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(54) **SYSTEM AND PROCESS FOR RECOVERING THE COLD OF LIQUEFIED NATURAL GAS IN REGASIFICATION PLANTS**

SYSTEM UND VERFAHREN ZUR RÜCKGEWINNUNG VON KÄLTE AUS EINER REGASIFIZIERUNGSANLAGE FÜR FLÜSSIGERDGAS

SYSTEME ET PROCEDE DE RECUPERATION DE FROID DU GNL DANS UNE INSTALLATION DE REGASIFICATION

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Description

OBJECT OF THE INVENTION

[0001] The present invention can be included in the technical field of liquefied natural gas regasification plants.

[0002] The system for recovering the cold of liquefied natural gas in regasification plants of the present invention proposes an alternative to the existing systems for recovering cold, at the same time that it guarantees the stability and reliability of the gas emission to the grid, and allows energy efficiency by not wasting energy nor minimising it, by using the extracted cold energy for other industrial uses.

[0003] Another aim of the invention is the associated process for recovering the cold of liquefied natural gas in regasification plants.

BACKGROUND OF THE INVENTION

[0004] Liquefied Natural Gas (hereinafter LNG) reception and regasification terminals are facilities that receive LNG from a transporter, generally by sea, via carrier ships, from the terminals wherein the liquefaction process take place, from the gas state thereof received from the wells from which the natural gas is extracted. This LNG is stored in a cryogenic state under conditions of saturation temperature and at a pressure very close to atmospheric pressure, approximately at -162 °C, in the tanks for storing LNG. The document EP 0828925 A1 discloses a system for recovering the cold of liquefied natural gas in a regasification plant.

[0005] The LNG from the storage tanks is pumped by low pressure pumps up to an intermediate pressure wherein it is mixed with the gas produced by evaporation during storage, previously compressed and, still in liquid state, it is subsequently pressurised by high pressure pumps and sent to the vaporisation systems, where it is vaporised at high pressure and sent to the high pressure natural gas grid from where it will be distributed to the end consumers.

[0006] Liquefaction processes, taking place in locations close to natural gas wells, require enormous amounts of energy necessary to generate the refrigeration cycles, generally by cascade systems, and to allow natural gas to cool from around 20-30 °C down to the final -162 °C, temperature at which natural gas liquefaction occurs. This allows LNG to be transported at a reasonable cost by sea.

[0007] In this manner, and as indicated above, LNG arrives at the reception and regasification terminals in liquid state where it must be regasified prior to being introduced into gas pipelines.

[0008] This regasification, which is usually produced by vaporisers with seawater or submerged combustion, also requires significant amounts of energy, which are the inverse to those that were required in the liquefaction process at source.

[0009] Seawater vaporisers achieve LNG vaporisation by means of heat exchange with enormous amounts of seawater, which are generally taken and returned to the sea in an open circuit so that the decrease in temperature does not affect the ecological environment in the vicinity of the regasification plant. Energy consumption is mainly required by the pumping systems.

[0010] Submerged combustion vaporisers, common in climatic environments wherein the low temperature of seawater makes the installation of the aforementioned vaporisers uneconomical, use the combustion energy of part of the natural gas to heat a water bath and vaporise the LNG. Energy consumption occurs mainly in the combustion of the natural gas stream used. In addition to this energy consumption, the exhaust gases produced in the combustion have an environmental impact.

[0011] The aforementioned regasification processes must guarantee stable and reliable operation at all times given the importance of the energy supply that falls on these facilities.

[0012] The present invention solves all the aforementioned drawbacks.

DESCRIPTION OF THE INVENTION

[0013] The invention presented herein incorporates a novel system for recovering cold, at the same time that it guarantees the stability and reliability of the gas emission to the grid, and allows energy efficiency by not wasting the energy used in the regasification process, or minimising it, by using the cold extracted for other industrial uses.

[0014] The present invention solves the technical problems posed by means of a system for recovering the cold of liquefied natural gas in regasification plants comprising:

- at least one tank of liquefied natural gas from which at least one first liquefied natural gas stream is extracted;
- a vaporiser configured to regasify at least the first liquefied natural gas stream, causing it to return to the gaseous state thereof by means of a first hot fluid;
- a first liquefied natural gas-second hot fluid heat exchanger wherein a first fraction of the first liquefied natural gas stream exchanges heat with a second hot fluid which is cooled;
- a liquefied natural gas mixer configured to mix the first fraction of the first liquefied natural gas stream with a second fraction of the first liquefied natural gas stream;

wherein the first liquefied natural gas stream leaving the mixer is introduced into the vaporiser.

[0015] In this way, LNG vaporisation together with the use of cold can be implemented in the terminals, offering a guarantee of stability and reliability and always preserving the priority objective of supplying the regasified natural gas to the high-pressure national gas grid.

[0016] Preferably, the first liquefied natural gas-second hot fluid heat exchanger comprises an intermediate fluid confined inside said first liquefied natural gas-second hot fluid heat exchanger.

[0017] This way, the second hot fluid uses the cold of the first liquefied natural gas stream to make use of the same in industrial processes and be sent to end users, while at the same time control of the first hot fluid is established, so that the flow rate thereof is reduced by the presence of the first liquefied natural gas-second hot fluid heat exchanger, thus contributing to lower consumption and higher energy efficiency.

[0018] Optionally, the first hot fluid is seawater or a heated water bath in the case of submerged combustion.

[0019] In other words, cold is extracted from the first natural gas stream at a pressure greater than the critical pressure and it is returned to enter into the vaporiser at a final temperature suitable for it to be sent to the gas pipeline grid under operating conditions which guarantee the stability of flows.

[0020] Optionally, the system comprises control means configured to ensure that the first fraction of the first liquefied natural gas stream at the outlet of the first heat exchanger remains at supercritical conditions, such that they are suitable for subsequent mixing in the mixer with the second fraction of the first liquefied natural gas stream and that it does not drop below a first pressure threshold, and establishing a second minimum temperature threshold, avoiding the freezing of the second hot fluid to be sent to the end users and/or the instability of the closed circuit of said second hot fluid.

[0021] Optionally, the control means are further configured to control the flow rate of the second fraction of the first liquefied natural gas stream. Preferably, the flow rate of the second fraction of the first liquefied natural gas stream is greater than the flow rate of the first fraction of the first liquefied natural gas stream.

[0022] In this manner, the instability of the mixtures of supercritical fluids or liquid-vapour dual-phase fluids is reduced by means of sophisticated instrumentation and the described control means. This results in a process compatible with the stability and reliability of the vaporisation process of the liquefied natural gas in the vaporiser.

[0023] Optionally, the control means are further configured to regulate the flow rate of the first hot fluid based on the heat required to bring the temperature of the liquefied natural gas to the temperature required by a gas pipeline grid for the distribution thereof.

[0024] Preferably, the first hot fluid is seawater.

[0025] Optionally, the second hot fluid is a cooling fluid that can be used for using the cold in industrial processes.

[0026] The advantages of the system for using the cold of liquefied natural gas in regasification plants explained above are:

- operation with LNG at pressures greater than the critical pressure thereof, which provides stability in the flows and avoids double phase flows, which avoids noise and vibrations (which in many cases lead to equipment failure)
- mixing of LNG streams at different temperatures in flow rates established by a minimum ratio to additionally guarantee stability in the flows.
- energy efficiency, since it allows for the reduction of the flow rates of the first hot fluid, preferably seawater, needed for increasing the temperature of the LNG to the temperature required for entering the gas pipeline. As a result of the above, the environmental impact caused by the cooled seawater stream that is returned to the sea is reduced.

[0027] Optionally, the system comprises a second intermediate fluid-third hot fluid heat exchanger, wherein the second hot fluid of the first liquefied natural gas-second hot fluid heat exchanger is an intermediate fluid and the third hot fluid of the second heat exchanger is a cooling fluid.

[0028] The additional advantages to the presence of the second heat exchanger are the following:

- control of the possible freezing of the second hot fluid or cooling fluid by establishing a control on the maximum flow rate of LNG sent to the LNG-intermediate fluid exchanger;
- control of the input of cold to the cooling fluid by means of controlling the flooding of the heat exchange area in at least one intermediate fluid-cooling fluid heat exchanger.

[0029] Preferably, the cooling fluid is water, a saline solution in water, NH3, or CO2.

[0030] The present invention further relates to the process of recovering the cold of liquefied natural gas in regasification plants carried out with the system described above, wherein the process comprises the following steps:

- a step of extracting at least a first liquefied natural gas stream from at least one tank of liquefied natural gas;
- a step of regasifying at least the first liquefied natural gas stream, causing it to return to the gaseous state thereof by means of a first hot fluid, carried out by means of the vaporiser;
- a first step of heat exchange between a first fraction of the first liquefied natural gas stream and a second hot fluid which is cooled, carried out in the first heat exchanger;
- a step of mixing the first fraction of the first liquefied natural gas stream with a second fraction of the first liquefied natural gas stream in the mixer; and
- a step of introducing the first liquefied natural gas stream that leaves the mixer in the vaporiser.

[0031] Optionally, the process comprises a second step of intermediate fluid-third hot fluid heat exchange, wherein the second hot fluid of the first step of heat exchange is an intermediate fluid and the third hot fluid of the second step of heat exchange is a cooling fluid.

DESCRIPTION OF THE DRAWINGS

[0032] To complement the description that is being made and for the purpose of helping to better understand the features of the invention, according to a preferred practical exemplary embodiment thereof, a set of drawings is attached as an integral part of said description, wherein the following has been depicted in an illustrative and non-limiting manner:

Figure 1 shows a schematic view of the system for using the cold of liquefied natural gas in regasification plants of the present invention according to a first preferred exemplary embodiment.

Figure 2 shows a schematic view of the system for using the cold of liquefied natural gas in regasification plants of the present invention according to a second preferred exemplary embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0033] Next, the system for using the cold of liquefied natural gas in regasification plants of the present invention is described in detail.

[0034] In a first preferred exemplary embodiment shown in Figure 1, LNG is pumped from at least one LNG tank (30) by first-stage or in-tank pumps (31) and is subsequently pumped up to pressures greater than the critical pressure by high-pressure pumps (32) outside the LNG tank (30). In this preferred exemplary embodiment, all (10, 11, 12, 13, 14, 15, 16) or part (12, 13, 14, 15) of the high-pressure stream or first stream is taken from these pumps (10).

[0035] A first fraction (12) of the first stream (10, 11, 12, 13, 14, 15, 16) is sent to a first heat exchanger (39) in flow rate control (43) carried out by the control means, wherein said first fraction (12) of the first LNG stream (10, 11, 12, 13, 14, 15, 16) transfers the cold to the second hot fluid (20, 21) or cooling fluid in this exemplary embodiment, wherein an intermediate fluid (39') is confined in the first exchanger (39) and contributes to the cooling of the second hot fluid (20, 21) or cooling fluid and cold extraction of LNG by means of an arrangement of heat exchange coils, with a first coil through which LNG circulates (39a) it is placed in the vapour phase and produces the condensation of the intermediate fluid (39') which is evaporated by the heat input of the cooling fluid that circulates through a lower coil (39b), this being in the liquid zone that allows the partial or total flooding of the coil. The function of this control (43) is to ensure on the one hand that the outlet stream (14) of the first heat exchanger (39) remains at supercritical conditions, which are suitable for stable subsequent mixing in a mixer (38) and, on the other hand, that it does not exceed a threshold (established by a control algorithm) that could cause the freezing of the fluid to be sent to end users and/or the instability of the closed circuit of the intermediate fluid).

[0036] A second fraction (13) of the first stream (10, 11, 12, 13, 14, 15, 16) is sent to the mixer (38) in flow rate control (44) by the control means. This flow rate will be greater than a ratio with respect to the flow rate of the first fraction (12) of the first stream (10, 11, 12, 13, 14, 15, 16) sent to the first exchanger (39), ensured by means of a control function (42), preferably FY.

[0037] The invention presented herein enables the instability of mixtures of supercritical fluids or liquid-vapour dual phase fluids to be reduced by means of sophisticated instrumentation and the described controls. This results in an operation compatible with the stability and reliability of the LNG vaporisation process.

[0038] Once the second fraction (13) of the first stream (10, 11, 12, 13, 14, 15, 16) and the outlet stream (14) of the first exchanger (39) have been mixed (15), this will be finally mixed with a third fraction (11) of the first stream (10, 11, 12, 13, 14, 15, 16) (in the event that this is not null) and sent (16) to the vaporiser (33), whether this is of the seawater or submerged combustion type.

[0039] The required input of seawater or first hot fluid (26) will be modulated based on the heat required to bring the LNG temperature to that required by the gas pipeline grid.

[0040] The invention presented herein establishes the flow rate control (47) of the seawater by means of the control means at a value lower than the value that would be necessary in the event of the cold retrieval described herein not occurring, thus contributing to lower consumption and higher energy efficiency.

[0041] Another control function (46) carried out by the control means calculates, by means of a predictive algorithm based on the energy content of the LNG streams sent to the vaporiser (33), the necessary flow rate of seawater, which it sends to another controller (47).

[0042] The temperature required by the end users is established in another controller (40). This will send, by means of a control function (41) carried out by the control means, the signal (set point) of the required LNG flow rate of the first fraction (12) of the first stream, and, by means of another control function (42), the minimum ratio of the second fraction (13) of the first stream (10, 11, 12, 13, 14, 15, 16), as stated above.

[0043] The intermediate fluid (39') in vapour phase, operating inside the first heat exchanger (39), is condensed to liquid phase due to the transfer of the LNG cold, and it will vaporise again due to the transfer of heat from the second hot fluid (20, 21) or cooling fluid, which is thus cooled to the temperature required by the users.

[0044] A level controller (48) establishes the intermediate fluid level (39') inside the first heat exchanger (39), enabling greater or lesser flooding of the exchange surface that controls the transfer of heat between the intermediate fluid (39') and the second hot fluid (20, 21) or cooling fluid.

[0045] A pressure controller (49) establishes a working pressure of the intermediate fluid (39'), which in turn conditions the saturation temperature of the intermediate fluid (39') which is the working temperature thereof, by working in liquid and vapour phase in a closed circuit.

[0046] In a second preferred exemplary embodiment shown in Figure 2, instead of only a first heat exchanger, there is a first heat exchanger (35) wherein the cold transmitted to the intermediate fluid (36') by means of the first heat exchanger (35) is transferred to a second intermediate fluid-third hot fluid or cooling fluid heat exchanger (36) to users. In this second heat exchanger (36), the hot cooling fluid (20, 21) from the end users (20) is cooled to a lower temperature valid for use thereof in the required industrial processes and sent to the end users (21).

[0047] The intermediate fluid (36') in vapour phase, operating in a closed circuit (18, 19), is condensed to liquid phase in the first heat exchanger (35) due to the transfer of the LNG cold, and it flows by gravity to the second heat exchanger (36) or intermediate fluid-cooling fluid exchanger. Here it will be evaporated again due to the transfer of heat from the cooling fluid, which is thus cooled to the temperature required by the users.

[0048] The second heat exchanger (36) or intermediate fluid-cooling fluid exchanger is interconnected on the intermediate fluid (36') side thereof with a container (37) configured to control the flooding of intermediate fluid (36') in the second heat exchanger (36) in addition to constituting an expansion tank for possible increases in the density of the intermediate fluid (36') at temperatures greater than the working temperature.

[0049] A level controller (48) establishes a liquid level in the container (37) configured to control the flooding of intermediate fluid (36'), and by means of communicating vessels, the corresponding level of intermediate fluid (36') in the second heat exchanger (36), enabling greater or lesser flooding of the exchange surface that controls the transfer of heat between the intermediate fluid (36') and the cooling fluid (20, 21).

[0050] Below is a list of the references used in the exemplary embodiments shown in the Figures. The following references are indicated in said Figures (Series 10 and 20 have been used for streams, series 30 for equipment and series 40 and 50 for controls):

- Series 10 and 20-

  10.- LNG flow rate pumped at high pressure (above the critical Pressure thereof)
  11.- LNG flow rate sent directly to Vaporisers
  12.- LNG flow rate sent to exchanger for cold transfer
  13.- LNG flow rate to Mixer
  14.- "Hot" LNG flow rate to Mixer
  15.- Mixed LNG flow rate to Vaporisers
  16.- Final LNG flow rate sent to Vaporisers
  17.- Vaporised Natural Gas flow rate to Gas Pipeline Grid
  18.- Intermediate Fluid Liquid flow rate in flow by gravity to Exchanger
  19.- Intermediate Fluid Vapour flow rate to Exchanger
  20.- "Hot" Cooling Fluid flow rate from end users
  21.- "Cold" Cooling Fluid flow rate to end users
  22.- Intermediate Fluid Inlet
  23.- Intermediate Fluid Outlet
  24.- Liquid phase equilibrium line between Exchanger and Intermediate Fluid Container
  25.- Vapour phase equilibrium line between Exchanger and Intermediate Fluid Container

- Series 30-

  30.- LNG tank
  31.- Low pressure pumps (First-stage pumps or In-Tank Pumps)
  32.- High-pressure pumps (Second-stage pumps or Send-out Pumps)
  33.- Vaporisers
  34.- Regulation and Measurement Station of Natural Gas to Grid
  35.- LNG-Intermediate Fluid Exchanger
  36.- Intermediate Fluid-Cooling Fluid Exchanger
  36'.- Intermediate fluid for the second exemplary embodiment 37.- Intermediate Fluid Container
  38.- Inline mixer
  39.- Integral LNG-Cooling Fluid Exchanger with internal Intermediate Fluid
  39a.- LNG-Intermediate Fluid Exchange Coil
  39b.- Intermediate Fluid-Cooling Fluid Exchange Coil
  39'.- Intermediate fluid for the first exemplary embodiment

- Series 40 and 50-

  40.- TC1 Temperature Controller
  41.- Calculation function of required LNG flow rate control
  42.- Calculation function of LNG flow rate ratio control
  43.- FC1 Flow Rate Controller
  44.- FC2 Flow Rate Controller
  45.- FC3 Flow Rate Controller
  46.- Calculation function of the sum of LNG flow rates and required Seawater flow rate control
  47.- FC4 Flow Rate Controller
  48.- LC1 Level Controller
  49.- Pressure Controller PC1
  50.- Calculation function of required Flooding
  60.- Natural gas Grid

Claims

1. A system for recovering the cold of liquefied natural gas in regasification plants comprising:

   - at least one tank (30) of liquefied natural gas from which at least one first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) is extracted;
   - a vaporiser (33) configured to regasify at least the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16), causing it to return to the gaseous state thereof by means of a first hot fluid (26);

   characterised in that the system additionally comprises:

   - a first liquefied natural gas-second hot fluid (20, 21) heat exchanger (35, 39) wherein a first fraction (12) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) exchanges heat with a second hot fluid (18, 19, 20, 21) which is cooled;
   - a liquefied natural gas mixer (38) configured to mix the first fraction (12) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) with a second fraction (13) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16); wherein the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) that leaves the mixer (38) is introduced in the vaporiser (33).

2. The system for recovering the cold of liquefied natural gas in regasification plants according to claim 1, **characterised in that** the first liquefied natural gas-second hot fluid (20, 21) heat exchanger (39) comprises an intermediate fluid (39') confined inside said first liquefied natural gas-second hot fluid heat exchanger (39).

3. The system for recovering the cold of liquefied natural gas in regasification plants according to claim 2, **characterised in that** it comprises control means (48) configured to control the level of intermediate fluid (39') inside the first heat exchanger (39), enabling greater or lesser flooding of the exchange surface that controls the transfer of heat between the intermediate fluid (39') and the second hot fluid (20, 21) or cooling fluid.

4. The system for recovering the cold of liquefied natural gas in regasification plants according to claim 1, **characterised in that** it comprises a second intermediate fluid-third hot fluid heat exchanger (36), wherein the second hot fluid of the first liquefied natural gas-second hot fluid heat exchanger is an intermediate fluid (36') and the third hot fluid of the second heat exchanger (36) is a cooling fluid (20, 21).

5. The system for recovering the cold of liquefied natural gas in regasification plants according to claim 4, **characterised in that** the intermediate fluid (36') is in vapour phase and operates in a closed circuit (18, 19), being condensed to liquid phase in the first heat exchanger (35) due to the transfer of cold from the liquefied natural gas from the first fraction (12) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16), and it flows by gravity to the second heat exchanger (36).

6. The system for recovering the cold of liquefied natural gas in regasification plants according to claim 5, **characterised in that** it comprises a container (37) configured to control the flooding of intermediate fluid (36') in the second heat exchanger (36) in addition to constituting an expansion tank for possible increases in the density of the intermediate fluid (36') at temperatures greater than the working temperature, wherein the container (37) is interconnected on the intermediate fluid (36') side of the second heat exchanger (36).

7. The system for recovering the cold of liquefied natural gas in regasification plants according to claim 6, **characterised in that** it comprises a level controller (48) configured to establish a liquid level in the container (37) configured to control the flooding of intermediate fluid (36'), and by means of communicating vessels, the corresponding level of intermediate fluid (36') in the second heat exchanger (36), enabling greater or lesser flooding of the exchange surface that controls the transfer of heat between the intermediate fluid (36') and the cooling fluid (20, 21).

8. The system for recovering the cold of liquefied natural gas in regasification plants according to any of the preceding claims, **characterised in that** it comprises control means configured to ensure that the first fraction (12) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) at the outlet of the first heat exchanger (35, 39) remains at supercritical conditions, such that they are suitable for subsequent mixing in the mixer with the second fraction (13) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) and that it does not drop below a first pressure threshold, and establishing a second minimum temperature threshold.

9. The system for recovering the cold of liquefied natural gas in regasification plants according to any of the preceding claims, **characterised in that** it comprises control means configured to control the flow rate of the second fraction (13) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16).

10. The system for recovering the cold of liquefied nat-

ural gas in regasification plants according to claim 9, **characterised in that** the flow rate of the second fraction (13) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) is greater than the flow rate of the first fraction (12) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16).

11. The system for recovering the cold of liquefied natural gas in regasification plants according to any of the preceding claims, **characterised in that** it comprises a grid of gas pipelines and control means configured to regulate the flow rate of the first hot fluid (26) based on the heat required to bring the temperature of the liquefied natural gas to a temperature required by the gas pipeline network for the distribution thereof.

12. The system for recovering the cold of liquefied natural gas in regasification plants according to any of the preceding claims, **characterised in that** the first hot fluid (26) is seawater.

13. The system for recovering the cold of liquefied natural gas in regasification plants according to any of the preceding claims, **characterised in that** the second hot fluid (20, 21) is a cooling fluid.

14. A process for recovering the cold of liquefied natural gas in regasification plants carried out with the system of any of the preceding claims, **characterised in that** it comprises the following steps:

- a step of extracting at least a first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) from at least one tank (30) of liquefied natural gas;
- a step of regasifying at least the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16), causing it to return to the gaseous state thereof by means of a first hot fluid (26), carried out by means of the vaporiser (33);
- a first step of heat exchange between a first fraction (12) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) and a second hot fluid (18, 19, 20, 21) which is cooled, carried out in the first heat exchanger (35, 39);
- a step of mixing the first fraction (12) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) with a second fraction (13) of the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) in the mixer (38); and
- a step of introducing the first liquefied natural gas stream (10, 11, 12, 13, 14, 15, 16) that leaves the mixer (38) in the vaporiser (33).

15. The process for recovering the cold of liquefied natural gas in regasification plants according to claim 14, **characterised in that** it comprises a second step of intermediate fluid-third hot fluid heat exchange, wherein the second hot fluid of the first step of heat exchange is an intermediate fluid and the third hot fluid of the second step of heat exchange is a cooling fluid.

Patentansprüche

1. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen, das Folgendes umfasst:

- mindestens einen Tank (30) mit Flüssiggas, aus dem mindestens ein erster Flüssiggasstrom (10, 11, 12, 13, 14, 15, 16) extrahiert wird;
- einen Verdampfer (33), der dazu ausgelegt ist, mindestens den ersten Flüssiggasstrom (10, 11, 12, 13, 14, 15, 16) zu regasifizieren, um zu bewirken, dass er mittels eines ersten Heißfluids (26) zum gasförmigen Zustand davon zurückkehrt;

dadurch gekennzeichnet, dass das System zusätzlich Folgendes umfasst:

- einen Wärmetauscher (35, 39) für das erste Flüssiggas und ein zweites Heißfluid (20, 21), wobei ein Teil (12) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) Wärme mit einem zweiten Heißfluid (18, 19, 20, 21) austauscht, das abgekühlt wird;
- einen Flüssiggasmischer (38), der dazu ausgelegt ist, den ersten Teil (12) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) mit einem zweiten Teil (13) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) zu mischen; wobei der erste Flüssiggasstrom (10, 11, 12, 13, 14, 15, 16), der den Mischer (38) verlässt, in den Verdampfer (33) eingeleitet wird.

2. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach Anspruch 1, **dadurch gekennzeichnet, dass** der Wärmetauscher (39) für das erste Flüssiggas und das zweite Heißfluid (20, 21) ein Zwischenfluid (39') umfasst, das im ersten Wärmetauscher (39) für das erste Flüssiggas und das zweite Heißfluid eingeschlossen ist.

3. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach Anspruch 2, **dadurch gekennzeichnet, dass** es ein Steuermittel (48) umfasst, das dazu ausgelegt ist, den Pegel des Zwischenfluids (39') im ersten Wärmetauscher (39) zu steuern, wodurch eine größere oder geringere Flutung der Tauschfläche ermöglicht wir, die die Übertragung von Wärme zwischen dem Zwischenfluid (39') und dem zweiten Heißfluid (20, 21) oder einem Kühlfluid steuert.

4. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach Anspruch 1, **dadurch gekennzeichnet, dass** es einen zweiten Wärmetauscher (36) für ein zweites Zwischenfluid und ein drittes Heißfluid umfasst, wobei das zweite Heißfluid des Wärmetauschers für das erste Flüssiggas und das zweite Heißfluid ein zweites Zwischenfluid (36') ist und das dritte Heißfluid des zweiten Wärmetauschers (36) ein Kühlfluid (20, 21) ist.

5. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach Anspruch 4, **dadurch gekennzeichnet, dass** sich das Zwischenfluid (36') in der Dampfphase befindet und in einem geschlossenen Kreislauf (18, 19) betrieben wird, wobei es im ersten Wärmetauscher (35) durch die Übertragung von Kälte vom Flüssiggasstrom vom ersten Teil (12) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) in die Flüssigphase kondensiert wird, und durch Schwerkraft zum zweiten Wärmetauscher (36) strömt.

6. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach Anspruch 5, **dadurch gekennzeichnet, dass** es einen Behälter (37) umfasst, der zusätzlich zum Konstituieren eines Ausdehnungstanks für mögliche Erhöhungen der Dichte des Zwischenfluids (36') bei Temperaturen über der Arbeitstemperatur dazu ausgelegt ist, die Flutung des Zwischenfluids (36') im zweiten Wärmetauscher (36) zu steuern, wobei der Behälter (37) auf der Seite des Zwischenfluids (36') mit dem zweiten Wärmetauscher (36) verbunden ist.

7. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach Anspruch 6, **dadurch gekennzeichnet, dass** es eine Pegelsteuerung (48) umfasst, die dazu ausgelegt ist, einen Flüssigkeitspegel im Behälter (37), der dazu ausgelegt ist, die Flutung des Zwischenfluids (36') zu steuern, sowie mittels Kommunikationsgefäßen den entsprechenden Zwischenfluidpegel (36') im zweiten Wärmetauscher (36) herzustellen, wodurch eine größere oder geringere Flutung der Tauschfläche ermöglicht wird, die die Übertragung von Wärme zwischen dem Zwischenfluid (36') und dem Kühlfluid (20, 21) steuert.

8. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** es Steuermittel umfasst, die dazu ausgelegt sind sicherzustellen, dass der erste Teil (12) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) am Auslass des ersten Wärmetauschers (35, 39) in einem superkritischen Zustand verbleibt und er nicht unter einen ersten Druckschwellwert abfällt, derart, dass sie zum nachfolgenden Mischen mit dem zweiten Teil (13) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) im Mischer, sowie zum Herstellen eines zweiten Mindesttemperaturschwellwerts geeignet sind.

9. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** es Steuermittel umfasst, die dazu ausgelegt, die Durchflussrate des zweiten Teils (13) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) zu steuern.

10. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach Anspruch 9, **dadurch gekennzeichnet, dass** die Durchflussrate des zweiten Teils (13) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) größer ist als die Durchflussrate des ersten Teils (12) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16).

11. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** es ein Raster von Gasleitungen sowie Steuermittel umfasst, die dazu ausgelegt sind, die Durchflussrate des ersten Heißfluids (26) auf Basis der Wärme zu steuern, die erforderlich ist, um die Temperatur des Flüssiggases auf eine Temperatur zu bringen, die zum Verteilen davon durch das Gasleitungsnetz erforderlich ist.

12. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das erste Heißfluid (26) Meerwasser ist.

13. System zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das zweite Heißfluid (20, 21) ein Kühlfluid ist.

14. Verfahren zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen, das mit dem System nach einem der vorhergehenden Ansprüche durchgeführt wird, **dadurch gekennzeichnet, dass** es die folgenden Schritte umfasst:

- einen Schritt zum Extrahieren von mindestens einem ersten Flüssiggasstrom (10, 11, 12, 13, 14, 15, 16) aus mindestens einem Tank (30) mit Flüssiggas;
- einen Schritt zum Regasifizieren mindestens des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16), um zu bewirken, dass er mittels eines

ersten Heißfluids (26) zum gasförmigen Zustand davon zurückkehrt, der mittels des Verdampfers (33) ausgeführt wird;
- einen ersten Schritt zum Wärmeaustausch zwischen einem ersten Teil (12) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) und einem zweiten Heißfluid (18, 19, 20, 21), das abgekühlt wird, der im ersten Wärmetauscher (35, 39) ausgeführt wird;
- einen Schritt zum Mischen des ersten Teils (12) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) mit einem zweiten Teil (13) des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16) im Mischer (38) und
- einen Schritt zum Einleiten des ersten Flüssiggasstroms (10, 11, 12, 13, 14, 15, 16), der den Mischer (38) verlässt, in den Verdampfer (33).

15. Verfahren zur Rückgewinnung der Kälte von Flüssiggas in Regasifizierungsanlagen nach Anspruch 14, **dadurch gekennzeichnet, dass** es einen zweiten Schritt zum Wärmeaustausch für ein zweites Zwischenfluid und ein drittes Heißfluid umfasst, wobei das zweite Heißfluid des ersten Schritts zum Wärmeaustausch ein Zwischenfluid ist und das dritte Heißfluid des zweiten Schritts zum Wärmeaustausch ein Kühlfluid ist.

Revendications

1. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification comprenant :

- au moins un réservoir (30) de gaz naturel liquéfié duquel au moins un premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) est extrait ;
- un vaporiseur (33) configuré pour regazéifier au moins le premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16), le faisant revenir à son état gazeux au moyen d'un premier fluide chaud (26) ;

caractérisé en ce que le système comprend en outre :

- un premier échangeur de chaleur (35, 39) de gaz naturel liquéfié-deuxième fluide chaud (20, 21) dans lequel une première fraction (12) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) échange de la chaleur avec un deuxième fluide chaud (18, 19, 20, 21) qui est refroidi ;
- un mélangeur de gaz naturel liquéfié (38) configuré pour mélanger la première fraction (12) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) avec une seconde fraction (13) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) ; dans lequel le premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) qui quitte le mélangeur (38) est introduit dans le vaporiseur (33).

2. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon la revendication 1, **caractérisé en ce que** le premier échangeur de chaleur (39) de gaz naturel liquéfié-deuxième fluide chaud (20, 21) comprend un fluide intermédiaire (39') confiné à l'intérieur dudit premier échangeur de chaleur (39) de gaz naturel liquéfié-deuxième fluide chaud.

3. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon la revendication 2, **caractérisé en ce qu'**il comprend un moyen de commande (48) configuré pour commander le niveau de fluide intermédiaire (39') à l'intérieur du premier échangeur de chaleur (39), permettant une submersion plus ou moins importante de la surface d'échange qui commande le transfert de chaleur entre le fluide intermédiaire (39') et le deuxième fluide chaud (20, 21) ou un fluide de refroidissement.

4. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon la revendication 1, **caractérisé en ce qu'**il comprend un second échangeur de chaleur (36) de fluide intermédiaire-troisième fluide chaud, dans lequel le deuxième fluide chaud du premier échangeur de chaleur de gaz naturel liquéfié-deuxième fluide chaud est un fluide intermédiaire (36') et le troisième fluide chaud du second échangeur de chaleur (36) est un fluide de refroidissement (20, 21).

5. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon la revendication 4, **caractérisé en ce que** le fluide intermédiaire (36') est en phase vapeur et fonctionne en circuit fermé (18, 19), étant condensé en phase liquide dans le premier échangeur de chaleur (35) en raison du transfert de froid du gaz naturel liquéfié de la première fraction (12) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16), et il s'écoule par gravité vers le second échangeur de chaleur (36).

6. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon la revendication 5, **caractérisé en ce qu'**il comprend un récipient (37) configuré pour commander la submersion de fluide intermédiaire (36') dans le second échangeur de chaleur (36) en plus de constituer un réservoir d'expansion pour de possibles augmentations de la densité du fluide intermédiaire (36') à des températures supérieures à la température de travail, dans lequel le récipient (37) est interconnecté sur le côté du fluide intermédiaire (36') du second échangeur de chaleur (36).

7. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon la revendication 6, **caractérisé en ce qu'**il comprend un contrôleur de niveau (48) configuré pour établir un niveau de liquide dans le récipient (37) configuré pour commander la submersion de fluide intermédiaire (36'), et au moyen de vases communicants, le niveau correspondant de fluide intermédiaire (36') dans le second échangeur de chaleur (36), permettant une submersion plus ou moins importante de la surface d'échange qui commande le transfert de chaleur entre le fluide intermédiaire (36') et le fluide de refroidissement (20, 21).

8. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**il comprend un moyen de commande configuré pour garantir que la première fraction (12) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) à la sortie du premier échangeur de chaleur (35, 39) reste dans des conditions supercritiques, de telle sorte qu'ils soient aptes à être mélangés ultérieurement dans le mélangeur avec la seconde fraction (13) du premier courant de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) et qu'il ne descende pas en dessous d'un premier seuil de pression, et établissant un second seuil de température minimale.

9. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**il comprend un moyen de commande configuré pour commander le débit de la seconde fraction (13) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16).

10. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon la revendication 9, **caractérisé en ce que** le débit de la seconde fraction (13) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) est supérieur au débit de la première fraction (12) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16).

11. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**il comprend un réseau de gazoducs et un moyen de commande configuré pour réguler le débit du premier fluide chaud (26) en fonction de la chaleur nécessaire pour amener la température du gaz naturel liquéfié à une température requise par le réseau de gazoducs pour la distribution de celui-ci.

12. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le premier fluide chaud (26) est de l'eau de mer.

13. Système de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le deuxième fluide chaud (20, 21) est un fluide de refroidissement.

14. Procédé de récupération du froid de gaz naturel liquéfié dans des usines de regazéification réalisé avec le système selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**il comprend les étapes suivantes :

- une étape d'extraction d'au moins un premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) d'au moins un réservoir (30) de gaz naturel liquéfié ;
- une étape de regazéification d'au moins le premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16), le faisant revenir à son état gazeux au moyen d'un premier fluide chaud (26), effectuée au moyen du vaporiseur (33) ;
- une première étape d'échange de chaleur entre une première fraction (12) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) et un deuxième fluide chaud (18, 19, 20, 21) qui est refroidi, effectuée dans le premier échangeur de chaleur (35, 39) ;
- une étape de mélange de la première fraction (12) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) avec une seconde fraction (13) du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) dans le mélangeur (38) ; et
- une étape d'introduction du premier flux de gaz naturel liquéfié (10, 11, 12, 13, 14, 15, 16) qui quitte le mélangeur (38) dans le vaporiseur (33).

15. Procédé de récupération du froid de gaz naturel liquéfié dans des usines de regazéification selon la revendication 14, **caractérisé en ce qu'**il comprend une seconde étape d'échange de chaleur de fluide intermédiaire-troisième fluide chaud, dans lequel le deuxième fluide chaud de la première étape d'échange de chaleur est un fluide intermédiaire et le troisième fluide chaud de la deuxième étape d'échange de chaleur est un fluide de refroidissement.

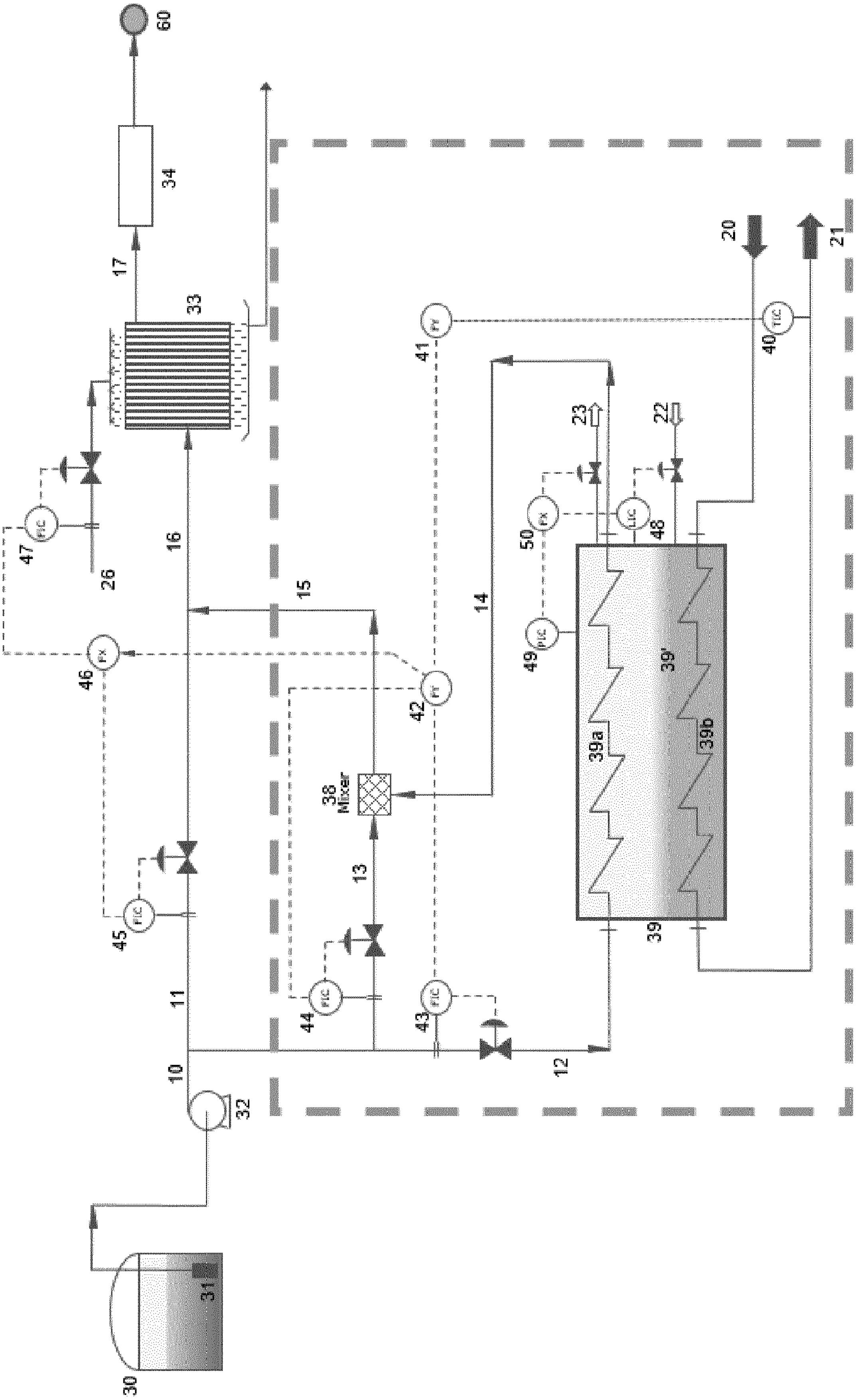
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FIG. 1

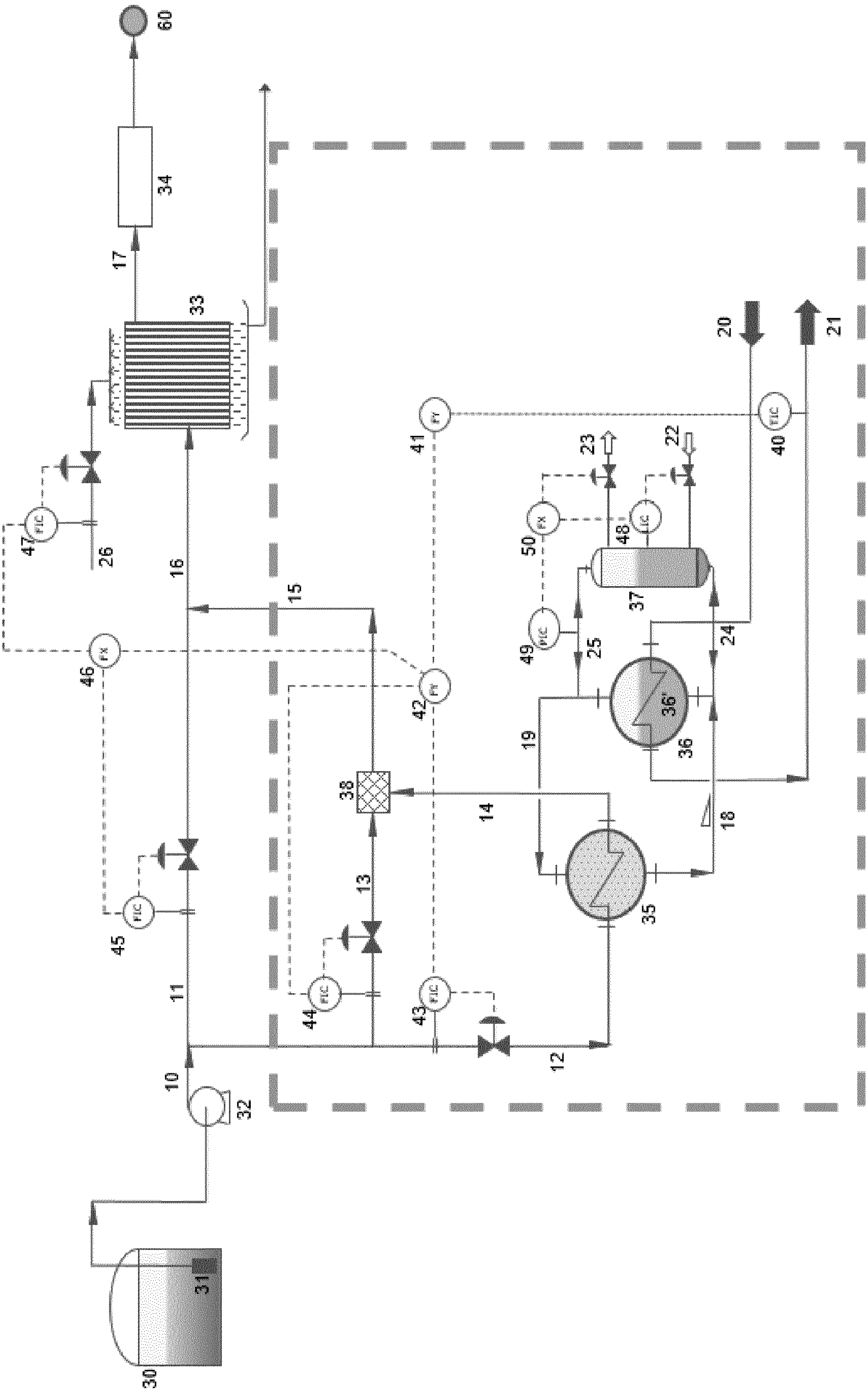
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FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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