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(54) Method and device for dynamically controlling frost formation on a refrigerator evaporator.

(57) The method for controlling frost formation on an evaporator (3) of a refrigerator (7) is based on the use of at least one sensor of capacitive type (10, 11) positioned at the evaporator (3), and comprises measuring and memorizing, subsequent to initial starting of the refrigerator and after each defrosting cycle (42) of the evaporator (3), an electrical signal (V_d) generated by said capacitive sensor (10, 11) and comparing this memorized signal (V_d) with actual electrical signals (V_F) generated during the normal refrigeration cycle (41) following said defrosting (42), said cycle (41) being halted for subsequent defrosting (42) whenever the actual signals (V_F) differ from the memorized signals (V_d) by a predetermined percentage. The method is implemented by a control circuit comprising capacitive sensor means (10, 11) connected to control means (1) connected to means (15, 16) for measuring the temperature in the refrigerator compartments.

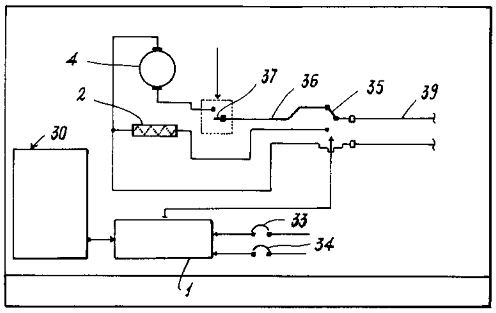

Fig. 2

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This invention relates to a method for controlling frost formation on a refrigerator evaporator, with said evaporator there being associated capacitive sensor means connected to evaporator defrosting control means which activate a usual electrical resistance element associated with said evaporator.

From a previous filing in the name of the present applicant a method and device are known for controlling frost formation on the evaporator of a refrigerator (upright refrigerator, freezer or the like) using capacitive sensor means associated with the evaporator. Specifically, this method comprises measuring the variation of an electrical signal generated by at least one electrically powered capacitive conductor (8) associated with the evaporator, and on the basis of this variation operating the usual heating element associated with the evaporator for its defrosting.

This method is implemented by a device comprising at least one electrical conductor associated with the evaporator, means for powering this conductor and means for controlling an electrical signal generated by said conductor, said signal varying on the basis of the frost present on the evaporator, said control means comparing said signal with a reference value and acting on the heating element on the basis of this comparison.

With this method, the known device operates by comparing the signal from the conductor or capacitive sensor with a predetermined reference signal. This reference signal is chosen on the basis of a particular distance between the sensor plates.

Although this device operates substantially well, it has proved too sensitive to even minimum variations in the distance between said plates, even though contained within tolerance limits. In particular it has been found that during the use of the refrigerator, even small differences between the distance between plates and an optimum value result in mistaken intervention of the defrosting control means on the heating element, this intervention occurring either when there is no need or only after the formation of a relatively thick layer of frost on the evaporator, according to the particular circumstances.

There has therefore arisen the need to preset the control means for each particular refrigerator so as to regulate its operation according to the actual distance between the plates of the capacitive sensor positioned on the evaporator. However, this results in a considerable increase in the manufacturing and maintenance costs of such refrigerators.

In addition, there are problems of operational type linked to the need to find an optimum value for the reference signal when several capacitive sensors are positioned on the evaporator, the distance between their plates varying from sensor to sensor, and linked to the always present tolerances involved in their assembly on the evaporator.

An object of the present invention is to provide a method and device for controlling frost formation on the evaporator and for implementing defrosting when necessary, which are totally independent of the conditions under which the capacitive sensors are positioned in relation to the evaporator, and which therefore do not require any presetting operation.

A further object is to provide a method and corresponding device of the aforesaid type which is able to compensate for the assembly tolerances of each capacitive sensor on the evaporator, which is not influenced by the temperature variations undergone by said sensor during measurement, and which is not sensitive to the transistors which switch the usual refrigerator compressor on and off.

These and further objects which will be apparent to the expert of the art are attained by a method of the aforesaid type, characterised in that subsequent to initial starting of the refrigerator and after each evaporator defrosting cycle, an electrical signal generated by the capacitive sensor means is measured and memorized and this memorized signal is compared with the actual electrical signals generated by said sensor means during the use of the refrigerator or following each defrosting cycle or the initial starting, the refrigerator being halted for subsequent defrosting whenever the actual signals differ from the memorized signals by a certain predetermined value.

Hence according to the invention the reference value (that memorized) is dynamic, ie is evaluated after each defrosting cycle and in any event after the initial starting of the refrigerator.

This value can also vary for the initial cycles following starting, but tends towards an optimum value which is unique for that refrigerator and can differ from that of other totally identical refrigerators. This therefore dispenses with the need for presetting to achieve acceptable evaporator defrosting, because in implementing the method an optimum evaporator defrosting cycle is automatically achieved.

The aforesaid method is implemented by a device comprising capacitive sensor means positioned at the usual evaporator of the refrigerator, this latter comprising at least one food preservation compartment, at least one heating element for defrosting said evaporator, and heating element control means connected to said sensor means, characterised in that said control means comprise means for memorizing an electrical signal generated by said sensor means subsequent to initial starting of the refrigerator and subsequent to each evaporator defrosting cycle, comparator means for comparing said memorized signal with actual signals generated by said sensor means during normal use of the refrigerator, ie during execution of the usual refrigeration cycle between two successive defrostings or after the starting of the refrigerator, and operating means for the heating element arranged to act thereon whenever said comparator means detect that the ratio of said memorized signal to the actual signals exceeds a predetermined value.

The present invention will be more apparent from the accompanying drawing, which is provided by way of non-limiting example and in which:

Figure 1 is a block scheme of a first embodiment of the device according to the invention;

Figure 2 is a block scheme of a second embodiment of the device according to the invention;

Figure 3 is a circuit diagram of part of the device of the invention shown in Figure 2;

Figure 4 is a general block scheme of the method according to the invention;

Figures 5 to 8 are flow diagrams relative to the implementation of particular stages of the method shown in Figure 4; and

Figure 9 is a practical embodiment of a part of the device of the invention which is common to both the embodiments thereof shown in Figures 1 and 2.

With reference to Figures 1 to 9, the device of the invention comprises a control unit 1, preferably of microprocessor type (provided with its own memory cells, not shown), for controlling and operating a usual electrical defrosting resistance element 2 (positioned at an evaporator 3, for example of flat type provided in a preservation or refrigeration compartment 5 of an upright refrigerator 7 which also comprises a usual freezer compartment 8) and a usual motor-compressor unit 4. In proximity to two opposing faces 3A and 3B of the evaporator there are provided flat elements 10 and 11 spaced from said faces by members 13 formed of any known electrically insulating material. The elements 10 and 11 and those portions of the evaporator 3 positioned in front of them define capacitive sensors connected to the unit 1, by means of which this latter senses and evaluates the presence of frost on the evaporator. By virtue of the arrangement of the elements 10 and 11 (which can also exceed two in number, as shown in Figure 9) the frost is measured on both evaporator faces and provides greater accuracy in the control of this frost without the measurement being negatively affected by the transistors which switch the compressor 4 on and off.

Two NTC (negative temperature coefficient) temperature sensors 15 and 16 are also connected to the unit 1, the sensor 15 being positioned at the evaporator 3 to measure its temperature and the second sensor 16 being positioned in the freezer compartment 8.

The first sensor enables the unit 1 to measure the evaporator temperature and feeds this unit with a reference value to start or stop the compressor 4. This sensor also determines the end of the evaporator defrosting stage effected by the resistance element 2.

For example, this stage is halted when the evaporator temperature reaches a value close to or slightly greater than 4 °C.

As stated, the second NTC sensor 16 measures the temperature of the compartment 8 to ensure that the temperature in this compartment does not fall below a predetermined value, for example -21 °C (preset by a usual potentiometer 17). When the sensor 16 senses this "critical" temperature, the unit 1 halts the motor-compressor unit 4 and operates the resistance element 2, which it maintains in operation until the evaporator temperature reaches a second predetermined maximum value of -5 °C. On reaching this temperature the motor-compressor unit 4 is automatically returned to operation to again cool the compartment 8.

The signal from the sensor 16 which senses the "critical" temperature in the compartment 8 has precedence in the control of the compressor or motor-compressor unit 4. In this respect, when this temperature appears, the motor-compressor unit is in any event halted (and is not further caused to operate) as this signifies that the temperature in the refrigeration compartment 5 is definitely low and sufficient for food preservation.

The sensors 15 and 16 are represented in Figure 1 by symbols known to the expert of the art and are therefore not further described.

The device of Figure 1, operating by the method described hereinafter, is completely electronic and comprises a unit 1 which, as stated, is preferably a microprocessor comprising usual analog/digital converters (not shown) which receive the electrical signals in analog form from the sensors 15, 16 and from the potentiometer 17 and convert them into digital signals which can be processed by the unit 1.

In Figures 2 and 3 (in which parts corresponding to those of the already described figures are indicated by the same reference numerals), the unit 1 is preferably a microprocessor circuit without analog/digital converters as it is no longer connected to a potentiometer or to NTC sensors (the function of which is performed by the unit 1 by presetting temperature data), it being connected instead to an electronic interface 30 of known type (from which the unit 1 receives signals at its input) based on a 14 stage binary counter 31 with an internal oscillator enabling a digital signal (V_u) to be generated as output; analog/digital conversion can be achieved with a standard internal timed event counter. The unit 30 is connected to usual electrical components well known to the expert of the art and therefore not further described. It should be noted that the capacitive sensor for detecting frost on the evaporator is connected in parallel with a further capacitor.

The unit 1 is connected to two temperature sensors 33 and 34 for sensing the "critical" temperature of the freezer compartment and evaporator 3 respectively in order to recognize when the defrosting stage has terminated. The sensors 33 and 34 are in the form of usual temperature-controlled relays (klixons).

The unit 1 controls a moving contactor 35 which enables power to be fed to either the compressor 4 (which is consequently operated) or to the electrical defrosting resistance element 2 via an electrical line 39. In the line 36 which connects the contactor 35 to the motor-compressor unit 4 there is a usual moving contactor 37 controlled in known manner by a usual thermostat for example of electromechanical type (not shown).

The method of the invention will now be described in terms of the operation and use of the devices of the described figures.

With reference to Figures 4 to 8, the method is implemented by the device of the invention (via its unit 1) in three main cycles, namely a procedure initiation cycle 40, a refrigeration cycles 41 in which the usual preservation and freezing temperatures are created in the refrigerator 7, and a defrosting cycle 42. This cycle is however partly contained in the cycle 41, as will be described. After the procedure initiation cycle, the cycles 41 and 42 alternate with each other.

With reference to Figure 5, teh cycle 40 comprises, following initial starting of the refrigerator 43, a stage 44 in which the temperature of the evaporator 3 is measured by the sensor 15; during this stage the compressor 4 does not operate and remains in this state until the measured evaporator temperature reaches or exceeds a predetermined value (eg. 4.5 ° C) beyond which it is certain that no more frost is present on the evaporator. When the temperature reaches this value, the procedure passes to a stage 45 in which the voltage V_d between the plates of the capacitive sensors 10 and 11 (in the form of an electrical signal therefrom) is measured and memorized; this voltage will be considered to be the reference voltage in defining a base value to be used for deciding on the need to defrost the evaporator after stage 41.

The unit 1 then activates the compressor (stage 46) and the (minimum) evaporator temperature is then checked (by the NTC sensor 15) to ascertain that it has not reached the "critical" temperature, equal to a predetermined value (preset the potentiometer 17), for example -24 ° C. This occurs in stage 47.

If this temperature is reached, the procedure passes to stage 48 in which the compressor is halted, and then to stage 49 in which the evaporator is checked for (maximum acceptable) temperature.

When this reaches a maximum determined value (eg. -5 ° C), the unit 1 evaluates (in stage 50) the temperature of the freezer compartment 8 (via the sensor 16). If this temperature is not less than a predetermined value (critical temperature), eg. -21 ° C, the compressor 4 is returned to operation and the procedure returns to stage 46. If it is less, then the procedure passes to the refrigeration cycle 41. It should be noted that the freezer critical temperature is normally never reached. However if the refrigerator were to be located in an environment in which there is a relatively low temperature (for example 10 ° C), as the heat losses through the usual refrigerator insulation are different for the freezer compartment 8 than for the preservation compartment 5 it can happen that whereas the sensor 15 on the evaporator measures a temperature sufficient to maintain the compartment 5 at an adequate value, the sensor 16 in the freezer compartment shows that there is too high a temperature greater than this latter; in this case cycle 41 is implemented, ie the compressor is returned to operation.

If however the temperature at the evaporator is relatively high (greater than -5 ° C) but the temperature in the compartment 8 is insufficiently low, the procedure returns to stage 46, ie the compressor is returned to operation without entering the cycle 41, which would also operate the electrical resistance element 2, as will be described. This is because it is obviously not necessary to defrost the evaporator.

In this latter (see Figure 6) the compressor is activated (stage 51), after which (stage 52) the temperature of the compartment 8 is again measured to determine if it is below a minimum acceptable value (-24 ° C). If it is not less than this critical temperature (-24 ° C), the compressor is maintained in operation. If it is less, the compressor is halted (stage 53) by the unit 1, which then evaluates whether the freezer temperature is less than the said -21 ° C (stage 54). If it is less, the unit 1 activates the electrical resistance element 2 for usual evaporator defrosting (stage 55), performed within the cycle 41 under examination (not to be confused with that performed within the cycle 42, which is of longer duration).

Following stage 54 and if the evaporator temperature is not less than -21 ° C, after a sufficiently long predetermined time (eg. 2 minutes) the unit executes stage 56 in which it evaluates (via the sensor 15) whether the evaporator temperature exceeds a maximum acceptable value (-5°C) (ie it detects when the maximum acceptable evaporator temperature is reached). If this temperature is unacceptable it returns to stage 53. Alternatively (if the temperature in stage 55 exceeds -5°C due to the activation of the resistance element 2), defrosting is halted by deactivating the element heating the evaporator (stage 57), and the voltage (V_F) across the capacitive sensors 10 and 11 is measured (by the electrical signals originating from them) (stage 59). If this voltage is greater than or equal to the previously memorized voltage V_d and if the ratio of these voltages exceeds a predetermined coefficient (for example by 10% or double, etc.), the unit 1 executes the defrosting cycle 42. The reference value is preferably equal to the value V_d increased by a percentage (or by a predefined coefficient); the measured value V_F is compared with this value (by the unit 1, which contains usual comparison means such as comparators, logic gates or the like).

If V_F is less than V_d (or a multiple thereof), the unit 1 returns to stage 51.

In the case of defrosting, the unit 1 activates the resistance element 2 in stage 60 and then checks the evaporator temperature (stage 61). When this exceeds the value at which all the frost is sure to have melted (4.5°C), the unit 1 deactivates the resistance element 2 (stage 62) and proceeds to measure the voltage across the plates of each capacitive sensor 10 and 11 (stage 63). In this manner a value V_d is defined (then multiplied by the correction percentage coefficient, or not), which can also be different from the value V_d previously defined in stage 45.

The unit 1 then determines a delay in starting the compressor equal to a minimum time necessary to be certain that the evaporator 3 has been defrosted (stage 64) and then restarts the refrigeration cycle (ie the stage 51).

The unit 1 executes the aforesaid stages in continuation. In particular the determination of the temperature of the evaporator 3 and of the freezer compartment and the comparison of the signals (V_F) from the capacitive sensors (10, 11) with the memorized and corrected signal (V_d) can be performed continuously during each cycle 40, 41 or 42 of operation of the refrigerator 7 or during successive time periods at equal times apart.

It should be noted that (with reference to Figure 8 in which parts corresponding to those of the already described figures are indicated by the same reference numerals), in order to comply with current regulations, following stage 59 and whenever the measured V_F value is not greater than or equal to V_d, the unit 1 executes a stage 70 in which it investigates whether the refrigeration cycle 41 has been underway continuously for more than a predetermined time period (for example 72 hours). If it has, then the unit 1 resets a counter (stage 71) which measures the duration of each cycle 41 and then executes the cycle 42 (ie the stage 60). If it has not, then it executes stage 51.

Consequently according to the method of the invention and using the described device, frost formation on the evaporator 3 is evaluated by evaluating a dynamic reference value which varies for each particular refrigerator and according to the temperature of the environment in which the refrigerator is situated, this reference value, suitably corrected by a predefined factor (a percentage, eg. 10%, or a multiple) acting as the basis for comparison with an "actual" value corresponding to frost formation on the evaporator. It should be noted that this value can also vary in accordance with the constructional details of the refrigerator 7 and its use.

In this manner, costly and lengthy operations involved in setting the device are avoided and in addition the device is used more correctly.

Different embodiments of the device have been described. Other embodiment are however possible within the light of the present description (such as embodiments in which the evaluation of V_F in stage 58 is not preceded by any evaporator defrosting - as in stage 55 - but is effected directly after stage 54), these falling within the scope of the present invention.

Claims

1. A method for controlling frost formation on a refrigerator evaporator, with said evaporator there being associated capacitive sensor means connected to evaporator defrosting control means which activate a usual electrical resistance element associated with said evaporator following stoppage of the usual compressor, characterised by measuring and memorizing, subsequent to initial starting of the refrigerator (7) and after each defrosting cycle (42) of the evaporator (3), an electrical signal (V_d) generated by the capacitive sensor (10, 11) and comparing this memorized signal (V_d) with actual electrical signals (V_F) generated by said sensor means (10, 11) during the use of the refrigerator (7) or following each defrosting cycle (42) or the initial starting, the refrigerator (7) being halted for a subsequent defrosting cycle whenever the actual signals (V_F) differ from the memorized signals (V_d) by more than a certain predetermined value.

2. A method as claimed in claim 1, characterised in that during the starting cycle (40) of the refrigerator (7) the evaporator temperature is measured and compared with a predetermined temperature at which the frost on said evaporator has at least largely melted, and if the measured temperature is found to be greater than or equal to the predetermined temperature, the electrical signal (V_d) generated by the sensor means (10, 11) is measured and memorized following this comparison and then compared with the actual signal (V_F) emitted by these latter.

3. A method as claimed in claim 1, characterised in that during the starting cycle (40) the evaporator temperature is checked for minimum and maximum acceptable value, and when this latter is achieved and exceeded the temperature in the freezer compartment (8) is measured in order to decide whether or not to start the operating cycle (41) of the refrigerator (7), ie its refrigeration cycle.

4. A method as claimed in claim 1, characterised in that during the refrigeration cycle (41) the evaporator temperature is checked for minimum acceptable value, and if this is attained the temperature of the freezer compartment (8) is measured following stoppage of the compressor (4), and if this is less than a minimum acceptable value the evaporator heating element (2) is activated for a limited period, said activation being followed by measuring the evaporator temperature for maximum acceptable value, the attaining and exceeding of which resulting in deactivation of said element (2) and measurement of the actual electrical signal (V_F) emitted by the capacitive sensor means, said measurement being followed by comparison between said actual signal and the memorized signal, the evaporator defrosting cycle (42) then being executed if the ratio of these signals exceeds a certain predetermined value.

5. A method as claimed in claim 1 or 4, characterised in that the predetermined value is a correction value for the memorized signal (V_d) emitted by the capacitive sensor means (10, 11), said correction value being a percentage value or a determined numerical multiplier.

6. A method as claimed in claim 1, characterised in that the defrosting cycle (42) comprises activating the heating element (2) until the evaporator temperature reaches or exceeds a value at which the frost on said evaporator is sure to have largely melted, after which said element (2) is deactivated and the electrical signal from the capacitive sensor means (10, 11) is evaluated and memorized to replace the corresponding previously memorized signal (V_d), the refrigeration cycle (41) then being restarted after a sufficiently long preset delay period.

7. A method as claimed in claim 1, characterised in that the comparison between the memorized signal (V_d) and the actual signals (V_F) is effected continuously.

8. A method as claimed in claim 1, characterised in that the comparison between the memorized signal (V_d) and the actual signals (V_F) is effected at discrete time intervals/

9. A method as claimed in claim 2 or 4 or 6, characterised in that the temperature evaluation of the evaporator (3) and freezer compartment (8) is effected continuously.

10. A method as claimed in claim 2 or 4 or 6, characterised in that the temperature evaluation of the evaporator (3) and freezer compartment (8) is effected at discrete time intervals.

11. A method as claimed in claim 1, characterised in that the defrosting cycle (42) is effected after a predetermined time period during which the presence of excessive frost on the evaporator is not detected.

12. A device for implementing the method of claim 1 in a refrigerator, comprising capacitive sensor means positioned at the usual evaporator of the refrigerator, this latter comprising at least one food preservation compartment, at least one heating element for defrosting said evaporator, and heating element control means connected to said sensor means, characterised in that said control means (1) comprise means for memorizing an electrical signal (V_d) generated by said sensor means (10, 11) subsequent to initial starting (40) of the refrigerator (7) and subsequent to each evaporator defrosting cycle (42), comparator means for comparing said memorized signal (V_d) with actual signals (V_F) generated by said sensor means (10, 11) during normal use of the refrigerator (7), ie during execution of the usual refrigeration cycle (41) between two successive defrostings (42) or after the starting (40) of the refrigerator (7), and operating means for the heating element (2) arranged to act thereon whenever said comparator means detect that the ratio of said memorized signal (V_d) to the actual signals (V_F) exceeds a predetermined value.

13. A device as claimed in claim 12, characterised in that the memorizing means, the comparator means and the operating means are a microprocessor unit (1).

14. A device as claimed in claim 12, characterised in that the microprocessor unit (1) is connected to temperature sensors (15, 16) associated respectively with the evaporator (3) and the freezer compartment (8), and to regulator means (17) for setting temperature values for comparison with corresponding actual values measured by said sensors (15, 16) during refrigerator operation.

15. A device as claimed in claim 12, characterised in that the microprocessor unit (1) controls usual moving contactor means (35) for activating the compressor (4) and the heating element (2).

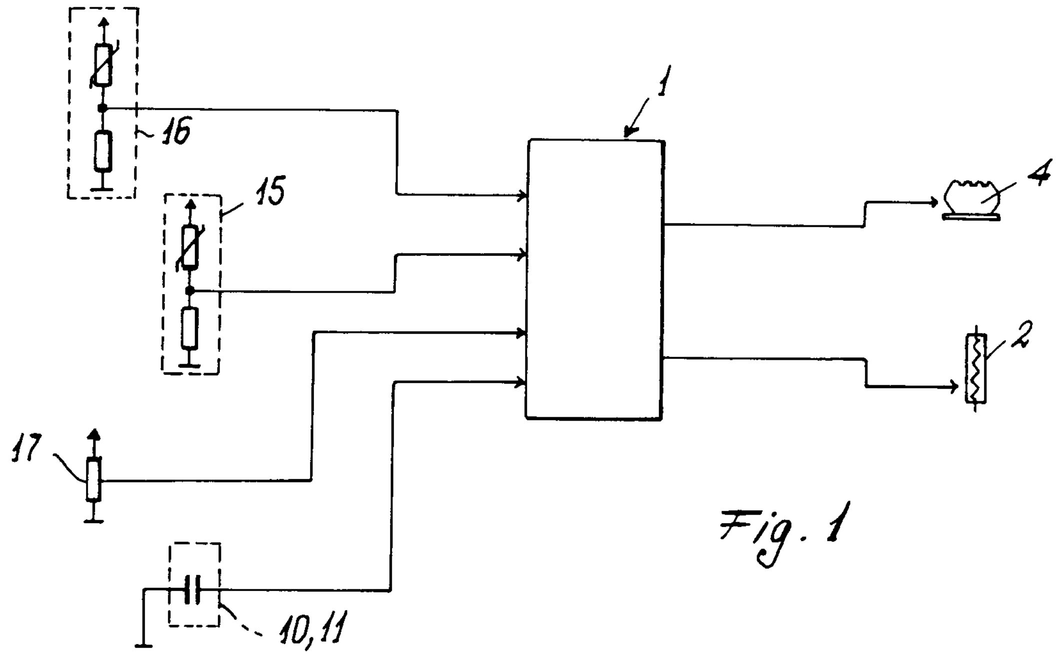


Fig. 1

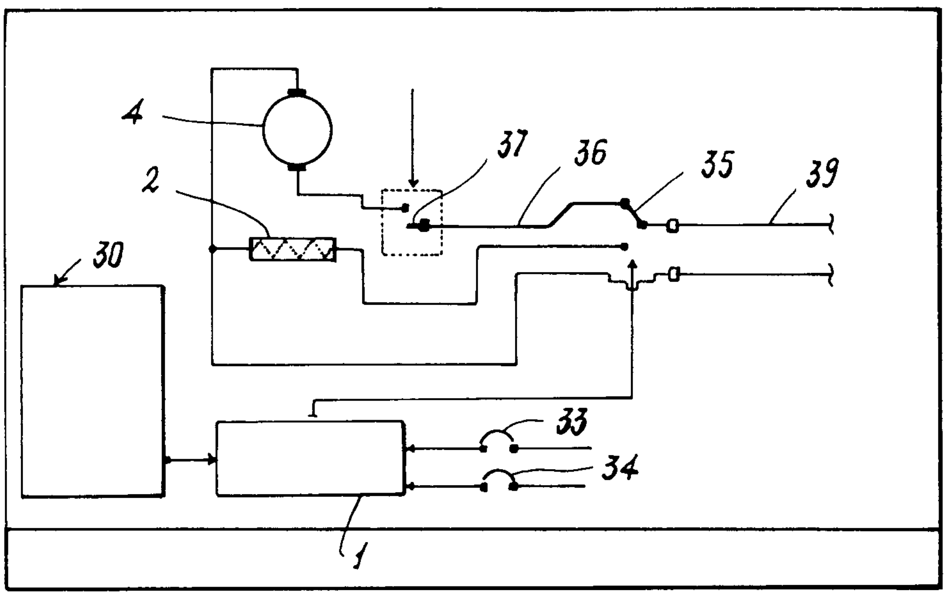


Fig. 2

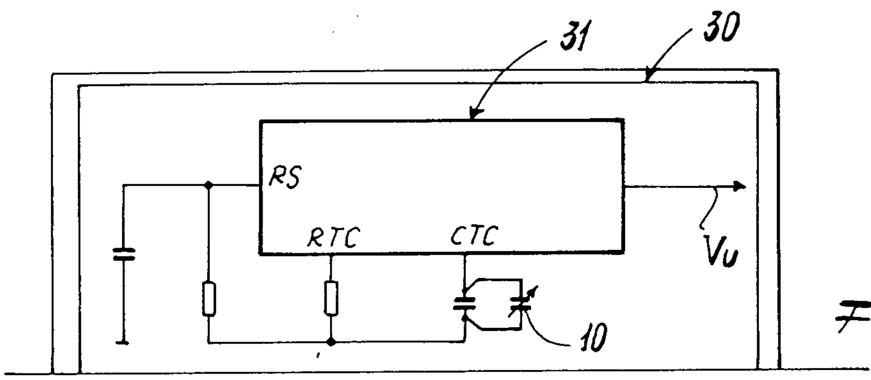
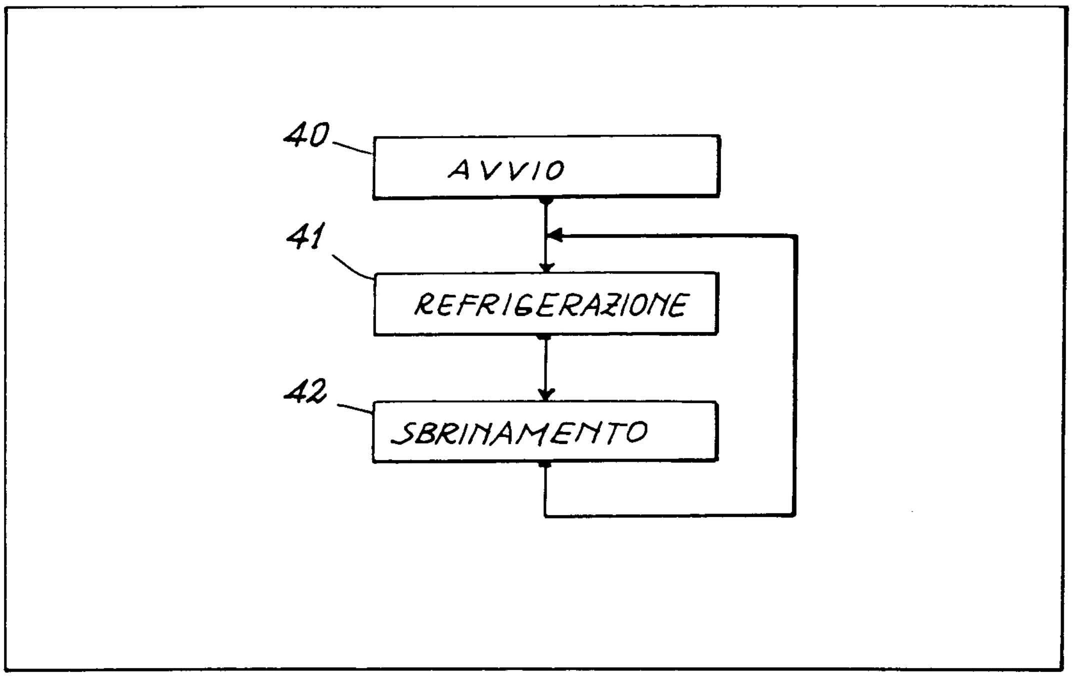


Fig. 3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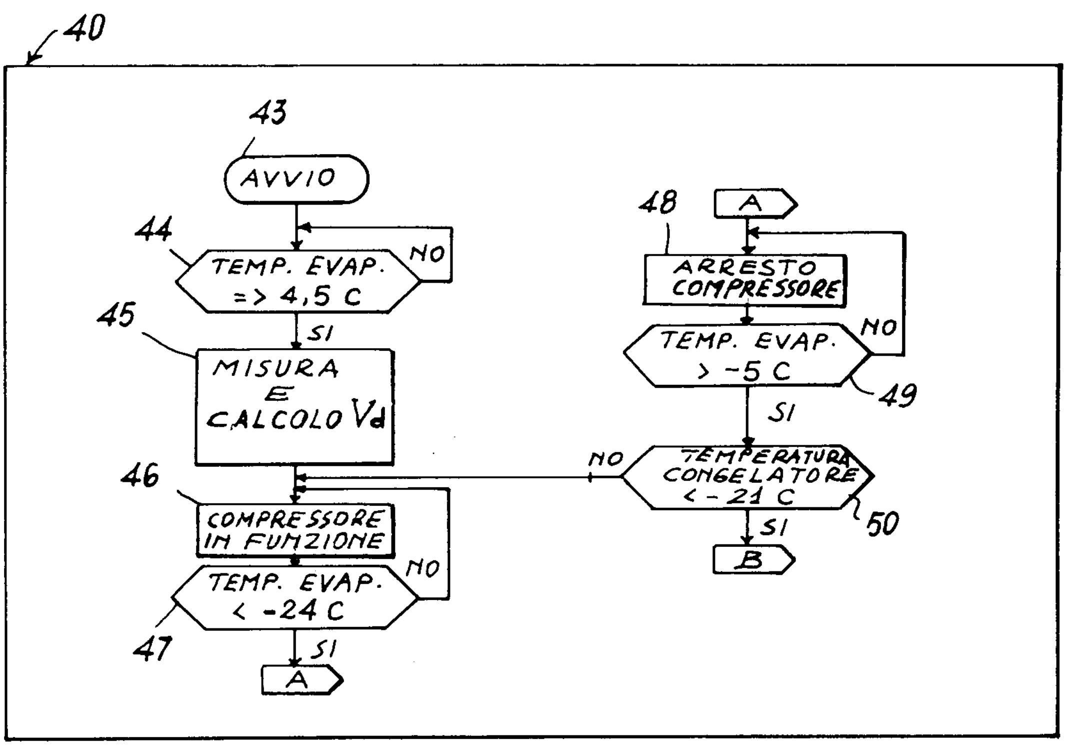
AVVIO
41
REFRIGERAZIONE
42
SBRINAMENTO

Fig. 4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B

Fig. 5

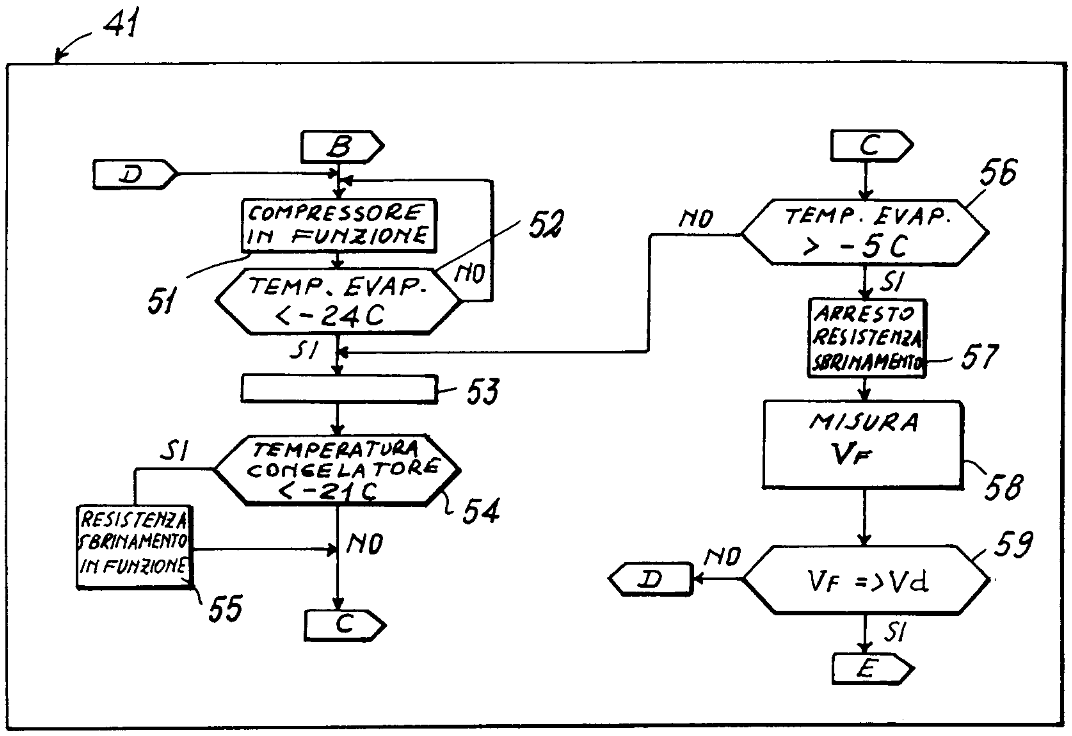
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Fig. 6

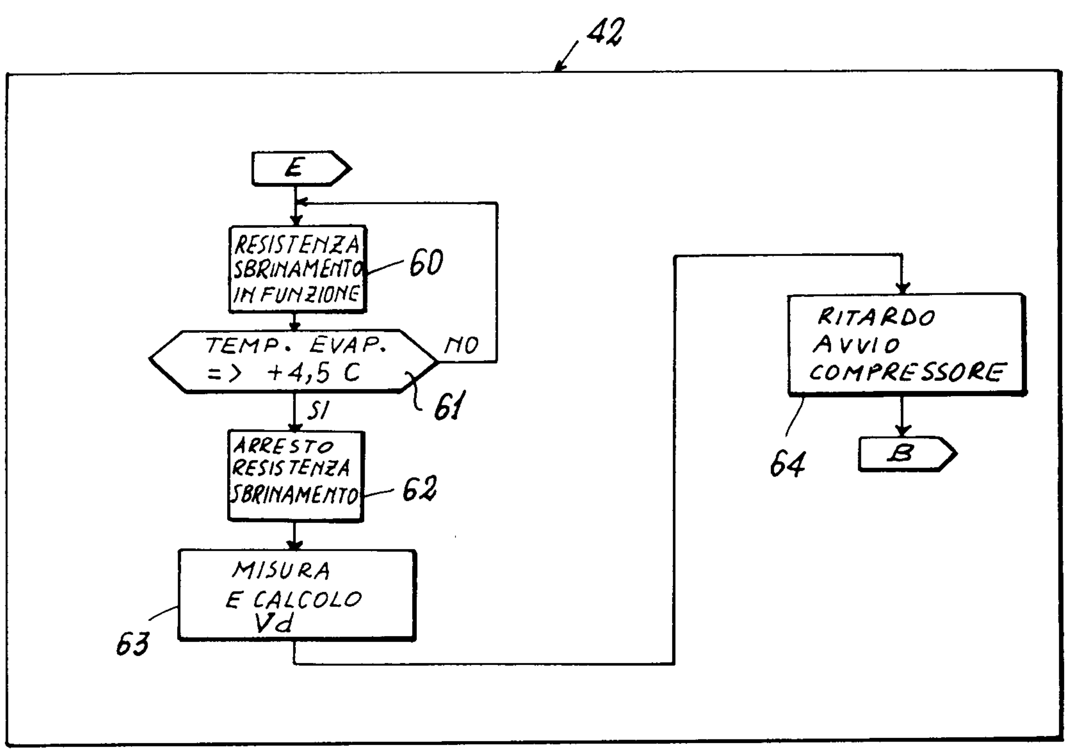
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Fig. 7

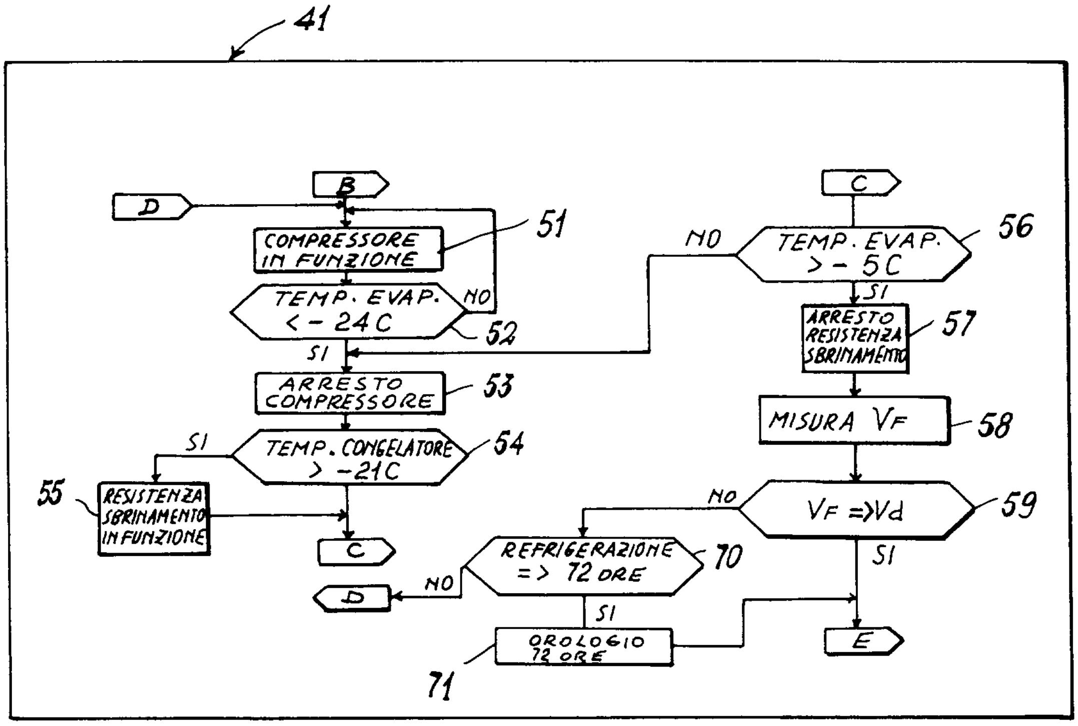
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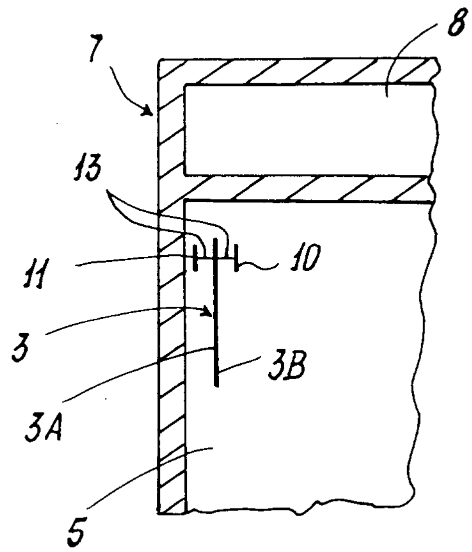
Fig. 8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8
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3
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3A
5

Fig. 9

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 11 5230

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.6)
A	US-A-4 400 949 (KINOSHITA) * column 3, line 66 - column 6, line 41; figures 1-5 * ---	1,4,5,7, 9,12-15	F25D21/02 F25D21/00
A	US-A-4 347 709 (WU) * column 1, line 62 - column 4, line 5; figures 1-5 * ---	1,12	
A	US-A-4 104 888 (REEDY) * column 2, line 66 - column 5, line 54; figures 1-2 * ---	1,7,9,12	
A	US-A-4 653 285 (POHL) * column 7, line 37 - column 16, line 49; figures 1-10 * ---	1,12,13	
A	US-A-4 474 024 (EPLETT) * column 3, line 51 - column 7, line 2; figures 1-4 * ---	1,12	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	EP-A-0 494 785 (MORRIS) * column 2, line 40 - column 5, line 36; figures 1-3 * ---	3,4,6,14	F25D
A	US-A-3 282 065 (FLANAGAN) ---		
A	GB-A-2 016 174 (P. R. MALLORY) ---		
A	US-A-3 681 933 (CHECK) -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 February 1994	Boets, A

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