(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 030 137 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
23.08.2000 Bulletin 2000/34

(51) Int Cl.[7]: **F25D 21/06**

(21) Application number: **99102741.8**

(22) Date of filing: **19.02.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: **Ranco Incorporated of Delaware**
Wilmington, Delaware 19801-1612 (US)

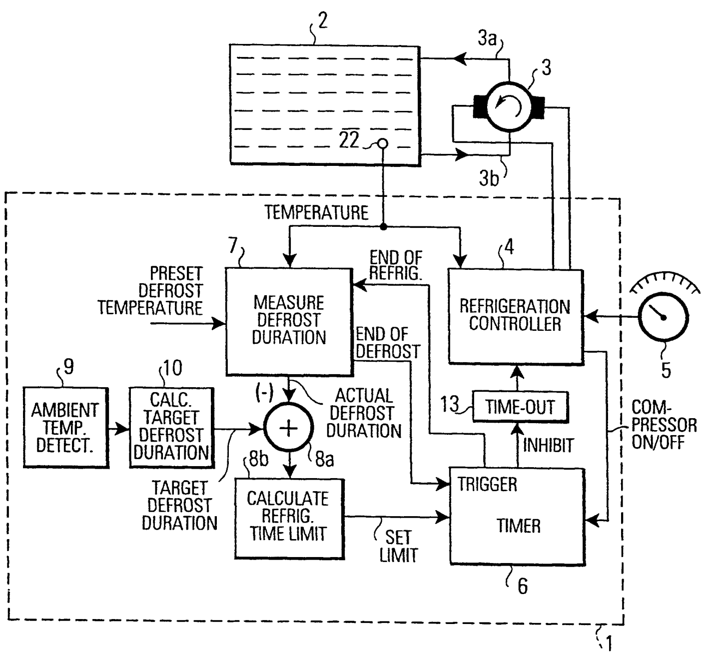
(72) Inventor: **Bailey, Graham**
67366 Weingarten (DE)

(74) Representative: **HOFFMANN - EITLE**
Patent- und Rechtsanwälte
Arabellastrasse 4
81925 München (DE)

(54) **Controller and method for controlling a defrost operation in a refrigerator**

(57) The present invention relates to a controller and a method of controlling a defrost operation in a refrigerator. The duration of a refrigeration period is determined by the amount of time needed for defrosting the evaporator of the refrigerator. If the defrost duration deviates from a target defrost duration, the next refrigeration period is adjusted accordingly, to maintain the actual defrost duration close to the target defrost duration. According to the invention, the target defrost duration is determined based on the detection of a thermal dispersion of the refrigerator. A high ambient temperature results in a reduced target defrost duration while in low ambient temperature conditions the target defrost duration is larger. Preferably, the thermal dispersion is detected based on the ratio of a rate of fall of evaporator temperature when the compressor is on to a rate of rise of evaporator temperature when the compressor is off, on a continuous basis during the refrigeration period.

FIG.5



Description

[0001] The present invention relates to a controller and a method for controlling a defrost operation in a refrigerator, according to the preamble of claims 1 and 21. A controller and a method of this kind are known from DE 29 45 691.

[0002] From this document a controller for defrosting the evaporator of a refrigerator is known, which adaptively controls a defrost operation for melting ice accumulated on the evaporator during a refrigeration period, that is during a period of normal operation of the refrigerator to maintain a food compartment of the refrigerator at a desired temperature. From this document it is known, that when the compressor of the refrigerator is switched off to start a defrost operation, the time taken for the evaporator to reach a preset temperature above 0°C is approximately proportional to the amount of ice accumulated on the evaporator during the preceding refrigeration period.

[0003] To reduce the frequency of defrost operations and therefore save energy, the known controller delays a next defrost operation by a factor dependent on the time the evaporator takes to reach the preset temperature during the defrost operation. The known controller measures the duration of a defrost time interval until the evaporator has reached the preset defrost temperature. If this duration is less than a predetermined target defrost duration, the known controller extends the next refrigeration period. If the defrost duration is larger than the target defrost duration, the known controller reduces the next refrigeration period and hence advances the beginning of the next defrost period. In this way, the known controller saves energy by carrying out less defrost operations in conditions of low ice formation rate. Similarly, if the ice formation rate is high, the frequency of defrost operations is increased thus ensuring that the evaporator stays largely ice free and hence operates at high efficiency.

[0004] The time taken by the evaporator to reach the preset defrost temperature above 0°C, signaling the end of a defrost operation, is influenced not only by the amount of ice on the evaporator, particularly if no additional source of energy is used for accelerating the defrost operation. The duration of the defrost time interval until the evaporator has reached the preset defrost temperature, also depends on the thermal dispersion through the refrigerator appliance insulation. Fig. 1a shows a typical behavior of the evaporator temperature T over time in a first condition A when the ambient temperature is low, and in a second condition B when the ambient temperature is high. From Fig. 1a it can be taken that when the ambient temperature is low, the thermal dispersion through the appliance insulation is low such that a defrost time interval t_1 is comparatively large. If the ambient temperature is high, the thermal dispersion through the appliance insulation is high, resulting in a reduced defrost time interval t_2 until the evaporator has reached the same defrost temperature as in condition A. In an ambient temperature condition A, the known controller will detect a defrost time interval T_1 larger than the target defrost duration and will, accordingly, increase the frequency of defrost operations. In am ambient condition B shown in Fig. 1a, for the same amount of ice as in case of condition A, the controller detects a shorter defrost time interval t_2 than the target defrost duration and, therefore, decreases the frequency of defrost operations, that is increases the refrigeration period between consecutive defrost operations. This shows that the behavior of the known controller is less than optimum, because in ambient condition A the controller will keep the refrigeration period much shorter than necessary and thus waste energy, while in ambient condition B the amount of ice accumulating on the evaporator will grow. This again results in a waste of energy due to a reduced efficiency of the evaporator.

[0005] The known controller is furthermore adapted to initiate a defrost immediately after the calculated refrigeration period time limit has expired. This has the disadvantage that the duration of the defrost time interval until the evaporator has reached the preset defrost temperature, depends on the temperature of the evaporator at the end of the refrigeration period. Fig. 1b shows a first situation A that the refrigeration period ends with the evaporator temperature having a comparatively high value. Fig. 1b furthermore shows a situation B where the refrigeration period ends with the evaporator temperature being at a comparatively low value. The total amount of time required for the evaporator to reach the preset defrost temperature differs in both situations A and B. In situation A, the known controller will set the next refrigeration period time limit different than in situation B, due to the timing error in the defrost time interval. This again results in refrigeration periods less than optimum and in an increased energy consumption of the refrigerator.

[0006] Moreover, the known controller always reacts to past icing conditions on the evaporator. The accumulation of ice on the evaporator generally results from opening the refrigerator door. If after a defrost operation a user frequently opens the refrigerator door in the subsequent refrigeration period, the amount of ice actually accumulating on the evaporator may differ substantially from what was detected during the previous defrost operation.

[0007] The known controller is not able to react appropriately to this situation. It cannot prevent that in the course of the current refrigeration period with many door openings a lot of ice accumulates hence lengthening the time taken for the evaporator to reach the preset defrost temperature. This will cause the known controller to shorten the next refrigeration period even if the rate of ice accumulation returns to normal. This results in an increased energy consumption of the refrigerator.

[0008] A special situation arises with the known controller when the refrigerator is operated in an ambient temperature which is close to or below the preset defrost temperature. Under these conditions the defrost operation will not terminate within a reasonable time because the evaporator temperature approaches the preset defrost temperature only slowly. The temperature of goods in a freezer compartment of the refrigerator will rise, reducing their preservation. If the ambient temperature later rises above the preset defrost temperature, the defrost operation will end and the thawed good will be refrozen. This poses a health risk due to the consumption of thawed and refrozen food.

[0009] It is, therefore, an object of the present invention, to provide a controller and a method for controlling a defrost operation in a refrigerator such that the refrigerator can operate energy-efficiently under varying ambient temperature conditions.

[0010] According to the present invention, this object is solved as defined in claims 1 and 21. According to the present invention, the thermal dispersion of the refrigerator is detected, and the target defrost duration is adjusted in accordance with the detected thermal dispersion. The thermal dispersion of the refrigerator depends on the ambient temperature of the refrigerator. Therefore, it is convenient to detect the thermal dispersion by means of detecting the ambient temperature of the refrigerator. The ambient temperature of the refrigerator can be detected by means of an ambient temperature sensor or by means of estimating the ambient temperature on the basis of the rate of rise of evaporator temperature when the compressor is off, or on the basis of a rate of fall of evaporator temperature when the compressor is on, or preferably, on the basis of a ratio of these rates.

[0011] By means of adjusting the target defrost duration in accordance with the thermal dispersion of the refrigerator, the present invention allows to adapt the duration of the refrigeration periods to the actual amount of ice accumulated on the evaporator essentially independent from the ambient conditions of the refrigerator. The present invention therefore improves the energy efficiency of a refrigerator with an adaptive defrost function and enables an adaptive defrost not requiring a heater at the evaporator for accelerating the defrost operation.

[0012] The optimum target defrost time can be determined during development testing of the refrigerator appliance at a number of different ambient temperatures which the appliance can be expected to see during its use. These various target defrost durations in association with various ambient temperatures can be stored in a memory and can be used at the end of each defrost to calculate a new value for the subsequent refrigeration period. Also, fuzzy logic can be used. Alternatively, the target defrost duration can be calculated through a mathematical formula as a function of the detected thermal dispersion. For example, a nominal target defrost duration of 30 minutes at 25°C can be adjusted by a factor proportional to the temperature deviation from the 25°C. For calculating target defrost durations a linear approximation can be sufficient. Preferably, the target defrost duration is calculated as a function of the thermal dispersion with a linear term and/or a quadratic term. A controller according to the present invention is preferably implemented using a microprocessor, and said look up table or said calculation routine of the target defrost duration can be stored in the microprocessor read-only memory or similar non volatile storage medium. The resulting programming complexity is well within the capabilities of a low-cost 4-bit or 8-bit microprocessor.

[0013] Preferably, the controller according to the present invention measures the refrigeration period in terms of compressor running time rather than in terms of total time between defrost operations. Reason for this is that the amount of ice accumulated on the evaporator can be regarded as approximately proportional to the accumulated running time of the compressor. It is, however, possible to use the total time, that is ON periods and OFF periods of the compressor during the refrigeration operation, for determining the refrigeration period.

[0014] In order to avoid that the duration of the defrost time interval varies at random due to different temperatures of the evaporator at the end of a refrigeration period, the controller according to the present invention preferably starts a defrost at a fixed evaporator temperature thus ensuring that the defrost operation is always timed between two fixed temperatures. The fixed evaporator temperature at which the defrost may be started can vary according to the type of appliance. The fixed evaporator temperature at which a defrost is started is preferably programmed into the memory of the microcontroller at the time of manufacture, for example by the use of an EEPROM or other non volatile programmable memory. It may be convenient for example to start a defrost after expiry of the refrigeration period time limit when the evaporator reaches a lower temperature threshold which is the thermostat cut-out point. This ensures that the defrost starts with a lower temperature in the food compartment thus avoiding excessive temperature rises during the defrost operation.

[0015] To cope in the manner indicated above with variations in the defrost time interval, it is not essential that means are provided for detecting a thermal dispersion, and for determining the target defrost duration in accordance with the detected thermal dispersion. Rather, this problem can also be solved using a preset target defrost duration.

[0016] In order to allow a quick reaction to changes in the icing conditions for the evaporator, it is advantageous to reduce the refrigeration period, that is the time to the next defrost period, by an amount proportional to the time the door is open during the refrigeration period between defrost periods, or proportional to the number of door openings during that period. Again, also this problem can be solved in the manner herein disclosed, regardless whether a conventional preset target defrost duration is used or whether the target defrost duration is determined based on a detected thermal dispersion of the refrigerator.

[0017] In order to avoid that in low ambient temperature conditions the defrost operation will possibly not terminate, it is advantageous to impose a time limit on the defrost operation. That is, if the evaporator has not reached the preset defrost temperature in a given time interval, the defrost operation is terminated by a fail safe timer and normal temperature regulation is resumed. Alternatively, to ensure full removal of ice, a compartment heater can be switched on. The compartment heater can take the form of a resistive heating element or can be the interior light within the food compartment. This will cause the evaporator temperature to rise to the desired preset defrost temperature at which point the defrost is terminated and normal temperature regulation is resumed. Again, also this problem can be solved in the manner herein disclosed, regardless whether a conventional preset target defrost duration is used or whether the target defrost duration is determined based on a detected thermal dispersion of the refrigerator.

[0018] In the following, preferred embodiments of the present invention will be described with reference to the accompanying drawings.

Fig. 1a shows time charts for illustrating the dependency of the duration of a defrost time interval on the ambient temperature;

Fig. 1b shows time charts for illustrating the dependency of the duration of a defrost time interval on the evaporator temperature at the end of a refrigeration period;

Fig. 2 shows an embodiment of a controller for controlling a defrost operation in a refrigerator in accordance with the present invention;

Fig. 3 shows a second embodiment of a controller for controlling a defrost operation according to the present invention;

Fig. 4a shows a third embodiment of a controller for controlling a defrost operation according to the present invention;

Fig. 4b shows a time chart for illustrating the function of the controller according to the embodiment of Fig. 4a; and

Fig. 5 shows a fourth embodiment of a controller for controlling a defrost operation according to the present invention.

[0019] Fig. 2 shows a first embodiment of a controller for controlling a defrost operation in a refrigerator in accordance with the present invention. Reference numeral 1 in Fig. 2 denotes the controller. Reference numeral 2 denotes an evaporator connected via pipe means 3a and 3b to a compressor 3 for circulating cooling fluid through the evaporator 2 to achieve a cooling effect. Reference numeral 22 denotes a temperature sensor mounted in thermal contact with the evaporator 2. Reference numeral 4 denotes a refrigeration controller for performing normal temperature regulation inside a food compartment of the refrigerator. The refrigeration controller 4 receives an input from evaporator temperature sensor 22 and controls the operation of compressor 3. This refrigeration controller can be any kind of temperature controller, for instance a wellknown 2-point controller which keeps the evaporator temperature during a refrigeration period between a low temperature threshold and a high temperature threshold. Reference numeral 5 denotes a user-adjustable temperature dial for setting a desired temperature in the food compartment. Reference numeral 6 denotes a timer means for inhibiting normal temperature regulation of the refrigeration controller 4 after expiry of a refrigeration period time limit. The timer means 6 has a trigger input for triggering the timer. It furthermore has an input for setting a value for the refrigeration period time limit. After the timer has been triggered through its trigger input, it will output an inhibit signal to the refrigeration controller 4 after expiry of the set refrigeration period time limit. In this embodiment, during the refrigeration period the timer 6 counts the compressor running time and does not count time when the compressor is off. To this end the timer 6 receives from the refrigeration controller an indication on the operating state of the compressor.

[0020] Reference numeral 7 denotes a unit for measuring a defrost duration. Unit 7 receives an input from evaporator temperature sensor 22. It furthermore receives a preset defrost temperature value. It also receives an input from timer 6 indicating when a refrigeration period time limit has been reached and a defrost operation starts. Unit 7 for measuring a defrost duration begins a time measurement whenever this indication has been received from timer 6. Unit 7 ends the measurement of the defrost time interval when the temperature measured by sensor 22 at the evaporator has reached the preset defrost temperature. Unit 7 outputs the actual defrost duration thus determined to a comparator 8a. Comparator 8a compares the actual defrost duration measured by unit 7 with a target defrost duration and outputs a difference between the actual defrost duration and the target defrost duration to a unit 8b which calculates a new refrigeration period time limit based on the deviation of the actual defrost duration from the target defrost duration. The calculated time limit in turn is input into timer 6 for setting the next refrigeration period time limit.

[0021] Reference numeral 9 denotes a means for detecting an ambient temperature of the refrigerator. The ambient temperature detected by unit 9 is input into a unit 10 for determining a target defrost duration on the basis of the detected ambient temperature. The target defrost duration thus determined is input into comparator 8a.

[0022] In this embodiment, the ambient temperature detector 9 is a temperature sensor mounted at the refrigerator in a location suitable for measuring the ambient temperature. Unit 10 for determining a target defrost duration receives the detected ambient temperature and converts the detected temperature into a digital value. This digital temperature value is then used by unit 10 to look up a table storing target defrost duration values for a variety of different ambient temperature values. Depending on whether the timer 6, the unit 7 for measuring a defrost duration, the comparator 8a and the unit 8b for calculating a refrigeration period time limit are implemented in digital or in analogue technology, the target defrost duration looked up in the table of unit 10 is either input into comparator 8a for digitally determining a deviation between the actual defrost duration and the target defrost duration, or unit 10 converts a value read from its look up table into an analogue value for further processing in comparator 8a.

[0023] Preferably, the controller 1 of this embodiment is implemented in digital technology by means of programming the functions of the timer 6, the unit 7 for measuring the defrost duration, the comparator 8a, the unit 8b for calculating a new refrigeration time limit and the unit 10 into a microcontroller. The microcontroller preferably has A/D conversion means on the chip, for processing the analogue signals provided by temperature sensor 22 and the temperature sensor 9 for detecting the ambient temperature. Preferably, the microcontroller furthermore implements the control functions of refrigeration controller 4.

[0024] Fig. 3 shows a second embodiment of a controller for controlling a defrost operation of a refrigerator in accordance with the present invention.

[0025] All elements in Fig. 3 identical with or corresponding to elements in Fig. 2 have been denoted with the same reference numerals. The description of these elements given with regard to Fig. 2 similarly applies to the embodiment of Fig. 3, unless stated otherwise in the following.

[0026] The embodiment of Fig. 3 differs from the embodiment of Fig. 2 in the ambient temperature detection means 9. According to the second embodiment of Fig. 3, the ambient temperature detection means 9 receives a signal from temperature sensor 22 on the evaporator 2. It furthermore receives a signal from refrigeration controller 4 indicating the operating state of the compressor, that is whether the compressor is currently in the ON state or in the OFF state. The embodiment of Fig. 3 is advantageous in that the ambient temperature detection means 9 does not require a separate temperature sensor for sensing the ambient temperature. Rather, the ambient temperature detection means 9 estimates thermal dispersion of the refrigerator based on the temperature curve of the evaporator temperature 22. Preferably, the ambient temperature detection means 9 calculates a rate of rise of evaporator temperature when the compressor is off. It furthermore calculates a rate of fall of evaporator temperature when the compressor is on. It then calculates the ratio of said rate of rise to said rate of fall. This ratio indicates the thermal dispersion of the refrigerator largely independent of food load variations in the food compartment of the refrigerator.

[0027] These rates of rise or fall can be measured either over a constant time period or over a constant temperature change. A simple way to determine the rate of change over a constant temperature is to measure the time t_{off} that the compressor is off and the time t_{on} that the compressor is on, during normal temperature regulation of the refrigeration controller 4, that is in the course of a refrigeration period. The ratio t_{on}/t_{off} is essentially equivalent to the ratio of the rate of rise of evaporator temperature when the compressor is off to the rate of fall of evaporator temperature when the compressor is on, as long as the low temperature threshold and the high temperature threshold used by the refrigeration controller 4 controlling the compressor 3, remain unchanged. Thus, if the ambient temperature detection means 9 is adapted to evaluate the thermal dispersion of the refrigerator from the ratio of t_{on}/t_{off}, then the ambient temperature detection means 9 need not receive a signal from temperature sensor 22.

[0028] The thermal disposion ratio is preferably calculated by unit 9 on a continuous basis in the course of every refrigeration period. Each time the compressor changes its operating state from ON to OFF or from OFF to ON, unit 9 provides a new value for the thermal dispersion ratio to unit 10. In order to avoid an adverse influence of disturbing factors like frequent or long door openings or the introduction of extremely or cold goods into the food compartment, onto the evaluation of the thermal dispersion, it is advantageous to provide the thermal dispersion detection means 9 with means for detecting whether said calculated thermal dispersion ratio is stable or not. To this end, unit 9 can be provided with memory locations for storing a predetermined number of preceding thermal dispersion ratios, and with means for investigating whether the stored thermal dispersion ratios differ from each other by more than a predetermined threshold variance. Each time a new thermal dispersion ratio is calculated by unit 9, the oldest thermal dispersion ratio in said memory locations is replaced by the newest. If the differences between the stored thermal dispersion ratios is smaller than said predetermined variance threshold, the detected thermal dispersion ratio will then be used by unit 10 for calculating an updated target defrost duration on the basis of the detected ambient conditions. Otherwise, unit 10 will maintain the target defrost duration output to unit 8a unchanged until the conditions for detecting a thermal dispersion ratio have been stabilized, that is, until all thermal dispersion ratios stored in unit 9 differ from each other by no more than said predetermined variance threshold.

[0029] Unit 8b for determining an updated refrigeration period time limit based on a deviation of the actual defrost duration from the target defrost duration given by unit 10, can be provided to increase the refrigeration period time limit each time the actual defrost duration is smaller than the target defrost duration, and to decrease the refrigeration period time limit each time the actual defrost duration has been found to be larger than the target defrost duration. In the alternative, unit 8b may contain a look up table storing a plurality of refrigeration period time limits in association with respective defrost duration deviation values.

[0030] Unit 7 for measuring the actual defrost duration comprises a time counter the operation of which is started when receiving an end of refrigeration period signal from timer 6. The time counter stops counting when a comparator for comparing the actual evaporator temperature from temperature sensor 22 with a preset defrost temperature value indicates that the evaporator temperature 22 has reached the preset defrost temperature. At this stage unit 7 outputs the end of defrost signal to trigger timer 6 for starting a new refrigeration period. Unit 7 then furthermore outputs the actual defrost duration value to comparator 8a.

[0031] Fig. 4a shows a third embodiment of a controller according to the present invention. This embodiment differs from the embodiment shown in Fig. 2 in the provision of a unit 11 for updating the refrigeration period time limit set in timer 6. Unit 11 for updating the time limit of timer 6 receives an input from a door position sensor 12. All remaining elements of Fig. 4a are identical with the corresponding elements of Fig. 2 and are denoted with the same reference numerals, such that their description need not be repeated.

[0032] The embodiment of Fig. 4a addresses the problem that the refrigeration period time limit calculated in unit 8b and set in timer 6, has been determined on the basis of the duration of the preceding defrost operation. If in the course of the refrigeration period there are frequent or long lasting door openings, the time limit for the refrigeration period calculated by unit 8b is no longer up to date.

[0033] Unit 11 for updating the refrigeration period time limit counts the total time for which the door of the food compartment of the refrigerator is open during the refrigeration period. The total time count is received by timer 6, and the timer 6 subtracts the current total time count from the current period of time left until the refrigeration period time limit is reached. As soon as the updated refrigeration period time limit has been reached, the defrost period starts and the timer means 6 outputs a signal to unit 11 to reset the open door time counter. By means of providing unit 11 for updating the refrigeration period time limit, the controller according to this embodiment is able to reduce the refrigeration period based on an estimation of additional ice accumulation due to door openings without waiting for the next measurement of a defrost duration. A controller according to this embodiment can, therefore, quickly cope with changes in the actual icing conditions of the evaporator and keep the defrost operation of the refrigerator energy-efficient.

[0034] In the alternative to measuring the total door open time period during a refrigeration period, unit 11 can be provided to count the number of door openings during the refrigeration period. This alternative is, however, inferior to counting the total door open time period in that it will not be able to appropriately react to the situation that the door of the food compartment is opened and left open.

[0035] While the embodiment of Fig. 4a includes a unit 10 for calculating a target defrost duration and a unit 9 for detecting an ambient temperature of the refrigerator, the units 9 and 10 are not mandatory for solving the problem, to enable to controller for controlling a defrost operation of a refrigerator to quickly react to changes of the icing conditions of the evaporator due to frequent or long lasting door openings.

[0036] Fig. 4b is a time chart illustrating the behavior of the evaporator temperature and the sequence of refrigeration periods and defrost periods according to the third embodiment shown in Fig. 4a. The time chart of Fig. 4b shows a refrigeration period n and the evaporator temperature T in the course of that refrigeration period n. No door openings take place during that period n. At the end of the refrigeration period n, an n^{th} defrost operation takes place. The measured duration of the n^{th} defrost period influences the duration of the subsequent refrigeration period (n+1). During that refrigeration period n+1, door openings take place, as indicated in the bottom part of Fig. 4b. The duration of these door openings is counted by unit 11 for updating the refrigeration period time limit, and the actual count is subtracted from the time count in timer 6 which indicates the remaining time of the refrigeration period n+1. This has the effect shown in Fig. 4b that the total refrigeration period n+1 with door openings having taken place, is shorter than the refrigeration period n. Updating the refrigeration period time limit on the basis of door openings furthermore has the effect that also the $(n+1)^{st}$ defrost duration is not significantly different from the n^{th} defrost duration since the increased accumulation of ice on the evaporator due to the door of the refrigerator having been open, is compensated by means of advancing the next defrost operation, such that both in refrigeration period n and in refrigeration period n+1 the peak amount of ice accumulated on the evaporator is substantially the same.

[0037] Fig. 5 shows a fourth embodiment of a controller for controlling a defrost operation according to the present invention. The embodiment of Fig. 5 differs from the embodiment of Fig. 2 in the provision of a time-out unit 13 in the path of the inhibit signal output by timer 6. This embodiment addresses the problem that if the refrigerator appliance is operated in an ambient temperature lower than the preset defrost temperature, the defrost operation will not terminate because the evaporator 2 will possibly not reach the preset defrost temperature which is used by unit 7 for measuring the defrost duration. Under the condition that the ambient temperature of the refrigerator is lower than the preset defrost temperature, unit 7 will thus not indicate an end of the defrost period and timer 6 will not be retriggered to start a new refrigeration period. In order to make the operation of the controller according to the present invention fail safe even when the ambient temperature is low, the embodiment of Fig. 5 outputs the inhibit signal of timer 6 to time-out unit 13. The time-out unit 13 passes the inhibit signal onto the refrigeration controller 4 as long as a preset time-out interval for unit 13 beginning with the arrival of the inhibit signal has not been exceeded. If the inhibit signal output by timer 6 prevails for more than the preset time-out interval in unit 13, this unit will no longer pass on the inhibit signal to the refrigeration controller 4 such that the refrigeration controller 4 can then resume normal temperature control operation. As soon as timer 6 is retriggered by unit 7, timer 6 switches off the inhibit signal and time-out unit 13 is reset such that a normal operation of the controller for controlling the defrost can be resumed.

[0038] While the embodiment of Fig. 5 has been described including the units 9 and 10 for detecting an ambient temperature of the refrigerator and for calculating a target defrost duration on the basis of the thermal dispersion of the refrigerator, these units are not mandatory for solving the problem addressed by the embodiment of Fig. 5. For solving this problem it is, therefore, possible to replace in Fig. 5 the unit 9 for detecting an ambient temperature and the unit 10 for determining a target defrost duration by a means for providing a preset target defrost duration.

Claims

1. A controller (1) for controlling a defrost operation in a refrigerator having at least one food compartment, at least one evaporator (2) for cooling said food compartment and a compressor (3) for circulating cooling fluid through said evaporator, the controller (1) comprising

- means (4) for controlling a refrigeration operation of said compressor (3);
- timer means (6) for defrosting said evaporator after expiry of a refrigeration period time limit;
- means (7) for measuring a duration of a defrost time interval ending with said evaporator (2) having reached a preset defrost temperature;
- means (8a, 8b) for comparing said defrost time interval duration with a target defrost duration and setting said refrigeration period time limit in accordance with a deviation of said defrost time interval from said target defrost duration;

characterized by

- means (9) for detecting a thermal dispersion of said refrigerator; and
- means (10) for determining said target defrost duration in accordance with said thermal dispersion.

2. The controller according to claim 1, characterized in that

- said means (9) for detecting a thermal dispersion comprises a temperature sensor for detecting an ambient temperature.

3. The controller according to claim 1, characterized in that

- said means (9) for detecting a thermal dispersion is adapted to estimate an ambient temperature of the refrigerator on the basis of a rate of rise of evaporator temperature when the compressor (3) is off and/or on the basis of a rate of fall of evaporator temperature when said compressor (3) is on.

4. The controller according to claim 3, characterized in that

- said means (9) for detecting a thermal dispersion is adapted to estimate the ambient temperature of said refrigerator on the basis of a thermal dispersion ratio of said rate of rise of evaporator temperature when said compressor (3) is off to said rate of rise of evaporator temperature when said compressor (3) is on.

5. The controller according to claim 4, characterized in that

- said means (9) for detecting a thermal dispersion is adapted to measure an OFF time period and an ON time period of the compressor (3) during said refrigeration period and to evaluate said thermal dispersion ratio based on a ratio of said compressor ON time period to said compressor OFF time period or based on a ratio of said compressor ON time period to a sum of said compressor ON time period and said compressor OFF time period.

6. The controller according to any one of the preceding claims, characterized in that

- said means (10) for determining a target defrost duration comprise memory means for storing a look up table which comprises a plurality of values of ambient temperatures and associated target defrost duration values.

7. The controller according to any one of the claims 1 to 5,
characterized in that

- said means (10) for determining a target defrost duration are adapted to calculate an offset value as a function of a deviation of said ambient temperature from a nominal ambient temperature value, and to calculate said target defrost duration by means of adding said calculated offset value to a nominal target defrost duration value.

8. The controller according to claim 7,
characterized in that

- said function is a linear function or a quadratic function or a function having a linear term and a quadratic term.

9. The controller according to any one of the preceding claims,
characterized in that

- said means (8a, 8b) for comparing said defrost time interval with a target defrost duration and setting said refrigeration period time limit in accordance with a deviation of said defrost time interval from said target defrost duration includes memory means for storing a look up table comprising a plurality of target defrost duration values, defrost time interval values and associated refrigeration period time limit values.

10. The controller according to any one of the claims 1 to 8,
characterized in that

- said means (8a, 8b) for comparing said defrost time interval with a target defrost duration and setting said refrigeration period time limit in accordance with a deviation of said defrost time interval from said target defrost duration is adapted to increment said refrigeration period time limit if said defrost time interval is smaller than said target defrost duration, and to decrement said refrigeration period time limit if said defrost time interval is larger than said target defrost duration.

11. The controller according to any one of the preceding claims,
characterized by

- means (12) for detecting whether a door of said food compartment is open, and for accumulating an open door time period during each refrigeration period; and

- means (11) for reducing said refrigeration period time limit in accordance with said accumulated open door time period.

12. The controller according to claim 1,
characterized in that

- said means (11) for reducing said refrigeration period time limit is adapted to reduce said refrigeration period time limit in proportion to said accumulated open door time period or in proportion to a counted number of door openings.

13. The controller according to any one of the preceding claims,
characterized in that

- said defrost time interval measuring means (7) is adapted to start measuring said defrost time interval with the expiry of said refrigeration period time limit.

14. The controller according to any one of the claims 1 to 12,
characterized by

- said timer means (6) for inhibiting an operation of said compressor (3) after expiry of a refrigeration period time limit and defrosting said evaporator is adapted to receive a signal indicating an actual temperature of said evaporator (2); and

- to inhibit the operation of said compressor (3) and start defrosting said evaporator (2) when said refrigeration period time limit has expired and said evaporator temperature has reached below a predetermined defrost start temperature;

- said defrost time interval measuring means (7) being adapted to start measuring said defrost time interval when said evaporator temperature has reached said defrost start temperature.

15. The controller according to claim 14,
characterized in that

- said timer means (6) is adapted to initiate an additional compressor ON phase when said refrigeration period time interval expires and said evaporator temperature is above said preset defrost start temperature, and to end said additional compressor ON phase when said evaporator (2) has reached said defrost start temperature.

16. The controller according to claim 14 or 15, characterized in that

- said means (4) for controlling a refrigeration operation is adapted to activate said compressor (3) when the evaporator temperature has reached an upper temperature threshold, and to switch off said compressor (3) when the evaporator temperature has reached a lower temperature threshold;

- said defrost start temperature being said lower temperature threshold.

17. The controller according to any one of the preceding claims,
characterized by

- means (13) for enabling the operation of said compressor (3) when said defrost time interval exceeds a preset defrost period time limit.

18. The controller according to any one of the claims 1 to 16,
characterized by

- means for heating said evaporator; and

- means for energizing said heating means when said defrost time interval exceeds a preset defrost period time limit and deenergizing said heating means when the evaporator temperature has reached said preset defrost temperature.

19. The controller according to any one of the claims 1 to 16,
characterized by

- a door operated light bulb for said food compartment; and

- means for energizing said light bulb when said defrost time interval exceeds a preset defrost period time limit and deenergizing said light bulb when the evaporator temperature has reached said preset defrost temperature.

20. The controller according to any one of the preceding claims,
characterized in that

- said timer means (6) is adapted to measure said refrigeration period by means of accumulating compressor running time only, or by means of measuring real time.

21. The controller according to any one of the preceding claims,
characterized in that

- said means (4) for controlling a refrigeration operation of said compressor (3) is adapted for controlling in accordance with a user settable food compartment target temperature value (5).

22. A method of controlling a defrost operation in a refrigerator having a food compartment, an evaporator (2) for cooling said food compartment and a compressor (3) for circulating cooling fluid through said evaporator, the method comprising the steps of

- controlling a refrigeration operation of said compressor (3)

- defrosting said evaporator (2) after expiry of a refrigeration period time limit and;

- measuring a defrost time interval ending with said evaporator (2) having reached a preset defrost temperature;

- comparing said defrost time interval with a target defrost duration and setting said refrigeration period time limit in accordance with a deviation of said defrost time interval from said target defrost duration;

characterized by

- detecting an ambient temperature of said refrigerator; and

- determining said target defrost duration in accordance with said detected ambient temperature.

FIG.1a

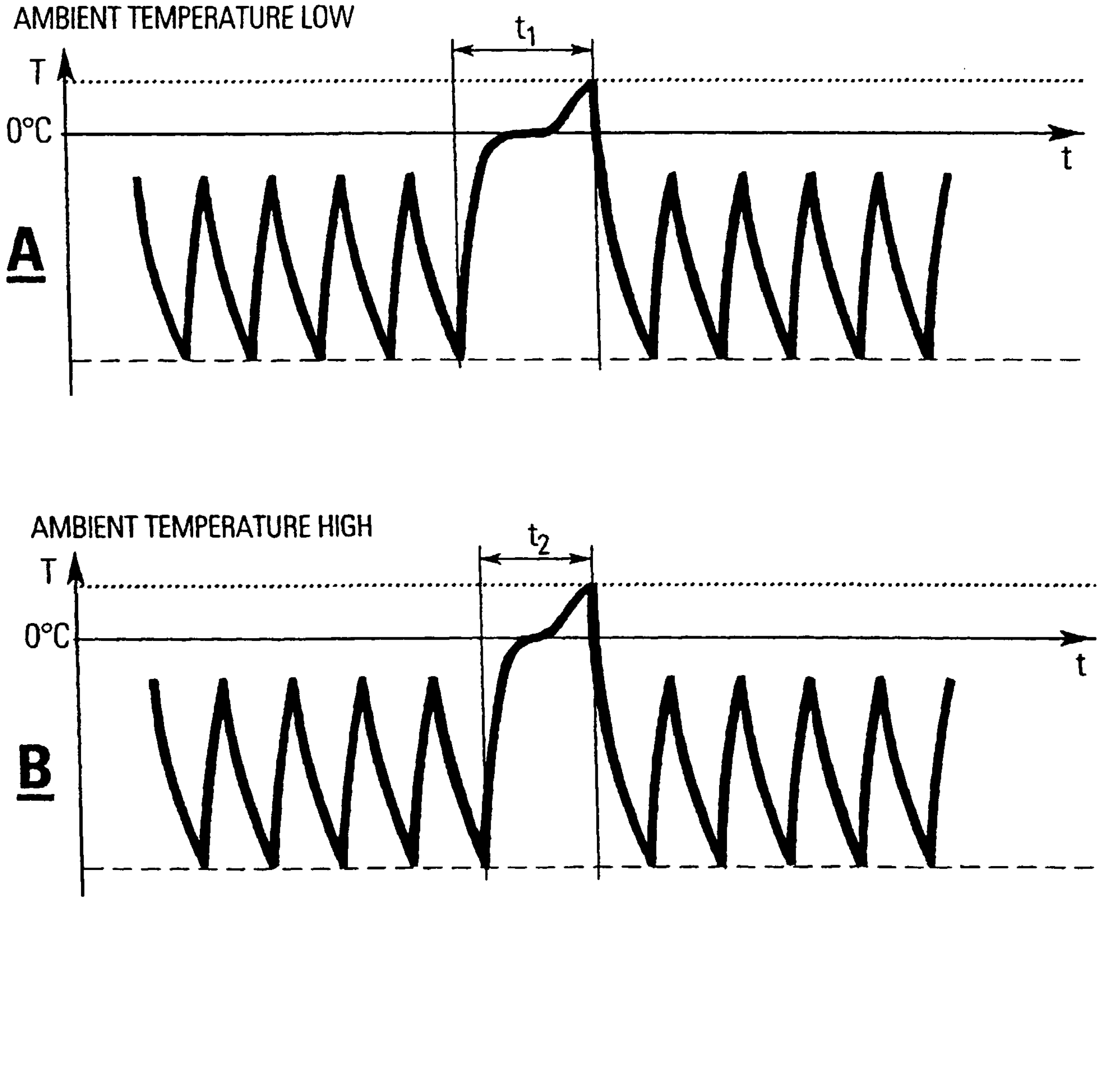

AMBIENT TEMPERATURE LOW
t_1
T
0°C
t
A
AMBIENT TEMPERATURE HIGH
t_2
T
0°C
t
B

FIG.1b

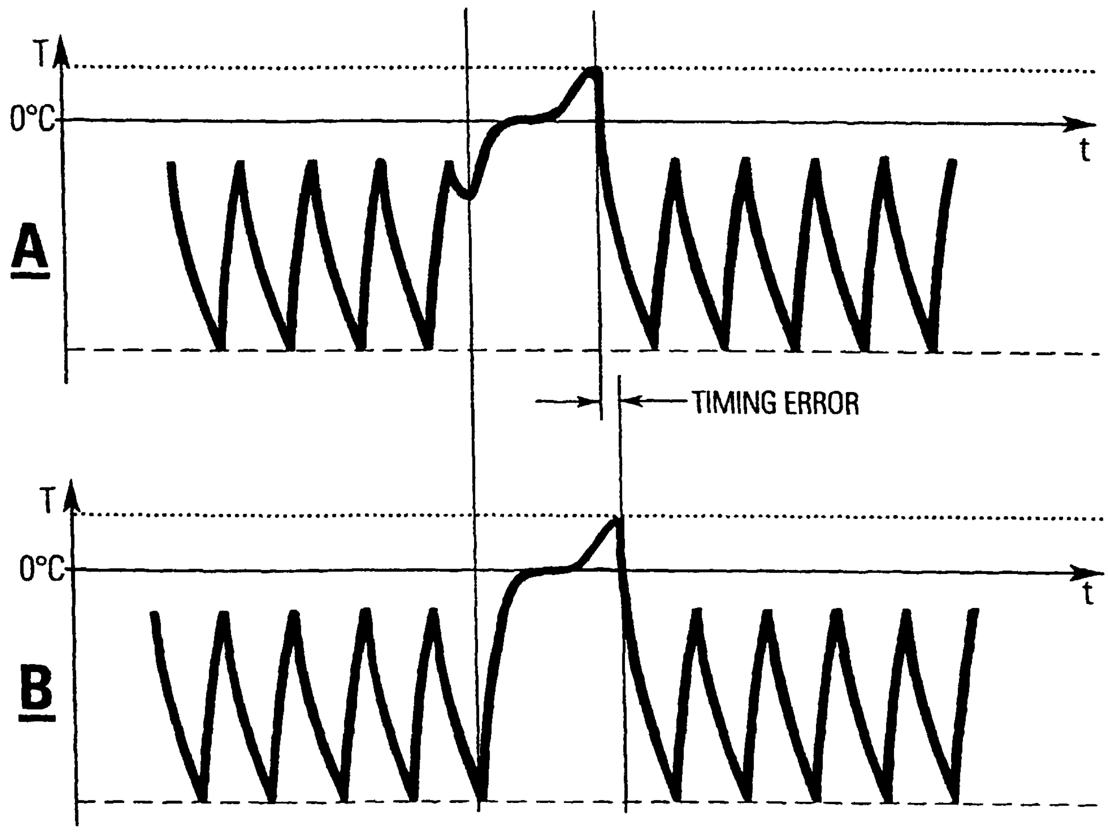


FIG.2

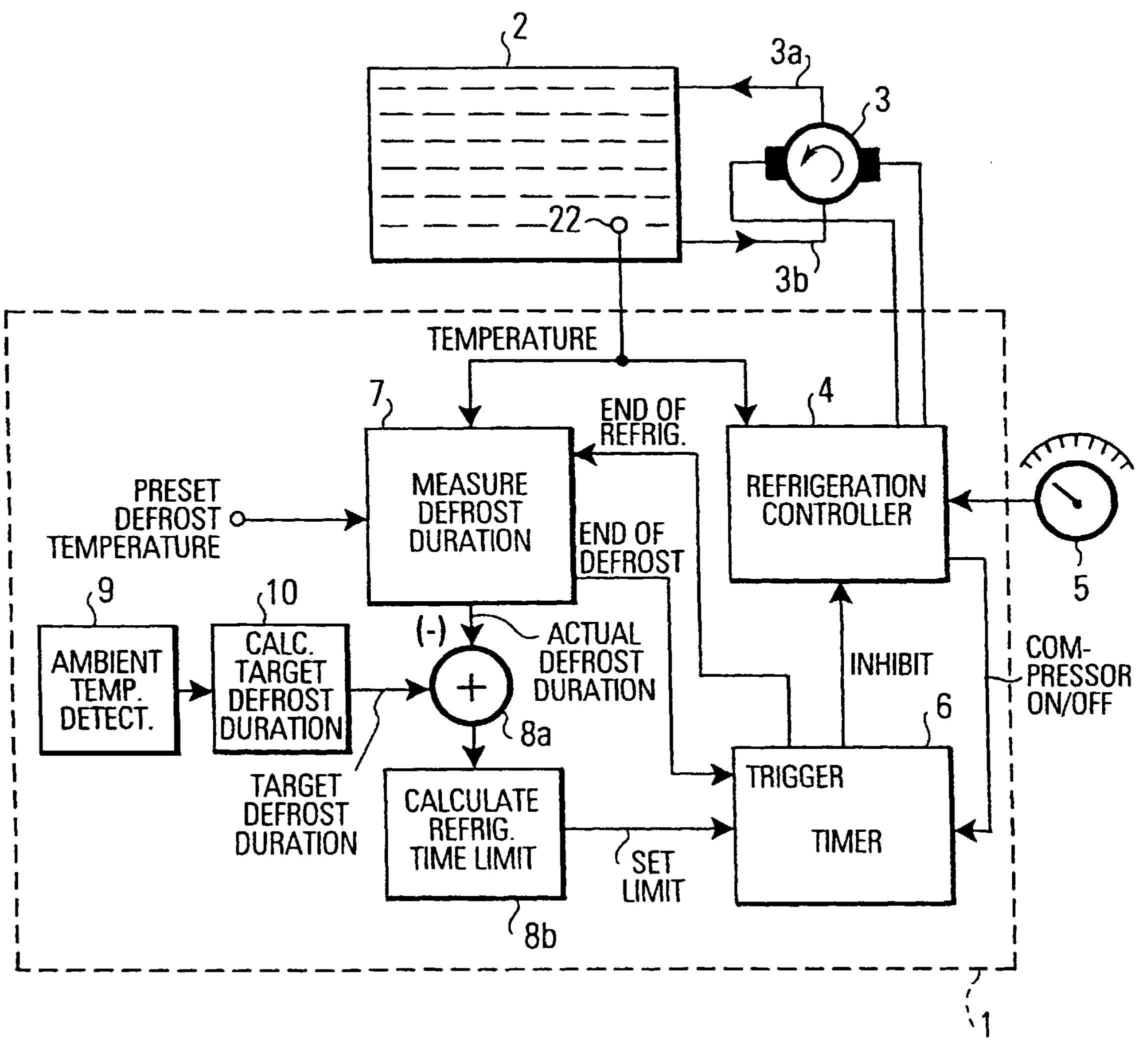

2
3a
3
22
3b
TEMPERATURE
7
END OF REFRIG.
4
MEASURE DEFROST DURATION
PRESET DEFROST TEMPERATURE
REFRIGERATION CONTROLLER
END OF DEFROST
5
9
10
(-)
ACTUAL DEFROST DURATION
INHIBIT
COM-PRESSOR ON/OFF
AMBIENT TEMP. DETECT.
CALC. TARGET DEFROST DURATION
6
8a
TARGET DEFROST DURATION
CALCULATE REFRIG. TIME LIMIT
TRIGGER
TIMER
SET LIMIT
8b
1

FIG.3

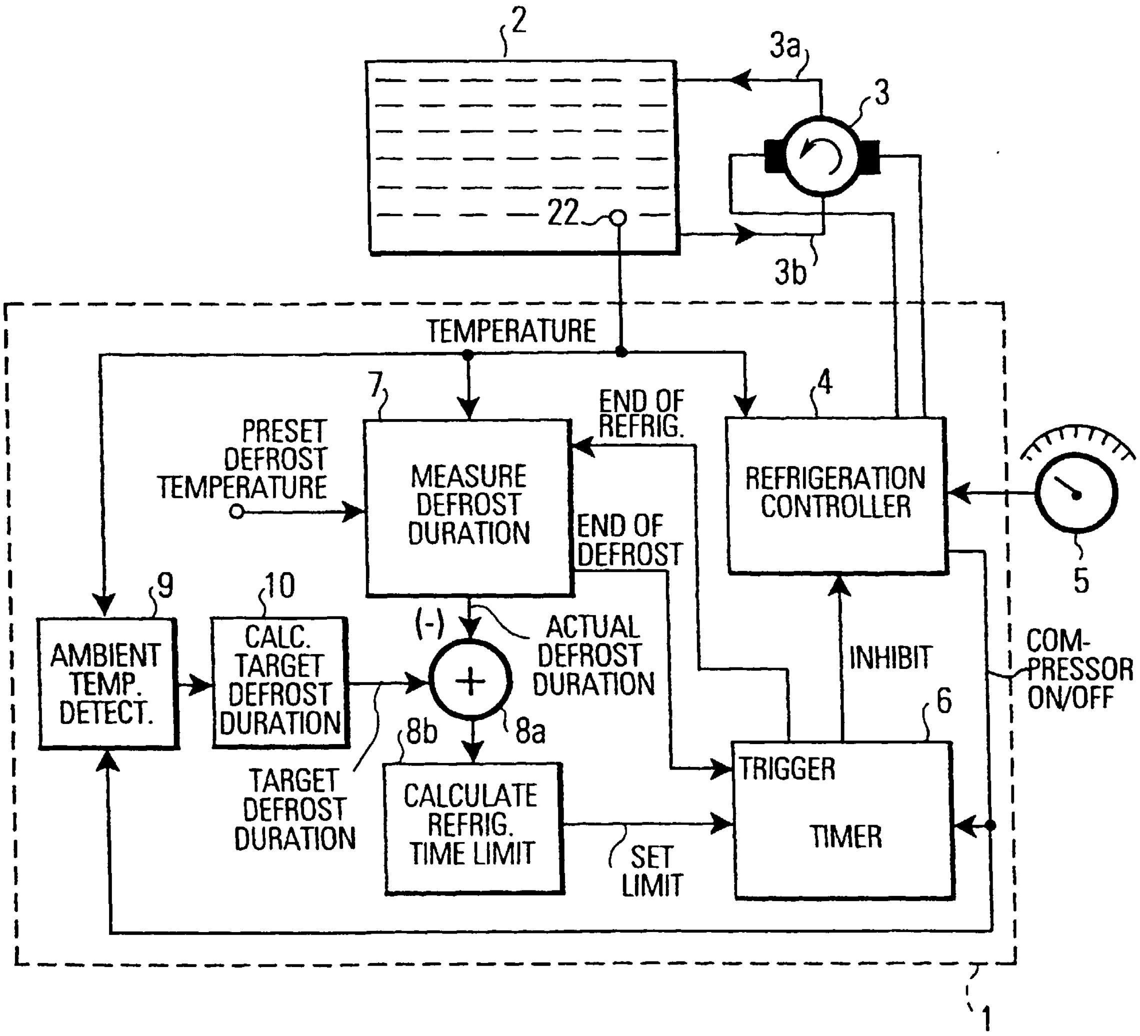

2
3a
3
22
3b
TEMPERATURE
7
4
END OF REFRIG.
PRESET DEFROST TEMPERATURE
MEASURE DEFROST DURATION
REFRIGERATION CONTROLLER
END OF DEFROST
5
9
10
(-)
ACTUAL DEFROST DURATION
AMBIENT TEMP. DETECT.
CALC. TARGET DEFROST DURATION
INHIBIT
COM-PRESSOR ON/OFF
6
8b
8a
TARGET DEFROST DURATION
CALCULATE REFRIG. TIME LIMIT
TRIGGER
TIMER
SET LIMIT
1

FIG.4a

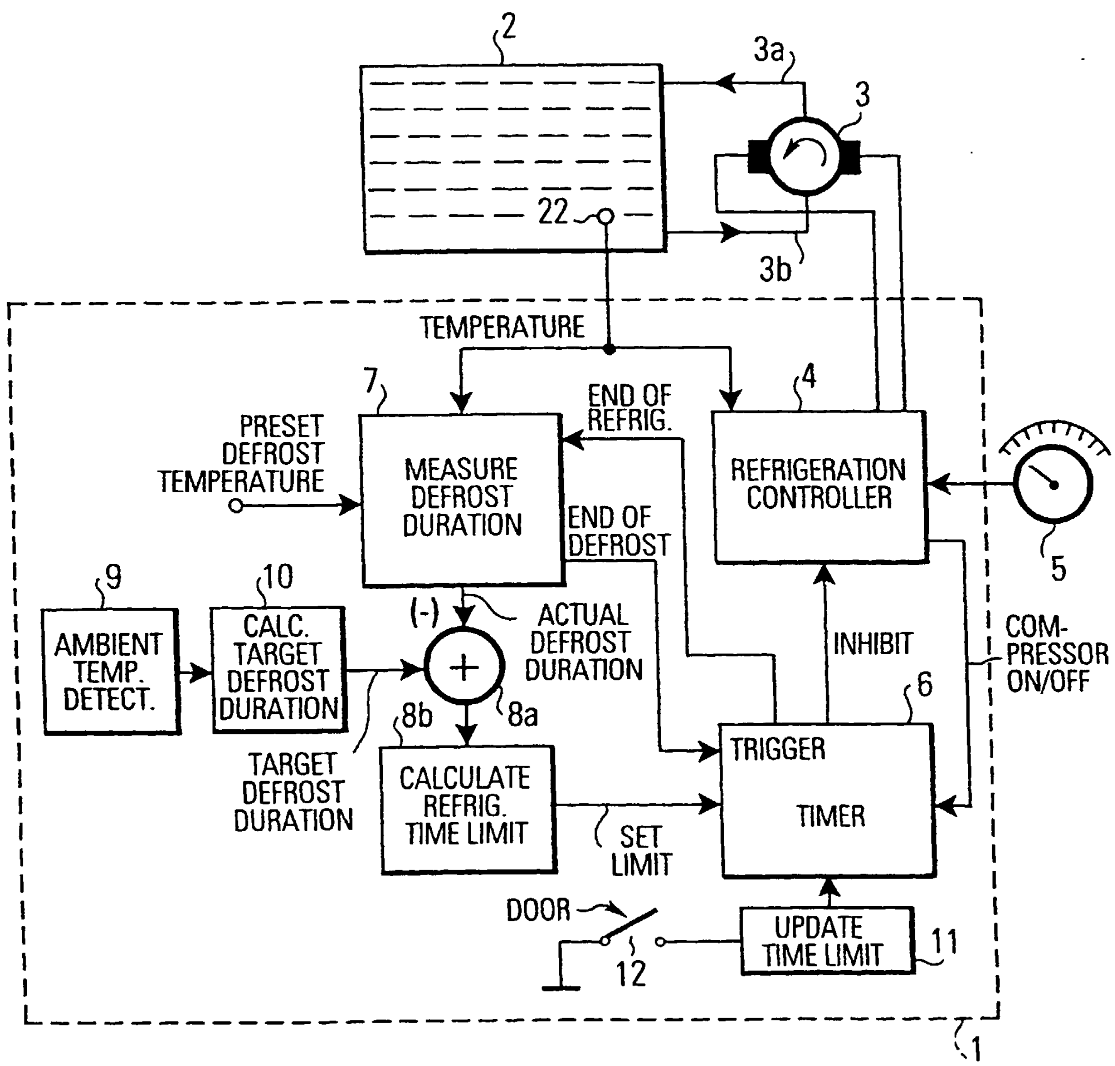

2
3a
3
22
3b
TEMPERATURE
7
4
END OF REFRIG.
PRESET DEFROST TEMPERATURE
MEASURE DEFROST DURATION
REFRIGERATION CONTROLLER
END OF DEFROST
5
9
10
(-)
ACTUAL DEFROST DURATION
AMBIENT TEMP. DETECT.
CALC. TARGET DEFROST DURATION
INHIBIT
COM-PRESSOR ON/OFF
6
8b
8a
TRIGGER
TARGET DEFROST DURATION
CALCULATE REFRIG. TIME LIMIT
TIMER
SET LIMIT
DOOR
UPDATE TIME LIMIT
11
12
1

FIG.4b

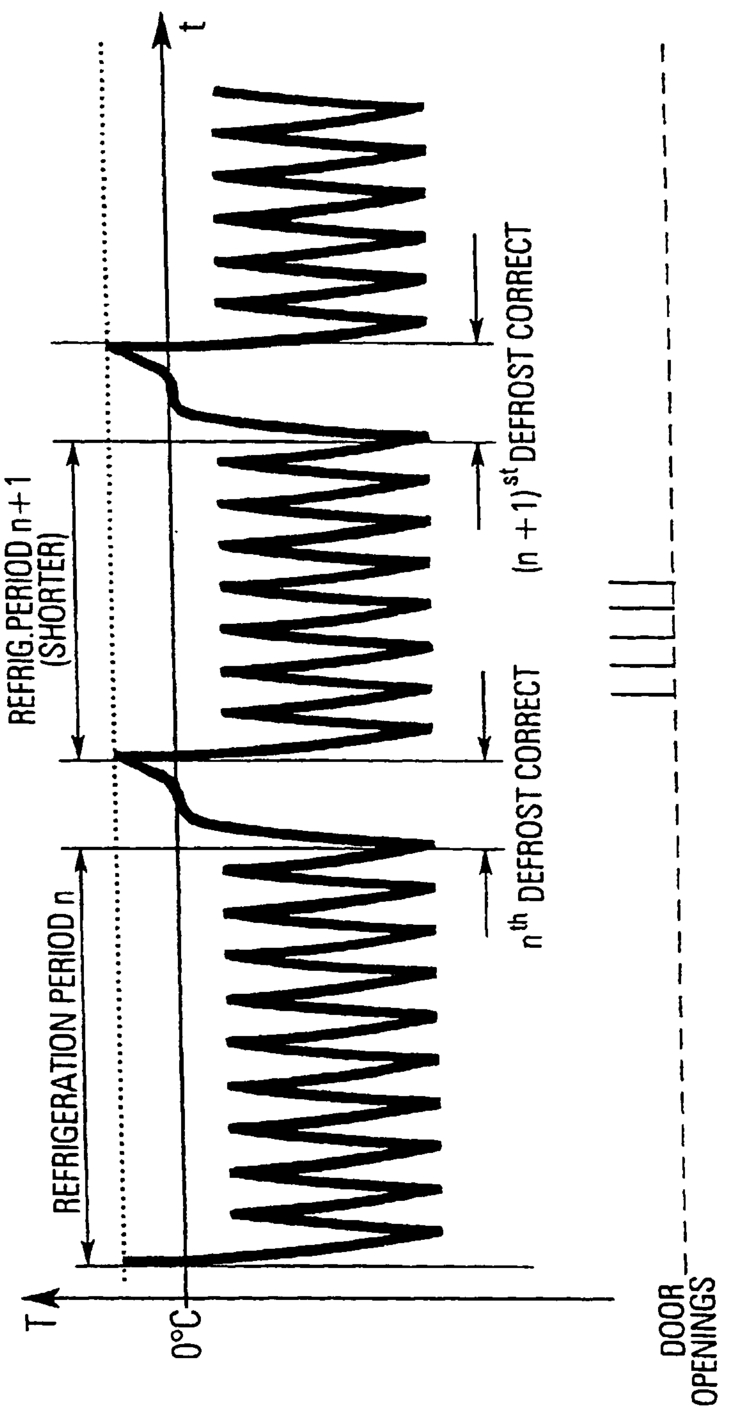
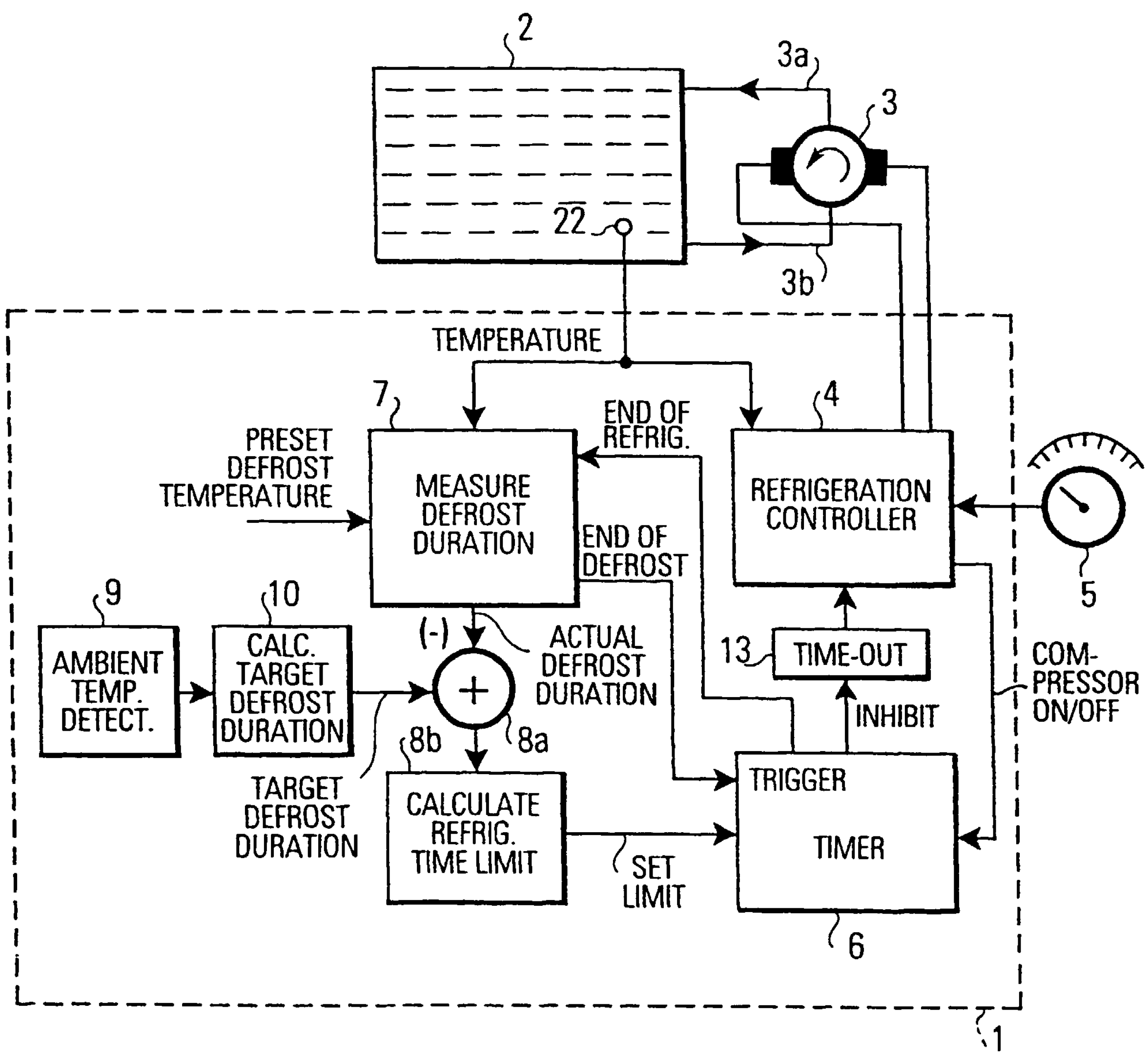

T
t
0°C
REFRIGERATION PERIOD n
REFRIG.PERIOD n+1
(SHORTER)
n^th DEFROST CORRECT
(n + 1)^st DEFROST CORRECT
DEFROST CORRECT
DOOR
OPENINGS

FIG.5


2
3a
3
22
3b
TEMPERATURE
7
4
END OF REFRIG.
PRESET DEFROST TEMPERATURE
MEASURE DEFROST DURATION
REFRIGERATION CONTROLLER
END OF DEFROST
9
10
5
(-)
ACTUAL DEFROST DURATION
AMBIENT TEMP. DETECT.
CALC. TARGET DEFROST DURATION
13
TIME-OUT
COM-PRESSOR ON/OFF
8b
8a
INHIBIT
TARGET DEFROST DURATION
CALCULATE REFRIG. TIME LIMIT
TRIGGER
TIMER
SET LIMIT
6
1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 10 2741

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION
D,Y	DE 29 45 691 A (AMF INC) 19 June 1980 (1980-06-19) * page 9, last paragraph - page 26, last paragraph; figures 1,2 * ---	1,22	F25D21/06
Y	US 5 533 350 A (GROMALA JOSEPH R ET AL) 9 July 1996 (1996-07-09)	1,22	
A	* column 3, line 37 - column 6, line 29; figures 1-6 * ---	5	
A	US 3 681 933 A (CHECK FRANK T JR) 8 August 1972 (1972-08-08) * column 2, line 36 - column 4, line 43; figures 1-4 * ---	1,2,22	
A	US 4 850 204 A (BOS PETER J ET AL) 25 July 1989 (1989-07-25) * column 4, line 63 - column 38, line 3; figures 1-11A * ---	1,2,22	
A	DE 32 35 642 A (3 E ELEKTRONIK ELEKTRO ENERGIE) 29 March 1984 (1984-03-29) * page 12, paragraph 4 - page 16, paragraph 1; figure * ---	1,6,22	TECHNICAL FIELDS SEARCHED
			F25D
A	EP 0 690 277 A (BOSCH SIEMENS HAUSGERAETE) 3 January 1996 (1996-01-03) * page 3, line 34 - page 6, line 9; figures 1-4 * ---	1,11-14, 16,20-22	
A	US 4 528 821 A (TERSHAK ANDREW T ET AL) 16 July 1985 (1985-07-16) * column 4, line 4 - column 16, line 24; figures 1-9 * ---	1,11,12, 22	
	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 August 1999	Boets, A

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

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 10 2741

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION
A	US 5 440 893 A (DAVIS KENNETH ET AL) 15 August 1995 (1995-08-15) * column 3, line 66 - column 5, line 38; figures 1-2B *	1,22	
A	US 4 689 965 A (JANKE DONALD E ET AL) 1 September 1987 (1987-09-01) * column 3, line 20 - column 7, line 62; figures 1-5 *	1,22	
A	EP 0 598 612 A (WHIRLPOOL CO) 25 May 1994 (1994-05-25)		
A	EP 0 686 818 A (MERLONI ELETTRODOMESTICI SPA) 13 December 1995 (1995-12-13)		
A	US 5 046 324 A (OTOH TADAO ET AL) 10 September 1991 (1991-09-10)		
			TECHNICAL FIELDS SEARCHED

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 August 1999	Boets, A

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

EPO FORM 1503 03 82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 10 2741

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-08-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 2945691 A	19-06-1980	US 4251988 A	24-02-1981
		AU 525792 B	02-12-1982
		AU 5072079 A	12-06-1980
		CA 1121874 A	13-04-1982
		FR 2443652 A	04-07-1980
		GB 2039081 A,B	30-07-1980
		IT 1164808 B	15-04-1987
		JP 55079967 A	16-06-1980
US 5533350 A	09-07-1996	EP 0803690 A	29-10-1997
US 3681933 A	08-08-1972	NONE	
US 4850204 A	25-07-1989	CA 1298383 A	31-03-1992
DE 3235642 A	29-03-1984	NONE	
EP 0690277 A	03-01-1996	DE 4418874 A	21-03-1996
		CN 1122437 A	15-05-1996
US 4528821 A	16-07-1985	US 4481785 A	13-11-1984
		CA 1214239 A	18-11-1986
		JP 59044568 A	13-03-1984
US 5440893 A	15-08-1995	NONE	
US 4689965 A	01-09-1987	CA 1260109 A	26-09-1989
EP 0598612 A	25-05-1994	US 5363669 A	15-11-1994
		CA 2106555 A	19-05-1994
		DE 69323043 D	25-02-1999
		DE 69323043 T	10-06-1999
		EP 0836063 A	15-04-1998
		EP 0836064 A	15-04-1998
		US 5369962 A	06-12-1994
		US 5373705 A	20-12-1994
		US 5394291 A	28-02-1995
		US 5363667 A	15-11-1994
		US 5493867 A	27-02-1996
		US 5454230 A	03-10-1995
		US 5469715 A	28-11-1995
		US 5456087 A	10-10-1995
		US 5533360 A	09-07-1996
EP 0686818 A	13-12-1995	IT T0940472 A	11-12-1995

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 10 2741

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-08-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5046324 A	10-09-1991	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82