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(54) ENHANCED COAL-BED METHANE PRODUCTION

(71) Applicant: **EXXONMOBIL UPSTREAM RESEARCH COMPAY**, Houston, TX (US)

(72) Inventors: **O. Angus Sites**, Spring, TX (US); **Lalit K. Bohra**, Spring, TX (US)

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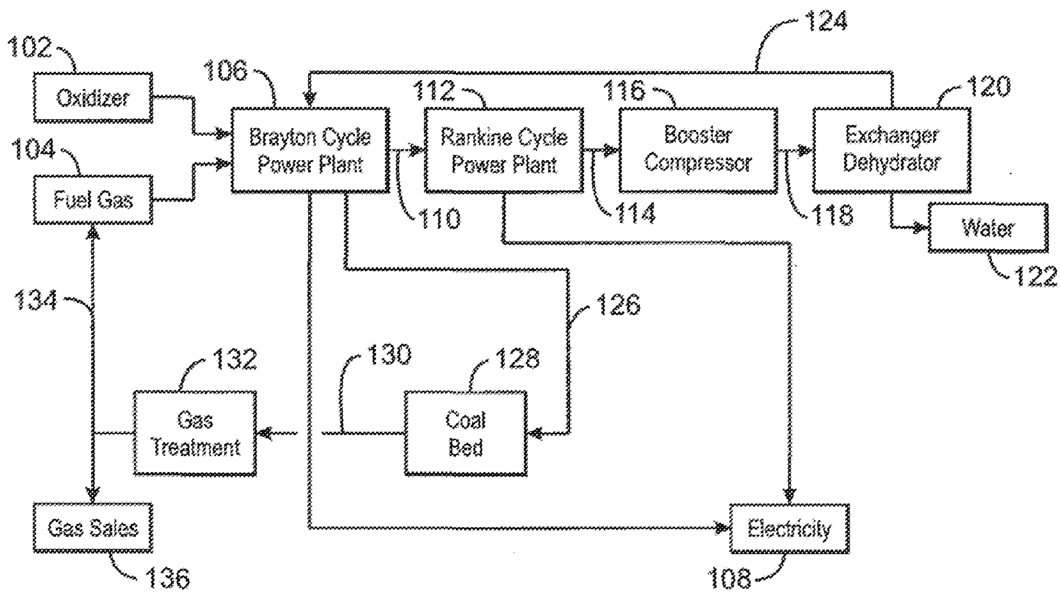
USPC **166/268**; 166/52

(57) **ABSTRACT**

Methods and systems for enhanced recovery of coal bed methane are described. A method includes generating a diluent gas mixture comprising N_2 and CO_2 in a semi-closed Brayton cycle power plant, injecting at least a portion of the diluent gas mixture into a coal bed, and recovering a mixed production gas comprising methane from the coal bed.



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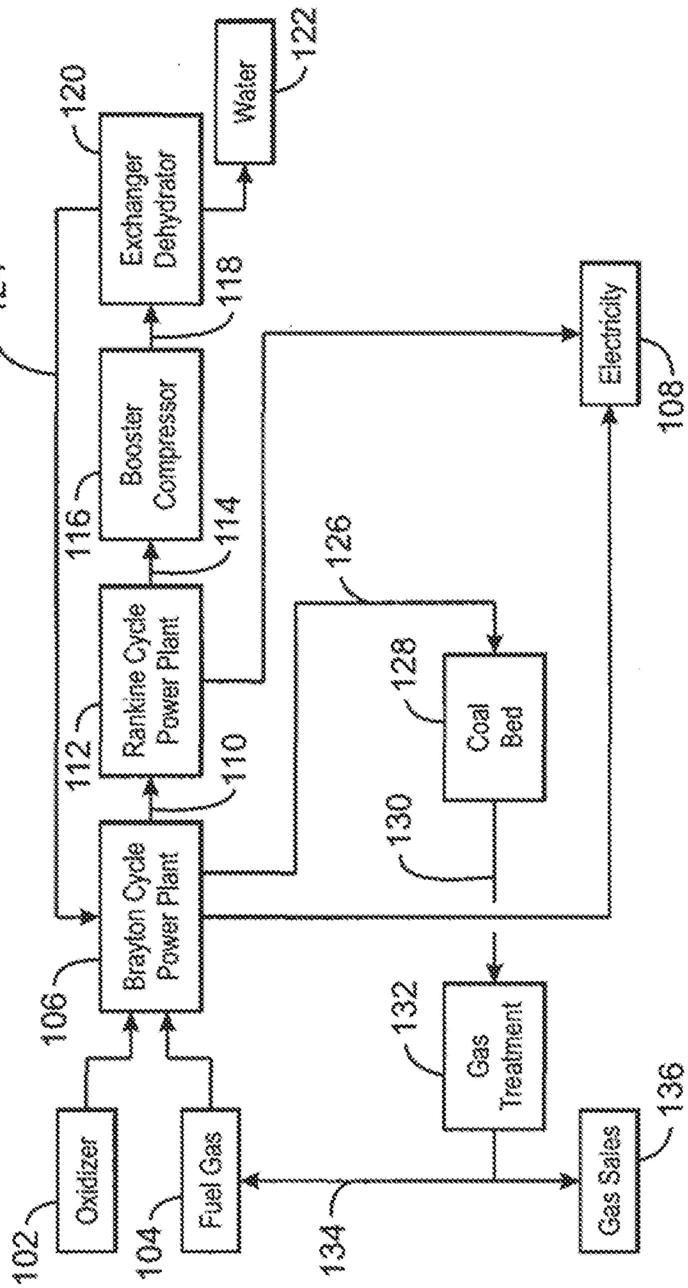
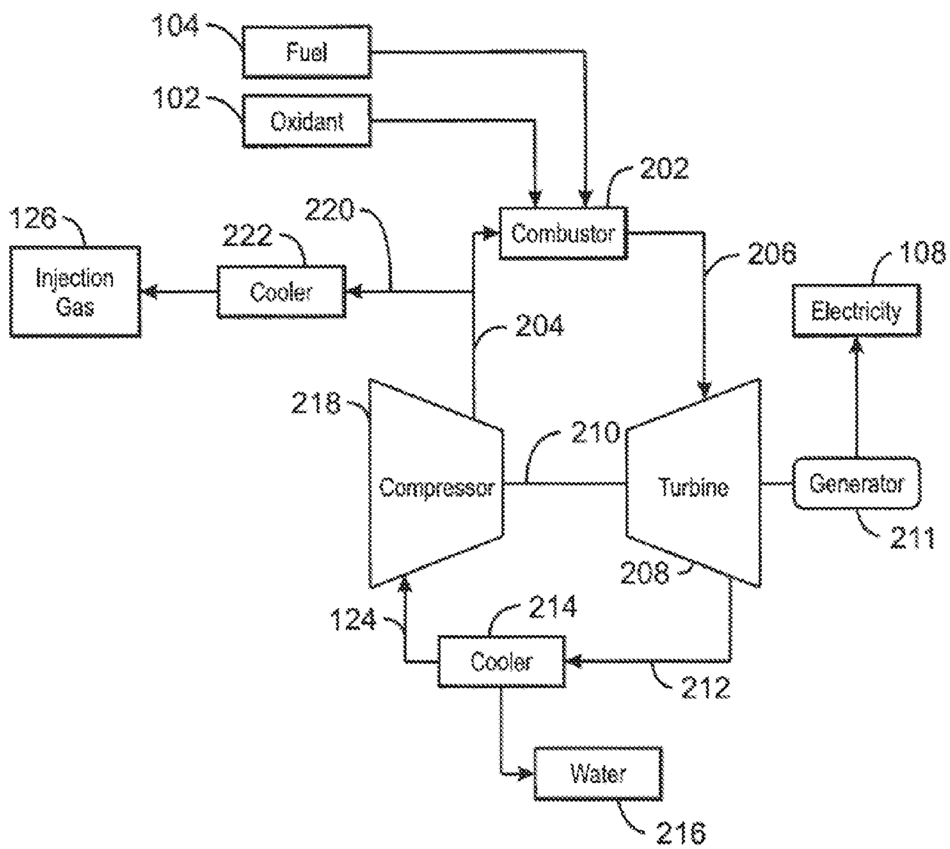

Oxidizer
102
Fuel Gas
104
Brayton Cycle Power Plant
106
110
Rankine Cycle Power Plant
112
114
Booster Compressor
116
118
Exchanger Dehydrator
120
Water
122
124
126
Coal Bed
128
130
Gas Treatment
132
134
Gas Sales
136
Electricity
108

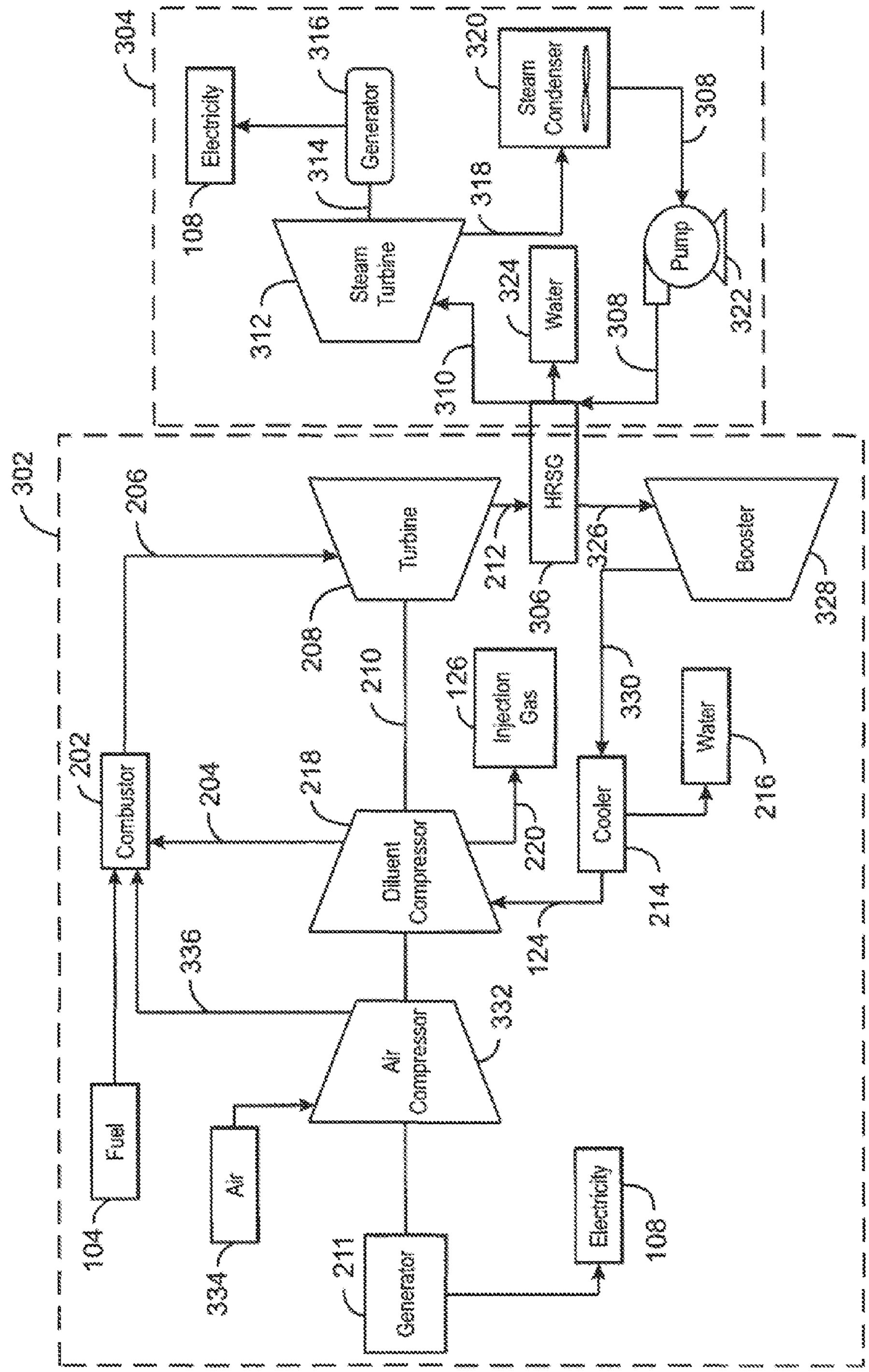
100

FIG. 1

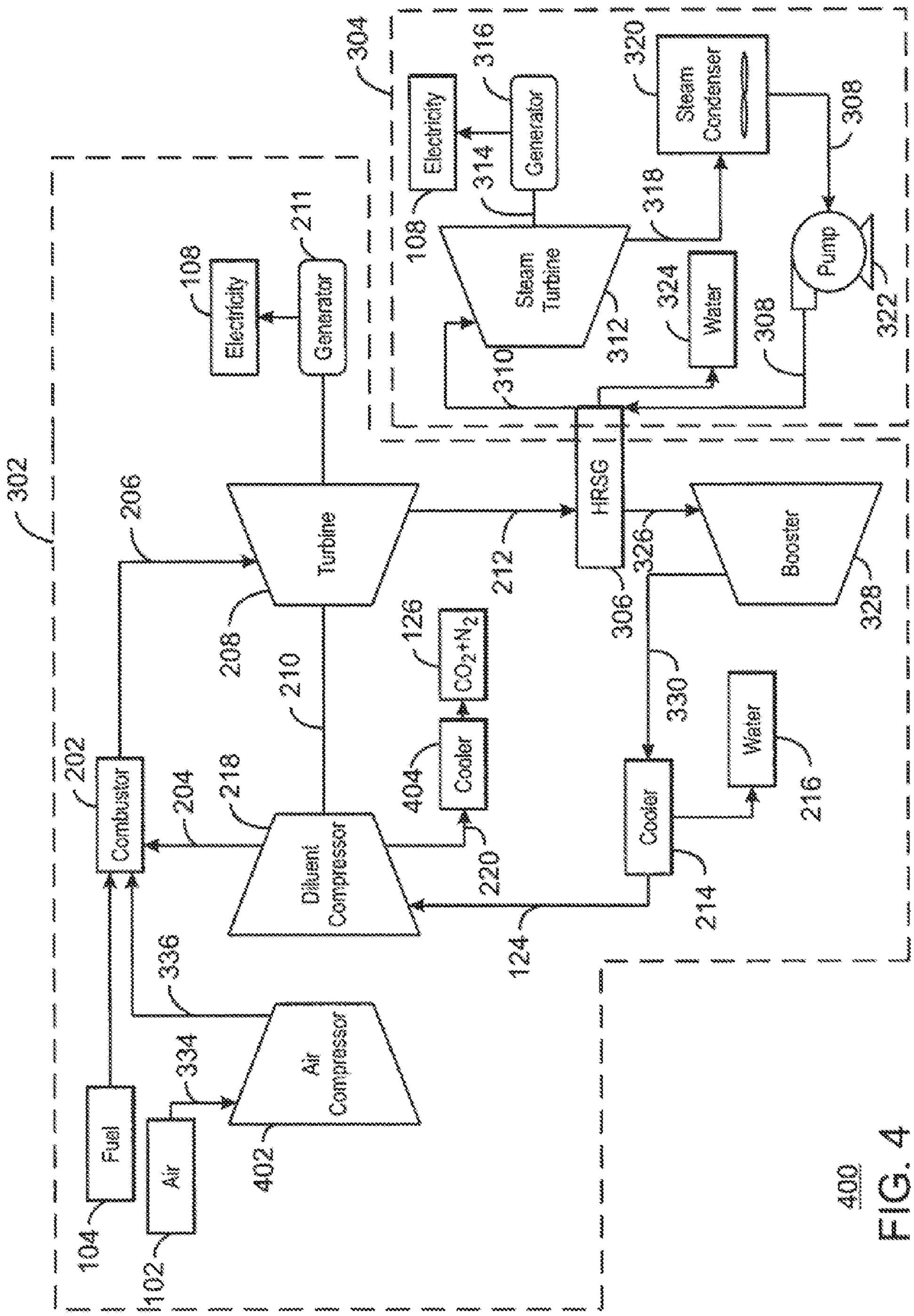

104
Fuel
102
Oxidant
202
Combustor
126
Injection Gas
222
Cooler
220
206
108
Electricity
204
218
Compressor
210
Turbine
Generator
211
208
124
214
Cooler
212
Water
216

200

FIG. 2


304
Electricity
108
Generator
316
314
Steam Turbine
312
318
Steam Condenser
320
308
Water
324
Pump
322
310
302
206
Combustor
202
204
Turbine
208
210
212
HRSG
306
326
Booster
328
Injection Gas
126
330
Cooler
214
Water
216
218
Diluent Compressor
220
124
336
Air Compressor
332
Fuel
104
Air
334
Generator
211
Electricity
108

300
FIG. 3


302
304
Fuel
104
Air
102
334
Air Compressor
402
336
Combustor
202
204
206
Turbine
208
210
Diluent Compressor
218
220
Cooler
404
CO_2+N_2
126
124
Generator
211
Electricity
108
212
HRSG
306
326
Booster
328
330
Cooler
214
Water
216
Steam Turbine
312
310
314
Generator
316
Electricity
108
318
Steam Condenser
320
308
Pump
322
Water
324
308

400
FIG. 4

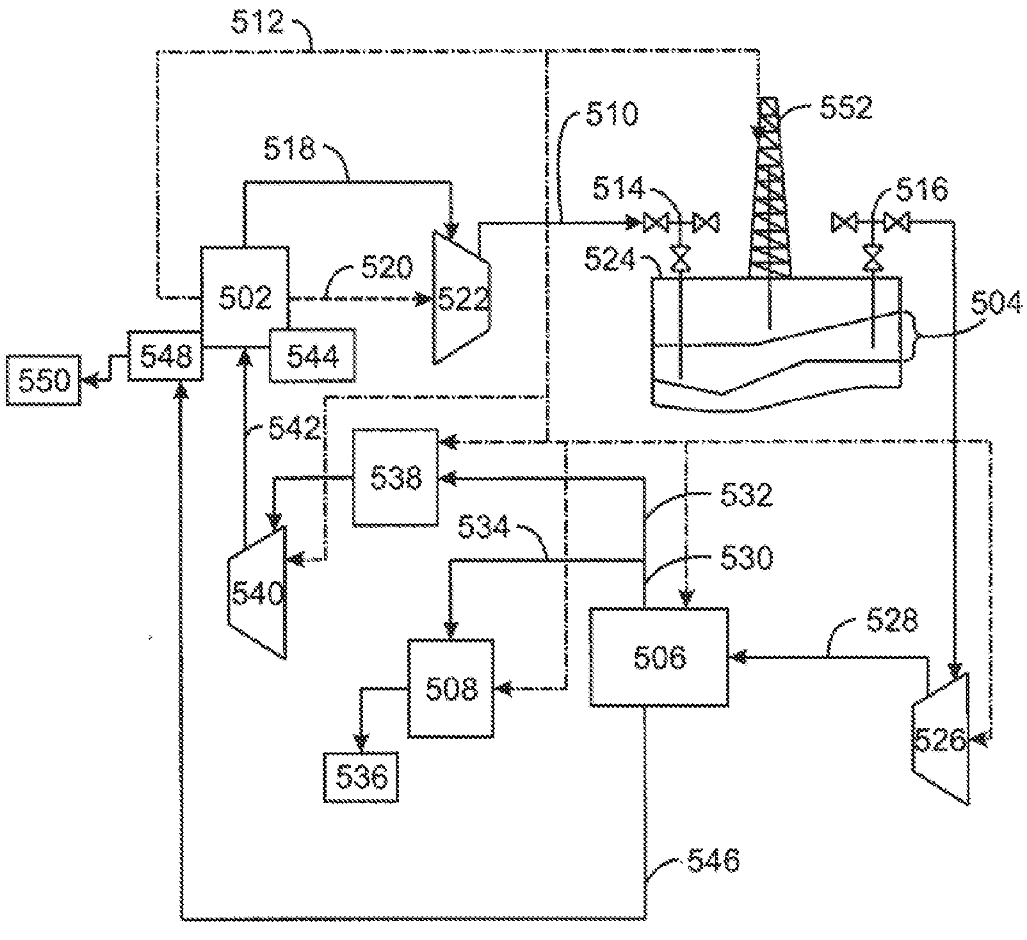

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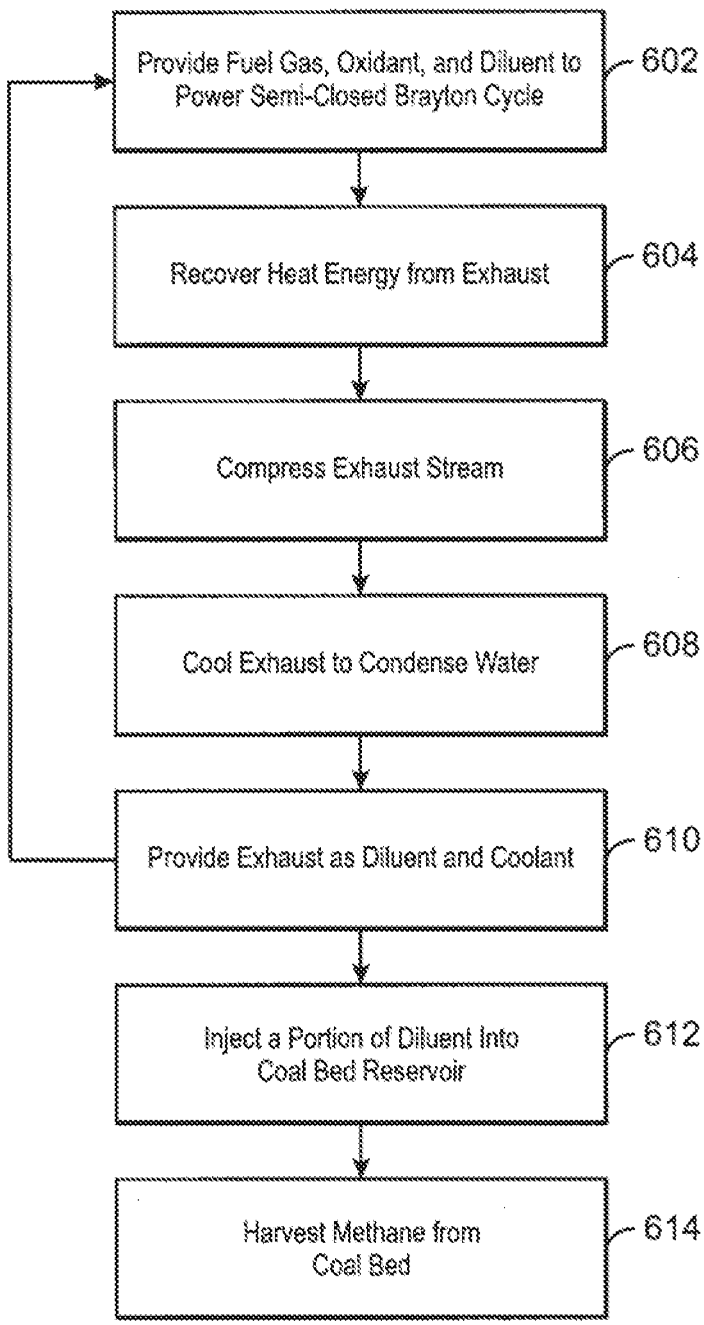
FIG. 5


Provide Fuel Gas, Oxidant, and Diluent to Power Semi-Closed Brayton Cycle
602
Recover Heat Energy from Exhaust
604
Compress Exhaust Stream
606
Cool Exhaust to Condense Water
608
Provide Exhaust as Diluent and Coolant
610
Inject a Portion of Diluent Into Coal Bed Reservoir
612
Harvest Methane from Coal Bed
614

600

FIG. 6

ENHANCED COAL-BED METHANE PRODUCTION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application 61/578,045 filed Dec. 20, 2011 entitled ENHANCED COAL-BED METHANE PRODUCTION, the entirety of which is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] Exemplary embodiments of the present techniques relate to techniques for enhancing the production of coal bed methane through injection of diluent from a gas turbine operating in a semi-closed Brayton cycle.

BACKGROUND

[0003] This section is intended to introduce various aspects of the art, which may be associated with exemplary embodiments of the present techniques. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present techniques. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0004] Coal deposits may hold significant amounts of hydrocarbon gases, such as methane, ethane, and propane, generally adsorbed onto the surface of the coal. A significant amount of natural gas reserves exists as adsorbed species within coal beds or as free gas within fractures (cleats) in the coal. The natural gas from coal beds, commonly referred to as "coalbed methane" (CBM), currently constitutes a major source of the natural gas production in the United States. Open fractures in the coal (called the cleats) can also contain free gas or can be saturated with water. Coal bed methane is often produced by reducing pressure, which reduces the partial pressure of methane in the cleats and causes desorption of methane from the coal. This pressure reduction can be performed by dewatering the coal bed. This, however, requires water handling and disposal.

[0005] Further, even using well stimulation methods, such as cavitation (see, for example, U.S. Pat. No. 5,147,111), only a small fraction of the CBM is economically recoverable. More specifically, depressurization is limited to higher permeability coal beds. This is because as pressure is decreased, coal cleats (i.e., natural fractures) may collapse and decrease the permeability of the coalbed. Loss of permeability is particularly a concern for deep coal beds, which may have a low initial permeability. Depressurization may also result in production of low-pressure gas needing significant power for compression to permit pipelining to market.

[0006] As an alternative to, or in conjunction with, depressurization, improved recovery of CBM may be obtained by injecting another gas into the coalbed. For example, CO_2 may be used to enhance the production of CBM (see, for example, U.S. Pat. Nos. 4,043,395; 5,085,274; and 5,332,036). CO_2 more strongly adsorbs to the coal than CBM and, thus, may displace adsorbed CBM. In other applications, nitrogen (N_2), which less strongly adsorbs onto coal than CBM, may be used (see, for example, U.S. Pat. Nos. 5,014,785; 5,566,756; Scott R. Reeves, "Geological Sequestration of CO_2 in Deep, Unmineable Coalbeds: An Integrated Research and Commercial-Scale Field Demonstration Project," SPE 71749 (Society of Petroleum Engineers, 2001); and Jichun Zhu, et al., "Recovery of Coalbed Methane by Gas Injection," SPE 75255 (Society of Petroleum Engineers, 2002). N_2, and other less strongly adsorbing gases, lower the partial pressure of the CBM components in the bulk gas phase, which causes the CBM to desorb from the coal. Both of these methods can maintain the coalbed at relatively high pressures and hence aid permeability by keeping the cleat system open.

[0007] Other gases have also been described as enhancing production of coalbed methane or modifying coal beds for other purposes. For example, U.S. Patent Publication No. 2007/0144747 describes a process for pretreating an underground coal bed to enhance the potential for carbon dioxide sequestration. The method involves injecting hydrogen into an underground coal bed, wherein the hydrogen is at a temperature below about 800° C.; extracting hydrogen and methane from the coalbed; separating the hydrogen and methane; delivering the methane as a product of the process; and injecting the separated hydrogen into the deposit to continue the process. When the sequestration of carbon dioxide is desired, hydrogen may be optionally produced from methane and carbon dioxide may optionally be injected for sequestration.

[0008] The methods above are generally limited by the availability of the gas in sufficient amounts for injection. Larger amounts of injection gas may be generated by coupling a power plant to the injection process, wherein sequestration of the exhaust gases occurs in tandem with the production of energy. For example, in S. Reeves, "Enhanced Coalbed Methane Recovery," presented in the SPE Distinguished Lecture Series, Society of Petroleum Engineers, 101466-DL (2003), the author discusses test projects for enhancing the production of coalbed methane from deep coal seams. The enhancement in the production of coal bed methane is related to adsorption isotherms. For example, N_2/CH_4 adsorption ratio is around 0.5/1, i.e., one unit of methane is adsorbed for every 0.5 units of nitrogen. In the case of CO_2, CO_2/CH_4 adsorption ratio is 2/1, i.e., one unit of methane is adsorbed for every two units of CO_2. In one project, N_2 was used to lower the partial pressure of methane in cleats in the coal, enhancing the desorption of methane from the coal. Another project discussed was the use of CO_2 from a pipeline to enhance production and sequester CO_2 in the coalbed. The sources discussed for the N_2 and CO_2 were commercial pipelines in the region of the fields. The author does not discuss the isolation process used to generate the injection gases, or the use of mixed streams of N_2 and CO_2 for the injection.

[0009] In U.S. Patent Application Publication No. 2010/0326084, by Anderson, et al., a method for power generation using a low heating value fuel is disclosed. In the method, an oxy-combustor is used to combust oxygen with a gaseous low heating value fuel. A compressor upstream of the combustor compresses the fuel. The combustor produces a drive gas including steam and carbon dioxide as well as other non-condensable gases, which pass through a turbine to output power. The drive gas can be recirculated to the combustor, either through the compressor, the oxygen inlet or directly to the combustor. Recirculation can occur before or after a condenser for separation of a portion of the water from the carbon dioxide. Excess carbon dioxide and steam is collected from the system. The turbine, combustor, and compressor can be derived from an existing gas turbine with fuel and air/oxidizer lines swapped. The excess carbon dioxide can be sequestered, for example, by use in enhanced oil recovery, enhanced natural gas recovery, or in enhanced coalbed methane recovery.

[0010] However, in the application described above, the oxygen supply for the combustor is provided by an air separation unit (ASU) or any other system capable of providing a substantially pure oxygen stream. The application does not disclose the use of air as an oxidizer and, thus, does not disclose the generation or use of a combined N_2 and CO_2 stream.

[0011] In addition to supply issues, the cost of separation to isolate gases, for example, by a swing adsorption process or a cryogenic air separation unit from either the atmosphere or produced gases may be prohibitively expensive. Further, after separation, the gases may need substantial compression, e.g., 2500 psia or more depending on subsurface depth, for injection into a formation. Thus, techniques for improving the enhanced recovery of coal bed methane would be valuable.

[0012] Other related material may be found in at least U.S. Patent Publication No. 2005/0201929, U.S. Pat. Nos. 5,402,847; 6,412,559; and 7,491,250, and P. van Hemert, et al., "Adsorption of carbon dioxide and a hydrogen-carbon dioxide mixture," 2006 International Coalbed Methane Symposium (Tuscaloosa, Ala., May 22-26, 2006), Paper 0615.

SUMMARY

[0013] An embodiment described herein provides a method for enhanced recovery of coalbed methane. The method includes generating a gas mixture including N_2 and CO_2 in a semi-closed Brayton cycle power plant. At least a portion of the gas mixture is injected into a coal bed and a mixed production gas including methane is recovered from the coal bed.

[0014] Another embodiment provides a system for enhancing the recovery of coalbed methane. The system includes a semi-closed Brayton cycle power plant, wherein an exhaust gas from the semi-closed Brayton cycle power plant provides a diluent gas mixture including substantial amounts of N_2 and CO_2. An injection well is configured to inject the diluent gas mixture from the semi-closed Brayton cycle power plant into a coalbed. A production well is configured to harvest a production gas mixture from the coal bed, wherein the production gas mixture includes methane.

[0015] Another embodiment provides a system for enhancing the recovery of coalbed methane. The system includes a gas turbine configured to operate at a substantially stoichiometrically balanced condition, wherein cooling is provided by a diluent gas injected into a combustor, and wherein the diluent gas substantially includes N_2 and CO_2. A generator is configured to convert mechanical energy provided by the gas turbine into electrical energy. A heat recovery steam generator (HRSG) is configured to generate steam by heating a boiler with an exhaust stream from the gas turbine. A Rankine cycle power plant is configured to generate electricity from the steam. A cooler is configured to condense water from the exhaust stream downstream of the HRSG, generating the diluent. A diluent compressor is configured to increase the pressure of the diluent and direct at least a portion of the diluent to the combustor. An injection system is configured to inject a portion of the diluent from the compressor into a coalbed and a production system is configured to harvest a production gas from the coalbed, wherein the production gas includes methane.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The advantages of the present techniques are better understood by referring to the following detailed description and the attached drawings, in which:

[0017] FIG. **1** is a block diagram of a system for using a diluent gas mixture of CO_2 and N_2 from a power plant in enhanced coalbed methane recovery;

[0018] FIG. **2** is a schematic diagram of a simple-cycle, semi-closed Brayton power plant utilizing a gas turbine generator that can be used to supply a diluent gas mixture for enhanced recovery of coal bed methane;

[0019] FIG. **3** is a schematic diagram of a combined-cycle, semi-closed Brayton power plant (CSBPP) that can be used to provide a diluent gas mixture for enhanced recovery of coal bed methane;

[0020] FIG. **4** is a schematic diagram of another combined cycle, semi-closed Brayton cycle power plant (CSBPP) that can be used to provide a diluent gas mixture for enhanced recovery of coal be methane;

[0021] FIG. **5** is a schematic diagram of an exemplary enhanced coal bed methane recovery (ECBM) system; and

[0022] FIG. **6** is a process flow diagram of a method for using a diluent gas mixture to enhance the recovery of coal bed methane.

DETAILED DESCRIPTION

[0023] In the following detailed description section, specific embodiments of the present techniques are described. However, to the extent that the following description is specific to a particular embodiment or a particular use of the present techniques, this is intended to be for exemplary purposes only and simply provides a description of the exemplary embodiments. Accordingly, the techniques are not limited to the specific embodiments described below, but rather, include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

[0024] At the outset, for ease of reference, certain terms used in this application and their meanings as used in this context are set forth. To the extent a term used herein is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Further, the present techniques are not limited by the usage of the terms shown below, as all equivalents, synonyms, new developments, and terms or techniques that serve the same or a similar purpose are considered to be within the scope of the present claims.

[0025] An "adsorbent material" is any material or combination of materials capable of adsorbing gaseous components. For example, an adsorbent material discussed herein is a natural coal bed, as discussed further below. Other material could include for examples zeolites.

[0026] "Adsorption" refers to a process whereby certain components of a mixture adhere to the surface of solid bodies that it contacts. This process is generally reversible.

[0027] A "combined cycle power plant" (CCPP) includes a gas turbine, a steam turbine, a generator, and a heat recovery steam generator (HRSG), and uses both steam and gas turbines to generate power. The gas turbine operates in an open Brayton cycle, and the steam turbine operates in a Rankine cycle. Combined cycle power plants utilize heat from the gas turbine exhaust to boil water in the HRSG to generate steam. The steam generated is utilized to power the steam turbine.

After powering the steam turbine, the steam may be condensed and the resulting water returned to the HRSG. The gas turbine and the steam turbine can be utilized to separately power independent generators, or in the alternative, the steam turbine can be combined with the gas turbine to jointly drive a single generator via a common drive shaft. These combined cycle gas/steam power plants generally have higher energy conversion efficiency than Rankine-cycle or steam-only power plants. Currently, simple-cycle plant efficiency can exceed 44% while combined cycle plant efficiency can exceed 60%. The higher combined cycle efficiencies result from synergistic utilization of a combination of the gas turbine with the steam turbine.

[0028] "Coal" is generally a solid hydrocarbon, including, but not limited to, lignite, sub-bituminous, bituminous, anthracite, peat, and the like. The coal may be of any grade or rank. This can include, but is not limited to, low grade, high sulfur coal that is not suitable for use in coal-fired power generators due to the production of emissions having high sulfur content.

[0029] "Coal bed methane" or CBM is natural gas that is adsorbed onto the surface of coal. CBM may be substantially comprised of methane, but may also include ethane, propane, and other hydrocarbons. Further, CBM may include some amount of other gases, such as carbon dioxide (CO_2), nitrogen (N_2), and H_2S, among others.

[0030] A "compressor" is a machine that increases the pressure of a gas by the application of work (compression). Accordingly, a low pressure gas (e.g., 5 psig) may be compressed into a high-pressure gas (e.g., 1000 psig) for transmission through a pipeline, injection into a well, or other processes.

[0031] A "dehydration device" is a device for removing water, in gaseous or liquid form, from a gas mixture. "Dewatered" describes broadly any reduction of water content. Typically, a dewatered hydrocarbon-containing material can have a majority of the water content substantially removed, e.g., less than about 5% by volume water or less than about 1% depending on the particular material and starting water content. Water contents much less than 1% may be desirable for certain gas streams.

[0032] "Enriched" as applied to any stream withdrawn from a process means that the withdrawn stream contains a concentration of a particular component that is higher than the concentration of that component in the feed stream to the process.

[0033] A "facility" is a representation of a tangible piece of physical equipment through which hydrocarbon fluids are either produced from a reservoir or injected into a reservoir. In its broadest sense, the term facility is applied to any equipment that may be present along the flow path between a reservoir and its delivery outlets, which are the locations at which hydrocarbon fluids either enter the reservoir (injected fluids) or leave the reservoir (produced fluids). Facilities may comprise production wells, injection wells, well tubulars, wellhead equipment, gathering lines, manifolds, pumps, compressors, separators, surface flow lines, and delivery outlets. As used herein, a facility may also include a gas treatment unit, such as an acid gas separation unit, a cryogenic separation system, or a dehydration unit. In some instances, the term "surface facility" is used to distinguish those facilities other than wells. A "facility network" is the complete collection of facilities that are present in the system, which would include all wells and the surface facilities between the wellheads and the delivery outlets.

[0034] The term "gas" is used interchangeably with "vapor," and means a substance or mixture of substances in the gaseous state as distinguished from the liquid or solid state. Likewise, the term "liquid" means a substance or mixture of substances in the liquid state as distinguished from the gas or solid state.

[0035] A "hydrocarbon" is an organic compound that primarily includes the elements hydrogen and carbon although nitrogen, sulfur, oxygen, metals, or any number of other elements may be present in small amounts. As used herein, hydrocarbons generally refer to organic materials that are harvested from hydrocarbon containing sub-surface rock layers, termed reservoirs. For example, natural gas, oil, and coal are hydrocarbons.

[0036] "Hydrocarbon production" or "production" refers to any activity associated with extracting hydrocarbons from a well or other opening. Hydrocarbon production normally refers to any activity conducted in or on the well after the well is completed. Accordingly, hydrocarbon production or extraction includes not only primary hydrocarbon extraction but also secondary and tertiary production techniques, such as injection of gas or liquid for increasing drive pressure, mobilizing the hydrocarbon or treating by, for example chemicals or hydraulic fracturing the well bore to promote increased flow, well servicing, well logging, and other well and wellbore treatments.

[0037] The term "natural gas" refers to a gas obtained from a crude oil well (associated gas), from a subterranean gas-bearing formation (non-associated gas), or from a coal bed. The composition and pressure of natural gas can vary significantly. A typical natural gas stream contains methane (CH_4) as a significant component. Raw natural gas may also contain ethane (C_2H_6), higher molecular weight hydrocarbons, acid gases (such as carbon dioxide, hydrogen sulfide, carbonyl sulfide, carbon disulfide, and mercaptans), and contaminants such as water, nitrogen, iron sulfide, wax, and crude oil.

[0038] "Pressure" is the force exerted per unit area by the gas on the walls of the volume. Pressure can be shown as pounds per square inch (psi).

[0039] As used herein, a "Rankine cycle power plant" includes a vapor generator, a turbine, a condenser, and a recirculation pump. For example when the vapor is steam, a "Rankine cycle power plant" includes a steam generator, a steam turbine, a steam condenser, and a boiler feedwater pump. The steam generator is often a gas fired boiler that boils water to generate the steam. However, in embodiments, the steam generator may be a geothermal energy source, such as a hot rock layer in a subsurface formation. The steam is used to generate electricity in the steam turbine generator, and the reduced pressure steam is then condensed in the steam condenser. The resulting water is recirculated to the steam generator to complete the loop.

[0040] "Reservoir formations" or "reservoirs" are typically pay zones include sandstone, limestone, chalk, coal and some types of shale. Pay zones can vary in thickness from less than one foot (0.3048 m) to hundreds of feet (hundreds of m). The permeability of the reservoir formation provides the potential for production.

[0041] "Sequestration" refers to the storing of a gas or fluid that is a by-product of a process rather than discharging the fluid to the atmosphere or open environment. For example, as described herein, carbon dioxide gas formed from the burning or steam reforming of hydrocarbons may be sequestered in underground formations, such as coal beds.

[0042] "Substantial" when used in reference to a quantity or amount of a material, or a specific characteristic thereof, refers to an amount that is sufficient to provide an effect that the material or characteristic was intended to provide. The exact degree of deviation allowable may in some cases depend on the specific context.

[0043] "Well" or "wellbore" refers to a hole in the subsurface made by drilling or insertion of a conduit into the subsurface. The terms are interchangeable when referring to an opening in the formation. A well may have a substantially circular cross section, or other cross-sectional shapes. Wells may be cased, cased and cemented, or open-hole well, and may be any type, including, but not limited to a producing well, an injection well, an experimental well, and an exploratory well, or the like. A well may be vertical, horizontal, or any angle between vertical and horizontal (a deviated well), for example a vertical well may comprise a non-vertical component.

[0044] Overview

[0045] Embodiments described herein provide methods for supplying a diluent gas mixture to a coal bed for the enhanced recovery of coal bed methane. The diluent gas mixture can include substantial amounts of N_2 and CO_2, which is generated from the exhaust stream of a semi-closed Brayton cycle power plant. The diluent gas mixture can be used as an injection gas for enhancing a recovery of methane from a coal bed. The semi-closed Brayton cycle generator is used to provide power in addition to the diluent gas mixture.

[0046] As noted above, lab studies indicate that coal adsorbs nearly twice as much volume of carbon dioxide as methane. The higher carbon dioxide adsorptivity forces more methane to be released while keeping carbon dioxide sequestered in coal beds. On the other hand, nitrogen has lower adsorptivity compared to methane and remains relatively free in the coal structure, i.e., in cleats or fractures in the coal. This larger quantity of free nitrogen reduces the partial pressure of methane in the cleats, resulting in an increased release of methane. Studies have indicated that for each volume of nitrogen that is injected, two volumes of methane are produced, while for CO_2 injection one volume of methane is released for every two volumes of CO_2 injected.

[0047] However, there are two issues associated with enhanced CBM recovery as currently performed. When using carbon dioxide injection in the enhanced CBM process, maintaining injectivity is a challenge, since the CO_2 adsorption may swell the coal, leading to closure of the cleats. Further, the use of nitrogen for enhanced CBM suffers from early breakthrough and reproduction of N_2.

[0048] In some embodiments described herein, this issue is addressed by using a N_2/CO_2 diluent gas mixture, in which the injection of N_2 provides rapid early recovery and the coinjection of CO_2 provides better displacement in later stages. Further, the cost of acquiring either substantially pure CO_2 or substantially pure N_2 for current injection processes may be uneconomical. For example, capturing CO_2 from the exhaust of a standard power plant exhaust is very expensive. The same is true for producing nitrogen via air separation or other means. Thus, a mixed N_2/CO_2 injection stream may provide a potential synergy for both issues. A semi-closed Brayton cycle power plant can generate a mixed N_2/CO_2 gas by using a stoichiometric ratio between oxygen and fuel, in which the oxygen is supplied by air. The resulting gases will predominately be a mixture of N_2 and CO_2.

[0049] Accordingly, a dedicated natural gas combined-cycle power plant can supply both electricity for hydrocarbon production from a coal bed and an injection gas for enhanced recovery. If other oil and gas fields are present, the power plant may also provide electricity and gases for enhanced oil recovery to those fields. The fuel for the power plant fuel can be supplied from the gas production, for example, as a portion of the gas harvested from the coal bed. Waste heat from power generation may be provided to oil and gas facilities. The power plant exhaust gas is treated, cooled, and compressed for use as a diluent in the power plant, and for use in enhanced hydrocarbon recovery (EHR).

[0050] FIG. **1** is a block diagram of a system **100** for using a diluent gas mixture of CO_2 and N_2 from a power plant in enhanced coalbed methane recovery. In the system **100**, oxidizer **102** and fuel gas **104** are provided to a semi-closed Brayton cycle power plant **106**, for example, using a gas turbine generator (GTG), at a substantially stoichiometric ratio. The oxidizer **102** can be air having about 70% N_2 and about 21% oxygen and, thus, the ratio would be calculated between the fuel gas **104** and the oxygen portion of the oxidizer **102**. The fuel gas **102** and oxygen are substantially completely combusted in the GTG of the semi-closed Brayton cycle power plant **106** to form an exhaust that includes N_2, CO_2, and H_2O, as well as trace amounts of CO, O_2, and fuel. The energy from the exhaust is used to drive a turbine expander that turns a shaft. A generator coupled to the shaft generates electricity **108**.

[0051] The exhaust stream **110** from the turbine expander of the gas turbine generator **106** can be used to boil water, or other heat transfer fluids, in a heat recovery steam generator (HRSG) that can be used to power a Rankine cycle power plant **112**. In the Rankine cycle power plant **112**, the steam, or other vapor, can be used to drive a turbine and generate more electricity **108**. The cooled, lower pressure, gas stream **114** can be dehydrated and fed to a booster compressor **116** to be pressurized, or may be fed directly to the booster compressor **116** before dehydration. The pressurized stream **118** from the booster compressor **116** can be cooled or chilled in a heat exchanger **120** to condense and remove water **122**.

[0052] The treated stream forms the diluent gas mixture **124** which may be returned to the semi-closed Brayton cycle power plant **106** for compression by the gas turbine's axial compressor. The compressed diluent gas is fed to a combustor in place of a portion of the fuel gas **104** and oxidizer **102**, cooling the combustor and allowing the use of a stoichiometric ratio between the reactants without overheating the combustor. The recycling of the diluent gas mixture **124** completes the semi-closed Brayton cycle. After compression, a portion of the diluent gas mixture **124** can be used as an injection gas **126**, which is injected into a coal bed **128** to enhance the recovery of coal bed methane (CBM), as described herein. A produced gas mixture **130** from the coal bed **128** can be processed in a gas treatment facility **132** to remove excess non-condensable gases, such as nitrogen, and other impurities, such as CO_2, H_2O, H_2S, solids, and the like. The gas treatment facility **132** may include a compressor to boost the pressure of the resulting gas **134** before sending the gas to a gas sales facility **136** for sales by pipeline, or returning a portion to the semi-closed Brayton cycle power plant **106** as the fuel gas **104**. The gas sales facilities **136** can be used to measure and further compress the gas for sale. Further, the gas sales facility **136** may include a gas liquefaction plant to produce liquefied natural gas (LNG) for shipment by tanker.

[0053] FIG. **2** is a schematic diagram of a simple-cycle, semi-closed Brayton power plant **200** utilizing a gas turbine generator that can be used to supply a diluent gas mixture **126** for enhanced recovery of coal bed methane. Like number items are as described with respect to FIG. **1**. In this example, the Rankine cycle power plant **112** (FIG. **1**) has been omitted to simplify the figure. The oxidant **102** and fuel gas **104** are fed to a combustor **202** to be burned. A compressed diluent stream **204** is also fed to the combustor **202** to lower the total amount of fuel gas **104** and oxidant **102**, allowing the combustion process to be run at near stoichiometric conditions without overheating. As a result, the amount of O_2 and CO generated in the combustion process is decreased, and the hot exhaust gases **206** include mostly CO_2, H_2O, and N_2, in addition to some trace gases.

[0054] The oxidant **102** and fuel gas **104** pressures may be increased, for example, using compressors, to boost the pressure to match the injection pressure of the compressed diluent stream **204** at the combustor **202**. The hot gases **206** from the combustor **202** are passed to a turbine **208**, which uses the energy of the hot gases **206** to spin a shaft **210**. The shaft **210** provides energy to an electric generator **211** to generate the electricity **108**. The electric generator **211** does not have to be directly coupled to the shaft **210** from the turbine **208**, but may instead be coupled to the shaft **210** by a gear box, clutch, or other device.

[0055] From the turbine **208**, the hot gas stream **212** is passed to a cooler **214**. The cooler **214** chills the hot gas stream **212**, causing the water vapor to condense out, allowing its removal as a separate water stream **216**. In this embodiment, the cooler **214** may correspond to the heat exchanger/dehydrator **120** and the water stream **216** may correspond to the water **122** of FIG. **1**. After removal of the water **216**, the diluent gas mixture **124** is provided to a compressor **218** for recompression, prior to feeding the compressed diluent stream **204** to the combustor **202** to help in cooling the combustor **202**. The recycling of the diluent gas mixture **124** partially closes the Brayton cycle in the simple-cycle, semi-closed Brayton power plant **200**, resulting in a semi-closed Brayton cycle. As fuel gas **104** and oxidant **102** are continuously being fed to the simple-cycle, semi-closed Brayton power plant **200** to maintain the combustion, a portion **220** of the diluent gas mixture **124** is continuously removed. This portion **220** can be fed through a cooler **222** to remove the heat of compression, generating the injection gas **126**, which can be used to enhance the recovery of coal bed methane. If the demand for the injection gas **126** is lower than the corresponding amount of oxidant **102** and fuel gas **104** injected into the simple-cycle, semi-closed Brayton power plant **200**, excess gases may be vented, sent to a separator, provided to customers in a pipeline, and the like.

[0056] Many options are available to increase the level of integration between the power generation process, hydrocarbon production facilities, and coal beds, as discussed further with respect to FIGS. **3-5**. Increased integration may improve overall system efficiency or reliability while reducing greenhouse gas emissions. For example, a coal bed can provide fuel gas **104** for the combustor **202** on the simple-cycle, semi-closed Brayton power plant **200**. A steam Rankine cycle, for example, using a HRSG, can be added to the power plant to increase the power produced and reduce the size the working fluid cooler. A water desalination process can be added to the power plant to reduce the size the working fluid cooler and produce clean water. Water produced with the gas from the coal bed is used as a feedstock for the desalination process. The power plant can be used to provide steam, heat, or electric power for the processing, treating, or refining hydrocarbons from the coal bed or a nearby reservoir. Water produced from working fluid condensation or desalination is used for well drilling, fracturing, processing, treating, or refining hydrocarbons.

[0057] FIG. **3** is a schematic diagram of a combined-cycle, semi-closed Brayton power plant (CSBPP) **300** that can be used to provide a diluent gas mixture for enhanced recovery of coal bed methane. Like numbered items are as discussed with respect to FIGS. **1** and **2** above. The CSBPP **300** has a semi-closed Brayton power plant **302**, coupled to a Rankine cycle power plant **304**. In this arrangement, the semi-closed Brayton power plant **302** will usually be considered the prime mover, i.e., the largest self powered equipment in the system.

[0058] In the CSBPP **300**, the hot gas stream **212** from the turbine **208** is passed through a heat-recovery steam generator (HRSG) **306**. The HRSG **306** uses the heat from the hot gas stream **212** to boil a water stream **308** and generate a steam stream **310**. In the Rankine cycle power plant **304**, the steam stream **310** is fed to a steam turbine **312** which converts some of the energy of the steam stream **310** to mechanical energy. The mechanical energy drives a shaft **314**, which powers a generator **316**. The generator **316** can provide electricity **108** to a plant power grid in addition to the electricity **108** generated by the generator **211** in the semi-closed Brayton power plant **302**. The remaining low pressure steam **318** is sent to a steam condenser **320** to be recondensed into the water stream **308**, which is returned to the HRSG **306** by a pump **322**. The steam condenser **320** may be a cooling tower, heat exchanger, or other device configured to harvest heat energy while condensing the steam. In an embodiment, the steam condenser **320** is a heat exchanger providing energy to boil an organic fluid, which may be used to provide more energy in an organic Rankine cycle. The HRSG **306** may also condense water **324** from the hot gas stream **212**, which can be combined with the water stream **216** from the cooler **214**.

[0059] The cooled gas stream **326** from the HRSG **306** may have a substantially lower pressure than the hot gas stream **212**. Accordingly, a booster compressor **328** can be used to increase the pressure. The high pressure stream **330** from the booster compressor **328** is passed through the cooler **214**, and returned to the diluent compressor **218** as the diluent gas mixture **124**. In the embodiment shown, an air compressor **332** is used to increase the pressure of an air stream **334**, prior to feeding the high pressure air stream **336** to the combustor **202**. The high pressure air stream **336** acts as the oxidizer **102** (FIG. **1**) and reacts with the fuel gas **104** in the combustor **202**.

[0060] The CSBPP **300** may be a single or a multi-shaft system. In a single shaft system, the shaft **210** in the semi-closed Brayton power plant **302** and the shaft **314** of the Rankine cycle power plant **304** are a single contiguous shaft with all units operating in tandem. The single-shaft arrangement has increased operating simplicity and higher reliability than multi-shaft blocks. In some configurations, the steam turbine **312** and generator **316** of the Rankine cycle power plant **304** can be decoupled, for example, using a hydraulic clutch, during startup or for simple-cycle operation of the semi-closed Brayton power plant **302**. In other embodiments, the shaft **210** of the semi-closed Brayton power plant **302** may be separate from the shaft **314** of the Rankine cycle power plant **304**. In multi-shaft systems, one or more semi-closed Brayton power plants **302** may use individual HRSGs **306** to supply steam through a common header to a Rankine cycle power plant **304**. Further, the booster compressor **328** may be located on a shaft with the other units, or may be a separate compressor powered by mechanical energy from the shaft or electrical energy, for example, from the generators.

[0061] Fuel treatment processes may be used to modify the fuel gas **104** to meet the requirements of the prime movers, e.g., the gas turbine generator of the semi-closed Brayton power plant **302**. Prime movers operate safely and reliably within defined ranges for fuel components that will allow acceptable prime mover performance. Typical requirements for gas turbines include limits for heating value, Wobbe Index, contaminants (for example, water, oils, hydrogen sulfide, carbon dioxide, nitrogen, etc), dew point, solid particle sizes, hydrogen and carbon monoxide. If the fuel gas source has a composition outside these ranges a fuel treatment process can be used to achieve the desired composition.

[0062] Fuel compressors are often used to increase the pressure of the fuel gas to optimize operation of the prime movers. Prime movers operate safely and reliably within a defined range of fuel pressure that will allow acceptable prime mover performance. If the fuel gas source is below this range a gas compressor is used to raise the pressure to the desired level. The minimum requirement for gas turbines depends on the pressure ratio and design of the gas turbine, for example, this may range from 10 bar to 60 bar. Gas scrubbers and coolers may be used with multiple stages of compressors to achieve higher pressure ratios.

[0063] FIG. **4** is a schematic diagram of another combined cycle, semi-closed Brayton cycle power plant (CSBPP) **400** that can be used to provide a diluent gas mixture for enhanced recovery of coal be methane. Like numbered items are as described with respect to FIGS. **1-3**. Any number of different equipment variations may be used as illustrated by the CCPP **400** in FIG. **4**. In this CCPP **400**, an air compressor **402** that is independent of the shaft **210** in the semi-closed Brayton power plant **302** is used to generate the high pressure air stream **336**. The separation from the shaft **210** allows the air compressor **402** to be powered by other means, such as electricity **108**, mechanical couplings to the shaft **210** of the semi-closed Brayton power plant **302**, mechanical couplings to the shaft **314** of the steam turbine **312**, and the like. Further, the portion **220** of the compressed diluent stream **204** is passed through an independent cooler **404** to form the injection gas **126**. These variations allow more flexibility in some embodiments, providing greater control over the CCPP **400**, and over the injection gas **126**.

[0064] As described herein, the semi-closed Brayton power plant **302** utilizes a thermodynamic process that uses a compressor **218**, combustor **202**, turbine **208** and cooler **214** (and HRSG **306** in some embodiments) to convert energy in the fuel gas **104** to mechanical power, driving the shaft **210**. As noted, adding oxidant **102**, for example, as high pressure air stream **336**, and fuel **104** to the combustor **202** requires that some of the diluent gas mixture **124** or cooled exhaust gas **326** be bled out of the system to maintain a steady state mass balance. An electrical generator **211** may be coupled to the turbine **208** to generate electrical power **108**, for example, for powering equipment associate with the gas production facility, including, for example, injection compressors, gas treating facilities, hydrocarbon sales facilities, a LNG liquefaction plant, equipment associated with production wells, injection wells, drilling, and the like. In some embodiments, the mechanical power generated may be used directly to perform other tasks for the field, such as powering compressors in an LNG plant.

[0065] FIG. **5** is a schematic diagram of an exemplary enhanced coal bed methane recovery system **500**. The system **500** includes a semi-closed Brayton cycle power plant **502**, coal bed **504**, and hydrocarbon production facilities **506**. In some embodiments, a liquefaction plant **508** may be used for LNG production. However, embodiments are not limited to the system shown, as those of skill in the art will recognize that any number of arrangements may be used to provide an injection gas **510** to a coal bed **504** using a semi-closed Brayton cycle power plant **502**. Using hydrocarbon fuel and an oxygen-containing oxidant, the semi-closed Brayton cycle power plant **502** generates electrical power **512** and the injection gas **510**, for example, including carbon dioxide and nitrogen. The electrical power **512** may be used in a plant grid to power any number of facilities, which may include compressors, purification systems, and measurement systems, among others. The injection gas **510** is injected into the coal bed **504** through an injection well **514**. The injection enhances the liberation of methane from the coal, which can then be produced with a producing well **516**.

[0066] The injection gas **510** is generated as an exhaust stream **518** from the semi-closed Brayton cycle power plant **502**. Power **520** from the semi-closed Brayton cycle power plant **502**, such as electricity or mechanical power, can be used to drive an injection compressor **522** to increase the pressure of the exhaust stream **518** prior to injection. Injection compressors **522** are often used to inject gas into subterranean formations, such as coal beds **504**. The injection compressors **522** increase the pressure of the injection gas **510** to allow the injection gas **510** to overcome the pressure of the subterranean coal bed **504**.

[0067] The injection well **514** is the conduit used to direct the gas from the surface **524** to the coal bed **504**. The injection well **514** can include valves located near the surface **524** to control the well, pipes to convey the injection gas **510** below the surface **524**, and pipe perforations to allow the injection gas **510** to leave the pipe and enter the coal bed. A cathodic protection system may be included to inhibit corrosion of the injection well **514**. Injection wells **514** often have measurement equipment installed near the well head to track the amount, pressure, and temperature, among others, of the injection gas **510**.

[0068] The production well **516** is used to produce gas from the coal bed **504**. The production well **516** can include valves located near the surface **524** to control the production well **516**. Pipes are used to convey the gas below the surface. Pipe perforations allow the produced gas to enter the pipe from the coal bed **504**. As for the injection well **514**, a cathodic protection system may be used to inhibit well corrosion in the production well **516**. Water, and other liquids, may enter the production well **516** and artificial lift can be used to remove the liquids. Production wells **516** that are primarily for gas production will often have measurement equipment and may use a compressor **526** to boost the pressure of the produced gas.

[0069] The produced gas stream **528** may be passed to the production facilities **506**. The production facilities **506** can include systems for heating produced fluids, separating liquids from gases, and for the injection of chemicals into the separated streams, among others. The chemicals can include corrosion inhibitors, emulsion breaking chemicals, hydrate inhibitors, and the like. Additionally, the production facilities **506** can include systems for measuring produced fluids, storing produced fluids, and pumping or compressing produced fluids.

[0070] A gas stream **530** from the production facilities **506** may be divided into a fuel stream **532** that is used to fuel the semi-closed Brayton cycle power plant **502** and a liquefaction feed stream **534**. The liquefaction feed stream **534** can be passed to a liquefaction plant **508** and is used to produce LNG **536** as a product. In other embodiments, the gas can be sold directly to a pipeline without liquefaction, as described below. The fuel stream **532** can be sent to a treatment facility **538** to remove contaminants or improve the suitability of the fuel gas prior to use in the prime movers. A compressor **540** can be used to boost the pressure of the fuel gas **542** to enable injection into the combustors of the GTG **502**.

[0071] Additional equipment may be included for enhanced production or efficiency. This equipment may include a Rankine cycle power plant **544**. The Rankine cycle power plant **544** can use a heat recovery steam generator (HRSG) to cool the hot exhaust stream **518** associated with the power generation process, for example, boiling water to create stream. The steam from the HRSG can then be used in a Rankine cycle to generate electricity by turning a steam turbine to power a generator. The steam is recondensed and recycled to the HRSG. Other fluids may be used instead of or in addition to water. For example, an organic Rankine may be used to recover further energy from the steam after it leaves the steam turbine, for example, by vaporizing an organic solvent which can be used to power a second Rankine cycle. The heat from the HRSG may be used to at least partially supply process heat to the production facilities **506**, gas treating facilities **538**, equipment associated with production wells **516**, injection wells **514**, and the like.

[0072] A gas stream **546** from the production facilities **506** can be sent to a treatment facility **548**, treated to pipeline quality, e.g., by the removal of acid gases, water vapor, and other contaminates and the addition of odorants or other compounds. The treated gas may then be provided to a market, for example, by a pipeline **550**.

[0073] The system **500** may also include a drilling rig **552** and other equipment to create additional injection wells **514** or production wells **516**. The equipment may include fracturing systems to increase the productivity of the wells **514** and **516**. Well fracturing is a technique to improve the performance of a production well **516** or injection well **514** by using a high pressure fluid injection to create new fractures in a formation or open old fractures in the formation. When this technique is applied it typically requires large amounts of clean water. The water may be supplied by the water condensed from the exhaust **518**, or may be obtained from desalination of water produced from the coal bed **504**.

[0074] A desalination system may be incorporated into the HRSG or use steam from the Rankine cycle power plant **544**. The desalination unit may use the heat from the exhaust stream **518** to power the desalination, e.g., by distilling produced water from the coal bed **504**. As the system **500** described above is a single integrated unit, a single control system may be used to control the power generation, injection compressors, production facilities, hydrocarbon sales facilities, any equipment associated with production wells or injection wells, drilling equipment, and the like.

[0075] In some embodiments, further separation of input or output gases may be useful. For example, treatment equipment may reduce oxygen and carbon monoxide in the exhaust gas **518** to lower the amount of hydrocarbons lost to oxidation in the coal bed **504**. Further, a nitrogen and carbon dioxide separation process may be used on the exhaust gas **518**, to create a rich carbon dioxide stream and lean carbon dioxide stream. Such processes can include CO_2 frost, membrane separation, and cryogenic separation processes. The use of a CO_2 rich injection gas **510** may increase the efficiency of the process or reduce the cost of mitigating greenhouse gases. In an embodiment, an air separation unit (ASU) could be used to provide an oxidant stream with a higher concentration of oxygen than air. The high oxygen stream will lower the amount of nitrogen in the exhaust gas **518** and subsequently increase the amount of CO_2 in the injection gases **510**.

[0076] FIG. **6** is a process flow diagram of a method **600** for using a diluent gas mixture to enhance the recovery of coal bed methane. The method begins at block **602**, when a fuel gas and oxidant are used to power a semi-closed Brayton cycle power plant. The fuel gas and oxidant are mixed with a diluent to provide cooling and lower the amount of oxidant used. At block **604**, heat energy may be recovered from the exhaust of the semi-closed Brayton cycle power plant. This may be performed by using a HRSG to boil water and generate electricity using a steam turbine. At block **606**, after the HRSG, the pressure of the exhaust stream from the semi-closed Brayton cycle power plant is boosted to allow injection into a combustor. At block **608**, the pressurized exhaust stream is cooled to condense water out. The pressurized, dewatered exhaust stream is provided to the combustor as a diluent and coolant at block **610**. At block **612**, a portion of the diluent is injected into a coal bed reservoir. At block **614**, coal bed methane is harvested from the reservoir.

Embodiments

[0077] Embodiments of the techniques described herein can include any combination of elements described in the following numbered paragraphs:

[0078] 1. A method for enhanced recovery of coalbed methane, including:

[0079] generating a gas mixture including N_2 and CO_2 in a semi-closed Brayton cycle power plant;

[0080] injecting at least a portion of the gas mixture into a coal bed; and

[0081] recovering a mixed production gas including methane from the coal bed.

[0082] 2. The method of paragraph 1, including completing an injection well in a coal bed.

[0083] 3. The methods of paragraphs 1 or 2, including completing a production well in a coal bed.

[0084] 4. The methods of paragraph 1, 2, or 3, including compressing the gas mixture prior to injection.

[0085] 5. The methods of any of the preceding paragraphs, including using at least a portion of the mixed production gas to fuel the semi-closed Brayton cycle power plant.

[0086] 6. The methods of any of the preceding paragraphs, including recovering heat energy from the exhaust of the semi-closed Brayton cycle power plant in a heat recovery steam generator (HRSG).

[0087] 7. The method of paragraph 6, including generating power with steam generated in the HRSG.

[0088] 8. The methods of any of the preceding paragraphs, including processing the mixed production gas to generate a pipeline quality natural gas.

[0089] 9. The method of paragraph 8, including liquefying the natural gas.

[0090] 10. The methods of any of the preceding paragraphs, including compressing a gaseous fuel for use in the semi-closed Brayton cycle power plant.

[0091] 11. The methods of any of the preceding paragraphs, including cooling the gas mixture prior to injection into the coal bed.

[0092] 12. The method of paragraph 11, including recovering heat from the gas mixture to supply process heat to a facility.

[0093] 13. The methods of any of the preceding paragraphs, wherein an oxidant for the semi-closed Brayton cycle power plant is air.

[0094] 14. The methods of any of the preceding paragraphs, wherein the oxygen concentration used by an oxidant for the semi-closed Brayton cycle power plant, is greater than 21%, by volume.

[0095] 15. A system for enhancing the recovery of coalbed methane, including:

[0096] a semi-closed Brayton cycle power plant, wherein an exhaust gas from the semi-closed Brayton cycle power plant provides a diluent gas mixture including substantial amounts of N_2 and CO_2;

[0097] an injection well configured to inject the diluent gas mixture from the semi-closed Brayton cycle power plant into a coalbed; and

[0098] a production well configured to harvest a production gas mixture from the coal bed, wherein the production gas mixture includes methane.

[0099] 16. The system of paragraph 15, including a heat recovery steam generator configured to use an exhaust heat from the semi-closed Brayton cycle power plant to generate steam.

[0100] 17. The systems of paragraphs 15 or 16, including a power plant configured to use the steam to generate electricity.

[0101] 18. The systems of paragraphs 15, 16, or 17, including a gas separation system configured to generate a CO_2 rich gas stream and a CO_2 lean gas stream.

[0102] 19. The systems of any of paragraphs 15-18, including injecting the CO_2 rich gas stream into the coalbed.

[0103] 20. The systems of any of paragraphs 15-19, including a liquefied natural gas plant configured to use electricity generated by the semi-closed Brayton cycle power plant to power a liquefaction process.

[0104] 21. A system for enhancing the recovery of coalbed methane, including:

[0105] a gas turbine configured to operate at a stoichiometrically balanced condition, wherein cooling is provided by a diluent gas injected into a combustor, and wherein the diluent gas substantially includes N_2 and CO_2;

[0106] a generator configured to convert mechanical energy provided by the gas turbine into electrical energy;

[0107] a heat recovery steam generator (HRSG) configured to generate steam by heating a boiler with an exhaust stream from the gas turbine;

[0108] a Rankine cycle power plant configured to generate electricity from the steam;

[0109] a cooler configured to condense water from the exhaust stream downstream of the HRSG, generating the diluent;

[0110] a diluent compressor configured to increase the pressure of the diluent and direct at least a portion of the diluent to the combustor;

[0111] an injection system configured to inject a portion of the diluent from the compressor into a coalbed; and

[0112] a production system configured to harvest a production gas from the coalbed, wherein the production gas includes methane.

[0113] 22. The system of paragraph 21, including a desalination unit integrated into the HRSG that is configured to produce a fresh water stream.

[0114] 23. The systems of paragraphs 21 or 22, including a compressor after a gas treating facility, wherein the compressor is configured to compress a stream of coal bed methane.

[0115] 24. The systems of paragraphs 21, 22, or 23, including a pipeline configured to convey the compressed stream of coal bed methane to a market.

[0116] 25. The systems of any of paragraphs 21-24, wherein at least a portion of the electricity from the power plant is used to power facilities associated with the production gas mixture.

[0117] While the present techniques may be susceptible to various modifications and alternative forms, the exemplary embodiments discussed above have been shown only by way of example. However, it should again be understood that the techniques is not intended to be limited to the particular embodiments disclosed herein. Indeed, the present techniques include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

What is claimed is:

1. A method for enhanced recovery of coalbed methane, comprising:

generating a gas mixture comprising N_2 and CO_2 in a semi-closed Brayton cycle power plant;

injecting at least a portion of the gas mixture into a coal bed; and

recovering a mixed production gas comprising methane from the coal bed.

2. The method of claim **1**, comprising completing an injection well in a coal bed.

3. The method of claim **1**, comprising completing a production well in a coal bed.

4. The method of claim **1**, comprising compressing the gas mixture prior to injection.

5. The method of claim **1**, comprising using at least a portion of the mixed production gas to fuel the semi-closed Brayton cycle power plant.

6. The method of claim **1**, comprising recovering heat energy from the exhaust of the semi-closed Brayton cycle power plant in a heat recovery steam generator (HRSG).

7. The method of claim **6**, comprising generating power with steam generated in the HRSG.

8. The method of claim **1**, comprising processing the mixed production gas to generate a pipeline quality natural gas.

9. The method of claim **8**, comprising liquefying the natural gas.

10. The method of claim **1**, comprising compressing a gaseous fuel for use in the semi-closed Brayton cycle power plant.

11. The method of claim **1**, comprising cooling the gas mixture prior to injection into the coal bed.

12. The method of claim **11**, comprising recovering heat from the gas mixture to supply process heat to a facility.

13. The method of claim **1**, wherein an oxidant for the semi-closed Brayton cycle power plant is air.

14. The method of claim **1**, wherein the oxygen concentration used by an oxidant for the semi-closed Brayton cycle power plant, is greater than about 21%, by volume.

15. A system for enhancing the recovery of coalbed methane, comprising:

a semi-closed Brayton cycle power plant, wherein an exhaust gas from the semi-closed Brayton cycle power plant provides a diluent gas mixture comprising substantial amounts of N_2 and CO_2;

an injection well configured to inject the diluent gas mixture from the semi-closed Brayton cycle power plant into a coalbed; and

a production well configured to harvest a production gas mixture from the coal bed, wherein the production gas mixture comprises methane.

16. The system of claim **15**, comprising a heat recovery steam generator configured to use an exhaust heat from the semi-closed Brayton cycle power plant to generate steam.

17. The system of claim **16**, comprising a power plant configured to use the steam to generate electricity.

18. The system of claim **15**, comprising a gas separation system configured to generate a CO_2 rich gas stream and a CO_2 lean gas stream.

19. The system of claim **15**, comprising injecting the CO_2 rich gas stream into the coalbed.

20. The system of claim **15**, comprising a liquefied natural gas plant configured to use electricity generated by the semi-closed Brayton cycle power plant to power a liquefaction process.

21. A system for enhancing the recovery of coalbed methane, comprising:

a gas turbine configured to operate at a substantially stoichiometrically balanced condition, wherein cooling is provided by a diluent gas injected into a combustor, and wherein the diluent gas substantially comprises N_2 and CO_2;

a generator configured to convert mechanical energy provided by the gas turbine into electrical energy;

a heat recovery steam generator (HRSG) configured to generate steam by heating a boiler with an exhaust stream from the gas turbine;

a Rankine cycle power plant configured to generate electricity from the steam;

a cooler configured to condense water from the exhaust stream downstream of the HRSG, generating the diluent;

a diluent compressor configured to increase the pressure of the diluent and direct at least a portion of the diluent to the combustor;

an injection system configured to inject a portion of the diluent from the compressor into a coalbed; and

a production system configured to harvest a production gas from the coalbed, wherein the production gas comprises methane.

22. The system of claim **21**, comprising a desalination unit integrated into the HRSG that is configured to produce a fresh water stream.

23. The system of claim **21**, comprising a compressor after a gas treating facility, wherein the compressor is configured to compress a stream of coal bed methane.

24. The system of claim **21**, comprising a pipeline configured to convey the compressed stream of coal bed methane to a market.

25. The system of claim **21**, wherein at least a portion of the electricity from the power plant is used to power facilities associated with the production gas mixture.

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