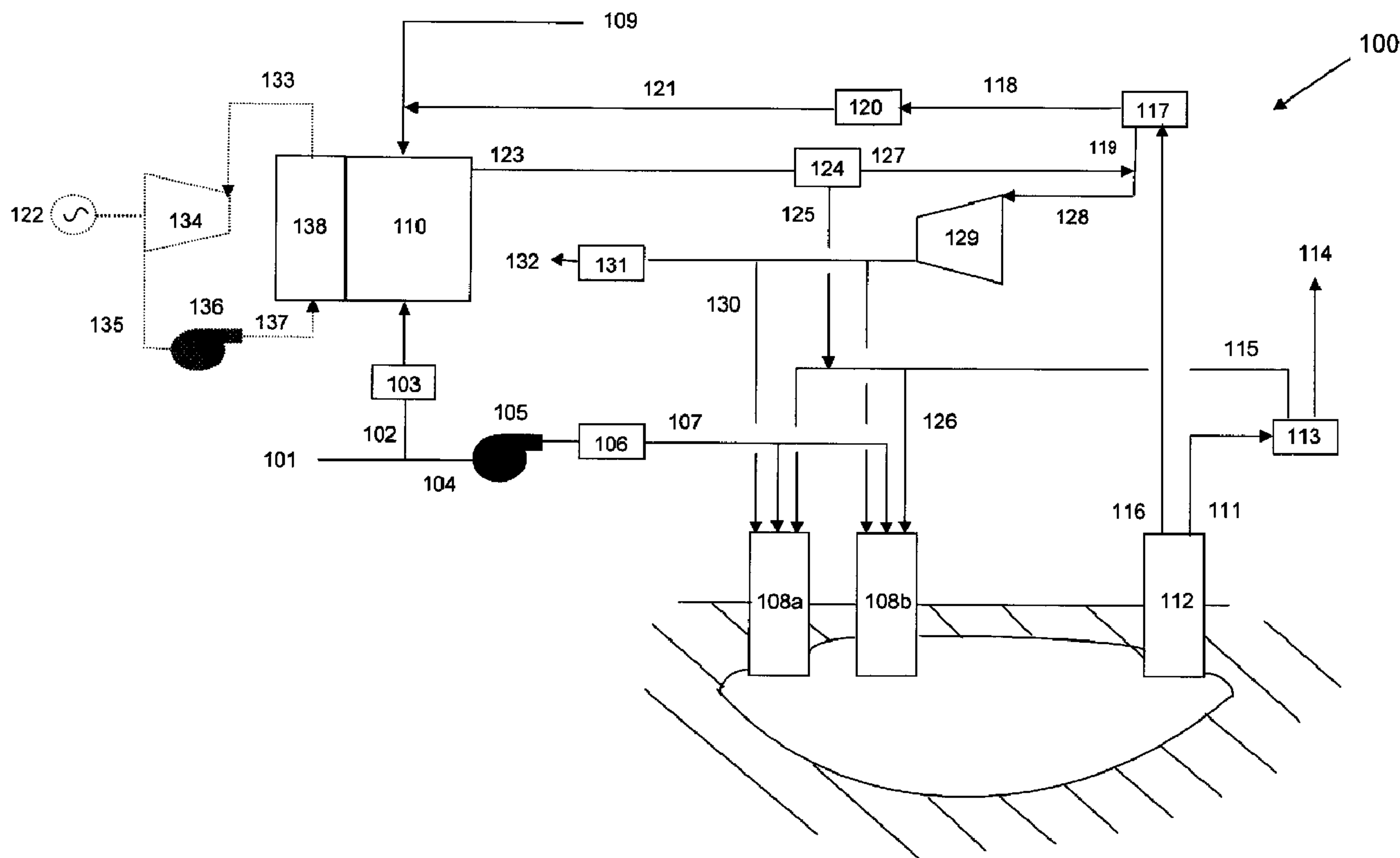




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(54) Titre : PRODUCTION DE CARBURANT LIQUIDE A ZERO EMISSION AU MOYEN D'INJECTION D'OXYGENE
 (54) Title: ZERO EMISSION LIQUID FUEL PRODUCTION BY OXYGEN INJECTION



(57) Abrégé/Abstract:

An enhanced oil recovery method is provided. This method includes; introducing a first essentially pure oxygen stream into a subterranean hydrocarbon-bearing formation traversed by at least one injection well and at least one production well, and initiating and sustaining in-situ combustion in the vicinity of the injection well. This method also includes introducing a second essentially pure oxygen stream and a hydrocarbon-containing fuel gas stream into the combustion device of a power generation system, wherein the combustion device produces an exhaust gas stream comprising water and carbon dioxide. This method also includes

(57) **Abrégé(suite)/Abstract(continued):**

separating the exhaust gas stream into a stream of essentially pure water, and a stream of essentially pure carbon dioxide, and introducing at least a portion of the essentially pure carbon dioxide stream into the subterranean hydrocarbon-bearing formation prior to initiating the in-situ combustion. The method may be used on a structure containing a carbonaceous substance such as coal, petcoke, or biomass.

Abstract

An enhanced oil recovery method is provided. This method includes; introducing a first essentially pure oxygen stream into a subterranean hydrocarbon-bearing formation traversed by at least one injection well and at least one production well, and initiating and sustaining in-situ combustion in the vicinity of the injection well. This method also includes introducing a second essentially pure oxygen stream and a hydrocarbon-containing fuel gas stream into the combustion device of a power generation system, wherein the combustion device produces an exhaust gas stream comprising water and carbon dioxide. This method also includes separating the exhaust gas stream into a stream of essentially pure water, and a stream of essentially pure carbon dioxide, and introducing at least a portion of the essentially pure carbon dioxide stream into the subterranean hydrocarbon-bearing formation prior to initiating the in-situ combustion. The method may be used on a structure containing a carbonaceous substance such as coal, petcoke, or biomass.

ZERO EMISSION LIQUID FUEL PRODUCTION BY OXYGEN INJECTION

Background

5 Since 2002, there has been a general trend of increasing oil prices. This trend is generally expected to continue as a result of a number of factors: increasing oil demand from emerging economies; geopolitical instability in important production areas; and reduced exploration and technological development within the last two decades due to low oil prices.

10

 Current oil prices, along with international regulations on CO₂ emissions (such as the Kyoto Protocol and beyond, Alberta “carbon tax”, California regulation on GHG footprint of fossil fuels, etc.) increases the industries interest in providing innovative solutions that will allow: the increase of oil recovery from a given existing reservoir at a reduced additional cost; reliable performance within a large range of oil/reservoir characteristics; and the reduction of carbon footprint of technologies for enhanced oil recovery.

 The techniques to be employed for oil recovery depend on the particular geological conditions (thin reservoirs..., porous reservoirs...) and are typically performed at different stages of the oil production.

 The term Primary Recovery Technologies includes recovery strategies using the natural energy of reservoirs. These technologies are based on the immiscible fluids displacement, and different mechanisms are possible, such as:

Gas Cap drive (expansion of the gas phase); Solution Gas Drive (ex-solution of solved Gas); Bottom Water Drive (aquifer displacement). For conventional oil typical performance for primary recovery techniques are around 19% of OOIP (Original Oil in Place): less for heavy oils, more for light oils.

5

In the Secondary Recovery, also known as water-flooding, the enhancement of oil production is performed by adding energy to the natural system. Water is typically injected in a well (or a pattern of wells) in order to maintain pressure in the reservoir and to displace oil towards a producer. Initially
 10 oil alone is produced. Then as water component progresses, both oil and water are produced. As time advances, the percentage of water (the watercut) increases progressively. For conventional oil, average recovery by Water Flooding is around 32% OIP (Oil In Place) after primary recovery.

15 Enhanced Oil Recovery (EOR) techniques are used to further increase the amount of recovered oil, in particular when water-flooding is not effective (or efficient). Some of the various EOR techniques that may be employed include: thermal-based oil recovery: steam flooding , cyclic thermal injection, in-situ combustion; electric heating, microwaves heating; chemical flooding: polymer
 20 flooding, micellar flooding; Immiscible Flooding: Nitrogen injection, CO2 injection; Miscible Flooding: lean gas injection, CO2 injection; and microbial injection.

For conventional oil, primary recovery is usually followed by water-flooding, but most of the enhanced oil technologies are not yet commercially
 25 proven. For unconventional oil reserves such as extra heavy oil in Venezuela and Albertan oil sands (characterized by high densities and high viscosities ($20 > \text{API} > 7$, $10000 \text{ cPo} < \mu < 100 \text{ cPo}$ or $12 > \text{API} < 7$, $\mu > 10000 \text{ cPo}$) primary and secondary recovery are not sufficient to guarantee oil production and the economic exploitation of these resources is strictly related to the successful

development of EOR technologies. The growing relevance of heavy oils in the world oil reserves and in particular of such unconventional oils results in the development of new EOR methods.

5 The SAGD (Steam Assisted Gravity Drainage) is a steam flooding technique improved by the use of two horizontal wells: one for steam injection and one for bitumen extraction. The steam heats the formation increasing the viscosity of bitumen which can flow through the producer. The main drawback of SAGD concerns high SOR (steam on oil ratio), ranging from 2 to 4. The
10 performance of SAGD are strictly dependent upon reservoir properties. Characteristics such as gas caps, aquifers, and shale in the reservoir can result in uneconomical operations.

 Steam flooding and SAGD are typically only efficient for shallow reservoirs
15 (<1000 m) thus not being a viable solution for heavy oil resources in areas such as the Arabian Gulf and Russia.

 The VAPEX (Vapor Extraction) process involves injecting a gaseous hydrocarbon solvent into the reservoir where it dissolves into the bitumen. The
20 bitumen then becomes less viscous and can drain into a lower horizontal well and be extracted. The solvent is typically propane, butane, or CO₂ along with a carrier gas. Main drawbacks of this technique are the following. In the case of bitumen or extra heavy oil, blending oil with the solvent without heating the formation produces only small improvements in oil recovery. Solvent is also
25 expensive, can be scarce, and therefore the losses in the reservoir can be important.

 A number of processes such as ES-SAGD, LASER or SAVEX are under development in order to provide a hybrid in-situ extraction technology coupling

the advantages of steam injection (thermal reduction of oil viscosity) and solvent injection. Light hydrocarbons are used and solutions to drawbacks such as reservoir depressurization and solvent losses have to be developed. None of these combine the advantages of thermal extraction and miscible and immiscible flooding.

The In-Situ Combustion (ISC) process is defined as “the propagation of a high temperature front for which the fuel is a coke-like substance, laid down by thermal cracking reactions”. In recent years, that has been a worldwide interest of ISC for conventional oil.

Compared to mining, SAGD and VAPEX, in-situ combustion based bitumen extraction has the potential to be applied in a wider range of reservoir characteristics and to provide partially upgraded bitumen with better thermal efficiency and reduced environmental impact: Benefits of ISC include: reduced GHG footprint – 50% less than SAGD; almost no water consumption; no need for land remediation. Within the ISC, bitumen is partially upgraded in the underground, and the production is performed by thermal flooding (viscosity reduction) and gas flooding (flue gas drive).

The use of oxygen injection represents one of the main areas of development for this technology. Advantages of oxygen injection for In-Situ combustion operations include: lower compression cost; simple ignition; better thermal efficiency: produced heat is not dispersed through an inert gas; and easier downstream operations: emulsions are easy to break. Additionally, as in the case of surface oxy-combustion, the use of oxygen will result in the possibility of recovering a CO₂-rich stream at the production well, to be used for additional EOR and storage. However, low oil prices and lack of GHG emissions regulations have not justified the use of oxygen in the last twenty years.

There is a need in society for an in-situ combustion oil recovery process that will improve the economics, improve the oil recovery, reduce the environmental impact, and improve safety.

5

Summary of the Invention

The present invention is an enhanced oil recovery method that includes; introducing a first essentially pure oxygen stream into a subterranean hydrocarbon-bearing formation traversed by at least one injection well and at least one production well, and initiating and sustaining in-situ combustion in the vicinity of said injection well. The present invention also includes introducing a second essentially pure oxygen stream and a hydrocarbon-containing fuel gas stream into the combustion device of a power generation system, wherein said combustion device produces an exhaust gas stream comprising water and carbon dioxide. The present invention also includes separating said exhaust gas stream into a stream of essentially pure water, and a stream of essentially pure carbon dioxide, and introducing at least a portion of said essentially pure carbon dioxide stream into said subterranean hydrocarbon-bearing formation either prior to initiating said in-situ combustion or during said in-situ combustion.

20 In accordance with another aspect of the present invention there is provided an enhanced oil recovery method comprising the steps of:

introducing a first essentially pure oxygen stream into a subterranean hydrocarbon-bearing formation traversed by at least one injection well and at least one production well, and initiating and sustaining in-situ combustion in the vicinity of said injection well thus allowing to upgrade and produce oil from the extraction well;

25

providing a power generation system, wherein said power generation system comprises a combustion device, introducing a second essentially

pure oxygen stream and a hydrocarbon-containing fuel gas stream into said combustion device, wherein said combustion device produces an exhaust gas stream comprising water and carbon dioxide,

5 separating said exhaust gas stream into a stream of essentially pure water, and a stream of essentially pure carbon dioxide, and

introducing at least a portion of said essentially pure carbon dioxide stream into said subterranean hydrocarbon-bearing formation during said
10 in-situ combustion.

In accordance with another aspect of the present invention the enhanced oil recovery method further comprises removing an off-gas stream from said production well, wherein said off-gas stream comprises carbon dioxide and a
15 high LHV fuel gas, and wherein said off-gas stream is separated into a second stream of essentially pure carbon dioxide, and a stream of high LHV fuel gas.

In accordance with another aspect of the present invention for an enhanced oil recovery method at least a portion of said second stream of essentially pure
20 carbon dioxide is compressed and injected into the subterranean hydrocarbon-bearing formation during said in-situ combustion.

In accordance with another aspect of the present invention for an enhanced oil recovery method said power generation system comprises a Rankine cycle. In
25 accordance with another aspect of the present invention for an enhanced oil recovery method said Rankine cycle comprises a combustion device, a steam generation device, and a steam turbine generator.

In accordance with another aspect of the present invention for an enhanced oil recovery method said power generation system comprises a Brayton cycle. In accordance with another aspect of the present invention for an enhanced oil recovery method said Brayton cycle comprises a combustion device, an
5 expander, and a compressor.

In accordance with another aspect of the present invention there is provided a liquid fuel production method comprising:

10 introducing a first essentially pure oxygen stream into a structure containing a carbonaceous substance such as coal, petcoke or biomass, said structure comprising at least one inlet line and at least one outlet line,

initiating and sustaining oxidation in the vicinity of said inlet line, allowing to upgrade such carbonaceous substance in order to produce oil;

15 providing a power generation system, wherein said power generation system comprises a combustion device, introducing a second essentially pure oxygen stream and a hydrocarbon-containing fuel gas stream into said combustion device, wherein said combustion device produces an
20 exhaust gas stream comprising water and carbon dioxide,

separating said exhaust gas stream into a stream of essentially pure water, and a stream of essentially pure carbon dioxide, and

25 introducing at least a portion of said essentially pure carbon dioxide stream into said carbonaceous substance containing structure during said oxidation.

In accordance with another aspect of the present invention there is provided a liquid fuel production method comprising:

- 5 introducing a first essentially pure oxygen stream into a structure containing a carbonaceous substance, said structure comprising at least one inlet line and at least one outlet line,
- initiating and sustaining oxidation in the vicinity of said inlet line, allowing to upgrade such carbonaceous substance in order to produce oil;
- 10 providing a power generation system, wherein said power generation system comprises a combustion device, introducing a second essentially pure oxygen stream and a hydrocarbon-containing fuel gas stream into said combustion device, wherein said combustion device produces an exhaust gas stream comprising water and carbon dioxide,
- 15 separating said exhaust gas stream into a stream of essentially pure water, and a stream of essentially pure carbon dioxide, and
- introducing at least a portion of said essentially pure carbon dioxide
- 20 stream into said carbonaceous substance containing structure prior to said oxidation.

Examples of a carbonaceous substance include coal, petcoke and biomass.

- 25 In accordance with another aspect of the present invention the liquid fuel production method further comprises removing an off-gas stream from said production well, wherein said off-gas stream comprises carbon dioxide and a high LHV fuel gas, and wherein said off-gas stream is separated into a second stream of essentially pure carbon dioxide, and a stream of high LHV fuel gas.

30

In accordance with another aspect of the present invention, in the liquid fuel production method, at least a portion of said second stream of essentially pure carbon dioxide is compressed and injected into the structure formation during said oxidation.

5

In accordance with another aspect of the present invention, in the liquid fuel production method, said power generation system comprises a Rankine cycle.

In accordance with another aspect of the present invention, in the liquid fuel production method, said Rankine cycle comprises a combustion device, a steam generation device, and a steam turbine generator.

10

In accordance with another aspect of the present invention, in the liquid fuel production method, said power generation system comprises a Brayton cycle. In accordance with another aspect of the present invention, in the liquid fuel production method, said Brayton cycle comprises a combustion device, an expander, and a compressor.

15

Brief Description of Drawings

20

The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, and in which:

Figure 1 is a schematic representation of one embodiment of the present invention, with a steam turbine for energy production.

25

Figure 2 is a schematic representation of another embodiment of the present invention with a combustion turbine for energy production.

Description of Preferred Embodiments

The present invention is the design of an improved process for enhanced oil recovery based on in-situ combustion. The present invention provides improved economics due to reduced compression costs, the virtual elimination of N₂ in the combustion exhaust, and the reduction of O₂ requirements. The present invention also provides improved ultimate oil recovery from oil reservoirs, by combining in-situ combustion and CO₂ flooding. The present invention provides the dramatic reduction of the environmental footprint of oil recovery technologies, with virtually zero CO₂ emissions, and virtually no water being used. The present invention provides improved safety, with CO₂ being injected for O₂ dilution.

The present invention accomplishes this by integrating Oxygen-based in situ combustion for oil recovery, oxycombustion for power-energy production, and CO₂-flooding.

In one aspect of the present invention, oil production is performed by O₂-based in-situ combustion. In-situ combustion off-gas separation is performed in order to recover a CO₂ stream and a fuel gas stream (comprising primarily light hydrocarbons, CO, and H₂). The CO₂ is compressed and can be either; partially recycled to the injection well (to improve sweep efficiency and High temperature front displacement); or partially sent to a pipe and used for EOR, ECBM, or storage. The oxycombustion water is used for additional injection, wet in-situ combustion. The fuel gas is blended with an additional fuel such as Natural Gas and oxy-burned in order to provide power for the compression of CO₂ (for example re-injection, pipeline, etc.).

The present invention of the integration of oxy-combustion within O₂-based in-situ combustion provides improved performance of the in-situ combustion process. This is accomplished by the recovery of a high LHV fuel gas, essentially nitrogen free, in order to reduce NG needs. This is also
5 accomplished by the production of a concentrated CO₂ stream as the only gaseous by-product of the process. This results in: the dramatic reduction of the environmental impact of oil upstream operations (zero GHG emissions, reduced water needs); the enhancement of oil recovery performance; and the availability on the oilfield for additional oil recovery.

10

Turning now to Figure 1, enhanced oil recovery system **100** is provided. Essentially pure liquid oxygen stream **101** is introduced and at least part of the oxygen is directed into stream **102** is vaporized in vaporizer **103** then into oxy-combustion boiler **110**. At least part of the oxygen is directed into stream **104**, is
15 increased in pressure in pump **105**, and vaporized in vaporizer **106**. The pressurized and vaporized oxygen **107** is then injected into the oil reservoir through an injection well **108a** / **108b** in order to support in-situ combustion. The pressure at which the vaporized oxygen is introduced into the reservoir may be between about 50% and about 80% of the breakdown pressure. A blended
20 stream **111**, containing at least oil, gas and water, is recovered from production well **112**

In another embodiment, the pressurized and vaporized oxygen **107** is injected into a structure containing a carbonaceous substance such as coal,
25 petroleum coke (petcoke), or biomass, thorough at least one inlet line **108a** / **108b**. A blended stream **111**, containing at least oil, gas and water, is recovered from at least one outlet line **112**.

This blended stream is separated in separator **113**, thereby producing recovered oil stream **114**, and separated water stream **115**. Separated water stream **115** may be used as water injection into injection well **108a / 108b**. Recovered gas **116**, which may include CO₂, CO, H₂O, CH₄, light hydrocarbons, H₂, and H₂S, is introduced to separator **117**. The exact composition of the recovered gas will depend on the nature of the produced oil and the recovery process itself. The recovered gas will be substantially free of nitrogen, due to the oxygen injection. Separator **117** may include, but is not limited to, the following processes: adsorption, absorption, cryogenic systems and membrane systems. The adsorption systems may include, but are not limited to, Rectisol, Selexol, or Amine wash systems. In one embodiment, the membrane system or the combination of cryogenics and membrane system is preferred. A high LHV fuel gas **118**, and a stream that is predominantly composed of CO₂ **119** are recovered from separator **117**. The high LHV fuel gas **118** may optionally be further purified in gas purification unit **120**. The purified high LHV gas **121** may be combined with natural gas stream **109**, prior to admission to combustion device **110**.

After combusting the oxygen stream **102** with the fuel gas streams (**109**, **121**), combustion device **110** outputs power **122** to the process (compression) facility, and also outputs an exhaust stream **123** that is predominantly H₂O and CO₂. Impurities may include predominantly SO_x, NO_x and Oxygen. Exhaust stream **123** enters separator **124**, which outputs H₂O stream **125** and CO₂ stream **127**. The H₂O stream **125** is then combined with water stream **115**, thereby producing combined stream **126**. Additives can be used in order to control PH Stream Streams 125 and 126.

126 is then admitted into injection well **108a / 108b**. CO₂ stream **127** is then combined with CO₂ stream **119**, thereby producing combined stream **128** which is partially purified, and introduced into compressor **129**. At least part of the

compressed CO2 **130** is admitted into injection well **108a / 108b**. If any CO2 remains, it may be further purified in purifier **131**, then sent to storage, to a local pipeline, or used for EOR **132**.

5 In one embodiment, a Rankine cycle may be employed as follows. Combustion device **110** may be thermally linked to a steam generation device **138**. Steam generation device **138** may produce steam stream **133**, which is introduced into steam turbine **134**. Steam turbine **134** produces power **122** and outputs lower pressure steam. This low pressure steam may be condensed,
10 thereby producing condensate stream **135**. Condensate stream **135** may be introduced to pump **136**, thereby producing higher pressure condensate stream **137** which is returned to the steam generation device **138**.

 Turning now to Figure 2, enhanced oil recovery system **200** is provided.
15 Essentially pure liquid oxygen stream **201** is introduced and increased in pressure in pump **202**. The pressurized oxygen is vaporized in vaporizer **203**. At least part of the oxygen is directed into stream **205** and introduced into combustion turbine combustor **208**. The remaining pressurized and vaporized oxygen **204** is then injected into the oil reservoir through an injection well **206a /**
20 **206b** in order to support in-situ combustion. The pressure at which the vaporized oxygen is introduced into the reservoir may be between about 50% and about 80% of the breakdown pressure. Natural gas stream **207** is blended with high LHV fuel gas stream **218** (discussed below) and introduced into combustor **208**.

25 A blended stream **209**, containing at least oil, gas and water, is recovered from production well **210**. This blended stream is separated in separator **211** thereby producing recovered oil stream **212**, and separated water stream **213**. Separated water stream **213** may be used as water injection into injection well **206a / 206b**. Recovered gas **214**, which may include CO2, CO, H2O, CH4, light

hydrocarbons, H₂, and H₂S, is introduced to separator **215**. The exact composition of the recovered gas will depend on the nature of the produced oil and the recovery process itself. The recovered gas will be substantially free of nitrogen, due to the oxygen injection. Separator **215** may include, but is not limited to, the following processes: adsorption, absorption, cryogenic systems and membrane systems. The adsorption systems may include, but are not limited to, Rectisol, Selexol, or Amine wash systems. In one embodiment, the membrane system or the combination of cryogenics and membrane system is preferred. A high LHV fuel gas **216**, and a stream that is predominantly composed of CO₂ **217** are recovered from separator **215**. The high LHV fuel gas **216** may optionally be further purified in gas purification unit **218**. The purified high LHV gas **219** may be combined with natural gas stream **207**, prior to admission to combustor **208**.

After combusting the oxygen stream **205** with the fuel gas streams (**207**, **219**), combustion turbine (Brayton cycle) (**223**, **208**, **224**) outputs power **230** to the process (compression) facility. The exhaust stream **225** that is predominantly H₂O and CO₂, impurities being SO_x, NO_x and Oxygen, exits expander **223**. Exhaust stream **225** then enters separator **220**, which outputs H₂O stream **226** and CO₂ stream **231**. The H₂O stream **226** is then combined with water stream **213** prior to admission into injection well **206a / 206b**. Additives can be used in order to control PH Stream 226. CO₂ stream **231** is then combined with stream **217**, partially purified, and introduced into compressor **224**. Compressed CO₂ stream **227** exits compressor **224** and is split into two streams **228**, **229**. The first stream **229** is admitted into injection well **206a / 206b**. The second stream **228** may be further purified in purifier **221** then sent to storage, to a local pipeline, or used for EOR **222**. At least part of the compressed CO₂ is admitted into injection well **206a /**

206b. If any CO₂ remains, **228**, it may be further purified in purifier **221**, then sent to storage, to a local pipeline, or used for EOR **222**.

5 The skilled artisan will recognize that the reinjected CO₂ will improve in-situ combustion process by improving sweep efficiency. The present invention will also improve ultimate oil recovery (miscible/immiscible flooding will act in addition to in-situ combustion). The synergetic CO₂ coinjection will reduce O₂ needs and improve process economics. The CO₂ will improve process safety
10 by diluting O₂ at the production well

 In one embodiment, at least a part of the CO₂ **228** is further purified **221** (to meet pipeline/use specification) and compressed to be exported for storage or can constitute a economically valuable gas supply to additional EOR-EGR-ECBM
15 sites. The present invention also applies to feedstock such as heavy oil, bitumen, petcoke, kerogene, and coal. This process can also be applied to biomass or coal and petcoke used as feedstock of a liquid fuel production process.

What is claimed is:

1. An enhanced oil recovery method comprising:
introducing a first essentially pure oxygen stream into a subterranean
5 hydrocarbon-bearing formation traversed by at least one injection well and at
least one production well, and initiating and sustaining in-situ combustion in the
vicinity of said injection well thus allowing to upgrade and produce oil from the
extraction well;
10 providing a power generation system, wherein said power generation system
comprises a combustion device, introducing a second essentially pure oxygen
stream and a hydrocarbon-containing fuel gas stream into said combustion
device, wherein said combustion device produces an exhaust gas stream
comprising water and carbon dioxide,
15 separating said exhaust gas stream into a stream of essentially pure water, and a
stream of essentially pure carbon dioxide, and
introducing at least a portion of said essentially pure carbon dioxide stream into
20 said subterranean hydrocarbon-bearing formation during said in-situ
combustion.
2. The enhanced oil recovery method of claim 1, further comprising removing an
off-gas stream from said production well, wherein said off-gas stream comprises
25 carbon dioxide and a high Lower Heating Value (LHV) fuel gas, and wherein said
off-gas stream is separated into a second stream of essentially pure carbon
dioxide, and a stream of high LHV fuel gas.

3. The enhanced oil recovery method of claim 2, wherein at least a portion of said second stream of essentially pure carbon dioxide is compressed and injected into the subterranean hydrocarbon-bearing formation during said in-situ combustion.

5

4. The enhanced oil recovery method of any one of claims 1 to 3, wherein said power generation system comprises a Rankine cycle, wherein said Rankine cycle comprises a combustion device, a steam generation device, and a steam turbine generator.

10

5. The enhanced oil recovery method of any one of claims 1 to 3, wherein said power generation system comprises a Brayton cycle, wherein said Brayton cycle comprises a combustion device, an expander, and a compressor.

15

6. A liquid fuel production method comprising:

introducing a first essentially pure oxygen stream into a structure containing a carbonaceous substance, said structure comprising at least one inlet line and at least one outlet line,

20

initiating and sustaining combustion in the vicinity of said inlet line, allowing to upgrade such carbonaceous substance in order to produce oil;

25

providing a power generation system, wherein said power generation system comprises a combustion device, introducing a second essentially pure oxygen stream and a hydrocarbon-containing fuel gas stream into said combustion device, wherein said combustion device produces an exhaust gas stream comprising water and carbon dioxide,

separating said exhaust gas stream into a stream of essentially pure water, and a stream of essentially pure carbon dioxide, and

introducing at least a portion of said essentially pure carbon dioxide stream into
5 said carbonaceous substance containing structure during said combustion.

7. The liquid fuel production method of claim 6, wherein said power generation system comprises a Rankine cycle, wherein said Rankine cycle comprises a combustion device, a steam generation device, and a steam turbine generator.

10

8. The liquid fuel production method of claim 6, wherein said power generation system comprises a Brayton cycle, wherein said Brayton cycle comprises a combustion device, an expander, and a compressor.

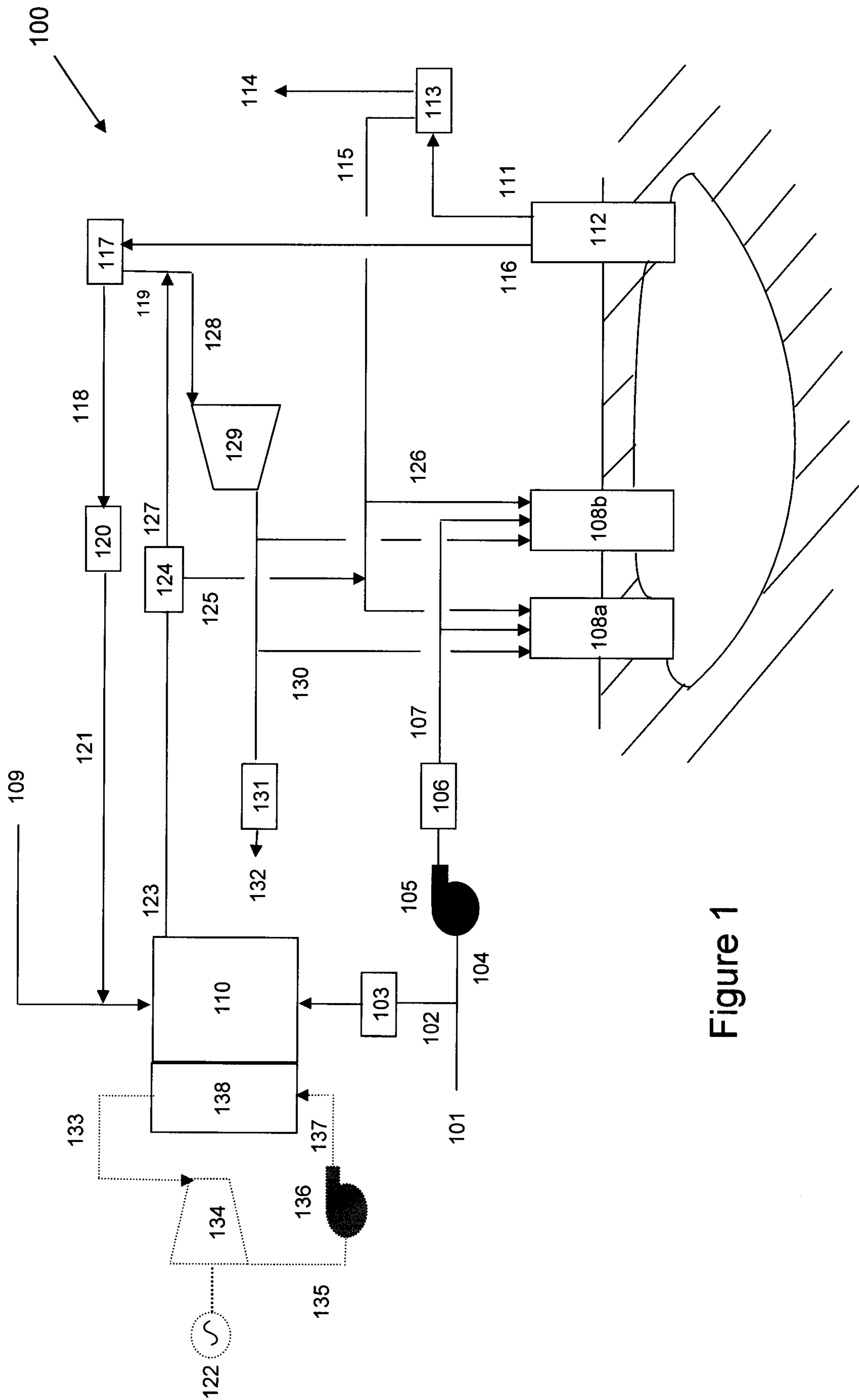


Figure 1

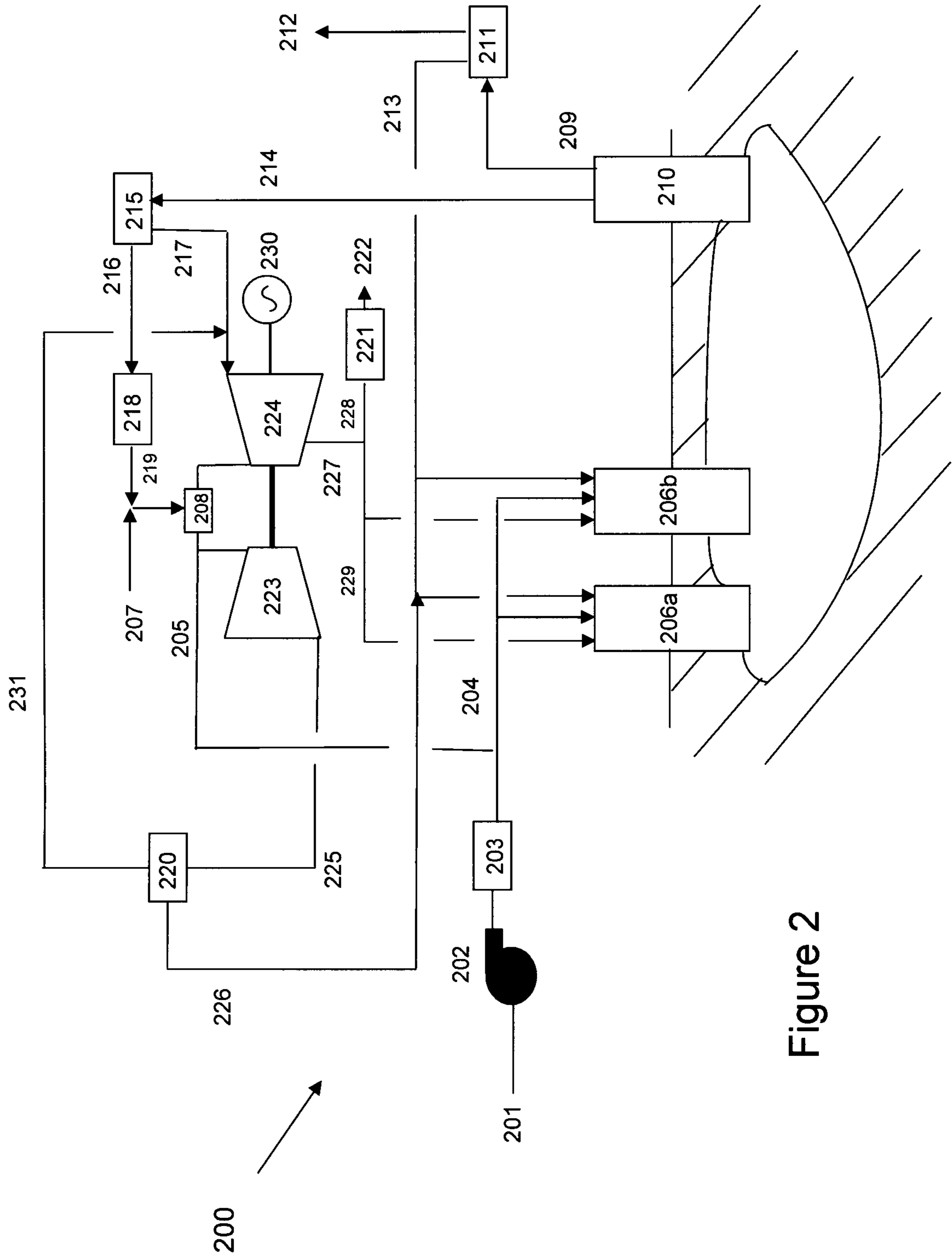


Figure 2

