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(71) Applicants: GENERAL ELECTRIC COMPANY [US/US]; 1 River Road, Schenectady, NY 12345 (US). EXXONMOBIL UPSTREAM RESEARCH COMPANY [US/US]; CORP-URC-SW 341, P.O. Box 2189, Houston, TX 77252-2189 (US).

(72) Inventors: FADDE, Elizabeth, Angelyn; 300 Garlington Road, Greenville, SC 29615 (US). BYRNE, William, Lawrence; 300 Garlington Road, Greenville, SC 29615

(US). ANTONIONO, Carolyn, Ashley; 300 Garlington Road, Greenville, SC 29615 (US).

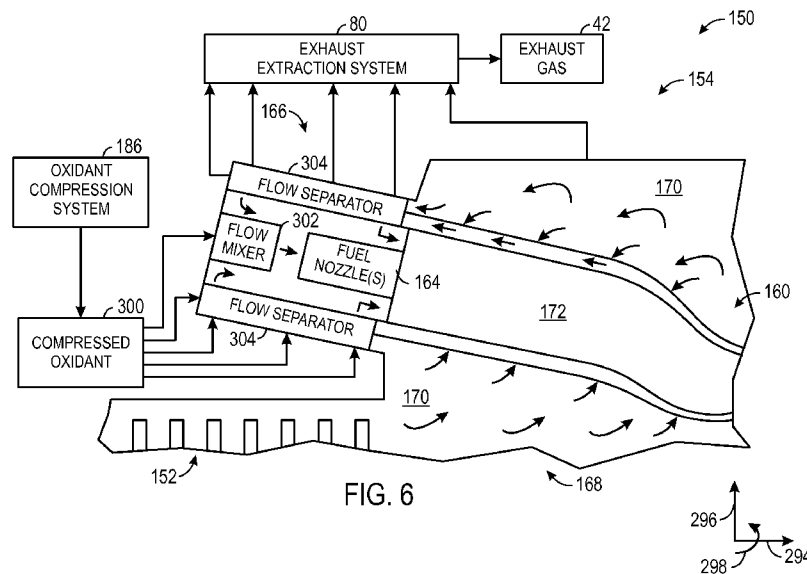
(74) Agents: SWANSON, Tait, R. et al.; P.O. Box 692289, Houston, TX 77269 (US).

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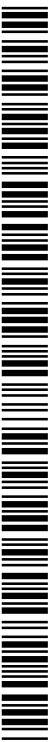
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[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR A TURBINE COMBUSTOR



(57) Abstract: A system includes a turbine combustor (150) that includes a head end portion (166) having a head end chamber, a combustion portion (168) having a combustion chamber disposed downstream from the head end chamber, a cap (331) disposed between the head end chamber and the combustion chamber, and a flow separator (304) configured to separate a first exhaust flow from an oxidant flow. The flow separator is configured to direct the first exhaust flow into the head end chamber. The turbine combustor also includes a mixing region configured to mix the first exhaust flow with the oxidant flow to provide an oxidant-exhaust mixture.



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- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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SYSTEM AND METHOD FOR A TURBINE COMBUSTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and benefit of U.S. Non-Provisional Patent Application No. 14/067,679, entitled "SYSTEM AND METHOD FOR A TURBINE COMBUSTOR," filed on October 30, 2013, U.S. Provisional Patent Application No. 61/747,198, entitled "SYSTEM AND METHOD FOR A TURBINE COMBUSTOR," filed on December 28, 2012, U.S. Provisional Patent Application No. 61/722,118, entitled "System and Method FOR DIFFUSION COMBUSTION IN A STOICHIOMETRIC EXHAUST GAS RECIRCULATION GAS TURBINE SYSTEM," filed on November 2, 2012, U.S. Provisional Patent Application No. 61/722,115, entitled "SYSTEM AND METHOD FOR DIFFUSION COMBUSTION WITH FUEL-DILUENT MIXING IN A STOICHIOMETRIC EXHAUST GAS RECIRCULATION GAS TURBINE SYSTEM," filed on November 2, 2012, U.S. Provisional Patent Application No. 61/722,114, entitled "SYSTEM AND METHOD FOR DIFFUSION COMBUSTION WITH OXIDANT-DILUENT MIXING IN A STOICHIOMETRIC EXHAUST GAS RECIRCULATION GAS TURBINE SYSTEM," filed on November 2, 2012, and U.S. Provisional Patent Application No. 61/722,111, entitled "SYSTEM AND METHOD FOR LOAD CONTROL WITH DIFFUSION COMBUSTION IN A STOICHIOMETRIC EXHAUST GAS RECIRCULATION GAS TURBINE SYSTEM," filed on November 2, 2012, all of which are herein incorporated by reference in their entirety for all purposes.

BACKGROUND OF THE INVENTION

[0002] The subject matter disclosed herein relates to gas turbine engines, and, more particularly, to systems and methods for turbine combustors of gas turbine engines.

[0003] Gas turbine engines are used in a wide variety of applications, such as power generation, aircraft, and various machinery. Gas turbine engines generally combust a fuel with an oxidant (e.g., air) in a combustor section to generate hot

combustion products, which then drive one or more turbine stages of a turbine section. In turn, the turbine section drives one or more compressor stages of a compressor section, thereby compressing oxidant for intake into the combustor section along with the fuel. Again, the fuel and oxidant mix in the combustor section, and then combust to produce the hot combustion products. Gas turbine engines generally premix the fuel and oxidant along one or more flow paths upstream from a combustion chamber of the combustor section. Unfortunately, certain components of the combustor section are exposed to high temperatures, which may reduce the life of the components. Furthermore, gas turbine engines typically consume a vast amount of air as the oxidant, and output a considerable amount of exhaust gas into the atmosphere. In other words, the exhaust gas is typically wasted as a byproduct of the gas turbine operation.

BRIEF DESCRIPTION OF THE INVENTION

[0004] Certain embodiments commensurate in scope with the originally claimed invention are summarized below. These embodiments are not intended to limit the scope of the claimed invention, but rather these embodiments are intended only to provide a brief summary of possible forms of the invention. Indeed, the invention may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

[0005] In a first embodiment, a system includes a turbine combustor that includes a head end portion having a head end chamber, a combustion portion having a combustion chamber disposed downstream from the head end chamber, a cap disposed between the head end chamber and the combustion chamber, and a flow separator configured to separate a first exhaust flow from an oxidant flow. The flow separator is configured to direct the first exhaust flow into the head end chamber. The turbine combustor also includes a mixing region configured to mix the first exhaust flow with the oxidant flow to provide an oxidant-exhaust mixture.

[0006] In a second embodiment, a system includes an oxidant compressor and a gas turbine engine. The gas turbine engine includes a combustor section having a

turbine combustor, a turbine driven by combustion products from the turbine combustor, and an exhaust gas compressor driven by the turbine. The exhaust gas compressor is configured to compress and route an exhaust flow to the turbine combustor and the oxidant compressor is configured to compress and route an oxidant flow to the turbine combustor. The gas turbine engine also includes an exhaust extraction port coupled to the combustor section and a flow separator coupled to a head end portion of the turbine combustor. The flow separator is configured to separate the oxidant flow from a first portion of the exhaust flow until the first portion reaches a mixing region within the head end portion. The flow separator is also configured to separate the oxidant flow from a second portion of the exhaust flow until the second portion reaches the exhaust extraction port. The flow separator includes a flow distributor having an exhaust path extending toward a head end region adjacent a cap in the head end portion of the turbine combustor.

[0007] In a third embodiment, a method includes extracting a first exhaust flow of an exhaust gas at a combustion section of a gas turbine engine, routing a second exhaust flow of the exhaust gas toward an end plate of a head end portion of a turbine combustor in the combustion section, and routing a third exhaust flow of the exhaust gas toward a cap of the head end portion. The cap is disposed between a head end region and a combustion region. The method also includes routing an oxidant flow into the head end portion and separating the oxidant flow at least from the first exhaust flow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0009] FIG. 1 is a diagram of an embodiment of a system having a turbine-based service system coupled to a hydrocarbon production system;

[0010] FIG. 2 is a diagram of an embodiment of the system of FIG. 1, further illustrating a control system and a combined cycle system;

[0011] FIG. 3 is a diagram of an embodiment of the system of FIGS. 1 and 2, further illustrating details of a gas turbine engine, exhaust gas supply system, and exhaust gas processing system;

[0012] FIG. 4 is a flow chart of an embodiment of a process for operating the system of FIGS. 1-3;

[0013] FIG. 5 is a flow chart of an embodiment of a process for operating a gas turbine engine with exhaust gas recirculation;

[0014] FIG. 6 is a schematic diagram of an embodiment of a combustor section of a gas turbine engine with exhaust gas recirculation;

[0015] FIG. 7 is a schematic diagram of an embodiment of a turbine combustor of the gas turbine engine of FIG. 6, illustrating a flow mixer disposed between an end plate and a cap;

[0016] FIG. 8 is a radial cross-sectional view of an embodiment of a turbine combustor taken along line 8-8 of FIG. 7;

[0017] FIG. 9 is a radial cross-sectional view of an embodiment of a turbine combustor taken along line 8-8 of FIG. 7;

[0018] FIG. 10 is a cross-sectional view of an embodiment of a turbine combustor of the gas turbine engine of FIG. 6, illustrating an oxidant intake port coupled to a head end portion of the turbine combustor;

[0019] FIG. 11 is a schematic diagram of an embodiment of a turbine combustor of the gas turbine engine of FIG. 6, illustrating an oxidant intake port coupled to a side wall of a head end portion of the turbine combustor;

[0020] FIG. 12 is a radial cross-sectional view of an embodiment of a turbine combustor taken along line 12-12 of FIG. 11;

[0021] FIG. 13 is a radial cross-sectional view of an embodiment of a turbine combustor taken along line 12-12 of FIG. 11;

[0022] FIG. 14 is a cross-sectional view of an embodiment of a turbine combustor of the gas turbine engine of FIG. 6, illustrating an oxidant intake port coupled to a side wall of a head end portion of the turbine combustor;

[0023] FIG. 15 is a schematic diagram of an embodiment of a turbine combustor of the gas turbine engine of FIG. 6, illustrating an oxidant intake port coupled to a head end portion of the turbine combustor;

[0024] FIG. 16 is a radial cross-sectional view of an embodiment of a turbine combustor taken along line 16-16 of FIG. 15;

[0025] FIG. 17 is a radial cross-sectional view of an embodiment of a turbine combustor taken along line 16-16 of FIG. 15; and

[0026] FIG. 18 is a cross-sectional view of an embodiment of a turbine combustor of the gas turbine engine of FIG. 6, illustrating an oxidant intake port coupled to a head end portion of the turbine combustor.

DETAILED DESCRIPTION OF THE INVENTION

[0027] One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0028] When introducing elements of various embodiments of the present invention, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0029] As discussed in detail below, the disclosed embodiments relate generally to gas turbine systems with exhaust gas recirculation (EGR), and particularly stoichiometric operation of the gas turbine systems using EGR. For example, the gas turbine systems may be configured to recirculate the exhaust gas along an exhaust recirculation path, stoichiometrically combust fuel and oxidant along with at least some of the recirculated exhaust gas, and capture the exhaust gas for use in various target systems. The recirculation of the exhaust gas along with stoichiometric combustion may help to increase the concentration level of carbon dioxide (CO₂) in the exhaust gas, which can then be post treated to separate and purify the CO₂ and nitrogen (N₂) for use in various target systems. The gas turbine systems also may employ various exhaust gas processing (e.g., heat recovery, catalyst reactions, etc.) along the exhaust recirculation path, thereby increasing the concentration level of CO₂, reducing concentration levels of other emissions (e.g., carbon monoxide, nitrogen oxides, and unburnt hydrocarbons), and increasing energy recovery (e.g., with heat recovery units). Furthermore, the gas turbine engines may be configured to combust the fuel and oxidant with one or more diffusion flames (e.g., using diffusion fuel nozzles), premix flames (e.g., using premix fuel nozzles), or any combination thereof. In certain embodiments, the diffusion flames may help to maintain stability and operation within certain limits for stoichiometric combustion, which in turn helps to increase production of CO₂. For example, a gas turbine system operating with diffusion flames may enable a greater quantity of EGR, as compared to a gas turbine system operating with premix flames. In turn, the increased quantity of EGR helps to increase CO₂ production. Possible target systems include pipelines, storage tanks, carbon sequestration systems, and hydrocarbon production systems, such as enhanced oil recovery (EOR) systems.

[0030] The disclosed embodiments provide systems and methods for turbine combustors of gas turbine systems with EGR. Specifically, the turbine combustor may include a head end portion having a head end chamber, a combustion portion having a combustion chamber disposed downstream from the head end chamber, a cap disposed between the head end chamber and the combustion chamber, and a flow separator configured to separate a first exhaust flow from an oxidant flow. The flow separator may direct the first exhaust flow into the head end chamber. In addition the turbine combustor may include a mixing region to mix the first exhaust flow with the oxidant flow to provide an oxidant-exhaust mixture. The turbine combustor may combust the oxidant-exhaust mixture together with a fuel to generate combustion products or gases that may be used to drive a turbine. In addition, a second exhaust flow may be separated from the first exhaust flow and used in an exhaust gas extraction system and/or a hydrocarbon production system. In certain embodiments, the turbine combustor may be part of a stoichiometric exhaust gas recirculation (SEGR) gas turbine engine. The SEGR gas turbine engine may include a combustor section having the turbine combustor, a turbine driven by the combustion products from the turbine combustor, and an exhaust gas compressor driven by the turbine. The exhaust gas compressor may compress and route an exhaust flow to the turbine combustor and an oxidant compressor may compress and route the oxidant flow to the turbine combustor. In addition, an exhaust extraction port may be coupled to the combustor section. Use of such embodiments of turbine combustors may provide several advantages compared to previous turbine combustors. For example, the disclosed embodiments of turbine combustors may directly provide the exhaust flow used in other applications, such as the hydrocarbon production system. In addition, such turbine combustors may provide improved cooling of internal components of the turbine combustor. Specifically, even though large amounts of the exhaust flow are removed from the turbine combustor, the internal configuration of the turbine combustor enables internal surfaces of the combustor that are exposed to high temperatures to be cooled by the exhaust flow. Thus, such turbine combustors may have increased longevity and/or reduced maintenance costs compared to previous combustors.

[0031] FIG. 1 is a diagram of an embodiment of a system 10 having an hydrocarbon production system 12 associated with a turbine-based service system 14. As discussed in further detail below, various embodiments of the turbine-based service system 14 are configured to provide various services, such as electrical power, mechanical power, and fluids (e.g., exhaust gas), to the hydrocarbon production system 12 to facilitate the production or retrieval of oil and/or gas. In the illustrated embodiment, the hydrocarbon production system 12 includes an oil/gas extraction system 16 and an enhanced oil recovery (EOR) system 18, which are coupled to a subterranean reservoir 20 (e.g., an oil, gas, or hydrocarbon reservoir). The oil/gas extraction system 16 includes a variety of surface equipment 22, such as a Christmas tree or production tree 24, coupled to an oil/gas well 26. Furthermore, the well 26 may include one or more tubulars 28 extending through a drilled bore 30 in the earth 32 to the subterranean reservoir 20. The tree 24 includes one or more valves, chokes, isolation sleeves, blowout preventers, and various flow control devices, which regulate pressures and control flows to and from the subterranean reservoir 20. While the tree 24 is generally used to control the flow of the production fluid (e.g., oil or gas) out of the subterranean reservoir 20, the EOR system 18 may increase the production of oil or gas by injecting one or more fluids into the subterranean reservoir 20.

[0032] Accordingly, the EOR system 18 may include a fluid injection system 34, which has one or more tubulars 36 extending through a bore 38 in the earth 32 to the subterranean reservoir 20. For example, the EOR system 18 may route one or more fluids 40, such as gas, steam, water, chemicals, or any combination thereof, into the fluid injection system 34. For example, as discussed in further detail below, the EOR system 18 may be coupled to the turbine-based service system 14, such that the system 14 routes an exhaust gas 42 (e.g., substantially or entirely free of oxygen) to the EOR system 18 for use as the injection fluid 40. The fluid injection system 34 routes the fluid 40 (e.g., the exhaust gas 42) through the one or more tubulars 36 into the subterranean reservoir 20, as indicated by arrows 44. The injection fluid 40 enters the subterranean reservoir 20 through the tubular 36 at an offset distance 46 away from the tubular 28 of the oil/gas well 26. Accordingly, the injection fluid 40

displaces the oil/gas 48 disposed in the subterranean reservoir 20, and drives the oil/gas 48 up through the one or more tubulars 28 of the hydrocarbon production system 12, as indicated by arrows 50. As discussed in further detail below, the injection fluid 40 may include the exhaust gas 42 originating from the turbine-based service system 14, which is able to generate the exhaust gas 42 on-site as needed by the hydrocarbon production system 12. In other words, the turbine-based system 14 may simultaneously generate one or more services (e.g., electrical power, mechanical power, steam, water (e.g., desalinated water), and exhaust gas (e.g., substantially free of oxygen)) for use by the hydrocarbon production system 12, thereby reducing or eliminating the reliance on external sources of such services.

[0033] In the illustrated embodiment, the turbine-based service system 14 includes a stoichiometric exhaust gas recirculation (SEGR) gas turbine system 52 and an exhaust gas (EG) processing system 54. The gas turbine system 52 may be configured to operate in a stoichiometric combustion mode of operation (e.g., a stoichiometric control mode) and a non-stoichiometric combustion mode of operation (e.g., a non-stoichiometric control mode), such as a fuel-lean control mode or a fuel-rich control mode. In the stoichiometric control mode, the combustion generally occurs in a substantially stoichiometric ratio of a fuel and oxidant, thereby resulting in substantially stoichiometric combustion. In particular, stoichiometric combustion generally involves consuming substantially all of the fuel and oxidant in the combustion reaction, such that the products of combustion are substantially or entirely free of unburnt fuel and oxidant. One measure of stoichiometric combustion is the equivalence ratio, or ϕ , which is the ratio of the actual fuel/oxidant ratio relative to the stoichiometric fuel/oxidant ratio. An equivalence ratio of greater than 1.0 results in a fuel-rich combustion of the fuel and oxidant, whereas an equivalence ratio of less than 1.0 results in a fuel-lean combustion of the fuel and oxidant. In contrast, an equivalence ratio of 1.0 results in combustion that is neither fuel-rich nor fuel-lean, thereby substantially consuming all of the fuel and oxidant in the combustion reaction. In context of the disclosed embodiments, the term stoichiometric or substantially stoichiometric may refer to an equivalence ratio of approximately 0.95 to approximately 1.05. However, the disclosed embodiments may also include an

equivalence ratio of 1.0 plus or minus 0.01, 0.02, 0.03, 0.04, 0.05, or more. Again, the stoichiometric combustion of fuel and oxidant in the turbine-based service system 14 may result in products of combustion or exhaust gas (e.g., 42) with substantially no unburnt fuel or oxidant remaining. For example, the exhaust gas 42 may have less than 1, 2, 3, 4, or 5 percent by volume of oxidant (e.g., oxygen), unburnt fuel or hydrocarbons (e.g., HCs), nitrogen oxides (e.g., NO_x), carbon monoxide (CO), sulfur oxides (e.g., SO_x), hydrogen, and other products of incomplete combustion. By further example, the exhaust gas 42 may have less than approximately 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 1000, 2000, 3000, 4000, or 5000 parts per million by volume (ppmv) of oxidant (e.g., oxygen), unburnt fuel or hydrocarbons (e.g., HCs), nitrogen oxides (e.g., NO_x), carbon monoxide (CO), sulfur oxides (e.g., SO_x), hydrogen, and other products of incomplete combustion. However, the disclosed embodiments also may produce other ranges of residual fuel, oxidant, and other emissions levels in the exhaust gas 42. As used herein, the terms emissions, emissions levels, and emissions targets may refer to concentration levels of certain products of combustion (e.g., NO_x, CO, SO_x, O₂, N₂, H₂, HCs, etc.), which may be present in recirculated gas streams, vented gas streams (e.g., exhausted into the atmosphere), and gas streams used in various target systems (e.g., the hydrocarbon production system 12).

[0034] Although the SEGR gas turbine system 52 and the EG processing system 54 may include a variety of components in different embodiments, the illustrated EG processing system 54 includes a heat recovery steam generator (HRSG) 56 and an exhaust gas recirculation (EGR) system 58, which receive and process an exhaust gas 60 originating from the SEGR gas turbine system 52. The HRSG 56 may include one or more heat exchangers, condensers, and various heat recovery equipment, which collectively function to transfer heat from the exhaust gas 60 to a stream of water, thereby generating steam 62. The steam 62 may be used in one or more steam turbines, the EOR system 18, or any other portion of the hydrocarbon production system 12. For example, the HRSG 56 may generate low pressure, medium pressure, and/or high pressure steam 62, which may be selectively applied to low, medium, and high pressure steam turbine stages, or different applications of the EOR system 18. In

addition to the steam 62, a treated water 64, such as a desalinated water, may be generated by the HRSG 56, the EGR system 58, and/or another portion of the EG processing system 54 or the SEGR gas turbine system 52. The treated water 64 (e.g., desalinated water) may be particularly useful in areas with water shortages, such as inland or desert regions. The treated water 64 may be generated, at least in part, due to the large volume of air driving combustion of fuel within the SEGR gas turbine system 52. While the on-site generation of steam 62 and water 64 may be beneficial in many applications (including the hydrocarbon production system 12), the on-site generation of exhaust gas 42, 60 may be particularly beneficial for the EOR system 18, due to its low oxygen content, high pressure, and heat derived from the SEGR gas turbine system 52. Accordingly, the HRSG 56, the EGR system 58, and/or another portion of the EG processing system 54 may output or recirculate an exhaust gas 66 into the SEGR gas turbine system 52, while also routing the exhaust gas 42 to the EOR system 18 for use with the hydrocarbon production system 12. Likewise, the exhaust gas 42 may be extracted directly from the SEGR gas turbine system 52 (i.e., without passing through the EG processing system 54) for use in the EOR system 18 of the hydrocarbon production system 12.

[0035] The exhaust gas recirculation is handled by the EGR system 58 of the EG processing system 54. For example, the EGR system 58 includes one or more conduits, valves, blowers, exhaust gas treatment systems (e.g., filters, particulate removal units, gas separation units, gas purification units, heat exchangers, heat recovery units, moisture removal units, catalyst units, chemical injection units, or any combination thereof), and controls to recirculate the exhaust gas along an exhaust gas circulation path from an output (e.g., discharged exhaust gas 60) to an input (e.g., intake exhaust gas 66) of the SEGR gas turbine system 52. In the illustrated embodiment, the SEGR gas turbine system 52 intakes the exhaust gas 66 into a compressor section having one or more compressors, thereby compressing the exhaust gas 66 for use in a combustor section along with an intake of an oxidant 68 and one or more fuels 70. The oxidant 68 may include ambient air, pure oxygen, oxygen-enriched air, oxygen-reduced air, oxygen-nitrogen mixtures, or any suitable oxidant that facilitates combustion of the fuel 70. The fuel 70 may include one or more gas

fuels, liquid fuels, or any combination thereof. For example, the fuel 70 may include natural gas, liquefied natural gas (LNG), syngas, methane, ethane, propane, butane, naphtha, kerosene, diesel fuel, ethanol, methanol, biofuel, or any combination thereof.

[0036] The SEGR gas turbine system 52 mixes and combusts the exhaust gas 66, the oxidant 68, and the fuel 70 in the combustor section, thereby generating hot combustion gases or exhaust gas 60 to drive one or more turbine stages in a turbine section. In certain embodiments, each combustor in the combustor section includes one or more premix fuel nozzles, one or more diffusion fuel nozzles, or any combination thereof. For example, each premix fuel nozzle may be configured to mix the oxidant 68 and the fuel 70 internally within the fuel nozzle and/or partially upstream of the fuel nozzle, thereby injecting an oxidant-fuel mixture from the fuel nozzle into the combustion zone for a premixed combustion (e.g., a premixed flame). By further example, each diffusion fuel nozzle may be configured to isolate the flows of oxidant 68 and fuel 70 within the fuel nozzle, thereby separately injecting the oxidant 68 and the fuel 70 from the fuel nozzle into the combustion zone for diffusion combustion (e.g., a diffusion flame). In particular, the diffusion combustion provided by the diffusion fuel nozzles delays mixing of the oxidant 68 and the fuel 70 until the point of initial combustion, i.e., the flame region. In embodiments employing the diffusion fuel nozzles, the diffusion flame may provide increased flame stability, because the diffusion flame generally forms at the point of stoichiometry between the separate streams of oxidant 68 and fuel 70 (i.e., as the oxidant 68 and fuel 70 are mixing). In certain embodiments, one or more diluents (e.g., the exhaust gas 60, steam, nitrogen, or another inert gas) may be pre-mixed with the oxidant 68, the fuel 70, or both, in either the diffusion fuel nozzle or the premix fuel nozzle. In addition, one or more diluents (e.g., the exhaust gas 60, steam, nitrogen, or another inert gas) may be injected into the combustor at or downstream from the point of combustion within each combustor. The use of these diluents may help temper the flame (e.g., premix flame or diffusion flame), thereby helping to reduce NO_x emissions, such as nitrogen monoxide (NO) and nitrogen dioxide (NO₂). Regardless of the type of flame, the combustion produces hot combustion gases or exhaust gas 60 to drive one or more turbine stages. As each turbine stage is driven by the exhaust gas 60, the SEGR gas

turbine system 52 generates a mechanical power 72 and/or an electrical power 74 (e.g., via an electrical generator). The system 52 also outputs the exhaust gas 60, and may further output water 64. Again, the water 64 may be a treated water, such as a desalinated water, which may be useful in a variety of applications on-site or off-site.

[0037] Exhaust extraction is also provided by the SEGR gas turbine system 52 using one or more extraction points 76. For example, the illustrated embodiment includes an exhaust gas (EG) supply system 78 having an exhaust gas (EG) extraction system 80 and an exhaust gas (EG) treatment system 82, which receive exhaust gas 42 from the extraction points 76, treat the exhaust gas 42, and then supply or distribute the exhaust gas 42 to various target systems. The target systems may include the EOR system 18 and/or other systems, such as a pipeline 86, a storage tank 88, or a carbon sequestration system 90. The EG extraction system 80 may include one or more conduits, valves, controls, and flow separations, which facilitate isolation of the exhaust gas 42 from the oxidant 68, the fuel 70, and other contaminants, while also controlling the temperature, pressure, and flow rate of the extracted exhaust gas 42. The EG treatment system 82 may include one or more heat exchangers (e.g., heat recovery units such as heat recovery steam generators, condensers, coolers, or heaters), catalyst systems (e.g., oxidation catalyst systems), particulate and/or water removal systems (e.g., gas dehydration units, inertial separators, coalescing filters, water impermeable filters, and other filters), chemical injection systems, solvent based treatment systems (e.g., absorbers, flash tanks, etc.), carbon capture systems, gas separation systems, gas purification systems, and/or a solvent based treatment system, exhaust gas compressors, any combination thereof. These subsystems of the EG treatment system 82 enable control of the temperature, pressure, flow rate, moisture content (e.g., amount of water removal), particulate content (e.g., amount of particulate removal), and gas composition (e.g., percentage of CO₂, N₂, etc.).

[0038] The extracted exhaust gas 42 is treated by one or more subsystems of the EG treatment system 82, depending on the target system. For example, the EG treatment system 82 may direct all or part of the exhaust gas 42 through a carbon capture system, a gas separation system, a gas purification system, and/or a solvent based treatment system, which is controlled to separate and purify a carbonaceous gas

(e.g., carbon dioxide) 92 and/or nitrogen (N₂) 94 for use in the various target systems. For example, embodiments of the EG treatment system 82 may perform gas separation and purification to produce a plurality of different streams 95 of exhaust gas 42, such as a first stream 96, a second stream 97, and a third stream 98. The first stream 96 may have a first composition that is rich in carbon dioxide and/or lean in nitrogen (e.g., a CO₂ rich, N₂ lean stream). The second stream 97 may have a second composition that has intermediate concentration levels of carbon dioxide and/or nitrogen (e.g., intermediate concentration CO₂, N₂ stream). The third stream 98 may have a third composition that is lean in carbon dioxide and/or rich in nitrogen (e.g., a CO₂ lean, N₂ rich stream). Each stream 95 (e.g., 96, 97, and 98) may include a gas dehydration unit, a filter, a gas compressor, or any combination thereof, to facilitate delivery of the stream 95 to a target system. In certain embodiments, the CO₂ rich, N₂ lean stream 96 may have a CO₂ purity or concentration level of greater than approximately 70, 75, 80, 85, 90, 95, 96, 97, 98, or 99 percent by volume, and a N₂ purity or concentration level of less than approximately 1, 2, 3, 4, 5, 10, 15, 20, 25, or 30 percent by volume. In contrast, the CO₂ lean, N₂ rich stream 98 may have a CO₂ purity or concentration level of less than approximately 1, 2, 3, 4, 5, 10, 15, 20, 25, or 30 percent by volume, and a N₂ purity or concentration level of greater than approximately 70, 75, 80, 85, 90, 95, 96, 97, 98, or 99 percent by volume. The intermediate concentration CO₂, N₂ stream 97 may have a CO₂ purity or concentration level and/or a N₂ purity or concentration level of between approximately 30 to 70, 35 to 65, 40 to 60, or 45 to 55 percent by volume. Although the foregoing ranges are merely non-limiting examples, the CO₂ rich, N₂ lean stream 96 and the CO₂ lean, N₂ rich stream 98 may be particularly well suited for use with the EOR system 18 and the other systems 84. However, any of these rich, lean, or intermediate concentration CO₂ streams 95 may be used, alone or in various combinations, with the EOR system 18 and the other systems 84. For example, the EOR system 18 and the other systems 84 (e.g., the pipeline 86, storage tank 88, and the carbon sequestration system 90) each may receive one or more CO₂ rich, N₂ lean streams 96, one or more CO₂ lean, N₂ rich streams 98, one or more intermediate concentration CO₂, N₂ streams 97, and one or more untreated exhaust gas 42 streams (i.e., bypassing the EG treatment system 82).

[0039] The EG extraction system 80 extracts the exhaust gas 42 at one or more extraction points 76 along the compressor section, the combustor section, and/or the turbine section, such that the exhaust gas 42 may be used in the EOR system 18 and other systems 84 at suitable temperatures and pressures. The EG extraction system 80 and/or the EG treatment system 82 also may circulate fluid flows (e.g., exhaust gas 42) to and from the EG processing system 54. For example, a portion of the exhaust gas 42 passing through the EG processing system 54 may be extracted by the EG extraction system 80 for use in the EOR system 18 and the other systems 84. In certain embodiments, the EG supply system 78 and the EG processing system 54 may be independent or integral with one another, and thus may use independent or common subsystems. For example, the EG treatment system 82 may be used by both the EG supply system 78 and the EG processing system 54. Exhaust gas 42 extracted from the EG processing system 54 may undergo multiple stages of gas treatment, such as one or more stages of gas treatment in the EG processing system 54 followed by one or more additional stages of gas treatment in the EG treatment system 82.

[0040] At each extraction point 76, the extracted exhaust gas 42 may be substantially free of oxidant 68 and fuel 70 (e.g., unburnt fuel or hydrocarbons) due to substantially stoichiometric combustion and/or gas treatment in the EG processing system 54. Furthermore, depending on the target system, the extracted exhaust gas 42 may undergo further treatment in the EG treatment system 82 of the EG supply system 78, thereby further reducing any residual oxidant 68, fuel 70, or other undesirable products of combustion. For example, either before or after treatment in the EG treatment system 82, the extracted exhaust gas 42 may have less than 1, 2, 3, 4, or 5 percent by volume of oxidant (e.g., oxygen), unburnt fuel or hydrocarbons (e.g., HCs), nitrogen oxides (e.g., NO_x), carbon monoxide (CO), sulfur oxides (e.g., SO_x), hydrogen, and other products of incomplete combustion. By further example, either before or after treatment in the EG treatment system 82, the extracted exhaust gas 42 may have less than approximately 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 1000, 2000, 3000, 4000, or 5000 parts per million by volume (ppmv) of oxidant (e.g., oxygen), unburnt fuel or hydrocarbons (e.g., HCs), nitrogen oxides (e.g., NO_x), carbon monoxide (CO), sulfur oxides (e.g., SO_x), hydrogen, and other

products of incomplete combustion. Thus, the exhaust gas 42 is particularly well suited for use with the EOR system 18.

[0041] The EGR operation of the turbine system 52 specifically enables the exhaust extraction at a multitude of locations 76. For example, the compressor section of the system 52 may be used to compress the exhaust gas 66 without any oxidant 68 (i.e., only compression of the exhaust gas 66), such that a substantially oxygen-free exhaust gas 42 may be extracted from the compressor section and/or the combustor section prior to entry of the oxidant 68 and the fuel 70. The extraction points 76 may be located at interstage ports between adjacent compressor stages, at ports along the compressor discharge casing, at ports along each combustor in the combustor section, or any combination thereof. In certain embodiments, the exhaust gas 66 may not mix with the oxidant 68 and fuel 70 until it reaches the head end portion and/or fuel nozzles of each combustor in the combustor section. Furthermore, one or more flow separators (e.g., walls, dividers, baffles, or the like) may be used to isolate the oxidant 68 and the fuel 70 from the extraction points 76. With these flow separators, the extraction points 76 may be disposed directly along a wall of each combustor in the combustor section.

[0042] Once the exhaust gas 66, oxidant 68, and fuel 70 flow through the head end portion (e.g., through fuel nozzles) into the combustion portion (e.g., combustion chamber) of each combustor, the SEGR gas turbine system 52 is controlled to provide a substantially stoichiometric combustion of the exhaust gas 66, oxidant 68, and fuel 70. For example, the system 52 may maintain an equivalence ratio of approximately 0.95 to approximately 1.05. As a result, the products of combustion of the mixture of exhaust gas 66, oxidant 68, and fuel 70 in each combustor is substantially free of oxygen and unburnt fuel. Thus, the products of combustion (or exhaust gas) may be extracted from the turbine section of the SEGR gas turbine system 52 for use as the exhaust gas 42 routed to the EOR system 18. Along the turbine section, the extraction points 76 may be located at any turbine stage, such as interstage ports between adjacent turbine stages. Thus, using any of the foregoing extraction points 76, the turbine-based service system 14 may generate, extract, and deliver the exhaust gas 42

to the hydrocarbon production system 12 (e.g., the EOR system 18) for use in the production of oil/gas 48 from the subterranean reservoir 20.

[0043] FIG. 2 is a diagram of an embodiment of the system 10 of FIG. 1, illustrating a control system 100 coupled to the turbine-based service system 14 and the hydrocarbon production system 12. In the illustrated embodiment, the turbine-based service system 14 includes a combined cycle system 102, which includes the SEGR gas turbine system 52 as a topping cycle, a steam turbine 104 as a bottoming cycle, and the HRSG 56 to recover heat from the exhaust gas 60 to generate the steam 62 for driving the steam turbine 104. Again, the SEGR gas turbine system 52 receives, mixes, and stoichiometrically combusts the exhaust gas 66, the oxidant 68, and the fuel 70 (e.g., premix and/or diffusion flames), thereby producing the exhaust gas 60, the mechanical power 72, the electrical power 74, and/or the water 64. For example, the SEGR gas turbine system 52 may drive one or more loads or machinery 106, such as an electrical generator, an oxidant compressor (e.g., a main air compressor), a gear box, a pump, equipment of the hydrocarbon production system 12, or any combination thereof. In some embodiments, the machinery 106 may include other drives, such as electrical motors or steam turbines (e.g., the steam turbine 104), in tandem with the SEGR gas turbine system 52. Accordingly, an output of the machinery 106 driven by the SEGR gas turbines system 52 (and any additional drives) may include the mechanical power 72 and the electrical power 74. The mechanical power 72 and/or the electrical power 74 may be used on-site for powering the hydrocarbon production system 12, the electrical power 74 may be distributed to the power grid, or any combination thereof. The output of the machinery 106 also may include a compressed fluid, such as a compressed oxidant 68 (e.g., air or oxygen), for intake into the combustion section of the SEGR gas turbine system 52. Each of these outputs (e.g., the exhaust gas 60, the mechanical power 72, the electrical power 74, and/or the water 64) may be considered a service of the turbine-based service system 14.

[0044] The SEGR gas turbine system 52 produces the exhaust gas 42, 60, which may be substantially free of oxygen, and routes this exhaust gas 42, 60 to the EG processing system 54 and/or the EG supply system 78. The EG supply system 78 may

treat and delivery the exhaust gas 42 (e.g., streams 95) to the hydrocarbon production system 12 and/or the other systems 84. As discussed above, the EG processing system 54 may include the HRSG 56 and the EGR system 58. The HRSG 56 may include one or more heat exchangers, condensers, and various heat recovery equipment, which may be used to recover or transfer heat from the exhaust gas 60 to water 108 to generate the steam 62 for driving the steam turbine 104. Similar to the SEGR gas turbine system 52, the steam turbine 104 may drive one or more loads or machinery 106, thereby generating the mechanical power 72 and the electrical power 74. In the illustrated embodiment, the SEGR gas turbine system 52 and the steam turbine 104 are arranged in tandem to drive the same machinery 106. However, in other embodiments, the SEGR gas turbine system 52 and the steam turbine 104 may separately drive different machinery 106 to independently generate mechanical power 72 and/or electrical power 74. As the steam turbine 104 is driven by the steam 62 from the HRSG 56, the steam 62 gradually decreases in temperature and pressure. Accordingly, the steam turbine 104 recirculates the used steam 62 and/or water 108 back into the HRSG 56 for additional steam generation via heat recovery from the exhaust gas 60. In addition to steam generation, the HRSG 56, the EGR system 58, and/or another portion of the EG processing system 54 may produce the water 64, the exhaust gas 42 for use with the hydrocarbon production system 12, and the exhaust gas 66 for use as an input into the SEGR gas turbine system 52. For example, the water 64 may be a treated water 64, such as a desalinated water for use in other applications. The desalinated water may be particularly useful in regions of low water availability. Regarding the exhaust gas 60, embodiments of the EG processing system 54 may be configured to recirculate the exhaust gas 60 through the EGR system 58 with or without passing the exhaust gas 60 through the HRSG 56.

[0045] In the illustrated embodiment, the SEGR gas turbine system 52 has an exhaust recirculation path 110, which extends from an exhaust outlet to an exhaust inlet of the system 52. Along the path 110, the exhaust gas 60 passes through the EG processing system 54, which includes the HRSG 56 and the EGR system 58 in the illustrated embodiment. The EGR system 58 may include one or more conduits, valves, blowers, gas treatment systems (e.g., filters, particulate removal units, gas

separation units, gas purification units, heat exchangers, heat recovery units such as heat recovery steam generators, moisture removal units, catalyst units, chemical injection units, or any combination thereof) in series and/or parallel arrangements along the path 110. In other words, the EGR system 58 may include any flow control components, pressure control components, temperature control components, moisture control components, and gas composition control components along the exhaust recirculation path 110 between the exhaust outlet and the exhaust inlet of the system 52. Accordingly, in embodiments with the HRSG 56 along the path 110, the HRSG 56 may be considered a component of the EGR system 58. However, in certain embodiments, the HRSG 56 may be disposed along an exhaust path independent from the exhaust recirculation path 110. Regardless of whether the HRSG 56 is along a separate path or a common path with the EGR system 58, the HRSG 56 and the EGR system 58 intake the exhaust gas 60 and output either the recirculated exhaust gas 66, the exhaust gas 42 for use with the EG supply system 78 (e.g., for the hydrocarbon production system 12 and/or other systems 84), or another output of exhaust gas. Again, the SEGR gas turbine system 52 intakes, mixes, and stoichiometrically combusts the exhaust gas 66, the oxidant 68, and the fuel 70 (e.g., premixed and/or diffusion flames) to produce a substantially oxygen-free and fuel-free exhaust gas 60 for distribution to the EG processing system 54, the hydrocarbon production system 12, or other systems 84.

[0046] As noted above with reference to FIG. 1, the hydrocarbon production system 12 may include a variety of equipment to facilitate the recovery or production of oil/gas 48 from a subterranean reservoir 20 through an oil/gas well 26. For example, the hydrocarbon production system 12 may include the EOR system 18 having the fluid injection system 34. In the illustrated embodiment, the fluid injection system 34 includes an exhaust gas injection EOR system 112 and a steam injection EOR system 114. Although the fluid injection system 34 may receive fluids from a variety of sources, the illustrated embodiment may receive the exhaust gas 42 and the steam 62 from the turbine-based service system 14. The exhaust gas 42 and/or the steam 62 produced by the turbine-based service system 14 also may be routed to the hydrocarbon production system 12 for use in other oil/gas systems 116.

[0047] The quantity, quality, and flow of the exhaust gas 42 and/or the steam 62 may be controlled by the control system 100. The control system 100 may be dedicated entirely to the turbine-based service system 14, or the control system 100 may optionally also provide control (or at least some data to facilitate control) for the hydrocarbon production system 12 and/or other systems 84. In the illustrated embodiment, the control system 100 includes a controller 118 having a processor 120, a memory 122, a steam turbine control 124, a SEGR gas turbine system control 126, and a machinery control 128. The processor 120 may include a single processor or two or more redundant processors, such as triple redundant processors for control of the turbine-based service system 14. The memory 122 may include volatile and/or non-volatile memory. For example, the memory 122 may include one or more hard drives, flash memory, read-only memory, random access memory, or any combination thereof. The controls 124, 126, and 128 may include software and/or hardware controls. For example, the controls 124, 126, and 128 may include various instructions or code stored on the memory 122 and executable by the processor 120. The control 124 is configured to control operation of the steam turbine 104, the SEGR gas turbine system control 126 is configured to control the system 52, and the machinery control 128 is configured to control the machinery 106. Thus, the controller 118 (e.g., controls 124, 126, and 128) may be configured to coordinate various sub-systems of the turbine-based service system 14 to provide a suitable stream of the exhaust gas 42 to the hydrocarbon production system 12.

[0048] In certain embodiments of the control system 100, each element (e.g., system, subsystem, and component) illustrated in the drawings or described herein includes (e.g., directly within, upstream, or downstream of such element) one or more industrial control features, such as sensors and control devices, which are communicatively coupled with one another over an industrial control network along with the controller 118. For example, the control devices associated with each element may include a dedicated device controller (e.g., including a processor, memory, and control instructions), one or more actuators, valves, switches, and industrial control equipment, which enable control based on sensor feedback 130, control signals from the controller 118, control signals from a user, or any combination thereof. Thus, any

of the control functionality described herein may be implemented with control instructions stored and/or executable by the controller 118, dedicated device controllers associated with each element, or a combination thereof.

[0049] In order to facilitate such control functionality, the control system 100 includes one or more sensors distributed throughout the system 10 to obtain the sensor feedback 130 for use in execution of the various controls, e.g., the controls 124, 126, and 128. For example, the sensor feedback 130 may be obtained from sensors distributed throughout the SEGR gas turbine system 52, the machinery 106, the EG processing system 54, the steam turbine 104, the hydrocarbon production system 12, or any other components throughout the turbine-based service system 14 or the hydrocarbon production system 12. For example, the sensor feedback 130 may include temperature feedback, pressure feedback, flow rate feedback, flame temperature feedback, combustion dynamics feedback, intake oxidant composition feedback, intake fuel composition feedback, exhaust composition feedback, the output level of mechanical power 72, the output level of electrical power 74, the output quantity of the exhaust gas 42, 60, the output quantity or quality of the water 64, or any combination thereof. For example, the sensor feedback 130 may include a composition of the exhaust gas 42, 60 to facilitate stoichiometric combustion in the SEGR gas turbine system 52. For example, the sensor feedback 130 may include feedback from one or more intake oxidant sensors along an oxidant supply path of the oxidant 68, one or more intake fuel sensors along a fuel supply path of the fuel 70, and one or more exhaust emissions sensors disposed along the exhaust recirculation path 110 and/or within the SEGR gas turbine system 52. The intake oxidant sensors, intake fuel sensors, and exhaust emissions sensors may include temperature sensors, pressure sensors, flow rate sensors, and composition sensors. The emissions sensors may include sensors for nitrogen oxides (e.g., NO_x sensors), carbon oxides (e.g., CO sensors and CO₂ sensors), sulfur oxides (e.g., SO_x sensors), hydrogen (e.g., H₂ sensors), oxygen (e.g., O₂ sensors), unburnt hydrocarbons (e.g., HC sensors), or other products of incomplete combustion, or any combination thereof.

[0050] Using this feedback 130, the control system 100 may adjust (e.g., increase, decrease, or maintain) the intake flow of exhaust gas 66, oxidant 68, and/or fuel 70

into the SEGR gas turbine system 52 (among other operational parameters) to maintain the equivalence ratio within a suitable range, e.g., between approximately 0.95 to approximately 1.05, between approximately 0.95 to approximately 1.0, between approximately 1.0 to approximately 1.05, or substantially at 1.0. For example, the control system 100 may analyze the feedback 130 to monitor the exhaust emissions (e.g., concentration levels of nitrogen oxides, carbon oxides such as CO and CO₂, sulfur oxides, hydrogen, oxygen, unburnt hydrocarbons, and other products of incomplete combustion) and/or determine the equivalence ratio, and then control one or more components to adjust the exhaust emissions (e.g., concentration levels in the exhaust gas 42) and/or the equivalence ratio. The controlled components may include any of the components illustrated and described with reference to the drawings, including but not limited to, valves along the supply paths for the oxidant 68, the fuel 70, and the exhaust gas 66; an oxidant compressor, a fuel pump, or any components in the EG processing system 54; any components of the SEGR gas turbine system 52, or any combination thereof. The controlled components may adjust (e.g., increase, decrease, or maintain) the flow rates, temperatures, pressures, or percentages (e.g., equivalence ratio) of the oxidant 68, the fuel 70, and the exhaust gas 66 that combust within the SEGR gas turbine system 52. The controlled components also may include one or more gas treatment systems, such as catalyst units (e.g., oxidation catalyst units), supplies for the catalyst units (e.g., oxidation fuel, heat, electricity, etc.), gas purification and/or separation units (e.g., solvent based separators, absorbers, flash tanks, etc.), and filtration units. The gas treatment systems may help reduce various exhaust emissions along the exhaust recirculation path 110, a vent path (e.g., exhausted into the atmosphere), or an extraction path to the EG supply system 78.

[0051] In certain embodiments, the control system 100 may analyze the feedback 130 and control one or more components to maintain or reduce emissions levels (e.g., concentration levels in the exhaust gas 42, 60, 95) to a target range, such as less than approximately 10, 20, 30, 40, 50, 100, 200, 300, 400, 500, 1000, 2000, 3000, 4000, 5000, or 10000 parts per million by volume (ppmv). These target ranges may be the same or different for each of the exhaust emissions, e.g., concentration levels of nitrogen oxides, carbon monoxide, sulfur oxides, hydrogen, oxygen, unburnt

hydrocarbons, and other products of incomplete combustion. For example, depending on the equivalence ratio, the control system 100 may selectively control exhaust emissions (e.g., concentration levels) of oxidant (e.g., oxygen) within a target range of less than approximately 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 250, 500, 750, or 1000 ppmv; carbon monoxide (CO) within a target range of less than approximately 20, 50, 100, 200, 500, 1000, 2500, or 5000 ppmv; and nitrogen oxides (NO_x) within a target range of less than approximately 50, 100, 200, 300, 400, or 500 ppmv. In certain embodiments operating with a substantially stoichiometric equivalence ratio, the control system 100 may selectively control exhaust emissions (e.g., concentration levels) of oxidant (e.g., oxygen) within a target range of less than approximately 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100 ppmv; and carbon monoxide (CO) within a target range of less than approximately 500, 1000, 2000, 3000, 4000, or 5000 ppmv. In certain embodiments operating with a fuel-lean equivalence ratio (e.g., between approximately 0.95 to 1.0), the control system 100 may selectively control exhaust emissions (e.g., concentration levels) of oxidant (e.g., oxygen) within a target range of less than approximately 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, or 1500 ppmv; carbon monoxide (CO) within a target range of less than approximately 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, or 200 ppmv; and nitrogen oxides (e.g., NO_x) within a target range of less than approximately 50, 100, 150, 200, 250, 300, 350, or 400 ppmv. The foregoing target ranges are merely examples, and are not intended to limit the scope of the disclosed embodiments.

[0052] The control system 100 also may be coupled to a local interface 132 and a remote interface 134. For example, the local interface 132 may include a computer workstation disposed on-site at the turbine-based service system 14 and/or the hydrocarbon production system 12. In contrast, the remote interface 134 may include a computer workstation disposed off-site from the turbine-based service system 14 and the hydrocarbon production system 12, such as through an internet connection. These interfaces 132 and 134 facilitate monitoring and control of the turbine-based service system 14, such as through one or more graphical displays of sensor feedback 130, operational parameters, and so forth.

[0053] Again, as noted above, the controller 118 includes a variety of controls 124, 126, and 128 to facilitate control of the turbine-based service system 14. The steam turbine control 124 may receive the sensor feedback 130 and output control commands to facilitate operation of the steam turbine 104. For example, the steam turbine control 124 may receive the sensor feedback 130 from the HRSG 56, the machinery 106, temperature and pressure sensors along a path of the steam 62, temperature and pressure sensors along a path of the water 108, and various sensors indicative of the mechanical power 72 and the electrical power 74. Likewise, the SEGR gas turbine system control 126 may receive sensor feedback 130 from one or more sensors disposed along the SEGR gas turbine system 52, the machinery 106, the EG processing system 54, or any combination thereof. For example, the sensor feedback 130 may be obtained from temperature sensors, pressure sensors, clearance sensors, vibration sensors, flame sensors, fuel composition sensors, exhaust gas composition sensors, or any combination thereof, disposed within or external to the SEGR gas turbine system 52. Finally, the machinery control 128 may receive sensor feedback 130 from various sensors associated with the mechanical power 72 and the electrical power 74, as well as sensors disposed within the machinery 106. Each of these controls 124, 126, and 128 uses the sensor feedback 130 to improve operation of the turbine-based service system 14.

[0054] In the illustrated embodiment, the SEGR gas turbine system control 126 may execute instructions to control the quantity and quality of the exhaust gas 42, 60, 95 in the EG processing system 54, the EG supply system 78, the hydrocarbon production system 12, and/or the other systems 84. For example, the SEGR gas turbine system control 126 may maintain a level of oxidant (e.g., oxygen) and/or unburnt fuel in the exhaust gas 60 below a threshold suitable for use with the exhaust gas injection EOR system 112. In certain embodiments, the threshold levels may be less than 1, 2, 3, 4, or 5 percent of oxidant (e.g., oxygen) and/or unburnt fuel by volume of the exhaust gas 42, 60; or the threshold levels of oxidant (e.g., oxygen) and/or unburnt fuel (and other exhaust emissions) may be less than approximately 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 1000, 2000, 3000, 4000, or 5000 parts per million by volume (ppmv) in the exhaust gas 42, 60. By further

example, in order to achieve these low levels of oxidant (e.g., oxygen) and/or unburnt fuel, the SEGR gas turbine system control 126 may maintain an equivalence ratio for combustion in the SEGR gas turbine system 52 between approximately 0.95 and approximately 1.05. The SEGR gas turbine system control 126 also may control the EG extraction system 80 and the EG treatment system 82 to maintain the temperature, pressure, flow rate, and gas composition of the exhaust gas 42, 60, 95 within suitable ranges for the exhaust gas injection EOR system 112, the pipeline 86, the storage tank 88, and the carbon sequestration system 90. As discussed above, the EG treatment system 82 may be controlled to purify and/or separate the exhaust gas 42 into one or more gas streams 95, such as the CO₂ rich, N₂ lean stream 96, the intermediate concentration CO₂, N₂ stream 97, and the CO₂ lean, N₂ rich stream 98. In addition to controls for the exhaust gas 42, 60, and 95, the controls 124, 126, and 128 may execute one or more instructions to maintain the mechanical power 72 within a suitable power range, or maintain the electrical power 74 within a suitable frequency and power range.

[0055] FIG. 3 is a diagram of embodiment of the system 10, further illustrating details of the SEGR gas turbine system 52 for use with the hydrocarbon production system 12 and/or other systems 84. In the illustrated embodiment, the SEGR gas turbine system 52 includes a gas turbine engine 150 coupled to the EG processing system 54. The illustrated gas turbine engine 150 includes a compressor section 152, a combustor section 154, and an expander section or turbine section 156. The compressor section 152 includes one or more exhaust gas compressors or compressor stages 158, such as 1 to 20 stages of rotary compressor blades disposed in a series arrangement. Likewise, the combustor section 154 includes one or more combustors 160, such as 1 to 20 combustors 160 distributed circumferentially about a rotational axis 162 of the SEGR gas turbine system 52. Furthermore, each combustor 160 may include one or more fuel nozzles 164 configured to inject the exhaust gas 66, the oxidant 68, and/or the fuel 70. For example, a head end portion 166 of each combustor 160 may house 1, 2, 3, 4, 5, 6, or more fuel nozzles 164, which may inject streams or mixtures of the exhaust gas 66, the oxidant 68, and/or the fuel 70 into a combustion portion 168 (e.g., combustion chamber) of the combustor 160.

[0056] The fuel nozzles 164 may include any combination of premix fuel nozzles 164 (e.g., configured to premix the oxidant 68 and fuel 70 for generation of an oxidant/fuel premix flame) and/or diffusion fuel nozzles 164 (e.g., configured to inject separate flows of the oxidant 68 and fuel 70 for generation of an oxidant/fuel diffusion flame). Embodiments of the premix fuel nozzles 164 may include swirl vanes, mixing chambers, or other features to internally mix the oxidant 68 and fuel 70 within the nozzles 164, prior to injection and combustion in the combustion chamber 168. The premix fuel nozzles 164 also may receive at least some partially mixed oxidant 68 and fuel 70. In certain embodiments, each diffusion fuel nozzle 164 may isolate flows of the oxidant 68 and the fuel 70 until the point of injection, while also isolating flows of one or more diluents (e.g., the exhaust gas 66, steam, nitrogen, or another inert gas) until the point of injection. In other embodiments, each diffusion fuel nozzle 164 may isolate flows of the oxidant 68 and the fuel 70 until the point of injection, while partially mixing one or more diluents (e.g., the exhaust gas 66, steam, nitrogen, or another inert gas) with the oxidant 68 and/or the fuel 70 prior to the point of injection. In addition, one or more diluents (e.g., the exhaust gas 66, steam, nitrogen, or another inert gas) may be injected into the combustor (e.g., into the hot products of combustion) either at or downstream from the combustion zone, thereby helping to reduce the temperature of the hot products of combustion and reduce emissions of NO_x (e.g., NO and NO_2). Regardless of the type of fuel nozzle 164, the SEGR gas turbine system 52 may be controlled to provide substantially stoichiometric combustion of the oxidant 68 and fuel 70.

[0057] In diffusion combustion embodiments using the diffusion fuel nozzles 164, the fuel 70 and oxidant 68 generally do not mix upstream from the diffusion flame, but rather the fuel 70 and oxidant 68 mix and react directly at the flame surface and/or the flame surface exists at the location of mixing between the fuel 70 and oxidant 68. In particular, the fuel 70 and oxidant 68 separately approach the flame surface (or diffusion boundary/interface), and then diffuse (e.g., via molecular and viscous diffusion) along the flame surface (or diffusion boundary/interface) to generate the diffusion flame. It is noteworthy that the fuel 70 and oxidant 68 may be at a substantially stoichiometric ratio along this flame surface (or diffusion

boundary/interface), which may result in a greater flame temperature (e.g., a peak flame temperature) along this flame surface. The stoichiometric fuel/oxidant ratio generally results in a greater flame temperature (e.g., a peak flame temperature), as compared with a fuel-lean or fuel-rich fuel/oxidant ratio. As a result, the diffusion flame may be substantially more stable than a premix flame, because the diffusion of fuel 70 and oxidant 68 helps to maintain a stoichiometric ratio (and greater temperature) along the flame surface. Although greater flame temperatures can also lead to greater exhaust emissions, such as NO_x emissions, the disclosed embodiments use one or more diluents to help control the temperature and emissions while still avoiding any premixing of the fuel 70 and oxidant 68. For example, the disclosed embodiments may introduce one or more diluents separate from the fuel 70 and oxidant 68 (e.g., after the point of combustion and/or downstream from the diffusion flame), thereby helping to reduce the temperature and reduce the emissions (e.g., NO_x emissions) produced by the diffusion flame.

[0058] In operation, as illustrated, the compressor section 152 receives and compresses the exhaust gas 66 from the EG processing system 54, and outputs a compressed exhaust gas 170 to each of the combustors 160 in the combustor section 154. Upon combustion of the fuel 60, oxidant 68, and exhaust gas 170 within each combustor 160, additional exhaust gas or products of combustion 172 (i.e., combustion gas) is routed into the turbine section 156. Similar to the compressor section 152, the turbine section 156 includes one or more turbines or turbine stages 174, which may include a series of rotary turbine blades. These turbine blades are then driven by the products of combustion 172 generated in the combustor section 154, thereby driving rotation of a shaft 176 coupled to the machinery 106. Again, the machinery 106 may include a variety of equipment coupled to either end of the SEGR gas turbine system 52, such as machinery 106, 178 coupled to the turbine section 156 and/or machinery 106, 180 coupled to the compressor section 152. In certain embodiments, the machinery 106, 178, 180 may include one or more electrical generators, oxidant compressors for the oxidant 68, fuel pumps for the fuel 70, gear boxes, or additional drives (e.g. steam turbine 104, electrical motor, etc.) coupled to the SEGR gas turbine system 52. Non-limiting examples are discussed in further

detail below with reference to TABLE 1. As illustrated, the turbine section 156 outputs the exhaust gas 60 to recirculate along the exhaust recirculation path 110 from an exhaust outlet 182 of the turbine section 156 to an exhaust inlet 184 into the compressor section 152. Along the exhaust recirculation path 110, the exhaust gas 60 passes through the EG processing system 54 (e.g., the HRSG 56 and/or the EGR system 58) as discussed in detail above.

[0059] Again, each combustor 160 in the combustor section 154 receives, mixes, and stoichiometrically combusts the compressed exhaust gas 170, the oxidant 68, and the fuel 70 to produce the additional exhaust gas or products of combustion 172 to drive the turbine section 156. In certain embodiments, the oxidant 68 is compressed by an oxidant compression system 186, such as a main oxidant compression (MOC) system (e.g., a main air compression (MAC) system) having one or more oxidant compressors (MOCs). The oxidant compression system 186 includes an oxidant compressor 188 coupled to a drive 190. For example, the drive 190 may include an electric motor, a combustion engine, or any combination thereof. In certain embodiments, the drive 190 may be a turbine engine, such as the gas turbine engine 150. Accordingly, the oxidant compression system 186 may be an integral part of the machinery 106. In other words, the compressor 188 may be directly or indirectly driven by the mechanical power 72 supplied by the shaft 176 of the gas turbine engine 150. In such an embodiment, the drive 190 may be excluded, because the compressor 188 relies on the power output from the turbine engine 150. However, in certain embodiments employing more than one oxidant compressor is employed, a first oxidant compressor (e.g., a low pressure (LP) oxidant compressor) may be driven by the drive 190 while the shaft 176 drives a second oxidant compressor (e.g., a high pressure (HP) oxidant compressor), or vice versa. For example, in another embodiment, the HP MOC is driven by the drive 190 and the LP oxidant compressor is driven by the shaft 176. In the illustrated embodiment, the oxidant compression system 186 is separate from the machinery 106. In each of these embodiments, the compression system 186 compresses and supplies the oxidant 68 to the fuel nozzles 164 and the combustors 160. Accordingly, some or all of the machinery 106, 178, 180

may be configured to increase the operational efficiency of the compression system 186 (e.g., the compressor 188 and/or additional compressors).

[0060] The variety of components of the machinery 106, indicated by element numbers 106A, 106B, 106C, 106D, 106E, and 106F, may be disposed along the line of the shaft 176 and/or parallel to the line of the shaft 176 in one or more series arrangements, parallel arrangements, or any combination of series and parallel arrangements. For example, the machinery 106, 178, 180 (e.g., 106A through 106F) may include any series and/or parallel arrangement, in any order, of: one or more gearboxes (e.g., parallel shaft, epicyclic gearboxes), one or more compressors (e.g., oxidant compressors, booster compressors such as EG booster compressors), one or more power generation units (e.g., electrical generators), one or more drives (e.g., steam turbine engines, electrical motors), heat exchange units (e.g., direct or indirect heat exchangers), clutches, or any combination thereof. The compressors may include axial compressors, radial or centrifugal compressors, or any combination thereof, each having one or more compression stages. Regarding the heat exchangers, direct heat exchangers may include spray coolers (e.g., spray intercoolers), which inject a liquid spray into a gas flow (e.g., oxidant flow) for direct cooling of the gas flow. Indirect heat exchangers may include at least one wall (e.g., a shell and tube heat exchanger) separating first and second flows, such as a fluid flow (e.g., oxidant flow) separated from a coolant flow (e.g., water, air, refrigerant, or any other liquid or gas coolant), wherein the coolant flow transfers heat from the fluid flow without any direct contact. Examples of indirect heat exchangers include intercooler heat exchangers and heat recovery units, such as heat recovery steam generators. The heat exchangers also may include heaters. As discussed in further detail below, each of these machinery components may be used in various combinations as indicated by the non-limiting examples set forth in TABLE 1.

[0061] Generally, the machinery 106, 178, 180 may be configured to increase the efficiency of the compression system 186 by, for example, adjusting operational speeds of one or more oxidant compressors in the system 186, facilitating compression of the oxidant 68 through cooling, and/or extraction of surplus power. The disclosed embodiments are intended to include any and all permutations of the

foregoing components in the machinery 106, 178, 180 in series and parallel arrangements, wherein one, more than one, all, or none of the components derive power from the shaft 176. As illustrated below, TABLE 1 depicts some non-limiting examples of arrangements of the machinery 106, 178, 180 disposed proximate and/or coupled to the compressor and turbine sections 152, 156.

106A	106B	106C	106D	106E	106F
MOC	GEN				
MOC	GBX	GEN			
LP MOC	HP MOC	GEN			
HP MOC	GBX	LP MOC	GEN		
MOC MOC	GBX	GEN			
HP MOC	GBX	GEN	LP MOC		
MOC MOC	GBX GBX	GEN DRV			
DRV	GBX	LP MOC	HP MOC	GBX	GEN
DRV	GBX	HP MOC	LP MOC	GEN	
HP MOC	GBX CLR	LP MOC	GEN		
HP MOC	GBX CLR	LP MOC	GBX	GEN	
HP MOC	GBX HTR STGN	LP MOC	GEN		
MOC	GEN	DRV			
MOC	DRV	GEN			
DRV	MOC	GEN			
DRV	CLU	MOC	GEN		
DRV	CLU	MOC	GBX	GEN	

TABLE 1

[0062] As illustrated above in TABLE 1, a cooling unit is represented as CLR, a clutch is represented as CLU, a drive is represented by DRV, a gearbox is represented as GBX, a generator is represented by GEN, a heating unit is represented by HTR, a main oxidant compressor unit is represented by MOC, with low pressure and high pressure variants being represented as LP MOC and HP MOC, respectively, and a steam generator unit is represented as STGN. Although TABLE 1 illustrates the machinery 106, 178, 180 in sequence toward the compressor section 152 or the turbine section 156, TABLE 1 is also intended to cover the reverse sequence of the machinery 106, 178, 180. In TABLE 1, any cell including two or more components is intended to cover a parallel arrangement of the components. TABLE 1 is not intended to exclude any non-illustrated permutations of the machinery 106, 178, 180. These components of the machinery 106, 178, 180 may enable feedback control of temperature, pressure, and flow rate of the oxidant 68 sent to the gas turbine engine 150. As discussed in further detail below, the oxidant 68 and the fuel 70 may be supplied to the gas turbine engine 150 at locations specifically selected to facilitate isolation and extraction of the compressed exhaust gas 170 without any oxidant 68 or fuel 70 degrading the quality of the exhaust gas 170.

[0063] The EG supply system 78, as illustrated in FIG. 3, is disposed between the gas turbine engine 150 and the target systems (e.g., the hydrocarbon production system 12 and the other systems 84). In particular, the EG supply system 78, e.g., the EG extraction system (EGES) 80, may be coupled to the gas turbine engine 150 at one or more extraction points 76 along the compressor section 152, the combustor section 154, and/or the turbine section 156. For example, the extraction points 76 may be located between adjacent compressor stages, such as 2, 3, 4, 5, 6, 7, 8, 9, or 10 interstage extraction points 76 between compressor stages. Each of these interstage extraction points 76 provides a different temperature and pressure of the extracted exhaust gas 42. Similarly, the extraction points 76 may be located between adjacent turbine stages, such as 2, 3, 4, 5, 6, 7, 8, 9, or 10 interstage extraction points 76 between turbine stages. Each of these interstage extraction points 76 provides a different temperature and pressure of the extracted exhaust gas 42. By further example, the extraction points 76 may be located at a multitude of locations

throughout the combustor section 154, which may provide different temperatures, pressures, flow rates, and gas compositions. Each of these extraction points 76 may include an EG extraction conduit, one or more valves, sensors, and controls, which may be used to selectively control the flow of the extracted exhaust gas 42 to the EG supply system 78.

[0064] The extracted exhaust gas 42, which is distributed by the EG supply system 78, has a controlled composition suitable for the target systems (e.g., the hydrocarbon production system 12 and the other systems 84). For example, at each of these extraction points 76, the exhaust gas 170 may be substantially isolated from injection points (or flows) of the oxidant 68 and the fuel 70. In other words, the EG supply system 78 may be specifically designed to extract the exhaust gas 170 from the gas turbine engine 150 without any added oxidant 68 or fuel 70. Furthermore, in view of the stoichiometric combustion in each of the combustors 160, the extracted exhaust gas 42 may be substantially free of oxygen and fuel. The EG supply system 78 may route the extracted exhaust gas 42 directly or indirectly to the hydrocarbon production system 12 and/or other systems 84 for use in various processes, such as enhanced oil recovery, carbon sequestration, storage, or transport to an offsite location. However, in certain embodiments, the EG supply system 78 includes the EG treatment system (EGTS) 82 for further treatment of the exhaust gas 42, prior to use with the target systems. For example, the EG treatment system 82 may purify and/or separate the exhaust gas 42 into one or more streams 95, such as the CO₂ rich, N₂ lean stream 96, the intermediate concentration CO₂, N₂ stream 97, and the CO₂ lean, N₂ rich stream 98. These treated exhaust gas streams 95 may be used individually, or in any combination, with the hydrocarbon production system 12 and the other systems 84 (e.g., the pipeline 86, the storage tank 88, and the carbon sequestration system 90).

[0065] Similar to the exhaust gas treatments performed in the EG supply system 78, the EG processing system 54 may include a plurality of exhaust gas (EG) treatment components 192, such as indicated by element numbers 194, 196, 198, 200, 202, 204, 206, 208, and 210. These EG treatment components 192 (e.g., 194 through 210) may be disposed along the exhaust recirculation path 110 in one or more series arrangements, parallel arrangements, or any combination of series and parallel

arrangements. For example, the EG treatment components 192 (e.g., 194 through 210) may include any series and/or parallel arrangement, in any order, of: one or more heat exchangers (e.g., heat recovery units such as heat recovery steam generators, condensers, coolers, or heaters), catalyst systems (e.g., oxidation catalyst systems), particulate and/or water removal systems (e.g., inertial separators, coalescing filters, water impermeable filters, and other filters), chemical injection systems, solvent based treatment systems (e.g., absorbers, flash tanks, etc.), carbon capture systems, gas separation systems, gas purification systems, and/or a solvent based treatment system, or any combination thereof. In certain embodiments, the catalyst systems may include an oxidation catalyst, a carbon monoxide reduction catalyst, a nitrogen oxides reduction catalyst, an aluminum oxide, a zirconium oxide, a silicone oxide, a titanium oxide, a platinum oxide, a palladium oxide, a cobalt oxide, or a mixed metal oxide, or a combination thereof. The disclosed embodiments are intended to include any and all permutations of the foregoing components 192 in series and parallel arrangements. As illustrated below, TABLE 2 depicts some non-limiting examples of arrangements of the components 192 along the exhaust recirculation path 110.

194	196	198	200	202	204	206	208	210
CU	HRU	BB	MRU	PRU				
CU	HRU	HRU	BB	MRU	PRU	DIL		
CU	HRSG	HRSG	BB	MRU	PRU			
OCU	HRU	OCU	HRU	OCU	BB	MRU	PRU	
HRU CU	HRU CU	BB	MRU	PRU				
HRSG OCU	HRSG OCU	BB	MRU	PRU	DIL			
OCU	HRSG OCU	OCU	HRSG OCU	OCU	BB	MRU	PRU	DIL
OCU	HRSG ST	HRSG ST	BB	COND	INER	WFIL	CFIL	DIL
OCU HRSG ST	OCU HRSG ST	BB	COND	INER	FIL	DIL		
OCU	HRSG ST	HRSG ST	OCU	BB	MRU HE COND	MRU WFIL	PRU INER	PRU FIL CFIL
CU	HRU COND	HRU COND	HRU COND	BB	MRU HE COND WFIL	PRU INER	PRU FIL CFIL	DIL

TABLE 2

[0066] As illustrated above in TABLE 2, a catalyst unit is represented by CU, an oxidation catalyst unit is represented by OCU, a booster blower is represented by BB, a heat exchanger is represented by HX, a heat recovery unit is represented by HRU, a heat recovery steam generator is represented by HRSG, a condenser is represented by COND, a steam turbine is represented by ST, a particulate removal unit is represented by PRU, a moisture removal unit is represented by MRU, a filter is represented by FIL, a coalescing filter is represented by CFIL, a water impermeable filter is

represented by WFIL, an inertial separator is represented by INER, and a diluent supply system (e.g., steam, nitrogen, or other inert gas) is represented by DIL. Although TABLE 2 illustrates the components 192 in sequence from the exhaust outlet 182 of the turbine section 156 toward the exhaust inlet 184 of the compressor section 152, TABLE 2 is also intended to cover the reverse sequence of the illustrated components 192. In TABLE 2, any cell including two or more components is intended to cover an integrated unit with the components, a parallel arrangement of the components, or any combination thereof. Furthermore, in context of TABLE 2, the HRU, the HRSG, and the COND are examples of the HE; the HRSG is an example of the HRU; the COND, WFIL, and CFIL are examples of the WRU; the INER, FIL, WFIL, and CFIL are examples of the PRU; and the WFIL and CFIL are examples of the FIL. Again, TABLE 2 is not intended to exclude any non-illustrated permutations of the components 192. In certain embodiments, the illustrated components 192 (e.g., 194 through 210) may be partially or completely integrated within the HRSG 56, the EGR system 58, or any combination thereof. These EG treatment components 192 may enable feedback control of temperature, pressure, flow rate, and gas composition, while also removing moisture and particulates from the exhaust gas 60. Furthermore, the treated exhaust gas 60 may be extracted at one or more extraction points 76 for use in the EG supply system 78 and/or recirculated to the exhaust inlet 184 of the compressor section 152.

[0067] As the treated, recirculated exhaust gas 66 passes through the compressor section 152, the SEGR gas turbine system 52 may bleed off a portion of the compressed exhaust gas along one or more lines 212 (e.g., bleed conduits or bypass conduits). Each line 212 may route the exhaust gas into one or more heat exchangers 214 (e.g., cooling units), thereby cooling the exhaust gas for recirculation back into the SEGR gas turbine system 52. For example, after passing through the heat exchanger 214, a portion of the cooled exhaust gas may be routed to the turbine section 156 along line 212 for cooling and/or sealing of the turbine casing, turbine shrouds, bearings, and other components. In such an embodiment, the SEGR gas turbine system 52 does not route any oxidant 68 (or other potential contaminants) through the turbine section 156 for cooling and/or sealing purposes, and thus any

leakage of the cooled exhaust gas will not contaminate the hot products of combustion (e.g., working exhaust gas) flowing through and driving the turbine stages of the turbine section 156. By further example, after passing through the heat exchanger 214, a portion of the cooled exhaust gas may be routed along line 216 (e.g., return conduit) to an upstream compressor stage of the compressor section 152, thereby improving the efficiency of compression by the compressor section 152. In such an embodiment, the heat exchanger 214 may be configured as an interstage cooling unit for the compressor section 152. In this manner, the cooled exhaust gas helps to increase the operational efficiency of the SEGR gas turbine system 52, while simultaneously helping to maintain the purity of the exhaust gas (e.g., substantially free of oxidant and fuel).

[0068] FIG. 4 is a flow chart of an embodiment of an operational process 220 of the system 10 illustrated in FIGS 1-3. In certain embodiments, the process 220 may be a computer implemented process, which accesses one or more instructions stored on the memory 122 and executes the instructions on the processor 120 of the controller 118 shown in FIG. 2. For example, each step in the process 220 may include instructions executable by the controller 118 of the control system 100 described with reference to FIG. 2.

[0069] The process 220 may begin by initiating a startup mode of the SEGR gas turbine system 52 of FIGS. 1-3, as indicated by block 222. For example, the startup mode may involve a gradual ramp up of the SEGR gas turbine system 52 to maintain thermal gradients, vibration, and clearance (e.g., between rotating and stationary parts) within acceptable thresholds. For example, during the startup mode 222, the process 220 may begin to supply a compressed oxidant 68 to the combustors 160 and the fuel nozzles 164 of the combustor section 154, as indicated by block 224. In certain embodiments, the compressed oxidant may include a compressed air, oxygen, oxygen-enriched air, oxygen-reduced air, oxygen-nitrogen mixtures, or any combination thereof. For example, the oxidant 68 may be compressed by the oxidant compression system 186 illustrated in FIG. 3. The process 220 also may begin to supply fuel to the combustors 160 and the fuel nozzles 164 during the startup mode 222, as indicated by block 226. During the startup mode 222, the process 220 also

may begin to supply exhaust gas (as available) to the combustors 160 and the fuel nozzles 164, as indicated by block 228. For example, the fuel nozzles 164 may produce one or more diffusion flames, premix flames, or a combination of diffusion and premix flames. During the startup mode 222, the exhaust gas 60 being generated by the gas turbine engine 156 may be insufficient or unstable in quantity and/or quality. Accordingly, during the startup mode, the process 220 may supply the exhaust gas 66 from one or more storage units (e.g., storage tank 88), the pipeline 86, other SEGR gas turbine systems 52, or other exhaust gas sources.

[0070] The process 220 may then combust a mixture of the compressed oxidant, fuel, and exhaust gas in the combustors 160 to produce hot combustion gas 172, as indicated by block 230. In particular, the process 220 may be controlled by the control system 100 of FIG. 2 to facilitate stoichiometric combustion (e.g., stoichiometric diffusion combustion, premix combustion, or both) of the mixture in the combustors 160 of the combustor section 154. However, during the startup mode 222, it may be particularly difficult to maintain stoichiometric combustion of the mixture (and thus low levels of oxidant and unburnt fuel may be present in the hot combustion gas 172). As a result, in the startup mode 222, the hot combustion gas 172 may have greater amounts of residual oxidant 68 and/or fuel 70 than during a steady state mode as discussed in further detail below. For this reason, the process 220 may execute one or more control instructions to reduce or eliminate the residual oxidant 68 and/or fuel 70 in the hot combustion gas 172 during the startup mode.

[0071] The process 220 then drives the turbine section 156 with the hot combustion gas 172, as indicated by block 232. For example, the hot combustion gas 172 may drive one or more turbine stages 174 disposed within the turbine section 156. Downstream of the turbine section 156, the process 220 may treat the exhaust gas 60 from the final turbine stage 174, as indicated by block 234. For example, the exhaust gas treatment 234 may include filtration, catalytic reaction of any residual oxidant 68 and/or fuel 70, chemical treatment, heat recovery with the HRSG 56, and so forth. The process 220 may also recirculate at least some of the exhaust gas 60 back to the compressor section 152 of the SEGR gas turbine system 52, as indicated by block 236. For example, the exhaust gas recirculation 236 may involve passage through the

exhaust recirculation path 110 having the EG processing system 54 as illustrated in FIGS. 1-3.

[0072] In turn, the recirculated exhaust gas 66 may be compressed in the compressor section 152, as indicated by block 238. For example, the SEGR gas turbine system 52 may sequentially compress the recirculated exhaust gas 66 in one or more compressor stages 158 of the compressor section 152. Subsequently, the compressed exhaust gas 170 may be supplied to the combustors 160 and fuel nozzles 164, as indicated by block 228. Steps 230, 232, 234, 236, and 238 may then repeat, until the process 220 eventually transitions to a steady state mode, as indicated by block 240. Upon the transition 240, the process 220 may continue to perform the steps 224 through 238, but may also begin to extract the exhaust gas 42 via the EG supply system 78, as indicated by block 242. For example, the exhaust gas 42 may be extracted from one or more extraction points 76 along the compressor section 152, the combustor section 154, and the turbine section 156 as indicated in FIG. 3. In turn, the process 220 may supply the extracted exhaust gas 42 from the EG supply system 78 to the hydrocarbon production system 12, as indicated by block 244. The hydrocarbon production system 12 may then inject the exhaust gas 42 into the earth 32 for enhanced oil recovery, as indicated by block 246. For example, the extracted exhaust gas 42 may be used by the exhaust gas injection EOR system 112 of the EOR system 18 illustrated in FIGS. 1-3.

[0073] FIG. 5 is a flow chart of a process 260 for operating the gas turbine engine 150 with exhaust gas recirculation. In a step 262, the process 260 compresses the oxidant 68 in the oxidant compressor 188 to generate compressed oxidant. Again, the oxidant 68 may include air, oxygen, oxygen-enriched air, oxygen-reduced air, oxygen nitrogen mixtures, or any combination thereof. For example, if the oxidant 68 includes air, then the compressor 188 may include an air compressor. In step 264, the exhaust gas 66 is compressed in a compressor section 152, such as an exhaust gas compressor of the gas turbine engine 150, to generate compressed exhaust gas 170. In a step 266, the compressed exhaust gas 170 and the compressed oxidant are routed from the compressor section 152 and the oxidant compressor 188, respectively, to one or more combustors 160 of the gas turbine engine 150. In a step 268, the compressed

exhaust gas 170 is isolated from the compressed oxidant prior to a flow mixer associated with each combustor 160, as described in detail below. In a step 270, the compressed exhaust gas 170 is split into first and second portions with a flow separator associated with each combustor 160, as described in detail below. In a step 272, the first portion of the compressed exhaust gas 170 is extracted for use in one or more applications, such as the oil/gas extraction system 16, the enhanced oil recovery (EOR) system 18, or another system 84. In a step 274, the second portion of the compressed exhaust gas 170 is mixed with oxidant to generate an exhaust gas/oxidant mixture using the flow mixer. In a step 276, the exhaust gas/oxidant mixture and the fuel 70 are injected into a combustion chamber of the combustion portion 168 of the combustor 160 to provide a combustible mixture. The fuel 70 may either be mixed with the exhaust gas/oxidant mixture in fuel nozzles (e.g., a premix design) or the fuel 70 may be kept separate from the exhaust gas/oxidant mixture until exiting the fuel nozzles (e.g., a diffusion design). In a step 278, the combustible mixture is combusted to generate the combustion gas or exhaust gas 172. In a step 280, the combustion gas or exhaust gas 172 is expanded in the turbine stages 174 of the gas turbine engine 150 to generate the exhaust gas 60. In a step 282, the expanded exhaust gas 60 is recirculated from the turbine stages 174 to the compressor stages 158 of the compressor section 152. The process 260 may then repeat by compressing oxidant in the oxidant compressor 188 to generate compressed oxidant in the step 262. With the overall process 260 for operating the gas turbine engine 150 shown in FIG. 5 in mind, specific embodiments of the combustor section 154 are shown in FIGS. 6-18 and discussed below.

[0074] FIG. 6 is a schematic diagram of an embodiment of the combustor section 154 that includes various features that are shown in detail in FIGS. 7-18. Elements in FIG. 6 in common with those shown in previous figures are labeled with the same reference numerals. The axial direction of the combustor 160 is indicated by arrow 294, the radial direction is indicated by arrow 296, and the circumferential direction is indicated by arrow 298. As shown in FIG. 6, the oxidant compression system 186 generates a compressed oxidant 300 that may be provided to various locations of the combustor 160. For example, the compressed oxidant 300 may be provided to a flow

mixer 302 to combine the compressed oxidant 300 with the compressed exhaust gas 170. As discussed in detail below, the flow mixer 302 may help to improve mixing of the oxidant 300 and exhaust gas 170 when space or length for mixing is limited. The compressed oxidant 300 may include air, oxygen, oxygen-enriched air, oxygen-reduced air, or oxygen nitrogen mixtures. The exhaust gas 170 may be substantially free of oxygen and unburnt fuel, and may result from stoichiometric combustion and exhaust gas recirculation, as discussed above. Thus, the exhaust gas 170 may be used as a diluent with the oxidant 300. Additionally or alternatively, the compressed oxidant 300 may be provided to a flow separator 304 that separates the compressed exhaust gas 170 into two or more portions. For example, the flow separator 304 may provide a portion of the compressed exhaust gas 170 to the exhaust extraction system 80 as the extracted exhaust gas 42. In addition, the flow separator 304 may also help to isolate the oxidant 300 from the exhaust gas 170. As shown in FIG. 6, the flow mixer 302 and the flow separator 304 may be disposed in the head end portion 166 of the combustor 160. Further details of the flow mixer 302 and the flow separator 304 are described below with respect to FIGS. 7-18.

[0075] FIG. 7 is a schematic diagram of the head end portion 166 of the combustor 160. As shown in FIG. 7, the combustor 160 is generally defined by a combustion casing 320, a flow sleeve 322, and a combustion liner 324. As illustrated, the flow sleeve 322 is disposed about the combustion liner 324. In certain embodiments, the flow sleeve 322 and the combustion liner 324 are coaxial with one another to define a first flow path 326 (e.g., annular passage), which may enable passage of the compressed exhaust gas 170 for cooling of the combustion liner 324 and for entry into the head end portion 166. In addition, the combustion casing 320 and the flow sleeve 322 may define a second flow path 328 (e.g., annular passage), which may also enable passage of the compressed exhaust gas 170 for cooling and for entry into the head end portion 166. A first exhaust extraction port 330 may be coupled to the combustion casing 320. As illustrated, the first exhaust extraction port 330 may be a radial port, thereby extracting the exhaust gas 42 radially 296 from the combustor 160. The first exhaust extraction port 330 may convey the compressed exhaust gas 170 (e.g., exhaust gas 42) from the second flow path 328 to the exhaust gas extraction system

80. In certain embodiments, a cap 331 may be disposed between the head end portion 166 and the combustion portion 168.

[0076] As shown in FIG. 7, the flow separator 304 separates the compressed exhaust gas 170 from the oxidant 68. Specifically, the flow separator 304 may include a flow distributor 332 and various other walls 333. For example, the flow distributor 332 may be disposed between the combustion casing 320 and the combustion liner 324 downstream of the first exhaust extraction port 330. In certain embodiments, the flow distributor 332 may be disposed between the walls 333 downstream of the first exhaust extraction port 330. The flow distributor 332 may extend crosswise across the first and second flow paths 326 and 328. In certain embodiments, the flow distributor 332 may include an exhaust gas flow path 334 that routes the compressed exhaust gas 170 in the second flow path 328 into the head end portion 166. Specifically, the exhaust gas flow path 334 may route the compressed exhaust gas 170 to a cooling region 335 adjacent the cap 331 in the head end portion 166 to help cool the cap 331. In certain embodiments, the flow distributor 332 does not extend completely circumferentially 298, as discussed in detail below. Thus, some of the compressed exhaust gas 170 may flow past, or bypass, the flow distributor 332 (e.g., the flow separator 304). For example, the compressed exhaust gas 170 that passes the flow distributor 332 may be extracted using a second exhaust extraction port 337 that is also coupled to the exhaust gas extraction system 80. As illustrated, the second exhaust extraction port 337 may be a radial port, thereby extracting the exhaust gas 42 radially 296 from the combustor 160. In certain embodiments, only one of the first or second exhaust extraction ports 330 or 337 may be present. In other embodiments, 1, 2, 3, 4, 5, or more of first or second exhaust extraction ports 330 or 337 may be at each location. Next, the compressed exhaust gas 170 moves past a radial fuel manifold 336 coupled to a fuel supply system 338. The radial fuel supply manifold 336 supplies the fuel 70 to the one or more fuel nozzles 164. In other embodiments, other types of fuel manifolds other than that shown in FIG. 7 may be coupled to the fuel nozzles 164. For example, in certain embodiments, an axial fuel injection manifold may be coupled to the fuel nozzles 164. Next, the compressed exhaust gas

170 reaches an end plate 340 of the head end portion 166. The compressed exhaust gas 170 may then turn toward a central portion 341 of the end plate 340.

[0077] As illustrated in FIG. 7, an oxidant intake port 342 may be coupled to the central portion 341 of the end plate 340. As illustrated, the oxidant intake port 342 may be an axial port, thereby supplying the oxidant 68 to the combustor 160 axially 294. The oxidant intake port 342 may be configured to route the oxidant 68 from the oxidant compression system 186 to the combustor 160. A baffle 344 may direct the compressed exhaust gas 170 to mix with the oxidant 68 in a mixing region 346 at least partially enclosed by the baffle 344 of the flow separator 304 to provide an oxidant-exhaust mixture 348. In certain embodiments, the mixing region 346 includes the flow mixer 302 disposed between the end plate 340 and the cap 331. The flow mixer 302 may be used to provide additional mixing of the compressed exhaust gas 170 and the oxidant 68, which may be desirable because of the limited mixing length available for mixing the compressed exhaust gas 170 with the oxidant 68. In certain embodiments, the flow mixer 302 may include at least one of a perforated plate, a flow disturber, or any combination thereof. As shown in FIG. 7, the oxidant-exhaust mixture 348 then enters the fuel nozzles 164 to be combined with the fuel 70 from the fuel manifold 336 before being combusted in the combustion portion 168 (e.g., premix fuel nozzles). In other embodiments, the oxidant-exhaust mixture 348 is not combined with the fuel 70 until exiting the fuel nozzles 164 (e.g., diffusion fuel nozzles).

[0078] FIG. 8 is a radial cross-sectional view of the combustor 160 taken along the line 8-8 of FIG. 7. As shown in FIG. 8, the path of the compressed exhaust gas 170 in the second flow path 328 may be blocked by an annular ring 360, which may be part of the flow distributor 332. Thus, the compressed exhaust gas 170 in the second flow path 328 is forced into the exhaust gas path 334. Specifically, the compressed exhaust gas 170 enters an entrance 362 of the exhaust gas path 334 and enters the head end chamber 166 through an exit 364 to help cool the cap 331. As shown in FIG. 8, a plurality of flow distributors 332 (e.g., radial inserts) may be spaced apart from one another circumferentially 298 about the head end portion 166 (e.g., fuel nozzles 164). Thus, the compressed exhaust gas 170 in the first flow path 326 passes through gaps 366 between the flow distributors 332. In other embodiments, the plurality of flow

distributors 332 may not be evenly spaced apart from one another circumferentially 298. For example, the plurality of flow distributors 332 may be disposed within approximately 60 degrees of top dead center of the combustor 160 because of packaging constraints associated with can-annular combustors.

[0079] FIG. 9 is a radial cross-sectional view of the combustor 160 taken along the line 8-8 of FIG. 7. As shown in FIG. 9, a second annular ring 380 may be disposed in the first flow path 326. The second annular ring 380, which may be part of the flow distributor 332, may include a plurality of openings 382 for the compressed exhaust gas 170 to pass through. Thus, the second annular ring 380 and the openings 382 may be used to adjust the flow rate of the compressed exhaust gas 170 through the first flow path 326. For example, providing more openings 382 may enable additional compressed exhaust gas 170 to flow through the first flow path 326. The openings 382 may be disposed circumferentially 298 about the fuel nozzles 164. Although the openings 382 are shown as circular openings in FIG. 9, the sizes, shapes, and/or locations of the openings 382 may be adjusted to provide the desired flow rate of the compressed exhaust gas 170 through the first flow path 326 and/or to accommodate packaging limitations of individual combustors 160. In addition, although the entrances 362 and exits 364 are shown spaced apart from one another circumferentially 298 in FIG. 9, in other embodiments, the entrances 362 and exits 364 may be disposed within approximately 60 degrees of top dead center of the combustor 160.

[0080] FIG. 10 is a cross-sectional view of an embodiment of the combustor 160. Elements in FIG. 10 in common with those shown in FIG. 7 are labeled with the same reference numerals. The cross-sectional view shown in FIG. 10 is similar to the view shown in FIG. 7, but focuses on the shape and arrangement of the components of the combustor 160 near the flow distributor 332. For example, in the illustrated embodiment, the second flow path 328 includes a contoured surface 390 near the flow distributor 332 to help guide the compressed exhaust gas 170 into the entrance 362. In addition, the contoured surface 390 may be used to adjust the flow rate of the compressed exhaust gas 170 through the exhaust gas flow path 334 in the flow distributor 332. Similarly, the first flow path 326 may include various contoured

surfaces to adjust the flow rate of the compressed exhaust gas 170 through the first flow path 326. Further, the walls 333 may converge in the direction of the flow of the compressed exhaust gas 170, which may help increase the velocity of the compressed exhaust gas 170.

[0081] FIG. 11 is a schematic diagram of an embodiment of the head end portion 166 of the combustor section 154. Elements in FIG. 11 in common with those shown in FIG. 7 are labeled referenced with the same reference numerals. As shown in FIG. 11, the compressed exhaust gas 170 in the first flow path 326 passes the flow distributor 332 and enters the mixing region 346 between the first and second walls 402 and 404 of the flow separator 304. Thus, the mixing region 346 is at least partially disposed within the first flow path 326. The compressed exhaust gas 170 in the second flow path 328 also passes the flow distributor 332 and flows toward the end plate 340, exiting the combustor 160 axially 294 through the first exhaust gas extraction port 330 to enter the exhaust gas extraction system 80. A portion of the compressed exhaust gas 170 flows through the exhaust gas path 334 through the flow distributor 332 to enter the head end portion 166 to help cool the cap 331. The oxidant 68 from the oxidant compression system 186 enters the oxidant intake port 342 radially 296 at the flow distributor 332 to enter an oxidant flow path 400. As shown in FIG. 11, the oxidant intake port 342 is coupled to the combustion casing 320 (or side wall) of the combustor 160. The oxidant flow path 400 routes the oxidant 68 to the mixing region 346 to mix with the compressed exhaust gas 170 to generate the oxidant-exhaust mixture 348.

[0082] As shown in FIG. 11, several walls are disposed downstream of the flow distributor 332. Specifically, a first wall 402 is disposed about the head end portion 166, a second wall 404 is disposed about the first wall 402 to define the first flow path 326, and a third wall 406 is disposed about the second wall 404 to define the second flow path 328. Thus, the flow separator 304 may include one or more of the walls 402, 404, 406, or the flow distributor 332. As shown in FIG. 11, the first wall 402 may generally coincide with the combustion liner 324, the second wall 404 may generally coincide with the flow sleeve 322, and the third wall 406 may generally coincide with the combustion casing 320. However, in other embodiments, the first,

second, and third walls 402, 402, and 406 may be disposed at different locations. As shown in FIG. 11, the second wall 404 separates the compressed exhaust gas 170 in the second flow path 328 from the oxidant 68. Thus, the walls 402, 404, and 406 may be considered part of the flow separator 304.

[0083] The oxidant-exhaust mixture 348 may travel to the end plate 340 before turning and entering the fuel nozzles 164. In certain embodiments, the compressed exhaust gas 170 may be extracted axially 294 using one or both of the first and second exhaust extraction ports 330 and 337. The fuel 70 may be supplied to the combustor 160 via the fuel supply system 338. Specifically, an axial fuel manifold 408 may supply the fuel 70 axially 294 to one or more fuel intake ports 410 coupled to the central portion 341 of the end plate 340. In certain embodiments, a dividing wall 412 may extend around the combustion liner 324 between the combustion liner 324 and the flow sleeve 322. As shown in FIG. 11, the dividing wall 412 may direct a portion of the compressed exhaust gas 170 in the first flow path 326 to combine with the compressed exhaust gas 170 in the second flow path 328 to be extracted via the first and second exhaust gas extraction ports 330 and 337. In addition, the controller 118 may be used to control the exhaust extraction system 80 and the oxidant compression system 186.

[0084] FIG. 12 is a radial cross-sectional view of the combustor 160 taken along the line 12-12 of FIG. 11. Elements in FIG. 12 in common with those shown in FIG. 11 are labeled with the same reference numerals. As shown in FIG. 12, the compressed exhaust gas 170 in the second flow path 328 enters the entrance 362 of the exhaust gas path 334 and enters the head end chamber 166 through the exit 364 to help cool the cap 331. The compressed exhaust gas 170 may also flow between the gaps 366 between the flow distributors 332. In addition, the oxidant 68 enters an oxidant entrance 420 of the oxidant path 400 and exits an oxidant exit 422 into the first flow path 326 to mix with the compressed exhaust gas 170 to generate the oxidant-exhaust mixture 348. As shown in FIG. 12, a plurality of flow distributors 332 may be distributed circumferentially 298 about the fuel nozzles 164. In other embodiments, the plurality of flow distributors 332 may be disposed in a non-uniform

manner, such as within approximately 60 degrees of top dead center of the combustor 160, for example.

[0085] FIG. 13 is a radial cross-sectional view of the combustor 160 taken along the line 12-12 of FIG. 11. As shown in FIG. 13, the first annular ring 360 is disposed in the second flow path 328 and the second annular ring 380 is disposed in the first flow path 326. The first annular ring 360 includes a plurality of openings 440 to control (e.g., restrict flow of) the compressed exhaust gas 170. Similarly the second annular ring 380 includes the plurality of openings 382 to control (e.g., restrict flow of) the compressed exhaust gas 170. As with the embodiment shown in FIG. 9, the sizes, shapes, and/or locations of the openings 382 and/or 440 may be adjusted to obtain a desired flow rate of the compressed exhaust gas 170 and/or to accommodate packaging limitations of individual combustors 160. In addition, although the entrances 362, exits 364, oxidant entrances 420, and oxidant exits 422 are shown spaced apart from one another circumferentially 298 in FIG. 13, in other embodiments, they may be disposed within approximately 60 degrees of top dead center of the combustor 160.

[0086] FIG. 14 is a cross-sectional view of the combustor 160. Elements in FIG. 14 in common with those shown in FIG. 11 are labeled with the same reference numerals. As shown in FIG. 14, the contoured surface 390 may be used to adjust the flow rate of the compressed exhaust gas 170 in the second flow path 328. In addition, the dividing wall 412 may be used to separate the compressed exhaust gas 170 to be mixed in the mixing region 346 from the compressed exhaust gas 170 extracted through the first exhaust gas extraction port 330. As shown in FIG. 14, the dividing wall 421 generally coincides with the second wall 404. Further, the second and third walls 404 and 406 may converge in the direction of the flow of the compressed exhaust gas 170, which may help increase the velocity of the compressed exhaust gas 170. In other respects, the combustor 160 is similar to the combustors of the previous embodiments.

[0087] FIG. 15 is a schematic diagram of an embodiment of the combustor 160. Elements in FIG. 15 in common with those shown in previous figures are labeled with

the same reference numerals. As shown in FIG. 15, the compressed exhaust gas 170 is extracted radially 296 through the first exhaust gas extraction port 330. In addition, the compressed exhaust gas 170 in the first flow path 326 passes the flow distributor 332 to enter the mixing region 346 between the first and second walls 402 and 404 of the flow separator 304. The compressed exhaust gas 170 in the second flow path 328 enters the entrance 362 of the exhaust gas path 334 and exits the exit 364 into the head end portion 166 to help cool the cap 331. The oxidant 68 from the oxidant compression system 186 enters the combustor 160 axially 294 via the oxidant intake ports 342 coupled to the end plate 340. The oxidant 68 flows toward the flow distributor 332 to enter the oxidant entrance 420 of the oxidant flow path 400 to exit the oxidant exit 422 to mix with the compressed exhaust gas 170 in the mixing region 346 to generate the oxidant exhaust mixture 348. The oxidant-exhaust mixture 348 then flows toward the end plate 340 to enter the fuel nozzles 164. Although the oxidant flow path 400 is shown in the flow distributor 332 in FIG. 15, the oxidant flow path 400 may be disposed outside of the flow distributor 332 in other embodiments, as discussed in detail below. The fuel 70 enters the fuel intake ports 410 axially 294. The flow separator 304 may include one or more of the walls 402, 404, 406, or the flow distributor 332. In other respects, the combustor 160 shown in FIG. 15 is similar to the combustor 160 shown in FIG. 11.

[0088] FIG. 16 is radial cross-sectional view of the combustor 160 taken along the line 16-16 of FIG. 15. Elements in FIG. 16 in common with those shown in FIG. 15 are labeled with the same reference numerals. As shown in FIG. 16, the compressed exhaust gas 170 in the second flow path 328 enters the entrance 362 to flow through the exhaust gas flow path 334 before exiting through the exit 364 into the head end portion 166 to help cool the cap 331. The first annular ring 360 blocks the flow of the compressed exhaust gas 170 other than the flow through the exhaust gas flow path 334. Thus, the first annular ring 360 helps to control or throttle the flow of the compressed exhaust gas 170. The compressed exhaust gas 170 in the first flow path 326 flows past the flow distributor 332 to mix with the oxidant 68. Specifically, the oxidant 68 enters the oxidant entrance 420, flows through the oxidant flow path 400 before exiting the oxidant exit 422 into the mixing region 346. As shown in FIG. 16, a

plurality of flow distributors 332 may be disposed circumferentially 298 about the fuel nozzles 164. In other embodiments, the plurality of flow distributors 332 may be disposed in a non-uniform manner, such as within approximately 60 degrees of top dead center of the combustor 160, for example. In certain embodiments, additional oxidant flow paths 400 may be disposed outside of the flow distributors 332, as indicated by the dotted lines in FIG. 16. The additional oxidant flow paths 400 may provide additional flow of the oxidant 68 to mix with the compressed exhaust gas 170 in the mixing region 346. The additional oxidant flow paths 400 may be disposed within approximately 60 degrees of top dead center of the combustor 160 in certain embodiments.

[0089] FIG. 17 is a radial cross-sectional view of the combustor 160. As shown in FIG. 17 the second annular ring 380 blocks the flow of the compressed exhaust gas 170 in the first flow path 326 except for through the plurality of openings 382. Thus, the second annular ring 380 and the plurality of openings 382 may be used to adjust the flow rate of the compressed exhaust gas 170 through the first flow path 326. As with previous embodiments, the shapes, sizes, and/or locations of the plurality of openings 382 may be adjusted to obtain a desired flow rate of the compressed exhaust gas 170 through the plurality of opening 382 and/or to accommodate packaging limitations of individual combustors 160. In addition, although the entrances 362, exits 364, oxidant entrances 420, and oxidant exits 422 are shown spaced apart from one another circumferentially 298 in FIG. 17, in other embodiments, they may be disposed within approximately 60 degrees of top dead center of the combustor 160.

[0090] FIG. 18 is a cross-sectional view of the combustor 160. Elements in FIG. 1 in common with those shown in FIG. 15 are labeled with the same reference numerals. As shown in FIG. 18, the contoured surface 390 may be used to adjust the flow rate of the compressed exhaust gas 170 flowing through the second flow path 328. In addition, the first wall 402 generally coincides with the combustion liner 324, the second wall 404 generally coincides with the flow sleeve 322 and the third wall 406 generally coincides with the combustion casing 320. In other embodiments, the first, second, and third walls 402, 404, and 406 may not coincide with the combustion liner 324, flow sleeve 322, and/or the combustion casing 320. Further, the second and

third walls 404 and 406 may converge in the direction of the flow of the compressed exhaust gas 170, which may help increase the velocity of the compressed exhaust gas 170. In other respects, the combustor 160 shown in FIG. 18 is similar to previous embodiments of the combustor 160.

[0091] As described above, certain embodiments of the combustor 160 may include the head end portion 166, the combustion portion 168 disposed downstream from the head end portion 166, the cap 331 disposed between the head end portion 166 and the combustion portion 68. In addition, the combustor 160 may include the flow separator 304 to separate a first portion of the compressed exhaust gas 170 from the oxidant 68. Specifically, the flow separator 304 directs the first exhaust flow into the head end portion 166. The combustor 160 may also include the mixing region 346 to mix the first exhaust flow with the oxidant 68 to provide the oxidant-exhaust mixture 348. In the disclosed embodiments, the compressed exhaust gas 170 may be used to cool the combustion liner 324, thereby extending the life span of the combustion liner 324. In addition, the flow separator 304 and the mixing region 346 may help provide sufficient mixing of the oxidant 68 with the compressed exhaust gas 170 before the oxidant-exhaust mixture 348 is directed into the fuel nozzles 164, thereby improving the combustion efficiency of the combustor 160.

ADDITIONAL DESCRIPTION

[0092] The present embodiments provide systems and methods for turbine combustors of gas turbine engines. It should be noted that any one or a combination of the features described above may be utilized in any suitable combination. Indeed, all permutations of such combinations are presently contemplated. By way of example, the following clauses are offered as further description of the present disclosure:

[0093] Embodiment 1. A system, comprising: a turbine combustor, comprising: a head end portion having a head end chamber; a combustion portion having a combustion chamber disposed downstream from the head end chamber; a cap disposed between the head end chamber and the combustion chamber; a flow separator configured to separate a first exhaust flow from an oxidant flow, wherein

the flow separator is configured to direct the first exhaust flow into the head end chamber; and a mixing region configured to mix the first exhaust flow with the oxidant flow to provide an oxidant-exhaust mixture.

[0094] Embodiment 2. The system of embodiment 1, wherein the system is configured to split an exhaust flow into the first exhaust flow and a second exhaust flow, and the system comprises at least one exhaust extraction port configured to extract the second exhaust flow.

[0095] Embodiment 3. The system defined in any preceding embodiment, wherein the at least one exhaust extraction port is coupled to a casing disposed about the turbine combustor.

[0096] Embodiment 4. The system defined in any preceding embodiment, wherein the at least one exhaust extraction port is coupled to the turbine combustor.

[0097] Embodiment 5. The system defined in any preceding embodiment, wherein the at least one exhaust extraction port is coupled to the head end portion of the turbine combustor.

[0098] Embodiment 6. The system defined in any preceding embodiment, comprising an oxidant intake port coupled to the head end portion of the turbine combustor.

[0099] Embodiment 7. The system defined in any preceding embodiment, wherein the oxidant intake port is coupled to a side wall of the head end portion of the turbine combustor.

[00100] Embodiment 8. The system defined in any preceding embodiment, wherein the side wall comprises a first wall disposed about the head end chamber, a second wall disposed about the first wall to define a first flow path, and a third wall disposed about the second wall to define a second flow path, wherein the flow separator comprises the second wall and a flow distributor extending crosswise through the first and second flow paths, wherein the first flow path is configured to route the first exhaust flow to the mixing region at least partially disposed within the

first flow path, the second flow path is configured to route the second exhaust flow to the at least one exhaust extraction port, the flow distributor comprises a third flow path configured to route the oxidant flow from the oxidant intake port into the mixing region at least partially disposed within the first flow path, and the flow distributor comprises a fourth flow path configured to route a third exhaust flow from the exhaust flow into the head end chamber.

[00101] Embodiment 9. The system defined in any preceding embodiment, wherein the fourth flow path of the flow distributor is configured to route the third exhaust flow to a cooling region adjacent the cap in the head end region.

[00102] Embodiment 10. The system defined in any preceding embodiment, wherein the flow distributor comprises a plurality of radial inserts disposed between the first and third walls, and the plurality of radial inserts are spaced apart from one another circumferentially about the head end region.

[00103] Embodiment 11. The system defined in any preceding embodiment, wherein each radial insert of the plurality of radial inserts comprises the third flow path and the fourth flow path.

[00104] Embodiment 12. The system defined in any preceding embodiment, wherein the at least one exhaust extraction port is coupled to an end plate of the head end portion of the turbine combustor.

[00105] Embodiment 13. The system defined in any preceding embodiment, wherein the head end portion comprises a side wall having a first wall disposed about the head end chamber, a second wall disposed about the first wall to define a first flow path, and a third wall disposed about the second wall to define a second flow path, wherein the oxidant intake port is coupled to the second flow path and configured to supply the oxidant flow into the second flow path, wherein the flow separator comprises a flow distributor extending crosswise through the first and second flow paths between the first and third walls, the flow distributor comprises a third flow path configured to route the oxidant flow from the second flow path into the first flow path to the mixing region at least partially disposed within the first flow

path, the flow distributor comprises a fourth flow path configured to route a third exhaust flow from the exhaust flow into the head end chamber, and the flow distributor comprises a fifth flow path configured to route the second exhaust flow into the mixing region at least partially disposed within the first flow path.

[00106] Embodiment 14. The system defined in any preceding embodiment, wherein the fourth flow path of the flow distributor is configured to route the third exhaust flow to a cooling region adjacent the cap in the head end region.

[00107] Embodiment 15. The system defined in any preceding embodiment, wherein the flow distributor blocks the second flow path except for the third flow path from the second flow path to the first flow path.

[00108] Embodiment 16. The system defined in any preceding embodiment, wherein the third flow path comprises a plurality of third flow paths.

[00109] Embodiment 17. The system defined in any preceding embodiment, wherein the flow distributor blocks the first flow path except for the fifth flow path into the first flow path.

[00110] Embodiment 18. The system defined in any preceding embodiment, wherein the fifth flow path comprises a plurality of fifth flow paths.

[00111] Embodiment 19. The system defined in any preceding embodiment, wherein the oxidant intake port is coupled to an end plate of the head end portion of the turbine combustor.

[00112] Embodiment 20. The system defined in any preceding embodiment, wherein the at least one exhaust extraction port is coupled to a casing disposed about the turbine combustor.

[00113] Embodiment 21. The system defined in any preceding embodiment, wherein the oxidant intake port is coupled to an end plate of the head end portion of the turbine combustor, and the at least one exhaust extraction port is coupled to a side wall of the head end portion of the turbine combustor.

[00114] Embodiment 22. The system defined in any preceding embodiment, wherein the side wall comprises a first wall disposed about the head end chamber and a second wall disposed about the first wall to define a first flow path, wherein the flow separator comprises a flow distributor extending crosswise through the first flow path between the first and second walls, the flow distributor comprises a second flow path configured to route the first exhaust flow into the first flow path, the flow distributor comprises a third flow path configured to route a third exhaust flow from the exhaust flow into the head end chamber.

[00115] Embodiment 23. The system defined in any preceding embodiment, wherein the third flow path of the flow distributor is configured to route the third exhaust flow to a cooling region adjacent the cap in the head end region.

[00116] Embodiment 24. The system defined in any preceding embodiment, wherein the mixing region is disposed at least partially adjacent the end plate.

[00117] Embodiment 25. The system defined in any preceding embodiment, wherein the mixing region comprises a flow mixer disposed between the end plate and the cap.

[00118] Embodiment 26. The system defined in any preceding embodiment, wherein the flow mixer comprises at least one of a perforated plate, or a flow disturber, or any combination thereof.

[00119] Embodiment 27. The system defined in any preceding embodiment, comprising a gas turbine engine having the turbine combustor, a turbine driven by combustion products from the turbine combustor, and an exhaust gas compressor driven by the turbine, wherein the exhaust gas compressor is configured to compress and route an exhaust gas to the turbine combustor.

[00120] Embodiment 28. The system defined in any preceding embodiment, comprising an exhaust gas extraction system coupled to the gas turbine engine, and a hydrocarbon production system coupled to the exhaust gas extraction system.

[00121] Embodiment 29. The system defined in any preceding embodiment, wherein the gas turbine engine is a stoichiometric exhaust gas recirculation (SEGR) gas turbine engine.

[00122] Embodiment 30. A system, comprising: an oxidant compressor; and a gas turbine engine, comprising: a combustor section having a turbine combustor; a turbine driven by combustion products from the turbine combustor; an exhaust gas compressor driven by the turbine, wherein the exhaust gas compressor is configured to compress and route an exhaust flow to the turbine combustor, and the oxidant compressor is configured to compress and route an oxidant flow to the turbine combustor; an exhaust extraction port coupled to the combustor section; and a flow separator coupled to a head end portion of the turbine combustor, wherein the flow separator is configured to separate the oxidant flow from a first portion of the exhaust flow until the first portion reaches a mixing region within the head end portion, the flow separator is configured to separate the oxidant flow from a second portion of the exhaust flow until the second portion reaches the exhaust extraction port, and the flow separator comprises a flow distributor having an exhaust path extending toward a head end region adjacent a cap in the head end portion of the turbine combustor.

[00123] Embodiment 31. The system defined in any preceding embodiment, wherein the exhaust extraction port is coupled to a side wall of the turbine combustor or a casing disposed about the turbine combustor, and an oxidant intake port is coupled to an end plate of the turbine combustor.

[00124] Embodiment 32. The system defined in any preceding embodiment, wherein the exhaust extraction port is coupled to the side wall of the head end portion between the flow distributor and the end plate, and the oxidant intake port is coupled to a central portion of the end plate.

[00125] Embodiment 33. The system defined in any preceding embodiment, wherein the exhaust extraction port is coupled to the casing, the flow distributor is disposed between the end plate and the exhaust extraction port, the oxidant intake port is coupled to the end plate between first and second walls of the side wall, the first

wall is disposed about the head end region, and the second wall is disposed about the first wall.

[00126] Embodiment 34. The system defined in any preceding embodiment, wherein an oxidant intake port is coupled to the flow distributor along a side wall of the turbine combustor.

[00127] Embodiment 35. The system defined in any preceding embodiment, wherein the exhaust extraction port is coupled to an end plate of the turbine combustor.

[00128] Embodiment 36. The system defined in any preceding embodiment, comprising a stoichiometric exhaust gas recirculation (SEGR) turbine system having the oxidant compressor and the gas turbine engine.

[00129] Embodiment 37. The system defined in any preceding embodiment, comprising an exhaust gas extraction system coupled to the exhaust extraction port of the SEGR turbine system, and a hydrocarbon production system coupled to the exhaust gas extraction system.

[00130] Embodiment 38. A method, comprising: extracting a first exhaust flow of an exhaust gas at a combustion section of a gas turbine engine; routing a second exhaust flow of the exhaust gas toward an end plate of a head end portion of a turbine combustor in the combustion section; routing a third exhaust flow of the exhaust gas toward a cap of the head end portion, wherein the cap is disposed between a head end region and a combustion region; routing an oxidant flow into the head end portion; and separating the oxidant flow at least from the first exhaust flow.

[00131] Embodiment 39. The method or system defined in any preceding embodiment, wherein extracting the first exhaust flow comprises extracting the first exhaust flow through an exhaust extraction port coupled to a side wall of the turbine combustor or a casing disposed about the turbine combustor, wherein routing the oxidant flow comprises supplying the oxidant flow through an oxidant intake port coupled to an end plate of the turbine combustor.

[00132] Embodiment 40. The method or system defined in any preceding embodiment, wherein routing the oxidant flow comprises supplying the oxidant flow through an oxidant intake port coupled to a flow distributor along a side wall of the turbine combustor, wherein routing the third exhaust flow comprises routing the third exhaust flow through an exhaust path through the flow distributor.

[00133] Embodiment 41. The method or system defined in any preceding embodiment, wherein extracting the first exhaust flow comprises extracting the first exhaust flow through an exhaust extraction port coupled to an end plate of the turbine combustor.

[00134] Embodiment 42. The method or system defined in any preceding embodiment, comprising stoichiometrically combusting a mixture of a fuel flow, the oxidant flow, and the second and third exhaust flows.

[00135] Embodiment 43. The method or system defined in any preceding embodiment, comprising routing the first exhaust flow to a hydrocarbon production system.

[00136] Embodiment 44. The method or system defined in any preceding embodiment, wherein the turbine combustor is configured to combust a mixture of a fuel and an oxidant with an equivalence ratio of approximately 0.95 to approximately 1.05.

[00137] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

CLAIMS:

1. A system, comprising:
 - a turbine combustor, comprising:
 - a head end portion having a head end chamber;
 - a combustion portion having a combustion chamber disposed downstream from the head end chamber;
 - a cap disposed between the head end chamber and the combustion chamber;
 - a flow separator configured to separate a first exhaust flow from an oxidant flow, wherein the flow separator is configured to direct the first exhaust flow into the head end chamber; and
 - a mixing region configured to mix the first exhaust flow with the oxidant flow to provide an oxidant-exhaust mixture.
2. The system of claim 1, wherein the system is configured to split an exhaust flow into the first exhaust flow and a second exhaust flow, and the system comprises at least one exhaust extraction port configured to extract the second exhaust flow.
3. The system of claim 2, wherein the at least one exhaust extraction port is coupled to a casing disposed about the turbine combustor.
4. The system of claim 2, wherein the at least one exhaust extraction port is coupled to the turbine combustor.
5. The system of claim 4, wherein the at least one exhaust extraction port is coupled to the head end portion of the turbine combustor.
6. The system of claim 5, comprising an oxidant intake port coupled to the head end portion of the turbine combustor.

7. The system of claim 6, wherein the oxidant intake port is coupled to a side wall of the head end portion of the turbine combustor.

8. The system of claim 7, wherein the side wall comprises a first wall disposed about the head end chamber, a second wall disposed about the first wall to define a first flow path, and a third wall disposed about the second wall to define a second flow path, wherein the flow separator comprises the second wall and a flow distributor extending crosswise through the first and second flow paths, wherein the first flow path is configured to route the first exhaust flow to the mixing region at least partially disposed within the first flow path, the second flow path is configured to route the second exhaust flow to the at least one exhaust extraction port, the flow distributor comprises a third flow path configured to route the oxidant flow from the oxidant intake port into the mixing region at least partially disposed within the first flow path, and the flow distributor comprises a fourth flow path configured to route a third exhaust flow from the exhaust flow into the head end chamber.

9. The system of claim 8, wherein the fourth flow path of the flow distributor is configured to route the third exhaust flow to a cooling region adjacent the cap in the head end region.

10. The system of claim 9, wherein the flow distributor comprises a plurality of radial inserts disposed between the first and third walls, and the plurality of radial inserts are spaced apart from one another circumferentially about the head end region.

11. The system of claim 10, wherein each radial insert of the plurality of radial inserts comprises the third flow path and the fourth flow path.

12. The system of claim 8, wherein the at least one exhaust extraction port is coupled to an end plate of the head end portion of the turbine combustor.

13. The system of claim 6, wherein the head end portion comprises a side wall having a first wall disposed about the head end chamber, a second wall disposed

about the first wall to define a first flow path, and a third wall disposed about the second wall to define a second flow path, wherein the oxidant intake port is coupled to the second flow path and configured to supply the oxidant flow into the second flow path, wherein the flow separator comprises a flow distributor extending crosswise through the first and second flow paths between the first and third walls, the flow distributor comprises a third flow path configured to route the oxidant flow from the second flow path into the first flow path to the mixing region at least partially disposed within the first flow path, the flow distributor comprises a fourth flow path configured to route a third exhaust flow from the exhaust flow into the head end chamber, and the flow distributor comprises a fifth flow path configured to route the second exhaust flow into the mixing region at least partially disposed within the first flow path.

14. The system of claim 13, wherein the fourth flow path of the flow distributor is configured to route the third exhaust flow to a cooling region adjacent the cap in the head end region.

15. The system of claim 13, wherein the flow distributor blocks the second flow path except for the third flow path from the second flow path to the first flow path.

16. The system of claim 15, wherein the third flow path comprises a plurality of third flow paths.

17. The system of claim 13, wherein the flow distributor blocks the first flow path except for the fifth flow path into the first flow path.

18. The system of claim 17, wherein the fifth flow path comprises a plurality of fifth flow paths.

19. The system of claim 13, wherein the oxidant intake port is coupled to an end plate of the head end portion of the turbine combustor.

20. The system of claim 13, wherein the at least one exhaust extraction port is coupled to a casing disposed about the turbine combustor.
21. The system of claim 6, wherein the oxidant intake port is coupled to an end plate of the head end portion of the turbine combustor, and the at least one exhaust extraction port is coupled to a side wall of the head end portion of the turbine combustor.
22. The system of claim 21, wherein the side wall comprises a first wall disposed about the head end chamber and a second wall disposed about the first wall to define a first flow path, wherein the flow separator comprises a flow distributor extending crosswise through the first flow path between the first and second walls, the flow distributor comprises a second flow path configured to route the first exhaust flow into the first flow path, the flow distributor comprises a third flow path configured to route a third exhaust flow from the exhaust flow into the head end chamber.
23. The system of claim 22, wherein the third flow path of the flow distributor is configured to route the third exhaust flow to a cooling region adjacent the cap in the head end region.
24. The system of claim 22, wherein the mixing region is disposed at least partially adjacent the end plate.
25. The system of claim 24, wherein the mixing region comprises a flow mixer disposed between the end plate and the cap.
26. The system of claim 25, wherein the flow mixer comprises at least one of a perforated plate, or a flow disturber, or any combination thereof.
27. The system of claim 1, comprising a gas turbine engine having the turbine combustor, a turbine driven by combustion products from the turbine combustor, and

an exhaust gas compressor driven by the turbine, wherein the exhaust gas compressor is configured to compress and route an exhaust gas to the turbine combustor.

28. The system of claim 27, comprising an exhaust gas extraction system coupled to the gas turbine engine, and a hydrocarbon production system coupled to the exhaust gas extraction system.

29. The system of claim 27, wherein the gas turbine engine is a stoichiometric exhaust gas recirculation (SEGR) gas turbine engine.

30. A system, comprising:

an oxidant compressor; and

a gas turbine engine, comprising:

a combustor section having a turbine combustor;

a turbine driven by combustion products from the turbine combustor;

an exhaust gas compressor driven by the turbine, wherein the exhaust gas compressor is configured to compress and route an exhaust flow to the turbine combustor, and the oxidant compressor is configured to compress and route an oxidant flow to the turbine combustor;

an exhaust extraction port coupled to the combustor section; and

a flow separator coupled to a head end portion of the turbine combustor, wherein the flow separator is configured to separate the oxidant flow from a first portion of the exhaust flow until the first portion reaches a mixing region within the head end portion, the flow separator is configured to separate the oxidant flow from a second portion of the exhaust flow until the second portion reaches the exhaust extraction port, and the flow separator comprises a flow distributor having an exhaust path extending toward a head end region adjacent a cap in the head end portion of the turbine combustor.

31. The system of claim 30, wherein the exhaust extraction port is coupled to a side wall of the turbine combustor or a casing disposed about the turbine combustor, and an oxidant intake port is coupled to an end plate of the turbine combustor.

32. The system of claim 31, wherein the exhaust extraction port is coupled to the side wall of the head end portion between the flow distributor and the end plate, and the oxidant intake port is coupled to a central portion of the end plate.

33. The system of claim 31, wherein the exhaust extraction port is coupled to the casing, the flow distributor is disposed between the end plate and the exhaust extraction port, the oxidant intake port is coupled to the end plate between first and second walls of the side wall, the first wall is disposed about the head end region, and the second wall is disposed about the first wall.

34. The system of claim 30, wherein an oxidant intake port is coupled to the flow distributor along a side wall of the turbine combustor.

35. The system of claim 34, wherein the exhaust extraction port is coupled to an end plate of the turbine combustor.

36. The system of claim 30, comprising a stoichiometric exhaust gas recirculation (SEGR) turbine system having the oxidant compressor and the gas turbine engine.

37. The system of claim 36, comprising an exhaust gas extraction system coupled to the exhaust extraction port of the SEGR turbine system, and a hydrocarbon production system coupled to the exhaust gas extraction system.

38. A method, comprising:

extracting a first exhaust flow of an exhaust gas at a combustion section of a gas turbine engine;

routing a second exhaust flow of the exhaust gas toward an end plate of a head end portion of a turbine combustor in the combustion section;

routing a third exhaust flow of the exhaust gas toward a cap of the head end portion, wherein the cap is disposed between a head end region and a combustion region;

routing an oxidant flow into the head end portion; and

separating the oxidant flow at least from the first exhaust flow.

39. The method of claim 38, wherein extracting the first exhaust flow comprises extracting the first exhaust flow through an exhaust extraction port coupled to a side wall of the turbine combustor or a casing disposed about the turbine combustor, wherein routing the oxidant flow comprises supplying the oxidant flow through an oxidant intake port coupled to an end plate of the turbine combustor.

40. The method of claim 38, wherein routing the oxidant flow comprises supplying the oxidant flow through an oxidant intake port coupled to a flow distributor along a side wall of the turbine combustor, wherein routing the third exhaust flow comprises routing the third exhaust flow through an exhaust path through the flow distributor.

41. The method of claim 40, wherein extracting the first exhaust flow comprises extracting the first exhaust flow through an exhaust extraction port coupled to an end plate of the turbine combustor.

42. The method of claim 38, comprising stoichiometrically combusting a mixture of a fuel flow, the oxidant flow, and the second and third exhaust flows.

43. The method of claim 38, comprising routing the first exhaust flow to a hydrocarbon production system.

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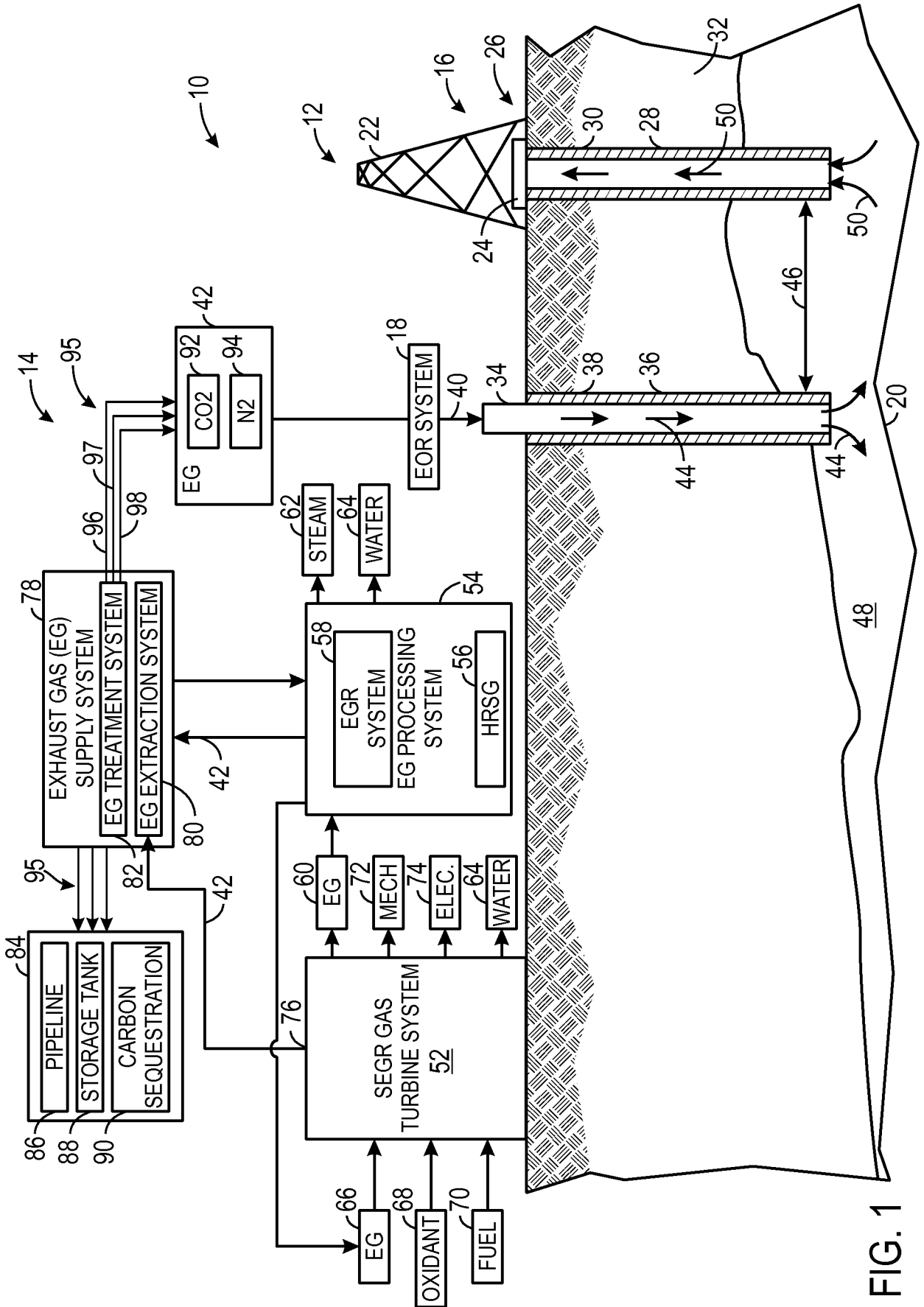


FIG. 1

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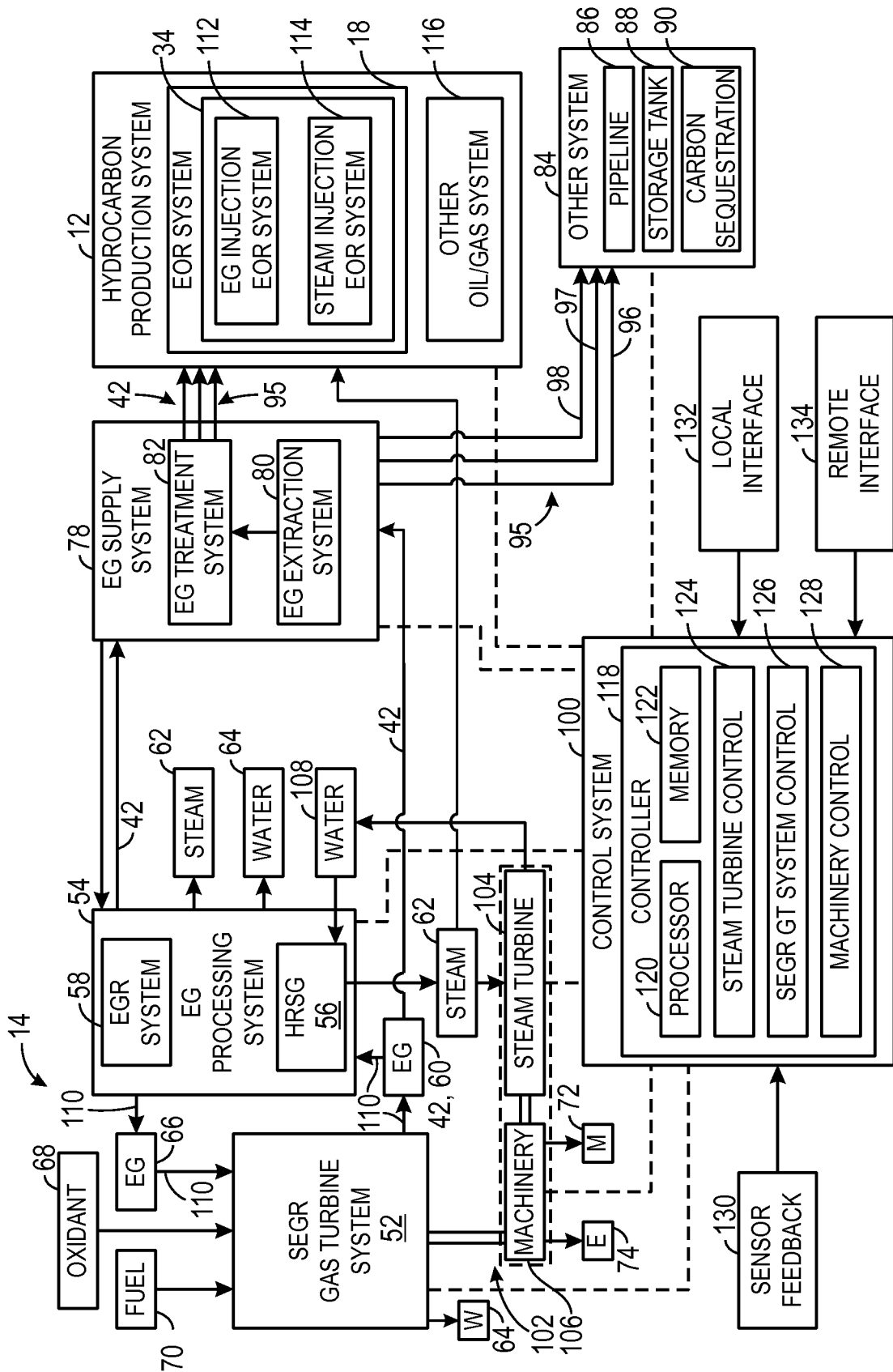


FIG. 2

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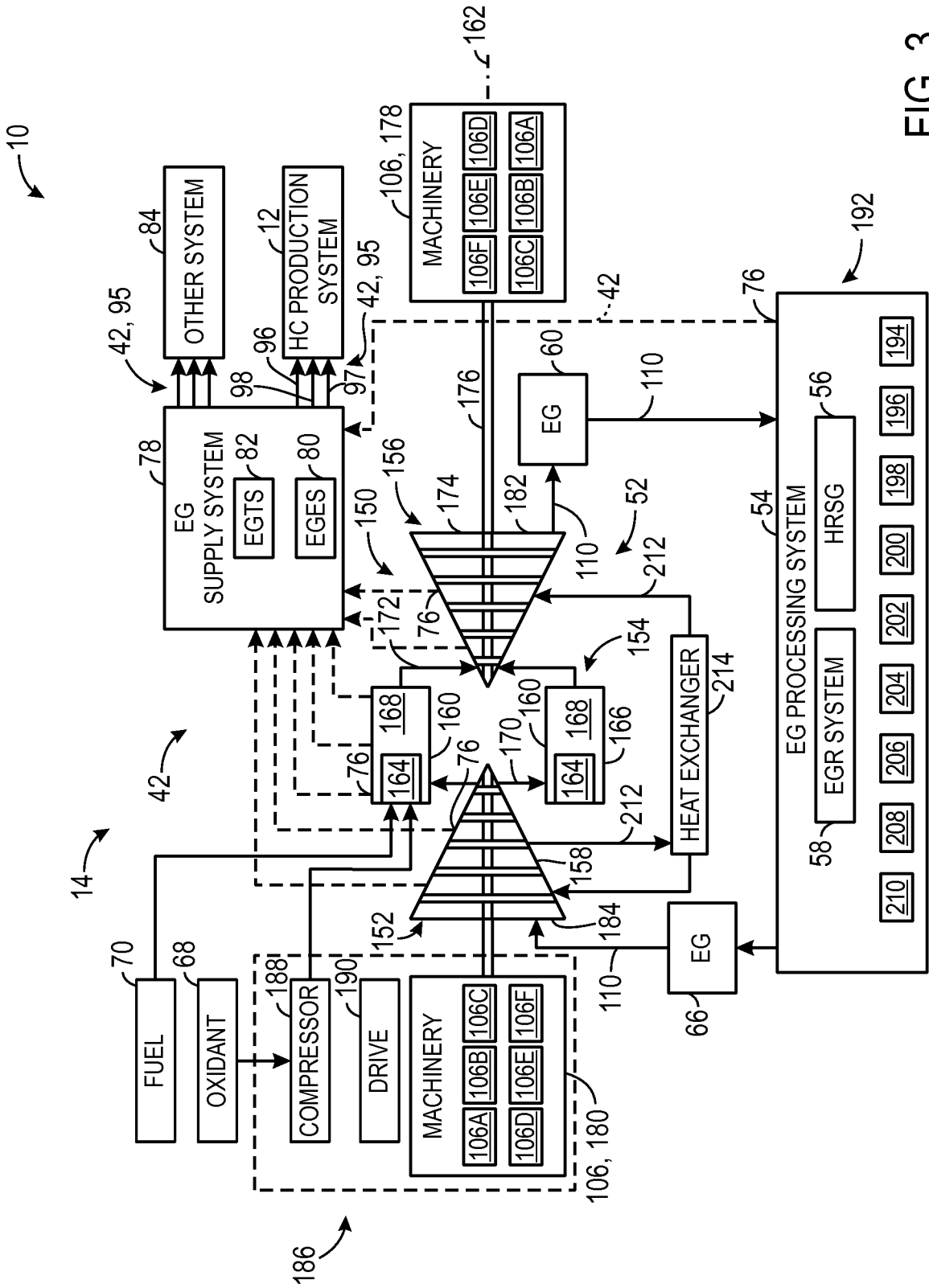


FIG. 3

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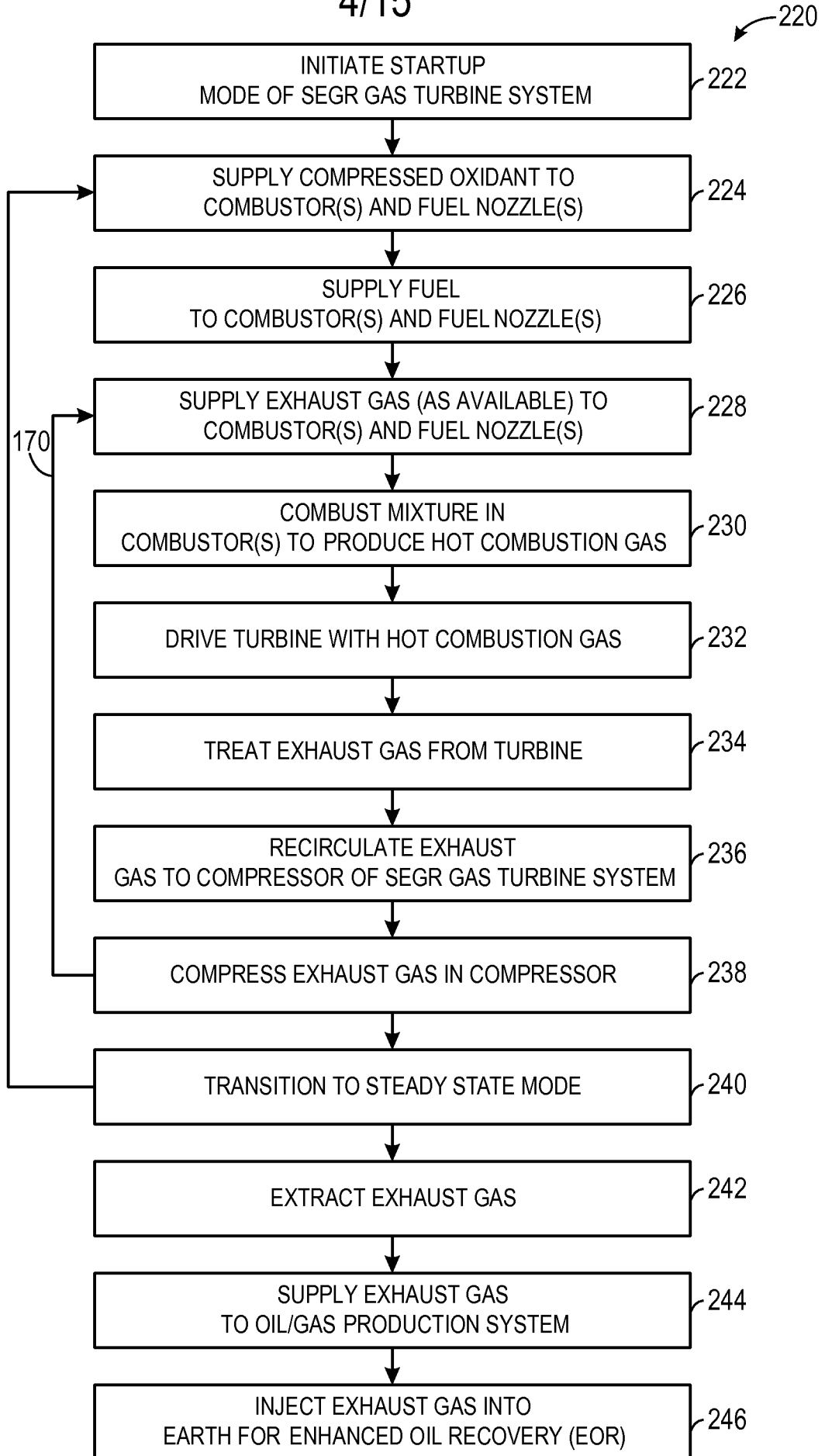


FIG. 4

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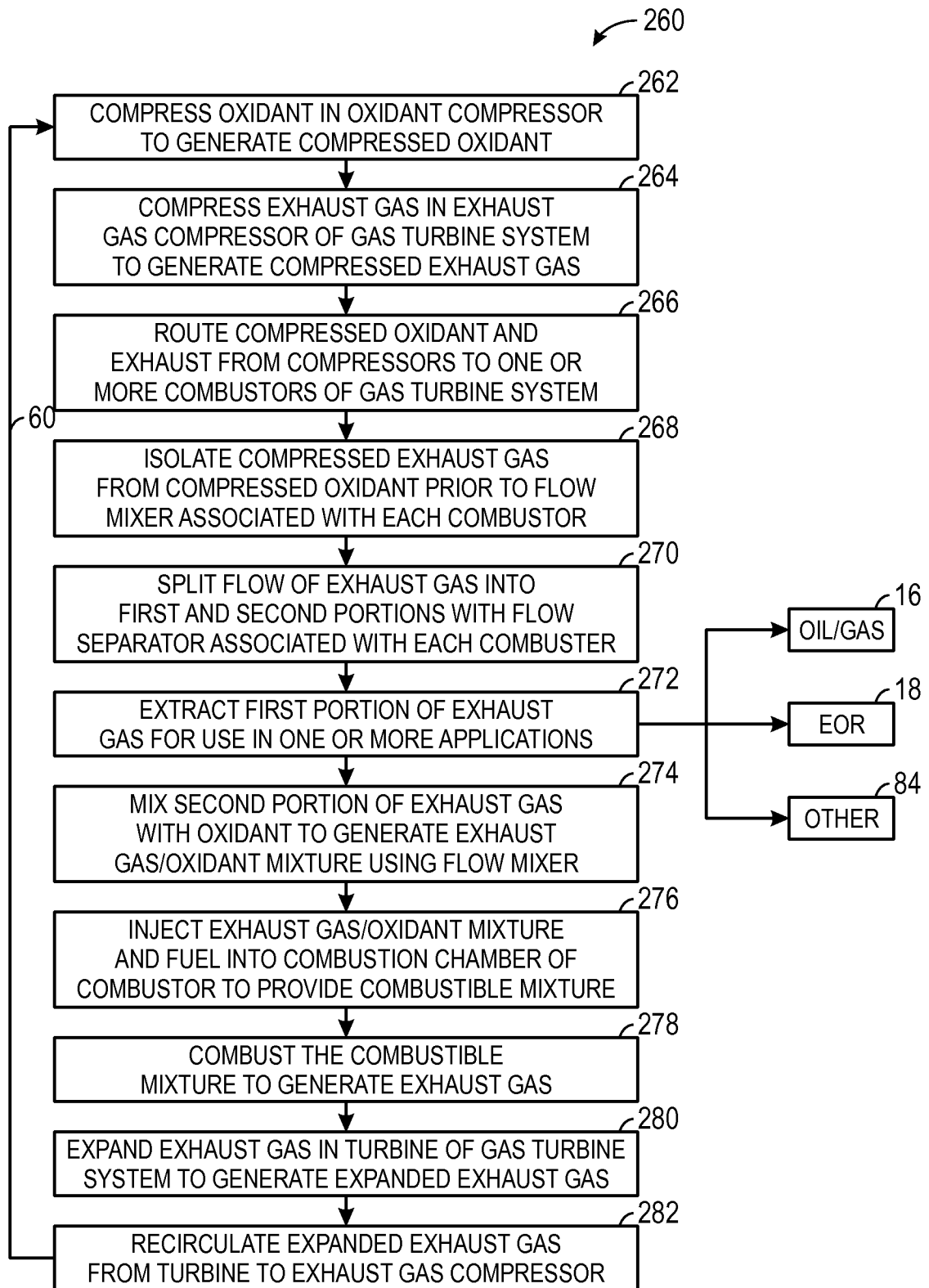


FIG. 5

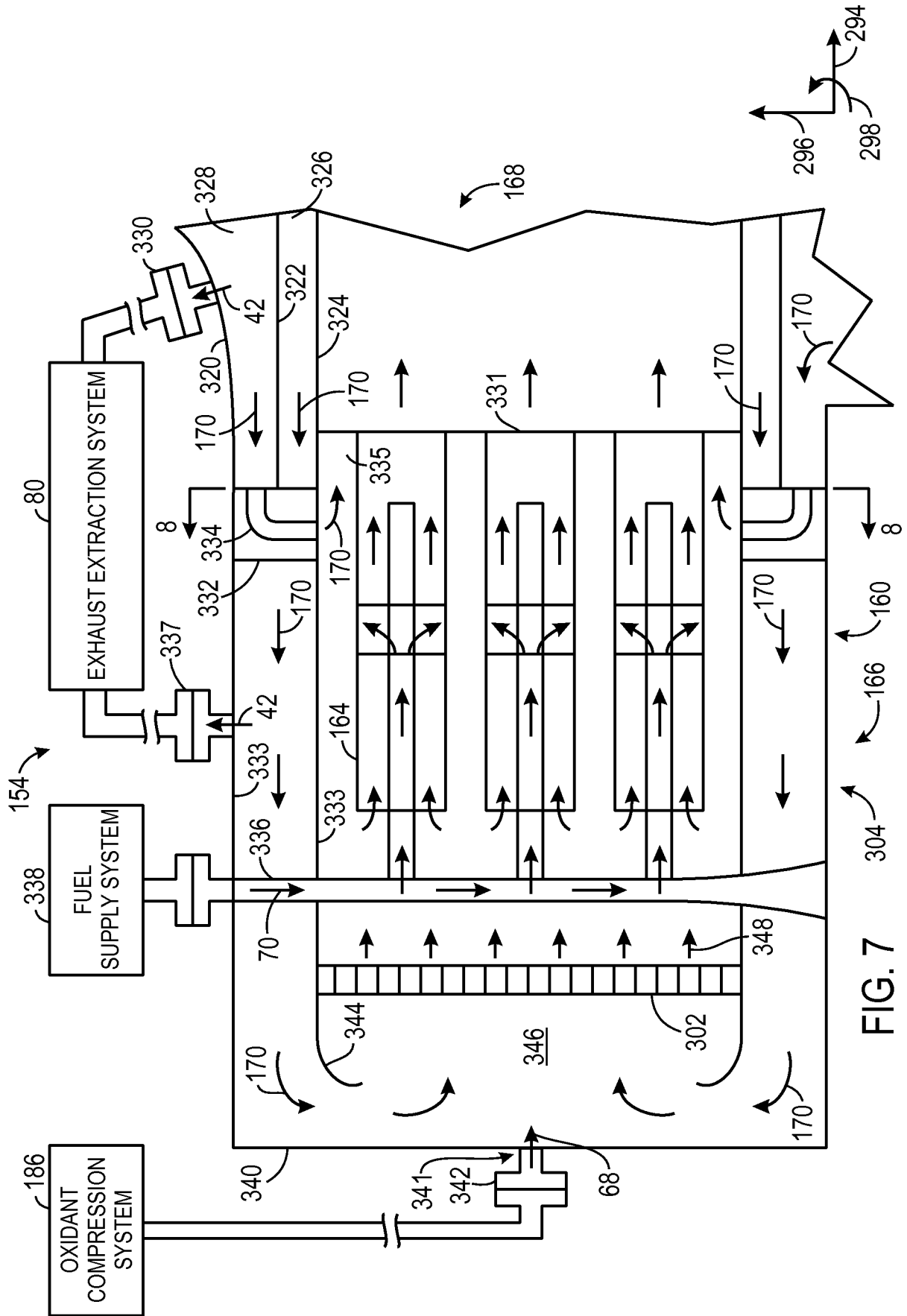


FIG. 7

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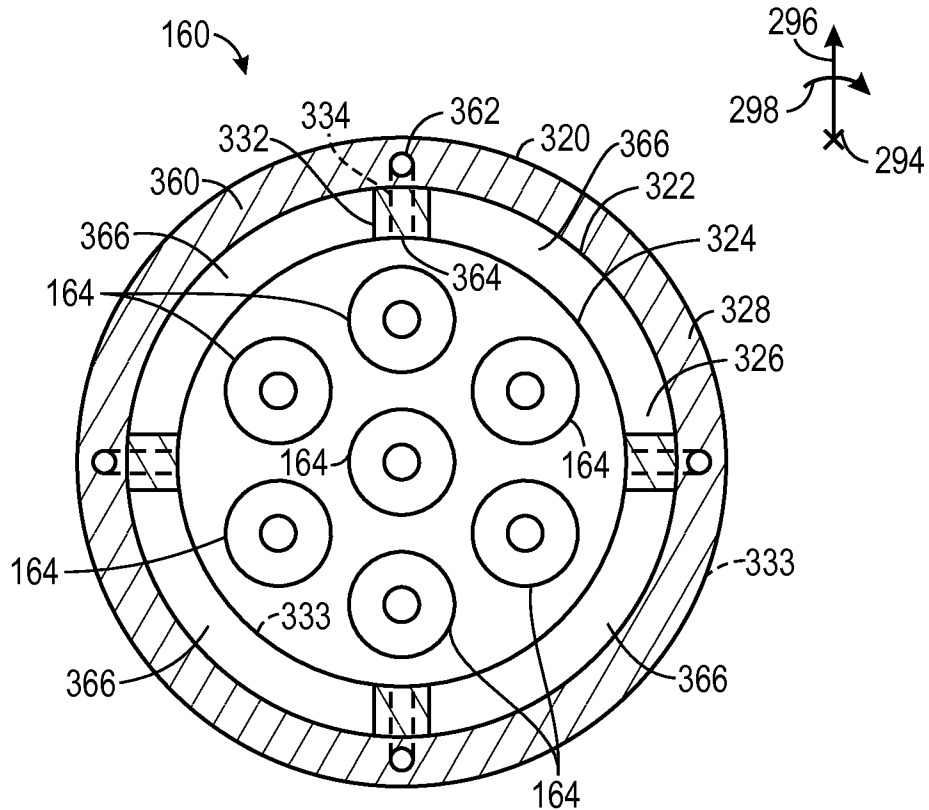


FIG. 8

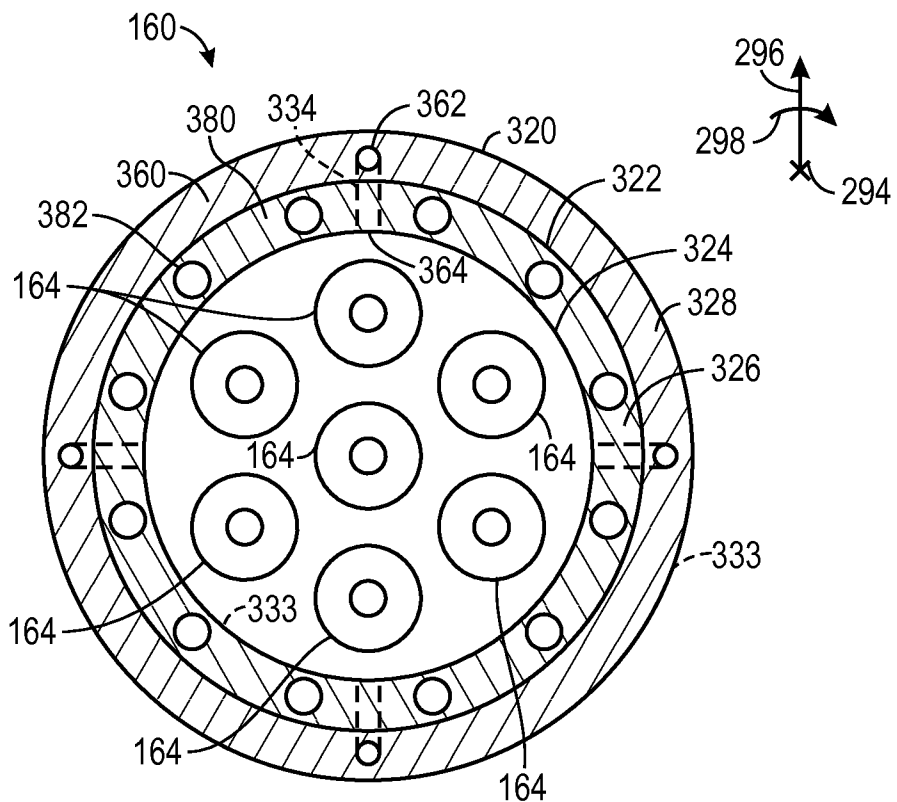


FIG. 9

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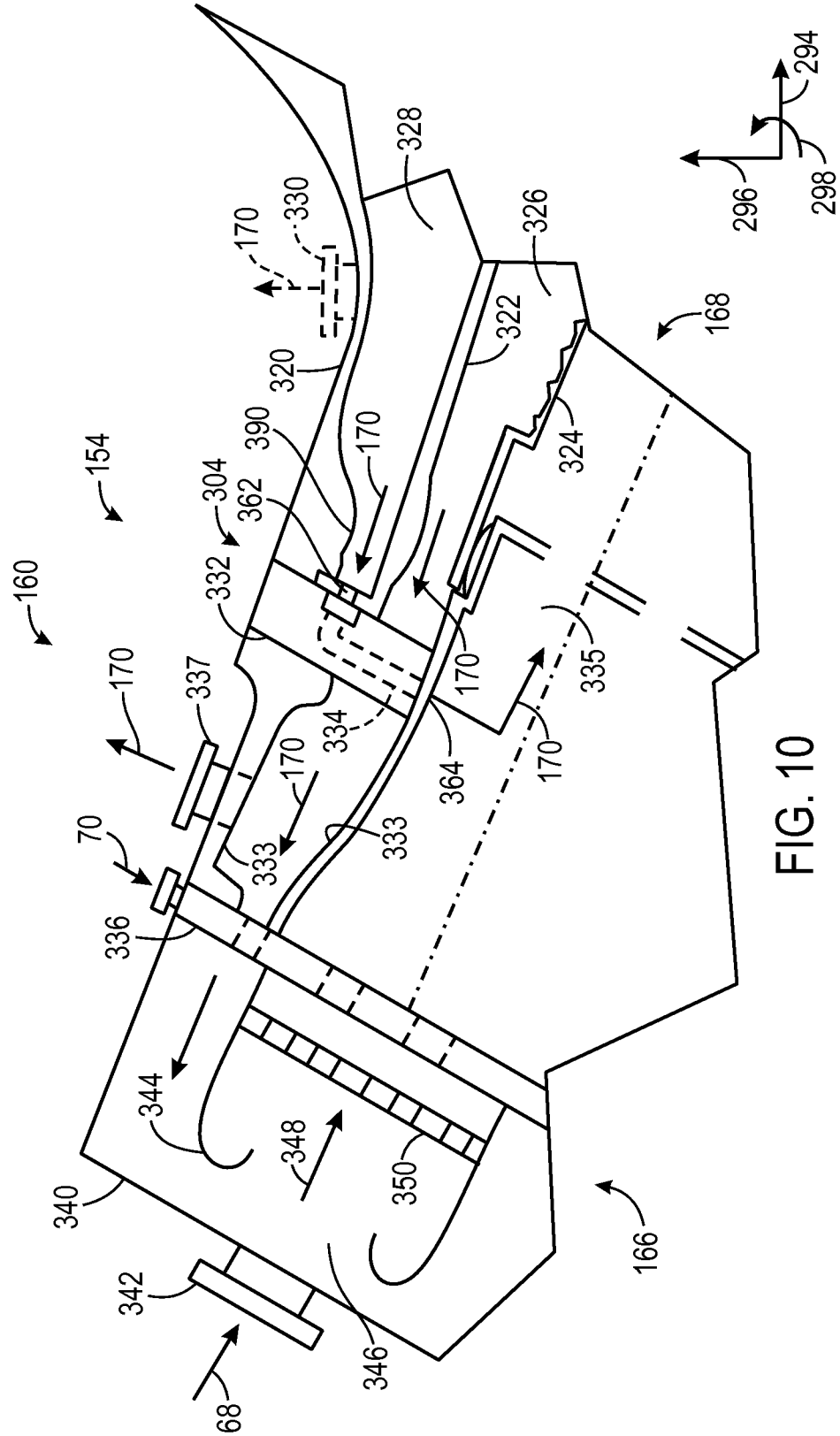


FIG. 10

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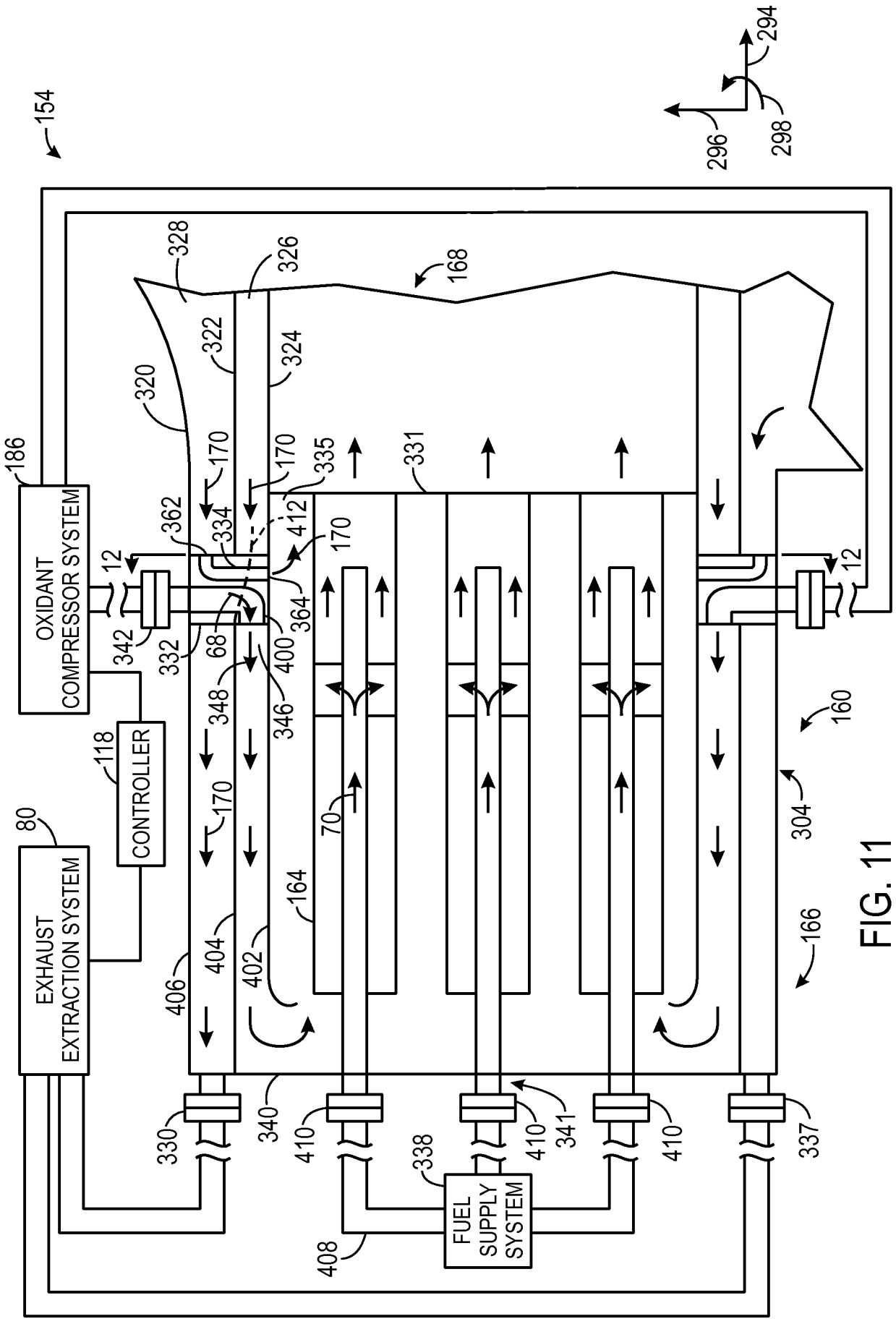


FIG. 11

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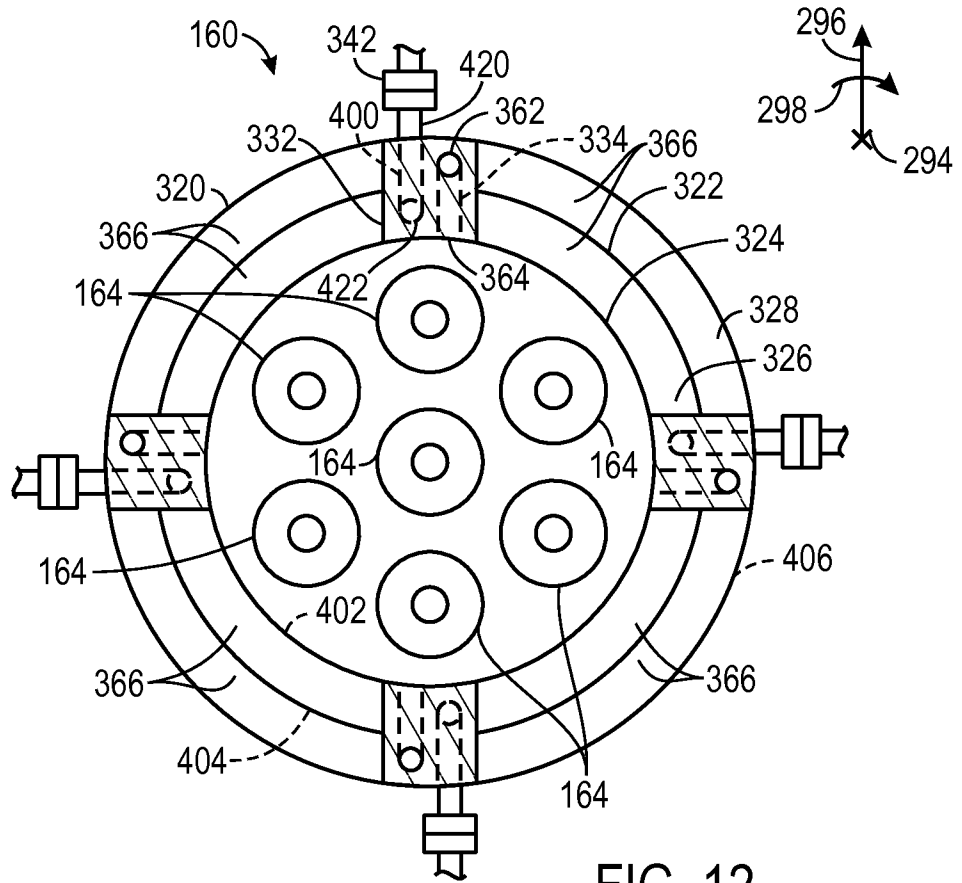


FIG. 12

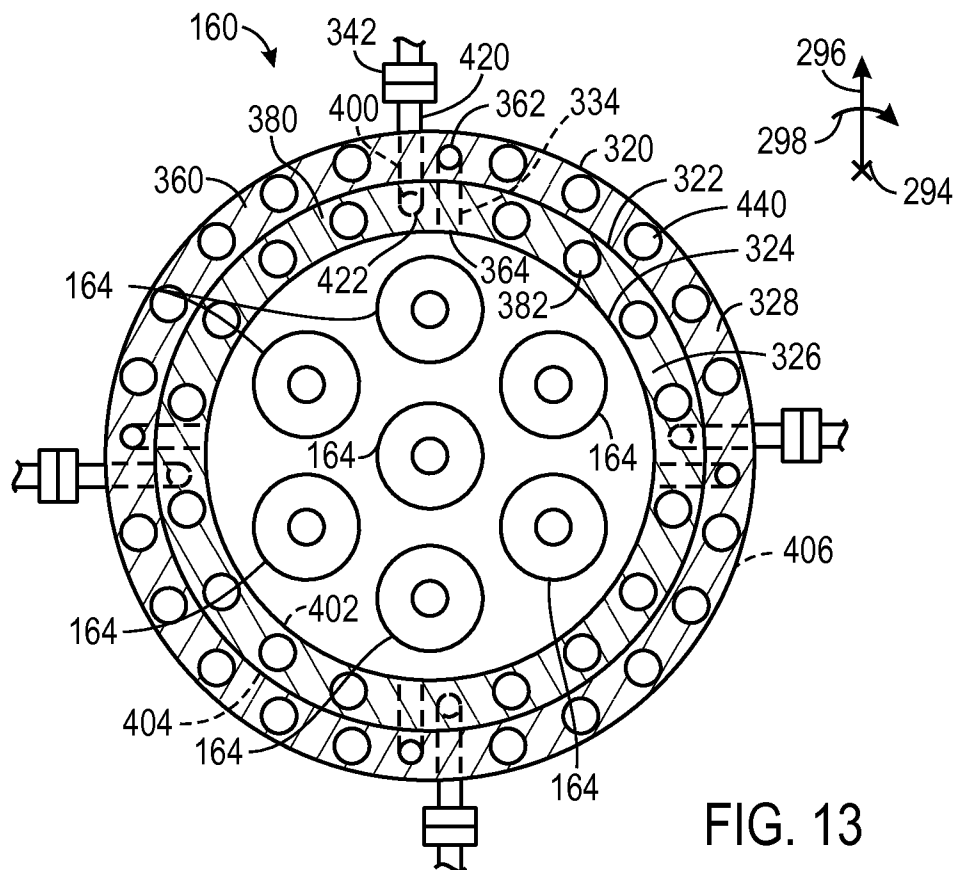


FIG. 13

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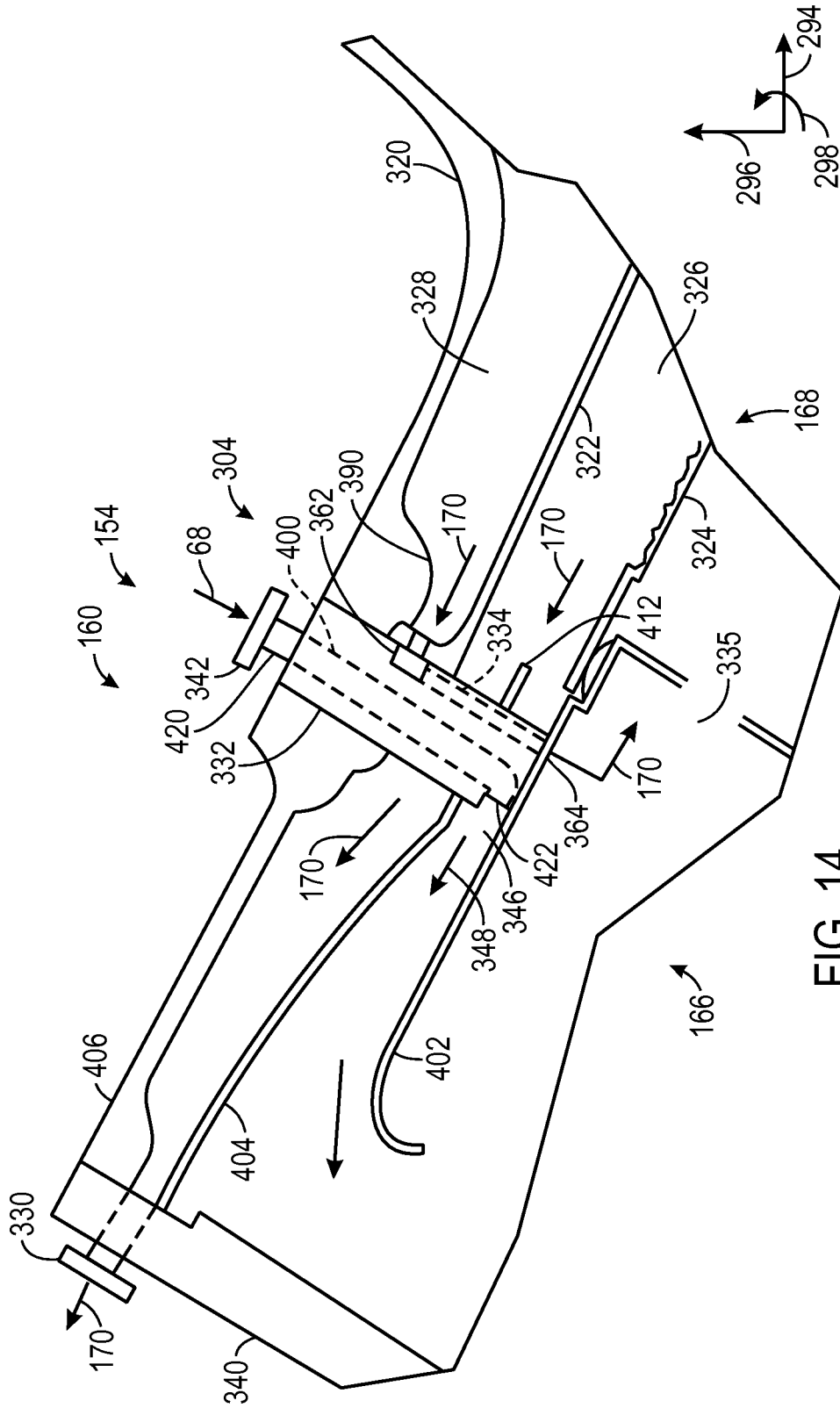


FIG. 14

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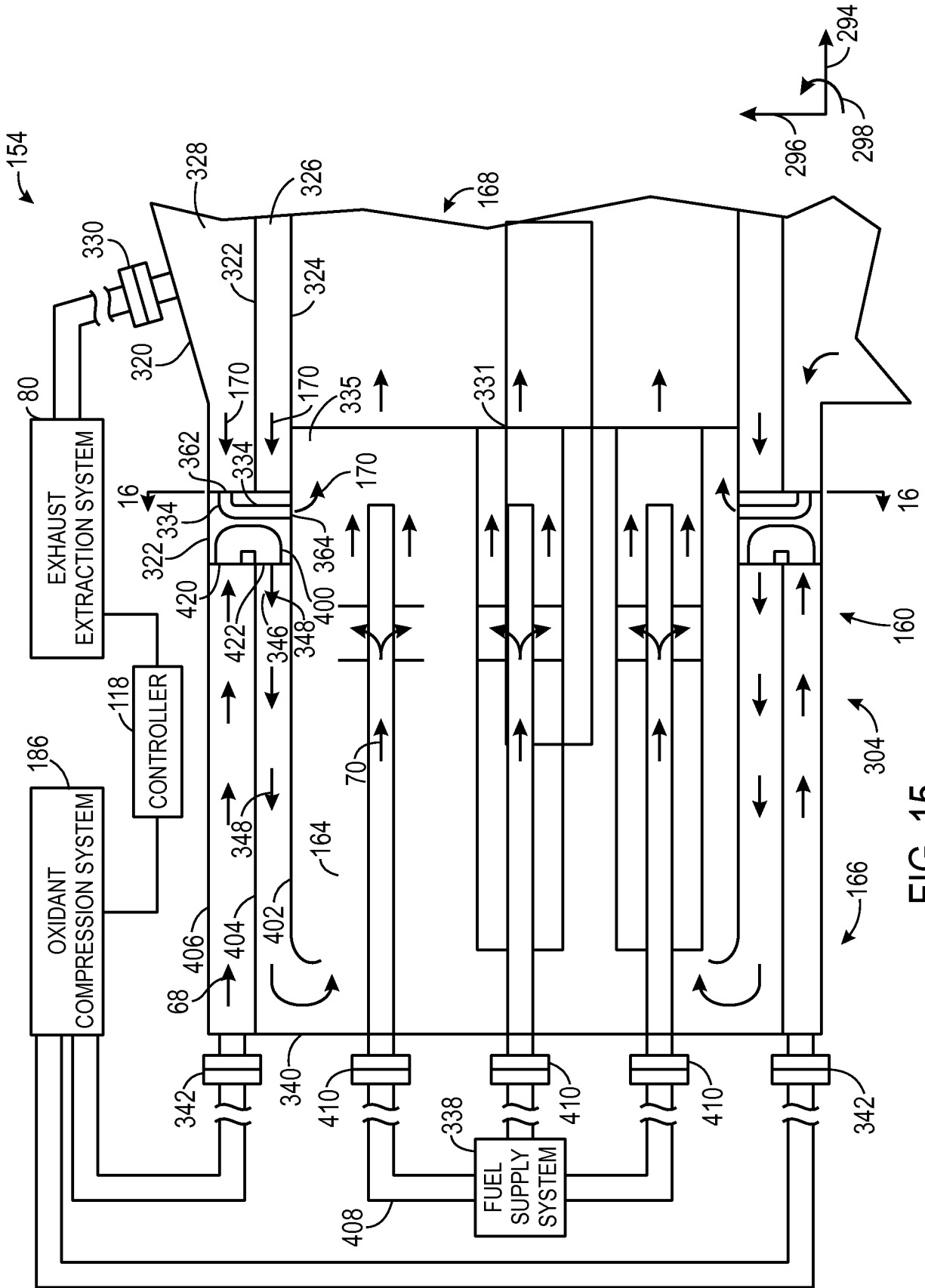


FIG. 15

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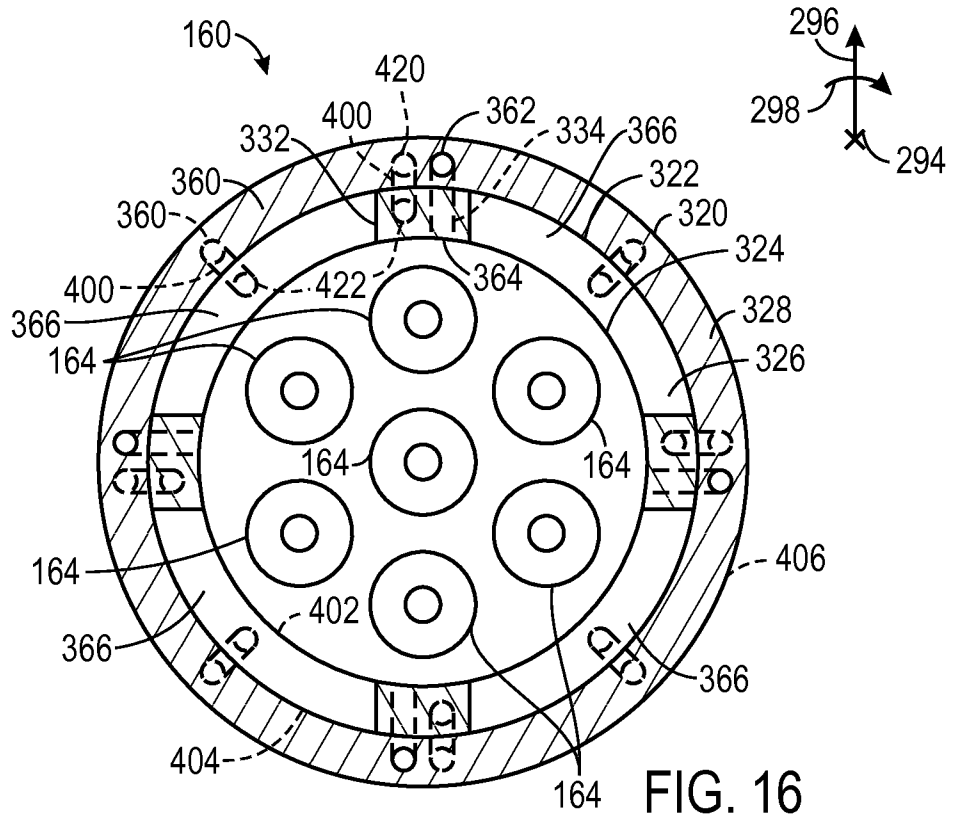


FIG. 16

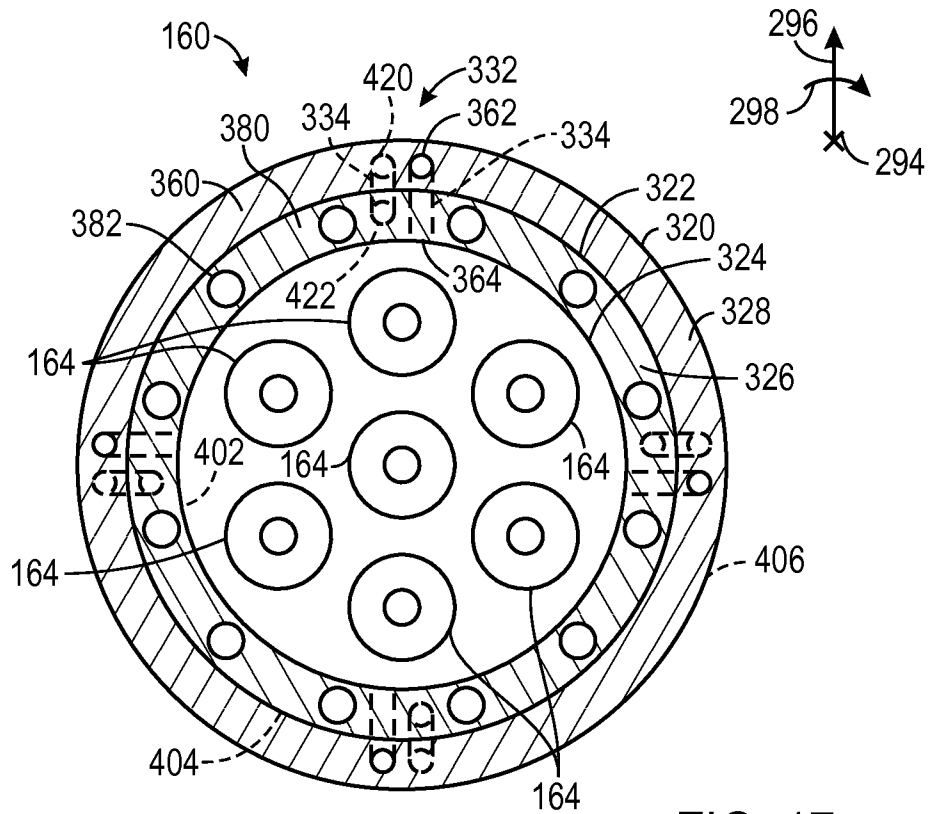
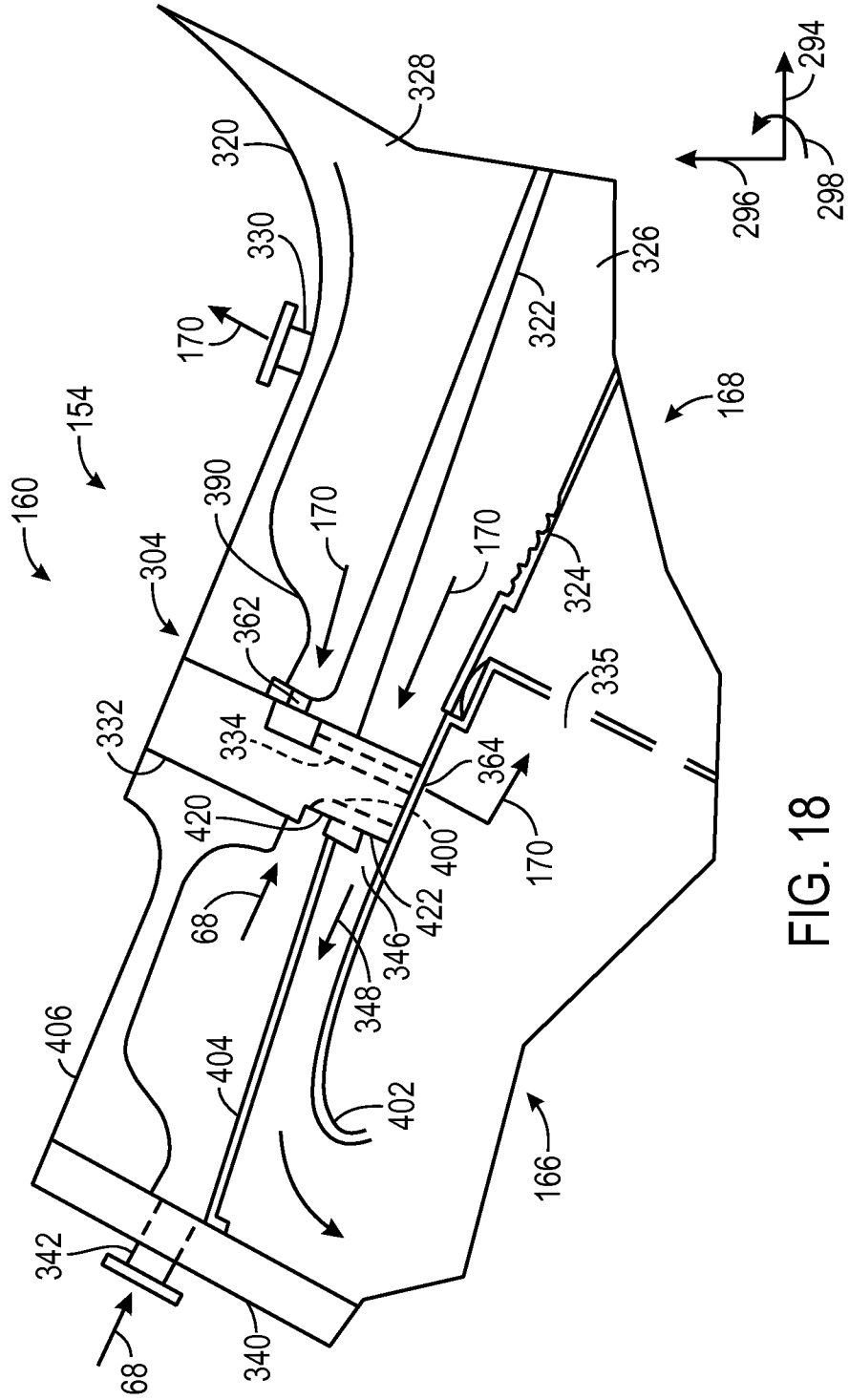


FIG. 17

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/067855

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F02C1/06 F02C3/34 F02C6/18 F01K23/10 F02C1/08
 F23R3/00
 ADD.
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 F02C F01K F23R

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/018458 A1 (EXXONMOBIL UPSTREAM RES CO [US]; MITTRICKER FRANKLIN F [US]; HUNTINGTO) 9 February 2012 (2012-02-09)	1-7,21, 27-43
A	paragraph [0053] - paragraph [0060] paragraph [0066] - paragraph [0067]; figures 1,3	8-20
X	US 2011/167828 A1 (SINGH ARJUN [IN] ET AL) 14 July 2011 (2011-07-14)	1-7, 21-26, 38-43
Y	paragraph [0015] - paragraph [0026];	27-29
A	figure 2	8-20
X	US 3 927 958 A (QUINN RONALD E) 23 December 1975 (1975-12-23) column 1, line 46 - column 3, line 68; figures 1,4	1-7
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Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search 25 February 2014	Date of mailing of the international search report 05/03/2014
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Robelin, Bruno
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/067855

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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X	GB 2 043 869 A (UNITED STIRLING AB & CO) 8 October 1980 (1980-10-08) page 1, line 119 - line 117; figures 1,3,4 -----	1
Y	US 2012/260660 A1 (KRAEMER GILBERT OTTO [US] ET AL) 18 October 2012 (2012-10-18) paragraph [0011] - paragraph [0019]; figures 1,2 -----	27-29

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