SUMMARY

[0005] Disclosed herein is a system comprising a first heat exchanger; the first heat exchanger being operative to reduce a temperature of a carbon dioxide rich flue gas stream to about -100 to about -60° C.; an absorber; the absorber being located downstream of the first heat exchanger; wherein the absorber facilitates contact between the flue gas stream and a solvent to form a carbon dioxide rich solvent stream; the solvent being operative to selectively absorb carbon dioxide over other gases present in the flue gas stream; and a valve; the valve being located downstream of the absorber; the valve being operative to reduce a pressure on the carbon dioxide rich solvent stream to produce carbon dioxide and a lean carbon dioxide solvent stream.

[0006] Disclosed herein is a method for capture of carbon dioxide from a flue gas stream, the process comprising receiving a carbon dioxide rich flue gas stream from an emitter; the carbon dioxide rich flue gas stream being at the pressure and temperature of the emitter; refrigerating the carbon dioxide rich flue gas stream to a pressure of greater than or equal to about 101.325 kPa and a temperature of about 0° C. to about the melting point of carbon dioxide for a given molar concentration of carbon dioxide within the carbon dioxide rich flue gas stream; contacting the refrigerated carbon dioxide rich flue gas stream with a lean liquid carbon dioxide solvent stream; the lean liquid carbon dioxide solvent stream having a higher solubility for carbon dioxide than of other gases

present in the carbon dioxide rich flue gas stream; absorbing carbon dioxide with a liquid solvent to provide a carbon dioxide rich solvent stream and a lean carbon dioxide flue gas stream; and decreasing pressure of the carbon dioxide rich solvent stream to provide the lean liquid carbon dioxide solvent stream and carbon dioxide gas.

BRIEF DESCRIPTION OF THE FIGURES

[0007] FIG. 1 depicts an exemplary system for capturing carbon dioxide from a flue gas stream; and

[0008] FIG. 2 schematically depicts an exemplary multi-stage desorption system that may be used in the system of FIG. 1.

DETAILED DESCRIPTION

[0009] Disclosed herein is a system and a method for treating a solvent stream that contains carbon dioxide that is extracted from a flue gas stream generated in a power plant. The system advantageously comprises an absorber tower in fluid communication with a flash tank, and a valve or a turbine. In the absorber tower (hereinafter ‘absorber’), carbon dioxide is selectively absorbed from a carbon dioxide rich flue gas stream into a solvent in an absorber, while in the flash tank, the absorbed carbon dioxide is released from the solvent and then discharged into a pipeline from which it is then sequestered or used for other processes.

[0010] In one embodiment, the method for capture of the carbon dioxide from a flue gas comprises refrigerating a carbon dioxide rich flue gas (RFG) stream at a pressure of greater than or equal to about 101.325 kPa and a temperature of about 0° C. to about the melting point of carbon dioxide for the given molar concentration of carbon dioxide within the carbon dioxide rich flue gas stream. The carbon dioxide rich flue gas stream emanating from the emitter has a pressure greater than or equal to about atmospheric pressure and a temperature of about 40 to about 60° C. In one embodiment, the pressure of the refrigerated carbon dioxide rich flue gas stream can be up to about 1000 kPa.

[0011] The method further comprises contacting the refrigerated carbon dioxide rich flue stream with a lean carbon dioxide solvent having a higher solubility for the carbon oxide (in the flue gas stream) than for nitrogen and oxygen at the carbon dioxide rich flue gas stream temperature. The contact between the carbon dioxide rich flue gas stream and the solvent results in the extraction of carbon dioxide from the carbon dioxide rich flue gas stream to produce a lean carbon dioxide flue gas stream and a carbon dioxide rich solvent stream. By decreasing the pressure of the carbon dioxide rich solvent stream, the carbon dioxide is desorbed along with the production of a lean carbon dioxide solvent stream. The desorbed carbon dioxide is separately sequestered.

[0012] This system has a number of advantages because the solvent selectively absorbs carbon dioxide from the flue gas, while not interacting with other flue gas constituents such as nitric oxides (NO_x), sulfur oxides (SO_x), and the like. The other flue gas constituents such as NO_x and SO_x may be removed upstream of the system if desired. This means that the stream of carbon dioxide obtained after the separation from the solvent can be advantageously used for other chemical purposes (other than sequestration) if desired.

[0013] The FIG. 1 depicts a system 100 for removing carbon dioxide from a carbon dioxide rich flue gas stream. The system comprises a first heat exchanger 102 in fluid commu-

nication with a first active cooling loop **200**, an absorption-desorption loop **300** and a second active cooling loop **400**. The absorption-desorption loop comprises an absorber **302**, a valve **304**, a flash tank **306**, absorber **302**, valve **304**, a pump **314** and a compressor **308**. The first heat exchanger **102** lies downstream of a flue gas emitter **110** at which the flue gas stream (from which carbon dioxide is to be removed) is generated. The flue gas stream may pass through other devices such as scrubbers (not shown) where other contaminants such as oxygen, nitrogen and particulate matter can be removed prior to entering the first heat exchanger **102**.

[0014] The first heat exchanger **102** lies upstream of the first active cooling loop **200**, the absorption-desorption loop **300** and the second active cooling loop **400**. The first heat exchanger **102** can comprise any type of heat exchanger or sequence of heat exchangers and serves to cool down the flue gas stream emanating from the flue gas stream emitter **110** to a temperature proximate to the melting point of carbon dioxide. With reference now to the exemplary embodiment depicted in the FIG. **1**, the carbon dioxide rich flue gas stream **101** emanating from flue gas stream emitter **110** is cooled in the first heat exchanger **102** by a counter current flow of a cooled lean carbon dioxide flue gas stream **107** that emanates from the absorber **302**. The carbon dioxide rich flue gas stream **101** generally contains about 3 to about 30 molar percent (mol %) carbon dioxide based on the total weight of the carbon dioxide rich flue gas stream **101**. The lean carbon dioxide flue gas stream **107** generally contains about 0 to about 10 mol % carbon dioxide based on the total weight of the lean carbon dioxide flue gas stream **107**. In one embodiment, the first heat exchanger **102** reduces the temperature of the flue gas stream from a temperature of about 40 to about 100° C. to a temperature of about -60° to about -100° C.

[0015] In one embodiment, the first heat exchanger **102** reduces the temperature of the flue gas stream to a temperature slightly above the melting temperature of carbon dioxide. In an exemplary embodiment, it is desirable to reduce the temperature of the flue gas stream to a temperature of -78 to -60° C. In an exemplary embodiment, for a molar carbon dioxide concentration of 14% in the flue gas stream, it is desirable for the carbon dioxide rich flue gas temperature after emanating from the first heat exchanger **102** to be about -100 to -60° C.

[0016] The first heat exchanger **102** may not be a single unit but may instead optionally comprise a collection of elements with the purpose of cooling down the flue gas stream to the temperature above the melting point of carbon dioxide. For example, the first heat exchanger **102** may comprise one or more heat exchangers; direct contact cooling (DCC) towers including the capability of (i) removing SO_x from the carbon dioxide rich flue gas (RFG) stream using a pH-control system and of (ii) sub-zero cooling using a brine solution; active cooling loops, auxiliary systems such as fluid pumps, fans, and the like; and the capability to dry the carbon dioxide rich flue gas through water removal in the DCC and heat exchangers.

[0017] As noted above, the first heat exchanger **102** can be one of a variety of heat exchangers. Examples of suitable heat exchangers are a shell and tube heat exchanger, plate heat exchanger, regenerative heat exchanger, adiabatic wheel heat exchanger, plate fin heat exchanger, pillow plate heat exchanger, dynamic scraped surface heat exchanger or a phase-change heat exchanger. One or more of these heat

exchangers may be used if desired. An exemplary first heat exchanger **102** is a plate-fin heat exchanger.

[0018] After being cooled down in the first heat exchanger **102**, the carbon dioxide rich flue gas stream **103** is discharged to the first active cooling loop **200**. The first active cooling loop **200** is optional. The first active cooling loop **200** is used only to further cool down the carbon dioxide rich flue gas stream **103** when it does not reach the low temperatures desired in the first heat exchanger **102**. In one embodiment, the first active cooling loop **200** is used when the mass flow of the lean carbon dioxide flue gas stream **107** is substantially less than the mass flow of the carbon dioxide rich flue gas stream **101** and therefore cannot reduce the temperature of the rich flue gas stream **103** to the desired value of -60 to -100° C. The representation of the active cooling system **200**, as a single refrigeration loop, is symbolic and in reality may be achieved using a standard low temperature, multi-stage cooling cascade. For example, the first active cooling loop **200** may include a heat exchanger **202** for exchanging heat from the carbon dioxide rich flue gas stream to a refrigerant **210**, a compressor **204** for circulating the refrigerant **210** within the first active cooling loop **200**, a heat exchanger **206** for removing heat from the refrigerant **210**, and a throttle valve **208**. Exemplary refrigerants **210** that can be used in the first active cooling loop **200** are non-halogenated hydrocarbons such as methane, propane, propene, iso-butane, or the like, ammonia, sulfur dioxide, or the like, or a combination comprising at least one of the foregoing refrigerants. While chlorofluorocarbons may also be used as refrigerants, it is desirable to use environment-neutral refrigerants in the active cooling loops **200** and **400** respectively.

[0019] The carbon dioxide rich flue gas stream **105** emanating from the first active cooling loop **200** is then discharged to the absorption-desorption loop **300**. The absorption-desorption loop **300** comprises an absorber **302**, a valve **304**, a flash tank **306**, an adiabatic compressor **308**, a heat exchanger **310** and an intercooled compressor **312**. The valve **304**, the flash tank **306**, the adiabatic compressor **308**, the heat exchanger **310** and the intercooled compressor **312** each lie successively downstream of the absorber **302** and are in fluid communication with one another.

[0020] With regard now to the absorber **302** in the FIG. **1**, the carbon dioxide rich flue gas stream **105** enters from the bottom. The carbon dioxide rich flue gas stream **105** flows up from the bottom of the absorber and exits the absorber **302** from the top as the lean carbon dioxide flue gas stream **107**. In the absorber **302**, the carbon dioxide rich flue gas stream **105** contacts a solvent that selectively absorbs carbon dioxide from the carbon dioxide rich flue gas stream **105**. The solvent can be any solvent that selectively absorbs carbon dioxide from the flue gas stream **105** in preference to other contaminants in the flue gas stream such as nitrogen, oxygen, nitrogen oxides, sulfur oxides, particulate matter, and the like. It is desirable for the solvent to have a low melting point and a low vapor pressure at the operating (sub-zero) temperatures. It is also desirable for the solvent to display a minimal viscosity at operating (sub-zero) temperatures.

[0021] Suitable solvents for use in absorbing the carbon dioxide in the absorber are alcohols. The alcohols can be monohydric, polyhydric, aliphatic, alicyclic alcohols, or the like, or a combination comprising at least one of the foregoing alcohols. Examples of alcohols are methanol, ethanol, propanol, butanol, pentanol, hexadecan-1-ol, ethane-1,2-diol, propane-1,2,3-triol, butane-1,2,3,4-tetraol, pentane-1,2,3,4,

5-pentol, hexane-1,2,3,4,5,6-hexyl, heptane-1,2,3,4,5,6,7-heptol, prop-2-ene-1-ol, 3,7-dimethylocta-2,6-dien-1-ol, prop-2-in-1-ol, cyclohexane-1,2,3,4,5,6-hexol, (2-propyl)-5-methyl-cyclohexane-1-ol, or the like, or a combination comprising at least one of the foregoing alcohols. Exemplary alcohols are methanol, ethanol, propanol, butanol, pentanol, or a combination comprising at least one of the foregoing exemplary alcohols.

[0022] As noted above, the carbon dioxide rich flue gas stream 105 enters the absorber tower 302 from the bottom, flows upwards during which it contacts the solvent and leaves the absorber 302 at the top. The solvent enters the absorber 302 from the top as a lean carbon dioxide solvent stream 309 and leaves the absorber 302 from the bottom as a carbon dioxide rich solvent stream 301.

[0023] The pressure within the absorber is maintained at proximately atmospheric pressure during the contact between the solvent and the carbon dioxide rich flue gas stream 105. During the contact between the solvent and the carbon dioxide rich flue gas stream 105 in the absorber 302, carbon dioxide and heat from the flue gas stream is absorbed by the solvent. Carbon dioxide from the flue gas stream 105 is absorbed by the solvent via physical absorption. The heat of absorption, is mainly extracted by the solvent that warms up during the process of absorption. The lean carbon dioxide flue gas stream 107, which leaves the absorber 302 at the top is used to pre-cool the incoming carbon dioxide rich flue gas stream 101 in the aforementioned first heat exchanger 102.

[0024] The carbon dioxide rich solvent stream 301 is collected at the bottom of the absorber tower 2 and is passed to the desorption portion of the absorption-desorption loop 300. The desorption portion of the absorption-desorption loop 300 comprises a valve 304, the flash tank 306, a pump 314 and an adiabatic compressor 308.

[0025] The valve 304 is effective to the pressure of the carbon dioxide rich solvent stream 301 to a level at which the carbon dioxide extracted from the carbon dioxide rich flue gas stream 105 can be desorbed from the solvent and returns into gas phase within the flash tank 306. The solvent enters the absorber 302 from the top and leaves the absorber 302 from the bottom as a carbon dioxide rich solvent stream 301. The valve 304 can be replaced with a turbine to effect the same decrease in pressure which causes the absorbed carbon dioxide to being desorbed from the solvent. The turbine can be used when it is desirable to improve the cooling effect of the expansion and produce power.

[0026] The reduced pressure is about 5 to about 500 times lower (for a 90% carbon dioxide capture rate) than the original partial pressure of the carbon dioxide in the carbon dioxide rich flue gas stream 105. As noted above, the pressure in the absorber 302 is around atmospheric pressure. The pressure of the carbon dioxide rich solvent stream after the valve is therefore about $1/5^{th}$ atmosphere to about $1/500^{th}$ atmosphere. In an exemplary embodiment, for the aforementioned molar concentration of 14% carbon dioxide in the flue gas stream 101 and 1 bar exhaust gas pressure the pressure after the valve 304 would be about 0.010 bar. Depending on the operating conditions, this pressure may also be lower or higher.

[0027] The carbon dioxide lean solvent stream 303 and the carbon dioxide released from the solvent is collected in the flash tank 306. The lean solvent, which is in liquid form is extracted from the flash tank by a lean solvent pump 314 and discharged back to the top of the absorber 302. The lean solvent pump 314 increases the pressure of the solvent to the

level that is desired at the top of the absorber 314. The pressure at the top of the absorber 302 is about 1 atmosphere or greater. In an exemplary embodiment, the pressure of the solvent at the top of the absorber 302 is about 1 atmosphere.

[0028] The carbon dioxide gas desorbed from the solvent is drawn from the flash tank 306 by an adiabatic compressor 308. The adiabatic compressor 308 increases the pressure of the carbon gas from about 0.010 bar to a level where the temperature of the gas is above the temperature of available cooling water. Depending on the specific conditions (flash tank 4 pressure, rich solvent temperature) the exhaust pressure of the adiabatic carbon dioxide compressor 308 may be up to about 1 bar, specifically about 0.001 to about 1 bar. In order to minimize the work needed to compress the carbon dioxide to the pipeline pressure of about 100 bar, the carbon dioxide gas leaving the adiabatic carbon dioxide compressor 308 may be cooled using cooling water in a heat exchanger 310. Downstream of the heat exchanger 310, the pressure of the carbon dioxide gas is raised in several steps in an inter-cooled compressor 312 to a desired pipeline pressure, where the carbon dioxide gas may be transported for use or sequestration. In one embodiment, this compression of the carbon dioxide gas may be similar to that used in post-combustion carbon dioxide capture processes based on chemical absorption and oxy-fuel processes.

[0029] In one embodiment, the desorption portion of the absorption-desorption loop 300 may comprise a plurality of valves, flash tanks and adiabatic carbon dioxide compressors with pressure in each succeeding flash tank being less than the pressure of the preceding flash tank. In other words, a flash tank that lies downstream of a preceding flash tank has a lower pressure than that of the preceding flash tank.

[0030] With reference now to the FIG. 2, a multistage desorption system 500 comprises a first valve 502 in fluid communication with a first flash tank 504, a second valve 506, a second flash tank 508, a third valve 510, a third flash tank 512, a first adiabatic compressor 514, a second adiabatic compressor 516 and a third adiabatic compressor 518. The adiabatic compressors 514, 516 and 518 are in mechanical communication with a motor. A first stage desorption system comprises the first valve 502, a first flash tank 504 and the first adiabatic compressor 514 is in fluid communication with a second stage desorption system comprising the second valve 506, the second flash tank 508 and the second adiabatic compressor 516 and a third desorption system comprising the third valve 510, the third flash tank 512 and the third adiabatic compressor 518. The pressure P1 of the carbon dioxide in the first stage desorption system after the first valve 502 is higher than the pressure P2 of the carbon dioxide in the second stage desorption system after the second valve 506, which is in turn greater than the pressure P3 of the carbon dioxide in the third stage desorption system after the third valve 510. The carbon dioxide released by the multistage desorption system 500 is pressurized (as detailed above) in the intercooled compressor 312. The carbon dioxide may also be cooled using cooling water in a heat exchanger 310 that lies upstream of the intercooled compressor 312.

[0031] This multi-stage arrangement allows the system to collect as much carbon dioxide as possible at a pressure greater than the aforementioned minimum pressure of about 0.010 bar. This arrangement also reduces the power consumption and the size and costs of the adiabatic carbon dioxide compressor. While the FIG. 2 shows a possible arrangement with three pressure level stages, it is contemplated that the

number of pressure level stages may be greater than 3 or less than 3 but greater than or equal to 1.

[0032] With reference now to the FIG. 1, it may be seen that a second active cooling system 400 may optionally be used on the lean solvent as well. The second active cooling system 400 is optional and functions in much the same manner as the first active cooling system 200. For example, the second active cooling loop 400 may include a second heat exchanger 402 for exchanging heat from the lean solvent stream 307 to a refrigerant 410, a compressor 404 for circulating the refrigerant 410 within the second active cooling loop 400, a heat exchanger 406 for removing heat from the refrigerant 410, and a throttle valve 408. The second active loop 400 may be used to cool down the lean carbon dioxide solvent stream 309 to temperatures where it will most selectively extract carbon dioxide from the carbon dioxide rich flue gas stream 105.

[0033] The disclosed process is advantageous in a variety of ways. The power consumption of the current method of system 100 is estimated to be low compared to other carbon dioxide capture systems that use solvents which selectively extract carbon dioxide from flue gas streams. This is because the carbon dioxide rich flue gas stream 105 is at about atmospheric pressure during the absorption stage (within absorber 302) no flue gas compression is needed, and since the solvent is regenerated via expansion by valve(s) 304 and flash tank(s) 306, the main power consuming element of system 100 are the carbon dioxide compressors 308 and 312. Use of a high-efficiency axial compressor as carbon dioxide compressor 308 can thus lead to low power consumption. Such a compressor could be based on technology used in gas turbines.

[0034] In addition, the solvent losses in the method of system 100 are expected to be very low because of the low operation temperature (e.g., a carbon dioxide rich flue gas stream temperature of about -100 to -60° C. in the absorber 302. Furthermore, because the system 100 may be installed with minimal changes to an existing carbon dioxide recovery system (e.g., no need to install compressors to increase the pressure of the rich flue gas stream), the system 10 can be installed on an existing power plant without a long shut-down period.

[0035] It will be understood that, although the terms “first,” “second,” “third” etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, “a first element,” “component,” “region,” “layer” or “section” discussed below could be termed a second element, component, region, layer or section without departing from the teachings herein.

[0036] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” or “includes” and/or “including” when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0037] Furthermore, relative terms, such as “lower” or “bottom” and “upper” or “top,” may be used herein to describe one element’s relationship to other elements as illustrated in the Figures. It will be understood that relative terms are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. For example, if the device in one of the figures is turned over, elements described as being on the “lower” side of other elements would then be oriented on “upper” sides of the other elements. The exemplary term “lower,” can therefore, encompass both an orientation of “lower” and “upper,” depending on the particular orientation of the figure. Similarly, if the device in one of the figures is turned over, elements described as “below” or “beneath” other elements would then be oriented “above” the other elements. The exemplary terms “below” or “beneath” can, therefore, encompass both an orientation of above and below.

[0038] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0039] Exemplary embodiments are described herein with reference to cross section illustrations that are schematic illustrations of idealized embodiments. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments described herein should not be construed as limited to the particular shapes of regions as illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, a region illustrated or described as flat may, typically, have rough and/or nonlinear features. Moreover, sharp angles that are illustrated may be rounded. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the precise shape of a region and are not intended to limit the scope of the present claims.

[0040] The term and/or is used herein to mean both “and” as well as “or”. For example, “A and/or B” is construed to mean A, B or A and B.

[0041] The transition term “comprising” is inclusive of the transition terms “consisting essentially of” and “consisting of” and can be interchanged for “comprising”.

[0042] While the invention has been described with reference to various exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A system comprising:

a first heat exchanger; the first heat exchanger being operative to reduce a temperature of a carbon dioxide rich flue gas stream to about -100 to about -60° C.;

an absorber; the absorber being located downstream of the first heat exchanger;

wherein the absorber facilitates contact between the flue gas stream and a solvent to form a carbon dioxide rich solvent stream; the solvent being operative to selectively absorb carbon dioxide over other gases present in the flue gas stream; and

a valve; the valve being located downstream of the absorber; the valve being operative to reduce a pressure on the carbon dioxide rich solvent stream to produce carbon dioxide and a lean carbon dioxide solvent stream.

2. The system of claim **1**, further comprising a flash tank; the flash tank being operative to facilitate a separation of the carbon dioxide from the lean carbon dioxide solvent stream.

3. The system of claim **2**, where the lean carbon dioxide solvent stream after separation from the carbon dioxide is recycled to the absorber.

4. The system of claim **2**, where the carbon dioxide after separation from the lean carbon dioxide solvent stream is discharged to an adiabatic compressor and to a intercooled compressor.

5. The system of claim **2**, where the carbon dioxide after separation from the lean carbon dioxide solvent stream is sequestered.

6. The system of claim **1**, further comprising a first active cooling system located downstream of the first heat exchanger; the first active cooling system comprising a second heat exchanger and a compressor in fluid communication with one another and where the first active cooling system is operative to reduce the temperature of the carbon dioxide rich flue gas stream.

7. The system of claim **1**, further comprising a second active cooling system located downstream of the first heat exchanger; the second active cooling system comprising a second heat exchanger and a compressor in fluid communication with one another and where the second active cooling system is operative to reduce the temperature of the lean carbon dioxide solvent stream.

8. The system of claim **2**, further comprising a plurality of throttle valves, flash tanks and adiabatic compressors to separate the lean carbon dioxide solvent stream from the carbon dioxide.

9. The system of claim **1**, wherein the solvent is an alcohol.

10. The system of claim **9**, where the alcohol is ethanol, methanol, propanol, butanol, or a combination comprising at least one of the foregoing.

11. A method for capture of carbon dioxide from a flue gas stream, the process comprising:

receiving a carbon dioxide rich flue gas stream from an emitter; the carbon dioxide rich flue gas stream being at the pressure and temperature of the emitter;

refrigerating the carbon dioxide rich flue gas stream to a pressure of greater than or equal to about 101.325 kPa and a temperature of about 0° C. to about the melting point of carbon dioxide for a given molar concentration of carbon dioxide within the carbon dioxide rich flue gas stream;

contacting the refrigerated carbon dioxide rich flue gas stream with a lean liquid carbon dioxide solvent stream; the lean liquid carbon dioxide solvent stream having a higher solubility for carbon dioxide than of other gases present in the carbon dioxide rich flue gas stream;

absorbing carbon dioxide with a liquid solvent to provide a carbon dioxide rich solvent stream and a lean carbon dioxide flue gas stream; and

decreasing pressure of the carbon dioxide rich solvent stream to provide the lean liquid carbon dioxide solvent stream and carbon dioxide gas.

12. The method of claim **11**, wherein the temperature to which the carbon dioxide rich flue gas stream is refrigerated is between about -100 to -60° C.

13. The method of claim **11**, wherein the refrigerating comprises cooling the carbon dioxide rich flue gas stream using the lean carbon dioxide flue gas stream.

14. The method of claim **11**, further comprising adiabatically compressing the carbon dioxide gas.

15. The method of claim **14**, wherein the adiabatic compression is performed using an axial compressor.

16. The method of claim **11**, wherein decreasing pressure of the carbon dioxide rich solvent stream is performed using a valve and a flash tank.

17. The method of claim **11**, wherein decreasing pressure of the carbon dioxide rich solvent stream is performed in a series of pressure reduction stages.

18. The method of claim **17**, wherein each pressure reduction stage includes a valve and a flash tank or a turbine and a flash tank.

19. The method of claim **11**, wherein at least one of the carbon dioxide rich flue gas stream and the carbon dioxide lean solvent stream is cooled by an active cooling loop.

20. The method of claim **11**, wherein the carbon dioxide rich flue gas stream is created by one of a fossil-fired power plant, a bio-fuel fired power plant or an industrial process.

* * * * *