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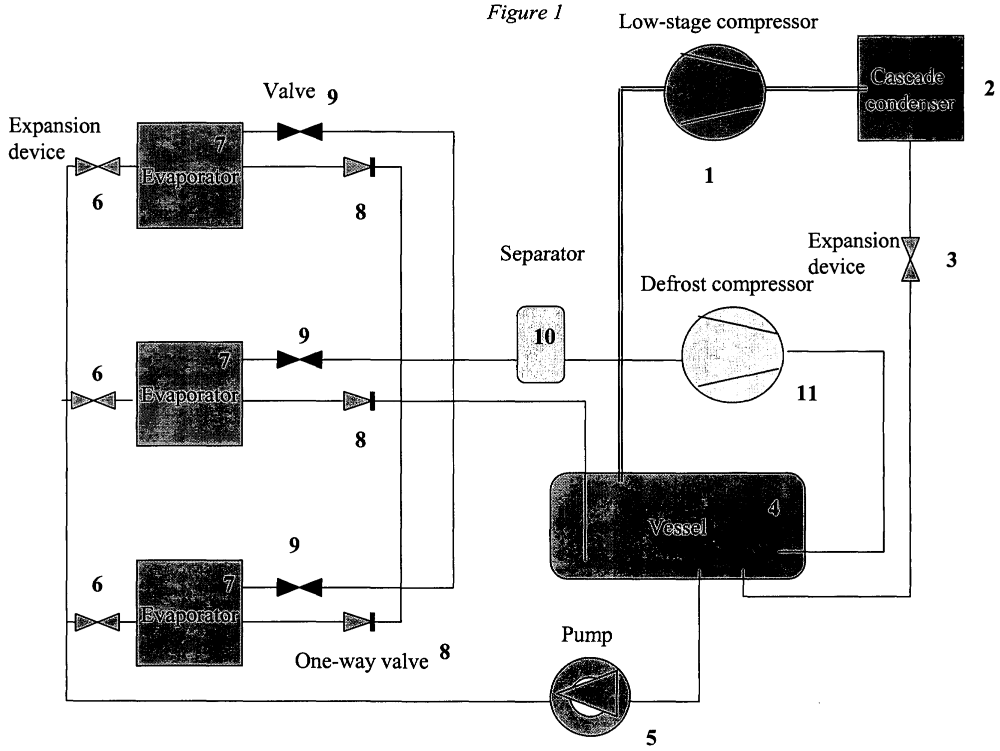
# (54) A method and a cooling system in which a refrigerant is used as a cooling agent and/or as a defrosting agent

(57) The invention provides a method in which a refrigerant is used as a cooling agent and/or as a defrosting agent, wherein the cooling of a medium is established by passing the refrigerant at a high pressure through a primary side of a cooler, whereby the medium to be cooled is passed through a secondary side of the cooler, and wherein the defrosting of the cooler is established by decreasing the gas pressure of the refrigerant in the primary side of the cooler to such an extent that ice which is adhered to the secondary side of the cooler is released. The invention further comprises a cooling system for carrying out said method.

*Figure 1*



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## Description

**[0001]** The present invention relates to a method in which a refrigerant is used as a cooling agent and/or a defrosting agent, and a cooling system for carrying out said method.

**[0002]** Coolers that are industrially applied are defrosted periodically to remove ice from the cooler, which ice is formed inside the coolers as a result of moisture present in the air to be cooled. Such periodical defrosting is needed to ensure that the coolers continue to perform at an appropriate level.

**[0003]** A variety of defrosting methods are known in the art. It is, for instance, known that coolers, in which $NH_3$ is used as the cooling agent, can be defrosted by leading hot $NH_3$ gas from the compressor into the cooler to be defrosted. However, such a defrosting method is relatively time-consuming making its application less attractive.

**[0004]** Another way to defrost a cooler is to provide the cooler with a separate circuit through which heated glycol can be recirculated. It will be understood that such a method is expensive since it requires a separate circuit to be arranged in the cooler.

**[0005]** It is further possible to defrost coolers electrically by using electric elements arranged on the secondary side of a cooler through which the air passes. Such system has the drawback that much energy is required to bring about an effective removal of ice, whereas in addition hot spots may be created which could weaken the cooler.

**[0006]** Yet another alternative approach is based on sprinkling the cooler with hot water or glycol. However, this approach has the disadvantage that products may be damaged by way of pollution or ice adherence.

**[0007]** Object of the present invention is to provide a method in which in an effective and relatively simple manner a refrigerant can be used as a cooling agent and/or defrosting agent.

**[0008]** Surprisingly, it has been found that this object can be realised by passing the refrigerant during cooling at a high pressure through the cooler and reducing the pressure of the refrigerant during defrosting of the cooler.

**[0009]** Accordingly, the present invention relates to a method in which a refrigerant is used as a cooling agent and/or as a defrosting agent, wherein the cooling of a medium is established by passing the refrigerant at a high pressure through a primary side of a cooler, whereby the medium to be cooled is passed through a secondary side of the cooler, and wherein the defrosting of the cooler is established by decreasing the gas pressure of the refrigerant in the primary side of the cooler to such an extent that ice which is adhered to the secondary side of the cooler is released.

**[0010]** A major advantage of the present invention is the fact that the energy which is needed to decrease the gas pressure of the refrigerant brings about the production of cold, which is attractive from energy-consumption perspective, and which clearly is not the case in the known defrosting processes.

**[0011]** Suitably, the gas pressure of the refrigerant in the primary side of the cooler is decreased by means of a compressor which is arranged downstream the cooler.

**[0012]** In a preferred embodiment of the present invention, the flow of refrigerant to the cooler is reduced during defrosting when compared to the flow of refrigerant as applied during cooling. This can, for instance, be realised by at least partly closing expansion means that are located upstream the cooler.

**[0013]** Preferably, the gas pressure of the refrigerant in the primary side of the cooler is in such a range that the equivalent boiling temperature of the refrigerant is lower than -50°C. More preferably, the gas pressure of the refrigerant in the primary side of the cooler is in such a range that the equivalent boiling temperature of the refrigerant is lower than -60°C.

**[0014]** In the method according to the present invention, the refrigerant circulation rate is preferably in the range of from 1-10, and more preferably in the range of from 3-5. In the context of the present invention the refrigerant circulation rate is defined as the ratio of the amount of refrigerant mass which is led into the cooler and the amount of refrigerant vapour mass which comes out of the cooler.

**[0015]** In accordance with the present invention a refrigerant can be used which enables the ice to be removed from the secondary side of the cooler.

**[0016]** Suitable refrigerants that can be used include for instance liquid nitrogen, refrigerants like R14, R23, R32, R50, R170, R1150 and R410A, and $CO_2$.

**[0017]** Preferably, the refrigerant to be used in accordance with the present invention comprises $CO_2$.

**[0018]** Preferably, use is made of one type of refrigerant.

**[0019]** When use is made of $CO_2$ as refrigerant, the gas pressure of $CO_2$ present in the primary side of the cooler is reduced to such extent that dry ice is obtained in the primary side of the cooler, which is accompanied with such a low temperature that ice adhered to the secondary side of the cooler is released.

**[0020]** In the method according to the present invention, the refrigerant can alternately or simultaneously be used as a cooling agent and as a defrosting agent. The refrigerant can alternately be used as a cooling agent and as a defrosting agent when use is made of a two-stage process, wherein in a first stage the cooling takes place, and in a second stage the defrosting of the cooler takes place. However, it can also be the case to carry out the method as one-stage process wherein cooling and defrosting is established simultaneously by using a decreased gas pressure of the refrigerant. In accordance with the present invention the refrigerant is preferably simultaneously used as a cooling agent and as a defrosting agent.

**[0021]** Various types of coolers can be used in accordance with the present invention. Suitable coolers include finned tubes, shell and tube heat exchangers, and contact freezers which comprise a number of elements in between which the material to be cooled can be arranged.

**[0022]** When the cooler used in accordance with the present invention is a contact freezer, the present method is suitably integrated with a method for cooling a material located between the elements of the contact freezer.

**[0023]** The present invention further relates to a cooling system for carrying out the present invention, which system comprises a cooler which is provided with means to allow refrigerant to pass through the first part the cooler, means to allow the medium to be cooled to pass through the second part of the cooler, which cooler is connected to means for decreasing the pressure of the refrigerant in the first part of the cooler of which latter means the suction side is connected to the cooler, and a heat exchanger which is connected to the high-pressure side of the means to decrease the gas pressure of the refrigerant, which heat exchanger is connected to a circuit for feeding the refrigerant into the cooler.

**[0024]** Preferably, the heat exchanger is connected to an expansion device, which expansion device is connected to the cooler.

**[0025]** Preferably, the means for decreasing the gas pressure of the refrigerant comprises a compressor.

**[0026]** In a preferred embodiment of the present invention, the cooling system comprises a plurality of coolers which are connected to the compressor and the circuit, whereby the coolers are arranged in parallel. The cooling system can for instance comprise a contact freezer or a plurality of contact freezers.

**[0027]** The cooling system in accordance with the present invention suitably comprises one or more compressors, one or more coolers, one or more condensors, and one or more expansion means

**[0028]** Cooling systems usually consist of one or more compressors, one or more evaporators, one or more condensers and one or more expansion devices. $CO_2$ cooling systems are usually two-stage installations in which $CO_2$ is the refrigerant for the low-temperature stage. An example of the low-temperature stage of a $CO_2$ cooling system in accordance with the present invention is depicted in Figure 1. Figure 1 also shows a defrost compressor [11] with ducts, a liquid-vapour separator [10] and valves [9].

**[0029]** During normal operation of the cooling system, the valves [9] of the defrost circuit are closed and the evaporators [7] supply cold to the air or the product to be cooled. To this purpose liquid refrigerant ($CO_2$) is pumped from the vessel [4] by means of the pump [5], through the expansion devices [6] into the evaporators [7]. The heat from the product and/or the air to be cooled causes a (partial) evaporation of the refrigerant. The two-phase mixture flows through the one-way valves [8] to the vessel [4], where liquid and vapour are separated. The vapour is extracted from the vessel by suction using a compressor [1]. In the compressor [1] the refrigerant vapour is compressed to a higher pressure, temperature and boiling point. In the cascade condenser [2] the vapour then condenses. Subsequently, the liquid flows through expansion device [3] into the vessel [4].

**[0030]** Condensation of refrigerant takes place in the cascade condenser [2]. The condensation heat causes the evaporation of refrigerant in the high-temperature stage of the cooling system. By way of a (not depicted) high-temperature stage compressor, this refrigerant vapour is brought to a temperature and boiling point which is higher than the temperature of the environment. The refrigerant concerned condenses against the environment and the liquid flows through an expansion device into the cascade condenser [2].

**[0031]** As soon as an evaporator has to be defrosted, the expansion device [6] which is located upstream the evaporator will be closed or in any case throttled as far as necessary so that less refrigerant flows into the evaporator. In case a fixed restriction is used as expansion device, a control valve will take over this function. Consequently, the valve [9] downstream the evaporator [7] will be opened and the defrost compressor [11] will be started. The capacity of this compressor [11] should be large enough to extract more vapour than the amount of vapour that is formed due to the heat load on the evaporator [7]. In this way, a decrease of refrigerant pressure will be realised, resulting in a decrease of temperature and boiling point. An illustration of this process is shown in Figure 2 wherein $CO_2$ is used as refrigerant. The flat part of the curve refers to the transition from liquid to solid $CO_2$ (dry ice). As the density of dry ice is higher than that of liquid $CO_2$, the transition to solid $CO_2$, does not damage the evaporator due to expansion. By decreasing the pressure and consequently the temperature in the evaporator [7], the adhesion forces of the ice at the secondary side of the evaporator [7] will decrease far enough to cause the ice to be removed from the secondary side. A one-way valve [8] between the vessel [4] and the evaporator [7] prevents the vapour flowing from the vessel [4] to the evaporator [7] during defrosting.

**[0032]** The discharge vapour of the defrost compressor [11] is led to the vessel [4]. As soon as the ice is removed from the evaporator [7], the defrost compressor [11] will be switched off and the expansion device [6] will be opened again.

**[0033]** This method of ice removal is very energy efficient. No heat will be brought in into the product or the coldstore. The energy that is used for defrosting also leads to a further cooling of the product and the evaporator [7].

**[0034]** The defrost compressor [11] can also be used as refrigeration compressor for useful cold supply. Figure 3 illustrates how the addition of only a few ducts [12, 13] and valves [14, 15, 16] enables the defrost compressor to be used as refrigeration compressor. During normal operation valve [14] is opened and the defrost compressor extracts refrigerant vapour from vessel [4] through duct [12].. The discharge vapour flows through valve [16] and duct [13] to the cascade condensor. Valve [15] is closed. In the defrost mode valves [14] and [16] are closed and valve [15] is opened, which gives the same result as in figure 1.

## Claims

**1.** A method in which a refrigerant is used as a cooling agent and/or as a defrosting agent, wherein the cooling of a medium is established by passing the refrigerant at a high pressure through a primary side of a cooler, whereby the medium to be cooled is passed through a secondary side of the cooler, and wherein the defrosting of the cooler is established by decreasing the gas pressure of the refrigerant in the primary side of the cooler to such an extent that ice which is adhered to the secondary side of the cooler is released.

**2.** A method according to claim 1, wherein the gas pressure of the refrigerant is decreased by means of a compressor which is arranged downstream the cooler.

**3.** A method according to claim 1 or 2, wherein the flow of refrigerant to the cooler is reduced during defrosting when compared to the flow of refrigerant as applied during cooling.

**4.** A method according to any one of claims 1-3, wherein the gas pressure of the refrigerant in the first part of the cooler is in such a range that the equivalent boiling temperature is lower than -50°C.

**5.** A method according to claim 4, wherein the gas pressure of the refrigerant is in such a range that the equivalent boiling temperature is lower than -60°C.

**6.** A method according to any one of claims 1-5, wherein the refrigerant circulation rate is in the range of from 1-10.

**7.** A method according to any one of claims 1-6, wherein the refrigerant comprises $CO_2$.

**8.** A method according to any one of claims 1-7, wherein the cooler comprises a contact freezer, and the method is integrated with a method for cooling a material located between the elements of the contact freezer.

**9.** A cooling system for carrying out the method according to any one of claims 1-8, which system comprises a cooler which is provided with means to allow refrigerant to pass through the first part the cooler, means to allow the medium to be cooled to pass through the second part of the cooler, which cooler is connected to means for decreasing the pressure of the refrigerant in the first part of the cooler of which latter means the suction side is connected to the cooler, and a heat exchanger which is connected to the high-pressure side of the means to decrease the gas pressure of the refrigerant, which heat exchanger is connected to a circuit for feeding the refrigerant into the cooler.

**10.** A cooling system according to claim 9 wherein the heat exchanger is connected to an expansion device, which expansion device is connected to the cooler.

**11.** A cooling system according to claim 9 or 10, wherein the means for decreasing the gas pressure of the refrigerant comprises a compressor.

**12.** A cooling system according to any one of claims 9-11, comprising a plurality of coolers which are connected to the compressor and the circuit, whereby the coolers are arranged in parallel.

**13.** A cooling system according to any one of claims 9-12, wherein the cooling system comprises a contact freezer or a plurality of contact freezers.

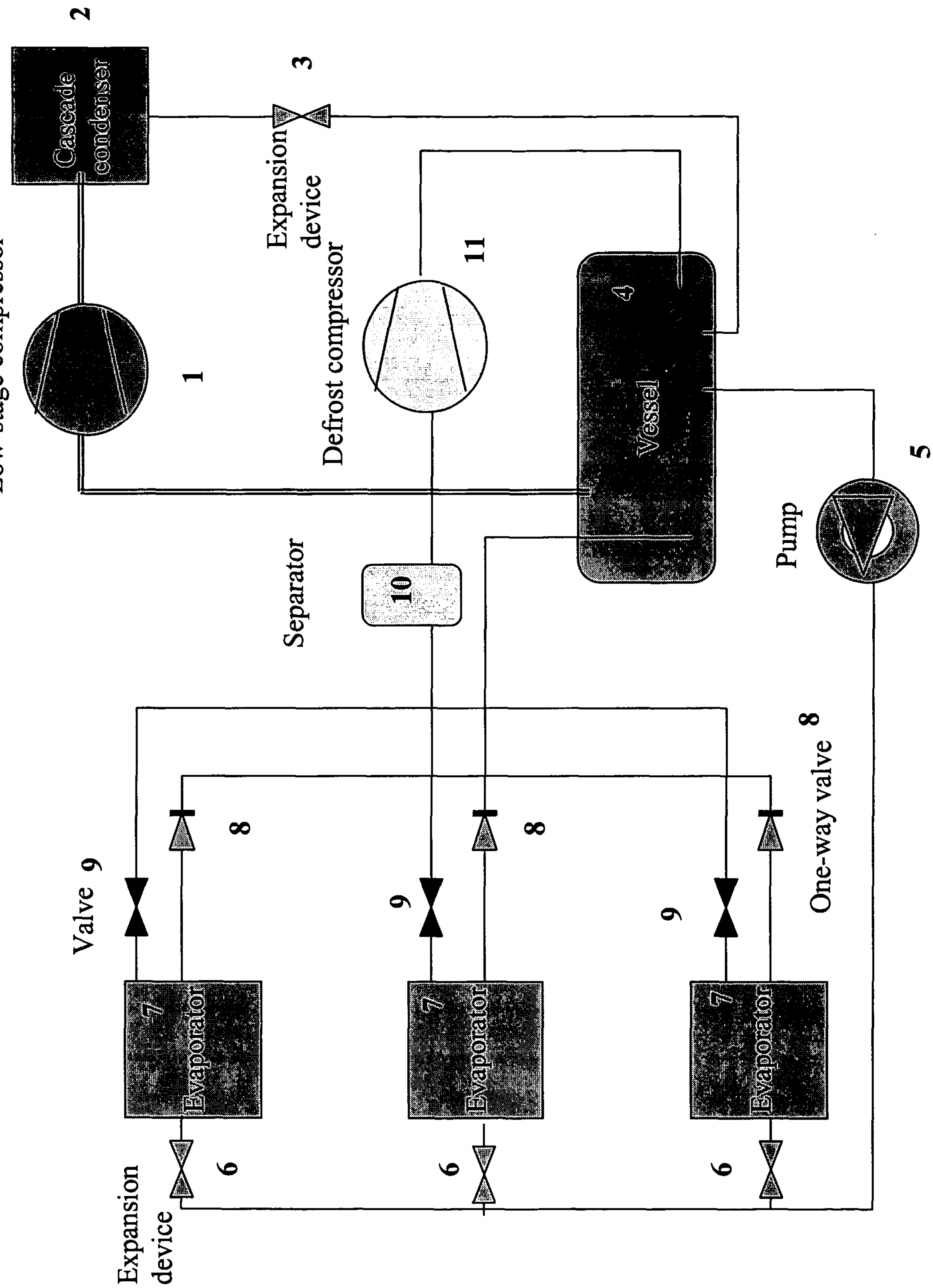
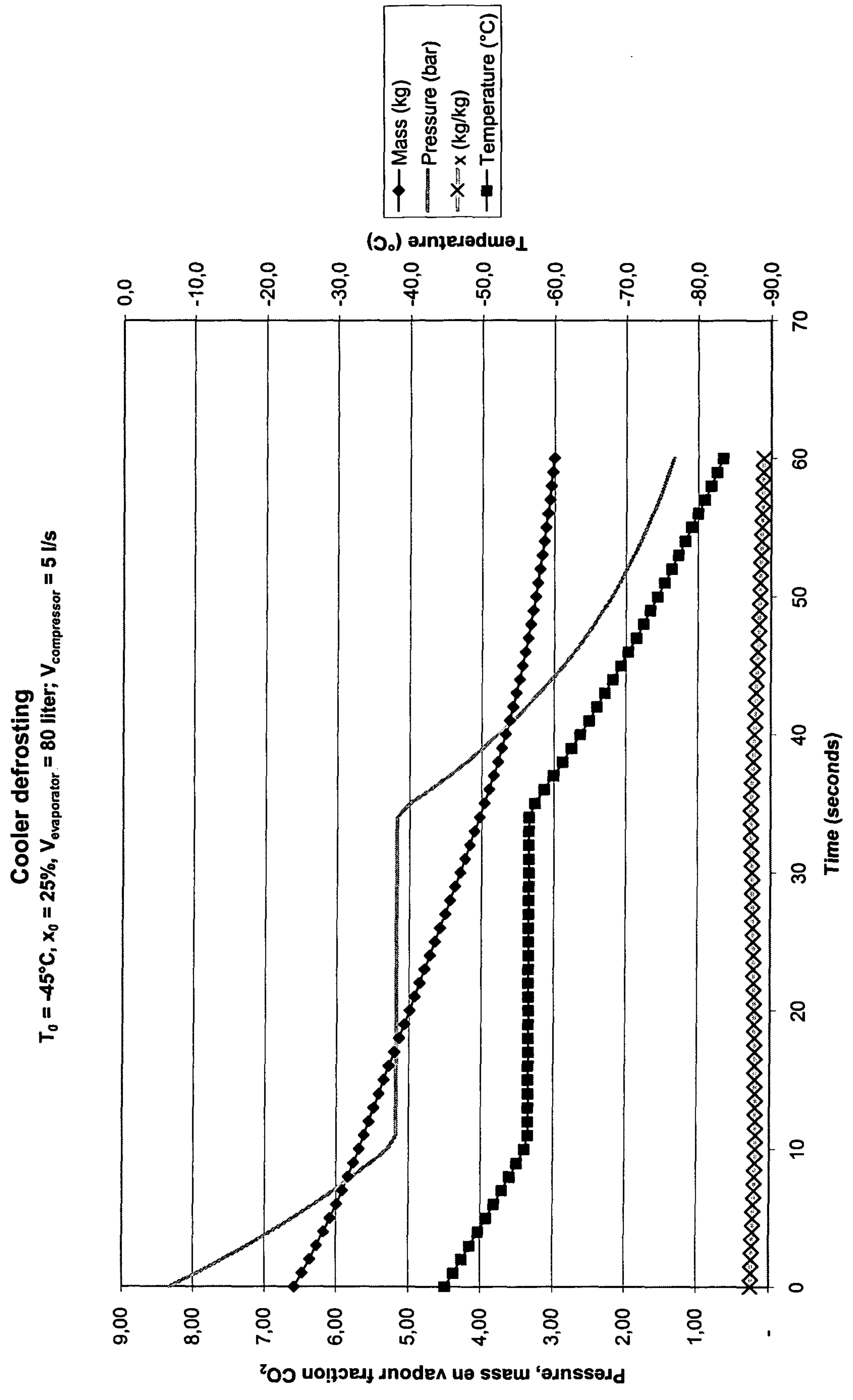

Cascade condenser
2
Low-stage compressor
1
Expansion device
3
Defrost compressor
11
Vessel
4
Pump
5
Separator
10
Valve
9
One-way valve
8
Evaporator
7
Expansion device
6

*Figure 1*

*Figure 2*


Cooler defrosting
$T_0$ = -45°C, $x_0$ = 25%, $V_{evaporator}$ = 80 liter; $V_{compressor}$ = 5 l/s
Mass (kg)
Pressure (bar)
x (kg/kg)
Temperature (°C)
Temperature (°C)
Pressure, mass en vapour fraction $CO_2$
Time (seconds)
0,0
-10,0
-20,0
-30,0
-40,0
-50,0
-60,0
-70,0
-80,0
-90,0
9,00
8,00
7,00
6,00
5,00
4,00
3,00
2,00
1,00
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0
10
20
30
40
50
60
70

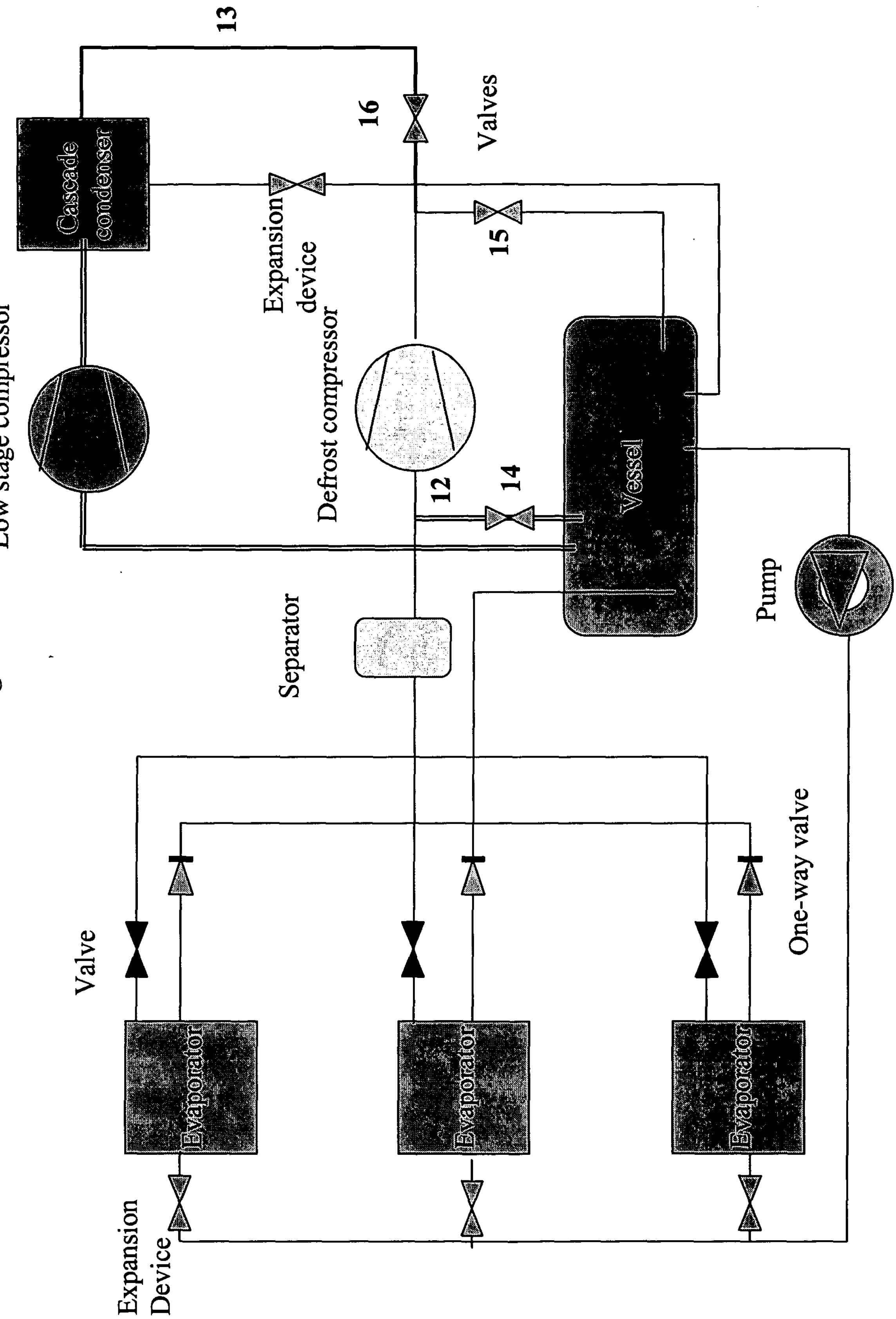
13
Cascade condenser
16
Valves
Expansion device
15
Low stage compressor
Defrost compressor
12
14
Vessel
Separator
Pump
Valve
One-way valve
Evaporator
Evaporator
Evaporator
Expansion Device

*Figure 3*

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 04 07 7391

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 7 February 2005 | De Graaf, J.D. |

2

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons

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# EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

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| Place of search | Date of completion of the search | Examiner |
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| The Hague | 7 February 2005 | De Graaf, J.D. |

CATEGORY OF CITED DOCUMENTS

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O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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EPO FORM 1503 03.82 (P04C01)

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 07 7391

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