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(54) **AN IMPROVED REFRIGERATION CIRCUIT**
VERBESSERTER KÜHLKREISLAUF
CIRCUIT DE RÉFRIGÉRATION AMÉLIORÉ

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(73) Proprietor: **ENEX S.R.L.**
31030 Breda di Piave (TV) (IT)

(72) Inventor: **GIROTTO Sergio**
31038 Paese (TV) (IT)

(74) Representative: **Piovesana, Paolo**
c/o Praxi Intellectual Property S.p.A.- Venezia
Via Francesco Baracca, 5/A
30173 Venezia-Mestre (IT)

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Description

[0001] The present invention relates to an improved refrigeration circuit.

[0002] Traditional water or glycol-water coolers, commonly called "chillers", are generally made - both in the case of use of synthetic cooling fluid, such as HFC (R404A, R507, R410A) or HFO (R1234ze), or in the case of pure refrigerating fluids such as propane (R290) or carbon dioxide (CO₂ or R744) - according to the traditional Evans-Perkins cycle.

[0003] In particular, the distribution of the cooling fluid to the evaporator or evaporators 52 occurs in most cases from a liquid tank 50 placed downstream of a high-pressure exchanger (condenser) 51 (see Fig.1). The tank 50 is kept at the condensation pressure which is indirectly controlled by the thermal capacity of the cooling fluid (air or water) flow and by the geometric characteristics of the high-pressure exchanger 51.

[0004] In the most common refrigeration systems that use CO₂ as refrigerant, a lamination valve 53 is interposed between the high-pressure exchanger 51 and the tank 50, while the pressure in said tank is limited by expansion of the flash vapor at low pressure through a pressure regulating valve 54 provided downstream of said tank 50 (see Figure 2).

[0005] The distribution of refrigerating fluid to the evaporator or to the evaporators 52 occurs by means of a thermostatic expansion valve 55, of the mechanical or electronic type, which regulates overheating. The dry vapor coming out from the evaporators 52 passes through the compressor 56 which increases its pressure and then is sent to the high-pressure exchanger 51 to be cooled and brought back to the liquid state, to be finally returned to the liquid tank 50.

[0006] A drawback of this solution is the energy loss due to the presence, in the evaporator 52, of the overheating zone.

[0007] Currently, the solutions proposed to overcome this drawback are rather expensive and complicated.

[0008] Moreover, when the fluid used (for example the air from the external environment) to remove heat from the high-pressure exchanger 51 is at high temperatures (for example, during summer period the air of the external environment is particularly hot), refrigeration systems that use CO₂ as refrigerant have lower efficiency than those using synthetic refrigerating fluids (e.g. HFC).

[0009] WO2012/092685 describes a refrigeration circuit which is provided with an ejector and a single evaporator, which is connected via a fluidic circuit at the inlet with the tank and at the outlet with the inlet of an ejector module provided for the fluidized bed flow.

[0010] The object of the invention is to propose refrigerating circuit which overcomes the drawbacks of traditional solutions and which, regardless of the used refrigerant, has a high efficiency.

[0011] Another object of the invention is to propose a circuit which exhibits high efficiency even by using carbon

dioxide as refrigerant.

[0012] Another object of the invention is to propose a circuit which has a high efficiency even in the presence of a high external environmental temperature, for example during the summer period.

[0013] Another object of the invention is to propose a circuit which can be used in all operating conditions.

[0014] Another object of the invention is to propose a flexible circuit which can be readily and correctly adapted to, even significant, variations in its operating use condition.

[0015] Another object of the invention is to propose a circuit which can be produced in a simple, easy and low-cost manner.

[0016] Another object of the invention is to propose a circuit which has an alternative and/or improved characterization, both in constructive and functional terms, with respect to the traditional ones.

[0017] All of these purposes, either alone or in any combination thereof, and others which will result from the following description are achieved, according to the invention, with a circuit as defined in claim 1.

[0018] The present invention is hereinafter further clarified in some of its preferred embodiments, which are given purely by way of non-limiting example with reference to the attached tables of drawings, in which:

Figure 1 shows a schematic view of a first refrigerating circuit according to the state of the art,
 Figure 2 shows a schematic view of a second circuit according to the state of the art which uses CO₂ as refrigerating fluid,
 Figure 3 shows a schematic view of a cooling circuit according to the invention,
 Figure 4 shows, according to a vertical section, an embodiment of an ejector provided in the circuit of Figure 3 with the corresponding pressure profiles therein, and
 Figure 5 shows for the circuit of Fig. 3 according to the invention the indicative temperature profiles during the thermal exchange occurring inside the evaporator between the refrigerating fluid and the fluid to be cooled, and
 Figure 6 shows an embodiment of a multiple ejector provided in Figure 3,
 Figure 7 shows a schematic view of a different embodiment of the refrigerating circuit according to the invention.

[0019] As can be seen in Figures 3 and 7, the refrigeration circuit according to the invention, generally indicated by reference number 20, comprises at least one compressor 1 which is installed so as to suck refrigerating fluid in the vapor state 7 from a tank 4 through a pipe 3 which connects the upper part of said tank 4 with the suction port of said compressor 1. The tank 4 contains refrigerating fluid in both the liquid state 5 and the vapor state 7.

[0020] Preferably, as envisaged in the embodiment of fig. 7 (and in general when a variable refrigerating load is provided), the circuit 20 comprises a plurality of compressors 1 in parallel with each other and configured to suck the refrigerating fluid in the vapor state 7 from the tank 4.

[0021] The discharge port of the compressor 1 is connected to the inlet of a high-pressure heat exchanger 2.

[0022] Preferably, the heat exchanger 2 comprises a condenser, in which the refrigerating fluid in the vapor state 7 and at high-pressure - as compressed by the compressor 1 - is cooled and brought to the liquid state or dense gas. In particular, in the high-pressure exchanger 2 the cooling fluid is cooled by exchanging heat with the external environment or with another fluid.

[0023] Suitably, in the embodiment of fig. 7, the high-pressure exchanger 2 provides that the cooling fluid exchanges heat with a fluid to be heated (for example water) which enters the high-pressure exchanger 2 from an inlet 27 and - after passing through said high-pressure exchanger 2 in order to exchange heat with the refrigerating fluid compressed by the compressor 1 - leaves the high-pressure exchanger 2 from an outlet 29.

[0024] The circuit 20 further comprises a pipe 9 which connects the outlet of the high-pressure exchanger 2 with the input 8_M of an ejector module 8 (unit).

[0025] In particular, as shown in Figure 4, the ejector module 8 comprises:

- at least one input 8_M for the motor (or primary) flow 37 coming from the outlet pipe 9 of the high-pressure exchanger 2,
- at least one input 8_T for the entrained (or secondary) flow 38; in particular, through this inlet, the refrigerating fluid in the pipe 10 is sucked/taken into the ejector module 8, and
- an outlet 8_{OUT} connected downstream, by means of a duct 14, to the tank 4 to eject inside the latter the mixture 39 of said motor 37 and entrained 38 flows.

[0026] Advantageously, the ejector module 8 comprises at least one ejector 8' provided with a convergent nozzle 60 which is associated with the input 8_M for the motor fluid and communicates at the outlet with a suction chamber 62; in particular, said suction chamber 62 is defined inside the same ejector 8' and communicates with the input 8_T for the entrained flow. Further, the ejector 8' comprises a mixing chamber 64 which terminates and is connected downstream with a diffuser 69. Preferably, the mixing chamber 64 is connected upstream with the suction chamber 62, while the diffuser 69 is connected downstream with the output 8_{OUT} .

[0027] Preferably, the ejector module 8 may comprise a single variable geometry ejector (not shown). In particular, this ejector comprises a convergent nozzle 60 in which the outlet section is appropriately adjusted, for example by means of a pin, according to the pressure value measured downstream of the compressor 1.

[0028] Preferably, as shown in Figure 6, the ejector module 8 can be of fixed geometry and comprise a plurality of ejectors 8' in parallel (multi-ejector), of the same or variable size (or a suitable combination thereof), which are activated/controlled based on the pressure value measured downstream from the compressor 1. In particular, in this case, the ejector module 8 comprises a plurality of shut-off valves 11, preferably of the on-off type, controlled in parallel and positioned at the input of the nozzle 62 of each ejector 8'. In this case, opportunely, in correspondence of the input of the ejector module 8, a portion of connection 12 is provided to divide the flow coming from the pipe 9 into a plurality of ducts, each of which is provided with its own shut-off valve 71 and it enters at the input 8_M of an ejector 8'. Moreover, the outputs 8_{OUT} of each ejector 8' are connected to a manifold 13 communicating, through the duct 14, with the tank 4.

[0029] Conveniently, it is provided a control/command unit 91 of the ejector module 8, and in particular of the pin, in the case of a single variable geometry ejector, or of shut-off valves 11, in the configuration with a plurality of parallel ejectors 8'.

[0030] More in detail, the control/command unit 91 is configured to control the ejector module 8, according to known algorithms, on the basis of the detected (by means of appropriate sensors 93) temperature and pressure values in any area of the outlet pipe 9, that is, in any zone positioned between the outlet of the high-pressure exchanger 2 and the input of the ejector module itself. Conveniently, the ejector module 8 controls/regulates the pressure of the refrigerating fluid at the input 8_M , on the basis of the temperature and pressure values measured in any area of the outlet pipe 9, according to a traditional efficiency optimization curve of a transcritical CO_2 cycle.

[0031] The circuit 20 also comprises a first evaporator 24 which, suitably, is gravity fed from the liquid tank 4 via a portion 50 and which at the outlet is connected directly to the tank by a recirculation circuit 21.

[0032] In particular, appropriately, the first evaporator 24 is placed at a lower geodetic level with respect to the tank 4 so as to allow gravity feeding of said first evaporator 24 with the refrigerating liquid 5 present in the tank itself. Conveniently, the outlet of the first evaporator 24 is connected to the liquid tank 4 by means of a recirculation circuit 21 in which the circulation of the refrigerating fluid occurs by density difference between the saturated liquid entering the first evaporator 24 and the liquid/vapor mixture or the vapor coming out of the latter, which, being lighter, enters the recirculation circuit 21.

[0033] The circuit 20 also comprises a second evaporator 30 which is connected at the inlet with the tank 4 and at the outlet with the input 8_T of the ejector module 8. Appropriately, the second evaporator 30 is supplied with liquid refrigerating fluid 5, present in the liquid tank 4, by means of a portion 51 provided with an expansion valve 32 which is controlled by a control/command unit (not shown), preferably but not exclusively, based on the temperature (overheating) and/or pressure of the refrigerating fluid.

erating fluid that is present, preferably in the vapor state, in correspondence of the pipe 10 positioned at the outlet of the second evaporator 30.

[0034] The outlet of the second evaporator 30 is connected by the pipe 10 to the input 8_T of the ejector module 8. Suitably, as shown in figure 6, in the case of ejector module 8 comprising a plurality of ejectors $8'$ in parallel, a connection portion 15 is provided for dividing the entrained flow of the pipe 10 into a plurality of suction ducts 16, each of which communicates with the entrained input (suction port) 8_T of one of the ejectors $8'$ of the module 8. Conveniently, a valve 17, preferably a non-return valve, is provided at each suction duct 16.

[0035] Conveniently, P_1 corresponds to the pressure of the refrigerating fluid in the pipe 10 connected to the input 8_T ; while P_2 corresponds to the pressure of the two-phase refrigerating fluid in the tank 4, the fraction thereof in the vapor state 7 is sucked by the compressor 1.

[0036] Conveniently, in this way in the circuit 20 two different levels of evaporating temperature of the refrigerating fluid are defined: compressor 1 sucks from the tank 4 the refrigerating fluid in the vapor state 7 at a higher pressure P_2 , the ejector module 8 sucks/draws the refrigerating fluid through the input 8_T at a lower pressure level P_1 .

[0037] In the embodiment of fig. 3, the path 40 of the fluid to be cooled, for example water, is configured in such a way as to pass in sequence the two evaporators 24 and 30 which, advantageously, are connected to each other in series, preferably on the side in which the fluid to be cooled flows. In particular, the path 40 of the fluid to be cooled comprises in sequence firstly the crossing of a first portion 41 provided on the primary side of the first gravity fed evaporator 24, which can be connected following or against the current, and subsequently comprises the crossing of a second portion 42 defined on the primary side of the second evaporator 30, the one fed through the expansion valve 32 and whose outlet is connected to the input 8_T of the ejector module 8. Basically, the second portion 42 of the second evaporator 30 is fluidically connected in series and downstream of the first portion 41 of the first evaporator 24.

[0038] Suitably, the circuit 20 of fig. 3 also comprises a further suitable control unit (not shown) for the temperature of the fluid to be cooled, for example water or other liquid, inside the path 40. In particular, said further control unit is configured to act on the suction pressure of the refrigerating fluid from the tank 4, in particular by acting on the suction capacity of the compressor 1 - and therefore on the saturation temperature of the refrigerating fluid in said tank 4 - so that the temperature of the cooled fluid detected downstream of said second evaporator 30 follows a determined reference temperature (set-point).

[0039] Suitably, in the embodiment of fig. 7, the path 40 of the fluid to be cooled, for example air or other gas, comprises at least one duct 45 in which they are inserted/housed in sequence (i.e. one after the other according to the crossing direction of said channel) the two evaporators 24 and 30.

Conveniently, in the duct 45 a fan 46 can be provided for the circulation of the air which passes through said ducting. In particular, the path 40 of the air to be cooled inside the duct 45 comprises in sequence: first the crossing of the secondary side of the first evaporator 24 fed by gravity, and subsequently the crossing of the secondary side of the second evaporator 30, that is fed by the expansion valve 32 and which output is connected to the input 8_T of the ejector module 8.

[0040] Conveniently, also in this embodiment of fig. 7, a control/command unit 91 of the ejector module 8 is provided, and in particular for the control of the pin in the case of a single variable geometry ejector or of the shut-off valves 11 in the case of a configuration with a plurality of parallel ejectors $8'$. In particular, said control/command unit 91 is configured to control the ejector module 8, according to known algorithms, on the basis of the temperature and pressure values detected (by appropriate sensors 93) in any area of the outlet pipe 9, i.e. in any area positioned between the outlet of the high-pressure exchanger 2 and the input 8_M of the ejector module 8 itself.

[0041] Conveniently, also in the embodiment of fig. 7, the second evaporator 30 is supplied with refrigerating fluid 5 in the liquid state, which is present in the liquid tank 4, through a portion 51 provided with an expansion valve 32 which is controlled by the command/control unit 91, preferably but not exclusively, on the basis of the temperature T_1 and/or pressure P_1 of the refrigerating fluid which is present, preferably in the vapor state, in correspondence of the pipe 10 positioned at the outlet of the second evaporator 30.

[0042] Advantageously, also in the embodiment of fig. 7, the circuit 20 also comprises a further capacity control unit (not shown) which is configured to act on the suction pressure of the refrigerating fluid from the tank 4, in particular by acting on the suction capacity of the compressor 1 - and therefore on the temperature saturation of the refrigerating fluid in said tank 4 - so that the temperature T_{out} of the fluid (for example water) at the outlet 29 of the high-pressure exchanger 2 follows a determined reference temperature (set-point). In particular, the temperature T_{out} of the fluid corresponds to the temperature that the fluid presents after it has exchanged heat with the refrigerating fluid compressed by the compressor 1 inside the high-pressure exchanger 2. More in detail, the capacity control unit is configured to act on the suction pressure P_2 of the refrigerating fluid from the tank 4, in particular by acting on the suction capacity of the compressor 1, so that the pressure difference ΔP between P_1 and P_2 (i.e. $\Delta P = P_1 - P_2$) remains constant at a value (K), which is variable according to the overheating in the pipe 10 connected to the input 8_T . Advantageously, the overheat is defined by the temperature difference ΔT between T_{SAT1} and T_1 (i.e. $\Delta T = T_{SAT1} - T_1$), where T_{SAT1} is the saturation temperature corresponding to the pressure P_1 of the refrigerating fluid in the pipe 10 connected to the input 8_T while T_1 is the corresponding temperature of the refrigerating fluid in the pipe 10 connected to the input 8_T .

[0043] Advantageously, the control units of the circuit 20 can be implemented by separate processors or, alternatively, can be implemented inside the same processor.

[0044] The operation of the circuit 20 according to the invention is as follows.

[0045] The fluid to be cooled, which enters in the path 40 at a temperature T_1 , for example of about 12°C, first passes through the first evaporator 24 where it passes to a temperature T_2 , for example about 9°C (see section 81 of the temperature profile 80 of the fluid to be cooled which passes through the first evaporator 24). In particular, this decrease in temperature from T_1 to T_2 of the fluid to be cooled is obtained, inside the first evaporator 24, by heat exchange with the refrigerating fluid which evaporates at a temperature of, for example, about 8°C (see section 85 of the temperature profile 83 of the refrigerating fluid passing through the first evaporator 24).

[0046] The heat that passes from the fluid to be cooled to the refrigerating fluid causes the latter to pass from the liquid state to the state of a two-phase liquid/vapor or vapor mixture which, in view of its lower density and through the recirculation circuit 21, returns in the tank 4 in the form of a two-phase mixture or vapor having a temperature of about 8°C for example.

[0047] The fluid to be cooled from the first evaporator 24, which is then at the aforementioned temperature T_2 , enters the second evaporator 30 where it passes to a temperature T_3 , for example about 7°C (see section 82 of the temperature profile 80 of the fluid to be cooled through the second evaporator 30). In particular, this further decrease in temperature from T_2 to T_3 of the fluid to be cooled is obtained, inside the second evaporator 30, by the heat exchange with the refrigerating fluid which is in the liquid state and at the temperature of about 4°C (see section 84 of the temperature profile 83 of the refrigerating fluid passing through the second evaporator 30).

[0048] In particular, as a result of the suction carried out by the ejector module 8 and acting on the expansion valve 32, the temperature of the refrigerating fluid entering the second evaporator 30 passes from a temperature of, for example, about 8°C (corresponding to the temperature of the refrigerating fluid inside the tank 4) at the aforementioned temperature of about 4°C. More in detail, the reduction (fall) of pressure that occurs inside the ejector module 8, causes a lowering of the pressure and therefore of the temperature, for example from 8°C to 4°C, of the refrigerating fluid entering the second evaporator 30 and circulating in the pipe 10 associated with the input 8_T .

[0049] Furthermore, at the second evaporator 30, the heat that passes from the fluid to be cooled to the refrigerating fluid causes the latter to pass from the liquid state to the vapor state which is then sucked through the pipe 10 and the input 8_T inside the ejector 8.

[0050] Inside the tank 4, the refrigerating fluid is at a temperature of, for example, about 8°C, both in the liquid

state 5 and in the vapor state 7. The compressor 1 sucks from the tank 4 the refrigerating fluid in the vapor state 7 - which is for example at a pressure of about 42 bar and at a temperature of about 8°C - and, after compressing it, increasing its pressure up to about 90 bar (at a temperature of about 100° - 120°C), sends it to the high-pressure exchanger 2 where it is cooled - if the air or the cooling fluid is at about 32-33°C - for example, to reach a temperature of about 35°C (with pressure remaining around 90 bar), and brought to a liquid or dense gas state.

[0051] Then the refrigerating liquid or dense gas which is at high pressure (i.e. at about 90bar) and at the temperature of 35°C, which exits the high-pressure exchanger 2, is sent to the input 8_M of the ejector module 8.

[0052] In particular, inside the ejector module 8 the high-pressure refrigerating liquid, which enters through the input 8_M (see section 70 of the pressure profile shown in Fig. 4), is passed through the convergent nozzle 60 so as to convert the pressure into velocity and create a sudden reduction in pressure inside the suction chamber 62 of the ejector module (see the second section 72 of the pressure profile shown in Fig. 4).

[0053] The aforementioned pressure reduction causes the suction/aspiration, inside the suction chamber 62 and through the input 8_T , of the refrigerating fluid which flows from the tank 4 through the second evaporator 30. In particular, the vapor present in the pipe 10 at the outlet of the second evaporator 30 (see section 74 of the pressure profile shown in Fig. 4) is sucked/aspirated inside the suction chamber 62 of the ejector module 8.

[0054] Hence, inside the mixing chamber (diffuser) 64, which is provided in the ejector module 8 immediately downstream of the suction chamber, the refrigerating liquid or dense gas, which has entered through the input 8_M , mixes with the sucked/aspirated one in the vapor state that enters through the input 8_T (see section 76 of the pressure profile shown in Fig. 4). Conveniently, the mixture so obtained is compressed in the diffuser 69 (see section 78 of the pressure profile shown in Fig. 4) so that at the output 8_{OUT} of the ejector module 8, the refrigerating fluid exits in the state of both liquid and vapor, for example at a pressure of about 42 bar and at a temperature of about 8°C, which then enters, through the duct 14, in tank 4. Preferably, the diffuser 69 downstream of the mixing chamber 64 is suitably shaped as a divergent duct and defines the chamber pressure recovery.

[0055] In essence, the pressure reduction which is carried out, in a controlled manner, at the input 8_M causes, through the input 8_T , the circulation of the refrigerating fluid through the second evaporator 30, thus allowing a further lowering of the temperature of the fluid to be cooled.

[0056] Moreover, the ejector module 8 reduces, before the injection in the tank 4 connected to the compressor 1, the pressure (and therefore the temperature) of the refrigerating fluid coming out from the high-pressure exchanger 2 and this allows the recovery of the expansion energy and at the same time, it increases efficiency, par-

ticularly in summer conditions, i.e. when the outside air is hot and does not allow a suitable cooling of the refrigerating fluid that passes through the high-pressure exchanger 2.

[0057] Conveniently, the ejector module 8 also allows to increase the pressure (and therefore the temperature) of the refrigerating fluid coming out from the second evaporator 30 before placing it in tank 4 connected to the compressor 1. Therefore, the compressor 1 sucks, from the tank 4, the refrigerating fluid in the vapor state 7 which is at a pressure higher than the outlet pressure from the second evaporator 30, and therefore the energy required for its compression is lower.

[0058] Preferably, the ratio (called "*Entrainment Ratio*") between the flow rate through the input 8_T and the flow rate through the input 8_M of the ejector module 8 depends on the temperature and pressure of the refrigerating fluid at the input 8_M . The above ratio is higher in summer conditions - that is when the cooling fluid (the outside air) is warmer - and therefore it is possible to recover a greater amount of energy suitable to generate a pressure difference that would induce circulation, through the second evaporator 30, of a greater refrigerating fluid flow that evaporates at a temperature lower than the saturation temperature corresponding to the suction pressure of the compressor 1.

[0059] Moreover, the circuit according to the invention can be used for cooling water or other liquids in conditioning or environmental comfort systems, in refrigeration systems and/or in industrial processes.

[0060] Conveniently, the operation of the circuit according to the invention in its embodiment of fig. 7 substantially corresponds to that described above, wherein the fluid to be cooled is air, which enters the path 40 defined by the duct 45, in order to first cross the first evaporator 24 (where there is a lowering of temperature from T_1 to T_2) and, subsequently, it passes through the second evaporator 30 (where a temperature drop from T_2 to T_3 occurs). Conveniently, the function (and therefore the relative control) of the circuit 20 in its embodiment of fig. 7 is to heat the fluid (for example water) which passes through the exchanger 2 and which, in particular, enters the latter at the inlet 27 and - after passing through said high-pressure exchanger 2 in order to exchange heat with the refrigerating fluid compressed by the compressor 1 - leaves the exchanger 2 at an outlet 29.

[0061] From what has been said, the circuit according to the invention is particularly advantageous because:

- it allows to obtain a high efficiency through flooded feeding and simultaneous automatic pressure optimization of suction, and in particular by recovering energy from the expansion process through the use of ejectors,
- can be used in all operating conditions,
- the switching between operation with energy recovery and operation without the recovery of expansion energy takes place in a substantially automatic, self-

regulating and continuous way,

- is easy and cheap to realize.

[0062] The invention is particularly suitable for use with natural refrigerating fluids, such as in particular carbon dioxide (CO₂ or R744), but it can also be used also with synthetic refrigerants.

10 Claims

1. Refrigerating circuit (20), preferably suitable for use with CO₂ as refrigerant, comprising:

- a tank (4) configured to receive and contain inside refrigerant both at the liquid state (5) and at the vapor state (7),
- at least one compressor (1) communicating with said tank (4) for sucking the refrigerant from the vapor state (7),
- a high-pressure heat exchanger (2) positioned downstream of said at least one compressor (1) and fluidically connected to it,
- at least an ejector module (8) comprising an input (8_M) for a motor flow (37), an input (8_T) for an entrained flow (38), and an output (8_{OUT}) for ejecting into said tank (4) the mixture (39) of said two flows, said input (8_M) for the motor flow (37) being fluidly connected to the output of said high-pressure heat exchanger (2),
- a first evaporator (24) that is fluidly connected both at the inlet and at the outlet with said tank (4), and
- a second evaporator (30) that is fluidly connected at the inlet with said tank (4) and at the outlet with said input (8_T) for an entrained flow of said ejector module (8).

2. Circuit according to claim 1, **characterized in that** said first evaporator (24) is of the gravity fed type and is fed by said tank (4) and is connected at the outlet with said tank by means of a recirculation circuit (21).

3. Circuit according to one or more of the preceding claims, **characterized in that** said first evaporator (24) is placed at a lower geodetic level with respect to the tank (4).

4. Circuit according to one or more of the preceding claims, **characterized in that** it comprises a path (40) of a fluid to be cooled which passes through, in sequence, said first evaporator (24) and said second evaporator (30).

5. Circuit according to claim 4, **characterized in that** said path (40) for the fluid to be cooled, preferably of water, comprises in sequence first a first portion

- (41), which is provided in the first evaporator (24), and then a second portion (42) which is provided in the second evaporator (30), said first portion (41) of the first evaporator (24) and said second portion (42) of the second evaporator (30) being fluidly connected together in series and being designed to be passed through by the fluid to be cooled.
6. Circuit according to claims 4 or 5, **characterized in that** said path (40) for the fluid to be cooled, preferably air, comprises at least one duct (45) in which said first evaporator (24) and said second evaporator (30) are housed in sequence.
7. Circuit according to one or more of the preceding claims, **characterized in that** the inlet of said second evaporator (30) is fluidly connected to said tank (4) by means of an expansion valve (32) which is configured to be controlled according to the temperature and/or the pressure of a cooling fluid exiting said second evaporator (30).
8. Circuit according to one or more of the preceding claims, **characterized in that** said ejector module (8) comprises a single ejector with variable geometry.
9. Circuit according to one or more of the preceding claims, **characterized in that** said ejector module (8) comprises a plurality of parallel ejectors, each of which is associated at the input to a corresponding control valve.
10. Circuit according to one or more of the preceding claims, **characterized in that** said ejector module (8) is configured to control under pressure the motor flow (37) at the input (8_M) of said module on the basis of temperature and/or pressure values measured in the section downstream of said high-pressure exchanger (2) and upstream of said ejector module (8).
11. Circuit according to one or more of the preceding claims, **characterized in that**, when CO_2 is used as refrigerant, said ejector module (8) is configured to control under pressure the motor flow (37) at the input (8_M) of said module according to an efficiency optimization curve of a transcritical CO_2 cycle.
12. Circuit according to one or more of the claims 4-6, **characterized in that** it comprises a unit for controlling the temperature of the fluid to be cooled which passes through said path (40), said control unit is configured to act on the capacity of said compressor (1), and then on the saturation temperature of the refrigerant in said tank (4), so that the temperature of the cooled fluid detected downstream of said second evaporator (30) follows a determined reference temperature.

13. Circuit according to one or more of the preceding claims, **characterized in that** it comprises a unit for controlling the temperature of a fluid to be heated that passes through said exchanger (2), said control unit is configured to act on the capacity of said compressor (1), and then on the saturation temperature of the refrigerant in said tank (4), so that the temperature (T_{out}) of the fluid at the outlet (29) of the exchanger (2), after passing through said exchanger (2) by exchanging heat with the refrigerant coming from said at least one compressor (1), follows a determined reference temperature.

Patentansprüche

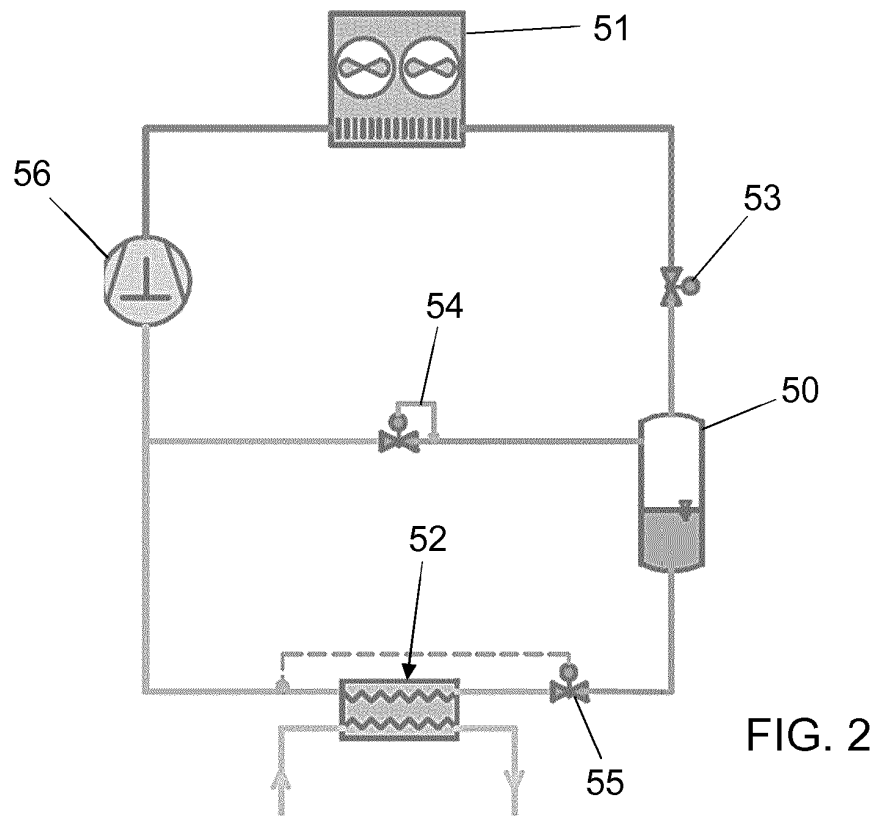
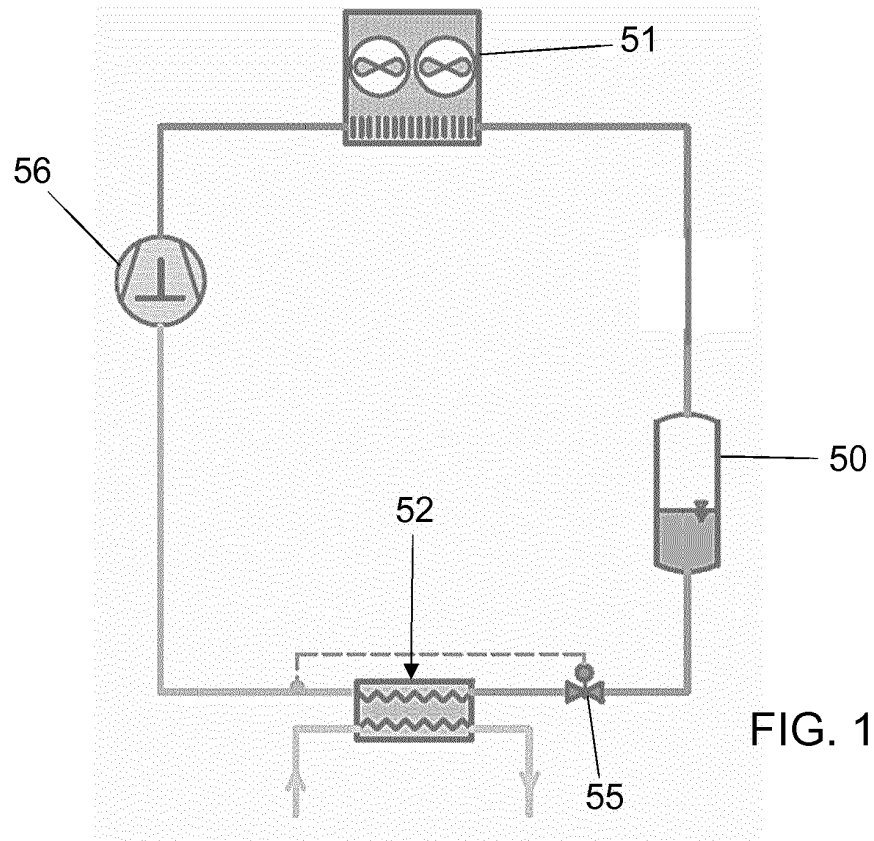
- Kühlkreislauf (20), vorzugsweise geeignet zur Verwendung mit CO_2 als Kältemittel, umfassend:
 - einen Tank (4), der so konfiguriert ist, dass er sowohl im flüssigen Zustand (5) als auch im Dampfungszustand (7) Kältemittel aufnimmt und darin enthält,
 - mindestens einen Verdichter (1), der mit dem Tank (4) kommuniziert, um das Kältemittel aus dem Dampfungszustand (7) zu saugen,
 - einen Hochdruckwärmetauscher (2), der stromabwärts des mindestens einen Verdichters (1) positioniert und fluidisch mit diesem verbunden ist,
 - mindestens ein Ejektormodul (8), umfassend einen Eingang (8_M) für einen Motorstrom (37), einen Eingang (8_T) für einen mitgeführten Strom (38) und einen Ausgang (8_{OUT}) zum Ausstoßen der Mischung (39) der zwei Ströme in den Tank (4), wobei der Eingang (8_M) für den Motorstrom (37) fluidisch mit dem Ausgang des Hochdruckwärmetauschers (2) verbunden ist,
 - einen ersten Verdampfer (24), der sowohl am Einlass als auch am Auslass mit dem Tank (4) fluidisch verbunden ist, und
 - einen zweiten Verdampfer (30), der am Einlass mit dem Tank (4) und am Auslass mit dem Eingang (8_T) für einen mitgeführten Strom des Ejektormoduls (8) fluidisch verbunden ist.
- Kreislauf nach Anspruch 1, **dadurch gekennzeichnet, dass** der erste Verdampfer (24) vom schwerkraftgespeisten Typ ist und von dem Tank (4) gespeist wird und am Auslass mit dem Tank (4) mittels eines Rezirkulationskreislaufs (21) verbunden ist.
- Kreislauf nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der erste Verdampfer (24) in Bezug auf den Tank (4) auf einem niedrigeren geodätischen Niveau angeordnet ist.

4. Kreislauf nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** er einen Weg (40) eines zu kühlenden Fluids umfasst, der nacheinander durch den ersten Verdampfer (24) und den zweiten Verdampfer (30) strömt. 5
5. Kreislauf nach Anspruch 4, **dadurch gekennzeichnet, dass** der Weg (40) für das zu kühlende Fluid, vorzugsweise Wasser, nacheinander zuerst einen ersten Abschnitt (41), der in dem ersten Verdampfer (24) bereitgestellt ist, und dann einen zweiten Abschnitt (42), der in dem zweiten Verdampfer (30) bereitgestellt ist, umfasst, wobei der erste Abschnitt (41) des ersten Verdampfers (24) und der zweite Abschnitt (42) des zweiten Verdampfers (30) fluidisch in Reihe miteinander verbunden sind und dazu ausgelegt sind, von dem zu kühlenden Fluid durchströmt zu werden. 10 15 20
6. Kreislauf nach Anspruch 4 oder 5, **dadurch gekennzeichnet, dass** der Weg (40) für das zu kühlende Fluid, vorzugsweise Luft, mindestens einen Kanal (45) umfasst, in dem der erste Verdampfer (24) und der zweite Verdampfer (30) nacheinander untergebracht sind. 25
7. Kreislauf nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Einlass des zweiten Verdampfers (30) mittels eines Expansionsventils (32), das konfiguriert ist, um gemäß der Temperatur und/oder dem Druck eines aus dem zweiten Verdampfer (30) austretenden Kühlfluids gesteuert zu werden, fluidisch mit dem Tank (4) verbunden ist. 30 35
8. Kreislauf nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Ejektormodul (8) einen einzelnen Ejektor mit variabler Geometrie umfasst. 40
9. Kreislauf nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Ejektormodul (8) eine Vielzahl von parallelen Ejektoren umfasst, von denen jeder am Eingang einem entsprechenden Steuerventil zugeordnet ist. 45
10. Kreislauf nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Ejektormodul (8) konfiguriert ist, um den Motorstrom (37) am Eingang (8_M) des Moduls auf der Grundlage von Temperatur-und/oder Druckwerten, die in dem Teilstück stromabwärts des Hochdruckaustauschers (2) und stromaufwärts des Ejektormoduls (8) gemessen wurden, unter Druck zu steuern. 50 55
11. Kreislauf nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass**, wenn CO₂ als Kältemittel verwendet wird, das Ejektormodul (8) konfiguriert ist, um den Motorstrom (37) am Eingang (8_M) des Moduls gemäß einer Effizienzoptimierungskurve eines transkritischen CO₂-Zyklus unter Druck zu steuern.
12. Kreislauf nach einem oder mehreren der Ansprüche 4-6, **dadurch gekennzeichnet, dass** er eine Einheit zum Steuern der Temperatur des zu kühlenden Fluids umfasst, das durch den Weg (40) strömt, wobei die Steuereinheit dazu konfiguriert ist, auf die Kapazität des Verdichters (1) und dann auf die Sättigungstemperatur des Kältemittels in dem Tank (4) einzuwirken, so dass die Temperatur des gekühlten Fluids, die stromabwärts des zweiten Verdampfers (30) erfasst wird, einer bestimmten Referenztemperatur folgt.
13. Kreislauf nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** er eine Einheit zum Steuern der Temperatur eines zu erwärmenden Fluids umfasst, das durch den Austauscher (2) strömt, wobei die Steuereinheit dazu konfiguriert ist, auf die Kapazität des Verdichters (1) und dann auf die Sättigungstemperatur des Kältemittels in dem Tank (4) einzuwirken, so dass die Temperatur (T_{out}) des Fluids am Auslass (29) des Austauschers (2) nach dem Strömen durch den Austauscher (2) durch Austauschen von Wärme mit dem Kältemittel, das von dem mindestens einen Verdichter (1) kommt, einer bestimmten Referenztemperatur folgt.

Revendications

1. Circuit de réfrigération (20), de préférence utilisable avec du CO₂ comme réfrigérant, comprenant :
- un réservoir (4) configuré pour recevoir et contenir le réfrigérant intérieur à l'état liquide (5) et à l'état de vapeur (7),
 - au moins un compresseur (1) communiquant avec ledit réservoir (4) pour aspirer le réfrigérant à l'état de vapeur (7),
 - un échangeur de chaleur à haute pression (2) placé en aval dudit au moins un compresseur (1) et relié fluidiquement à celui-ci,
 - au moins un module éjecteur (8) comprenant une entrée (8_M) pour un flux moteur (37), une entrée (8_T) pour un flux entraîné (38), et une sortie (8_{OUT}) pour éjecter dans ledit réservoir (4) le mélange (39) desdits deux flux, ladite entrée (8_M) pour le flux moteur (37) étant reliée fluidiquement à la sortie dudit échangeur de chaleur à haute pression (2),

- un premier évaporateur (24) qui est relié fluidiquement à l'entrée et à la sortie dudit réservoir (4), et
 - un second évaporateur (30) qui est relié fluidiquement à l'entrée avec ledit réservoir (4) et à la sortie avec ladite entrée (8_T) pour un flux entraîné dudit module éjecteur (8).
2. Circuit selon la revendication 1, **caractérisé en ce que** ledit premier évaporateur (24) est du type à alimentation par gravité et est alimenté par ledit réservoir (4) et est relié à la sortie avec ledit réservoir au moyen d'un circuit de recirculation (21).
3. Circuit selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit premier évaporateur (24) est placé à un niveau géodésique inférieur par rapport au réservoir (4).
4. Circuit selon une ou plusieurs des revendications précédentes, **caractérisé en ce qu'il** comprend un parcours (40) d'un fluide à refroidir qui traverse, en séquence, ledit premier évaporateur (24) et ledit second évaporateur (30).
5. Circuit selon la revendication 4, **caractérisé en ce que** ledit chemin (40) pour le fluide à refroidir, de préférence de l'eau, comprend en séquence d'abord une première partie (41), qui est prévue dans le premier évaporateur (24), et ensuite une seconde partie (42) qui est prévue dans le second évaporateur (30), ladite première partie (41) du premier évaporateur (24) et ladite seconde partie (42) du second évaporateur (30) étant reliées fluidiquement ensemble en série et étant conçues pour être traversées par le fluide à refroidir.
6. Circuit selon les revendications 4 ou 5, **caractérisé en ce que** ledit chemin (40) pour le fluide à refroidir, de préférence de l'air, comprend au moins un conduit (45) dans lequel ledit premier évaporateur (24) et ledit second évaporateur (30) sont logés en séquence.
7. Circuit selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** l'entrée dudit second évaporateur (30) est reliée fluidiquement audit réservoir (4) au moyen d'un détendeur (32) qui est configuré pour être commandé en fonction de la température et/ou de la pression d'un fluide de refroidissement sortant dudit second évaporateur (30).
8. Circuit selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit module éjecteur (8) comprend un seul éjecteur à géométrie variable.
9. Circuit selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit module éjecteur (8) comprend une pluralité d'éjecteurs parallèles, chacun d'eux étant associé à l'entrée à une soupape de commande correspondante.
10. Circuit selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit module éjecteur (8) est configuré pour réguler sous pression le flux moteur (37) à l'entrée (8_M) dudit module sur la base de valeurs de température et/ou de pression mesurées dans la section en aval dudit échangeur à haute pression (2) et en amont dudit module éjecteur (8).
11. Circuit selon une ou plusieurs des revendications précédentes, **caractérisé en ce que**, lorsque le CO₂ est utilisé comme réfrigérant, ledit module éjecteur (8) est configuré pour réguler sous pression le flux moteur (37) à l'entrée (8_M) dudit module selon une courbe d'optimisation de l'efficacité d'un cycle CO₂ transcritique.
12. Circuit selon une ou plusieurs des revendications 4 à 6, **caractérisé en ce qu'il** comprend une unité de commande de la température du fluide à refroidir qui passe par ledit chemin (40), ladite unité de commande est configurée pour agir sur la puissance dudit compresseur (1), puis sur la température de saturation du réfrigérant dans ledit réservoir (4), de sorte que la température du fluide refroidi détectée en aval dudit second évaporateur (30) suive une température de référence déterminée.
13. Circuit selon une ou plusieurs des revendications précédentes, **caractérisé en ce qu'il** comprend une unité de commande de la température d'un fluide à chauffer qui traverse ledit échangeur (2), ladite unité de commande est configurée pour agir sur la puissance dudit compresseur (1), puis sur la température de saturation du réfrigérant dans ledit réservoir (4), pour que la température (T_{out}) du fluide à la sortie (29) de l'échangeur (2), après avoir traversé ledit échangeur (2) en échangeant de la chaleur avec le réfrigérant provenant dudit au moins un compresseur (1), suive une température de référence déterminée.



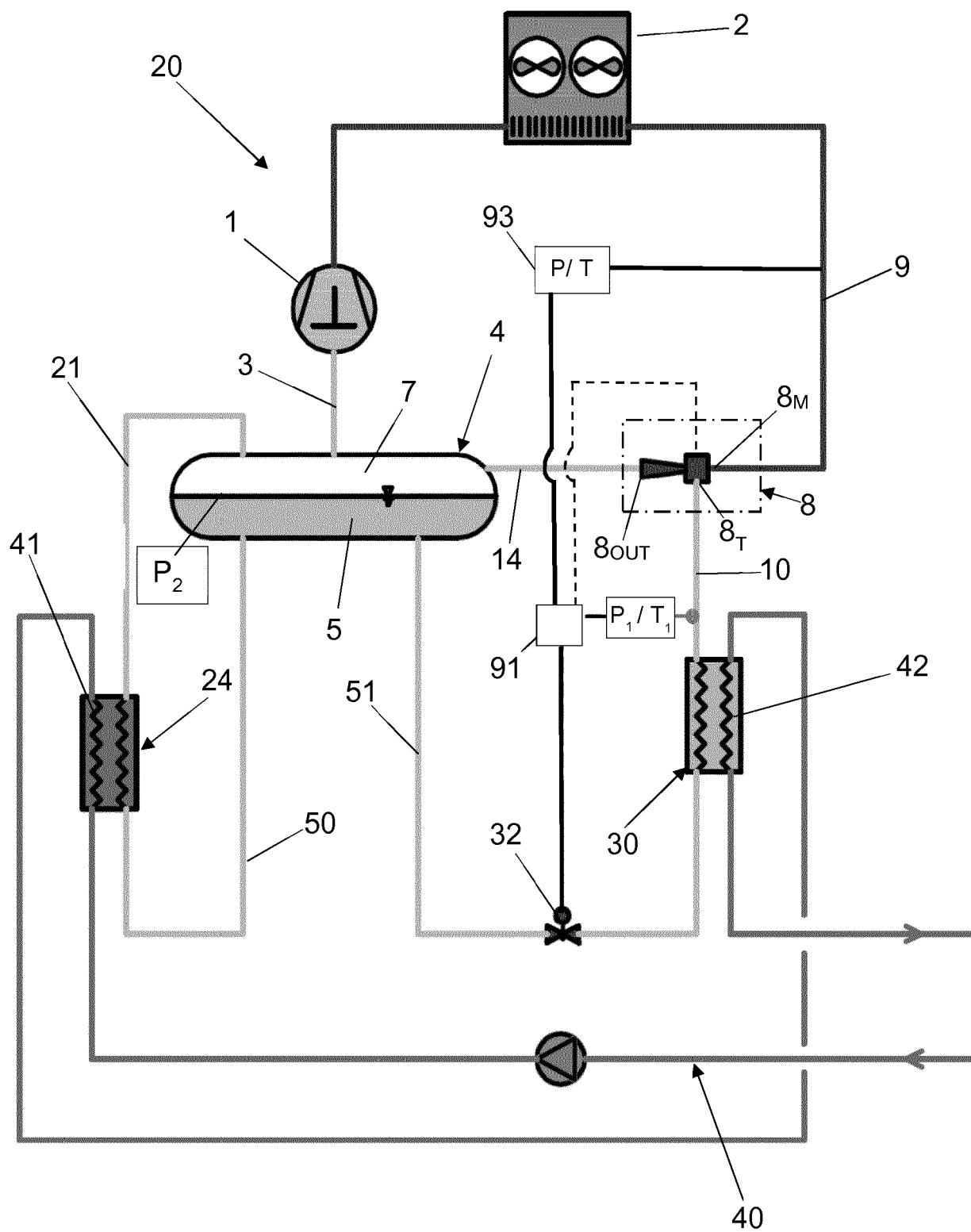
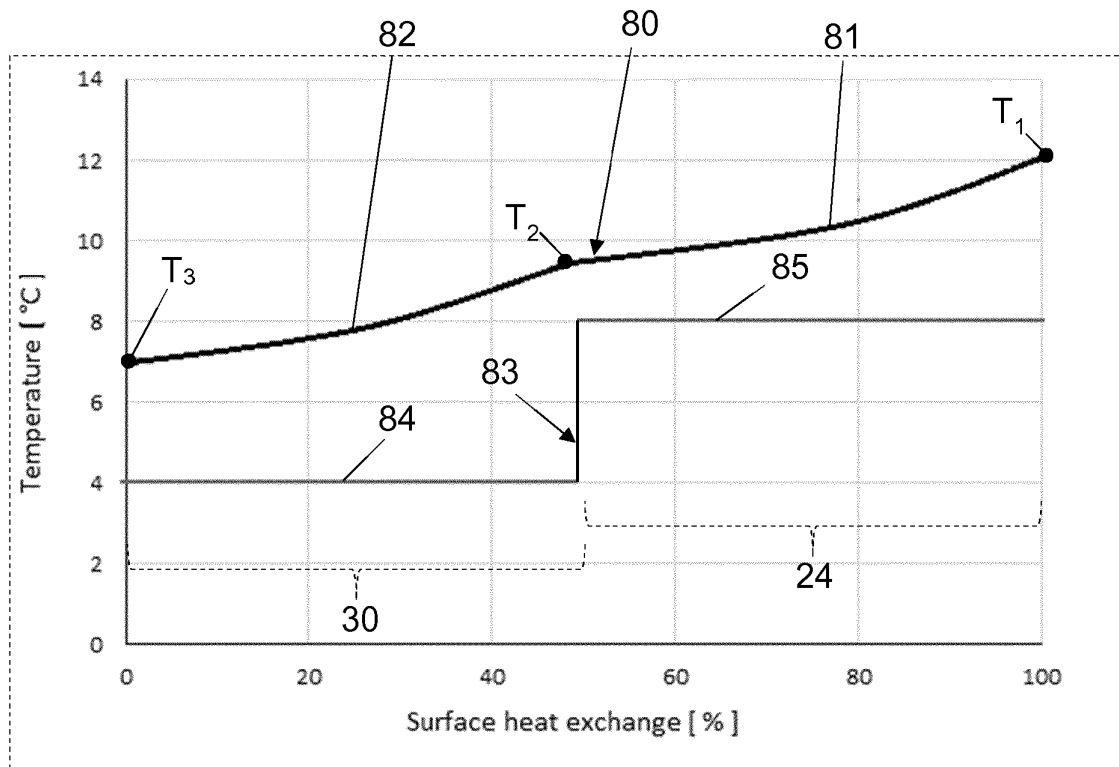
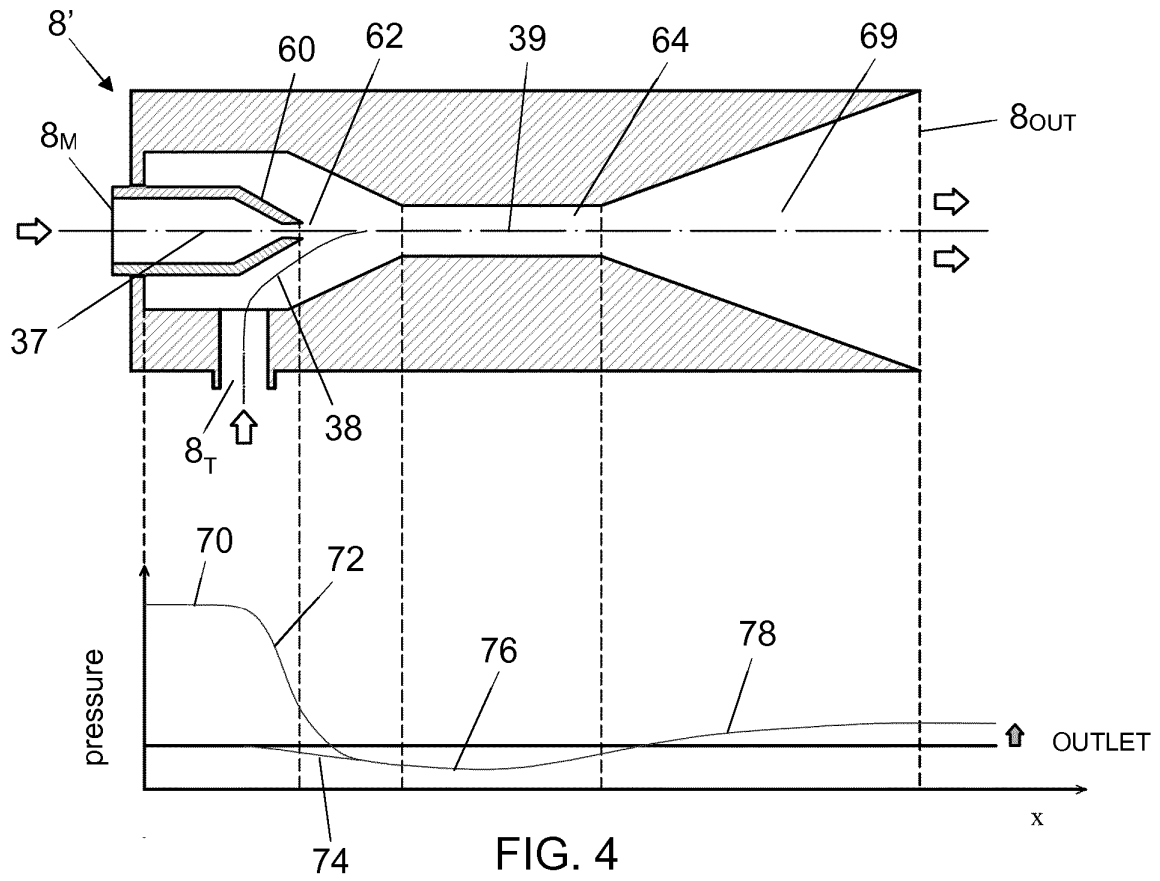


FIG. 3



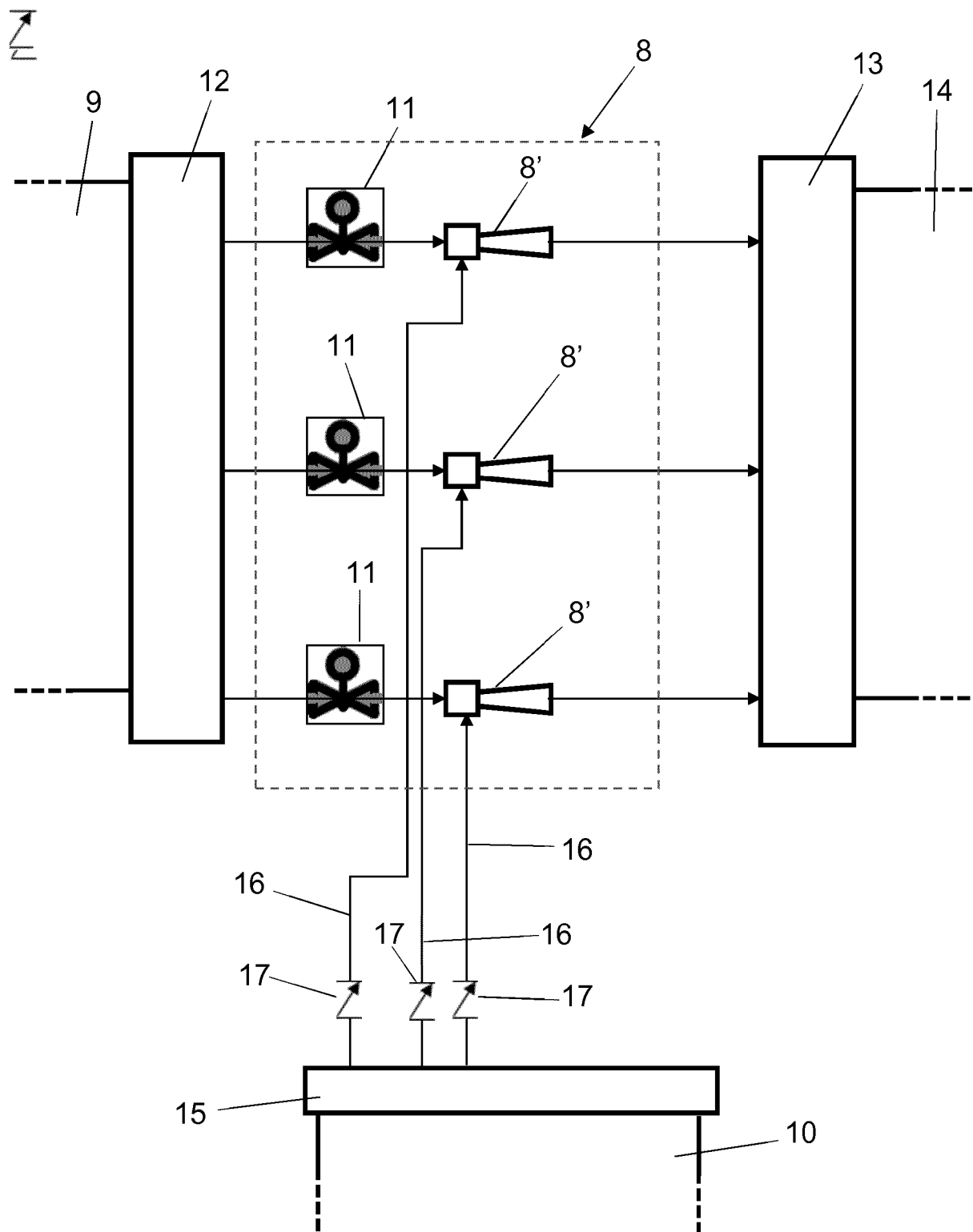


FIG. 6

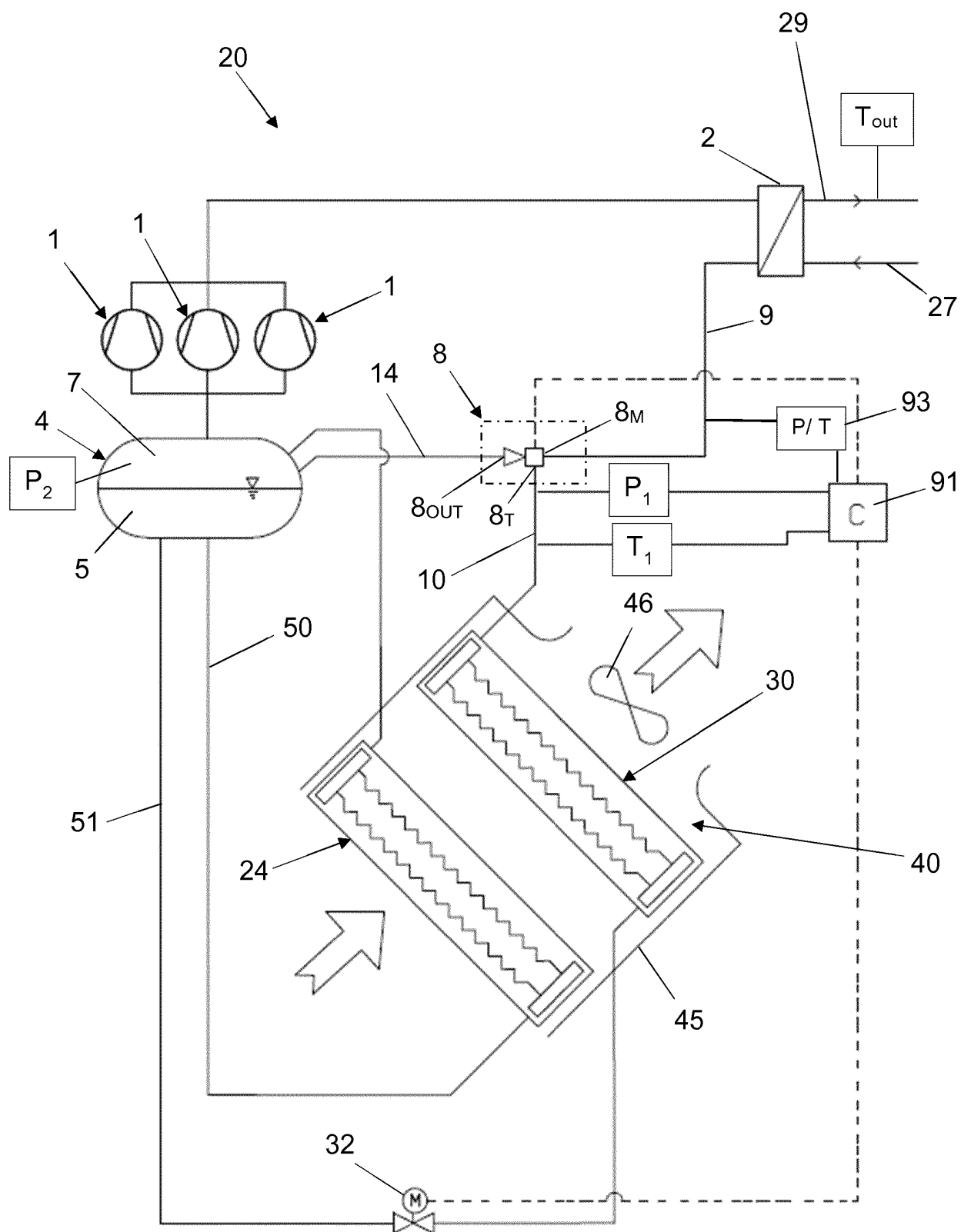


FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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