US 20120009075A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2012/0009075 A1

(43) Pub. Date: Jan. 12, 2012

Ravikumar et al.

(54) SYSTEMS FOR COMPRESSING A GAS

(75) Inventors: **Rajeshkumar Ravikumar**, Bangalore (IN); **Indrajit Mazumder**, Bangalore (IN); **Bhaskar Pemmi**, Durg (IN); **Anil Kumar Sharma**, Dist (IN)

(73) Assignee: **GENERAL ELECTRIC COMPANY**, Schenectady, NY (US)

(21) Appl. No.: **12/831,183**

(22) Filed: **Jul. 6, 2010**

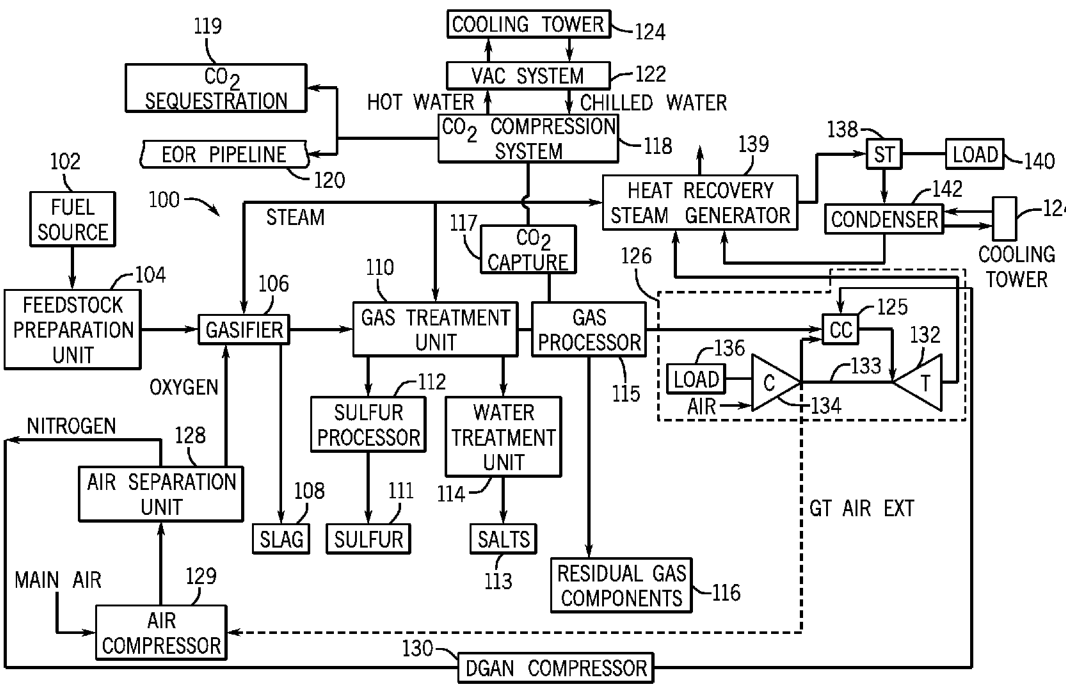
Publication Classification

(51) Int. Cl.
F04B 39/00 (2006.01)

(52) U.S. Cl. 417/313

(57) ABSTRACT

Systems for efficiently compressing a gas are included. In one embodiment, a system includes a carbonous gas compression system and a vapor absorption chiller (VAC). The carbonous gas compression system comprises a compressor configured to compress the carbonous gas. The VAC is configured to circulate a coolant through at least one coolant path through the carbonous gas compression system. Utilization of the VAC may aid in cooling the carbonous gas, which may allow for less energy to be expended by the compression system.



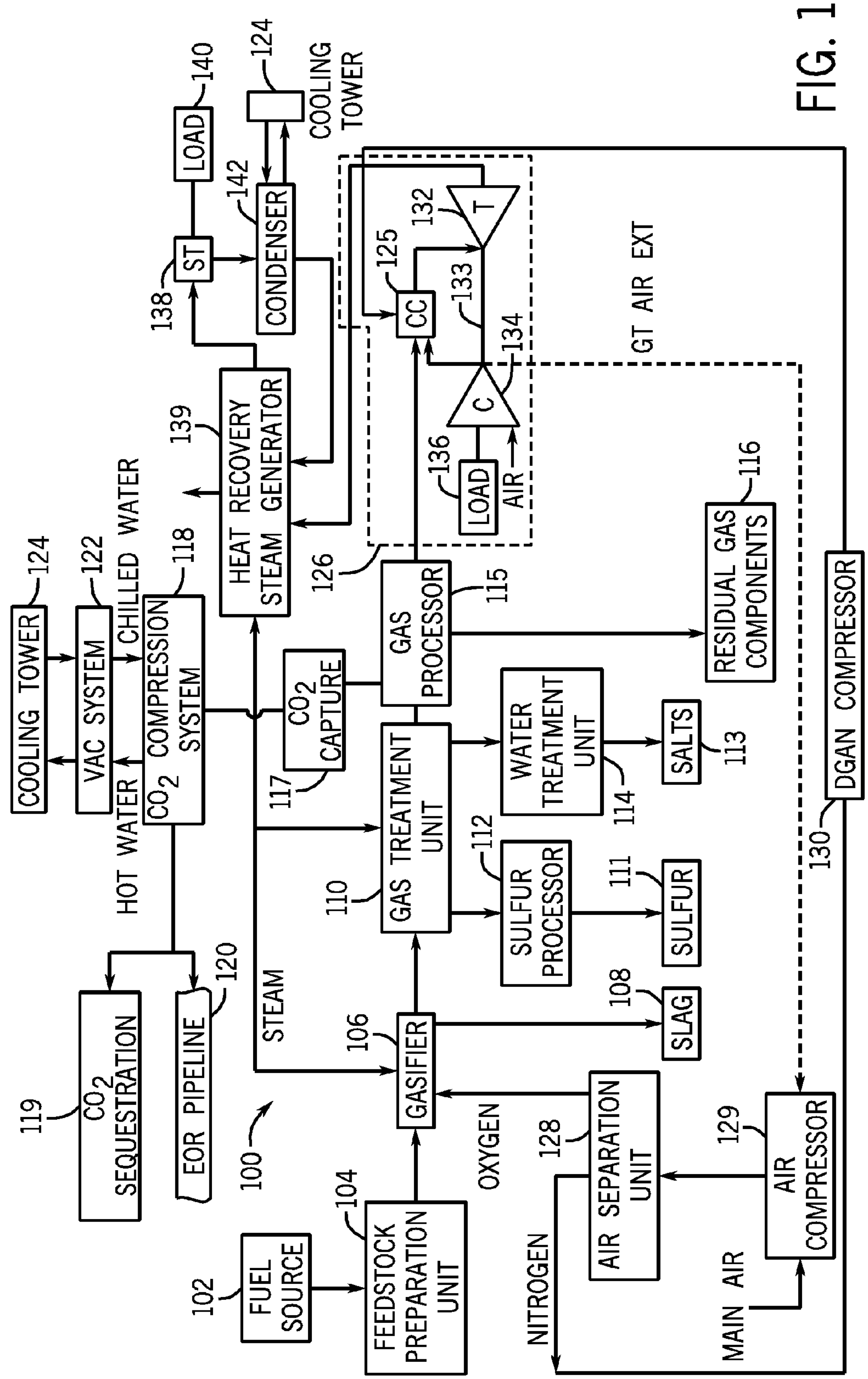

FUEL SOURCE
102
FEEDSTOCK PREPARATION UNIT
104
GASIFIER
106
SLAG
108
GAS TREATMENT UNIT
110
SULFUR
111
SULFUR PROCESSOR
112
SALTS
113
WATER TREATMENT UNIT
114
GAS PROCESSOR
115
RESIDUAL GAS COMPONENTS
116
CO_2 CAPTURE
117
CO_2 COMPRESSION SYSTEM
118
CO_2 SEQUESTRATION
119
EOR PIPELINE
120
VAC SYSTEM
122
COOLING TOWER
124
CC
125
126
AIR SEPARATION UNIT
128
AIR COMPRESSOR
129
DGAN COMPRESSOR
130
T
132
133
C
134
LOAD
136
ST
138
HEAT RECOVERY STEAM GENERATOR
139
LOAD
140
CONDENSER
142
COOLING TOWER
124
100
STEAM
HOT WATER
CHILLED WATER
OXYGEN
NITROGEN
MAIN AIR
AIR
GT AIR EXT

FIG. 1

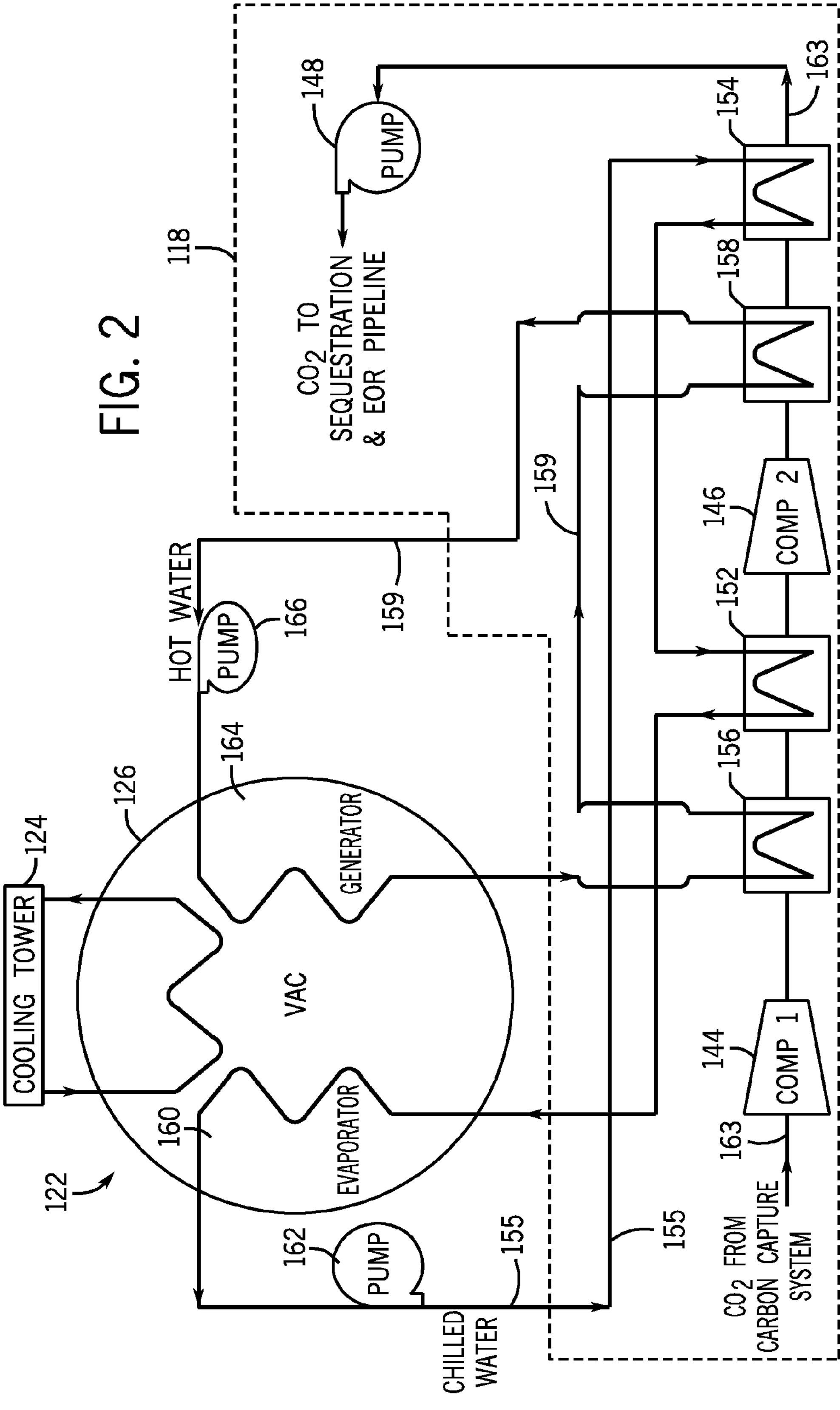

118
148
PUMP
CO_2 TO SEQUESTRATION & EOR PIPELINE
163
154
158
159
146
COMP 2
152
156
HOT WATER
PUMP
166
159
164
126
124
COOLING TOWER
GENERATOR
VAC
EVAPORATOR
160
122
144
COMP 1
163
CO_2 FROM CARBON CAPTURE SYSTEM
162
PUMP
155
155
CHILLED WATER

FIG. 2

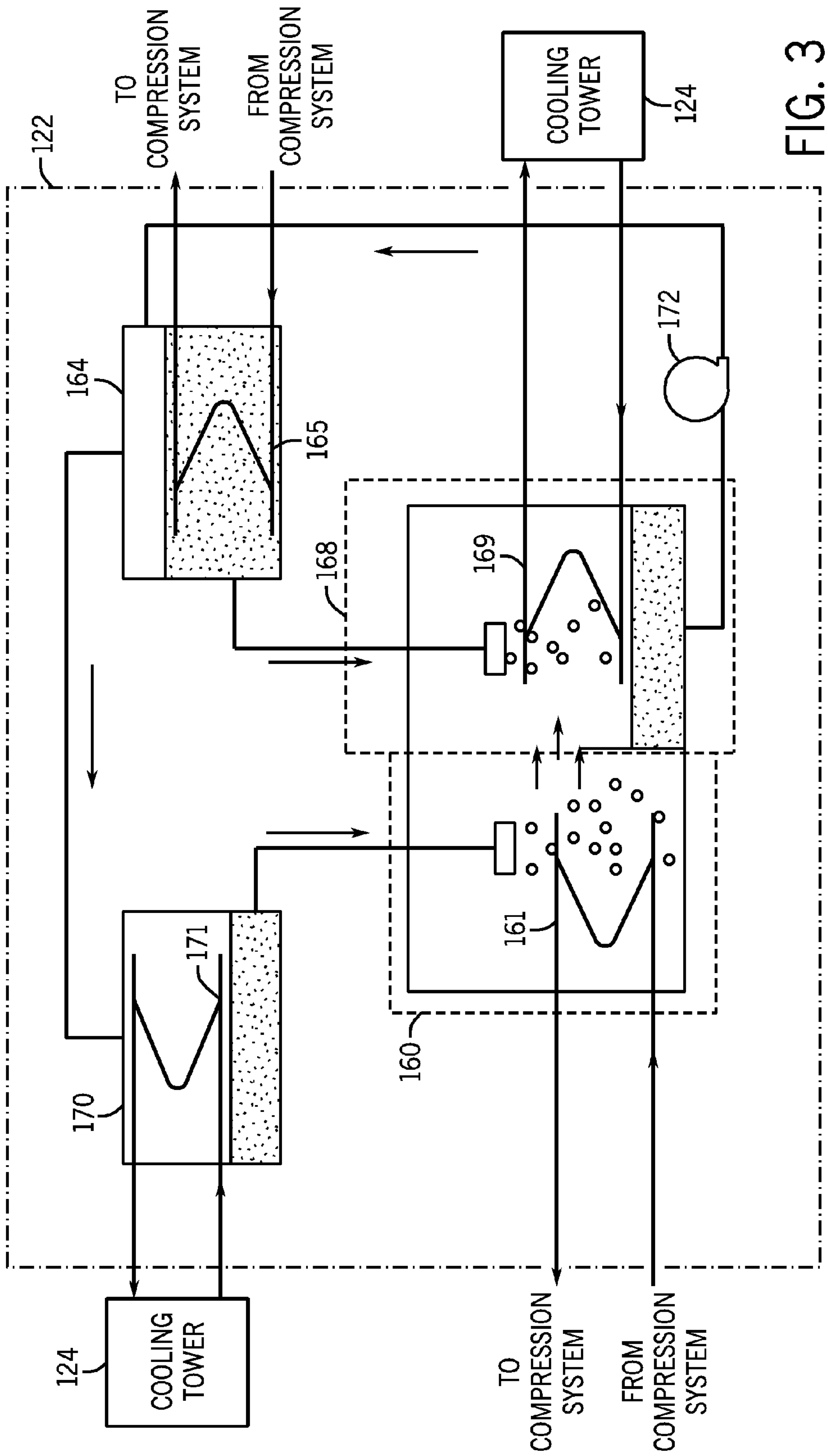
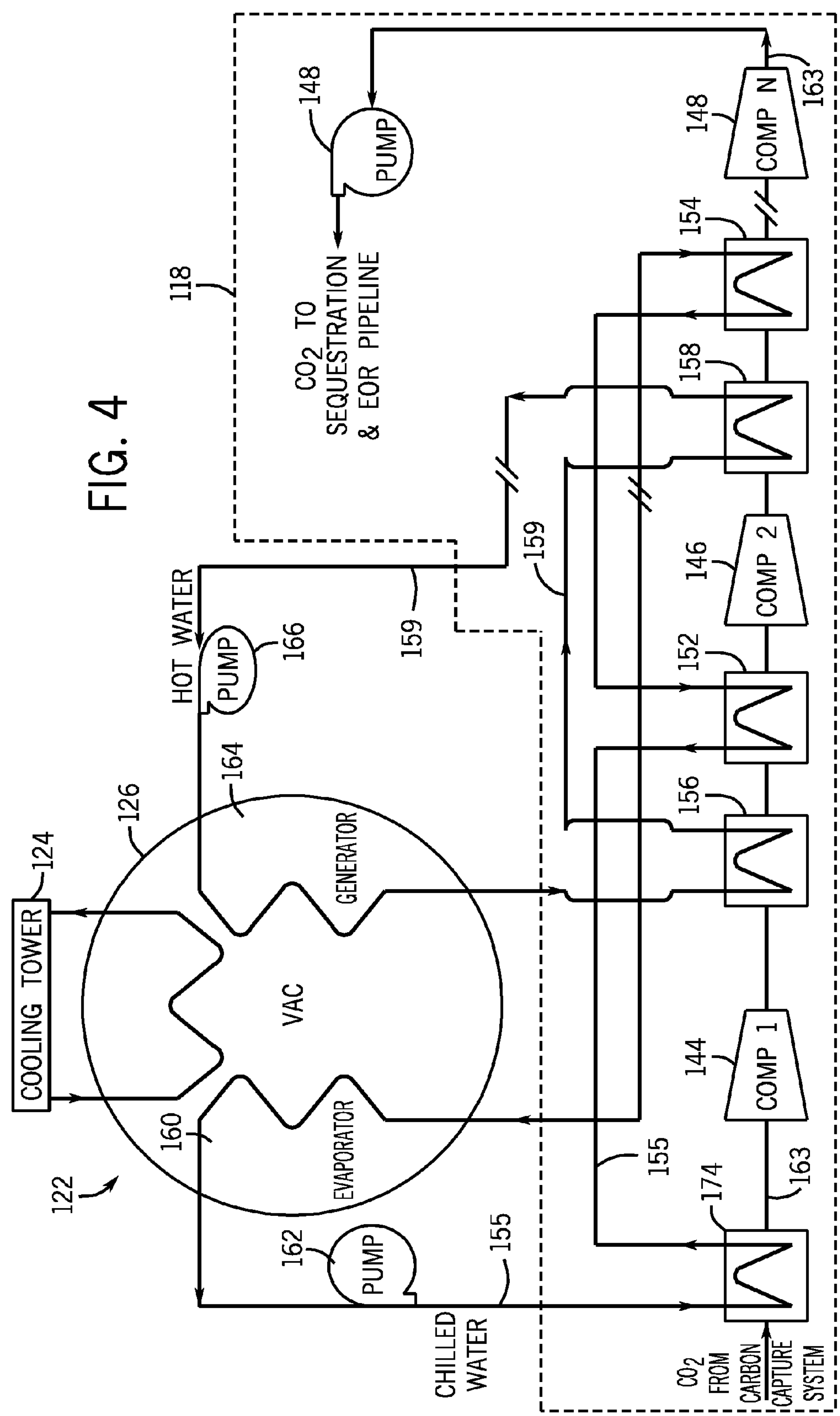

122
TO COMPRESSION SYSTEM
FROM COMPRESSION SYSTEM
COOLING TOWER
124
172
164
165
168
169
161
160
170
171
COOLING TOWER
124
TO COMPRESSION SYSTEM
FROM COMPRESSION SYSTEM

FIG. 3

FIG. 4



118
148
PUMP
CO_2 TO SEQUESTRATION & EOR PIPELINE
163
148
COMP N
154
158
159
HOT WATER
PUMP
166
159
146
COMP 2
152
156
124
COOLING TOWER
126
164
GENERATOR
VAC
144
COMP 1
160
EVAPORATOR
122
155
174
163
162
PUMP
155
CHILLED WATER
CO_2 FROM CARBON CAPTURE SYSTEM

SYSTEMS FOR COMPRESSING A GAS

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to systems for efficiently compressing a gas, such as carbon dioxide (CO_2), in a power plant such as an integrated coal gasification combined cycle (IGCC) or a coal-fired conventional power plant.

[0002] Power plants, for example IGCC power plants, may produce a carbonous gas such as CO_2. In IGCC power plants, a syngas is created by gasifying a carbonaceous fuel such as coal. The syngas may be utilized as fuel for power generation. The syngas may be fed into a combustor of a gas turbine of the IGCC power plant and ignited to power the gas turbine, which may then drive a load such as an electrical generator. One byproduct of such plants may be CO_2. Carbon capture and sequestration is very likely to be a key element of any future greenhouse gas legislation, such as CO_2 legislation. Thus, power plants may be under provisions to separate the CO_2, either pre-combustion or post combustion. The CO_2 may be captured, compressed, and sequestered. However, the compression of CO_2 requires a considerable amount of energy. Accordingly, there is a need for systems that can reduce power consumption and overall cost in the compression of CO_2.

BRIEF DESCRIPTION OF THE INVENTION

[0003] Certain embodiments commensurate in scope with the originally claimed invention are summarized below. These embodiments are not intended to limit the scope of the claimed invention, but rather these embodiments are intended only to provide a brief summary of possible forms of the invention. Indeed, the invention may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

[0004] In a first embodiment, a system includes a carbonous gas compression system and a vapor absorption chiller (VAC). The carbonous gas compression system comprises a compressor configured to compress the carbonous gas. The VAC is configured to circulate a coolant through at least one coolant path through the carbonous gas compression system.

[0005] In a second embodiment, a system includes a carbonous gas capture system, a carbonous gas compression system, a vapor absorption chiller (VAC), and at least a carbon sequestration system or an enhanced oil recovery (EOR) pipeline. The carbonous gas capture system is configured to extract the carbonous gas. The carbonous gas compression system comprises at least a compressor which is configured to receive the carbonous gas from the carbonous gas capture system and to compress and liquefy the carbonous gas. The VAC is configured to circulate a coolant through at least one coolant path through the carbonous compression system. The carbon sequestration system or the enhanced oil recovery (EOR) pipeline are configured to receive carbonous gas compressed and liquefied by the carbonous gas compression system.

[0006] In a third embodiment, a system includes a carbon dioxide (CO_2) compression system, a VAC, and a liquid pump. The CO_2 compression system comprises at least a compressor configured to compress the CO_2. The VAC is configured to circulate a coolant through at least one coolant path through the CO_2 compression system. The liquid pump is configured to raise the pressure of the CO_2.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. **1** depicts a block diagram of an embodiment of an integrated gasification combined cycle (IGCC) power plant, including a gas compression system and a vapor absorption chiller system;

[0009] FIG. **2** depicts a block diagram of embodiments of the gas compression system and the vapor absorption chiller system depicted in FIG. **1**;

[0010] FIG. **3** is a depicts a block diagram of an embodiment of a vapor absorption chiller system; and,

[0011] FIG. **4** depicts a block diagram of other embodiments of the gas compression system and the vapor absorption chiller system depicted in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

[0012] One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0013] When introducing elements of various embodiments of the present invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0014] The disclosed embodiments include systems for efficiently compressing a carbonous gas (e.g., CO_2) produced, for example, by extracting CO_2 from syngas in the integrated gasification combined cycle (IGCC) system. The compression of the carbonous gas allows the gas to be stored, for example, in a carbon sequestration system or redirected to an enhanced oil recovery (EOR) pipeline. Power plants such as IGCC power plant described in more detail with respect to FIG. **1** below, may gasify a fuel and provide for the pre-combustion capture of CO_2 from the fuel. Additionally, the CO_2 may be extracted after the fuel is combusted (i.e., post-combustion extraction), for example, from a flue gas. The CO_2 may then be transported, and stored or sequestered, for example, in a supercritical state. The supercritical state of the CO_2 refers to CO_2 that is in a fluid state while also being above both of its critical pressure and critical temperature. In such a supercritical state, CO_2 may behave as a supercritical fluid, expanding to fill a container like a gas but with a density like that of a liquid. Compressors are used to increase the CO_2

pressure from near atmospheric pressure to a supercritical phase (i.e., state), in some cases, of upwards of approximately 2215 pounds per square inch absolute (PSIA) at upwards of approximately 100° F. A more efficient system for compressing the carbonous gas is disclosed that is capable of using vapor absorption chiller (VAC) systems to lower the carbonous gas temperatures, resulting in a more efficient and less costly compression of the carbonous gas. Further, liquid compressors (e.g., liquid pumps) may also be used that use significantly less power to operate than gas compressors. Indeed, by combining vapor chiller systems with liquid compressors it may be possible to substantially reduce the amount of energy expended in reaching a supercritical phase of the carbonous gas, thereby increasing efficiency and reducing cost.

[0015] With the foregoing in mind, FIG. **1** depicts an embodiment of an IGCC power plant **100** that may produce and burn a synthetic gas, i.e., syngas. Elements of the IGCC power plant **100** may include a fuel source **102**, such as a solid feed, that may be utilized as a source of energy for the IGCC power plant **100**. The fuel source **102** may include coal, petroleum coke, biomass, wood-based materials, agricultural wastes, tars, coke oven gas and asphalt, or other carbon containing items.

[0016] The solid fuel of the fuel source **102** may be passed to a feedstock preparation unit **104**. The feedstock preparation unit **104** may, for example, resize or reshape the fuel source **102** by chopping, milling, shredding, pulverizing, briquetting, or palletizing the fuel source **102** to generate feedstock. Additionally, water, or other suitable liquids may be added to the fuel source **102** in the feedstock preparation unit **104** to create slurry feedstock. In certain embodiments, no liquid is added to the fuel source, thus yielding dry feedstock. The feedstock may be conveyed into a gasifier **106** for use in gasification operations.

[0017] The gasifier **106** may convert the feedstock into a syngas, e.g., a combination of carbon monoxide and hydrogen. This conversion may be accomplished by subjecting the feedstock to a controlled amount of any moderator and limited oxygen at elevated pressures (e.g., from approximately 600 pounds per square inch gauge (PSIG)-1200 PSIG) and elevated temperatures (e.g., approximately 2200° F.-2700° F.), depending on the type of feedstock used. The heating of the feedstock during a pyrolysis process may generate a solid (e.g., char) and residue gases (e.g., carbon monoxide, hydrogen, and nitrogen).

[0018] A combustion process may then occur in the gasifier **106**. The combustion may include introducing oxygen to the char and residue gases. The char and residue gases may react with the oxygen to form carbon dioxide and carbon monoxide, which provides heat for the subsequent gasification reactions. The temperatures during the combustion process may range from approximately 2200° F. to approximately 2700° F. In addition, steam may be introduced into the gasifier **106**. The gasifier **106** utilizes steam and limited oxygen to allow some of the feedstock to be burned to produce carbon monoxide and energy, which may drive a second reaction that converts further feedstock to hydrogen and additional carbon dioxide.

[0019] In this way, a resultant gas is manufactured by the gasifier **106**. This resultant gas may include approximately 85% of carbon monoxide and hydrogen in equal proportions, as well as CH_4, HCl, HF, COS, NH_3, HCN, and H_2S (based on the sulfur content of the feedstock). This resultant gas may be termed untreated syngas, since it contains, for example, H_2S. The gasifier **106** may also generate waste, such as slag **108**, which may be a wet ash material. This slag **108** may be removed from the gasifier **106** and disposed of, for example, as road base or as another building material. To treat the untreated syngas, a gas treatment unit **110** may be utilized. In one embodiment, the gas treatment unit **110** may be a water gas shift reactor. The gas treatment unit **110** may scrub the untreated syngas to remove the HCl, HF, COS, HCN, and H_2S from the untreated syngas, which may include separation of sulfur **111** in a sulfur processor **112** by, for example, an acid gas removal process in the sulfur processor **112**. Furthermore, the gas treatment unit **110** may separate salts **113** from the untreated syngas via a water treatment unit **114** that may utilize water purification techniques to generate usable salts **113** from the untreated syngas. Subsequently, the gas from the gas treatment unit **110** may include treated syngas, (e.g., the sulfur **111** has been removed from the syngas), with trace amounts of other chemicals, e.g., NH_3 (ammonia) and CH_4 (methane). A gas processor **115** may be used to remove additional residual gas components **116**, such as ammonia and methane, as well as methanol or any residual chemicals from the treated syngas. However, removal of residual gas components from the treated syngas is optional, since the treated syngas may be utilized as a fuel even when containing the residual gas components, e.g., tail gas.

[0020] In some embodiments, a carbon capture system **117** may extract and process the carbonous gas (e.g., CO_2 that is approximately 60-80 percent, approximately 80-100 percent or approximately 90-100 percent pure by volume) from the syngas (i.e., pre-combustion extraction). Additionally, the carbon capture system **117** may extract and process the carbonous gas after combustion (i.e., post-combustion extraction), for example, by extracting the CO_2 from a flue gas. An extracted CO_2 may then be transferred into a gas compression system **118**. In certain embodiments, the gas compression system **118** may compress, dehydrate, and liquefy the extracted CO_2, resulting in a CO_2 that is more easily transported and stored. The CO_2 may then be redirected into a carbon sequestration system **119**, and/or an EOR pipeline **120** for use in, for example, oil recovery activities. Accordingly, emissions of the extracted CO_2 into the atmosphere may be reduced or eliminated by redirecting the extracted CO_2 for use in such activities.

[0021] Gas compression activities may be able to more efficiently compress the extracted CO_2 by cooling the compressed CO_2 to lower temperatures. Accordingly, a VAC system **122** may operate to transmit water to cool the compression system **118** during operation. The VAC system **122** may also operate to retrieve water made hot through absorption of heat generated by the compression system **118** while compressing. The VAC system **122** may further cycle the water used in conjunction with the compression system **118** through a cooling tower **124** that may act as a water reservoir. By cooling the compression system **118** via the VAC system **122** utilizing the cooling tower **124**, the CO_2 in the compression system **118** may be compressed more easily, that is, use less energy to compress the CO_2, and, thus, the efficiency of the compression system **118** may be increased. Furthermore, the use of the VAC system **122** may be beneficial because of its ability to reuse heat that might otherwise be wasted.

[0022] Continuing with the syngas processing, once the CO_2 has been captured from the syngas, the treated syngas may be then transmitted to a combustor **125**, e.g., a combustion chamber, of a gas turbine engine **126** as combustible fuel. The IGCC power plant **100** may further include an air separation unit (ASU) **128**. The ASU **128** may operate to separate air into component gases by, for example, distillation techniques. The ASU **128** may separate oxygen from the air supplied to it from a supplemental air compressor **129**, and the ASU **128** may transfer the separated oxygen to the gasifier **106**. Additionally the ASU **128** may transmit separated nitrogen to a diluent nitrogen (DGAN) compressor **130**.

[0023] The DGAN compressor **130** may compress the nitrogen received from the ASU **128** at least to pressure levels equal to those in the combustor **125**, so as not to interfere with the proper combustion of the syngas. Thus, once the DGAN compressor **130** has adequately compressed the nitrogen to a proper level, the DGAN compressor **130** may transmit the compressed nitrogen to the combustor **125** of the gas turbine engine **126**. The nitrogen may be used as a diluent to facilitate control of emissions, for example.

[0024] As described previously, the compressed nitrogen may be transmitted from the DGAN compressor **130** to the combustor **125** of the gas turbine engine **126**. The gas turbine engine **126** may include a turbine **132**, a drive shaft **133** and a compressor **134**, as well as the combustor **125**. The combustor **125** may receive fuel, such as syngas, which may be injected under pressure from fuel nozzles. This fuel may be mixed with compressed air as well as compressed nitrogen from the DGAN compressor **130**, and combusted within combustor **125**. This combustion may create hot pressurized exhaust gases.

[0025] The combustor **125** may direct the exhaust gases towards an exhaust outlet of the turbine **132**. As the exhaust gases from the combustor **125** pass through the turbine **132**, the exhaust gases force turbine blades in the turbine **132** to rotate the drive shaft **133** along an axis of the gas turbine engine **126**. As illustrated, the drive shaft **133** is connected to various components of the gas turbine engine **126**, including the compressor **134**.

[0026] The drive shaft **133** may connect the turbine **132** to the compressor **134** to form a rotor. The compressor **134** may include blades coupled to the drive shaft **133**. Thus, rotation of turbine blades in the turbine **132** may cause the drive shaft **133** connecting the turbine **132** to the compressor **134** to rotate blades within the compressor **134**. This rotation of blades in the compressor **134** causes the compressor **134** to compress air received via an air intake in the compressor **134**. The compressed air may then be fed to the combustor **125** and mixed with fuel and compressed nitrogen to allow for higher efficiency combustion. Drive shaft **133** may also be connected to a load **136**, which may be a stationary load, such as an electrical generator for producing electrical power, for example, in a power plant. Indeed, the load **136** may be any suitable device that is powered by the rotational output of the gas turbine engine **126**.

[0027] The IGCC power plant **100** also may include a steam turbine engine **138** and a heat recovery steam generation (HRSG) system **139**. The steam turbine engine **138** may drive a second load **140**. The second load **140** may also be an electrical generator for generating electrical power. However, both the first and second loads **136**, **140** may be other types of loads capable of being driven by the gas turbine engine **126** and steam turbine engine **138**. In addition, although the gas turbine engine **126** and steam turbine engine **138** may drive separate loads **136** and **140**, as shown in the illustrated embodiment, the gas turbine engine **126** and steam turbine engine **138** may also be utilized in tandem to drive a single load via a single shaft. The specific configuration of the steam turbine engine **138**, as well as the gas turbine engine **126**, may be implementation-specific and may include any combination of sections.

[0028] The system **100** may also include the HRSG **139**. Heated exhaust gas from the gas turbine engine **126** may be transported into the HRSG **139** and used to heat water and produce steam used to power the steam turbine engine **138**. Exhaust from, for example, a low-pressure section of the steam turbine engine **138** may be directed into a condenser **142**. The condenser **142** may utilize the cooling tower **124** to exchange heated water for chilled water. The cooling tower **124** acts to provide cool water to the condenser **142** to aid in condensing the steam transmitted to the condenser **142** from the steam turbine engine **138**. Condensate from the condenser **142** may, in turn, be directed into the HRSG **139**. Again, exhaust from the gas turbine engine **126** may also be directed into the HRSG **139** to heat the water from the condenser **142** and produce steam.

[0029] In combined cycle power plants such as IGCC power plant **100**, hot exhaust may flow from the gas turbine engine **126** and pass to the HRSG **139**, where it may be used to generate high-pressure, high-temperature steam. The steam produced by the HRSG **139** may then be passed through the steam turbine engine **138** for power generation. In addition, the produced steam may also be supplied to any other processes where steam may be used, such as to the gasifier **106**. The gas turbine engine **126** generation cycle is often referred to as the "topping cycle," whereas the steam turbine engine **126** generation cycle is often referred to as the "bottoming cycle." By combining these two cycles as illustrated in FIG. **1**, the IGCC power plant **100** may lead to greater efficiencies in both cycles. In particular, exhaust heat from the topping cycle may be captured and used to generate steam for use in the bottoming cycle.

[0030] FIG. **2** illustrates the compression system **118** in conjunction with the VAC system **122** of the IGCC system **100**. As illustrated, compression system **118** may be a multi-stage compression system **118**. That is, the compression system **118** may include a first stage compressor **144**, a second stage compressor **146**, and a liquid pump **148**. The compressors **144** and **146** may operate in conjunction (e.g., in series) with the liquid pump **148** to compress the CO_2 received from the CO_2 extraction system (e.g., pre-combustion or post-combustion extraction) to a level that facilitates transmission to the CO_2 sequestration system **119** and/or EOR pipeline **120**. The VAC system **122** is capable of using the chilled water **155** to liquefy the CO_2 at intermediate pressures and then use the liquid pump **148** to raise the liquid CO_2 to a super critical pressure. Such a method is a more efficient way of liquefying CO_2 than, for example, when the chilled water **155** is not used. Because of the irreversibility during compression, the exit temperature of the CO_2 after compression increases. To reduce this temperature increase, inter-cooling between the stages of compression and/or the liquid pump may be desirable. Indeed, by using VAC inter-cooling as detailed below, it may be possible to more efficiently compress and liquefy the CO_2.

[0031] The compression system **118** may include an intermediate chilled water heat exchanger **152**, and a final chilled water heat exchanger **154** that may receive a coolant through a chilled temperature coolant path **155**. The compression system **118** may also include an intermediate heated water heat exchanger **156**, and a final heated water heat exchanger **158** that may receive a coolant through a heated temperature coolant path **159**. Collectively, the chilled water heat exchangers **152**, **154** and the heated water heat exchangers **156**, **158** may be utilized to reduce the temperature of the CO_2 flowing through a gas path **163** of the compression system **118**. It should be noted that instead of water, other suitable liquids may be utilized in conjunction with the heat exchangers **152**, **154**, **156**, **158** as a coolant. An example of the operation of the heat exchangers **152**, **154**, **156**, **158** in conjunction with the compressors **144**, **146** and the liquid pump **148** will be discussed below.

[0032] A CO_2 flow from, for example, the carbon capture system **117** may be redirected to the first stage compressor **144**. The CO_2 flow may be at an inlet pressure of approximately 15 PSIA to 40 PSIA and a temperature of between approximately 80° F.-120° F. The first stage compressor **144** may compress the CO_2 to a pressure of approximately 200 PSIA-400 PSIA and a temperature of approximately between 400° F. to 600° F. To aid in reducing the temperature of the CO_2, so that the second stage compressor **146** may expend less energy in compressing the CO_2, the CO_2 may pass through the intermediate heated water heat exchanger **156**.

[0033] The intermediate heated water heat exchanger **156** may receive heated water from a generator **164**, e.g. a heat exchanger, of the VAC system **122**. The water may be at a temperature of approximately 90° F.-200° F. The heated water may pass through the intermediate heated water heat exchanger **156**, through a conduit (e.g., coolant path **159**), such as a tube. This coolant path **159** may contact the CO_2 as it passes through the intermediate heated water heat exchanger **156**, thus reducing the temperature of the CO_2 from, for example, approximately 400° F.-600° F., to approximately 100° F.-to 300° F., while increasing the temperature of the heated water to, for example, approximately 150° F.-250° F. Subsequent to passing through the intermediate heated water heat exchanger **156**, the CO_2 may be passed to the intermediate chilled water heat exchanger **152**, so as to come into contact with a conduit (e.g., coolant path **155**), containing chilled water. The chilled water may be transmitted from an evaporator **160** of the VAC system **122** via a pump **162** to the final chilled water heat exchanger **154** and then subsequently to the intermediate chilled water heat exchanger **152**. The CO_2 may contact the conduit carrying the chilled water as it passes through the intermediate chilled water heat exchanger **152**, thus reducing the temperature of the CO_2, for example, to approximately 60° F.-100° F., while increasing the temperature of the chilled water to approximately 50° F.-80° F.

[0034] The CO_2 may then pass to the second stage compressor **146**. The CO_2 entering the second stage compressor **146** may be at a temperature of approximately 60° F.-100° F. and at a pressure of approximately 200 PSIA-400 PSIA. The second stage compressor **146** may compress the CO_2 to approximately 550 PSIA-950 PSIA. However, in compressing the CO_2, the temperature of the CO_2 may also increase from, for example, approximately 60° F.-100° F. to approximately 150° F.-350° F. Again, to aid in reducing the temperature of the CO_2 such that it may be condensed or liquefied at a more reduced pressure, and so that the liquid pump **148** may expend less energy for raising the liquid CO_2 to supercritical stage, the CO_2 may pass through the final heated water heat exchanger **158**.

[0035] The final heated water heat exchanger **158** may receive heated water from the intermediate heated water heat exchanger **156**. The water may be at a temperature of approximately 90° F.-250° F. The heated water may pass through the final heated water heat exchanger **158**, through a conduit, such as a tube. This conduit may contact the CO_2 as it passes through the final heated water heat exchanger **158**, thus reducing the temperature of the CO_2 from, for example, approximately 150° F.-350° F. to approximately 100° F.-300° F., while increasing the temperature of the heated water. The heated water may then be transmitted to the generator **164** of the VAC system **122** via a pump **166**. Subsequent to passing through the final heated water heat exchanger **158**, the CO_2 may be passed to the final chilled water heat exchanger **154**, so as to come into contact with a conduit containing chilled water. Chilled water may be transmitted from the evaporator **160** of the VAC system **122** via the pump **162** to the final chilled water heat exchanger **154**. The chilled water may be, for example, at approximately 20° F.-50° F. The chilled water may pass through the final chilled water heat exchanger **154**, through a conduit, such as a tube. The CO_2 may contact the conduit carrying the chilled water as it passes through the final chilled water heat exchanger **154**, thus reducing the temperature of the CO_2 from, for example, approximately 100° F.-300° F. to approximately 25° F.-75° F., while increasing the temperature of the chilled water from approximately 20° F.-50° F. to approximately 40° F.-70° F. Indeed, the temperature of the CO_2 in the gas path **163** after the chilled water heat exchanger **154** may be set such that all gaseous CO_2 becomes condensed or liquefied.

[0036] The liquefied CO_2 may then pass to the liquid pump **148**. The CO_2 entering the liquid pump **148** may be at a temperature of approximately 25° F.-75° F. and at a pressure of approximately 550 PSIA-950 PSIA. The liquid pump **148** may further compress the CO_2 to super critical pressure. Accordingly, CO_2 exiting the liquid pump **148** may be at a pressure of upwards of approximately 2215 PSIA at a temperature of upwards of approximately 60° F. At this pressure, the compressed CO_2 may be introduced into, for example the carbon sequestration system **119** and/or the EOR pipeline **120**. The flow of chilled and warm water through the compression system **118** above may be supplied by the VAC system **122**, increasing compression and liquefaction efficiency. Accordingly, FIG. **3** illustrates the operation of a VAC system **122**.

[0037] FIG. **3** illustrates an embodiment of VAC system **122**. Heat from, for example, the heat exchangers **156** and **158** of FIG. **2**, may operate as waste heat sources to provide hot water or steam that may be used to power the VAC system **122**. The use of waste heat is advantageous because heat that may have otherwise have been wasted or cast off is used to aid in compression activities. Accordingly, the VAC system **122** may include an evaporator **160**, a generator **164**, an absorber **168**, and a condenser **170**. The evaporator **160** may be kept at low pressure, for example, at a pressure approximately near a vacuum. The low-pressure of the evaporator **160** may cause a refrigerant, such as NH_3 (ammonia), to boil at very low temperatures. As illustrated, the evaporator **160** includes a heat exchanger **161** to exchange heat with the compression system **118** via heat exchangers **152** and **154**. In particular, heat exchangers **152** and **154** remove heat from the compression system **118**, and the heat exchanger **161** adds heat to the evaporator **160**. The evaporator **160** may also take heat from the surroundings of the evaporator **160**. Because of this heat transfer, the refrigerant may be converted into vapor which may flow into the absorber **168**. The absorber **168** may combine the refrigerant vapor with water. In addition, the absorber **168** cools and condenses the refrigerant vapor and water via a heat exchanger **169** that circulates a coolant (e.g., water) with cooling tower **124**. The water, rich with refrigerant, may then be pumped via an absorbent pump **172** to the generator **164**.

[0038] In the generator **164**, heat may be transferred to the refrigerant rich liquid by an external heat source, such as hot water or steam from the compression system **118** (e.g., heat exchangers **156** and **158**). In particular, the generator **164** has a heat exchanger **165** to receive heat from the heat exchangers **156** and **158** in the compression system **118**. The heat from the hot water or steam may boil the refrigerant off from the refrigerant rich liquid. The hot and refrigerant lean liquid then may return back to the absorber **168**, where heat may be removed by cooling water flow from cooling tower **124**. The refrigerant vapor from the generator **164** may be transmitted to the condenser **170**, where the refrigerant vapor may be converted into liquid by exchanging heat with cooling water from the cooling tower **124**. In particular, the condenser **170** has a heat exchanger **171** to remove heat via circulation of water with the cooling tower **124**. The cooled refrigerant may then returned to the low-pressure evaporator **160**, where it takes heat from the water from the compression system **118**, thus completing a VAC thermodynamic cycle. The VAC thermodynamic cycle may be able to capture heat from the compression activities and reuse the heat to create a chilling effect to cool the CO_2 flow, thus more efficiently compressing the CO_2.

[0039] FIG. **4** illustrates an embodiment of an N-stage compression system **118** in conjunction with the VAC system **122** of the IGCC system **100**. As illustrated, the compression system **118** may be a multi-stage compression system **118**. That is, the compression system **118** may include a first stage compressor **144**, a final stage compressor **148**, and multiple intermediate stages (e.g., 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) each stage including a compressor **146**. These compressors **144**, **146**, **148** may operate in conjunction (e.g., in series) with the liquid pump **148** to compress and liquefy the CO_2 received from the carbon capture system **117** to a level that is easily transported and stored. The compression system **118** may include an inlet chilled water heat exchanger **174**, a final chilled water heat exchanger **154**, and multiple intermediate chilled water heat exchangers **152**, for example, one or more per each of the multiple intermediate stages including an intermediate compressor **146**. The chilled water heat exchangers **152**, **154**, **174** may receive a coolant through the chilled temperature coolant path **155**. Collectively, the chilled water heat exchangers **152**, **154**, **174** and the heated water heat exchangers **156**, **158** may be utilized to reduce the temperature of the CO_2 flowing through the gas path **163** of the compression system **118**. The compression system **118** may also include a final heated water heat exchanger **158** and multiple intermediate heated water heat exchangers **156**, one or more per each of the multiple intermediate stages including an intermediate compressor **146**, as described below. The heated water heat exchangers **152**, **154**, **174** may receive a coolant through the heated temperature coolant path **159**.

[0040] Chilled water may be transmitted from the evaporator **160** of the VAC system **122** via the pump **162** to the inlet chilled water heat exchanger **174**. The chilled water may pass through the inlet chilled water heat exchanger **174**, through a conduit (e.g., coolant path **155**), such as a tube. This conduit may contact the CO_2 as it passes through the inlet chilled water heat exchanger **174**, thus reducing the temperature of the CO_2 while increasing the temperature of the chilled water. The CO_2 may then pass to the first stage compressor **144**. The first stage compressor **144** may compress the CO_2. However, in compressing the CO_2, the temperature of the CO_2 may also increase. To aid in reducing the temperature of the CO_2, so that the intermediate compressor **146** may expend less energy in compressing the CO_2, the CO_2 may pass through the intermediate heated water heat exchanger **156**.

[0041] The intermediate heated water heat exchanger **156** may receive heated water from the generator **164**, e.g. a heat exchanger, of the VAC system **122**. The heated water may pass through the intermediate heated water heat exchanger **156**, through a conduit, such as a tube. This conduit may contact the CO_2 as it passes through the intermediate heated water heat exchanger **156**, thus reducing the temperature of the CO_2 while increasing the temperature of the heated water. The temperate of the CO_2 is reduced because the heated water may be cooler than the CO_2. Subsequent to passing through the intermediate heated water heat exchanger **156**, the CO_2 may be passed to the intermediate chilled water heat exchanger **152**, so as to come into contact with a conduit containing chilled water. The CO_2 may contact the conduit carrying the chilled water as it passes through the intermediate chilled water heat exchanger **152**, thus reducing the temperature of the CO_2 while increasing the temperature of the chilled water.

[0042] The CO_2 may then pass to the intermediate compressor **146**. The intermediate compressor **146** may compress the CO_2. However, in compressing the CO_2, the temperature of the CO_2 may also increase. To aid in reducing the temperature of the CO_2, so that the next compressor stage may expend less energy in compressing the CO_2, the CO_2 may pass through a final heated water heat exchanger **158**. The final heated water heat exchanger **158** may receive heated water from the intermediate heated water heat exchanger **156**. The heated water may pass through the final heated water heat exchanger **158**, through a conduit, such as a tube. This conduit may contact the CO_2 as it passes through the final heated water heat exchanger **158**, thus reducing the temperature of the CO_2, while increasing the temperature of the heated water. The heated water may then be transmitted to the generator **164** of the VAC system **122** via a pump **166**. Subsequent to passing through the final heated water heat exchanger **158**, the CO_2 may be passed to the final chilled water heat exchanger **154**, so as to come into contact with a conduit containing chilled water. The CO_2 may contact the conduit carrying the chilled water as it passes through the final chilled water heat exchanger **154**, thus reducing the temperature of the CO_2, while increasing the temperature of the chilled water. The CO_2 may then pass to the liquid pump **148**. The liquid pump **148** may compress the CO_2 to super critical state. Consequently, the liquefied CO_2 may be more easily transported and stored, through, for example, the use of liquid pumps and liquid conduits.

[0043] Collectively, the chilled water heat exchangers **152**, **154**, **174** and the heated water heat exchangers **156**, **158** may be utilized to reduce the temperature of the CO_2 flowing through the compression system **118**. In this manner, each stage of a N-stage compression system **118** may include corresponding heat exchangers designed to cool the CO_2 gas flowing through the various compressors corresponding to a given compression stage.

[0044] Technical effects of the invention include the ability to capture and employ waste heat to efficiently compress a carbonous gas, e.g., CO_2. Vapor absorption chiller (VAC) systems may be utilized to reclaim heat generated during compression activities. The reclaimed heat may be further utilized to drive a thermodynamic cycle that can result in cooling of the CO_2 flow at a reduced pressure such that it becomes liquid, thus allowing for enhanced efficiencies of CO_2 compression in reaching the super-critical state. Indeed, by combining vapor chiller systems with liquid compressors it may be possible to substantially reduce the amount of energy expended in reaching a liquid phase of the carbonous gas, increasing efficiency and reducing cost. The liquefied CO_2 may be more efficiently transported and stored. Accordingly, more efficient and less costly liquid conduits and liquid pumps may be used to transport the CO_2 for storage and use, for example, in oil recovery activities.

[0045] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

1. A system, comprising:
- a carbonous gas compression system comprising a compressor configured to compress the carbonous gas; and
- a vapor absorption chiller (VAC) configured to circulate a coolant through at least one coolant path through the carbonous gas compression system.

2. The system of claim **1**, wherein the carbonous gas comprises carbon dioxide that is at least approximately 60 percent pure by volume.

3. The system of claim **1**, wherein the carbonous gas compression system comprises a heat exchanger in a gas path upstream of the compressor, and the at least one coolant path of the VAC extends through the heat exchanger.

4. The system of claim **3**, wherein the heat exchanger upstream of the compressor comprises a heated water heat exchanger.

5. The system of claim **3**, wherein the heat exchanger upstream of the compressor comprises a chilled water heat exchanger.

6. The system of claim **1**, wherein the carbonous gas compression system comprises a chilled water heat exchanger and a heated water heat exchanger in a gas path upstream of the compressor, and the at least one coolant path of the VAC comprises a chilled temperature coolant path extending through the first chilled water heat exchanger and a heated temperature coolant path extending through the heated water heat exchanger.

7. The system of claim **1**, wherein the carbonous gas compression system comprises a first chilled water heat exchanger in a gas path downstream of the compressor, a second chilled water heat exchanger and a heated water heat exchanger in the gas path upstream of the compressor, and the at least one coolant path of the VAC comprises a chilled temperature coolant path extending through the first chilled water heat exchanger and through the second chilled water heat exchanger, and a heated temperature coolant path extending through the heated water heat exchanger.

8. The system of claim **1**, wherein the carbonous gas compression system is configured to liquefy the carbonous gas.

9. The system of claim **8**, wherein the carbonous gas compression system comprises a liquid pump configured to raise the pressure of the liquefied carbonous gas to a super critical pressure.

10. The system of claim **8**, wherein the carbonous gas compression system comprises a plurality of compression stages with respective compressors, the carbonous gas compression system comprises a heat exchanger in a gas path between the plurality of compression stages and the liquid pump, and wherein the at least one coolant path extends through the heat exchanger.

11. The system of claim **1**, wherein the VAC comprises an evaporator configured to boil a refrigerant, an absorber configured to generate a refrigerant vapor from the refrigerant, a generator configured to transfer heat to the refrigerant vapor, and a condenser configured to liquefy the refrigerant vapor.

12. A system, comprising:
- a carbonous gas capture system configured to extract a carbonous gas;
- a carbonous gas compression system comprising a compressor configured to receive the carbonous gas from the carbonous gas capture system and to compress and liquefy the carbonous gas;
- a vapor absorption chiller (VAC) configured to circulate a coolant through at least one coolant path through the carbonous gas compression system; and
- a carbon sequestration system or an enhanced oil recovery (EOR) pipeline configured to receive the carbonous gas compressed and liquefied by the carbonous gas compression system.

13. The system of claim **12**, wherein the carbonous gas comprises carbon dioxide that is at least approximately 60 percent pure by volume.

14. The system of claim **12**, wherein the carbonous gas compression system comprises a heat exchanger in a gas path upstream of the compressor, and the at least one coolant path of the VAC extends through the heat exchanger.

15. The system of claim **12**, wherein the carbonous gas compression system comprises a heat exchanger in a gas path downstream of the compressor, and the coolant path extends through the heat exchanger.

16. The system of claim **12**, comprising a liquid pump configured to raise the pressure of the liquefied carbonous gas compressed by the carbonous gas compression system to a supercritical pressure, wherein the carbonous gas compression system comprises a plurality of compression stages with respective compressors and with at least one heat exchanger in a gas path between the plurality of compression stages and the liquid pump, and the at least one coolant path extends through the heat exchanger.

17. The system of claim **12**, wherein the at least one coolant path comprises a chilled temperature coolant path extending through a chilled water heat exchanger in a gas path upstream of the compressor, and a heated temperature coolant path extending through a heated water heat exchanger in the gas path upstream of the compressor.

18. A system, comprising:
- a carbon dioxide (CO_2) compression system comprising a compressor configured to compress the CO_2;

a vapor absorption chiller (VAC) configured to circulate a coolant through at least one coolant path through the CO_2 compression system; and

a liquid pump configured to raise the pressure of the CO_2.

19. The system of claim **18**, wherein the CO_2 is converted to a supercritical liquid.

20. The system of claim **18**, wherein the CO_2 compression system comprises a heat exchanger in a gas path upstream of the compressor, and the at least one coolant path of the VAC extends through the heat exchanger.

* * * * *