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(54) ## METHOD AND APPARATUS FOR PRODUCING HIGH-PRESSURE NITROGEN

(57) A method for producing a high-pressure gas from an air separation unit including the steps of introducing a cold air feed into a distillation column system (20) under conditions effective for separating the cold air feed into a first air gas (22) and a second air gas; withdrawing the first and second air gases from the distillation column system and warming said first and second air gases in a main heat exchanger (10), wherein the first air gas is withdrawn from the distillation column system at a medium pressure; splitting the first air gas into a first fraction (24) and a second fraction (26); expanding the first fraction in a turbine (30); and compressing the second fraction in a booster (40) to a pressure that is higher than the medium pressure, wherein the booster is powered by the turbine

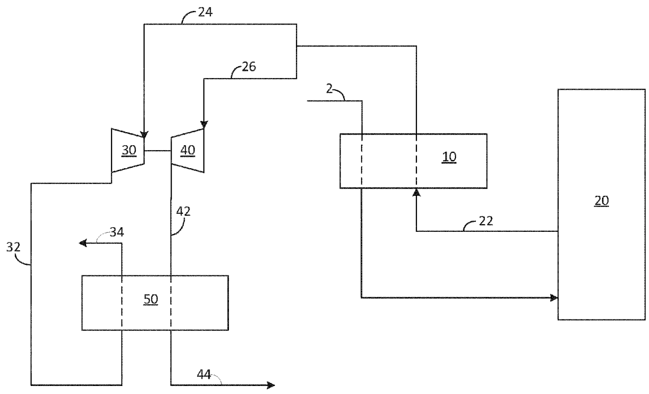

FIG. 1

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Description

Technical Field of the Invention

[0001] The present invention relates to a method and apparatus for producing high-pressure nitrogen from a cryogenic air separation unit.

Background of the Invention

[0002] Cryogenic air separation units (ASUs) produce pure nitrogen and oxygen streams by taking atmospheric air and separating it into nitrogen and oxygen using distillation, most commonly using a double distillation column having a low pressure and a medium-pressure column, at cryogenic temperatures. Under normal circumstances, the ASU will produce a low-pressure nitrogen stream from the low-pressure column and a medium-pressure stream from the medium-pressure column.

[0003] If high-pressure nitrogen is desired (e.g., at a pressure greater than the pressure of the medium-pressure column, for example at 7 to 11 bara), there are normally two ways to achieve this goal: (1) internal compression and (2) external compression. With internal compression, liquid nitrogen (LIN) is withdrawn from the medium-pressure column and sent to a liquid pump for pressurization to the desired high pressure. This pressurized LIN is then vaporized in the main heat exchanger. With external compression, a medium-pressure or low-pressure gas is withdrawn from the medium-pressure column or low-pressure column, respectively, before it is warmed in the main heat exchanger. After warming in the main heat exchanger, the warmed gas is then compressed in a dedicated compressor.

[0004] Unfortunately, when retrofitting an existing ASU using internal compression, a new LIN pump is required and the operation of the heat exchanger and the main air compressor (and/or booster air compressor) will also be affected. In fact, in some circumstances, the existing heat exchanger might not be designed to handle LIN vaporization, and therefore, a new heat exchanger could be required. Additionally, operating expenses will increase as well.

[0005] With respect to external compression, both CAPEX and OPEX will be increased due to the dedicated nitrogen compressor used to compress the nitrogen downstream the heat exchanger.

Summary of the Invention

[0006] The present invention is directed to a device and a method that can provide pressurized nitrogen without increasing both the CAPEX and OPEX. In one embodiment, the invention can include splitting the medium-pressure GAN from the main heat exchanger into two parts, with one part going to a turbine to produce low-pressure GAN, while the other portion goes to a nitrogen booster. While the CAPEX is increased, the OPEX is largely unchanged, as the turbine can be used to drive the booster.

[0007] In another embodiment, the invention can include an additional heat exchanger that is used to exchange heat between the resulting high-pressure nitrogen from the booster and the low-pressure nitrogen from the turbine.

[0008] In certain embodiments of the invention, there is no need to extract any extra streams from the column system to warm up, which means there is no impact on the existing heat exchanger and column system. Furthermore, because the nitrogen booster is powered by the nitrogen turbine, little to no additional power is needed, which means OPEX remain largely unchanged.

[0009] In one embodiment, a method for producing a high-pressure gas from an air separation unit is provided. In this embodiment, the method can include the steps of: introducing a cold air feed into a distillation column system under conditions effective for separating the cold air feed into a first air gas and a second air gas; withdrawing the first and second air gases from the distillation column system and warming said first and second air gases in a main heat exchanger, wherein the first air gas is withdrawn from the distillation column system at a medium pressure; splitting the first air gas into a first fraction and a second fraction; expanding the first fraction in a turbine; and compressing the second fraction in a booster to a pressure that is higher than the medium pressure, wherein the booster is powered by the turbine.

[0010] In optional embodiments of the method for producing a high-pressure gas:

- the method can also include a step of warming the expanded first fraction;
- the expanded first fraction is warmed in a second heat exchanger against the boosted second fraction;
- the expanded first fraction is warmed in the main heat exchanger;
- the boosted second fraction is cooled to ambient temperature using a dedicated cooler;
- the dedicated cooler is a water cooler;
- the first fraction and the second fraction are withdrawn at an intermediate location of the heat exchanger, such that the first fraction and the second fraction are partially warmed in the main heat exchanger;
- the method can also include a step of warming the expanded first fraction in the main heat exchanger, and wherein

the boosted second fraction is at ambient temperature at an outlet of the booster;

- the second fraction is withdrawn at an intermediate location of the heat exchanger and the first fraction is withdrawn at a warm end of the heat exchanger, such that the first fraction is fully warmed and the second fraction is partially warmed;
- the method can also include a step of warming the expanded first fraction in the main heat exchanger, and wherein the boosted second fraction is at ambient temperature at an outlet of the booster;
- the distillation column system comprises at least one distillation column;
- the distillation column system comprises a double column; and/or
- the first air gas is nitrogen and the second air gas is oxygen;
- the first air gas is split in two downstream of the main heat exchanger at a temperature equal to that of the warm end of the main heat exchanger;
- the turbine entry temperature is above 0°C;
- the booster entry temperature is above 0°C;
- the booster entry temperature is below 0°C;
- the turbine entry temperature is below 0°C;
- the stream to be expanded is not warmed between the main heat exchanger and the turbine;
- the stream to be expanded is not cooled between the main heat exchanger and the turbine;
- the stream sent to the booster is not cooled between the main heat exchanger and the booster;
- the stream sent to the booster is not warmed between the main heat exchanger and the booster.

[0011] According to another aspect of the invention, there is provided an apparatus for producing a high-pressure gas from an air separation unit, the apparatus comprising:

- a main heat exchanger having a warm end and a cold end;
- a distillation column system comprising at least one column, the system being in fluid communication with the cold end of the main heat exchanger, wherein the distillation column system is configured to receive a cold air feed from the cold end of the main heat exchanger and separate the cold air feed into a first air gas and a second air gas, wherein the distillation column system is also configured to send the first air gas to the cold end of the main heat exchanger;
- a turbine in fluid communication with the main heat exchanger, wherein the turbine is configured to receive a first fraction of the first air gas after warming in the main heat exchanger;
- a warm booster in fluid communication with the main heat exchanger, wherein the warm booster is configured to receive a second fraction of the first air gas after warming in the main heat exchanger thereby providing a high-pressure gas that is at a pressure greater than an operating pressure of the column within the distillation column system,

wherein the turbine is configured to power the warm booster.

[0012] According to a further aspect of the invention, there is provided a revamping process in which an existing air separation unit comprising a column system and a main heat exchanger is modified by adding a booster; an expander, means for dividing a first air gas stream from the air separation unit warmed in the main heat exchanger into a first fraction and a second fraction, means for sending the first fraction to be expanded in the expander and means for sending the second fraction to be compressed in the booster.

[0013] The process may also include the addition of a supplemental heat exchanger to exchange heat indirectly between the boosted second fraction and the expanded first fraction.

Brief Description of the Drawings

[0014] These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, claims, and accompanying drawings. It is to be noted, however, that the drawings illustrate only several embodiments of the invention and are therefore not to be considered limiting of the invention's scope as it can admit to other equally effective embodiments.

FIG. 1 represents an embodiment of the present invention.
FIG. 2 represents a second embodiment of the present invention.
FIG. 3 represents a third embodiment of the present invention.
FIG. 4 represents a fourth embodiment of the present invention.

Detailed Description

[0015] While the invention will be described in connection with several embodiments, it will be understood that it is not intended to limit the invention to those embodiments. On the contrary, it is intended to cover all the alternatives, modifications and equivalence as may be included within the spirit and scope of the invention defined by the appended claims.

[0016] In FIG. 1, air feed 2, which is already compressed and purified, is cooled in main heat exchanger 10 and introduced into distillation column system 20. Those of ordinary skill in the art will recognize that distillation column system can be any system that is suitable for separating air into its constituent components (e.g., nitrogen, oxygen, argon). In the embodiment shown in FIG. 1, a gaseous nitrogen stream 22, which is preferably at medium pressure (i.e., pressure matching the medium-pressure column of a double column system), is withdrawn from the distillation column system 20 and warmed in heat exchanger 10.

[0017] After warming, gaseous nitrogen stream 22 is preferably split into a first fraction 24 and a second fraction 26. First fraction 24 is expanded across turbine 30 to produce low-pressure nitrogen 32. Second fraction 26 is compressed in booster 40 to produce high-pressure nitrogen 42. The heat of compression can be removed from high-pressure nitrogen 42 by cooling it against low-pressure nitrogen 32 in supplemental heat exchanger 50 to yield both low-pressure nitrogen product stream 34 and high-pressure nitrogen product stream 44.

[0018] The embodiment shown in FIG. 1 is particularly useful in instances with an existing plant in that there is no need to modify the existing heat exchanger 10. Instead, supplemental heat exchanger 50 is used to provide the appropriate cooling for stream 42.

[0019] In FIG. 2, the setup can be largely the same, with the exception of the cooling and warming of streams 42 and 32, respectively. In this embodiment, high-pressure nitrogen 42 can be cooled via cooling water in cooler 45, and low-pressure nitrogen 32 can be warmed in main heat exchanger 10. An advantage of the embodiment shown in FIG. 2 is that the cooling provided by expansion of stream 32 can be used to further cool the incoming air, thereby allowing for additional flexibility in the main process (e.g., increased liquid production and/or lower operating expenses).

[0020] In the embodiment shown in FIG. 3, high-pressure nitrogen 42 does not require any additional cooling to get to ambient temperatures after compression, since gaseous nitrogen stream 22 is only partially warmed within heat exchanger 10.

[0021] FIG. 4 provides an additional embodiment similar to that of FIG. 3; however, in the embodiment of FIG. 4, first fraction 24 is fully warmed in heat exchanger 10 prior to being expanded in turbine 30. Stream 42 for both FIG. 3 and FIG. 4 is preferably at ambient temperature following compression in booster 40. By fully warming first fraction 24 to ambient temperature, either more power can be produced within expansion turbine 30 due to a higher enthalpy change or a lower flow rate for stream 24 can be used to achieve the same pressure for stream 42. Therefore, the embodiment of FIG. 4 allows for the potential of power savings and/or increased HP GAN production.

[0022] The tables below show comparative flows, temperatures and pressures of the various streams for each figure.

Table I: Comparative Data for FIG. 1

	2	22	24	32	34	26	42	44
F(Nm3/h)	158550	36360	18000	18000	18000	18360	18360	18360
P(bar a)	5.967	5.748	5.535	1.220	1.106	5.535	10.262	10.162
T(C)	26.0	-177.4	15.6	-60.7	20.0	15.6	89.6	11.4

Table II: Comparative Data for FIG. 2

	2	22	24	32	34	26	42	44
F(Nm3/h)	159170	36360	17990	17990	17990	18370	18370	18370
P(bar a)	5.961	5.742	5.544	1.320	1.197	5.544	10.034	9.934
T(C)	26.0	-177.4	8.1	-63.3	8.1	8.1	77.2	29.0

Table III: Comparative Data for FIG. 3

	2	22	24	32	34	26	42
F(Nm3/h)	159750	36360	17840	17840	17840	18520	18520
P(bara)	5.969	5.750	5.552	1.290	1.176	5.552	10.031
T (C)	26.0	-177.3	-50.0	-107.7	17.2	-50.0	4.7

Table IV: Comparative Data for FIG. 4

	2	22	24	32	34	26	42
F (Nm3/h)	158400	31300	12800	12800	12800	18500	18500
P(bar a)	5.988	5.773	5.750	1.190	1.171	5.576	10.068
T (C)	26.0	-177.3	17.1	-62.1	17.1	-50.0	4.7

[0023] While the embodiments above have been disclosed with reference to stream 22 being medium-pressure nitrogen, those of ordinary skill in the art will recognize that stream 22 could also be low-pressure oxygen.

[0024] While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations as fall within the spirit and broad scope of the appended claims. The present invention may suitably comprise, consist or consist essentially of the elements disclosed and may be practiced in the absence of an element not disclosed. Furthermore, language referring to order, such as first and second, should be understood in an exemplary sense and not in a limiting sense. For example, it can be recognized by those skilled in the art that certain steps can be combined into a single step.

[0025] The singular forms "a", "an", and "the" include plural referents, unless the context clearly dictates otherwise.

[0026] Optional or optionally means that the subsequently described event or circumstances may or may not occur. The description includes instances where the event or circumstance occurs and instances where it does not occur.

[0027] Ranges may be expressed herein as from about one particular value, and/or to about another particular value. When such a range is expressed, it is to be understood that another embodiment is from the one particular value and/or to the other particular value, along with all combinations within said range.

Claims

1. A method for producing a high-pressure gas from an air separation unit, the method comprising the steps of:

- introducing a cold air feed into a distillation column system (20) under conditions effective for separating the cold air feed into a first air gas (22) and a second air gas;
- withdrawing the first and second air gases from the distillation column system and warming said first and second air gases in a main heat exchanger (10), wherein the first air gas is withdrawn from the distillation column system at a medium pressure;
- splitting the first air gas into a first fraction (24) and a second fraction (26);
- expanding the first fraction in a turbine (30); and
- compressing the second fraction in a booster (40) to a pressure that is higher than the medium pressure, wherein the booster is powered by the turbine.

2. The method as claimed in Claim 1, further comprising the step of warming the expanded first fraction (32).

3. The method as claimed in Claim 2, wherein the expanded first fraction (32) is warmed in a second heat exchanger (50) against the boosted second fraction (42).

4. The method as claimed in Claim 2, wherein the expanded first fraction (32) is warmed in the main heat exchanger (10).

5. The method as claimed in Claim 4, wherein the boosted second fraction (42) is cooled to ambient temperature using a dedicated cooler (45).

6. The method as claimed in Claim 5, wherein the dedicated cooler is a water cooler (45).

7. The method as claimed in Claim 1, wherein the first fraction (24) and the second fraction (26) are withdrawn at an intermediate location of the heat exchanger, such that the first fraction and the second fraction are partially warmed in the main heat exchanger (10).

8. The method as claimed in Claim 7, further comprising the step of warming the expanded first fraction (32) in the main heat exchanger, and wherein the boosted second fraction (42) is at ambient temperature at an outlet of the booster (40).

9. The method as claimed in Claim 1, wherein the second fraction is withdrawn at an intermediate location of the main heat exchanger (10) and the first fraction is withdrawn at a warm end of the main heat exchanger, such that the first fraction (24) is fully warmed and the second fraction (26) is partially warmed.

10. The method as claimed in Claim 9, further comprising the step of warming the expanded first fraction (32) in the main heat exchanger (10), and wherein the boosted second fraction (42) is at ambient temperature at an outlet of the booster (40).

11. The method as claimed in Claim 1, wherein the distillation column system (20) comprises at least one distillation column.

12. The method as claimed in Claim 1, wherein the distillation column system (20) comprises a double column.

13. The method as claimed in Claim 1, wherein the first air gas (22) is nitrogen and the second air gas is oxygen.

14. An apparatus for producing a high-pressure gas from an air separation unit, the apparatus comprising:

- a main heat exchanger (10) having a warm end and a cold end;
- a distillation column system(20) comprising at least one column, the system being in fluid communication with the cold end of the main heat exchanger, wherein the distillation column system is configured to receive a cold air feed from the cold end of the main heat exchanger and separate the cold air feed into a first air gas (22) and a second air gas, wherein the distillation column system is also configured to send the first air gas to the cold end of the main heat exchanger;
- a turbine (30) in fluid communication with the main heat exchanger, wherein the turbine is configured to receive a first fraction (24) of the first air gas after warming in the main heat exchanger;
- a warm booster (40) in fluid communication with the main heat exchanger, wherein the warm booster is configured to receive a second fraction (26) of the first air gas after warming in the main heat exchanger thereby providing a high-pressure gas that is at a pressure greater than an operating pressure of the column within the distillation column system,

wherein the turbine is configured to power the warm booster.

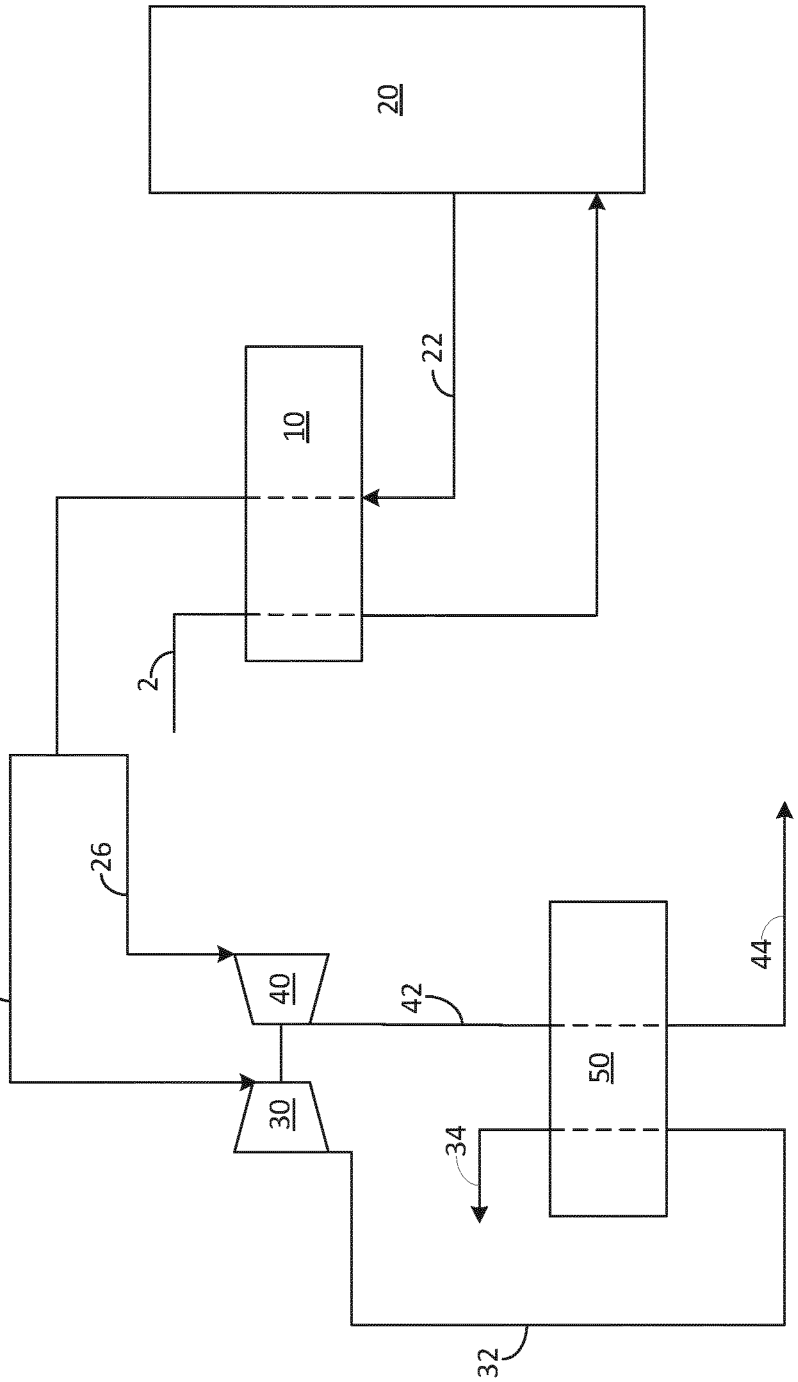

FIG. 1

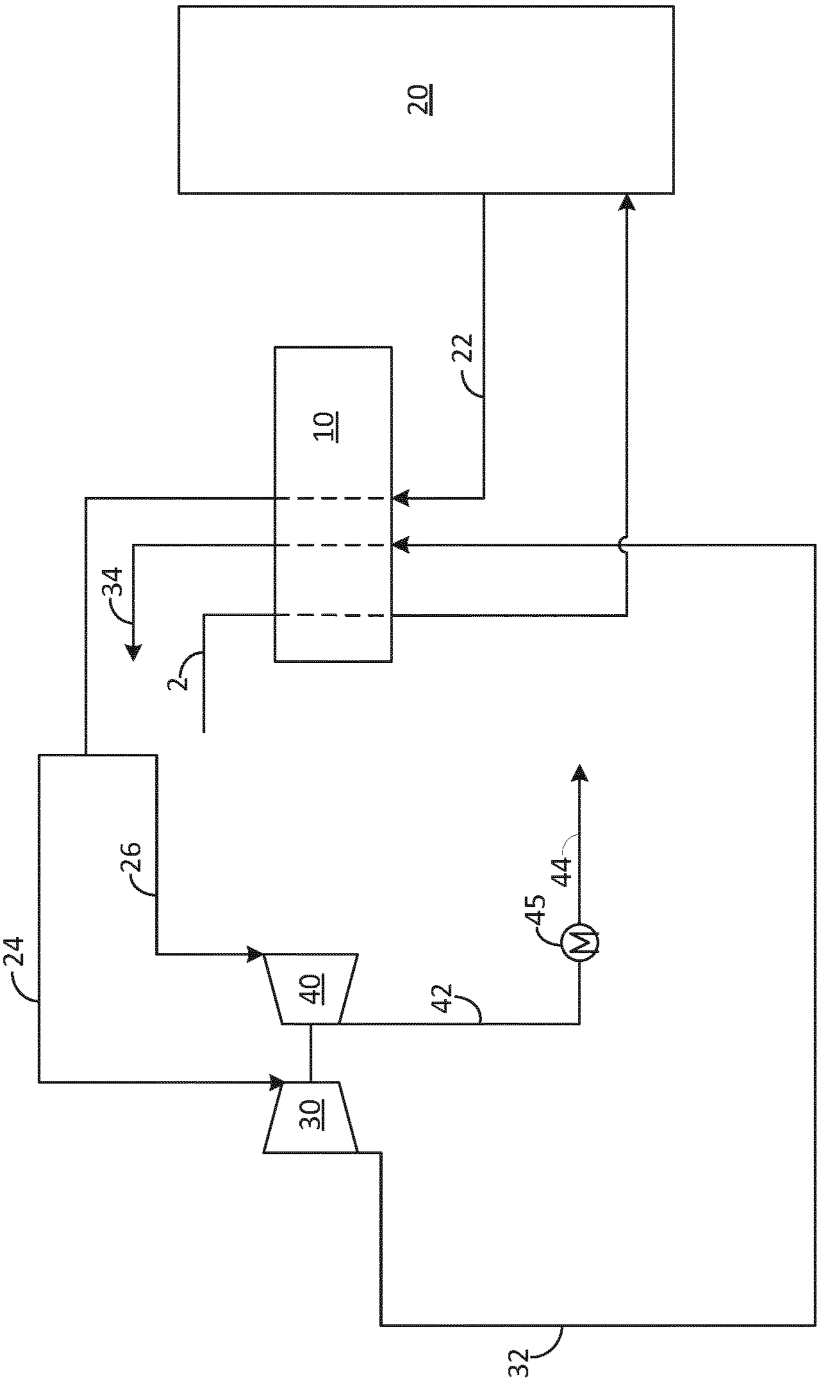

FIG. 2

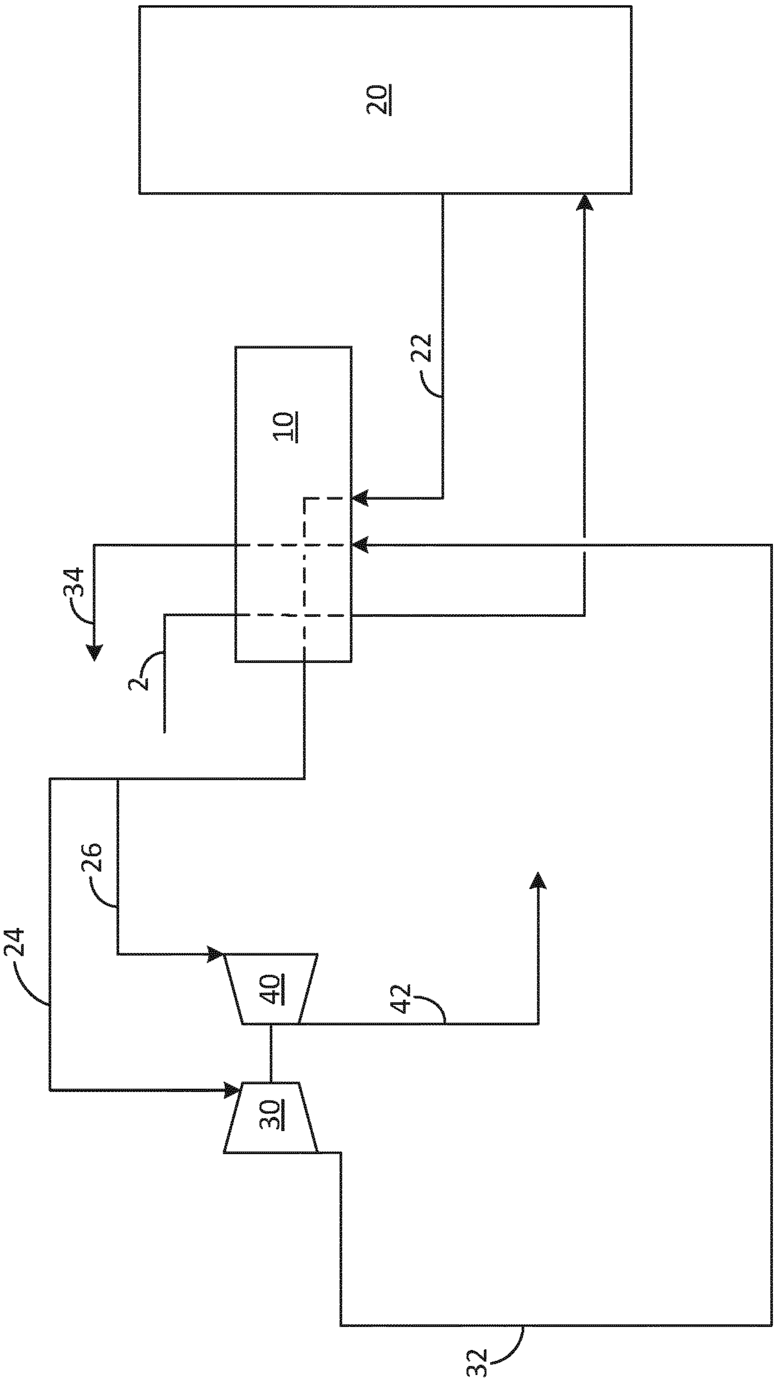

FIG. 3

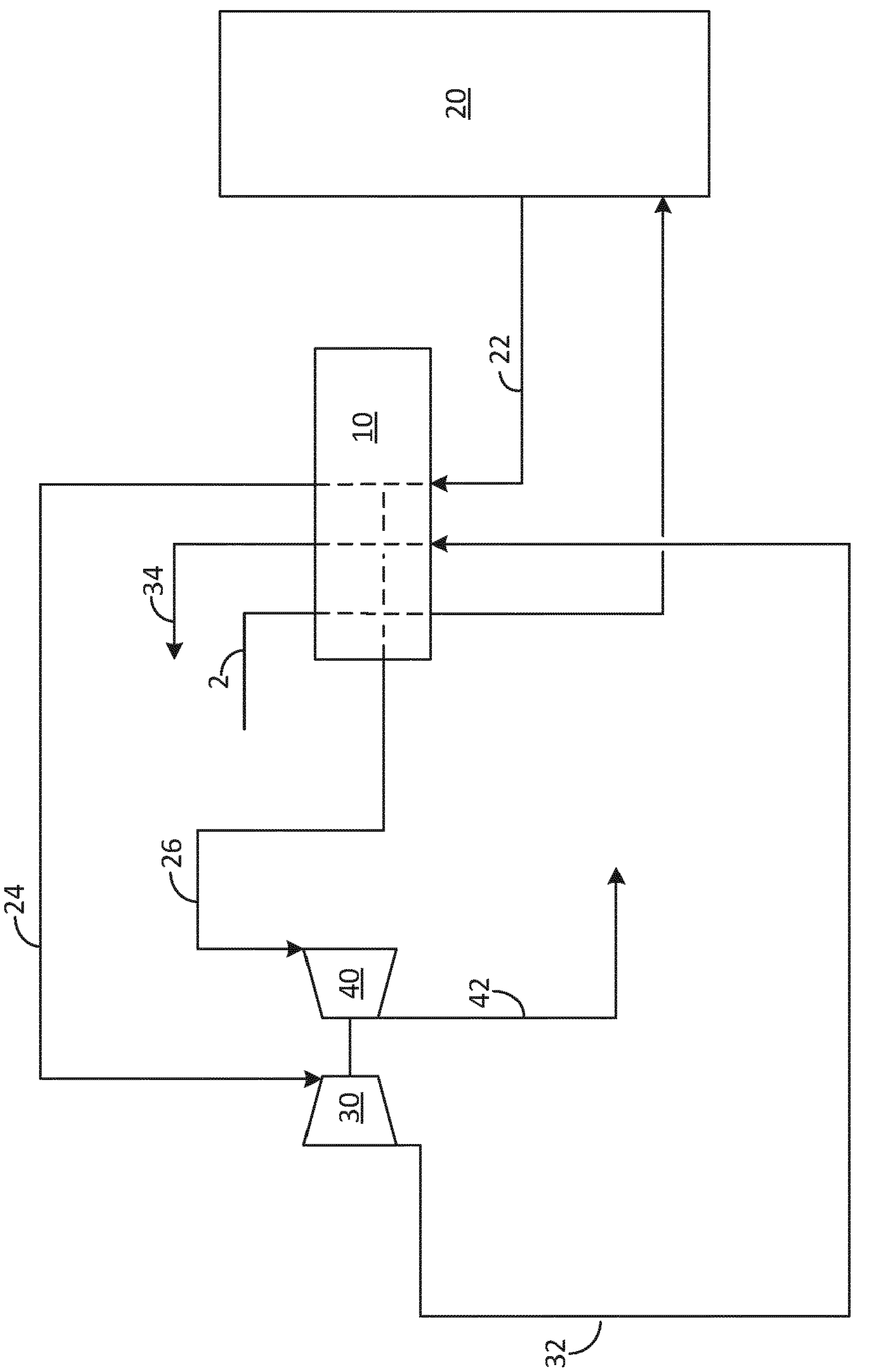

FIG. 4