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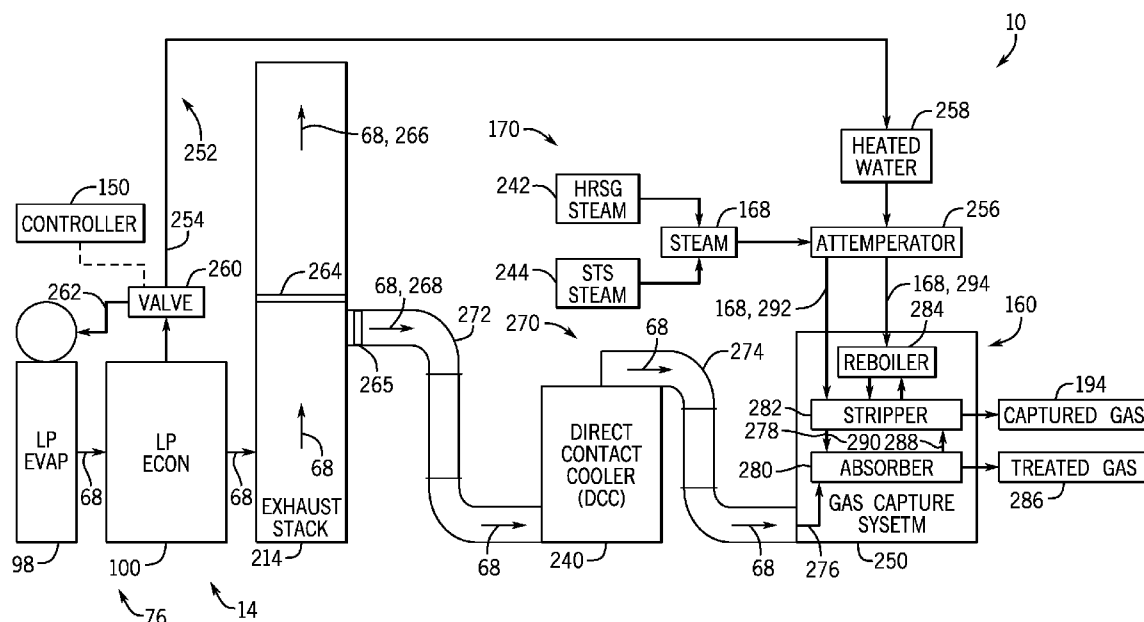


FIG. 2

(57) Abstract: A system includes a gas treatment system having a gas capture system configured to capture an undesirable gas from a gas flowing along a gas circuit. A steam supply circuit is configured to supply a steam from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system. A fluid supply circuit is configured to supply a heated water from a low-pressure section of the HRSG to an attemperor. The attemperor is configured to attemperate the steam with the heated water.

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SYSTEM AND METHOD FOR CARBON CAPTURE USING HEATED WATER FROM HEAT RECOVERY STEAM GENERATOR

BACKGROUND

[0001] The present application relates generally to a system and method for capturing undesirable gases, such as carbon containing gases, associated with a power plant.

[0002] An industrial plant, such as a power plant, may produce a variety of gases, such as an exhaust gas of a combustion system. The combustion system may include a gas turbine engine, a reciprocating piston-cylinder engine, a furnace, a boiler, or other industrial equipment. These exhaust gases may include one or more undesirable gases, such as acid gases and/or greenhouse gases. For example, the undesirable gases may include carbon oxides (CO_x) such as carbon dioxide (CO₂) and carbon monoxide (CO), nitrogen oxides (NO_x) such as nitrogen dioxide (NO₂), and/or sulfur oxides (SO_x) such as sulfur dioxide (SO₂). CO₂ is both an acid gas and a greenhouse gas. Unfortunately, the atmospheric content of CO₂ has generally increased over thousands of years, and currently exceeds about 420 parts per million by volume (ppmv) or 643 parts per million by weight (ppmw) in the atmosphere. With various regulations and environmental concerns regarding global warming, it would be desirable to reduce the output of undesirable gases (e.g., CO₂) into the atmosphere, particularly for hydrocarbon fuel consuming equipment such as combustion systems.

BRIEF DESCRIPTION

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

[0004] In certain embodiments, a system includes a gas treatment system having a gas capture system configured to capture an undesirable gas from a gas flowing along a gas circuit. The gas treatment system further includes a steam supply circuit coupled to the gas capture system, wherein the steam supply circuit is configured to supply steam from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system. The gas treatment system further includes a fluid supply circuit configured to couple to a low-pressure section of the HRSG, wherein the HRSG is configured to cool the gas upstream from the gas capture system. The gas treatment system further includes an attenuator coupled to the steam supply circuit and the fluid supply circuit, wherein the attenuator is configured to attenuate the steam with a heated water from the low-pressure section of the HRSG.

[0005] In certain embodiments, a system includes a controller configured to control a gas capture system of a gas treatment system to capture an undesirable gas from a gas flowing along a gas circuit. The controller is further configured to control a supply of a steam through a steam supply circuit from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system. The controller is further configured to control a supply of a heated water through a fluid supply circuit from a low-pressure section of the HRSG to an attenuator coupled to the steam supply circuit, wherein the HRSG is configured to cool the gas upstream from the gas capture system, and the attenuator is configured to attenuate the steam with the heated water.

[0006] In certain embodiments, a method includes controlling a gas capture system of a gas treatment system to capture an undesirable gas from a gas flowing along a gas circuit. The method further includes controlling a supply of a steam through a steam supply circuit from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system. The method further includes controlling a supply of a heated water through a fluid supply circuit from a low-pressure section of the HRSG to an attenuator coupled to the steam supply circuit, wherein the HRSG is configured to cool the gas upstream from

the gas capture system, and the attemperator is configured to attemperate the steam with the heated water.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other features, aspects, and advantages of the presently disclosed techniques 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 is a schematic view of an embodiment of a combined cycle power plant having a gas turbine system, a heat recovery steam generator (HRSG), a steam turbine system, and a plurality of gas capture systems configured to capture an undesirable gas (e.g., CO₂).

[0009] FIG. 2 is a schematic view of a portion of the combined cycle power plant of FIG. 1, further illustrating an embodiment of a gas capture system downstream from the HRSG, a steam supply system coupled to the gas capture system, and a fluid supply system extending between a low-pressure (LP) section of the HRSG and the steam supply system.

[0010] FIG. 3 is a flow chart of an embodiment of a process for operating a gas capture system using exhaust gas cooling in the LP section of the HRSG and using heated water from the LP section of the HRSG to attemperate steam for the gas capture system.

DETAILED DESCRIPTION

[0011] One or more specific embodiments of the presently disclosed systems are 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.

[0012] When introducing elements of various embodiments of the presently disclosed embodiments, 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.

[0013] The disclosed embodiments include systems and methods to reduce the carbon footprint of combustion systems, such as combustion-driven power plants and/or combined cycle power plants, using a gas treatment system having one or more gas capture systems. The gas capture systems are configured to remove undesirable gases (e.g., CO₂) from the exhaust gas of the combustion systems. While the disclosed embodiments are illustrated and described in context of CO₂ removal for combustion systems, the disclosed embodiments may be used for the removal of any undesirable gases, including but not limited to carbon oxides (CO_x) such as CO₂ and CO, nitrogen oxides (NO_x) such as NO₂, sulfur oxides (SO_x) such as SO₂, and various other acid gases and/or greenhouse gases.

[0014] As discussed below, the combined cycle power plant may include a gas turbine engine that drives an electrical generator, a heat recovery steam generator (HRSG) that uses heat from the exhaust gas of the gas turbine engine to generate steam, and a steam turbine system driven by the steam to drive an electrical generator. The steam used for the gas treatment systems may be extracted from one or more locations throughout the HRSG, the steam turbine system, and other steam sources. For example, the steam may include a low-pressure (LP) steam, an intermediate-pressure (IP) steam, and/or a high-pressure (HP) steam extracted from the HRSG and/or the steam turbine system. Additionally, as discussed below, a low-pressure (LP) section of the HRSG may include a low-pressure (LP) evaporator and a low-pressure (LP) economizer, wherein at least the LP economizer

is increased in size and cooling capacity (e.g., greater capacity of heater exchanger tubes). The increased cooling capacity of the LP economizer enables an increased cooling of the exhaust gas from the gas turbine engine, thereby enabling a substantial reduction in size and cooling capacity of a direct contact cooler (DCC) downstream of the HRSG (or a complete elimination of the DCC) used for cooling the exhaust gas prior to the gas treatment system (e.g., gas capture system). The increased cooling capacity of the LP economizer also enables a greater water flow through tubing (e.g., coils) of a heat exchanger of the LP economizer, such that heated water from the LP economizer can be split between the LP evaporator of the HRSG and an attenuator for steam supplied to the gas treatment system. For example, the heated water may be sprayed into the steam supplied to the gas treatment system, thereby attenuating the steam. The steam is then supplied to the gas treatment system (e.g., gas capture system). For example, the steam may be used with a solvent-based gas capture system, such as by supplying the steam to a stripper and/or a reboiler coupled to the stripper as discussed in further detail below. Various aspects and embodiments of the gas treatment system are discussed in further detail below.

[0015] FIG. 1 is a schematic of an embodiment of a combined cycle power plant 10 having a gas turbine system 12, a heat recovery steam generator (HRSG) 14, a steam turbine system 16, and a gas treatment system 18. As discussed in further detail below, the gas treatment system 18 is configured to treat one or more intake and/or exhaust gases in the combined cycle power plant 10, wherein steam may be extracted from the HRSG 14 and the steam turbine system 16 for use in desorbing and/or stripping the undesirable gas in the gas treatment system 18. The various features and stages of the gas treatment system 18 are discussed in further detail below, and the various features and stages may be used in any suitable combination with one another. However, before moving on to the gas treatment system 18, the combined cycle power plant 10 will be described as one possible context for use of the gas treatment system 18.

[0016] As illustrated, the gas turbine system 12 includes an air intake section 20, a compressor section 22, a combustor section 24, a turbine section 26, and a load 28, such as an electrical generator. The compressor section 22 includes multiple compressor stages 30, each having multiple rotating compressor blades 32 coupled to a compressor shaft 38 and multiple stationary compressor vanes 34 coupled to a compressor casing 36. The combustor section 24 includes one or more combustors 40. A shaft 42 extends between the compressor section 22 and the turbine section 26. Each combustor 40 includes one or more fuel nozzles 44 coupled to one or more fuel supplies 46, which may supply fuel through primary and secondary fuel circuits. The fuel supplies 46 may supply natural gas, syngas, biofuel, fuel oils, or any combination of liquid and gas fuels. The turbine section 26 includes multiple turbine stages 56, each having multiple rotating turbine blades 48 coupled to a turbine shaft 54 and multiple stationary turbine vanes 50 coupled to a turbine casing 52. The turbine shaft 54 also connects to the load 28 via a shaft 58.

[0017] In operation, the gas turbine system 12 routes an air intake flow 60 from the air intake section 20 into the compressor section 22. The compressor section 22 progressively compresses the air intake flow 60 in the stages 30 and delivers a compressed airflow 62 into the one or more combustors 40. The one or more combustors 40 receive fuel from the fuel supply 46, route the fuel through the fuel nozzles 44, and combust the fuel with the compressed airflow 62 to generate hot combustion gases in a combustion chamber 64 within the combustor 40. The one or more combustors 40 then route a hot combustion gas flow 66 into the turbine section 26. The turbine section 26 progressively expands the hot combustion gas flow 66 and drives rotation of the turbine blades 48 in the stages 56 before discharging an exhaust gas flow 68. As the hot combustion gas flow 66 drives rotation of the turbine blades 48, the turbine blades 48 drive rotation of the turbine shaft 54, the shafts 42 and 58, and the compressor shaft 38. Accordingly, the turbine section 26 drives rotation of the compressor section 22 and the load 28. The exhaust gas flow 68 may be partially or entirely directed to flow through the HRSG 14 to enable heat recovery and steam generation. In certain embodiments, one or more additional gas turbine engines 12 may be included as part of the combined cycle power plant 10, wherein the additional gas turbine

engines 12 may discharge exhaust gas flows 68 to the HRSG 14. Thus, the collective exhaust gas flow 68 from the gas turbine engines 14 (e.g., 1, 2, 3, 4, or more) may pass through the HRSG 14 to generate steam for the steam turbine system 16, and the exhaust gas flow 68 is then treated by the gas treatment system 18.

[0018] The HRSG 14 may include a plurality of heat exchangers and/or heat exchange components 70 disposed in different sections, such as a first pressure section 72 (e.g., high-pressure (HP) section), a second pressure section 74 (e.g., an intermediate-pressure (IP) section), and a third pressure section 76 (e.g., a low-pressure (LP) section). In certain embodiments, the LP section is substantially enlarged to provide additional cooling and water flow, rather than adding a fourth pressure section (e.g., additional LP section). As discussed in further detail below, one or more of the first, second, and third pressure sections may be configured to provide steam suitable for use in the gas treatment system 18, such as for use as a heat source to enable desorption of undesirable gases from sorbent materials and/or to enable stripping of undesirable gases from solvent in one or more of the gas capture systems 160 (e.g., 162, 164, and 166). In certain embodiments, the third pressure section (e.g., heat exchanger and/or heat exchange components 70) may be configured to produce low-pressure steam for the gas treatment system 18 while also cooling the exhaust gas flow 68 to a temperature range (e.g., within upper and lower temperature thresholds) suitable for gas capture in the gas capture systems 164 and 166. The temperature range may depend on the undesirable gases in the exhaust gas flow 68, an acid dew point determined by fuel pollutants and NO_x, a temperature margin over the acid dew point, and other considerations. With the acid dew point in mind, the third pressure section may include corrosion resistant materials used for construction of the heat exchanger and heat exchange components 70 (e.g., materials for parts and/or coatings disposed on surfaces). The corrosion resistant materials may include, for example, nickel, cobalt, palladium, platinum, and combinations and alloys thereof, including stainless steels and nickel-based alloys. In certain embodiments, the temperature range may correspond to a water vapor condensing range. For example, the temperature range may be approximately 45 degrees Celsius plus or minus 5, 10, or 15 degrees Celsius. In certain

embodiments, the third pressure section in the HRSG 14 is configured to cool the exhaust gas flow 68 to the temperature range suitable for the gas capture systems 164 and 166, such that a cooling system (e.g., direct contact cooler (DCC) and/or indirect cooler) can be eliminated or downsized along an exhaust path of the exhaust gas flow 68 between the HRSG 14 and the gas capture systems 164 and 166.

[0019] The components 70 may include economizers, evaporators, superheaters, or any combination thereof, in each of the HP, IP, and LP sections 72, 74, and 76. The components 70 may be coupled together via various conduits and headers, and the HRSG 14 may route one or more flows of steam (e.g., low-pressure steam, intermediate-pressure steam, and high-pressure steam) to the steam turbine system 16. In the illustrated embodiment, the components 70 of the HRSG 14 include a finishing high-pressure superheater 78, a secondary re-heater 80, a primary re-heater 82, a primary high-pressure superheater 84, an inter-stage attemperator 86, an inter-stage attemperator 88, a high-pressure evaporator 90 (HP EVAP), a high-pressure economizer 92 (HP ECON), an intermediate-pressure evaporator 94 (IP EVAP), an intermediate-pressure economizer 96 (IP ECON), a low-pressure evaporator 98 (LP EVAP), and a low-pressure economizer 100 (LP ECON). Additionally, in certain embodiments, the components 70 of the HRSG 14 further include a low-pressure superheater between the low-pressure evaporator 98 and the low-pressure admission of steam into a low-pressure steam turbine 110 of the steam turbine system 16 as discussed below. The HRSG 14 also includes an enclosure or duct 102 housing the various components 70. The functionality of the components 70 is discussed in further detail below.

[0020] The steam turbine system 16 includes a steam turbine 104 having a high-pressure steam turbine (HP ST) 106, an intermediate-pressure steam turbine (IP ST) 108, and the low-pressure steam turbine (LP ST) 110, which are coupled together via shafts 112 and 114. Additionally, the steam turbine 104 may be coupled to a load 116 via a shaft 118. Similar to the load 28, the load 116 may include an electrical generator. The HRSG 14 may be configured to generate a high-pressure steam for the high-pressure steam turbine

106, an intermediate-pressure steam for the intermediate-pressure steam turbine 108, and a low-pressure steam for the low-pressure steam turbine 110. In certain embodiments, an exhaust from the high-pressure steam turbine 106 may be routed into the intermediate-pressure steam turbine 108 through the primary re-heater 82, the inter-stage attemperator 88, and the secondary re-heater 80 within the HRSG 14, and an exhaust from the intermediate-pressure steam turbine 108 may be routed into the low-pressure steam turbine 110. The steam turbine 104 may discharge a condensate 120 (or the steam may be condensed in a condenser 122 downstream from the steam turbine 104), such that the condensate 120 can be pumped back into the HRSG 14 via one or more pumps 124.

[0021] In operation, the exhaust gas flow 68 passes through the HRSG 14 and transfers heat to the components 70 to generate steam for driving the steam turbine 104. The exhaust steam from the low-pressure steam turbine 110 may be directed into the condenser 122 to form the condensate 120. The condensate 120 from the condenser 122 may, in turn, be directed into the low-pressure section 76 of the HRSG 14 with the aid of the pump 124. The condensate 120 may then flow through the low-pressure economizer 100, which is configured to heat a feedwater 126 (including the condensate 120) with the exhaust gas flow 68. From the low-pressure economizer 100, the feedwater 126 may flow into the low-pressure evaporator 98. The feedwater 126 from low-pressure economizer 100 may be directed toward the intermediate-pressure economizer 96 and the high-pressure economizer 92 with the aid of a pump 125. Steam from the low-pressure evaporator 98 may be directed to the low-pressure steam turbine 110. Likewise, from the intermediate-pressure economizer 96, the feedwater 126 may be routed into the intermediate-pressure evaporator 94 and/or toward the high-pressure economizer 92. In addition, steam from the intermediate-pressure economizer 96 may be routed to a fuel gas heater 95, where the steam may be used to heat fuel gas for use in the combustion chamber 64 of the gas turbine system 12. Steam from the intermediate-pressure evaporator 94 may be routed to the intermediate steam turbine 108.

[0022] The feedwater 126 from the high-pressure economizer 92 may be routed into the high-pressure evaporator 90. Steam from the high-pressure evaporator 90 may be routed into the primary high-pressure superheater 84 and the finishing high-pressure superheater 78, where the steam is superheated and eventually routed to the high-pressure steam turbine 106. The inter-stage attemperator 86 may be located in between the primary high-pressure superheater 84 and the finishing high-pressure superheater 78. The inter-stage attemperator 86 may enable more robust control of the exhaust temperature of steam from the finishing high-pressure superheater 78. Specifically, the inter-stage attemperator 86 may be configured to control the temperature of steam exiting the finishing high-pressure superheater 78 by injecting a cooler feedwater spray into the superheated steam upstream of the finishing high-pressure superheater 78 whenever the exhaust temperature of the steam exiting the finishing high-pressure superheater 78 exceeds a predetermined value.

[0023] In addition, an exhaust from the high-pressure steam turbine 106 may be directed into the primary re-heater 82 and the secondary re-heater 80, where it may be re-heated before being directed into the intermediate-pressure steam turbine 108. The primary re-heater 82 and the secondary re-heater 80 may also be associated with the inter-stage attemperator 88, which is configured to control the exhaust steam temperature from the re-heaters. Specifically, the inter-stage attemperator 88 may be configured to control the temperature of steam exiting the secondary re-heater 80 by injecting cooler feedwater spray into the superheated steam upstream of the secondary re-heater 80 whenever the exhaust temperature of the steam exiting the secondary re-heater 80 exceeds a predetermined value. The arrangement of the components 70 of the HRSG 14 is merely one possible example for use with the combined cycle power plant 10 and the gas treatment system 18, and the components 70 may be arranged differently within the scope of the present disclosure.

[0024] The combined cycle power plant 10 further includes a fluid connection system 130 between stages of the HRSG 14 and stages of the steam turbine system 16. For example, the fluid connection system 130 includes a high-pressure steam supply conduit or line 132 coupled to the finishing high-pressure superheater 78 and an inlet into the high-

pressure steam turbine 106, and a discharge or return line 134 coupled to an outlet of the high-pressure steam turbine 106 and the primary re-heater 82. The fluid connection system 130 also includes an intermediate-pressure steam supply conduit or line 136 and a discharge or return line 138. The intermediate-pressure steam supply line 136 is fluidly coupled to outlets of the intermediate-pressure evaporator 94 and the secondary re-heater 80 and an inlet into the intermediate-pressure steam turbine 108. The discharge or return line 138 is fluidly coupled to an outlet of the intermediate-pressure steam turbine 108 and an inlet into the low-pressure steam turbine 110. The fluid connection system 130 also includes a low-pressure steam supply conduit or line 140 and a discharge or return line 142. The low-pressure steam supply line 140 is fluidly coupled to outlets of the low-pressure evaporator 98 and the discharge or return line 138 from intermediate-pressure steam turbine 108 and to an inlet into the low-pressure steam turbine 110. The discharge or return line 142 is fluidly coupled to an outlet of the low-pressure steam turbine 110 and an inlet into the low-pressure economizer 100. As discussed above, the return line 142 includes the condenser 122 and the pump 124.

[0025] The combined cycle power plant 10 may include a control system 144 communicatively coupled with a monitoring system 146, wherein the control system 144 and the monitoring system 146 are communicatively coupled with various components of the gas turbine system 12, the HRSG 14, the steam turbine system 16, and the gas treatment system 18. The monitoring system 146 is configured to monitor a plurality of sensors 148, designated as “S”, distributed throughout the combined cycle power plant 10. The control system 144 includes a controller 150, wherein the controller 150 includes one or more processors 152, memory 154, and instructions 156 stored on the memory 154 and executable by the processor(s) 152 to perform various control functions for operating the gas turbine system 12, the HRSG 14, the steam turbine system 16, and the gas treatment system 18. In certain embodiments, the control system 144 may communicate information (e.g., sensor feedback, alerts, alarms, etc.) to a user interface, cloud storage, a remote computer system, or any combination thereof.

[0026] The sensors 148 may be communicatively coupled to the control system 144 via communication wires or wireless communication circuitry. The sensors 148 may be disposed at one or more locations in the air intake section 20, the compressor section 22, the combustor section 24, the turbine section 26, the HRSG 14, the steam turbine system 16, and the gas treatment system 18. For example, the sensors 148 may be disposed at one or more locations in each of the high-pressure steam turbine 106, the intermediate-pressure steam turbine 108, and the low-pressure steam turbine 110, thereby enabling monitoring of steam properties (e.g., temperature, pressure, etc.) at the various locations. The sensors 148 also may be disposed along each of the lines 132, 134, 136, 138, 140, and 142 of the fluid connection system 130, thereby helping to monitor various fluid parameters between the HRSG 14, the steam turbines 106, 108, and 110, and the gas treatment system 18. Additionally, the sensors 148 may be coupled to and/or distributed throughout the gas treatment system 18 to enable monitoring and control of the gas treatment (e.g., gas capture) from various intake and/or exhaust flows. In certain embodiments, the sensors 148 may include flow sensors, pressure sensors, temperature sensors, fluid composition sensors, flame sensors, vibration sensors, clearance sensors, trip sensors, or any combination thereof. The fluid composition sensors may monitor composition levels of various undesirable gases, such as composition levels of carbon oxides (e.g., CO₂, CO), nitrogen oxides (e.g., NO₂), sulfur oxides (e.g., SO₂), and various other acid gases and/or greenhouse gases as well as oxygen, hydrogen and unreacted fuel gas content. Accordingly, the sensor feedback from the sensors 148 may be used to adjust various aspects of the gas treatment system 18 to reduce the carbon footprint of the combined cycle power plant 10, such as by substantially removing undesirable gases (e.g., CO₂) such that the carbon footprint is at least reduced below a target threshold (e.g., low carbon, carbon neutral, or carbon negative). Additional details of the monitoring and control of the gas treatment system 18 are discussed further below.

[0027] As discussed in further detail below, the gas treatment system 18 is configured to remove and/or capture one or more undesirable gases (e.g., exhaust emissions gases, acid gases, greenhouse gases, etc.) from an air intake flow 60 into the gas turbine engine

12 (e.g., upstream of the compressor section 22 and/or combustor section 24) and/or the exhaust gas flow 68 (e.g., downstream from the turbine section 26 and/or the HRSG 14). The undesirable gases are intended to cover any gases that may be undesirable in the air intake flow 60 and/or exhaust gas flow 68. For example, the undesirable gases may include acid gases and/or greenhouse gases. By further example, the undesirable gases may include any gases typically subject to regulation, including but not limited to, carbon oxides (CO_x) such as carbon dioxide (CO₂) and carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x) such as sulfur dioxide (SO₂), methane (CH₄) or any combination thereof. The disclosed embodiments are particularly well suited for gas adsorption or absorption of CO₂ from the air intake flow 60 and/or exhaust gas flow 68. However, the following discussion is intended to cover each of these examples when referring to undesirable gases.

[0028] The gas treatment system 18 may include a plurality of gas capture systems 160 (e.g., gas capture systems 162, 164, and 166) disposed throughout the combined cycle power plant 10 to treat a gas flow (e.g., intake airflow, fuel flow, exhaust flow, etc.). Each of the gas capture systems 160 (e.g., 162, 164, and 166) may be configured to use one or more heat sources to facilitate gas capture, wherein the gas capture systems 160 may include sorbent-based gas capture systems, solvent-based gas capture systems, one or more other technologies for gas capture using a heated fluid (e.g., a heated fluid 168 being attemperated by a heated water), or a combination thereof. As noted above, an absorbent fluid other than a solvent may be used for gas treatment. Although the solvent-based gas capture systems are discussed as using a solvent as an absorbent fluid, the disclosed embodiments may use any suitable absorbent fluid for capturing undesirable gases. Additionally, for the solvent-based gas capture systems, the solvent may be an aqueous or non-aqueous solvent. Accordingly, the solvent-based gas treatment system also may be described as a fluid absorbent-based gas treatment system. As discussed below, the heat sources may include heated fluid 168 (e.g., steam and/or heated water) extracted from the HRSG 14 and/or the steam turbine system 16 and supplied to the gas capture systems 160 via a steam supply system 170 (e.g., steam supply circuit), waste heat recovered by a waste heat recovery (WHR) system 172 of the combined cycle power plant 10, or a combination

thereof. The steam supply system 170 may include steam supply conduits or lines 174 and 176 coupled to the HRSG 14 and/or the steam turbine system 16 at one or more locations. In the illustrated embodiment, the steam supply lines 174 and 176 may be coupled to the HRSG 14 and/or the steam turbine system 16 at or between low-pressure sections and intermediate-pressure sections, such as between the low-pressure steam turbine 110 and the intermediate-pressure steam turbine 108 and/or between the LP section 76 and the IP section 74 of the HRSG 14. However, in certain embodiments, the steam supply system 170 may be selectively coupled to any one, multiple, or all of the components of the HRSG 14 (e.g., one or more components or locations in each of the HP, IP, and LP sections 72, 74, and 76), and/or any one, multiple, or all stages of the steam turbine system 16 (e.g., HP, IP, and LP steam turbines 106, 108, and 110), such that the heated fluid 168 (e.g., steam and/or heated water) can be extracted at one or more pressures, temperatures, or conditions for use in the gas capture systems 160. For example, the control system 144 may be configured to control various valves coupled to steam lines to control steam flow from the various components of the HRSG 14 and the stages of the steam turbine system 16. Additionally, in certain embodiments, the heated fluid 168 (e.g., steam and/or heated water) may be extracted from other sources, such as a waste heat steam generator using waste heat from the waste heat recovery system 172 to generate steam. The gas treatment system 18, via control by the control system 144, is also configured to combine the steam 18 from various steam sources (e.g., HRSG 14, steam turbine system 16, waste heat recovery system 172, waste heat steam generator, etc.) to provide a mixed steam with desired steam characteristics, e.g., steam temperature and associated pressure between upper and lower temperature thresholds. In addition, the quality of the steam (saturated or superheated) can be monitored to meet specific heating requirements of the gas treatment system 18.

[0029] The control system 144 and the monitoring system 146 are communicatively coupled to the gas treatment system 18, including the various gas capture systems 160, to provide control of the gas treatment and capture processes, including control of the heated fluid 168 (e.g., steam and/or heated water) being used by the gas capture systems 160. The

steam can be applied to the gas treatment system 18 as indirect heating through a heat exchanger process or direct heating of the CO₂ loaded sorbent or solvent. If the monitoring system 146 (e.g., sensors 148) indicates that the temperature of the extracted heated fluid 168 (e.g., steam and/or heated water) is above an upper temperature threshold, then the control system 144 may be configured to control the gas treatment system 18 to attemperate or cool the heated fluid 168 (e.g., via attemperator, cooler, or heat exchanger) to lower the steam temperature to be within upper and lower temperature thresholds. As discussed in detail below, a heated fluid (e.g., heated water) may be extracted from the LP economizer 100 and used for attempering the heated fluid 168. If the monitoring system 146 (e.g., sensors 148) indicates that the temperature of the extracted heated fluid 168 (e.g., steam and/or heated water) is below a lower temperature threshold, then the control system 144 may be configured to control the gas treatment system 18 to heat the heated fluid 168 (e.g., via heater or heat exchanger) to increase the steam temperature to be within the upper and lower temperature thresholds. In certain embodiments, the upper and lower temperature thresholds may be approximately 120 to 180 degrees Celsius for the gas capture systems 160.

[0030] For temperature adjustments, the steam supply lines 174 and 176 may include respective heat exchangers 178 and 180 (e.g., direct and/or indirect heat exchangers) configured to adjust the heated fluid 168 (e.g., steam and/or heated water) being supplied to the gas capture systems 160. The heat exchangers 178 and 180 may use another fluid to heat or cool the steam, e.g., by direct heat exchanger (e.g., injection of fluid) or indirect heat exchanger (e.g., separate flow paths). For example, a heated fluid (e.g., heated water) extracted from the LP economizer 100 may be used to exchange heat (e.g., cool) with the heated fluid 168 via the heat exchangers 178 and 180, such that the heated fluid 168 is within the upper and lower temperature thresholds. By further example, the waste heat recovery system 172 may be configured to exchange heat (e.g., via heat exchange fluids) with the heat exchangers 178 and 180 to heat or cool the heated fluid 168 (e.g., steam and/or heated water) to be within the upper and lower temperature thresholds. The control system 144 may be coupled to various valves, pressure regulators, and sensors 148 to help

control the respective flows through the heat exchangers 178 and 180, thereby controlling the heat exchange and resulting temperatures of the heated fluid 168 (e.g., steam and/or heated water). Additionally or alternatively, as noted above, the waste heat recovery system 172 may be configured to transfer heat between the waste heat and the heated fluid 168 (e.g., steam and/or heated water), such as in a waste heat steam generator, to adjust the temperature of the heated fluid 168.

[0031] The waste heat recovery system 172 may include a plurality of distributed waste heat recovery systems 182, 184, and 186. The waste heat recovery system 182 is coupled to the load 28 (e.g., electrical generator) of the gas turbine engine 12, the waste heat recovery system 184 is coupled to the load 116 (e.g., electrical generator) of the steam turbine system 16, and the waste heat recovery system 186 is coupled to a compression system 188 of the gas treatment system 18. The waste heat recovery systems 182, 184, and 186 may include one more heat exchangers configured to transfer heat between the respective heat generating components (e.g., 28, 116, and 188) and one or more fluids. In some embodiments, the waste heat recovery system 172 may be configured to convey a heated fluid (e.g., water, coolant, lubricant, etc.) to provide heat to the gas capture systems 160, wherein the heated fluid may be used alone or in combination with the heated fluid 168 (e.g., steam and/or heated water) as the heat source for the gas capture systems 160.

[0032] In certain embodiments, the gas capture systems 160 (e.g., 162, 164, and 166) may be arranged in series (e.g., multiple stages), in parallel, or a combination thereof, relative to a direction of flow through the combined cycle power plant 10. However, the illustrated embodiment includes at least two of the gas capture systems 160 arranged in series, such that multiple stages of gas capture help to sequentially reduce the content of undesirable gases to a target level (e.g., low carbon, net neutral, or net negative capture status). In some embodiments, the gas capture systems 160 include a single gas capture system. Additionally, the gas capture systems 160

[0033] The gas capture systems 162, 164, and 166 may differ in design and gas treatment capacities at least partially due to their placements in the combined cycle power

plant 10. In the illustrated embodiment, the gas capture system 162 is coupled to the combined cycle power plant 10 along the air intake flow 60 (e.g., at the air intake section 20), while the gas capture systems 164 and 166 are coupled to the combined cycle power plant 10 along the exhaust gas flow 68 (e.g., downstream from the turbine section 26). In some embodiments, one or more of the gas capture systems 162, 164, and 166 may be excluded and/or combined as a single gas capture system with multiple stages. For example, the gas capture system 162 may be excluded, the gas capture systems 164 and 166 may be combined as a single gas capture system with multiple stages, and/or the combined cycle power plant 10 may include only one of the gas capture systems 164 or 166.

[0034] The gas capture system 162 is configured to capture undesirable gases (e.g., CO₂) from a flow of air (airflow) 190 prior to entry and/or combustion in the gas turbine engine 12, wherein the gas capture system 162 uses the heated fluid 168 (e.g., steam and/or heated water) as a heat source. The steam supply line 174 is coupled to the gas capture system 162, and provides the heated fluid 168 (e.g., steam and/or heated water) as a steam flow and/or water flow as indicated by arrow 192. As discussed above, the steam supply system 170 may include one or more steam supply lines (e.g., line 174) coupled to the HRSG 14 and/or the steam turbine system 16 at one or more locations, such that the heated fluid 168 (e.g., steam and/or heated water) can be supplied to the gas capture system 162 at a variety of conditions (e.g., pressures, temperatures, steam content, water content, etc.). In certain embodiments, the gas capture system 162 may be configured to treat a recirculated exhaust gas (EGR), such as the exhaust gas 68 recirculated into the compressor section 22, and thus the gas capture system 162 may be sized to handle greater concentrations of undesirable gases that are recirculated as part of the EGR process. In certain embodiments, the EGR flow may route the exhaust gas 68 from a location downstream from the HRSG 14 (e.g., upstream or downstream from one or more dryers 200) and into the gas capture system 162. The EGR flow (if present) may mix with the airflow 190 directed into the gas capture system 162. The gas capture system 162 generally treats the airflow 190 (and optionally EGR flow) directed into the gas turbine engine 12,

such that the concentration of undesirable gases is low, while also routing a captured gas 194 to the compression system 188 via a discharge conduit or line 196. The discharge line 196 also may include post-processing equipment, such as a dryer 198 configured to remove moisture content from the captured gas 194.

[0035] As further illustrated in FIG. 1, the gas capture systems 164 and 166 are coupled to the combined cycle power plant 10 along the exhaust gas flow 68 downstream from the gas turbine section 26 and the HRSG 14. In the illustrated positions, the gas capture systems 164 and 166 are configured to remove undesirable gas from the exhaust gas flow 68 discharged from the gas turbine engine 12 and the HRSG 14. Along the exhaust gas flow 68, the gas treatment system 18 may include one or more dryers 200, one or more fans 202, and one or more valves 204 along an exhaust flow path (e.g., exhaust duct) 206 upstream from the gas capture systems 164 and 166. The one or more dryers 200 may include one or more coolers configured to reduce the temperature of the exhaust gas 68 to a suitable temperature (e.g., 35 to 50 degrees Celsius) for treatment in the gas capture systems 164 and 166, thereby also causing water to condense out of the exhaust gas 68. The one or more fans 202 (e.g., electric motor driven fans) are configured to boost a pressure and/or flow rate of the exhaust gas flow 68. The one or more valves 204 are configured to adjust a pressure, flow rate, and/or distribution of the exhaust gas flow 68 into the gas capture systems 164 and 166. In certain embodiments, the illustrated dryers 200, fans 202, and valves 204 are partially or entirely shared by the gas capture systems 164 and 166. However, in some embodiments, one or more dryers 200, fans 202, and valves 204 may be disposed independently upstream of each of the gas capture systems 164 and 166. The exhaust gas flow 68 flows through each of the gas capture systems 164 and 166 in series for staged removal of the undesirable gases to achieve desired capture amounts.

[0036] The gas capture system 164 removes a portion of the undesirable gases from the exhaust gas flow 68, discharges a treated exhaust gas flow (e.g., upstream or first stage treated exhaust gas) to the gas capture system 166, and discharges a captured gas portion

of the captured gas 194 as indicated by discharge conduit or line 208. Similarly, the gas capture system 166 removes a portion of the undesirable gases from the exhaust gas flow 68, discharges a treated exhaust gas flow (e.g., downstream or second stage treated exhaust gas) to a subsequent gas capture system or an exhaust stack 214, and discharges a captured gas portion of the captured gas 194 as indicated by discharge conduit or line 216. As discussed in further detail below, the gas capture systems 164 and 166 may include a sorbent-based gas capture system, a solvent-based gas capture system, one or more other technologies for gas capture using a heated fluid (e.g., a heated fluid 168 being attemperated by a heated water), or a combination thereof. The steam supply line 176 is coupled to the gas capture systems 164 and 166, and provides the heated fluid 168 (e.g., steam and/or heated water) as a steam flow and/or a heated water flow into the gas capture systems 164 and 166. As discussed above, the steam supply system 170 may include one or more steam supply lines (e.g., line 176) coupled to the HRSG 14 and/or the steam turbine system 16 at one or more locations, such that the heated fluid 168 (e.g., steam and/or heated water) can be supplied to the gas capture systems 164 and 166 at a variety of conditions (e.g., pressures, temperatures, steam content, water content, etc.). The discharge lines 208 and 216 may include a variety of post-processing equipment, such as dryers 210 and 218 configured to remove moisture (e.g., water content or steam) and dry the captured gas 194 to generated dried captured gas as indicated by discharge conduits or lines 212 and 220. The captured gas 194 then flows to the compression system 188 as discussed below. In certain embodiments, the dryers 210, 218 may be included in the compression system 188.

[0037] The compression system 188 may include a single stage or multistage compression system. In the illustrated embodiment, the compression system 188 includes one or more first or upstream compressors 222 configured to compress the captured gas 194 in one or more upstream stages, one or more second or downstream compressors 224 configured to compress the captured gas 194 after compression by the compressors 222, and one or more intercoolers 226 configured to cool the captured gas 194 between the compressors 222 and 224. The compression system 188 outputs a compressed captured

gas 194 to a storage unit and/or pipeline 228 at a specified pressure and gas purity, as indicated by discharge conduit or line 230.

[0038] As discussed above, the control system 144 and the monitoring system 146 are communicatively coupled to the gas capture systems 160 and various sensors 148 to provide monitoring and control of the gas capture of undesirable gases (e.g., CO₂). For example, the sensors 148 may include gas composition sensors configured to provide concentration levels of the undesirable gases (e.g., CO₂) and other gases (e.g., oxygen, hydrogen) upstream, within, and/or downstream from each of the gas capture systems 160. The sensors 148 also may include temperature, pressure, and flow rate sensors configured to provide associated feedback regarding the flows of gas (e.g., air, exhaust gas) being treated by the gas capture systems 160, and flows of steam or other fluids being used in support of the gas capture systems 160. The control system 144 may use the sensor feedback to adjust operation of the gas capture systems 160, such as by adjusting characteristics of steam or other fluids (e.g., temperature, pressure, flow rate, and/or flow paths) in the gas capture systems 160, adjusting residence times in the gas capture systems 160, activating or deactivating one or more of the gas capture systems 160, adjusting the dryers (e.g., 200, 210, and 218), adjusting the fans 202, adjusting the valves 204, adjusting the HRSG 14 and/or extraction of the heated fluid 168 (e.g., content and conditions of steam and/or water, extraction points, etc.), adjusting the fluid extraction and split (e.g., flow distribution) of heated water from the LP economizer 100 for use in the LP evaporator 98 and the heat exchangers 178 and 180 (e.g., direct and/or indirect heat exchangers or attemperators), adjusting the gas turbine engine 12 (e.g., adjusting fuel/air ratio, combustion characteristics, fuel type, fuel additives, etc.), or any combination thereof, depending on concentration levels of the undesirable gases. By adjusting various aspects of the gas treatment system 18 (e.g., multiple stages of gas capture systems 160) in coordination with the gas turbine engine 12 and the HRSG 14, the combined cycle power plant 10 may be configured to provide a low carbon, a net neutral, or a net negative carbon footprint.

[0039] FIG. 2 is a schematic of a portion of the combined cycle power plant 10 of FIG. 1, further illustrating an embodiment of the gas capture system 160 (e.g., a solvent-based gas capture system 250) downstream from the HRSG 14, the steam supply system 170 coupled to the gas capture system 160, and a fluid supply system 252 extending between the LP section 76 of the HRSG 14 and the steam supply system 170. The combined cycle power plant 10 is the same as described in detail above with reference to FIG. 1. Accordingly, the HRSG 14 includes the HP section 72, the IP section 74, and the LP section 76, although FIG. 2 shows only a portion of the HRSG 14 having the LP section 76 for simplicity. Nevertheless, the HRSG 14 includes all sections shown in FIG. 1. As illustrated, the LP section 76 includes the LP evaporator 98 and the LP economizer 100 that is substantially increased in size and cooling capacity. For example, the LP economizer 100 may be increased in size and cooling capacity to help cool the exhaust gas 68 to a temperature suitable for treatment in the gas capture system 160, such as a temperature of 35 to 50 degrees Celsius. However, in some embodiments, the temperature range may be 30 to 60 degrees Celsius, 25 to 75 degrees Celsius, or some other suitable temperature range. By further example, the LP economizer 100 may be configured to cool the exhaust gas 68 to an exhaust temperature in the exhaust stack 214 to the foregoing temperature ranges or at least equal to or less than 75 degrees Celsius, such that the exhaust temperature entering the gas capture system 160 is within the foregoing temperature ranges or at least equal to or less than 50, 55, 60, 65, 70, or 75 degrees Celsius. As discussed above, the LP economizer 100 may include corrosion resistant materials and/or coatings (e.g., nickel, cobalt, palladium, platinum, stainless steel, nickel-based alloys, etc.) on various heat exchanger tubing (e.g., coils).

[0040] In certain embodiments, the LP economizer 100 is configured to cool the exhaust gas 68 sufficiently to substantially reduce the size and cooling capacity of a direct contact cooler (DCC) 248 used for cooling the exhaust gas 68 prior to the gas capture system 160, such as by reducing the size and cooling capacity of the DCC 240 by at least 50, 60, 70, 80, or 90 percent or completely eliminating the DCC 240. The DCC 240, if included, may include a plurality of spray nozzles or atomizers configured to spray water

into the exhaust gas 68, thereby directly contacting the water with the exhaust gas 68 and directly cooling the exhaust gas 68. However, in certain embodiments, with the increased size and cooling capacity of the LP economizer 100, no additional cooling may be required or included between the LP section 76 and the gas capture system 160 (i.e., no DCC 240 or other cooling systems). The reduced size or elimination of the DCC 240 helps reduce the equipment associated with the gas capture system 160. The increased size and cooling capacity of the LP economizer 100 also results in a greater water flow through the LP economizer 100, such that excess heated water is available for other uses in the combined cycle power plant 10 (e.g., tempering the heated fluid 168 for the gas capture system 160).

[0041] In the illustrated embodiment, the fluid supply system 252 includes a fluid circuit 254 (e.g., fluid conduit) extending between the LP economizer 100 and an attemperator 256, wherein the attemperator 256 is configured to temper the heated fluid 168 (e.g., steam and/or heated water) from the steam supply system 170 with a heated water 258 from the LP economizer 100. The steam supply system 170 may provide the heated fluid 168 as a HRSG steam 242 from the HRSG 14 (e.g., HP, IP, or LP steam from sections 72, 74, and/or 76) and/or a steam turbine system (STS) steam 244 from the steam turbine system 16 (e.g., HP, IP, or LP steam from sections 106, 108, or 110). For example, the heated fluid 168 may be extracted from one or more LP extraction locations, IP extraction locations, or steam flow paths between the LP and IP extraction locations in the HRSG 14 and/or the steam turbine system 16. The controller 150 may selectively control (e.g., open, close, or vary flow) of the HP, IP, and LP steam from the HRSG 14 and/or the STS 16 as the heated fluid 168. The attemperator 256 then adjusts the temperature of the heated fluid 168. For example, the attemperator 256 (e.g., direct heat exchanger or indirect heat exchanger) may be configured to enable direct heat transfer and/or indirect heat transfer between the heated fluid 168 (e.g., steam and/or heated water) and the heated water 258, thereby helping to regulate or control the temperature of the heated fluid 168 for use in the gas capture system 160. By further example, the attemperator 256 may be configured to spray the heated water 258 (e.g., via a plurality of spray nozzles or atomizers) directly

into the heated fluid 168, thereby providing direct contact and heat transfer with the heated fluid 168.

[0042] In the illustrated embodiment, the LP economizer 100 outputs the heated water 258 to one or more valves 260, which are configured to control a flow distribution or split of the heated water 258 through the fluid circuit 254 to the attemperator 256 or through a fluid circuit 262 (e.g., fluid conduit) to the LP evaporator 98. The controller 150 may be configured to control the one or more valves 260 to control the flow distribution of the heated water 258 through the fluid circuits 254 and 262 based on needs in the LP evaporator 98 and the attemperator 256. For example, if more or less heated water 258 is needed for attempering the heated fluid 168 in the attemperator 256, then the controller 150 may control the one or more valves 260 to increase or decrease the flow of the heated water 258 through the fluid circuit 254 to the attemperator 256. Similarly, if more or less heated water 258 is needed for evaporation in the LP evaporator 98, then the controller 150 may control the one or more valves 260 to increase or decrease the flow of the heated water 258 through the fluid circuit 262 to the LP evaporator 98. By further example, if more or less total heated water 258 is need by the LP evaporator 98 and the attemperator 256, then the controller 150 may control the supply of water through the LP economizer 100 to supply the total heated heater 258 output by the LP economizer 100. Advantageously, the heated water 258 provided by the LP economizer 100 may reduce or eliminate the need for other feedwater to attemperate the heated fluid 168 in the attemperator 256, while the LP economizer 100 simultaneously cools the exhaust gas 68 to a suitable temperature for treatment in the gas capture system 160.

[0043] The exhaust gas 68 output from the gas turbine system 12 generally flows through the HRSG 14 for heat recovery and steam generation in the HP section 72, the IP section 74, and the LP section 76 before entering the exhaust stack 214. The exhaust stack 214 may include one or more flow controls (e.g., dampers) 264, 265 configured to control the flow of the exhaust gas 68 selectively along an exhaust discharge flow path 266 out through the exhaust stack 214 and/or an exhaust treatment flow path 268 through one or

more ducts 270 (e.g., ducts 272 and 274) leading to the gas capture system 160. For example, the controller 150 may be configured to open the damper 264 and close the damper 265 to direct all of the exhaust gas 68 along the exhaust discharge flow path 266, the controller 150 may be configured to close the damper 264 and open the damper 265 to direct all of the exhaust gas 68 along the exhaust treatment flow path 268, or the controller 150 may be configured to partially open each of the dampers 264 and 265 to direct portions of the exhaust gas 68 along both the exhaust discharge flow path 266 and the exhaust treatment flow path 268. In certain embodiments, the exhaust treatment flow path 268 includes the DCC 240 between the ducts 272 and 274, wherein the DCC 240 is substantially reduced in size and cooling capacity as discussed above. In some embodiments, the DCC 240 is completely eliminated from the exhaust treatment flow path 268 by sufficiently increasing the size and cooling capacity of the LP economizer 100. In either case, the duct 274 may output the exhaust gas 68 to the gas capture system 160 with a temperature suitable for treatment, as discussed above.

[0044] The gas capture system 160 may include the solvent-based gas capture system 250 as discussed above, or any other suitable gas capture system that can utilize the heated fluid 168 being attemperated by the heated water 258. For example, the gas capture system 160 may include a sorbent-based gas capture system using a temperature swing adsorption (TSA) process, a vacuum temperature swing adsorption (VTSA) process, a concentration swing adsorption (CSA) process, or any combination thereof. However, in the illustrated embodiment, the gas capture system 160 includes the solvent-based gas capture system 250 having an absorber 280, a stripper 282, a reboiler 284 coupled to the stripper 282, a gas circuit 276 (e.g., exhaust gas circuit or flow path) through the absorber 280, and an absorbent fluid circuit 278 (e.g., solvent circuit, flow path, or closed loop) through the absorber 280 and the stripper 282. The absorbent fluid circuit 278 circulates an absorbent fluid (e.g., solvent) through and between the absorber 280 and the stripper 282. Example absorbent fluids (e.g., solvents) include monoethanolamine (MEA), diglycolamine (DGA), advanced amine solvents, amino acid salts, carbonate solvents, aqueous ammonia, immiscible liquids, and ionic liquids.

[0045] In operation, the absorber 280 absorbs an undesirable gas (e.g., CO₂) from the exhaust gas 68 along the gas circuit 276 into the solvent along the absorbent fluid circuit 278, thereby outputting a treated gas 286 (e.g., treated exhaust gas) and a CO₂-rich solvent 288. For example, the gas circuit 276 and the absorbent fluid circuit 278 may be oriented in opposite flow directions through the absorber 280, such that the exhaust gas 68 flows counter to the absorbent fluid flow. In certain embodiments, the undesirable gas may include any of the undesirable gases discussed above, such as carbon oxides (CO_x) such as carbon dioxide (CO₂) and carbon monoxide (CO), nitrogen oxides (NO_x) such as nitrogen dioxide (NO₂), and/or sulfur oxides (SO_x) such as sulfur dioxide (SO₂). However, the present discussion uses CO₂ as one non-limiting example. The stripper 282 receives the CO₂-rich solvent 288 along the absorbent fluid circuit 278 and strips the CO₂ from the CO₂-rich solvent 288, thereby outputting the captured gas 194 (e.g., CO₂) and a CO₂-lean solvent 290. The CO₂-lean solvent 290 returns to the absorber 280 along the absorbent fluid circuit 278 for another cycle through the absorber 280 and the stripper 282. The stripper 282 is configured to strip the CO₂ using a heat source, such as the reboiler 284. For example, the reboiler 284 is configured to reheat and reboil the solvent for use in the stripper 282. In the illustrated embodiment, the steam supply system 170 is configured to inject the heated fluid 168 (e.g., after attemperation by the attemperator 256) directly into the stripper 282 along a fluid circuit 292 (e.g., fluid conduit) and/or indirectly into the stripper 282 via a fluid circuit 294 coupled to the reboiler 284.

[0046] In certain embodiments, the steam supply system 170 is configured to supply the heated fluid 168 (e.g., after attemperation by the attemperator 256) to one or more components of the gas capture system 160 that use heat to desorb the CO₂ captured from the exhaust gas 68. For example, the one or more components may include a sorbent unit having a sorbent material of a sorbent-based carbon capture system, wherein the heated fluid 168 is used to increase a temperature of the sorbent material to enable desorption of the CO₂ adsorbed from the exhaust gas 68. By further example, the one or more components may include a heat exchanger or other component of a cryogenic carbon

capture system. However, the disclosed embodiments may be used with any suitable gas capture systems 160 that can use the heated fluid 168.

[0047] FIG. 3 is a flow chart of an embodiment of a process 320 for operating the combined cycle power plant 10 of FIGS. 1 and 2, wherein the process may be implemented at least partially or entirely with the controller 150 based on sensor feedback from the sensors 148. In the illustrated embodiment, the process 320 includes controlling a gas turbine system 12 to drive a load 28 (e.g., electrical generator) and output an exhaust gas 68 (block 322). The process 320 further includes controlling a heat recovery steam generator (HRSG) 14 to recover heat from the exhaust gas 68 and generate steam in the HP section 72, the IP section 74, and the LP section 76 of the HRSG 14 (block 324). The process 320 further includes controlling a water flow (e.g., feedwater, condensate) through the LP economizer 100 of the LP section 76 of the HRSG 14 to control an exhaust gas temperature of the exhaust gas 68 for the exhaust stack 214 and the gas capture system 160 (e.g., solvent-based gas capture system 250) (block 326). For example, the process 320 may control the exhaust gas temperature to achieve a desired temperature range of the exhaust gas 68 within the exhaust stack 214, and to achieve a desired temperature range of the exhaust gas 68 entering the gas capture system 160. By further example, the process 320 may control the exhaust gas temperature to a sufficiently low temperature to reduce or eliminate the need for any DCC 240.

[0048] The process 320 may further include controlling flows of heated water 258 from the LP economizer 100 to the LP evaporator 98 of the HRSG 14 and from the LP evaporator 98 to the attemperator 256 of the steam supply system 170 (block 328). For example, the process 320 may control (e.g., increase or decrease) the flow of the heated water 258 to the LP evaporator 98 depending on needs for LP steam, and the process 320 may control (e.g., increase or decrease) the flow of the heated water 258 to the attemperator 256 depending on needs for attempering the heated fluid 168 (e.g., steam) for use in the gas capture system 160. Thus, the process 320 may control the total water flow through the LP economizer 100 (block 326) in combination with a split or distribution of the heated water 258 between

the LP evaporator 98 and the attemperator 256 (block 328) depending on sensor feedback in the HRSG 14, the steam turbine system 16, the gas capture system 160, and the steam supply system 170. The sensor feedback may include steam measurements, such as temperature and pressure of the steam. The sensor feedback may include solvent measurements, such as temperature of the solvent in the stripper 282 and/or the reboiler 284. The sensor feedback may include exhaust gas measurements, such as temperature, pressure, flow rate, gas composition (e.g., CO₂), or any combination thereof.

[0049] The process 320 may further include controlling a flow of steam from the steam supply system 170 (e.g., after passing through the attemperator 256) to the stripper 282 and/or the reboiler 284 of the gas capture system 160 (e.g., solvent-based gas capture system 250) (block 330), thereby providing heat in the form of the steam to strip undesirable gases (e.g., CO₂) from a CO₂-rich solvent from the absorber 280. In particular, the process 320 may control the flow, temperature, and/or pressure of the steam for use in the stripper 282 and/or the reboiler 284. The process 320 may further include controlling capture of undesirable gases (e.g., CO₂) from the stripper 282 of the gas capture system 160 (e.g., solvent-based gas capture system 250) (block 332), thereby obtaining the captured gas 194 (e.g., CO₂). Additionally, the process 320 may include outputting the treated exhaust gas 286 (block 334). As discussed above, the process 320 may control the various steps 322-334 to cool the exhaust gas 68 via the LP section 76 sufficient for the gas capture system 160 (e.g., 250) without or with a size-reduced DCC 240, while also generating excess heated water 258 from the LP economizer 100 for use in attempering steam supplied to the stripper 282 and/or the reboiler 284 of the gas capture system 160 (e.g., 250).

[0050] Technical effects of the disclosed embodiments include a gas treatment system having at least one gas capture system 160 (e.g., 162, 164, 166), which may include the solvent-based gas capture systems (e.g., 250, FIG. 2) with heated fluid 168 (e.g., steam and/or heated water) being attemperated in an attemperator 256 using heated water 258 from the LP section 76 (e.g., LP economizer 100) of the HRSG 14. The disclosed

embodiments substantially reduce the concentration levels of undesirable gases (e.g., CO₂) to reduce the carbon footprint for the combined cycle power plant 10. In certain embodiments, the gas capture systems 160 (e.g., 162, 164, 166, 250) use the heated fluid 168 (e.g., steam and/or heated water) from intermediate-pressure and/or low-pressure extraction locations at the HRSG 14 and the steam turbine system 16. The attemperator 256 then adjusts the temperature of the heated fluid 168 prior to delivery into the gas capture systems 160. In certain embodiments, the LP economizer 100 of the HRSG 14 is substantially increased in size and cooling capacity, such that the LP economizer 100 is configured to cool the exhaust gas flow 68 within upper and lower temperature thresholds suitable for the gas capture systems 160 without the need for the DCC 240. Additionally, the increased size and cooling capacity of the LP economizer 100 results in excess heated water 258 being available beyond the needs of the LP evaporator 98, such that the excess heated water 258 can be used to attemperate the steam in the attemperator 256 rather than relying on other sources of heated water. Thus, the increased size and cooling capacity of the LP economizer 100 simplifies and reduces the footprint of the gas capture system 160.

[0051] The subject matter described in detail above may be defined by one or more clauses, as set forth below.

[0052] A system includes a gas treatment system having a gas capture system configured to capture an undesirable gas from a gas flowing along a gas circuit. The gas treatment system further includes a steam supply circuit coupled to the gas capture system, wherein the steam supply circuit is configured to supply steam from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system. The gas treatment system further includes a fluid supply circuit configured to couple to a low-pressure section of the HRSG, wherein the HRSG is configured to cool the gas upstream from the gas capture system. The gas treatment system further includes an attemperator coupled to the steam supply circuit and the fluid supply circuit, wherein the attemperator is configured to attemperate the steam with a heated water from the low-pressure section of the HRSG.

[0053] The system of the preceding clause, wherein the attemperator is configured to directly contact the heated water with the steam.

[0054] The system of any preceding clause, wherein the attemperator is configured to spray the heated water into the steam.

[0055] The system of any preceding clause, wherein the attemperator is configured to attemperate the steam with the heated water only from the low-pressure section of the HRSG.

[0056] The system of any preceding clause, wherein the steam includes a low-pressure steam, an intermediate-pressure steam, or a combination thereof.

[0057] The system of any preceding clause, wherein the low-pressure section of the HRSG includes a low-pressure economizer and a low-pressure evaporator, and the low-pressure economizer is configured to supply the heated water to the low-pressure evaporator and the attemperator.

[0058] The system of any preceding clause, including one or more valves configured to control flows of the heated water to the low-pressure evaporator and the attemperator, wherein the one or more valves are adjustable via a controller.

[0059] The system of any preceding clause, wherein the controller is configured to adjust the one or more valves in response to sensor feedback including a temperature and/or a pressure of the steam.

[0060] The system of any preceding clause, wherein the low-pressure economizer is configured to cool the gas within upper and lower temperature thresholds suitable for treatment of the gas in the gas capture system.

[0061] The system of any preceding clause, wherein the gas circuit is configured to extend from the HRSG to the gas capture system, and the gas circuit excludes a direct contact cooler (DCC) configured to cool the gas.

[0062] The system of any preceding clause, wherein the gas capture system includes an absorber, a stripper, the gas circuit through the absorber, and an absorbent fluid circuit through the absorber and the stripper, wherein the absorber is configured to absorb the undesirable gas from the gas flowing along the gas circuit into an absorbent fluid flowing along the absorbent fluid circuit, wherein the stripper is configured to strip the undesirable gas from the absorbent fluid.

[0063] The system of any preceding clause, wherein the undesirable gas includes carbon dioxide (CO₂).

[0064] The system of any preceding clause, wherein the steam supply circuit includes at least one steam supply circuit configured to provide the steam to heat at least one component of the gas capture system to desorb the undesirable gas captured from the gas.

[0065] The system of any preceding clause, including the HRSG having a high-pressure section, an intermediate-pressure section, and the low-pressure section, wherein the steam supply circuit is configured to supply the steam from the low-pressure section and/or the intermediate pressure section of the HRSG to the gas capture system.

[0066] The system of any preceding clause, including the steam turbine system having a high-pressure steam turbine, an intermediate-pressure steam turbine, and a low-pressure steam turbine, wherein the steam supply circuit is configured to supply the steam from the low-pressure steam turbine and/or the intermediate pressure steam turbine of the steam turbine system to the gas capture system.

[0067] The system of any preceding clause, including a gas turbine system configured to generate an exhaust gas flow, wherein the HRSG is configured to transfer heat from the exhaust gas flow for steam generation, wherein the gas capture system is configured to capture the undesirable gas from the exhaust gas flow as the gas.

[0068] A system includes a controller configured to control a gas capture system of a gas treatment system to capture an undesirable gas from a gas flowing along a gas circuit.

The controller is further configured to control a supply of a steam through a steam supply circuit from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system. The controller is further configured to control a supply of a heated water through a fluid supply circuit from a low-pressure section of the HRSG to an attemperator coupled to the steam supply circuit, wherein the HRSG is configured to cool the gas upstream from the gas capture system, and the attemperator is configured to attemperate the steam with the heated water.

[0069] The system of the preceding clause, wherein the gas includes an exhaust gas from a gas turbine system, the undesirable gas includes carbon dioxide (CO₂), and the steam includes a low-pressure steam, an intermediate-pressure steam, or a combination thereof, from the HRSG and/or the steam turbine system.

[0070] A method includes controlling a gas capture system of a gas treatment system to capture an undesirable gas from a gas flowing along a gas circuit. The method further includes controlling a supply of a steam through a steam supply circuit from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system. The method further includes controlling a supply of a heated water through a fluid supply circuit from a low-pressure section of the HRSG to an attemperator coupled to the steam supply circuit, wherein the HRSG is configured to cool the gas upstream from the gas capture system, and the attemperator is configured to attemperate the steam with the heated water.

[0071] The method of the preceding clause, wherein the gas includes an exhaust gas from a gas turbine system, the undesirable gas includes carbon dioxide (CO₂), and the steam includes a low-pressure steam, an intermediate-pressure steam, or a combination thereof, from the HRSG and/or the steam turbine system.

[0072] This written description uses examples to describe the present embodiments, including the best mode, and also to enable any person skilled in the art to practice the presently disclosed embodiments, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the presently disclosed

embodiments 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 language of the claims.

CLAIMS:

1. A system, comprising:
a gas treatment system, comprising:
a gas capture system configured to capture an undesirable gas from a gas flowing along a gas circuit;
a steam supply circuit coupled to the gas capture system, wherein the steam supply circuit is configured to supply steam from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system;
a fluid supply circuit configured to couple to a low-pressure section of the HRSG, wherein the HRSG is configured to cool the gas upstream from the gas capture system; and
an attemperator coupled to the steam supply circuit and the fluid supply circuit, wherein the attemperator is configured to attemperate the steam with a heated water from the low-pressure section of the HRSG.
2. The system of claim 1, wherein the attemperator is configured to directly contact the heated water with the steam.
3. The system of claim 2, wherein the attemperator is configured to spray the heated water into the steam.
4. The system of claim 1, wherein the attemperator is configured to attemperate the steam with the heated water only from the low-pressure section of the HRSG.
5. The system of claim 1, wherein the steam comprises a low-pressure steam, an intermediate-pressure steam, or a combination thereof.
6. The system of claim 1, wherein the low-pressure section of the HRSG comprises a

low-pressure economizer and a low-pressure evaporator, and the low-pressure economizer is configured to supply the heated water to the low-pressure evaporator and the attemperator.

7. The system of claim 6, comprising one or more valves configured to control flows of the heated water to the low-pressure evaporator and the attemperator, wherein the one or more valves are adjustable via a controller.

8. The system of claim 7, wherein the controller is configured to adjust the one or more valves in response to sensor feedback including a temperature and/or a pressure of the steam.

9. The system of claim 6, wherein the low-pressure economizer is configured to cool the gas within upper and lower temperature thresholds suitable for treatment of the gas in the gas capture system.

10. The system of claim 9, wherein the gas circuit is configured to extend from the HRSG to the gas capture system, and the gas circuit excludes a direct contact cooler (DCC) configured to cool the gas.

11. The system of claim 1, wherein the gas capture system comprises an absorber, a stripper, the gas circuit through the absorber, and an absorbent fluid circuit through the absorber and the stripper, wherein the absorber is configured to absorb the undesirable gas from the gas flowing along the gas circuit into an absorbent fluid flowing along the absorbent fluid circuit, wherein the stripper is configured to strip the undesirable gas from the absorbent fluid.

12. The system of claim 1, wherein the undesirable gas comprises carbon dioxide (CO₂).

13. The system of claim 1, wherein the steam supply circuit comprises at least one steam supply circuit configured to provide the steam to heat at least one component of the gas capture system to desorb the undesirable gas captured from the gas.

14. The system of claim 1, comprising the HRSG having a high-pressure section, an intermediate-pressure section, and the low-pressure section, wherein the steam supply circuit is configured to supply the steam from the low-pressure section and/or the intermediate pressure section of the HRSG to the gas capture system.

15. The system of claim 1, comprising the steam turbine system having a high-pressure steam turbine, an intermediate-pressure steam turbine, and a low-pressure steam turbine, wherein the steam supply circuit is configured to supply the steam from the low-pressure steam turbine and/or the intermediate pressure steam turbine of the steam turbine system to the gas capture system.

16. The system of claim 1, comprising a gas turbine system configured to generate an exhaust gas flow, wherein the HRSG is configured to transfer heat from the exhaust gas flow for steam generation, wherein the gas capture system is configured to capture the undesirable gas from the exhaust gas flow as the gas.

17. A system, comprising:

a controller configured to:

control a gas capture system of a gas treatment system to capture an undesirable gas from a gas flowing along a gas circuit

control a supply of a steam through a steam supply circuit from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system; and

control a supply of a heated water through a fluid supply circuit from a low-pressure section of the HRSG to an attemperor coupled to the steam supply

circuit, wherein the HRSG is configured to cool the gas upstream from the gas capture system, and the attemperator is configured to attemperate the steam with the heated water.

18. The system of claim 17, wherein the gas comprises an exhaust gas from a gas turbine system, the undesirable gas comprises carbon dioxide (CO₂), and the steam comprises a low-pressure steam, an intermediate-pressure steam, or a combination thereof, from the HRSG and/or the steam turbine system.

19. A method, comprising:

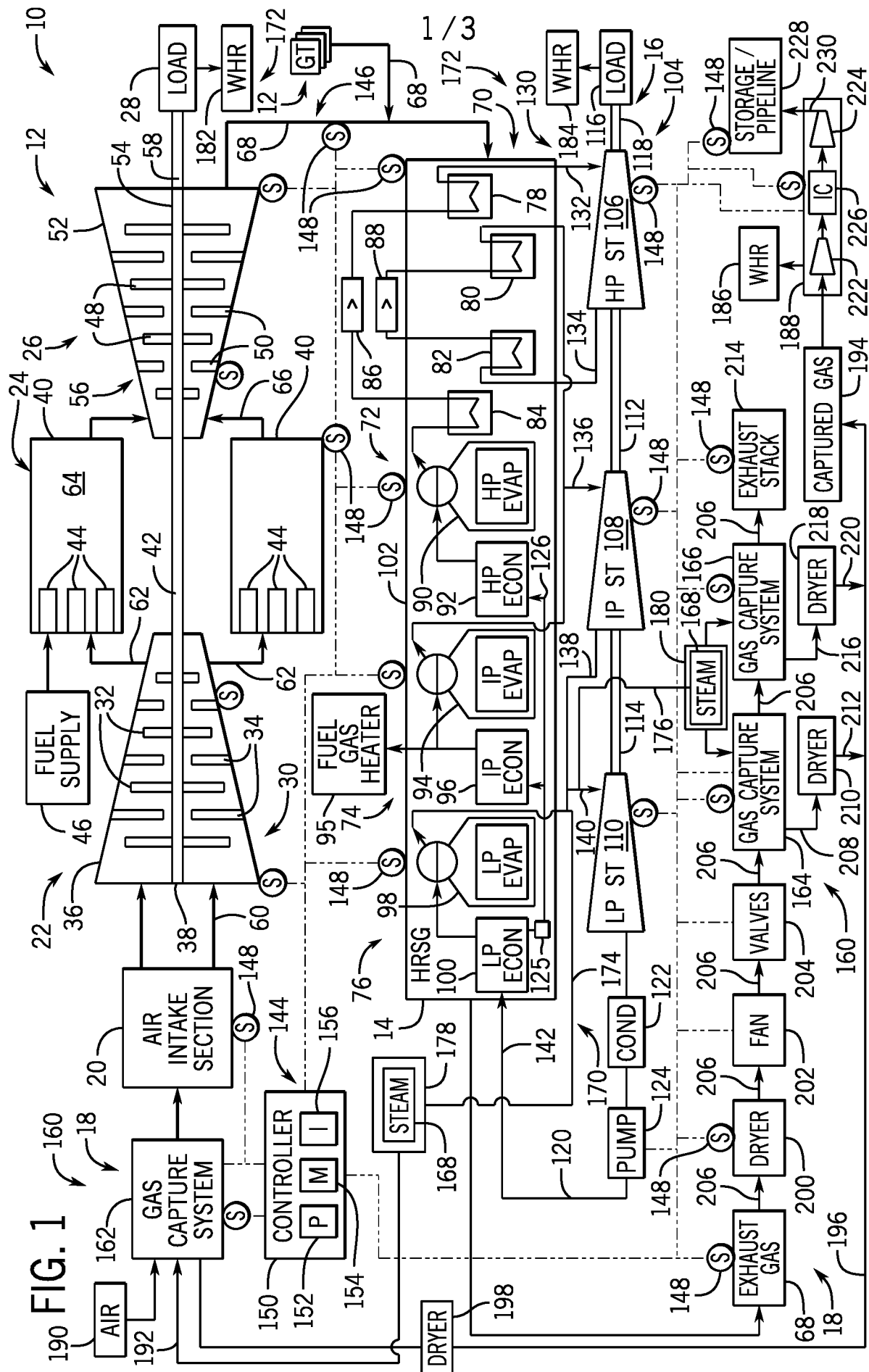
controlling a gas capture system of a gas treatment system to capture an undesirable gas from a gas flowing along a gas circuit;

controlling a supply of a steam through a steam supply circuit from a heat recovery steam generator (HRSG) and/or a steam turbine system to the gas capture system; and

controlling a supply of a heated water through a fluid supply circuit from a low-pressure section of the HRSG to an attemperator coupled to the steam supply circuit, wherein the HRSG is configured to cool the gas upstream from the gas capture system, and the attemperator is configured to attemperate the steam with the heated water.

20. The method of claim 19, wherein the gas comprises an exhaust gas from a gas turbine system, the undesirable gas comprises carbon dioxide (CO₂), and the steam comprises a low-pressure steam, an intermediate-pressure steam, or a combination thereof, from the HRSG and/or the steam turbine system.

FIG. 1



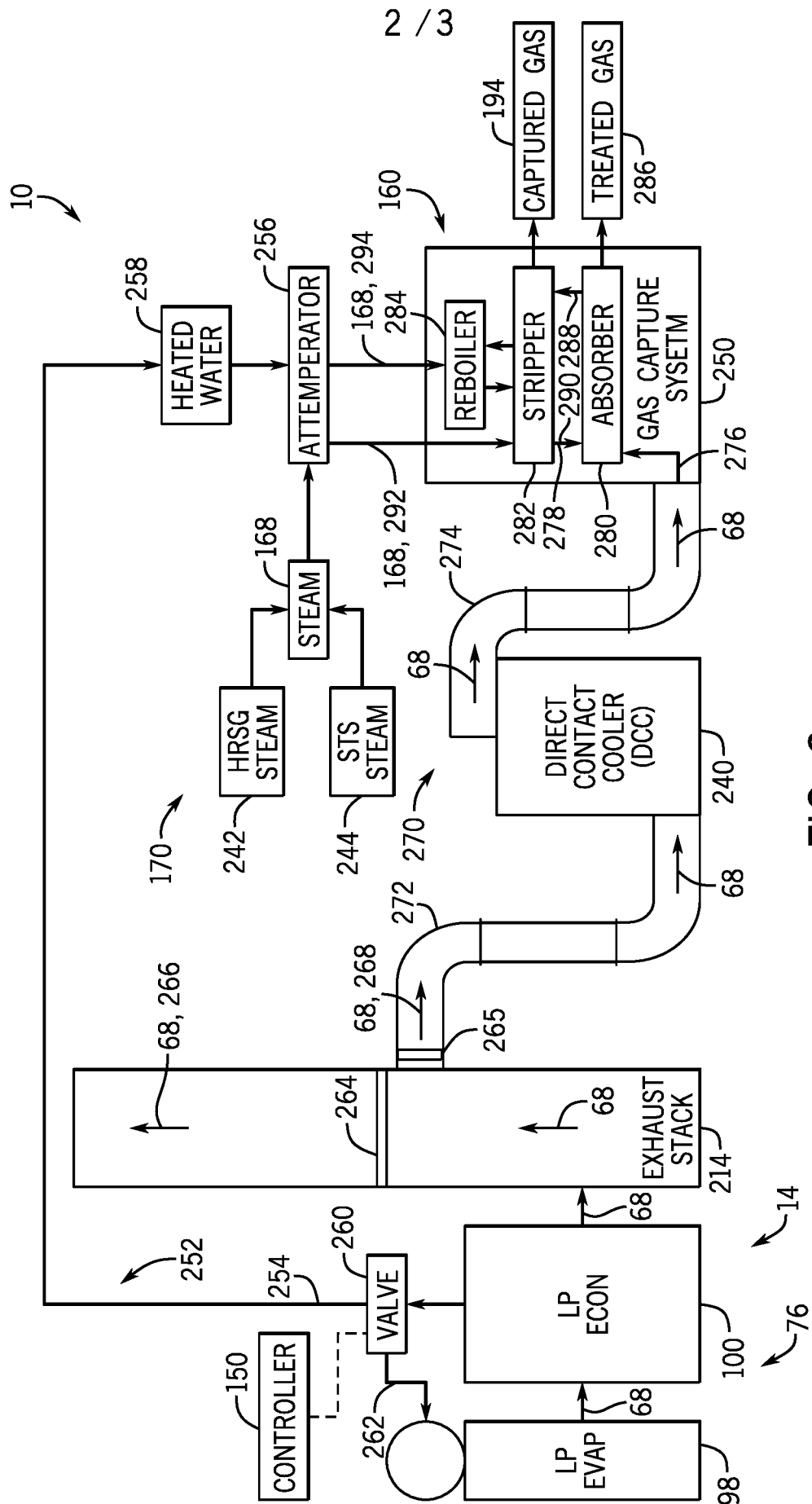


FIG. 2

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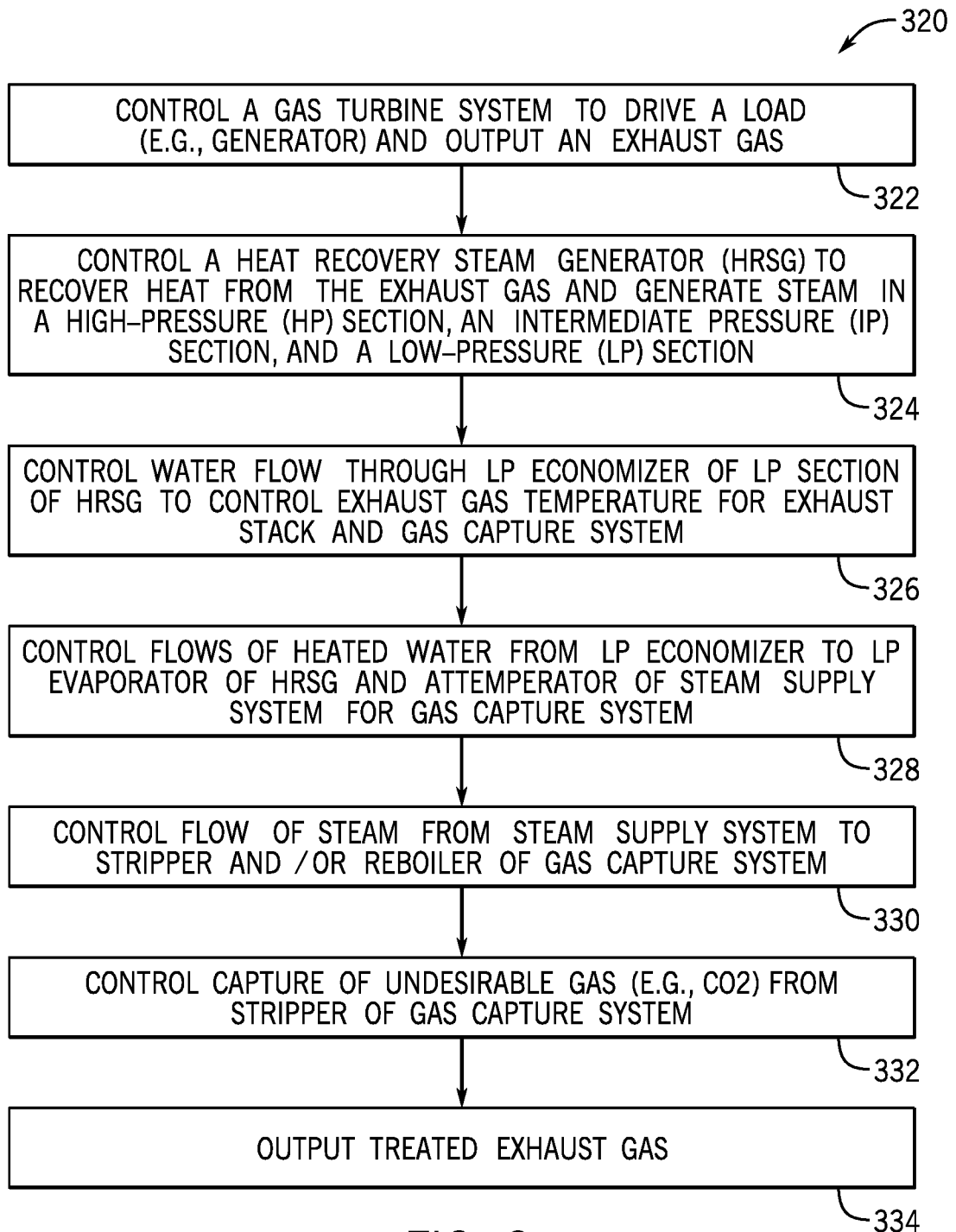


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 23/84838

A. CLASSIFICATION OF SUBJECT MATTER
 IPC - INV. F01K 23/10, F02C 6/18 (2024.01)
 ADD. F01K 7/22 (2024.01)

CPC - INV. F01K 23/10, F02C 6/18

ADD. F01K 7/22, F05D 2260/61

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y --- A	WO 2023/195985 A1 (General Electric Company) 12 October 2023 (12.10.2023), entire document, especially Fig. 2, para [0024], [0025], [0027], [0029], [0032], [0045]	1-6, 9-10, 12, 14-16, 19-20 ----- 7-8, 17-18 ----- 11, 13
Y	US 2014/0150438 A1 (General Electric Company) 5 June 2014 (05.06.2014), entire document, especially Fig. 1, para [0018], [0020], [0021], [0022]	7-8, 17-18
A	US 2012/0260668 A1 (Rogers et al.) 18 October 2012 (18.10.2012), entire document	1-20
A	US 2017/0038060 A1 (General Electric Company) 9 February 2017 (09.02.2017), entire document	1-20
A	US 2018/0340473 A1 (General Electric Company) 29 November 2018 (29.11.2018), entire document	1-20
A	US 2010/0180567 A1 (Nattanmai et al.) 22 July 2010 (22.07.2010), entire document	1-20

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

21 February 2024

Date of mailing of the international search report

APR 01 2024

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Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

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