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(71) Applicants:
- **Air Liquide Deutschland GmbH**
  40235 Düsseldorf (DE)
  Designated Contracting States:
  DE
- **L'Air Liquide Société Anonyme à Directoire et Conseil de Surveillance pour l'Etude et l'Exploitation des Procédés Georges Claude**
  75321 Paris Cedex 07 (FR)
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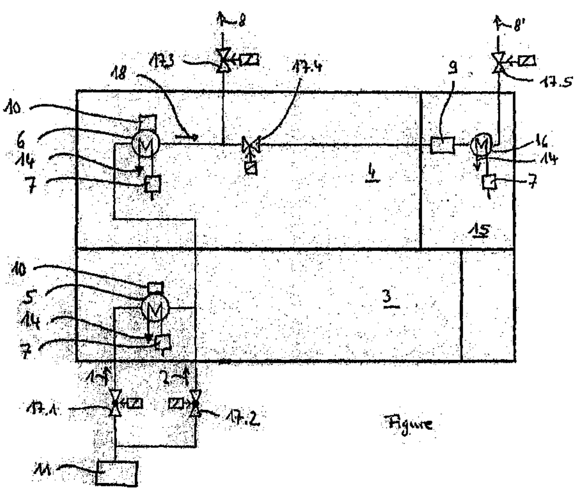
(72) Inventor: **Lürken, Franz**
47906 Kempen (DE)

(74) Representative: **Kahlhöfer, Hermann**
Patentanwälte
Kahlhöfer Neumann
Herzog Fiesser
Karlstrasse 76
40210 Düsseldorf (DE)

(54) Cooling process and cooling apparatus for refrigerated vehicles

(57) The invention relates to a cooling process for cooling at least one refrigeration chamber (3, 4) of a refrigerated vehicle, having at least one first heat exchanger (5) in a first refrigeration chamber (3), and
at least one second heat exchanger (6), the first heat exchanger (5) being flow-connected to the second heat exchanger (6), and a first stream of coolant (1), in particular of liquid and/or gaseous nitrogen, flowing firstly through the first heat exchanger (5) and then through the second heat exchanger (6), the first stream of coolant (1) releasing a refrigeration content to the refrigeration chambers (3, 4) and then itself being discharged into the open air as a waste gas, in which process a second stream of coolant (2), in particular liquid and/or gaseous nitrogen, is fed to the first stream of coolant (I) downstream of the first heat exchanger (5) and upstream of the second heat exchanger (6), and to a cooling apparatus which is suitable for carrying out the process according to the invention. The invention is distinguished by the fact that it realizes operationally safe and reliable, accurately controllable, indirect, highly effiaent cooling in a simple way, which can be used in particular in refrigerated vehicles, even in the event of extreme fluctuations in the outside temperature.



EP 1 659 355 A2

Description

[0001] The invention relates to a cooling process and a cooling apparatus for a refrigerated vehicle which has at least one refrigeration chamber, in particular to a cooling process and cooling apparatus for cooling a freight or loading space, or parts of this space, of a lorry with the aid of liquid nitrogen.

[0002] Nitrogen has been used for cooling vehicles with multi-chamber systems for about 30 years. The process is known under the name CryogenTrans (CT). In the CT process, nitrogen in liquid, cryogenic form is carried in a vacuum-insulated tank on or in the vehicle. When refrigeration is required, this nitrogen is removed via a pipeline and sprayed directly into the space that is to be cooled by the pressure of the medium itself. The process is particularly simple and unsusceptible to disruption. Furthermore, the refrigeration capacity is always the same irrespective of the ambient temperature. It is in principle limited only by the throughput through the spray nozzles. Therefore, CT-cooled lorries which are used to transport foodstuffs for distribution and the doors of which are of course opened numerous times during cooling operation, have considerable advantages in terms of the quality of cooling. The CT process demonstrates its efficiency, reliability and performance advantages in particular in high summer, when mechanical refrigeration installations have to battle with losses of power at the condensers and with the formation of ice on the evaporators. The set temperature is restored again within seconds of a door having been opened.

[0003] However, the process also has drawbacks: the consumption of nitrogen is relatively high, since at least some of the gas which is sprayed into a chamber also escapes again as waste gas. For example, if a freezing chamber is cooled, the waste gas temperature is approx. -30 to -40°C. Another drawback is that a loading space has to be completely vented before it can be entered, for safety reasons. This leads to unnecessarily large amounts of warm air entering the loading space. Although subsequent receding is very fast, it takes more energy and therefore entails greater costs than necessary. The installation of refrigeration-retaining systems, such as for example a curtain, which is otherwise customary is not possible with CT-cooled vehicles, since such systems would dangerously impede the ventilation.

[0004] It is a fundamental aim for the individual refrigeration chambers to be particularly controllable. In known cooling systems, independent control of the individual refrigeration chambers has in some instances been restricted in favour of a reduced total consumption of coolant.

[0005] A cooling unit for a space that is to be cooled and a corresponding process are described, for example, in EP-B1 0 826 937.

[0006] It is an object of the invention to provide an improved cooling process and an improved cooling apparatus for refrigerated vehicles allowing efficient cooling, which operates reliably, can be controlled substantially independently in the respective refrigeration chambers and has a high level of efficiency in a refrigerated vehicle.

[0007] This object is achieved by the cooling process and the cooling apparatus for refrigerated vehicles as described in the independent claims. Further advantageous configurations and refinements which can in each case be employed individually or combined with one another in any desired way, form the subject matter of the dependent claims.

[0008] The cooling process according to the invention for cooling at least one refrigeration chamber of a refrigerated vehicle, having at least one first heat exchanger in a first refrigeration chamber, and at least one second heat exchanger, the first heat exchanger being flow-connected to the second heat exchanger, and a first stream of coolant, in particular of liquid and/or gaseous nitrogen, flowing firstly through the first heat exchanger and then through the second heat exchanger, the first stream of coolant releasing a refrigeration content to the refrigeration chamber and then itself being discharged into the open air as a waste gas, is characterized in that a second stream of coolant, in particular liquid and/or gaseous nitrogen, is fed to the first stream of coolant downstream of the first heat exchanger and upstream of the second heat exchanger or a further heat exchanger. It is advantageous for the second heat exchanger to be located in a second refrigeration chamber, which is arranged separately from the first. In this case, the second heat exchanger is used to cool the second refrigeration chamber.

[0009] The process according to the invention is an indirect cooling process, since the refrigerant is not passed into the open interior of the refrigeration chamber or chambers, but rather merely releases a refrigeration content to the refrigeration chamber or chambers via heat exchangers, while itself flowing into the open atmosphere, i.e. outside the refrigeration chambers. In this case, a fluid which releases its refrigeration to the cooling chamber through heat exchangers and is itself discharged to atmosphere is used for the cooling, with the gas properties being controlled at the entry or exit of a heat exchanger and at a suitable location in the heat exchanger, and the power of the heat exchangers themselves being controlled. This avoids safety risks caused by a lack of oxygen in the refrigeration chambers. The first refrigeration chamber is advantageously used for frozen food (e.g. -18°C), and the second refrigeration chamber is advantageously used for refrigerated fresh food (e.g. +8°C). In principle, with multi-chamber systems, it is expedient if the fluid-carrying connection between the refrigeration chambers connected in series can be sealed off from time to time in order to enable the respective streams of coolant to be controlled or regulated freely depending on the demand for refrigeration in the respective chamber. Depending on the particular application, the heat exchangers can be switched off from time to time or permanently or connected to at least one different refrigeration chamber or can each be operated independently. In particular, a valve may be arranged in the fluid-carrying connection upstream and/or downstream of the first heat exchanger. Feeding the second stream of coolant to the first stream of coolant makes the supply of refrigeration particularly controllable, offering the option of separate control of the cooling in the respective refrigeration chambers with particularly good utilization of the refrigeration. This allows very high waste gas temperatures close to ambient temperature to be realized, resulting in a high efficiency during cooling. The refrigerant used is advantageously a fluid, such as for example nitrogen or carbon dioxide, in which the heat of evaporation of the liquid-gas phase change and the specific heat of the cold gas are utilized for cooling. The heat exchangers of a plurality of refrigeration chambers can be connected in series or in parallel, with a stream of coolant preferably flowing firstly through refrigeration chambers for a lower temperature and then through refrigeration chambers for higher temperatures, in order to enable the refrigeration to be utilized as completely as possible.

[0010] There are three main degrees of freedom for controlling the cooling capacity: the level of coolant consumption (which corresponds to the sum of the streams of coolant), the ratios of the magnitude of the streams of coolant with respect to one another and the refrigeration capacity (or refrigeration utilization) of the heat exchangers (ventilation and gas outlet temperature). This is true in particular if a liquid coolant, such as for example liquid nitrogen, which evaporates on warming is used, since on account of the liquid-gas phase change the boiling point is fixed at a given pressure, and therefore the quantity of refrigeration which results from the heat of evaporation and the quantity of refrigeration which results from the heat capacity of the gas are predetermined. The maximum cooling capacity is therefore limited by the total consumption of the coolant, which corresponds to the sum of the streams of coolant. However, this maximum cooling capacity is not realized if the coolant is released as waste gas at a temperature which is cooler than ambient temperature. By virtue of the second stream of coolant being fed to the first stream of coolant, the refrigeration capacity of the respective heat exchangers can be controlled substantially independently of one another, despite the heat exchangers being connected in series. At least one of the streams of coolant can optionally be controlled by the pressure, the position of a proportional control valve or the cycle rate of a valve which opens and closes at regular intervals.

[0011] In one configuration of the process according to the invention, the cooling capacity of at least one heat exchanger is controlled with the aid of a fan. The cooling capacity of the heat exchanger can be crucially influenced by the air flow through the fan which acts on a heat exchanger. A greater quantity of refrigeration can be withdrawn from the heat exchanger by blowing onto the heat exchanger. This allows the fan power to be used as a further control variable for predetermining the refrigeration released at a heat exchanger.

[0012] In a further configuration, accumulations of snow on a heat exchanger are reduced and/or the loading space atmosphere is mixed up with the aid of pulsed operation and/or full-load operation of the fan. Accumulations of snow caused by resublimation of water vapour from the ambient air on the heat exchangers can therefore be removed. Furthermore, pulsed operation or full-load operation can be used to compensate for spatial temperature inhomogeneities in a refrigeration chamber. Temperature inhomogeneities of this nature arise if the air circulation in the refrigeration chamber is impeded, for example as a result of products (material to be cooled) in the refrigeration chamber and the low power of a low ventilation stage cannot overcome and compensate for these obstacles. They can lead to errors in temperature determination. To prevent this, the ventilation is briefly switched to full power at regular intervals, in order in this way to feed the refrigeration even to relatively remote or hidden regions of air.

[0013] Advantageously, one or more of the following variables for cooling (R1) to (R7), (R1) power of the fan, (R2) first stream of coolant, (R3) second stream of coolant, (R4) temperature of the first stream of coolant at the entry to the first heat exchanger, (R5) temperature of the first stream of coolant at the exit of the first heat exchanger, (R6) temperature of the second stream of coolant at the entry to the second heat exchanger, and

(R7) temperature of the second stream of coolant at the exit of the second heat exchanger is controlled as a function of one or more of the following variables (S1) to (S7), (S1) discharge temperature of the waste gas,

(S2) ambient temperature, (S3) at least one temperature in the first refrigeration chamber, (S4) at least one temperature in the second refrigeration chamber, (S5) pressure in the first stream of coolant, (S6) pressure in the second stream of coolant, and (S7) duration of the opening of a door of at least one of the refrigeration chambers. It is preferably possible for all the variables to have an influence on the control. In particular, the fan power - i.e. the control of the capacity released by the heat exchangers - can also be used to control the release of refrigeration from the stream of coolant. The ambient temperature also plays an important role as a variable, since it considerably shifts the demand for refrigeration in the refrigeration chambers relative to one another, and consequently the utilization of refrigerant has to be shifted between the refrigeration chambers. The maximum supply of refrigerant in the respective refrigeration chambers can be accurately predetermined with the aid of the variables of the streams of coolant. The ratio between the first stream of coolant and the second stream of the coolant and/or the sum of the streams of coolant is set according to the temperature which is to be reached in the respective chambers. The demand for refrigeration can be estimated and/or the cooling profile as a function of time optimized as a function of the duration of opening of a door. While a door of the motor vehicle is open, it is advantageous for the heating or cooling of the heat exchangers to be controlled as a function of the time for which the door is open. It is advantageous for the program sequence to be matched to the operating mode of the vehicle by the duration of the opening of a door being the factor which determines whether the heat exchangers are thawed and run cold or just run cold while the door is open.

[0014] In one particular configuration, the first stream of coolant and/or the second stream of coolant flows through a phase separator. The phase separator limits the liquid phase of the coolant to predetermined regions in the line or in the heat exchangers, which is advantageous for safety reasons.

[0015] In one refinement, at least one of the heat exchangers is warmed by a heater from time to time, in particular during a thawing phase or during a door-open phase, preferably for a period of from 0.01 to 1 hour, particularly preferably for a period of from 0.1 to 0.5 hour. For this purpose, the stream of coolant advantageously does not flow through it. The heating can advantageously perform two functions: firstly, it can be used to remove ice on the heat exchangers by melting the ice; secondly, it can be used to control the temperature of a cooling chamber to a predetermined temperature range (heating in controlled long-term operation). In particular during the winter, it is advantageous to control the temperature of at least one refrigeration chamber, such as for example a refrigeration chamber for refrigerated fresh food, to ensure that products which are vulnerable to frost (vegetables, fruit, flowers, etc.) do not spoil.

[0016] A thawing phase is advantageously at the same time utilized to check the sealing and/or functioning of the cooling system. In this case, the stability (time constancy) of a superatmospheric pressure in the pipe system is observed with the waste gas pipe closed and the feed pipe for cold refrigerant closed (feed from the refrigerant reservoir is switched off). If the superatmospheric pressure drops, there is a leak in the system. To rule out the possibility of both the system and the feed valve being leaky, the stability of a standard pressure is also observed. If the pressure rises, the feed valve is defective. Only if both the superatmospheric pressure and the standard pressure are constant is it possible to be certain that the system is operating correctly.

[0017] The cooling apparatus according to the invention for a refrigerated vehicle for cooling at least one refrigeration chamber of a refrigerated vehicle, comprises at least one reservoir for a coolant, in particular for liquid nitrogen, at least one first heat exchanger for cooling the first refrigeration chamber, at least one second heat exchanger, and at least one outlet for discharging the coolant to atmosphere as waste gas, in which apparatus, with respect to the first stream of coolant, the reservoir is flow-connected to the first heat exchanger, the first heat exchanger is flow-connected to the second heat exchanger, and the second heat exchanger is flow-connected to the outlet, and is characterized in that a second stream of coolant, in particular liquid and/or gaseous nitrogen, can be fed to the first stream of coolant downstream of the first heat exchanger and upstream of the second heat exchanger or a following heat exchanger. It is advantageous for the heat exchanger to be located in a second refrigeration chamber, which is arranged separately from the first refrigeration chamber. In this case, the second heat exchanger is used to cool the second refrigeration chamber.

[0018] The cooling apparatus advantageously has from 1 to 4, in particular 2 to 3, refrigeration chambers. Valves are advantageously arranged upstream and/or downstream of the respective heat exchangers, in order to control the flow of the respective streams of coolant through the heat exchanger separately for the respective heat exchanger. The first refrigeration chamber is advantageously intended for a lower temperature, in particular between -40°C and -10°C, preferably between -25°C and -18°C, and the second refrigeration chamber is advantageously intended for a higher temperature, in particular between +1°C and +14°C, preferably between +4°C and 10°C. This allows different products to be stored and transported at correspondingly different refrigeration temperatures. It is advantageous for a stream of coolant which originates from a heat exchanger of a refrigeration chamber with a lower temperature to be fed to a heat exchanger of a refrigeration chamber with a higher temperature, in order also to allow the residual refrigeration to be utilized on account of the temperature difference between the higher temperature and the lower temperature. The series connection allows particularly efficient use to be made of the refrigeration content of the coolant The coolant used is preferably liquid nitrogen or carbon dioxide. The use of a liquid coolant, in particular nitrogen or carbon dioxide, which evaporates on warming has the advantage that first the heat of evaporation can be utilized, and secondly the temperature of the liquid coolant is constant through the boiling point, and furthermore the cooling apparatus can be run with low operating pressures and approx. 50% of the total refrigeration content can be passed on into other heat exchangers in the form of the specific heat. The overall result, therefore, is efficient, controllable and operationally reliable cooling.

[0019] Since the evaporated coolant does not simply flow into the interior of the refrigeration chambers, but rather releases its refrigeration content to the refrigeration chamber via heat exchangers, and then flows into the open atmosphere outside the refrigeration chamber, there is no need to ventilate the refrigeration chambers before they can be entered. This means that it is possible to use standard refrigeration-retaining systems, such as for example ribbon curtains, which prevent hot air from the outside penetrating into the refrigeration chambers or cold air from the refrigeration chambers escaping to the outside. This allows considerable saving of refrigeration, typically between 20 and 40%. Furthermore, the cooled products are subject to fewer temperature fluctuations.

[0020] The apparatus advantageously has a fan for controlling the refrigeration capacity of at least one heat exchanger. Correspondingly increased refrigeration can be withdrawn from the heat exchanger by using the fan to blow onto the heat exchanger. The refrigeration capacity, i.e. the amount of refrigeration energy per unit time which is released to a refrigeration chamber, and therefore the temperature in the refrigeration chambers can be additionally influenced or predetermined by suitably selecting the flow of air generated by the fan. Furthermore, the fan can counteract temperature differences in the refrigeration chambers.

[0021] The apparatus advantageously has a control means for controlling one or more of the following variables (R1) to (R^7), (R1) power of the fan, (R2) first stream of coolant, (R3) second stream of coolant, (R4) temperature of the first stream of coolant at the entry to the first heat exchanger, (R5) temperature of the first stream of coolant at the exit of the first heat exchanger, (R6) temperature of the second stream of coolant at the entry to the second heat exchanger, and (R7) temperature of the second stream of coolant at the exit of the second heat exchanger as a function of one or more of the following variables (S1) to (S7), (S1) discharge temperature of the waste gas, (S2) ambient temperature, (S3) at least one temperature in the first refrigeration chamber, (S4) at least one temperature in the second refrigeration chamber, (S5) pressure in the first stream of coolant, (S6) pressure in the second stream of coolant, and (S7) duration of the opening of a door of at least one of the refrigeration chambers. It is advantageous for all the setting and control variables to be taken into account in the control.

[0022] Efficient, accurate and controllable cooling with a high level of efficiency can be achieved for the desired temperature profile in the refrigeration chambers at a given outside temperature with the aid of the fan power, the variables of the two streams of coolant and the ratio of these streams of coolant with respect to one another.

[0023] It is advantageous during the control to store a library, from which all the measurement and control variables are actuated as stored in the hardware catalogue and actually connected, by means of a characteristic number assigned to the selected hardware configuration.

[0024] In an advantageous configuration, the apparatus has at least one phase separator for the first stream of coolant and/or the second stream of coolant The phase separator prevents liquid coolant from reaching regions of the cooling system which are not designed for it

[0025] In one specific development, the apparatus has at least one heater for at least one heat exchanger, in particular for controlling the temperature of at least one refrigeration chamber, preferably for frost protection at outside temperatures below freezing point (e.g, in the winter). The heater can be used both to remove ice on the heat exchangers and to prevent the temperature from falling below a defined minimum temperature. By way of example, this allows products which are vulnerable to frost (e.g, vegetables, fruit, flowers, etc.) to be protected from spoiling by their temperature being controlled.

[0026] It will be readily understood that the process for checking the sealing of the cooling apparatus and the process for removing snow on the heat exchangers, as well as the use of an indirect cooling device for controlling the temperature, in particular the process for avoiding undesirable formation of frost, can in each case also be operated and carried out on their own, independently of the features listed in the main claims.

[0027] Further advantages and particular configurations are explained with reference to the following drawing, which are intended merely to illustrate examples of the invention and not to restrict the fundamental concept of the invention.

[0028] The figure diagrammatically depicts a cooling apparatus according to the invention for carrying out the cooling process according to the invention for a refrigerated vehicle, in particular a lorry, having a first refrigeration chamber 3 for frozen food, designed for temperatures of between -25°C and -18°C, a second refrigeration chamber 4 for refrigerated fresh food, such as for example milk products, designed for temperatures from +4°C to +8°C, and a third refrigeration chamber 15 for refrigerated fresh food, such as for example bananas, designed for temperatures from +13°C to +14°C. Liquid nitrogen at a temperature of from -192°C to - 196°C and at a pressure of 2-4 bar is removed from a reservoir 11 and fed as a first stream of coolant 1 to a first heat exchanger 5 in the first refrigeration chamber 3 and/or as a second stream of coolant 2 to a second heat exchanger 6 in the second refrigeration chamber 4. The respective streams of coolant 1, 2 can be throttled or stopped by means of corresponding valves 17.1 and 17.2. Downstream of the first heat exchanger 5, the first stream of coolant 1 is combined with the second stream of coolant 2 and fed to the second heat exchanger 6, so that the first stream of coolant 1, after it has released part of its refrigeration content into the first refrigeration chamber 3, can also make a contribution to cooling the second refrigeration chamber 4, with the result that the efficiency of cooling can be increased. However, as a result of the second stream of coolant 2 being added to the first stream of coolant or used as an alternative feed, the refrigeration supply in the second cooling chamber 4 can be controlled independently, separately from the cooling capacity of the first refrigeration chamber 3, by means of a control means (not shown), or the cooling capacity of the first refrigeration chamber 3 is independent of the cooling capacity in the second refrigeration chamber 4. This allows refrigeration contents to be distributed between the two refrigeration chambers 3, 4 in a ratio of between 1:0 and 0:1, resulting in a high degree of flexibility of control.

[0029] A stream of coolant 18 which flows out of the second heat exchanger 6 is either passed directly to atmosphere as waste gas 8 or is first of all fed via a phase separator 9 to a third heat exchanger 16 and then passed to atmosphere as waste gas 8'. The phase separator 9 is used to keep a liquid phase of the third stream of coolant 18 away from the third heat exchanger. Valves 17.3 and 17.4 control the flow of the third stream of refrigerant 18. A flow of air 14 can be passed onto the respective heat exchangers by corresponding fans 7, 7', 7'', allowing the release of the refrigeration content of the respective streams of coolant 1, 2, 18 to be influenced. In particular, an optimum temperature in the respective cooling chambers 3, 4, 15 for a maximum waste gas temperature, which is limited by the ambient temperature, can be set by means of the respective power of the fans 7, 7', 7'' and the magnitude of the streams of coolant 1, 2. Snow which has formed on the heat exchangers 5, 6, 16 can be blown off by the fans 7, 7', 7'' and these fans can also be used to effect a good circulation of the air within the respective refrigeration chambers 3, 4, 15 in order to avoid temperature gradients by virtue of the fans being operated in pulsed mode, in particular for a period of from 10 to 300 seconds, preferably from 20 to 30 seconds, or at maximum power.

[0030] The heat exchangers 5, 6, 16 can be heated by means of heaters 10, 10', 10". By way of example, this can be used to thaw ice on the heat exchangers 5, 6, 16. This also allows the temperature of the refrigeration chambers 4, 15 to be controlled, which is particularly important in particular in the winter, at temperatures below the freezing point, for refrigeration chambers for refrigerated fresh food, such as for example the third refrigeration chamber 15, which contains, for example, temperature-sensitive products, such as for example bananas.

[0031] The sealing of the cooling apparatus can be checked with the aid of the valves 17.1 to 17.5 by measuring the time constancy of a superatmospheric pressure and that of a standard pressure (outside pressure) in the pipes: if a superatmospheric pressure in the system of pipes drops between the closed valves 17.1, 17.2, 17.3 and 17.5, or the standard pressure in the system of pipes rises between the closed valves 17.1, 17.2, 17.3 and 17.5, either the cooling system has a leak or the valves are leaking.

[0032] The individual valves 17.1, ..., 17.5 for the streams of fluid 1, 2, 8, 8', 18, the power of the fans 7 and the heaters 10 are controlled with the aid of the control means (not shown) as a function of the demand for refrigeration and as a function of the ambient temperature in order for the process to be carried out economically.

[0033] The power of the cooling system is determined by two variables: firstly by the throughput of nitrogen per hour and secondly by the heat transfer capacity of the heat exchangers. The first of these variables can in principle be increased as desired. Practical values are between 5 and 1501 1 of nitrogen per hour. This corresponds to 0.5 to 15 kW of power. The heat exchangers 5, 6, 16 also run down this power, but they can be switched accordingly. In concrete terms, this means that both the number of heat exchangers per chamber and their respective temperature at the exit and the fan power have to be accurately controlled. This is reflected in the table below: the table shows how much refrigeration two heat exchangers together run down for various fan powers. This power is split between the two heat exchangers according to the temperature which is set. A second heat exchanger is only viable beyond approximately 5000 W. Smaller powers can be run via one heat exchanger. The maximum long-term power of the system with two heat exchangers is over 10 kW. With the aid of the fans, it is possible to shift the power back and forth between the heat exchangers.

Fan power [m^3/h]	Temperature downstream of heat exchanger [K]	Evaporator power [W]	Heater power [W]	Total power [W]
2000	5	2121	29	2150
	50	5110	802	5913
	100	5248	1954	7203
	150	5355	3675	9030
	170	5502	4710	10213
1200	5		15	15
	50	2788	438	3225
	100	3917	1458	5375
	150	3506	2406	5913

[0034] Normally, the chambers 3, 4, 15 of a vehicle are of different sizes and are used for different temperatures. Therefore, it is not possible to say which chamber will have the greater demand for refrigeration at any particular time. Furthermore, a system should in principle be connected in such a way that chambers 3, 4, 15 can be switched off and connected up as desired. The control software recognizes the specific situation on the vehicle on the basis of what are known as hardware numbers. Both the operating level and the control variables and the programme sequence are controlled on the basis of these numbers. The piping is selected in such a way that the refrigeration chamber 3 which normally has the lowest set temperature is located upstream of the other refrigeration chambers 4, 15 in terms of the stream of coolant. As a result, the gas stream is warmed further in the warmer chamber, and the efficiency of the overall process rises (if the chambers are supposed to change frequently, the feed can always be diverted into the coldest chamber by different switching operations). In this way, the majority of the expected cooling capacity is automatically run with the optimum series connection.

[0035] Only in the event of extreme heat and defined surface ratios can the demand for power of the warmer chamber be above what the series circuit is able to offer (up to 50% of the total cooling capacity). In this case, the deviation between the set and actual values in the warmer chamber becomes greater and the gas stream is automatically fed directly to the second chamber. Although this temporarily means a slightly lower efficiency, it also means that the control range for the distribution of refrigeration between two refrigeration chambers can be set as desired from 1:0 to 0:1.

[0036] If one of the chambers in a two-chamber vehicle is disconnected, the control which has been described is carried out as if the vehicle were a single-chamber vehicle with one heat exchanger. Control is then based on the measurement variables from the refrigeration chamber which is switched on. If the refrigeration chambers are then combined - for example by removing the partition - the control is carried out in the same way as for a single-chamber vehicle with two heat exchangers. In this case, all the measurement variables are processed in the control. Only the valve 17.2 is no longer actuated, since the refrigeration always passes into the same chamber, but the efficiency is not to be unnecessarily worsened. These switching operations make it easier to reprogramme the control for a single-chamber vehicle. It is merely necessary to input a characteristic variable which predetermines the configuration. The control then operates without a change in programme in this way. This allows single-chamber control to be realized without additional programming outlay. Separate actuation of the respective streams of coolant through the respective heat exchangers can be realized with the aid of software. As a result, a single-chamber vehicle can be controlled by this two-chamber control being operated with one chamber switched off. This allows a particularly high degree of flexibility during control even if the partitions between the refrigeration chambers have been moved or removed.

[0037] The invention relates to a cooling process for cooling at least two refrigeration chambers 3, 4 of a refrigerated vehicle, having at least one first heat exchanger 5 in a first refrigeration chamber 3, and at least one second heat exchanger 6 in a second refrigeration chamber 4, the first heat exchanger 5 being flow-connected to the second heat exchanger 6, and a first stream of coolant 1, in particular of liquid and/or gaseous nitrogen, flowing firstly through the first heat exchanger 5 and then through the second heat exchanger 6, the first stream of coolant 1 releasing a refrigeration content to the refrigeration chambers 3, 4 and then itself being discharged into the open air as a waste gas, in which process a second stream of coolant 2, in particular liquid and/or gaseous nitrogen, is fed to the first stream of coolant 1 downstream of the first heat exchanger 5 and upstream of the second heat exchanger 6, and to a cooling apparatus which is suitable for carrying out the process according to the invention. The invention is distinguished by the fact that it realizes operationally safe and reliable, accurately controllable, indirect, highly efficient cooling in a simple way, which can be used in particular in refrigerated vehicles, even in the event of extreme fluctuations in the outside temperature. The cooling process described and the cooling apparatus described can also be used to cool foodstuffs, in particular to cool frozen food, in stationary installations.

List of designations

[0038]

1	First stream of coolant
2	Second stream of coolant
3	First refrigeration chamber
4	Second refrigeration chamber
5	First heat exchanger
6	Second heat exchanger
7, 7', 7"	Fan
8, 8'	Waste gas
9	Phase separator
10, 10', 10"	Heater
11	Reservoir
12	Outlet
14	Air stream
15	Third refrigeration chamber
16	Third heat exchanger
17.1-17.5	Valves
18	Third stream of coolant

Claims

1. Cooling process for cooling at least one refrigeration chamber (3, 4) of a refrigerated vehicle, having
at least one first heat exchanger (5) in a first refrigeration chamber (3), and
at least one second heat exchanger (6), preferably in a second refrigeration chamber (4),
the first heat exchanger (5) being flow-connected to the second heat exchanger (6), and a first stream of coolant

(1), in particular of liquid and/or
gaseous nitrogen, flowing firstly through the first heat exchanger (5) and then through the second heat exchanger (6), the first stream of coolant (1) releasing a refrigeration content to the refrigeration chamber (3) and then itself being discharged to atmosphere as waste gas,
characterized in that
a second stream of coolant (2), in particular liquid and/or gaseous nitrogen, is fed to the first stream of coolant (1) downstream of the first heat exchanger (5) and upstream of the second heat exchanger (6).

2. Process according to Claim 1, **characterized in that** the cooling capacity of at least one heat exchanger (5, 6) is controlled with the aid of a fan (7).

3. Process according to Claim 2, **characterized in that** accumulations of snow on a heat exchanger (3, 4) are reduced and/or the loading space atmosphere is mixed up with the aid of pulsed operation and/or full-load operation of the fan (7).

4. Process according to Claim 1, 2 or 3, **characterized in that** one or more of the following variables (R1) to (R7)

   (R1) power of the fan (7),
   (R2) first stream of coolant (1),
   (R3) second stream of coolant (2),
   (R4) temperature of the first stream of coolant (1) at the entry to the first heat exchanger (5),
   (R5) temperature of the first stream of coolant (1) at the exit of the first heat exchanger (1),
   (R6) temperature of the second stream of coolant (2) at the entry to the second heat exchanger (6), and
   (R7) temperature of the second stream of coolant (2) at the exit of the second heat exchanger (6)

   is controlled as a function of one or more of the following variables(S1) to

   (S7)
   (S1) discharge temperature of the waste gas (8),
   (S2) ambient temperature,
   (S3) at least one temperature in the first refrigeration chamber (3),
   (S4) at least one temperature in the second refrigeration chamber (4),
   (S5) pressure in the first stream of coolant (1),
   (S6) pressure in the second stream of coolant (2), and
   (S7) duration of the opening of a door of at least one of the refrigeration chambers (1, 2).

5. Process according to one of Claims 1 to 4, **characterized in that** the first stream of coolant (1) and/or the second stream of coolant (2) flows through a phase separator (9).

6. Process according to one of Claims 1 to 5, **characterized in that** at least one of the heat exchangers (4, 5) is warmed by a heater (10) from time to time, in particular during a thawing phase or during a door-open phase, preferably for a period of from 0.01 to 1 hour, particularly preferably for a period of from 0.1 to 0.5 hour.

7. Process according to Claim 6, **characterized in that** the temperature of at least one refrigeration chamber (3, 4) is controlled with the aid of the warming, and in particular frost protection is effected in the winter.

8. Process according to one of Claims 1 to 7, **characterized in that** a thawing phase is simultaneously utilized to check the sealing and/or functioning of the cooling system.

9. Cooling apparatus for a refrigerated vehicle for cooling at least one refrigeration chamber (3, 4) of the refrigerated vehicle, comprising
   at least one reservoir (11) for a coolant, in particular for liquid nitrogen,
   at least one first heat exchanger (5) for cooling a first refrigeration chamber (3),
   at least one second heat exchanger (6), preferably for cooling a second refrigeration chamber (4), and
   at least one outlet (12) for discharging the coolant to atmosphere as waste gas (8),
   in which apparatus, with respect to the first stream of coolant (1), the reservoir (11) is flow-connected to the first heat exchanger (5), the first heat exchanger (5) is flow-connected to the second heat exchanger (6), and the second heat exchanger is flow-connected to the outlet (12),

characterized in that
a second stream of coolant (2), in particular liquid and/or gaseous nitrogen, can be fed to the first stream of coolant (1) downstream of the first heat exchanger (5) and upstream of the second heat exchanger (6).

10. Apparatus according to Claim 9, **characterized by** a fan (7) for controlling the cooling capacity of at least one heat exchanger (5, 6).

11. Apparatus according to Claim 9 or 10, **characterized by** a control means (13) for controlling at least one or more of the following variables (R1) to (R7):

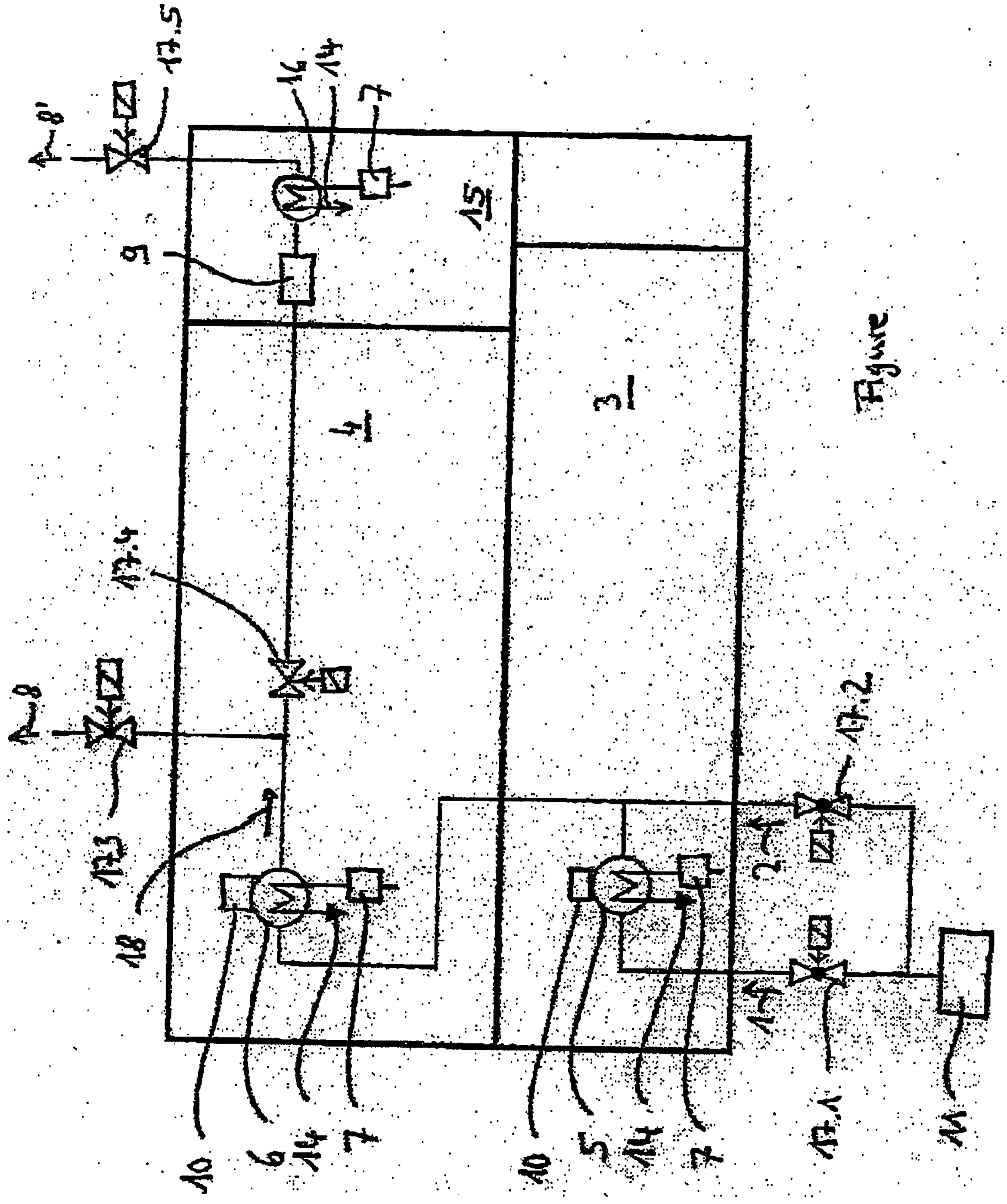
(R1) power of the fan (7),
(R2) first stream of coolant (1),
(R3) second stream of coolant (2),
(R4) temperature of the first stream of coolant (1) at the entry to the first heat exchanger (5),
(R5) temperature of the first stream of coolant (1) at the exit of the first heat exchanger (1),
(R6) temperature of the second stream of coolant (2) at the entry to the second heat exchanger (6), and
(R7) temperature of the second stream of coolant (2) at the exit of the second heat exchanger (6)

as a function of one or more of the following variables (S1) to (S7):

(S1) discharge temperature of the waste gas (8),
(S2) ambient temperature,
(S3) at least one temperature in the first refrigeration chamber (3),
(S4) at least one temperature in the second refrigeration chamber (4),
(S5) pressure in the first stream of coolant (1),
(S6) pressure in the second stream of coolant (2), and
(S7) duration of the opening of a door of at least one of the refrigeration chambers (1, 2).

12. Apparatus according to one of Claims 9 to 11, **characterized by** at least one phase separator (9) for the first stream of coolant (1) and/or the second stream of coolant (2).

13. Apparatus according to one of Claims 9 to 12, **characterized by** at least one heater (18) for at least one heat exchanger (4, 5), in particular for controlling the temperature of at least one refrigeration chamber (3, 4), preferably for frost protection in the winter.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