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(54) A refrigeration system and method for refrigerating two compartments with evaporators in series

(57) A refrigeration system (10) for cooling at least two compartments (12,14) comprises a compressor (16), a freezer compartment (12) including a first evaporator (20) and a fan (24) associated therewith and a fresh food compartment (14) including a second evaporator (22), wherein said first and second evaporators are arranged in series. The compressor is a variable capacity compressor and the system comprises a control unit adapted to control the fan associated with the first evaporator in order to keep temperatures in both compartments close to set points independently on changes in environmental or use conditions.

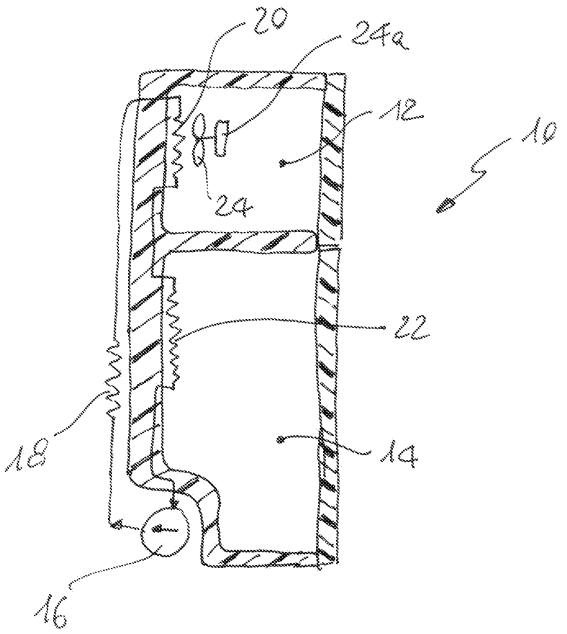

Fig. 1

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Description

[0001] The present invention relates to a refrigeration system for cooling at least two compartments comprising a compressor, a first compartment including a first evaporator and a fan associated therewith, a second compartment including a second evaporator, wherein said first and second evaporators are arranged in series and said first compartment is to be maintained at a temperature lower than said second compartment.

[0002] These refrigeration systems, called also "mono-circuit combi" refrigerators, have many advantages deriving from the simplicity of the refrigeration circuit thereof which has only one compressor and two evaporators in series, the first one being usually associated with the freezer compartment end the second one being associated with the fresh food compartment.

[0003] It is well known in the art of domestic refrigerators the use of variable capacity compressors (VCC) which allow energy saving during the standard working mode of a refrigerator appliance. This is mainly due to the capability of increasing the cooling capacity only when required (door opening, start-up, temperature recovery after automatic de-frost), maintaining a low power absorption when higher values are not required. Such variable capacity compressors may have an electric motor whose rotational speed can be adjusted, or may be of the kind in which the stroke of the compressor piston can be adjusted as well.

[0004] For the time being these variable capacity compressor have never been used in a mono-circuit combi refrigerator (two evaporators in series, one dedicated to freezer and one to refrigerator). The reason lies in the difficult to reach a proper balance of the dimension of the two evaporators, designed with respect to a particular value of overall cooling capacity. Increasing (or decreasing) the cooling capacity provided by the compressor could drive to an improper distribution of the cooling capacity between freezer and fresh food compartment evaporators. As a result, it becomes impossible to maintain the set temperature levels selected by the user in the two cavities.

[0005] In a mono-circuit refrigerator appliance, with two evaporators directly linked in series, only standard ON-OFF compressors have been used, giving up to the advantages in terms of energy saving that a VCC may afford.

[0006] It is an object of the present invention to provide a refrigeration system of the above kind which can solve the above technical problem.

[0007] Such object is reached thanks to the features listed in the appended claims.

[0008] The refrigeration system according to the invention deals with a mono-circuit refrigerator appliance provided with a No-Frost freezer evaporator. This means that a forced airflow is blown across the freezer evaporator thanks to a dedicated fan. When VCC compressor turns on, it starts cooling both freezer and refrigerator evaporators with a certain cooling capacity. Once a door is opened, or another event which requires an increase in cooling capacity, comprising a low temperature setting selected by the user occurs in refrigerator compartment, a higher cooling capacity is required only in this compartment, while freezer compartment still keeps requiring the same level of cooling capacity already provided by the compressor. Control logic, according to refrigerator requirement, increases the cooling capacity provided by VCC. This generates an undesired over-cooling of the freezer compartment. Main drawbacks are related to energy consumption (both for power absorbed by freezer from evaporator and for fan consumption) and food preservation (over-cooling causes ice crystal formation inside food, destroying tissue and causing loss of nutrients). In the solution according to the invention, freezer fan is controlled in such a way that when no increase in cooling capacity is required in the freezer compartment (but it is required in fresh food compartment), it is turned off for limited periods, not removing heat from freezer evaporator. This allows taking advantage of the benefits of VCC, avoiding causing improper balance of the dimensions of two evaporators.

[0009] According to a second embodiment of the invention, the cooling capacity delivered to the freezer compartment is controlled by changing the rotational speed of the fan, instead of controlling the fan with an ON-OFF duty cycle. Further advantages and features of a refrigeration system according to the present invention will become clear from the following detailed description, provided as non limiting example, with reference to the attached drawings in which:

- figure 1 is a schematic cross section view of a refrigerator according to the present invention;
- figure 2 is a diagram showing the temperatures and power consumption of a refrigerator as shown if figure 1 and in which the fan associated with the freezer evaporator is not switched off when the variable speed compressor is switched on;
- figure 3 is a diagram similar to figure 2 in which the ambient temperature is passed from 25°C to 32°C, showing an unbalance of the refrigeration circuit; and
- figure 4 is a diagram similar to figure 3 in which the fun is turned off when the compressor is switched on in order to reduce power consumption and maintaining a balanced refrigeration circuit.

With reference to the drawings, with 10 it is indicated a mono-circuit combi refrigerator having a freezer compartment 12 and a fresh food compartment 14. The refrigerant circuit of the refrigerator 10 comprises a variable capacity compressor 16, a condenser 18, a first evaporator 20 associated with the freezer compartment 12 and a second evaporator 22 associated with the fresh food compartment 14. The first evaporator is a no-frost evaporator and is provided with a fan 24 driven by a motor 24a. The compressor 16, the motor 24a and the temper-

ature sensors (not shown) are connected to an electronic control unit (not shown) which supervises the overall function of the refrigerator.

[0010] In figure 2 it is shown a condition in which the refrigeration circuit id optimized for a certain fixed cooling capacity provided by the compressor when the ambient temperature is 25°C. In this particular situation temperature in both compartments (solid lines C and E) are cycling close to set-point values (dotted lines A and B). This "balance" situation is maintained up to a perturbation of the system, as shown for instance in figure 3 where the ambient temperature is increased up to 32°C (this disturbance is taken only as an example, since every kind of disturbance leads to an "unbalanced" situation). In this situation, an increased cooling capacity is required and, as it clear by considering line E of figure 3, the circuit is no longer balanced and the freezer evaporator 20 is cooled down too much. In both figure 2 and 3 the fan 24 is switched on when the compressor is switched on, according to the usual method of controlling no-frost evaporators. It is interesting to notice in portion K of figure 3 how the power consumption is increased with respect to similar portion in figure 2 due to an increased speed of the compressor 16.

[0011] Figure 4 shows the behavior of the refrigerator according to the invention when a control according to the invention is activated. By cycling the freezer evaporator fan 24 it is possible to avoid delivering too much cold air to the freezer compartment 12, obtaining a proper duty cycle across set-point. In portion H of figure 4 it is shown the reduction in power absorption when fan 24 is switched off, while portion Q shows that once fan 24 is turned off, temperature in freezer evaporator (curve F) decreases suddenly (compressor 16 still ON), but temperature of freezer compartment 12 (curve E) is no longer decreased due to the lack of forced air circulation.

[0012] Even if the fresh food compartment evaporator 22 is schematically shown as a plate located in the cavity, it can be as well of the type in contact with the outside surface of the cavity liner. Also the freezer evaporator 20 can be of any kind used for no-frost evaporator.

Claims

1. A refrigeration system (10) for cooling at least two compartments (12, 14) comprising a compressor (16), a first compartment (12) including a first evaporator (20) and a fan (24) associated therewith, a second compartment (14) including a second evaporator (22), wherein said first and second evaporators (20, 22) are arranged in series and said first compartment (12) is to be maintained at a temperature lower than said second compartment (14), **characterized in that** the compressor (16) is a variable capacity compressor and **in that** the system comprises a control unit adapted to control the fan (24) associated with the first evaporator (20) in order to keep temperatures in both compartments (12, 14) close to set points independently on changes in environmental or use conditions.

2. A refrigeration system according to claim 1, wherein the fan (24) is controlled with an on/off pattern.

3. A refrigeration system according to claim 1, wherein the fan (24) is controlled by adjusting its rotational speed.

4. Method for refrigerating a first and a second compartment of a refrigerator having a first and second evaporator (20, 22) arranged in series and associated with said first and second compartments (12, 14) respectively and in which the first compartment (12) is to be maintained at a cooler temperature than the second compartment (14), the method comprising operating a variable capacity compressor (16) in response to a determination that cooling is needed in at least one of said first and second compartments (12, 14), **characterized in that** the motor (24a) of a fan (24) associated with the first evaporator (20) is controlled in order to keep temperatures in both compartments (12, 14) close to set points independently on changes in environmental or use conditions.

5. Method according to claim 4, wherein the fan motor (24a) is switched off when cooling is needed in the second compartment (14) in order to avoid an undesired under-cooling of the first compartment (12).

6. Method according to claim 4, wherein the rotational speed of the fan is adjusted depending on the cooling which is needed in the second compartment (14) in order to avoid an undesired under-cooling of the first compartment (12).

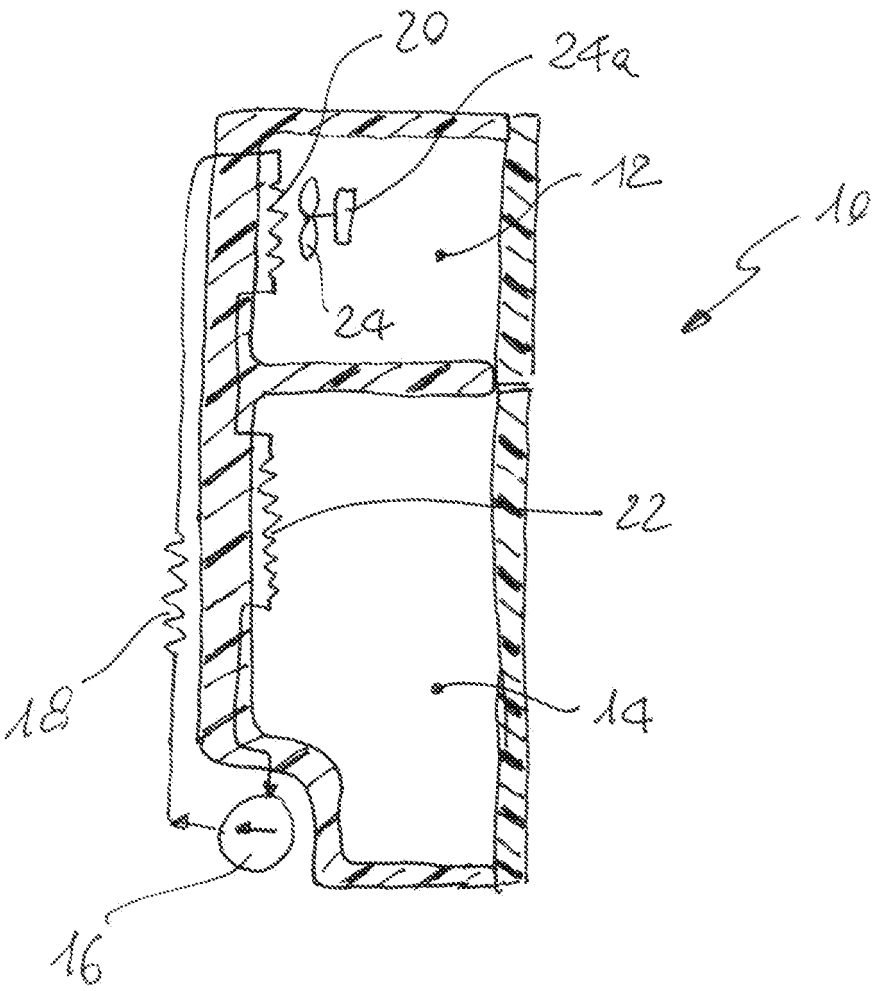
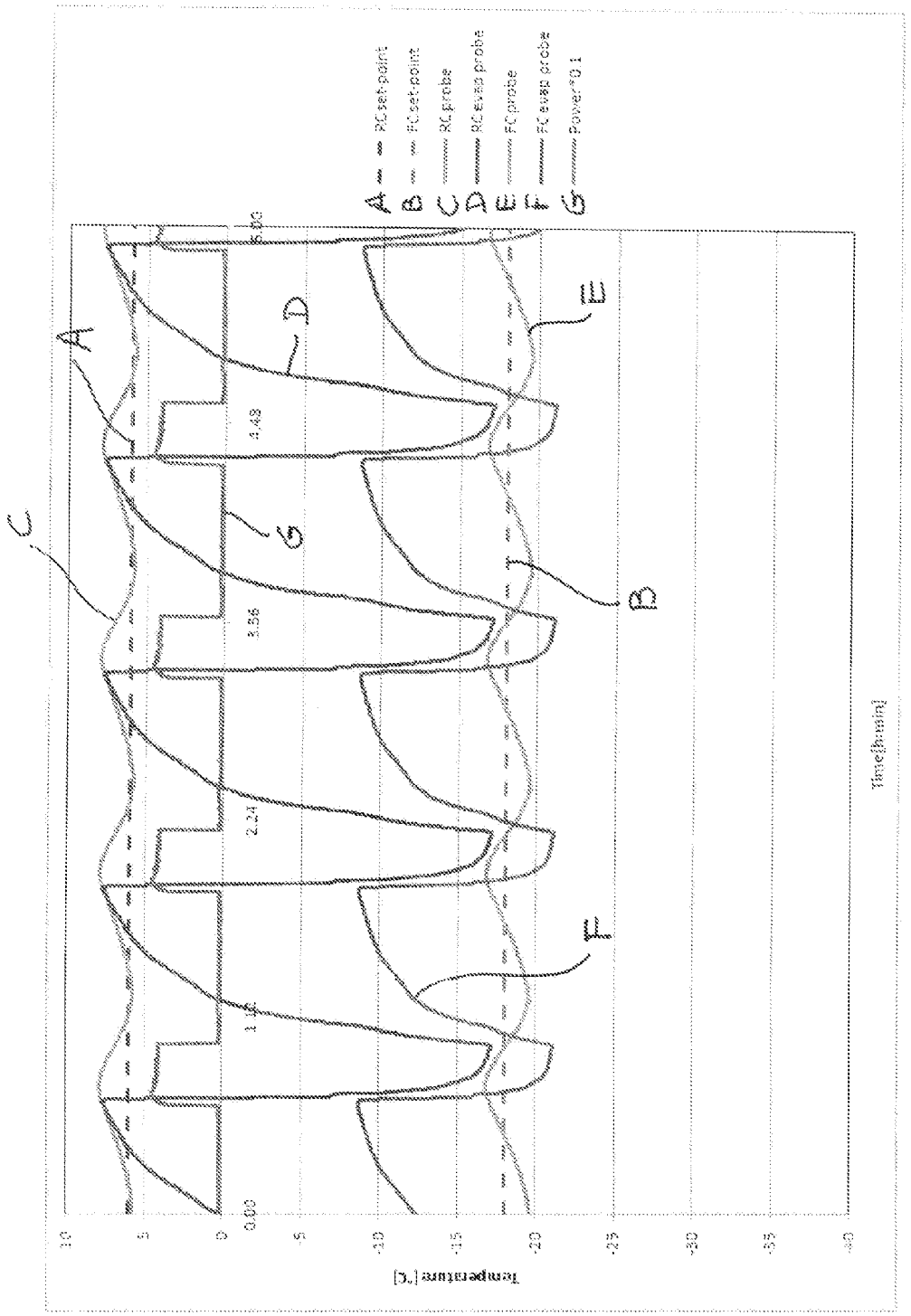


Fig. 1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B
C
D
E
F
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B FC set point
C RC probe
D RC evap probe
E FC probe
F FC evap probe
G Power *0.1
Temperature [°C]
Time [h:min]
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1.48
2.24
3.36
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6.00
10
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-5
-10
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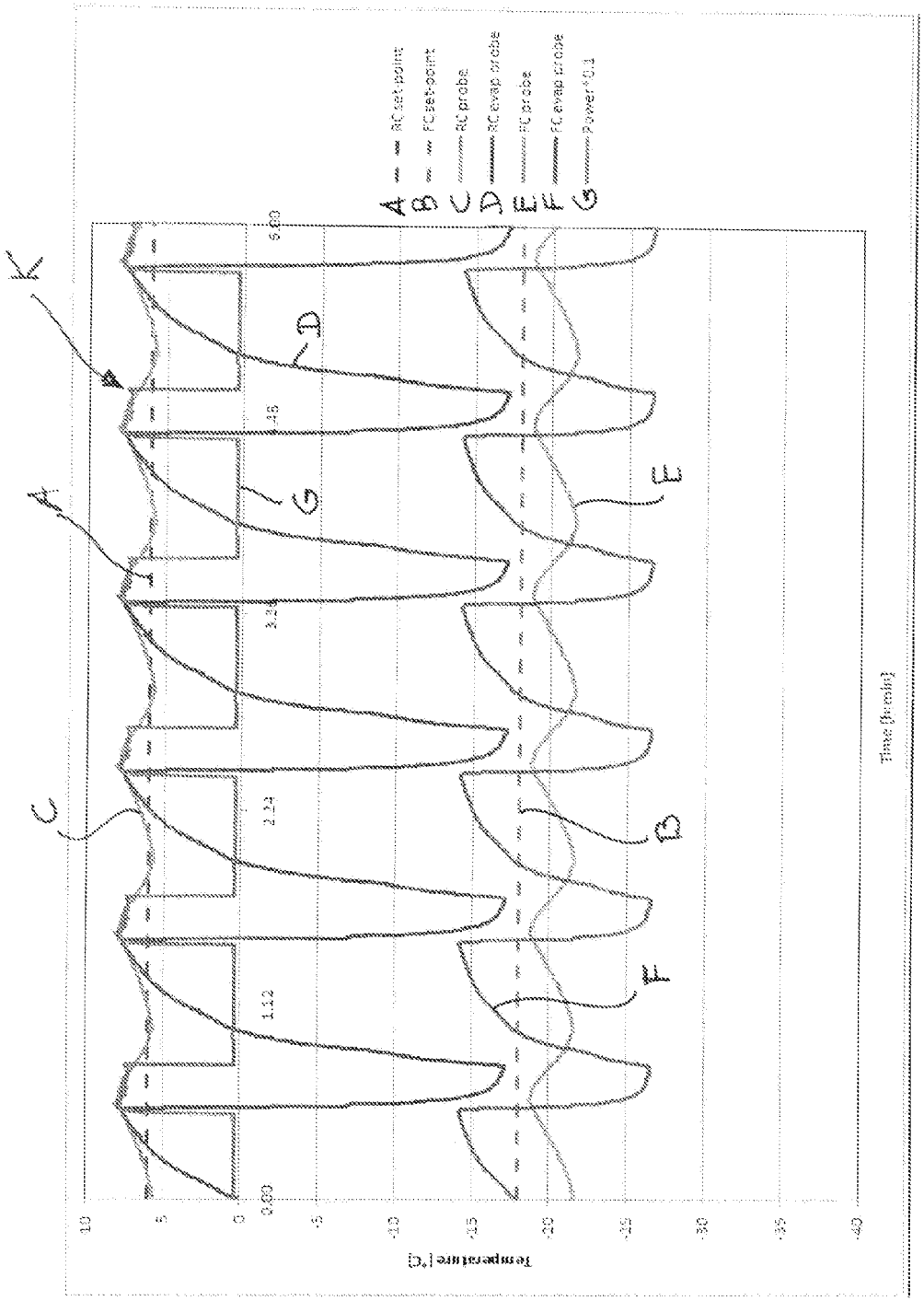
-35
-40

Fig 2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B
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D
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F
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K
Temperature [°C]
Time [hr:min]
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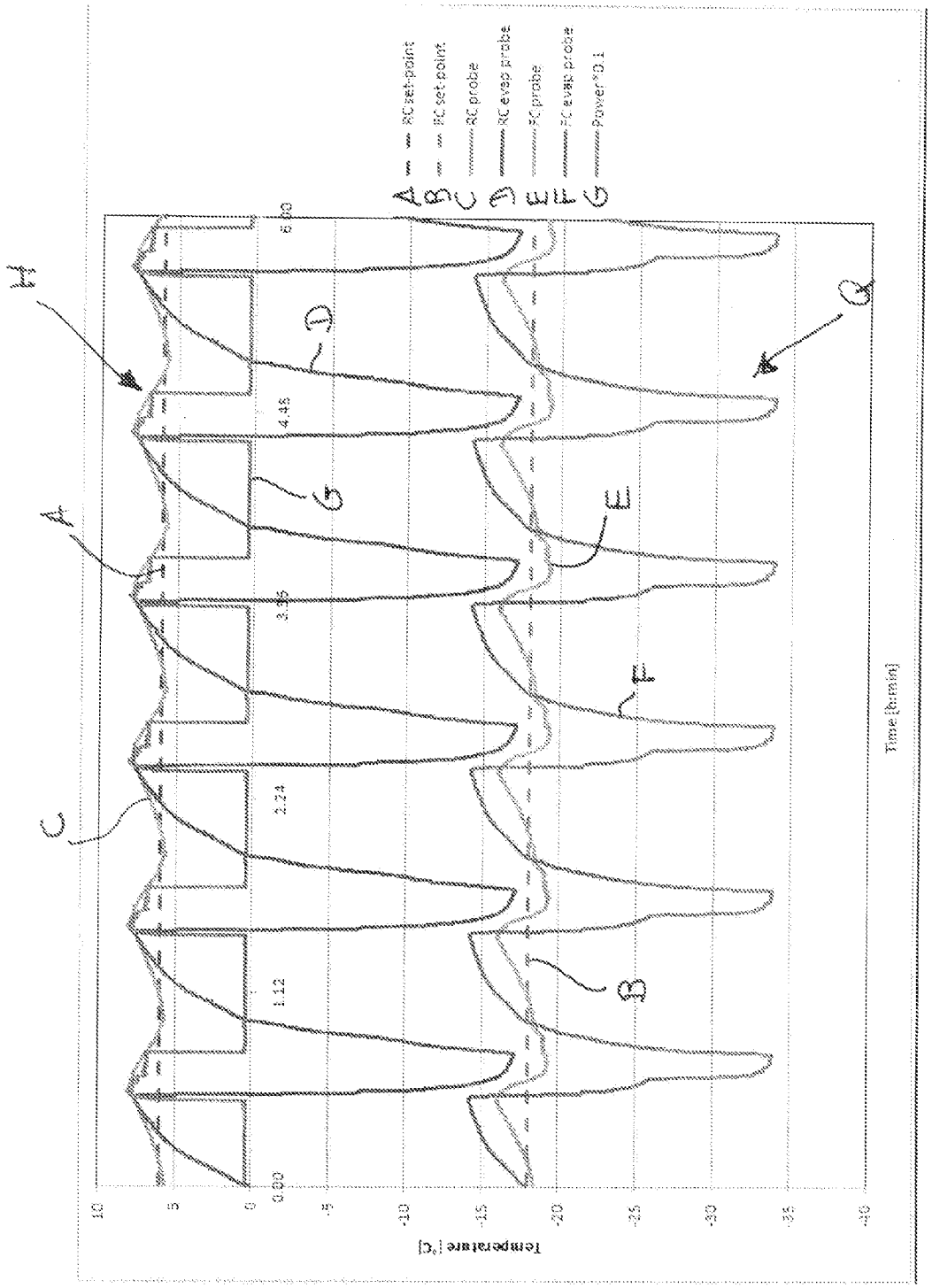
Fig 3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D
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F
G
H

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 11 16 5082

DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 0 990 862 A1 (TOSHIBA KK [JP]) 5 April 2000 (2000-04-05) * paragraph [0014] * * paragraph [0015] * * paragraph [0023] * * figure 1 * -----	1-6	
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X	US 6 327 867 B1 (HYODO AKIRA [JP] ET AL) 11 December 2001 (2001-12-11) * figure 2 * -----	1-6	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 August 2011	Melo Sousa, Filipe

CATEGORY OF CITED DOCUMENTS

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82