The invention relates to a method for determining thermal profiles of products leaving a cryogenic cooling installation, said method consisting of: a step (18) for determining a validity value and/or a range of validity values for operating parameters of the installation, forming a modulable set of operating parameters; a step (20) for simulating the operation of the installation on the basis of thermodynamic and physical characteristics of the enclosure (2) and the products (A) and on the basis of regulating parameters of the installation, in order to obtain a complete set of operating parameters including regulating parameters and characteristic quantities of the operation of the installation, said simulation step (20) providing a thermal profile of the products (A) treated, which includes at least one temperature at the surface and one temperature at the centre of the products; and a cycle (30) for the automatic repetition of the simulation step (20) for all of the authorised values of the operating parameters of the modulable set, in order to obtain a complete set of operating parameters for each simulation, forming an operation mapping of the installation.
METHOD FOR DETERMINING THERMAL PROFILES OF FOOD PRODUCTS LEAVING A CRYOGENIC INSTALLATION, AND CORRESPONDING COOLING INSTALLATION

[0001] The present invention relates to a method for determining (predicting) the thermal profiles of products, particularly food products, leaving a cryogenic apparatus and to a corresponding cooling installation.

[0002] The invention applies in particular to installations for the deep-freezing of food items.

[0003] Known installations for the deep-freezing of food items comprise, for example, a cryogenic deep-freezing chamber or tunnel right through which there passes a belt conveyor on which the items for freezing are placed, the conveyor running continuously or sequentially through the deep-freezing tunnel.

[0004] Such a cryogenic chamber uses an inert fluid at low temperature which exchanges heat directly by contact with the items that are to be deep-frozen.

[0005] Conventionally, the fluid used as a carrier for the cold is dry ice (−80°C), liquid air or liquid nitrogen (−196°C). Dry ice allows fresh or deep-frozen products to be transported without fear of breaking the cold chain. Liquid air and nitrogen allow either individual deep-freezing of food products or the hardening of fragile, deformable or sticky (of the ice cream, etc. type) products.

[0006] The set of operating parameters of the installations is commonly known as a recipe and is defined experimentally. A recipe comprises the setting parameters for setting an installation for a given production run and magnitudes characteristic of the operation and in particular of the item exit temperature.

[0007] If the system made up of the chamber and of the load of items is examined, there are several parameters that can influence the temperature of the items as they leave: the production rate which, for a given level of load, involves a variation in the residence time in the chamber, the flow rate of fluid which has an influence on the temperature profile, the temperature at which the items enter, the convective profile of the chamber, and the fill level.

[0008] The system is therefore a multi-variable system and the existing methods for determining parameters require complex calculations.

[0009] The methods used to determine recipes generally comprise a step of automatically simulating the operation of the installation on the basis of the thermodynamic and physical characteristics of the chamber and of the items and on the basis of the setting parameters in order to obtain a complete set of operating parameters comprising setting parameters and magnitudes characteristic of the operation of the installation.

[0010] This simulation step is repeated manually, updating some of the parameters empirically and on the basis of the operator's experience in order to define one or more operating recipes which will then be validated and adjusted through destructive tests and trials.

[0011] It is therefore evident that the recipes determined using the conventional determination methods require experienced operators and destructive trials.

[0012] Thus, a limited number of recipes is determined and, if the production conditions vary, the user of the installation has only very little autonomy and has to confine himself to empirical corrections validated by destructive testing.

[0013] The present invention sets out to remedy these problems by proposing a method for determining (predicting) thermal profiles of products, particularly food products, leaving a cryogenic apparatus.

[0014] To this end, the subject of the invention is a method for determining thermal profiles of items, particularly food items, leaving a cryogenic cooling installation, the installation comprising a processing chamber through which said items pass between an inlet and an outlet and using a cryogenic cooling fluid, this method comprising:

[0015] a step of determining a validity value and/or a range of validity values for operating parameters of the installation, forming an updatable set of operating parameters;

[0016] a step of simulating the operation of the installation on the basis of thermodynamic and physical characteristics of the chamber and of the items and of installation setting parameters in order to obtain a complete set of operating parameters comprising setting parameters and magnitudes characteristic of the operation of the installation, said simulation step delivering a thermal profile of the processed items comprising at least a surface temperature and a core temperature of these items;

[0017] a cycle of automatically repeating the simulation step for all the authorized values of the operating parameters in the updatable set so as to obtain, for each simulation, a complete set of operating parameters forming a map of the operation of the installation.

[0018] According to other features:

[0019] said simulation step delivers a thermal profile of the temperatures within said processing chamber;

[0020] said automatic repetition cycle comprises a step of logging each complete set of operating parameters delivered by said simulation step, in a data structure, so as to form said operating map;

[0021] said automatic repetition cycle involves, on each iteration, a step of automatically updating one or several operating parameters of said updatable set of operating parameters;

[0022] said step of determining said updatable set is designed to automatically limit the magnitude of said ranges of validity values according to the hardware resources available for implementing said method;

[0023] it further comprises:

[0024] a step of determining a datum value and/or a range of datum values for operating parameters forming a set of datum values; and

[0025] a step of automatically comparing said set of datum values with said operating map of the installation in order to obtain one or more complete sets of operating parameters comprising setting parameters and magnitudes characteristic of the operation of the
installation, this or these complete set(s) of parameters comprising said set of datum values;

[0026] said step of determining said set of datum values is designed to automatically determine at least one datum value on the basis of physical measurements;

[0027] said automatic comparison step involves interpolating between complete sets of operating parameters forming said map in order to deliver at least one complete set of operating parameters comprising said set of datum values;

[0028] it further comprises a step of automatically determining an optimum complete set of operating parameters from among the complete set or sets of operating parameters delivered by said automatic comparison step.

[0029] Another subject of the invention is an installation for the thermo cooling of items comprising a processing chamber through which said items pass between an inlet and an outlet and using a cooling fluid, comprising at least means for controlling its operation associated with data-storage means, characterized in that said storage means comprise a map of the operation of said installation which map is determined using a method as described hereinabove and in that said installation is designed to implement a method for determining operating parameters as described hereinabove.

[0030] According to still other features of this installation:

[0031] it further comprises means for measuring operating parameters so as to determine all or some of the set of datum values as determined during implementation of the method;

[0032] it comprises man-machine interface means for determining all or some of the set of datum values as determined during implementation of the method.

[0033] The invention will be better understood from reading the description which will follow, given solely by way of example and made with reference to the attached drawings in which:

[0034] FIG. 1 depicts a block diagram illustrating a cooling installation;

[0035] FIG. 2a is a flowchart of a first part of the method of the invention; and

[0036] FIG. 2b is a flowchart of a second part of the method of the invention.

[0037] FIG. 1 depicts a conventional installation for processing food items, for which the operating parameters are determined using a method according to the invention.

[0038] This installation comprises a cryogenic chamber or tunnel 2 of the conventional type, for freezing food items A by bringing them into the presence of a cryogenic fluid 4 carried by a supply line 5, from any source.

[0039] For example, the chamber 2 has the shape of a rectangular parallelepiped.

[0040] As stated previously, the cryogenic fluid 4 used may, for example, be dry ice or liquid nitrogen and is injected at various points in the chamber 2.

[0041] This chamber 2 is associated with a conveyor 6 of a conventional type, allowing the items A to be introduced into the chamber 2 and extracted therefrom and operating either sequentially or continuously.

[0042] In the embodiment described, the installation comprises means 8 of measuring operating parameters these means being produced, for example, in the form of two infrared sensors 8a and 8b positioned one at the inlet and one at the outlet of the chamber 2 so as to obtain an estimate of the change in temperature of the items A.

[0043] Furthermore, the installation comprises means 10 for controlling its operation.

[0044] These means comprise a module 12 for controlling the flow rate of cryogenic fluid 4. For example, the control module 12 consists of systems of electrically operated valves or proportional valves of a conventional type, positioned on the supply line 5 supplying the cryogenic fluid 4.

[0045] According to the invention, the installation also comprises, in the means 10 for controlling its operation, a man-machine interface module 14 for determining operating parameters, data storage means formed of a storage unit 15, in this instance of the hard disk type, and a correction module 16 connected to the sensors 8a and 8b, to the module 14 and to the unit 15.

[0046] The installation has several setting parameters, namely the profile of the temperatures in the chamber, the residence time of the items in the chamber 2 or the speed at which the conveyor 6 runs and the temperature at which the items A enter.

[0047] Advantageously, the installation also comprises a gas ventilation system controlling the streams of gas and the ventilation of the atmosphere in the chamber 2 and the means 10 are able to monitor these.

[0048] For example, the ventilation system is made up of special-purpose fans allowing the gases to be brought up to speed, of fans controlling the recirculation of gases and a combination of fans and moving doors controlling the balance between the air inlets and the gas outlets.

[0049] In such an embodiment, the operating parameters also include setting parameters concerning the ventilation system, the control of intermediate partitions, etc.

[0050] The installation described also has magnitudes characteristic of its operation, such as the exit core and/or surface temperature of the items A, the fluid 4 consumption or the change in enthalpy of the items A.

[0051] A general flowchart of the method according to the invention will now be described with reference to FIGS. 2a and 2b.

[0052] This method first of all involves a step 18 of determining a validity value and/or a range of validity values for the operating parameters forming an updatable set of operating parameters.

[0053] An operator may thus manually define validity ranges for some of the operating parameters of the installation that form the updatable set. For example, this step allows the manual definition of an initial temperature range for the items A to be processed, ranging from +90° C. to −5° C., a final stabilized range of temperatures for the items,
ranging from +90°C to -50°C, a chamber regulation temperature range ranging from -20°C to -140°C, a residence time for the items A in the chamber 2 ranging from 200 to 400 seconds, and a load level for the conveyor belt 6 ranging from 50 to 60%.

[0054] The step 18 also allows a step interval for covering the ranges of validity of each parameter in the updatable set to be determined.

[0055] The operating parameters for which a validity range is determined during step 18 may be setting parameters of the installation and magnitudes characteristic of the operation and particularly the temperature of the items A leaving the chamber 2.

[0056] Some of the operating parameters of the installation are fixed automatically and are invariable, such as, for example, the operating parameters resulting from the nature of the items A and from the nature of the installation, namely, for example, the enthalpy capacity of the items A, the dimensions of the chamber 2 or alternatively the nature of the cryogenic fluid 4 used.

[0057] Advantageously, depending on the calculation means available for implementing the method, the step 18 is designed to automatically limit the magnitude of the ranges of validity values, so as to limit the amount of calculation to be performed.

[0058] For example, this automatic limiting is performed on the basis of the time available and the processing speed of the processor implementing the method of the invention and on the basis of the updatable set.

[0059] Of course, certain operating parameters may be fixed at an invariable value during this step 18.

[0060] The method then comprises a step 20 of simulating the operation of the installation on the basis of the thermodynamic and physical characteristics of the chamber 2 and of the items A to be processed, and on the basis of setting parameters in order to obtain a complete set of operating parameters comprising setting parameters and magnitudes characteristic of the operation of the installation.

[0061] This step 20 is performed by automatic calculating devices such as computers, neural networks or the like.

[0062] In particular it makes it possible, on the basis of the setting parameters for the installation and the thermodynamic and physical characteristics of the items A and of the chamber 2, to obtain magnitudes characteristic of the operation of the installation and, in particular, a prediction of the temperature of the items A leaving the chamber 2.

[0063] In the embodiment described, this simulation step 20 delivers the profile of the temperatures within the chamber 2 and, on the basis of that, the thermal profile of the processed items and therefore their surface temperature and their core temperature (from all that, it is then possible to deduce a mean temperature within the products).

[0064] The results delivered on completion of this simulation step 20 are logged during a memory-recording step 22, in the form of a matrix or any other data structure, collating all of the operating parameters, namely setting parameters and magnitudes characteristic of operation.

[0065] The method then comprises a step 24 of testing the operating parameters in order to determine whether all the combinations allowed for the updatable set as determined in step 18 have been implemented.

[0066] If all the operating parameters are within the ranges of validity, the method then involves a step 26 of updating the operating parameters one by one on the basis of the increment intervals and validity ranges determined during step 18.

[0067] The parameters are therefore updated in succession, individually or in groups.

[0068] The method thus comprises a cycle 30 of automatically repeating the simulation step 20 comprising the simulation step 20, logging step 22, test step 24 and updating step 26. The cycle 30 allows the simulation step 20 to be performed automatically for all the combinations of allowable values of operating parameters contained within the updatable step defined during step 18.

[0069] The automatic repetition cycle 30 is interrupted when the test step 24 detects that all the combinations have been implemented by the simulation step 20. For example, the test step 24 detects that all the operating parameters of the updatable set have reached their extreme value.

[0070] All the complete sets of operating parameters obtained at the end of the automatic repetition cycle 30 are thus stored in memory in a data structure and form an operations map listing a substantial number of operating points.

[0071] In the light of the calculation resources and the time needed to perform the repetition cycle 30, it is preferable to perform these steps of the method as a background task.

[0072] For example, these steps are implemented when an installation is ordered from the supplier so that the operating map is delivered at the same time as the thermal cooling installation.

[0073] Of course, a different operating map needs to be different for each installation and for each type of item to be processed.

[0074] The method as described therefore makes it possible automatically to obtain an operating map of an installation for a type of item such that an operator can easily manually determine what corrections have to be made to a set of recycling parameters in order to adapt it to variations in the operator conditions by consulting this map.

[0075] The determining of such corrections may also be performed automatically using a second part of the method described with reference to FIG. 2b.

[0076] This part of the method may be implemented directly after the part described with reference to FIG. 2a, or alternatively, may be implemented later, for example, when a thermal cooling installation requiring adjustment of the operating parameters is to be used.

[0077] This second part of the method involves a step 40 of determining a datum value and/or a range of datum values for operating parameters of the installation to form a set of datum values.
[0078] For example, during this step 40, an operator manually defines the datum value or range of values for operating parameters of the installation such as, for example, the fill level of the conveyor belt 6, or the residence time in the chamber 2.

[0079] During this step 40, an operator may for example determine strict datum values for operating parameters that he does not wish to update and wider ranges of values for operating parameters that he wishes to vary.

[0080] Advantageously, certain datum values are determined by experimental measurement. For example, infrared sensors can be used to measure the initial temperatures of the items that need to be processed.

[0081] The method then involves a step 42 of automatically comparing the set of datum values defined during step 40 with the operating map delivered at the end of the automatic repetition cycle 30 in order to obtain one or more complete sets of operating parameters containing the set of datum values.

[0082] This automatic comparison step 42 is based on a compilation of the data structure comprising the operating map on the basis of the set of datum values and is implemented by conventional database processing means such as computers, calculation processes and neural networks.

[0083] Advantageously, this step 42 involves interpolating between the matrices that make up the operating map so as to result in a complete set of operating parameters containing all the datum values.

[0084] The method of the invention therefore delivers, on completion of step 42, one or more set(s) of operating parameters containing the set of datum values.

[0085] Advantageously, the method finally comprises a step 44 of automatically determining an optimum set of operating parameters on the basis of the set or sets of operating parameters delivered at the end of the comparison step 42.

[0086] For example, this step 44 is designed to take account of information regarding efficiency, cost or energy consumption so as to determine whether one of the complete sets of operating parameters is advantageous over the others.

[0087] This second part of the method of the invention thus makes it possible automatically to determine a set of operating parameters that is able to be adapted to suit variations in the operating conditions.

[0088] For example, if for any reason the temperature of the items entering the chamber 2 is higher than anticipated, the operator can determine strict datum values for the item inlet and outlet temperatures and a wider datum value on the flow rate of fluid to be injected into the chamber 2 so as, on completion of step 42 and advantageously step 44, to obtain a complete set of operating parameters containing the inlet and outlet temperatures of the items as specified and a fluid flow rate tailored to carrying out the processing operation.

[0089] The method of the invention can be implemented by one or more computer programs or any other suitable software means executed by computing devices such as computers.

[0090] In particular, the method of the invention can be implemented by two different computer programs, the first program comprising code instructions designed for implementing the first part of the method as described with reference to 2a, involving the step 18 of determining the updatable set of operating parameters and the cycle 30 for repeating the simulation step 20. Such a program makes it possible automatically to obtain an operating map as defined hereinabove.

[0091] A second computer program for determining operating parameters then comprises code instructions designed to implement at least steps 40 of determining the set of datum values and step 42 of automatically comparing the set of datum values with the operating map so as to deliver one or more complete sets of operating parameters containing all the datum values. Advantageously, this program is also able to implement the aforementioned step 44.

[0092] These two computer programs can be run at distant and mutually independent sites, for example the first being run at the site of the manufacture of the installation and the second at the site where the installation is being used.

[0093] Thus, the method of the invention can be implemented by an installation for the thermal cooling of items, such as the installation described with reference to FIG. 1.

[0094] In this installation, the unit 15 allows access to an operating map obtained by virtue of the method of the invention as described with reference to FIG. 2a, and, for example, in the form of a database.

[0095] In this installation, the man-machine interface module 14 allows the step 40 of determining a set of datum values by an operator to be performed.

[0096] In the embodiment described, the step 40 of determining a set of datum values is also performed through the sensors 8a and 8b which respectively deliver estimates of the inlet and outlet temperatures of the items, forming datum values.

[0097] The correction module 16 or, alternatively, a computer program stored on a storage support accessible via the unit 15, is designed to implement the automatic comparison step 42 and advantageously the step 44 of automatically determining a complete set of optimum operation parameters.

[0098] Implementing the method of the invention thus makes it possible to obtain at least one set of operating parameters containing all the datum values.

[0099] The correction module 16 then compares this set of parameters with the parameters used in the installation so as to determine the corrections to be made particularly to the installation setting parameters.

[0100] Furthermore, the corrections may be applied automatically by the module 16 for example to the module 12 that controls the flow rate of cryogenic fluid 4.

[0101] It is therefore evident that the installation comprising an operating map obtained by virtue of the first part of the method of the invention and designed for implementing the second part of the method of the invention makes it possible easily and automatically to determine the corrections to be made to the installation operating parameters in order to conform to a set of datum values.
13. A method for determining thermal profiles of items (A), particularly food items, leaving a cryogenic cooling installation, the installation comprising a processing chamber (2) through which said items (A) pass between an inlet and an outlet and using a cryogenic cooling fluid (4), this method comprising:

a step (18) of determining a validity value and/or a range of validity values for operating parameters of the installation, forming an updatable set of operating parameters;

a step (20) of simulating the operation of the installation on the basis of thermodynamic and physical characteristics of the chamber (2) and of the items (A) and of installation setting parameters in order to obtain a complete set of operating parameters comprising setting parameters and magnitudes characteristic of the operation of the installation, said simulation step (20) delivering a thermal profile of the processed items (A) comprising at least a surface temperature and a core temperature of these items;

a cycle (30) of automatically repeating the simulation step (20) for all the authorized values of the operating parameters in the updatable set so as to obtain, for each simulation, a complete set of operating parameters forming a map of the operation of the installation.

14. The method of claim 13, characterized in that said simulation step (20) delivers a thermal profile of the temperatures within said processing chamber (2).

15. The method of claim 13, characterized in that said automatic repetition cycle (30) comprises a step (22) of logging each complete set of operating parameters delivered by said simulation step (20), in a data structure, so as to form said operating map.

16. The method of claim 13, characterized in that said automatic repetition cycle (30) involves, on each iteration, a step (26) of automatically updating one or several operating parameters of said updatable set of operating parameters.

17. The method of claim 13, characterized in that said step (18) of determining said updatable set is designed to automatically limit the magnitude of said ranges of validity values according to the hardware resources available for implementing said method.

18. The method of claim 13, characterized in that it further comprises:

a step (40) of determining a datum value and/or a range of datum values for operating parameters forming a set of datum values; and

a step (42) of automatically comparing said set of datum values with said operating map of the installation in order to obtain one or more complete sets of operating parameters comprising setting parameters and magnitudes characteristic of the operation of the installation, this or these complete set(s) of parameters comprising said set of datum values.

19. The method of claim 18, characterized in that said step (40) of determining said set of datum values is designed to automatically determine at least one datum value on the basis of physical measurements.

20. The method of claim 18, characterized in that said automatic comparison step (42) involves interpolating between complete sets of operating parameters forming said map in order to deliver at least one complete set of operating parameters comprising said set of datum values.

21. The method of claim 18, characterized in that it further comprises a step (44) of automatically determining an optimum complete set of operating parameters from among the complete set or sets of operating parameters delivered by said automatic comparison step (42).

22. An installation for the thermo cooling of items (A) comprising a processing chamber (2) through which said items (A) pass between an inlet and an outlet and using a cooling fluid (4), comprising at least means (10) for controlling its operation associated with data-storage means (15), characterized in that said storage means (15) comprise a map of the operation of said installation which map is determined using a method as claimed in any one of claims 1 to 5 and in that said installation is designed to implement a method for determining operating parameters of claim 18.

23. The installation of claim 22, characterized in that it further comprises means (8) for measuring operating parameters so as to determine all or some of the set of datum values as determined during implementation of the method of claim 18.

24. The installation of claim 22, characterized in that it comprises man-machine interface means (14) for determining all or some of the set of datum values as determined during implementation of the method of claim 18.