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KRYOGEN VÆSKE, OG TIL FORSYNING AF EN GASMOTOR MED GAS UNDER**
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SYSTEM FOR TREATING A GAS PRODUCED BY THE EVAPORATION OF A CRYOGENIC LIQUID AND FOR SUPPLYING A GAS ENGINE WITH PRESSURISED GAS

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The present invention relates to a system and a method for treating gas produced by the evaporation of a cryogenic liquid and for supplying a gas engine with pressurized gas.

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The present invention belongs more particularly to the field of transport by sea of cryogenic liquids and even more particularly of Liquefied Natural Gas (LNG). However, the systems and the methods that will be proposed below may also find applications in land-based facilities.

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When considering liquefied natural gas, it has a temperature of -163°C (or lower) at ambient pressure. When LNG is transported by sea, it is placed in tanks on a vessel, an LNG carrier. Although these tanks are thermally insulated, thermal leaks exist and the external environment heats the liquid contained in the tanks. The liquid heats and thus evaporates. Considering the size of the tanks on an LNG carrier, depending on the thermal insulation conditions and the external conditions, several tons of gas can evaporate every hour.

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It is not possible to keep the boil-off gas inside the tanks of the vessel for safety reasons. The pressure inside the tanks would rise dangerously. It is thus necessary to allow the boil-off gas to escape from the tanks. Regulations forbid discharging this gas (if it is natural gas) into the atmosphere as it is. It must be burnt.

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In order to avoid losing this boil-off gas, it is also known, on the one hand, to use it as fuel for the engines on board the vessel transporting it and, on the other hand, to reliquefy it in order to place it back into the tanks from which it originates.

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To reliquefy the boil-off gas, it is known to cool this gas in order to return it to temperature and pressure conditions that allow it to return to the liquid phase. This cooling is most commonly performed by heat exchange with a refrigerating circuit comprising, for example, a loop of refrigerant fluid such as nitrogen.

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In addition, some LNG carriers use the natural gas they transport as fuel for their own propulsion. There are several types of engines that run on natural gas. The present invention relates more particularly to those that are supplied with natural gas in the gaseous phase at high pressure. In order thus to supply the propulsion engine of the LNG carrier, gas is pumped out of a liquefied natural gas tank located on board the LNG carrier, and is then pressurized by means of a pump before being vaporized in order to supply the engine.

Document EP-2 746 707 A1 relates to a natural gas evaporating from tanks for storing liquefied natural gas, typically disposed on board a seagoing vessel, which is compressed inside a compressor with several compression stages. At least one portion of the flow of compressed natural gas is sent to a liquefier, which typically operates according to a Brayton cycle, in order to be reliquefied. The temperature of the compressed natural gas originating from the final stage is reduced to a value lower than 0 °C by passing through a heat exchanger. The first compression stage operates here as a cold compressor, and the resulting cold compressed natural gas is used in the heat exchanger so as to proceed with the necessary cooling of the flow originating from the compression stage. Downstream of its passage through the heat exchanger, the cold compressed natural gas circulates through the remaining stages of the compressor. If it is so wished, a portion of the compressed natural gas can serve as fuel to supply the engines of the seagoing vessel. In an alternative embodiment (§[0026]), it is provided to cool the compressed gas in the gaseous state prior to its liquefaction in part with compressed liquid before it is expanded in order to be used in an engine or a turbine.

The presence of a cooling loop with nitrogen in the Brayton cycle, or any other refrigerant gas separate from the fluid to be refrigerated, implies providing specific equipment for the refrigerant fluid. Thus, for example, when a nitrogen

refrigerant circuit is provided on board a vessel (or elsewhere), a nitrogen treatment (purification) unit is needed in order to allow the nitrogen to be used in the field of cryogenics. It is also advisable to provide a specific tank, valves or other devices for regulating the circulation of the nitrogen.

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When the natural gas supplying the engines of the LNG carrier is collected directly from the tanks of the vessel, it is preferable to have high liquefaction efficiency since the consumption of gas in the gaseous phase is then limited.

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The present invention thus aims to provide an optimized system that makes it possible to reliquefy boil-off gas and to supply a gas engine under high pressure. Preferably, the proposed system will make it possible to optimize the amount of liquid recovered as far as the portion of gas to be reliquefied is concerned. Advantageously, the proposed system may also be used on board a vessel such as an LNG carrier. Preferably, the system will operate without using a refrigerant fluid such as nitrogen or another in order to avoid having two separate circuits with fluids of different natures. The proposed solution also will preferably not be any more expensive to implement than the solutions of the prior art.

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To this end, the present invention proposes a system for treating a gas produced by the evaporation of a cryogenic liquid and for supplying a gas engine with pressurized gas, said system comprising, on the one hand, from upstream to downstream, a reliquefaction unit with compression means, a first heat exchanger and expansion means, and, on the other hand, a pressurized gas supply line comprising from upstream to downstream a pump to pressurize liquid and vaporization means under high pressure.

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According to the present invention, the pressurized gas supply line has, upstream of the vaporization means, a bypass for feeding a second heat exchanger between, on the one hand, pressurized liquid from the supply line and, on the other hand, a line of the reliquefaction unit downstream of the first heat exchanger and upstream of the expansion means, characterized in that the gas produced by the evaporation of a cryogenic liquid, then compressed and cooled is at least partially condensed within the first heat exchanger (17) .

The proposed solution makes it possible to create synergy between the reliquefaction of the boil-off gas and the production of pressurized gas in order to supply an engine, for example a MEGI engine. Indeed, on the one hand, there is a need to cool gas, and on the other hand, there is a need to heat liquid before vaporizing it. The second exchanger proposed thus makes it possible simultaneously to limit the needs (for cold) of the reliquefaction unit and the needs (for heat) of the high-pressure gas supply line. In an original manner, it is proposed herein to “sub-cool” condensed gas. Indeed, after the first exchanger the compressed gas is cooled enough to condense and to return mostly to the liquid phase under pressure. This pressurized liquid must then be expanded in order to be injected back into the tanks which are substantially at atmospheric pressure (just a bit higher to prevent the entry of air). During this expansion, a portion of the condensed gas revaporizes. By cooling the condensed gas prior to expansion, since it is thus in the liquid phase, this gas is sub-cooled and this makes it possible to limit during expansion the portion of condensed gas that revaporizes.

In order to further optimize the use of the cold source coming from the flow of pressurized liquid intended to be vaporized in order to supply an engine, the bypass can feed downstream of the second exchanger a cooling system. This can be, for example, a third exchanger mounted in series with and downstream of the second exchanger and/or a heat exchanger mounted in parallel with the second exchanger.

It is possible to provide in the system described above for the bypass to feed, in addition to the second exchanger, one or more exchangers for cooling gas prior to its reliquefaction.

A particular variant of a system as described above provides for it to further comprise, downstream of the expansion means a balloon separating the gaseous phase from the liquid phase in the expanded fluid; for a line to lead the gaseous phase to a manifold in order to mix it with the gas produced by the evaporation of the cryogenic liquid, and for the bypass to feed a heat exchanger for cooling the gaseous phase prior to introduction into the manifold.

The system described above is particularly well suited to a reliquefaction unit which uses as refrigerant liquid the same fluid as the fluid to be liquefied. In this advantageous alternative, said unit thus comprises for example, downstream of its compression means a bypass to a loop comprising second expansion means, and the loop joins the circuit upstream of the compression means after having passed through the first heat exchanger in the opposite direction to the gas fraction of the circuit not bypassed by the loop. In this embodiment, it is preferably provided for the compression means to comprise several compression stages each with a compressor wheel, for the second expansion means to comprise an expansion turbine, and for each compressor wheel and the expansion turbine to be associated with a same mechanical transmission. It is also possible to provide for the system, with such a reliquefaction unit, to further comprise a third heat exchanger between bypassed pressurized liquid of the supply line and gas between the compression means and the second expansion means. This third exchanger makes it possible to increase the exchanges and thus to optimize the system. As mentioned above, according to a first alternative embodiment, the third exchanger can be mounted in parallel with the second exchanger and according to another alternative embodiment, the third exchanger can be mounted in series with the second exchanger.

The present invention likewise relates to a vessel, in particular an LNG carrier, propelled by a gas engine, characterized in that it comprises a system for treating a gas produced by the evaporation of a cryogenic liquid and for supplying a gas engine with pressurized gas as described above.

Finally, the present invention proposes a method for treating a flow of gas produced by the evaporation of a cryogenic liquid and for supplying an engine with gas under high pressure, said flow of gas being first compressed and then cooled and condensed at least partially within a first heat exchanger before being expanded, and the supplying of gas under high pressure being carried out by pressurizing the cryogenic liquid and then vaporizing same, and after its compression, the flow of pressurized liquid being separated into a first part of liquid flow and a second part of liquid flow, and the first part of the liquid flow being used to cool compressed and condensed gas within a second exchanger prior to

expansion of the condensed gas, and the second part of the liquid flow receiving the first part of the liquid flow after the latter has cooled the compressed gas, the entire liquid flow then being vaporized.

5 This method advantageously provides for more than half, and preferably at least 90 % by mass of the compressed gas to be condensed before being cooled within the second exchanger.

 In order to increase the reliquefaction efficiency, it is advantageously
10 provided for the flow of pressurized liquid to also be used to cool gas before it is condensed.

 In a method as described above, it is advantageously provided for part of the compressed gas to be taken from within the first heat exchanger in order to be
15 expanded within an expansion turbine, and for the expanded gas to be introduced into the first heat exchanger counter currently to cool the compressed gas and cause its condensation. In this way, the fluid to be reliquefied is also used as refrigerant fluid and it is therefore not necessary to provide a refrigerant circuit using another fluid to allow the reliquefaction.

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 Details and advantages of the present invention will appear more clearly from the following description, made in reference to the enclosed schematic drawing, in which:

 Figures 1 to 8 are each a schematic view, according to several variants, of
25 a tank of cryogenic liquid associated with a system for recovering boil-off gas from said tank, with a system for treating a portion of the recovered gas in order to liquefy it and with a line for supplying gas under high pressure to a gas engine.

 Each of the enclosed figures shows a tank 1. Throughout the remainder of
30 the description, this will be presumed to be a tank of Liquefied Natural Gas (or LNG) among several other similar tanks on board a seagoing LNG carrier.

 The numerical values in the following description are given as merely illustrative numerical examples that have no limiting effect. They are suitable for

treating LNG on board a vessel but may vary, particularly if the nature of the gas changes.

The tank 1 stores the LNG at a temperature of the order of -163 °C which
5 corresponds to the usual storage temperature for LNG at a pressure close to atmospheric pressure. This temperature depends of course on the composition of the natural gas and the storage conditions. When the atmosphere around the tank 1 is at a much higher temperature than that of the LNG, even if the tank 1 is very well thermally insulated, heat energy is added to the liquid which heats up and
10 vaporizes. As the volume of the boil-off gas is much greater than that of the corresponding liquid, the pressure inside the tank 1 tends to increase as time passes and heat energy is added to the liquid.

To avoid reaching excessively high pressures, the boil-off gas is gradually
15 removed from the tank 1 (and from the other tanks of the vessel) and ends up in a manifold 2 connected to several tanks. In the remainder of the description, the boil-off gas is called “gas” even when it is subsequently reliquefied. It is thus distinguished from the LNG, which is collected in liquid form from the tanks in order to supply an engine.

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It is provided in the systems shown in the drawing to use the boil-off gas as an energy source on board the vessel (for example to generate electricity) and to reliquefy the surplus gas. The aim here is to avoid losing the boil-off gas and thus either to use it on board the vessel, or to recover it and return it, in the liquid
25 phase, to the tank 1. Moreover, a line is provided for supplying a MEGI-type gas engine with high-pressure gas from liquid LNG collected from the tanks of the vessel.

In order to be used on board the vessel, the boil-off gas from the tanks
30 must first be compressed. This compression is thus carried out in a first compression unit 3 which can be, as shown in the drawing, multi-stage. This unit, by way of illustrative numerical example with no limiting effect, brings the pressure of the gas collected in the manifold 2 from a pressure substantially equal to atmospheric pressure to a pressure of the order of 15 to 20 bar (1 bar=10⁵ Pa).

After this first compression step, the gas passes into an intermediate cooler 4 in which it is cooled without substantially modifying its pressure. The gas that was heated during its compression is at a temperature of the order of 40 °C to 45 °C at the outlet of the intermediate cooler (these values are provided merely for illustration and apply in particular for natural gas). The gas thus compressed and cooled can then be sent in the gaseous phase via a pipe 5 to a generator on board the vessel.

The gas demand in the generator(s) of the vessel is thus lower than the "production" of gas by evaporation in all the tanks that are on board the vessel. The gas not used in the generator(s) is thus sent to a reliquefaction unit 10.

The reliquefaction unit 10 comprises at the inlet thereof a valve 6 intended in particular for controlling the pressure of the gas inside the pipe 5, followed by a main circuit and a loop that will be described hereunder.

The main circuit makes it possible from the gas (in the gaseous phase and which is at a pressure of the order of several bars at around 50 bar –non-limiting values–) to obtain gas in the liquid phase which can return to the tank 1.

The method for obtaining this gas in the liquid phase to be returned to the tank is conventional. It consists of compressing the gas, cooling it to condense it and then expanding it so that it returns to the pressure inside the tanks. This procedure is conventional in the field of cryogenics.

Thus, the main circuit is found to include first a multi-stage compressor which here comprises three consecutive stages with references 11, 12 and 13. Each stage is formed by a compression wheel and the three compression wheels are driven by a same transmission 15 with shafts and sprockets. The line between the compression stages in the figures symbolizes the mechanical connection therebetween. In the embodiment shown in Figure 1, the gas arriving in the multi-stage compressor arrives in the second stage 12 of this compressor. Depending on the system, it may also arrive at the first –as shown in the other figures of the drawing– or at the third (or more generally the n^{th} stage) of this compressor.

After this second compression, the gas passes into an intermediate cooler 16. Its pressure is then several dozen bars, for example around 50 bar, and its temperature once again is of the order of 40 °C to 45 °C.

5 The gas thus compressed is then cooled and condensed inside a first multi-flow exchanger 17. The gas circulates in this first exchanger 17 in a first direction. The fluids circulating in the opposite direction (to this first direction) and being used to cool same will be described hereunder.

10 At the outlet of the first exchanger 17, the compressed gas cooled to a temperature of the order of -110 °C to -120 °C is mostly (almost entirely) in the liquid phase and is sent, still at a pressure of the order of several dozen bars (for example around 50 bar) via an insulated pipe 22 to an expansion valve 30.

15 Expansion through the expansion valve 30 of the condensed gas simultaneously provides methane-rich gas in the liquid phase and a nitrogen-rich gas in the gaseous phase. The separation of this liquid phase and this gaseous phase is carried out inside a balloon 40 in which the pressure is of the order of several bars, for example between 3 bar and 5 bar.

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 The gas in the gaseous phase of the balloon 40 is preferably sent back to the manifold 2. In this way, it can be used as fuel in a generator, or pass back into the reliquefaction unit 10. Since this gas is cold, it can be used to cool and condense the compressed gas in the first exchanger 17. It is thus provided to
25 circulate it in the opposite direction in this first exchanger 17 before returning it to the manifold 2.

 If the gas in the gaseous phase of the balloon 40 for various reasons, in particular during transient phases, cannot be recycled to the manifold 2, it is
30 provided to send it to a flare or a combustion unit. A set of valves 31, 32 controls the sending of the gas in the gaseous phase from the balloon 40 respectively to the manifold 2 by a connecting pipe 35 or to a combustion unit (not shown).

The gas in the liquid phase recovered at the bottom of the balloon 40 is, conversely, intended for being returned to the tank 1. Depending on the operating conditions, the gas in the liquid phase can be sent to the tank 1 directly (passage controlled by a valve 33), or by means of a pump 41 (passage controlled by a valve 34).

The return of the gas in the liquid phase coming from the balloon 40, directly or by means of the pump 41, to the tank 1 takes place via an insulated pipe 36 provided herein with a valve 54, for example a shut-off valve.

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In the reliquefaction unit 10, it is advisable to cool the compressed gas in the multi-stage compressor (stages 11, 12 and 13). This cooling is generally carried out using a separate thermodynamic machine, operating for example according to a Brayton cycle, and using nitrogen as refrigerant fluid. It is possible to use in the reliquefaction unit 10 such a refrigeration machine which then cools and condenses the gas within the first exchanger 17. However, it is proposed herein as mentioned above, to provide this reliquefaction unit with a cooling loop using the natural gas as refrigerant fluid. This loop starts with a branch pipe 18 that separates the flow of gas downstream of the multi-stage compressor (stages 11, 12, 13) into a first flow, or main flow, which corresponds to the main circuit described above, and into a second flow, or branched flow.

The branch pipe 18 is preferably connected to the main circuit at the first exchanger 17. The gas in the gaseous phase which thus enters the branch pipe 18 is at "high pressure" (around 50 bar in the numerical example provided) and at an intermediate temperature between 40 °C and -110 °C.

The gas collected by the branch pipe 18 is expanded within expansion means formed by an expansion turbine 14. This expansion turbine 14 is, in the preferred embodiment shown in the drawing, mechanically connected to the three compression wheels corresponding to stages 11, 12 and 13 of the multi-stage compressor of the reliquefaction unit 10. The transmission 15 by shafts and sprockets connects the expansion turbine 14 and the compression wheels of the

multi-stage compressor. This transmission 15 is symbolized by a line connecting the expansion turbine 14 to stages 11, 12 and 13 in the figures.

The gas is expanded for example to a pressure level that would
5 correspond to the pressure level thereof at the intake of the reliquefaction unit 10, that is about 15 bar to 20 bar. Its temperature drops below -120 °C. This flow of gas (gaseous phase) is then sent to the first exchanger 17 in the opposite direction in order to cool and condense the pressurized gas of the main circuit, initially in a portion 19 located downstream of the branch pipe 18 and then in a portion of this
10 main circuit in the first exchanger 17 upstream of this branch pipe 18. At the outlet of the first exchanger 17, the expanded gas reaches temperatures of the order of 40 °C and can be reinjected in the gaseous phase into the main circuit of the reliquefaction unit, upstream of the multi-stage compressor by a return pipe 21.

15 An open cooling loop is thus formed which uses as cooling gas the same gas as that which is to be liquefied.

As indicated above, the shown system also has a line for supplying gas under (high) pressure to a gas engine, for example a MEGI-type engine (not
20 shown). This supply line starts in a tank 1. It is first fed by a submersible pump 50 which feeds cryogenic liquid (LNG) to a pipe 51 in order to convey it towards a high-pressure pump 48. The liquid under high pressure is then carried through a pipe 56 into a vaporizer 61, performing for example a heat exchange with steam, in order to produce vapor (natural gas in the gaseous phase) under high pressure
25 which can then supply a MEGI-type engine via a supply line 62.

The presence of a bypass 57 on the pipe 56 is noted in the figures. This bypass 57 will feed with pressurized liquid, still in the liquid phase, a second exchanger 60 intended for sub-cooling the condensate exiting from the first
30 exchanger 17 in the main circuit of the reliquefaction unit 10. This second exchanger 60, in the embodiment shown in Figure 1, is provided here for performing a heat exchange between on the one hand the pressurized liquid of the pipe 56 supplying the MEGI engine (or others) and bypassed by the bypass 57

and on the other hand the condensate located in the insulated pipe 22 between the first exchanger 17 and the expansion valve 30.

By way of merely illustrative numerical example with no limiting effect, the liquid bypassed in the bypass 57 is at around -150°C upstream of the second exchanger 60 and exits from the latter for example at -140°C (still in the liquid phase). In the insulated pipe 22, the condensed gas exiting the first exchanger 17 passes for example from -120°C to -135°C .

In the embodiment of Figure 1, the regulation of the flows in the pipe 56 and the bypass 57 is provided by means of a valve 55 placed on the pipe 56 upstream of the bypass 57 and of another valve 59 built into the bypass 57 (shown downstream of the second exchanger 60 but a person skilled in the art would understand that this valve 59 can likewise be disposed upstream of this second exchanger 60). A valve 58, with manual or automatic control, is likewise provided between the two connection points of the bypass 57 with the pipe 56.

Finally, Figure 1 (and the following figures) show the presence of a junction 52 provided with a valve 53 between the insulated pipe 36 and the pipe 51. This junction 52 makes it possible to pass the liquid obtained from the reliquefaction unit 10 directly to the pipe 51 and thus to the high-pressure pump 48 without passing back through a tank 1. It is thus clearly possible to limit the losses of load and the heat losses.

Figure 2 shows an alternative embodiment of the system of Figure 1 with two modifications that are completely independent of one another. It is provided first of all, as was already mentioned above, to inject the compressed gas into the first compression unit 3 in the first stage 11 of the multi-stage compressor of the reliquefaction unit. Next, it is provided to perform the regulation at the second heat exchanger 60 in a slightly different manner. Instead of adjusting the exchanges in the exchanger by varying the flow rates in the bypass 57 (Figure 1), it is provided herein to vary the flow rates passing through the exchanger in the insulated pipe 22. The embodiment of Figure 2 thus provides for passing into the second exchanger 60 between 0 % and 100 % of the flow (mixture of gaseous and liquid

phase but mostly liquid phase) circulating in the insulated pipe 22. For this purpose, a branch pipe 66 short-circuits the second exchanger 60. A three-way valve 65 is provided upstream of the second exchanger 60 for regulating the flow of the insulated pipe 22 passing through the second exchanger 60 and that
5 passing through the branch pipe 66. Other regulation means may be contemplated (for example in the bypass 57, with one valve upstream of the branch pipe and one valve in the branch pipe and/or in the circuit branch containing the second exchanger). In this embodiment, it is provided to be able also to isolate the second exchanger 60 from the supply line of the MEGI engine (pipe 56). For this purpose,
10 the embodiment of Figure 2 simply contemplates providing each branch of the bypass 57, an upstream branch and a downstream branch of the second exchanger 60, with a valve, 64a and 64b, respectively, with manual control or controlled.

15 In the embodiment of Figure 3, it is provided to simplify the structure of the first exchanger 17 (this simplification can also be proposed in the other alternative embodiments of the invention). Here, the connection pipe 35 between the balloon 40 and the manifold 2 no longer passes through the first exchanger 17, the structure of which is thus simplified. By virtue of the exchanges carried out inside
20 the second exchanger 60, it is possible to obtain good reliquefaction of the boil-off gases in the reliquefaction unit 10 with a first exchanger 17 having a simpler structure and thus a reduced cost price.

In the embodiment of this Figure 3, another regulation of the flows in the
25 bypass 57 is proposed. In this variant, a valve 63 is disposed between the two connection points of the bypass 57 with the pipe 56 of the supply line of the engine (not shown).

Figure 4 provides for passing all the boil-off gas recovered in the tanks 1
30 by the manifold 2 first into the first compression unit 3 and then into the reliquefaction unit 10.

Figures 5 and 6 show embodiments that use a third heat exchanger 70 to cool the gas in the gaseous phase entering the open refrigeration loop of the

reliquefaction unit 10. The exchange is carried out here between the liquid of the line 56 and the compressed gas in the gaseous phase and already partially cooled of the bypassed pipe 18.

5 In the embodiment of Figure 5, the third exchanger 70 is mounted in parallel with the second exchanger 60 while in the embodiment of Figure 6, the third exchanger 70 is mounted in series with the (and downstream of the) second exchanger 60.

10 Figure 7 proposes an embodiment in which four heat exchangers 80a-d are provided at several points of the main circuit of the reliquefaction unit 10 in order to further cool the gas in the gaseous phase before liquefying it. The exchanger 80a is intended herein for cooling the compressed gas in the first stage 11 of the multi-stage compressor before it enters the second stage 12 of this
15 compressor. The exchanger 80b is arranged in a similar manner between the second stage 12 and the third stage 13. Another exchanger 80c is arranged downstream of the multi-stage compressor, before or after the intermediate cooler 16 and before the first exchanger 17. Finally, it is proposed herein to also provide a heat exchanger 80d on the connection pipe 35 in order to cool the gas returning
20 to the manifold 2.

 This embodiment is provided for the purpose of illustration (with no limiting effect) of the various possibilities for positioning exchangers supplied with cryogenic liquid under high pressure. These exchangers can number four, or
25 more, or less. They are preferably mounted in parallel as shown, the exchangers 80n forming an exchange system mounted in series with the second exchanger 60. Other mounting options (in series or in parallel) can be contemplated. It is also possible to provide exchangers on the open-loop cooling circuit.

30 Finally, Figure 8 is enclosed to show that the pressurized liquid (still in the liquid phase) in the pipe 56 can also be used, partially, to cool other elements in a cooling system 90 on board the vessel. The liquid used for the cooling system 90 is preferably arranged downstream of the second exchanger 60 so that the liquid of the pipe 56 collected in the bypass 57 serves mainly for cooling at the

reliquefaction unit 10. The cooling system can be, for example, an air-conditioning unit, an industrial cooling unit, etc.

The variants proposed in the various embodiments can be combined in
5 several ways in order to produce other embodiments according to the present invention but which are not shown.

The system proposed herein performs a cooperation between a
liquefaction unit and a supply of gas under high pressure, for example for
10 supplying a MEGI-type engine. Synergy is created between these two sub-systems, one needing cold to liquefy a gas and the other needing energy to vaporize liquid under high pressure. The system as proposed makes it possible to increase the performance of the reliquefaction unit, i.e. to increase the proportion of the boil-off gas that is reliquefied, to limit the cold needs to be provided in order
15 to reliquefy the boil-off gas and at the same time to limit the energy needs in order to obtain a gas under high pressure to supply an engine (MEGI engine or another system running on gas under high pressure).

The system proposed herein is particularly well adapted to a reliquefaction
20 unit having an open loop for refrigerating gas corresponding to the refrigerated gas with cold production at two different temperatures, a temperature of around -120 °C at the outlet of the expansion turbine and a temperature of around -160 °C at the outlet of the expansion valve.

25 The system is independent of the engines located on board the vessel and which are supplied with the boil-off gas. There can be two different types of gas engines, one supplied by the high-pressure supply line and the other by the boil-off gas compressed by the first compression unit. The system also makes it possible, from the boil-off gas, independently of any external cold source, to perform a
30 liquefaction.

In the bypass created on the high-pressure gas supply line, the cold production can be adapted to the load of the reliquefaction unit and can be regulated in a broad range.

The proposed system does not need a unit for treating nitrogen or the like. Its structure is simplified by the use of a refrigerant gas of the same nature as the gas to be refrigerated and liquefied and which also serves as fuel for an engine (or the like).

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The present invention is obviously not limited to the embodiments of the systems and methods described above as non-limiting examples but it likewise relates to all the alternative embodiments that are available to a person skilled in the art in the context of the claims hereunder.

10

PATENTKRAV

1. System til behandling af en gas, der fremstilles ved fordampning af en kryogen væske, og til forsyning af en gasmotor med gas under tryk, hvilket system
5 på den ene side, fra opstrøms mod nedstrøms, omfatter en genlikvefaktionsenhed (10) med komprimeringsmidler (11, 12, 13), en første varmeveksler (17) og ekspansionsmidler (30) og på den anden side omfatter en forsyningsledning med gas under tryk, der fra opstrøms mod nedstrøms omfatter en pumpe (48) til at sætte væske under tryk og fordampningsmidler (61) under højt tryk, idet
10 forsyningsledningen med gas under tryk opstrøms for fordampningsmidlerne (61) har en omføring (57) til tilførsel til en anden varmeveksler (60) mellem, på den ene side, væske, der er sat under tryk, fra forsyningsledningen (56) og, på den anden side, en ledning (22) i genlikvefaktionsenheden (10) nedstrøms for den første varmeveksler (17) og opstrøms for ekspansionsmidlerne (30),
15 **kendetegnet ved, at** gassen som følge af fordampning af en kryogen væske, derefter komprimeret og afkølet, mindst delvist kondenseres i den første varmeveksler (17).
2. System ifølge krav 1, **kendetegnet ved, at** omføringen (57) nedstrøms
20 for den anden veksler (60) tilfører materiale til et kølesystem.
3. System ifølge krav 2, **kendetegnet ved, at** det omfatter en tredje veksler (70), som er seriemonteret med og nedstrøms for den anden veksler (60).
- 25 4. System ifølge et af kravene 1 eller 2, **kendetegnet ved, at** det omfatter en varmeveksler (70), som er parallelmonteret med den anden veksler (60).
5. System ifølge et af kravene 1 til 4, **kendetegnet ved, at** omføringen (56) yderligere tilfører materiale til den anden veksler (60), én eller flere
30 varmevekslere til afkøling af gassen inden likvefaktionen deraf.
6. System ifølge et af kravene 1 til 5, **kendetegnet ved, at** det nedstrøms for ekspansionsmidlerne (30) omfatter en ballon (40), der separerer den gasformige fase fra den flydende fase i det ekspanderede fluid, **ved, at** en ledning leder den

gasformige fase til en manifold til blanding deraf med gassen fra fordampningen af den kryogene væske, og **ved, at** omføringen (56) tilfører materiale til en varmeveksler (80dd') til afkøling af den gasformige fase inden indføring i manifolden (2).

5 7. System ifølge et af kravene 1 til 6, **kendetegnet ved, at**
genlikvefaktionsenheden nedstrøms for komprimeringsmidlerne (11, 12, 13)
omfatter en omføring til en løkke med et andet ekspansionsmiddel (14), og **ved, at**
løkken tilslutter sig kredsløbet opstrøms for komprimeringsmidlerne (11, 12, 13)
efter at have passeret gennem den første varmeveksler (17) i den modsatte retning i
10 forhold til den gasfraktion i kredsløbet, som ikke omføres ved hjælp af løkken.

8. System ifølge krav 7, **kendetegnet ved, at** komprimeringsmidlerne
omfatter adskillige komprimeringstrin (11, 12, 13), hver især med et
kompressorhjul, **ved, at** det andet ekspansionsmiddel omfatter en
15 ekspansionsturbine (14), og **ved, at** hvert kompressorhjul og ekspansionsturbinen
(14) er forbundet med en samme mekanisk transmission (15).

9. System ifølge krav 3 samt ifølge et af kravene 7 eller 8, i det omfang de
afhænger af krav 3, **kendetegnet ved, at** den tredje varmeveksler (70) udveksler
20 varme mellem væske, der er sat under tryk og er afledt af forsyningsledningen
(56), og gas mellem komprimeringsmidlerne (11, 12, 13) og det andet
ekspansionsmiddel (14).

10. Fartøj, især LNG-tankskib, der fremdrives med en gasmotor,
25 **kendetegnet ved, at** det omfatter et system til behandling af en gas, som
fremstilles ved fordampning af en kryogen væske, og til forsyning af en gasmotor
med gas under tryk ifølge et af kravene 1 til 9.

11. Fremgangsmåde til behandling af en gasstrøm, der fremstilles ved
30 fordampning af en kryogen væske, og til forsyning af en motor med gas under
højt tryk,

hvilken gasstrøm først komprimeres, derefter afkøles i en første
varmeveksler (17), inden den ekspanderes, og

tilførslen af gas under højt tryk opnås ved at sætte kryogen væske under tryk, derefter fordampe den,

kendetegnet ved, at strømmen af væske, der er sat under tryk, efter komprimeringen separeres i en første del af væskestrøm og en anden del af væskestrøm,

ved, at den første del af væskestrømmen anvendes til at afkøle komprimeret og kondenseret gas i en anden veksler (60) inden ekspansion af den kondenserede gas, og

ved, at den anden del af væskestrømmen modtager den første del af væskestrømmen, efter at sidstnævnte har afkølet komprimeret gas, idet hele væskestrømmen derefter fordampes, **kendetegnet ved, at** gassen som følge af fordampningen af en kryogen væske, og efterfølgende komprimeret og afkølet, mindst delvist kondenseres i den første varmeveksler.

12. Fremgangsmåde ifølge krav 11, **kendetegnet ved, at** mere end halvdelen og fortrinsvis mindst 90 masse-% af den komprimerede gas kondenseres, inden den afkøles i den anden veksler (60).

13. Fremgangsmåde ifølge et af kravene 11 eller 12, **kendetegnet ved, at** strømmen af væske, der er sat under tryk, også anvendes til at afkøle gas, inden den kondenseres.

14. Fremgangsmåde ifølge et af kravene 11 til 13, **kendetegnet ved, at** en del af den komprimerede gas tages fra den første varmeveksler med henblik på at blive ekspanderet i en ekspansionsturbine (14), og **ved, at** den ekspanderede gas indføres i den første varmeveksler (17) i modstrøm med henblik på at afkøle den komprimerede gas og få den til at kondensere.

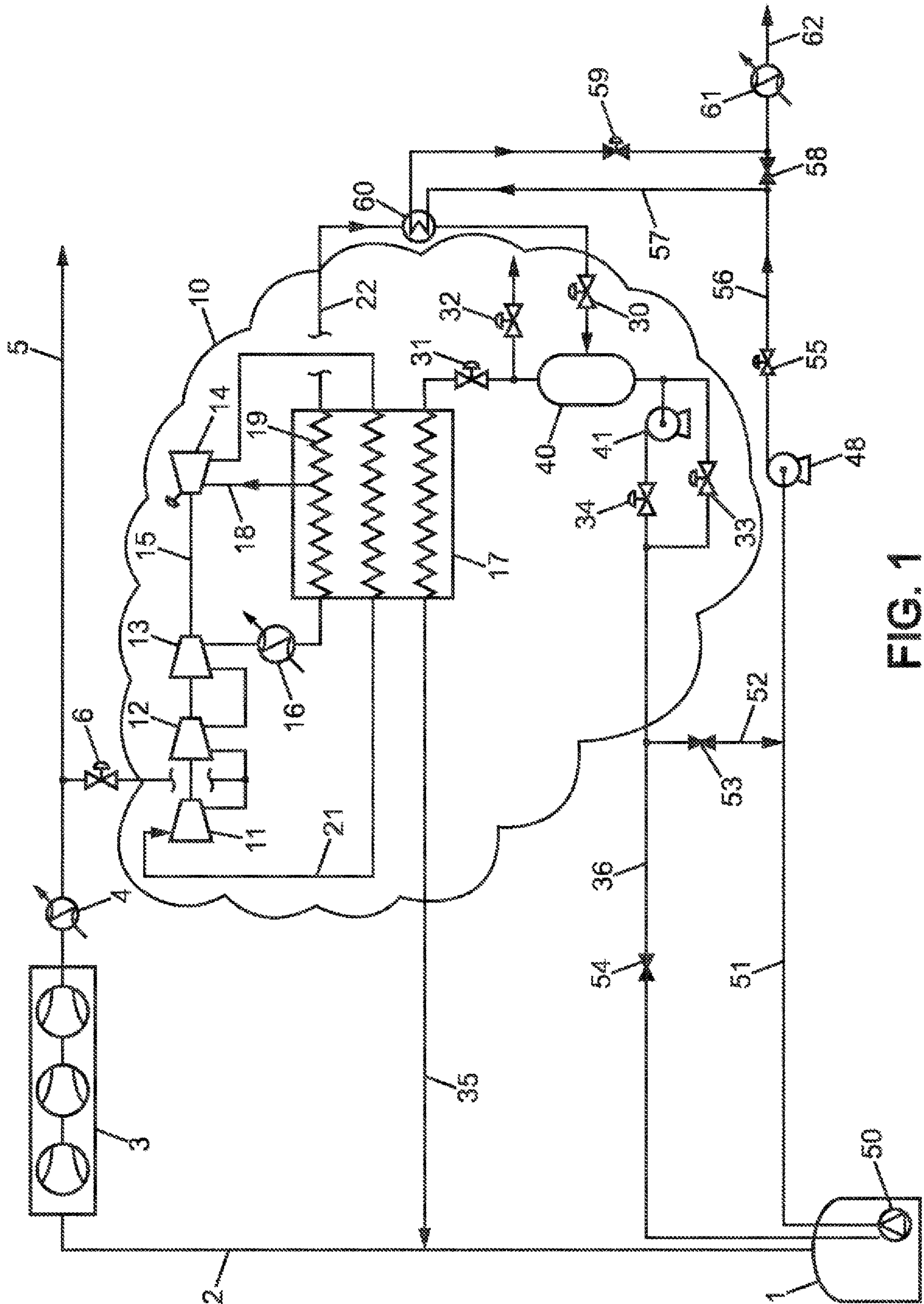


FIG. 1

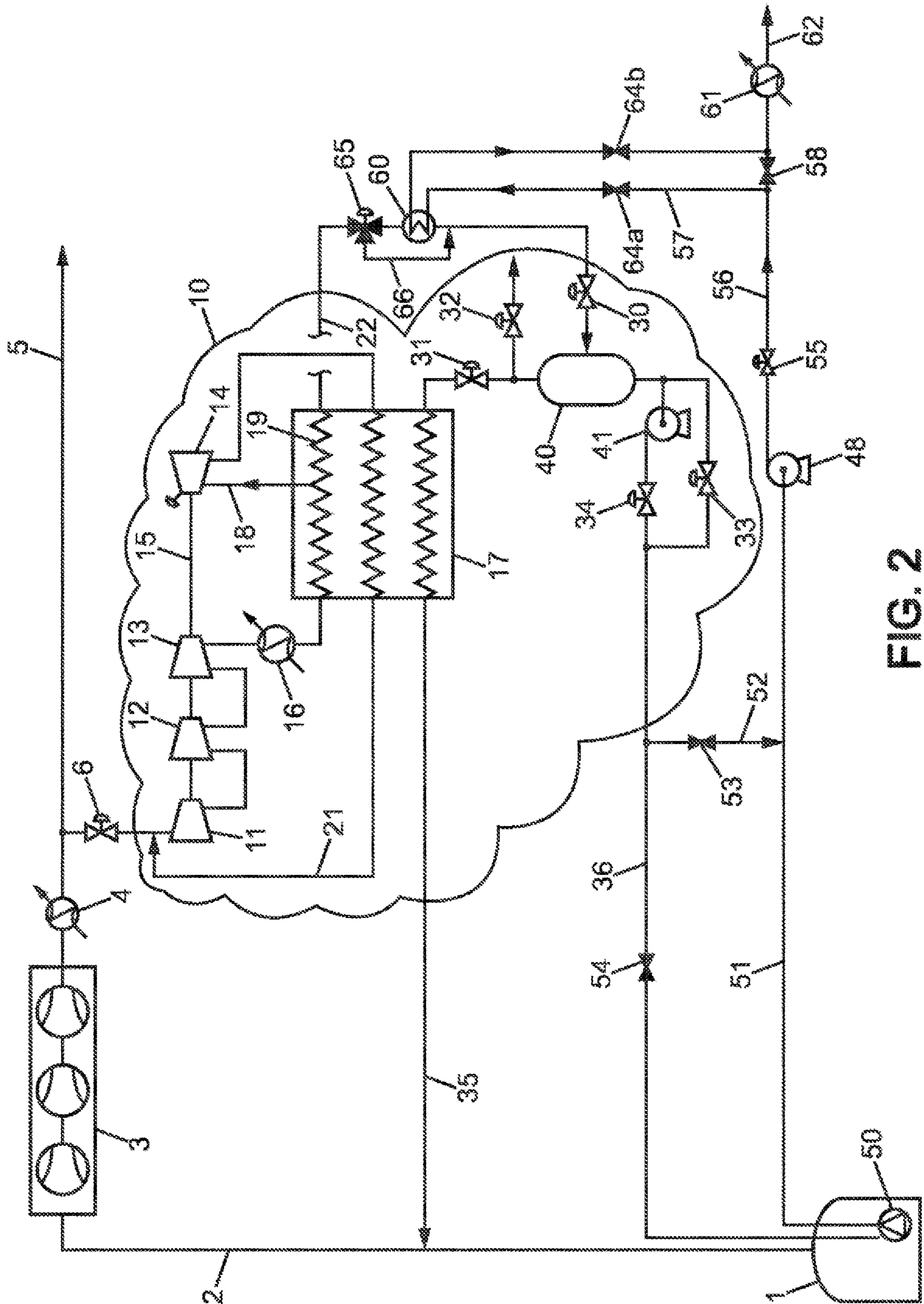


FIG. 2

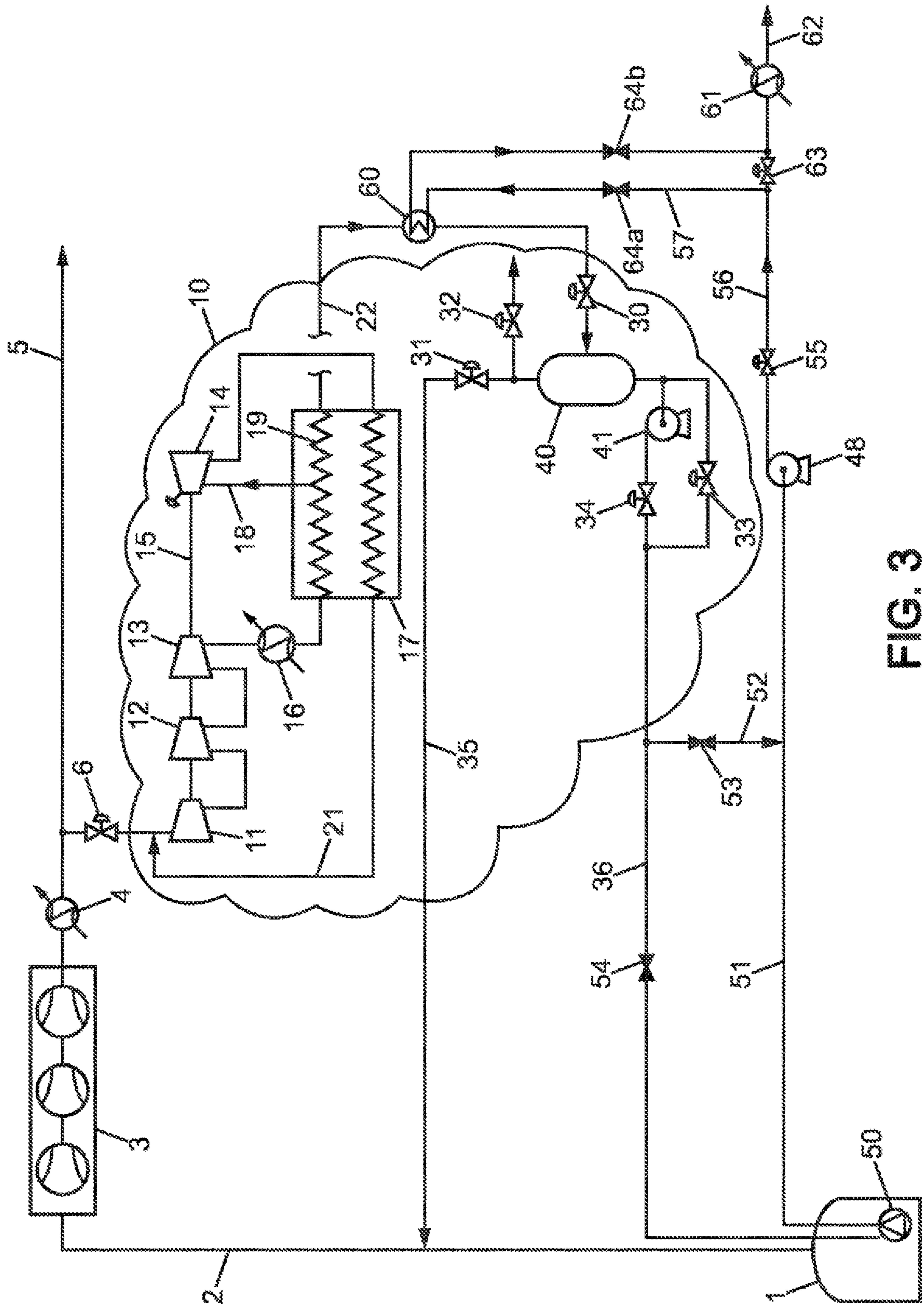


FIG. 3

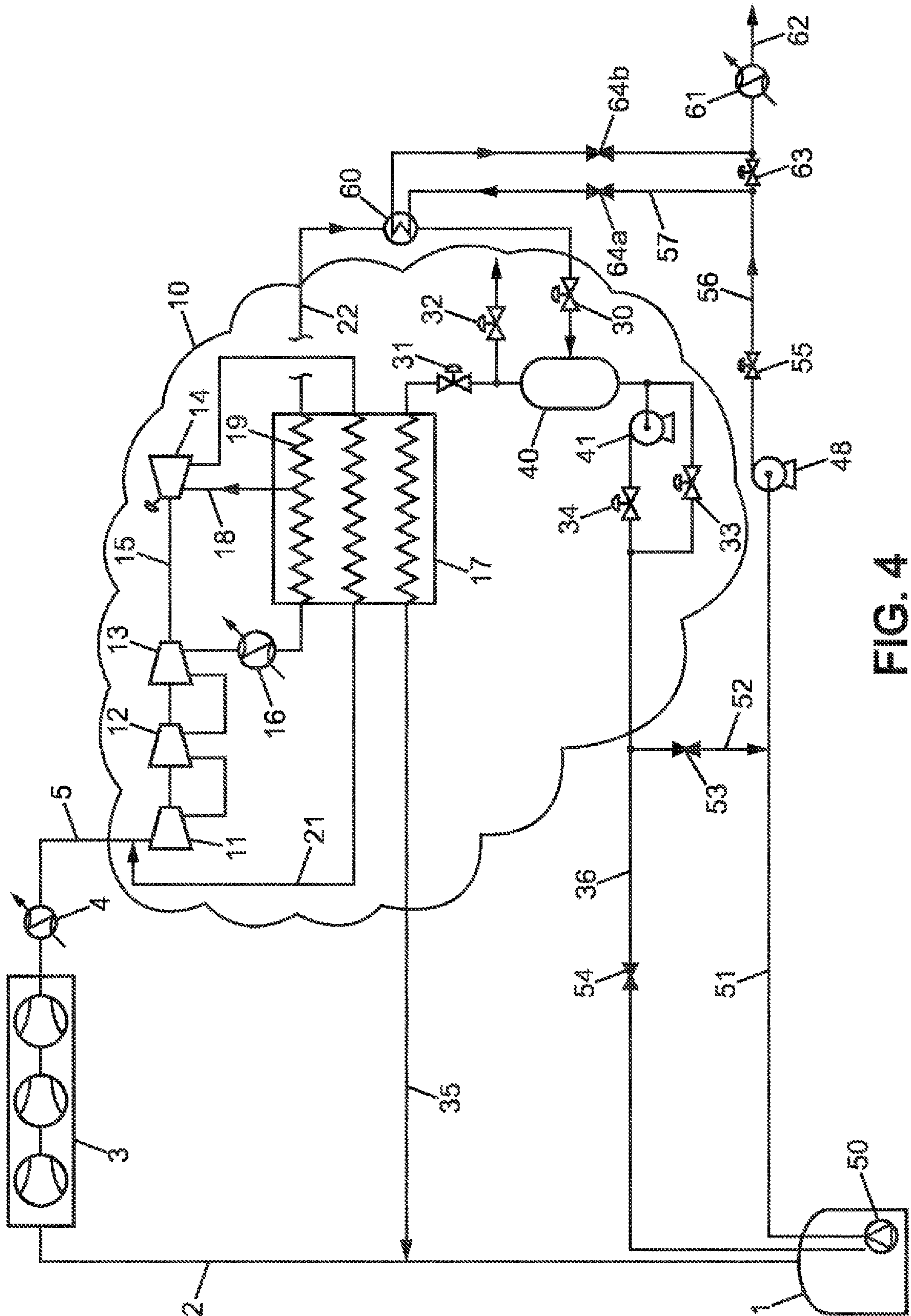
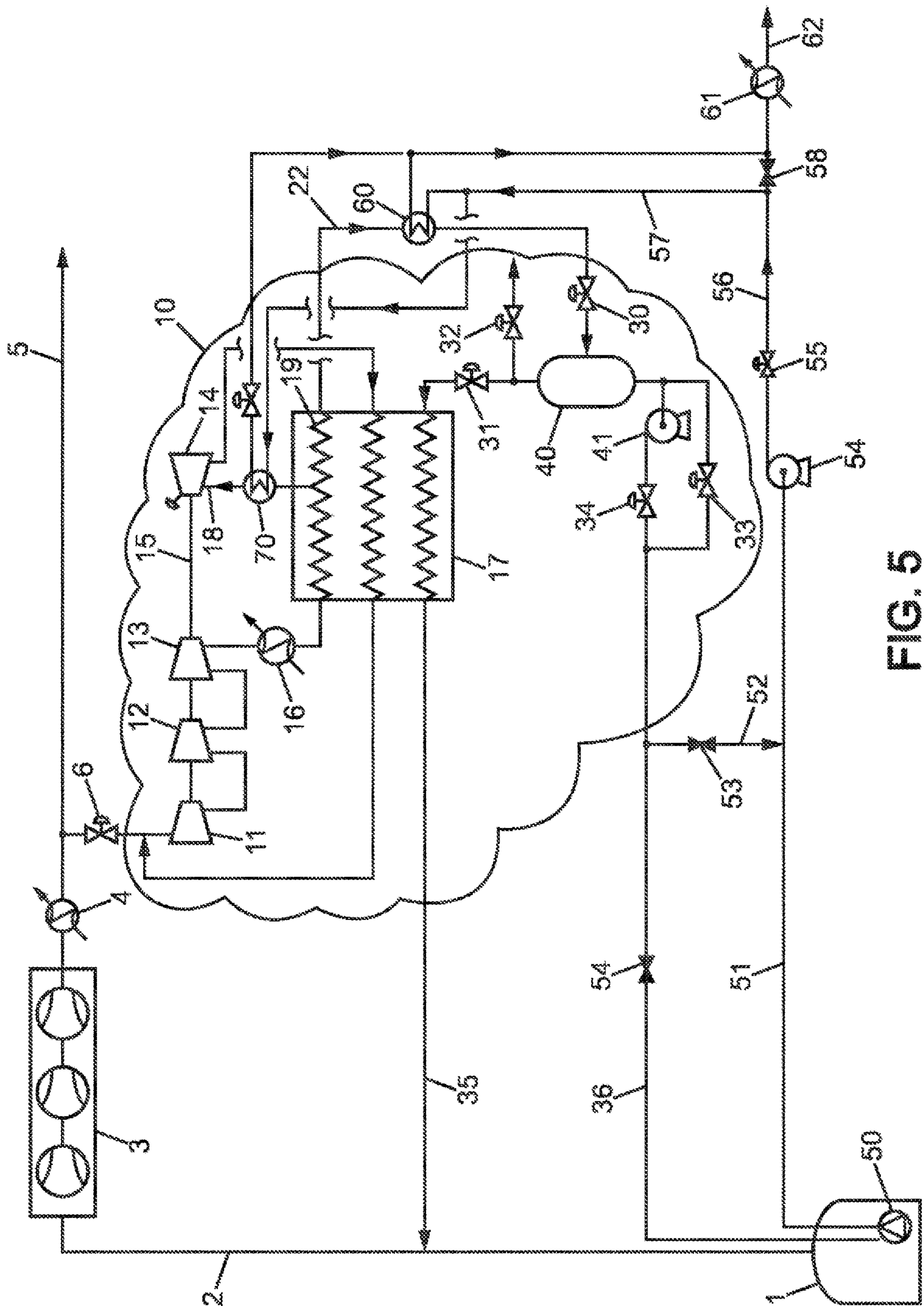


FIG. 4



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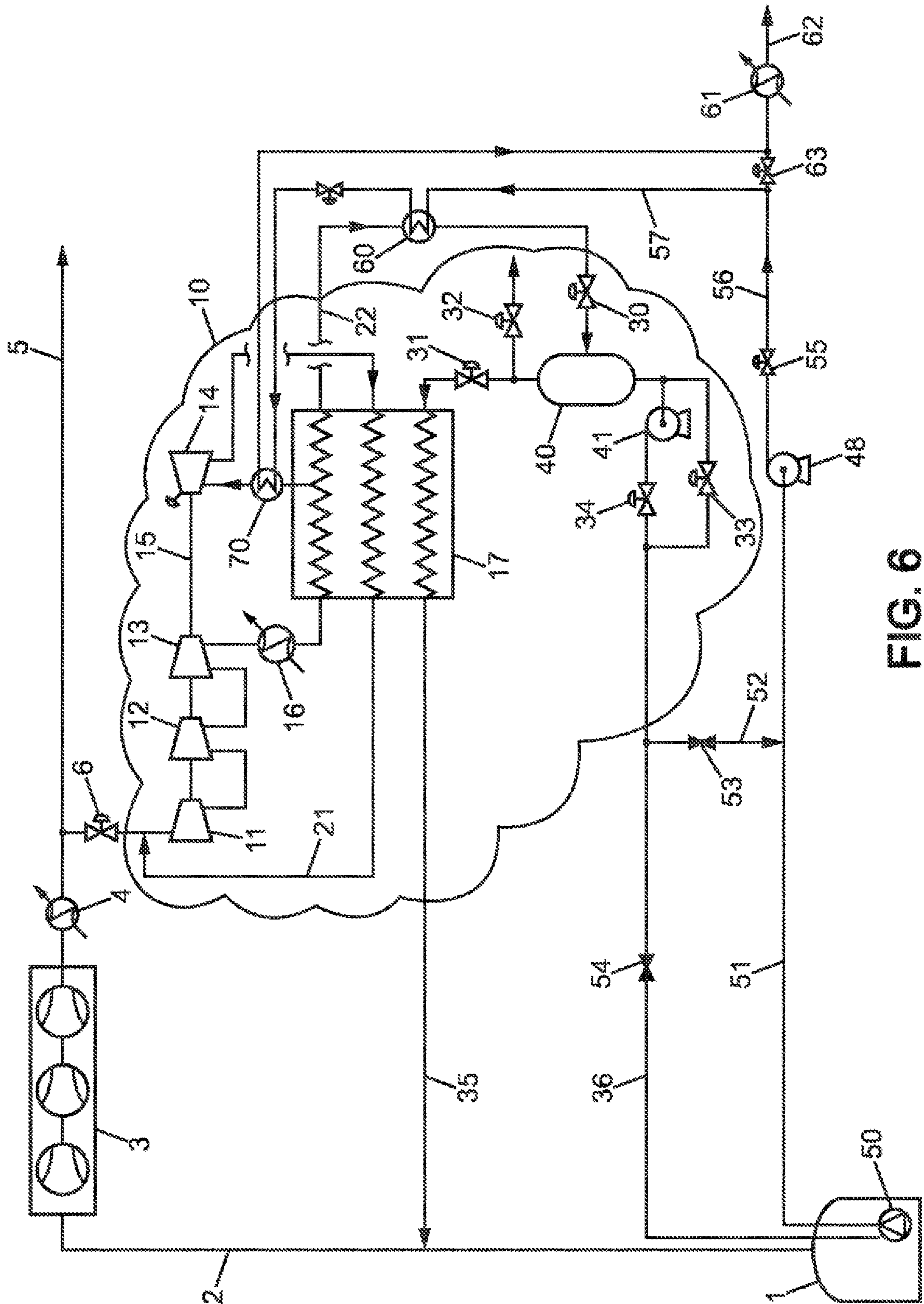
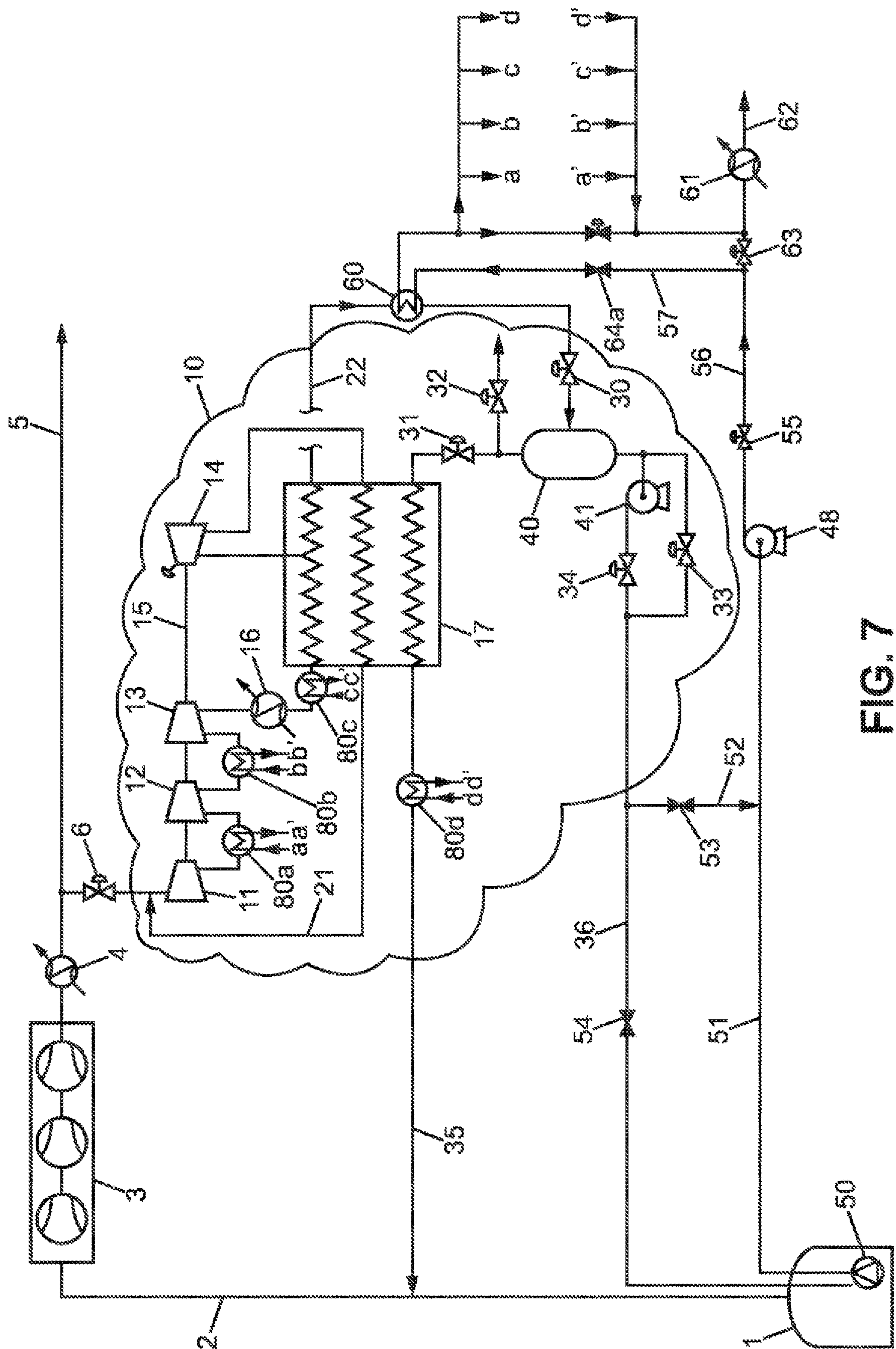


FIG. 6



COLL

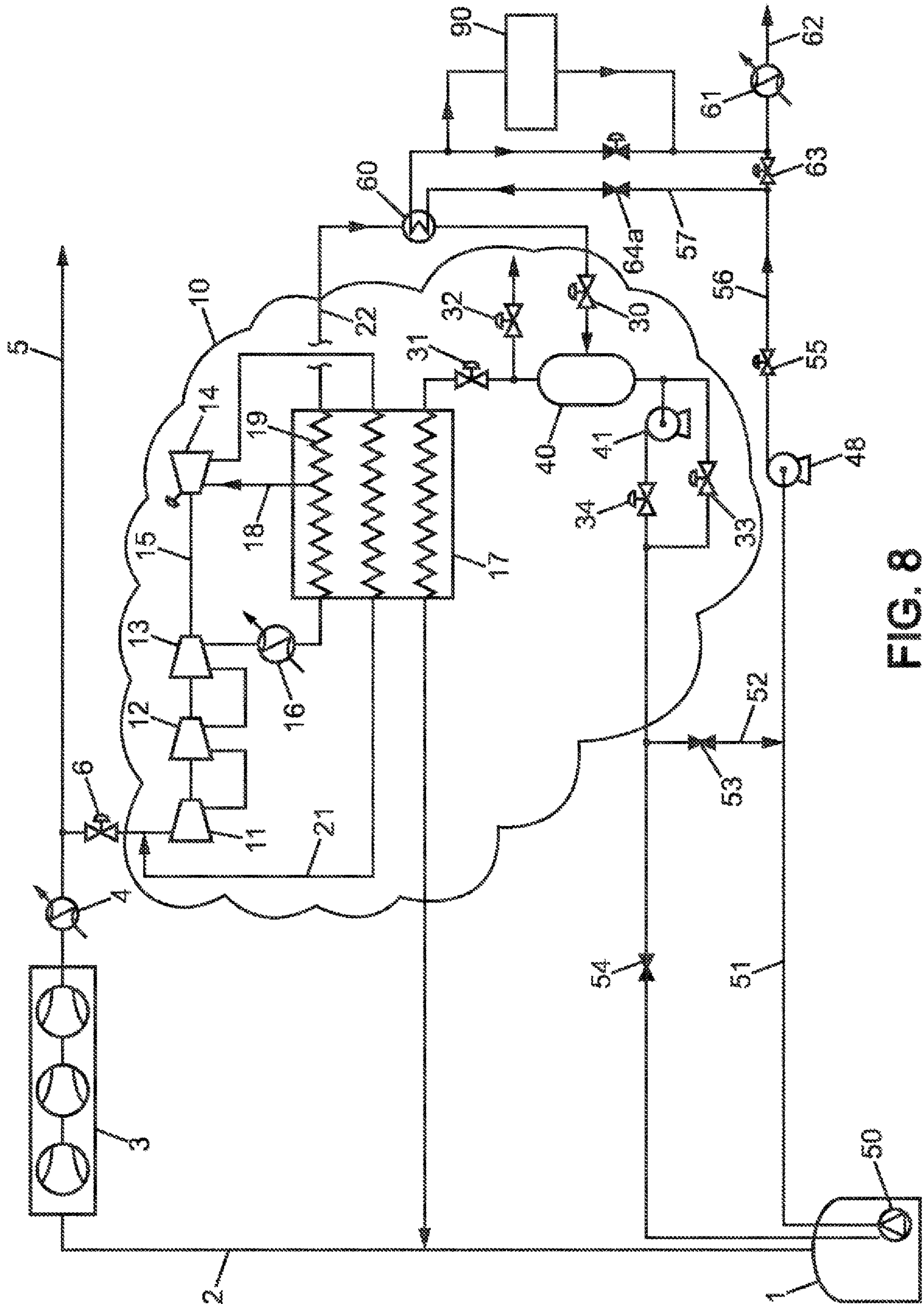


FIG. 8