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(54) **A METHOD FOR OPERATING A LAUNDRY DRYING MACHINE EQUIPPED WITH A HEAT PUMP SYSTEM AND A LAUNDRY DRYING MACHINE IMPLEMENTING SAID METHOD**

(57) The invention relates a method for controlling a laundry drying machine (1; 201) equipped with a heat pump system (50) during a drying cycle. The laundry drying machine (1; 201) comprises: a control unit (UC1); a rotatable treating chamber (9) where laundry can be introduced to be dried with a drying air stream; a heat pump system (50) including a compressor (52); a passive switching device (70), not controllable by the control unit (UC1), adapted to cut the power supplied to the compressor (52); an active switching device (72), controllable by the control unit (UC1), for selectively switching on and off the compressor (52).

The method comprises the steps of: starting a drying cycle; activating the heat pump system (50) by switching on the compressor (52); rotating the treating chamber (9); evaluating if an inversion of direction of rotation of the treating chamber (9) has to be performed and, if an inversion of direction of rotation has to be performed, evaluating if an operating condition of the compressor (52) which can cause the activation of the passive switching device (70) exists; if the operating condition does not exist, then performing the inversion of direction of rotation of the treating chamber (9), otherwise if the operating condition exists then performing the following steps: switching off the compressor (52); performing the inversion of direction of rotation of the treating chamber (9); switching on the compressor (52).

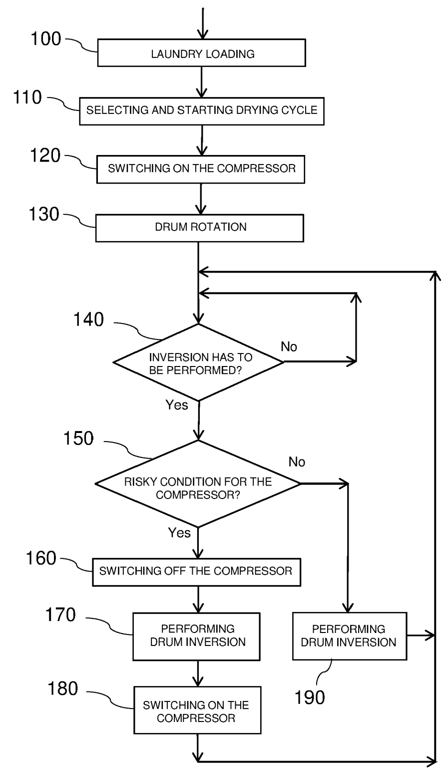

FIG. 3

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to the field of laundry drying machines equipped with a heat pump system, more particularly to a method for operating such machines during a drying cycle.

BACKGROUND ART

[0002] Laundry drying machines capable of carrying out a drying process on laundry, hereinafter simply indicated as laundry dryers, generally comprise a casing that houses a treating chamber, preferably a rotating drum, where laundry to be treated is received. A closed air stream circuit carries out drying operation by circulating hot air through the treating chamber containing the wet laundry.

[0003] The present invention can be usefully applied to all the machines performing a drying process on laundry, or wet clothes, such as a combined laundry washing-drying machine. In the present description, therefore, the term "laundry drying machine" will refer either to a simple laundry drying machine or a laundry washing-drying machine.

[0004] In laundry dryers, the heat pump technology is the most efficient way to save energy during the drying process/cycle. In conventional heat pump laundry dryers a drying air stream flows in a close loop. The drying air stream is moved by a fan, passes the rotating drum and removes water from wet clothes. Then the drying air stream is cooled down and dehumidified and then heated up in a heat pump system and finally reinserted again into the laundry drum.

[0005] The heat pump system comprises a refrigerant flowing in a closed-loop refrigerant circuit realized with pipes and comprising a compressor, a condenser, an expansion device and an evaporator. The condenser heats up the drying air while the evaporator cools and dehumidifies the drying air leaving the drum. The refrigerant flows in the refrigerant circuit where it is compressed by the compressor, condensed in the condenser, expanded in the expansion device and then vaporized in the evaporator.

[0006] Laundry dryers of the known type are typically equipped with overload protection devices to prevent the compressor from being damaged. An overload protection device typically used in laundry dryers preferably comprises a passive switch which interrupts the power supplied to the heat pump compressor from the mains when predetermined compressor temperature thresholds of heat or voltage load or absorbed current thresholds are exceeded.

[0007] The passive switch opens when a threshold temperature of the heat pump compressor is reached and/or when the current flowing through the passive switch is reached.

[0008] When normal functioning conditions are re-established the passive switch (e.g. a thermo protector device) is adapted to go back to the operative status closing the circuit for supplying again electrical power to the compressor.

[0009] However, there is a considerable delay before the overload protection device goes back to the operative status, due to the big inertia of the device for turning back to the closed position, typically about 40 minutes.

[0010] Therefore, a drawback of this known technique derives from the fact that intervention of the overload protection device causes increasing of the drying cycle duration and hence customer dissatisfaction.

[0011] It is an object of the present disclosure to overcome at least some of the problems associated with the prior art.

[0012] It is an object of the invention to implement a system for laundry drying machines equipped with a heat pump system apt to prevent the activation of the overload protection device.

[0013] It is another object of the invention to implement a system for laundry drying machines equipped with a heat pump system apt to prevent unwanted extension of the drying cycle duration.

DISCLOSURE OF INVENTION

[0014] The applicant has found that by providing a laundry treating machine having a rotating treating chamber, a heat pump system including a compressor, at least a passive switching device not controllable by control unit adapted to cut the power supplied to the compressor and by providing a method wherein the compressor is opportunely temporarily deactivated when the inversion of rotation of the treating chamber has to be performed, it is possible to solve the drawbacks of the known systems.

[0015] According to one aspect of the present disclosure there is provided a method for controlling a laundry drying machine equipped with a heat pump system during a drying cycle, as defined in claim 1.

[0016] Further characteristics of the method according to the invention may be found in dependent claims.

[0017] In a further aspect the present invention relates to a laundry drying machine implementing the method according to the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Further characteristics and advantages of the present invention will be highlighted in greater detail in the following detailed description of preferred embodiments of the invention, provided with reference to the enclosed drawings. In said drawings:

- Figure 1 shows an isometric view of a laundry drying machine which can implement the method of the present invention;
- Figure 2 is a schematic representation of the main

components of the machine of figure 1 implementing the method of the present invention;

- Figure 3 is a simplified flow chart of the basic operations of a method for operating a laundry drying machine according to a preferred embodiment of the invention;
- Figure 4 is a simplified flow chart of the basic operations of a method for operating a laundry drying machine according to another preferred embodiment of the invention;
- Figure 5 is a simplified flow chart of the basic operations of a method for operating a laundry drying machine according to a further preferred embodiment of the invention;
- Figure 6 is a schematic representation of the main components of a further preferred embodiment of the machine implementing the method of the present invention;
- Figure 7 illustrates a refrigerant temperature in the heat pump system of the machine of figure 6 as a function of the time.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0019] The present invention has proved to be particularly successful when applied to a front-loading drying machine with a rotatable laundry container/drum; however it is clear that the present invention can be applied as well to a top-loading drying machine and, generally to laundry drying machines where the laundry container may rotate in a first direction of rotation and in a second direction of rotation opposite to the first direction of rotation.

[0020] Furthermore, the present invention can be usefully applied to all the machines performing the drying process on laundry, or wet clothes, such as a combined laundry washing-drying machine.

[0021] The term "laundry drying machine" refers, therefore, either to a simple laundry drying machine or a laundry washing-drying machine.

[0022] Generally, a laundry drying machine, o laundry dryer, according to the present invention includes a rotating treating chamber where the laundry items can be introduced to be treated with a drying air stream; a circuit where the drying air stream circulates; a heat pump system including a first heat exchanger for cooling a refrigerant and heating the air stream, expansion means and a second heat exchanger for heating the refrigerant; at least an active switching device for selectively activating/deactivating the compressor; at least a passive switching device adapted to cut the power supplied to the compressor when predetermined operative parameters thresholds are exceeded.

[0023] Figures 1 and 2 illustrate a laundry dryer 1 with a heat pump system 50 where the method of the invention may be implemented according to a preferred embodiment of the present invention.

[0024] The laundry dryer 1 preferably comprises, though not necessarily, a substantially parallelepiped-shaped outer boxlike casing 2 which is preferably structured for resting on the floor. A treating chamber 9 preferably consisting of a rotatably drum 9 is provided within the casing 2. A front door 8, pivotally coupled to the front upright side wall 2a, is provided for allowing access to the drum interior region to place laundry to be dried therein.

[0025] The drum 9 is advantageously rotated by a drum motor 10, preferably an electric motor, which preferably transmits the rotating motion to the shaft of the drum 9, advantageously by means of a belt/pulley system (not shown). In a different embodiment of the invention, the drum motor can be directly associated with the shaft of the drum 9.

[0026] More preferably, the drum motor 10 allows the rotation of the drum 9 in a first direction of rotation and in a second direction of rotation opposite to the first direction of rotation.

[0027] A user control interface 15 is preferably arranged on the top of the casing 2. The user control interface 15 is preferably accessible to the user for the selection of the drying cycle and insertion of other parameters, for example the type of fabric of the load, the degree of dryness, etc. The user control interface 15 preferably displays machine working conditions, such as the remaining cycle time, alarm signals, etc. For this purpose, the user control interface 15 preferably comprises a display 13.

[0028] In different embodiments, for example in a combined laundry washing and drying machine, the user may select and insert other types of parameters, for example the washing temperature, the washing spinning speed, etc.

[0029] In further embodiments, the user control interface may be differently realized, for example remotely arranged in case of a remote-control system.

[0030] An air inlet path 20 is preferably connected to a side of the drum 9 and an air outlet path 22 is preferably connected to the other side of the drum 9. The air inlet path 20, the air outlet path 22 and the drum 9 define a drying air circuit 26 for the drying air stream. A circulating fan 28 is normally provided for moving drying air along the circuit 26. A dedicated motor 30 preferably operates the circulating fan 28, but in a possible simpler implementation the same motor can operate the circulating fan 28 and the drum 9 (in other words only one of the two motors 10 and 30 can be present).

[0031] The laundry dryer 1, as said above, then comprises a heat pump system 50 comprising a compressor 52, a first heat exchanger 54 (also called condenser), acting as a hot sink (i.e. condenser or gas cooler in case the refrigerant operates at least at critical pressure), a second heat exchanger 56 (also called evaporator), acting as a cold sink (i.e. evaporator or gas heater in case refrigerant operates at least at critical pressure). A throttle 58 is normally provided between the first heat exchanger 54 and the second heat exchanger 56.

[0032] Alternative solutions to the throttle include expansion means, capillary tube or controlled expansion valve.

[0033] In the embodiment shown in figure 2 the drying air circuit 26 forms a substantially closed loop and the air stream from the drum 9 passes through the second heat exchanger 56 (evaporator) and then through the first heat exchanger 54 (condenser).

[0034] A control unit UC1 is connected to the various parts of the laundry dryer 1 in order to ensure its operation. The user control interface 15 preferably communicates with the control unit UC1.

[0035] Electrical power is supplied to the laundry dryer 1 from a power main PM, preferably through wire connections L, N, e.g. line wire L and neutral wire N connected to the power main PM.

[0036] Electrical power is supplied to various parts of the laundry dryer 1. In figure 2, only some parts of the laundry dryer 1 are explicitly shown as supplied by the electrical power, namely the control unit UC1 and the compressor 52.

[0037] The compressor 52 is preferably connected in series with a passive switching device 70, and the assembly formed by the compressor 52 and the passive switching device 70 is connected to the line wire L and to the neutral wire N of the power main PM.

[0038] The passive switching device 70 is not controllable by control unit UC1 and is preferably adapted to cut the power supplied from the main power PM when predetermined operative parameters thresholds are exceeded. In a preferred embodiment of the invention, the passive switching device 70 comprises a thermo protector device adapted to cut the power supplied to the compressor 52 from the power main PM when predetermined temperature or absorbed current thresholds are exceeded.

[0039] An active switching device 72, typically a relay or a solid state device, such as a triac, etc., is placed along the neutral wire N and controllable by the control unit UC1 to activate/deactivate the compressor 52. The active switching device 72 will be also referred to as "relay" in the following, but it is understood that it could be a different switching device.

[0040] The laundry dryer 1 is also preferably provided with a first temperature detecting device 80, or temperature sensor, for monitoring an operative temperature of the laundry dryer and/or of the heat pump. Preferably, the first temperature sensor 80 monitors the operative temperature at the heat pump system 50. More preferably, the first temperature sensor 80 is placed at a predetermined position along the pump system 50 to measure the refrigerant temperature To. The first temperature sensor 80 conveys the information to the control unit UC1. In particular, the first temperature sensor 80 is an NTC thermistor placed in such a way to measure the refrigerant temperature To at the outlet of the condenser 54 (or at the inlet of the throttle 58). Additionally, or alternatively, one or more than one temperature sensor can be arranged at different locations of the heat pump system 50, for example at the outlet of compressor 52 or more preferably directly on the compressor 52.

[0041] In further preferred embodiments of the invention, the operative temperature of the heat pump system 50 may correspond to any temperature or a combination of temperatures detected by any temperature sensor placed at different location of the heat pump system, for example at the outlet of compressor or directly on the compressor.

[0042] More generally, the laundry dryer 1 may be preferably provided with a temperature detecting device, or temperature sensor, to detect an operative temperature other than the operative temperature of the heat pump system 50

[0043] Preferably, the laundry dryer 1 may be provided with a temperature sensor placed inside the casing of the machine to detect an operative temperature of the machine, for example a temperature sensor mounted on an electronic board. Additionally, or alternatively, the laundry dryer 1 may be provided with a temperature sensor to detect the ambient temperature and/or a drying air stream temperature sensor. The laundry dryer 1 implementing the method according to a preferred embodiment of the present disclosure is preferably controlled by the control unit UC1 which receives information and output control signals to components of the laundry dryer 1.

[0044] As mentioned above, thermo protector device opening, or cut-off event, is an event that should be avoided during functioning of the laundry dryer 1 in normal conditions.

[0045] Applicant has recognized that opening of the thermo protector device 70 may be affected by high peaks of the electrical current absorbed by the compressor 52. In particular, applicant has recognized that peaks of the electrical current absorbed by the compressor 52 which may cause opening of the thermo protector device 70 occurs when an inversion of rotation of the drum 9 is performed.

[0046] As known, a drying cycle preferably comprises successive phases where the drum 9 is alternatively rotated in a first direction of rotation R1 (e.g. clockwise direction) and in a second direction of rotation R2 (e.g. counterclockwise direction).

[0047] In a preferred embodiment, the drum 9 is alternatively rotated in the first and second directions of rotation R1, R2 to prevent laundry from getting wrinkled. More preferably, the drum 9 is rotated mainly in the first direction of rotation R1 during the drying cycle, while is periodically rotated in the second direction of rotation R2 for short periods of time. For example, the drum 9 may be rotated in the first direction of rotation R1 for predetermined main regular intervals which may last 4 to 5 minutes and periodically rotated in the second direction of rotation R2, or inverted direction of rotation, for 20-30 seconds.

[0048] During an inversion of rotation direction of the drum 9, the air mass flow rate of the drying air generated by the circulating fan 28 along the circuit 26 rapidly decreases. This causes a decreasing of the thermal exchange between the evaporator 56 and the condenser 54 and, in turn, it causes a decreasing of the refrigerant pressure at the evaporator outlet. In order to re-establish the correct refrigerant pressure in the heat pump system, the compressor 52 rapidly increases its action and consequently absorbs a high current (a peak of current).

[0049] Therefore, according to an aspect of the present invention, a proper action is taken when it is determined that an inversion of rotation of the drum 9 has to be performed. Preferably, as better described below, said action consists of switching off the compressor 52. More preferably, the action of switching off the compressor 52 is performed before, or concurrently, the inversion of direction of rotation. Figure 3 illustrates a schematic flow chart diagram of a method for operating the laundry dryer 1 according to a first preferred embodiment of the present invention. The laundry to be dried is first placed inside the drum 9 (step 100).

[0050] By operating on the interface unit 15 the user selects and starts the desired type of drying cycle/program (step 110), preferably according to the type of fabric of clothes to be dried.

[0051] It is clear that the user may select the desired drying cycle before the laundry is placed inside the drum 9.

[0052] In a next step (step 120) the heat pump system 50 is activated by switching on the compressor 52. At the same time the circulating fan 28 is preferably switched on. A drying air stream is therefore generated and circulated through the drying air circuit 26 and the laundry starts to be dried inside the drum 9.

[0053] As a next step (step 130) the method provides for rotating the drum 9 in a first direction of rotation R1 (e.g. clockwise direction).

[0054] In a next step (step 140) it is evaluated if an inversion of rotation of the drum 9 has to be performed, i.e. the drum 9 has to be rotated in a second direction of rotation R2 (e.g. counterclockwise or inverted direction of rotation) opposite to the first the direction of rotation R1.

[0055] In a preferred embodiment of the invention, the evaluation of an inversion of rotation is intrinsically performed by the control unit UC1 since the exact time of the inversion is scheduled according to the type of drying cycle previously selected by the user. The exact time of the inversions are preferably stored in the control unit UC1.

[0056] In further preferred embodiments, the step of evaluating if the inversion has to be performed (step 140) may be carried out differently.

[0057] In further preferred embodiments, in fact, the exact time of the inversion is not predetermined but rather is determined in real time during the drying cycle on the base of particular events affecting the operating conditions of the laundry drying machine and/or of the heat pump system, which require an inversion of direction of rotation of the treating chamber.

[0058] For example, the inversion of rotation of the drum 9 may be required when the load is unbalanced. Preferably, unbalancing may be detected through a dedicated sensor or by analysing the current absorbed by the drum motor 10.

[0059] In a further embodiment, the inversion of rotation may be determined in real time according to the degree of humidity of the laundry and/or of the inside of the drum 9, preferably detected through a humidity sensor arranged inside the drum 9 or along the drying air circuit 26. For example, the inversion of rotation may be performed when the degree of humidity of the laundry and/or of the inside the drum 9 reaches pre-fixed values.

[0060] In another preferred embodiment, the time of the inversion of the drum 9 may be determined by other particular event, or events. For example, an inversion of rotation of the drum 9 may occur as a consequence of a necessity of an inversion of direction of rotation of the circulating fan 28. This situation relates, in particular, to a laundry dryer wherein the circulating fan 28 and the drum 9 are operated by the same common motor.

[0061] In some cases, in fact, it may happen that during the drying cycle the flow of the drying air stream needs to be reversed, for example in case the drying efficiency suddenly decreases. Inversion of the flow is thus obtained through the inversion of rotation of the circulating fan 28. Being the motor of the circulating fan 28 the same of the drum 9, the inversion of rotation of the drum 9 is also performed.

[0062] In a next step of the method (step 150) it is evaluated if there is a risky condition for the compressor 52.

[0063] With the term "risky condition" we will refer hereinafter as an operating condition of the compressor 52 which can cause the activation of the passive switching device 70. In a preferred embodiment of the invention, as better described later, a risky condition means a condition indicating that the drying cycle 1 is at an advanced stage and/or that the heat pump system 50 is reaching a critical working point.

[0064] If no risky condition is evaluated (output "No" of step 150), then the inversion of direction of rotation is performed (step 190).

[0065] Conversely, if a risky condition is evaluated (output "Yes" of step 150), then the method provides for switching off the compressor 52 (step 160), performing the inversion of direction of rotation of the drum 9 (step 170) and switching on the compressor 52 (step 180).

[0066] In a preferred embodiment, the step of switching off the compressor 52 (step 160) is performed before the inversion of direction of rotation (step 170), for example 1 second before.

[0067] In a further preferred embodiment, the step of switching off the compressor 52 (step 160) and the step of inverting the direction of rotation (step 170) are performed at the same time.

[0068] The step of switching on the compressor 52 (step 180) is preferably performed after the inversion of direction of rotation (step 170) has ended. Preferably, the time during which the compressor 52 is deactivated, i.e. the time between the step of switching off the compressor 52 (step 160) and the step of switching on the compressor 52 (step 180), is of some minutes (for example 2-3 minutes).

[0069] In a further preferred embodiment, the step of switching on the compressor 52 (step 180) is preferably performed after the inversion of direction of rotation (step 170) has started but before it ends.

[0070] It is clear, in fact, that the inversion of direction of rotation of the drum 9 requires that the drum 9 is firstly slowed to a halt and then the inversion of direction of rotation is started from zero speed and the drum 9 is accelerated up to the desired rotation speed (end of the inversion of rotation).

[0071] Advantageously, when the inversion of direction of rotation of the drum 9 (step 170) occurs, the compressor 52 is switched off. Therefore, absorption of high current (peak of current) by the compressor 52 during an inversion of direction of rotation is avoided and unwanted thermo protector opening of the passive switching device 70 is also avoided.

[0072] According to the preferred embodiment of the method according to the above description and as illustrated in Figure 3, the step of switching off the compressor 52 (step 160) is performed before, or at the same time of, the inversion of direction of rotation (step 170) and the step of switching on the compressor 52 (step 180) is performed after the inversion of direction of rotation (step 170).

[0073] Figure 4 illustrates a flow chart of a second implementation of the method. In the flow chart, steps corresponding to the steps of the first preferred embodiment as illustrated in Figure 3 are identified by the same numbers.

[0074] This embodiment differs from the embodiment previously described in that the step of switching off the compressor 52 (step 160) is performed after the step of performing the inversion of direction of rotation (step 170) of the treating chamber 9 has started, and the step of switching on the compressor 52 (step 180) is performed after the step of switching off the compressor 52 (step 160).

[0075] In a preferred embodiment, the step of switching off the compressor 52 (step 160) is performed after the inversion of direction of rotation (step 170) has ended.

[0076] Preferably, the step of switching off the compressor 52 (step 160) is performed within a first delay time DT1 after the inversion of direction of rotation (step 170) of the treating chamber 9 has ended. In this case the first delay time DT1 is preferably at most some seconds.

[0077] In a further preferred embodiment, the step of switching off the compressor 52 (step 160) is performed after the inversion of direction of rotation (step 170) has started but before it ends. In this case the first delay time DT1 is preferably at most some seconds, more preferably 3 seconds, which is the time generally needed to perform the inversion of direction of rotation.

[0078] Figure 5 illustrates a flow chart of a third implementation of the method. In the flow chart, steps corresponding to the steps of the first preferred embodiment as illustrated in Figure 3 are identified by the same numbers.

[0079] This embodiment differs from the embodiment previously described with reference to Figure 3 in that the step of performing the inversion of direction of rotation (step 170) of the treating chamber 9 is performed after the step of switching on the compressor 52 (step 180).

[0080] The step of switching off the compressor 52 (step 160) is obviously still performed before the step of switching on the compressor 52 (step 180).

[0081] Preferably, the step of performing the inversion of direction of rotation (step 170) of the treating chamber 9 is performed within a second delay time DT2 after the step of switching on the compressor 52 (step 180). More preferably, the second delay time DT2 is at most some seconds.

[0082] In a further preferred embodiment, the second delay time DT2 is set as to be at most 10% of the time during which the treating chamber 9 rotates in the inverted direction of rotation R2. For example, the second delay time DT2 may last 2,5 seconds when the time during which the treating chamber 9 rotates in the inverted direction of rotation R2 is 25 seconds.

[0083] Irrespective of the embodiment considered and described, a first risky condition according to the invention is preferably a condition wherein an operative temperature To of the laundry dryer 1 is higher than a first threshold operative temperature T1. The operative temperature To is preferably an operative temperature related to the heat pump system 50. In such a case, a high value of the operative temperature To is indicative that the heat pump system 50 has reached a critical working point.

[0084] In a more preferred embodiment of the invention, the operative temperature To corresponds to the refrigerant temperature, preferably detected by the first temperature sensor 80, and the first threshold temperature corresponds to a first refrigerant threshold temperature T1 (for example 80°).

[0085] In further preferred embodiments of the invention, nevertheless, the operative temperature may correspond to any operative temperature as defined above, for example a machine temperature detected by a sensor placed inside the casing of the machine, a machine temperature detected by a sensor mounted on an electronic board, a temperature detected by an ambient temperature or a drying air stream temperature.

[0086] A second risky condition according to the invention is based on how long the laundry dryer 1 is working.

[0087] Preferably, the second risky condition is to evaluate if the elapsed time from the start of the drying cycle, or working time, is higher than a first time threshold t1.

[0088] In fact, a high value of the working time is indicative that the drying cycle 1 is at an advanced stage, for example between the middle and the end of the drying cycle, or in other words the first part of the drying process has elapsed. It is known that at the beginning of the drying cycle the laundry is wet and generally not warm. Therefore, in this case, the heat pump system 50, in particular the refrigerant temperature To, is typically working at low temperature and hence in favourable condition. Conversely, between the middle and the end of the drying cycle, the laundry is drier and warmer than at the beginning of the drying cycle and, consequently, the heat pump system 50, in particular the refrigerant temperature To, is typically working at higher temperatures and hence potentially closed to a critical working point.

[0089] The second risky condition is therefore indicative that the laundry dryer 1 is moving towards a critical working point.

[0090] The first time threshold t1 preferably depends on the type of drying cycle selected by the user. For example, the first time threshold t1 may be 1 hour for a wool drying cycle and 2 hours for a cotton drying cycle.

[0091] A third risky condition according to the invention is preferably a condition wherein the degree of humidity M of the laundry or inside the drum 9, preferably detected by a humidity sensor, is lower than a degree of humidity threshold M1.

[0092] In fact, a low value of humidity is indicative that the drying cycle 1 is at an advanced stage, for example between the middle and the end of the drying cycle, or in other words the first part of the drying process has elapsed. It is known that at the beginning of the drying cycle the clothes are very humid and therefore the degree of humidity of the clothes or inside the drum 9 has a high value, i.e. above a given degree of humidity threshold M1. The heat pump system 50, in particular the refrigerant and the compressor 52, is therefore working in a safe condition at safe working temperature. Conversely, at an advanced stage of the drying cycle the clothes are dry, or almost dry, the degree of humidity of the clothes or inside the drum 9 has a low value, i.e. below a given degree of humidity threshold M1, and therefore the heat pump system 50, in particular the refrigerant and the compressor 52, is closed to critical working temperatures.

[0093] The third risky condition is therefore indicative that the heat pump system 50 is moving towards a critical working point.

[0094] In a preferred embodiment of the invention, the steps of switching off the compressor 52 (step 160) and of performing the inversion of direction of rotation of the drum 9 (step 170) are performed if only one risky condition has been evaluated, for example if the refrigerant temperature To is higher than a first threshold temperature T1 or if the elapsed time from the start of the drying cycle is higher than a first time threshold t1 or if the degree of humidity M of the laundry or inside the drum 9 is lower than a first degree of humidity threshold M1.

[0095] In further preferred embodiments of the invention, the steps of switching off the compressor 52 (step 160) and performing the inversion of rotation of the drum 9 (step 170) are performed if a combination of two or more risky conditions has been evaluated.

[0096] From the above it follows, therefore, that by temporarily deactivating the compressor 52 when the inversion of direction of rotation of the drum 9 has to be performed (step 170) and one or more risky conditions are evaluated, it is possible to prevent the activation of the overload protection device 70.

[0097] Advantageously, it is possible to prevent the cut-off event, i.e. opening of the thermo protector device 70, that would imply the deactivation of the compressor 52 and the suspension of the drying cycle for a long time, typically about 40 minutes.

[0098] According to the invention, the time of deactivation of the compressor 52, namely the time between the switching off (step 160) and the switching on (step 180), is a short time (some minutes, e.g. 2-3 minutes) thus significantly reducing suspension time of the drying cycle compared to a suspension caused by the deactivation of the compressor 52 through intervention of the thermo protector device 70. Figure 6 shows a schematic diagram of a laundry dryer 201 according to another embodiment of the present invention where the method of the invention may be implemented.

[0099] The laundry dryer 201 according to this embodiment comprises the same components as the laundry dryer 1 described with reference to Figure 2, except for the fact that it further preferably comprises a cooling fan 60 which is provided to cool down the compressor 52, as better described later, and a dedicated motor 62 that operates the cooling fan 60. The control unit UC1 is then preferably connected to the motor 62 for its control. Corresponding characteristics and/or components of the two embodiments are identified by the same reference numbers. According to another aspect of the invention, further to the above described control relating to the rotation inversions, other corrective actions are taken in order to prevent the activation of the overload protection device 70 while the laundry dryer 201 is working, i.e. after the drying cycle has started.

[0100] A first preferred corrective action provides for selectively operating the cooling fan 60 in order to cool down the compressor 52.

[0101] The first corrective action is preferably performed under the control of the control unit UC1 on the base of the detected operative temperature.

[0102] Preferably, the cooling fan 60 is switched on if the detected operative temperature, preferably the refrigerant temperature To detected by the first temperature sensor 80, is above a given threshold temperature Fan_Ton, hereinafter indicated as "switch ON threshold temperature". The cooling fan 60 is then switched off if the detected operative temperature, preferably the refrigerant temperature To detected by the first temperature sensor 80, is below a given threshold temperature Fan_Toff, hereinafter indicated as "switch OFF threshold temperature". Activation of the cooling fan 60 helps the decreasing of the compressor temperature and, in turn, the decreasing of the refrigerant temperature To. Conversely, when the cooling fan 60 is deactivated the compressor temperature and the refrigerant temperature To increases.

[0103] Figure 7 exemplary shows a schematic diagram of the refrigerant temperature To as a function of the time where the switch ON threshold temperature Fan_Ton of the refrigerant at which the cooling fan 60 is switched on is set to 80°C and the switch OFF threshold temperature Fan_Toff of the refrigerant at which the cooling fan 60 is switched off is set to 78°C.

[0104] It can be appreciated that refrigerant temperature To falls and rises between the two threshold temperatures Fan_Ton and Fan_Toff according to respective activations and deactivations of the cooling fan 60.

[0105] Advantageously, therefore, the control unit UC1 opportunely selectively switches on-off the cooling fan 60 on the base of the detected operative temperature so that the compressor 52 cools down and does not reach critical working conditions which may cause the undesired opening of the thermo protector device 70.

[0106] A second preferred corrective action provides for switching off the compressor 52, preferably through the relay 72. The compressor 52 is switched off if the operative temperature, preferably the refrigerant temperature To detected by the first temperature sensor 80, is above, or equal to, a given threshold temperature Comp_Ton/off, hereinafter indicated as "switch ON/OFF threshold temperature". For example, the compressor 52 is switched off if the refrigerant temperature To detected by the first temperature sensor 80, is above, or equal to, 90°C. Deactivation of the compressor 52 causes the decreasing of the compressor temperature and, in turn, the decreasing of the refrigerant temperature To.

[0107] In case the compressor 52 is switched off, preferably, a predetermined period of time is set before the compressor 52 is available to be switched on again. Said period of time allows reestablishment of correct pressure of the refrigerant in the pump system 50. Said predetermined period of time is preferably set to 2-3 minutes. In a further preferred embodiment, the compressor 52 may be switched on again only if the refrigerant temperature To has decreased below a predetermined temperature.

[0108] Advantageously, therefore, the control unit UC1 opportunely switches off the compressor 52 on the base of the detected operative temperature so that the compressor 52 cools down and does not reach critical working conditions which may cause the undesired opening of the thermo protector device 70.

[0109] Still advantageously, said corrective actions may prevent the cut-off event occurs, i.e. opening of the thermo protector device 70, that would imply the deactivation of the compressor 52 and the suspension of the drying cycle for a long time, typically about 40 minutes.

[0110] By means of corrective actions, at worst, the compressor 52 is deactivated for 2-3 minutes thus significantly reducing suspension time of the drying cycle compared to a suspension caused by the deactivation of the compressor 52 through intervention of the thermo protector device 70.

[0111] In a preferred embodiment of the method, corrective actions may be performed from the very beginning of the drying cycle.

[0112] In a more preferred embodiment of the method, corrective actions may be performed based upon one or more events.

[0113] For example, in a first preferred embodiment of the invention, said corrective actions are performed after a period of time has lapsed from the beginning of the drying cycle, for example 30 minutes after the drying cycle started. It is clear that such a period may depend on the type of cycle selected, for example may be proportional to the duration of the selected cycle.

[0114] In a further preferred embodiment of the invention, for example, said corrective actions are performed at the reaching of a predetermined degree of humidity inside the drum 9.

[0115] Advantageously, from the above description it has been shown that by selectively switching off the compressor unwanted cut-off events may be prevented.

[0116] Although illustrative embodiments of the present invention have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to that precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

Claims

1. A method for controlling a laundry drying machine (1; 201) equipped with a heat pump system (50) during a drying cycle, said laundry drying machine (1; 201) comprising:

- a control unit (UC1);
- a treating chamber (9) where laundry can be introduced to be dried with a drying air stream, said treating chamber (9) apt to be rotated;
- a heat pump system (50) including a compressor (52), a first heat exchanger (54) for cooling a refrigerant and heating the air stream, expansion means (58) and a second heat exchanger (56) for heating the refrigerant;
- at least a passive switching device (70), not controllable by the control unit (UC1), adapted to cut the power supplied to the compressor (52) when one or more predetermined operative parameters thresholds are exceeded;
- at least an active switching device (72), controllable by the control unit (UC1), for selectively switching on and off the compressor (52);

wherein said method is **characterized in that** it comprises the steps of:

- starting a drying cycle;
- activating said heat pump system (50) by switching on said compressor (52);
- rotating said treating chamber (9);
- evaluating if an inversion of direction of rotation of said treating chamber (9) has to be performed and, if an inversion of direction of rotation has to be performed, evaluating if an operating condition of said compressor (52) which can cause the activation of said passive switching device (70) exists;
- if said operating condition does not exist, then performing the inversion of direction of rotation of said treating chamber (9), otherwise if said operating condition exists, then performing the following steps:

  a) switching off said compressor (52);
  b) performing the inversion of direction of rotation of said treating chamber (9);
  c) switching on said compressor (52).

2. The method according to claim 1, **characterized in that** the step of evaluating if an operating condition of said compressor (52) which can cause the activation of said passive switching device (70) exists comprises evaluating one of the following conditions or a combination thereof:

- if an operative temperature (To) is higher than a first threshold operative temperature (T1), wherein said operative temperature (To) is detected by at least one temperature sensor (80);
- if the elapsed time from the start of the drying cycle is higher than a first time threshold (t1);
- if the degree of humidity (M) of the laundry and/or the degree of humidity inside the chamber (9) is lower than a first threshold (M1), wherein said degree of humidity (M) is detected by at least one humidity sensor.

3. The method according to claim 2, **characterized in that** said operative temperature (To) is the temperature of the heat pump system (50) and/or the operative temperature of the laundry drying machine (1; 201) and/or the ambient temperature and/or the drying air stream temperature, wherein said operative temperatures are detected by at least one temperature sensor (80).

4. The method according to claim 2 or 3, **characterized in that** said operative temperature (To) is the refrigerant temperature (To) and said first threshold operative temperature (T1) is a first refrigerant threshold temperature.

5. The method according to any preceding claim 2 to 4, **characterized in that** the value of said first time threshold (t1) depends on the type of drying cycle selected by the user.

6. The method according to any preceding claim, **characterized in that** said step of evaluating if an inversion of direction of rotation of said treating chamber (9) has to be performed comprises the step of considering the scheduled time for inverting the direction of rotation of the treating chamber (9) according to the type of drying cycle selected by the user.

7. The method according to any preceding claim 1 to 5, **characterized in that** said step of evaluating if an inversion of direction of rotation of said treating chamber (9) has to be performed comprises the step of determining during the drying cycle the presence of one of the following condition or a combination thereof of the laundry drying machine (1; 201) and/or of the heat pump system (50) that requires an inversion of direction of rotation of the treating chamber (9): unbalance of the load, degree of humidity (M) of the laundry reaches a pre-fixed value, degree of humidity (M) of the treating chamber (9) reaches a pre-fixed value, inversion of direction of rotation of a drying air circulating fan (28).

8. The method according to any preceding claim, **characterized in that** said step a) of switching off said compressor (52) is performed before, or at the same time, of said step b) of performing the inversion of direction of rotation of said treating chamber (9) and **in that** said step c) of switching on said compressor (52) is performed after said step b) of performing the inversion of direction of rotation of said treating chamber (9), preferably after the beginning of said step b) of performing the inversion of direction of rotation of said treating chamber (9), more preferably after the end of said step b) of performing the inversion of direction of rotation of said treating chamber (9).

9. The method according to any preceding claim 1 to 7, **characterized in that** said step a) of switching off said compressor (52) is performed after said step b) of performing the inversion of direction of rotation of said treating chamber (9), preferably after the beginning of said step b) of performing the inversion of direction of rotation of said treating chamber (9), more preferably after the end of said step b) of performing the inversion of direction of rotation of said treating chamber (9) and **in that** said step c) of switching on said compressor (52) is performed after said step a) of switching off said compressor (52).

10. The method according to claim 9, **characterized in that** said step a) of switching off said compressor

(52) is performed within a first delay time (DT1) after said step b) of performing the inversion of direction of rotation of said treating chamber (9) has started or ended.

11. The method according to claim 1 to 7, **characterized in that** said step b) of performing the inversion of direction of rotation of said treating chamber (9) is performed after said step c) of switching on said compressor (52) and **in that** said step a) of switching off said compressor (52) is performed before said step c) of switching on said compressor (52).

12. The method according to claim 11, **characterized in that** said step b) of performing the inversion of direction of rotation of said treating chamber (9) is performed within a second delay time (DT2) after said step c) of switching on said compressor (52).

13. The method according to any preceding claim, **characterized in that** said machine (201) comprises at least one compressor cooling fan (60) and the method comprises the steps of:

c) detecting an operative temperature (To) of the heat pump system (50) and/or of the laundry drying machine (1; 201);
e) switching on said cooling fan (60) if said detected operative temperature (To) is above a switch ON threshold temperature (Fan_Ton);
f) switching off said cooling fan (60) if said detected operative temperature (To) is below a switch OFF threshold temperature (Fan_Toff).

14. A laundry drying machine (1; 201) equipped with a heat pump system (50), said laundry drying machine (1; 201) comprising:

- a control unit (UC1);
- a treating chamber (9) where laundry can be introduced to be dried with a drying air stream, said treating chamber (9) apt to be rotated;
- a heat pump system (50) including a compressor (52), a first heat exchanger (54) for cooling a refrigerant and heating the air stream, expansion means (58) and a second heat exchanger (56) for heating the refrigerant;
- at least a passive switching device (70), not controllable by the control unit (UC1), adapted to cut the power supplied to the compressor (52) when one or more predetermined operative parameters thresholds are exceeded;
- at least an active switching device (72), controllable by the control unit (UC1), for selectively switching on and off the compressor (52);

characterized in that said control unit (UC1) is configured to control said compressor (52) and the rotation of said treating chamber (9) according to the method of any of the preceding claims.

15. The machine (1; 201) according to claim 14, **characterized in that** it further comprises at least one temperature sensor (80) and/or at least one humidity sensor.

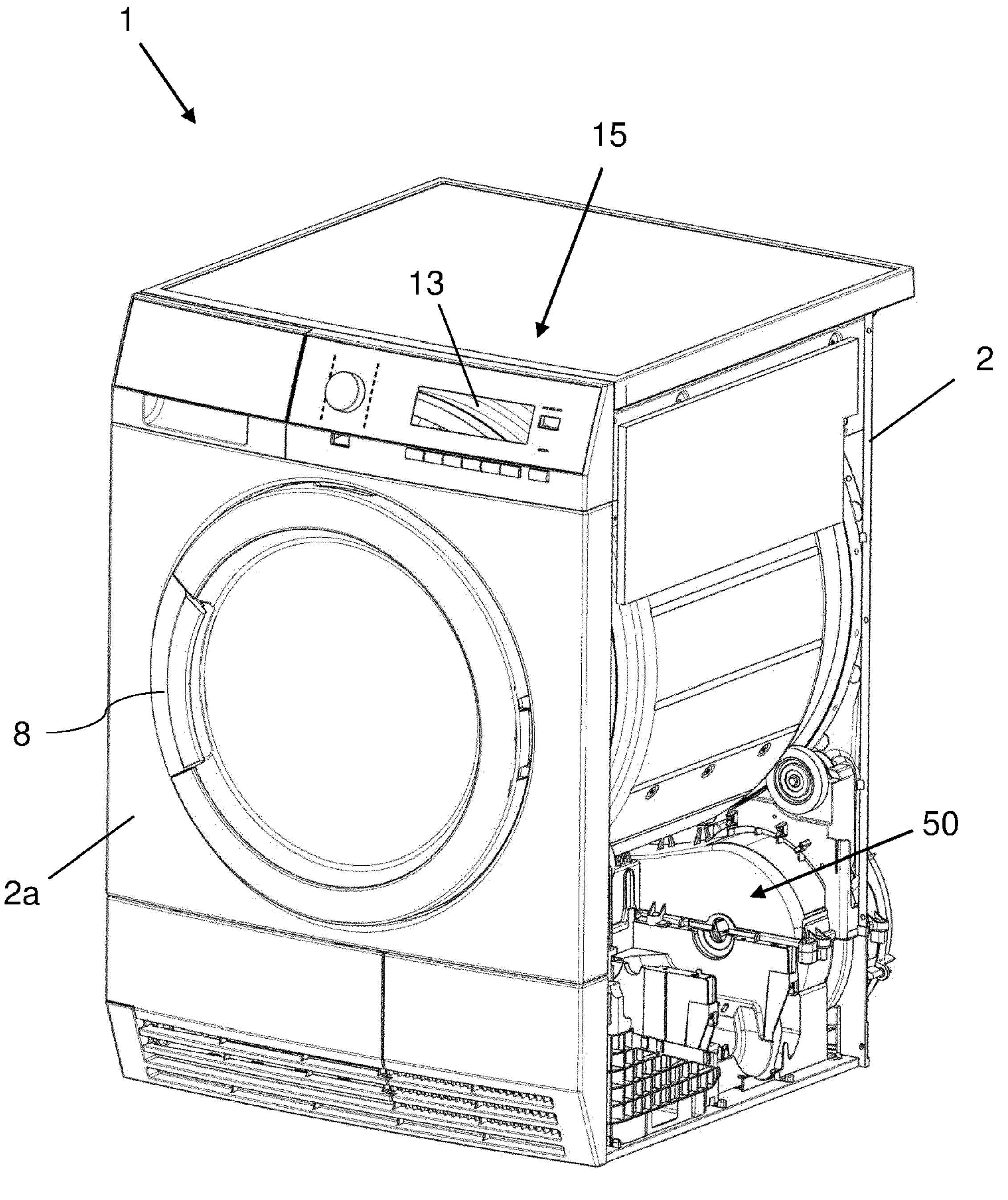
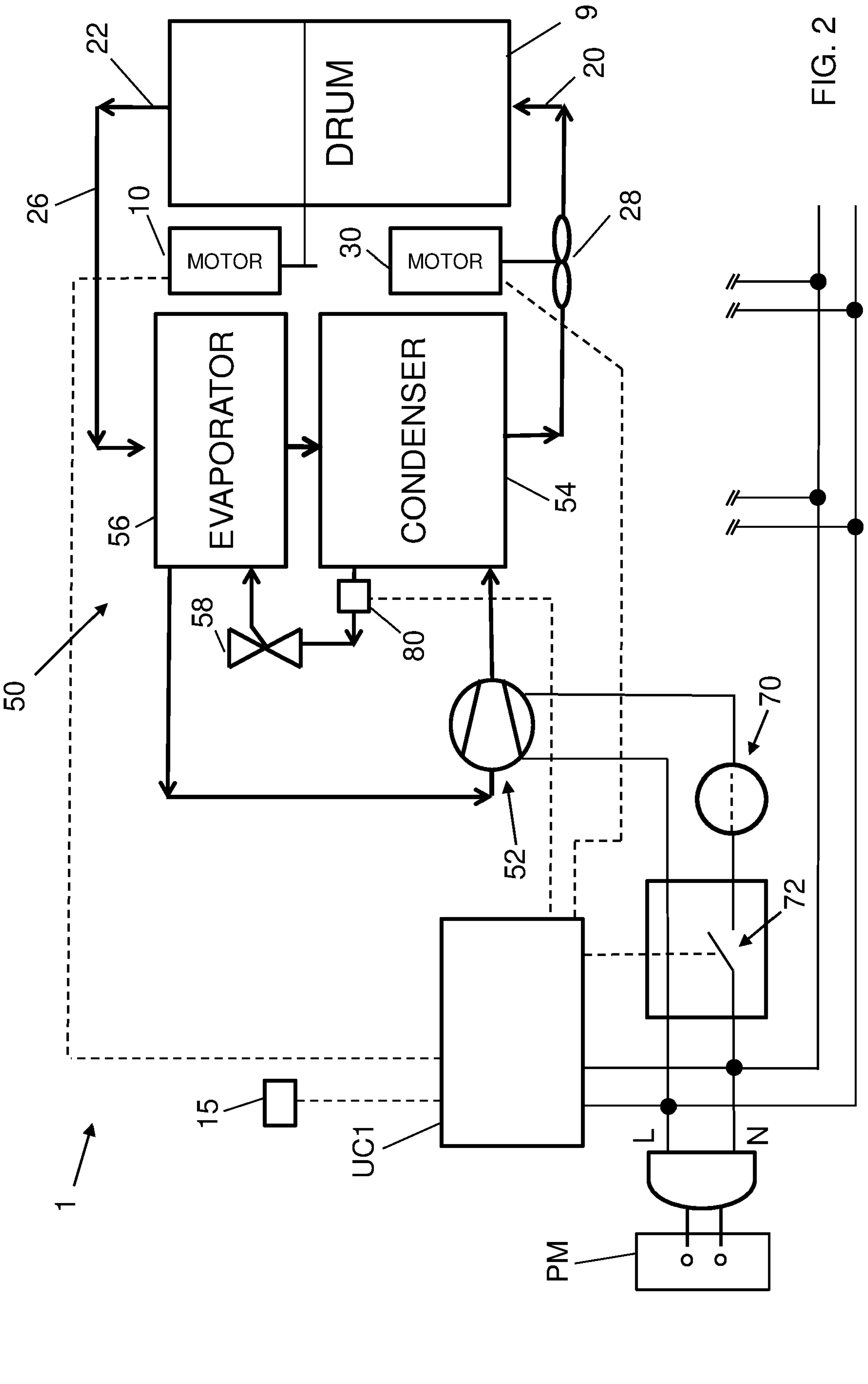


FIG. 1


DRUM
MOTOR
MOTOR
EVAPORATOR
CONDENSER
1
9
10
15
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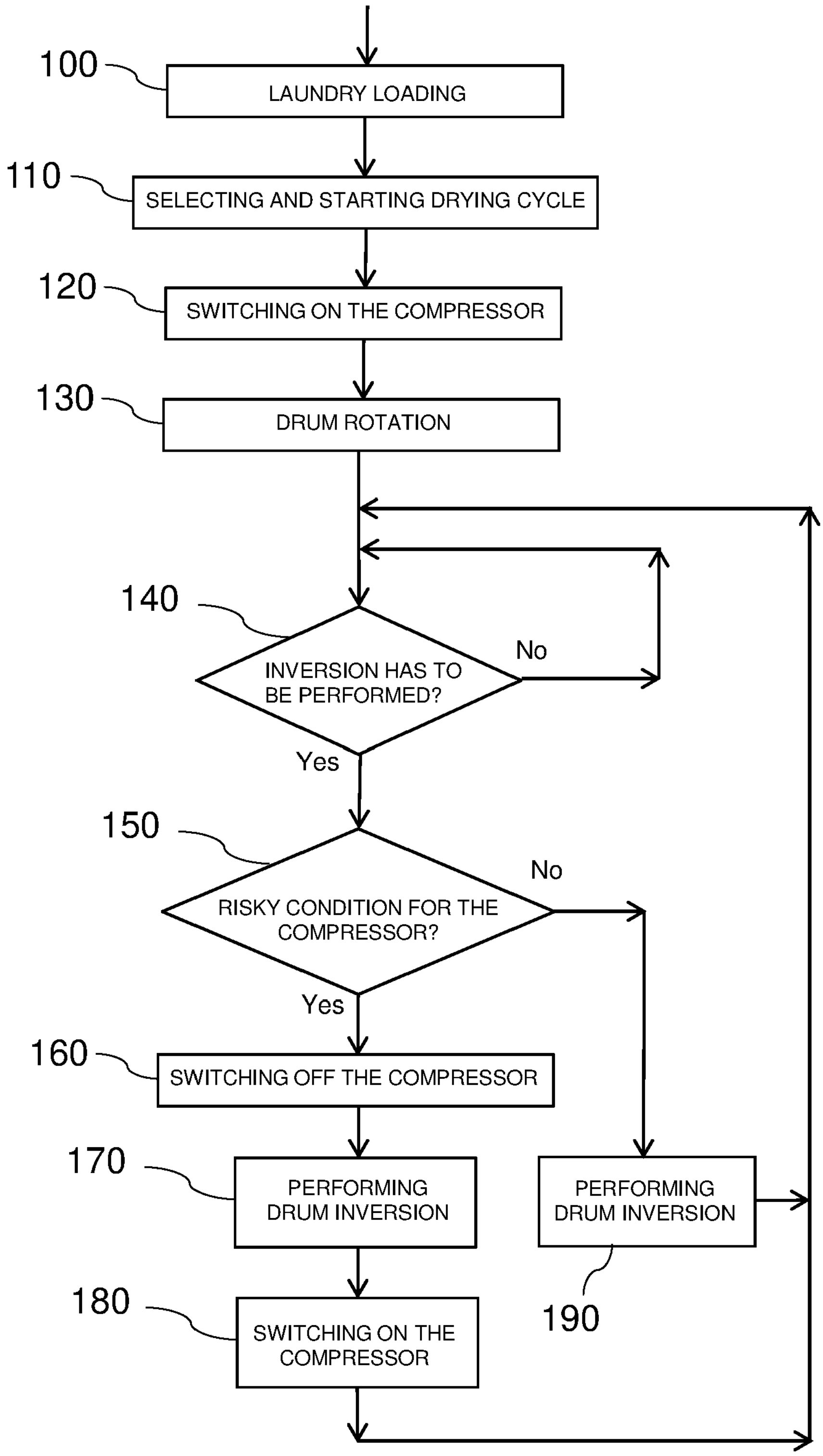
50
52
54
56
58
70
72
80
UC1
PM
L
N

FIG. 2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110
SELECTING AND STARTING DRYING CYCLE
120
SWITCHING ON THE COMPRESSOR
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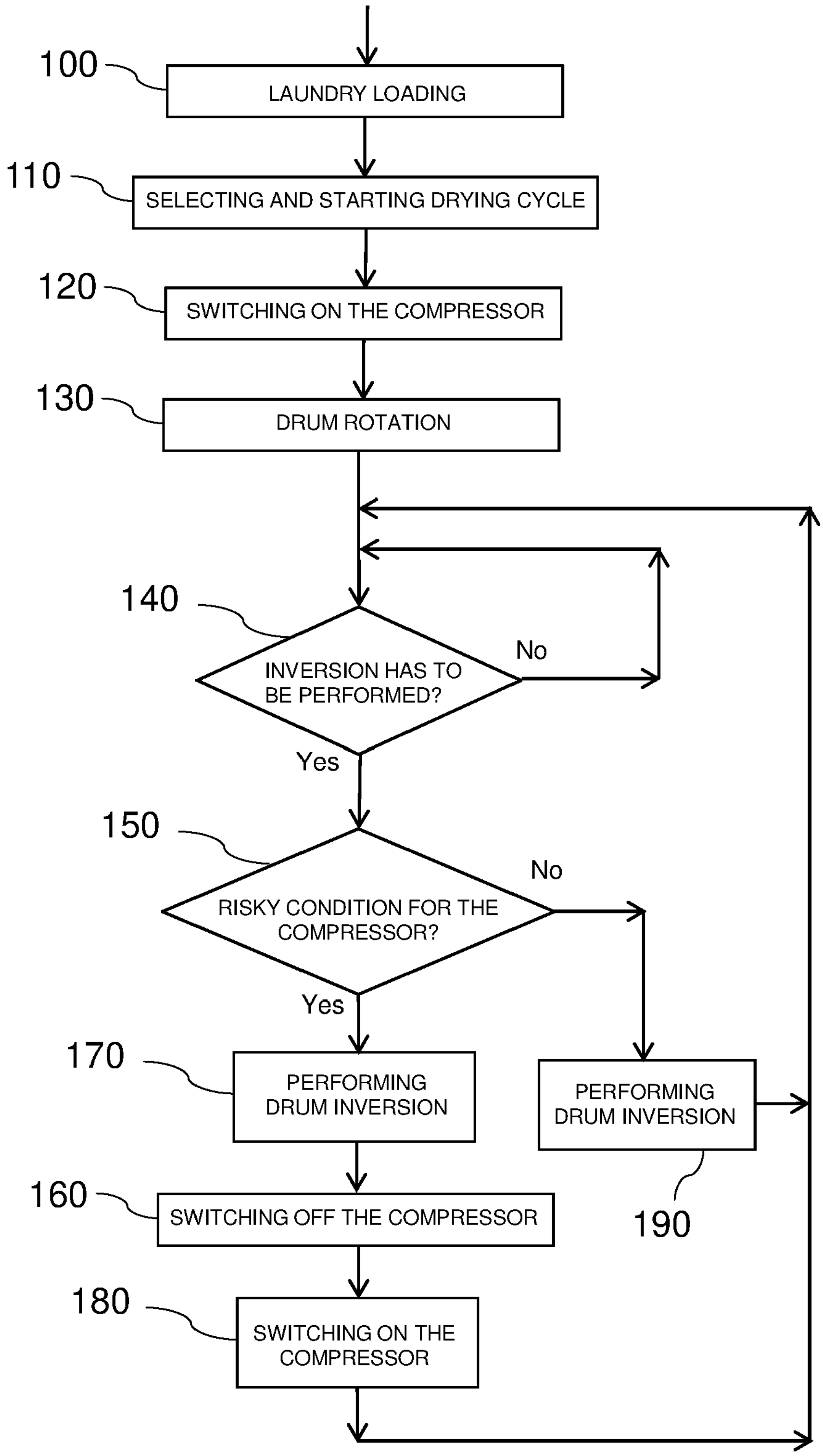
DRUM ROTATION
140
INVERSION HAS TO BE PERFORMED?
No
Yes
150
RISKY CONDITION FOR THE COMPRESSOR?
No
Yes
160
SWITCHING OFF THE COMPRESSOR
170
PERFORMING DRUM INVERSION
PERFORMING DRUM INVERSION
190
180
SWITCHING ON THE COMPRESSOR

FIG. 3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110
SELECTING AND STARTING DRYING CYCLE
120
SWITCHING ON THE COMPRESSOR
130
DRUM ROTATION
140
INVERSION HAS TO BE PERFORMED?
No
Yes
150
RISKY CONDITION FOR THE COMPRESSOR?
No
Yes
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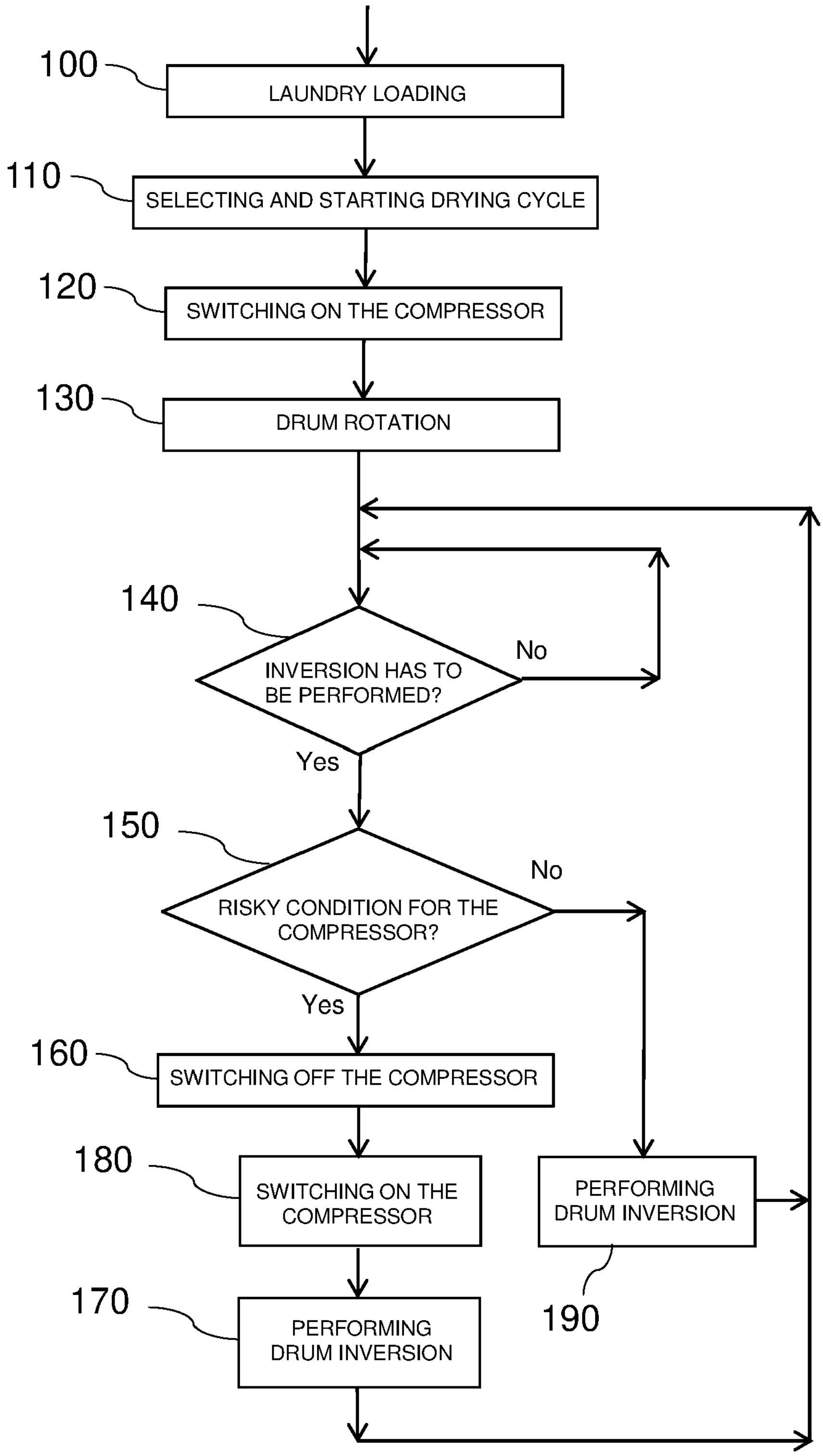
PERFORMING DRUM INVERSION
PERFORMING DRUM INVERSION
190
160
SWITCHING OFF THE COMPRESSOR
180
SWITCHING ON THE COMPRESSOR

FIG. 4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SWITCHING ON THE COMPRESSOR
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DRUM ROTATION
140
INVERSION HAS TO BE PERFORMED?
No
Yes
150
RISKY CONDITION FOR THE COMPRESSOR?
No
Yes
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SWITCHING OFF THE COMPRESSOR
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SWITCHING ON THE COMPRESSOR
PERFORMING DRUM INVERSION
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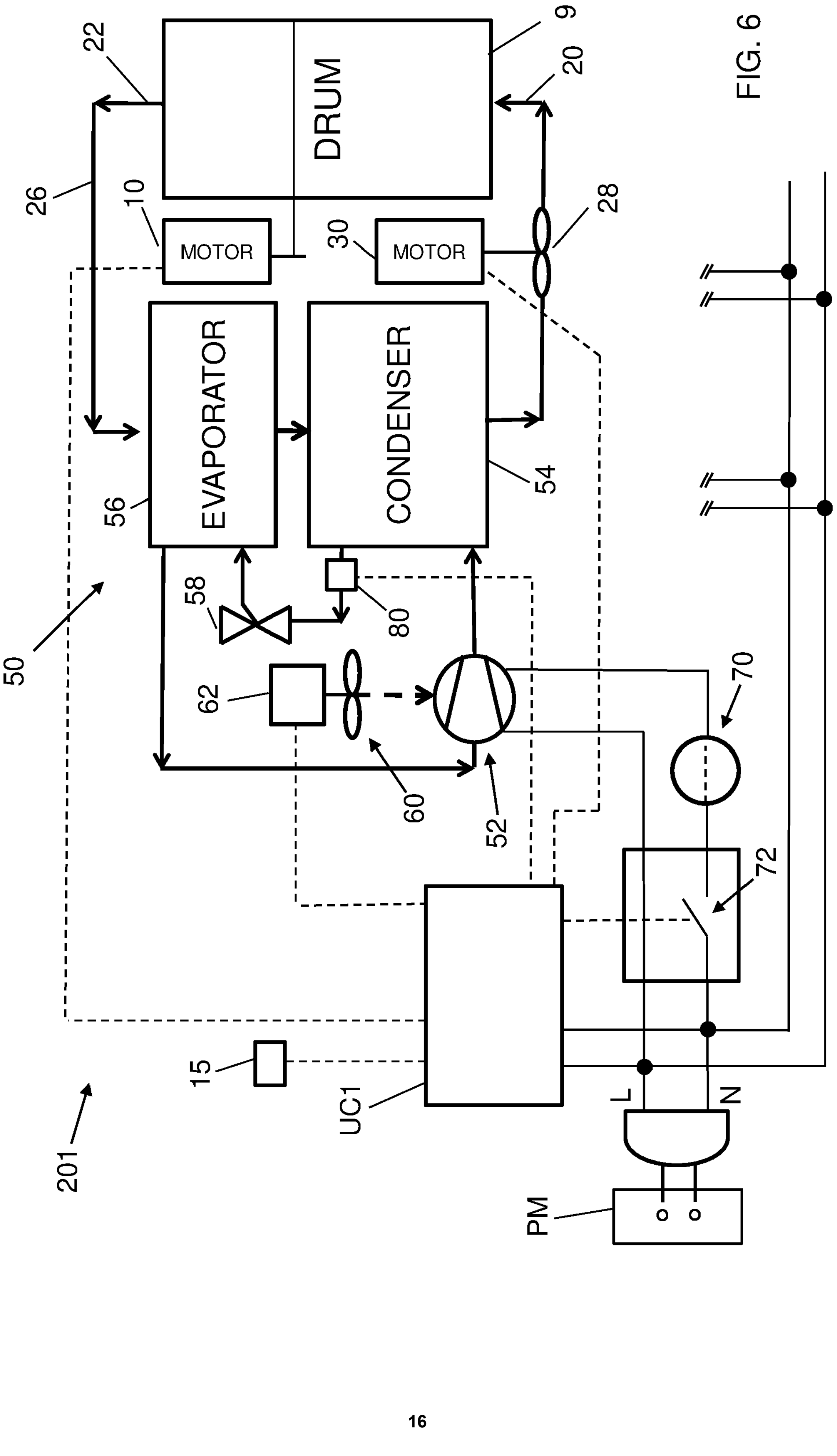
PERFORMING DRUM INVERSION

FIG. 5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MOTOR
EVAPORATOR
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52
72
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UC1
201
L
N
PM

FIG. 6

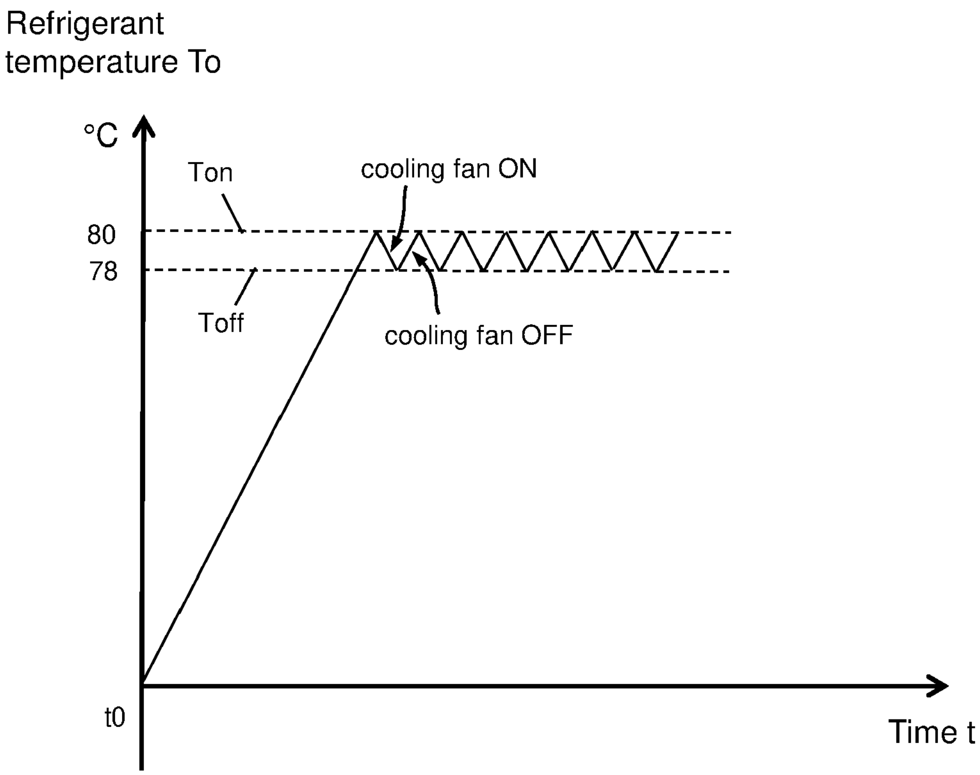
Refrigerant
temperature To
°C
Ton
cooling fan ON
80
78
Toff
cooling fan OFF
t0
Time t

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 20 17 8481

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 9 605 375 B2 (WHIRLPOOL CO [US]) 28 March 2017 (2017-03-28) * column 3, line 14 - line 54 * * column 4, line 18 - line 24 * * claims; figures * -----	1-15	INV. D06F58/46 ADD. D06F58/20 D06F34/26 D06F103/32 D06F103/34 D06F103/38 D06F105/26 D06F105/30 D06F105/46 D06F58/30
A	EP 2 392 725 A2 (V ZUG AG [CH]) 7 December 2011 (2011-12-07) * paragraph [0028] - paragraph [0030] * * claims; figures * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			D06F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	21 August 2020	Popara, Velimir

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons
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21-08-2020

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US 9605375 B2	28-03-2017	EP 2918722 A1 US 2015259848 A1	16-09-2015 17-09-2015
EP 2392725 A2	07-12-2011	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82