



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
28.09.2011 Bulletin 2011/39

(51) Int Cl.:
F25D 17/06 (2006.01)

(21) Application number: **10157474.7**

(22) Date of filing: **24.03.2010**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR
Designated Extension States:
AL BA ME RS

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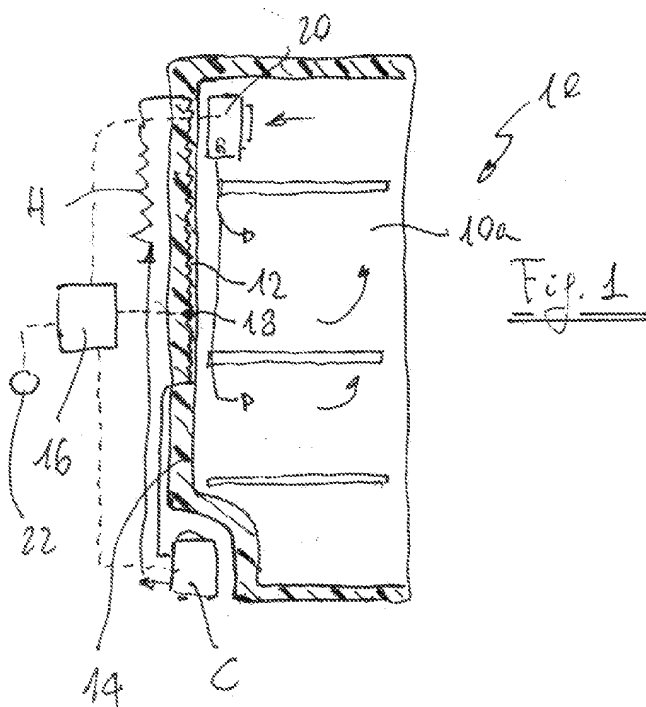
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(54) **A method for controlling a refrigerator with a blowing fan and refrigerator controlled with such method**

(57) A method for controlling a refrigerator (10) having a cavity (10a), an evaporator (12), a blowing fan (20) inside the refrigerator cavity (10a), and a control unit (16) adapted to receive signals (S,A) indicative of the temper-

ature set by the user and of the working condition of the refrigeration circuit comprises an estimation of the thermal load (T_{AMB}) of the refrigerator (10) on the basis of said signals (S,A), the estimated thermal load (T_{AMB}) being preferably used for controlling the blowing fan (20).



Description

[0001] The present invention relates to a method for controlling a refrigerator having a cavity, a refrigeration circuit including an evaporator, a fan inside the refrigerator cavity and a control unit adapted to receive signals indicative of the cooling performances of the cavity set by the user and of the working conditions of the refrigeration circuit.

[0002] With the term refrigerator we mean any kind of domestic appliance, either fridge or freezer or a combination thereof, in which a cavity is maintained at a predetermined temperature set by the user below the ambient temperature. With the term adjacent referred to the fan we mean a relative position so that the fan can induce an air flow which passes over or impinges the evaporator.

[0003] The above control methods are known in the art, in which the control unit adjusts the activation of a compressor (i.e. the duty cycle thereof) or of an electro valve associated to the refrigeration circuit upstream the evaporator in order to maintain the actual temperature in the cavity very close to the value set by the user, such value being either a general value corresponding to a desired cooling performance or a specific food conservation temperature.

[0004] In a refrigerator cavity or compartment, equipped by a ventilation device, like a fan, the control of the fan is usually obtained by means of a manual switch (or fan enabler) that permits the ventilation to operate as to provide a uniform temperature inside the refrigerator cavity. Once the switch is in the ON condition, manually selected by the customer, the fan will run in correspondence of the cooling phase (compressor in an ON state for single cavity refrigerator like cabinets or multiple cavities without electro valve, or with electro valve in a configuration in which the refrigerator is demanding for combined products in which a single compressor feeds two or more evaporators). This known solution is particularly used in products in which the use of a fan is not requested at normal condition (generally with ambient temperature around 25°C). In case the external temperature is increasing (i.e. above 32°C), the temperature of the cavity set by the user could be difficult to be obtained or high level of condensation can be generated within the cavity, with the undesired effect of water dropping from the walls and from the shelves. In these cases the manual activation of the fan is recommended in the instructions for use of the product.

[0005] There are also known solutions in which there is no switch and the fan will operate according to the above logic (i.e. fan switched on when the compressor or electro valve are switched on), i.e. without any manual intervention of the user and independently on the actual temperature of the ambient in which the refrigerator is installed. In this case, due to continuous ventilation during the cooling phase, food inside the refrigerator appliance might be dehydrated causing rapid weight losses of the food itself. As a consequence the food preservation index might be compromised.

[0006] It is therefore an object of the present invention to provide a control method which can solve the above problem without the need of any manual intervention of the user.

[0007] It is another object of the present invention to provide a refrigerator capable of optimizing the intervention of the fan for decreasing the risk of water condensation in the cavity and for maintaining a good food preservation index for any ambient temperature.

[0008] According to the invention, such objects are reached thanks to the features listed in the appended claims.

[0009] One of the main aspects of the present invention is an estimation of the actual thermal load of a refrigerator in all operating conditions, in order to adjust accordingly the air flow generated by a ventilation system.

[0010] The method according to the present invention is able to discriminate automatically between different conditions, for example normal conditions in which the refrigerator is operating at usual ambient temperatures (below 25-30°C) and with a normal load of food inside the cavity and critical conditions at very high ambient temperatures or with high amount of warm foods loaded into the cavity. In both cases the ventilation control is automatically adapting the working conditions of the fan, particularly the running time thereof, in order to optimize the food preservation. In particular, the fan can be activated to run for a certain period of time when the cooling phase is OFF (compressor or electro valve switched off), in order to improve the % of relative humidity inside the cavity, or it can be activated for a longer time, also when the cooling phase is ON, to compensate the sudden increase of thermal load caused by a prolonged door opening, by the loading of warm food in the cavity or by an increased external temperature. The estimation of the thermal load can be used for providing the user, through the user interface of the refrigerator, with a value related to the thermal load of the refrigerator, for instance as estimated ambient temperature.

[0011] Further features and advantages of the method and of a the refrigerator according to the present invention will be clear from the following detailed description, with reference to the attached drawings in which:

- figure 1 shows a schematic section view of a refrigerator according to a first embodiment of the invention;
- figure 2 shows a view similar to figure 1 and according to a second embodiment of the invention;
- figure 3 is a block diagram showing how the method according to the invention works;
- figure 4 is a diagram showing the correlation vs. time between the evaporator temperature and working condition of the fan and of the refrigeration circuit in a first thermal load condition;
- figure 5 is a diagram similar to figure 4 and it is related to a second thermal load condition; and
- figure 6 is an experimental diagram showing how the method according to the invention can simulate the actual

behavior of the thermal load parameter, in the specific example referred to as external temperature.

[0012] With reference to figure 1, with 10 is indicated a refrigerator having a refrigerating compartment 10a provided with an evaporator 12 embedded in the rear insulated wall 14 and fed by a compressor C with refrigerant fluid downstream a condenser H. The refrigerator 10 comprises a control unit 16 connected to a temperature sensor 18 on the evaporator 12, to the compressor C, to a blowing fan 20 inside the refrigerator cavity 10a and to a device 22 for a manual setting the temperature or the level of cooling inside the compartment.

[0013] The refrigerator shown in figure 2 is very similar to the one of figure 1 and the same reference numerals are used for indicating similar or identical components or parts. The difference between the refrigerator of figure 1 and the one of figure 2 is that the refrigerator of figure 2 comprises a freezing compartment 10b having and evaporator 13 upstream the evaporator 12 of the refrigerating compartment 10a. Between the two evaporators 13 and 12 it is provided an electro valve EV connected to the control unit 16 and adapted to close or open the passage of refrigerant fluid to the evaporator 12. The function of the valve EV of the refrigerator shown in figure 2 is similar to the function of the compressor C in the embodiment of figure 1, since both such components feed are able to feed the evaporator 12 with refrigerant fluid. Of course the solutions shown in figure 1 and 2 are only two example of how the method according to the invention can be used for different kind of refrigeration appliances, and such method can adapt to other configurations in which the refrigerator have more compartments, more than one compressor, or valve or more than one temperature sensors connected to the control unit 16.

[0014] The tests carried out by the applicant on known refrigerators lead to the conclusion that the main driver for the duty cycle DC% of the cooling phase (compressor C or valve EV state) are the ambient temperature T_{AMB} and the temperature set by the user T_{SET} .

[0015] A simple law can be derived from the above conclusion with a generic linear model formulation.

$$DC\% = K_0 + K_1 * T_{AMB} + K_2 * T_{SET} + K_3 * f_{CC}$$

[0016] Where K_0 , K_1 , K_2 and K_3 are experimental constant values and f_{cc} is a Boolean coefficient (0 or 1). During a cooling cycle the value of DC% can be measured, while T_{set} is known (customer setting). Therefore the equation can be solved with respect to T_{AMB} (the only unknown variable).

$$T_{AMB} = \frac{DC\%}{K_1} - \frac{K_2}{K_1} * T_{SET} - \frac{K_3}{K_1} * f_{CC} - \frac{K_0}{K_1}$$

[0017] Simplifying the above equation, we have:

$$T_{AMB} = a * DC\% + b * T_{SET} + c * f_{CC} + d$$

[0018] In the above equation T_{AMB} is a value which is not necessarily linked to the external temperature only, but it is a general estimation of the actual thermal load of the refrigerator (such thermal load including the external temperature and comprising other factors, for instance the temperature of the food loaded in the compartment). For sake of simplicity such parameter is called T_{AMB} ; nevertheless it is clear that such estimated parameter provides information on other actual components of the overall thermal load. The above equation shows that a linear regression can provide an estimation of the thermal load in term of an "equivalent external temperature" assessment. Of course the above equation is only one example of how T_{AMB} can be assessed, and other terms can be added as well in order to increase the control accuracy. For instance, it is possible to add another term based on the % working time (i.e. duty cycle) of the blowing fan 20. In figure 3 it is shown a basic algorithm scheme according to the present invention. With the reference A it is indicated a signal from the compressor C or from the electro valve EV which in block 24 is converted in a duty cycle value DC%. The control logic block 28 needs to know the state of the cooling phase (compressor C state, or the state of the valve EV position responsible for cooling the refrigerator cavity 10a). The DC% block 24 computes the time OFF respect the time ON and feed this value to a filter block 26.

[0019] The "filter" block computes an average of last samples of the DC% (for instance the last three DC% values) to

evaluate a consistent and robust computation. This computation causes a certain delay (d in figure 6) of the thermal load estimation response, but the filter 26 allows eliminating certain disturbances, for instance due to a short opening of the door. A door status signal D , indicated in dotted line in figure 3 as preferable but not essential for carrying out the invention, is indicating if the door (not shown) of the refrigerator is open or close and this information can be used to compensate the estimation of the thermal load.

[0020] With reference S it is indicated the compartment set point as the temperature (or cooling degree) set by the user.

[0021] The ambient temperature estimator logic block 28 operates according the above last equation, issuing a value T_{AMB} .

[0022] The temperature and humidity level control block 32 uses a reference value T (evaporator temperature of the refrigerator) from temperature sensor 18 to decide the best condition for driving the blowing fan 20 in order to adjust humidity inside the compartment (i.e. to extract humidity from the evaporator). The temperature sensor 18 on the evaporator is normally used in all refrigerators and therefore does not increase the overall cost of the appliance. Moreover the sensor 18 is used in the known control logic of the refrigerator (working condition of the compressor or of the electro valve dependent on the temperature of the evaporator) on which the blowing fan control logic according to the present invention is added. Upstream the block 32 there is an optional comparison temperature logic block 30 which represents a simplified logic to discriminate between two significant conditions i.e. Winter or Summer condition. In this case the T_{AMB} (i.e. estimated external temperature or thermal load) value will be compared to a reference value R (i.e. 32°C) and the block 30 provides a digital logic value F (critical condition flag: f_{cc}). This information will be then used by the temperature and humidity level control block 32 to operate accordingly in order to adjust the blowing fan operating functions. The F value f_{cc} is also an input that might be useful as a feedback to the ambient temperature estimator logic block 28 because the DC% can be significantly affected by the different use of the fan 20. The F value f_{cc} can also be used to indicate on the user interface different external conditions.

[0023] The humidity level control block 32 provides driving signals P , Q and V to compressor C , blowing fan 20 and electro valve EV respectively. In figure 4 is shown an example in which two reference evaporator temperature values T have been identified to run the blowing fan 20 (F cycle) in opposition to the electro-valve EV (E cycle) in a normal condition that is when the thermal load is considered in normal operating condition (i.e. $T_{\text{external}} < 30^{\circ}\text{C}$). In this case the blowing fan 20 is switched off before the cooling phase E is started. In figure 5 it is shown a second example in which the fan 20 is operating also during the cooling phase E . In this case the fan 20 is switched off at the end of the cooling phase E because the refrigerator is operating at very high thermal load condition, i.e. $T_{\text{external}} > 40^{\circ}\text{C}$. Of course between the two conditions shown in figures 4 and 5 there is a plurality of intermediate conditions in which the fan 20 is switched off inside the cooling phase E (i.e. when T_{external} is comprised between 30° and 40°C). In certain condition the ON cycle F of the fan 20 can be also longer than the ON cycle E of the valve EV or compressor C .

[0024] Figure 6 shows an example of the thermal load computation during an experimental test in which $T_{\text{set}}=5^{\circ}\text{C}$, $a=62.8930$, $b=-0.8553$, $c=0.3711$ and $d=-4.9057$. From figure 6 it is clear how a refrigerator according to the invention is able to estimate the external temperature that is varying in a controlled room from 25°C to 35.2°C and then goes back to 25°C again.

[0025] Even if in the described example the control of the fan is an ON/OFF one, it is clear that the method according to the invention can also be used by controlling the fan having a variable speed motor, therefore adjusting gradually the air flow rate among a plurality of values.

[0026] From the above detailed description it is clear how the method according to the invention provides a thermodynamic control optimization in critical conditions, particularly when ambient temperature is high or when warm heavy loads are put in the refrigeration compartment. According to the invention, it is also obtained an automatic elimination of visible condensation on the refrigerator shelves.

Claims

1. A method for controlling a refrigerator (10) having a cavity (10a), a refrigeration circuit including an evaporator (12), a fan (20) inside the refrigerator cavity (10a), and a control unit (16) adapted to receive signals (S , 22, A) indicative of the cooling performances set by the user and of the working condition of the refrigeration circuit, **characterized in that** it comprises an estimation of the thermal load (T_{AMB}) of the refrigerator (10) on the basis of said signals (S , A).
2. A method according to claim 1, wherein said estimated thermal load (T_{AMB}) is used for controlling the fan (20) .
3. A method according to claim 1 or 2, wherein the working conditions of the refrigeration circuit comprise the duty cycle (DC%) of a compressor (C) or of an electro valve (EV) upstream the evaporator (12) or a combination thereof.
4. A method according to any of the preceding claims , wherein the estimation of the thermal load (T_{AMB}) is further

based on a comparison between such estimated thermal load (T_{AMB}) and a predetermined value (R) indicative of a high thermal load or a high ambient temperature.

5. A method according to any of the preceding claims, wherein the fan (20) is driven also according to a measure (T) of the temperature of the evaporator (18).
6. A method according to any of the preceding claims, wherein the estimation of the thermal load (T_{AMB}) is further based on a signal (D) indicative of the past or present status of the door of a compartment (10a) of the refrigerator (10) and/or on the duty cycle of the fan (20).
7. A method according to any of claims 3-6, wherein the thermal load is estimated according to an equation:

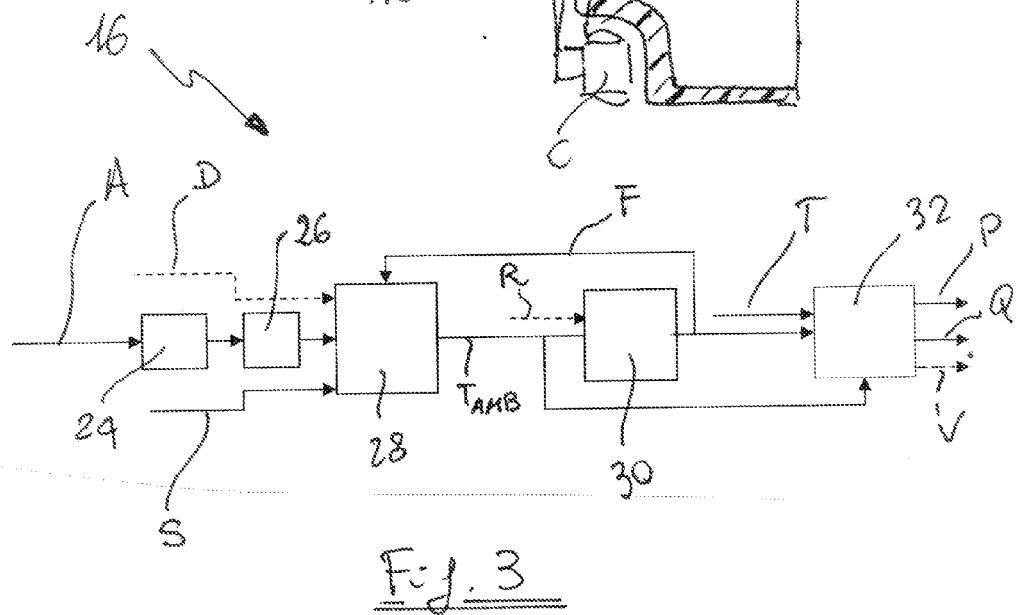
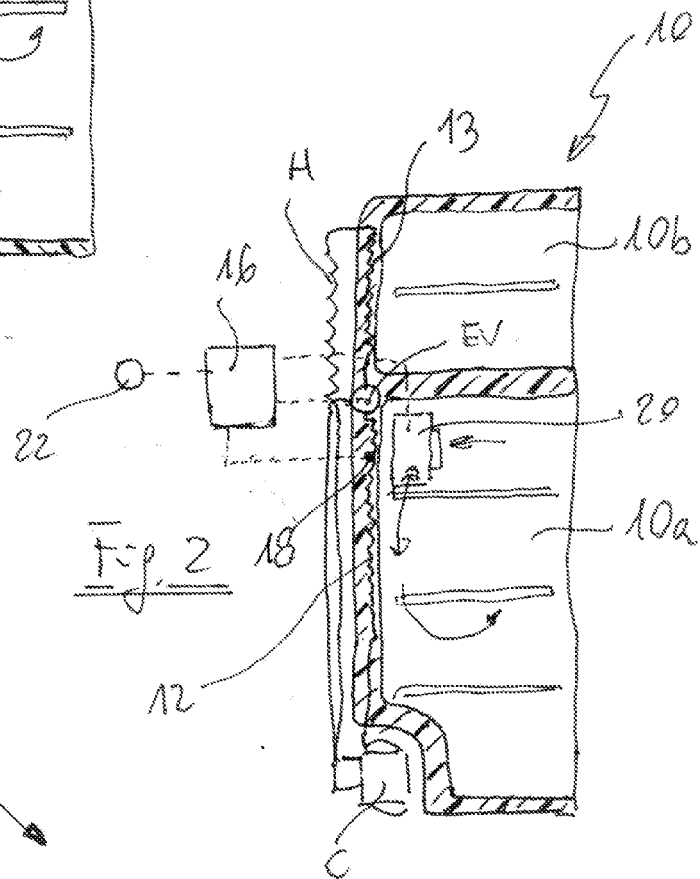
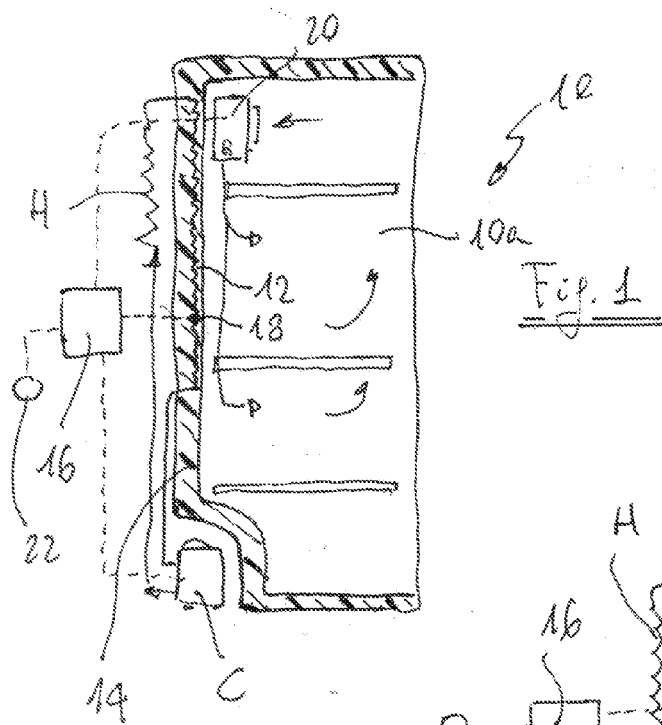
$$T_{AMB} = a * DC\% + b * T_{SET} + c * f_{CC} + d$$

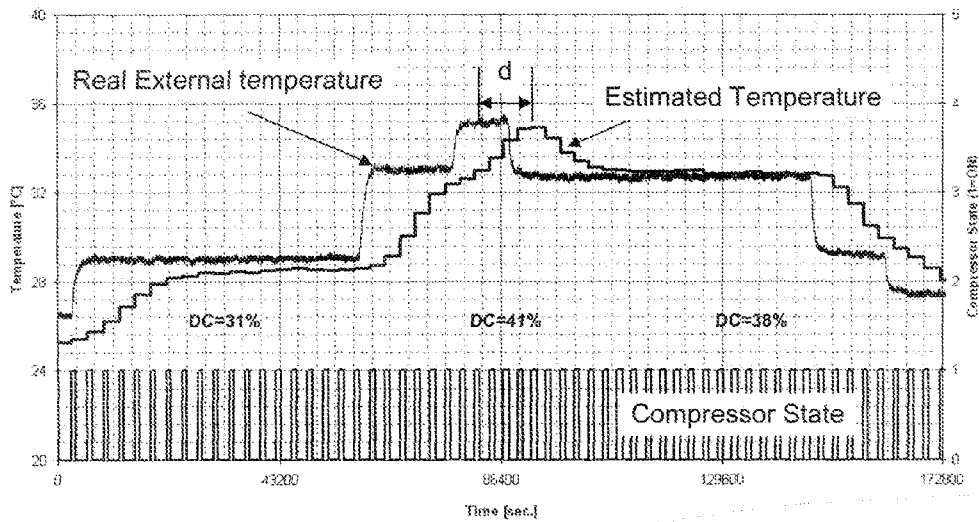
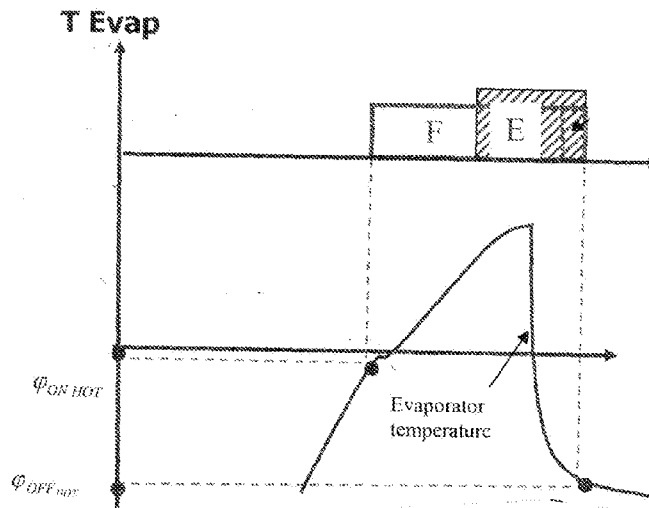
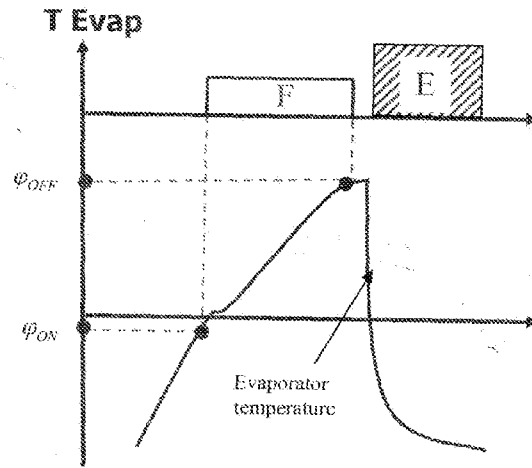
where a, b, c, and d are constant values, DC% is the duty cycle of the compressor (C) or of the electro valve (EV), Tset is the temperature of the compartment (10a) set by the user and fcc is a Boolean factor 0 or 1.

8. A method according to claims 4 and 7, wherein the Boolean factor fcc depends on the comparison of the estimated thermal load (T_{AMB}) and said predetermined value (R).
9. A refrigerator (10) comprising a cavity (10a), a refrigerating circuit including a compressor (C), an evaporator (12), a fan (20) inside the refrigerator cavity (10a), and a control unit (16) adapted to receive signals (S, A) indicative of the cooling performances set by the user and of the working condition of the refrigeration circuit, **characterized in that** said control unit (16) is capable of estimating the thermal load (T_{AMB}) of the refrigerator (10) on the basis of said signals (S, A)
10. A refrigerator according to claim 9, wherein said estimated thermal load (T_{AMB}) is used for controlling the fan (20) .
11. A refrigerator (10) according to claim 9 or 10, wherein the signal indicative of the working conditions of the refrigerating circuit is the duty cycle (DC%) of the compressor (C) or an average based on a certain number of last duty cycles (DC%) of the compressor (C) or a combination thereof.
12. A refrigerator (10) according to claim 9 having an electro valve (EV) controlling the flow of a refrigerating fluid in the evaporator (12), wherein the signal indicative of the working conditions of the refrigerating circuit is the duty cycle of the electro valve (EV).
13. A refrigerator according to any of claims 9-12, wherein the control unit (16) is capable of comparing said estimated thermal load (T_{AMB}) with a predetermined value (R) indicative of a high thermal load or a high ambient temperature or it is adapted to drive the fan (20) also according to a measure (T) of the temperature of the evaporator (18).
14. A refrigerator according to any of claims 8-13, wherein the control unit (16) is adapted to estimate the thermal load (T_{AMB}) also on a basis of a signal (D) indicative of the past or present status of the door of the compartment (10a) of the refrigerator (10).
15. A refrigerator according to any of claims 8-14, wherein the control unit (16) is adapted to estimate the thermal load by using an equation:

$$T_{AMB} = a * DC\% + b * T_{SET} + c * f_{CC} + d$$

where a, b, c, and d are constant values, DC% is the duty cycle of the compressor (C) or of the electro valve (EV), Tset is the compartment set by the user and fcc is a Boolean factor 0 or 1.







EUROPEAN SEARCH REPORT

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