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(54) **Title:** METHOD AND SYSTEM FOR PRODUCING LIQUID HYDROCARBONS

(57) **Abstract:** Systems and a method are provided for producing an aromatic hydrocarbon and generating electricity from a tail gas stream. The method includes feeding a first stream including a raw natural gas into a reactor. The method includes converting the first stream, at least in part, to a second stream including an aromatic hydrocarbon within the reactor. The method includes separating the second stream into a tail gas stream and a liquid aromatic hydrocarbon stream and combusting at least a portion of the tail gas stream to generate electricity.



WO 2015/084518 A1

METHOD AND SYSTEM FOR PRODUCING LIQUID HYDROCARBONS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of United States Patent Application
5 61/913,009 filed December 6, 2013 entitled METHODS AND SYSTEMS FOR
PRODUCING LIQUID HYDROCARBONS, the entirety of which is incorporated by
reference herein.

[0002] In addition U.S. Provisional patent application number 61/913,009 is related to
but does not claim priority to ExxonMobil Chemical Company's U.S. Provisional patent
10 application number 61/912,877 (2013EM330) filed on December 6, 2013 entitled
HYDROCARBON CONVERSION; U.S. Provisional patent application number 61/912,866
filed on December 6, 2013 entitled PRODUCTION OF C2+ OLEFINS; U.S. Provisional
patent application number 61/912,886 filed on December 6, 2013 entitled PRODUCTION
OF C2+ OLEFINS; and U.S. Provisional patent application number 61/912,901 filed on
15 December 6, 2013 entitled HYDROCARBON CONVERSION.

FIELD

[0003] The present techniques generally relate to producing an aromatic hydrocarbon
stream and generating power. Particularly, the present techniques provide for the conversion
of raw natural gas into an aromatic hydrocarbon stream and the generation of electricity from
20 a tail gas stream.

BACKGROUND

[0004] This section is intended to introduce various aspects of the art, which may be
associated with exemplary embodiments of the present techniques. This description is
believed to assist in providing a framework to facilitate a better understanding of particular
25 aspects of the present techniques. Accordingly, it should be understood that this section
should be read in this light, and not necessarily as admissions of prior art.

[0005] Some processing technologies provide for the conversion of a high quality gas
into longer-chain hydrocarbons. As used herein a "high quality gas" can be formed by
purification and fractionation to form a narrow molecular weight material. For example,
30 recovered raw natural gas may be separated from recovered crude oil and later processed for
the removal of water, natural gas condensate, acid gases, and other contaminants, and then
fractionated into different molecular weight components to produce the high quality gas. The

purification and fractionation may be done before the gas product is converted into the higher molecular weight hydrocarbons. This may be due in part to mainline transportation systems imposing restrictions on the make-up of the hydrocarbons before entry into additional processing units, pipelines facilities, or storage.

- 5 [0006] The technologies for the process of converting the high quality gas into the higher molecular weight hydrocarbons include relatively well-known and well-proven techniques that have been in development through the years. One example of a process that can convert a gas product into higher molecular weight hydrocarbons may include the Cyclar™ process from UOP. The Cyclar™ process is a non-integrated chemical production facility that
- 10 converts liquefied petroleum gas (LPG) directly into a liquid, aromatic product. Particularly, the Cyclar™ process provides a process for upgrading lower value propane and butane (C₃/C₄ hydrocarbons) into a higher value, liquid aromatic concentrate (benzene, toluene, xylene, or “BTX”) that may be used as feedstock to an aromatics complex. The process may be typically operated at temperatures higher than 800 °F (425 °C). Another process is the
- 15 Choudhary process, which also converts a percentage of methane, along with the C₃/C₄ hydrocarbons, to yield up to a 30% conversion of the methane along with a higher conversion rate of the C₃/C₄ hydrocarbons. *See* Journal of Natural Gas Chemistry 18(2009) 260–272, Review: Energy-Efficient coaromatization of methane and propane, Jianjun Guo, Hui Lou, Xiaoming Zheng.
- 20 [0007] The Fischer-Tropsch process can also be used to convert hydrocarbons or natural gas into higher molecular weight hydrocarbons. The Fischer-Tropsch process is an exothermic conversion process including a collection of chemical reactions that can convert a mixture of carbon monoxide and hydrogen into liquid hydrocarbons. The more useful reactions produce mostly straight-chain alkanes, suitable for diesel fuel. Generally, the
- 25 Fischer-Tropsch process is operated in the temperature range of 302 °F to 572 °F. In this case, higher temperatures lead to faster reactions and higher conversion rates while favoring methane production. An increase in pressure in the process leads to higher conversion rates and also favors the formation of long-chained alkanes, both of which are desirable. Typical pressures can range from one to several tens of atmospheres.
- 30 [0008] Another process is the RZ™ Platforming process from UOP. The RZ™ Platforming process is designed to efficiently convert paraffins and naphthenes to aromatics with limited ring opening or cracking. Specifically, the RZ™ Platforming process utilizes a fixed bed system for the production of high yields of benzene toluene (BT) aromatics and hydrogen. Additionally, the Aromax® Process from Chevron Phillips selectively converts

light paraffins and naphthenes to both hydrogen and aromatic products utilizing fixed-bed reforming equipment. The aforementioned process are just a few of the techniques used to convert high quality gas into aromatic products.

[0009] U.S. Patent Application Publication No. 2012/0036889 by Denton et al. discloses
5 a methane conversion process. The process includes the conversion of a gaseous hydrocarbon feed, including methane, to an aromatic hydrocarbon. The methane conversion process is integrated with a liquefied natural gas (LNG) and/or pipeline gas process. In operation, the gaseous hydrocarbon stream is feed to a conversion zone with specified parameters to produce a gaseous effluent stream, including at least one aromatic compound,
10 unreacted methane, and hydrogen.

[0010] U.S. Patent No. 8,455,707 to Hershkowitz discloses a process for converting methane into acetylene and other higher hydrocarbons. The process includes a reverse-flow reactor system where first and second reactants are supplied in a first reactor bed such that both reactants serve to quench the reactor bed and to control combustion for thermal
15 regeneration. *See* also U.S. Patent No. 6,130,260 to Synfuels, which discloses converting methane into acetylene and then into liquid fuels.

[0011] U.S. Patent Application Publication No. 2007/0260098 by Iaccino et al. discloses the production of aromatic hydrocarbons from methane. The process includes a process to convert methane to aromatic hydrocarbons to produce first and second effluent streams. The
20 hydrogen within the first effluent stream is reacted with an oxygen-containing species to produce a second effluent stream including a reduced hydrogen content.

[0012] U.S. Patent Application Publication No. 2009/0247804 by Sauer et al. discloses a method for converting methane to useful hydrocarbons. The process includes combining a methane/hydrogen fluid with a catalyst composition derived from an aluminum compound
25 and a transition metal halide to produce higher molecular weight hydrocarbons.

[0013] Many other conversion process techniques exist for the production of aromatics from a high quality gas. However, the processes generally rely on an existing infrastructure, such as a chemical plant and purification systems. Accordingly, there is a need for an independent infrastructure process for the conversion of an unprocessed raw hydrocarbon gas
30 to an aromatic product that may also incorporates other processing techniques including power generation and heat removal.

SUMMARY

[0014] An exemplary embodiment provides a method for producing liquid hydrocarbons and power. The method includes producing a first stream including methane. The method includes reacting the first stream in a reactor to form a second stream having at least a portion
5 of the methane converted to a higher molecular weight hydrocarbon. The method includes separating the second stream into a tail stream that is enriched in methane and a product stream enriched in the higher molecular weight hydrocarbon. The method includes combusting at least a portion of the tail stream to generate power.

[0015] Another exemplary embodiment provides a system for producing liquid
10 hydrocarbons from a first stream including methane and generating power. The system includes a reactor configured to convert the first stream into a second stream having at least a portion of the methane in the first stream converted to a higher molecular weight hydrocarbon. The system includes a separation vessel configured to separate the second stream into a tail gas stream and a liquid hydrocarbon stream. The system includes a
15 combustor to combust the tail gas stream to generate power.

[0016] Another exemplary embodiment provides a method for producing an aromatic hydrocarbon and generating electricity from a tail gas stream. The method includes feeding a first stream including raw natural gas into an aromatic reactor. The method includes converting the first stream, at least in part, to a second stream including the aromatic
20 hydrocarbon. The method includes separating the second stream into the tail gas stream and a liquid aromatic hydrocarbon stream. The method includes burning at least a portion of the tail gas stream in a gas turbine to generate the electricity.

DESCRIPTION OF THE DRAWINGS

[0017] The advantages of the present techniques are better understood by referring to the
25 following detailed description and the attached drawings, in which:

[0018] Fig. 1 is an illustration of an oil and gas well reservoir including trapped oil and gas within rock formations;

[0019] Fig. 2 is a block diagram of a system for producing a higher molecular weight hydrocarbons product;

[0020] Fig. 3 is a simplified process flow diagram for a natural gas liquid recovery and
30 stabilization unit including a distillation column;

[0021] Fig. 4 is a process flow diagram for a natural gas liquid recovery and stabilization unit including a crude wash;

[0022] Fig. 5 is a process flow diagram for a natural gas liquid recovery and stabilization unit that recovers hydrogen from the tail gas; and

[0023] Fig. 6 is a flow block diagram of a method for producing liquid hydrocarbons.

DETAILED DESCRIPTION

5 [0024] In the following detailed description section, specific embodiments of the present techniques are described. However, to the extent that the following description is specific to a particular embodiment or a particular use of the present techniques, this is intended to be for exemplary purposes only and simply provides a description of the exemplary
10 described below, but rather, include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

[0025] At the outset, for ease of reference, certain terms used in this application and their meanings as used in this context are set forth. To the extent a term used herein is not defined below, it should be given the broadest definition persons in the pertinent art have given that
15 term as reflected in at least one printed publication or issued patent. Further, the present techniques are not limited by the usage of the terms shown below, as all equivalents, synonyms, new developments, and terms or techniques that serve the same or a similar purpose are considered to be within the scope of the present claims.

[0026] The term “aromatic hydrocarbons” refers to molecules containing one or more
20 aromatic rings. Examples of aromatic hydrocarbons are benzene, toluene, xylenes, naphthalene, and methylnaphthalenes

[0027] The term “aromatic” refers to unsaturated compounds with at least one closed ring of at least 6 atoms, with all of the ring atoms being co-planar or almost co-planar and covalently linked, and with all of the ring atoms being part of a mesomeric system. As used
25 herein, when the “aromatic” substituent is monocyclic, it preferably contains 6 ring atoms, and when the “aromatic” substituent is polycyclic, it preferably contains 10 ring atoms contained in fused rings.

[0028] The term “C_n” hydrocarbon refers to a hydrocarbon with “n” carbon atoms, and “C_n-C_m hydrocarbons” represents hydrocarbons having between “n” and “m” carbon atoms.

30 [0029] The term “catalyst” refers to a material, which under certain conditions of temperature or pressure increases the rate of specific chemical reactions. A catalyst may also be a material that performs as a physisorbent or chemisorbent for specific components of the feed stream.

[0030] The term “chain length” may broadly refer to a number of atoms forming and/or making a backbone and/or structure of a molecule and/or compound, such as carbon atoms for a hydrocarbon.

5 [0031] The term “chemical reaction” refers to any process including the breaking or making of chemical bonds including a dissociation, recombination, or rearrangement of atoms.

[0032] The term “coke” refers to the solid residue remaining from the pyrolysis of hydrocarbons.

10 [0033] The term “crude oil” refers to hydrocarbons formed primarily of carbon and hydrogen atoms. The hydrocarbons may also include other elements, such as, but not limited to, halogens, metallic elements, nitrogen, oxygen, or sulfur. Hydrocarbons derived from an oil-bearing formation may include, but are not limited to, kerogen, bitumen, pyrobitumen, asphaltenes, resins, oils, or combinations thereof.

15 [0034] The term “fixed-bed reactor” refers to a reactor containing catalyst material typically in pellet form, packed in a static bed.

[0035] The term “gas turbine” refers to a unit including a compressor, a combustion chamber, and turbine mechanically connected to the compressor, most preferably connected on a common shaft. Generally, a gas turbine uses energy from burning a fuel in the combustion chamber to power a compressor that provides an oxidant stream to the combustion chamber. This is termed the Brayton cycle. A “turbine” is used in the meaning of an expansion unit for converting of the energy of high temperature gas to rotational energy.

20 [0036] The term “higher hydrocarbons” refers to hydrocarbon(s) having more than one carbon atom per molecule, oxygenate having at least one carbon atom per molecule, e.g., ethane, ethylene, propane, propylene, benzene, toluene, xylenes, naphthalene, and/or methyl naphthalene; and/or organic compound(s) including at least one carbon atom and at least one non-hydrogen atom, e.g., methanol, ethanol, methylamine, and/or ethylamine.

25 [0037] The term “hydrocarbon” refers to an organic compound that includes primarily, if not exclusively, the elements hydrogen and carbon. Hydrocarbons may also include other elements, such as, but not limited to, halogens, metallic elements, nitrogen, oxygen, and/or sulfur. Hydrocarbons generally fall into two classes: aliphatic, or straight chain hydrocarbons, and cyclic, or closed ring hydrocarbons, including cyclic terpenes. Examples of hydrocarbon-containing materials include any form of natural gas, oil, coal, and bitumen.

30 [0038] The term “hydrocarbon diluent” refers to any substance containing one or more hydrocarbon compounds and/or substituted hydrocarbon compounds, which is suitable for

use for diluting a hydrocarbon in the practice of the invention. For example, a tail gas stream containing hydrocarbons may be an added diluent for natural gas.

[0039] The term “hydrocarbon stream” refers to a hydrocarbon or mixtures of hydrocarbons that are gases or liquids. For example, hydrocarbon fluids may include a hydrocarbon or mixtures of hydrocarbons that are gases or liquids at formation conditions, at processing conditions or at ambient conditions (15 °C and 1 atm pressure). Hydrocarbon fluids may include, for example, oil, natural gas, coalbed methane, shale oil, pyrolysis oil, pyrolysis gas, a pyrolysis product of coal, and other hydrocarbons that are in a gaseous or liquid state

[0040] The term “light hydrocarbons” refer to hydrocarbons having carbon numbers in a range from 1 to 5.

[0041] The term “natural gas” refers to a multi-component gas obtained from a crude oil well (associated gas) or from a subterranean gas-bearing formation (non-associated gas). The composition and pressure of natural gas can vary significantly. A typical natural gas stream contains methane (C1) as a significant component. Raw natural gas may also contain ethane (C2), higher molecular weight hydrocarbons, acid gases (such as carbon dioxide, hydrogen sulfide, carbonyl sulfide, carbon disulfide, and mercaptans), and minor amounts of contaminants such as water, nitrogen, iron sulfide, wax, and crude oil. As used herein, natural gas includes gas resulting from the regasification of a liquefied natural gas, which has been purified to remove contaminants, such as water, acid gases, and most of the higher molecular weight hydrocarbons.

[0042] The term “high quality gas” refers to a gas that has undergone natural gas processing to separate various hydrocarbons and fluids from a raw natural gas. Also referred to as pipeline quality dry natural gas.

[0043] The term “raw natural gas” refers to a gas that is included of methane, but may also include numerous other light hydrocarbons including ethane, propane, and butanes. Higher molecular weight hydrocarbons, including pentanes, hexanes, and impurities like benzene may also be present in small amounts. Furthermore, raw natural gas may contain amounts of non-hydrocarbon impurities, such as nitrogen, hydrogen sulfide, carbon dioxide, and traces of helium, carbonyl sulfide, various mercaptans, and water.

[0044] The term “oil and gas reservoir” refers to a well or reservoir that is a subsurface zone that produces oil and/or gas and lacks communication other reservoirs. As used in the claims, “oil and gas well” and “oil and gas reservoir” are interchangeable.

[0045] The term “reservoir” refers to a formation or a portion of a formation that includes

sufficient permeability and porosity to hold and transmit fluids, such as hydrocarbons or water.

Overview

[0046] Embodiments of the present disclosure provide a method and system for
5 producing liquid hydrocarbons from unpurified, raw natural gas while generating power. More specifically, various embodiments may provide a raw hydrocarbon gas stream converted in a reactor, at least in part, to a higher molecular weight hydrocarbons stream. The reactor is endothermic and the heat supplied to the reaction may be generated in other units within the system. The separation of the higher molecular weight hydrocarbons stream
10 may yield a liquid hydrocarbons stream and a tail gas stream where at least a portion of the tail gas may be combusted and utilized for power generation.

[0047] Raw natural gas recovered at a well-head usually contains impurities and contaminants including water vapor, hydrogen sulfide, carbon dioxide, nitrogen, and other compounds. However, most techniques for converting light hydrocarbons into aromatic, or
15 heavy hydrocarbons, utilize a feedstock of purified hydrocarbons having 2 to 5 carbon atoms per molecule. Some of the methods for purification may include hydrogenation, dehydrogenation, sulfur, and acid gas removal techniques, among other processes, to remove the aforementioned impurities and contaminants. Thus, the purified hydrocarbon feed utilized in the conventional production of aromatic hydrocarbons usually includes propane,
20 propylene, butanes, butylenes, with unsaturated compounds being preferred in many processes. Further, specific hydrocarbon reactants can be separated from the purified stream by fractionation. The resulting gaseous hydrocarbons may then be recycled or transported for further processing or commercialization.

[0048] However, in remote locations, the appropriate infrastructures may not exist to
25 purify and fractionate the raw natural gas before it can be used. Thus, the recovery of raw natural gas may not outweigh the cost to implement the necessary facilities to remove, purify, and transport the natural gas from remote locations. Thus, the raw natural gas may be burned or flared as a byproduct of oil production. Unfortunately, flaring wastes the energy content of the gaseous hydrocarbons. Furthermore, flaring can pose a hazard to human health due to
30 constituents that may be present in the natural gas, such as sulfur compounds.

[0049] Fig. 1 is an illustration of an oil and gas well reservoir **100** including trapped oil and gas within rock formations. As shown in Fig. 1, an oil and gas well reservoir **100** can be a subsurface pool of hydrocarbons contained in porous sedimentary rock **102**. A layer of impermeable rock formations, termed cap rock **104**, may prevent the escape of the naturally

occurring hydrocarbons into overlying sediment and rock formations **107** (the overburden). Various recovery methods may be implemented to extract and recover both the oil and gas hydrocarbons. During recovery, the oil and gas reservoir **100** may produce the crude oil and raw natural gas along with other liquid, gaseous, and solid hydrocarbons.

5 [0050] A hydrocarbon stream **106** can be produced from the reservoir **102**, which may include gas, oil, water, and any combinations thereof. The hydrocarbon stream **106** can be flowed into a gas-oil separator **108**, where the raw natural gas may be processed for the removal of an oil stream **110** including oil and other liquids. An overhead gas stream **114** from the gas-oil separator **108** may be further processed in a reactor **116**.

10 [0051] The liquid/gas mixture stream **118** generated in the reactor **116** may flow to a separator **120** where a bottoms liquid stream **122** can be combined with the oil stream **110**. A tail gas stream **124** may be produced overhead and later combusted, for example, in a gas turbine generator **126**, to generate power. In some embodiments, the pressure in the reservoir **102** can be maintained by recycling a portion of the tail gas **124** back into the reservoir **100**,
15 via a compressor **128**, to maintain the pressure of a gas cap located within the reservoir **100**. The tail gas hydrogen content may be relatively high and processes known to those skilled in the art can be used to separate the tail gas into a hydrogen rich stream and hydrogen poor stream. Accordingly, the hydrogen poor tail gas can be reinjected via compressor **128**, while the hydrogen rich stream can be used as fuel or recycled, as required.

20 [0052] Fig. 2 is a block diagram of a system **200** for producing a higher molecular weight hydrocarbons product. As shown in Fig. 2, a raw hydrocarbon **202** may be produced from a reservoir and may flow into a production separator **204**. In some embodiments, the raw hydrocarbon **202** may contain crude oil and raw natural gas along with water, trace organic compounds, trace metals, and other entrained liquids and solids. A crude oil stream **206** can
25 be taken from the bottom of the separator **204**. The crude oil stream **206** can be directed to a field crude stabilizer **208**, where water, light hydrocarbons, and gas contaminants are boiled off to produce a stabilized crude oil liquid stream **210**. As shown in Fig. 2, an overhead gas stream **212** from the field crude stabilizer **208** may be directed to a reactor **214**.

[0053] A raw natural gas stream **216** can be taken from the top of the separator **204** and
30 combined with the overhead gas stream **212** before being flowed into the reactor **214**. In various embodiments, the stream **216** may include methane, ethane, propane, butanes, nitrogen, carbon dioxide, and hydrogen, among other components. Within the reactor **214**, conversion reactions may enable the conversion of lower molecular weight hydrocarbons in the raw natural gas to higher molecular weight hydrocarbons. In some embodiments, the

lower molecular weight hydrocarbons may include methane and C₂ to C₅₊ hydrocarbons and the higher molecular weight hydrocarbons may include C₆ to C₉ aromatics. In some examples, the overhead gas stream **212** may include sulfur compounds, such as mercaptans, sulfides, and other organosulfur compounds, in addition to hydrogen sulfide (H₂S). The organosulfur compounds may be at least partially converted in the reactor, forming further amounts of H₂S.

[0054] A stream **218** containing higher molecular weight hydrocarbons may flow from the reactor **214** and into a liquid separator **220**. As shown in Fig. 2, the liquid separator **220** may separate the higher molecular weight hydrocarbons containing stream **218** into a tail gas stream **222** and a liquid hydrocarbons stream **224**. The product value and transportability of a hydrocarbons stream in liquid form may be enhanced since liquid hydrocarbons can achieve a higher reduction in volume than hydrocarbons in gas form. Thus, it may be more cost effective to recover the natural gas and convert it into a liquid hydrocarbons stream, instead of flaring the natural gas, since it can now be transported by methods other than pipelines.

[0055] To reduce the volatility of the liquid hydrocarbons stream **224** during transportation, the liquid hydrocarbons stream **224** may be subjected to liquid stabilization. A liquid stabilizer **226** may operate at a low pressure to remove any volatile hydrocarbons and other gaseous contaminants within the liquid hydrocarbons stream **224** to produce a stabilized liquid hydrocarbons stream **228**. As shown in Fig. 2, the stabilized liquid hydrocarbons stream **228** and the stabilized crude oil liquid stream **210** may merge together to form a liquid hydrocarbons product stream **230**.

[0056] If the overhead gas stream **212** used as the feed contains organosulfur compounds, H₂S, or both, the resulting tail gas stream **222** may be treated to reduce or remove the H₂S, for example, if the concentration is greater than about 10 ppm, greater than 1000 ppm, or greater than 1 %, depending on the sensitivity of the environment to SO_x's formed from combusting the H₂S. The H₂S can be removed by an adsorption column, a Claus process, a counter-current separation column, or any number of other techniques. If removal of the H₂S is not convenient, for example, due to the remoteness of the site, treating the combustion exhaust to remove SO_x's may be performed. This could be done by passing the exhaust gas through a water scrubbing column.

[0057] The tail gas stream **222** may be utilized for on-site generation of power to turn a power generator **232**, where power may be generated and used by those in remote areas with limited access to power grids. This type of distributed power generation may be attractive since it can provide electricity that may be more reliable, more efficient, and cheaper than

purchasing power from a centralized utility. Distributed power generation may also allow for increased local control over an electricity supply in remote areas, as well as, possibly lowering electricity losses during transmission. Additionally, the tail gas stream **222** may be used in heat integration to supply energy to the reactor **214**. In some embodiments, the power generator may include a gas turbine or combustion engine.

5 **[0058]** The block diagram of Fig. 2 is not intended to indicate that the gas system **200** is to include all of the components shown in Fig. 2. Further, any number of additional components may be included within the method of producing a higher molecular weight hydrocarbons product. The system **200** may include any suitable types of heaters, chillers, 10 condensers, pumps, compressors, other types of separation and/or fractionation equipment, among others, including any desirable purification steps prior to introducing the gas streams **216** and **212** into reactor **214**. For example, the system **200** may include a suitable device or structure for condensing at least a portion of the gas streams **216** and/or **212**, e.g., a pressure expansion device, an external refrigeration system, etc., prior to introduction into the reactor 15 **214**. Condensing in this way may create a liquid stream comprising higher molecular weight hydrocarbons and a gas stream comprising methane and other light components (e.g., nitrogen, helium, carbon dioxide, etc.). The liquid stream may be vaporized and introduced into the reactor **214** as feedstock, while the gas stream may be reinjected into the ground or used for another purpose. Those of skill in the art will recognize that this technique may be 20 utilized to variably control the composition of the tail stream, and therefore the amount of co-produced power that may be generated.

25 **[0059]** Fig. 3 is a simplified process flow diagram **300** for a natural gas liquid recovery and stabilization unit including a distillation column. The raw natural gas stream **302** may include methane and lower molecular weight hydrocarbons, for example, C_2 to C_{5+} hydrocarbons. The pressure of a raw natural gas stream **302** may be decreased by flashing the raw natural gas stream **302** across a valve **303**, generating a low-pressure stream **304**. The low-pressure stream **304** may be warmed in a product chiller **305** and heated in a reactor feed heater **306** to form a warm gas stream **312**. The warm gas stream **312** can be further heated, for example, to operating temperatures of about 510 °C (about 950 °F) to about 30 600 °C (about 1100 °F) in a furnace heater **314** to form a reactor feed gas **315** that is fed to the reactor **308**. The reactor feed gas **315** may undergo conversion reactions to form higher molecular weight hydrocarbons within the reactor **308**. In some embodiments, the reactor feed gas **315** may be at a pressure range of about 280 KPa (about 40 psia) to about 480 KPa (about 70 psia). The pressure may be increased before entering the reactor **308**, for example,

by a compressor (not shown). A gaseous diluent, such as methane, may be blended with the raw natural gas stream **302** to reduce the formation of a byproduct, coke, which tends to accumulate on the catalyst pores and lower the reaction efficacy.

[0060] Any number of types of reactor **308** may be used, including a catalytic membrane
5 reactor, a fixed-bed catalyst reactor, continuous catalytic regeneration reactor, or a fluidized bed reactor. The type of reactor utilized may depend on feed compositions and feed rates, conversion reaction temperatures, yield compositions, among other input and output factors. Moreover, the reaction rates and production yields may be enhanced by the use of a selective catalyst for the optimization of reaction conditions.

10 [0061] The catalyst can include at least one metal component on an inorganic support, such as amorphous silica, or alumina. The inorganic support may be a porous material such as a micro-porous crystalline material or a meso-porous material. Additionally, suitable molecular sieves may be utilized in the present catalyst and may include at least one medium pore molecular sieve having a Constraint Index of 2-12 (as defined in U.S. Patent No.
15 4,016,218). Examples of such medium pore molecular sieves include ZSM-5, ZSM-11, ZSM-12, ZSM-22, ZSM-23, ZSM-35, ZSM-48, MCM-22 and MCM-49 and mixtures and intermediates thereof. ZSM-5 is described in detail in U.S. Patent Nos. 3,702,886 and Re. 29,948. ZSM-11 is described in detail in U.S. Patent No. 3,709,979. A ZSM-5/ZSM-11 intermediate structure is described in U.S. Patent No. 4,229,424. ZSM-12 is described in U.S.
20 Patent No. 3,832,449. ZSM-22 is described in U.S. Patent No. 4,556,477. ZSM-23 is described in U.S. Patent No. 4,076,842. ZSM-35 is described in U.S. Patent No. 4,016,245. ZSM-48 is more particularly described in U.S. Patent No. 4,234,231.

[0062] The metal component of the catalyst may be present in an amount of at least 0.1 wt. %, such as from 0.1 to 5 wt. %, of the overall catalyst. The metal component may include
25 one or more neutral metals selected from Groups 3 to 13 of the Periodic Table of the Elements, such as Ga, In, Zn, Cu, Re, Mo, W, La, Fe, Ag, Pt, Pd, and/or one or more oxides, sulfides and/or carbides of these metals. The metal component can be provided on the catalyst in any known manner, for example by impregnation or ion exchange of the molecular sieve with a solution of a compound of the relevant metal, followed by conversion of the metal
30 compound to the desired form, namely neutral metal, oxide, sulfide and/or carbide. Part or all of the metal may also be present in a crystalline framework of the molecular sieve.

[0063] In a preferred embodiment, a bifunctional catalyst may be selected from the group consisting of Ga and/or In-modified ZSM-5 type zeolites, such as Ga and/or In-impregnated H-ZSM-5, Ga and/or In-exchanged H-ZSM-5, H-gallosilicate of ZSM-5 type structure and

H-galloaluminosilicate of ZSM-5 type structure. These zeolites can also be prepared by methods known in the prior art.

[0064] For example, the bifunctional catalyst may contain tetrahedral aluminum or gallium, which is present in the zeolite framework or lattice. The bifunctional catalyst may also contain octahedral gallium or indium, which is not present in the zeolite framework, but present in the zeolite channels in close vicinity to the zeolitic protonic acid sites that may be attributed to the presence of tetrahedral aluminum and gallium in the catalyst. The tetrahedral or framework of Al or Ga can be responsible for the acid function of the catalyst and octahedral or non-framework Ga or In may be responsible for the dehydrogenation function of the catalyst. In a preferred embodiment, the bifunctional catalyst may include H-galloaluminosilicate of ZSM-5 type structure having framework (tetrahedral) Si/Al and Si/Ga mole ratios of about 10:1 to 100:1 and 15:1 to 150:1, respectively, and non-framework (octahedral) Ga of about 0.5 to 0 wt. %.

[0065] In addition to the molecular sieve and hydrogenation component, the catalyst may be composited with other materials, which may be resistant to the temperatures and other conditions employed in the conversion reaction. Such other materials can include active and inactive materials and synthetic or naturally occurring zeolites as well as inorganic materials such as clays and/or oxides such as alumina, silica, silica-alumina, zirconia, titania, magnesia or mixtures of these and other oxides. The latter may be either naturally occurring or in the form of gelatinous precipitates or gels including mixtures of silica and metal oxides. Clays may also be included with the oxide type binders to modify the mechanical properties of the catalyst or to assist in its manufacture. Use of a material in conjunction with the molecular sieve, i.e., combined therewith or present during its synthesis, which itself is catalytically active may change the conversion and/or selectivity of the catalyst.

[0066] Additionally, inactive materials may serve as diluents to control the amount of conversion so that products can be obtained without employing other means for controlling the rate of reaction. These materials may be incorporated into naturally- occurring clays, e.g., bentonite and kaolin, to improve the crush strength of the catalyst under commercial operating conditions and function as binders or matrices for the catalyst. The relative proportions of molecular sieve and inorganic oxide matrix may vary, with the sieve content ranging from about 1 to about 90 percent by weight and more usually, particularly, when the composite is prepared in the form of beads, in the range of about 2 to about 80 weight percent of the composite.

[0067] The product of the conversion reactions in the reactor 308 may include a higher

molecular weight hydrocarbons stream **316**, e.g., including C₆ to C₉ aromatics, and other entrained solid and liquid hydrocarbons. The higher molecular weight hydrocarbons stream **316** may be cooled upon exiting the reactor **308** by an air cooler **318**. For initial liquids recovery, the higher molecular weight hydrocarbons stream **316** may further be chilled to a temperature range of about 10 °C (50 °F) to about 26 °C (80 °F) by exchanging heat with the low-pressure stream **304** in the product chiller **305**. The chilled higher molecular weight hydrocarbons stream **320** may then flow into a gas liquid separator **322** for the initial recovery of liquid hydrocarbons. During separation, a tail gas stream **324** may be produced overhead and a liquid hydrocarbons stream **326** may be produced as a bottoms stream.

[0068] The tail gas stream **324** can be compressed in a tail gas compressor **328** and chilled in a heat exchanger **330** to remove the heat of compression. From the heat exchanger **330**, the tail gas **324** may be sent to a distillation column **332**. An overhead gas stream from the distillation column **332** may be chilled in a refrigeration cycle **334**, and returned to the distillation column **332** as a reflux stream **335**. A liquid stream **336** can be taken from the bottom of the distillation column **332** at a relatively high pressure (e.g. 300 psia). A portion of the liquid stream **336** may be passed through a reboiler **340** and returned as a vapor **342** to the column **332**. The remainder of the liquid stream **336** can be combined with the liquid hydrocarbons stream **326** from the two-phase separator **322**.

[0069] A product gas stream **338** taken from the overhead of the distillation column **332** can be heated against the hot tail gas stream from the compressor **328** forming a fuel gas stream **346**. The fuel gas stream **346** may include methane, ethane, as well as non-hydrocarbon gases such as hydrogen, carbon dioxide, hydrogen sulfide, and nitrogen. The fuel gas stream **346** can be burned in a combustor **344** to power a gas turbine generator **356**.

[0070] A portion of the fuel gas stream **346** can be sent to a pressure maintenance system **347** to be re-injected into the reservoir **102** (Fig. 1) to maintain the pressure of a gas cap located within the reservoir **102** or recycled to the front to mix with the inlet feed gas. Likewise, as stated earlier the fuel gas may be divided into hydrogen rich and hydrogen poor streams, so that only the hydrogen poor stream is reinjected, if required. Further, the fuel gas stream **346** may be used to supply heat to the reactor **308**, for example, by being combusted in a burner to heat the stream **346** in the furnace heater **314**.

[0071] In the gas turbine generator **356**, an air compressor **348** can compress an air stream taken from the atmosphere **350**, and feed the compressed stream to the combustor **344**. The hot gas stream **352** from the combustion is flowed through a turbine expander **354** to turn a shaft **355**. The shaft **355** can provide the power to turn the air compressor **348**, closing the

Brayton cycle. Further, the shaft **355** can be used to drive the generator **356**, providing electricity that can be used on-site, placed on a power grid, or both. The gas turbine generator **356** may burn up to 1% hydrogen sulfide in the hot gas stream **352**. If desired, a gas treatment system can be added to remove at least a portion of the hydrogen sulfide, or
5 other impurities, to generate acceptable gas turbine performance or lower exhaust pollutants.

[0072] After flowing through the turbine expander **354**, the pressure of a hot gas stream **352** is lowered, forming an exhaust **358**. The heat in the exhaust **358** may be used in other processes in the facility. For example, a portion of the exhaust **358** can be used to heat the reactor feed gas **315** in the furnace heater **314**, before being released to the atmosphere **350**.

10 This may be implemented, for example, by flowing the warm gas stream **312** through a tube bundle in a heat recovery unit placed at the end of the expander turbine **354**. As described herein, the furnace heater **314** is not limited to using the exhaust **358**, but may be heated by a burner that combusts a portion of the fuel gas stream **346**. Further, the reactor **308** may also contain a tube bundle to maintain a reasonable isothermal reactor. A fluid from the reactor
15 **308** may be pulled and re-injected into the furnace heater **314** and into multiple points of heat inputs within the reactor **308**. The tube bundle of the reactor **308** may be located on the outside of the reactor **308** and heated by an external burner.

[0073] Another portion of the exhaust **358** may be used to heat a heat exchange fluid in a heat exchanger **360**, before being released to the atmosphere **350**. A hot fluid **362** can be
20 used to heat any number of other systems, as described herein. The resulting cool fluid **364** can then be returned to the heat exchanger **360** to close the cycle. In addition, a convective section the furnace heater **314** could be used to supply the heat source from stream **362**.

[0074] The gas turbine generator may operate on the same concept as larger centralized gas turbine generators as used in many processing facilities. However, instead of being
25 located in a centralized plant, the gas turbine generator may be located in close proximity to where the electricity being generated can be used. Thus, the tail gas may provide power to remote locations without a substantial power generation system making small electrical grids possible, or increasing the capacity of existing electrical grids.

[0075] The liquid hydrocarbons stream **326** from the two-phase separator **322**, combined
30 with the liquid stream **336** from the distillation column **322**, forming a combined stream **368**, can be flowed into a stabilizer vessel **366**, for example, operating in a pressure range of about 207 KPa (about 30 psia) to about 414 KPa (about 60 psia). The combined stream **368** may include a liquid hydrocarbons mixture of higher molecular weight hydrocarbons with lesser amounts of light hydrocarbons and other gases. A reboiler **370** can be used to heat the liquid

in the stabilizer vessel **366**, for example, with heat from the hot fluid **362**. The heat applied to the stabilizer vessel **366** strips the light hydrocarbons from the combined stream **366**, forming a liquid product **372** that meets vapor pressure specifications for transportation. A small quantity of overhead vapor **374** from the stabilizer vessel **366** may be sent to a flare **376**, for example, if recovery and recompression is not economical. The liquid product **372** may be sold as a separate product, or may be mixed into a crude oil stream

[0076] The process flow diagram of Fig. 3 is not intended to indicate that the system **300** is to include all of the components shown in Fig. 3. Further, any number of additional components may be included in the system **300**. For example, the system **300** may include any suitable types of heaters, chillers, condensers, pumps, compressors, other types of separation and/or fractionation equipment, valves, pumps, pressure-measuring devices, or temperature-measuring device, among others.

[0077] Fig. 4 is a process flow diagram **400** for a natural gas liquid recovery and stabilization unit including a crude or condensate wash. Like numbered items are as described with respect to Fig. 3. Although similar to Fig. 3, the system in Fig. 4 washes the tail gas stream **324** with crude oil **402** to remove the liquid hydrocarbons, resulting in crude oil or condensate product **404** that includes the liquid hydrocarbons.

[0078] To perform the wash, the tail gas stream **324** is fed into the bottom of a crude wash column **406**. The crude oil **402** is fed into the top of the crude wash column **406**, solubilizing the higher molecular weight hydrocarbons in a counter current extraction. The crude oil **402** and solubilized hydrocarbons are recovered as a bottom liquids stream **408**. The crude oil **402** for the crude wash may include a produced crude oil, or any other available hydrocarbon stream such as a stabilized condensate.

[0079] As shown in Fig. 4, the liquid hydrocarbons stream **326** from the two-phase separator **322** and a liquid bottoms stream **408** from the crude wash column **406** may flow into a stabilizer vessel **366** as a combined stream **410**. As described with respect to Fig. 3, the light hydrocarbons and trace gases can be stripped from the combined stream **410** to produce a crude oil product **404** that contains the higher molecular weight hydrocarbons formed in the process.

[0080] A vapor stream **412** can be taken from the top of the crude wash column **406** and flowed into a multi-stage compressor unit **414**. The multi-stage compressor unit **414** can be used to compensate for low pressures that may be used during the crude oil wash. In the multi-stage compressor unit **414**, a first compressor **416** may increase the pressure of the vapor stream **412** from a pressure between about 280 KPa (about 40 psia) and about 480 KPa

(about 70 psia) up to a pressure between about 670 KPa (about 100 psia) and about 3500 KPa (about 500 psia). An inter-cooler **418** may be used to remove the heat of compression from the vapor stream, before it is fed to a second compressor **420**. The second compressor **420** may further increase the pressure to about 3500 KPa (about 500 psia) or higher, to produce a high pressure fuel gas **422** that can be combusted in the combustor **344**, as described with respect to Fig. 3. As for the system **300** in Fig. 3, a portion of the high-pressure fuel gas **422** can be sent to a pressure maintenance system **347** or recycled to the feed stream. Further, a portion may be combusted in a burner to heat the furnace heater **314**, instead of, or in addition to, the exhaust **358** from the gas turbine generator.

10 [0081] The process flow diagram of Fig. 4 is not intended to indicate that the system **400** is to include all of the components shown in Fig. 4. Further, any number of additional components may be included within the system **400**. For example, the system **400** may include any suitable types of heaters, chillers, condensers, pumps, compressors, other types of separation and/or fractionation equipment, valves, pumps, pressure-measuring devices, or temperature-measuring device, among others.

[0082] Fig. 5 is a process flow diagram **500** for a natural gas liquid recovery and stabilization unit that recovers hydrogen from the tail gas. Like numbered items are as described with respect to Fig. 3. Although similar to Fig. 3, Fig. 5 incorporates a hydrogen recovery system to separate hydrogen from the tail gas stream.

20 [0083] As discussed with respect to Fig. 3, a fuel gas stream **346** may be formed in a process that creates higher molecular weight hydrocarbons. The fuel gas stream **346** primarily includes methane, but may also include other gases, such as hydrogen formed in the reaction. The hydrogen may provide a useful feedstock, for example, to place a chemical plant near the site of the well. Accordingly, recovery of the hydrogen can increase the value of the products produced.

25 [0084] To recover the hydrogen, a portion of fuel gas stream **346** may be redirected to a hydrogen separation unit **502**, for example, based on membrane technology although any number of technologies may be used. A membrane separation provides a simpler technology, which is more suited to use in remote locations. A membrane separation is generally based on the difference between in permeation rates between the hydrogen and impurities across a gas-permeable membrane. Hydrogen, which has a higher permeability, may diffuse through the membrane from the high-pressure side to the low-pressure side. Before entering the hydrogen separation unit **502**, the fuel gas stream **346** may be cooled using an air cooler **504** to produce a cool gas stream **506**. A low-pressure, hydrogen-enriched stream **508** that may

30

be formed from the low-pressure side of the membrane may be compressed in a multi-stage compressor unit **510** to produce compressed hydrogen **512**. The compressed hydrogen **512** can be used at the site for chemical reactions, sold to market, or recombined with the fuel gas stream **346**, for example, to enhance the BTU content of the fuel gas. A hydrogen-depleted stream **514** may be mixed with the raw natural gas stream **302** for additional conversion within a reactor **308** or reinjected into the reservoir, as required.

[0085] The process flow diagram of Fig. 5 is not intended to indicate that the system **500** is to include all of the components shown in Fig. 5. Further, any number of additional components may be included within the system **500**. For example, the system **500** may include any suitable types of heaters, chillers, condensers, pumps, compressors, other types of separation and/or fractionation equipment, valves, pumps, pressure-measuring devices, or temperature-measuring device, among others.

[0086] Fig. 6 is a flow block diagram of a method **600** for producing an aromatic hydrocarbon. According to embodiments described herein, the method may produce an aromatic hydrocarbon and generate electricity from a tail gas stream.

[0087] The method **600** begins at block **602**, when a first stream including raw natural gas is fed into an aromatic reactor. At block **604**, the first stream is converted, at least in part, to a second stream including the aromatic hydrocarbon. At block **606**, the second stream is separated into a tail gas stream and a liquid aromatic hydrocarbon stream. At block **608**, at least a portion of the tail gas stream is burned in a gas turbine to generate electricity.

Simulations

[0088] Simulations were conducted to test the operation of the system described herein. The following Table 1 provides simulated data at various stages of the system for producing a higher molecular weight hydrocarbons product. In particular, the case studies included the flow rate, the volumetric flow, the molecular weight, and the composition of the reactor feed for the reactor feed, the liquid hydrocarbons product, the fuel gas, and the flare gas. Further, for various stages of the system, a particular catalyst was provided based on conversion rates measured against the varying flow rates, the volumetric flows, the molecular weights, and the compositions of the reactor feed.

[0089] As shown in Table 1, Case 1 and Case 2 represent the use of Catalyst 1 during simulation. Case 1 depicts separation of a tail gas stream from a liquid hydrocarbons stream using a liquid separator or a demethanizer. Conversely, Case 2 depicts separation of a tail gas stream from a liquids hydrocarbons stream using a crude wash column. Particularly, Figure 3 of the present disclosure illustrates Case 1 and Figure 4 of the present disclosure illustrates

Case 2.

[0090] Case 3 represents a simulation with little to no conversion using Catalyst 2. Moreover, Cases 4 and 5 depict conversion using Catalyst 3. Additionally, Figure 5 also illustrates Case 5 where recovered hydrogen is remixed with a fuel gas stream, where the
5 combined streams are feed to a gas turbine for power production.

[0091] While the present techniques may be susceptible to various modifications and alternative forms, the embodiments discussed above have been shown only by way of example. However, it should again be understood that the techniques is not intended to be limited to the particular embodiments disclosed herein. Indeed, the present techniques include
10 all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

[0092] Table 1: Simulations of Hydrocarbon Conversion

Case	1	2	3	4	5
	Catalyst 1	Catalyst 1	Catalyst 2	Catalyst 3	Catalyst 3
	Demethanizer	Crude Wash			Recycle
Reactor Feed					
Mass Rate (kg/hr)	74,886	74,886	74,886	55,333	131,988
Std. Vol. Flow (m3/hr)	58,994	58,994	58,994	58,994	146,304
Mol Weight (g/gmol)	30.07	30.07	30.07	22.22	21.27
Composition (mol%)					
<i>N2</i>	2.70	2.70	2.70	1.70	1.91
<i>CO2</i>	0.75	0.75	0.75	0.60	0.69
<i>H2</i>	0.00	0.00	0.00	0.00	1.92
<i>C1</i>	44.80	44.80	44.80	73.60	73.84
<i>C2</i>	23.10	23.10	23.10	13.80	12.86
<i>C3</i>	18.00	18.00	18.00	6.00	5.25
<i>C4</i>	7.30	7.30	7.30	2.60	2.14
<i>C5-C7</i>	3.35	3.35	3.35	1.70	1.38
Liquid Product					
Mass Rate (kg/hr)	35,101	33,461	35,975	22,378	50,846
Volume (m3/hr)	40.9	38.8	41.9	25.9	58.7
Mol Weight (g/gmol)	94.60	159.7	94.50	91.96	91.76
API	52.0	79.78	52.0	52.1	52.1
TVP (bara)	0.72	0.72	0.72	0.72	0.73
Composition (mol%)		Blended w/ Crude			
<i>C2</i>	0.52	0.89	0.54	0.66	0.65

Case	1	2	3	4	5
	Catalyst 1	Catalyst 1	Catalyst 2	Catalyst 3	Catalyst 3
<i>C3</i>	2.14	0.02	2.11	0.74	0.70
<i>C4</i>	1.07	0.78	1.05	0.40	0.36
<i>C5-C7</i>	1.52	0.97	1.48	1.01	0.89
<i>Benzene</i>	23.91	13.27	23.3	31.96	32.55
<i>Toluene</i>	23.19	12.74	25.06	31.35	31.90
<i>Ethylbenzene</i>	14.2	7.81	13.85	10.51	10.10
<i>O-xylene</i>	14.2	7.81	13.85	10.22	9.98
<i>P-xylene</i>	12.19	5.72	11.88	8.99	8.88
<i>1,3,5-Trimethylbenzene</i>	7.05	3.87	6.87	4.09	3.92
Fuel Gas					
Mass Rate (kg/hr)	39,628	41,294	38,759	32,905	59,686
Std. Vol. Flow (m3/hr)	83,771	82,591	83,771	75,512	155,743
Mol Weight (g/gmol)	11.24	11.76	10.90	10.28	9.06
Composition (mol%)					
<i>N2</i>	1.91	1.91	1.89	1.32	1.28
<i>CO2</i>	0.52	0.52	0.52	0.46	0.45
<i>H2</i>	52.84	50.97	55.06	51.70	58.33
<i>C1</i>	33.43	34.99	31.32	39.98	34.87
<i>C2</i>	7.37	7.33	7.31	4.95	3.91
<i>C3</i>	3.40	3.31	3.37	1.27	0.95
<i>C4</i>	0.40	0.37	0.40	0.17	0.12

Case	1	2	3	4	5
	Catalyst 1	Catalyst 1	Catalyst 2	Catalyst 3	Catalyst 3
<i>C5-C7</i>	0.08	0.50	0.08	0.06	0.04
<i>Benzene</i>	0.05	0.02	0.05	0.08	0.05
<i>Toluene</i>	0.0001	0	0.0002	0.0004	0.0002
Flare					
Mass Rate (kg/hr)	157	131	152	49	133
Mol Weight (g/gmol)	25.70	18.89	25.63	18.92	19.46
Composition (mol%)					
<i>N2</i>	0.58	1.31	0.61	0.70	0.74
<i>CO2</i>	2.89	1.14	2.96	1.16	1.45
<i>H2</i>	5.44		6.05	10.24	9.77
<i>C1</i>	38.77	67.26	38.00	71.16	70.1
<i>C2</i>	41.18	12.42	41.34	11.49	12.14
<i>C3</i>	8.86	4.67	8.75	2.88	3.00
<i>C4</i>	0.96	0.57	0.95	0.42	0.42
<i>C5-C7</i>	0.23	0.12	0.23	0.16	0.16
<i>Benzene</i>	0.79	0.67	0.79	1.35	1.63
<i>Toluene</i>	0.20	0.16	0.22	0.36	0.45

CLAIMS

What is claimed is:

1. An integrated method for co-producing liquid hydrocarbons and power, including:
producing a first stream including methane;
5 reacting the first stream in a reactor to form a second stream having at least a portion
of the methane converted to a higher molecular weight hydrocarbon;
separating the second stream into a tail stream that is enriched in methane and a
product stream enriched in the higher molecular weight hydrocarbon; and
combusting at least a portion of the tail stream to generate power.
- 10 2. The method of claim 1, including:
producing the first stream from a production system including a well-head, a water
separation vessel, or a gas/oil separation vessel, or any combinations thereof; and
flowing the first stream from the production system to the reactor.
- 15 3. The method of claim 1-2, including generating electrical power from the combustion
and at least one of:
using at least a portion of the electrical power to run the production system; or
providing at least a portion of the electrical power to an electrical grid in local to the
production system.
- 20 4. The method of claim 3, comprising:
condensing a portion of the first stream prior introducing the first stream to the reactor
to create a liquid stream and a gas stream, wherein the gas stream comprises methane; and
vaporizing the liquid stream;
feeding the vaporized liquid stream to the reactor;
wherein reacting the first stream comprises reacting the vaporized liquid stream.
- 25 5. The method of claim 4, comprising reinjecting the gas stream into the ground.
6. The method of claim 4, comprising using the condensing step to control a
composition of the tail stream.
7. The method of claim 1-5, comprising contacting the tail stream with a crude oil to
remove at least a portion of the higher molecular weight hydrocarbon from the second
30 stream; and
including producing the crude oil as a mixture with the higher molecular weight
hydrocarbon.
8. The method of claim 1-7, including maintaining pressure in a reservoir by re-injecting

- at least a portion of the tail stream.
9. The method of claim 1-8, including injecting at least a portion of the tail stream into the first stream as a diluent to lower coke formation within the reactor.
10. The method of claim 1-9, including heating the first stream with an exhaust heat from the combustion of the tail stream.
11. The method of claim 1-10, including combusting the tail stream to directly heat the reactor.
12. The method of claim 1-11, including treating the tail stream in a gas treatment system before it is combusted.
13. The method of claim 1-12, including compressing the tail stream and sending the compressed tail stream to a distillation column, wherein the compressed tail stream may include methane (CH_4), ethane (C_2H_6), carbon dioxide, carbon monoxide, hydrogen sulfide, nitrogen, hydrogen, or in any combination thereof.
14. The method of claim 1-13, including stabilizing the product stream.
15. The method of claim 1-14, including transporting the product stream to market by tanker truck.
16. A system for producing liquid hydrocarbons from a first stream including methane and generating power, including:
- a reactor configured to convert the first stream into a second stream having at least a portion of the methane in the first stream converted to a higher molecular weight hydrocarbon;
- a separation vessel configured to separate the second stream into a tail gas stream and a liquid hydrocarbon stream; and
- a combustor to combust the tail gas stream to generate power.
17. The system of claim 16, wherein the first stream is substantially unpurified.
18. The system of claim 16-17, wherein at least a portion of organic sulfur compounds in the first stream are converted to hydrogen sulfide in the reactor.
19. The system of claim 16-18, wherein the first stream contains greater than about 0.25 wt. % of organic sulfur.
20. The system of claim 16-19, wherein the higher molecular weight hydrocarbon includes a C_6 to C_9 aromatic compound.
21. The system of claim 16-20, including a pressure maintenance system to increase a pressure in a reservoir using a portion of the tail gas stream.
22. The system of claim 16-21, wherein the reactor includes a fixed-bed catalyst reactor

or a fluidized bed reactor configured to convert at least a portion of the first stream into the second stream.

23. The system of claim 16-22, wherein a catalyst for the reactor may include metal modified molecular sieve-based catalysts.

5 24. The system of claim 16-23, including a crude wash column to remove hydrocarbons from the tail gas stream to form a liquid product, wherein the liquid product is combined with the second stream.

25. The system of claim 16-24, including a gas treatment system to treat the tail gas stream before entering the combustor.

10 26. The system of claim 16-25, including a stabilizer to remove lower molecular weight hydrocarbons from the second stream.

27. The system of claim 16-26, including transportation facilities to transport the liquid hydrocarbons stream to on-site tankers, pipelines, or any combinations thereof.

28. An integrated method for producing an aromatic hydrocarbon and generating
15 electricity from a tail gas stream, the method including:

feeding a first stream including raw natural gas into an aromatic reactor;

converting the first stream, at least in part, to a second stream including the aromatic hydrocarbon;

20 separating the second stream into the tail gas stream and a liquid aromatic hydrocarbon stream; and

burning at least a portion of the tail gas stream in a gas turbine to generate the electricity.

29. The method of claim 28, wherein the first stream includes methane, C₂-C₅⁺ hydrocarbons, CO, CO₂, N₂, H₂S, organic sulfur compounds, or any combinations thereof.

25 30. The method of claim 28-29, including drying the first stream using a solvent or a molecular sieve.

31. The method of claim 28-30, wherein the second stream includes C₆ to C₉ aromatics.

32. The method of claim 28-31, including increasing the pressure of the flow of the first stream into the aromatic reactor by implementing a pressure maintenance system.

30 33. The method of claim 28-32, wherein components in the first stream are converted at a temperature range from about 750 °F to 1200 °F.

34. The method of claim 28-33, including heating the first stream with an exhaust heat from the burning of the portion of the tail gas stream either in a gas turbine or in a furnace.

35. The method of claim 28-34, including heating a cooling fluid return with an exhaust

from the burning of the portion of the tail gas stream either in a gas turbine or in a furnace.

36. The method of claim 28-35, including compressing and sending the tail gas stream to a distillation column, wherein a compressed tail gas stream may include methane (CH_4), ethane (C_2H_6), carbon dioxide, carbon monoxide, hydrogen sulfide, nitrogen, hydrogen, or in
5 any combination thereof.

37. The method of claim 28-36, including treating the tail gas stream in a gas treatment system before entering the gas turbine.

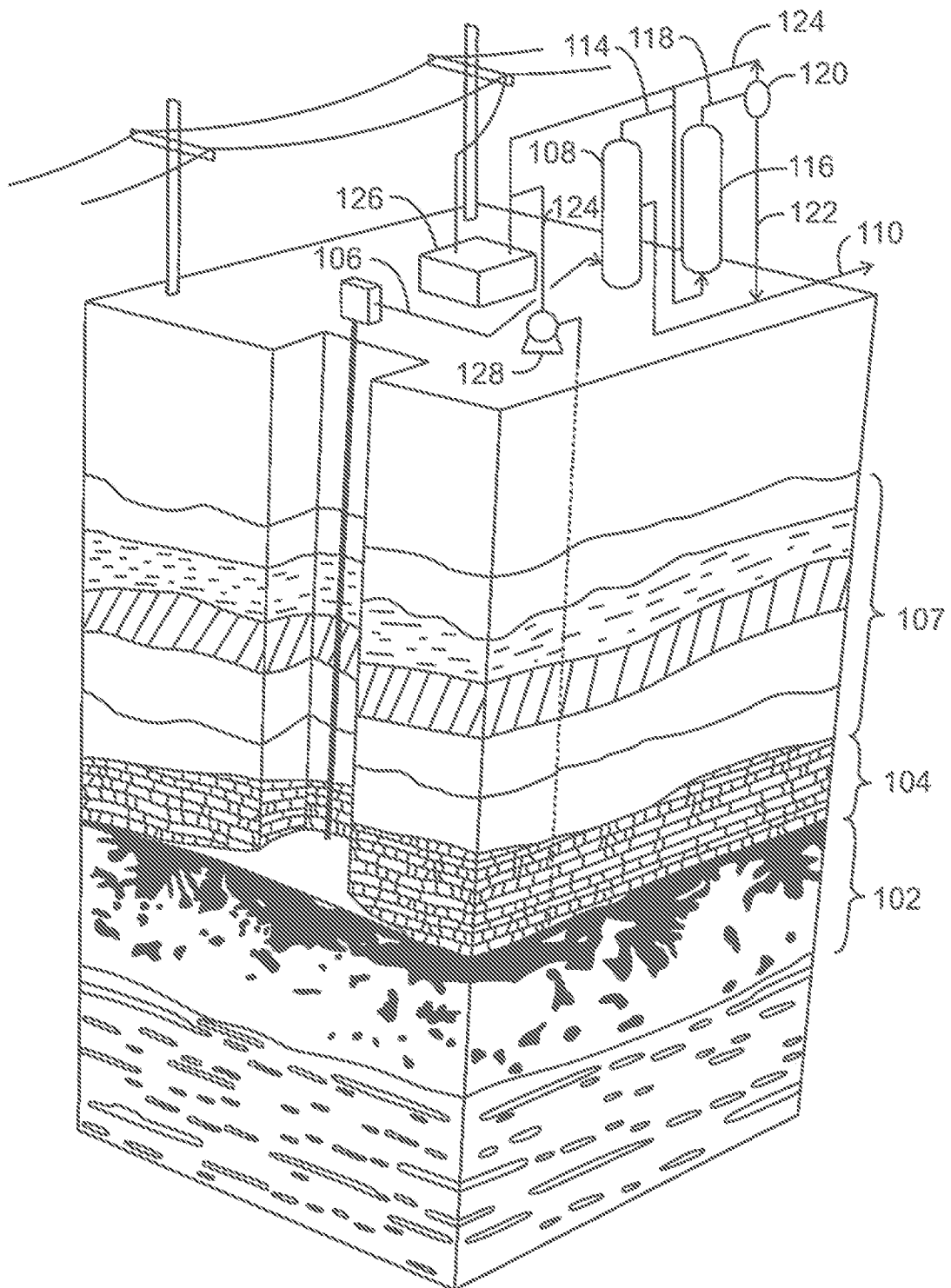
38. The method of claim 28-37, including flowing the tail gas stream to a crude wash column, wherein liquids in the tail gas stream are solubilized with a crude oil wash and
10 recovered as a liquid product, wherein the liquid product is combined with the liquid aromatic hydrocarbon stream.

39. The method of claim 28-38, including recycling at least a portion of the tail gas stream into the aromatic reactor as a diluent.

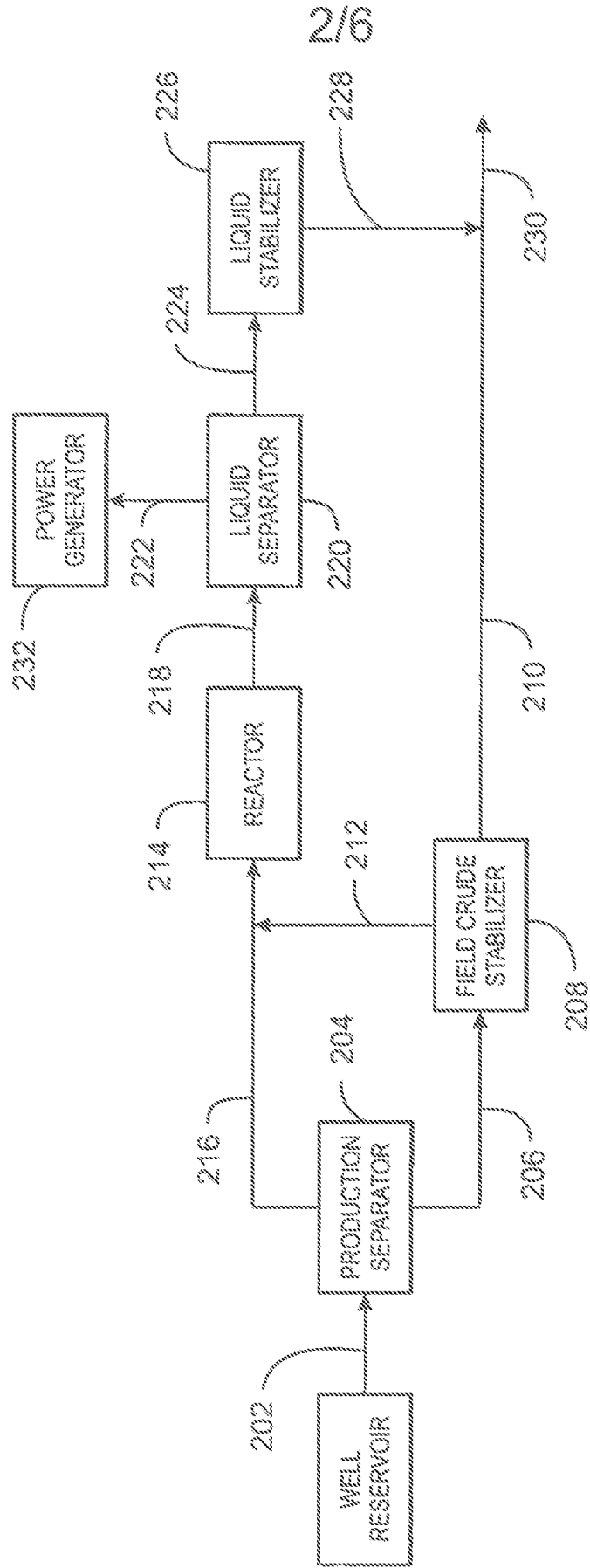
40. The method of claim 28-39, including stabilizing the liquid aromatic hydrocarbon
15 stream by lowering the pressure of the liquid aromatic hydrocarbon stream to remove non-valuable hydrocarbons as vapor.

41. The method of claim 28-40, including transporting the liquid aromatic hydrocarbon stream to market as a neat product.

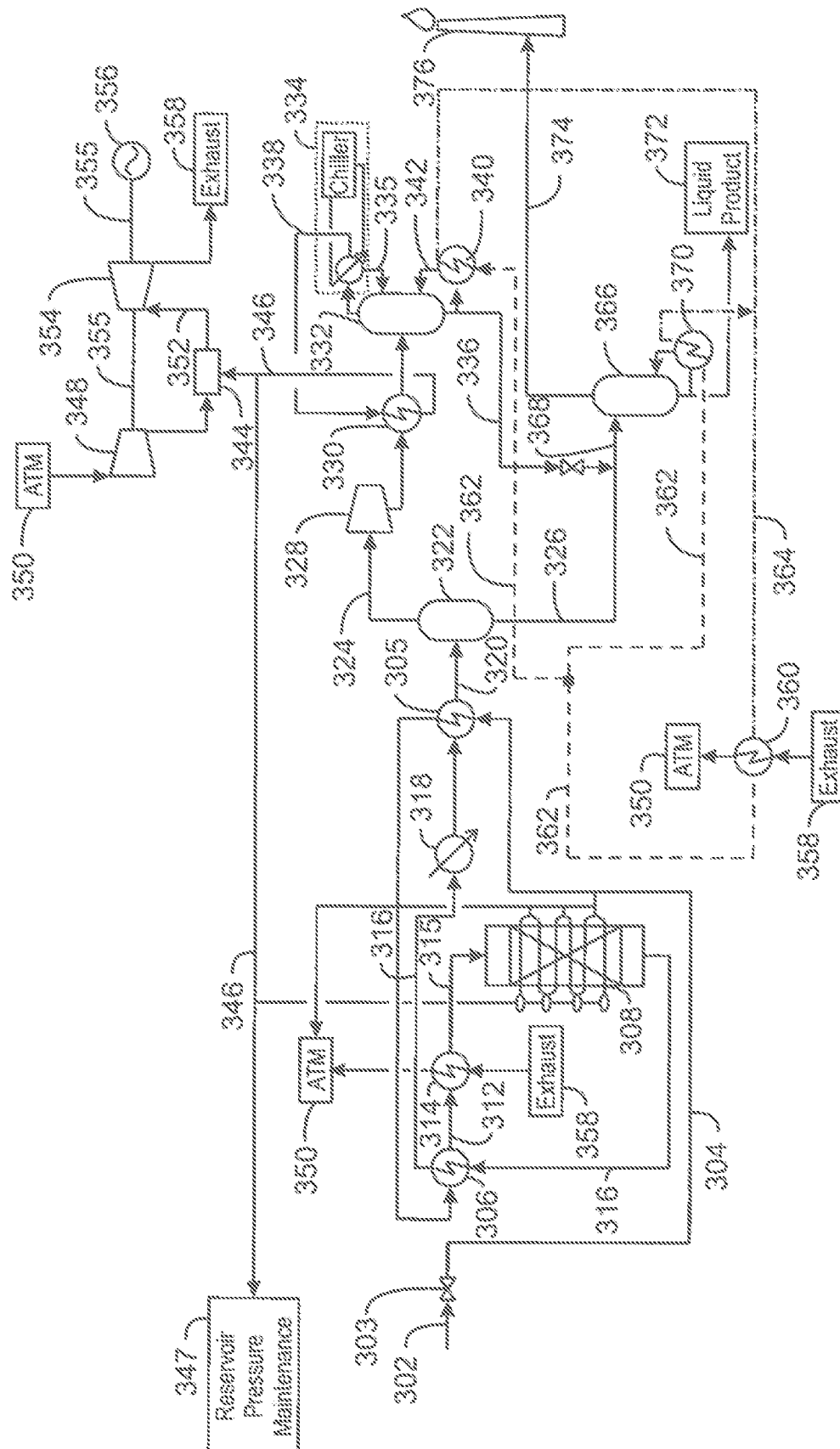
16



100
FIG. 1



200
FIG. 2



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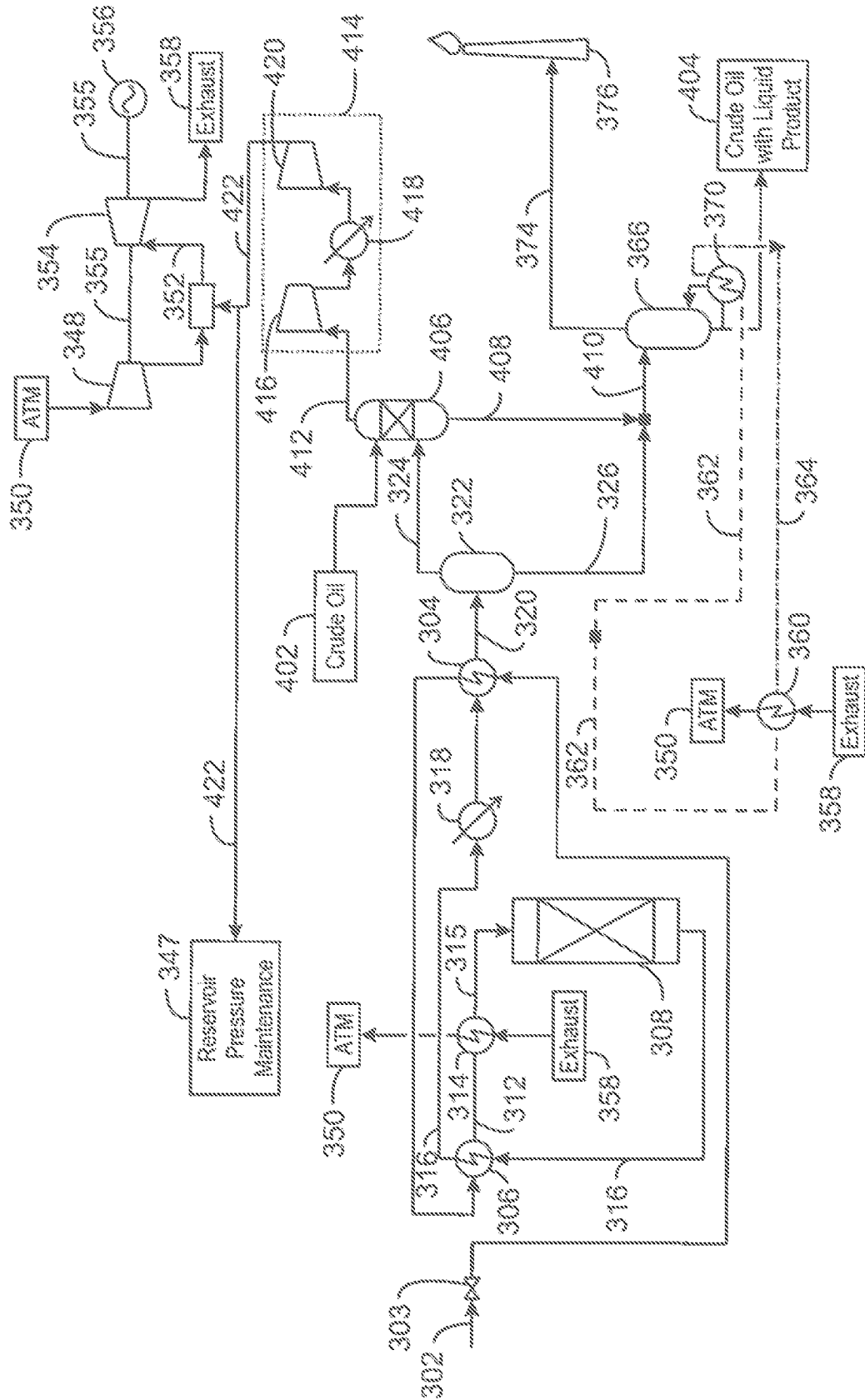


FIG. 4

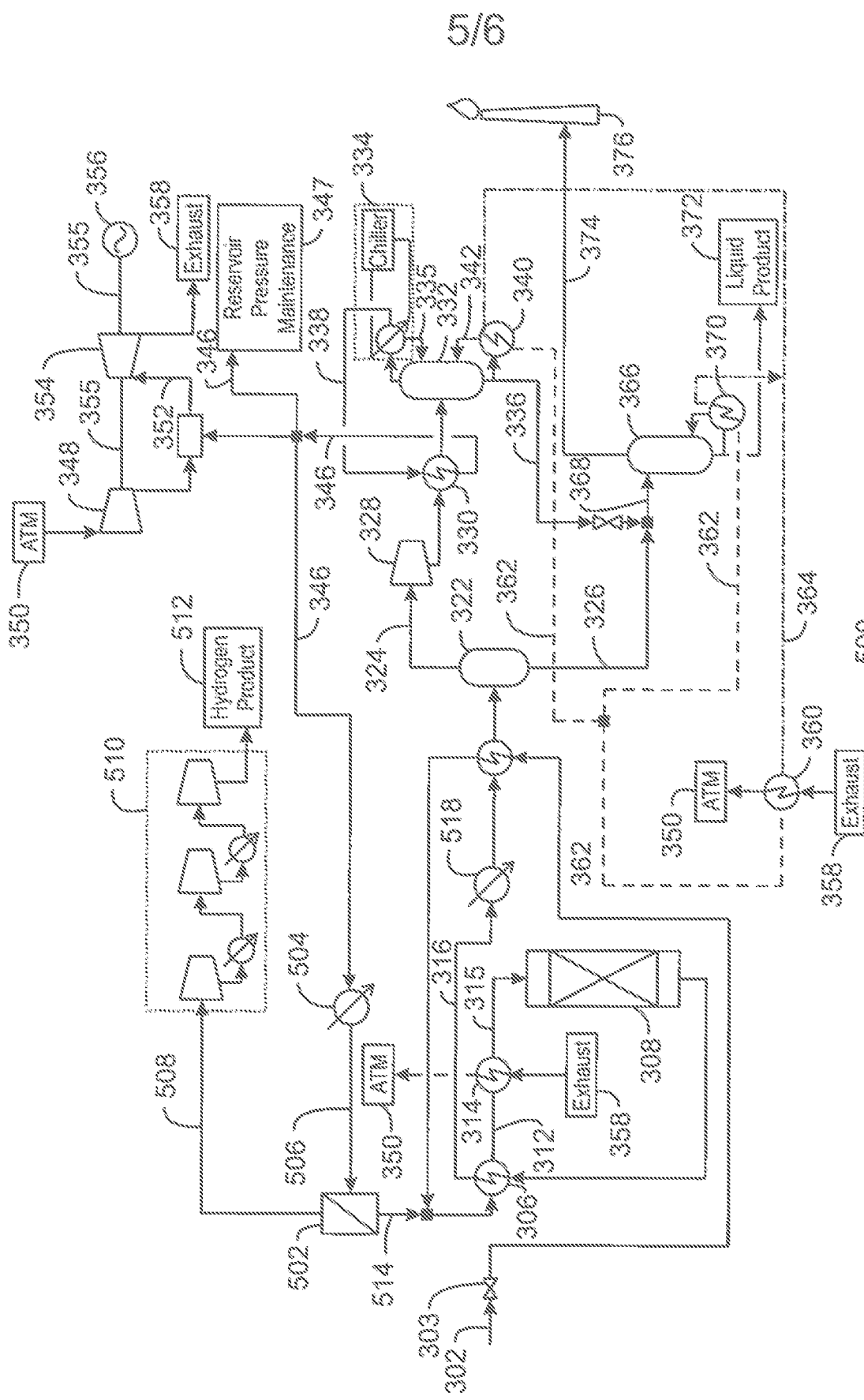
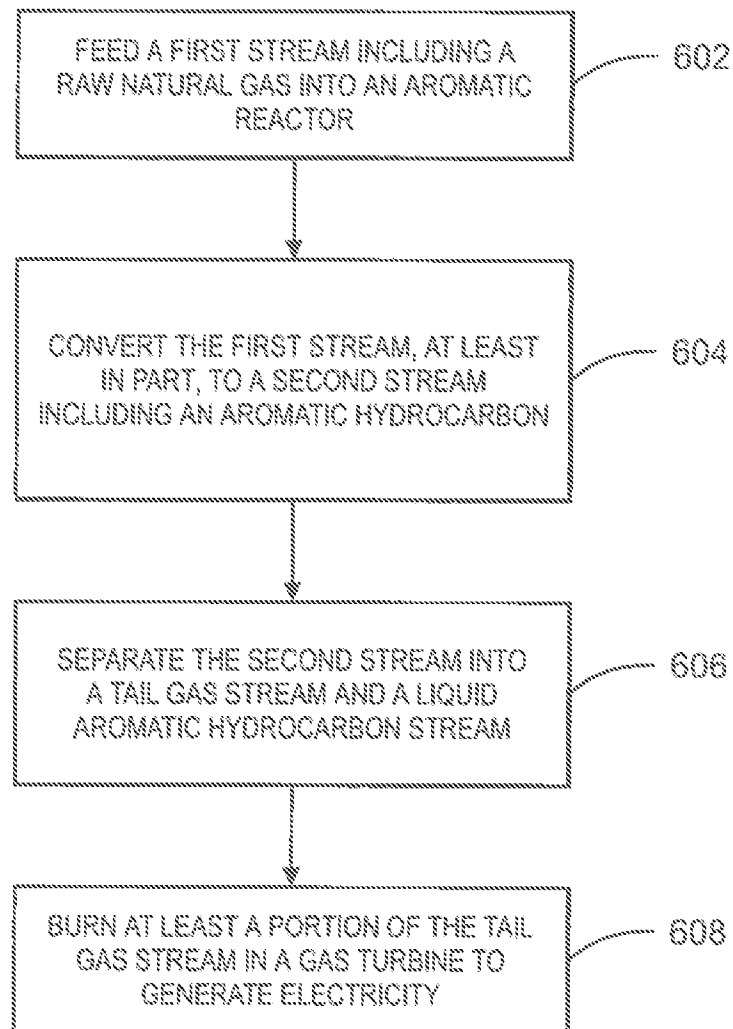


FIG. 5

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6/6



600
FIG. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2014/063718

A. CLASSIFICATION OF SUBJECT MATTER

INV. C10G50/00 C07C2/00 C07C15/00
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)

C10G C07C

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)

EP0-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	EP 1 106 788 A1 (ABB RESEARCH LTD [CH]) 13 June 2001 (2001-06-13) paragraphs [0053], [0054]; claim 1; figure 1 -----	1-27
X	EP 2 184 269 A1 (MITSUI CHEMICALS INC [JP]; AGENCY SCIENCE TECH & RES [SG]) 12 May 2010 (2010-05-12) paragraph [0070]; claim 1 -----	1-27
X	US 2010/256245 A1 (IACCINO LARRY L [US] ET AL) 7 October 2010 (2010-10-07) claim 1; figure 4 -----	1-27
X	GB 2 191 212 A (BRITISH PETROLEUM CO PLC BRITISH PETROLEUM CO PLC [GB]) 9 December 1987 (1987-12-09) claim 1; figure 1 ----- -/-	1-17

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

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

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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

"&" document member of the same patent family

Date of the actual completion of the international search

26 January 2015

Date of mailing of the international search report

13/04/2015

Name and mailing address of the ISA/

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Authorized officer

Deurinck, Patricia

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/063718

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>US 2007/129587 A1 (IACCINO LARRY L [US] ET AL) 7 June 2007 (2007-06-07) paragraphs [0075], [0092], [0093]; claim 1</p> <p>-----</p>	1-27

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/063718

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-27

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-27

an integrated method and system for co-producing liquid hydrocarbons and power

2. claims: 28-41

An integrated method for producing an aromatic hydrocarbon and generating electricity from a tail gas stream

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2014/063718

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		WO 2007067285 A1	14-06-2007
