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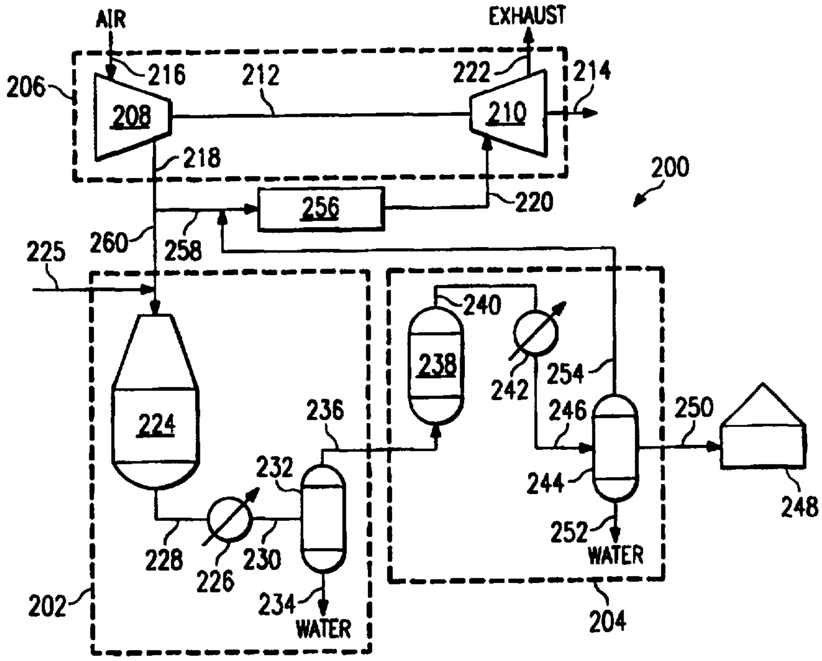
(54) **Title:** TURBINE-POWERED, SYNTHESIS-GAS SYSTEM AND METHOD

(57) **Abstract**

A turbine-powered, synthesis-gas system and method include a gas turbine (206) having a synthesis gas production unit (202) and a synthesis unit (204) disposed between the compression section (208) and expansion-turbine section (210) of the turbine (206). Additionally, a booster compressor may be added between the synthesis gas production unit and the synthesis unit. Also, a compressor may be added after the synthesis production unit and the gas turbine.



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TURBINE-POWERED, SYNTHESIS-GAS SYSTEM AND METHOD

TECHNICAL FIELD OF THE INVENTION

The present invention relates to an improved process and system for the production of heavier hydrocarbons from lighter hydrocarbons, and more particularly to turbine-powered, synthesis-gas system and method.

BACKGROUND OF THE INVENTION

The synthetic production of hydrocarbons by the catalytic reaction of carbon monoxide and hydrogen is well known and is generally referred to as the Fischer-Tropsch reaction. Numerous catalysts have been used in carrying out the reaction, and at relatively low to medium pressure (near atmospheric to 600 psig) and temperatures in the range of from about 300° F. to 600° F., both saturated and unsaturated hydrocarbons can be produced. The synthesis reaction is very exothermic and temperature sensitive whereby temperature control is required to maintain a desired hydrocarbon product selectivity. The Fischer-Tropsch reaction can be characterized by the following general reaction:

$$2H_2 + CO \xrightarrow[\text{Catalyst}]{} -CH_2^- + H_2O$$

Two basic methods have been employed for producing ("syngas") the synthesis gas utilized as feedstock in the Fischer-Tropsch reaction. The two methods are steam reforming, wherein one or more light hydrocarbons such as methane are reacted with steam over a catalyst to form carbon monoxide and hydrogen, and partial oxidation, wherein one or more light hydrocarbons are combusted sub-stoichiometrically to produce synthesis gas.

The basic steam reforming reaction of methane is represented by the following formula:

$$CH_4 + H_2O \xrightarrow[\text{Catalyst}]{} CO + 3H_2$$

The steam reforming reaction is endothermic and a catalyst containing nickel is often utilized.

Partial oxidation is the non-catalytic, sub-stoichiometric combustion of light hydrocarbons such as methane to produce the synthesis gas. The basic reaction is represented as follows:

$$CH_4 + \frac{1}{2} O_2 \rightarrow CO + 2H_2$$

The partial oxidation reaction is typically carried out using high purity oxygen. High purity oxygen, however, can be quite expensive.

In some situations these approaches may be combined. A combination of partial oxidation and steam reforming, known as autothermal reforming, wherein air is used as a source of oxygen for the partial oxidation reaction has also been used for producing synthesis gas heretofore. For example, U.S. Patents 2,552,308 and 2,686,195 disclose low pressure hydrocarbon synthesis processes wherein autothermal reforming with air is utilized to produce synthesis gas for the Fischer-Tropsch reaction. Autothermal reforming is a simple combination of partial oxidation and steam reforming where the exothermic heat of the partial oxidation supplies the necessary heat for the endothermic steam reforming reaction. The autothermal reforming process can be carried out in a relatively inexpensive refractory lined carbon steel vessel whereby low cost is typically involved.

The autothermal process results in a lower hydrogen to carbon monoxide ratio in the synthesis gas than does steam reforming alone. That is, the steam reforming reaction with methane results in a ratio of about 3:1

while the partial oxidation of methane results in a ratio of about 2:1. A good ratio for the hydrocarbon synthesis reaction carried out at low or medium pressure over a cobalt catalyst is 2:1. When the feed to the autothermal reforming process is a mixture of light hydrocarbons such as a natural gas stream, some form of additional control is required to maintain the ratio of hydrogen to carbon monoxide in the synthesis gas at the optimum ratio of about 2:1.

For the Fischer-Tropsch process to become widely used will require efficient conversion techniques. Efforts have been made toward that end. See U.S. Patents 4,883,170 and 4,973,453, which are assigned to the owner of this application and which are incorporated by reference herein for all purposes.

SUMMARY OF THE INVENTION

Therefore, a need has arisen for a turbine-power synthesis-gas system and method that address disadvantages and problems associated with previously-developed systems and methods. According to an aspect of the present invention, a synthesis gas production unit and synthesizing unit are disposed between the compression section and turbine expansion section of a gas turbine. According to another aspect of the present invention, a synthesis gas production unit and synthesizing unit are disposed between the compression section and turbine expansion section of a gas turbine with an additional compressor disposed after the synthesis gas production unit and before a synthesizing reactor.

A technical advantage of the present invention is that it allows for a self-powered, low-pressure synthesis gas production unit to be produced in a cost-effective manner. Another technical advantage of the present invention is that a system and method are provided that provide a self-powered, low-pressure synthesis gas production unit with a relatively-high-pressure synthesizing unit.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings in which like reference numbers indicate like features, and wherein:

FIGURE 1 is a schematic representation of a process flow in which the present invention is particularly well suited;

FIGURE 2 is a schematic representation of a process flow showing an aspect of the present invention;

FIGURE 3 is a schematic representation of a process flow showing an aspect of the present invention; and

FIGURE 4 is a schematic representation of a process flow showing an aspect of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The preferred embodiment of the present invention and its advantages are best understood by referring to FIGURES 1-4 of the drawings, like numerals being used for like and corresponding parts of the various drawings.

A. INTRODUCTION

The present invention is applicable in process flows involving the production of a synthesis gas and synthesizing to produce methanol, DME, gasoline, or numerous other substances. The invention is believed to be particularly well suited for inclusion in a Fischer-

Tropsch process, and for illustration purposes, the invention is presented in that context although it is to be understood its application is broader. A process flow in which the invention may be incorporated is first presented, and then a few specific embodiments are described.

B. THE CONVERSION OF HEAVIER HYDROCARBONS FROM GASEOUS LIGHT HYDROCARBONS.

Referring now to FIGURE 1, a continuous stream of normally gaseous light hydrocarbons (e.g., gaseous at atmosphereic pressure and 70 degrees Fahrenheit) conducted to a heat exchanger 10 of a conduit 12. The gasesous light hydrocarbons may be, for example, a natural gas stream. While flowing through the heat exchanger 10, the stream of light hydrocarbons is heated by exchange of heat with a process stream of generated synthesis gas that, as will be described below, comes from reactor 28. Typically, the feed stream of light hydrocarbons is at a pressure in the range of from near atmospheric pressure to 600 psig and is heated in the heat exchanger 10 to a temperature in the range of from about 500° F. to about 1000° F. From the heat exchanger 10, the preheated feed stream is conducted by a conduit 14 to a synthesis gas generator 16.

Air is drawn into an air compressor 18 by way of an inlet conduit 20, and from the compressor 18, a stream of air is conducted to a heat exchanger 22 by a conduit 21. The stream of air is preheated in the heat exchanger 22 to a temperature in the range of from about 500° F. to about 1000° F. by exchange of heat with the synthesis gas stream exiting the heat exchanger 10. From the heat exchanger 22, the preheated air is conducted to the synthesis gas generator 16 by a conduit 24.

While the synthesis gas generator 16 can take various forms, it generally includes a burner 26 connected to one end of a reactor vessel 28. A bed of steam reforming catalyst 30, which typically contains nickel, is disposed within the reactor 28 at the end opposite the burner 26.

In this embodiment, the reactor 28 is a refractory lined carbon steel vessel. Steam or water, which instantly converts to steam, is introduced into the reactor 28 by way of a conduit 32 connected thereto, and optionally carbon dioxide may be introduced into the reactor 28 by way of a conduit 34 connected thereto.

In the operation of the synthesis gas generator 16, the preheated feed stream of gaseous light hydrocarbons from conduit 14 is thoroughly mixed with a preheated stream of air from conduit 24 in the burner 26 and ignited whereby the combustion reaction takes place within the reactor 28. The combustion reaction is carried out at a temperature in the range of from about 2000° F. to about 3000° F. under sub-stoichiometric conditions whereby the light hydrocarbons are partially oxidized. A gas stream including nitrogen, unreacted light hydrocarbons, hydrogen and carbon monoxide is produced.

The unreacted light hydrocarbons in the combustion gas stream react with steam introduced into the reactor 28 in the presence of the reforming catalyst whereby additional hydrogen and carbon monoxide are produced therefrom. Simultaneously, carbon dioxide may be introduced into the reactor 28 to react with unreacted light hydrocarbons to produce additional carbon monoxide and hydrogen. The resulting synthesis gas stream generated within the generator 16 includes hydrogen, carbon monoxide, carbon dioxide, nitrogen and unreacted light hydrocarbons. The synthesis gas exits the reactor 28 by way of a conduit 36.

In order to control the ratio of hydrogen to carbon monoxide in the synthesis gas stream produced in the synthesis gas generator 16 at a ratio preferably close to 2:1, the rates of water introduced into the reactor 28 by way of the conduit 32 and carbon dioxide introduced by way of the conduit 34 are varied. That is, the ratio of hydrogen to carbon monoxide in the produced synthesis gas stream, or the composition of the feed light hydrocarbon stream, or both, are monitored and used as the basis for changing the flow rates of steam and carbon dioxide to the reactor 28 whereby a constant ratio of hydrogen to carbon monoxide preferably at about 2:1 is maintained in the existing synthesis gas.

The synthesis gas product stream produced in the generator 16 is conducted by the conduit 36 through the heat exchanger 10, then through the heat exchanger 22 and then to the inlet connection of a first hydrocarbon synthesis reactor 38. Upon exiting the generator 16, the synthesis gas is at a temperature in the range of from about 1000° F. to about 2000° F. As the synthesis gas stream flows through the heat exchanger 10 on conduit 36, it gives up heat to the feed light hydrocarbon stream. The light hydrocarbon stream in conduit 14 is preheated to a temperature in the range of from about 500° F. to about 1000° F. In a like manner, as the synthesis gas stream flows through the heat exchanger 22 on conduit 36, it gives up heat to the air flowing to the generator 16 through conduit 24 whereby the air is also preheated to a temperature in the range of from about 500° F. to about 1000° F. Additional cooling of the synthesis gas stream is provided by a cooler or heat exchanger 23 disposed in the conduit 36 whereby the temperature of the synthesis gas entering the reactor 38 is then in the range of from about 350° F. to about 550° F.

In the hydrocarbon synthesis case, reactor 38 can take various forms, but in the embodiment shown, it is a tubular reactor containing a fixed bed 37 of hydrocarbon synthesis catalyst. The catalyst of bed 37 may be of cobalt that is supported on silica, alumina or silica-alumina material in an amount in the range of from about five to about fifty parts by weight of cobalt per 100 parts by weight of the support material. The catalyst may also contain in the range of from about 0.05 to about 1 parts by weight of ruthenium per 100 parts by weight of support material as a promoter.

The synthesis gas stream flows into and through the reactor 38. The gas is delivered to reactor 38 by conduit 36 and carried on its way by conduit 40. As mentioned above, the temperature within the reactor 38 is in the range of from about 350° F. to about 550° F., and upon contact with the catalyst, hydrogen and carbon monoxide in the synthesis gas stream react to form heavier hydrocarbons and water.

The product stream produced in the reactor 38 exits the reactor by way of a conduit 40 connected thereto. Conduit 40 leads the stream to a condenser 42. While flowing through the condenser 42, the heavier hydrocarbons and water contained in the stream are condensed. From the condenser 42, a conduit 44 conducts the stream containing condensed components to a separator 46 wherein the condensed heavier hydrocarbons and water are separated and separately withdrawn. That is, the condensed water is withdrawn from the separator 46 by way of a conduit 48 connected thereto, and the condensed heavier hydrocarbons are withdrawn from the separator 46 by way of a conduit 50 connected thereto.

A residue gas stream from the separator 46 includes nitrogen and unreacted hydrogen, carbon monoxide, light hydrocarbons and carbon dioxide. A conduit 52 connected to the separator 46 leads the residue gas stream from the separator 46 to a second hydrocarbon synthesis reactor 54 containing a fixed bed 56 of a hydrocarbon synthesis catalyst, such as the one described above. The pressure and temperature of the gas stream flowing through the reactor 54 are maintained at approximately the same levels as the pressure and temperature within the reactor 38 by means of a heater or heat exchanger 58 disposed in the conduit 52 between the separator 46 and reactor 54. While flowing through the reactor 54, additional heavier hydrocarbons are formed from hydrogen and carbon monoxide in the residue gas stream and the resulting product stream exits the reactor 54 by way of a conduit 60 connected thereto. The conduit 60 leads the stream to a condenser 62 wherein heavier hydrocarbons and water contained therein are condensed. From the condenser 62, the stream containing condensed components is conducted to a chiller 66 of a refrigeration unit by a conduit 64 wherein additional hydrocarbons and water are condensed. The resulting stream is conducted from the chiller 66 to a separator 70 by a conduit 68 connected therebetween. Separator 70 will have water, heavier hydrocarbons, and residue gas exit through three conduits 72, 74, 86, respectively.

Water is withdrawn from the separator 70 by a conduit 72 connected thereto. The conduit 72 is in turn connected by way of conventional valves and controls (not shown) to the conduit 48, to a drain conduit 31 and to the conduit 32 previously described whereby all or part of the condensed water separated in the separators 46 and

70 is selectively conducted to the synthesis gas generator 16.

The condensed heavier hydrocarbons separated within the separator 70 are withdrawn therefrom by a conduit 74 which connects to the conduit 50 from the separator 46. The conduit 50 leads the heavier hydrocarbons from both the separators 46 and 70 to a conventional fractionation unit 76. A hydrocarbon product stream containing selected components is withdrawn from the fractionation unit 76 by way of a conduit 78 which conducts the product stream to storage or other location. The product stream includes heavier hydrocarbons, which are liquid or solid at standard tempterature and pressure (e.g., 14.7 psia and 70 degrees Fahrenheit). Undesirable light and heavy hydrocarbon fractions produced in the fractionation unit 76 are withdrawn therefrom by conduits 80 and 82, respectively. The conduits 80 and 82 connect to a conduit 84 which conducts the undesirable hydrocarbons to the inlet conduit 12 where they mix with the feed stream of gaseous light hydrocarbons and are recycled.

The residue gas stream produced in the separator 70, which may include nitrogen and unreacted hydrogen, carbon monoxide, light hydrocarbons and carbon dioxide, is withdrawn therefrom by a conduit 86 which leads the residue gas stream to a catalytic combustor 88. The catalytic combustor 88 may include a burner 90 into which the residue gas stream is conducted.

A stream of air is conducted to the burner 90 by a conduit 92 connected to the discharge of an air blower 94. The residue gas stream from the separator 70 and the air conducted to the burner 90 are thoroughly mixed therein, ignited and discharged into a reactor 96 connected to the burner 90.

The reactor 96 contains a fixed bed of suitable novel metal containing catalyst 98, e.g., platinum or palladium, for promoting and catalyzing the oxidation of the oxidizable components in the residue gas stream. As a result of such oxidation an oxidation product stream including carbon dioxide, water vapor and nitrogen is produced and withdrawn from the combustor 88 by a conduit 100 connected thereto. Conduit 100 optionally leads the product stream to a conventional carbon dioxide removal unit 102. Carbon dioxide and water are removed from the stream by the carbon dioxide removal unit 102 thereby producing a relatively pure nitrogen product stream which is conducted from the unit 102 by a conduit 104 to a location of sale, storage or further processing.

The carbon dioxide removed by the unit 102 is withdrawn therefrom by a conduit 106 which leads the carbon dioxide to a compressor 108. The discharge of the compressor 108 is connected by way of conventional valves and controls (not shown) to a vent 35 and to the conduit 34 previously described whereby all or part of the carbon dioxide is selectively introduced into the synthesis gas generator 16.

As previously described, the flow rates of the water conducted to the synthesis gas generator 16 by way of the conduit 32 and carbon dioxide conducted thereto by way of the conduit 34 are varied as is necessary to control the ratio of hydrogen to carbon monoxide in the synthesis gas stream produced to preferably a 2:1 ratio. This in turn improves the efficiency of the hydrocarbon synthesis reactions carried out in the reactors 38 and 54. Further, the use of air, delivered by conduit 24, in the synthesis gas generator 16 as the source of oxygen for the partial oxidation reaction carried out therein produces nitrogen in the synthesis gas stream. Such nitrogen acts as a diluent in the hydrocarbon synthesis reactors 38 and 54 and prevents hot spots on the catalyst and further increases the efficiency of the hydrocarbon synthesis reactions. The nitrogen together with the additional nitrogen produced in the catalytic combustor 88, after carbon dioxide removal, forms a relatively pure nitrogen product stream. In addition, the recycling of all or part of the optional carbon dioxide, which is transported in conduit 106 provides additional carbon for producing heavier hydrocarbons and increases overall process efficiency.

As an important aspect of the present invention, the system of FIGURE 1 could be redesigned to include a gas turbine as will be further described below. As an example of one way the system of FIGURE 1 could be redesigned, catalytic combustor 88, the burner 90, the blower 94, and air compressor 18 may be removed and replaced with a gas turbine. The gas turbine could include a combustor to burn the gas and the compressor section of the gas turbine could provide combustion air as blower 94 previously did and compressed air as compressor 18 previously did. Other examples will be given further below.

C. GAS TURBINE ENHANCEMENTS

Referring now to FIGURE 2, advantages may be obtained for a system 200 by combining a synthesis gas unit 202 with a synthesis unit 204 and a gas turbine 206. System 200 uses gas turbine 206 to provide power for the process at a minimum, but may be designed to provide at least some additional power.

Gas turbine 206 has a compressor section 208 and an expansion turbine section 210. The power generated by the expansion turbine section 210 drives the compressor section 208 by means of linkage 212, which may be a shaft, and any excess power beyond the requirements of compressor section 208 may be used to generate electricity or drive other equipment as figuratively shown by output 214. Compressor section 208 has inlet or conduit 216, where in the embodiment shown compressor 208 receives air. Compressor section 208 also has an outlet or conduit 218 for releasing compressed air. Outlet 218 of compressor section 208 provides compressed air to synthesis gas unit 202 through conduit 260. Expansion turbine 210 has inlet or conduit 220 and outlet or conduit 222.

Synthesis gas unit 202 may take a number of configurations, but in the specific embodiment shown, includes syngas reactor 224, which as shown here may be an autothermal reforming reactor. A stream of gaseous light hydrocarbons, e.g., a natural gas stream, is delivered to syngas reactor 224 by inlet or conduit 225. In some instances it may be desirable to use natural gas containing elevated levels of components, i.e., N_2, CO_2 He, etc. that reduce the BTU value of the gas in conduit 225. The synthesis gas unit 202 may also include one or more heat exchangers 226, which in the embodiment shown is a cooler for reducing the temperature of the synthesis gas exiting outlet 228 of syngas reactor 224. Heat exchanger 226 delivers its output to inlet 230 of separator 232. Separator 232 removes moisture which is delivered to outlet 234. It may be desirable in some instances to introduce the water in conduit 234 as steam to expansion turbine 210. Synthesis gas exits separator 232 through outlet or conduit 236. The synthesis gas exiting through outlet 236 is delivered to synthesis unit 204.

Synthesis unit 204 may be used to synthesize a number of materials as previously mentioned, but in the specific example here is used to synthesize heavier hydrocarbons as referenced in connection with FIGURE 1. Synthesis unit 204 includes Fischer-Tropsch reactor 238, which contains an appropriate catalyst. The output of Fischer-Tropsch reactor 238 is delivered to outlet 240 from which it travels to heat exchanger 242 and on to separator 244.

The product entering separator 244 is first delivered to inlet 246. Separator 244 distributes the heavier hydrocarbons separated therein to storage tank or container 248 through outlet or conduit 250. Conduit 250 may include additional components such as a conventional fractionation unit as shown in FIGURE 1. Water withdrawn from separator 244 is delivered to outlet or conduit 252. It may be desirable in some instances to deliver the water in conduit 252 as steam into expansion turbine 210. The residue gas from separator 244 exits through outlet or conduit 254.

System 200 includes a combustor 256. Combustor 256 receives air from compression section 208 delivered through conduit 258, which is fluidly connected to conduit 260 connecting outlet 218 with syngas reactor 224. Also, residue gas delivered by separator 244 into conduit 254, which is connected to combustor 256. Residue gas within conduit 254 is delivered to conduit 258 and then to combustor 256. Intermediate conduit 260 and the connection of conduit 254 with conduit 258 may be a valve system (not explicitly shown) for dropping the pressure delivered from compressor section 208 to combustor 256 in order to match the pressure in conduit 254 as necessary. The output of combustor 256 is delivered to expansion turbine 210. Combustor 256 may include a catalyst that is useful for promoting combustion reactions; the combustion-promoting catalyst may facilitate combustion of low BTU gas in combustor 256. In some embodiments, combustor 256 may be incorporated as part of gas turbine 206 itself.

Referring now to FIGURES 3 and 4, systems 300 and 400 are shown. Systems 300 and 400 are analogous in most respects to system 200. Analogous or corresponding parts are shown with reference numerals having the same last two digits to show their correspondence with that of FIGURE 2. The modifications in FIGURES 3 AND 4 will be described later.

The preferred operating pressure of the process described in connection with FIGURES 2-4 is in the range of 50 psig to 500 psig, and more specifically, in the range of 100 psig to 400 psig. This relatively low operating pressure has the benefit of being in the range of most gas turbines so additional compression is minimized. Also, the operating of the syngas production unit 202 at relatively low pressure has the benefit of improved efficiency of the reforming reactions resulting in higher conversion of carbonaceous feeds like natural gas into carbon monoxide instead of carbon dioxide. Additionally, undesirable reactions that lead to the formation of carbon are less likely to occur at lower pressures.

In some instances, it may be desirable to increase the process pressure of system 200 if the pressure drop is too great to recover sufficient energy to drive the compressor section 208 or if the catalyst used in the Fischer-Tropsch reactor 238 requires higher operating pressure. In either case, if higher pressure is required, the synthesis gas produced in syngas unit 202 may be further compressed by an additional compressor. This alternative embodiment is shown as System 300 in FIGURE 3. The additional compressor, or syngas compressor, is shown by reference numeral 364. In this configuration, the syngas unit 302 is operated at a relatively low pressure for the reasons provided above (greater efficiency of reactor 224 and less probability of forming solid carbons) while the Fischer-Tropsch reactor 338 is operated at an elevated pressure. System 300 has the advantage of recovering more power from turbine 306, but most of this power will probably be required to drive the syngas booster compressor 364. This configuration also has the advantage of operating the Fischer-Tropsch reactor 338 at an elevated pressure, which depending on the catalyst employed, improves the efficiency of that reaction.

Referring to FIGURE 4, another version of the process is shown having a compressor 464 used to compress the residue gas from the reactor 438 to make up for all or a part of the system pressure losses and to improve turbine efficiencies.

In an alternative embodiment shown in hidden lines in FIGURE 4, excess energy from heat exchanger 426 and reactor 438 may be used to power a steam turbine 480. Steam from heat exchanger 426 is delivered by conduit 482 to an expansion portion 484 of turbine 480. In addition or in lieu thereof, steam from a coil running in reactor 438 may be delivered by conduit 486 to conduit 482 and then to expansion section 484. Expansion section 484 drives compressor section 488 of turbine 480 and exhausts 494. Compressor section 488 receives air through conduit 490, compresses the air, and delivers the air to conduit 492. Conduit 492 delivers the additional compressed air to conduit 460 for delivery to reactor 424. The excess energy of system 400 (e.g., from exchanger 426 and reactor 438) may also be used to provide driving energy to other devices such as compressor 464 (FIG. 4) or syngas booster 364 (FIG. 3).

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of invention as defined by the appended claims. For example, a number of methods of heat integration could be used with the system and still be within the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A natural-gas-conversion method for the conversion of normally gaseous hydrocarbons into liquid organic products, the method comprising the steps of:

(a) compressing air;

(b) reacting a feed stream consisting substantially of gaseous hydrocarbons in the presence of the compressed air from step (a) in a first reactor to create an intermediate feed stream containing carbon monoxide and molecular hydrogen;

(c) reacting the intermediate stream in the presence of a catalyst in a second reactor to produce a hydrocarbon product stream of substantially C_{5+} hydrocarbons; and

(d) combusting the residue gas from the second reactor in a gas turbine, which is used for compressing a portion of the compressed air in step (a).

2. The method of Claim 1 wherein step (a) comprises compressing enriched air.

3. The method of Claim 1 further comprising the step of further compressing the intermediate stream before step (c).

4. The method of Claim 1 further comprising the step of further compressing the residue gas before the residue is delivered to the gas turbine in step (d).

5. The method of Claim 1 wherein normally gaseous hydrocarbons are converted to liquid organic products that are at least as heavy as C_5.

6. The method of Claim 1 wherein normally gaseous hydrocarbons are converted to methanol.

7. The method of Claim 1 wherein normally gaseous hydrocarbons are converted to dimethyl ether (DME).

8. The method of Claim 1 wherein the combusting of step (d) is conducted in the presence of a combustion-promoting catalyst.

9. The method of Claim 1 further comprising the steps of:

(e) removing excess heat energy developed during the reacting step (b); and

(f) using the excess heat energy from step (e) to compress additional air in combination with step (a).

10. The method of Claim 1 further comprising the steps of:

(e) removing excess heat energy developed during the reacting step (c); and

(f) using the excess heat energy from step (e) to compress additional air in combination with step (a).

11. The method of Claim 1 further comprising the steps of:

(e) removing excess heat energy developed during the reacting step (b);

(f) removing excess heat energy developed during the reacting step (c); and

(g) using the excess heat energy from steps (e) and (f) to compress additional air in combination with step (a).

12. A process to convert normal gaseous hydrocarbons into heavier hydrocarbons, which are liquid or solid at standard temperature and pressure, the process comprising the steps of:

(a) reacting air and gaseous hydrocarbons in a reactor to produce a gas containing quantities of H_2 and CO and N_2 from the air;

(b) reacting the produced gas in step (a) over a Fischer-Tropsch catalyst to produce heavier hydrocarbon products;

(c) separating the heavier hydrocarbon products and water from gaseous light hydrocarbon products and unreacted H_2, CO, and N_2;

(d) combusting the residue gas from step (c) in a gas turbine;

(e) extracting a portion of the air from a compressor section of the gas turbine of step (d) to react with gaseous hydrocarbons in step (a); and

(f) reacting the remaining air left from step (e) along with the residue gas in step (d).

13. The process of Claim 12, wherein step (a) comprises the step of reacting an enriched air with gaseous light hydrocarbons in the reactor.

14. The process of Claim 12, further comprising the step of introducing CO_2 into the reactor in step (a) to adjust the ratio of H_2 to CO.

15. The process of Claim 12, further comprising the step of introducing steam into the reactor in step (a) to adjust the ratio of H_2 to CO.

16. The process of Claim 12, further comprising the step of compressing the gaseous light hydrocarbon products and unreacted H_2, CO, and N_2 from step (c) to at least partially compensate for the pressure drop associated with steps (b) and (c).

17. The process of Claim 12, wherein the step of further compressing the gaseous light hydrocarbon products and unreacted H_2, CO, and N_2 comprises compressing the gaseous light hydrocarbons and unreacted H_2, CO and N_2 to a level substantially equal to the pressure of the air extracted in step (e).

18. The process of Claim 12, wherein the step (a) comprises reacting compressed air and gaseous hydrocarbons in an autothermal reformer.

19. The process of Claim 12, wherein the step (a) comprises the step of reacting air and gaseous hydrocarbons in a non-catalytic partial oxidation reactor.

20. The process of Claim 12, further comprising the steps of:

collecting moisture produced in steps (a) and (b); and

delivering the collected moisture to an expansion-turbine section of the gas turbine referenced in step (d).

21. The process of Claim 12, wherein step (a) comprises reacting air and natural gas in a reactor to produce a gas containing quantities of H_2, CO and N_2.

22. The method of Claim 12 wherein the combusting of step (d) is conducted in the presence of a combustion-promoting catalyst.

23. A system for converting normal gaseous hydrocarbons into heavier hydrocarbons, which are liquid or solid at standard temperature and pressure, the system comprising:

a gas turbine having a compressor section, an expansion section, an air intake, and an exhaust;

a synthesis gas production unit coupled to the compressor section of gas turbine for receiving compressed air therefrom and having a feedstack inlet for receiving the normal gaseous hydrocarbons and an outlet for delivering synthesis gas;

a synthesis unit having an inlet coupled to the outlet of the synthesis gas production unit for receiving synthesis gas therefrom and having a first outlet for delivering a residue gas and a second outlet for delivering the heavier hydrocarbons;

a combustor associated with the gas turbine and having a combustor inlet and combustor outlet, the combustor inlet coupled to the first outlet of the synthesis unit for receiving residue gas and the combustor outlet coupled to the expansion section of the gas turbine, the combustor inlet also coupled to a portion of the compressor section for receiving compressed air therefrom; and

wherein the combustor is operable to burn residue gas and compressed air and supply a resultant product to the expansion section of the gas turbine to at least drive the compressor section.

24. The system of Claim 23 further comprising a boosting compressor coupled to the combustor inlet and first outlet of the synthesis unit, the boosting compressor operable to boost a pressure of the residue gas delivered by the synthesis unit prior to the residue gas entering the combustor.

25. The system of Claim 23 further comprising a booster compressor coupled to the outlet of the synthesis gas unit and the inlet of the synthesis unit for boosting a pressure of the synthesis gas prior to delivery to the synthesis unit.

26. The system of Claim 23 wherein the gas turbine further comprises an energy off-take for removing excess power beyond what is required to drive the compressor section.

27. The system of Claim 23 wherein the gas turbine further comprises a combustion-promoting catalyst for facilitating combustion of gases therein.

28. The system of Claim 23 further comprising:

a supplemental gas turbine having a compressor section, an expansion section, an air intake, and an exhaust, for providing additional compressed air to the synthesis gas production unit;

wherein the synthesis gas production unit further comprises a heat exchanger; and

a conduit for delivering excess heat energy from the heat exchanger of the synthesis gas production unit to the supplemental gas turbine to power the supplemental gas turbine.

29. The system of Claim 23 further comprising:

a supplemental gas turbine having a compressor section, an expansion section, an air intake, and an exhaust, for providing additional compressed air to the synthesis gas production unit;

wherein the synthesis unit further comprises a heat exchanger coupled to a reactor for removing excess heat from the reactor; and

a conduit for delivering excess heat energy from the heat exchanger of the synthesis unit to the supplemental gas turbine to power the supplemental gas turbine.

30. The system of Claim 23 further comprising:

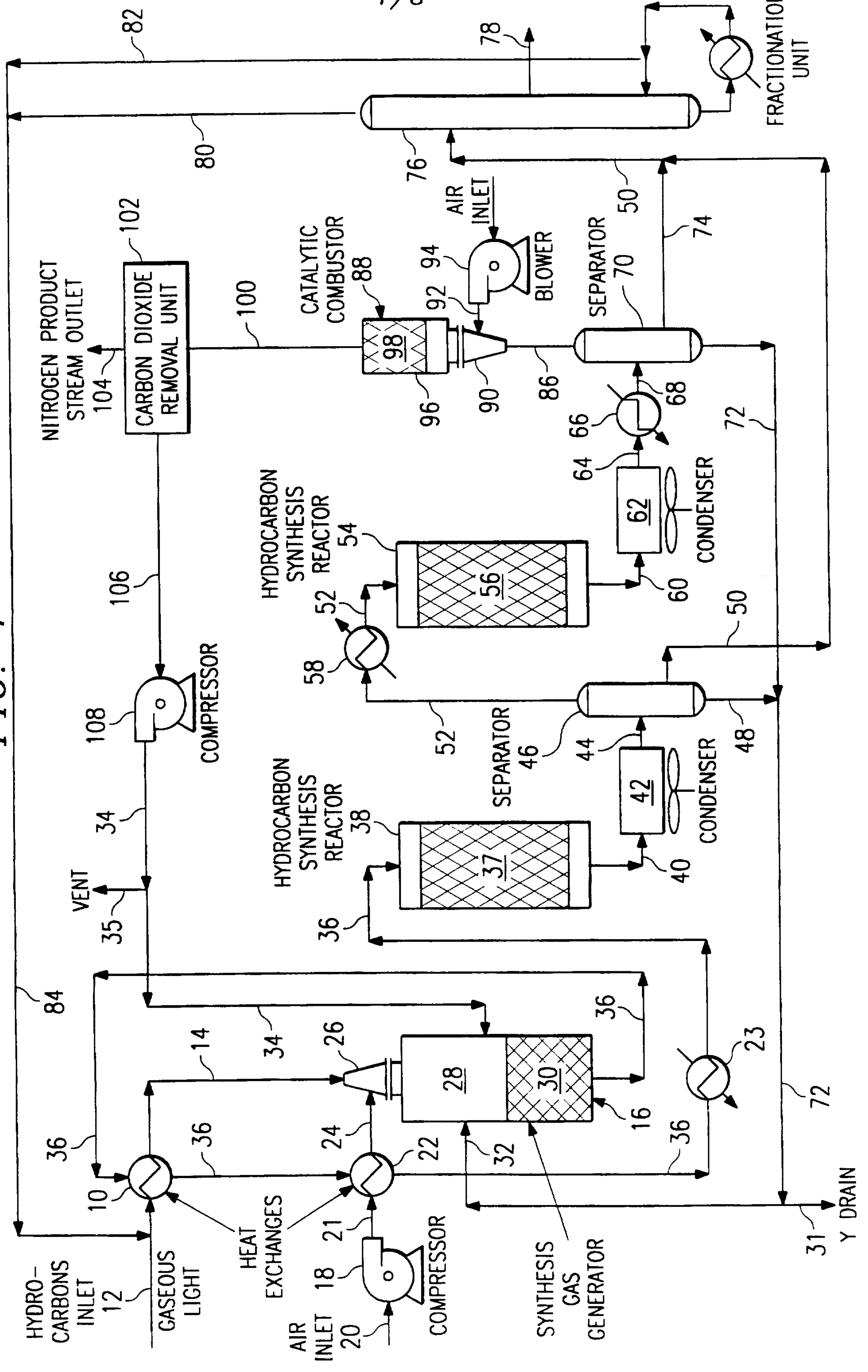
a supplemental gas turbine having a compressor section, an expansion section, an air intake, and an exhaust, for providing additional compressed air to the synthesis gas production unit;

wherein the synthesis unit further comprises a heat exchanger coupled to a reactor for removing excess heat from the reactor;

wherein the synthesis gas production unit further comprises a heat exchanger; and

a plurality of conduits for delivering excess heat energy from the heat exchanger of the synthesis unit and from the heat exchanger of the synthesis gas production unit to the supplemental gas turbine to power the supplemental gas turbine.

FIG. 1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CONDENSER
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SEPARATOR 46
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HYDROCARBON SYNTHESIS REACTOR
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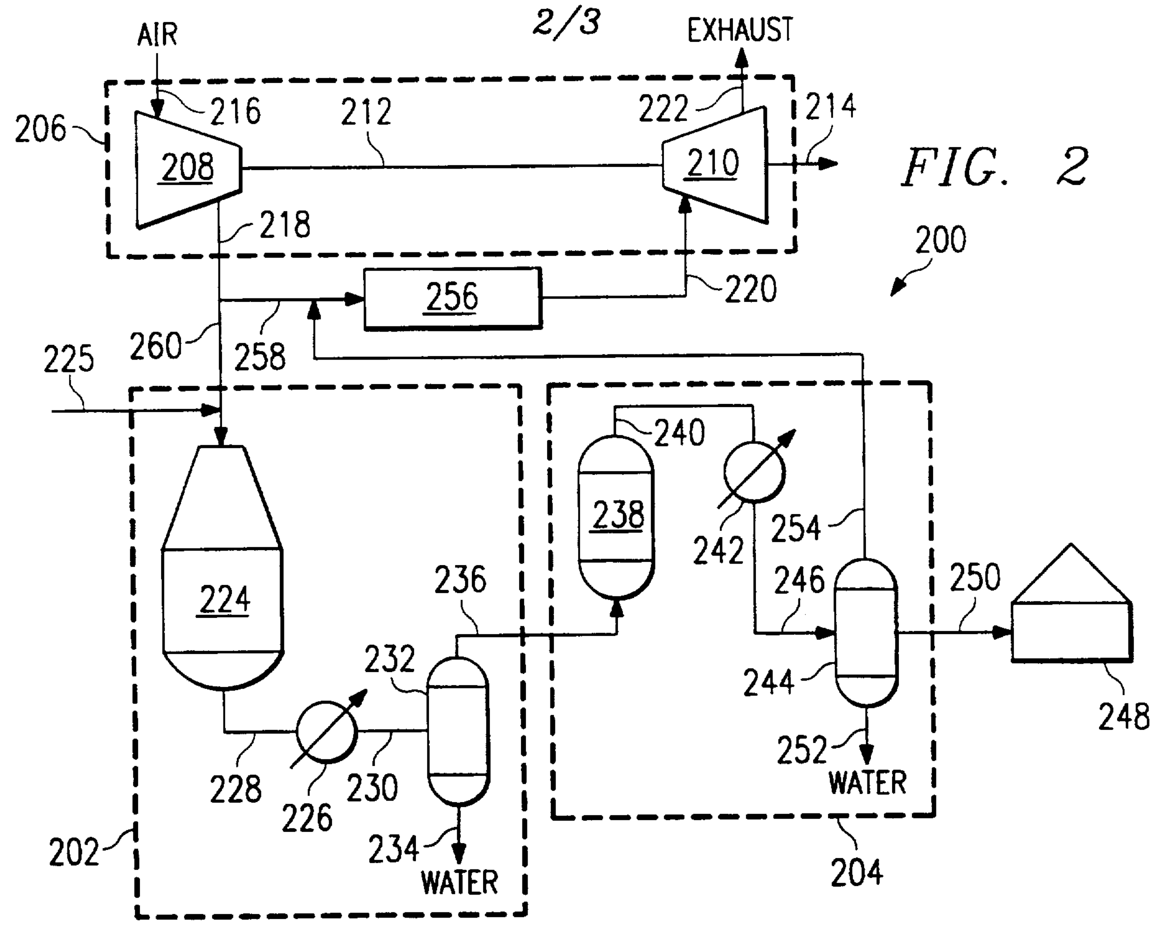
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FIG. 2

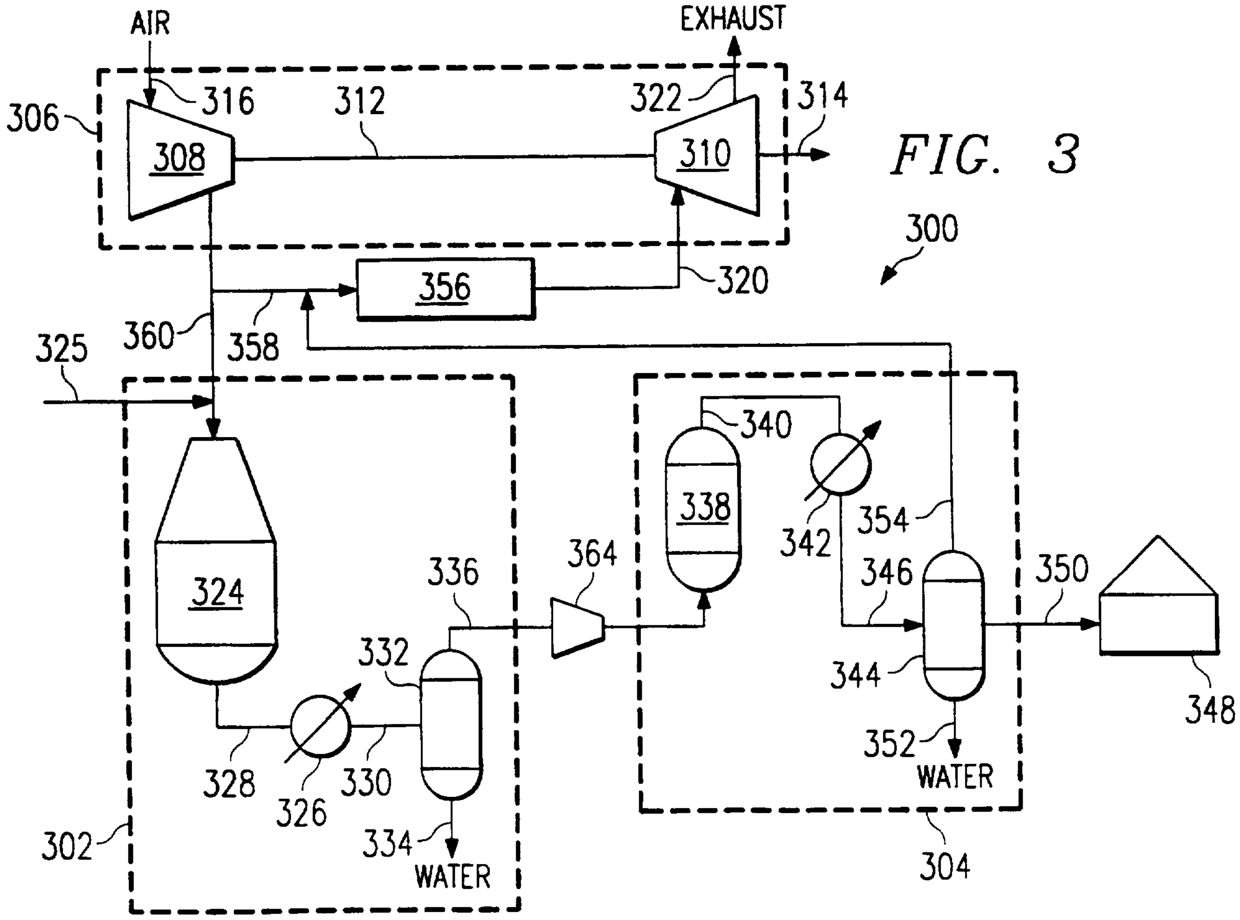
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FIG. 3

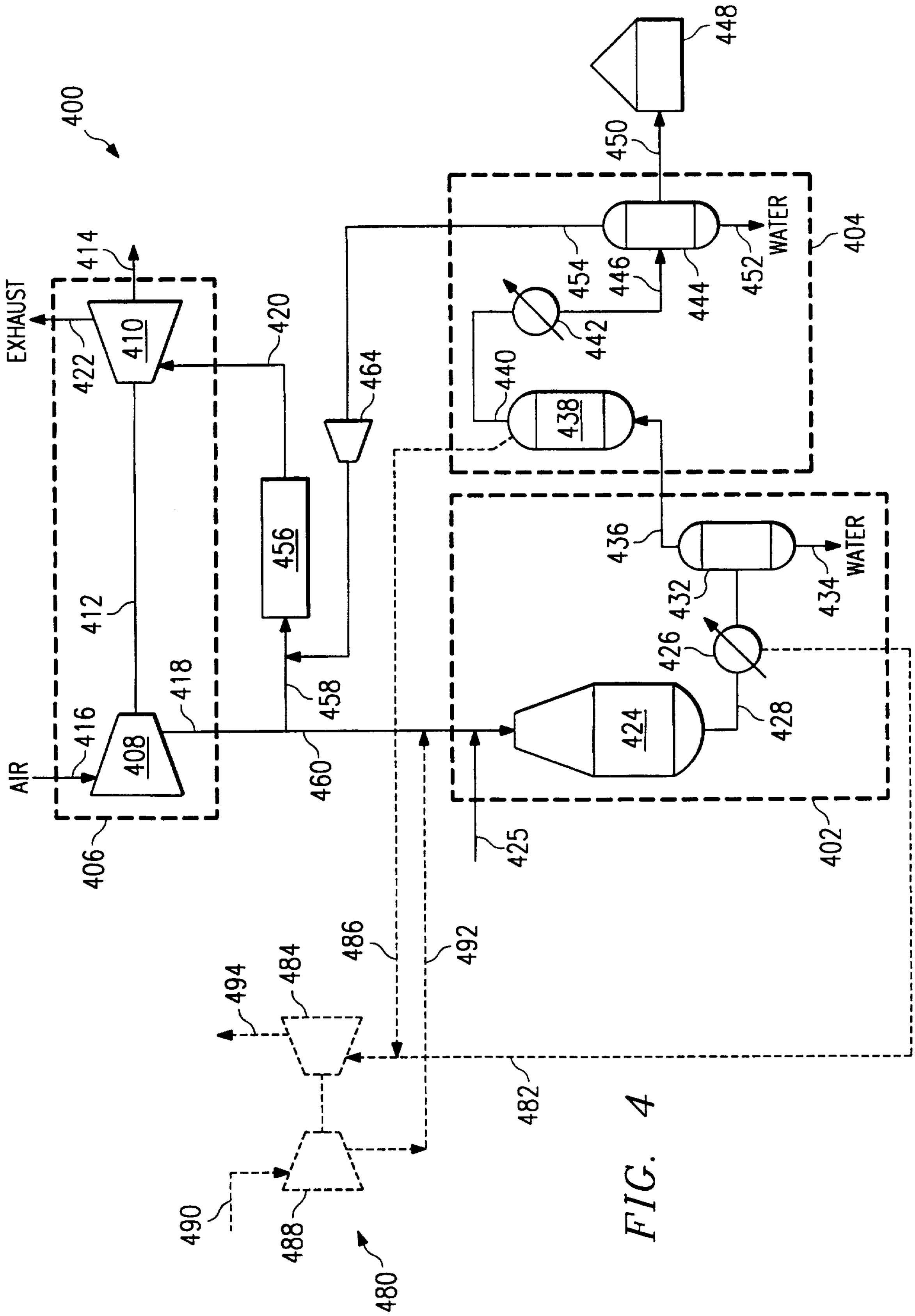
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FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/03729

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C07C1/04 C07C31/04 C07C29/151 C07C43/04 C07C41/01
C10G2/00

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)
IPC 6 C07C C10G

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 232 (C-1056), 12 May 1993 & JP 04 364142 A (CHIYODA CORP), 16 December 1992, see abstract ---	1,6
A	EP 0 497 425 A (SHELL INT RESEARCH) 5 August 1992 ---	
A	WO 93 06041 A (STARCHEM INC) 1 April 1993 -----	

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

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
3 June 1997	11.06.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van Geyt, J

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 97/03729

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