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(54) **DEFROSTING METHOD AND DEVICE FOR REFRIGERATING OR AIR CONDITIONING APPARATUS**

(57) A method for controlling an intelligent defrosting device, in particular for refrigerating or air conditioning apparatus, heat pumps and evaporators, comprising the steps of measuring a pressure in the environment to be refrigerated; measuring a pressure at a preset point of the evaporator, and selecting a time for starting a defrosting cycle as a pressure difference between the pressure of the environment to be refrigerated and that at a preset point of the evaporator exceeds a preset pressure threshold.

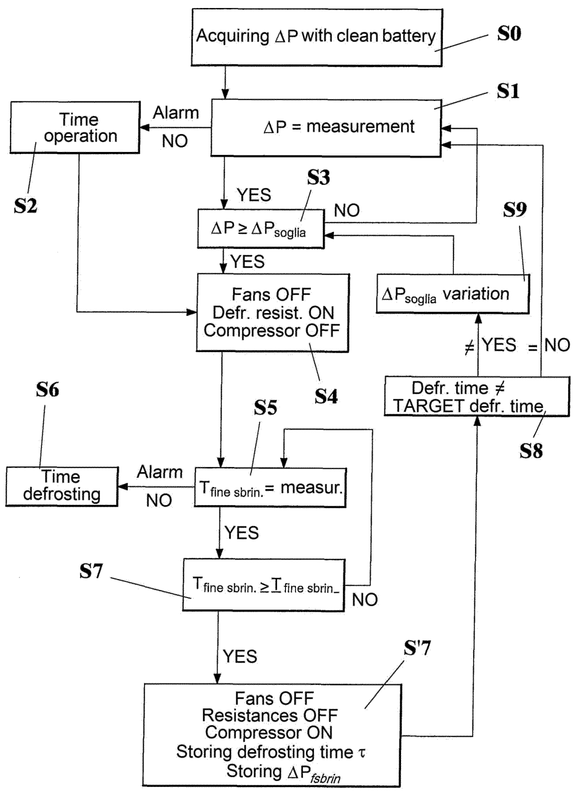


FIG. 1

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a defrosting method and device in particular for air refrigerating and air conditioning apparatus.

[0002] As is known, a formation of frost or ice on thermal exchange surfaces contacting wet air in devices for air refrigerating and air conditioning, including the heat pumps (air evaporators and air refrigerators) operating based on single-phase and two-phase fluids, which will be hereinafter called for conciseness "evaporators", causes a progressive deterioration of said apparatus performance, with negative consequences on the energy performance of the systems in which said apparatus are arranged.

[0003] In order to limit the negative effect of the frost or ice, the prior art provides to carry out defrosting methods on different types of evaporators (of an electric, water, hot gas type and so on) for recovering the operating conditions of a clean evaporator.

[0004] In such a prior use, it is provided that the defrosting operating cycles are performed at constant time intervals, being set by the system operator (for example a defrosting operation every 6 hours) independently of an effective need of performing such a defrosting operation, or after a preset number of evaporator operating hours.

[0005] To perform a defrosting operating cycle, if it is not really required, involves obvious drawbacks, both in terms of energy consumption (in addition to an energy waste required for performing the defrosting operation it should be also considered the fact that a substantial part of the thermal energy used for the defrosting operation is discharged into the environment to be refrigerated and accordingly must be removed with a further energy consumption), and in terms of the refrigerating performance, since, as it should be apparent, during the defrosting operating cycle no refrigerating power is produced and, accordingly, it is necessary to increase, the overall refrigerating energy being the same, the installed refrigerating power.

[0006] Significant energetic disadvantages are also involved as the defrosting operation is carried out with a delay over an optimal defrosting period, since this causes the evaporator to operate under bad operating conditions, with consequent deteriorated COPs (coefficients of performance) of the refrigerating/heat pump operating cycle.

[0007] Several approaches have been attempted to provide an "intelligent" or smart defrosting device, that is a device designed for determining the optimal time to perform a defrosting operation, independently of the time elapsed from a preceding defrosting operating cycle.

[0008] The present application is related to solving the above mentioned problems by novel solutions specifically designed for overcoming the above mentioned drawbacks.

SUMMARY OF THE INVENTION

[0009] Accordingly, the aim of the present invention is to provide a defrosting method and device adapted to carry out a defrosting operation always at an optimal defrosting time, while preventing the evaporator from operating in non-optimal operating conditions, that is with non-optimal COPs of the refrigerating/heat pump operating cycle.

[0010] Within the scope of the above mentioned aim, a main object of the present invention is to provide such a defrosting method and device which may be applied to any type of evaporators, independently of the evaporator performance or power, the refrigerating fluid used and the operating conditions of said evaporator, the number of compressors with which it cooperates, the number of evaporators arranged in a parallel relationship, and so on.

[0011] Another object of the present invention is to provide a method and device of the above indicated type, allowing a user to change at will a preset value of the defrosting cycle time, based on the user's specific requirements.

[0012] Another object of the present invention is to provide a method and device of the above indicated type, adapted to detect and signal any operation faults, or non-operating conditions, for example because of damages or malfunctions of one or more components of the apparatus to be defrosted, for example the operating fans.

[0013] Yet another object of the present invention is to provide such a defrosting method and device designed for properly detecting and signaling a possible lack of operation, for example due to damages or other malfunctions of one or more heating resistances.

[0014] Yet another object of the present invention is to provide such a defrosting method which may be carried out by a small number of hardware operating means easily commercially available to assure a very safe and reliable operation of the refrigerating apparatus and/or the like.

[0015] Yet another object of the present invention is to provide such an intelligent defrosting device which requires almost no maintenance.

[0016] Yet a further object of the present invention is to provide such an intelligent defrosting device which does not require any calibration either by the evaporator maker or by the installing operator or user.

[0017] According to the present invention, the above mentioned aim and objects, as well as yet other objects which will become more apparent hereinafter, are achieved by a defrosting method and device, in particular for air refrigerating and air conditioning apparatus, according to the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Further characteristics and advantages of the method and device according to the present invention will become more apparent hereinafter from the following detailed disclosure of a preferred embodiment thereof, which is illustrated, by way of an indicative but not limitative example, in the accompanying drawings, where:

Figure 1 shows a flow diagram of the defrosting method according to the present invention;
Figures 2 and 2A show air pressure sensing means constituting an integral part of the inventive device and being applied to a generic refrigerating and/or air conditioning apparatus in which a defrosting operation must be carried out periodically;
Figure 2B is a schematic view showing the main hardware components of the inventive device;
Figure 3 is a further schematic view showing a screened pressure gauge assembly included in the intelligent defrosting device according to the present invention;
Figures 3A and 3B schematically show a preferred location of the defrosting end sensors, for example on a refrigerating apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] With reference to Figure 1, will be hereinafter disclosed the main operating steps of the inventive method controlling a related inventive defrosting device.
[0020] According to the present invention, a measurement controlling the logic means for selecting the time at which a defrosting operating cycle is started is the pressure difference between the environment to be refrigerated and that measured at a suitable point of the evaporator.
[0021] For example, for an evaporator including a plurality of air sucking/delivering fans, that parameter is the pressure existing in the plenum or negative/positive pressure chamber downstream/upstream of a thermal exchange battery, which pressure difference is measured by a suitable differential pressure sensor.
[0022] According to the present invention, is herein stored the differential pressure value measured by a suitable pressure sensor at a time at which the refrigerating apparatus fans are started again upon an end of a defrosting operating cycle, and an evolution of this signal over the operating time is followed (as ice or frost is formed, the pressure signal will increase because an increased aerodynamic resistance to be compensated for by the air fans).
[0023] With reference again to Figure 1, in the operating step S0 is acquired a pressure difference with the battery in a clean condition, whereas in the operating step S1 a pressure difference is measured.
[0024] If a response in the step S1 is NO, than the diagram flow goes to the time operating step S2 (alarm condition).
[0025] If a response in the operating step S1 is YES, then it is determined, in the operating step S3, if the pressure difference is higher than or equal to a threshold pressure difference.
[0026] If the response is NO, the flow returns to the operating step S1.
[0027] If the response is YES, the flow goes to the step S4, where the air fans are put in an OFF or switched off condition, whereas the defrosting resistances are switched to an ON status or energized and the compressor is switched to an OFF condition.
[0028] As is shown, into the operating step S4 also flows the step S2 related to the time operation (alarm condition).
[0029] From the step S4, the flow goes to the step S5, where the defrosting end temperature is measured.
[0030] From the step S5 the flow goes, if the response is NO, to the time defrosting step S6.
[0031] Vice versa, if the response is YES, from the step S5 the flow goes to the step S7, where it is determined if the defrosting end temperature is higher than or equal to the set defrosting end temperature.
[0032] If the response is NO, from the step S7 the flow returns to the step S5.
[0033] If the response is YES, from the step S7 the flow goes to the step S'7, wherein the air fans are in an ON condition, the heating resistances are OFF, the compressor is ON and the defrosting time and also the value ΔP_{fsbrin} are stored.
[0034] From the operating step S'7, the flow goes to the operating step S8.
[0035] In this step S8 it is determined if the defrosting time is different from the Target or desired defrosting time.
[0036] If the response is YES, the flow goes to the step S9, where is determined the pressure difference variation ΔP_{soglia}.
[0037] From the step S9, the flow goes to the step S3.
[0038] If the response in the step S8 is NO, the flow returns to the pressure difference measuring step S1.
[0039] Thus, from the above disclosure of Figure 1, it should be apparent that, advantageously, the differential pressure

increase actuating the defrosting cycle start is self-calibrated based on the following operating sequence:

1. at the first operating cycle, is assumed a preset percent increase of the value with the battery in a clean condition (stored in a memory for the whole evaporator life or up to a time at which a novel measurement is performed) on a conservative preset value (for example 60% of the value with the apparatus in a clean condition) of the differential pressure determining the start of the first frosting cycle.
2. a time required for performing the defrosting operation is measured.
According to a further aspect of the present invention, the defrosting operation end is determined as is achieved a fixed and preset temperature value measured by further suitable temperature sensors arranged at a plurality of suitable points of the evaporator, for example on a bend of the evaporating circuit and on the top portion of the finned pack on the manifold side and so on, as it will be disclosed in a more detailed manner hereinafter.
The achieving of the above mentioned temperature should be verified by all the sensors, the last sensor achieving that value determining the defrosting end time.
3. The defrosting time determined in the preceding step of item 2 is compared with the preset value and, based on an a "follow-up" or tracking algorithm, the preset differential pressure value is modified, said follow-up algorithm being, according to the present invention:

$$\Delta P_{soglia,i} = \Delta P_{soglia,i-1} \ \{1 - k\ (\frac{\Delta t_{defrosting,\ i-1}}{\Delta t_{defrosting,\ target}} - 1)\}$$

where:

defrosting = ice or frost removing
k = under-releasing factor

4. The start of a subsequent frosting cycle is determined as a new differential pressure increasing value is achieved.
5. The defrosting time is then measured and is determined, based on the follow-up algorithm, the new differential pressure value determining a start of the frosting operations.
6. Then, the operating steps 4 and 5 are continuously followed for the whole operating life of the evaporator.

[0040] According to a further aspect of the present invention, the intelligent defrosting device performs, under the control of the inventive method, a series of control operations, followed by alarm signals related to the evaporator operation through the defrosting step, by using the operating logic arrangements disclosed hereinbelow.
[0041] In this connection it should be pointed out that all the mentioned values and/or number parameters are only indicative, since their selection will depend on the specific applications.

3'. <u>Alarm operating logic</u>

[0042] These logic means provide to perform a series of checking operations, followed by alarm signals, related to the evaporator operating status during the defrosting step.
[0043] More specifically, during such a defrosting step, the following operation status of the following components is monitored: a) the air fans; b) the defrosting electric resistances (or other defrosting devices); c) any anomalous formations of ice at the end of the defrosting operation.
[0044] Hereinbelow are indicated, only by way of an example, the alarms which are preferably built-in in the system, for monitoring the operation of the evaporator:

$\Delta P>0$ during the defrosting operation (the air fan being ON during the defrosting)
NTC probe malfunction: as their difference exceeds by 50°C
ΔP after an i-th defrosting < ΔP with clean battery x 0.80
ΔP after an i-th defrosting > ΔP with clean battery x 1.20
Resistance malfunction: defrosting time > maximum time (for example 45 minutes)
Fan malfunction: ΔP after an i-th defrosting = 0 (tolerance $\pm$ 3 Pa) (and pressure sensor malfunction $L_{>}\Delta P=0$.

4'. "Safety" logic means

[0045] The safety logic means will be operated in a case in which ΔP_{soglia} > fan ΔP_{max}, that is as the threshold ΔP, which varies in a convergence cycle, exceeds the maximum ΔP value which can be achieved by the air fan associated with a given exchange battery.
[0046] In this case, the threshold value is never achieved, and accordingly the defrosting operation could not be actuated.
[0047] Another case in which the threshold ΔP could not be achieved is when an excessively high defrosting Target time value is set.
[0048] In this case, the inventive method will comprise the steps of:

Storing a value of No. 10 ΔP_i every x time (for example 60s)
Performing a X1 average operation
Storing the values of following No. 10 ΔP_i every x time (for example 60s).
Performing a X2 average operation

COMPARING THE TWO AVERAGE VALUES:

[0049]

if X1 <X2 negative control (upward curve)
VARIABLE VALUE A=0
if X1 >X2 positive control (downward curve)
VARIABLE VALUE A=1

[0050] Repeating the preceding operations for No. 3 times

If No. 3 A following values equal to 1 are achieved, then checking ΔP_i:

if $\Delta P_i / \Delta P_{batteria\ pulita}$ > 1.6, then performing a defrosting operation and checking the defrosting time:

if $T_{sbrinam} > T_{Target}$, then decreasing the T Target (for example -5 minutes)
if $T_{sbrinam} \leq T_{Target}$, then restarting with a base logic
if $\Delta P_i / \Delta P_{batteria\ pulita} \leq 1.6$ then restarting with a base logic

If No. 3 following A values equal to 1 are not achieved, then continue to operate with the base logic.

[0051] With reference to Figures 2, 2A and 2B, is herein shown a possible mode of application of the intelligent defrosting device of the present invention on an apparatus, for example a refrigerating apparatus, which has been generally indicated by the reference number 100.
[0052] Figures 2 and 2A respectively show the two sides of the refrigerating apparatus including the sensor means of the inventive device.
[0053] The above schematic figures has been included herein only for showing the very simple and quick manner for installing the above mentioned sensors and their reduced number, in particular of some differential pressure sensors and defrosting end sensors.
[0054] With reference to Figure 2B, it shows the main hardware components of the intelligent defrosting device of the present invention.
[0055] In this Figure 2B, the arrow A shows the air flow, the dashed semicircular line 101 shows a fan-coil assembly; the letters T1, T2 and T3 show temperature sensors; 102 shows a differential pressure measuring device; 103 shows a pressure probe; 104 shows a control panel; the arrow F1 shows a power supply of the control panel 104; the arrow F2 shows the output drive signal; the reference T4 shows a further temperature sensor.
[0056] Figures 3 to 3B show further hardware components of the intelligent defrosting device according to the present invention.
[0057] In particular, a main hardware component thereof is a screened pressure gauge assembly 105, advantageously using a membrane 106, for example consisting of a commercially available GORE-TEX® material.
[0058] The pressure gauge assembly 105 further comprises an anti-turbulence cover 107.
[0059] Figures 3A and 3B schematically show defrosting end sensors which has been generally indicated by the reference letters T4, T1, T2, T3.

[0060] Figure 3B is a left side front view of Figure 3A.

[0061] Figures 3A and 3B clearly show possible positions of the defrosting end sensors T4, T1, T2, T3, that is on a bend portion of the refrigerating circuit, at a top central position on the manifold side (0) and inside the finned pack at a diagonal position T1, T2, T3.

[0062] Figures 3, 3A and 3B also clearly show that the defrosting device 100 of the present invention comprises a small number of hardware components which, besides reducing the cost of the device, allow said device to be nearly free from maintenance.

[0063] From the above disclosure it should be apparent that the present invention fully achieves the intended aim and objects.

[0064] In fact, the invention has provided an "intelligent" defrosting method and an "intelligent" defrosting device, which may always perform the defrosting operation at an optimal defrosting time, thereby preventing the evaporator from operating in non-optimal operating conditions, that is with non-optimal performance coefficients of the refrigerating/heat pump cycle.

[0065] A further advantage of the method and device according to the present invention is that the subject intelligent defrosting device may be applied to any type of evaporators, independently of their power or the refrigerating fluid used and the operating conditions thereof.

[0066] Yet another advantage of the present invention is that the operator may change at will the defrosting cycle time preset value, based on the operator requirements.

[0067] While the invention has been disclosed with reference to a currently preferred embodiment of the inventive method and device, it should be apparent that the invention is susceptible to several modifications and variations, all coming within the scope of the invention.

[0068] For example, while the inventive method and device have been herein disclosed as used in air refrigerating and/or air conditioning apparatus, they could be obviously also used in other frost or ice forming apparatus, which ice, for an efficient and optimal operation of the apparatus, must be quickly removed, for example apparatus operating based on sucked air or air delivered on the exchange battery, as well as for any types of air fans (either of an axial or centrifugal type, and so on).

[0069] Then, the scope of the invention should be intended as defined by the following claims, rather than the preceding disclosure.

Claims

1. A method for controlling an intelligent defrosting device, in particular for refrigerating, air conditioning apparatus, heat pumps and evaporators, said apparatus being installed in an environment to be refrigerated, **characterized in that** said method comprises the steps of measuring a pressure in said environment to be refrigerated; measuring a pressure at a preset point of a said evaporator, and selecting a time for starting a defrosting cycle as a pressure difference between the pressure of said environment to be refrigerated and that at said preset point of said evaporator exceeds a preset pressure threshold.

2. A method, according to claim 1, **characterized in that** said pressure at said preset point of said evaporator, for a said evaporator including a suction/delivery fan, is a pressure existing in a depressurized/pressurized plenum downstream/upstream a thermal exchange battery.

3. A method, according to claim 1, **characterized in that** said method comprises a step of measuring said pressure difference by a differential pressure sensor.

4. A method, according to any of the preceding claims, **characterized in that** said method comprises method steps of measuring a differential pressure value measured by said differential pressure measuring sensor at a time at which said fans are restarted after an end of a defrosting cycle and following variation of the signal over time.

5. A method, according to any of the preceding claims, **characterized in that** said method comprises the step of actuating a start of a defrosting cycle based on a self-calibrated differential pressure increase by the following sequence of steps:

   a) assuming, at a first cycle, a preset percent increase of the value with the battery in a clean condition, said value being held in a memory for the whole life of the apparatus or up a time at which a new storing operation is performed, on a preset conservative value of the differential pressure, determining the start of said first frosting cycle;

b) measuring a time required for the defrosting operation, the end of said defrosting operation being determined as a preset fixed temperature value is achieved;
c) comparing the defrosting time determined in said step 2) with the preset value and modifying, based on a "follow-up" or tracking algorithm, the preset differential pressure value, said tracking algorithm being expressed by:

$$\Delta P_{soglia,i} = \Delta P_{soglia,i-1} \left\{1 - k \left(\frac{\Delta t_{defrosting,\ i-1}}{\Delta t_{defrosting,\ target}} - 1\right)\right\}$$

wherein k = under-releasing factor;
d) starting a subsequent frosting cycle as a new differential pressure increase value is achieved;
e) measuring the defrosting time and determining, based on said tracking algorithm, a new differential pressure value determining a start of the frosting operations;
f) repeating the steps d) and e) for the whole operating life of said evaporator.

6. A method, according to any of the preceding claims, **characterized in that** said preset conservative value corresponds to substantially 60% of the value, at a clean apparatus condition, of the differential pressure determining the start of the first frosting cycle.

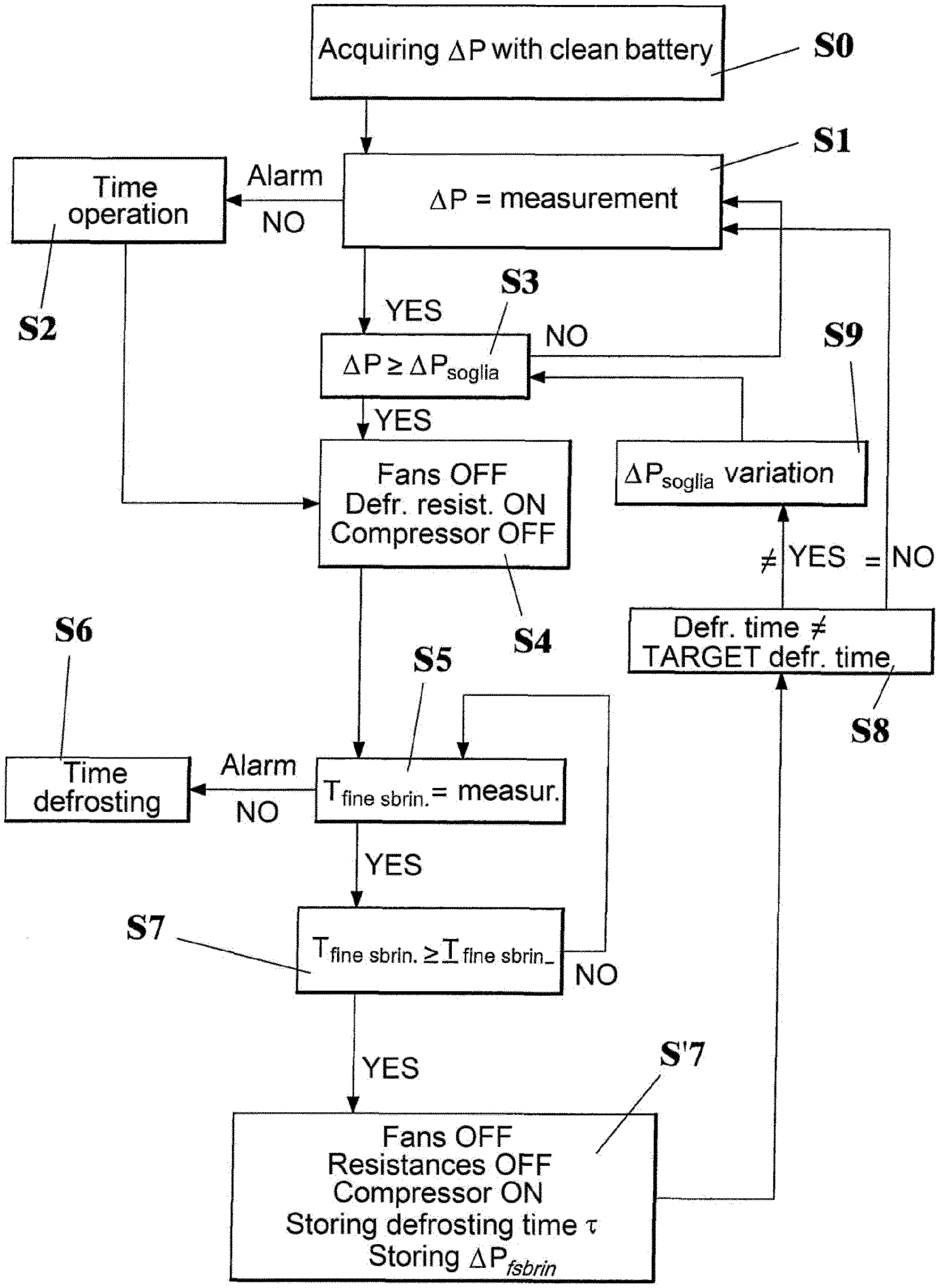
7. A method, according to any of the preceding claims, **characterized in that** said fixed temperature value is preset and measured by temperature sensors arranged at several points of the evaporator, said several points being preferably arranged on a curve of an evaporating circuit, at a central/high position on a manifold side and in a finned pack at a diagonal position.

8. A method, according to any of the preceding claims, **characterized in that** the detection of achieving said temperature is carried out by all the sensors, the last sensor achieving said value determining the defrosting end.

9. An intelligent defrosting device, in particular for a refrigerating or air conditioning apparatus, said apparatus including at least an evaporator, said defrosting device including basic logic means operatively coupled to alarm means and safety logic means, **characterized in that** said device further comprises differential pressure sensor means operatively coupled to said apparatus to drive said basic logic means to start a frosting cycle of said apparatus as a pressure difference between a pressure of an environment to be refrigerated and a pressure measured at a set point of said evaporator exceeds a preset threshold.

10. An intelligent defrosting device, according to the preceding claim, **characterized in that** said safety logic means are adapted to operate as a threshold pressure difference, varying in a convergence cycle, exceeds a maximum pressure difference value which may be achieved by a fan coupled to a preset exchange battery.

11. An intelligent defrosting device, according to claims 9 and 10, **characterized in that** said device further comprises a screened pressure gauge assembly, including filter membrane means and anti-turbulence covering means, and that said sensors comprise differential pressure sensors and defrosting end sensors which are preferably arranged on a curve of a refrigerating circuit; at a high central position on a manifold side and within a finned pack at a diagonal position.



Acquiring ΔP with clean battery
S0
S1
Alarm
NO
Time operation
ΔP = measurement
S2
YES
S3
NO
ΔP ≥ ΔP soglia
S9
YES
Fans OFF
Defr. resist. ON
Compressor OFF
ΔP soglia variation
≠ YES
= NO
Defr. time ≠ TARGET defr. time
S4
S6
S5
S8
Time defrosting
Alarm
NO
T fine sbrin. = measur.
YES
S7
T fine sbrin. ≥ T fine sbrin_
NO
YES
S'7
Fans OFF
Resistances OFF
Compressor ON
Storing defrosting time τ
Storing ΔP fsbrin

FIG. 1

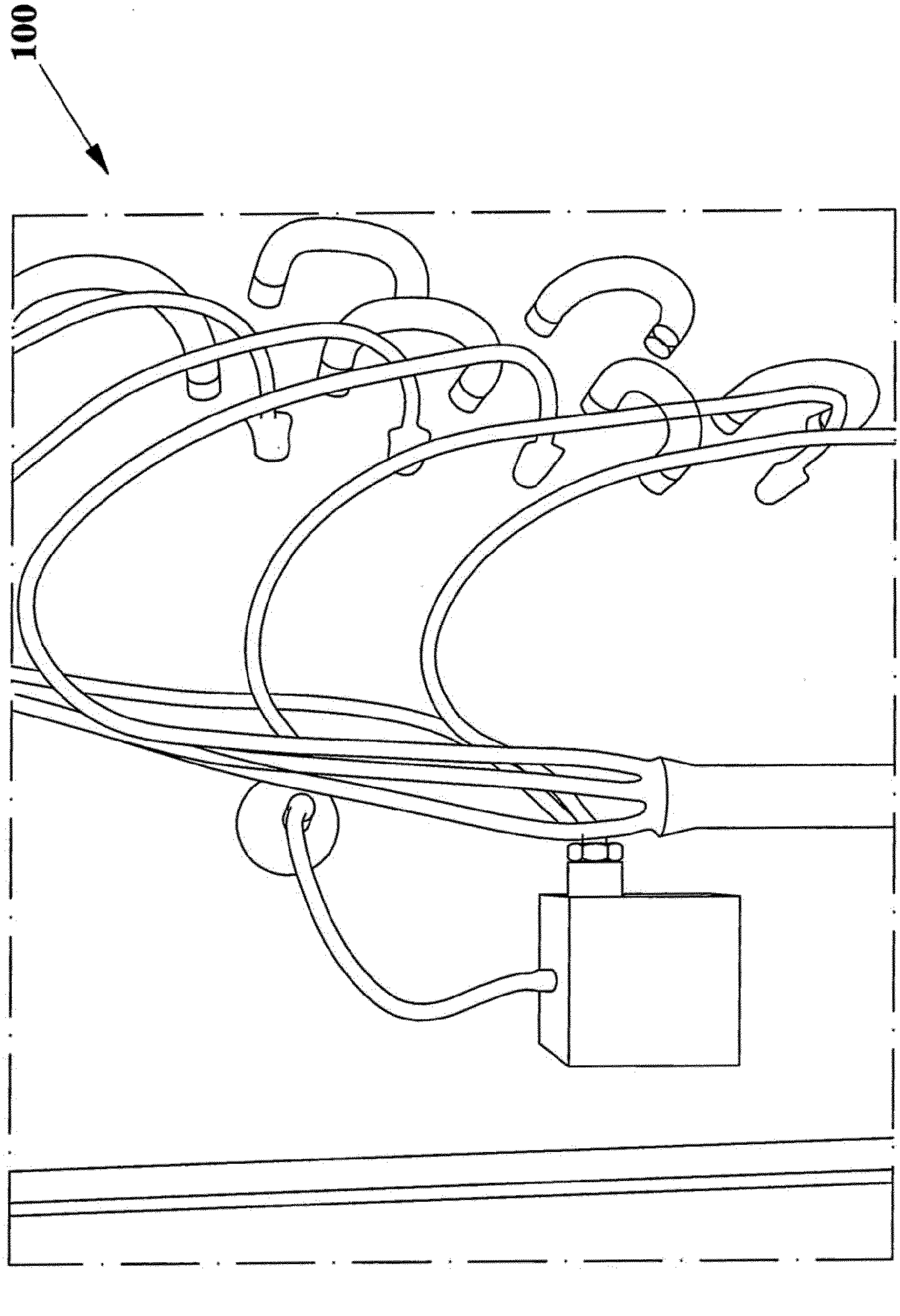


FIG. 2

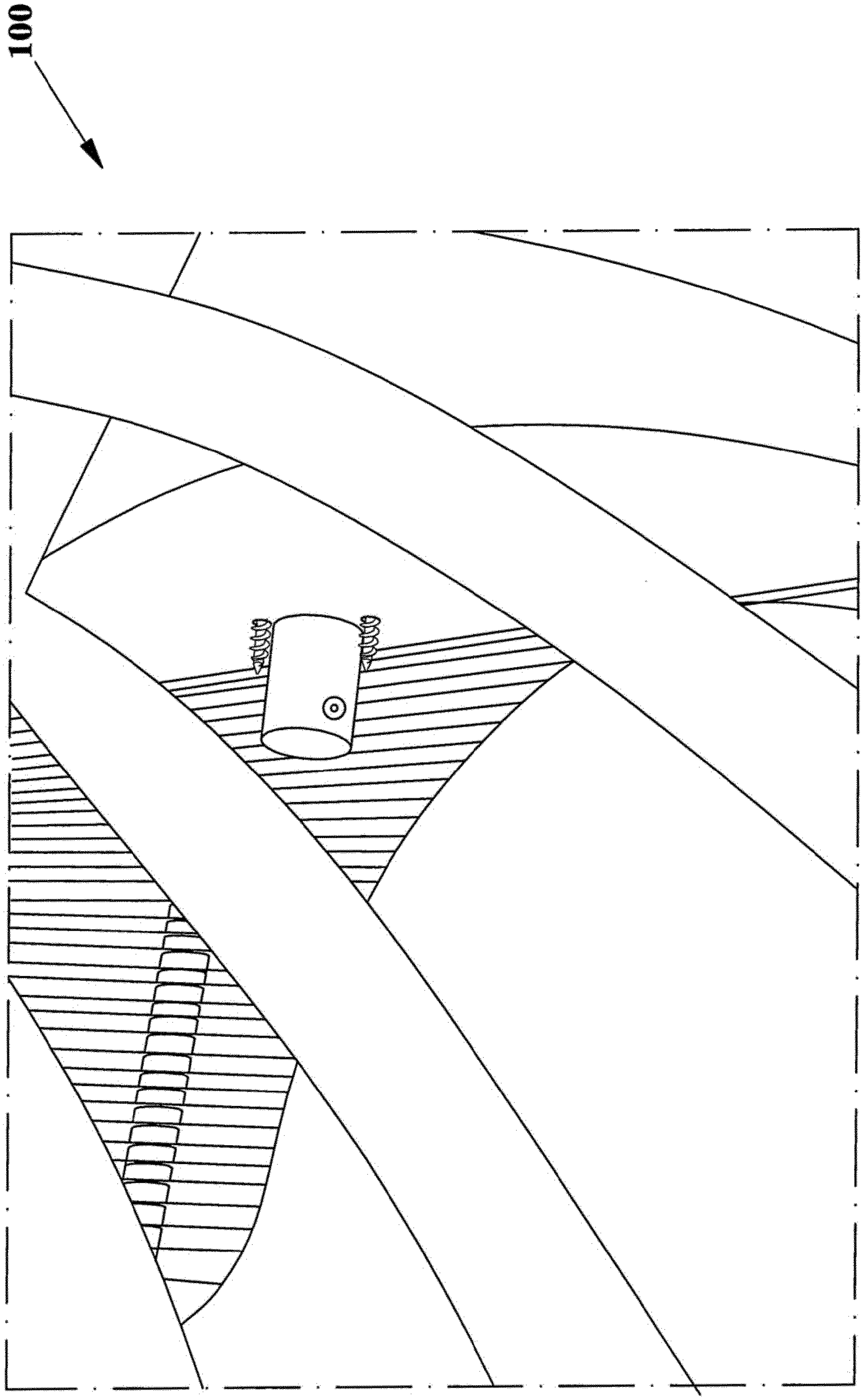


FIG. 2A

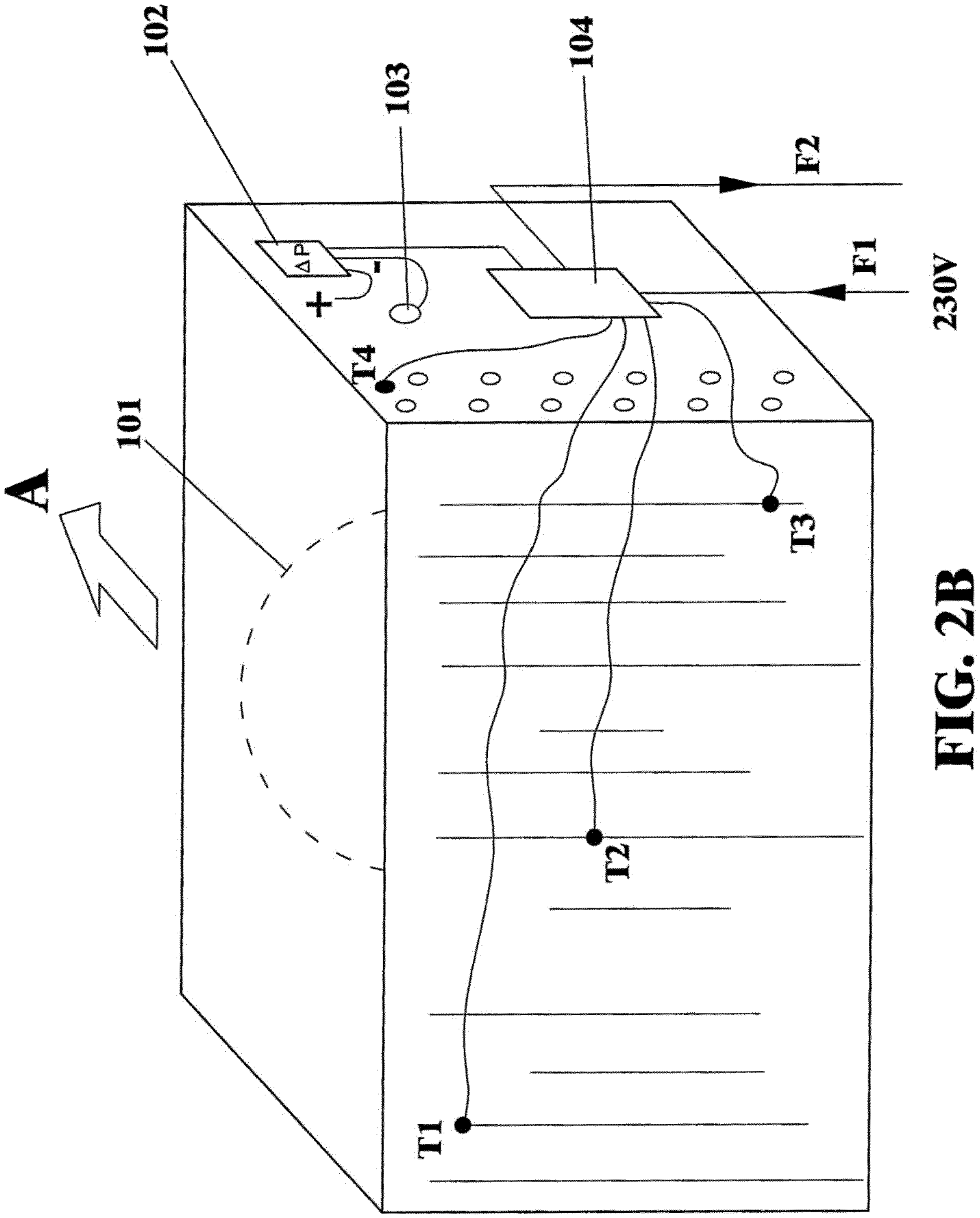


FIG. 2B

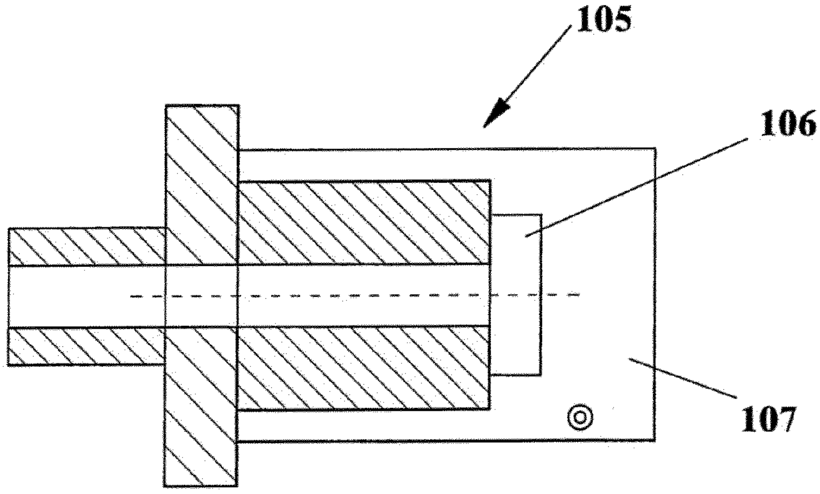


FIG. 3

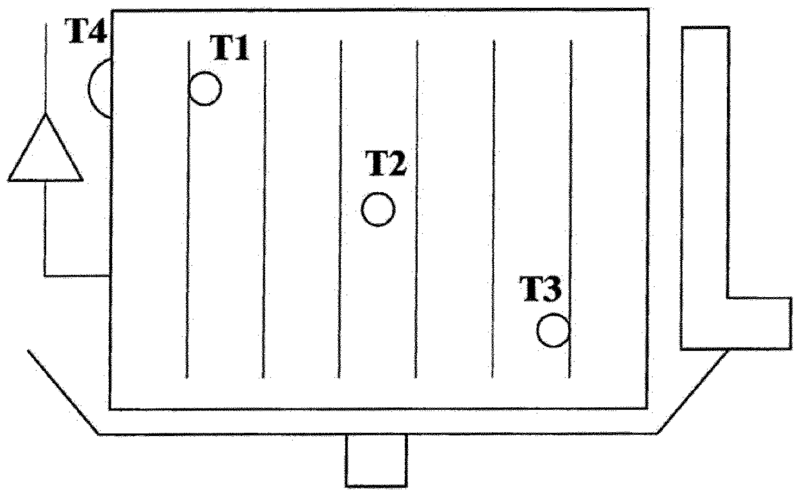


FIG. 3A

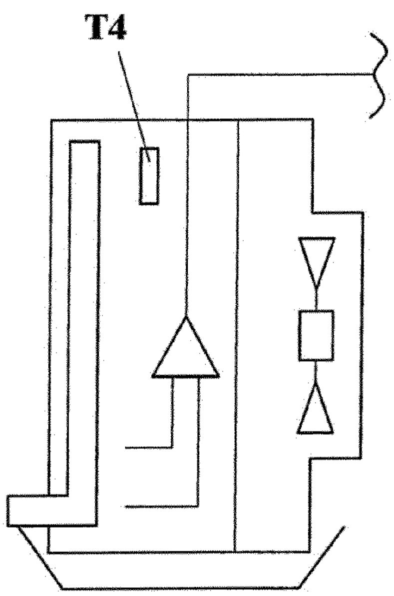


FIG. 3B

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EUROPEAN SEARCH REPORT

Application Number
EP 16 02 0148

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X	JP 2011 247525 A (PANASONIC CORP) 8 December 2011 (2011-12-08) * paragraphs [0025] - [0028]; figures *	1-3,9,10	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	23 August 2016	Vigilante, Marco

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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