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(54) PRESSURE CONTROLLED MULTISTAGE COOLING PLANT AND CONTROL METHOD

(57) A pressure controlled multistage cooling plant has a high stage (3) comprising at least a set of first compressors (5), a set of first condensers (7), at least a first receiver means (11) and a first duct (15) of an intermediate heat exchanger means (18) mutually connected to form the high stage refrigeration circuit.

Said plant (1) is further provided with a low stage (20) comprising at least a set of second compressors (22), a second duct (24) of the intermediate heat exchanger means (18), at least a second receiver means (26), a set of low stage user apparatus (28) mutually connected to form the low stage refrigeration circuit.

Said plant comprises pressure sensor means (30) assigned to detect the pressure of the fluid of the low stage (20) and connected to control means assigned to activate a feeding means (31) when said pressure of the fluid of the idle low stage (20) reaches or exceeds a predetermined threshold value. Said feeding means (31) are activated and connected to a duct of the intermediate heat exchanger means (18) to feed in said duct a cooling fluid for cooling the fluid of the low stage (20) in a condition of activation of said feeding means (31). Said duct of the intermediate heat exchanger means (18) that can be connected to the feeding means (31) consists of the first duct (15) of the intermediate heat exchanger means (18) and the cooling fluid feed by the feeding means (31) consists of the fluid of the high stage (3).

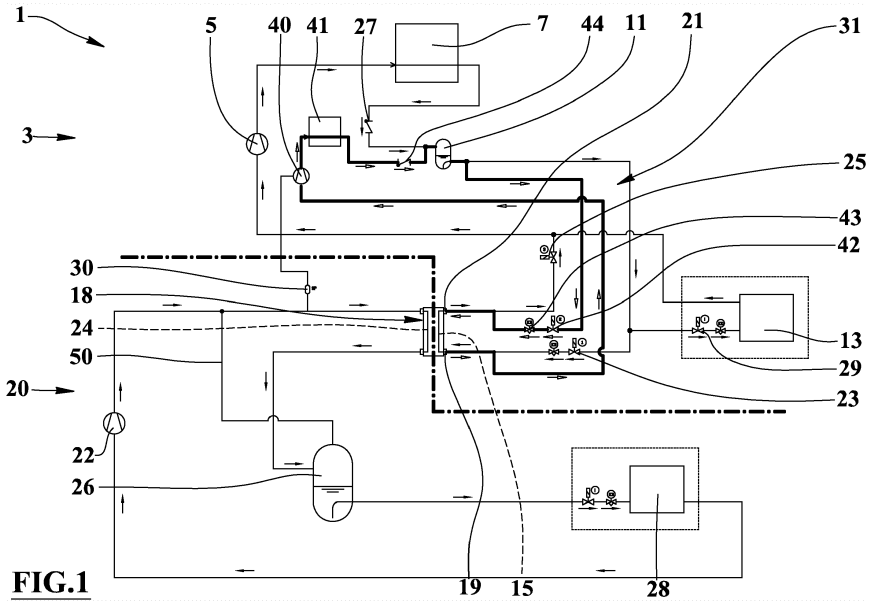

FIG.1

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Description

[0001] The present invention relates to the field concerning the plant for the cooling, warming and/or cooling air conditioning and relates to a pressure controlled multistage cooling plant with a pressure controlled method of a lower stage when it is in a non-active condition.

[0002] There are known cascade systems, i.e. plants in which the cooling system is slaved by another cooling system to allow its proper functioning, into which the so-called low-stage circuit can be used cooling fluids, such as carbon dioxide, that at the standard environmental temperatures of the temperate climate zones, have equivalent quite high pressures. This rise of the pressures, normally happens during plant shutdown periods between a cold cycle and the other, in function of various parameters such as the external temperature, the operative pressure before the stop, the thermal insulation, etc..

[0003] To counteract this phenomenon and to maintain the pressure within safety values a known solution, illustrated in Figure 2, provides the use of a small refrigerator system S which cools the cooling fluid contained in the storage tank when the pressure sensor "SP" will reach consensus value corresponding to a predetermined maximum pressure threshold. Obviously the cooling of the low stage cooling fluid, contained in the receiver, causes the desired reduction of the pressure.

[0004] This known solution has the drawback of high complexity, of a high cost and of a reduced efficiency.

[0005] There are also known solutions which provide a drawing of fluid in the liquid state from the high stage and the expansion of this fluid in an evaporator contained in the low stage receiver when the pressure sensor "SP" indicates the reaching of the threshold pressure.

[0006] One of the drawbacks of this configuration, for example, is that the high stage cooling plant is not installable in a single environment since it is necessary to bring a connection to the storage tank of the low stage cooling. Something that complicates the life when they are dealing with hazardous fluids such as hydrocarbons (e.g. propane also referred to as R290) is that said fluids are highly flammable.

[0007] One common disadvantage of said two known solution consists in that they require a receiver of the low stage internally provided with an exchanger, that is complicated and expensive also in consideration of all the connections that it requires.

[0008] One object of the present invention is to propose a multistage cooling plant with simple pressure control, reliable and inexpensive.

[0009] Further object is to propose a plant which allows using a low stage receiver simple, reliable, safe and cheap.

[0010] Another object is to have the entire high stage circuit in a unique environment by limiting to the latter all the provisions and tests on the safety against fire and explosion risks related to the particular cooling fluid usable in this stage.

[0011] Further object is to propose a highly efficient and secure system.

[0012] Other object is to propose a plant saving the main compressor of the high stage from wear and to save energy consumption.

[0013] Further object is to propose a method for the control and for the limitation of the pressure of the low stage fluid in inactivity conditions.

[0014] The document WO 2014/024837 discloses a multistage cooling plant with pressure control having at least a high stage comprising at least a set of first compressors, a set of first condensers, and a first duct of an intermediate heat exchanger means connected to form the high stage cooling circuit. This known plant is provided with at least a low stage comprising at least a set of second compressors, a second duct means of the intermediate heat exchanger means, a set of user apparatus connected to form the low stage cooling circuit. The plant comprises pressure sensor means assigned to detect the pressure of the low stage fluid and connected to control means assigned to activate feeding means when said pressure of the idle low stage fluid reaches or exceeds a predetermined threshold value. The feeding means in the activation condition are connected to a duct of the intermediate heat exchanger means in said duct a cooling fluid of refrigerator of the low stage fluid.

[0015] The characteristics of the invention are highlighted in the following with particular reference to the accompanying drawings in which:

- Figure 1 shows a schematic view of the multistage cooling plant with pressure control object of the present invention;
- Figure 2 shows a schematic view of a plant made on the basis of known prior art.

[0016] With reference to figure 1, numeral 1 indicates the multistage cooling plant with pressure control, object of the present invention, having a high stage 3, for example assigned to refrigerate, by means of its evaporators or heat exchangers, a set of medium temperature user equipment 13 or cells or rooms to be maintained at temperatures approximately between -5° C and + 5° C; obviously the high stage can carry out additional and/or alternative tasks, for example, the heating, cooling or air conditioning or, as better clarified in the following, the high stage 3 can be in the service of another stage of the plant for cooling the fluid thereof.

[0017] In the following, the term "users" will be used to indicate evaporators, or exchangers in general of the plant and assigned for such users.

[0018] The high stage 3 comprises a first compressor 5 or a set of first compressors, a first condenser 7 or a set of first condenser, at least a first receiver means 11, said set of user equipment 13 and a first duct 15 of an intermediate heat exchanger means 18; these elements are connected, via pipes, valves etc., to form the high

stage cooling circuit in which circulates a respective cooling fluid consisting, for example in propane.

[0019] The first duct 15 may be connected in parallel to the set of user equipment 13.

[0020] The plant 1 is also provided with at least a low stage 20 comprising at least a second compressor 22 or a set of second compressors, a second duct 24 of the intermediate heat exchanger means 18, at least a second receiver means 26, a set of user apparatus 28 connected to form the low stage cooling circuit in which circulates a respective refrigerator fluid consisting, for example, in carbon dioxide; in the following the user apparatus are also indicated as the low stage user apparatus 28.

[0021] The intermediate exchanger is placed at a greater height with respect to the second receiver means 26 of the low stage 20 circuit.

[0022] In alternative, the invention provides that the high stage 3 can be completely free of user equipment 13 for example in the case in which such high stage is totally dedicated to the cooling of the refrigerating fluid of the low stage 20; in other words the user equipment can consist in the first duct 15 of the intermediate heat exchanger means 18 so that, in this case, is the only user.

[0023] The plant 1 is provided with pressure sensor means 30, for example placed into the low stage circuit 20 upstream of the second duct 24 for detecting the pressure of the low stage fluid.

[0024] The pressure sensor means 30 are connected to control means, for example of microprocessor, programmable type, and provided with analog and/or digital inputs for sensors or detectors and outputs for the control and the operation of the various elements controlled by said control means.

[0025] The plant 1 is provided with feeding means 31 controlled by the control means to feed the intermediate heat exchanger means 18 with a cooling fluid.

[0026] The control means are programmed to activate the feeding means 31 when said pressure of the fluid of idle low stage 20 reaches or exceeds a predetermined threshold value.

[0027] In said activation condition, the feeding means 31 are connected to a duct of the intermediate heat exchanger means 18 to feed said duct with a cooling fluid and to expand the latter for refrigerating the fluid of the low stage 20.

[0028] In particular, but not exclusively, said duct means of the intermediate heat exchanger means 18 connected to the feeding means 31 consists in the first duct 15 of the intermediate heat exchanger means 18 and the refrigeration cooling fluid adducted by the feeding means 31 consists in the fluid of the high stage 3 in the liquid state that is expanded by special members of the feeding means 31 in this first duct 15.

[0029] A simple alternative of the invention, not illustrated, provides that said duct of the intermediate heat exchanger means 18 connected to the feeding means 31 is run through by any refrigerating fluid which expands in it or by any low temperature carrier liquid assigned to cool such intermediate heat exchanger means and in particular the low stage fluid contained therein.

[0030] As illustrated in Figure 1, the first embodiment of the invention provides that the feeding means 31 and the expansion means include a safety compressor 40 whose input is connected to a first inlet 19 of the first duct 15 of the intermediate heat exchanger means 18 whose outlet is connected to an inlet of the safety condenser 41 the outlet of which is connected to the inlet of the first receiver means 11.

[0031] The outlet of the first receiver means 11 is connectable, by a first cut-off valve 42 and by a first expansion means 43 actuated by the control means, to the second inlet 21 of the first duct 15.

[0032] Said first duct 15, safety compressor 40, safety condenser 41, first receiver means 11, the first cut-off valve 42 and first expansion means 43 in the actuating condition operated by the control means, made the circuit of the feeding means 31 for the cooling of the fluid of the low stage 20.

[0033] This solution allows to use the fluid and many of the standard circuit elements of the high stage, for example the intermediate heat exchanger means 18, and allows at the same time to save the wear of the first compressor 5 and to save part of the energy necessary for the running of this latter because the safety compressor 40 is of lower power.

[0034] The plant comprises a first check valve 27 interposed and oriented between the outlet of the at least a first condenser 7 and the inlet of the first receiver means 11 and comprises a second check valve 44 interposed and oriented between the outlet of the at least one safety condenser 41 and the inlet of the first receiver means 11; these check valves prevent reflux of the high stage fluid.

[0035] The high stage 3 also comprises a second cut-off valve 23 interposed between the outlet of the first receiver means 11 and the first inlet 19 of the first duct 15 and a third cut-off valve 25 interposed between the second inlet 21 of the first duct 15 and the inlet of the at least one first compressor 5, where such second 23 and third 25 cut-off valves are actuated by the control means.

[0036] For example, during the operation of the safety compressor 40 for refrigerating the low stage, the third cut-off valve 25 is close actuated by the control means.

[0037] The plant comprises a fourth cut-off valve 29 for each possible user equipment 13. These fourth cut-off valves 29 are actuated to manage the production of cold in each of the user equipment 13.

[0038] In the above mentioned closing condition of the third cut-off valve 25, the first compressor 5 can cool the user equipment 13 whose fourth cut-off valves 29 are open.

[0039] In case of lack of the user equipment 13, it is also possible to eliminate the third cut-off valve 25 and replace it with a continuous length of duct so as to ensure the continuity of the connection between the second inlet 21 of the first duct 15 and the inlet of the first compressor 5.

[0040] It is thus possible to alternately operate the safety compressor 40 or the first compressor 5 for feeding the first duct 15 and cool the fluid of the low stage in the second duct 24 of the intermediate heat exchanger means 18.

[0041] The ducts and connections in the installation 1 are arranged in such a way that when it is active at least one of the first compressor 5, the fluid of the high stage 3 flows from the first inlet 19 to the second inlet 21 of the first duct 15; when the at least one safety compressor 40 is active, the fluid of the high stage 3 flows from the second inlet 21 to the first inlet 19 of the first duct 15.

[0042] In summary the cut-off valves 23, 25, 29, 42, actuated in a coordinated manner with the first compressor 5, for example allow to switch the high stage 3 in a cooling and pressure reduction condition of the fluid of the low stage 20.

[0043] It's important to observe that it is sufficient to equip this first embodiment with a small generator able to feed the small safety compressor 40, the control means, the remotely operated valves and the other electrically operated elements for ensuring the pressure control of the low stage also in case of electric power blackout.

[0044] The invention provides that the plant can be provided with an optional third duct 50 assigned to put in flow communication the top of the second receiver 26, or the outlet for the vapors or gases of the second receiver 26, with the duct connecting the outlet of the at least a second compressor 22 with the inlet of the second duct 24 of the intermediate heat exchanger means 18. This third duct 50 is of small inner lumen, for example the diameter of its inner lumen ranges from the half to one tenth of the average diameter, or minimum diameter, of the other ducts and tubes of the low stage 20. Surprisingly this third duct 50 provides a better operation of the plant, perhaps because it creates a small differential pressures inside the intermediate exchanger, low stage side, during the pressure control phases.

[0045] The method for controlling the pressure of a cooling fluid of an idle low stage of a multistage plant made according to one of the described embodiments, provides that in an condition in which the low stage 20 is idle and the plant pressure sensor means 30 detects and provides the control means with a pressure value of the fluid of the low stage higher than a predetermined threshold, to actuate, by means of said control means, the feeding means 31 to feed a refrigerant fluid of any nature in a duct of an intermediate heat exchanger means 18 assigned to the thermic exchange between the cooling fluids of a high and lower stages of the plant.

[0046] The feeding of the refrigerant fluid in the intermediate heat exchanger means 18 cools the cooling fluid of such low stage housed in a second duct 24 of the intermediate heat exchanger means 18 and being part of the cooling circuit of the low stage itself. Such cooling produces the reduction of pressure of the cooling fluid of the low stage.

[0047] In particular, the method provides to expand the cooling fluid of the high stage of the plant in a first duct 15 of the intermediate heat exchanger means 18 having the second duct 24 inserted in the cooling circuit of the lower stage 20.

[0048] When this condition ceases the method provides to deactivate, via said control means, the feeding means 31.

Claims

1. Pressure controlled multistage cooling plant having at least a high stage (3) comprising at least a set of first compressors (5), a set of first condensers (7), at least a first receiver means (11) and a first duct (15) of an intermediate heat exchanger means (18) mutually connected to form the high stage refrigeration circuit; said plant (1) being further provided with at least a low stage (20) comprising at least a set of second compressors (22), a second duct (24) of the intermediate heat exchanger means (18), at least a second receiver means (26), a set of low stage user apparatus (28) mutually connected to form the low stage refrigeration circuit; said plant comprises pressure sensor means (30) assigned to detect the pressure of the fluid of the low stage (20) and connected to control means assigned to activate a feeding means (31) when said pressure of the fluid of the idle low stage (20) reaches or exceeds a predetermined threshold value; said feeding means (31) are activated and connected to a duct of the intermediate heat exchanger means (18) to feed in said duct a cooling fluid for cooling the fluid of the low stage (20) in a condition of activation of said feeding means (31); said duct of the intermediate heat exchanger means (18) that can be connected to the feeding means (31) consists of the first duct (15) of the intermediate heat exchanger means (18) and the cooling fluid feed by the feeding means (31) consists of the fluid of the high stage (3); said plant is **characterized in that** the feeding means (31) comprise at least a safety compressor (40) whose inlet is connected to a first inlet (19) of the first duct (15) of the intermediate heat exchanger means (18) and whose outlet is connected to an inlet of at least one safety condenser (41) whose outlet is connected to the inlet of the first receiver means (11) whose outlet is connectable, by means of a first cut-off valve (42) and a first expansion means (43) operated by the control means, to the second inlet (21) of the first duct (15), where said first duct (15), safety compressor (40), safety condenser (41), first receiver means (11), first cut-off valve (42) and first expansion means (43), in the condition of activation operated by the control means, carry out the circuit of the feeding means (31) for cooling the fluid of the low stage (20).

2. Plant according to claim 1 **characterized in that** the high stage (3) comprises a second cut-off valve (23) interconnected between the outlet of the first receiver means (11) and the first inlet (19) of the first duct (15) and a possible optional third cut-off valve (25) interconnected between la second inlet (21) of the first duct (15) and the inlet of the at least a first compressor (5), where said second (23) and optional third (25) cut-off valve are operated by the control means.

3. Plant according to claim 1 or 2 **characterized in that** it comprises a first check valve (27) interconnected between and oriented from the outlet of the at least a first condenser (7) to the inlet of the first receiver means (11) and it comprises a second check valve (44) interconnected between and oriented from the outlet of the at least a safety condenser (41) to the inlet of the first receiver means (11).

4. Plant according to any of claims 2 or 3 **characterized in that** it comprises a set of user equipment (13) and a set of corresponding fourth cut-off valves (29) operated to manage the cool production into each of the user equipment (13).

5. Plant according to claim 1 **characterized in that** the ducts and linkages of the plant (1) are arranged in a manner that, when at least one of the set of first compressors (5) is active, the fluid of the high stage (3) flows from the first inlet (19) to the second inlet (21) of the first duct (15); when the at least one safety compressor (40) is active, the fluid of the high stage (3) flows from the second inlet (21) to the first inlet (19) of the first duct (15).

6. Plant according to claim 1 **characterized in that** the feeding means (31) comprises a control means connected to the pressure sensor means (30) and assigned to operate at least a first compressor of the set of first compressors (5).

7. Plant according to claim 6 **characterized in that** it comprises a second cut-off valve (23) interconnected between the outlet of the first receiver means (11) and la first inlet (19) of the first duct (15), said second cut-off valve (23) being opened by the control means at least during the operation of at least one of the set of first compressors (5) and optionally it comprises a set of user equipment (13) and a set of corresponding fourth cut-off valves (29) operated to manage the cool production in each of the user equipment (13).

8. Plant according to any of the preceding claims **characterized in that** it comprises a third duct (50) connecting in flow communication the upper portion of the second receiver means (26) with the duct connecting the outlet of the at least one second compressor (22) with the inlet of the second duct (24) of the intermediate heat exchanger means (18).

9. Plant according to claim 8 **characterized in that** the diameter of the inner lumen of said third duct (50) ranges from the half to one tenth of the diameter of the lumen of the other ducts and tubes of the low stage (20).

10. Method for controlling the pressure of a fluid of an idle low stage of a multistage cooling plant of any of claims 1 - 7 **characterized in that**, in an idle condition of the low stage (20) and when a control means of the plant receives from a pressure sensor means (30) a detected pressure value exceeding a predetermined threshold, to operate, by means of said control means, a feeding means (31) to feed a cooling fluid into an intermediate heat exchanger means (18) belonging to the refrigeration circuits of the low stage (20) and of a high stage (3) of the multistage cooling plant and assigned at least to the heat exchange between the fluids of said low (20) and high (3) stages.

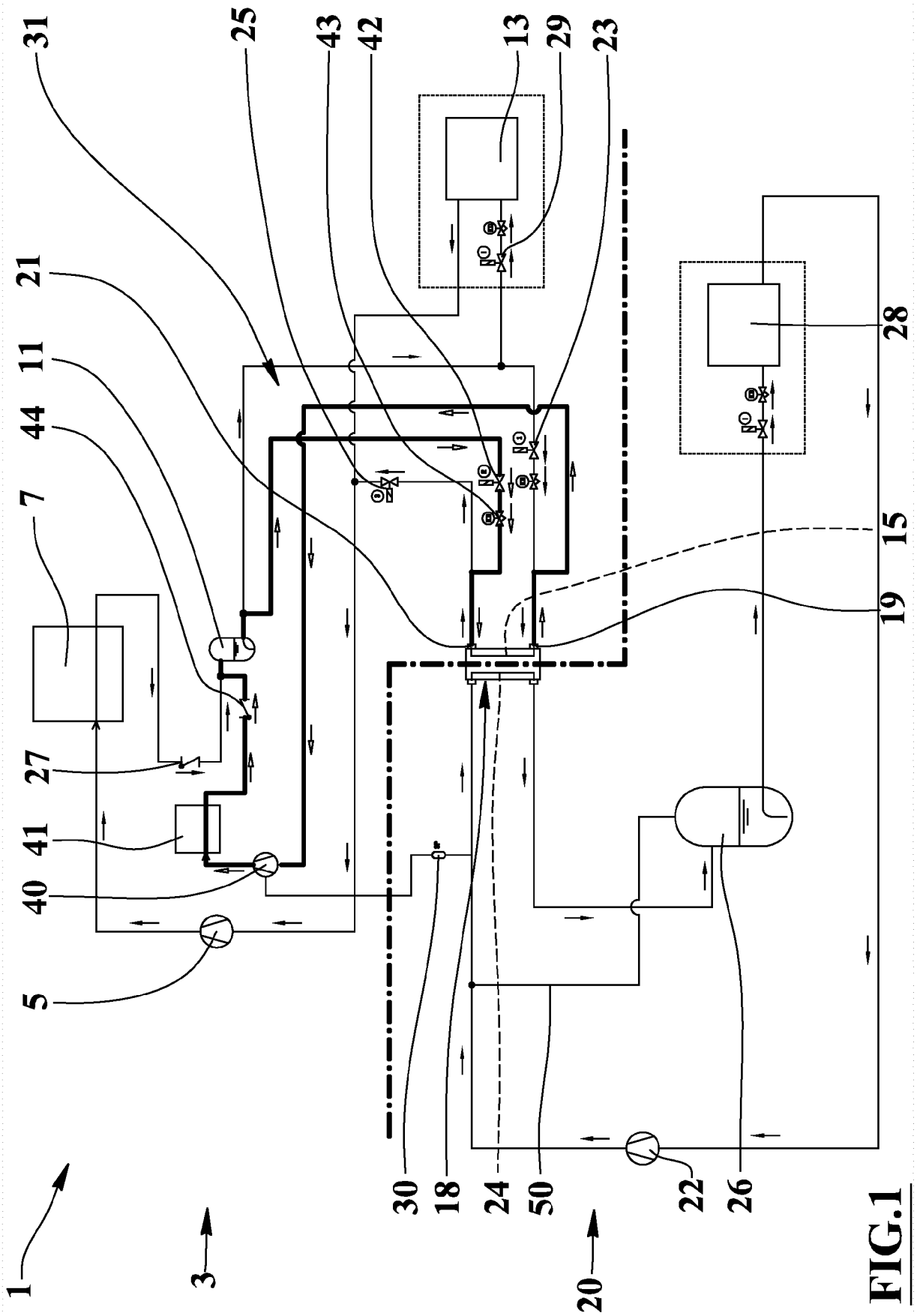
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FIG.1

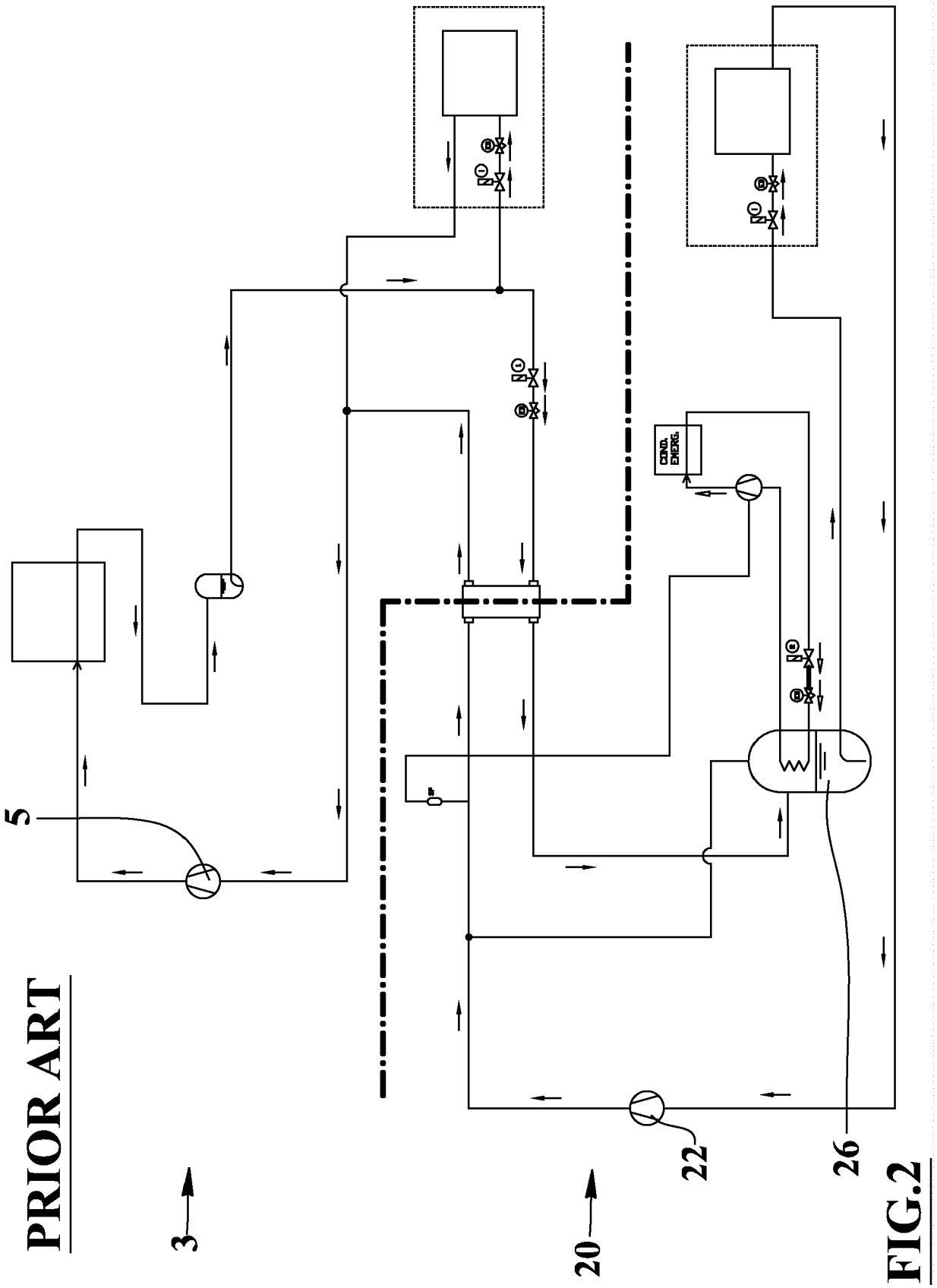

FIG.2

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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 8435

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	1 July 2016	Szilagyi, Barnabas

CATEGORY OF CITED DOCUMENTS

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