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

(11) EP 1 564 514 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
17.08.2005 Bulletin 2005/33

(51) Int Cl.[7]: **F25D 29/00**, F25B 49/02

(21) Application number: **04008721.5**

(22) Date of filing: **13.04.2004**

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

(30) Priority: **12.02.2004 EP 04003144**

(71) Applicant: **WHIRLPOOL CORPORATION**
Benton Harbor Michigan 49022 (US)

(72) Inventors:
- **Boer, Alessandro, c/o Whirlpool Europe s.r.l. 21025 Comerio (IT)**
- **Paganini, Raffaele, c/o Whirlpool Europe s.r.l. 21025 Comerio (IT)**
- **Petrigliano, Rocco, c/o Whirlpool Europe s.r.l. 21025 Comerio (IT)**

(74) Representative: **Guerci, Alessandro**
Whirlpool Europe S.r.l.
Patent Department
Viale G. Borghi 27
21025 Comerio (VA) (IT)

Remarks:
A request for correction of the numbering of the claims has been filed pursuant to Rule 88 EPC. A decision on the request will be taken during the proceedings before the Examining Division (Guidelines for Examination in the EPO, A-V, 3.).

(54) A refrigerator and a method for controlling variable cooling capacity thereof

(57) A refrigerator comprises a compressor and control means for controlling such compressor in response to the temperature inside the refrigerator. The control means are adapted to detect how the temperature changes inside the refrigerator due to the loading of a warm food item, and to adjust the cooling capacity of the compressor accordingly.

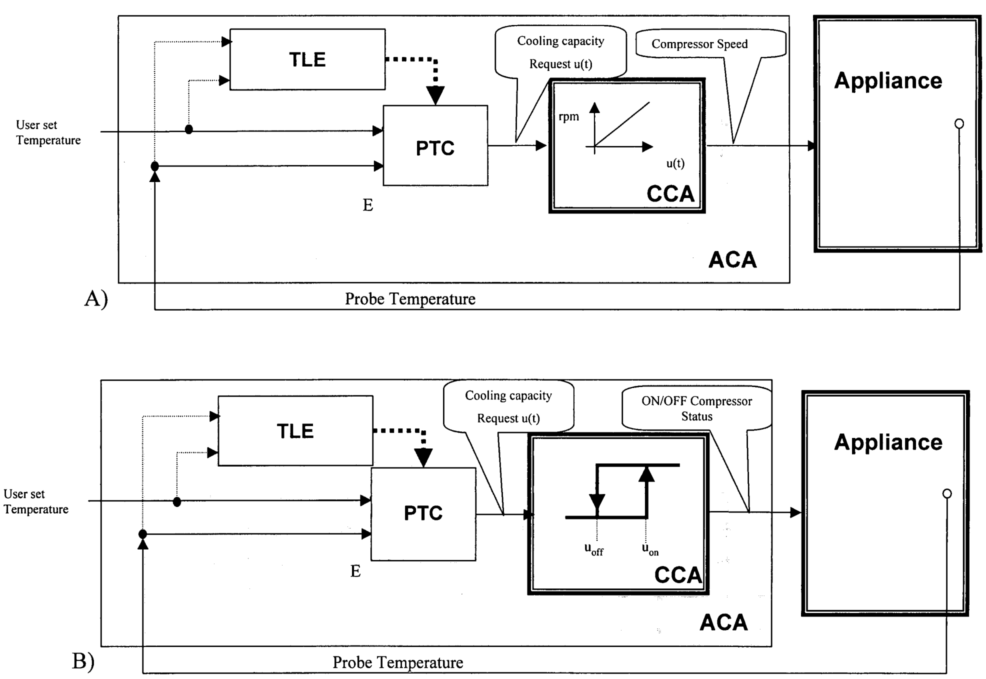


Figure 2

EP 1 564 514 A1

Description

[0001] The present invention relates to a refrigerator comprising a compressor having a fixed or variable cooling capacity and control means for controlling such compressor in response to the temperature inside the refrigerator, as well as to a method for automatically speeding up the cooling time of the food stored in a refrigerator without user interaction and with limited energy consumption. With the term "refrigerator" as used in the description and in the appended claims we mean any kind of domestic refrigerator and freezer. With the term compressor having variable cooling capacity we mean all kind of compressors having the possibility of changing the output, either by changing displacement of the compressor (for instance with the so called free piston compressor) or by changing the speed of the compressor (in case of fixed displacement) either continuously or stepwise. In general, modern freezers and refrigerators have a fast freezing or fast cooling feature. This feature must be activated by the user and consists in keeping the compressor running at its maximum cooling capacity for an appropriate fixed time (i.e. 24 hours). Such a known technique guarantees the maximum cooling speed and is suitable for the fast cooling of large amounts of food. When the amount of food is not very large, it leads to unnecessary food over-cooling and energy waste. On the other hand, the user often forgets to activate the function or he doesn't consider the amount of food large enough to manually activate the function. As a consequence in these cases, the cooling process is relatively slow.

[0002] A refrigerator having the features listed in the appended claims solves the above problem.

[0003] The present invention provides a control algorithm able to estimate the amount of warm food inserted into the refrigerator or freezer. On the basis of this estimation, the algorithm automatically tunes the compressor response in order to speed-up the cooling process without wasting any energy for unnecessary over-cooling.

[0004] In this way the user is not required to activate manually engage the fast cooling function, and any waste of energy, due to over-cooling, is avoided.

[0005] The above mentioned and other features and objects of the present invention, and the manner of attaining them, will become more apparent and the invention itself will be better understood by reference to the following description taken in conjunction with the accompanying drawings in which:

- Figure 1 shows a typical temperature trend inside a known freezer when the user puts a quantity of warm food inside the cavity without any "Fast-Freezing" function;
- Figures 2a and 2b show a block scheme describing the logical architecture of the appliance control algorithm (ACA) according to the present invention in case a variable speed compressor or an on/off compressor is respectively used;
- Figure 3 show a typical overshoot probe temperature caused by the introduction of warm food;
- Figure 4 show the main parameters that can be considered to characterized the overshoot shape and to estimate the warm food enthalpy;
- Figure 5 shows a warm food temperature recovery, with an appliance control algorithm according to the present invention;
- Figure 6 shows the auto-fast freezing obtained by estimating the warm food enthalpy just on the basis of the probe overshoot temperature peak; in figure 6a just a door opening was considered, while in figure 6b a door opening with 10 kg of warm food loading was considered;
- Figure 7 shows the auto-fast freezing obtained by estimating the warm food enthalpy on the basis of the probe overshoot temperature peak and on the probe temperature overshoot area; in figure 7a just a door opening was considered, while in figure 7b a door opening with 10 kg of warm food loading was considered.
- Figure 8 highlights the faster recovery and pull-down obtained by considering the temperature probe overshoot area A_{over} in addition to the peak temperature T_{peak};
- Figure 9 a and b show a comparison between a warm food pull-down with the known "Fast-Freezing" function activated and a recovery according to the present invention respectively, highlighting how the traditional fast freezing function can cause an excessive and unnecessary food "under-cooling" (medium load was considered);
- Figure 10 shows a comparison between energy consumption vs. time obtained with the known fast freezing function (in the working condition shown in fig. 9a) and the energy consumption obtained with a refrigerator according to the present invention (in the working condition of fig. 9b); and
- Figures 11 and 12 show an example of auto fast-freezing function obtained by applying the present invention to an appliance with a variable speed compressor and to an/on off compressor respectively.

[0006] With reference to the drawings, in which experimental data were obtained with a Whirlpool side by side refrigerator model *s25brww20-a/g*., figure 1 shows a typical and well-known temperature trend inside a freezer when the user puts a quantity of warm food inside the cavity. In the first instants the probe temperature rapidly increases. When the user closes the door, the temperature starts going down thanks to the traditional temperature control action, based on a consequent increase of the cooling capacity of the compressor (in the example the speed of the variable speed compressor increases from 1500 rpm to 4000 rpm). The higher is the amount of warm food inside the freezer, the slower the probe temperature tends to go down. An additional important effect of the warm food introduction (figure 1) consists in heating the "cold packages" (we indicate "cold package" the package already stored in the appliance when the warm food is loaded). The present invention relates to a refrigerator and to a method of controlling such refrigerator with the triple objective of controlling the appliance actuators (compressor, valves, damper) in order to:

- maximize the warm food temperature pull-down;
- reduce the "cold package" over temperature; and
- minimize the energy consumption.

[0007] Figure 2 shows a block diagram describing the logical architecture of the appliance control algorithm (ACA) according to the present invention. It is composed of three main blocks: the warm food thermal load estimator (TLE), the probe temperature controller (PTC) and the cooling capacity adapter (CCA).

[0008] The first block (TLE) has the purpose of detecting the warm food introduction event and estimating the amount of this warm food.

[0009] With the terms "Thermal load" we refers to the warm food enthalpy E defined as E = (food mass) · (specific food thermal capacity) · (food temperature).

[0010] The PTC block has the purpose of controlling the temperature measured by the traditional sensor by providing an appropriated "cooling capacity" request according the above mentioned three objectives.

[0011] The cooling capacity adapter CCA converts the cooling capacity request into an appropriated actuator command. Such command can be either the compressor speed if a variable speed compressor is used (figure 2a) or the compressor status (on/off) if a fixed speed compressor is used (figure 2b). In the second case, the block CCA works according to an hysteresis logic, i.e. if the cooling request u(t) is greater than a predetermined value $u(t)_{on}$, the compressor will be switched off, if such cooling request is lower than a predetermined value $u(t)_{off}$, the compressor will be switched off. Of course, it is possible to use another logic for converting the continuous quantity u(t) into a binary value, for instance a PWM (pulse width modulation) technique.

[0012] The thermal load estimation TLE block and the probe temperature controller PTC block are within the main features of the present invention.

[0013] The TLE block consists on a estimation algorithm based on a accurate analysis of the probe temperature signal in order to obtain the warm food enthalpy E. This is done by processing the shape of the probe temperature overshoot (figure 3) as a consequence to the warm food introduction. With the term of shape factor we mean all the factors that characterize the probe temperature overshoot, and particularly its derivatives, area over an average temperature value (steady state), peak height, overshoot duration, power spectrum or combination thereof.

[0014] Fig 4 shows the main factors characterizing this temperature overshoot shape and that have to be considered to obtain the warm food temperature enthalpy E, according to the present invention. These main factors are here summarized:

- the probe temperature derivative during the rising phase dTr (average maximum and minimum)
- the probe temperature derivative during the decreasing (slope) phase dTs (average max and min)
- the peak over temperature T_{peak}
- the probe temperature overshoot area A_{over}
- the overshoot duration $\Delta t_{overshhot}$
- the power spectrum of the probe temperature overshoot.

[0015] The way in which the above factors are detected/measured is not disclosed here in detail since this is considered within the usual skill of a refrigerator control designer.

[0016] Figure 5 shows a warm food temperature recovery, with an appliance control algorithm implementing the present invention. By comparing this chart with the chart in fig 1 (traditional control) it can be noticed how the proposed algorithm performs an appropriate probe "over-cooling". According to the block diagram of figure 2, the probe temperature control block PTC requires the compressor switch off (cooling capacity request = 0) when the warm food temperature (obtained through the TLE block) is considered close enough to the user set temperature.

[0017] It is important to notice that the traditional control doesn't perform any probe "under-cooling": as the temperature probe reaches the cut-off temperature, the compressor is shut down but the food is not yet completely cooled. On the contrary, the proposed algorithm performs an appropriate probe "under-cooling" depending on the estimation of the introduced warm food enthalpy provided by the TLE block (figure 2). The TLE block recognizes the warm food introduction, it processes the probe temperature overshoot and provide the PTC block with the estimated warm food enthalpy E. The PTC block decides an appropriated probe temperature undershoot "under-cooling". During this phase, the usual control based on cut-off and cut-on temperature is overruled, i.e. the compressor is no longer switched on and switched off when the temperature inside the refrigerator reaches nominal cut-on and cut-off temperature respectively. During such phase the cut-off and cut-on temperatures are automatically reduced according to the estimated loaded food enthalpy and are progressively increased to the nominal values in order to provide an energy efficient temperature pull-down. This is clearly shown in figure 5.

[0018] After the package loaded into the freezer is considered sufficiently cooled, the usual method of controlling the compressor, in which the compressor is switched off when the cut off temperature is reached, is resumed.

[0019] Referring to figure 4, a possible technique for estimating the amount of warm food and to carry out an appropriated probe "over-cooling" is based on the estimation of the A_{over} area, i.e. the integral of the curve representing the increase of temperature above a steady state average temperature T. If A_{over} is the probe temperature area caused by the warm package insertion, the control algorithm drives the compressor to an appropriate speed in order to guarantee an "over-cooling" area A_{under} that is proportional to the area A_{over}, i.e. $A_{under}=k \cdot A_{over}$. The parameter k may depend on the type of appliance. Furthermore, on the same appliance, this parameter may be constant or changed with the working conditions (i.e. external temperature, temperature set by the user etc), and fuzzy logic may be used for purposively adjusting k value.

[0020] An alternative technique consists in having an area A_{under} based on time derivative of the probe temperature, i.e. with A_{under} proportional to such derivative either in the temperature rising phase or in the temperature decreasing phase: the lower is the derivative in the decreasing phase, the higher must be A_{under}, the higher is the derivative in the increasing phase, the higher must be A_{under} (time derivative being in absolute value).

[0021] Nevertheless other parameters (in addition to the amount of warm food) may affect these parameters (dT_r, dTs, $\Delta t_{overshoot}$ and A_{over}) and one of these is the external temperature. For this reason, if an external temperature sensor is available in addition to the usual internal temperature sensor, the measure of the above three parameters can be correlated with the measure of external temperature sensor to improve the warm food temperature estimation.

[0022] The same techniques described in the previous paragraphs can be used also to decide an appropriated interval time Dt in which the compressor must be forced to run at an appropriated level of power (for instance at the maximum one).

[0023] Of course any combination of the previous techniques can be used.

[0024] Fuzzy logic and "neural network" techniques can be used for this kind of application. For examples a control algorithm based on a set of Fuzzy rules can receive as input all the mentioned parameters shown in figure 4 and convert them into an estimation of both the mass and the temperature of the inserted food or its enthalpy E (as the product of thermal mass by temperature). This estimation can then be passed to a second task which converts it into a request of compressor cooling capacity u(t) and it can provide one or more additional parameters such as: probe sub-cooling area $A_{under,}$ cut-off temperature T_{off}, interval time Dt in which the compressor must be forced to run at an appropriate level of power (if different levels of power are available).

[0025] Alternatively or in addition to such kind of technical solution, a temperature control algorithm based on the PID (Proportional-derivative-integral) technique can obtain the control.

[0026] With such a kind of algorithm, the compressor cooling capacity request u(t) will depend on the error temperature e(t) according to the following formula:

$$u(t) = Kp * [e(t) + \frac{1}{Ti} * \int_0^t e(\tau) d\tau + Td * \frac{de(t)}{dt}]$$

[0027] Where the temperature error *e(t)* is defined as: *e(t)= Tprobe-Ttarget,* Ti is the integral time, Td is the derivative time, Ttarget is a temperature reference depending on the user set temperature and Kp is a predetermined coefficient.

[0028] The integral component plays the main role in adapting the cooling capacity to the amount of warm food. In fact it is proportional to the area of the error *e(t)* along the time axes. During a recovery, this area is significantly affected by the amount of warm food: the higher is the amount of warm food, the longer *e(t)* tends to be "high" (>0) with a consequent increasing of its area (see area A_{over} in fig 4). This condition leads to a progressive increasing of the compressor cooling capacity u(t). Furthermore, the integrative component guarantees an appropriate probe "under-cooling" to compensate the positive area caused by the insertion of the warm food. To enhance this effect, an adaptive PID can be used. A "steady state PID" will control the appliance temperature when no disturbances affect the system (no door opening, no food introduction). Once door opening and food introduction events are detected, the "steady state PID" will be disabled and a "pull-down PID" algorithm will be engaged. Such "pull-down PID" will provide a fast and energy efficient warm food temperature pull-down. This can be obtained by adjusting the Ti parameter according to the following criteria:

- during the steady state, Ti will be set to its nominal value ($Ti= Ti_N$);
- once a warm food introduction is detected and the probe temperature overshoot starts, the Ti is reduced by a k1 factor ($Ti=Ti_N/k1$, k1>=1). This will enhance the dependence of the integral part of the PID from the probe temperature over shoot area A_{over} that is one of the main factors affected by the warm food enthalpy;
- at the end of the probe temperature overshoot (when e(t) pass from negative to positive) the Ti will be increased by a k2 factor: ($Ti=Ti_N*k2$, k2>=1). This will slow down the integral part discharge with a consequent probe temperature over-cooling area. Such over-cooling will be proportional to the previous temperature overshoot area and, by consequence to the warm food enthalpy. The adjustment of Ti (and/or of other parameters as Td and Kp) can act together with or replacing the well-known "anti wind-up" technique in which the integrative part of the temperature error may or not be saturated to a pre determinate value.

[0029] It is important to highlight the fact that the effectiveness of the invention in providing an appropriate warm food temperature pull-down depends on the precision of the food enthalpy estimation. The more accurate is the estimation, the more precise will be the pull-down in respect to the above-mentioned triple objective. The quality of the estimation mainly depends on what probe temperature overshoot parameters (see fig 4) are considered by the TLE block to obtain the warm food enthalpy estimation. In particular an intuitive solution would

[0030] suggest to estimates the food enthalpy just on the basis of the peak temperature T_{peak} without any consideration about the shape of the overshoot probe temperature. Such kind of solution wouldn't get the appliance control algorithm able to correctly recognize the amount of the warm food and would provide a wrong temperature pull-down in the sense that it can provide an excessive food under-cooling when the amount of warm food is low (with a consequent waste of energy). Or it can provide a not enough fast pull-down in presence of large amount of warm food. This fact is highlighted in figures 6a and 6b. These figures show the pull down obtained with an appliance control that estimates the food enthalpy just on the basis of the probe overshoot peak temperature (Tpeak) and set a continuous compressor run time proportional to Tpeak. Figure 6a show the response of such kind of algorithm to a door opening of 3 minutes without any food introduction. Figure 6b shows the behavior of the same algorithm in response to a door opening with 10 Kg of warm food introduction at the external ambient temperature (20°C). In both the cases, the peak temperature value (Tpeak) is roughly the same and the algorithm decides for 2 hours of compressor continuous running. After 2 hours, the compressor will be switched off according to the normal cut-off temperature. It can be noticed how the algorithm performs a good cold package temperature recovery in the first condition (figure 6a): the compressor is switched off as the cold package temperature returns to the steady state value: any additional sub-cooling would cause a waste of energy. When 10 kg of warm package are introduced (figure 6b) the algorithm decides again for 2 hours of compressor continuous running (being the T_{peak} value the same). After two hours, the temperature is still above the cut-off value; the control algorithm can decide to keep the compressor in a switched on condition up to the cut-off temperature is reached. But in this case the performances of the control are not optimal. In fact the compressor is switched off when the cold package is still more than 3°C above the steady state value and the warm package is still 5°C up the steady state value.

[0031] Figures 7a and 7b show the behavior of a control appliance in which the estimation of the warm food enthalpy is based on both the peak temperature and the overshoot area. The disturbances here considered are exactly the same considered with the previous algorithm (3 minutes of door opening without load introduction, door opening with 10 kg of load introduction). In particular an adaptive PID according to the above mentioned idea was here considered as a control algorithm (with k1=1 and k2=2, Ti =3600 sec.).

[0032] By analyzing figures 7a and b, it can be noticed how the pull-down and recovery are correctly performed in both the conditions proving the capability of the algorithm in adapting automatically the compressor response and the probe temperature over-cooling to the amount of introduced warm load. In fact in the first case the compressor was switched off when the cold package was close enough to the steady state value (just 0.5°C above the steady state value). In the second case (10 kg of warm load introduction), again the compressor was switched off when the warm packages reached the steady state value and the cold package is just 1 °C over steady state the temperature and it returns to its steady state value in half of the time. Furthermore, it can be noticed how in both the cases the algorithm doesn't restore immediately the cut off and the cut-on temperatures after the first switch off but it increases them progressively up to the steady state value. This is done in order to have a fast package recovery and pull-down avoiding excessive cold probe temperatures which would cause waste of energy (the colder is the probe temperature, the colder is the evaporator temperature and, by consequence, the less efficient is the thermodynamic cycle).

[0033] Figure 8 highlights the recovery performed by the two considered algorithms.

[0034] The main advantages of the present invention are as follows. The algorithm adapts the compressor response to the warm thermal mass avoiding any waste of energy for unnecessary over-cooling. In particular, figure 9a shows the effects of the traditional fast freezing function manually activated by the user: in this case "medium load" quantity of warm food has been inserted into the freezer. The traditional fast freezing function keeps the compressor running at its maximum capacity for 24 hours with a consequent under cooling of the food with a consequent waste of energy.

Figure 9b shows the automatic fast freezing performed by the method according to the present invention in the same working condition of figure 9a: without any user interaction the same amount of warm food is rapidly recovered without unnecessary food "under-cooling". Figure 10 shows the comparison between the energy consumption in the two above cases.

[0035] The method according to the invention is completely automatic, this means that the user is not required to activate any function. So the risk of a slow temperature recovery, when the user forgets to activate the fast freezing function present in known refrigerators, is avoided. Finally it is important to underline that the present invention can be applied both for appliance with variable capacity compressor and on-off compressor. According to the block scheme of fig. 2, In case of variable speed compressor, the cooling request provided by the PTC block will be converted into a speed request through an appropriated curve (ex. linear). In case of a traditional on/off compressor, the cooling request will be converted into a compressor state command according with an appropriated logic (hysteresis, PWM). Figures 11 and 12 show an example of application according to the invention to a variable speed compressor and to an on/off compressor respectively.

[0036] Even if the description is mainly focused on an example of algorithm applied to a freezer, the same algorithm can be used also in a refrigerator or in a fresh food compartment of an appliance having more than one refrigerating cavity.

Claims

1. A refrigerator comprising a compressor having control means for controlling it in response to the temperature inside the refrigerator, **characterized in that** the control means are adapted to detect how the temperature inside the refrigerator varies due to the loading of a food item or to a similar event, and to adjust the cooling capacity of the compressor and/or its status (on/off) accordingly.

1. A refrigerator according to claim 1, **characterized in that** the control means are adapted to increase the cooling capacity of the compressor and/or the compressor run time proportionally to an estimated enthalpy (E) of the loaded food item.

2. Method for controlling the variable cooling capacity of a compressor in a refrigerator having a variable cooling capacity compressor, in which such control is based on temperature signal from a temperature sensor inside the refrigerator, **characterized in that** the variation of temperature due to the loading of a food item or to a similar event is detected and the cooling capacity of the compressor is adjusted accordingly in order to have a quicker cooling of such food item.

3. Method for controlling the status of an on/off compressor in which such control is based on temperature signal from a temperature sensor inside the refrigerator, **characterized in that** the variation of temperature due to the loading of a food item or to a similar event is detected and the compressor status, together with the compressor run time, are adjusted accordingly in order to have a quicker cooling of such food item.

4. Method according claims 3 or 4, **characterized in that** it comprises the following step:

- detecting any variation of the probe temperature above a predetermined average temperature value due to the loading of a food item inside the refrigerator;
- analyzing the shape factors of said probe temperature variation, preferably such shape factors being selected in the group consisting of derivatives, area, peak, overshoot duration, power spectrum or combination thereof;
- estimating the enthalpy (E) of the loaded food from the analysis of the probe temperature shape and related shape factors; and
- increasing the cooling capacity of the variable capacity compressor or the compressor run time of the on/off compressor so that the integral and/or the peak of the variation of the probe temperature below said predetermined average temperature is proportional to the estimated loaded food enthalpy.

5. Method according to claims 3 or 4, **characterized in that** it comprises the following step:

- detecting any variation of the probe temperature above a predetermined average temperature value due to the loading of a food item inside the refrigerator;
- estimating the integral of said probe temperature variation vs. time; and
- increasing the cooling capacity of the variable capacity compressor or the compressor run time of the on/off

compressor so that the integral and/or the peak of the variation of the probe temperature below said predetermined average temperature, due to the increased cooling capacity of the compressor, is proportional to the integral of the variation of temperature above said predetermined value.

6. Method according to claims 3 or 4, **characterized in that** it comprises the following steps:

- detecting any variation of the probe temperature above an average predetermined value due to the loading of a food item inside the refrigerator;
- estimating the derivative of the probe temperature vs. time in the decrease of temperature due to the intervention of the control; and
- increasing the cooling capacity of the variable capacity compressor or the compressor run time of the on/off compressor so that the integral and/or the peak of the variation of the probe temperature below said average predetermined temperature value, due to the increased cooling capacity of the compressor, is inversely proportional to said temperature derivative.

7. Method according to claim 4, **characterized in that** the cooling capacity u(t) of the compressor is adjusted with a control algorithm based on a PID technique according to the following formula:

$$u(t) = Kp * [e(t) + \frac{1}{Ti} * \int_0^t e(\tau) d\tau + Td * \frac{de(t)}{dt}]$$

where the temperature error *e(t)* is defined as: *e(t)= Tprobe-Ttarget,* Ti is the integral time, Td is the derivative time and Kp is a constant coefficient.

8. Method according to claim 8, **characterized in that** the parameters Ti, Td, Kp are adjusted according to an opening of the refrigerator door or from a sudden rising temperature detection in order to speed up the food cooling time.

9. Method according to claim 5 or 6, **characterized in that** parameters such as areas and derivatives of the measured temperatures are processed using soft computing techniques as fuzzy logic and neural networks to provide an estimation of the inserted food enthalpy and to adapt the compressor response by consequence.

10. Method according to claim 4, **characterized in that** the cooling capacity request is converted from a continuous quantity into a discrete quantity to control an on/off compressor.

11. Method according to claim 5, in which the compressor is switched on and switched off when the temperature inside the refrigerator reaches nominal cut-on and cut-off temperature respectively, **characterized in that** such cut-off and cut-on temperatures are reduced according to the estimated loaded food enthalpy and are progressively increased to the nominal values in order to provide an energy efficient temperature pull-down.

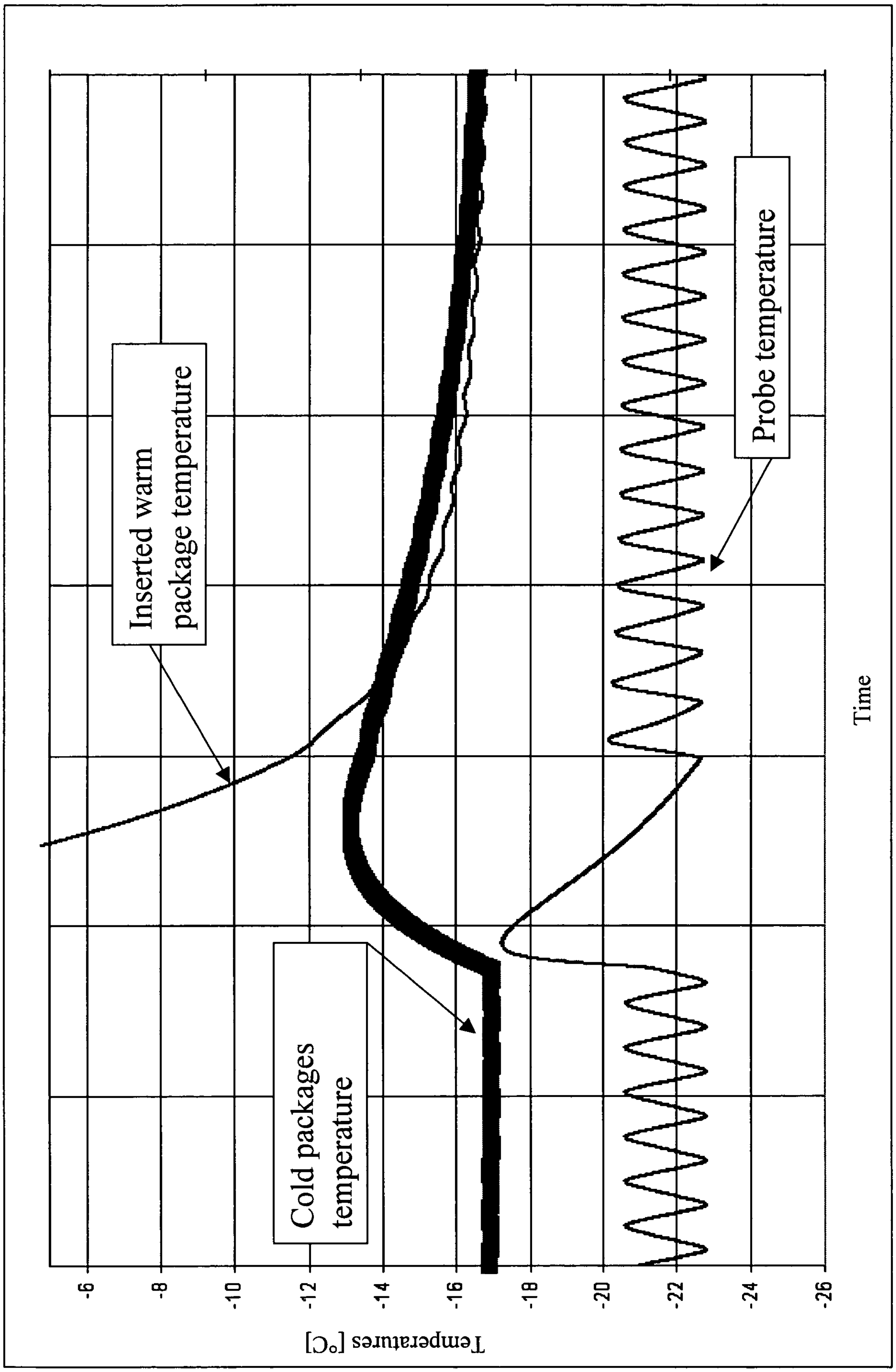

Inserted warm package temperature
Cold packages temperature
Probe temperature
Time
Temperatures [°C]
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26

Figure 1

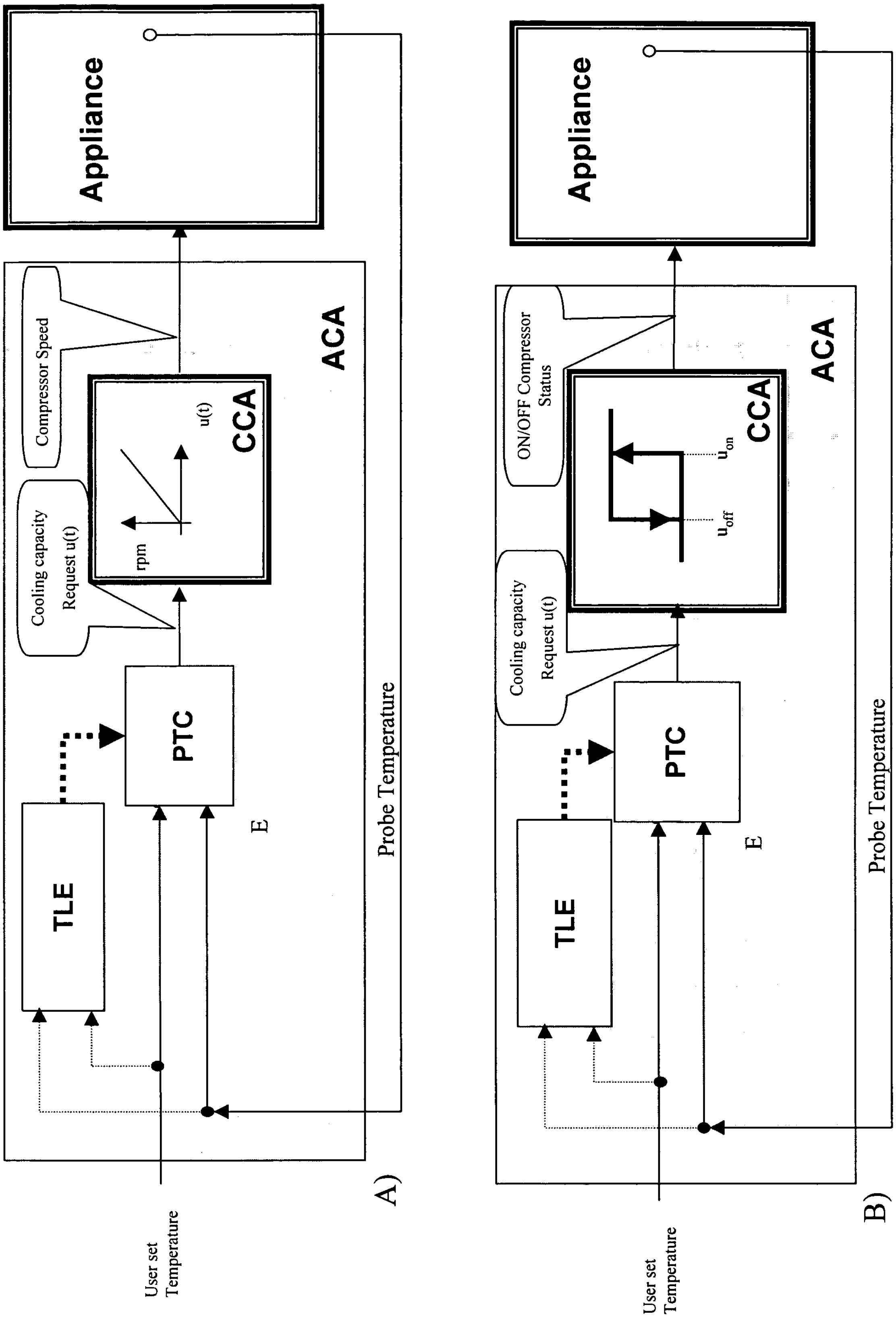

A)
Appliance
ACA
Compressor Speed
CCA
u(t)
rpm
Cooling capacity
Request u(t)
PTC
TLE
E
Probe Temperature
User set
Temperature
B)
Appliance
ACA
ON/OFF Compressor
Status
CCA
u_{on}
u_{off}
Cooling capacity
Request u(t)
PTC
TLE
E
Probe Temperature
User set
Temperature

Figure 2

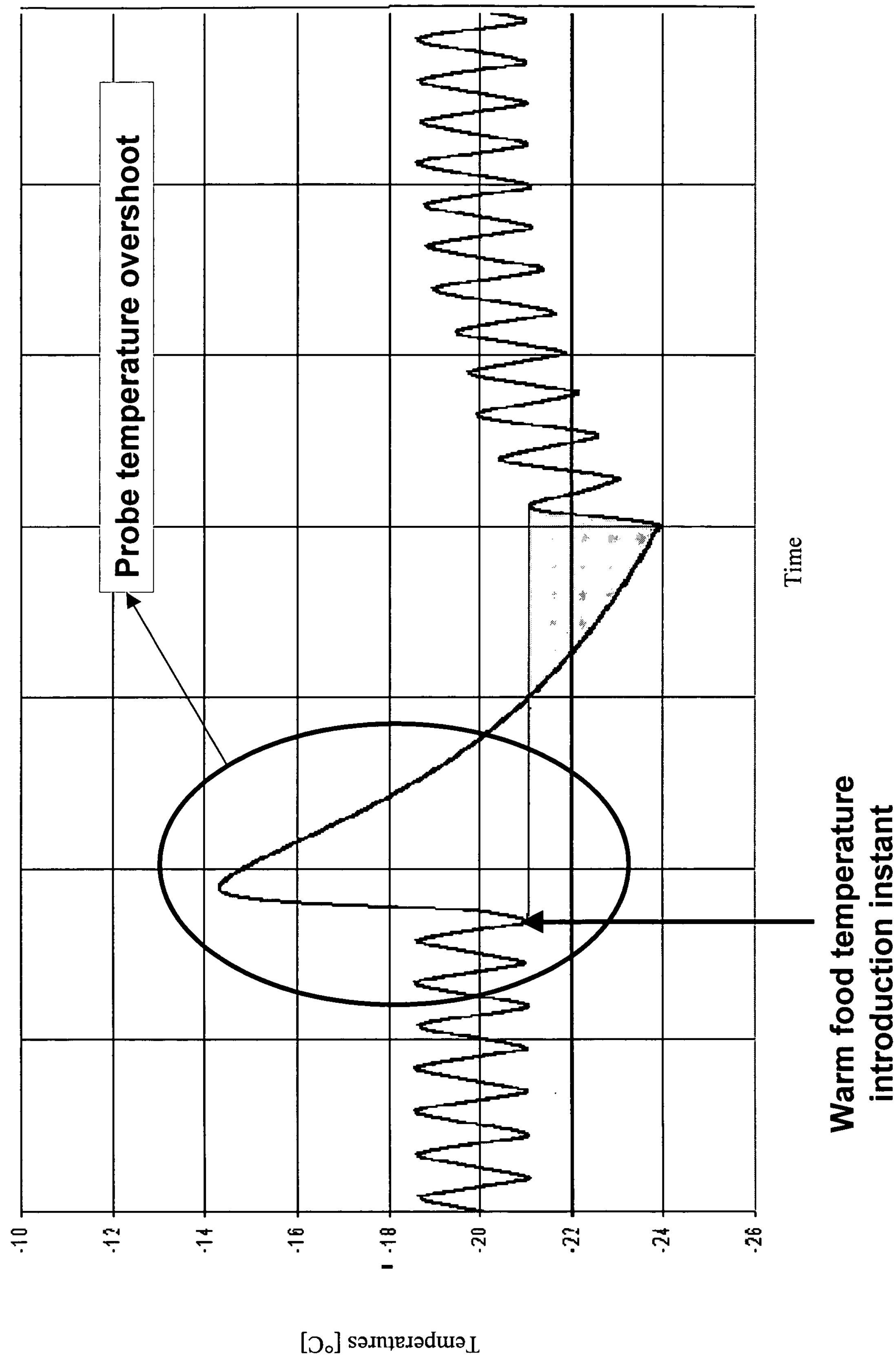

Probe temperature overshoot
Warm food temperature introduction instant
Time
Temperatures [°C]
-10
-12
-14
-16
-18
-20
-22
-24
-26

Figure 3

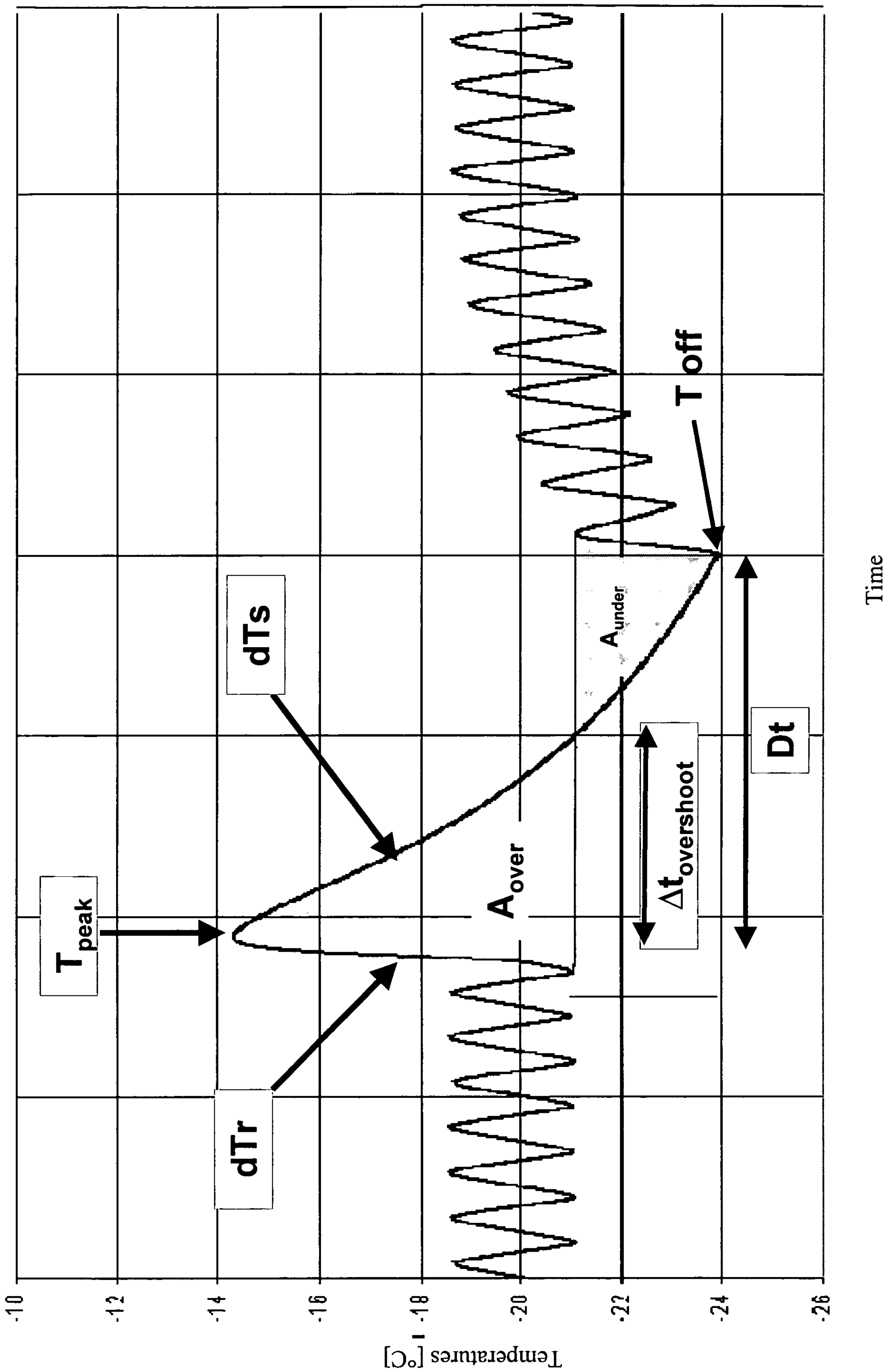

-10
-12
-14
-16
-18
-20
-22
-24
-26
Temperatures [°C]
Time
T peak
dTr
dTs
A over
A under
Δt overshoot
Dt
T off

Figure 4

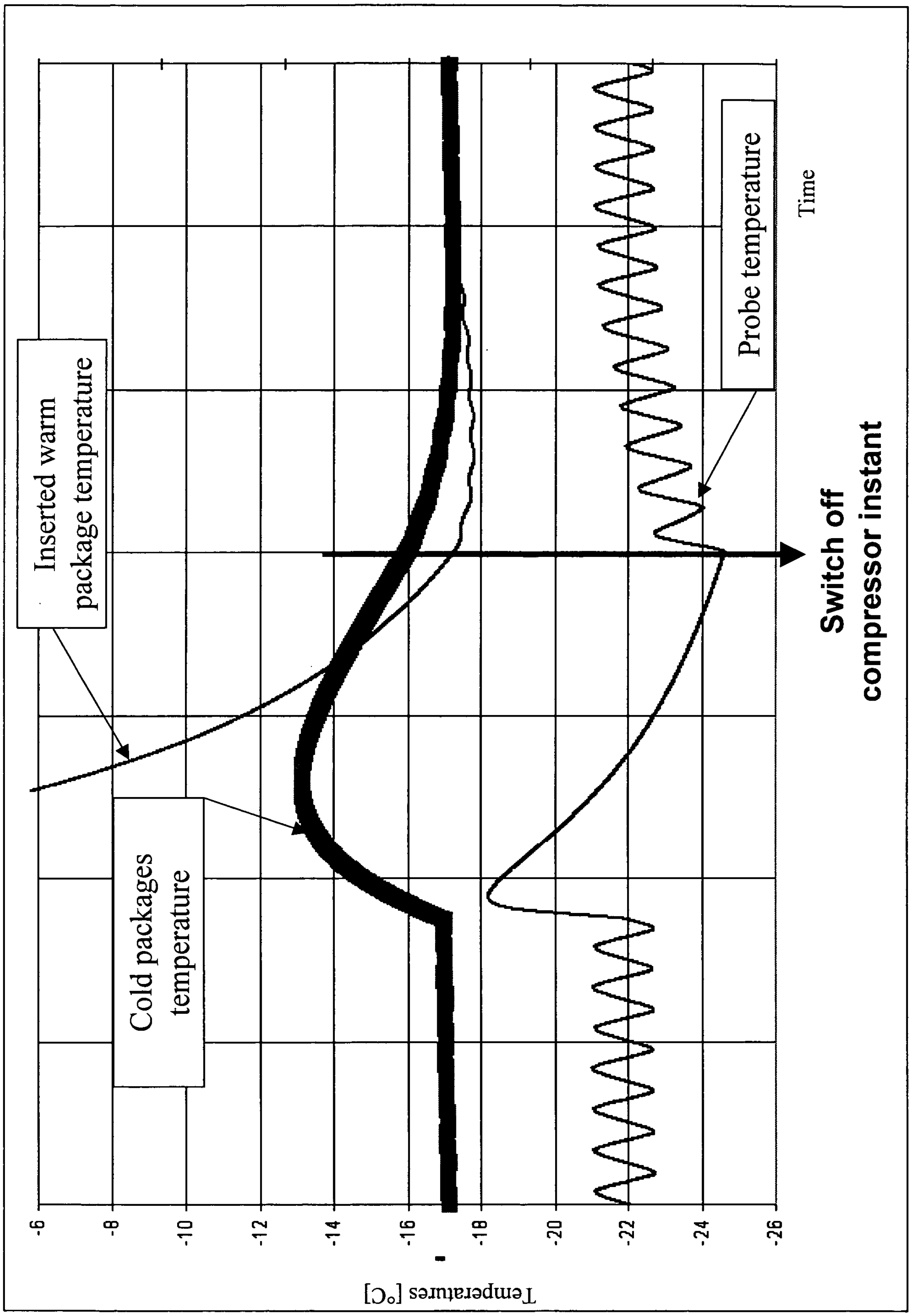

Inserted warm package temperature
Cold packages temperature
Probe temperature
Switch off compressor instant
Time
Temperatures [°C]
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26

Figure 5

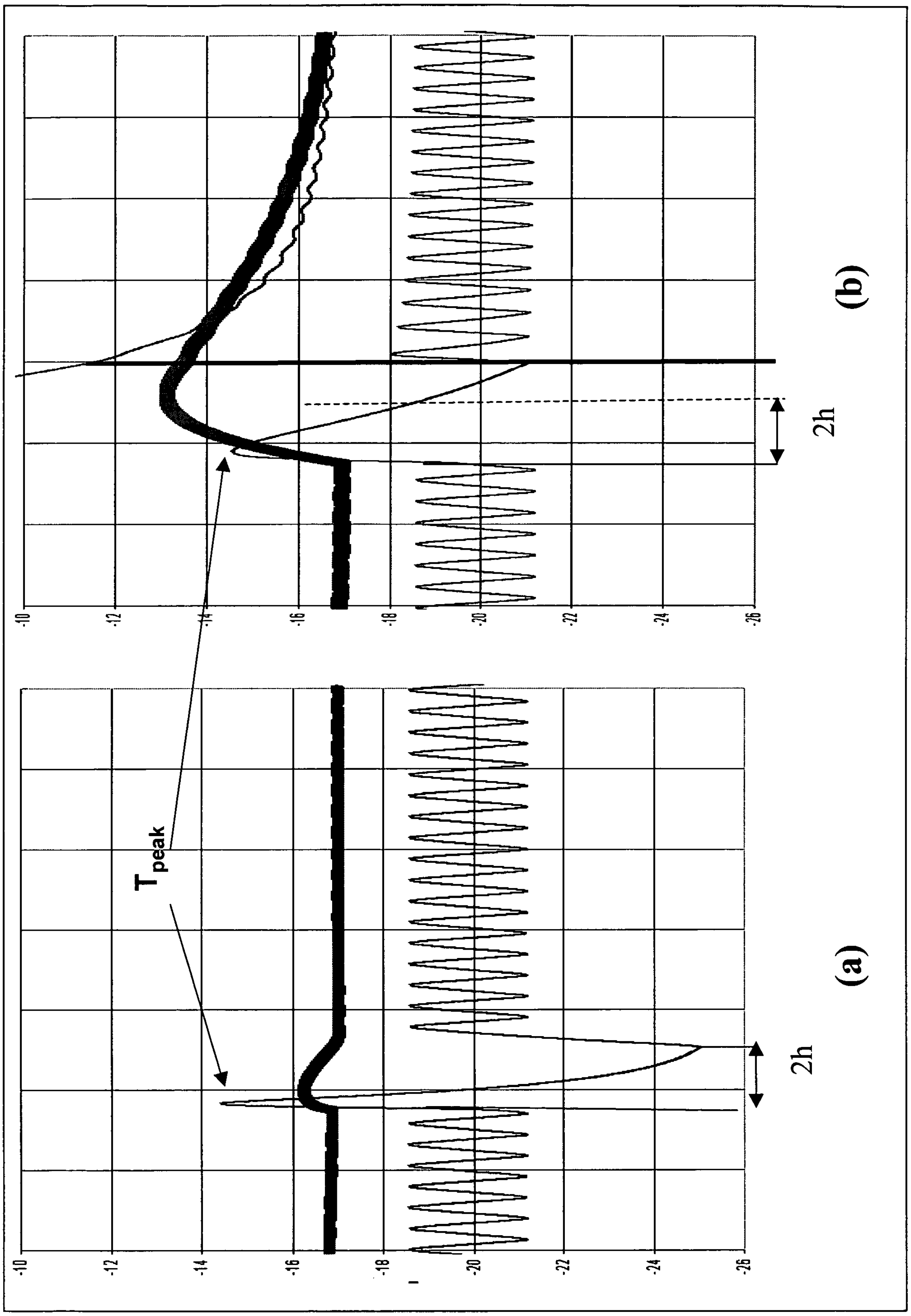


Figure 6

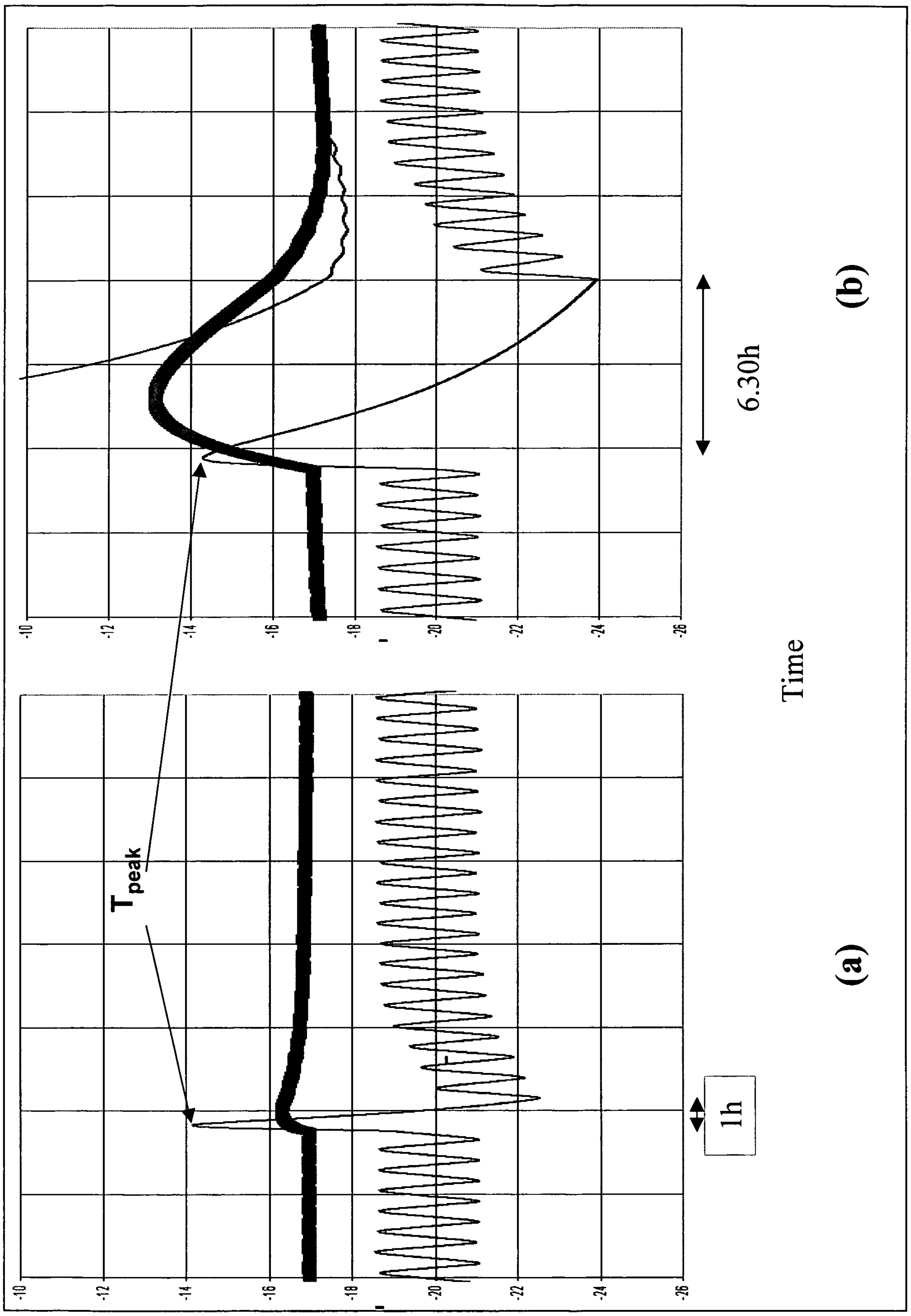


Figure 7

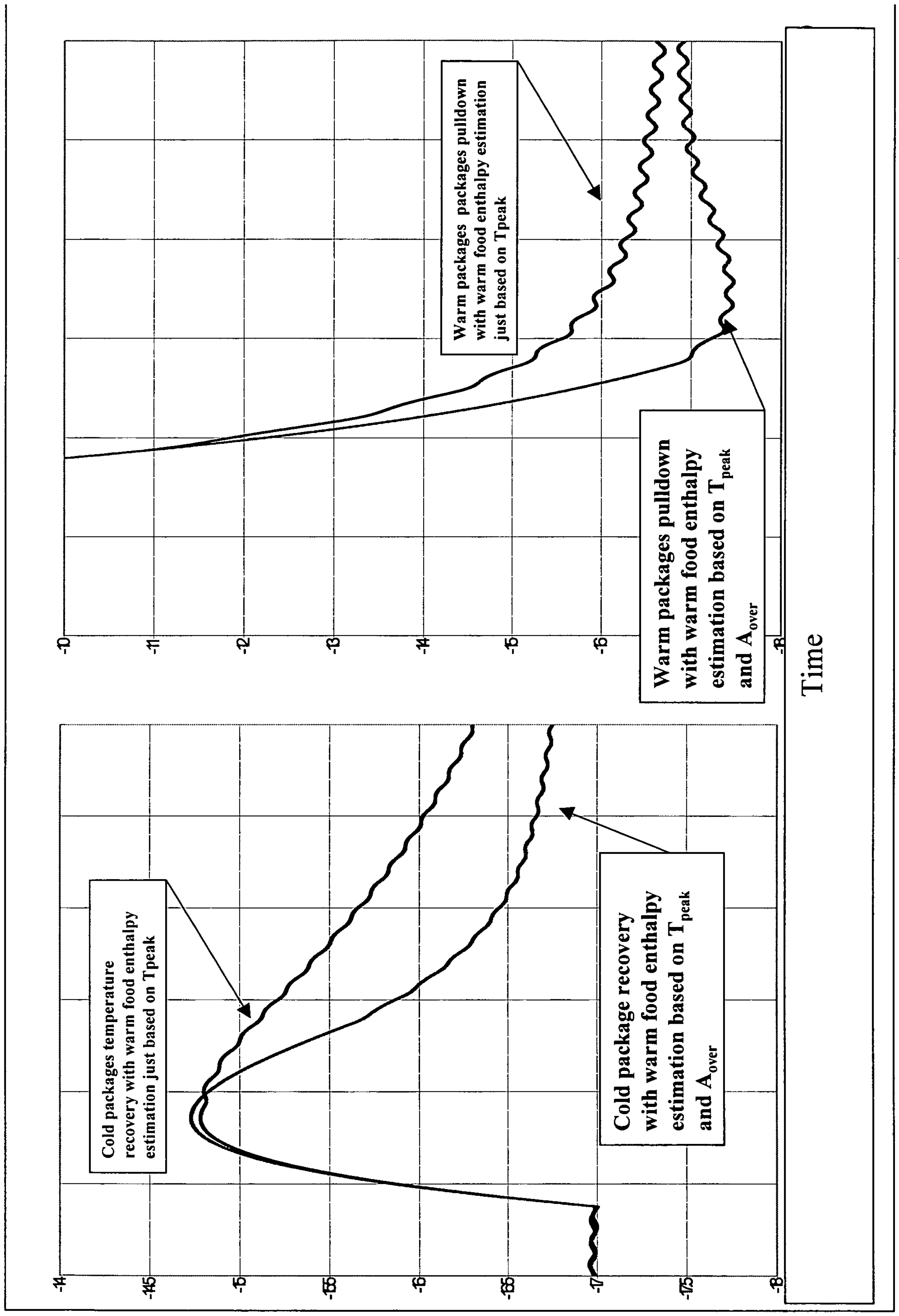

Cold packages temperature recovery with warm food enthalpy estimation just based on Tpeak
Cold package recovery with warm food enthalpy estimation based on T_{peak} and A_{over}
Warm packages packages pulldown with warm food enthalpy estimation just based on Tpeak
Warm packages pulldown with warm food enthalpy estimation based on T_{peak} and A_{over}
Time

Figure 8

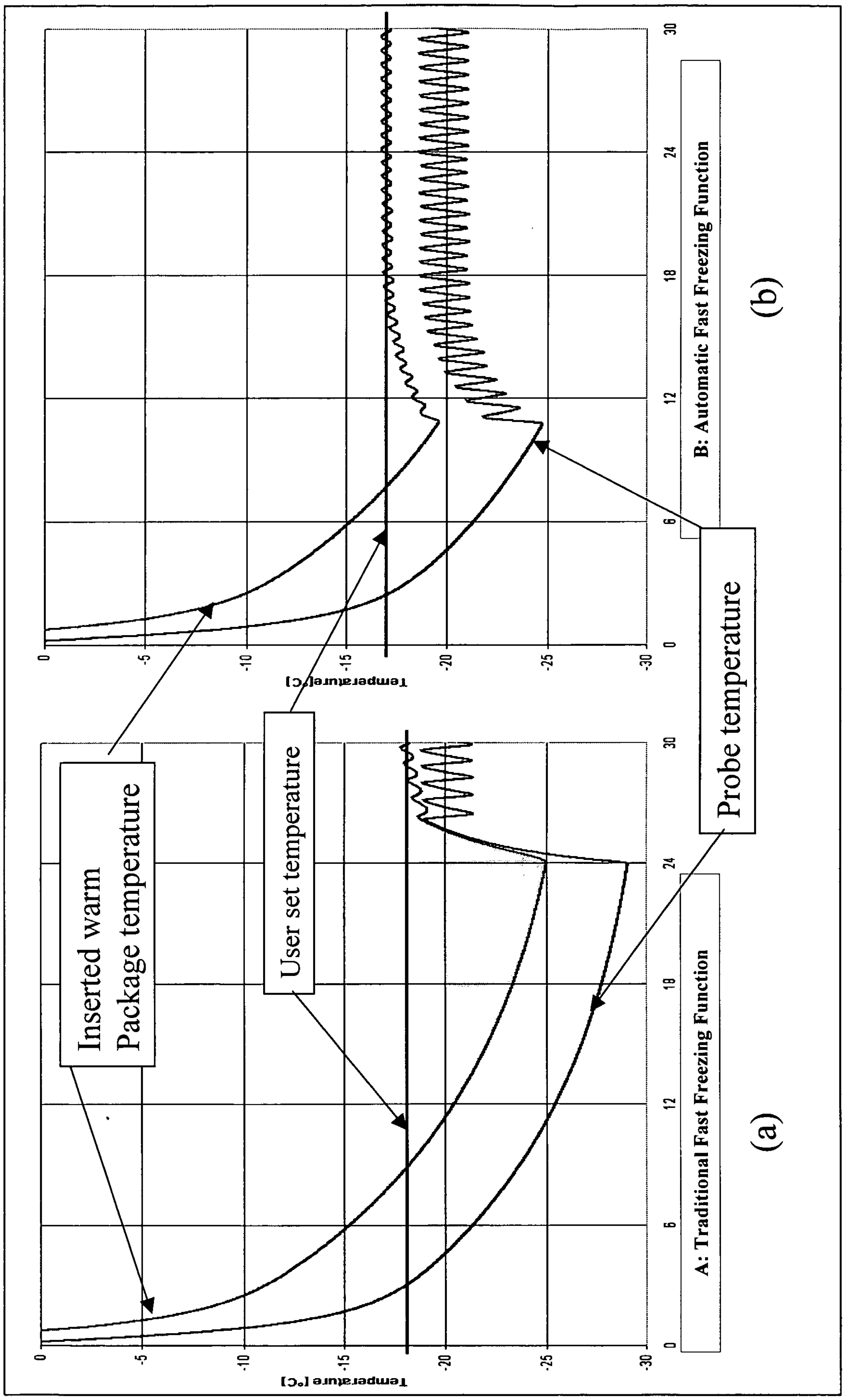

Inserted warm
Package temperature
User set temperature
Probe temperature
Temperature [°C]
0
-5
-10
-15
-20
-25
-30
0
6
12
18
24
30
A: Traditional Fast Freezing Function
(a)
B: Automatic Fast Freezing Function
(b)

Figure 9

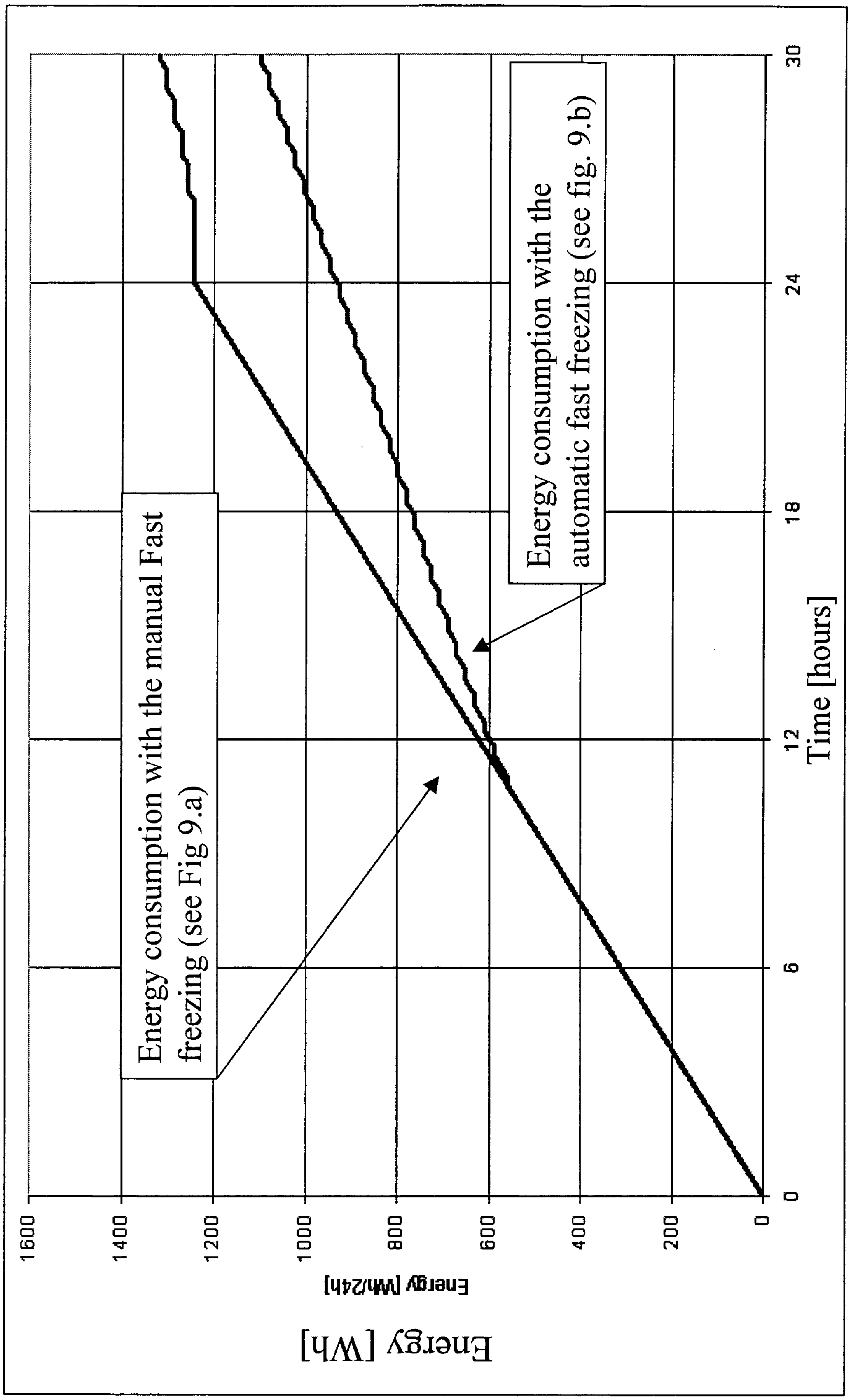

Energy [Wh]
Energy [Wh/24h]
0
200
400
600
800
1000
1200
1400
1600
0
6
12
18
24
30
Time [hours]
Energy consumption with the manual Fast freezing (see Fig 9.a)
Energy consumption with the automatic fast freezing (see fig. 9.b)

Figure 10

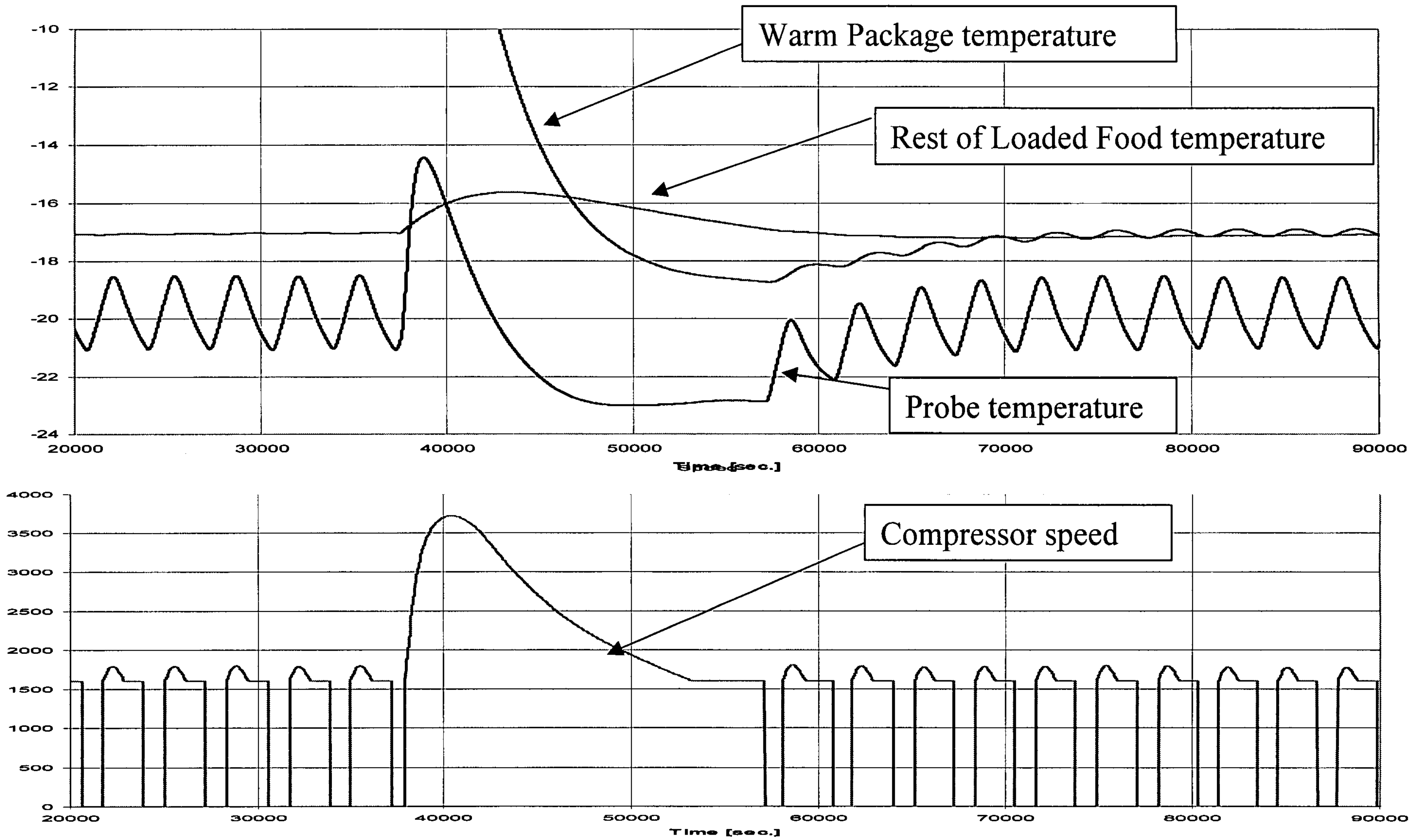
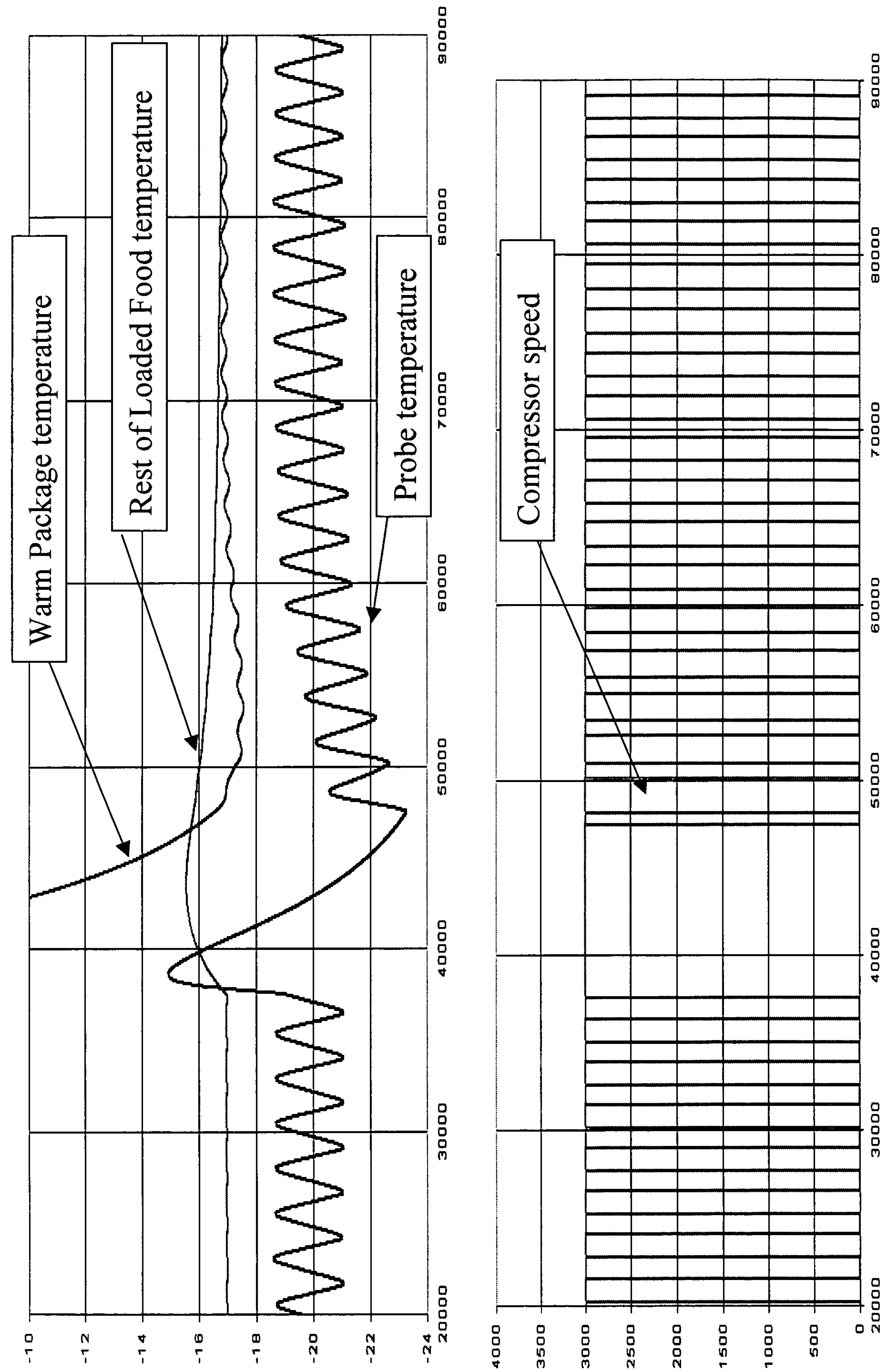

Warm Package temperature
Rest of Loaded Food temperature
Probe temperature
Compressor speed
Time [sec.]
-10
-12
-14
-16
-18
-20
-22
-24
4000
3500
3000
2500
2000
1500
1000
500
0
20000
30000
40000
50000
60000
70000
80000
90000

Figure 11



Warm Package temperature
Rest of Loaded Food temperature
Probe temperature
-10
-12
-14
-16
-18
-20
-22
-24
20000
30000
40000
50000
60000
70000
80000
90000
Compressor speed
4000
3500
3000
2500
2000
1500
1000
500
0
20000
30000
40000
50000
60000
70000
80000
90000

Figure 12

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 00 8721

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X A	US 5 586 444 A (FUNG ET AL) 24 December 1996 (1996-12-24) * the whole document * -----	1-4,8,9, 11 6,7	F25D29/00 F25B49/02
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 051 (M-1548), 26 January 1994 (1994-01-26) -& JP 05 272854 A (SANYO ELECTRIC CO LTD), 22 October 1993 (1993-10-22) * the whole document * -----	1-5,10, 11	
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 053 (M-1361), 3 February 1993 (1993-02-03) -& JP 04 263771 A (SANYO ELECTRIC CO LTD), 18 September 1992 (1992-09-18) * abstract * -----	1-5,10, 11	
X	EP 0 836 065 A (HERMANN FORSTER AG) 15 April 1998 (1998-04-15) * the whole document * -----	1,3,4	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 031 (M-1356), 21 January 1993 (1993-01-21) -& JP 04 254179 A (MATSUSHITA REFRIG CO LTD), 9 September 1992 (1992-09-09) * the whole document * -----	1-3	F25D F25B
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 507 (M-1327), 20 October 1992 (1992-10-20) -& JP 04 187968 A (MATSUSHITA REFRIG CO LTD), 6 July 1992 (1992-07-06) * the whole document * ----- -/--	1-3	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	24 May 2005	De Graaf, J.D.

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

1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 00 8721

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X A	DE 197 00 544 A1 (AEG HAUSGERAETE GMBH, 90429 NUERNBERG, DE) 16 July 1998 (1998-07-16) * the whole document * -----	1,3 5-7,12	
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 196 (M-1589), 6 April 1994 (1994-04-06) -& JP 06 003021 A (MATSUSHITA REFRIG CO LTD), 11 January 1994 (1994-01-11) * the whole document * -----	1-4	
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 521 (M-896), 21 November 1989 (1989-11-21) -& JP 01 212881 A (FUJITSU GENERAL LTD), 25 August 1989 (1989-08-25) * the whole document * -----	1,4	
X	EP 0 727 628 A (AEG HAUSGERAETE GMBH) 21 August 1996 (1996-08-21) * the whole document * -----	4	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
X	US 4 662 185 A (KOBAYASHI ET AL) 5 May 1987 (1987-05-05) * the whole document * -----	1	
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 507 (M-1327), 20 October 1992 (1992-10-20) -& JP 04 187970 A (MATSUSHITA REFRIG CO LTD), 6 July 1992 (1992-07-06) * the whole document * -----	1	
X	US 5 255 530 A (JANKE ET AL) 26 October 1993 (1993-10-26) * the whole document * ----- -/--	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	24 May 2005	De Graaf, J.D.

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

1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 00 8721

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 555 736 A (WILLS ET AL) 17 September 1996 (1996-09-17) * the whole document * -----	1	
X	US 6 216 478 B1 (KANG KWANG HWA) 17 April 2001 (2001-04-17) * the whole document * -----	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 May 2005	De Graaf, J.D.

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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 00 8721

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.

24-05-2005

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5586444	A	24-12-1996	AU	690826	B2	30-04-1998
			AU	4897796	A	18-11-1996
			DE	69630849	D1	08-01-2004
			DE	69630849	T2	04-11-2004
			EP	0765457	A1	02-04-1997
			ES	2211944	T3	16-07-2004
			JP	10513545	T	22-12-1998
			NZ	302828	A	26-02-1998
			WO	9634238	A1	31-10-1996
			ZA	9602069	A	25-09-1996
JP 05272854	A	22-10-1993	JP	3454522	B2	06-10-2003
JP 04263771	A	18-09-1992	JP	2686182	B2	08-12-1997
EP 0836065	A	15-04-1998	CH	691236	A5	31-05-2001
			AT	209326	T	15-12-2001
			DE	59705462	D1	03-01-2002
			EP	0836065	A2	15-04-1998
JP 04254179	A	09-09-1992	JP	3098780	B2	16-10-2000
JP 04187968	A	06-07-1992	JP	2022343	C	26-02-1996
			JP	7058149	B	21-06-1995
DE 19700544	A1	16-07-1998	IT	PN970063	A1	10-07-1998
JP 06003021	A	11-01-1994	NONE			
JP 01212881	A	25-08-1989	NONE			
EP 0727628	A	21-08-1996	DE	19505706	A1	22-08-1996
			DE	59611083	D1	21-10-2004
			EP	0727628	A2	21-08-1996
			ES	2227566	T3	01-04-2005
US 4662185	A	05-05-1987	JP	2107067	C	06-11-1996
			JP	8014452	B	14-02-1996
			JP	61203891	A	09-09-1986
JP 04187970	A	06-07-1992	JP	2026623	C	26-02-1996
			JP	7060048	B	28-06-1995
US 5255530	A	26-10-1993	CA	2106559	A1	10-05-1994
US 5555736	A	17-09-1996	US	5460009	A	24-10-1995

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 04 00 8721

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.

24-05-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6216478 B1	17-04-2001	KR 2000038802 A	05-07-2000
		JP 3238916 B2	17-12-2001
		JP 2000171140 A	23-06-2000

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