



(51) International Patent Classification:
F17C 5/06 (2006.01) *F17C 9/00* (2006.01)

(21) International Application Number:
PCT/US2011/060090

(22) International Filing Date:
10 November 2011 (10.11.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/413,122 12 November 2010 (12.11.2010) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

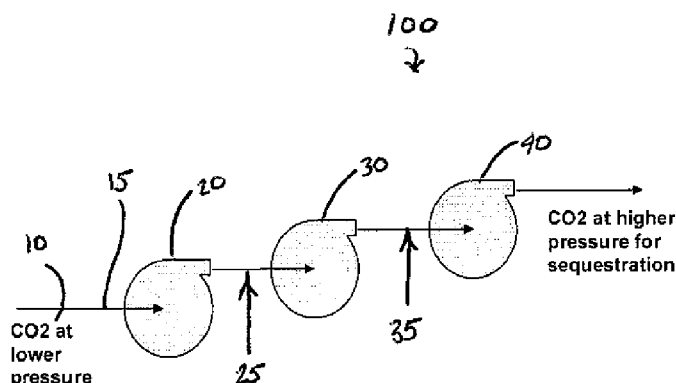
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: ABSORPTION CHILLING FOR COMPRESSING AND TRANSPORTING GASES

Figure 1



Multi-Stage Compression for CO2 Sequestration

(57) Abstract: A gas transport system including a conduit (e.g., a pipeline) containing a feed of a gas at a first temperature and first pressure, a source of a refrigerant from an adsorption system in thermal communication with the conduit to cool the feed of gas to a reduced temperature, and at least one compressor to receive the cooled feed of gas and increase the amount of cooled feed of gas to a second pressure, in which the second pressure is greater than the first pressure.

ADSORPTION CHILLING FOR COMPRESSING AND TRANSPORTING GASES

FIELD

[0001] The present invention relates to methods and systems of employing an adsorption process to cool a gas in the process of being compressed or transported. These methods and systems are particularly applicable to greenhouse gas sequestration efforts, such as for use in carbon dioxide sequestration.

BACKGROUND

[0002] Gas is transported in a variety of ways for a variety of needs. For example, natural gas often must be transported a great distance from a source to substations and/or consumers. Furthermore, it is often necessary or beneficial to compress a gas for transportation or subsequent treatment. For example, during carbon capture and sequestration efforts, gases must be compressed and transported by pipeline or conduit to a remote location. This is particularly relevant in refineries and the like since carbon sequestration could play a significant role in helping to reduce CO₂ emission from the use of fossil fuels. To achieve this high pressure, it often may be necessary to use a multi-stage compression technique, as compressors have a limited compression ratio. Furthermore, although the use of multi-stage compressors can adequately increase the pressure of CO₂, this process can also increase the temperature of CO₂ to unacceptable levels. If the temperature at intermediate compression stages can be reduced, it can significantly increase the moles of CO₂ being compressed by the next stage, thus increasing the efficiency of the process.

[0003] Accordingly, there remains a need to cool gas streams that are transported with the aid of compressors. Preferably, the cooling can be provided with little to no operating costs and can take advantage of resources provided by the conduit or pipeline itself.

SUMMARY

[0004] According to one aspect of the present application, a gas transport system is provided. The gas transport system includes a conduit (e.g., a pipeline) containing a feed of a gas at a first temperature and first pressure, a source of a refrigerant from an adsorption system in thermal communication with the conduit to cool the feed of gas to a reduced temperature, and at least one compressor to receive the cooled feed of gas and increase the cooled feed of gas to a second pressure, in which the second pressure is greater than the first pressure.

[0005] According to another aspect of the present application, a method of transporting a gas is provided. The method of transporting the gas includes providing a conduit containing a feed of a gas at a first temperature and first pressure, directing a source of a refrigerant from an adsorption system to the conduit to thermally communicate with the conduit and cool the feed of gas to a reduced temperature, and introducing the cooled feed of gas to at least one compressor to increase the cooled feed of gas to a second pressure, in which the second pressure is greater than the first pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 is a schematic representation of a multi-stage compression system for carbon dioxide sequestration, along with possible points in which inter-stage adsorption chilling can be applied to cool the compressed gas and improve compressor performance downstream.

[0007] Figure 2 is a schematic representation of the multi-stage compression system of Figure 1, in which an adsorption system refrigerant is used to cool the transported gas via a heat exchanger.

DETAILED DESCRIPTION

Definitions

[0008] As used herein, the term “fluid” refers to a liquid or gas that can reversibly bind to the adsorbent, in a chemical or physical sense. Because the fluid is generally directed to an expansion valve, or other apparatus to provide a cooled fluid stream, the term “refrigerant” can generally be used interchangeably with the term “fluid.”

[0009] As used herein, the term “vessel” refers to an enclosed container suitable for containing an absorbent and a fluid under suitable conditions to permit adsorption and desorption.

[0010] As used herein, an “exhaust gas” includes any gas that is emitted from a process (e.g. an industrial process) or combustion operation.

[0011] As used herein, the term “flue gas” refers to a gas that is emitted from combustion operation and which is directly or indirectly emitted to the atmosphere (e.g., via a flue, stack, pipe or other conduit). A flue gas includes gases emitted from furnaces, boilers, ovens and combustion operations associated with petrochemical refining or chemical processing operations. Flue gas is also intended to include turbine exhausts.

[0012] As used herein, the term “unutilized heat” or “unutilized heat source” refers to the residual or remaining heat source (e.g., steam) remaining following the processing operation after the heat source has been used for its primary purpose in the refining or petrochemical processing operation. Unutilized heat is also referred to as waste heat. The unutilized heat or unutilized heat source refers to a heat source that is no longer any use in the refining and/or petrochemical processing operation and would traditionally be discarded. The unutilized heat can be provided as a unutilized heat stream. For example, but not limitation, unutilized heat can include steam that was employed in a heat exchanger used in petroleum and petrochemical processing, and is of no value to current processes and is being discarded. Flue gases are an effective waste heat source.

[0013] As used herein, the term “pump” refers to a device to assist in transporting fluids from one place to another.

[0014] According to one aspect of the present application, a gas transport system is provided. The gas transport system includes a conduit containing a feed of a gas at a first temperature and first pressure, a source of a refrigerant from an adsorption system in thermal communication with the conduit to cool the feed of gas to a reduced temperature, and at least one compressor to receive the cooled feed of gas and increase the cooled feed of gas to a second pressure, in which the second pressure is greater than the first pressure.

[0015] According to one embodiment, the conduit contains a feed of a greenhouse gas, such as carbon dioxide. Particularly in those embodiments in which the gas is a

greenhouse gas, the system can further include a subterranean outlet to receive and sequester the greenhouse gas. The subterranean outlet can further include a hydrocarbon deposit. In addition to sequestering the greenhouse gas, introducing the greenhouse gas to the subterranean outlet can also aid in the extraction of the hydrocarbon deposit.

[0016] The gas, particularly for example, a greenhouse gas such as carbon dioxide, can be obtained, at least in part, from an exhaust gas (e.g., a flue gas), including exhaust gases from petrochemical refining operations. In one embodiment, a pre-transport adsorption system is provided that selectively adsorbs the carbon dioxide from the exhaust gas to selectively adsorb carbon dioxide from the exhaust gas to obtain the feed to the gas transport system. Further details of this method are described in co pending US Patent Application No. 13--/292,393, which claims priority to US Provisional Patent Application No. 61/413,111 filed on November 12, 2010, entitled "Recovery of Greenhouse Gas and Pressurization for Transport", which is hereby incorporated by reference in its entirety.

[0017] In one embodiment, the adsorption system includes an adsorbent capable of adsorbing the refrigerant and in fluid communication with the refrigerant, a heating source to heat the adsorbent and desorb the refrigerant therefrom, and an expansion valve to receive a supply of the refrigerant that has been desorbed from the adsorbent. In a preferred embodiment, the adsorption system further includes a cooling source to cool the adsorbent and adsorb the refrigerant. The adsorbents used in the adsorption system can be selected from, for example, zeolites, zeolitic imidazolate frameworks (ZIFs), Metal-Organic Frameworks (MOFs), and any combination thereof.

[0018] In certain embodiments, the adsorption system makes use of the existing gas pipeline infrastructure to achieve additional efficiencies. For example, when the gas to be transported is carbon dioxide, the refrigerant can also be carbon dioxide. Thus, a supply of refrigerant for the adsorption system can be readily obtained from the pipeline itself. In an alternative embodiment, the heat source includes a supply of heating fluid in thermal communication with the feed of gas exiting the compressor to heat the heating fluid. The heating fluid is heated since the feed of gas exiting the compressor is at higher temperature, thereby also lowering the temperature of the gas in the conduit.

[0019] In one embodiment, a series of at least two compressors are provided to obtain the pressurized source of greenhouse gas. The refrigerant can be introduced to the gas downstream of a first compressor and upstream of a second compressor so as to exchange heat with the gas exiting the first compressor and cool the gas prior to entering the second compressor.

[0020] Another aspect of the present application provides a method of transporting a gas. The method includes providing at least one pipeline containing a supply of a gas, obtaining a source of a refrigerant from an adsorption system, introducing the refrigerant to the supply of gas, and introducing at least a portion of the supply of the gas to at least one compressor to obtain a pressurized source of gas.

[0021] The method will be understood from, and described in further detail with the description of the system.

[0022] Generally, and solely for exemplary purposes of illustration, an adsorption chilling system is described that include adsorbents (e.g., MOF/ZIFs/Zeolites) that adsorb a refrigerant (e.g., CO₂) at lower temperature (T₂) and lower pressure (P₂). The adsorbent bed is heated to release adsorbed working fluid (i.e., the refrigerant) in a contained vessel. The heat used can be, for example, heat from compressed CO₂, exhaust of turbines being used for compressors or some other waste heat. Alternatively, a dedicated steam source can be employed to provide heat to drive the desorption stroke. Desorption increases the pressure of the released working fluid to P₁ (> P₂). The pressurized working fluid is introduced to an expansion valve for adiabatic expansion to pressure P₂ and to reduce temperature to T₃. Chilled working fluid (i.e., refrigerant) can be used to chill compressed gas, such as greenhouse gas like CO₂, at one (or more) of the intermediate stages of CO₂ compression.

[0023] For purposes of illustration, and not limitation, an exemplary multi-stage compression system (100) for carbon dioxide sequestration is shown in Figure 1. A feed of carbon dioxide (10) is provided. This feed can be obtained, for example, from an industrial flue gas based on the techniques disclosed in co pending US Patent Application No. 13/292,393, which claims priority to US Provisional Patent Application No. 61/413,111, which is, hereby incorporated by reference in its entirety. This feed is directed, via a conduit (e.g., pipeline (15)) to a series of compressors (20, 30, 40) which

yield successively higher-pressure carbon dioxide (e.g., to a few thousand psi) for eventual sequestration, for example, in a subterranean deposit. After each compression stage, however, the temperature of the gas is increased, which in turn, reduces the amount of molecules that can be compressed by the next compressor. Accordingly, interstage adsorption chilling can be provided via, for example, heat exchangers (not shown), such as air fin heat exchangers, at locations 25 and 35.

[0024] As shown in Figure 2, an adsorption bed (110) is provided, that contains tubes packed with adsorbents (e.g., MPFs/MOFs/ZIFs/Zeolites/Carbon). The adsorption bed is adapted to receive either a feed of heat (e.g., steam) (120) or cold water (130). During an adsorption stroke, the adsorption bed is provided with a feed of cold water and the adsorbents adsorb refrigerant (e.g., CO₂). The cold water supply is valved off, and a feed of heat is then fed to the adsorption bed to heat the adsorbent bed to release adsorbed refrigerant. The present invention is not intended to be limited to the use of packed tubes; rather, other beds and arrangements are well within the scope of the present invention provided such arrangements are capable of receiving either a feed of heat or cold water.

[0025] During the desorption stroke, the temperature of the desorbed refrigerant is increased. The pressurized refrigerant is introduced to a heat exchanger (140) to reduce the temperature of the refrigerant. After exiting the heat exchanger, the refrigerant (145) is introduced to an expansion valve (150) to provide a cold refrigerant stream that can be applied, via a heat exchanger (160), for interstage cooling of a multi-stage compression carbon dioxide system in which carbon dioxide is transported at high pressure for eventual sequestration and/or to enhance downhole crude oil recovery (see Figure 1).

[0026] The adsorption system shown in Figure 2 is equipped with a second adsorption bed (170), also adapted to receive a feed of either heat (180) or cold water (190). Having two adsorption beds in parallel allows one adsorption bed to be regenerated (adsorption stroke) while the other adsorption bed is in the desorption stroke.

[0027] As shown in Figure 2, adsorption chilling which has no moving parts can be used for inter-stage cooling of compressed CO₂. Figure 2, for purposes of simplicity, shows only one intermediate stage for cooling, however, adsorption chilling could be used after

each intermediate stage for cooling the compressed CO₂. In certain embodiments, the adsorption chilling process can be employed without use of a pump.

Gases Being Transported

[0028] The systems and methods of the presently disclosed subject matter can be used to cool any gas that is being transported (e.g., in a pipeline). For example, gases being transported in a pipeline are often compressed via one or more compressors. As compressors have a limited compression ratio, a typical gas pipeline employs multiple compressors. The multi-stage compression compresses the gas to, for example, several thousand psi. Compressors increase the pressure of the gas (e.g., CO₂), but in this process, it also increases the temperature of the gas. If the temperature of the gas at an intermediate stage can be reduced, it can significantly increase the amount of moles of gas being compressed by the next stage compressor.

[0029] Accordingly, one embodiment of the presently disclosed subject matter employs an adsorption process to provide inter-stage cooling of a gas that is in the process of being transported. In other words, in certain embodiments, the cooling from an adsorption process is applied downstream from one compressor, but upstream from a second compressor to, among other things, increase the amount of gas that can be processed by the second compressor.

[0030] While not necessarily limited thereto, the systems and methods of the presently disclosed subject matter are particularly useful to cool greenhouse gases that are in the process of being transported for purposes of sequestration. Alternatively, or additionally, the greenhouse gases that are being transported can be deposited in subterranean natural resource reserves to aid in the extraction of oil, for example, or natural gas.

[0031] A person of ordinary skill in the art can determine procedures for the sequestration of greenhouse gases (e.g., carbon dioxide), once the greenhouse gas is transported to a proper location. Furthermore, sequestration details can be found, for example, in U.S. Patent Nos. 7,726,402, and 7,282,189, each of which hereby incorporated by reference. Further details regarding techniques for depositing gases downhole to aid in the recovery of crude oil and/or natural gas can be found, for example, in U.S. Published Application No. 2007/0215350, hereby also incorporated by reference.

[0032] Accordingly, an adsorption process can be used to cool, for example, carbon dioxide, methane, nitrous oxides, ozone, chlorofluorocarbons, and other greenhouse gases for which sequestration is desirable. In a preferred embodiment, the gas that is being transported is carbon dioxide.

Adsorbents

[0033] Adsorbents that can be used in embodiments of the present invention include, but are not limited to, metal-organic framework-based (MOF-based) sorbents, zeolitic imidazole framework (ZIF) sorbent materials, zeolites and carbon.

[0034] MOF-based adsorbents include, but are not limited to, MOF-based adsorbents with a plurality of metal, metal oxide, metal cluster or metal oxide cluster building units. As disclosed in International Published Application No. WO 2007/111738, which is hereby incorporated by reference, the metal can be selected from the transition metals in the periodic table, and beryllium. Exemplary metals include zinc (Zn), cadmium (Cd), mercury (Hg), and beryllium (Be). The metal building units can be linked by organic compounds to form a porous structure, where the organic compounds for linking the adjacent metal building units can include 1,3,5- benzenetribenzoate (BTB); 1,4-benzenedicarboxylate (BDC); cyclobutyl 1,4- benzenedicarboxylate (CB BDC); 2-amino 1,4 benzenedicarboxylate (H₂N BDC); tetrahydropyrene 2,7-dicarboxylate (HPDC); terphenyl dicarboxylate (TPDC); 2,6 naphthalene dicarboxylate (2,6-NDC); pyrene 2,7-dicarboxylate (PDC); biphenyl dicarboxylate (BDC); or any dicarboxylate having phenyl compounds.

[0035] Specific materials MOF-based adsorbent materials include: MOF-177, a material having a general formula of $Zn_4O(1, 3, 5\text{-benzenetribenzoate})_2$; MOF-5, also known as IRMOF-1, a material having a general formula of $Zn_4O(1,4\text{-benzenedicarboxylate})_3$; IRMOF-6, a material having a general formula of $Zn_4O(\text{cyclobutyl } 1,4\text{-benzenedicarboxylate})$; IRMOF-3, a material having a general formula of $Zn_4O(2\text{-amino } 1,4 \text{ benzenedicarboxylate})_3$; and IRMOF-11, a material having a general formula of $Zn_4O(\text{terphenyl dicarboxylate})_3$, or $Zn_4O(\text{tetrahydropyrene } 2,7\text{-dicarboxylate})_3$; and IRMOF-8, a material having a general formula of $Zn_4O(2,6 \text{ naphthalene dicarboxylate})_3$.

[0036] Exemplary zeolitic imidazole framework (ZIF) sorbent materials include, but are not limited to, ZIF-68, ZIF-60, ZIF-70, ZIF-95, ZIF-100 developed at the University of

California at Los Angeles and generally discussed in Nature 453, 207-211 (8 May 2008), hereby incorporated by reference in its entirety.

[0037] Zeolite adsorbent materials include, but are not limited to, aluminosilicates that are represented by the formula $M_{2/n}O \cdot Al_2O_3 \cdot ySiO_2 \cdot wH_2O$, where y is 2 or greater, M is the charge balancing cation, such as sodium, potassium, magnesium and calcium, N is the cation valence, and w represents the moles of water contained in the zeolitic voids. Examples of zeolites that can be included in the methods and systems of the present application include natural and synthetic zeolites.

[0038] Natural zeolites include, but are not limited to, chabazite (CAS Registry No. 12251-32-0; typical formula $Ca_2[(AlO_2)_4(SiO_2)_8] \cdot 13H_2O$), mordenite (CAS Registry No. 12173-98-7; typical formula $Na_8[(AlO_2)_8(SiO_2)_{40}] \cdot 24H_2O$), erionite (CAS Registry No. 12150-42-8; typical formula $(Ca, Mg, Na_2, K_2)_{4.5}[(AlO_2)_9(SiO_2)_{27}] \cdot 27H_2O$), faujasite (CAS Registry No. 12173-28-3, typical formula $(Ca, Mg, Na_2, K_2)_{29.5}[(AlO_2)_{59}(SiO_2)_{133}] \cdot 235H_2O$), clinoptilolite (CAS Registry No. 12321-85-6, typical formula $Na_6[(AlO_2)_6(SiO_2)_{30}] \cdot 24H_2O$) and phillipsite (typical formula: $(0.5Ca, Na, K)_3[(AlO_2)_3(SiO_2)_5] \cdot 6H_2O$).

[0039] Synthetic zeolites include, but are not limited to, zeolite A (typical formula: $Na_{12}[(AlO_2)_{12}(SiO_2)_{12}] \cdot 27H_2O$), zeolite X (CAS Registry No. 68989-23-1; typical formula: $Na_{86}[AlO_2]_{86}(SiO_2)_{106} \cdot 264H_2O$), zeolite Y (typical formula: $Na_{56}[(AlO_2)_{56}(SiO_2)_{136}] \cdot 250H_2O$), zeolite L (typical formula: $K_9[(AlO_2)_9(SiO_2)_{27}] \cdot 22H_2O$), zeolite omega (typical formula: $Na_{6.8}TMA_{1.6}[AlO_2]_8(SiO_2)_{28} \cdot 21H_2O$, where TMA is tetramethylammonium) and ZSM-5 (typical formula: $(Na, TPA)_3[(AlO_2)_3(SiO_2)_{93}] \cdot 16H_2O$, where TPA is tetrapropylammonium).

[0040] Zeolites that can be used in the embodiments of the present application also include the zeolites disclosed in the Encyclopedia of Chemical Technology by Kirk-Othmer, Volume 16, Fourth Edition, under the heading "Molecular Sieves," which is hereby incorporated by reference in its entirety.

[0041] Synthetic zeolite adsorbent materials are commercially available, such as under the Sylosiv[®] brand from W.R. Grace and Co. (Columbia, Md.) and from Chengdu

Beyond Chemical (Sichuan, P.R. China). For example, Sylosiv[®] A10 is one commercially available zeolite 13 X product.

Fluids/Refrigerants

[0042] Non-limiting examples of fluids that can be used in accordance with the present application include, but are not limited to, carbon dioxide, methane, ethane, propane, butane, ammonia and freon. As noted above, certain embodiments make use of the gas that is being transported. For example, when carbon dioxide is being transported for sequestration, carbon dioxide can also be used as the fluid (i.e. refrigerant) in the adsorption process to provide, for example, inter-stage cooling.

Selection of Sorbent Materials and Fluids/Refrigerants

[0043] As disclosed in U.S. Published Application No. 2010/0132359, hereby incorporated by reference, a “pressure index” can be determined at various desorbing temperatures and can be used to select the sorbent material and refrigerant (i.e., the adsorption system working fluid). The pressure index is determined by the following method. One hundred (100) grams of sorbent material are placed in a 1 liter vessel designed to be isolated from associated equipment with existing valves on both ends of the vessel. The vessel also has indicators to measure inside pressure and temperature. The vessel is flushed and filled with pure fluid (e.g., CO₂) at one atmospheric pressure. The sorbent material adsorbs fluid and the sorbent may heat up. The vessel is equilibrated at 298 K and 1 atmospheric pressure, this sorbing pressure being defined as $P_I = 1.0$. The vessel is heated to a pre-selected desorbing temperature (e.g. 348 K). When the vessel and sorbent material reach the pre-selected desorbing temperature, the internal vessel pressure is measured to determine P_F . The pressure index is defined as the ratio of P_F to P_I .

[0044] Certain embodiments of the present application make use of lower temperature, unutilized heat (also referred to as waste heat). In order to select a sorbent material/fluid combination that can be used with, for example, relatively low grade waste heat, adsorbents and refrigerants can be selected with minimum pressure indexes, as defined above. In one embodiment the adsorbent and refrigerant are selected such that the pressure index is at least 1.2, or at least 1.5, or at least 3, or at least 4, or at least 6.

[0045] While not limited thereto, U.S. Published Application No. 2010/0132359 discloses details regarding an embodiment in which carbon dioxide is used as a working fluid and Zeolite 13 X is used as the adsorbent. Other appropriate adsorbents can be selected based on, for example, the working fluid (refrigerant) employed and the heat available to drive the desorption stroke.

[0046] The present invention is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and the accompanying figures. Such modifications are intended to fall within the scope of the appended claims.

[0047] It is further to be understood that all values are approximate, and are provided for description.

[0048] Patents, patent applications, publications, product descriptions, and protocols are cited throughout this application, the disclosures of each of which is incorporated herein by reference in its entirety for all purposes.

CLAIMS

1. A gas transport system comprising:
 - (a) a conduit containing a feed of a gas at a first temperature and first pressure;
 - (b) a source of a refrigerant from an adsorption system in thermal communication with the conduit to cool the feed of gas to a reduced temperature; and
 - (c) at least one compressor to receive the cooled feed of gas and increase the amount of cooled feed of gas to a second pressure, wherein the second pressure is greater than the first pressure.
2. The gas transport system of claim 1, wherein the adsorption system includes,
 - (i) an adsorbent capable of adsorbing the refrigerant and in fluid communication with the refrigerant;
 - (ii) a heating source to heat the adsorbent and desorb the refrigerant therefrom;and
 - (iii) an expansion valve to receive a supply of the refrigerant that has been desorbed from the adsorbent.
3. The gas transport system of claim 2, wherein the adsorption system further includes a cooling source to cool the adsorbent and adsorb the refrigerant.
4. The gas transport system of claim according to anyone of the preceding claims, wherein the gas is a greenhouse gas.
5. The gas transport system of claim 4, wherein the greenhouse gas is carbon dioxide.
6. The gas transport system of claim 4 or claim 5, further comprising a subterranean outlet to receive and sequester the greenhouse gas.
7. The gas transport system of claim 6, wherein the subterranean outlet to receive and sequester the greenhouse gas includes a hydrocarbon deposit.
8. The gas transport system of claim 5, wherein the feed of the carbon dioxide is obtained, at least in part, from an exhaust gas.
9. The gas transport system of claim 8, further comprising a pre-transport adsorption system to selectively adsorb carbon dioxide from the exhaust gas to obtain upon desorption the feed of the carbon dioxide at the first temperature and first pressure.

10. The gas transport system of claim 5, wherein the refrigerant is carbon dioxide.
11. The gas transport system of according to anyone of the preceding claims, wherein the heat source includes a supply of heating fluid in thermal communication with the feed of gas exiting the compressor to heat the heating fluid, wherein the feed of gas exiting the compressor is at a second temperature, the second temperature greater than the reduced temperature.
12. The gas transport system according to anyone of the preceding claims, wherein the adsorbent is selected from zeolites, zeolitic imidazolate frameworks (ZIFs), Metal-Organic Frameworks (MOFs), and any combination thereof.
13. The gas transport system according to anyone of the preceding claims, wherein a series of at least two compressors are provided to pressurize the feed of gas to an increased pressure.
14. The gas transport system of claim 13, wherein the refrigerant is introduced downstream of a first compressor and upstream of a second compressor to cool the feed of gas prior to entering the second compressor.
15. A method of transporting a gas utilizing the gas transport system according to any one of the preceding claims, the method comprising:
 - directing the source of a refrigerant from the adsorption system to the conduit to thermally communicate with the conduit and cool the feed of gas to a reduced temperature; and
 - introducing the cooled feed of gas to the at least one compressor to increase the amount of cooled feed of gas to the second pressure.

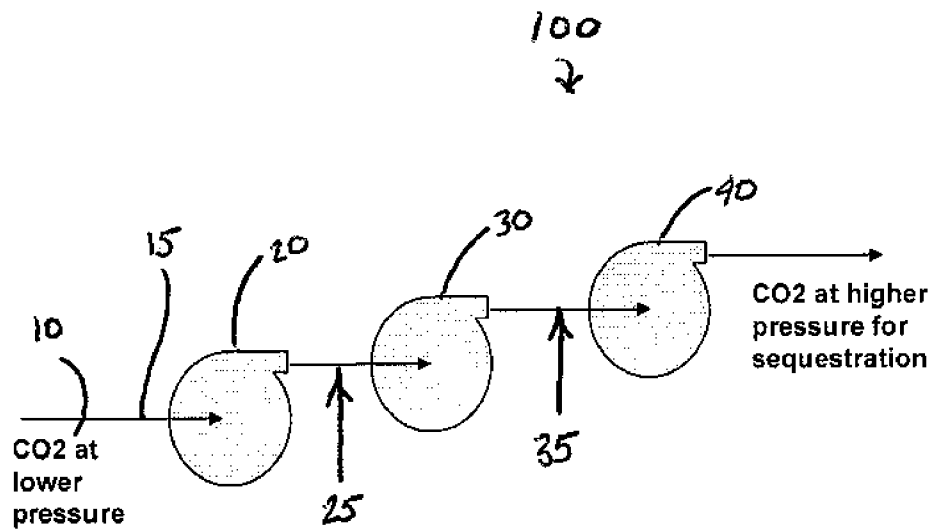
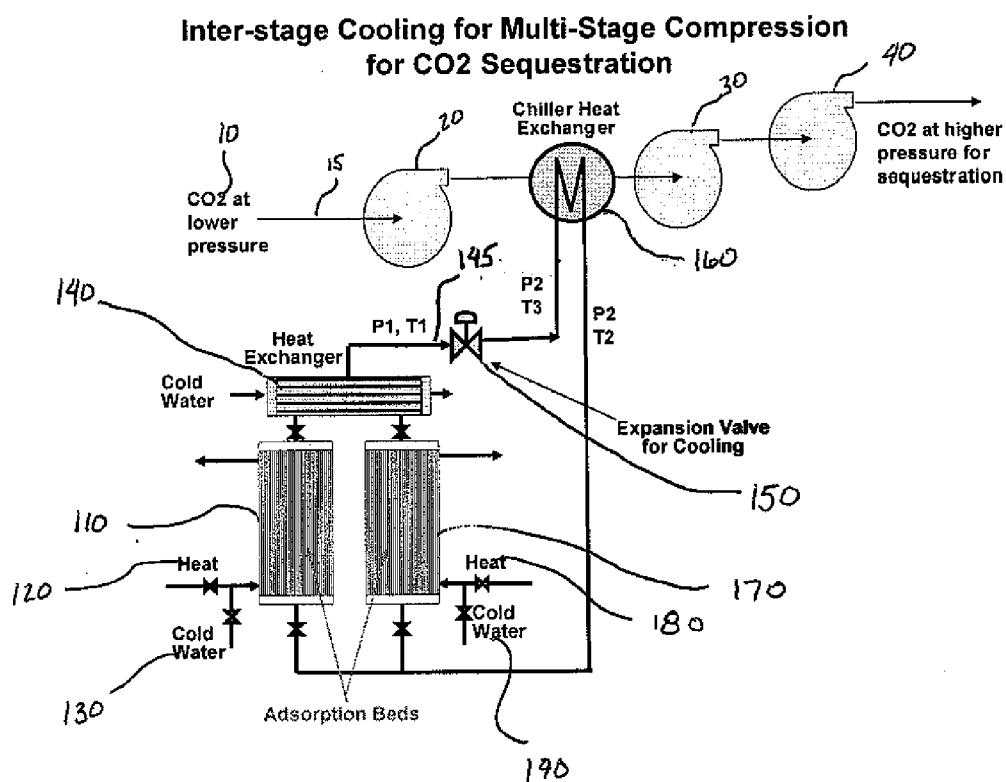
Figure 1**Multi-Stage Compression for CO2 Sequestration**

Figure 2

200



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/060090

A. CLASSIFICATION OF SUBJECT MATTER
INV. F17C5/06 F17C9/00
ADD.

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)
F17C

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 practical, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 675 890 A1 (AIR PROD & CHEM [US]) 30 October 1992 (1992-10-30) the whole document -----	1-15
X	EP 1 353 112 A1 (LINDE AG [DE]) 15 October 2003 (2003-10-15) the whole document -----	1-15
E	US 2011/302932 A1 (HOPKINS RYAN REID [US]) 15 December 2011 (2011-12-15) the whole document -----	1-15

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Further documents are listed in the continuation of Box C.

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See patent family annex.

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Date of the actual completion of the international search

23 February 2012

Date of mailing of the international search report

02/03/2012

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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