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(54) **CONTROL PROCESS FOR CONTROLLING THE ICING OF THE EVAPORATOR IN A BLAST CHILLER**

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graph TD
    200[START AND WAIT FOR STABILIZATION] --> 201[CONTINUOUS DETECTION OF ATD]
    201 --> 202{ATD ≥ ATDset + vtATD}
    202 -- NO --> 201
    202 -- YES --> 203[OPENING OF VALVE HGDV]
    203 --> 204[HOT GAS FLOWS INTO THE EVAPORATOR  
variable (td)]
    204 --> 205{td > td/set or  
Tc > Tc/set + vtTc}
    205 -- YES --> 206[WARNING]
    205 -- NO --> 207{ATD ≤ ATDset - 2vtATD}
    206 --> 208[CLOSING OF VALVE HGDV AND RE-START OF REFRIGERATION CYCLE]
    207 -- YES --> 208
    207 -- NO --> 203
    208 --> 200

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Fig. 3

Description

[0001] The present invention relates to a control process for controlling the icing of the evaporator, of the continuous and automatic type, in a blast chiller.

Field of the invention

[0002] The invention proposes a control process that optimizes the hot gas or electrical defrosting of the evaporator, for a modern blast chiller that operates by means of a refrigeration circuit at evaporation temperatures lower than 0°C. Therefore, the invention relates to the industrial sector of refrigeration equipment for foodstuffs, with particular reference to blast chillers and freezers for professional kitchens. As a non-exhaustive example, the proposed solution is particularly suitable for blast chillers of the cabinet type with a front closing door and with an evaporator arranged vertically inside the treatment chamber or cell. Furthermore, the invention can be applied to any apparatus for treating foodstuffs with a refrigeration circuit wherein the evaporator is subject to icing; as a non-exhaustive example, one should remember the different types of blast chillers, freezers and/or deep-freezers, of the combined type as well, for professional or residential or industrial use, or for logistics as in the case of refrigerated containers.

[0003] Modern food blast chillers are recent refrigeration machines that are widespread in professional practice in different sectors of food production since they are intended to rapidly cool a fresh or just cooked foodstuff, in combination with high ventilation, bringing it to an ideal temperature for preservation or for postponed use. Such a treatment allows to preserve the taste and the organoleptic characteristics of the product, preventing the formation of microcrystals on its inside, and performs a bacteriostatic function as it prevents bacterial proliferation in the short time of passage from the cooking temperature to a food safety temperature, for example -18°C for deep-freezing, thus enabling a long preservation of the foodstuffs in conventional equipment.

[0004] Said blast chillers are used in restaurants, for example for preserving the wholesomeness of fish to be eaten raw or for preparing in advance some foodstuffs to be served later, keeping the perceived quality of just cooked food. Furthermore, said apparatuses are used in delis, bars, pastry shops, bakeries or ice-cream parlours to safely preserve both fresh and just cooked products. In particular, the use of said blast chillers in professional activities related to food preparation has turned out to be extremely effective to prevent the proliferation of unhealthy microorganisms, to such an extent that recent regulations have imposed their use. Therefore, a wider spread of said blast chillers has recently been noticed; furthermore, ameliorative technical solutions are required with respect to the conventional and known ones.

[0005] In principle, blast chillers allow to bring the temperature at the core of the foodstuffs to +3°C in less than

90 minutes, for a so-called positive chilling for fridge preservation, or to about -18°C in less than 240 minutes for a so-called negative chilling or deep freezing, wherein the temperature inside the treatment chamber or cell gets to -45°C. In particular, in both cases, a few minutes are required to significantly reduce the cooking temperature and keep the organoleptic qualities of the just cooked food unchanged. It was also observed that a modern blast chiller can perform both positive and negative chilling. In the industrial sector of refrigeration machines for professional use many companies propose blast chillers; for example, one should remember the blast chiller named The One by the Italian company Hiber Ali Group s.r.l. - 20063 Cernusco sul Naviglio MI, which can be seen at www.hiber.it. It was then observed that, in known solutions, the conventional control and defrosting systems have some problems and can be improved; the solution proposed by the present invention relates to an advantageous control process for an evaporator subject to icing, that is to say, with evaporation temperatures lower than 0°C as it occurs in said blast chillers or blast freezers.

[0006] In further technical detail, blast chillers are refrigeration machines basically deriving from the conventional freezers or deep-freezers, in which the problem of the progressive formation of frost and ice on the evaporator, which acts as a heat exchanger between the cooling fluid flowing in the circuit and the air in the cell, according to a conventional cooling cycle of the compression - condensation - expansion - evaporation type, is widely known. Where evaporation occurs at a temperature lower than 0°C, the air that in the cell is in contact with the exchanger, having a dew point higher than 0°C, that is to say, a positive dew point, will tend to condense humidity on the surface of the evaporator itself, which will turn it first into a thin layer of frost and then into a progressively thicker layer of ice. The phenomenon of icing of the evaporator has multiple negative consequences, both on the machine and on the product in the cell; in fact, as said ice formation increases, acting as an insulator, the heat exchange and machine efficiency are progressively reduced, with greater energy consumptions and with an increase in the temperature in the cell, which may cause problems of preservation and decay of the products contained therein. In some cases, the evaporator itself may even break.

[0007] For some reasons, the companies producing blast chillers and/or freezers have tried to integrate into the apparatus automatic or semiautomatic defrosting systems, manually or time operated; basically, such defrosting systems perform one dedicated cycle of defrosting of the evaporator alternately to the ordinary blast chilling cycle. In principle, three main defrosting systems can be found: a first air system in which, upon opening the door, the refrigeration circuit is stopped and only the cell ventilation continues, a second system in which electrical resistors heat the external surface of the evaporator, or a third more evolved and technically complex system, which is called a hot gas system; in this third system the

same hot gas coming out of the compressor is diverted into a dedicated channel, which is called defrosting or by-pass line, which injects it directly into the inlet of the evaporator, without passing through the condenser, in such a way as to progressively heat it from the inside. Therefore, the innovative control process according to the present invention is intended to optimize a hot gas or electrical defrosting system.

[0008] It was also observed that the known evaporator defrosting systems have some problems that strongly limit professional activity. In particular, a complete defrosting cycle lasts some minutes and occurs when blast chilling has ended, that is to say, it does not provide the presence of foodstuffs in the cell since said defrosting cycle is alternate to the ordinary blast chilling cycle. In fact, the difficulty of keeping a low and uniform temperature in the cell when said hot gas is injected into the evaporator, for a time sufficient for complete de-icing, is widely known; therefore, in the case in which a defrosting cycle is performed during blast chilling, in the conventional modes, the blast chilling times would be excessively extended and there would be the risk of damaging the foodstuffs and/or affecting food safety. Nowadays, in order to solve this problem and allow to defrost the evaporator even during the treatment of the load, that is to say, with foodstuffs inside the cell, some specific solutions for large industrial freezers or for containers, which in particular comprise multiple evaporators are known, wherein the circuits are throttled by selectively defrosting one icy evaporator after the other. However, such an operating logic cannot be applied to professional blast chillers and freezers having one evaporator only, according to the purpose of the present invention.

[0009] It was then observed that in the conventional and known hot gas or electrical defrosting systems there is no (and is desirable) effective and reliable automatic control process able to automatically start and end the defrosting of the evaporator according to contextual needs, also during food blast chilling, guaranteeing food safety and high exchange efficiency. Nowadays, in general, defrosting control is based on pre-defined times, wherein the start of a defrosting cycle is manual or pre-set. Some more evolved solutions are also known, in which a complete defrosting cycle is automatically activated as a function of some parameters indicating the presence of ice on the evaporator; for example, it is known to use temperature sensors positioned inside the cell, in the compartment or on the surface of the evaporator, or in the foodstuff with probes at the core thereof, in such a way as to open the valve of the by-pass line if the detected temperature is higher or lower than a pre-set value, like a thermostat. Among the conventional solutions, in order to detect the presence of ice on said evaporator, it is also known to detect any variations in the operating parameters of the compressor, such as energy absorption, or optoelectronic solutions are also known in which video cameras are positioned inside the cell to directly monitor the surface of the evaporator.

[0010] All these solutions for detecting ice on the evaporator, however, proved little accurate and sometimes ineffective in professional practice due to the remarkable variability in the conditions surrounding the systems and in the detection modes; for example, one should think about the superficial temperature of the evaporator, which changes significantly not only as a function of said icing, but also as a function of the positioning of the probe along the coil and/or of the condition of the fluid on its inside, being also variable due to the particular atmospheric conditions inside and/or outside the cell. Basically, said known solutions are suitable for determining the start of a complete standard defrosting cycle at the end of a blast chilling cycle, but are inaccurate and/or unreliable, that is to say, unsuitable, when one wants to dynamically open and close said by-pass line in such a way as to prevent said ice layering on the surface of the evaporator, as is provided, on the other hand, by the present invention. In particular, the known systems based on the detection of a variable, such as the temperature in the cell or on the surface of the evaporator, do not ensure a sufficient degree of sensitivity and/or significance in order to precisely detect the particular moment of start of icing corresponding to the first frosting of the condensation depositing on the surface of the evaporator like a thin icy coat. It was thus observed that all the known defrosting control solutions, in the professional blast chillers available on the market, intervene at an advanced icing stage, that is to say, in correspondence of an already formed and rather thick ice layer, which insulates and alters heat exchange, by activating a complete defrosting cycle alternately to ordinary blast chilling. Other control systems activate time-based defrosting, that is to say, in a pre-set mode, anticipating real needs and wasting energy.

Prior art

[0011] In order to determine the prior art related to the proposed solution, a conventional search was made in patent literature, browsing public archives, which has led to some prior art documents, among which:

D1 JP2014119122 (Ishihara et al.)

D2 WO2018178405 (Albets Chico et al.)

[0012] D1 describes a cooling cycle apparatus having a hot gas by-pass line for defrosting, wherein by means of a controllable valve it is possible to adjust the flow of said hot gas in the evaporator on the basis of the overheating level and of the output saturation temperature of the evaporator.

[0013] D2, on the other hand, proposes an adaptive control method for refrigeration systems, comprising the detection of the frost level in the evaporator using an NTU (Number of Transfer Units) rate calculation method, in such a way as to define the most suitable moment for supplying the defrosting resistors, in combination with the fan of the evaporator itself; different operating modes

are provided, both with ice and ice-free. For the NTU rate calculation, the dry evaporator at the start is used as a reference, and when the refrigeration system is in operation, the NTU rate calculation is carried out with an operating mode with a variable frequency depending on the performance of the evaporator or level of ice and the comparison thereof with said reference.

[0014] Therefore, in principle, it is reasonable to consider as known, in a blast chiller, a defrosting system having a hot gas by-pass line provided with a flow adjusting valve or also a defrosting system with electrical resistors positioned in correspondence of the evaporator. Furthermore, systems are known for adjusting the speed of the evaporator fans, also in combination with resistors, in order to slow down the formation of frost and ice as well as to improve the heat exchange efficiency. Finally, processes are known for detecting and comparing the superficial temperature of the evaporator with respect to other variable parameters of the circuit, in order to determine the presence of ice and activate a defrosting cycle.

Drawbacks

[0015] It may be said that in the conventional and known solutions in which the defrosting system uses hot gas or is electrical, in blast chillers or freezers, the evaporator icing control occurs by means of complete defrosting cycles performed when the blast chilling cycle has ended, that is to say, at the end and not during ordinary use; generally, in such cases, time-based control is provided, by setting a timer, or by means of conventional thermostats or pressure switches.

[0016] Another drawback, which is related to the first one, concerns the recurring machine downtimes intended to enable the execution of said complete defrosting cycles; therefore, during such interruptions of the ordinary blast chilling cycle, the foodstuffs are removed from the cell.

[0017] Furthermore, there is the problem of a reduced efficiency in heat exchange since the evaporator progressively freezes, acting as an insulator.

[0018] Another drawback, which is related to the previous one, concerns the non-optimal use of the compressor, with high energy consumptions and limited duration.

[0019] Furthermore, there is the drawback of the formation of condensation in the cell, with the consequent problem of disposing of the water and possible risks of accidents for the operators.

[0020] It was also observed that the most evolved currently used solutions for controlling the icing of the evaporator, in a blast chiller, comprise little accurate detection and calculation methods, that is to say, unsuitable to determine in real time the progressive formation of frost and ice on the evaporator, and/or the related reduction in heat exchange between the coolant and the inside of the cell.

[0021] In particular, it was experimentally observed that all the known systems in which one directly detects the temperature on the surface of the evaporator, or the

ice level, do not provide sufficient response speed and reliability in order to continuously and dynamically activate defrosting to keep the exchange surface, if at all, covered by an icy coat that does not insulate as, on the other hand, is provided by the present invention. In fact, all the known solutions are based on parameters and calculation algorithms that provide a too slow response and/or a response that is unsuitable for the solution according to the invention, since they provide defrosting cycles with no foodstuffs in the cell. For example, in the industrial and/or commercial refrigeration sector it is known to control the icing level by continuously monitoring said superficial temperature of the evaporator, on the basis of the fact that, if said superficial temperature rises rapidly, it means that it is freezing, as the ice layer is a thermal insulator; such a detection and comparison method is delayed, for the purposes of the invention, as it is based on the effect caused by an already formed ice layer. The present invention overcomes this drawback as it does not consider the superficial temperature, but a temperature difference between the cooling fluid, for example freon, and the temperature in the cell, before the ice forms an insulating layer, then comparing such difference with pre-set reference values; it was experimentally verified that the solution proposed by the invention has the advantage of immediately and accurately determining the start of icing, that is to say, when the frost is still in a thin and non-insulating layer. Basically, the present invention anticipates the activation of the defrosting means with respect to all the known solutions, with greater accuracy and a shorter duration, in such a way as to operate during ordinary use with the foodstuffs in the cell.

[0022] Furthermore, it was observed that the conventional and known algorithms for starting the defrosting of the evaporator, in a blast chiller, process the detected temperature or pressure values with little effective calculation logics, due to the low reliability in detecting the variations of said parameters but also due to the high tolerances allowed. In particular, such detection and calculation approximations do not allow to activate the defrosting system according to actual needs, in a dynamic and automatic way, during ordinary blast chilling and with foodstuffs in the cell.

[0023] The most effective detection and calculation methods known, as for example in D1, aim at preserving the life of the compressor by controlling the condition of the gas being sucked into the compressor itself; the present invention, on the other hand, has a different aim and allows to continuously adjust the icing of the evaporator, keeping it at a controlled minimum level, and to prevent icing in the cell; in fact, the invention does not refer to an overheating condition of the compressor but accurately controls a temperature difference that is more significant than icing, such as the temperature in the cell with respect to the saturation temperature. Moreover, expensive controllable valves are not used. The calculation of said rate NTU, too, as in D2, is not sufficiently rapid

and accurate as to enable the maintenance of said controlled minimum level.

[0024] Considering these aspects as well, the need for the sector to find some more efficient and practical solutions, able to facilitate professional activity and provide greater food safety, being also cost-effective, without affecting the quality characteristics of the so treated products, is evident.

Short description

[0025] The present invention relates to a control process (20a, 20b) for controlling the icing of the evaporator (104), to optimize defrosting in a blast chiller, which operates by means of a refrigeration circuit (101-104) at evaporation temperatures lower than 0°C; it includes a Phase of detection (201) of the value ATD, equal to the difference between the air temperature in the cell (105) and the temperature of the cooling fluid, processed in the following Phases of calculation for opening (202) and closing (207) the defrosting means (106-107, 125-126) according to opening algorithms (113a-113b) and closing algorithms (114a-114d) that continuously consider the variations of said value ATD in such a way as to automatically and dynamically open them (203) and close them (208), keeping the evaporator (104) in a controlled minimum icing condition. The proposed solution is suitable for hot gas defrosting systems (106-107) or for defrosting systems with electrical resistors (125-126).

Aims and advantages

[0026] The above-disclosed solution provides many aims and advantages, which are not to be considered as limitative, it being possible to find some others that, although not mentioned, must be included anyway.

[0027] In general, the present invention allows to control in an optimized way a hot gas defrosting system or a defrosting system with electrical resistors, by basically eliminating the need for a dedicated defrosting cycle alternate to ordinary blast chilling, in order to operate rapidly and dynamically, during blast chilling, that is to say, with foodstuffs in the cell, ensuring maximum food safety. Basically, a continuous control process is provided, based on the real-time detection of multiple parameters and on the processing of data by means of algorithms intended to determine the opening and/or closing of the defrosting means only when necessary, thus minimizing the duration of defrosting. For example, in the preferred case of a hot gas defrosting system, according to said detections and algorithms, small quantities of said hot gas are allowed to automatically flow into the evaporator, like rapid injections, that is to say, micro defrosting cycles, in such a way as to keep the exchange surface in a controlled minimum icing condition that essentially corresponds to said icy coat, that is to say, a thin frost layer that does not insulate and does not affect the correct heat exchange. To this purpose, on the other hand, it is known

that such a coat can improve said heat exchange thanks to an advantageous superficial roughness.

[0028] In further detail, a first aim and advantage of the present invention consists in optimizing the opening and the closing of a hot gas or electrical defrosting system to eliminate the need for the conventional defrosting cycles, in such a way as to operate even with the foodstuffs in the cell and ensuring food safety. Basically, such an aim is achieved thanks to an effective control process for controlling the degree of icing of the evaporator, with high detection and intervention accuracy, such as to never exceed said initial frosting condition in the form of an icy coat and to obtain a blast chiller without the natural ice layer on the evaporator, that is to say, a no-frost blast chiller.

[0029] A second aim and advantage of the present invention consists in eliminating machine downtimes due to the conventional defrosting cycles, thus obtaining a continuous operation blast chiller, that is to say, a non-stop blast chiller.

[0030] A third aim and advantage of the present invention consists in obtaining greater energy efficiency and a more regular heat exchange, since the evaporator never freezes; as a consequence, one obtains energy saving as well as greater duration and operating regularity of the components of the machine, as in the case of the evaporator and of the compressor. Basically, the proposed control process for continuously controlling the icing of the evaporator makes the blast chiller highly efficient.

[0031] A fourth aim and advantage of the present invention consists in significantly reducing the formation of condensation inside the cell, with fewer water disposal problems and greater safety for the operators.

[0032] These and other aims and advantages will be clear in the following detailed embodiment description with the aid of the enclosed drawings, whose details of execution are not to be considered limitative but only illustrative.

Content of the drawings

[0033]

Figures 1 and 2 are simplified diagrams of the refrigeration circuit of a blast chiller provided with a defrosting system of the evaporator with a hot gas bypass line including a defrosting valve HGDV, being both suitable for the control process (20a, 20b) according to the present invention; said valve is connected to the control logic unit (111) provided with programs (112) for automatically performing opening and closing on the basis of the detection of variable parameters. Figure 1, in particular, refers to the preferred embodiment (10a) wherein the by-pass line comprises a discharge line (108) of the compressor with a dedicated valve, and wherein the expansion member is a capillary tube (103a); Figure 2 re-

fers to a simplified variant (10b), which is equivalent for the purpose of the invention, without said discharge line and without the probe detecting the suction pressure, and wherein the expansion member is a thermostatic valve (103b).

Figures 3 and 4 show block diagrams of the control process (20a, 20b) according to the invention, according to operating and control Phases (200-208) that are consequential and interrelated to each other; Figure 3 refers to a process (20a) in which in the Phases of calculation for opening (202) and closing (207) a first calculation logic (LC1) with the related algorithms (113a, 114a) is followed, while Figure 4 refers to a process (20b) in which in said Phases a second calculation logic (LC2) with the related algorithms (113b, 114b) is followed. Said block diagrams of the process refer to a hot gas defrosting system, as a preferred embodiment; however, they can be equally applied to an alternative electrical defrosting system in which the opening (203-204) and closing (208) refer to the current flow supplying the electrical resistors.

Figure 5 is a simplified diagram of said refrigeration circuit in another embodiment (10c) suitable for the control process (20a, 20b) proposed by the invention, wherein defrosting is performed by means of electrical resistors (125) instead of hot gas, with an opening-closing means (126) connected to said control logic unit (111), which is provided with the programs (112) for automatically switching on and off said resistors on the basis of the detection of variable parameters.

Practical realization of the invention

[0034] With reference to the schematic Figures (Figs. 1, 2, 3, 4, 5) as well, the present invention proposes an advantageous control process (20a, 20b) for controlling the degree of icing of the surface of the evaporator (104) of a blast chiller, able to optimize the opening and closing of a by-pass line (106a, 106b) of the hot gas that, coming out of the compressor (101), directly enters the evaporator (104), in a dynamic and automatic way as described below. The proposed solution allows to eliminate the conventional defrosting cycles by performing frequent and rapid injections of hot gas when required during ordinary blast chilling, with the foodstuffs in the cell (105) and in a safety condition, thus obtaining an essentially no-frost blast chiller, intended to always operate in the ordinary way during blast chilling, with no interruptions and with maximum heat exchange efficiency.

[0035] It is proposed to continuously compare at least two variable parameters, such as two temperature values, which are directly related to a cause-effect logic, considering the minimal variations in the difference. For the purpose of the invention, one considers the difference between the air temperature in the cell (105, 120, Tc) and the temperature of the cooling fluid (121-124); for

maximum detection reliability, this value is preferably detected inside the circuit and derived from a pressure value. In further detail, said temperature of the cooling fluid is advantageously obtained by measuring, by means of respective probes (121-124), one of the following variable parameters (Pe, Ps, Te, Ts) (Figs. 1, 2):

- the pressure in the evaporator (Pe), detected by means of a probe (121) at its inlet, corresponding to the gas saturation temperature (Tsat/e) in the evaporator, wherein this is the preferred way of detecting said temperature of the cooling fluid;
- the evaporation temperature (Te), detected by means of a probe (122) preferably at the inlet of the evaporator;
- the suction temperature (Ts) of the compressor, detected by means of a probe (123) at the outlet of the evaporator;
- the suction pressure (Ps) of the compressor, detected by means of a probe (124) at the outlet of the evaporator, corresponding to the gas saturation temperature (Tsat/s) in suction.

[0036] The invention proposes to set and control the degree of icing of the surface of the evaporator (104); in fact, it is sized by keeping constant a particular value defined as Approach Temperature Difference (ATD), which in the present invention is the difference between said air temperature in the cell and said temperature of the cooling fluid in the evaporator. Therefore, said ATD has a fixed and pre-set reference value (ATDset), which is calculated or measured during design in optimal conditions; when heat exchange gets worse due to the progressive icing of the evaporator (104), said value ATD tends to increase because the evaporation temperature of the cooling fluid remains constant, as it is adjusted by the expansion member (103a, 103b), while the air temperature in the cell (Tc) will tend to increase. By the proposed control process (20a, 20b), it is possible to automatically open and close the defrosting valve HGDV (107) of the hot defrosting gas on the basis of the variations of said ATD, dynamically, with extreme accuracy and effectiveness. Basically, if the detected variation of ATD exceeds a given pre-set value like a variation tolerance, said valve (107) opens; vice versa, the closing of said valve (107) is adjusted on the basis of an opposite variation of ATD, or by a maximum defrosting time or by a too high temperature increase in the cell.

[0037] It was experimentally observed that the use of said value ATD, for the purpose of the invention, is more accurate and reliable than the conventional precise detection of the air temperature in the cell or of the superficial temperature of the evaporator or of the pressure in a point of the circuit, and provides greater sensitivity in detecting any slight variation due to progressive icing, thus allowing to dynamically control said hot gas by-pass line (106a, 106b, 107), when required and not according to complete defrosting cycles. Basically, a differential ap-

proach with respect to detection is used, according to a cause-effect logic wherein the air temperature in the cell is an effect immediately caused by a cooling fluid, having known and regular characteristics inside a closed circuit, and by the interposed ice that acts as an insulator and progressively reduces heat exchange.

[0038] In further technical detail, in order to ensure the necessary accuracy and reliability in the continuous detection of the variations of said value ATD, with respect to said optimal value (ATDset) that is pre-set as a fixed reference, one uses at least one of the following modes for detecting the value ATD (ATD1, ATD2, ATD3, ATD4), which alternatively consider said variable parameters (Pe, Ps, Te, Ts) with respect to said temperature in the cell (Tc):

- $$\text{ATD1} = (Tc) - (Ts_{\text{at}}/e)$$

deriving from (Pe);

- $$\text{ATD2} = (Tc) - (Te);$$

- $$\text{ATD3} = (Tc) - (Ts_{\text{at}}/s)$$

deriving from (Ps);

- $$\text{ATD4} = (Tc) - (Ts);$$

[0039] The control process (20a, 20b) proposed by the invention includes the opening or closing of said defrosting valve HGDV (107) of the hot defrosting gas on the basis of slight variations detected in at least one of said detection modes (ATD1-ATD4) during ordinary operation, that is to say, with foodstuffs in the cell, in such a way as to avoid the complete defrosting cycles that are conventionally performed between one blast chilling cycle and the other. The duration of the de-icing of the evaporator or defrosting time (td), corresponding to the variable duration of the hot gas flow entering the evaporator, is variable on the basis of said detections (120-124, Pe, Ps, Tc, Te, Ts) and thus of said detected variations of ATD. In particular, in a first operating logic (20a, LC1) the variation of ATD is to be understood as an increase, wherein the detected value (ATD1-ATD4) is compared with a tolerated reference value (vrATD) that is pre-set as a threshold; in a second operating logic (20b, LC2), which is even more sensitive, said variation of ATD is considered in time as a growth rate or tangent, wherein the tangent (TanATD) of said detected value is compared with a tolerated reference value (vtTanATD) that is pre-set as a threshold. Said opening of the valve occurs according to opening algorithms (113a, 113b) specific to said first control logic (113a, 20a, LC1) and to said second control logic (113b, 20b, LC2).

[0040] Basically, as soon as the detected variation of

ATD exceeds the respective tolerated reference value, then the defrosting valve HGDV (107) opens the by-pass line (106a, 106b) and the hot gas flows into the evaporator for a rapid defrosting of the thin ice layer that is progressively forming on its surface; the closing of said valve HGDV can, alternatively, be determined by an opposite variation of said ATD or, for good measure, by a fixed time (td/max) equal to the maximum defrosting time, or by a too high increase in the temperature in the cell corresponding to the maximum temperature allowed (Tc/max) to prevent the foodstuffs from decaying. Said closing of the valve occurs according to closing algorithms (110a, 110b) specific to said first control logic (110a, 20a, LC1) and to said second control logic (110b, 20b, LC2).

[0041] The control process (20a, 20b) for controlling the icing of the evaporator (104), proposed by the invention (Figs. 3, 4), is for optimizing defrosting in a food blast chiller, which operates by means of a refrigeration circuit (10a, 10b) (Figs. 1, 2) at evaporation temperatures lower than 0°C and is provided with a hot gas defrosting system of the evaporator. Said defrosting system is of the type having a by-pass line (116a, 116b) wherein the hot gas coming out of the compressor (101) is diverted to be directly injected into the inlet of the evaporator (104) without passing through the condenser (102), and with at least one valve for automatically adjusting flow (106), which is called defrosting valve or HGDV, which is the acronym for hot gas duct valve, which is connected to a control logic unit (120) for controlling the whole apparatus and provided with programs (121) that also comprise said algorithms (113a, 113b, 114a, 114b) for its opening and closing, on the basis of the continuous detection of said variable parameters (Pe, Ps, Tc, Te, Ts, 120-124) and of said ATD (ATD1-ATD4).

[0042] In the preferred embodiment (10a) (Fig. 1), in order to perform the control process (20a, 20b) according to the invention, a refrigeration circuit is provided, which is equipped with a defrosting system of the type having a hot gas by-pass line (106a) including a defrosting valve HGDV (107, 111) that controls the entry thereof into the evaporator; in order to maximize the control of pressures and, as a consequence, of temperatures, a discharge line (108) of the compressor is included, having a dedicated valve (109), and an expansion member of the capillary tube type (103a). In said configuration (Fig. 1), for the purpose of said detection of ATD, all said variable parameters (Pe, Ps, Tc, Te, Ts) measured by means of the respective probes (120-124), can be advantageously detected. In a simplified variant (10b) (Fig. 2), which is equivalent for the purpose of the invention, there is a direct by-pass line (106b, 107) without said discharge line (108, 109), and there is not even the probe detecting the suction pressure of the compressor, at the outlet of the evaporator; furthermore, the expansion member is different and is a thermostatic valve (103b). Therefore, in this configuration (Fig. 2) the probe detecting the suction pressure (124, Ps) may be unreliable and is not pro-

vided.

[0043] In both said configurations (10a, 10b), in order to perform the control process (20a, 20b) according to the invention (Figs. 3, 4), said defrosting valve HGDV (107), said probe in the cell (120, Tc) and at least one of said probes (121-124) for detecting the temperature of the cooling fluid, are installed and electronically connected with said control logic unit (111), whose programs (112) also include said calculation algorithms for opening (113a, 113b) and closing (114a, 114b) said valve HGDV. Said algorithms, being used in the Phases of calculation (202, 207) of said process (20a, 20b), follow said first control logic (20a, LC1), in which the variation of ATD is assessed, or said second control logic (20b, LC2), in which the rate of said variation is further assessed, respectively, as set forth in detail below.

[0044] Therefore, the invention proposes an advantageous control process (20a, 20b) for controlling the icing of the evaporator (104) in a blast chiller of the type having a refrigeration cycle with a hot gas by-pass line (106a, 106b, 107), comprising the following Phases:

- an initial Phase of start and stabilization of the system (200);
- a Phase of detection (201) of said variable parameters (Pe, Ps, Tc, Te, Ts) measured by means of the respective probes (120-124) connected to said logic unit (111), as disclosed above, in such a way as to continuously determine said detected value of ATD (ATD1, ATD2, ATD3, ATD4) like a temperature difference, between the air in the cell and the cooling fluid, which progressively increases as the ice layer on the evaporator (104) gets thicker and, conversely, progressively decreases as it melts, getting back to an optimal value of ATD that is pre-set as a reference (ATDset);
- a Phase of calculation for opening (202) said valve HGDV (107), in which said opening algorithms are applied (113a, 113b);
- a Phase of opening (203) of said valve HGDV (107), a Phase of defrosting (204), in which the hot gas flows into the evaporator (104);
- a Phase of additional precautionary calculation (205) with an optional Phase of warning (206), if the maximum duration (td/max) planned for defrosting is reached or when the temperature in the cell (Tc) undergoes an excessive increase or exceeds a pre-set maximum temperature (Tc/max), there being a risk of food decay;
- a Phase of calculation for closing (207) said valve HGDV (107), in which said closing algorithms (114a, 114b) are applied;
- a final Phase of closing (208) of said valve HGDV (107).

[0045] In particular, in said Phases of calculation for opening (202) and closing (207) said valve HGDV (107) one continuously processes the detected value of ATD

(ATD1, ATD2, ATD3, ATD4), which comes from the previous Phase of detection (201) and is progressively variable, according to said opening algorithms (113a, 113b) and closing algorithms (114a, 114b) in such a way as to open (203) and close (208) said valve HGDV (107) during ordinary operation, that is to say, with foodstuffs in the cell (105), keeping the evaporator (104) in a controlled minimum icing condition in which there is, if at all, a frost coat that does not affect heat exchange. Said opening algorithms (202, 113a-113b) activate the injection of hot gas (106a, 106b, 107, 203) into the evaporator (104) as soon as ice starts forming on top of said coat, acting as a thermal insulator that immediately changes said value ATD, while said closing algorithms (202, 114a-114b) interrupt said injection in correspondence of an opposite variation, considering both during opening (202-203, 113a-113b) and during closing (207-208, 114a-114b) a suitable variation tolerance.

[0046] In further detail as to said Phase of calculation for opening (202), said detected value ATD (201, ATD1-ATD4) is assessed according to a first opening algorithm (20a, 113a, LC1) or to a second opening algorithm (20b, 113b, LC2), as set forth below. Said first algorithm (113a) considers the increase in ATD and provides opening when the detected value is greater than or equal to the pre-set optimal value (ATDset) plus a tolerated variation (vtATD) or deviation, thus applying one of the following cases on the basis of said detected parameters (Pe, Ps, Te, Ts):

- $ATD1 \geq ATDset + vtATD$;
- $ATD2 \geq ATDset + vtATD$;
- $ATD3 \geq ATDset + vtATD$;
- $ATD4 \geq ATDset + vtATD$.

[0047] Said second algorithm (113b), on the other hand, assesses the growth rate, that is to say, considers said variation of ATD over time, calculating with greater sensitivity said opening, that is to say, when the tangent of the detected value (TanATD) is higher than or equal to the pre-set optimal value of said rate (TanATDset) plus a tolerated variation (vtATD):

- $TanATD \geq TanATDset$.

[0048] On the other hand, in further detail as to said Phase of calculation for closing (207), said detected value ATD is assessed according to a first closing algorithm (20a, 114a, LC1) or to a second closing algorithm (20b, 114b, LC2), as set forth below. Said first algorithm (114a) considers the decrease in ATD and provides closing when the detected value is lower than or equal to the pre-set optimal value (ATDset) minus twice said tolerated variation (vtATD), which here is increased to allow a margin for ordinary operativeness during blast chilling, and wherein said twofold subtraction indicates a preferred but not limitative value, thus applying one of the following cases on the basis of said detected parameters (Pe, Ps,

Te, Ts):

- $ATD1 \leq ATDset - 2vtATD$;
- $ATD2 \leq ATDset - 2vtATD$;
- $ATD3 \leq ATDset - 2vtATD$;
- $ATD4 \leq ATDset - 2vtATD$.

[0049] Said second algorithm (114b), on the other hand, considers the slowdown in the variation of ATD and provides closing when the tangent of the detected value (TanATD) is lower than the pre-set optimal value (TanATDset) minus a tolerated variation (vtTanATD):

- $TanATD < TanATDset - vtTanATD$.

[0050] The proposed control process (20a, 20b), in both said calculation logics (LC1, LC2), for good measure, also includes the start of said Phase of closing (208) of the valve HGDV (107) when a pre-set maximum duration of the Phase of defrosting (204) is exceeded, that it to say, when in a Phase of precautionary calculation (205):

- $td > td/set$.

[0051] Furthermore, said control process (20a, 20b) in both said calculation logics (LC1, LC2), for good measure, also includes the start of said Phase of closing (208) of the valve HGDV (107) when an excessive increase in the temperature in the cell (105) is detected, that is to say, when in a Phase of precautionary calculation (205) the detected temperature (Tc, 120) is greater than a pre-set optimal temperature (Tc/set) plus a tolerated variation (vtTc):

- $Tc > Tc/set + vtTc$.

[0052] It was thus observed in practice that the proposed control process (20a, 20b), performed as set forth above (200-208), optimizes the defrosting of the evaporator in said blast chillers operating at evaporation temperatures lower than 0°C, to such an extent as to make machine downtimes for performing defrosting cycles essentially useless, since the defrosting valve is opened and closed in such a rapid and accurate way as to actually keep the evaporator in a controlled minimum icing condition in which heat exchange remains optimal or close to an optimal condition.

[0053] As an alternative to said hot gas defrosting system of the evaporator (10a, 10b) (Figs. 1-4), the invention provides an equivalent electrical defrosting system (10c) (Fig. 5), which does not include said by-pass line but comprises at least one electrical resistor (125) or a group of electrical resistors, in correspondence of the evaporator (104), with an opening-closing means (126) of the power supply of the resistors, and thus of defrosting, which is connected to the control logic unit (111) provided with the same programs (112) described above, which

in this case automatically switch on and off said electrical resistors on the basis of the detection of the same variable parameters described above, by the same detection means (120-123) and by means of the same calculation logics.

[0054] Basically, said electrical defrosting system (10c) is automatically controlled by a control process equivalent to the one described above (20a, 20b, 201-208, LCI-LC2) wherein, instead of adjusting the hot gas flow by opening (203, 204) and closing (208) said valve HGDV, the flow of electric current supplying the resistor (125) is controlled. This occurs by means of a suitable opening-closing means (126) that switches it on and/or off like a circuit breaker, advantageously exploiting the intrinsic activation speed and the thermal inertia of said resistors, in such a way as to dynamically start and end a Phase of electrical defrosting (204) during ordinary operation, that is to say, with foodstuffs in the cell, keeping the evaporator (104) in a controlled minimum icing condition corresponding to a frost coat that does not thermally insulate.

Reference

[0055]

(10a, 10b) refrigeration circuit of a blast chiller with a hot gas defrosting system, according to the present invention, comprising a hot gas by-pass line adjusted by an opening-closing means (107) of the valve HGDV type, connected to the logic unit (111, 112). In the preferred configuration (10a, 106a) there is a discharge line of the compressor, with a dedicated valve; in a simplified variant (10b, 106b), equivalent for the purpose of the invention, there is no discharge line and the expansion member is different.

(10c) refrigeration circuit of a blast chiller, according to the previous invention, in the alternative variant with a defrosting system with electrical resistors (125) and an opening-closing means (126) connected to the logic unit (111, 112);

(101) compressor;

(102) condenser;

(103a, 103b) expansion member, which in the preferred configuration (10a) is a capillary tube (103a), while in the simplified variant (10b) it is a thermostatic valve (103b);

(104) evaporator;

(105) refrigerated cell for the treatment of foodstuffs;

(106a, 106b) hot gas by-pass line, in the preferred configuration (10a, 106a) with a discharge line of the compressor, and in the equivalent simplified variant (10b, 106b) with no discharge line, respectively;

(107) opening-closing means of the defrosting valve or HGDV type, for adjusting the flow in the by-pass line in a hot gas defrosting system;

(108) optional discharge line of the compressor;

(109) opening and closing valve of the optional dis-

charge line of the compressor;
 (110) flow direction;
 (111) control logic unit of the machine and of its components;
 (112) programs for operation and control, comprising the calculation algorithms for opening and closing the valve HGDV for the purpose of the invention;
 (113a) opening algorithms, for the first control logic;
 (113b) opening algorithms, for the second control logic;
 (114a) closing algorithms, for the first control logic;
 (114b) closing algorithms, for the second control logic;
 (120, 121, 122, 123, 124) probes for detecting temperature (Tc, Te, Ts) and pressure (Pe, Ps);
 (125) electrical resistor, single or in groups, for defrosting the evaporator;
 (126) opening-closing means, of the circuit breaker type, of the electric current in a defrosting system with electrical resistors;
 (20a, 20b) control process for controlling the icing of the evaporator, of the continuous and automatic type, according to the present invention. Said process comprises some Phases (200-208);
 (200) initial Phase of start and stabilization of the system;
 (201) Phase of detection of the variable parameters, such as temperature and pressure, for determining the detected value ATD;
 (202) Phase of calculation for opening the opening-closing means (107, 126), according to opening algorithms diversified according to a first (113a, LC1) or to a second (113b, LC2) control logic;
 (LC2) second control logic;
 (203) Phase of opening of the opening-closing means (107, 126);
 (204) Phase of defrosting;
 (205) Phase of precautionary calculation;
 (206) optional Phase of warning;
 (207) Phase of calculation for closing the opening-closing means (107, 126) according to closing algorithms diversified according to a first (114a, LC1) or to a second (114b, LC2) control logic;
 (208) Phase of closing of the opening-closing means (107, 126);
 (ATD) acronym for Approach Temperature Difference, which in the present invention is the detected difference between the air temperature in the cell and the temperature of the cooling fluid in the evaporator;
 (ATD1) in a first embodiment is equal to: $T_c - T_{sat}/e$ (Pe);
 (ATD2) in a second embodiment is equal to: $T_c - T_e$;
 (ATD3) in a third embodiment is equal to: $T_c - T_s$;
 (ATD4) in a fourth embodiment is equal to: $T_c - T_{sat}/s$ (Ps);
 (ATDset) pre-set ATD value, for example amounting to 8°C;

(LC1) first control logic, in which the increase in ATD is considered;
 (LC2) second control logic, in which the growth rate of ATD is considered; (Pe) pressure of the cooling fluid in the evaporator, at inlet (121);
 (Ps) pressure of the cooling fluid in suction (124);
 (td) duration of defrosting, variable time during which the hot gas flows in the evaporator, according to needs;
 (td/set) pre-set maximum defrosting time;
 (TanATD) tangent of ATD or growth rate;
 (Tc) air temperature in the cell (120);
 (Tc/set) maximum temperature in the cell, pre-set for food safety or load decay;
 (Te) temperature of the cooling fluid in the evaporator, at inlet (122);
 (Ts) suction temperature of the cooling fluid (123);
 (Tsat/e) saturation temperature of the cooling fluid in the evaporator, obtainable with accuracy from (121, Pe);
 (Tsat/s) saturation temperature of the cooling fluid in suction, obtainable with accuracy from (124, Ps);
 (vtATD) tolerated variation of the increase in ATD;
 (vtTanATD) tolerated variation of the tangent of ATD;
 (vtTc) maximum variation of the temperature in the cell;
 (vt/d) tolerated variation in the defrosting duration, with respect to the pre-set optimal value (td/set).

Claims

1. Control process (20a, 20b) for controlling the icing of the evaporator (104), of the continuous and automatic type, to optimize defrosting in a food blast chiller, which works by means of a refrigeration circuit (10a, 10b, 10c, 101-104) at evaporation temperatures lower than 0°C and is provided with a defrosting system of the evaporator, with at least one opening-closing means (107, 126) of the defrosting system connected to a control logic unit (111) provided with programs (112) for automatically performing said opening and said closing on the basis of the detection of variable parameters, such as temperature; said defrosting system being alternatively of the hot gas type (10a, 10b, 106-107) or of the electrical type with resistors (10c, 125-126); and wherein, in case of a hot gas defrosting system (10a 10b), a by-pass line (106a, 106b) is provided in which the hot gas coming out of the compressor (101) is diverted to be directly injected into the inlet of the evaporator (104) without passing through the condenser (102), and wherein the opening-closing means is a valve for adjusting the hot gas flow, of the defrosting valve type or HGDV (107); and wherein, on the other hand, in case of an electrical defrosting system (10c), at least one electrical resistor (125) is provided near the evaporator (104), with an opening-closing means (126) that is

intended to control the electric current supplied to said resistor (125), by turning it on and/or off like a circuit breaker; said control process (20a, 20b) comprising an initial Phase of start (200) and stabilization of the system, a Phase of detection (201) of said variable parameters by means of probes connected to said logic unit (111), a Phase of calculation for opening (202) said opening-closing means (107, 126), a Phase of opening (203) of said opening-closing means (107, 126), a Phase of defrosting (204) in which defrosting takes places by means of said hot gas flowing into the evaporator (104, 106-107) or by means of the electric current flowing into said resistor (125, 126), a Phase of additional precautionary calculation (205) with an optional Phase of warning (206), a Phase of calculation for closing (207) said opening-closing means (107, 126) and a final Phase of closing (208) of said opening-closing means (107, 126); said control process (20a, 20b) being **characterised in that** in said Phase of detection (201) the air temperature (TC) in the cell (105) and the temperature of the cooling fluid in the evaporator (104) are continuously detected, comparing them with each other to obtain a detected value ATD - which is the acronym for Approach Temperature Difference - which corresponds to the difference (ATD1, ATD2, ATD3 or ATD4) between said air temperature in the cell (120) and said temperature of said cooling fluid (121-124) obtained with at least one of the following parameters:

- the pressure in the evaporator (Pe), detected by means of a probe (121) at its inlet, corresponding to the gas saturation temperature (Tsat/e) in the evaporator, wherein ATD1 is equal to (Tc) minus (Tsat/e) derived from (Pe);
- the evaporation temperature (Te), detected by means of a probe (122) preferably at the inlet of the evaporator, wherein ATD2 is equal to (Tc) minus (Te);
- the suction temperature (Ts) of the compressor, detected by means of a probe (123) at the outlet of the evaporator, wherein ATD3 is equal to (Tc) minus (Ts);
- the suction pressure (Ps) of the compressor, detected by means of a probe (124) at the outlet of the evaporator, corresponding to the gas saturation temperature (Tsat/s) in suction, wherein ATD4 is equal to (Tc) minus (Tsat/s) derived from (Ps);

said control process (20a, 20b), wherein in a first calculation logic (20a, LC1) the detected variation of ATD (201, ATD1-ATD4) is an increase, continuously assessed according to related opening (113a, 202) and closing algorithms (114a, 207), or wherein in a second calculation logic (20b, LC2) said detected variation of ATD is a rising speed, continuously as-

essed according to related opening (113b, 202) and closing algorithms (114b, 207); and wherein in said Phases of calculation for opening (202) and for closing (207) said opening-closing means (107, 126) the detected values of ATD (201, ATD1-ATD4) are processed according to said opening algorithms (113a-113b, 202) and closing algorithms (114a-114b, 207), which are intended to automatically open (203) and close (208) said opening-closing means (107, 126) in such a way as to dynamically start and end the Phase of defrosting (204) during the ordinary operation, with food in the cell, keeping the evaporator (104) in a controlled minimum icing state corresponding to a thin layer of frost that does not provide thermal insulation; and wherein said opening algorithms (113a-113b, 202), in said Phase of opening (203), automatically open said opening-closing means (107, 126) in correspondence of a positive variation of ATD due to the ice that begins to be formed above said thin layer acting as thermal insulation; and wherein said closing algorithms (114a-114b, 207), in said Phase of closing (208), automatically close said opening-closing means (107, 126) in correspondence of an opposite variation of ATD due to the melting of said ice; said opening (113a-113b, 202) and closing algorithms (114a-114b, 207) considering a tolerated value of variation (vtATD, vtTanATD) with respect to a pre-set optimal value (ATDset, TanATDset), like a margin for the ordinary operativeness of the refrigeration circuit (101-104, 111-112); said algorithms (113a, 113b, 114a, 114b) being included in said programs (112) of said control logic (111) of the blast chiller.

2. Control process (20a) according to claim 1, **characterised in that**, according to said first calculation logic (LC1), said Phase of opening (203) is started as soon as the opening algorithm (113a, 202) calculates that the detected value ATD (201) is higher than or equal to the pre-set optimal value (ATDset) plus a tolerated variation (vtATD), thus applying one of the following cases according to the detected parameters (Pe, Ps, Te, Ts):

- $ATD1 \geq ATDset + vtATD$;
- $ATD2 \geq ATDset + vtATD$;
- $ATD3 \geq ATDset + vtATD$;
- $ATD4 \geq ATDset + vtATD$.

3. Control process (20a) according to the previous claim, **characterised in that** said Phase of closing (208) is started as soon as the closing algorithm (114a, 202) calculates that the detected value ATD (201) is lower than or equal to the pre-set optimal value (ATDset) minus twice said tolerated variation (vtATD), thus applying one of the following cases according to the detected parameters (Pe, Ps, Te, Ts):

- $ATD1 \leq ATDset - 2vtATD$;
- $ATD2 \leq ATDset - 2vtATD$;
- $ATD3 \leq ATDset - 2vtATD$;
- $ATD4 \leq ATDset - 2vtATD$.

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4. Control process (20b) according to claim 1, **characterised in that**, according to said second calculation logic (LC2), said Phase of opening (203) is started as soon as the opening algorithm (113b) calculates that the tangent (TanATD) of the detected value ATD (201) is higher than or equal to a pre-set optimal value for said tangent (TanATDset):

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- $TanATD \geq TanATDset$.

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5. Control process (20b) according to the previous claim, **characterised in that** said Phase of closing (208) is started as soon as the closing algorithm (114b) calculates that said tangent (TanATD) of the detected value ATD (201) is lower than said pre-set optimal value (TanATDset) minus a tolerated variation (vtTanATD):

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- $TanATD < TanATDset - vtTanATD$.

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6. Control process (20a, 20b) according to claim 1, **characterised in that** said Phase of closing (208) of said opening-closing means (107, 126) is started when in a Phase of precautionary calculation (205) the maximum duration in the Phase of defrosting (204) is exceeded, that is to say, when:

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- $td > td/set$;

and wherein said Phase of closing (208) is also started when in said Phase of precautionary calculation (205) there is an excessive increase in the temperature in the cell (105), that is to say, when the detected temperature (Tc, 120) is higher than a pre-set optimal temperature (Tc/set) plus a tolerated variation (vtTc):

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- $Tc > Tc/set + vtTc$.

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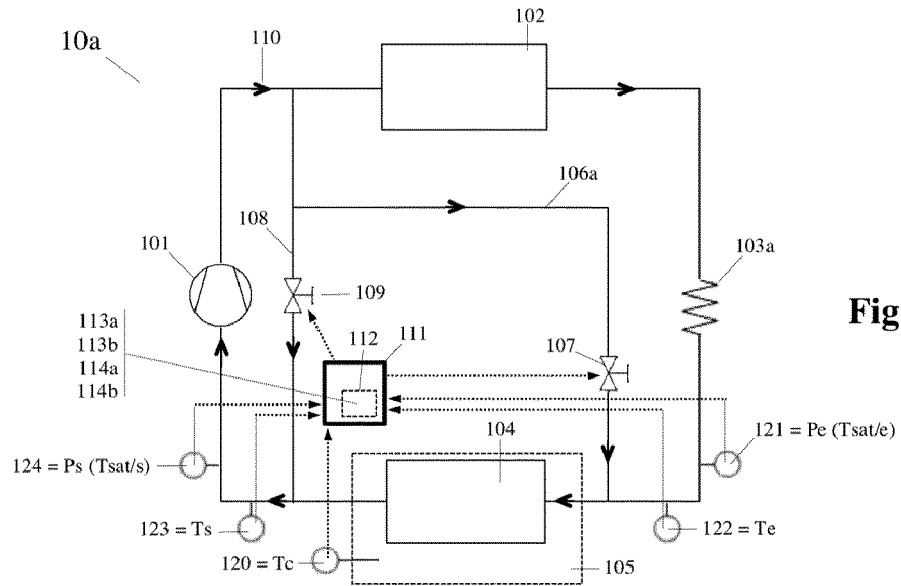


Fig. 1

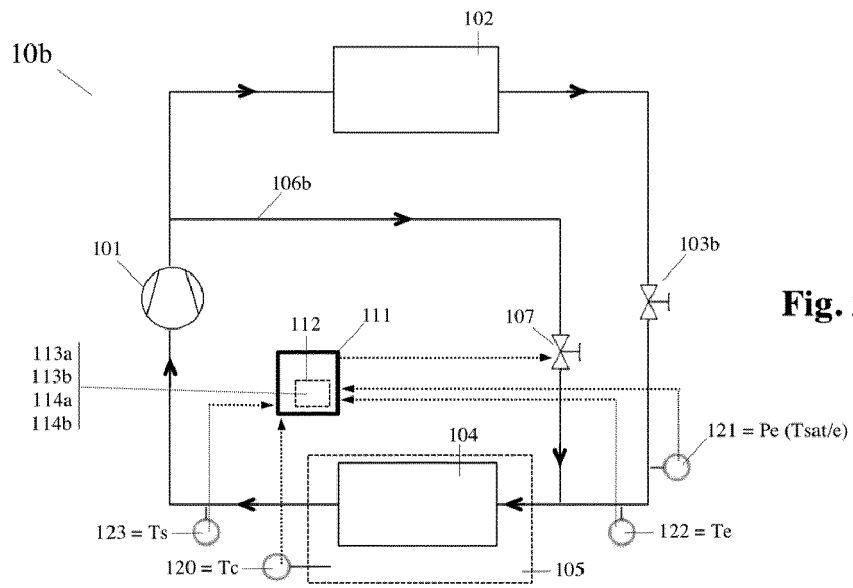


Fig. 2

20a

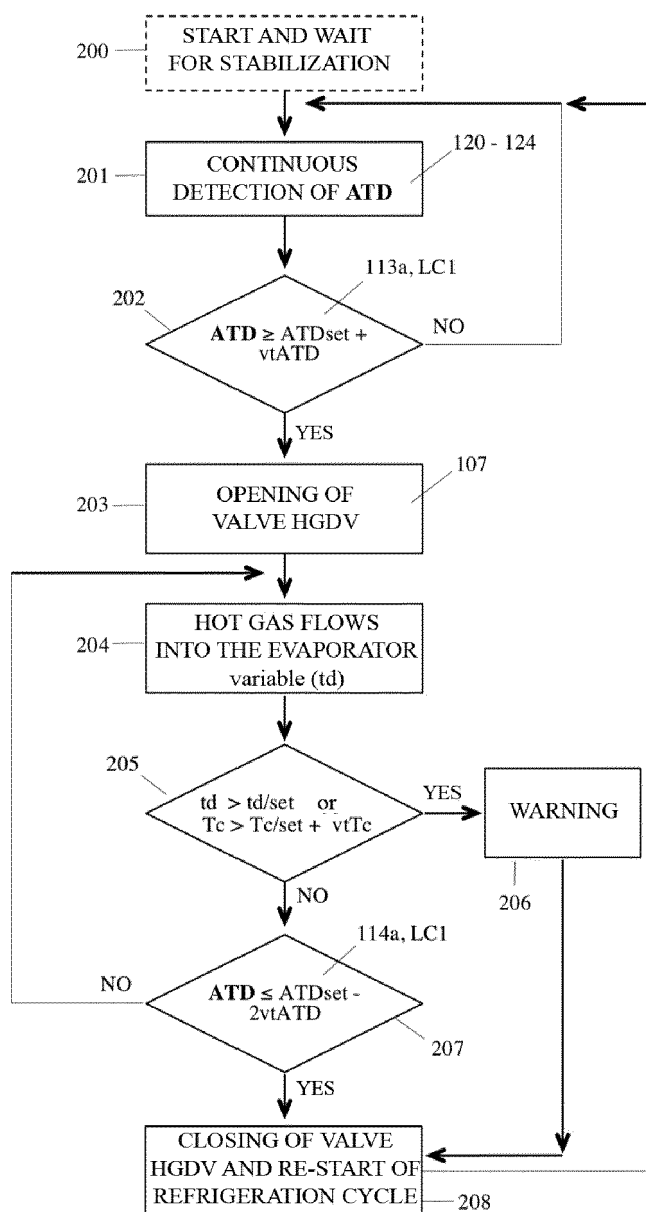


Fig. 3

20b

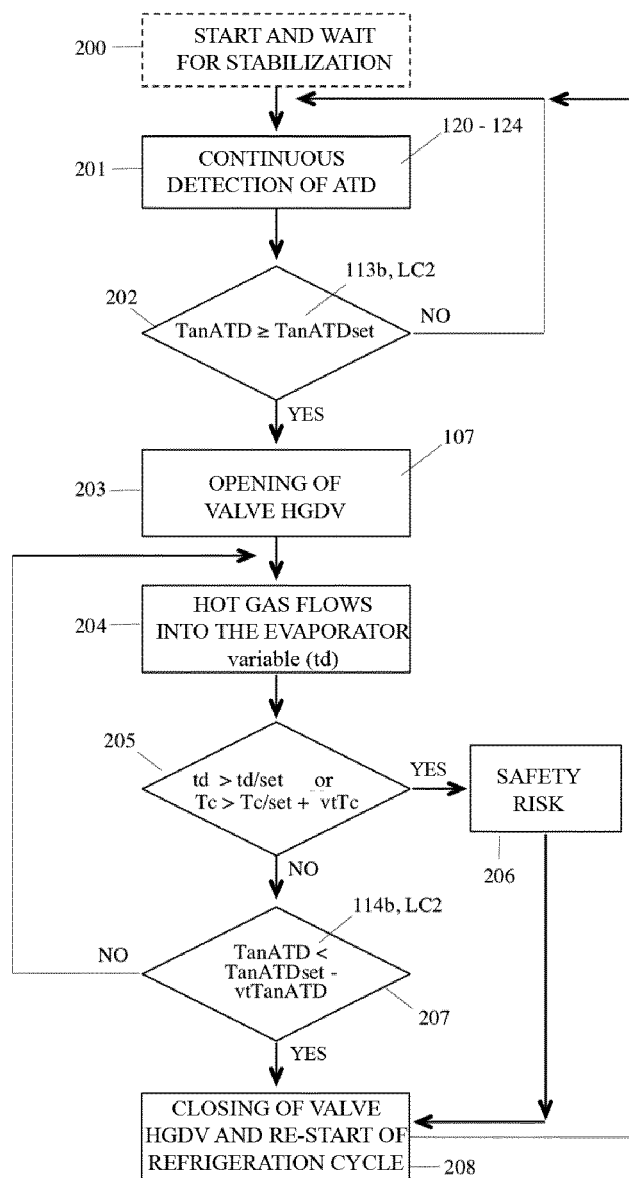


Fig. 4

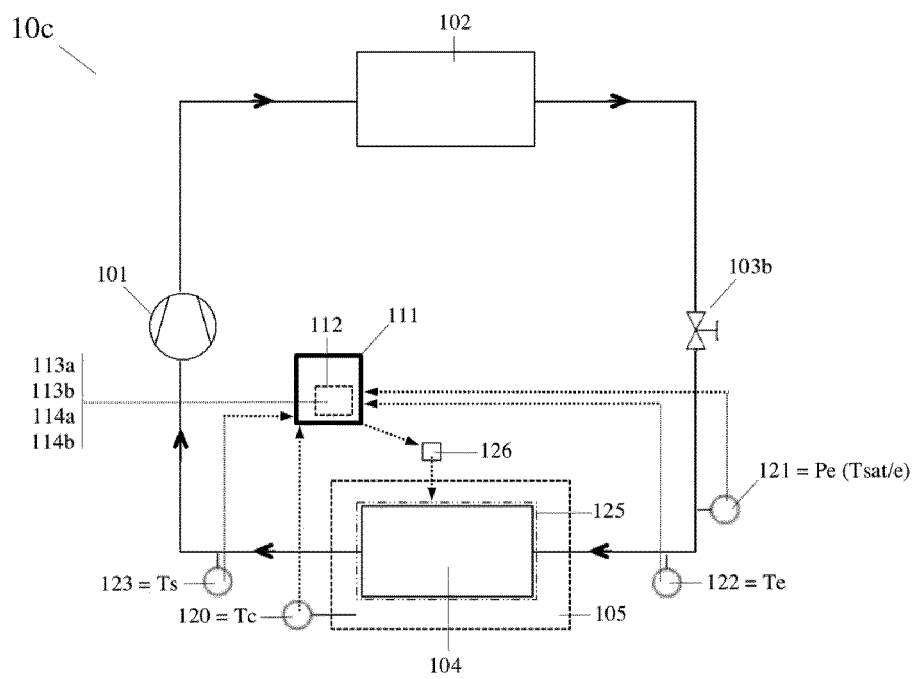


Fig. 5



EUROPEAN SEARCH REPORT

Application Number
EP 20 02 0177

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			F25D F25B
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 26 August 2020	Examiner Bidet, Sébastien
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background 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 D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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