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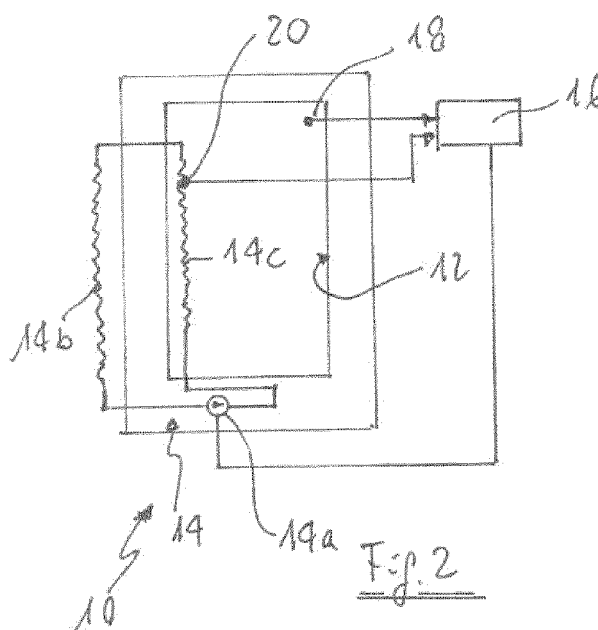
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(54) **Method for controlling a domestic refrigeration appliance**

(57) A method for controlling a domestic refrigeration appliance comprising an evaporator, a first temperature sensor placed in the cavity of the refrigeration appliance and a second temperature sensor placed on the evaporator, comprises estimating the amount of frost on the

evaporator on the basis of an integral over time of the difference between the temperature of the cavity and the temperature of the evaporator and performing a defrost cycle when the above integral is above a predetermined threshold value.



Description

[0001] The present invention relates to a method for controlling a domestic refrigeration appliance comprising a heat exchanger, a first temperature sensor placed in a cavity of the refrigeration appliance and a second temperature sensor placed on or in the proximity of the heat exchanger.

[0002] The present invention relates to a refrigeration appliance as well. With the term refrigeration appliance we mean every kind of refrigerator which has one or more cavities for food conservation. It includes either refrigerators having only one cavity (fresh food refrigerator or freezer) or refrigerators having multiple cavities and multiple evaporators, either direct cool or no frost. It also includes refrigerators using electrovalves for controlling the working of evaporators, particularly when two or more evaporators (sued for different cavities) are placed in series.

[0003] Refrigerator cavity (known also as compartment), when provided with dedicated evaporator, needs to be defrosted during operating cycles in order to prevent from frost built-up (especially over the evaporator, causing a decay in refrigeration performances). Such operation requires the entire amount of frost and ice present in the cavity to melt and collect in a dedicated water tray, typically located outside the appliance.

[0004] During the melting phase, the cooling circuit of the refrigerator has to be kept OFF and therefore temperature in the cavity rises up. If the melting phase lasts for a long time, that causes a reduction in food preservation performance (temperature increase with growth of bacterial activity and food degradation).

[0005] Moreover, to maintain the average temperature of the cavity close to the set-point selected by the user, each temperature rise-up phase is followed by an over-cooling phase. If, during the over-cooling phase, temperature in the cavity falls down below 0°C, ice crystal formation within food stuff can cause tissue damage and juice loss.

[0006] It appears clear that, the more frequent the defrosting action takes place, the worse the level of food preservation within compartment is.

[0007] For freezer compartments, similar type of drawbacks can be found as well, even if less severe. Differently from the "fresh food" case, the effect of temperature fluctuation on frozen food is less perceivable than on unfrozen food, and moreover defrost is usually performed seldom. Conversely, since an active defrosting method is usually applied (i.e. a defrost carried out with a heater), each defrost occurrence has a large impact on energy consumption performances. The evaluation of the need of a defrosting action shall optimize energy consumption and performances.

[0008] For refrigerator compartments, considering that fresh food cavity temperature is supposed to be above 0°C, it is usually not necessary to use active means to perform defrost (such as an electrical heater, a heat loop or mechanical way to remove frost). Most common solution is to leave air to circulate, by natural convection, over the evaporator area, where frost is usually collected.

[0009] The end of the defrost phase is typically determined by using the measure of one or more temperature probes. One solution is to measure the evaporator temperature (by mean of a probe attached on its surface, in its colder point) and let the cooling circuit to switch ON only when the temperature has overcome a pre-determined threshold. This is shown in figure 1 which refers to a fresh food compartment with a set temperature of about 8°C and an amplitude of the cavity temperature oscillation of 3,7°C. In this known solution at each single cycle evaporator temperature measured by a probe has to reach a threshold value in order to guarantee a proper defrost of the evaporator. If the threshold is a constant value, the lower is the temperature set-point (selected by user), the higher are the temperature fluctuations in the cavity.

[0010] Being an open-loop control, this known method doesn't allow good performances in terms of temperature set-point following, it is not responsive to different operating conditions and it is unable to manage the effects of different actuators in the refrigeration circuit (compressor, electrovalve, fans) in order to obtain best energy performances.

[0011] Furthermore, if the defrost is performed at each single operating cycle with an open loop control system (i.e. every time the refrigerator compartment is in OFF phase, temperature has to reach the pre-determined threshold before reactivation), with no feedback on real frost amount, both the cycling frequency and the cycling amplitude are impacted, with negative results on food preservation.

[0012] For freezer compartments, defrost need is usually determined in open loop as well, with a temperature probe or a bimetal attached on the evaporator to evaluate the end of the defrosting phase.

[0013] Feedback from doors opening sensors can be provided in the known control method, to apply correction to the pre-determined time-span between two defrost phases.

[0014] Among known methods of controlling defrost, US 6715304 discloses a method for assessing the defrost delay time on the basis of the load, such load being assessed from the load of the evaporator fan. KR 2011007334 discloses an integration of time during the normal working of the refrigerator, but only for assessing the duration of defrost period.

[0015] It is an object of the present invention to provide a method to evaluate the real need of defrost, preventing from performing defrost too frequently and contemporarily granting excellent robustness from frost accumulation.

[0016] Another object according to the invention is to provide a refrigeration appliance with improved performances either in terms of low energy consumption and better food preservation.

[0017] The above objects are reached thanks to the features listed in the attached claims.

[0018] One of the main features according to the invention is the adoption of a closed loop criteria to evaluate when a defrost phase in refrigerator or freezer compartment is really required by frost formation. It can be applied to each refrigerating appliance, irrespective of the type of cooling circuit which is dedicated to remove heat from the cavity (i.e.: vapor compressor circuit with any type of compressor, magnetic refrigerator, Stirling cycles, thermoelectric cooling devices, etc.). The only condition required is that at least two temperatures probes shall be present, one located on the heat exchanger device (hereinafter referred to as "evaporator", even if it can be replaced by different types of heat exchangers, depending on the cooling technology) and one located within the refrigerated compartment.

[0019] Amount of frost on the evaporator surface is evaluated through a simple frost estimator, hereinafter referred to as "Defrost_counter", proportional to the integral over a selected time-span of the temperature difference among the values measured by the two probes.

$$\text{Defrost_counter} = \int_0^t (T_{RC} - T_{RC_{\text{evap}}})$$

[0020] Where T_{RC} is the temperature measured in the cavity and $T_{RC_{\text{evap}}}$ is the temperature of the evaporator. Defrost_counter is measured in degree Celsius multiplied by second.

[0021] This value is calculated at each sampling time and compared with a pre-determined threshold value, hereinafter referred to as "Defrost_max_counter". Once Defrost_counter is higher than Defrost_max_counter, there is evidence of frost accumulation over the heat exchanger and a defrost cycle is performed. Different defrosting methods are feasible: natural convection of air at a temperature over than 0°C on the evaporator, active removal of ice by mechanical methods, melting of frost by usage of various heaters (electrical, heat loops, etc.).

[0022] The threshold Defrost_max_counter has to be calibrated considering the particular appliance and the typical operating conditions, in order to grant that, once it is reached, the maximum amount of frost without any significant decay in performance has been accumulated on the heat exchanger surface.

[0023] The relationship between the integral over the selected time-span (corresponding to the period in which the maximum amount of frost affordable has been accumulated over the heat exchanger) of the difference between the temperature of the cavity and the temperature of the evaporator is proportional to the average of the cooling capacity provided to the appliance in the same period. The higher the cooling capacity provided, the faster is the frost formation process: by making use of the method according to the invention, an automatic compensation is provided in closed loop to any external interference (door opening, warm load insertion, etc.), adjusting the interval between two following defrosting actions.

[0024] Further advantages and features according to the present invention will be clear from the following detailed description, provided as a non-limiting example, with reference to the attached drawings in which:

- Figure 1 is a diagram showing temperature vs. time of temperature signal coming from temperature probes on evaporator and in the cavity according to a current defrost process in a direct cooling refrigerator;
- Figure 2 is a schematic view of a refrigerator according to the invention;
- Figure 3 is a diagram showing temperature vs. time of temperature signal coming from temperature probes shown in figure 1;
- Figure 4 is a diagram where temperature behavior of the evaporator is shown, particularly in connection with an adaptive defrost phase;
- Figure 5 shows the integral vs. time of the difference between the above two temperatures; and
- Figure 6 is a block diagram of the defrost control system according to the invention.

[0025] With reference to the drawings, with 10 it is indicated a direct cool refrigerator having a fresh food cavity 12 closed by a door (not shown). The refrigerator 10 comprises a cooling circuit 14 having a compressor 14a, a condenser 14b and an evaporator 14c. It further comprises a control process unit 16 connected to the compressor 14a and to temperature sensors, particularly a temperature sensor 18 in the cavity 12 and a temperature sensor 20 on the evaporator 14c. The control process unit can be also linked to different sensors or actuators as well.

[0026] Figure 3 shows an experimental diagram of how temperatures of the sensor 18 and sensor 14c change over time. In this diagram the amplitude of the temperature oscillation within the fresh food compartment is around 0,1°C (set point of 8°C). This is mainly due to the fact that control is free to enable evaporator cooling phase even if temperature measured by the probe 20 is below the threshold value. Figure 5 shows the integral of the difference between the above temperatures vs. time.

[0027] The control process unit 16 is designed for measuring Defrost_counter, i.e. the integral of the temperature difference between the values given by sensor 18 and sensor 20, giving an indication of the real thermal load absorbed

by the evaporator 14c, providing an useful estimation of the frost amount over it. It is measured in degree Celsius multiplied by second, and indirectly provides a feedback about the time distance between two subsequent defrost: next defrost should happen when the estimated ice formation overcomes a defined threshold value Defrost_counter_max. That can be a single fixed value or it can be adaptive, changing between one minimum value and one maximum value.

[0028] In case it is a single value, Defrost_counter_max is fixed and corresponds to the measured value of Defrost_counter after 72 hours in energy consumption test conditions. This time-span is determined by the present normative as the maximum duration of an energy consumption test in no-frost appliances, where the start and stop of the test phase are identified by two defrost phases. Reaching this condition, in standard working mode, allows reaching

the best performance level. During a dedicated test campaign, the value of $\int_0^t (T_{RC} - T_{RC_{evap}})$ is measured at the end of a standard energy consumption test lasting 72 h without defrost, and Defrost_counter_max is evaluated as follows:

$$\text{Defrost_counter_max} = \int_0^{72h} (T_{RC} - T_{RC_{evap}})$$

[0029] Figure 4 shows how the temperature of the evaporator varies when the condition to carry out defrost is reached, i.e. evaporator temperature is allowed to reach a value (4,5°C in the example) which guarantees a complete melting of frost.

[0030] The method according to the invention may be represented in the block diagram of figure 6. Defrost_counter_max can be adaptive. In this case, it is required to provide a calibration law, thanks to which it is possible to adapt the maximum distance between two subsequent defrost to several operating conditions. By consequence, additional input parameters are required by control algorithm, in order to assess how to change the value of Defrost_counter_max: they can be represented by time counters (compressor ON phase, electrovalve ON phase, time between two compressor ON phases, etc.) or temperature measures, as well as by electrical values (power absorption, etc.).

[0031] Using the calibration method according to the invention, the need of a defrost cycle is assessed in close loop, basing on frost formation estimation. During a standard energy consumption test, the differences compared to standard open loop method can be less significant, especially in case of no frost appliances, where defrost already occurs every 72 hours. Differences compared with actual solutions are more evident in case of direct cooled evaporators, where defrost is usually performed every single compressor ON/OFF cycle, particularly when used in fresh food compartment. In any case, the possibility to have a feedback in closed loop allows reacting in more reliable way to any external noise or action, performing defrost only when amount of ice is over the acceptable limit: differences with actual technical solutions are much more visible during operating conditions, when customer usage involves door openings, temperature setting variation, hot food insertion and sudden changes in thermal load.

Claims

1. Method for controlling a domestic refrigeration appliance (10) comprising a heat exchanger (14c), a first temperature sensor (18) placed in the cavity (12) of the refrigeration appliance (10) and a second temperature sensor (20) placed on or in the proximity of the heat exchanger (14c), **characterized in that** it comprises estimating the amount of frost on the heat exchanger (14c) on the basis of an integral over time of the difference between the temperature of the cavity (12) and the temperature of the heat exchanger (14c), and performing a defrost cycle when the above integral is above a predetermined threshold value.
2. Method according to claim 1, wherein said predetermined threshold value is the integral of the difference between the temperature of the cavity (12) and the temperature of the heat exchanger (14c) at a predetermined time span.
3. Method according to claim 2, wherein said predetermined time span is around 72 hours.
4. Method according to claim 1, wherein the predetermined threshold value is assessed on the basis of a plurality of parameters, including time counters of compressor ON phase, electrovalve ON phase, time between two compressor ON phases, temperature measures, and electrical parameters.
5. Method according to any of the preceding claims, wherein the heat exchanger is an evaporator (14c).

6. Refrigeration appliance (10) comprising a heat exchanger (14c), a first temperature sensor (18) placed in the cavity (12) of the refrigeration appliance (10), a second temperature sensor (20) placed on or in the proximity of the heat exchanger (14c) and a control process unit (16) for controlling the operation of the refrigeration appliance (10), **characterized in that** the control process unit (16) is adapted to estimate the amount of frost on the heat exchanger (14c) on the basis of an integral over time of the difference between the temperature of the cavity (12) and the temperature of the heat exchanger (14c), and to perform a defrost cycle when the above integral is above a pre-determined threshold value.
7. Refrigeration appliance according to claim 6, wherein said cavity (12) is a fresh food compartment.
8. Refrigeration appliance according to claim 4, wherein said cavity (12) is a freezer compartment.
9. Refrigeration appliance according to any of claims 6-8, wherein the heat exchanger is an evaporator (14c).

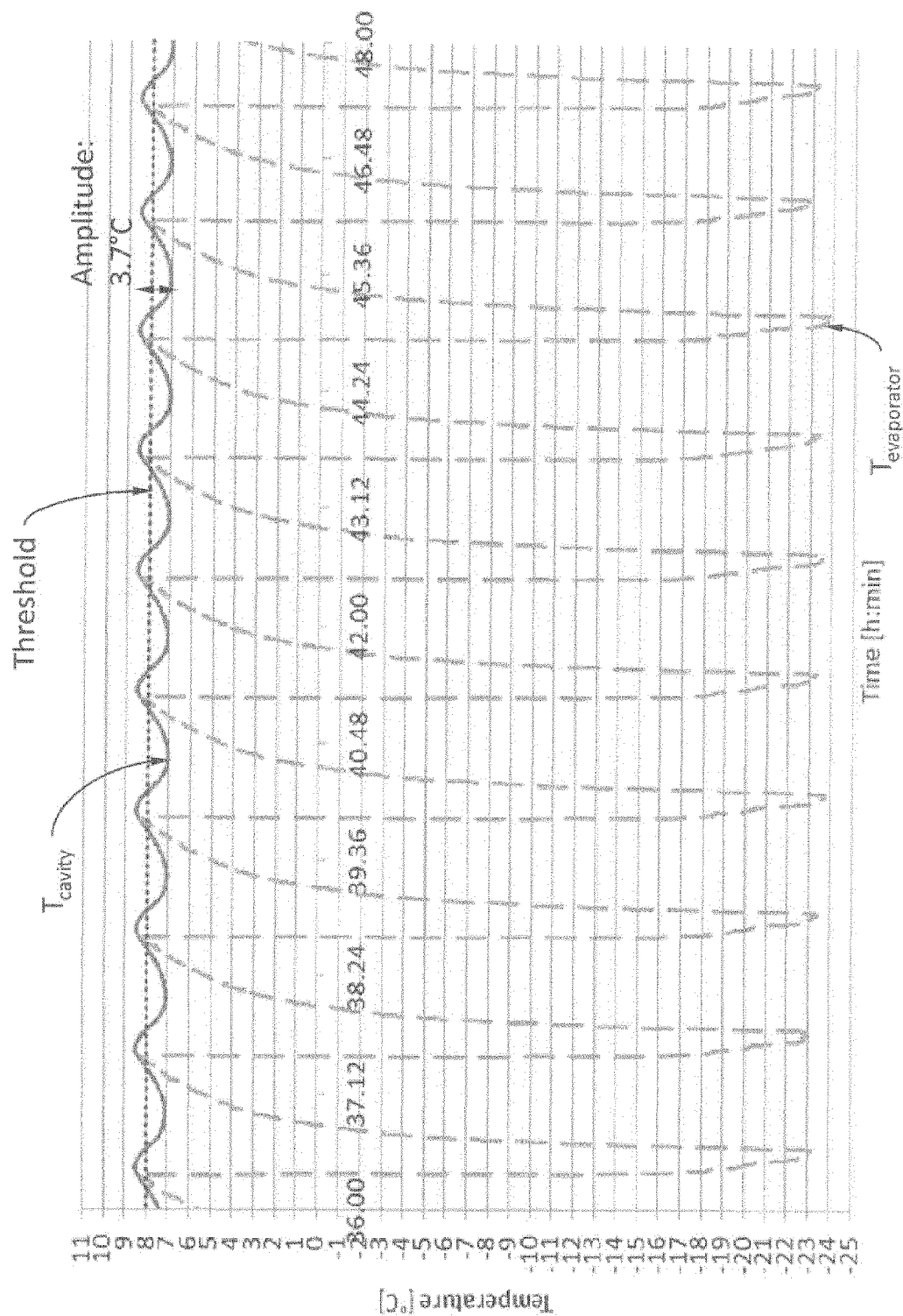
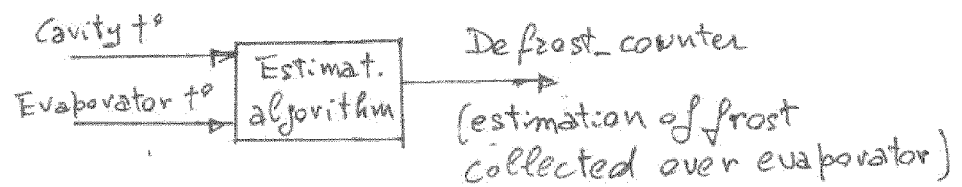
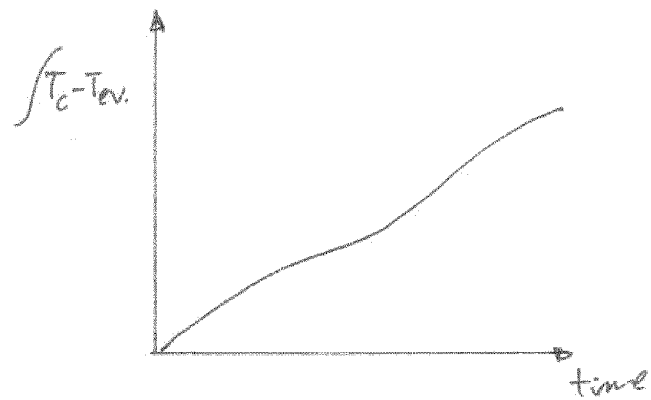
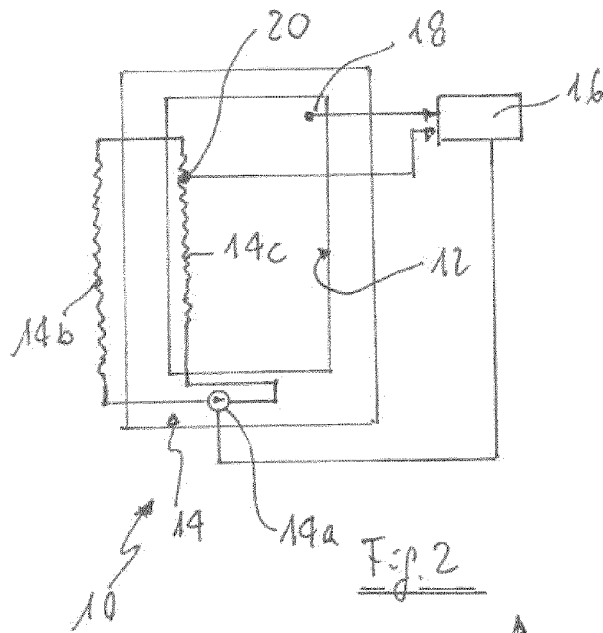


Fig. 1 (PRIOR ART)



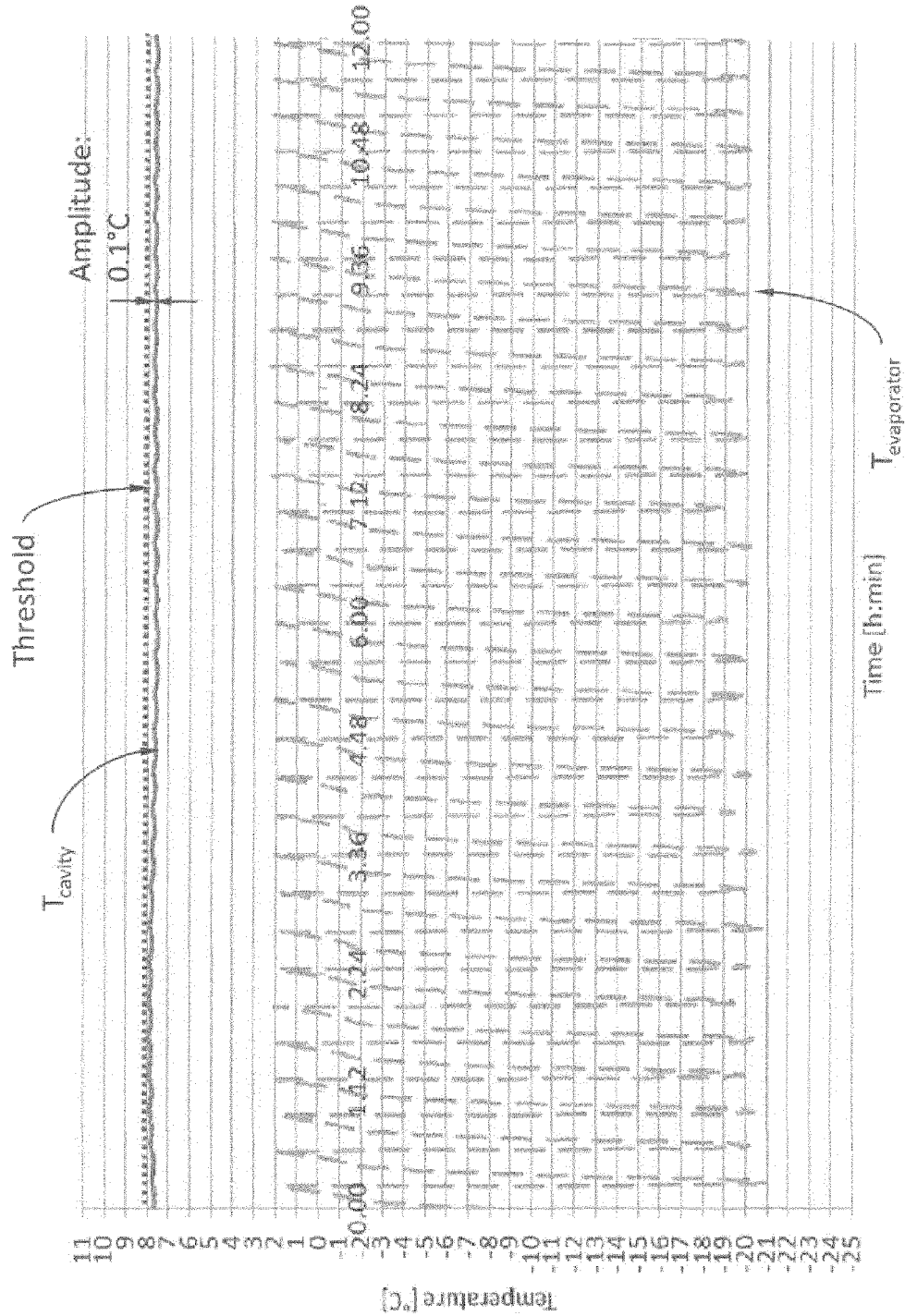


Fig. 3

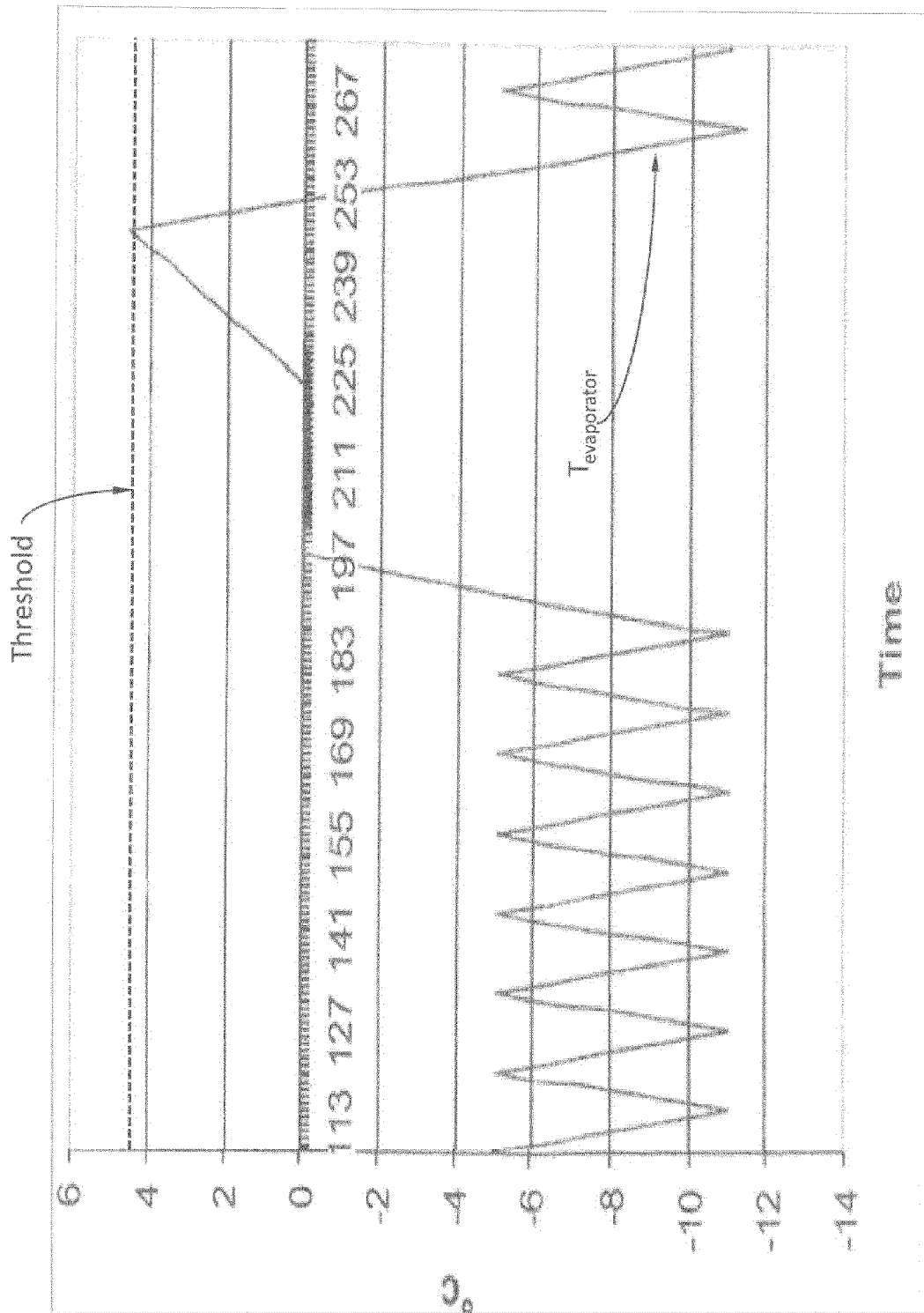


Fig. 4



EUROPEAN SEARCH REPORT

Application Number
EP 12 18 8551

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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			F25D
Place of search		Date of completion of the search	Examiner
Munich		17 January 2013	Jessen, Flemming
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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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 12 18 8551

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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