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(54) A method of controlling the defrosting cycles in a heat heat-pump system

(57) A method (200) of controlling the defrosting cycles of a battery in a heat-pump system, comprising the steps of detecting (207) a first value indicative of a state parameter relating to a refrigerant fluid used in the system, comparing (239) the first value with a threshold value, and performing (245) a defrosting cycle in dependence on a result of the comparison, includes the steps of determining (221-227) a second value correlated with a maximum value of the first value and modifying (230) the threshold value in dependence on the second value.

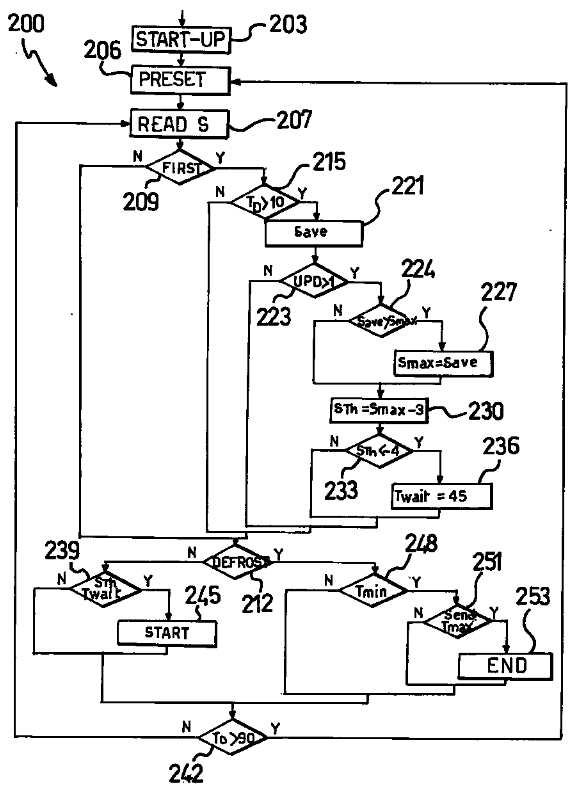

FIG.2

EP 0 893 663 A1

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Description

The present invention relates to a method of controlling the defrosting cycles in a heat-pump system and, in particular, to a method according to the preamble of the first claim.

A heat pump is a thermal machine which, with an expenditure of mechanical work, draws a quantity of heat from an outside environment (a source) and sends all of the thermal energy into an inside environment (a recipient) so as to heat it. Typically, the heat pump can also operate in reverse as a cooler, taking thermal energy from the inside environment (source) so as to cool it.

A problem with heat-pump systems in which an air heat-exchanger (a battery) is used in the outside environment is that, when the temperature of a surface of the battery which is contact with the outside environment falls below 0°C, a layer of frost forms on the battery owing to atmospheric water vapour. This layer of frost obstructs the flow of air through the battery, compromising the exchange of heat.

Known heat-pump systems have a transducer which periodically measures the value of a state parameter (pressure or temperature) of a refrigerant fluid passing through the outside battery, or the temperature of the surface of the battery which is in contact with the outside environment. When this measurement falls below a predetermined threshold value, the heat-pump system performs a defrosting cycle, for example, by reversing the operation of the system. The outside battery is thus heated (taking heat from the inside environment) and melts the frost formed thereon.

A disadvantage of known heat-pump systems is that, particularly when the outside temperature and the relative humidity value are low, the defrosting cycle is triggered even when the outside battery is not frosty; unnecessary defrosting cycles are therefore performed, consequently reducing the output of the system as a whole.

The object of the present invention is to prevent the aforementioned drawbacks. To achieve this object, a method as described in the first claim is proposed.

The method of the present invention triggers the defrosting cycle in dependence on the actual conditions of the outside battery. The frequency of the defrosting cycles can thus be reduced considerably. This achieves a greater output and improved performance of the heat-pump system with a consequent considerable energy saving.

Further characteristics and advantages of the method according to the present invention will become clear from the following description of a preferred embodiment thereof, given by way of non-limiting example, with reference to the appended drawings, in which:

Figure 1 is a basic block diagram of a heat-pump system in which the method according to the invention can be used,

Figure 2 is a flow chart of an embodiment of the method according to the present invention.

With reference, in particular, to Figure 1, a heat-pump system, indicated 100, is constituted, in particular, by an air-conditioner for winter heating and for summer cooling; the method of the present invention may, however, also be used in different applications, for example, in a central heating plant, in a distillation device, etc. The heat-pump system 100 uses a refrigerant fluid (for example, Freon) which is subjected to a thermodynamic cycle (as described in detail below) and which flows through a circuit 103 formed by suitable pipes.

The heat-pump system 100 includes a heat exchanger 130 which is in contact with an outside environment and which operates as a heat source or as a heat recipient during winter and summer, respectively. The exchange of heat takes place in air; in particular, the heat exchanger 130 (the battery) is constituted by pipes, generally having fins, the refrigerant fluid flowing through the pipes and the air passing over them externally. Typically, the air circulation is forced by means of a fan 135 or takes place by natural convection.

A similar battery 140 in contact with an inside environment operates as a heat recipient or a heat source in winter and in summer, respectively; a fan 145 forces, for example, the air circulation in the inside environment from an intake duct 150 to an outlet duct 153. The present invention may, however, also be used with internal heat exchangers of different types, for example, with an exchange of heat in water, in the floor, etc.

In the embodiment in question, the heat-pump system 100 is constituted by a single body; alternatively, two separate units are provided in the outside environment and in the inside environment, respectively.

Between the outside battery 130 and the inside battery 140 there is a compressor unit 150 connected by means of a three-way valve (not shown in the drawing) for the winter-summer reversal of the circuit 103, and two expansion valves 155, 156 (or, alternatively, small calibrated holes or sections of capillary tube) for the winter and summer refrigerant-fluid circuits, respectively.

A transducer 160 periodically measures a state parameter relating to the refrigerant fluid and supplies a value S indicative of this measurement to an electronic microprocessor board 165 (or other equivalent logic means). In a particularly inexpensive embodiment, a temperature transducer with a defrosting probe disposed inside the battery 130 is used; alternatively, the temperature transducer is disposed in the inside battery 140, or a pressure transducer is used. The microprocessor 165 is connected to the compressor 150 in order to control the operation of the heat-pump system 100 by means of suitable control signals and to perform a cycle for defrosting the outside battery 130.

In winter when the system 100 is operating as a heat pump, the refrigerant fluid in the vapour state at the output of the outside battery 130 is compressed in the unit 150. In this condition, the battery 140 operates as a condenser in which the refrigerant fluid cools until it condenses to the liquid state, supplying heat to the inside environment 120. The refrigerant fluid then expands with partial vaporization in the valve 155 so as to regulate the flow-rate of the refrigerant fluid so that it is completely vaporized in the battery 130 (which acts as an evaporator) owing to the heat taken from the outside environment. In summer, on the other hand, when it is operating as a cooler, the outside battery 130 acts as a condenser; the refrigerant fluid expands partially in the valve 156 and the inside battery 140 acts as an evaporator so as to take heat from the inside environment. As an alternative to the above-described vapour compression system, however, the present invention may also be used in a water-vapour, air, or absorption system etc.

In winter, when the system 100 is operating as a heat pump, a defrosting cycle is performed periodically (as described in detail below) in order to melt a layer of frost deposited on an outside surface of the battery 130. In particular, the operation of the system 100 is reversed, so that the outside battery 130 (acting as a condenser) is heated, melting the frost. Alternatively, the operation of the heat-pump system 100 is interrupted and the frost is melted by electrical heating, by a flow of air or of water at a suitable temperature, or by the injection of hot gas coming from inside the outside battery.

With reference now to Figure 2, a method 200 of controlling the defrosting cycles in the heat-pump system described above, starts in box 203, in which the system is activated, for example, when it is switched on, when it leaves a stand-by state, or when it starts up again after a thermostatic intervention to regulate the temperature of the inside environment. Going on to box 206, a parameter S_{Th} which represents a threshold temperature for the implementation of the defrosting cycle is set at a predetermined initial (default) value, for example, equal to a few degrees centigrade below zero, such as -2°C. A parameter T_{Wait}, which represents a minimum waiting time between two consecutive defrosting cycles or between the activation of the system and a first defrosting cycle (used for limiting the repetition of the defrosting cycles with regard to time) is preferably set at a further predetermined initial value, for example, of a few minutes, such as 15 minutes. It should be noted that, in general, the time is measured in relation to the operation of the heat-pump system, for example, as the period of operation of the compressor.

Going on to box 207, the value S of the temperature measured by the defrosting probe is then acquired. In box 209, the method checks whether a first defrosting cycle has been carried out since the heat-pump system was activated; this preferably enables the parameters (S_{Th} and T_{Wait}) of the system to be modified only after this first defrosting cycle. If the answer is negative, the method goes on to box 212 (described below). If the answer is affirmative, the method checks, in box 215, whether the operating time T_D which has elapsed since the last defrosting cycle exceeds a predetermined minimum value, for example, of a few minutes, such as 10 minutes; the system parameters are preferably modified only after this operating period, so as to allow the system to reach a steady state. If the answer is negative, the method goes directly to box 212. If the operating time T_D since the last defrosting cycle is greater than 10 minutes, the method according to the present invention calculates a value correlated with a maximum value of the measured temperature S. In a preferred embodiment, an average value of the measured temperatures S is calculated periodically for this purpose. For example, in the box 221, an average value S_{Ave} of the temperatures S measured since a last modification cycle is updated. The method then goes on to box 223 in which it is checked whether a predetermined period of time, for example of 1 minute, has elapsed since a last modification cycle. If the answer is negative, the method goes directly to box 212. If 1 minute has elapsed since the last modification cycle, the method then goes on to box 224 in which it is checked whether the average value S_{Ave} is greater than a maximum temperature value S_{Max} (set initially at an invalid value). If the answer is affirmative, in box 227 the value S_{Max} is set at the average value S_{Ave} and the method then goes on to box 230. If the average value S_{Ave} is not greater than the maximum value S_{Max}, the method goes directly to box 230. With reference now to box 230, the method according to the present invention modifies the parameter S_{Th} which is representative of the threshold temperature for performing the defrosting cycle in dependence on the maximum value S_{Max}; the parameter S_{Th} is preferably set at the maximum value S_{Max} minus a predetermined value, for example, of a few degrees centigrade, such as 3°C.

The parameter T_{Wait} which is representative of the minimum waiting time between two consecutive defrosting cycles is advantageously modified in dependence on the value of the parameter S_{Th}. For example, in box 233, the method checks whether the parameter S_{Th} is below a predetermined minimum value, for example, of a few degrees centigrade below zero, such as -4°C. If the answer is negative, the method goes directly to box 212. If the parameter S_{Th} is below the minimum value, the parameter T_{Wait} is set at a higher predetermined value, for example, 45 minutes, in box 236. The method then goes on to box 212.

With reference now to box 212, the method checks whether a defrosting cycle is in operation. If not, the method goes to box 239 in which it is checked whether the measured temperature S is below the parameter S_{Th} and whether the time T_D since the last defrosting cycle (or since the activation of the system) is greater than the parameter T_{Wait}. If at least one of these conditions is not satisfied, the method goes to box 242 (described below). If, on the other hand, both of the conditions are satisfied, the method goes to box 245 in which a defrosting cycle is started, for example, by the reversal of the operation of the heat-pump system; if this is the first defrosting cycle, the parameter T_{Wait} is also modified, preferably to a predetermined value, for example, of 30 minutes, between the initial value (15 minutes) and the value set in box 236 (45 minutes). The method then goes to box 242.

Returning to box 212, if a defrosting cycle is in progress, the method preferably controls the duration of this operation. For example, in box 248 it is checked whether a predetermined minimum time T_{Min}, for example, of 2.5 minutes, has elapsed since the start of the defrosting cycle. In general, it is in fact preferable for the defrosting cycle to have a minimum duration since excessively frequent reversals of the operation of the heat-pump system may cause excessive leakage of oil in the compressor with consequent damage to the system. If the minimum defrosting time T_{Min} has not elapsed, the method goes directly to box 242. Otherwise, the method goes to box 251 in which it is checked whether the measured temperature S is greater than a predetermined maximum end of defrosting temperature S_{End}, for example, of a few tens of degrees centigrade, such as 20°C, or whether a predetermined maximum time T_{Max}, for example, of 6 minutes, has elapsed since the start of the defrosting cycle. If at least one of these conditions is satisfied, the defrosting cycle is terminated in box 253 and the method then goes to box 242. If neither of the conditions is satisfied, however, the method goes directly to box 242.

With reference now to box 242, the method preferably checks whether the time T_D which has elapsed since the last defrosting cycle is greater than a predetermined maximum value, for example of a few tens of minutes, such as 90 minutes. If not, the method returns to box 207 in order to repeat the steps described above. If a longer time has elapsed, however, the method goes back to box 206 so as to reset the initial values of the parameters of the system.

Naturally, in order to satisfy contingent and specific requirements, an expert in the art may apply to the above-described method of controlling the defrosting cycles in a heat-pump system many modifications and variations, all of which, however, are included within the scope of protection of the invention as defined by the following claims.

Claims

1. A method (200) of controlling the defrosting cycles of a battery (130) in a heat-pump system (100), comprising the steps of:

detecting (207) a first value (S) indicative of a state parameter relating to a refrigerant fluid used in the system (100),
comparing (239) the first value (S) with a threshold value (S_{Th}),
performing (245) a defrosting cycle in dependence on a result of the comparison,
characterized by the steps of:
determining (221-227) a second value (S_{Max}) correlated with a maximum value of the first value (S),
modifying (230) the threshold value (S_{Th}) in dependence on the second value (S_{Max}).

2. A method (200) according to Claim 1, in which the step of determining (221-227) the second value (S_{Max}) includes the steps of:

periodically calculating (221, 223) an average value (S_{Ave}) of the first value (S),
setting (224, 227) the second value (S_{Max}) at a maximum of the average values (S_{Ave}).

3. A method (200) according to Claim 2 or Claim 3, in which the step of modifying (230) the threshold value (S_{Th}) consists in setting the threshold value (S_{Th}) at the second value (S_{Max}) minus a first predetermined value.

4. A method according to any one of Claims 1 to 3, further comprising the step of setting (206) the threshold value (S_{Th}) at an predetermined initial value upon each activation of the system (100).

5. A method according to Claim 4, further comprising the step of setting (242, 206) the threshold value (S_{Th}) at the predetermined initial value when a period of operation (T_D) since a last defrosting cycle is greater than a first predetermined maximum value.

6. A method (200) according to any one of Claims 1 to 5, in which the step of modifying (230) the threshold value (S_{Th}) is carried out only (209) after a first defrosting cycle after the activation of the system (100).

7. A method (200) according to any one of Claims 1 to 6, in which the step of modifying (230) the threshold value (S_{Th}) is carried out only (215) when the period of operation (T_D) since the last defrosting cycle is greater than a first predetermined minimum value.

8. A method according to any one of Claims 1 to 7, in which the defrosting cycle (239, 245) is carried only if, at the same time, the period of operation (T_D) since the last defrosting cycle or since the activation of the system (100) is greater than a further threshold value (T_{Wait}), the method (200) further comprising the steps of setting (206) the further threshold value (T_{Wait}) at a further predetermined initial value each time the system (100) is activated, modifying (245) the further threshold value (T_{Wait}) to a second predetermined value greater than the further predetermined initial value after the execution of the first defrosting cycle, and modifying (233, 236) the further threshold value (T_{Wait}) to a third predetermined value greater than the second predetermined value when the threshold value (S_{Th}) is below a second predetermined minimum value.

9. A method according to Claim 8, further comprising the step of setting (242, 206) the further threshold value (T_{Wait}) at the further predetermined initial value when the period of operation (T_D) since the last defrosting cycle is greater than the first predetermined maximum value.

10. A method (200) according to any one of Claims 1 to 9, in which a duration of each defrosting cycle is greater than a third predetermined minimum value (248) and the defrosting cycle is terminated (253) when the first value (S) exceeds a second predetermined maximum value or the duration exceeds a third predetermined maximum value (251).

11. A method (200) according to any one of Claims 1 to 10, in which the step of performing (245) the defrosting cycle consists of the reversal of the operation of the heat-pump system (100) in order to heat the battery (130).

12. A method (200) according to any one of Claims 1 to 11 in which the state parameter is a temperature.

13. A heat-pump system (100) comprising a battery (130), means (160) for detecting a first value (S) indicative of a state parameter relating to a refrigerant fluid used in the system (100), and logic means (165) for comparing the first value (S) with a threshold value (S_{Th}) and performing a cycle for defrosting the battery (130) in dependence on a result of the comparison,

characterized in that it includes:

logic means (165) for determining a second value (S_{Max}) correlated with a maximum value of the first value (S) and modifying (230) the threshold value (S_{Th}) in dependence on the second value (S_{Max}).

14. A heat-pump system (100) according to Claim 13, in which the detection means (160) include a temperature transducer disposed in the battery (130).

15. A heat-pump system (100) according to Claim 13 or Claim 14, in which the system (100) is an air-conditioner.

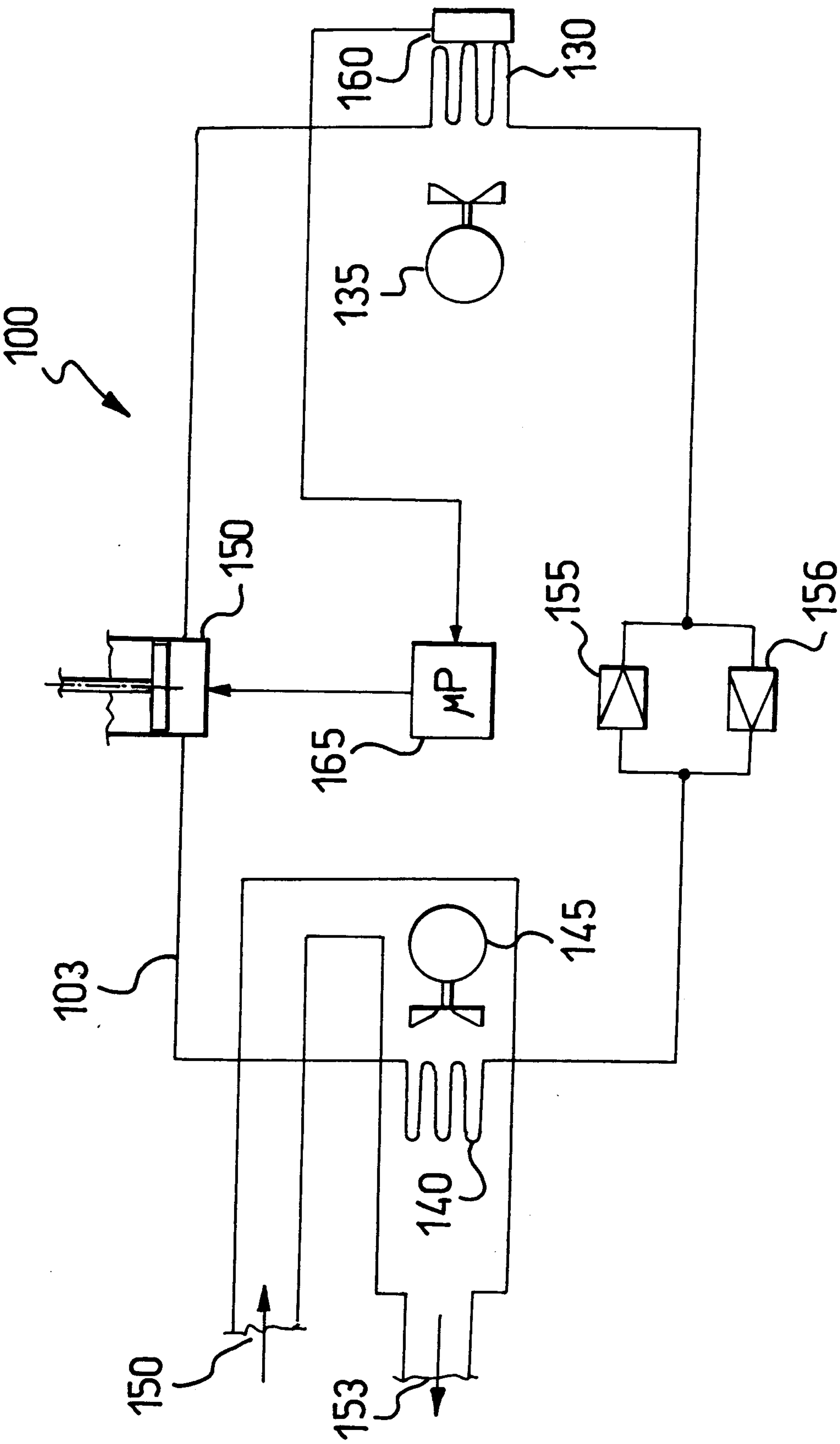
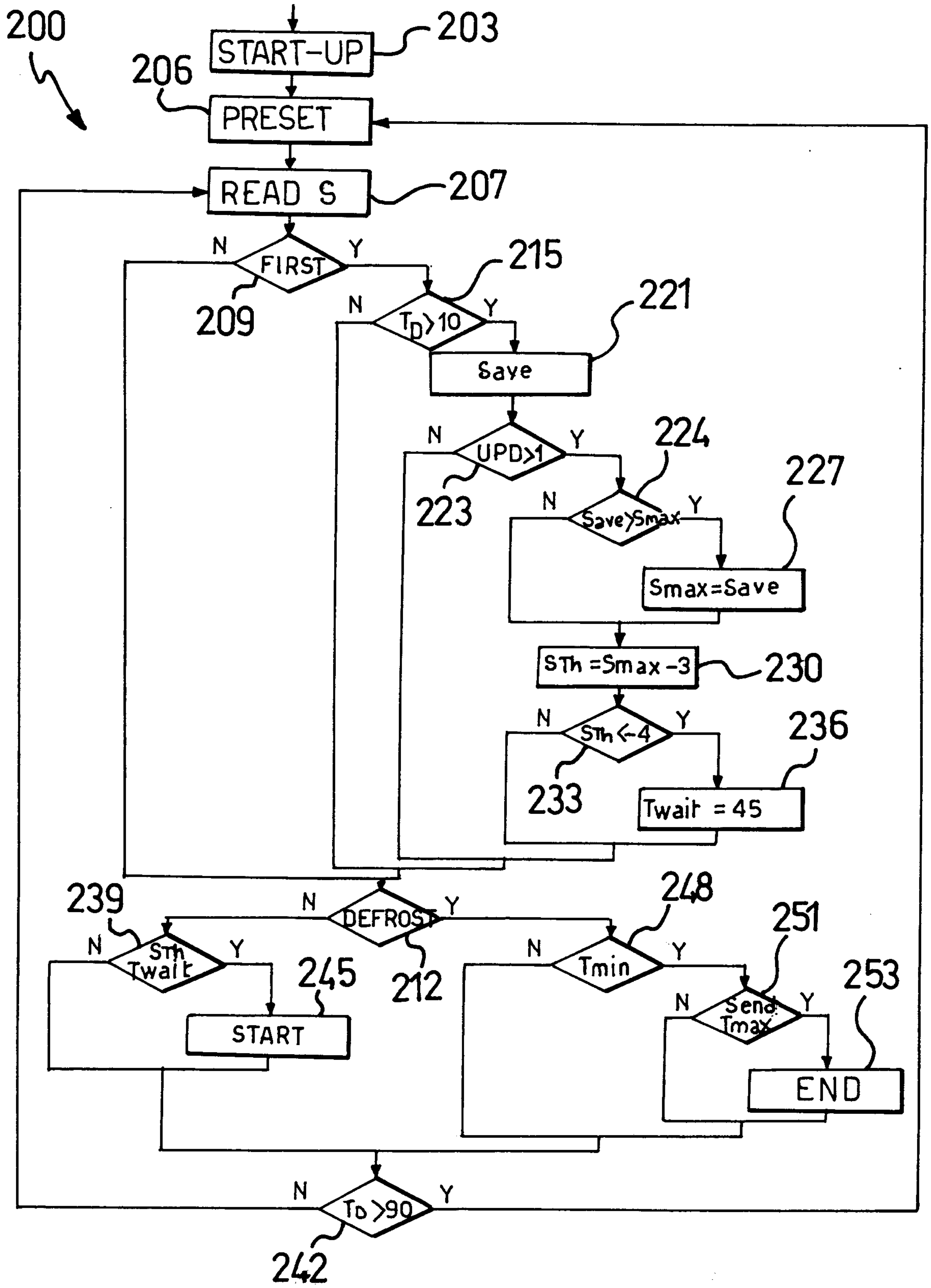


FIG.1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Y
224
223
N
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Y
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STh =Smax -3
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N
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Y
236
233
Twait = 45
239
N
DEFROST
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STh Twait
Y
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Tmin
Y
251
START
N
Send Tmax
Y
253
END
N
TD>90
Y
242

FIG.2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 83 0379

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 4 373 349 A (MUELLER DALE A) * column 2, line 16 - column 6, line 56; figures 1-3 *	1,3,6-8, 10-15	F25D21/06
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 222 (M-504), 2 August 1986 & JP 61 059137 A (SANYO ELECTRIC CO LTD;OTHERS: 01), 26 March 1986, * abstract *	1,11-15	
A	US 4 302 947 A (MUELLER DALE A ET AL) * column 2, line 12 - column 6, line 18; figures 1-4 *	1,11-15	
A	US 4 790 144 A (YOKOUCHI AKIRA ET AL) * column 3, line 35 - column 10, line 31; figures 1-8 *	1,11-15	
A	FR 2 486 217 A (ANECTRON) * page 2, line 6 - page 5, line 23; figures 1-3 *	1,11-15	
A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 055 (M-362), 9 March 1985 & JP 59 189243 A (MATSUSHITA DENKI SANGYO KK), 26 October 1984, * abstract *		
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A	US 4 882 908 A (WHITE LEE A)		
A	US 4 887 436 A (ENOMOTO TOSHIHIKO ET AL)		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
F25D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 December 1997	Boets, A

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