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(54) Horizontal freezer

(57) A horizontal freezer comprises a food storage compartment, a cooling circuit provided with a compressor, a temperature sensor (16) positioned in said compartment and a control system capable of controlling the compressor in relation to a signal from said temperature sensor. On the basis of the temperature reported by the sensor (16), the control system defines the proportion of the connection time of the compressor in an ON-OFF cycle of said compressor, with the aim of optimising the performance of the freezer.

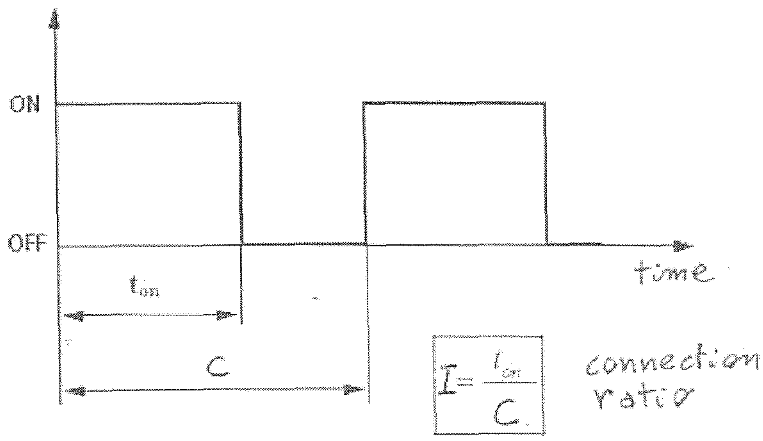

Fig. 2

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Description

[0001] The present invention concerns a refrigerator, particularly a horizontal freezer, of the type comprising a food storage compartment, a cooling circuit provided with a compressor, a temperature sensor positioned in said compartment and a control system capable of controlling the compressor in relation to a signal from said temperature sensor.

[0002] This type of horizontal freezer, in which the sensor it is preferably positioned on a lower face of the door that closes the compartment, has advantages over the traditional type of horizontal freezer, the hysteresis control of which is based on measuring the temperature on the evaporator. The sensor on the evaporator presents problems in terms of design, the thermal stresses of the sensor and the standardisation of parts, arising from the machining necessary in order to allow the passage of the wire connecting to the control card positioned near the door handle. Positioning the sensor on the door, near the user interface positioned on the handle, greatly simplifies electrical connections and reduces the number of cable junctions, with all the advantages of lower cost and greater reliability of the electrical appliance.

[0003] In traditional freezers the temperature on the evaporator is measured by means of a sensor applied to the tube of the evaporator. A thermostat (mechanical or electronic) controls the switching on of the motor when the temperature of the evaporator goes above a predetermined upper limit (based on the set value for temperature), and controls switching off when this temperature falls below a lower limit.

[0004] In horizontal freezers of the known type with a temperature sensor in the door, the same type of control is used as with the sensor on the evaporator, modifying the parameters of the thermostat. The temperature measured with the sensor in the new position is in fact less sensitive to the switching on and off of the motor, and is very similar to the temperature of the contents. The discrepancy between the two levels must therefore be much smaller if the temperature of the contents is to be kept very close to the set temperature, for example by a few tenths of a degree. The small deviation between the upper temperature and the lower temperature requires a microchip with greater precision in order to discriminate even to a hundredth of a degree. This characteristic can be found in microchips provided with an analogue-to-digital converter, which, however, are more expensive than the microchips used on traditional products with a sensor on the evaporator.

[0005] Moreover, the system with a sensor on the door is more delicate than the previous one. For example, if the user opens the door as soon as the motor starts up, the temperature rises more quickly than intended and, since the upper level is extremely close, it could make the motor switch on after too short a time. Alternatively, when the freezer is empty, since the temperature of the sensor changes much more quickly than when it has a load, because of the greater convective motion of the air inside, the control would tend to produce cycles of just a few minutes. This is technically unacceptable because compressors have minimal OFF times. Switching off and on too rapidly would cause the motor to break down.

[0006] Another important defect of freezers with a sensor in the door is the poor performance of the freezer. The cycles are very long and the temperatures of some frozen products oscillate with amplitudes of up to 2°C. The cycles can last for 3 or 4 hours, and even longer, and therefore the temperature pattern of the frozen products is extremely variable even if they have high thermal lag. With the current control, in fact, the cycle time cannot be controlled directly, but varies particularly with ambient temperature. Since it is known that the optimal performance of the freezer depends on a given cycle time, cycles that are too long or too short in freezers of the known type with a sensor in the door do not ensure optimal performance of the electrical appliance.

[0007] With cycles that are too short, consumption rises because the compressor starts up too frequently while, with long cycles, the temperature of the frozen foodstuffs fluctuates at great amplitudes, and therefore more energy than necessary is expended in order to ensure that the contents are kept at the required temperature.

[0008] The aim of the present invention is to overcome the aforesaid disadvantages, while maintaining all the existing advantages of a horizontal freezer with a temperature sensor in the door.

[0009] This aim is achieved through the characteristics listed in the attached claims.

[0010] One of the main characteristics of the present invention is the ability of the control system of the freezer to define, on the base of the temperature reported by the sensor, a value linked to the connection time of the compressor. This value is preferably the connection ratio of the compressor, keeping the cycle time to a predetermined constant value. According to another characteristic of the invention, the control system of the freezer is also capable of determining the cycle time in relation to the temperature pattern monitored in the previous cycles, with the possibility of subsequently auto-adapting the control system to the operating conditions of the freezer (ambient temperature, amount of contents, frequency of door opening, efficiency of insulation etc.). According to another embodiment of the invention, the value fixed by the system is actually the activation time of the compressor, the deactivation time being free to fluctuate in relation to the time required in order to return to the set temperature.

[0011] According to another embodiment of the invention, the value fixed by the system is actually the deactivation time of the compressor, the activation time being free to fluctuate in relation to the time required in order to return to the set temperature.

[0012] Other advantages and characteristics of a refrigerator according to the present invention will become apparent from the following detailed description, provided purely as a non-exhaustive example and with reference to the attached drawings in which:

- Figure 1 is a schematic drawing in cross-section of a horizontal freezer according to the invention,
- Figure 2 is a schematic diagram that illustrates the ON-OFF operation of the compressor used in the freezer in Figure 1,
- Figure 3 is an outline diagram that illustrates one of the possible control algorithms used in the freezer according to the invention, and
- Figure 4 is a temperature/time diagram for the freezer according to the invention, and the related diagram that illustrates the variation in the connection ratio of the compressor.

[0013] With reference to the drawings, the number 10 illustrates as a whole a horizontal freezer (also known as a "chest freezer") having a compartment 10a and a door 12 hinged at 14 to the structure of the freezer. The door is provided at the front with a control panel 12a provided with a visual display unit (not illustrated) associated with a user interface through which the user can for example set the desired temperature. The door is also provided, on top of a lower face 12b, with a temperature sensor 16 facing the compartment 10a. This sensor 16 is connected to the user interface card associated with the control panel 12a and both are connected to an electronic control unit (not illustrated) to which the control for the relay of the electric motor of the compressor (not illustrated) also leads.

[0014] The solution for control according to the invention consists of a feedback control with a cycle time that is preferably fixed and a connection ratio I (Figure 2) that is the regulation variable. At the beginning of every ON-OFF cycle of the compressor this variable | is determined as a function of the connection ratio of the previous cycle, the temperature set and the temperature measured.

[0015] The law underlying regulation is preferably linear, but it can also be third-degree and can be implemented even with the microchips currently in production at no extra cost. Obviously, more sophisticated regulation can be used, guaranteeing a limited error, limited overshoot and an optimal response time.

[0016] The algorithm for the electronic card associated with the control unit of the freezer is illustrated in Figure 3, where the constants of the diagram L_c, L_F, C, K and K' are determined on the basis of experimental tests:

- L_c and L_F are the two limit values that determine the regulation zone. If the temperature Tc reported by the sensor 16 is found to be above this zone (Tc - Ts > L_C, where Ts is the set temperature) the motor runs continuously (and therefore with connection ratio equal to 100%), until the measured temperature reaches the set temperature Ts; if it is below this (Tc - Ts < L_F), the motor remains off (connection ratio equal to 0%) until the sensor 16 reaches the set temperature with zero error;
- C is the cycle time, and is established essentially on the basis of consumption tests. Every model or capacity of freezer in fact has a minimum consumption for a particular value of such a variable;
- K and K' are the regulation constants, which express the degree of influence of the error measured on the variation of connection in the next cycle, and determine the frequency of temperature oscillations before stabilisation;
- A and B are connection ratios that determine respectively the continuous operation or deactivation of the compressor, and are preferably equal to approximately 84% and 10%.

[0017] The control system functions as follows. The temperature sensor 16 reads the temperature inside the compartment 10a and sends it to the microcontroller. The latter checks whether the temperature Tc is outside a certain range of regulation defined by the set temperature Ts and by the upper L_C and lower L_F values within which this temperature can vary. If the temperature Ts has been exceeded by more than L_C (block 20) then the compressor is commanded to work at 100% connection (left branch of the algorithm, block 22) until the temperature Tc measured by the sensor is lower that the set temperature Ts (block 24). If the value is lower than the temperature Ts by more than L_F (block 26) then the compressor is switched off (right branch of the algorithm, block 28) until the temperature Tc measured by the sensor is above the set temperature Ts (block 30). When the set temperature Ts is substantially reached (whether from higher temperatures or from lower temperatures), the system sets a fixed connection ratio, for example 50% (block 32) until the cycle time C is completed (blocks 34 and 36). At the end of the cycle, the function |(t+1) = |(t) + K(Tc(t)-Ts) + K'(Tc(t)-Tc(T-1)) is applied and, on the basis of the actual temperature Tc reached after this cycle, the temperature reached at the end of the previous cycle and the regulation constants K and K', this determines the connection ratio that will be used in the next cycle (block 38). In the aforesaid equation, |(t+1) represents the connection ratio of the compressor to be used in the next cycle, |(t) the connection ratio in the current cycle, Tc(t) the temperature recorded at the end of the current cycle and Tc(T-1) is the temperature recorded at the end of the previous cycle. The connection ratio calculated in block 38 will actually be used in the next cycle, unless, in block 40, it is found that the temperature range is still over the aforesaid upper limit L_c. If this condition is not found, the connection ratio determined in block 40 is compared in block 42 with a predetermined connection ratio value A over which it is not however convenient to make the compressor work, a 100% connection being preferable. If the connection ratio calculated at 38 is lower than A and if the temperature Tc is not below the lower limit of regulation Lf (block 44), the system checks whether the connection ratio I determined at 38 is lower than a predetermined minimum value B (block 46) below which consumption would be too high. If the connection ratio is above B, the system repeats the control cycle constituted by the blocks 34, 36 and 38 in order to arrive, by successive approximations, at the optimum value for the connection ratio.

[0018] The aforesaid values A and B for maximum and minimum connection ratios have been provided as emergency measures for the lifetime of the compressor. A normal compressor must in fact have a minimal "rest" time between being switched on and switched off again, of at least five minutes. If the ratio falls below levels that are too low, the motor should be kept switched off completely until the assigned temperature is reached again, rather than making the motor work for just a few minutes every half hour. The minimum ratio B is therefore set at 10%. The damping, the frequency of oscillations and the maximum overshoot of the regulation system depend on several factors, including the mass of the freezer contents and the regulation constants K and K'.

[0019] In the embodiment described here the system regulates the operation of the horizontal freezer, establishing the connection ratio on the basis of the temperature recorded by the sensor 16 positioned in the compartment 10a. Optimal results in terms of energy savings have been obtained in comparison with those obtained on freezers using a traditional type of temperature control. Obviously, the control algorithm can also provide for the possibility of determining the optimum time cycle for the freezer, for example starting from values for ambient temperature and/or from the temperature value set by the user and/or the value of the connection ratio of the compressor. In this case the algorithm, as well as following a logic such as that illustrated in Figure 3, will have the possibility of comparing the conditions in the surroundings and, from time to time, fixing the optimum cycle time C for such conditions. Another embodiment of the algorithm according to the invention provides for the variable regulated to be the connection time of the compressor rather than its connection ratio. In this case the ON-OFF cycle time will be variable in that the OFF time will not be fixed a priori by the algorithm itself but will be variable in relation to the operating conditions of the freezer, and in particular in relation to the time required in order to return to the set temperature. Similarly, according to another embodiment of the invention, the variable regulated is the deactivation time of the compressor. In this case the ON time will not be fixed a priori by the algorithm, but will be variable in relation to the time required in order to return to the set temperature.

[0020] Although, in the description of the embodiment example, reference has been made mainly to a horizontal freezer, the type of control according to the present invention can also be used to advantage for other types of refrigerators and freezers, for example refrigerators with or without a separate freezer compartment and upright freezers.

Claims

1. Domestic refrigerator, particularly freezer, of the type comprising a food storage compartment, a cooling circuit provided with a compressor, a temperature sensor (16) positioned in said compartment and a control system capable of controlling the compressor in relation to a signal from said temperature sensor, **characterised by** the fact that the control system is capable of defining, on the basis of the temperature reported by said sensor (16), a value linked to the connection time of the compressor with the aim of optimising the performance of the refrigerator.

2. Refrigerator according to Claim 1, **characterised by** the fact that said value is the connection ratio in an ON-OFF cycle of the compressor, the cycle time (C) being fixed at a predetermined value.

3. Refrigerator according to Claim 2, **characterised by** the fact that the control system is also capable of defining an optimum time cycle (C) for the compressor.

4. Refrigerator according to Claim 1, **characterised by** the fact that said value is the connection time of the compressor.

5. Refrigerator according to Claim 1, **characterised by** the fact that said value is the deactivation time of the compressor.

6. Refrigerator according to any one of the preceding claims, particularly a horizontal freezer provided with an upper horizontal door, **characterised by** the fact that the temperature sensor (16) is positioned on said door (12) on its face facing the compartment (10a).

7. Refrigerator according to Claim 2 or 3, **characterised by** the fact that the connection ratio of the compressor is calculated on the basis of the following equation:

$$I(t+1) = I(t) + K(Tc(t)-Ts) + K'(Tc(t)-Tc(T-1))$$

where |(t) is the connection ratio of the compressor calculated in the current cycle, |(t+1) is the connection ratio to be used in the next cycle, K and K' are the regulation constants, Tc(t) is the temperature recorded at the end of the current cycle, Tc(T-1) is the temperature recorded at the end of the previous cycle and Ts is the set temperature.

8. Refrigerator according to Claim 7, **characterised by** the fact that the control system is capable of comparing the connection ratio (I) calculated with a predetermined maximum value (A), and making the compressor work at a connection ratio equal to 100% in the next cycle if the calculated connection ratio exceeds said maximum value (A).

9. Refrigerator according to Claim 7, **characterised by** the fact that the control system is capable of comparing the calculated connection ratio (I) with a predetermined minimum value (B), and of making the compressor work at a connection ratio equal to 0% in the next cycle if the calculated connection ratio is lower than said minimum value (B).

10. Method for regulating the temperature in a domestic refrigerator, particularly in a horizontal freezer (10) provided with a food storage compartment (10a), a cooling circuit with a compressor and a temperature sensor (16) positioned in said compartment, **characterised by** the fact that it comprises the definition of a regulated value linked to the connection time of the compressor.

11. Method according to Claim 10, **characterised by** the fact that it comprises the comparison of the recorded temperature (Tc) with a predetermined set value and with two values (L_C, L_F) capable of defining a regulation range within which said set value (Ts) is comprised, the definition of the connection ratio (I) in an ON-OFF cycle of the compressor at 100% and 0% respectively if the recorded temperature (Tc) is found to be above or below this regulation range, the definition of a connection ratio (I) with a value corresponding to the following equation |(t+1) = |(t) + K(Tc(t)-Ts) + K'(Tc(t)-Tc(T-1)) if the recorded temperature is found to be within said regulation range, where |(t) is the connection ratio of the compressor calculated in the current ON-OFF operation cycle of the compressor, |(t+1) is the connection ratio to be used in the next cycle, K and K' are the regulation constants, Tc(t) is the temperature recorded at the end of the current cycle, Tc(T-1) is the temperature recorded at the end of the previous cycle and Ts is the set temperature.

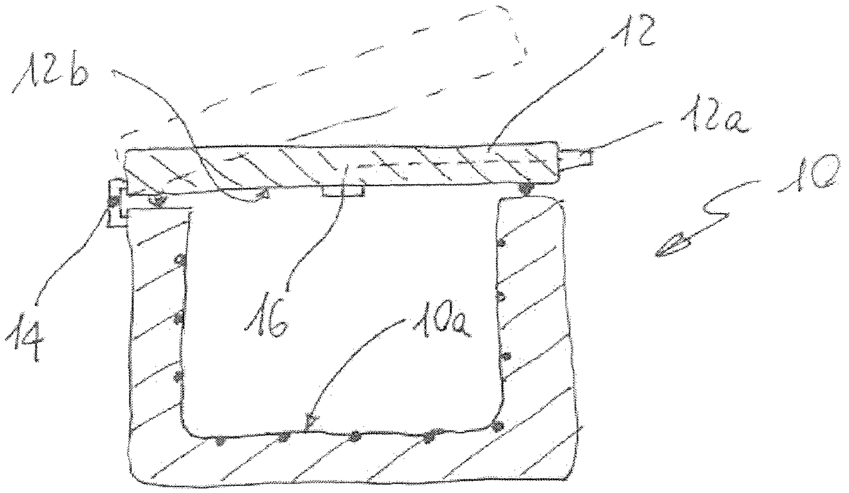
12b
12
12a
10
14
16
10a

Fig. 1

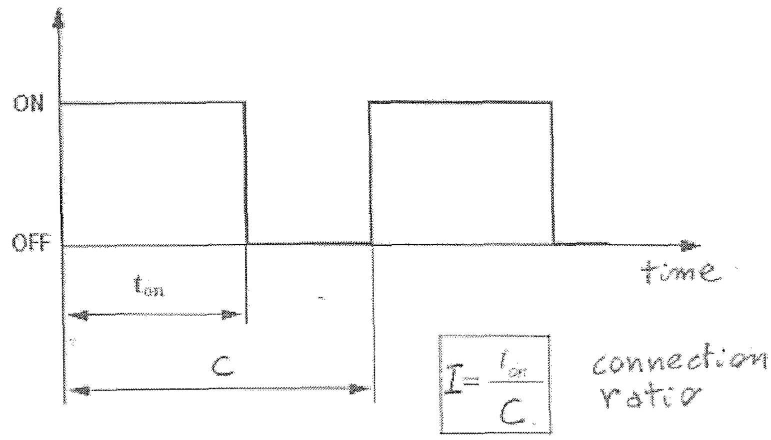
ON
OFF
time
t_{on}
c
$I = \frac{t_{on}}{C}$
connection ratio

Fig. 2

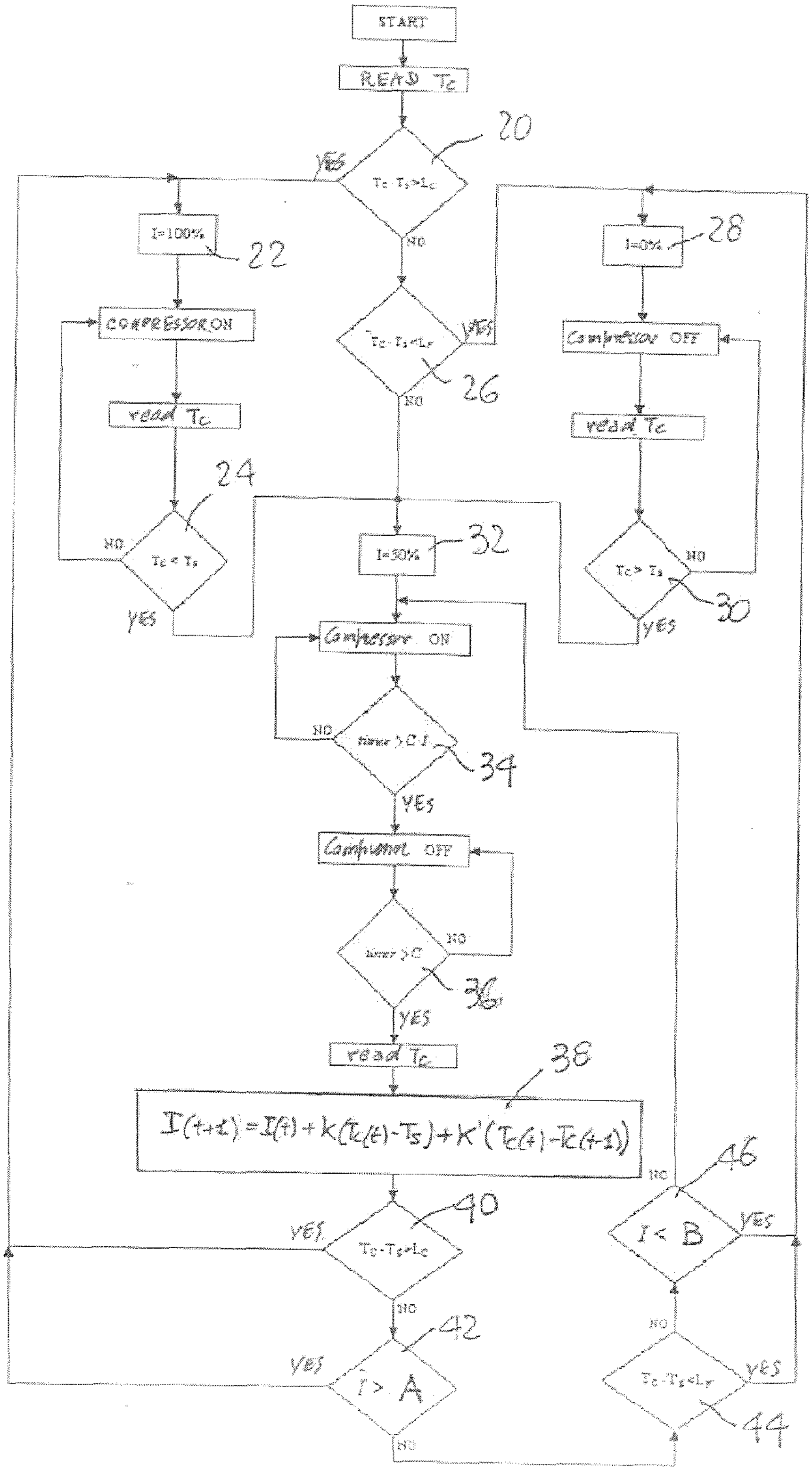
START
READ Tc
20
Tc-Ts>Lc
YES
NO
I=100%
22
COMPRESSOR ON
read Tc
24
Tc<Ts
NO
YES
Tc-Ts<Lr
YES
NO
26
I=0%
28
Compressor OFF
read Tc
Tc>Ts
NO
YES
30
I=50%
32
Compressor ON
>C·I
NO
YES
34
Compressor OFF
>C
NO
YES
36
read Tc
38
I(t+1)=I(t)+k(Tc(t)-Ts)+k'(Tc(t)-Tc(t-1))
Tc-Ts>Lc
YES
NO
40
I>A
YES
NO
42
I<B
NO
YES
46
Tc-Ts<Lr
NO
YES
44

Fig. 3

No load test : Cycle = 30 min.

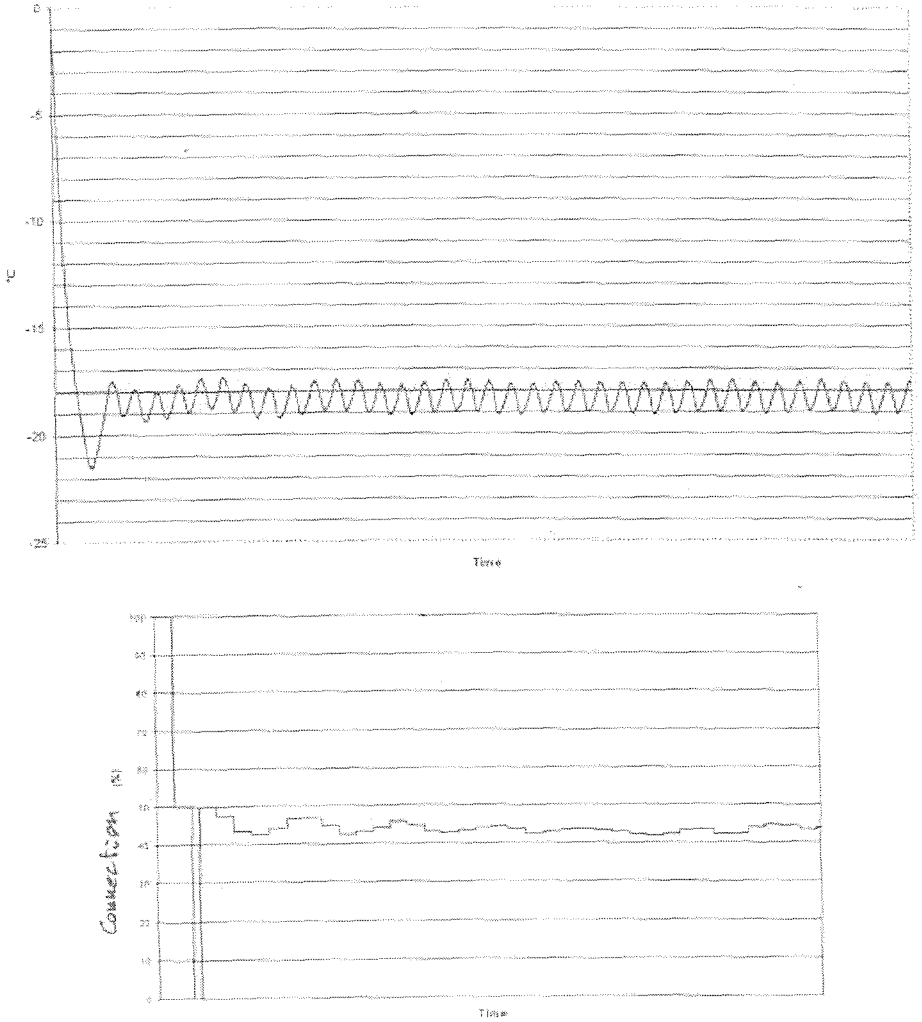

Fig. 4