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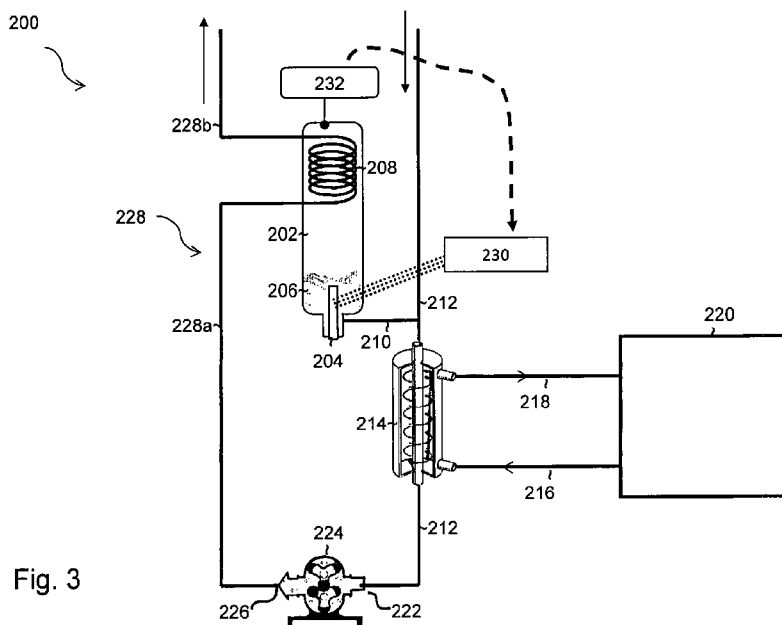


Fig. 3

(57) Abstract: In an integrated two-phase accumulator controlled loop cooling system, the pumped refrigerant is employed to cool the supply of refrigerant in the accumulator vessel. No external cooling of the accumulator vessel is required, and a standard heater in the accumulator is sufficient to regulate the boiling pressure. This allows to provide a cooling system in which sub-cooling in the pump is guaranteed by the laws of nature, and which is hence more reliable, structurally simpler, better to control and cheaper.

COMPACT COOLING SYSTEM AND METHOD FOR ACCURATE TEMPERATURE CONTROL

Field of the Present Invention

The present invention relates to a compact and structurally simple cooling system and cooling method, in particular to a two-phase cooling system and cooling method for evaporative CO₂ cooling with high temperature accuracy.

Background and Relevant State of the Art

Carbon dioxide (CO₂) cooling was widespread in the late 19th century and early 20th century before being replaced by synthetic refrigerants, but is now again gaining increasing attention for many applications in science and technology, ranging from fridges and air-conditioning, in particular for motor vehicles, to ice-skating rings and cooling of detector equipment for high energy physics experiments. A manifold range of applications, both old and new, is described by A. Pearson, "Carbon Dioxide – New Uses for an Old Refrigerant", International Journal of Refrigeration 28 (2005) 1140 -1148.

CO₂ cooling is attractive because it offers the combination of high heat transfer coefficients (one order of magnitude higher than traditional refrigerants) with low mass cooling structures. In addition, CO₂ has a relatively high evaporation pressure, so that the vapor volumes remain small, resulting in small diameter tubing. CO₂ also has a large latent heat of evaporation, which allows for a reduced fluid flow and even smaller tubing diameters. Since CO₂ cannot exist as a liquid under atmospheric pressure, any leak or spilling of CO₂ will lead to immediate vaporization of the leaked CO₂, and will not harm the equipment by a liquid spill. This is a clear advantage over conventional liquid refrigerants, and makes CO₂ a good choice for cooling sensitive objects or objects placed in sensitive environments, such as for the temperature control of scientific equipment inside clean laboratories.

In summary, CO₂ cooling allows for an accurate thermal control of distant setups with only small additional cooling hardware, which is a frequent desire in many high-tech applications today.

A conventional two-phase accumulator controlled loop (2PACL) evaporative CO₂ cooling system 100 as employed for the LHCb-VELO experiment at CERN and described in further detail in B. Verlaet *et al.*, "CO₂ Cooling for the LHCb-VELO Experiment at CERN", 8th IIF/IIR Gustav Lorentzen Conference on Natural Working Fluids 2008, Copenhagen, CDP 16-T3-08 is schematically shown in Fig. 1. This cooling system 100 comprises an accumulator vessel 102 for storing a supply of CO₂ in a liquid and vapor mixture. The CO₂ boiling pressure is controlled using a combination of heating and cooling, wherein heating is achieved by means of an electrical heater such as a thermo siphon heater 104, and cooling of the supply of CO₂ in the accumulator vessel 102 can be performed by employing an integrated cooling spiral 106 connected to an external chiller 108.

The external chiller 108 also serves to sub-cool the refrigerant in the condenser 110, which is in fluid communication both with the accumulator vessel 102 and a liquid pump 112. The chiller 108 remains always cooler than the accumulator 102 saturation temperature, and this is needed to provide subcooled liquid inside the pump 112. From the liquid pump 112, the sub-cooled refrigerant is supplied to a heat exchanger 114, where the liquid refrigerant is pre-heated to the saturation temperature by bringing it into thermal contact with a return pipe 116 comprising CO₂ in a mixed liquid/vapor phase returning from the object to be cooled. After having been pre-heated by means of the heat exchanger 114, liquid CO₂ 118 with a temperature that corresponds to the boiling temperature of the return pipe 116 is supplied to an evaporator (not shown) in thermal contact with the experiment to be cooled. The pressure drop towards the evaporator causes the supplied liquid to boil in the evaporator and realizes a direct temperature control of the attached experiment via the system pressure regulated in the accumulator 102. After thermal interaction with the object to be cooled, the refrigerant returns to the cooling system 100 via the return pipe 116, and is channeled through the heat exchanger 114 to the condenser 110, whereupon the cooling cycle begins anew.

The cooling cycle and operation of the conventional 2PACL system is further illustrated in the pressure-enthalpy phase diagram of Fig. 2. The sub-cooled liquid (1) is pumped into the system by means of the liquid pump 112 (1-2). The internal heat exchanger (2-3) 114 heats up the pumped sub-cooled liquid to the saturation temperature of the evaporator, causing the inlet of the evaporator always to be saturated after liquid injecting (point 4 within the two-phase zone of the pressure-enthalpy diagram). Point 4 after expansion 3-4 in the phase diagram of Fig. 2 designates the moment when the fluid starts boiling due to the initial temperature set-

ting of the liquid temperature in point 3. The fluid state in the evaporator is two-phase, and nearly independent of the absorbed heat. The independence of the heat absorption is ideal for scientific experiments as a temperature control under loaded and unloaded conditions is often demanded. The pressure drop between the evaporator (4-5) and the accumulator connection (1) is low, and hence the accumulator 102 directly controls the pressure and hence temperature of the evaporator.

The conventional CO₂ evaporative cooling system as described with reference to Figs. 1 and 2 allows for an accurate (isothermal) and direct temperature control of even distant objects to be cooled, and does not require any active components near the object. Tubes of very small diameter are sufficient to provide the refrigerant to the evaporator, possibly over very long transfer lines, while all the active hardware may be placed in a distant cooling plant which can be made easy accessible. This is particularly advantageous for high energy physics experiments, in which the cooling plant is in general far away from the detector device to be cooled, and local control or monitoring of the cooling at the detector device is usually unfeasible due to the high levels of radiation encountered there.

However, a reliable operation of the conventional system shown in Fig. 1 requires that the refrigerant supplied to the liquid pump 112 is carefully kept sub-cooled in order to avoid any cavitation that could interfere with the pumping. The system hence requires a careful control of the temperature and pressure in the accumulator vessel 102 and the inlet pipe of the pump 112. In the configuration shown in Fig. 1, this can be achieved by means of a programmable logic control unit 120 which governs the operation of both the electric heater 104 and the cooling spiral 106 in response to the user-required evaporator temperature or temperature at the inlet of the liquid pump 112 in case sub cooling is insufficient (measured by means of a temperature gauge 122) and the pressure in the accumulator vessel 102 (measured by means of a pressure gauge 124). Since proper operation of the cooling system 100 crucially depends on a careful and delicate control of the pressure and temperature, the system is rather complex and expensive. Moreover, a complex external chiller 108 is needed both for cooling of the accumulator vessel 102 and for cooling of the condenser 110, sometimes causing both cooling actions to interfere with each other. Together with the associated piping, the chiller 108 adds to the complexity and size of the system.

As a result, conventional CO₂ evaporative cooling systems to date are bigger, more complex and more expensive than competing systems relying on thermostatic baths, such as cooling systems employing liquid water, glycol or silicone oil. This may be why, in spite of their superior performance, evaporative CO₂ cooling systems have so far been limited to specific applications and have not yet realized their full potential.

What is needed, therefore, is an evaporative cooling system that is compact, structurally simple and does not require any sophisticated control.

Overview of the Present Invention

These objectives are achieved with a cooling system and cooling method according to independent claims 1 and 14, respectively. The dependent claims relate to preferred embodiments.

A cooling system according to the present invention comprises a liquid pump having an inlet and an outlet, said liquid pump adapted for pumping a liquid refrigerant, an outlet fluid path for said refrigerant, said outlet fluid path connected to said outlet of said liquid pump, and an inlet fluid path for said refrigerant, said inlet fluid path connected to said inlet of said liquid pump, as well as an accumulator adapted for storing a supply of said refrigerant, said accumulator in fluid communication with said inlet fluid path. The system further comprises a condenser adapted for cooling said refrigerant, said condenser arranged in said inlet fluid path between said accumulator and said inlet of said fluid pump, wherein said outlet fluid path is in thermal contact with said accumulator so to allow said refrigerant flowing through said outlet fluid path to exchange heat with said accumulator.

It is the insight of the inventor that a more compact cooling system that is easier to control can be achieved by dispensing with a separate external heat exchanger (as described with reference to Fig. 1), and instead providing an outlet fluid path from the liquid pump in thermal contact with said accumulator, in particular with said supply of refrigerant stored in said accumulator. Refrigerant flowing through said outlet fluid path may then exchange heat with said accumulator, in particular to cool said supply of refrigerant stored in said accumulator and/or to heat up said refrigerant in said outlet fluid path.

In the configuration according to the present invention, the accumulator may hence be cooled by the discharge liquid of the pump, which is always warmer than the saturation temperature of the refrigerant at the pump inlet. This provides a self-regulation that prevents the accumulator from becoming cooler than the saturation temperature of the pump inlet, and hence automatically preserves the sub-cooling level needed to guarantee uninterrupted operation of the liquid pump, without requiring external sub-cooling control by means of a programmable logic control unit.

At the same time, the thermal contact of the outlet fluid path with the accumulator allows to set the temperature of the outgoing refrigerant to the accumulator temperature. This ensures that the refrigerant is set to boiling temperature for delivery to the object to be cooled.

In a cooling system according to the present invention, the accumulator in thermal contact with the outlet fluid path integrates the functionalities of a standard accumulator and an external heat exchanger of a conventional 2PACL cooling system. The cooling system according to the present invention thus allows dispensing both with a separate heat exchanger and a complex PLC controller, and is hence structurally simpler, smaller and easier to build.

According to a preferred embodiment, the outlet fluid path traverses said accumulator or contacts said accumulator.

Preferably, the cooling system comprises a heat exchanger adapted for exchanging heat with said accumulator, said heat exchanger arranged in said outlet fluid path.

Preferably, said heat exchanger comprises a cooling spiral in fluid communication with said outlet fluid path, said cooling spiral arranged in said accumulator.

These provisions allow for an efficient heat exchange between the supply of refrigerant stored in said accumulator and said outlet fluid path.

In a preferred embodiment, the cooling system further comprises a chiller or external cold source thermally connected to said condenser, so to cool said refrigerant in said inlet fluid path.

Preferably, said chiller or external cold source is not thermally connected to said accumulator.

In a preferred embodiment, said system is adapted to cool said supply of refrigerant stored in said accumulator exclusively through thermal contact of the refrigerant vapor with said outlet
5 fluid path. Preferably, said accumulator is not connected to an external cooling source.

It is the insight of the inventor that the system according to the present invention allows cooling the supply of refrigerant in said accumulator efficiently merely by way of heat exchange with said outlet fluid path and refrigerant vapor. The accumulator does not need to be connected to an external chiller or cooling source, which reduces the complexity and size of the
10 overall cooling system.

The accumulator may merely comprise a heating unit for regulating the boiling pressure of the refrigerant by boiling the liquid content in the accumulator. The heating unit may comprise a
15 thermo siphon heater for an efficient contact to the liquid phase. Without a heating unit, the boiling pressure would only be regulated by the outlet fluid path temperature and hence the external chiller temperature. By providing a heating unit, the boiling pressure in the accumulator may be controlled with a better accuracy.

According to this latter embodiment, the accumulator comprises a heating unit adapted for heating said supply of refrigerant to a predetermined pressure or temperature, in particular to a
20 predetermined boiling temperature or saturation temperature by evaporating the liquid content.

Said accumulator may be adapted to adjust a temperature of said refrigerant in said outlet fluid path to a predetermined temperature, in particular to raise the temperature of said refrigerant to said predetermined temperature, in particular to a boiling temperature of said refrigerant, by way of said thermal contact of said accumulator with said outlet fluid path.
25

Said outlet fluid path may be adapted to supply said refrigerant to an object to be cooled after exchanging heat with said accumulator.
30

Said inlet fluid path may be adapted to receive said refrigerant from said object after cooling said object.

The cooling system according to the present invention may be an evaporative cooling system, in particular a two-phase evaporative cooling system. Preferably, said refrigerant is or comprises CO₂, but other refrigerants may be employed as well.

5

In a preferred embodiment, said system further comprises a control unit adapted to control said heating unit and/or said liquid pump, preferably in response to a temperature and/or a pressure measured in said inlet fluid path and/or in said accumulator.

10

The present invention likewise relates to a method for cooling an object, comprising the steps of providing a supply of a refrigerant in an accumulator at a predetermined temperature and/or at a predetermined pressure, providing or supplying at least part of said refrigerant to a condenser for sub-cooling said refrigerant, providing or supplying said sub-cooled refrigerant to a liquid pump, and establishing a thermal contact of said pumped refrigerant with said accumulator to allow said pumped refrigerant to exchange heat with said supply of refrigerant in said accumulator, as well as subsequently providing or supplying said pumped refrigerant to said object to be cooled.

15

In a preferred embodiment, the method comprises a step of regulating a boiling pressure of said refrigerant by adjusting a pressure and/or a temperature of said supply of refrigerant in said accumulator.

20

Preferably, the method comprises a step of adjusting a pressure and/or a temperature of said supply of refrigerant in said accumulator by heating said supply by means of a heating unit.

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In a preferred embodiment, the method comprises a step of adjusting a pressure and/or a temperature of said supply of refrigerant in said accumulator by cooling said supply with said pumped refrigerant.

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Preferably, said supply of refrigerant in said accumulator is cooled exclusively with said pumped refrigerant.

In a preferred embodiment, the method comprises a step of channeling said pumped refrigerant through said accumulator.

In a preferred embodiment, the method comprises a step of adjusting a temperature of said pumped refrigerant to a predetermined temperature, in particular to a boiling temperature of said refrigerant, by means of said thermal contact with said supply of refrigerant in said accumulator. In particular, the method comprises the step of raising said temperature of said pumped refrigerant to said predetermined temperature.

According to a preferred embodiment, the method comprises the step of receiving said refrigerant from said object to be cooled, and providing or supplying said received refrigerant to said condenser.

The method according to any of these embodiments may employ a cooling system with some or all of the features as described above.

The invention further relates to a data storage device adapted to store computer-readable instructions, such that said computer-readable instructions, when read on a computer connected to a cooling system with some or all of the features as described above, implement on said cooling system a method with some or all of the features as described above.

Description of Preferred Embodiments

The features and numerous advantages of the present invention will be best understood from a detailed description of the preferred embodiments in conjunction with the accompanying figures, in which:

Fig. 1 schematically shows a conventional two-phase accumulator controlled loop cooling system;

Fig. 2 shows a pressure-enthalpy phase diagram illustrating the cooling cycle in a conventional two-phase accumulator controlled loop cooling system as shown in Fig. 1; and

Fig 3 schematically shows an integrated two-phase accumulator controlled loop cooling system according to an embodiment of the present invention.

The invention will now be described for the specific example of a two-phase evaporative CO₂ cooling system that improves on, but is otherwise similar in design and functionality to the conventional 2PACL CO₂ cooling system described above with reference to Figs. 1 and 2.

The integrated 2PACL cooling system 200 shown in Fig. 3 comprises an accumulator vessel 202 that is similar in design to the accumulator vessel 102 described above with reference to Fig. 1. In particular, the accumulator vessels 202 comprises an electrical heater 204, such as a thermo siphon heater, for heating and hence evaporating a supply of refrigerant 206 stored in the accumulator vessel 202, as well as a cooling spiral 208 for cooling and hence condensing said supply of refrigerant 206.

The accumulator vessel 202 is connected, via a branch line 210, to an inlet fluid pipe or inlet fluid tube 212 in which a condenser 214 is provided. In the context of the present invention, the terms "pipe" and "tube" may be used interchangeably. The condenser 214 shown in Fig. 3 is generally identical or similar to the condenser 110 described previously with reference to the 2PACL cooling system of Fig. 1 and may be any condenser as conventionally employed in cooling systems.

The condenser 214 is connected, via an input line 216 and an output line 218, to an external chiller 220. The external chiller 220 may be any conventional chiller as employed in cooling systems or any other cold source, and in general may be similar to the external chiller 108 described with reference to the conventional 2PACL system of Fig. 1. However, in contrast to the configuration of Fig. 1, the external chiller 220 is merely connected to the condenser 214, and does not also serve to cool the accumulator vessel 202. Compared to the external chiller 108, the external chiller 220 according to the present invention may hence be smaller, and the amount of piping may also be reduced. No interference between the multiple cooling connections is present anymore.

The condenser 214 serves to sub-cool the CO₂ supplied to the condenser 214 from the accumulator vessel 202 via the branch line 210 and inlet fluid pipe 212. Sub-cooled CO₂ leaves the condenser 214 and is supplied, still via the inlet fluid pipe 212, to an inlet 222 of a liquid pump 224. The liquid pump 224 may be similar to the liquid pump 112 described with reference to Fig. 1, and can in general be any pump suitable for pumping liquid CO₂ (or other fluids if used instead of CO₂ in the invention). An outlet 226 of the liquid pump 224 is connected to an outlet fluid pipe 228, which supplies the pumped CO₂ to an object to be cooled (not shown).

On its way to the object to be cooled, the pumped CO₂ traverses the cooling spiral 208 provided in the accumulator vessel 202, and hence exchanges heat with the supply of refrigerant 206 stored in said accumulator vessel 202. The outlet fluid path can hence be subdivided into two sections, a first section 228a connecting the outlet 226 of the liquid pump 224 to an inlet of the cooling spiral 208, and a second section 228b downstream from an outlet of the cooling spiral 208. In operation, the accumulator vessel 202 will in general be filled with saturated liquid and vapor, and hence the pumped CO₂ in the outlet fluid pipe 228 will have been heated up to the accumulator temperature once it reaches the outlet of the accumulator cooling spiral 208. At this stage, the fluid is still supplied via the outlet fluid pipe 228 and is not yet boiling, although its temperature now coincides with the temperature of the boiling fluid in the accumulator vessel 202, or nearly so. This is due to the higher pressure in the outlet fluid pipe 228. The liquid CO₂ at boiling temperature is then supplied to an evaporator (not shown) in thermal contact with the object to be cooled. Once the liquid CO₂ at boiling temperature reaches the evaporator, the pressure is lowered and the fluid starts boiling, thereby cooling the object.

The integrated 2PACL according to the present invention is nearly isotherm during boiling from the evaporator to the inlet of the liquid pump. Only the pressure drop in this part of the system causes a small temperature gradient, much smaller than in systems using a liquid cooling flow. In the latter systems, the liquid flow is difficult to control as it is subject to heating during transfer. Local sensor control may be employed, but will usually lead to the system having a low response time. In contrast, the system according to the present invention controls the distant temperature by controlling the pressure, which is transmitted with the speed of sound, and hence almost without any delay.

CO₂ in a mixed liquid/vapor phase returns from the object to be cooled and is channeled through the inlet fluid pipe 212 to the condenser 214 for subsequent cooling, and hence the cooling cycle is closed.

In particular, when illustrated in a pressure-enthalpy phase diagram, the cooling cycle of the integrated two-phase accumulator controlled loop cooling system according to the embodiment of Fig. 3 is generally identical to the cooling cycle of a conventional 2PACL cooling system, and hence reference may be made to the phase diagram of Fig. 2.

The functionality of the cooling system according to the embodiment of Fig. 3 is in general very similar to the conventional 2PACL cooling system known from the art.

However, in the invention, the cooling of the supply of refrigerant 206 stored in said accumulator vessel 202 is achieved exclusively by means of thermal contact with the pumped refrigerant via the cooling spiral 208, and no external cooling of the accumulator vessel 202 is required. In operation, the CO₂ boiling pressure in the accumulator vessel 202 is controlled solely by means of heating via the electrical heater 204. A control unit 230 controls operation of the electrical heater 204 in response to a pressure in the accumulator vessel 202 detected by means of a pressure gauge 232. Since the control unit 230 is needed solely for controlling the electrical heater 204, it does not require a complex programmable logic control such as the control unit 120 described with reference to Fig. 1.

Cooling the supply of refrigerant 206 in the accumulator vessel 202 by means of the discharge liquid of the pump 224 has the additional advantage that the accumulator temperature cannot fall below the temperature of the discharge liquid of the pump, which is higher than the saturation temperature at the pump inlet 222. In this way, the sub-cooling of the pump is guaranteed by the laws of nature, and the risk of evaporation of the refrigerant in the liquid pump 224 is avoided without any additional sub-cooling control, which conventionally also had to be provided by the programmable logic control unit 120.

The invention hence results in a two-phase evaporative CO₂ cooling system that is structurally simpler, more reliable, better to control and cheaper to build, but without compromising on the functionality of a conventional 2PACL system. The integrated 2PACL cooling system according to the present invention is similar in complexity and price to conventional cooling systems employing thermostatic baths, but has the additional advantage of accurate (isothermal) and direct temperature control on distant experiments in combination with very small cooling tubes.

The description of the preferred embodiments and the figures merely serve to illustrate the invention and the beneficial effects associated therewith, but should not be understood to imply any limitation. The scope of the invention is to be determined solely based on the appended set of claims.

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Reference Signs

10	100	2PACL cooling system
	102	accumulator vessel
	104	electrical heater
	106	cooling spiral
	108	external chiller or cold source
15	110	condenser
	112	liquid pump
	114	heat exchanger
	116	return pipe
	118	liquid CO ₂ with the same temperature as the boiling temperature in the accu-
20		mulator
	120	programmable logic control unit
	122	temperature gauge
	124	pressure gauge
	200	integrated 2PACL cooling system
25	202	accumulator vessel
	204	electrical heater
	206	supply of refrigerant
	208	cooling spiral
	210	branch line
30	212	inlet fluid pipe
	214	condenser
	216	input line of condenser 214
	218	output line of condenser 214
	220	external chiller or cold source
35	222	inlet of liquid pump 224
	224	liquid pump

	226	outlet of liquid pump 224
	228	outlet fluid pipe
	228a	first section of outlet fluid pipe 228
	228b	second section of outlet fluid pipe 228
s	230	control unit
	232	pressure gauge

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Claims

- 10 1. A cooling system (200) comprising:
a liquid pump (224) having an inlet (222) and an outlet (226), said liquid pump (224)
adapted for pumping a liquid refrigerant;
an inlet fluid path (212) for said refrigerant, said inlet fluid path (212) connected to said
inlet of said liquid pump (224);
15 an accumulator (202) adapted for storing a supply (206) of said refrigerant, said accu-
mulator (202) being in fluid communication with said inlet fluid path (212);
a condenser (214) adapted for cooling said refrigerant, said condenser (214) arranged in
said inlet fluid path (212) between said accumulator (202) and said inlet (222) of said
liquid pump (224); and
20 an outlet fluid path (228) for said refrigerant, said outlet fluid path (228) connected to
said outlet (226) of said liquid pump (224);
wherein said outlet fluid path (228) is in thermal contact with said accumulator (202) so
to allow said refrigerant flowing through said outlet fluid path (228) to exchange heat
with said accumulator (202).
25
2. The cooling system (200) according to claim 1, wherein said outlet fluid path (228)
traverses said accumulator (202) or contacts said accumulator (202).
3. The cooling system (200) according to claim 1 or 2, further comprising a heat ex-
30 changer (208) adapted for exchanging heat with said accumulator (202), said heat ex-
changer (208) arranged in said outlet fluid path (228).
4. The cooling system (200) according to claim 3, wherein said heat exchanger comprises
a cooling spiral (208) in fluid communication with said outlet fluid path (228), said
35 cooling spiral (208) arranged in said accumulator (202).

5. The cooling system (200) according to any of the preceding claims, further comprising a chiller or an external cold source (220) connected to said condenser (214).
6. The cooling system (200) according to claim 5, wherein said chiller or external cold source (220) is not thermally connected to said accumulator (202).
7. The cooling system (200) according to any of the preceding claims, wherein said system (200) is adapted to cool said supply (206) of refrigerant stored in said accumulator (202) exclusively through thermal contact with said outlet fluid path (228), and said accumulator (202) is not thermally connected to an external cooling source.
8. The cooling system (200) according to any of the preceding claims, wherein said accumulator (202) comprises a heating unit (204) adapted for heating said supply (206) of refrigerant to a predetermined pressure or temperature, in particular to a predetermined boiling temperature.
9. The cooling system (200) according to any of the preceding claims, wherein said accumulator (202) is adapted to adjust a temperature of said refrigerant in said outlet fluid path (228) to a predetermined temperature, in particular to a boiling temperature of said refrigerant in the said accumulator, by means of said thermal contact of said accumulator (202) with said outlet fluid path (228).
10. The cooling system (200) according to any of the preceding claims, wherein said outlet fluid path (228) is adapted to supply said refrigerant to an object to be cooled after exchanging heat with said accumulator (202).
11. The cooling system (200) according to claim 10, wherein said inlet fluid path (212) is adapted to receive said refrigerant from said object after cooling said object.
12. The cooling system (200) according to any of the preceding claims, wherein said cooling system (200) is a two-phase cooling system and said refrigerant comprises CO₂.
13. The cooling system (200) according to any of the preceding claims, further comprising a control unit (230) adapted to control said heating unit (204) preferably in response to a

temperature and/or a pressure measured in said inlet fluid path (212) and/or in said accumulator (202).

14. A method for cooling an object, comprising the steps of:

5 providing a supply (206) of a refrigerant in an accumulator (202) at a predetermined temperature and/or at a predetermined pressure;

supplying at least part of said refrigerant to a condenser (214) for sub-cooling said refrigerant;

supplying said sub-cooled refrigerant to a liquid pump (224); and

10 establishing a thermal contact of said pumped refrigerant with said accumulator (202) to allow said pumped refrigerant to exchange heat with said supply (206) of refrigerant in said accumulator (202); and

subsequently supplying said pumped refrigerant to said object to be cooled.

15 15. The method according to claim 14, further comprising a step of regulating a boiling pressure of said refrigerant by adjusting a pressure and/or temperature of said supply (206) of refrigerant in said accumulator (202).

20 16. The method according to claim 14 or 15, further comprising a step of adjusting a pressure and/or temperature of said supply (206) of refrigerant in said accumulator (202) by heating said supply (206) by means of a heating unit (204).

25 17. The method according to any of the claims 14 to 16, further comprising a step of adjusting a pressure and/or temperature of said supply (206) of refrigerant in said accumulator (202) by cooling said supply (206) with said pumped refrigerant.

18. The method according to claim 17, wherein said supply (206) of refrigerant in said accumulator (202) is cooled exclusively with said pumped refrigerant.

30 19. The method according to any of the claims 14 to 18, further comprising a step of channelling said pumped refrigerant through said accumulator (202).

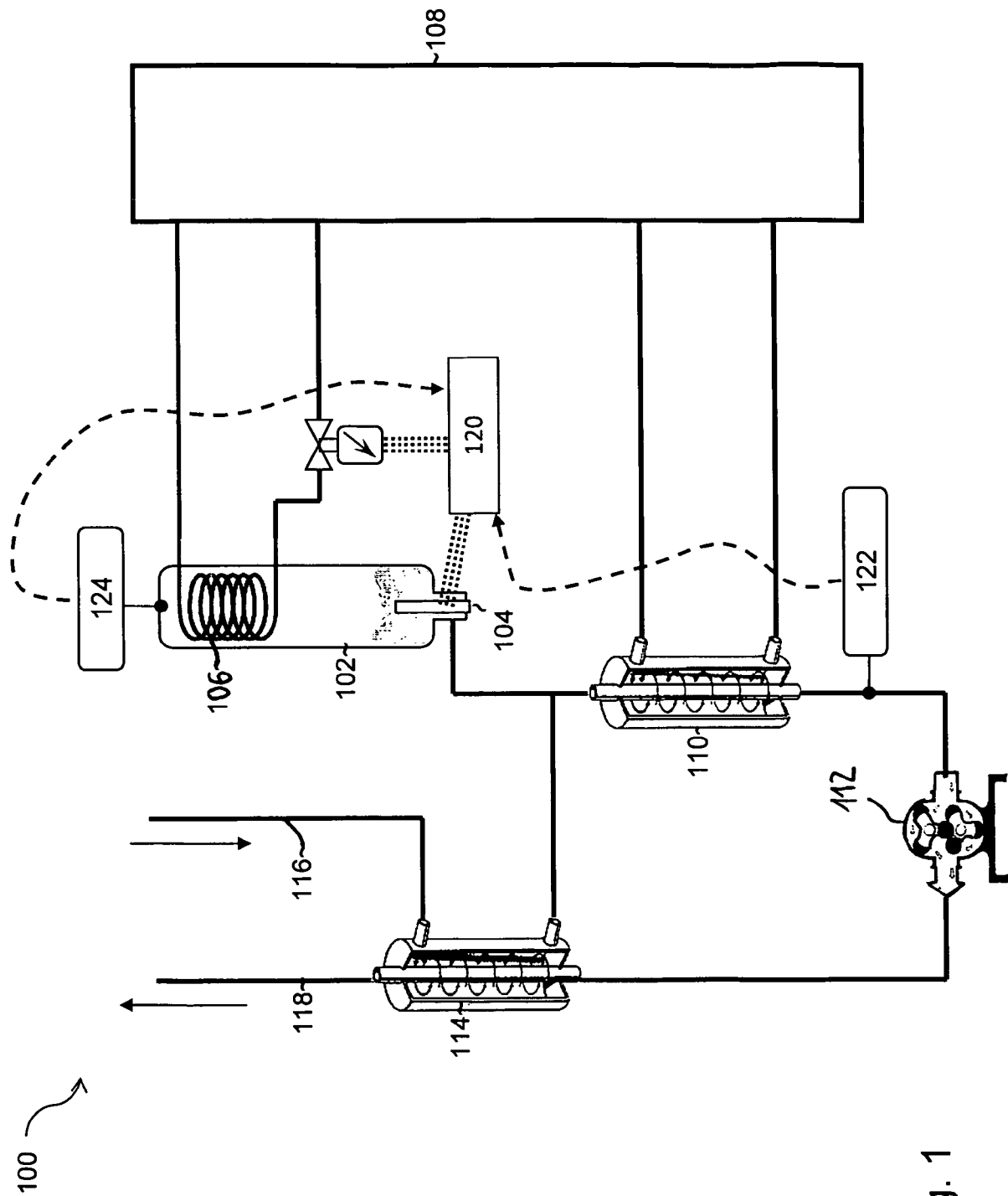
20. The method according to any of the claims 14 to 19, further comprising a step of adjusting a temperature of said pumped refrigerant to a predetermined temperature, in particu-

lar to a boiling temperature of said refrigerant in said accumulator (202), by means of said thermal contact with said supply (206) of refrigerant in said accumulator (202).

21. The method according to any of the claims 14 to 20, further comprising a step of receiving said refrigerant from said object to be cooled, and supplying said received refrigerant to said condenser (214).

22. The method according to any of the claims 14 to 21, employing a cooling system (200) according to any of the claims 1 to 13.

23. A data storage device adapted to store computer-readable instructions, such that said computer-readable instructions, when read on a computer connected to a cooling system (200) according to any of the claims 1 to 13, implement on said cooling system (200) a method according to any of the claims 14 to 22.



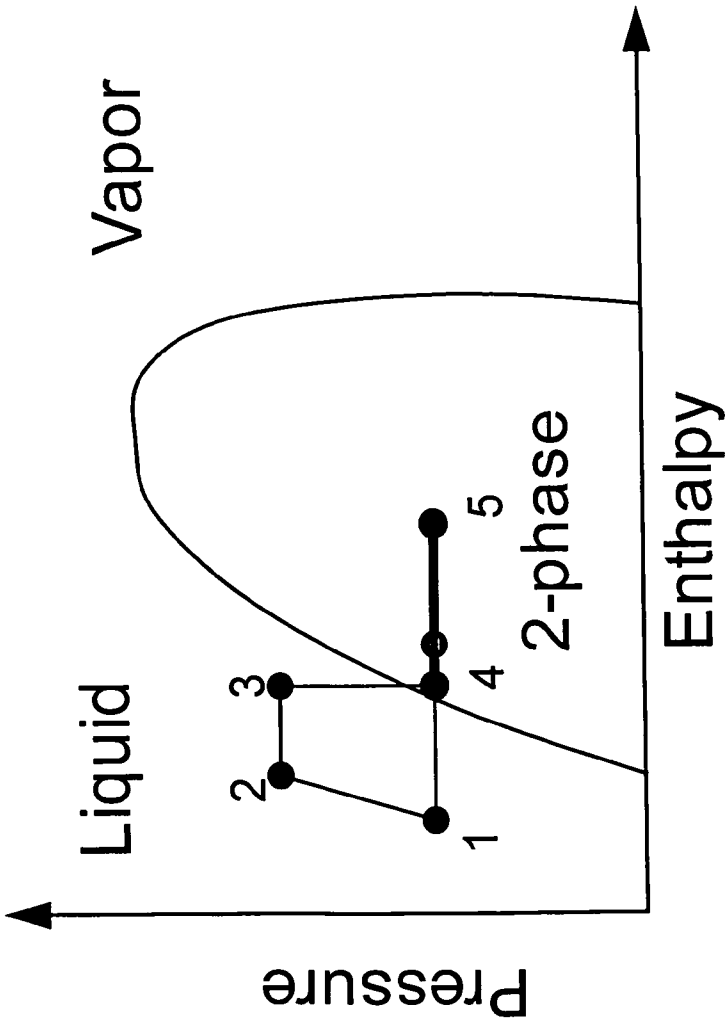


Fig. 2

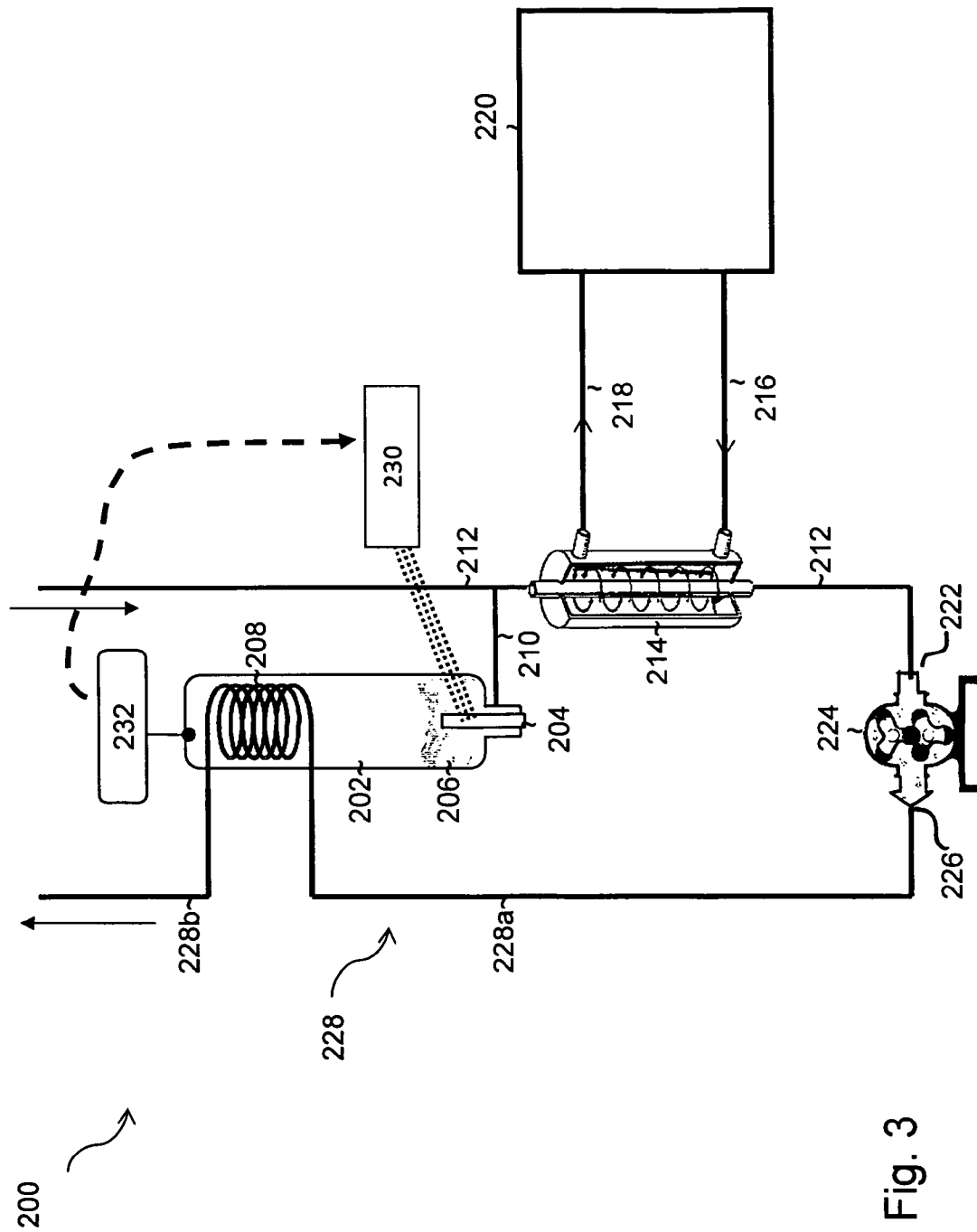


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2011/004557

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F25B23/00
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 866 092 B1 (MOLIVADAS STEPHEN [US]) 15 March 2005 (2005-03-15) column 3, line 57 - column 180, line 35; figures 1-117 column 45, line 52 - column 46, line 15; figure 4 column 161, line 23 - column 162, line 48; figure 102 -----	1-3,5-7, 9-11,14, 15,17-23
Y	US 2005/120737 A1 (BORROR STEVEN A [US] ET AL) 9 June 2005 (2005-06-09) paragraph [0015] - paragraph [0027]; figures 1-4 -----	1,14
Y	US 6 681 597 B1 (YIN JIAN-MIN [US] ET AL) 27 January 2004 (2004-01-27) column 4, line 3 - column 6, line 24; figures 1-7 -----	1,14



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

9 May 2012

Date of mailing of the international search report

16/05/2012

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2011/004557

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