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(54) **METHOD FOR CONTROLLING A HEAT PUMP LAUNDRY DRYING MACHINE**

(57) The present invention relates to a method to operate a laundry drying appliance including:
• a treating chamber where laundry is introduced and treated with process air;
• a heat pump system having a refrigerant circuit in which a refrigerant can flow, said refrigerant circuit including a first heat exchanger where the refrigerant is cooled off, a second heat exchanger where the refrigerant is heated up, a compressor to pressurize and circulate the refrigerant through the refrigerant circuit, and a pressure-lowering device; said first and/or second heat exchanger being apt to perform heat exchange between said refrigerant flowing in said refrigerant circuit and said process air;
• a selector adapted to select alternatively one of a plurality of drying programs, each drying program including a main drying phase;
said method comprising:
• setting a first limit temperature value representative of the limit temperature of the compressor;
• setting a second limit temperature value representative of the limit temperature of the compressor;
• selecting a drying program among the plurality and starting its drying phase;
• sensing an operating parameter representative of the humidity of the laundry in the treating chamber;
• measuring a temperature value representative of the temperature of said compressor;
• selecting the first limit temperature value for a first plurality of values of the sensed operating parameter representative of the humidity of the laundry during the drying phase;
• selecting the second limit temperature value for a second plurality of values of the sensed operating parameter representative of the humidity of the laundry during the drying phase; and
• limiting power supply to or switching off said compressor if the measured temperature value is higher than the first or the second limit temperature value, depending on which one is selected when the measured temperature value exceeds the limit temperature value.

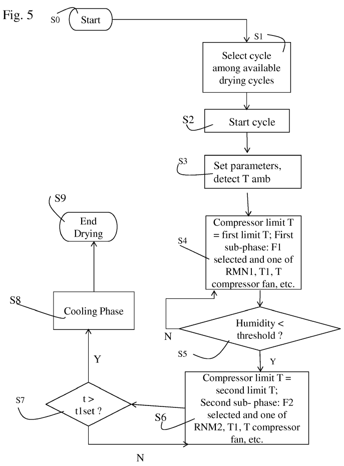

Fig. 5

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Description

Technical field

[0001] The present invention relates to a method for controlling a heat pump laundry drying machine, in particular including a drying cycle in which a relatively high temperature of process air is achieved.

Background art

[0002] Heat pump dryer are widespread due to their drying efficiency.

[0003] However, heat pump laundry dryers are not generally designed to operate at such high temperatures, that is, generally, heat pump laundry dryers operate at temperatures of the process air, and thus reached by the laundry, below 50°C, which are commonly considered high enough to dry standard clothes or textiles. If a heat pump laundry dryer reaches temperatures above 50° - 55° C in the process air, it may happen that safety measures activate which block or limit either the dryer functioning or further raise in process air temperature.

[0004] For the purpose of the present disclosure, outdoor textiles have a waterproof and breathable thin film material with a micro-porous structure.

[0005] Often, clothes designed and realized for outdoor conditions include a durable water repellent (DWR), which is a coating added to fabrics at the factory to make them water-resistant or hydrophobic. Most factory-applied treatments are fluoropolymer based. Durable water repellents are commonly used in conjunction with waterproof breathable fabrics such as Gore-Tex to prevent the outer layer of fabric from becoming saturated with water. This saturation, called "wetting out", can reduce the garment's breathability (moisture transport through the breathable membrane) and let water through. Methods for factory application of DWR treatments involve for example applying a solution of a chemical onto the surface of the fabric by spraying or dipping. More recently the chemistry is applied in the vapor phase using Chemical Vapor Deposition (CVD) machinery.

[0006] This hydrophobic chemical treatment penetrates the fibres and lowers the surface tension of the fabric, causing water to bead up and roll off the outer layer of fabric, instead of being absorbed. The DWR treatment is not permanent: the surface coating can degrade through regular wear and tear, exposure to dirt, detergent, insect repellent and other impurities causing the outer fabric to absorb water. As the DWR wears off over time, re-treatment is recommended when necessary. Certain types of fabrics need to be re-treated to maintain water-repellency, as fluoropolymers decompose over time when exposed to water and chemicals. As the garment becomes saturated with water, the breathability decreases, as the absorbed water prevents water vapour (perspiration) from passing from the inside to the outside of the garment creating a humid and wet environment inside the garment. Another drawback is that a saturated fabric attracts dirt particles, which clog the pores in the waterproof membrane, reducing breathability even after the garment has dried.

[0007] Affected garments can be treated with a "spray-on" or "wash-in" treatment to improve water-repellence. Heat treatment may reactivate the factory applied repellent finish and aids the repelling of water, and other liquids such as oils.

[0008] In EP2622120, a method for controlling drying machine is provided, which includes selecting and starting an outdoor textiles drying procedure, and then entering a preheating stage, a main drying stage, and a cooling stage. In the main drying stage, a working temperature of the drying machine is lower than a working temperature of an ordinary drying procedure, and after the cooling stage, nominal water content of loaded outdoor textiles is higher than nominal water content after the ordinary drying procedure is performed. By setting an appropriate drying working temperature, damages on material and sealing strips at seams of the outdoor textiles during the drying procedure are prevented to the greatest extent. Moreover, after the drying procedure is finished, nominal water content of the outdoor textiles is higher than nominal water content of the other textiles after the ordinary drying procedure is performed, which ensures that wrinkles caused by over-drying do not occur to the outdoor textiles, and at the same time, the material and sealing strips at the seams of the outdoor textiles are prevented from being damaged. A drying machine having a control unit programmed for implementing the method is also provided.

[0009] However, the disclosed treatment in a dryer does not provide the optimal solution for re-activating, also called re-proofing, outdoor clothing and textile.

Summary of the invention

[0010] The present invention relates to a method for controlling a heat pump drying machine where a relatively "high temperature" is preferred. The meaning of "high temperature" is relative, that is, the method of the invention is preferably, but not necessarily, used when a "higher than standard" temperature is required during a drying cycle. As an example, the method of the invention could be used when an outdoor drying cycle is provided, to re-activate (or "re-proof") the water repellent characteristics of outdoor textiles, such as outdoor clothes and garments.

[0011] Applicant has indeed found that the outdoor textile, in order to have the surface treatment "re-activated", needs a drying cycle, or drying cycle phase, having relatively high temperature and low humidity, for example a temperature above 55°C and a humidity below 5%.

[0012] Other drying program may need a temperature which is generally higher than the standard temperatures used in heat pump dryer.

[0013] There is therefore the need for a method for which relatively high temperature can be safely reached in a heat pump dryer.

[0014] According to an aspect, the invention relates to a method to operate a laundry drying appliance including:

- a treating chamber where laundry is introduced and treated with process air;
- a heat pump system having a refrigerant circuit in which a refrigerant can flow, said refrigerant circuit including a first heat exchanger where the refrigerant is cooled off, a second heat exchanger where the refrigerant is heated up, a compressor to pressurize and circulate the refrigerant through the refrigerant circuit, and a pressure-lowering device; said first and/or second heat exchanger being apt to perform heat exchange between said refrigerant flowing in said refrigerant circuit and said process air;
- a selector adapted to select alternatively one of a plurality of drying programs, each drying program including a main drying phase;

said method comprising:

- setting a first limit temperature value representative of the limit temperature of the compressor;
- setting a second limit temperature value representative of the limit temperature of the compressor;
- selecting a drying program among the plurality and starting its drying phase;
- sensing an operating parameter representative of the humidity of the laundry in the treating chamber;
- measuring a temperature value representative of the temperature of said compressor;
- selecting the first limit temperature value for a first plurality of values of the sensed operating parameter representative of the humidity of the laundry during the drying phase;
- selecting the second limit temperature value for a second plurality of values of the sensed operating parameter representative of the humidity of the laundry during the drying phase; and
- limiting power supply to or switching off said compressor if the measured temperature value is higher than the first or the second limit temperature value, depending on which one is selected when the measured temperature value exceeds the limit temperature value.

[0015] The laundry drying machine or appliance of the invention may be preferably a laundry dryer or a laundry washer dryer.

[0016] A heat pump laundry drying machine includes a rotatable treating chamber, such as a drum, in which the load of laundry, e.g., clothes, or other items to be washed and/or dried are placed. The laundry is made of a given textile. The treating chamber is adapted to rotate in a direction and in an opposite direction, reversing its rotation, for example driven by a motor, such as a variable speed motor in order to regulate the speed of rotation of the treating chamber.

[0017] The treating chamber is part of a process circuit, in particular for example a closed-loop air circuit in case of a condensed dryer or an open air circuit in case of a vented dryer, which in both cases includes an air duct for channelling a stream of process air to dry the load. The process air circuit is connected with its two opposite ends to the drum. For example, in case of a dryer, hot dehumidified air is fed into the drum, flowing over the laundry, and the resulting humid cool air exits the same. The humid air stream rich in water vapour is then fed into an evaporator of a heat pump, where the moist warm process air is cooled and the humidity present therein condenses. The resulting cool dehumidified air is then either vented outside the appliance in the environment where the latter is located or it continues in the closed-loop circuit. In this second case, the dehumidified air in the process air circuit is then heated up before entering again in the drum by means of a condenser of the heat pump, and the whole loop is repeated till the end of the drying cycle. Alternatively, environment air enters into the drum from the environment via an inlet duct and it is heated up by the condenser of the heat pump before entering the drum. The process air is preferably blown within the process air circuit by means of a process air fan for example a variable speed fan, driven by a motor. Preferably, the motor of the fan and the motor of the treating chamber are the same motor. Different circuits are known in the art in case of a washer-dryer.

[0018] The heat pump of the drying machine includes a refrigerant circuit in which a refrigerant can flow and which connects via piping a first heat exchanger or condenser, a second heat exchanger or evaporator, a compressor and a pressure-lowering device. The refrigerant is pressurized and circulated through the system by the compressor. On the discharge side of the compressor, the hot and highly pressurized vapour is cooled in the first heat exchanger, called the condenser, until it condenses into a high pressure, moderate temperature liquid, heating up the process air before the latter is introduced into the drying chamber. The condensed refrigerant then passes through the pressure-lowering device such as an expansion device, e.g., a choke, a valve or a capillary tube. The low pressure liquid refrigerant then enters the second heat exchanger, the evaporator, in which the fluid absorbs heat and evaporates due to the heat exchange with the warm process air exiting the drum. The refrigerant then returns to the compressor and the cycle is repeated.

[0019] In order to compress the refrigerant, the compressor preferably includes an electric motor which is commonly powered by a current, for example a current coming from the mains.

[0020] The drying machine of the invention preferably includes a selector, for example operable by the user, with which a plurality of drying cycles can be alternatively selected. A drying machine generally includes a plurality of drying cycles each designed to treat laundry made of a specific textile type or composition, such as a cotton cycle at high temperature for cotton textile; permanent press, which generally refers to coloured garments and utilizes medium heat; a knits/delicate cycle is for delicate textiles which cannot withstand very much heat; the delicate cycle uses air slightly above room temperature to gently and slowly dry fragile garments, etc. Therefore, generally the cycle is selected depending on the type of textile to be dried. Among the cycles which can be selected by the selector of the drying machine, the drying machine of the invention includes an outdoor cycle to properly dry outdoor textiles and re-activate - at least partially - their waterproof and/or water repellent qualities.

[0021] Many different types of drying cycles can be present in the drying machine of the invention or only two different cycles.

[0022] Each cycle can differ from the other cycles by a plurality of different settings, such for example the temperature of the process air which flows inside the drum to dry the textile, the time duration of the cycle, the speed of revolution of the drum, the number of changes in direction of revolution of the drum, the degree of humidity at which the textile is considered to be dry and the cycle terminated, etc. All these settings and the corresponding program lines for each cycle are for example included in a memory of the drying machine, for example in a main controller circuit of the drying machine. Further, each cycle, although preferably not visible to the user, may include one or more settings for the heat pump operation.

[0023] Each drying cycle includes a main drying phase, which is the phase in which the clothes and/or textile introduced in the drum are dried. Each cycle may include also other phases, such as a cooling phase after the main drying phase, in which the laundry is cooled before the user may access them. In the cooling phase, the temperature reached by the textile in the main drying cycle is reduced. Further, one or more of the drying cycles may include a pre-heating phase where the drum and other components of the drying machine are heated up in order to pre-warm the machine so that it reaches the optimal temperature to start the main drying phase.

[0024] The selection of a laundry drying cycle or program can be made in any possible way, for example by means of a mechanical switch or a rotatable knob, by means of buttons, one per cycle, by means of a touch screen, etc. Further, the selection can be performed by the user manually, by means of a remote control or by means of a wireless command signal, automatically due to a pre-set timer, etc.

[0025] The selection of the cycle preferably depends on the type of clothes, garment, textiles, etc. inserted in the drum.

[0026] Once the selection of the drying cycle is performed, the drying cycle starts.

[0027] In a heat pump laundry drying machine, the laundry is dried at a relatively low temperature, e.g. the temperature of the textile present in the drum commonly does not exceed 50°C-55°C. According to the method of the invention, in order to raise the temperature of the textile in the drum, for example above 50°C, the temperature of the compressor is monitored.

[0028] It is known in the art that a compressor of a heat pump, such as the heat pump present in laundry washing and/or drying appliances, can work under safety condition if it works within a field of temperature values. These values may follow a given curve, which depends on the type of compressor. Each compressor has its own specific curve delimiting its own safety working area which depends on the characteristics of the compressor itself.

[0029] In an embodiment, the compressor, in order to work in safety conditions, should not overheat, that is, there is a field of working conditions, function of the temperature of the compressor and of the absorbed current of the electric motor of the compressor, in which the compressor can work without overheating. The field of safe working conditions for the compressor is generally delimited by a compressor curve.

[0030] Therefore, preferably, there is a "limit temperature" above which the compressor is preferably not allowed to work. This limit temperature may depend on several parameters, not only on the type of compressor. For example, it may depend on the environment temperature surrounding the laundry.

[0031] Preferably, for example, the limit temperature of the compressor is sensed anywhere in the refrigerant circuit.

[0032] Commonly, also a "over safe" area around the safe working range is present, that is, in order to increase the safety, a lower temperature or lower current than the one at the boundary of the real safe working range is considered as a limit temperature for the compressor, above which the compressor is preferably switched off or the power applied to the compressor should be limited.

[0033] In order to always work within the safety field of the compressor, safety precautions may be taken in the laundry dryer. For example, the requirement of working in such a safe field or working area is generally assured by the presence of a passive switch which interrupts the power supply to the heat pump compressor when predetermined thresholds of heat or current (or voltage load) are exceeded. The passive switch - called OLP - opens when a threshold temperature of the heat pump compressor is reached or when a power load or current through the passive switch is reached, because also in this case a high current causes the bimetallic switch to overheat and reach the switching temperature.

[0034] Alternatively or in addition to the OLP, the limit temperature may be set via software, that is, as soon as the temperature of the compressor reaches a given limit value, the compressor is not allowed to work.

[0035] Alternatively or in addition, the limit temperature may be set with reference to another variable. For example, the limit temperature may depend on the temperature at which a fan cooling the compressor starts blowing.

[0036] Both OLP limit temperature and software limit temperature may be present as well, for example, the software limit temperature for example may be lower than the OLP temperature for a higher security margin.

[0037] The limit temperature for the compressor may be set also in other ways.

[0038] If this limit temperature is reached, regardless on how the limit temperature is set, the compressor is either switched off or the power supplied to the compressor, for example the current supplied to the compressor motor, is limited. The power could be for example lowered, or interrupted for a time interval.

[0039] According to the invention, a first limit temperature and a second limit temperature are set, in any manner known in the art, for example according to one of the above embodiments.

[0040] Preferably, the first limit temperature is different from the second limit temperature.

[0041] The difference between the first and the second limit temperature may be cycle dependent, that is, it may vary depending on the drying cycle or program which has been selected. Further, it may depend on the type of compressor, on the type of dryer, on the amount of laundry to be dried, on the external temperature, conducibility value of water (for example set by the user), etc.

[0042] Further, also the value of the first and second limit temperature may depend on the variables above listed with reference to the difference between the first and the second limit temperature.

[0043] Just as an example, in all drying cycle, the temperature of the drying machine or appliance at the beginning of the drying cycle is sensed. This temperature is the temperature of the surrounding to the machine, that is, it is an "environment" temperature. The first and second limit temperature may vary depending on this initial temperature of the dryer. For example, as a first or second limit temperature, the temperature at which a fan cooling the compressor is activated is chosen, plus a given constant. Therefore, in an embodiment:

$$T_{1\ \text{or}\ 2\ \text{limit temperature}} = T_{\text{compressor fan activation}} + 5°C.$$

[0044] The constant temperature chosen can be not only 5°C, but any, and it may vary depending on the selected drying cycle.

[0045] In the following, the first limit temperature values are given as examples for different drying cycles:

Cotton cycle:

[0046] $T_{1\ \text{limit temperature}}$=95°C, if temperature at the beginning of the cycle is "cool", or normal, that is, if the temperature is below or equal27°C.

[0047] $T_{1\ \text{limit temperature}}$=90°C, if temperature at the beginning of the cycle is "warm", that is, if the temperature is above 27°C. ool cycle:

$T_{1\ \text{limit temperature}}$=85°C, if temperature at the beginning of the cycle is "cool", or normal, that is, if the temperature is below or equal 27°C.

[0048] $T_{1\ \text{limit temperature}}$= 75°C, if temperature at the beginning of the cycle is "warm", that is, if the temperature is above 27°C.

Outdoor cycle:

[0049] $T_{1\ \text{limit temperature}}$=100°C, if temperature at the beginning of the cycle is "cool", or normal, that is, if the temperature is below or equal 27°C.

[0050] $T_{1\ \text{limit temperature}}$=90°C,if temperature at the beginning of the cycle is "warm", that is, if the temperature is above 27°C.

[0051] The second temperature limit is set higher than the first temperature limit ($T_{1\ \text{limit temperature}}$) in all the above examples. For example, the second temperature limit is set equal to

$$T_{2\ \text{limit temperature}} = 2°C + T_{1\ \text{limit temperature}};$$

or

$$T_{2\ \text{limit temperature}} = 5°\ C + T_{1\ \text{limit temperature}};$$

or

$$T_{2\ \text{limit temperature}} = 10°C + T_{1\ \text{limit temperature}}.$$

[0052] Most preferably,

$$T_{2\ \text{limit temperature}} = 5°\ C + T_{1\ \text{limit temperature}}.$$

[0053] The first temperature is applicable in a first condition of the laundry dryer and the second temperature is applicable in a second condition of the laundry dryer.

[0054] The first and second conditions are defined by a humidity value of the laundry. That is, the first limit temperature is selected, that is, is applicable, when the humidity of the laundry has a value among a first set of humidity values. Likewise, the second limit temperature is selected when the humidity of the laundry has a value among a second set of humidity values.

[0055] Preferably, the first and second set are distinct set, that is, the first and second set do not overlap. Therefore, if the humidity of the laundry belongs to the first set, then the first limit temperature is selected, if the humidity of the laundry belongs to the second set, then the second limit temperature is selected.

[0056] It is thus clear that the limit temperature may vary during the drying cycle, because the humidity of the laundry changes during the cycle. At the beginning of the drying cycle, the humidity of the laundry is rather high, while towards the end of the drying cycle, the humidity of the drying cycle is rather low. Therefore, for a time interval of the drying cycle, the set limit temperature may be the first one, while for another time interval, the set limit temperature for the compressor may be the second one.

[0057] Among the plurality, there might be drying programs for which the compressor limit temperature does not vary, that is, regardless of the value of the humidity the compressor limit temperature remains always the same, for example equal to either the first or the second limit temperature. However, the change in limit temperature of the compressor takes place at least for one program among the plurality.

[0058] According to the invention, two values are monitored during the drying cycle. A first value is relative to the humidity of the laundry. The humidity of the laundry may be sensed in many different ways. Any known method or sensor may be used. Each of these methods or sensors outputs a value which depends on the humidity of the laundry and may be translated in a humidity value. This humidity value may be a continuous value, that is, it may be an "analogic" value, or a step-like value, so that only a plurality of values is admitted.

[0059] Further, also the temperature of the compressor is monitored. Also in this case, any method or sensor used to monitor the temperature of the compressor can be used.

[0060] The limit temperature of the compressor is selected depending on the output of the humidity sensor. Thus, at any point in time during the drying cycle, the first or the second limit value of the temperature of the compressor may be selected.

[0061] The temperature of the compressor is monitored preferably during the whole drying cycle. A value indicative of this temperature is detected. If this temperature is too high, that is, it is higher than the first limit value if the first limit value has been selected, or it is higher than the second limit value, if the second limit value has been selected, then the compressor is either switched off, or the power supplied to the compressor is limited. For example, it is reduced.

[0062] The decision whether the power is reduced or cut off completely depends, among others, on the choice of a predetermined safe field are aof working for the compressor, which in turn imply the choice of the limit temperature for the compressor. In case for example the limit temperature coincides with the real boundary for a safe functioning of the compressor, when such a safety field is exceeded, it is preferred to cut the power supply completely (that is, the compressor is switched off). Alternatively, in a case where although the limit temperature is exceeded by the measured value, the real safety field probably is not exceeded yet, thus the power to the compressor could be reduced, because there is a "buffer" of safety field area before reaching the real boundary of the safety field of the compressor.

[0063] Otherwise, if the temperature of the compressor stays below the first or the second limit temperatures, the selected drying cycle continues as programmed.

[0064] In this way, the limit temperature during the drying cycle can be varied. The variation depends on the humidity value of the laundry.

[0065] This variation may help, among others, to raise the temperature inside the drum. An increase of temperature inside the drum may be achieved if first the water in the outdoor textile is preferably evaporated so that the heat provided by means of the heated process air can be used to increase the temperature of the laundry and not only to evaporate the water contained therein. It is known that the latent heat of water is relatively high and a substantial temperature increase can take place only when the phase change from liquid to vapour is preferably substantially over.

[0066] Thus preferably the change in limit temperature, for example from a lower first limit temperature to a higher second limit temperature, the humidity of the laundry should be relatively low.

[0067] Preferably, the invention, according to the above mentioned aspect, includes in combination or alternatively, one or more of the following characteristics. Preferably, the step of limiting power supply to or switching off said compressor if the measured temperature value is higher than the first or second limit temperature value includes limiting power supply to or switching off said compressor if any of the following takes place:

- the measured temperature remains above the first or second limit temperature value for a time interval longer than a time threshold;
- the measured temperature reaches or exceeds the first or second limit temperature value for a number of times above a number of times threshold;
- the difference between the measured temperature and the first or second limit temperature value exceeds a temperature difference threshold.

[0068] Preferably, the compressor is not switched off, or the power is not limited, immediately after a first data of the temperature value of the compressor above the first or second limiting value has been retrieved. Indeed, an occasional high temperature value might be due to an error in the measurement or to a transient event. Therefore, the switching off or power limitation takes place only when a "reasonably correct" over-temperature is detected. The chances of an error may be limited if the temperature is above the limit temperature for a given "long" time interval, or if the temperature becomes higher than the limit temperature several times, or if the measured temperature far exceed the limit temperature. A combination of the above can be used as well.

[0069] Preferably, sensing an operating parameter representative of the humidity of the laundry in the treating chamber includes one or more of:

- sensing an electrical conductivity of laundry within the treating chamber;
- sensing a capacitance of a volume comprising the laundry;
- measuring a value representative to a torque of a motor rotating the treating chamber;
- measuring a temperature of the process air leaving the treating chamber;
- measuring a temperature difference between a temperature of the process air entering the process chamber and a temperature of the process air leaving the chamber.

[0070] The humidity of the laundry present inside the drum can be detected using one (or more) of a plurality of different sensors. A combination of signals provided by different sensors can be used as well. The signal can be a direct humidity signal, for example coming from a sensor measuring a resistance of the laundry which is contacting one or more electrodes located within the drum. A higher degree of dryness corresponds to a higher electrical resistance. Alternatively or in addition, the temperature of the process air, either at the inlet or at the outlet of the drum, may give an indication of the degree of dryness of the laundry. Further, the temperature of the process air can also be measured at the exit of one of the heat exchanger of the heat pump. The temperature of the refrigerant might also give an indication of the humidity of the laundry in the drum. Further, measuring the level of water in a container where the condense water collects, or the temporal gradient of a level of water removed from the container, may also indicate whether the laundry is dry or not: if for example the level of water does not increase for a given time interval, reasonably it means that there is no more water to be removed from the textile in the drum and that the textile is thus substantially dry. The number of activations of a pump driving water removed from the textile contained in the drum to a container, may also be representative of the laundry humidity status within the drum. Further, one or more electrical parameters of the drum motor may also indicate the level of humidity of the textile, such as for example the absorbed power. The textile is heavier when water is contained therein and becomes lighter the dryer it is.

[0071] Preferably, said compressor includes a casing and an oil circuit in which oil flows, and wherein measuring a temperature value representative of the temperature of said compressor includes one or more of:

- measuring a temperature of said compressor casing;

- measuring a temperature of the refrigerant;
- measuring a temperature of the oil.

[0072] Several ways to measure the temperature of the compressor are possible as well. A "direct" measurement can be made for example measuring the temperature of the casing of the compressor. A more indirect measurement can be made measuring the temperature of the oil and/or of the refrigerant in the oil or refrigerant conduit, from which the temperature of the compressor can be evaluated.

[0073] Preferably, selecting the first limit temperature value includes selecting the first limit temperature value when the humidity of the laundry is below a first humidity threshold. Preferably, selecting the second limit temperature value includes selecting the second limit temperature value when the humidity of the laundry is above a second humidity threshold. More preferably, said first humidity threshold is equal to the second humidity threshold. Therefore, according to an embodiment, the first limit temperature is selected when the humidity of the laundry is below a certain threshold. That is to say, for "dry" laundry, the first limit temperature is selected. On the other hand, for "wet" laundry, that is, for humidity above another or the same threshold, the second limit temperature is selected.

[0074] Preferably the first limit temperature is higher than the second limit temperature. Thus, when the laundry is relatively dry, it is allowed to increase the limit temperature of the compressor, so that a higher temperature can be reached in the drum.

[0075] Preferably, the method includes the step of setting the first or second humidity threshold, the setting of the first or second humidity threshold being based on one or more of:

- the selected drying program;
- a weight of the laundry;
- a laundry fabric type or composition;
- duration of the selected drying program;
- an electrical parameter supplied to a motor rotating the treating chamber.

[0076] The first or second humidity threshold may be dependent on a plurality of parameters. Therefore, they might also differ depending on the selected drying program. Indeed, depending on the weight or on the type of textile, high temperatures could be reached with dryer or wetter laundry. Further, in short drying program a "very dry" laundry might not be obtained and therefore the threshold on humidity might be higher.

[0077] Preferably, the first or second humidity threshold is indicative of a humidity value of the laundry of about 1% or less. More preferably, the first limit temperature is used for laundry dryer than this threshold (i.e. humidity lower than 1%), while for wetter laundry, i.e. for laundry having a humidity higher than this threshold, the second limit temperature is used.

[0078] Preferably, the method includes:

- sensing a temperature of an environment external to said laundry drying appliance; and
- wherein the first or second limit temperature value is a function of said environment temperature.

[0079] The environment temperature may affect the functioning of the heat pump. Indeed, in hot external conditions, the compressor is already slightly overheated and it is more difficult to keep it cool. Thus, the limit temperature for example in hot external temperature may be lower than the limit temperature in standard or cool external conditions.

[0080] Preferably, said laundry appliance includes a fan adapted to blow air towards said compressor to cool the same and wherein selecting the first limit temperature value for a first plurality of values of the sensed operating parameter representative of the humidity of the laundry during the drying phase; or selecting the second limit temperature value for a second plurality of values of the sensed operating parameter representative of the humidity of the laundry during the drying phase, includes selecting a first or second temperature threshold, respectively, provided to

- activate and /or deactivate said fan;
- modify the airflow supplied by said fan.

[0081] A cooling fan unit or blower unit may be arranged close to the compressor to remove heat from the compressor, i.e. from the heat pump system, during a drying operation. The cooling air flow, which is an environment air flow in the embodiments, is actively driven by the cooling fan unit and is taking heat from the compressor. The fan unit comprises a blower or fan which is for example driven by a fan motor controlled by a control unit of the dryer. By transferring heat from the compressor, during a steady state of operation of the heat pump system, thermodynamic balance is achieved between the closed loops of the process air loop and refrigerant loop. Thereby the electrical power consumed by the compressor and which is not transformed to work power by compressing the refrigerant, is removed from the heat pump system, i.e. heat power of o the compressor is balanced in the - under ideal consideration - closed loops of refrigerant and process air. This means, in the steady state of the heat pump system in which maximum or nearly maximum operation condition or efficiency is achieved after the warm-up period, the heat deposited by the compressor in the refrigerant loop is balanced by the cooling fan unit to prevent overheating.

[0082] The fan of the compressor starts blowing air when a given temperature of the compressor is reached. Selecting a first limit temperature of the compressor and a second limit temperature of the compressor in a preferred embodiment also includes selecting a first and a second temperature at which the fan starts blowing air towards the compressor (or stops blowing air toward the compressor). Alternatively, a first and a second temperature may be selected at which the fan changes the airflow supplied towards the compressor (for example, providing more or less air). Thus the activation/deactivation temperature of the fan or the change-airflow temperature of the fan of the compressor may vary depending on whether the first or the second limit temperature has been selected.

[0083] Preferably, said plurality of drying programs includes an outdoor drying program for drying outdoor textiles which have a waterproof and breathable thin film material with a micro-porous structure, and at least an additional drying program for drying other types of textiles, wherein the outdoor drying program includes an outdoor drying phase having settings for a frequency of reversion of rotations of the drum and for the heat pump operation and the additional drying program comprises an additional drying phase having settings for a frequency of reversion of rotations of the drum and for the heat pump operation; and wherein:

- selecting a drying program among the plurality and starting its drying phase includes selecting the outdoor drying program; and
- reversing the rotation of the treating chamber in the outdoor drying program at a frequency lower than a frequency in the additional main drying phase at least for a portion of the drying phase.

[0084] Outdoor clothes or garments are herewith considered as those clothes which include a water repellent layer and/or a waterproof film or layer. Both waterproof and water repellent layers can be present in the same garment.

[0085] It is preferred to achieve a high enough temperature in the drum, that is, a temperature which has been found to be optimal for "proofing", that is, for re-activating at least partially the waterproof and/or water repellent layer of the outdoor textile. In order to reach a relatively high temperature in the outdoor first sub-phase, preferably the frequency of reversing the rotation of the drum is set lower than a frequency of reversing the rotation in the additional main drying phase.

[0086] Indeed, when rotation of the drum is reversed, a deceleration and a stop of the drum itself take place. Since a process air fan is generally driven by the same motor that drives the drum into rotation, these deceleration and interruption of motion consequently reduce the amount of process air flowing in the drum, lowering the temperature. For this reason, the number of reversions may influence the temperature of the textile present inside the drum. Keeping the number of reversions low, that is, lower than in the additional drying cycle present in the laundry dryer, may help to increase the overall temperature of the outdoor textile contained in the drum.

[0087] More preferably, the outdoor drying program includes a first drying sub-phase and a second-drying sub-phase, wherein:

- in the second drying sub-phase, reversing the rotation of the drum at a frequency lower than the drum rotation reversal frequency operated in the outdoor first sub-phase; and
- in the second drying sub-phase, selecting the first limit temperature of the compressor.

[0088] As mentioned, in a heat pump laundry drying machine, the laundry is dried at a relatively low temperature, e.g. the temperature of the textile present in the drum commonly does not exceed 50°C - 55°C. According to the method of the invention, in order to raise the temperature of the textile to a temperature which has been found to be optimal for "proofing", that is, for re-activating at least partially the waterproof and/or water repellent layer of the outdoor textile, first the water in the outdoor textile is preferably evaporated so that the heat provided by means of the heated process air can be used to increase the temperature of the outdoor textile and not only to evaporate the water contained therein. It is known that the latent heat of water is relatively high and a substantial temperature increase can take place only when the phase change from liquid to vapour is preferably substantially over.

[0089] Thus the outdoor first sub-phase is a phase of drying the outdoor textile till a first threshold of humidity, below which the "proofing" phase starts, which is the outdoor second sub-phase. In order to reach a relatively high temperature in the outdoor first sub-phase, preferably the frequency of reversing the rotation of the drum is set lower than a frequency of reversing the rotation in the additional main drying phase.

[0090] Keeping the number of reversions low, that is, lower than in the additional drying cycle present in the laundry dryer, may help to increase the overall temperature of the outdoor textile contained in the drum.

[0091] Further, when the humidity in the laundry is equal or below the first threshold, the outdoor second sub-phase starts. At the same time, the first limit temperature is selected, being the threshold for the beginning of the second sub-phase and for the selection of the first limit temperature the same.

[0092] In the second sub-phase, the heat introduced by process air is not only transformed in latent heat but may further increase the temperature of the textile itself. In order to reach a relatively high temperature for a heat pump dryer, that is, in order to reach a temperature preferably above 59°C in the outdoor second sub-phase, the air flow in the drum is to be "limited", that is, the air flow is reduced, when compared to the air flow present in the first sub-phase of the outdoor cycle or when compared to the airflow present in the additional main drying phase. A reduction in air flow allows a further heating up of the laundry present inside the drum, therefore achieving a "proofing phase" for the outdoor garments.

[0093] Preferably, said outdoor drying program includes a first drying sub-phase and a second-drying sub-phase, and wherein:

- in the outdoor second drying sub-phase, increasing a flow rate of the process air in the treating chamber with respect to a flow rate in the outdoor first drying sub-phase and with respect to a flow rate in the additional drying phase.

[0094] The comparison between flow rates is performed in the whole sub-phase, that is, the mean flow rate in the first second sub-phase per time unit should be compared with the mean flow rate of the first sub-phase per time unit or the mean flow rate in the additional main drying cycle per time unit. Indeed, there can be time interval(s) in the first sub-phase or in additional drying cycle in which the flow rate is at that instant lower than the flow rate in another different instant in the second sub-phase, for example when the fan in the first sub-phase or additional cycle is not rotating.

[0095] Therefore, the "mean" in the whole sub-phase, divided by the time of duration, should be compared.

[0096] Preferably, the laundry drying appliance includes an overload protector adapted to cut power to said compressor, said overload protector defining a tripping temperature, and wherein setting a first limit temperature value or setting a second limit temperature value representative of the limit temperature of the compressor includes setting a first or second limit temperature value lower than the tripping temperature of the overload protector.

[0097] In an embodiment, the laundry appliance of the invention includes an OLP. In the invention, the setting of a first sand second temperature, preferably lower than the OLP tripping temperature, prevents the OLP from tripping because the method interrupts or limit the flow of current to the compressor electric motor even before the activation of the OLP, that is, as soon as the temperature of the compressor gets higher than the first or second limit temperature, both lower than the tripping temperature of the OLP. In this way, the compressor can be cooled and restarted in a much quicker way than in cases in which the OLP interrupts the current flows. Further, in case the laundry appliance includes an OLP, the method and appliance of the invention act as a "double security", so that in case of a double failure of two components in a control circuit in the laundry appliance, the compressor still will not overheat, being shut down or having a more limited power either by the OLP or by the control of the invention.

[0098] On the other hand, also when the OLP is not present, the control of the invention forces the compressor to work always in the predetermined safety field of operation, because otherwise - outside such a field - the current to the compressor is cut off or reduced.

[0099] It is to be understood that the inclusion of an OLP is only one of the possible embodiments of the invention. The laundry appliance of the invention and/or operating according to the method of the invention could also be "OLP-free", that is the control of the invention allows removing the OLP from the laundry appliance and at the same time to guaranteeing the same safety level.

Brief description of the drawings

[0100] Reference is made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying figures, where:

- Fig. 1 is a perspective view of a drying machine according to the invention,
- Fig. 2 is a schematic overview of some components of the drying machine of Fig. 1,
- Fig. 3 is a block diagram depicting some of the components of the drying machine of Fig. 1 providing signals to a control unit and/or being controlled by the control unit,
- Fig. 4 is a plurality of graphs showing the temporal behaviour of several parameters of the drying machine of the invention during the outdoor drying cycle, and
- Fig. 5 is a flow chart of the method of the invention.

[0101] Fig. 1 shows a perspective outer appearance of an exemplary laundry drying machine 2. In this embodiment, the laundry drying machine is a laundry dryer only, but in alternative embodiments the dryer function according to the control method is implemented by a laundry washer-dryer in which the rotatable drum is arranged in a tub and which provides a washing arrangement including (for example) a detergent dispenser, a heater for heating wash liquid and a drain pump for draining out of the liquids.

[0102] As shown in Fig. 1, the laundry drying machine 2 has an outer housing 4 or cabinet including a front wall 6. Further, the laundry drying machine 2 includes a drum 16, also named treating chamber, where the laundry is positioned in order to be dried. At the front wall 6 a loading opening 8 is provided which is closed by a door 10, to access the drum 16. In the depicted embodiment, the laundry dryer is a front-loading laundry dryer having a horizontal drum rotation axis, but in alternative embodiments the drum may be inclined relative to the horizontal and vertical directions, or the dryer may be a vertical rotation axis dryer in which the drum rotates around a vertical axis and where top-loading is provided.

[0103] The laundry drying machine 2 has a control panel 12 arranged at the upper region of the front wall 6 and a condensate drawer 14 in which the condensate collected from drying is stored until removal by the user.

[0104] In the schematic diagram of components shown in Fig. 2, the drum 16 is arranged inside the housing 4, in which laundry 18 is received. The flow of process drying air A is indicated by the arrows, wherein the drying air A leaves the drum 16 at an outlet 24 and enters a process air channel 20 at the front channel 20c. By the front channel 20c the process drying air is guided through a fluff filter element 26 towards a second heat exchanger 34 and a first heat exchanger 32. The first and second heat exchangers 32, 34 are arranged in a battery channel 20a of the process air channel 20. The first heat exchanger 32 is a condenser which heats the process drying air and the second heat exchanger 34 is an evaporator which cools the process drying air for humidity removal in form of condensed water.

[0105] The process drying air leaving the first heat exchanger 32 is entering a rear channel 20b in which a drying process air fan 28 is arranged which conveys the drying air. The process air fan 28 is driven by a motor 30, which preferably at same time drives the rotation of the drum 16. However two different motors can be provided as well. The rotation of the drum 16 can be in one direction and also in the opposite direction, that is, reversing the rotation of the drum is possible in the laundry dryer operation, by opportunely driving the drum driving motor. In the depicted embodiment, a belt driven by the motor 30 is wound around the drum mantel for driving the fan. In the depicted embodiment, in which the single motor 30 drives the process air fan 28 as well as the drum 16, the drum and process air fan 28 are driven in a synchronous manner according to the gear ratio. Preferably, the speed of the drum and/or the process air fan is adjustable. Synchronous rotation of the drum includes a forward and backward rotation according to the motor forward and backward rotation, so that the direction of rotation of the drum can also be changed, from a forward to a backward or vice versa. As an example, the fan speed is identical to the motor speed as the process air fan is arranged on an axis of the motor 30, while via the belt the rotation of the motor is gear-reduced in an exemplary ratio of motor rotation speed/drum rotation speed of 50:1.

[0106] The first and second heat exchangers 32, 34 are part of a heat pump system 44 which further comprises an expansion device 38 and a compressor 36. In the heat pump system 44 a refrigerant loop 40 is formed, wherein the refrigerant pumped by the compressor 36 passes first the condenser 32, is forwarded to the expansion device 38 from where it expands into the second heat exchanger 34 and from where it is sucked into the compressor 36. Heat can be removed from the heat pump system (in addition to the heat deposited in the drying air and laundry for drying the laundry) by activating a compressor cooling fan 42 which provides a flow of cooling air from the outside of the cabinet 4 towards the outer surfaces of the compressor 36. The compressor cooling fan can be activated, that is, it can start blowing air against the compressor, for example above a given compressor temperature, and/or it may be deactivated, that is, it may stop blowing air against the compressor, for example below a given compressor temperature. In addition, the flow rate of the air moved by the compressor cooling fan 42 may be varied as well. After passing the compressor 36, the cooling air blown by the compressor cooling fan 42 is exhausted out of the cabinet 4.

[0107] The condensate that is formed at the evaporator 34 flows down and collects in a condensate collector 48. From the condensate collector 48 the condensate is pumped by a draining pump 50 through a drain conduit 52 into the condensate drawer 14 from where it can be removed by the user as mentioned above. Preferably, in the condensate collector 48, the level of water can be measured by means of a level sensor and/or the temporal gradient of a level of water removed from the outdoor textile to be dried and collected can be measured as well.

[0108] One or more of the following can be present in the laundry dryer as well: at the outlet 24 of the drum 16 a temperature sensor, for example a thermocouple, is provided which detects the outlet temperature To of the drying air. At the inlet 22 of the drum 16 another temperature sensor, for example a thermocouple, is provided which detects the inlet temperature Ti of the drying air. At the outlet of the condenser 32 a temperature sensor is provided which detects the refrigerant temperature Tr at this position. Inside the drum, electrodes may be present as well to determine the degree of humidity Hum of the laundry when it contacts the electrodes, for example by means of a resistivity measurement. Further, an environment temperature Tamb, that is, a temperature of the external surrounding of the laundry dryer is detected as well, by an additional sensor.

[0109] Fig. 3 is a block diagram of components of the dryer 2 that interact for enabling a control unit 60 to control the drying operations or programs. The control unit 60 has a memory 62 in which program parameters and look-up tables are stored such that the control unit, by retrieving corresponding data from the memory 62, can control different basic drying programs preferably under conditions as set by the user via option selectors at the control panel 12. The user can select a program cycle among a list of different program cycles. The selection can be performed by means of a selector (not shown in the drawings and standard per se) in the panel 12. Such user-settable options are for example: the type of drying cycle (cotton, delicate, outdoor, etc.), the final drying degree, the load of the laundry loaded by the user and inputted by him/her, the type of laundry, the duration of drying, an energy option, etc.

[0110] Among the cycles, an outdoor cycle is included, which is preferably selected when outdoor textile is introduced in the laundry 16.

[0111] Preferably, each cycle includes a main drying phase and a subsequent cooling phase. A pre-heating phase may be optionally included as well.

[0112] With now reference to figure 5, the dryer 2 is switched on in step S0 and a drying cycle is selected among those selectable by the selector S1.

[0113] In any selected drying cycle, the control unit 60 sends control signals to a drum motor inverter 64 and may receive operation parameters therefrom. The drum motor inverter 64 supplies the power to the motor 30 driving the drum 16 and the drying air fan 28. The control unit 60 may send control signals to a compressor motor inverter 66 and may receive operation parameters therefrom. The inverter 66 powers a compressor motor 67 for driving the compressor 36. Further, the control unit 60 may control the draining pump 50, a motor 68 for driving the compressor cooling air fan 42 and optionally, if a separate motor 70 is provided for the drying air fan 28, the drying air fan motor 70. The command signals sent by the control unit 60 depend on the specific settings of the specific program (drying cycle) selected.

[0114] For example, an outdoor program may be selected. However, the following applies to any drying program. Further, there might be programs for which the limit temperature of the compressor does not change with humidity. These programs are not described in the following.

[0115] The settings of the main drying cycle of the selected programs are stored in the memory 62 and they may relate to one or more of: a frequency of the reversion of rotations of the drum 16 during the main drying cycle, a speed of the process or drying air fan 28, the speed of the drum 16, the heat pump operation parameters.

[0116] Further, the environment temperature Tamb is detected.

[0117] At the beginning of the program S2, the humidity of the laundry is high due to the fact that the drying program has just started. Therefore, the humidity of the laundry is above a given threshold. The limit temperature for the compressor is thus set equal to a second limit temperature, which is valid for "wet" laundry. This second limit temperature may depend on Tamb. For example, the second limit temperature may be retrieved in a database in a memory of control unit 60.

[0118] The second limit temperature selection and/or the value of Tamb determine also a temperature level at which the compressor cooling fan 42 activates or deactivates. This temperature is for example T1 when the second limit temperature is selected. The value of the temperature level at which the cooling fan 42 activates or deactivates as a function of the limit temperature of the compressor is also saved in a memory of the control unit 60.

[0119] The selected drying cycle, after the above mentioned parameter setting, starts S2. Preferably, during the drying cycle, the control unit 60 monitors not only the signals coming from the motor 30 or its inverter, the compressor cooling fan 42, the compressor motor inverter, the process air fan 28, etc, but also it preferably further monitors the signals coming from one or more sensors, for example it may receive the signals from the sensors for the refrigerant temperature Tr, or for the inlet temperature Ti of the drying air, or for the outlet temperature To of the drying air, or the conductivity measurements Hum made by the electrodes in the drum 16, or the level of water in the condensate collector 48 and/or the temporal gradient of a level of water removed from the outdoor textile to be dried and collected can be measured as well, or relative to the number of activations of the draining pump 50 of the condensate collector 48.

[0120] The control unit 60 starts the outdoor main drying phase. In certain embodiment of the invention, previously to the main drying phase, additional phases may be present, for example an outdoor pre-heating phase. The outdoor main drying phase starts with the outdoor first sub-phase, step S4. The control unit 60 thus sends command signals to the drum motor inverter 64 so that a frequency F1 of reversion of rotations of the drum 16 is reduced with respect to an additional cycle present in the memory 62 of the control unit 60. Preferably, the frequency F1 is lower than the frequency of any other cycle stored in the memory 62 and selectable by the selector. For example, the frequency F1 is selected to be equal to 6 reversions per hour.

[0121] Further, one or more of the following can be performed. The number of revolutions per minute RPM1 of the motor driving the drum 16 in the outdoor first sub-phase may be increased with respect to the rpm present in the main drying phase of additional drying cycles present in the laundry machine by means of command signals sent by the control unit 60 to the drum motor inverter 64, so as to increase the flow rate of process air in the drum 16. For example, the RPM1 can be of about 2750 rpm or 2900 rpm. Alternatively or in addition, the control unit 60 may send command signals to the drying air fan motor 70, 30 to increase its velocity with respect to a velocity in the additional drying cycle selectable in the selector. Alternatively or in addition, the control unit 60 may send command signal to the compressor motor inverter 66 so as to increase the velocity of or the power supply to the motor 67 of the compressor 36 with respect to the velocity in the additional main drying cycle.

[0122] The first outdoor sub-phase then takes place with the settings above indicated.

[0123] The control unit 60 further monitors the signals coming from one or more sensors, for example it may receive the signals from the sensors for the refrigerant temperature Tr, or for the inlet temperature Ti of the drying air, or for the outlet temperature To of the drying air, or the conductivity measurements Hum made by the electrodes in the drum 16, or the level of water in the condensate collector 48. The control unit 60, therefore, constantly checks the humidity level of the laundry, and compare it with a threshold. For example, the threshold could for example a humidity below 1 %. If the humidity is below such a threshold S5, the control unit commands the drying machine 2 to enter the second sub-phase S6 of the outdoor main drying cycle. If the degree of humidity of the outdoor is not below this first threshold, then the outdoor first sub-phase continues.

[0124] In the outdoor second sub-phase, step S6, the control unit 60 thus sends command signals to the drum motor inverter 64 so that the frequency F2 of reversion of rotations of the drum 16 is reduced with respect to the outdoor first sub-phase. Preferably, the frequency F2 is lower than the frequency of any other program in the memory 62 selectable by the selector. For example, the frequency F2 is selected to be equal to zero.

[0125] In this second sub-phase, the compressor limit temperature is also changed, and now the compressor limit temperature is a first limit temperature which is higher than the second limit temperature present in the first sub-phase.

[0126] Alternatively or in addition, the control unit 60 may send command signals to the compressor cooling fan motor 68 in order to increase the temperature T1 at which the compressor cooling fan 42 activates/deactivates with respect to a temperature at which the compressor cooling fan activates/deactivates in the additional drying cycle selectable by the selector. The new temperature is called T2, which is higher than T1.

[0127] Further one or more of the following can be performed. The number of revolutions per minute RPM2 of the motor driving the drum 16 may be increased with respect to the outdoor first sub-phase by means of the control unit 60 sending command signals to drum motor inverter 64. This is particularly advantageous when the drum 16 and the fan 28 are driven by the same motor 30 because the flow rate of process air in the drum 16 is increased. For example the RPM can be of about 3000 rpm. Alternatively or in addition, the control unit 60 may send command signals to the drying air fan motor 70 to increase its velocity with respect to a velocity in the outdoor first sub-phase. Alternatively or in addition, the control unit 60 may send command signals to the compressor motor inverter 66 so as to increase the velocity of or the power supply to the motor of the compressor 36 with respect to the velocity of or the power supply to the motor of the compressor in the outdoor first sub-phase.

[0128] The second sub-phase of the outdoor main drying phase terminates when the outdoor sub-phae has lasted at least for a predetermined duration time t1set S7. This time interval can be constant, that is, in the memory 62 a fixed value of the t1set is present, or it may change. For example this duration time may be adjusted depending on the amount of time at which the outdoor textile inside the drum 16 exceeds a temperature threshold Tthr which is preferably of about 59°C. Thus, in this embodiment, the outdoor second sub-phase is terminated when a duration time t1set has elapsed, where t1set depends on how much time the temperature of the outdoor textile during the second sub-phase exceeds Tthr. In this way it is ensured that the outdoor textile is kept at a desired temperature for a minimum time. Therefore this t1set is constantly updated during the cycle and only the fraction of the time during which the temperature of the outdoor textile is above Tthr is considered. The second sub-phase therefore terminates when the t1set is elapsed thereby ensuring that the time during which the temperature of outdoor textiles is above Tthr is sufficiently long to re-activate (or "re-proof") the water repellent characteristics of outdoor textiles. Alternatively, it is sensed how many times the temperature during the second outdoor sub-phase goes below Tthr and after a given number of times in which the temperatures drop below Tthr, the second sub-phase is duration time is adjusted, in particular extended. Alternatively, this t1set can be set depending on the environment temperature and/or pressure conditions of the environment in which the drying machine 2 is located, for example at the beginning of the outdoor cycle several parameters of the environment are sensed and a corresponding fixed value of the t1set is selected, for example from a look-up table or curve of t1set vs. environment conditions present in the memory 62 of the control unit 60.

[0129] After this t1set has elapsed, then the outdoor second sub-phase is terminated and then a cooling phase may start, step S8, in order to cool the outdoor textile which has reached relatively high temperatures due to the re-activation phase (second sub-phase).

[0130] The cooling phase preferably lasts for more than 10 minutes.

[0131] The drying cycle then ends S9.

[0132] Figure 4 shows the temporal behaviour of several parameters during an outdoor cycle in a drying machine 2 of the invention. In the dryer 2, an outdoor cycle has been selected. In figure 4, the division between the main drying phase and the cooling phase has been depicted, as a first vertical line which divides the first and the second sub-phase of the main drying phase, and the division between the main drying phase and the cooling phase is shown as well as another vertical line. In the graph, only the behaviour over time of the curves has been depicted, in order to show the overall curve shape, the units used are arbitrary.

[0133] The depicted graphs represent the following signal (from top to bottom):

- temperature of the process air at drum INLET (signal from a thermocouple);
- temperature of the process air at drum OUTLET (signal from a thermocouple);

- electric power supply to the dryer (total amount);
- limit temperature of the compressor.

[0134] As clear from the graphs, the temperature in the outdoor first sub-phase constantly increases and in the outdoor second sub phase is substantially kept constant at a high value.
[0135] The limit temperature of the compressor is changed from the first to the second sub-phase.

Claims

1. A method to operate a laundry drying appliance (2) including:

    • a treating chamber (16) where laundry (18) is introduced and treated with process air;
    • a heat pump system (44) having a refrigerant circuit (40) in which a refrigerant can flow, said refrigerant circuit including a first heat exchanger (32) where the refrigerant is cooled off, a second heat exchanger (34) where the refrigerant is heated up, a compressor (36) to pressurize and circulate the refrigerant through the refrigerant circuit, and a pressure-lowering device (38); said first and/or second heat exchanger being apt to perform heat exchange between said refrigerant flowing in said refrigerant circuit and said process air;
    • a selector adapted to select alternatively one of a plurality of drying programs, each drying program including a main drying phase;

    said method comprising:

    • setting a first limit temperature value representative of the limit temperature of the compressor (36);
    • setting a second limit temperature value representative of the limit temperature of the compressor (36);
    • selecting a drying program among the plurality and starting its drying phase;
    • sensing an operating parameter representative of the humidity of the laundry in the treating chamber (16);
    • measuring a temperature value representative of the temperature of said compressor (36);
    • selecting the first limit temperature value for a first plurality of values of the sensed operating parameter representative of the humidity of the laundry (18) during the drying phase;
    • selecting the second limit temperature value for a second plurality of values of the sensed operating parameter representative of the humidity of the laundry (18) during the drying phase; and
    • limiting power supply to or switching off said compressor (36) if the measured temperature value is higher than the first or the second limit temperature value, depending on which one is selected when the measured temperature value exceeds the limit temperature value.

2. The method according to claim 1, wherein the step of limiting power supply to or switching off said compressor (36) if the measured temperature value is higher than the first or second limit temperature value includes limiting power supply to or switching off said compressor if any of the following takes place:

    • the measured temperature remains above the first or second limit temperature value for a time interval longer than a time threshold;
    • the measured temperature reaches or exceeds the first or second limit temperature value for a number of times above a number of times threshold;
    • the difference between the measured temperature and the first or second limit temperature value exceeds a temperature difference threshold.

3. The method according to claim 1 or 2, wherein sensing an operating parameter representative of the humidity of the laundry (18) in the treating chamber (16) includes one or more of:

    • sensing an electrical conductivity of laundry within the treating chamber (16);
    • sensing a capacitance of a volume comprising the laundry (18);
    • measuring a value representative to a torque of a motor rotating the treating chamber (16);
    • measuring a temperature of the process air leaving the treating chamber (16);
    • measuring a temperature difference between a temperature of the process air entering the treating chamber and a temperature of the process air leaving the treating chamber (16).

4. The method according to any of the preceding claims, wherein said compressor (36) includes a casing and an oil

circuit in which oil flows, and wherein measuring a temperature value representative of the temperature of said compressor (36) includes one or more of:

- measuring a temperature of said compressor casing;
- measuring a temperature of the refrigerant;
- measuring a temperature of the oil.

5. The method according to any of the preceding claims, wherein selecting the first limit temperature value includes selecting the first limit temperature value when the humidity of the laundry is below a first humidity threshold.

6. The method according to any of the preceding claims, wherein selecting the second limit temperature value includes selecting the second limit temperature value when the humidity of the laundry (18) is above a second humidity threshold.

7. The method according to claim 5 and 6, wherein said first humidity threshold is equal to the second humidity threshold.

8. The method according to any of claims 5 - 7, including the step of setting the first or second humidity threshold, the setting of the first or second humidity threshold being based on one or more of:

- the selected drying program;
- a weight of the laundry (18);
- a laundry fabric type or composition;
- duration of the selected drying program;
- an electrical parameter supplied to a motor rotating the treating chamber (16).

9. The method according to any of the preceding claims, wherein the first or second humidity threshold is indicative of a humidity value of the laundry of about 1% or less.

10. The method according to any of the preceding claims, including:

- sensing a temperature of an environment external to said laundry drying appliance (2); and
- wherein first or second limit temperature value is a function of said environment temperature.

11. The method according to any of the preceding claims, wherein said laundry drying appliance (2) includes a fan (42) adapted to blow air towards said compressor (36) to cool the same and wherein selecting the first limit temperature value for a first plurality of values of the sensed operating parameter representative of the humidity of the laundry during the drying phase; or selecting the second limit temperature value for a second plurality of values of the sensed operating parameter representative of the humidity of the laundry during the drying phase, includes selecting a first or second temperature threshold, respectively, provided to

- activate and /or deactivate said fan (42);
- modify the airflow supplied by said fan (42).

12. The method according to any of the preceding claims, wherein said plurality of drying programs includes an outdoor drying program for drying outdoor textiles which have a waterproof and breathable thin film material with a micro-porous structure, and at least an additional drying program for drying other types of textiles, wherein the outdoor drying program includes an outdoor drying phase having settings for a frequency of reversion of rotations of the drum and for the heat pump operation and the additional drying program comprises an additional drying phase having settings for a frequency of reversion of rotations of the drum and for the heat pump operation; and wherein:

- selecting a drying program among the plurality and starting its drying phase includes selecting the outdoor drying program; and
- reversing the rotation of the treating chamber in the outdoor drying program at a frequency lower than a frequency in the additional main drying phase at least for a portion of the drying phase.

13. The method according to claim 12, wherein said outdoor drying program includes a first drying sub-phase and a second-drying sub-phase, including:

- in the second drying sub-phase, reversing the rotation of the drum at a frequency (F2) lower than the drum rotation reversal frequency (F1) operated in the outdoor first sub-phase; and
- in the second drying sub-phase, selecting the first limit temperature of the compressor (36).

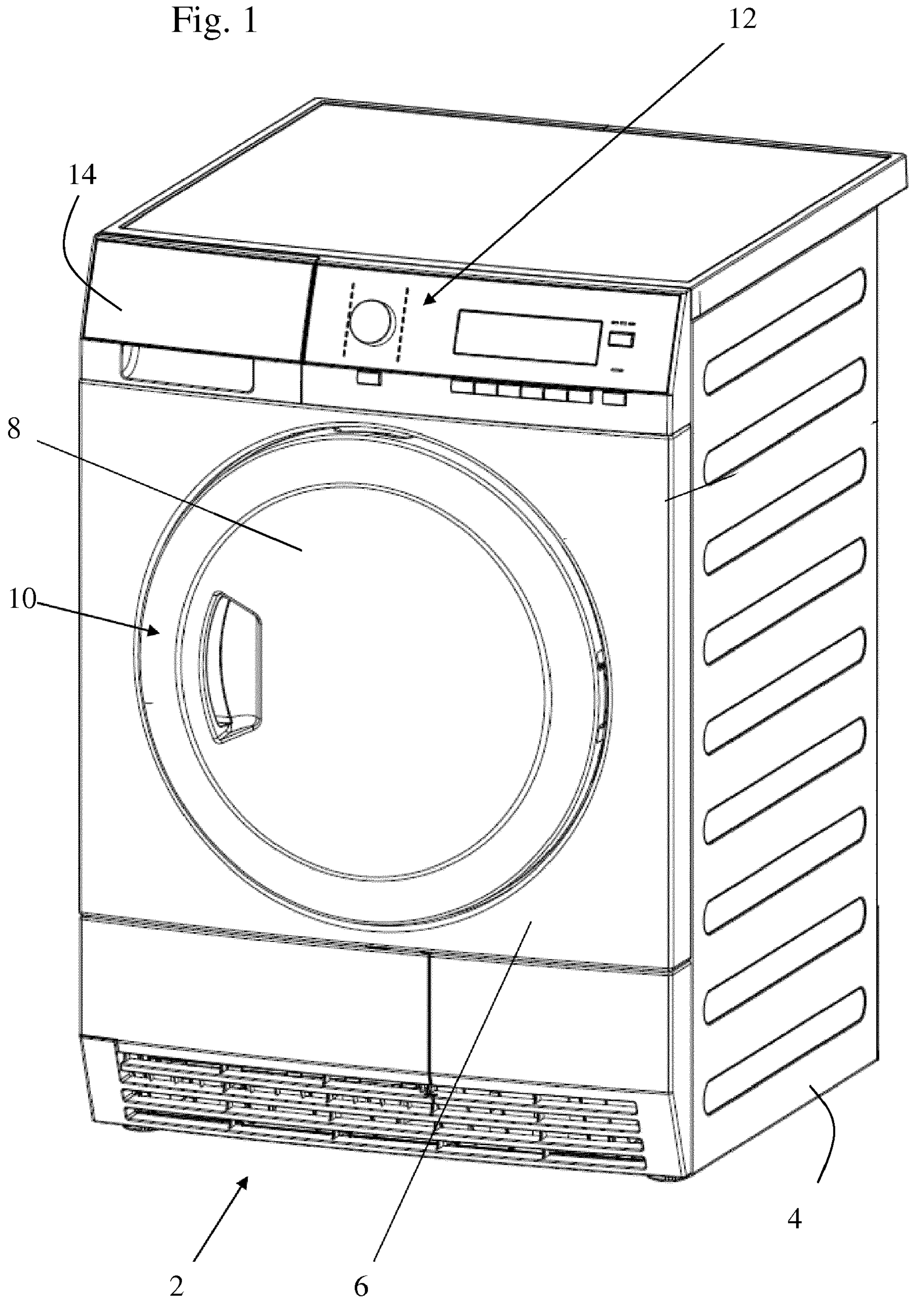
14. The method according to claim 12 or 13, wherein said outdoor drying program includes a first drying sub-phase and a second-drying sub-phase, and including:

- in the outdoor second drying sub-phase, increasing a flow rate of the process air in the treating chamber with respect to a flow rate in the outdoor first drying sub-phase and with respect to a flow rate in the additional drying phase.

15. The method according to any of the preceding claims, wherein the laundry drying appliance (2) includes an overload protector adapted to cut power to said compressor, said overload protector defining a tripping temperature, and wherein setting a first limit temperature value or setting a second limit temperature value representative of the limit temperature of the compressor includes setting a first or second limit temperature value lower than the tripping temperature of the overload protector.

16. A laundry drying appliance (2) having a control unit (60) programmed for implementing the method according to any claim 1 to 15.

Fig. 1



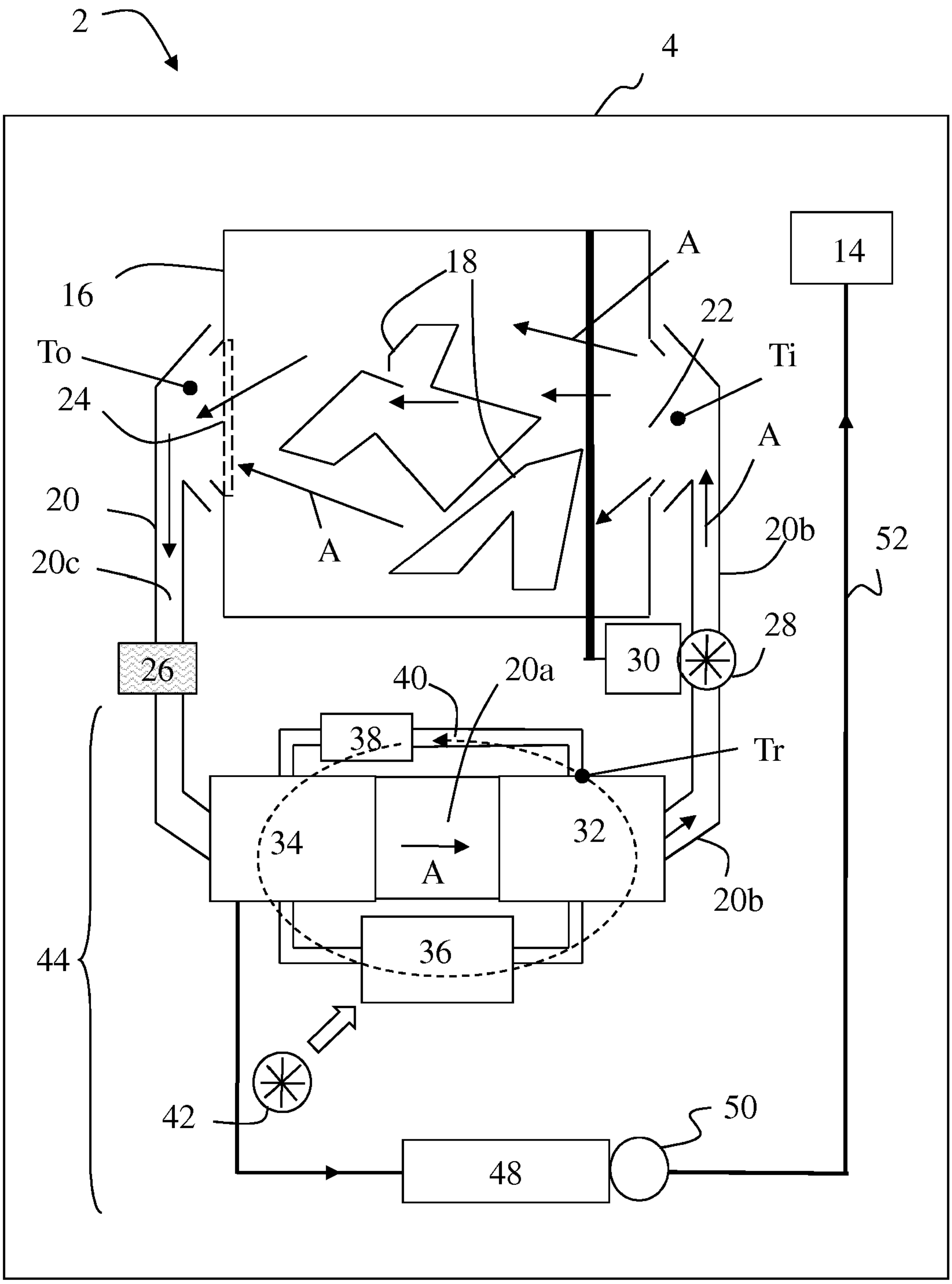
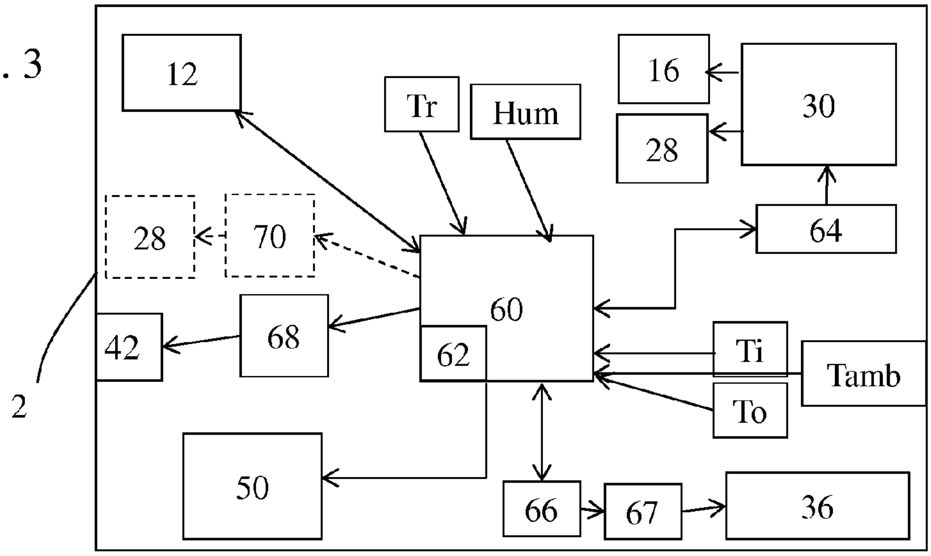

2
4
14
A
18
16
22
To
Ti
24
A
20
A
20b
52
20c
30
28
26
40
20a
38
Tr
34
32
A
20b
44
36
42
50
48

Fig. 2

Fig. 3


12
Tr
Hum
16
28
30
28
70
64
60
42
68
62
Ti
Tamb
To
2
50
66
67
36

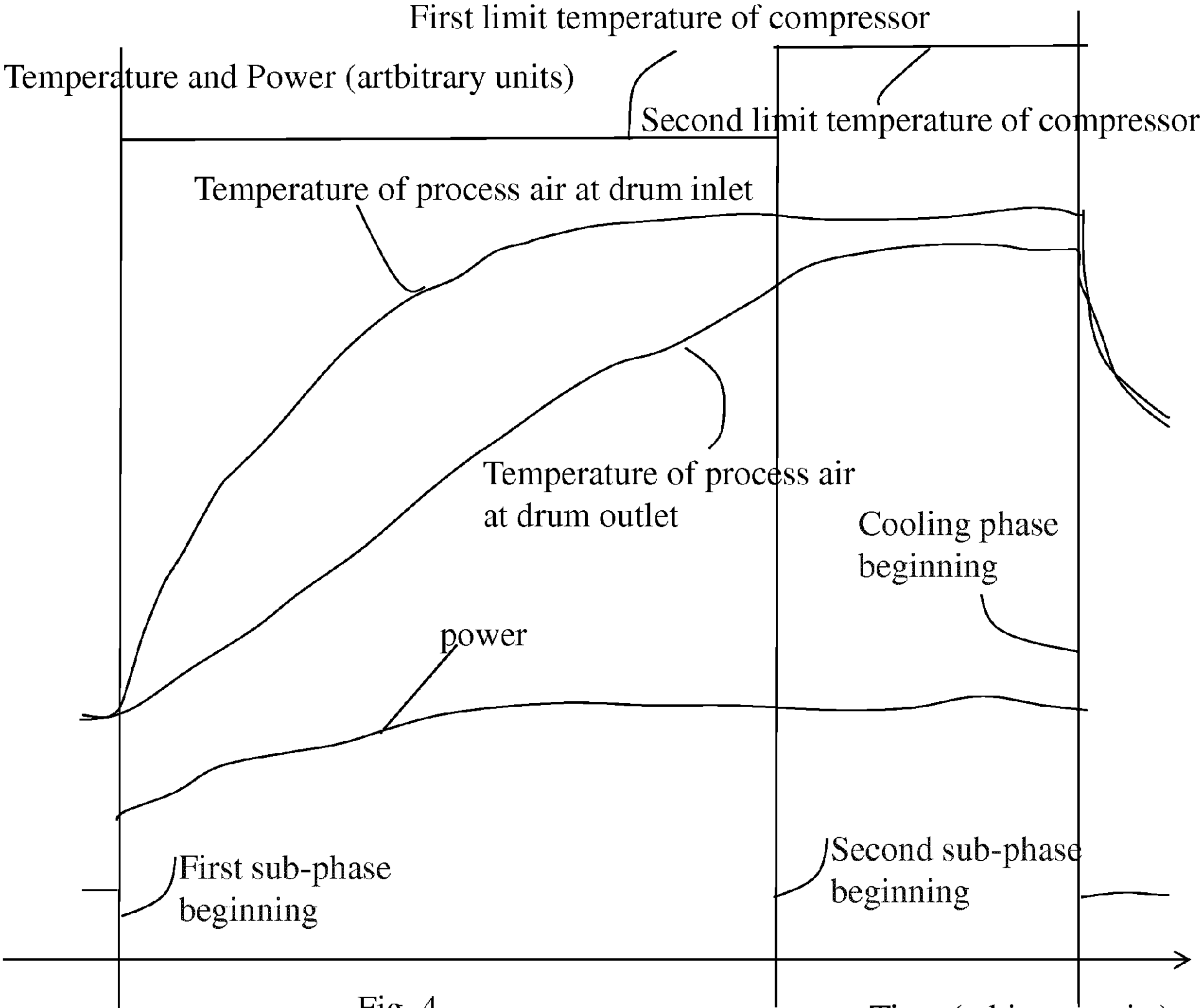
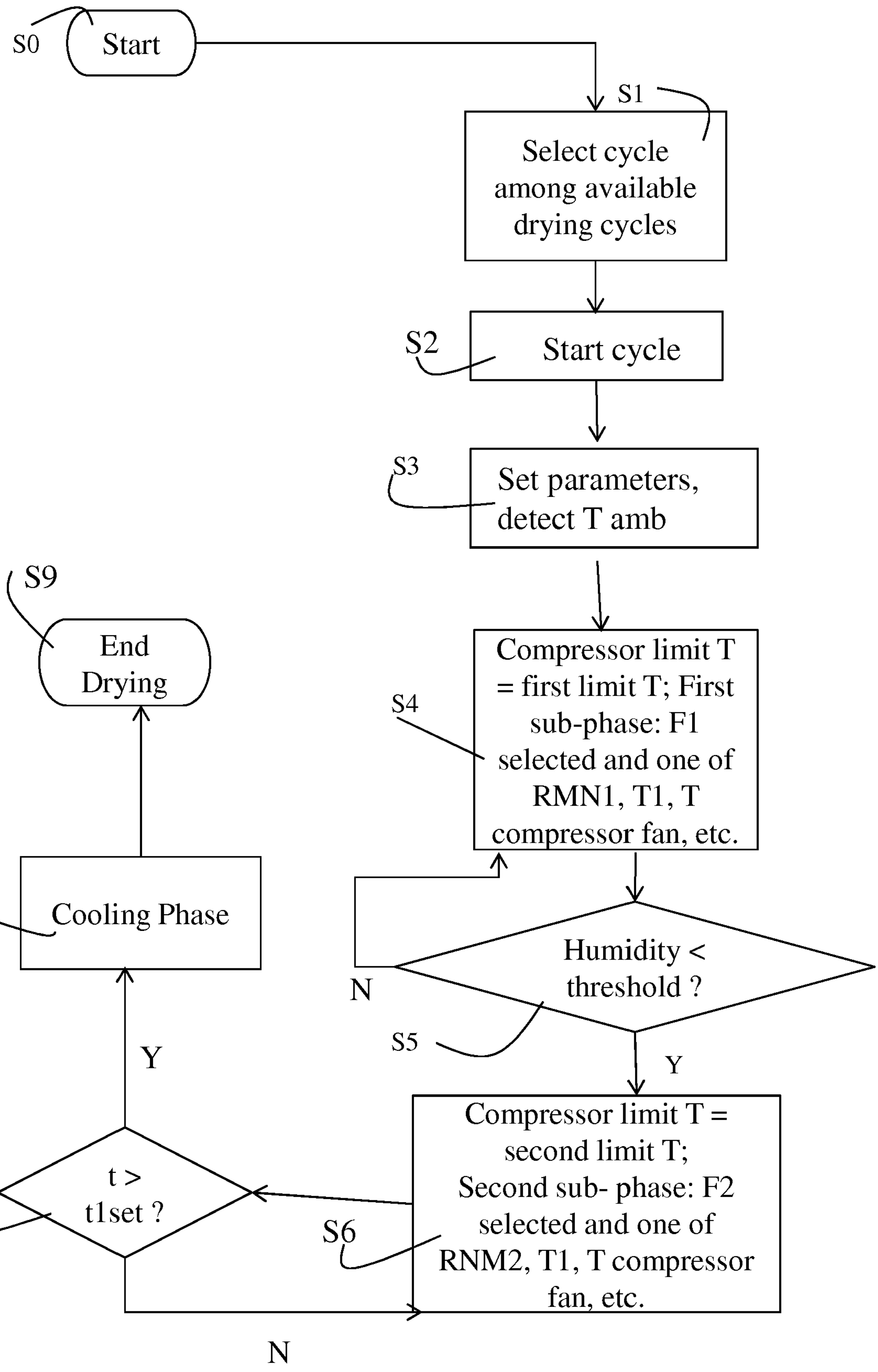

First limit temperature of compressor
Temperature and Power (artbitrary units)
Second limit temperature of compressor
Temperature of process air at drum inlet
Temperature of process air
at drum outlet
Cooling phase
beginning
power
First sub-phase
beginning
Second sub-phase
beginning
Time (arbitrary units)

Fig. 4

Fig. 5


S0
Start
S1
Select cycle among available drying cycles
S2
Start cycle
S3
Set parameters, detect T amb
S4
Compressor limit T = first limit T; First sub-phase: F1 selected and one of RMN1, T1, T compressor fan, etc.
Humidity < threshold ?
N
S5
Y
Compressor limit T = second limit T; Second sub- phase: F2 selected and one of RNM2, T1, T compressor fan, etc.
S6
t > t1set ?
S7
N
Y
S8
Cooling Phase
S9
End Drying

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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 0175

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	EP 3 124 678 A1 (ELECTROLUX APPLIANCES AB [SE]) 1 February 2017 (2017-02-01) * paragraph [0006] - paragraph [0089]; figures *	1 2-16	INV. D06F58/00 D06F58/28
A	EP 3 187 652 A1 (ELECTROLUX APPLIANCES AB [SE]) 5 July 2017 (2017-07-05) * paragraph [0007] - paragraph [0057] * * paragraph [0064]; figures *	1-16	
A	WO 2015/078523 A1 (ARCELIK AS [TR]) 4 June 2015 (2015-06-04) * paragraph [0010] - paragraph [0040]; claims; figures *	1-16	

TECHNICAL FIELDS SEARCHED (IPC)

D06F

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	28 September 2017	Beckman, Anja

CATEGORY OF CITED DOCUMENTS

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28-09-2017

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EP 3124678 A1	01-02-2017	AU 2016204990 A1	16-02-2017
		CN 106400430 A	15-02-2017
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EP 3187652 A1	05-07-2017	NONE	
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