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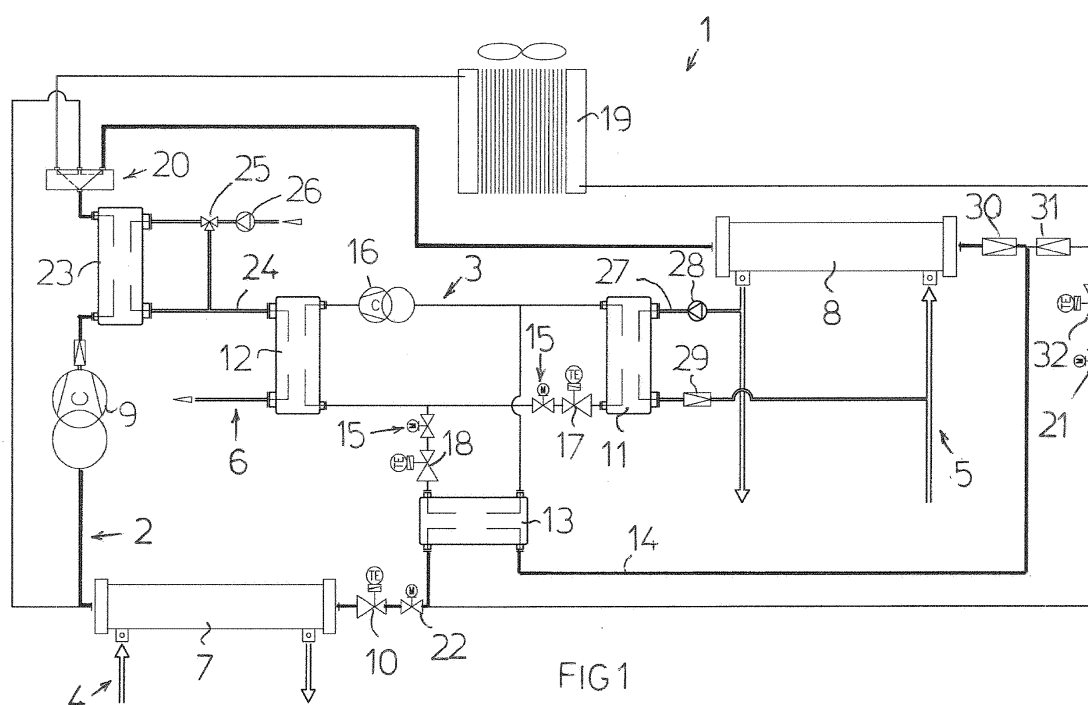
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(54) **Heating and refrigerating unit and method for the control thereof**

(57) A multipurpose heating and refrigerating unit (1) comprising a primary refrigerating circuit (2), a secondary refrigerating circuit (3), a first water-producing circuit (4) producing water at a first temperature, a second circuit (5) producing water at a second temperature above the first temperature, a third circuit (6) producing water at a third temperature above the second temperature, the primary refrigerating circuit (2) comprising at least one first

low-pressure primary heat exchanger (7) connected to the first water-producing circuit (4) and at least one first high-pressure primary heat exchanger (8) connected to the second water-producing circuit (5), the secondary refrigerating circuit (3) comprising at least one first low-pressure secondary heat exchanger (11) connected to the second water-producing circuit (5), and at least one first high-pressure secondary heat exchanger (12) connected to the third water-producing circuit (6).



Description

[0001] The present invention relates to a multipurpose heating and refrigerating unit and a method for the control thereof.

[0002] The use of two heating and refrigerating units which, working in cascade one after the other, produce water at different temperature levels, in particular cold water, water at a medium temperature and water at a high temperature, is well known. The drawbacks tied to the use of two heating and refrigerating units working in cascade to produce water at different temperature levels essentially regards their structural and operating costs and their efficiency, which is not always adequate. The technical task the present invention has set itself is therefore to realize a system for producing water at at least three temperature levels, which allows the aforementioned technical drawbacks of the prior art to be eliminated.

[0003] Within the scope of this technical task, one object of the invention is to realize a system which assures both high operating flexibility and an adequate efficiency in the production of water at low, medium and high temperatures, also when demand in terms of the different loads requested by users varies.

[0004] The technical task, as well as these and other objects according to the present invention, are achieved by realizing a multipurpose heating and refrigerating unit and a method for the control thereof in accordance with the independent claims set forth below.

[0005] Other features of the present invention are defined, moreover, in the subsequent claims.

[0006] The multipurpose heating and refrigerating unit used to produce water at various temperatures can achieve adequate efficiency also when the user load demand conditions vary.

[0007] This is because the primary and secondary refrigeration cycles can function without mutual interference, or with limited mutual interference, in such a way as to optimize the unit's efficiency.

[0008] In particular, it is possible to meet the high temperature load without requiring activation of the primary circuit when there is no load requested at a low or medium temperature.

[0009] This necessarily means a lower consumption of energy to achieve the useful effect desired and ultimately an increase in unit efficiency.

[0010] One of the advantageous effects resulting from the adoption of the construction and integrated control logic of the unit according to the invention thus consists in avoiding or limiting the stop and restart cycles of the primary circuit.

[0011] The control logic provides for cooling energy to be accumulated in the cold water-producing circuit even when the cold load demand is met.

[0012] Similarly, the control logic provides for thermal energy to be accumulated in the circuit for producing water at a medium temperature also when the medium tem-

perature load demand is met.

[0013] Additional features and advantages of the invention will be more apparent from the description of a preferred, but not exclusive, embodiment of the multipurpose heating and refrigerating unit and method for the control thereof according to the invention, illustrated by way of non-restrictive example in the appended drawings, in which:

10 Figure 1 shows a possible system layout of the multipurpose heating and refrigerating unit in accordance with the invention, wherein the primary refrigerating circuit, in the operating mode which provides for the selection of a low-pressure water heat exchanger and a high-pressure water heat exchanger, is shown with a line in boldface;

15 Figure 2 shows the system layout of the multipurpose heating and refrigerating unit of figure 1, wherein the primary refrigerating circuit, in the operating mode which provides for the selection of a low-pressure air heat exchanger and a high-pressure water heat exchanger, is shown with a line in boldface;

20 Figure 3 shows the system layout of the multipurpose heating and refrigerating unit of figure 1, wherein the primary refrigerating circuit, in the operating mode which provides for the selection of a low-pressure water heat exchanger and a high-pressure air heat exchanger, is shown with a line in boldface.

25 **[0014]** With reference to the aforementioned figures, there is shown a multipurpose heating and refrigerating unit 1 comprising a primary refrigerating circuit 2, a secondary refrigerating circuit 3, a first water-producing circuit 4 producing water at a first temperature, a second water-producing circuit 5 producing water at a second temperature above the first temperature, and a third water-producing circuit 6 producing water at a third temperature above the second temperature.

30 **[0015]** By way of example, the first circuit 4 is suitable for cooling water entering at 12 °C to produce water at an outlet temperature of 7 °C, the second circuit 5 is suitable for heating water entering at 40 °C to produce water at an outlet temperature of 45 °C, and the third circuit 6 is suitable for heating water entering at 70 °C to produce water at an outlet temperature of 80 °C.

35 **[0016]** The scope of the invention naturally extends to a unit 1 which also has a larger number refrigerating circuits, even though in the minimal configuration illustrated the unit 1 has only one primary refrigerating circuit 2 and only one secondary refrigerating circuit 3.

40 **[0017]** The primary refrigerating circuit 2 comprises at least one first low-pressure primary heat exchanger 7 connected to the first water-producing circuit 4 and at least one first high-pressure primary heat exchanger 8 connected to the second water-producing circuit 5, a compressor 9, and an expansion device 10.

45 **[0018]** The primary refrigerating circuit 2 can naturally include more than one compressor 9, even though in the

minimal configuration illustrated it has only one compressor 9.

[0019] The secondary refrigerating circuit 3 comprises at least one first low-pressure secondary heat exchanger 11 connected to the second water-producing circuit 5, at least one first high-pressure secondary heat exchanger 12 connected to the third water-producing circuit 6, at least one second low-pressure secondary heat exchanger 13 connected to a high-pressure section 14 of the primary refrigerating circuit 2 downstream of the first high-pressure primary heat exchanger 8.

[0020] Preferably, in the secondary refrigerating circuit 3 the first low-pressure secondary heat exchanger 11 and the second low-pressure secondary heat exchanger 13 are connected to each other in parallel.

[0021] Preferably, the second refrigerating circuit 3 comprises valve means 15 for selecting one or both the first low-pressure secondary heat exchanger 11 and the second low-pressure secondary heat exchanger 13.

[0022] In particular, the first low-pressure secondary heat exchanger 11 operates on a branch 27 of the second water-producing circuit 5 which originates downstream of the first high-pressure primary heat exchanger 8 and connects back to the second water-producing circuit 5 upstream of the first high-pressure primary heat exchanger 8.

[0023] In the branch 27 there is present a feed pump 28 and a check valve 29.

[0024] The secondary refrigerating circuit further has a compressor 16, a first expansion device 17 upstream of the first low-pressure secondary heat exchanger 11, and a second expansion device 18 upstream of the second low-pressure secondary heat exchanger 13.

[0025] In this case as well, the secondary refrigerating circuit 3 can naturally include more than one compressor 16, even though in the minimal configuration illustrated it has only one compressor 16.

[0026] Preferably, the primary refrigerating circuit 2 comprises at least one second primary air heat exchanger 19 suitable for acting selectively in a high-pressure heat exchanger mode as an alternative to the first high-pressure primary heat exchanger 8, or in a low-pressure heat exchanger mode as an alternative to the low-pressure first primary heat exchanger 7, and valve means 20, 21, 22 for selecting the low-pressure heat exchanger and high-pressure heat exchanger of the primary refrigerating circuit 2.

[0027] The primary refrigerating circuit 2 further comprises check valves 30, 31 and a further expansion device 32, which is set upstream of the second primary air heat exchanger 19 when the latter is operating in the low-pressure heat exchanger mode. Finally, the primary refrigerating circuit 2 preferably comprises, upstream of the first high-pressure primary heat exchanger 8, a second high-pressure primary heat exchanger 23 connected to a section 24 of the third water-producing circuit 6 upstream of the first high-pressure secondary heat exchanger 12.

[0028] The third water-producing circuit 6 has a feed

pump 26 and valve means 25, for example a three-way valve, for excluding the second high-pressure primary heat exchanger 23.

[0029] In a possible variant of the invention, the first low-pressure secondary heat exchanger 11 is integrated into the first high-pressure primary heat exchanger 8. This makes it possible to render the unit 1 more compact, to eliminate the branch 27 with the feed pump 28 and check valve 29, and to limit the exposed parts which must be covered and protected from freezing.

[0030] The logical controller of the unit 1 can activate different operating states of the unit 1 in relation to the various possible combinations of the loads to be met in the first, second and third water-producing circuits 4, 5 and 6.

[0031] The basic idea of the invention is to force the unit 1 to operate in a state wherein the first refrigerating circuit 2 is activated with the first high-pressure primary heat exchanger 8 and the first low-pressure primary heat exchanger 7 selected even when a load is requested only of the first water-producing circuit 4 or the second water-producing circuit 5.

[0032] By way of example we shall describe the following situations.

[0033] The unit 1 is working in the state wherein the first refrigerating circuit 2 is activated with the first high-pressure primary heat exchanger 8 and the first low-pressure primary heat exchanger 7 selected. This initial configuration of the unit 1 is illustrated in figure 1, in which the valve means 20, in particular a four-way valve, connect the heat exchanger 23 to the heat exchanger 8, the valve means 21 are closed and the valve means 22 are open. The load requested of the second water-producing circuit 5 is met, whereas the load requested of the first water-producing circuit 4 has not yet reached its set point. The unit 1 should change its operating state by excluding the first high-pressure primary heat exchanger 8 and including instead the second primary air heat exchanger 19 operating in the high-pressure mode (as shown in figure 3, in which the valve means 20 connect the heat exchanger 23 to the heat exchanger 19, the valve means 21 are closed and the valve means 22 are open). The unit 1 is instead forcedly maintained in the state wherein the first refrigerating circuit 2 is activated with the first high-pressure primary heat exchanger 8 and the first low-pressure primary heat exchanger 7 selected. In this manner, thermal energy will be accumulated in the second water-producing circuit 5, in which, consequently, the water temperature will rise a few degrees, thus exceeding its set point.

[0034] The logical controller of the unit 1 operates according to the thermodynamic variables of the first refrigerating circuit 2 (evaporation and condensation temperatures) and the historical temperature trend in the first, second and third water-producing circuits 4, 5 and 6.

[0035] Let us make a first hypothesis that there is subsequently no longer any load requested of the first water-producing circuit 4, but only of the second water-pro-

ducing circuit 5. If thermal energy were not stored in the second water-producing circuit 5 as previously done, the unit 1 would have to activate the first refrigerating circuit 2 with the first high-pressure primary heat exchanger 8 and the second primary air heat exchanger 19 operating in the low-pressure mode selected (as shown in figure 2, wherein the valve means 20 connect the heat exchanger 23 to the heat exchanger 8, the valve means 21 are open and the valve means 22 are closed). Instead, before activating the first refrigerating circuit 2, the unit 1 exploits the previously accumulated thermal energy. In this manner, the start and stop cycles of the unit 1 are decreased and less efficient operating states are limited. Let us make a second hypothesis that there is subsequently no longer any load requested of the first water-producing circuit 4, but only of the third water-producing circuit 6. The secondary refrigerating circuit 3 is activated, while the primary refrigerating circuit 2 remains deactivated. If thermal energy were not stored in the second water-producing circuit 5 as previously done, when the first low-pressure secondary heat exchanger 11 went to cool the water of the second water-producing circuit 5, the load in the second water-producing circuit 5 would no longer be met and the controller would have to activate the first refrigerating circuit 2 with the first high-pressure primary heat exchanger 8 selected. In this manner as well, the start and stop cycles of the unit 1 are decreased, resulting in a reduction in energy consumption and component wear, and less efficient operating states are limited.

[0036] The same advantage is obtained by accumulating cooling energy in the first water-producing circuit 4.

[0037] Let us consider a situation in which the unit 1 is working in a state wherein the first refrigerating circuit 2 is activated with the first high-pressure primary heat exchanger 8 and the first low-pressure primary heat exchanger 7 selected. The load requested of the first water-producing circuit 4 is met whereas the load requested of the second water-producing circuit 5 has not yet reached its set point. The unit 1 should change its operating state by excluding the first low-pressure primary heat exchanger 7 and including the second primary air heat exchanger 19 operating in the low-pressure mode. The unit 1 is instead forcedly maintained in the state wherein the first refrigerating circuit 2 is activated with the first high-pressure primary heat exchanger 8 and the first low-pressure primary heat exchanger 7 selected. In this manner, thermal energy is accumulated in the first water-producing circuit 4, in which the water temperature consequently falls by a few degrees, exceeding its set point.

[0038] Let us make the hypothesis that there is subsequently no longer any load requested of the second water-producing circuit 5, but only of the first water-producing circuit 4. If thermal energy were not stored in the first water-producing circuit 4 as previously done, the unit 1 would have to activate the first refrigerating circuit 2 with the first low-pressure primary heat exchanger 7 and the second primary air heat exchanger 19 operating in the high-pressure mode selected. Instead, before activating

the first refrigerating circuit 2, the unit 1 exploits the previously accumulated thermal energy. In this manner, the start and stop cycles of the unit 1 are decreased and less efficient operating states are limited.

[0039] In addition to the concept of energy accumulation, there are no doubt further benefits deriving from the integrated, synergetic control of the primary refrigerating circuit 2 and secondary refrigerating circuit 3.

[0040] When the first refrigerating circuit 2 is already activated and there is a load requested also of the third water-producing circuit 6, the second refrigerating circuit 3 can be more favourably activated by initially selecting at least the second low-pressure secondary heat exchanger 13, which also acts as a subcooler for the primary refrigerating circuit 2. In this manner, the consumption of the feed pump 28 will be eliminated, the water of the second water-producing circuit 5 will not be cooled and, thanks to the high subcooling obtainable, the enthalpic jump - that is to say, the useful effect obtainable in the first low-pressure primary heat exchanger 7 - will be increased, and, consequently, so will the overall efficiency of the unit 1. If the primary circuit 2 is working in a capacity-controlled mode and does not have at its disposal a sufficient flow of refrigerant fluid to efficiently disperse the evaporation capacity of the secondary circuit 3, it is forced within certain limits to work at 100% capacity, accumulating the excess energy in the other heat exchangers. If this is not sufficient or not more economical in terms of overall efficiency, the first low-pressure secondary heat exchanger 11 will also be selected and the pump 28 will be switched on so that the secondary circuit 3 can have two evaporators operating in parallel.

[0041] In order to maximise the useful effect of the unit 1, this solution is used when the first primary high-pressure heat exchanger 8 and the first low-pressure primary heat exchanger 7 are selected in the primary refrigerating circuit 2, but it can also be used when the second primary air heat exchanger 19 is selected as a replacement for the first low-pressure primary heat exchanger 7 or as a replacement for the first high-pressure primary heat exchanger 8.

[0042] On the other hand, when the primary refrigerating circuit 2 is deactivated or fails and a load is requested solely of the third water-producing circuit 6, only the first low-pressure secondary heat exchanger 11 can be selected in the secondary refrigerating circuit 3 to meet the load.

[0043] Another advantageous aspect in the control of the unit 1 consists in the use of the second high-pressure primary heat exchanger 23 with the function of a desuperheater in the primary refrigerating circuit 2. When a load is requested of the third water-producing circuit 6, the logical controller checks whether the primary refrigerating circuit 2 is activated and whether the use of the desuperheater is useful and sufficient for such a purpose; if not, the secondary refrigerating circuit 3 will be activated.

[0044] In particular, if the primary refrigerating circuit

2 is activated, the logical controller of the unit 1 checks whether the load on the second water-producing circuit 6 is met. If it is, the logical controller will switch the valve 25 to include the second high-pressure primary heat exchanger 23 in the primary refrigerating circuit 2. If the load cannot be met, only at this point will the secondary refrigerating circuit 3 also be activated. If, on the other hand, the load on the second water-producing circuit 6 is not met, the logical controller will switch the valve 25 to exclude the second high-pressure primary heat exchanger 23 from the primary refrigerating circuit 2 and directly activate the secondary refrigerating circuit 3.

[0045] The multipurpose heating and refrigerating unit and method for the control thereof thus conceived are susceptible of numerous modifications and variants, all falling within the scope of the inventive concept; moreover, all the details may be replaced with technically equivalent ones.

[0046] In practice, all of the materials used, as well as the dimensions, can be any whatsoever according to need the state of the art.

Claims

1. Multipurpose heating and refrigerating unit (1) **characterised in that** it comprises a primary refrigerating circuit (2), a secondary refrigerating circuit (3), a first water-producing circuit (4) producing water at a first temperature, a second water-producing circuit (5) producing water at a second temperature above the first temperature, a third circuit (6) producing water at a third temperature above the second temperature, said primary refrigerating circuit (2) comprising at least one low-pressure primary heat exchanger (7) connected to said first water-producing circuit (4), at least one first high-pressure primary heat exchanger (8) connected to said second water-producing circuit (5), at least one second primary air heat exchanger (19) suitable for acting selectively in high-pressure heat exchanger mode as an alternative to the first high-pressure primary heat exchanger (8) or in low-pressure heat exchanger mode as an alternative to the low-pressure first primary heat exchanger (7), and valve means (20, 21, 22) for selecting the low-pressure heat exchanger and the high-pressure heat exchanger for the primary refrigerating circuit (2), said secondary refrigerating circuit (3) comprising at least one first low-pressure secondary heat exchanger (11) connected to said second water-producing circuit (5), and at least one first high-pressure secondary heat exchanger (12) connected to said third water-producing circuit (6).
2. Multipurpose heating and refrigerating unit (1) according to claim 1, **characterised in that** said secondary refrigerating circuit (3) further comprises at least one second low-pressure secondary heat exchanger (13) connected to a high-pressure section (14) of the primary refrigerating circuit (2) downstream of the first high-pressure primary heat exchanger (8).
3. Multipurpose heating and refrigerating unit (1) according to the preceding claim, **characterised in that** in said secondary refrigerating circuit (3) said first low-pressure secondary heat exchanger (11) and said second low-pressure secondary heat exchanger (13) are connected to one another in parallel.
4. Multipurpose heating and refrigerating unit (1) according to the preceding claim, **characterised in that** said second connected refrigerating circuit (3) comprises valve means (15) for selecting one or both said first low-pressure secondary heat exchanger (11) and said second low-pressure secondary heat exchanger (13).
5. Multipurpose heating and refrigerating unit (1) according to any preceding claim, **characterised in that** said primary refrigerating circuit (2) comprises, upstream of said first high-pressure primary heat exchanger (8), a second high-pressure primary heat exchanger (23) connected to a section (24) of said third water-producing circuit (6) upstream of said first high-pressure secondary heat exchanger (12).
6. Multipurpose heating and refrigerating unit (1) according to the preceding claim, **characterised in that** said third water-producing circuit (6) has valve means (25) excluding said second high-pressure primary heat exchanger (23).
7. Multipurpose heating and refrigerating unit (1) according to any preceding claim, **characterised in that** said first low-pressure secondary heat exchanger (11) is integrated into said first high-pressure primary heat exchanger (7).
8. Method for controlling a multipurpose heating and refrigerating unit (1) according to any one of claims 2 to 7, **characterised in that** when the primary refrigerating circuit (2) is already activated and a load to the third water-producing circuit (6) is requested, in said second refrigerating circuit (3) at least said second low-pressure secondary heat exchanger (13) is selected to increase the enthalpy jump to said first low-pressure primary heat exchanger (7), and also the secondary refrigerating circuit (3) is activated.
9. Method for controlling a multipurpose heating and refrigerating unit (1) according to the preceding claim, **characterised in that** when a load is requested only to the third water-producing circuit (6), in said

secondary refrigerating circuit (3) only said first low-pressure secondary heat exchanger (11) is selected, and only the secondary refrigerating circuit (3) is activated.

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10. Method for controlling a multipurpose heating and refrigerating unit (1) according to any one of claims 8 and 9, **characterised in that** when a load to the first water-producing circuit (4) is requested and the request to load the second water-producing circuit (5) is met, said first high-pressure primary heat exchanger (8) is anyway selected to accumulate thermal energy in said second water-producing circuit (5).

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11. Method for controlling a multipurpose heating and refrigerating unit (1) according to any one of claims 8 to 10, **characterised in that** when a load to the second water-producing circuit (5) is requested and the request to load the first water-producing circuit (4) is met, said first low-pressure primary heat exchanger (7) is selected to accumulate refrigerating energy in said first water-producing circuit (4).

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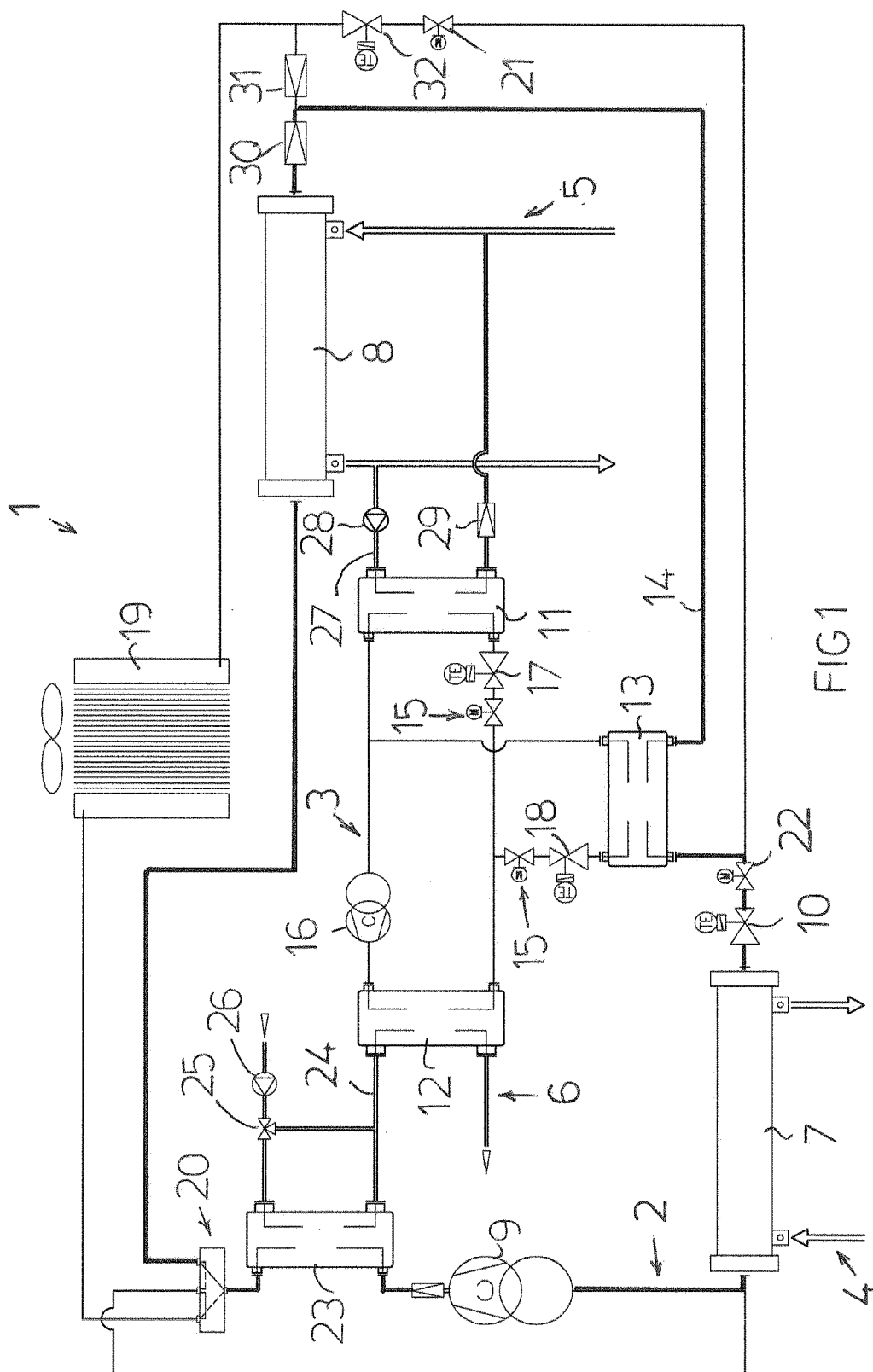


FIG 1

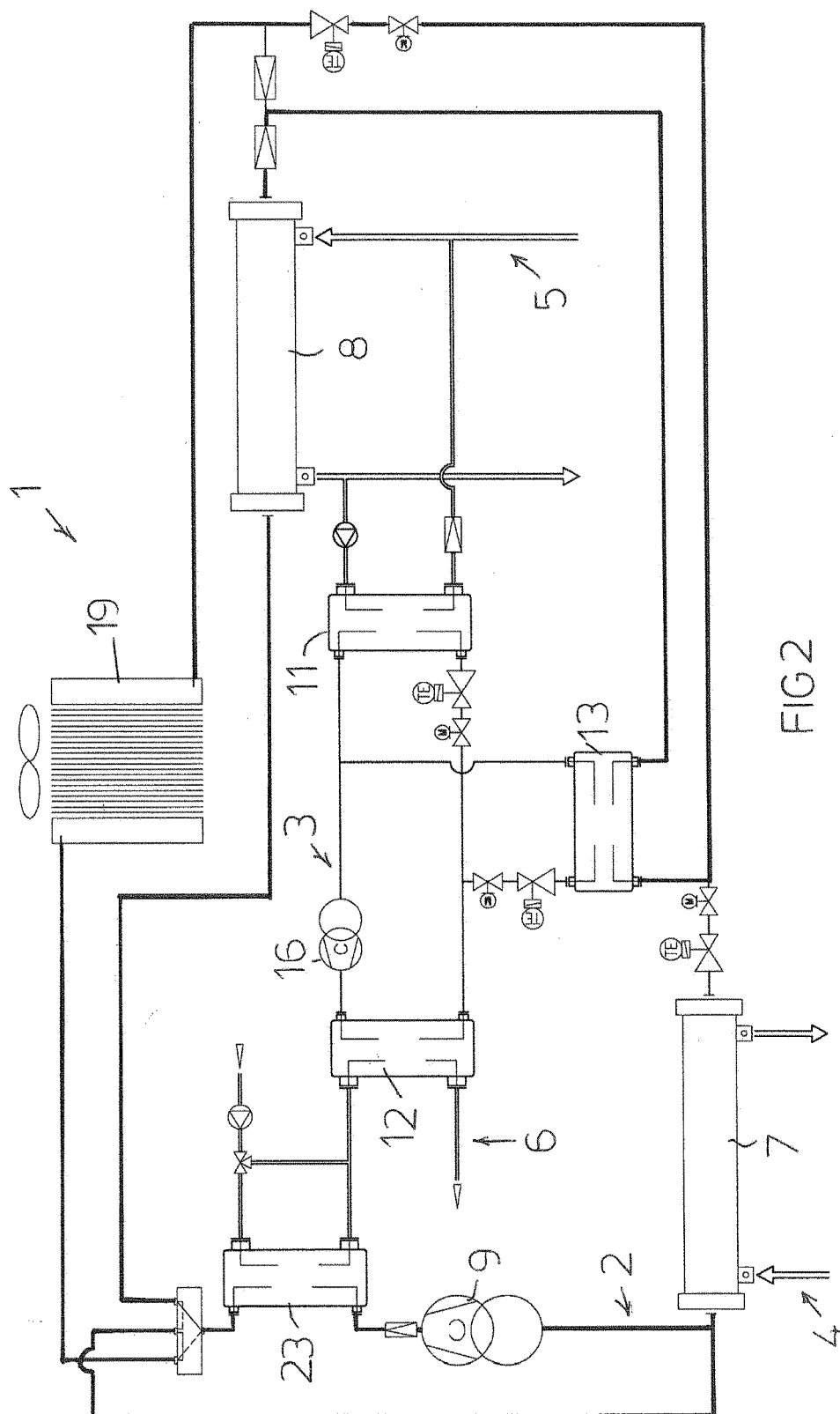


FIG 2

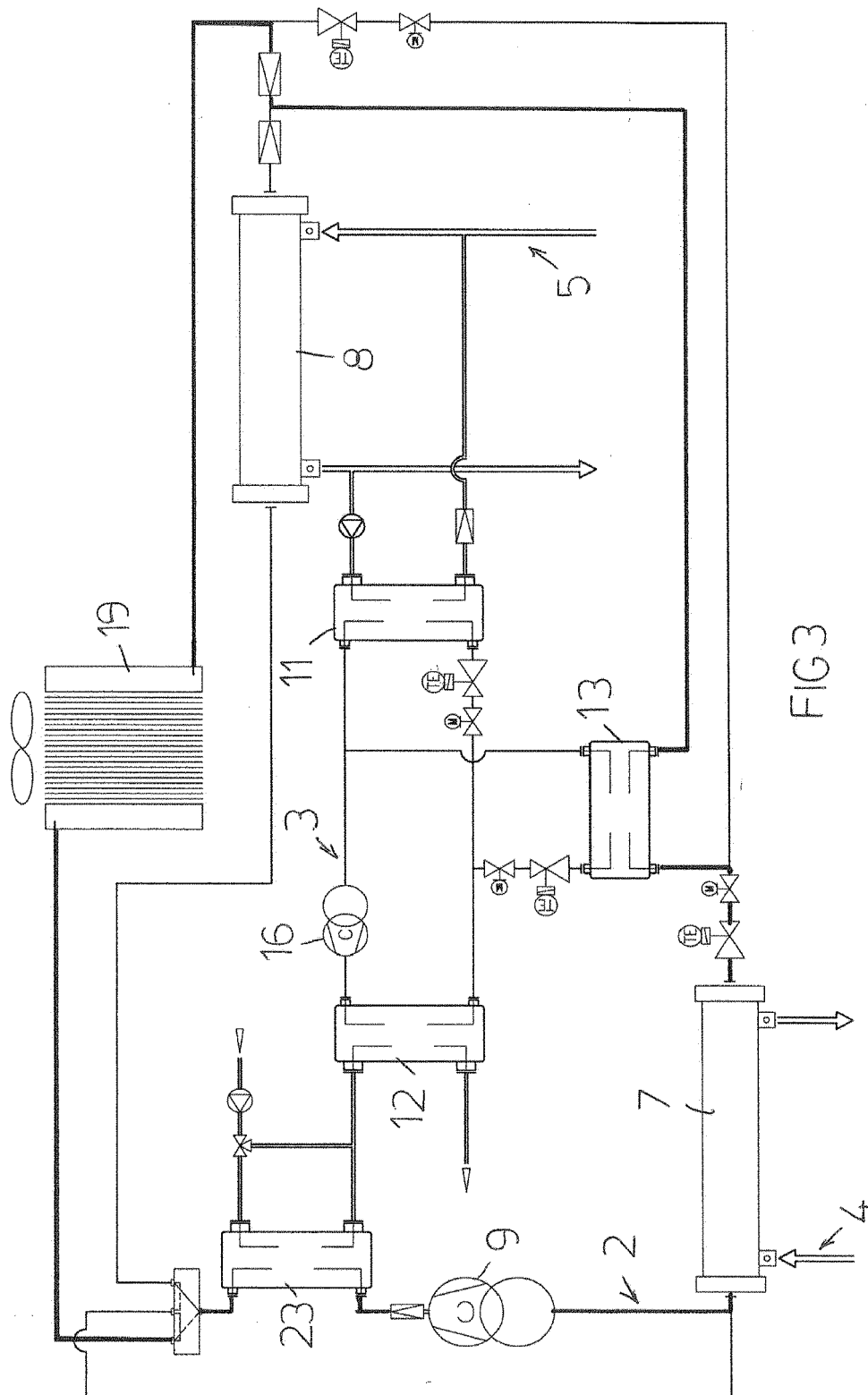


FIG 3



EUROPEAN SEARCH REPORT

Application Number
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Place of search Munich		Date of completion of the search 8 January 2013	Examiner Szilagyi, Barnabas
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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