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(54) **Method for operating a laundry treatment apparatus and laundry treatment apparatus**

(57) The invention relates to a method for operating a laundry treatment apparatus, in particular a heat pump tumble dryer or a washing machine having a drying function, and to a treatment apparatus, wherein the apparatus comprises: a heat pump system and a laundry treatment chamber for treating laundry using process air, and wherein the heat pump system comprises: a first heat exchanger for heating the refrigerant fluid, a second heat exchanger for cooling a refrigerant fluid, an expansion device, a refrigerant loop, in which the refrigerant fluid is circulated through the first and second heat exchangers and the expansion device, a variable speed and/or variable power compressor for circulating the refrigerant fluid through the refrigerant loop, and a cooling air blower

for conveying cooling air to the compressor. The method comprises: monitoring a first temperature signal (T1) and activating the cooling air blower or increasing the conveying capacity of the cooling air blower when the first temperature signal exceeds a first temperature level (TL1), and monitoring the first temperature signal (T1) or a second temperature signal (T2) and reducing the compressor speed and/or compressor power when the first temperature signal (T1) or the second temperature signal (T2) exceeds a second temperature level (TL2), wherein, if it is the first temperature signal (T1) which is monitored for exceeding the second temperature level (TL2), the second temperature level (TL2) is higher than the first temperature level (TL1).

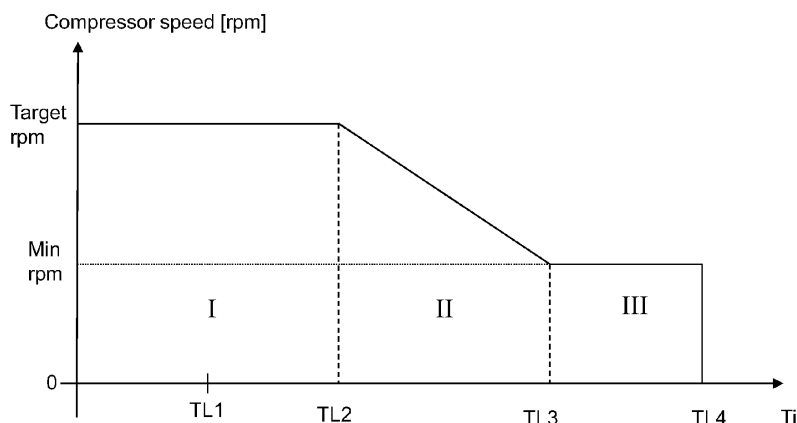


Fig. 4

Description

[0001] The invention relates to a method for operating a laundry treatment apparatus and a laundry treatment apparatus having a heat pump system.

[0002] EP 2 455 526 A1 discloses a heat pump tumble dryer with a variable speed compressor. An operating or control unit for controlling a drying operation of the heat pump tumble dryer comprises a power sensor for measuring a power input to operate the compressor and a temperature sensor for measuring a temperature of a refrigerant of the heat pump system. The compressor is powered with a predetermined power input when the refrigerant temperature is lower than a predetermined threshold temperature. The compressor is operated at a lower power input than the predetermined power input to keep the temperature at the predetermined threshold temperature until a drying operation or cycle is completed. According to an embodiment a cooling unit comprising a blower is provided to cool the heat pump system, including the compressor, when the temperature exceeds the predetermined threshold temperature.

[0003] It is an object of the invention to provide a method for operating a laundry treatment apparatus having a heat pump system and a laundry treatment apparatus which provide an improved drying performance/operation.

[0004] The invention is defined in claim 1, 13 and 14, respectively.

[0005] Particular embodiments are set out in the dependent claims.

[0006] According to claim 1, a method for operating a laundry treatment apparatus is provided, wherein the treatment apparatus may be a heat pump tumble dryer or a washing machine having a drying function. The apparatus comprises a heat pump system and a laundry treatment chamber (e.g. laundry drum) for treating laundry using process air. The heat pump system comprises a first heat exchanger (evaporator) for heating a refrigerant fluid, a second heat exchanger (condenser) for cooling the refrigerant fluid, an expansion device and a refrigerant loop, in which the refrigerant fluid is circulated through the first and second heat exchangers and the expansion device. A compressor is provided which is adapted to operate at variable speed and additionally or alternatively at variable power for circulating the refrigerant fluid through the refrigerant loop. The treatment apparatus further comprises a cooling air blower or cooling fan for conveying cooling air to the compressor, i.e. the cooling air blower is adapted to cool the compressor during a drying operation of the treatment apparatus. In other words, the blower removes heat from the heat pump system e.g. to provide that after a warm-up period at the beginning of a drying cycle the energy-efficient steady state or targeted operation state of the heat pump system is maintained during the drying operation.

[0007] The method for operating the laundry treatment apparatus comprises monitoring a first temperature sig-

nal and activating the cooling air blower or increasing the conveying capacity of the cooling air blower when the first temperature signal exceeds a first temperature level, i.e. a first threshold temperature. For example the treatment apparatus may have a first temperature sensor arranged in the cabinet or housing of the apparatus for detecting the first temperature signal. The control unit may be adapted to increase the conveying capacity of the cooling air blower by increasing a fan rotation speed and/or a fan duty cycle ratio.

[0008] According to one solution the first temperature signal is further monitored (i.e. after the first temperature level is exceeded), wherein the compressor speed and/or compressor power is reduced when the first temperature signal exceeds a second (predetermined) temperature level or threshold. When the first temperature signal, e.g. of the first temperature sensor, is monitored for exceeding the first as well as the second temperature level, then the second temperature level is higher than the first temperature level. I.e. it is provided that the blower is started or the blower speed is increased before the compressor speed or power is reduced.

[0009] According to an alternative solution a second temperature signal may be monitored, e.g. a temperature signal from a different position in the apparatus than the first temperature signal, wherein the compressor speed and/or compressor power is reduced when the second temperature signal exceeds a second temperature level. E.g. when the first and second temperature is detected at different positions within the apparatus cabinet, the laundry dryer apparatus comprises a second temperature sensor arranged in the housing of the apparatus. I.e. the second temperature sensor is arranged at a position different of the position of the first temperature sensor. When providing two temperature sensors for determining whether the first and second temperature level is exceeded, then it is possible that the first temperature level is higher than the second temperature level. However, the first and second temperature levels or thresholds are preferably set such that it is provided that the first measure or step to remove excess heat from the heat pump system is activating the cooling air blower before the compressor power or speed is reduced in a second step.

[0010] The decision whether a second temperature level is exceeded may be determined on either the first temperature signal (of the first temperature sensor) or the second temperature signal (of the second temperature sensor) or a combination thereof. For example the second temperature level, i.e. the second threshold temperature, may be dependent on the first and second temperature signal (i.e. on signals of two or more temperature sensors at different positions in the housing of the treatment apparatus). For example the second temperature level may be a mean value of the first and second temperature signal. However for both above described solutions the decision whether the first temperature level is exceeded may only be determined in dependency of the first temperature signal or sensor, respectively.

[0011] For example the first temperature signal and the second temperature signal which are used to determine whether the first or second temperature level are exceeded may be a condenser output temperature, an electronic board (e.g. a PCB or a board as described in more detail below) temperature, temperatures of the heat pump system, e.g. a refrigerant temperature at the compressor output or process air flow temperature, or a combination of these temperatures.

[0012] Summarizing both above described solutions have the common feature that if the first temperature signal exceeds the first temperature level, a first step for removing excess heat from compressor (i.e. the heat pump system) is activating the cooling blower or increasing its cooling capacity, e.g. by increasing a fan rotation speed and/or a fan duty cycle ratio. Only if a second temperature level is exceeded, the compressor speed or power is reduced.

[0013] When reducing compressor speed or power more time is required to dry a laundry load, i.e. the duration of a drying cycle is increased. In other words the drying performance of the treatment apparatus deteriorates. The above described method prevents or at least minimizes such a deterioration of the drying performance by providing that reduction of compressor speed or power is minimized. I.e. in that as a first measure or step a blower is activated to remove excess heat from the compressor before in a second step the compressor power or speed is reduced. With respect to the method disclosed in EP 2 455 526 A1 the drying performance of a treatment apparatus operating according to the above described method is improved, in particular with respect to drying cycle duration.

[0014] It is preferred that if the first temperature signal or the second temperature signal exceeds the second temperature level, the compressor speed and/or the compressor power is reduced in dependency of the first temperature signal or the second temperature signal or in dependency of a combination of the first and second temperature signal. For example a linear reduction or a progressive reduction of the compressor speed or power is provided with a temperature increase of the first or second temperature signal. Alternatively a linear or progressive reduction is provided in dependency of a combination of the first and second temperature, e.g. when the second temperature level is dependent on the first and second temperature signals as described above (e.g. dependent on a mean value of first and second temperature signals). Thus the compressor speed is smoothly adapted to requirements of the drying operation which extends a service life of the compressor.

[0015] Preferably the compressor speed and/or compressor power is reduced until the compressor speed and/or compressor power reaches a predefined minimum value and/or until the first temperature signal or the second temperature signal exceeds a third temperature level. By operating the compressor at a minimum speed value and/or minimum power value a reliable operation

of the compressor is provided, while at the same time heat input from the (operating) compressor into the heat pump system is minimized. A minimum value for compressor speed and/or power is determined by the minimum speed/power necessary for effectively operating the compressor and/or for operating the compressor without damage.

[0016] The compressor power may be maintained constant until or up to a temperature where the first temperature signal or the second temperature signal reaches the first or second temperature level from the lower temperature side and when the first temperature signal or the second temperature signal exceeds the first or second temperature level the compressor speed is controlled in dependency of the first temperature signal or second temperature signal. In other words a combined power and speed control is applied to the compressor, i.e. up to the first or second temperature level a power target control is applied and when the first or second temperature level is exceeded a speed control is applied. For example the compressor speed is decreased when the first or second temperature signal increases as described above. Preferably the compressor speed linearly decreases with increasing (first and/or second) temperature signal.

[0017] According to an embodiment, when the first temperature signal or the second temperature signal exceeds the second temperature level, the compressor speed and the compressor power are reduced in dependency of the first temperature signal or second temperature signal, wherein over a first temperature range above the second temperature level the compressor speed is controlled in dependency of the first temperature signal or second temperature signal, and over a second temperature range, which is above the second temperature level and which is different of the first temperature range, the compressor power is controlled in dependency of the first temperature signal or second temperature signal. I.e. above the second temperature level two temperature ranges are provided which do not overlap, wherein in one temperature range power control is applied to the compressor and in the other temperature range speed control.

[0018] Preferably the temporal gradient or averaged temporal gradient of the change of the compressor speed and/or compressor power is below a predefined maximum gradient. I.e. sudden operation changes for operating the compressor are avoided, thus increasing service life of the compressor. Different gradients or gradient values may be applied for the increase and decrease of the compressor speed and/or power, wherein the different gradients provide a smooth operation of the compressor during changing compressor speed and/or power.

[0019] A predefined maximum gradient and/or the gradient as such may be depending on one or more of the following: an operation state of the laundry treatment apparatus, an operation state of the heat pump system, a program cycle, a selected program for laundry treatment,

a third temperature signal of the heat pump system, or a user input or selection input by a user of the laundry treatment apparatus. For example a user selection may be a selected cycle, a selected cycle option or drying program type (e.g. fast-drying or night operation (silent and slow mode), a residual laundry humidity, final humidity or drying level (e.g. extra-dry or iron-aid having a higher residual laundry humidity), a laundry amount (input by user or detected by a weight sensor of the treatment apparatus (e.g. laundry dryer), a laundry type (e.g. cotton, wool etc.), an energy-saving option, a drying process time-saving option (e.g. eco-mode, rapid), and the laundry amount.

[0020] Preferably the method comprises monitoring the first temperature signal or the second temperature signal and switching off the compressor (i) if the first temperature signal or the second temperature signal exceeds a fourth temperature level, and/or (ii) if the first temperature signal or the second temperature signal exceeds the third temperature level or a temperature level higher than the third temperature level for a predefined time period. I.e. either the compressor is switched-off immediately after exceeding a predetermined (fourth) temperature level, or the compressor is switched-off after exceeding the third or a higher (e.g. fourth) temperature level for a predefined time. Thereby it is avoided that the compressor is switched-off and -on repeatedly for short-periods, when the (third or fourth) temperature level is only exceeded for short period(s). Preferably the fourth temperature level is higher than the third temperature level. This embodiment provides a safety switch-off function to prevent a damage of the compressor or heat pump system during a drying operation.

[0021] In a preferred embodiment, when the compressor was switched-off, the compressor is switched-on again under one or more of the following conditions: (i) the compressor was switched-off for a predetermined time period, and/or (ii) the first temperature signal or second temperature signal falls below a fifth temperature level. Preferably the fifth temperature level is lower than the fourth temperature level. Thereby it is provided that the compressor is switched-on at a safe temperature level, i.e. below the switch-off temperature level. Preferably or consequently the fifth temperature level is lower than the third temperature level.

[0022] It is preferred that when the second temperature signal exceeding the second temperature level is monitored and the second temperature signal exceeds the second temperature level, the first temperature signal exceeds the first temperature level, or the reduction of the compressor speed and/or compressor power is suppressed as long as the first temperature signal does not exceed the first temperature level. Thus it is provided that the first temperature signal has to exceed the first temperature level before the compressor speed and/or power is reduced, i.e. the first temperature level has a higher weight than the second temperature level. Thereby it is provided that the cooling air blower is in any case activated before compressor speed or power is reduced.

[0023] Preferably the level of at least one of the first, the second, the third, the fourth and the fifth temperature level is depending on one or more of the following: an operation state of the laundry treatment apparatus, an operation state of the heat pump system, a program cycle, a selected program for laundry treatment, a third temperature signal of the heat pump system, and a user input or selection input by a user of the laundry treatment apparatus.

[0024] The blower may be switched off, if the first temperature signal or the second temperature signal falls below a sixth temperature level. Alternatively the blower conveyance capacity may be reduced if the first temperature signal or the second temperature signal is decreasing. Preferably the sixth temperature level is lower than the first temperature level, such that it is provided that the compressor is cooled down to a safe operating temperature level below the first temperature level before the blower is switched-off. It is preferred that the blower conveyance capacity (i.e. blower speed) is reduced only to a minimum value after which the blower is switched off. Thereby it is avoided that the blower is operated at inefficient speeds or conveyance capacities.

[0025] The first temperature signal or the second temperature signal may be a signal corresponding to a temperature or corresponding to a refrigerant fluid temperature detected at one of the following positions in the heat pump system or is a combined signal detected on at least two of the following positions in the heat pump system or within the cabinet of the laundry treatment apparatus: a refrigerant fluid outlet position at the first or second heat exchanger, an electronic board or inverter position of an electronic board or inverter controlling a component of the heat pump system, an electronic board or inverter position of an electronic board or inverter controlling a motor for driving the laundry treatment chamber being a drum, a refrigerant fluid outlet position at the compressor, the compressor, the expansion device or a position in the air flow of the process air.

[0026] According to claim 13 a laundry treatment apparatus is provided, in particular heat pump tumble dryer or washing machine having a drying function, wherein the apparatus comprises a heat pump system, a control unit adapted to control the operation of the heat pump system and a laundry treatment chamber for treating laundry using process air, and wherein the heat pump system comprises: a first heat exchanger for cooling a refrigerant fluid, a second heat exchanger for heating the refrigerant fluid, an expansion device, a refrigerant loop, in which the refrigerant fluid is circulated through the first and second heat exchangers and the expansion device, and a compressor for circulating the refrigerant fluid through the refrigerant loop, wherein the compressor is adapted to be operated at different compressor speeds and/or different compressor powers under the control of the control. A control unit of the treatment apparatus is adapted to implement a method according to any of the above described embodiments. In contrast to above de-

scribed embodiments the treatment apparatus does not necessarily comprise a cooling air blower. I.e. the above described methods for operating a treatment apparatus may be implemented in this treatment apparatus with the exception features relating to operating a cooling air blower. In particular a compressor speed control and/or power control may be implemented as described above.

[0027] According to claim 14, a laundry treatment apparatus is provided, in particular heat pump tumble dryer or washing machine having a drying function, wherein the apparatus comprises a heat pump system, a control unit adapted to control the operation of the heat pump system and a laundry treatment chamber for treating laundry using process air, wherein the heat pump system comprises: a first heat exchanger for cooling a refrigerant fluid, a second heat exchanger for heating the refrigerant fluid, an expansion device, a refrigerant loop, in which the refrigerant fluid is circulated through the first and second heat exchangers and the expansion device, and a compressor for circulating the refrigerant fluid through the refrigerant loop, wherein the compressor is adapted to be operated at different compressor speeds and/or different compressor powers under the control of the control unit, and wherein the apparatus further comprises: a cooling air blower for conveying cooling air to the compressor, a first temperature sensor for detecting a first temperature at a first position in the cabinet of the laundry treatment apparatus and for providing a first temperature signal, and optionally a second temperature sensor for detecting a second temperature at a second position in the cabinet of the laundry treatment apparatus and for providing a second temperature signal, wherein the second position is different of the first position. The control unit is adapted to operate the cooling air blower in dependency of the first temperature signal. E.g. the control unit is adapted to activate the blower if the first temperature signal exceeds a first temperature level. Further the control unit is adapted to control the speed and/or the power of the compressor in dependency of the first temperature signal or the second temperature signal. If the compressor is operated in dependency of the first temperature signal, the control unit starts to change or changes the speed and/or power of the compressor at a second level of the first temperature signal which is higher than the first level of the first temperature signal at which the control unit starts or activates the cooling air blower. I.e. as described above in relation to the method for operating a treatment apparatus, it is provided that as a first measure for removing heat from the heat pump system (i.e. compressor) the blower is activated and only in a second step the compressor speed and/or power is changed, e.g. reduced. Preferably the control unit is adapted to control the treatment apparatus according to any of the above described embodiments of the method for operating a treatment apparatus.

[0028] Preferably the control unit is adapted to operate the compressor at maximum speed and/or power, if the first temperature signal or the second temperature signal

or a combination of the first and second temperature signal is below a second temperature level, and/or the control unit is adapted to control the reduction of the compressor speed and/or power, if the first temperature signal or the second temperature signal or a combination of the first and second temperature signal exceeds a second temperature level.

[0029] Method according to any of the above described embodiments for operating a treatment apparatus or laundry treatment apparatus according to any according to any of the above described embodiments, wherein the laundry treatment apparatus comprises a first temperature sensor for providing the first temperature signal or a first temperature sensor for providing the first temperature signal and a second temperature sensor for providing the second temperature signal, wherein the first and second temperature sensors are arranged at different positions within the cabinet of the apparatus. The first temperature sensor and, if applicable the second temperature sensor, is arranged at one of the following laundry treatment components or one of the following laundry treatment positions: the heat pump system, the refrigerant loop, the first heat exchanger, the second heat exchanger, the expansion device, the compressor, an electronic board for powering the motor of the compressor, an electronic board for powering the motor for driving the drum being the laundry treatment compartment and/or process air blower and a position within a process air channel for detecting the process air temperature. The first and/or second temperature sensor may be arranged at any component of the refrigerant loop, i.e. the heat pump system, wherein it is preferred that the refrigerant temperature or a temperature corresponding to the refrigerant temperature is detected.

[0030] Any of the above described features and elements of the method of operating a treatment apparatus may be combined in any arbitrary combination and may be implemented in a treatment apparatus, e.g. a heat pump laundry dryer or heat pump washing machine having drying function, as described above.

[0031] Reference is made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying figures, which show:

Fig. 1 a schematic view of a laundry treatment apparatus having a heat pump system,

Fig. 2 a schematic block diagram of components of the apparatus of Fig. 1,

Fig. 3 a graph schematically illustrating the compressor speed in relation to temperature according to a first embodiment,

Fig. 4 a graph schematically illustrating the compressor speed in relation to temperature according to a second embodiment,

Fig. 5 a graph schematically illustrating the compressor speed in relation to temperature according to a third embodiment, and

Fig. 6 a graph schematically illustrating in combination the compressor speed, the compressor power and the cooling air blower control in relation to temperature according to a fourth embodiment.

[0032] Fig. 1 depicts in a schematic representation a laundry treatment apparatus 2 which in this embodiment is a heat pump tumble dryer. The tumble dryer comprises a heat pump system 4, including in a closed refrigerant loop 6 in this order of refrigerant flow B: a first heat exchanger 10 acting as evaporator for evaporating the refrigerant R and cooling process air, a compressor 14, a second heat exchanger 12 acting as condenser for cooling the refrigerant R and heating the process air, and an expansion device 16 from where the refrigerant R is returned to the first heat exchanger 10. Together with the refrigerant pipes connecting the components of the heat pump system 4 in series, the heat pump system 4 forms a refrigerant loop 6 through which the refrigerant R is circulated by the compressor 14 as indicated by arrow B. If the refrigerant R in the heat pump system 4 is operated in the transcritical or totally supercritical state, the first and second heat exchanger 10, 12 can act as gas heater and gas cooler, respectively.

[0033] The expansion device 16 is a controllable valve that operates under the control of a control unit 30 (Fig. 2) to adapt the flow resistance for the refrigerant R in dependency of operating states of the heat pump system 4. In an embodiment the expansion device 16 may be a fixed, non-controllable device like a capillary tube.

[0034] The process air flow within the treatment apparatus 2 is guided through a compartment 18 of the treatment apparatus 2, i.e. through a compartment 18 for receiving articles to be treated, e.g. a drum 18. The articles to be treated are textiles, laundry 19, clothes, shoes or the like. In the embodiments here these are preferably textiles, laundry or clothes. The process air flow is indicated by arrows A in Fig. 1 and is driven by a process air blower 8 or fan. The process air channel 20 guides the process air flow A outside the drum 18 and includes different sections, including the section forming the battery channel 20a in which the first and second heat exchangers 10, 12 are arranged. The process air exiting the second heat exchanger 12 flows into a rear channel 20b in which the process air blower 8 is arranged. The air conveyed by blower 8 is guided upward in a rising channel 20c to the backside of the drum 18. The air exiting the drum 18 through the drum outlet (which is the loading opening of the drum) is filtered by a fluff filter 22 arranged close to the drum outlet in or at the channel 20.

[0035] When the heat pump system 4 is operating, the first heat exchanger 10 transfers heat from process air A to the refrigerant R. By cooling the process air to lower

temperatures, humidity from the process air condenses at the first heat exchanger 10, is collected there and drained to a condensate collector 26. The process air which is cooled and dehumidified after passing the first heat exchanger 10 passes subsequently through the second heat exchanger 12 where heat is transferred from the refrigerant R to the process air. The process air is sucked from exchanger 12 by the blower 8 and is driven into the drum 18 where it heats up the laundry 19 and receives the humidity therefrom. The process air exits the drum 18 and is guided in front channel 20d back to the first heat exchanger 10. The main components of the heat pump system 4 are arranged in a base section 5 or basement of the dryer 2.

[0036] The dryer 2 comprises a first temperature sensor 28 for monitoring or detecting a temperature of the refrigerant R (or of a temperature dependent on the refrigerant temperature) at the compressor output to provide a first temperature signal T1 for the control unit 30. In the embodiment depicted in Fig. 2 a second temperature sensor 29 is provided to monitor or detect the temperature of an electronic board of the control unit 30, which provides a second temperature signal T2 for the control unit 30. Alternatively only one temperature sensor is provided. The one or more temperature sensors may be positioned at a refrigerant fluid outlet of the first or second heat exchanger 10, 12, an electronic board or inverter position of an electronic board or inverter controlling a component of the heat pump system 4, an electronic board or inverter position of an electronic board or inverter controlling the drum motor 32 or the compressor motor, a refrigerant fluid outlet position at the compressor 14, the compressor 14, the expansion device 16 or a position in the air flow A of the process air. I.e. one or more temperature sensors are positioned such that an operating state of the heat pump system 4 may be derived or deduced from the detected temperature or from a combination of temperature signals of two or more temperature sensors.

[0037] A cooling air blower 24 or fan unit is arranged close to the compressor 14 to remove heat from the compressor 14, i.e. from the heat pump system 4, during a drying operation. The cooling air flow C, which is an ambient air flow in the embodiments, is actively driven by the cooling air blower 24 and is taking heat from (the surface of) the compressor 14. The air blower 24 comprises a blower or fan 36 which is driven by a fan motor 34 controlled by the control unit 30 of the dryer 2. An electronic board (e.g. inverter) or power relay for powering the fan motor 34 under the control of unit 30 is not separately shown. Also the circuit board (e.g. inverter) for powering the process air and/or drum motor or the circuit board (e.g. inverter) for powering the compressor motor under power and/or speed control of the unit 30 are not separately shown.

[0038] The cooling air C conveyed by the cooling air blower 24 is entering the cabinet or housing 3 of the dryer 2 through one or more ambient air inlet openings 40. For

example a cooling air inlet 40 is provided at the lower bottom region at the base section 5 of the housing 3. One or more outlet openings 42 for discharging cooling air are provided at the dryer housing 3, for example at the bottom of base section 5 and/or at an upper region of the rear cover forming part of housing 3. The blower 36 directs the cooling air flow C mainly towards the compressor, however a portion of the air flow and/or the air flow that has passed the compressor circulates within the dryer housing 3 where it induces an air exchange of internal air with ambient air sucked in by the blower. A portion of this air exchange cooling cools electronic boards (like the electronic board of the control unit, the power board for the drum and/or process air blower, and/or the inverter for powering the compressor motor).

[0039] By transferring heat from the compressor 14, during a steady state of operation of the heat pump system 4, thermodynamic balance is achieved between the closed loops of the process air loop and refrigerant loop 6. Thereby the electrical power consumed by the compressor 14 and which is not transformed to work power by compressing the refrigerant, is removed from the heat pump system 4, i.e. heat power of the compressor is balanced in the - under ideal conditions - closed loops of refrigerant and process air. This means, in the steady state of the heat pump system 4 (in which maximum or nearly maximum operation condition or efficiency is achieved after the warm-up period) the heat deposited by the compressor 14 in the refrigerant loop 6 is balanced by the cooling air blower 24 to prevent overheating. After starting the dryer 2 from a cold or ambient state the heat pump system 4 runs through a warm-up phase before reaching the steady state (i.e. normal mode after the warm-up period). As the heat pump system operation status changes (depending mainly on the refrigerant temperature) in the warm-up phase, cooling requirement over time changes.

[0040] Fig. 2 shows a schematic block diagram of components of the dryer of Fig. 1 illustrating the control of the dryer components. The control unit 30 is adapted to control the operation of the components of the dryer 2, i.e. the drum motor 32, the compressor 14, the valve 16 (optionally) and the fan motor 34, according to the selected program. Via an input panel 38 a user may select a drying program or cycle, e.g. FAST, ECONOMY, IRON-AID. Optionally further inputs may be made, e.g. residue humidity, laundry amount or laundry type. Further, the control unit 30 is adapted to control the air blower 24 and the compressor 14 (speed and/or power) such that after a warm-up period a balanced state of the heat pump system 4 is maintained by operating the air blower 24 and compressor 14 for example as described below.

[0041] Common for all embodiments of a method for operating a treatment apparatus as described above and below is that after a detected or monitored first temperature signal T1 exceeds a first temperature level TL1 the cooling air blower 24 is switched-on to remove heat from the heat pump system 4. The detected temperature sig-

nal T1 may be received from the first or the second temperature sensor 28, 29 or may be a combined temperature signal of the temperature signals of both temperature sensors 28, 29. For example the control unit 30 is adapted to calculate a mean value of the temperature signals of the first and second temperature sensors 28, 29 to obtain the (first) temperature signal T1 used for deciding whether the first temperature level TL1 is exceeded. Only when a monitored second temperature signal T2 exceeds a predetermined second temperature level TL2 the compressor (target) speed or the compressor (target) power is reduced.

[0042] The origin of the monitored temperature signals described above and below may change from e.g. detecting a first temperature signal T1 of the first sensor 28 for activating the air blower 24 to detecting a second temperature signal T2 of the second sensor 29 for exceeding the second temperature level TL2. I.e. the temperature signals used for deciding whether a temperature level is exceeded may be selected from the first or second sensor 28, 29 or may be a combination of temperature signals from both sensors 28, 29 as described above.

[0043] For all embodiments the origin of monitored temperature signals used for deciding whether a temperature level is exceeded (or vice versa whether it is below the temperature level) may be the same for each temperature level or may change depending on the respective temperature level or threshold. I.e. for each temperature level decision a temperature signal of the first or second sensor 28, 29 or combination of temperature signals from the temperature sensors 28, 29 may be used. Alternatively only one temperature sensor, e.g. sensor 28, is provided and only one temperature signal is used to decide whether the temperature levels are exceeded or whether the temperature signal falls below temperature levels. For clarity in below description of exemplary embodiments of the invention only one reference sign 'Ti' is used for all monitored temperature signals which are used to decide whether a respective temperature level TL1..TL4 is exceeded (or vice versa whether the signal is below the temperature level), bearing in mind that the origin of the respective temperature signals may be the same for each temperature level decision or may change in dependency of the respective temperature level as described above. I.e. for each decision concerning the temperature levels as described above and below the respective monitored temperature signal Ti may be a signal of the first temperature sensor 28, the second temperature sensor 29 or a combined temperature signal of both sensors 28, 29.

[0044] If a detected temperature signal Ti (of the first and/or second temperature sensor 28, 29) continues to grow above a third temperature level TL3 - despite reduced compressor speed/power and activated air blower - the compressor 14 is operated at a predetermined minimum speed (Min rpm) which is a predetermined minimum speed at which the compressor 14 still works effectively. Should a detected temperature signal Ti rise

above a fourth temperature level TL4, then the compressor 14 is switched-off to prevent damage of components of the heat pump system 4.

[0045] With the method for operating a heat pump dryer 2 it is provided that during a drying operation the reduction of compressor speed/power or compressor switch-off is minimized, in particular as the first step for removing heat from the heat pump system 4 is activating the cooling air blower 24. Repeated reduction of compressor power/speed and switching-off the compressor 14 increases the duration of a drying program as more time is required to remove humidity from laundry to be dried. I.e. the operating performance of a dryer 2 as described above and below is improved as the duration of a drying operation is minimized.

[0046] The following power and speed graphs schematically illustrate the control of the compressor 14 according to several exemplary embodiments. Power and speed graphs or curves based on real-time process data are more complex, but the schematic graphs as shown in Figs. 3 to 6 clearly illustrate the concept of the invention and can be considered a very close approximation of the real behavior of compressor speed and power.

[0047] Fig. 3 shows a graph schematically illustrating compressor speed in relation to a detected temperature according to a first embodiment. As described above the detected temperature may be received from either the first or the second temperature sensors 28, 29 or may be a combination of temperature signals from both sensors 28, 29, in particular depending on the respective temperature level.

[0048] During normal or desired operating state of the heat pump system 4 the compressor 14 is operated at a predetermined target speed (Target rpm). When a monitored (first) temperature signal T_i - e.g. a refrigerant temperature at the compressor outlet - increases above a first temperature level TL1 or threshold temperature the cooling air blower 24 is activated to remove excess heat from the compressor 14, i.e. from the heat pump system, while the compressor speed is maintained at target speed. As an example Fig. 6 shows activation (switching-on) / deactivation (switching-off) of the fan at or around TL1.

[0049] If despite the activated blower 24 a monitored temperature signal T_i exceeds a second temperature level TL2 the compressor speed is reduced to a predetermined minimum value (Min rpm) at which the compressor 14 still works effectively. During the reduction of the compressor speed the cooling air blower 24 is operated to remove excess heat.

[0050] When a detected temperature signal T_i exceeds a final temperature level TL4 or threshold the compressor 14 is switched-off. If the temperature signal T_i drops below the temperature level TL4, the compressor 14 is switched-on and is operated at the minimum speed value (Min rpm). When the temperature signal T_i falls below the second temperature level TL2 the compressor 14 is once again operated at its target speed. If eventually the

temperature signal T_i falls below the first temperature level TL1 the cooling air blower 24 is switched-off.

[0051] Fig. 4 shows a graph schematically illustrating compressor speed in relation to temperature according to a second embodiment. As described above with respect to Fig. 3 during normal or desired operating state of the heat pump system 4 the compressor 14 is operated at a predetermined target speed. When the first temperature level TL1 is exceeded the cooling air blower 24 is activated as described above. In contrast to the above embodiment of Fig. 3 when reaching the second temperature level TL2 the compressor speed is not reduced immediately to a minimum speed value (Min rpm). The compressor speed is linearly decreased from the target speed to a minimum speed in temperature region II, i.e. between the second and a third temperature level TL2, TL3. When the third temperature level TL3 is exceeded the compressor 14 is operated at the minimum speed value (region III). When a temperature signal T_i exceeds the fourth temperature level TL4 the compressor 14 is switched-off for safety reasons. In this embodiment the compressor 14 is controlled by speed. Alternatively, the compressor 14 may be controlled by power (not depicted) in a similar manner.

[0052] Fig. 5 shows a graph schematically illustrating compressor speed in relation to temperature according to a third embodiment. In contrast to the embodiment of Fig. 4 which shows a speed target control over the whole temperature range, Fig. 5 shows a combination of power target control (region I) and speed target control (regions II, III).

[0053] In the control diagram of Fig. 5 (and in contrast to above embodiments of Fig. 3 and 4), a power target control is applied to the compressor 14 below the second temperature level TL2, i.e. the compressor is operated in temperature region I at constant power. When the compressor power is controlled at the beginning of the drying cycle a predetermined value of power is supplied to the compressor 14 which helps in increasing the refrigerant pressure in the refrigerant loop branch between the compressor 14 and the expansion device 16 to reach nominal or desired working conditions of the heat pump system 4 as soon as possible. As shown in Fig. 5 during the compressor power target control, the compressor speed decreases because as refrigerant temperature and pressure increases. With an increasing refrigerant pressure, a higher portion of the motor power is consumed for the compressing work and consequently the rotation speed decreases.

[0054] When a monitored temperature signal T_i exceeds the second temperature level TL2 speed target control is applied to the compressor 14 as described above with respect to Fig. 4. The speed target control will remain active until the monitored temperature T_i falls under the second temperature level TL2. Then the compressor 14 is again operated by power target control as described above.

[0055] Fig. 6 shows a graph schematically illustrating

compressor speed, compressor power and cooling air blower control in relation to a detected temperature T_i of a fourth embodiment. Unless otherwise mentioned the present embodiment correspond to the embodiment of Fig. 5.

[0056] As described above, when a monitored temperature signal T_i exceeds a first temperature level TL1 the cooling air blower 24 is switched-on and remains activated. When the detected first temperature signal T_i falls below a switch-off temperature level TL1' - which is lower than the first temperature level TL1 - the blower 24 is switched-off. I.e. it is ensured that the cooling air blower 24 is switched-off at a save temperature level. In temperature region I the power target control is depicted, i.e. the compressor 14 is operated at constant power while the compressor speed is reduced with increasing temperature as described above.

[0057] In temperature region I, i.e. the temperature region up to the second temperature level TL2, the compressor 14 is operated at target power as described above with respect to Fig. 5. In temperature regions II and III speed target control is implemented as described above. When a temperature signal T_i exceeds the second temperature level TL2 compressor speed is reduced linearly with the rising temperature signal T_i . With decreasing compressor speed the compressor power is also reduced.

[0058] When a temperature signal T_i exceeds the third temperature level TL3 the compressor 14 is operated at minimum speed until the fourth temperature level TL4 is reached or exceeded by a temperature signal T_i . Then the compressor 14 is switched-off until the detected temperature signal T_i falls below a switch-on temperature level TL4' which is lower than the fourth temperature level TL4. Thus it is ensured that the compressor 14 is switched-on at a save temperature level (TL4').

[0059] Below temperature level TL4 the compressor 14 is again operated at constant speed (Min rpm) until the monitored temperature signal T_i falls below the third temperature level TL3. In temperature region II the compressor speed is linearly increased with decreasing temperature until the temperature signal T_i is below the second temperature level TL2. Then the compressor control changes back from speed target control to power target control as described above, i.e. in temperature region I the compressor 14 is again operated at target power. When the detected temperature signal T_i falls below the switch-off temperature level TL1' the cooling blower 24 is switched-off while the compressor is operated at target power.

[0060] As indicated in Fig. 6, a temperature hysteresis may be provided for switching the blower motor 34 on at the higher temperature TL1 and off at the lower temperature TL1'. Alternatively or additionally the compressor safety deactivation is set to the higher hysteresis temperature TL4 and the compressor activation in the high temperature regime III is set at the lower hysteresis temperature TL4'. In both cases a permanent switching on

and off of the blower motor 34 and the compressor motor 14 is avoided.

Reference Numeral List

[0061]

2	heat pump tumble dryer
3	dryer cabinet / housing
10 4	heat pump system
5	base section
6	refrigerant loop
8	blower
10	first heat exchanger (evaporator)
15 12	second heat exchanger (condenser)
14	compressor
16	expansion device
18	drum (laundry compartment)
19	laundry
20 20	process air channel
20a	battery channel
20b	rear channel
20c	rising channel
20d	front channel
25 22	fluff filter
24	cooling air blower
26	condensate collector
28	temperature sensor (compressor exit)
29	temperature sensor (electronic board)
30 30	control unit
32	drum motor
34	fan motor
36	fan
38	input panel
35 40	ambient air inlet
42	cooling air outlet
A	process air flow
B	refrigerant flow
C	cooling air flow
40 R	refrigerant

Claims

- 45 1. Method for operating a laundry treatment apparatus, in particular a heat pump tumble dryer or a washing machine having a drying function, wherein the apparatus comprises a heat pump system and a laundry treatment chamber for treating laundry using process air, and wherein the heat pump system comprises:

- 50 a first heat exchanger (10) for heating the refrigerant fluid (R),
 55 a second heat exchanger (12) for cooling a refrigerant fluid (R),
 an expansion device (16),
 a refrigerant loop (6), in which the refrigerant

fluid is circulated through the first and second heat exchangers and the expansion device, a variable speed and/or variable power compressor (14) for circulating the refrigerant fluid (R) through the refrigerant loop, and a cooling air blower for conveying cooling air to the compressor,

characterized by the method comprising:

monitoring a first temperature signal (T1) and activating the cooling air blower or increasing the conveying capacity of the cooling air blower when the first temperature signal exceeds a first temperature level (TL1), and

monitoring the first temperature signal (T1) or a second temperature signal (T2) and reducing the compressor speed and/or compressor power when the first temperature signal (T1) or the second temperature signal (T2) exceeds a second temperature level (TL2), wherein, if it is the first temperature signal (T1) which is monitored for exceeding the second temperature level (TL2), the second temperature level (TL2) is higher than the first temperature level (TL1).

2. Method according to claim 1, wherein when the first temperature signal (T1) or the second temperature signal (T2) exceeds the second temperature level (TL2), the compressor speed and/or compressor power is reduced in dependency of the first temperature signal (T1) or second temperature signal (T2) or in dependency of a combination of the first and second temperature signal (T1, T2).

3. Method according to claim 1 or 2, wherein the compressor speed and/or compressor power is reduced until the compressor speed and/or compressor power reaches a predefined minimum value, or the first temperature signal (T1) or the second temperature signal (T2) exceeds a third temperature level (TL3).

4. Method according to claim 1, 2 or 3, wherein the compressor power is maintained constant until a temperature where the first temperature signal (T1) or the second temperature signal (T2) reaches the first or second temperature level (TL1, TL2) from the lower temperature side, and when the first temperature signal (T1) or the second temperature signal (T2) exceeds the first or second temperature level (TL1, TL2) the compressor speed is controlled in dependency of the first temperature signal (T1) or second temperature signal (T2).

5. Method according to any of the previous claims, wherein when the first temperature signal (T1) or the second temperature signal (T2) exceeds the second temperature level (TL2), the compressor speed and

the compressor power are reduced in dependency of the first temperature signal (T1) or second temperature signal (T2), wherein

over a first temperature range above the second temperature level (TL2) the compressor speed is controlled in dependency of the first temperature signal (T1) or second temperature signal (T2), and over a second temperature range, which is above the second temperature level (TL2) and which is different of the first temperature range, the compressor power is controlled in dependency of the first temperature signal (T1) or second temperature signal (T2).

6. Method according to any of the previous claims, wherein the temporal gradient or averaged temporal gradient of the change of the compressor speed and/or compressor power is below a predefined maximum gradient.

7. Method according to any of the previous claims, wherein the method comprises monitoring the first temperature signal (T1) or the second temperature signal (T2) and switching off the compressor if the first temperature signal (T1) or the second temperature signal (T2) exceeds a fourth temperature level (TL4), or if the first temperature signal (T1) or the second temperature signal (T2) exceeds the third temperature level (TL3) or a temperature level higher than the third temperature level for a predefined time period.

8. Method according to claim 7, wherein, when the compressor (14) was switched off, the compressor (14) is switched on again under one or more of the following conditions:

the compressor (14) was switched off for a predetermined time period, and the first temperature signal (T1) or second temperature signal (T2) falls below a fifth temperature level (TL4').

9. Method according to any of the previous claims, wherein when the second temperature signal (T2) exceeding the second temperature level (TL2) is monitored and the second temperature signal (T2) exceeds the second temperature level, the first temperature signal (T1) exceeds the first temperature level (TL1), or the reduction of the compressor speed and/or compressor power is suppressed as long as the first temperature signal (T1) does not exceed the first temperature level (TL1).

10. Method according to any of the previous claims, wherein the level of at least one of the first temperature level (TL1),

the second temperature level (TL2),
the third temperature level (TL3),
the fourth temperature level (TL4), and
the fifth temperature level (TL4')
is depending on one or more of the following:

- an operation state of the laundry treatment apparatus,
- an operation state of the heat pump system (4),
- a program cycle,
- a selected program for laundry treatment,
- a third temperature signal of the heat pump system (4), and
- a user input or selection input by a user of the laundry treatment apparatus.

11. Method according to any of the previous claims, wherein the blower (24) is switched off, if the first temperature signal (T1) or the second temperature signal (T2) falls below a sixth temperature level (TL1'), or
wherein the blower conveyance capacity is reduced if the first temperature signal (T1) or the second temperature signal (T2) is decreasing.

12. Method according to any of the previous claims, wherein the first temperature signal (T1) or the second temperature signal (T2) is a signal corresponding to a temperature or corresponding to a refrigerant fluid temperature detected at one of the following positions in the heat pump system (4) or is a combined signal detected on at least two of the following positions in the heat pump system or within the cabinet of the laundry treatment apparatus (2):

- a refrigerant fluid outlet position at the first or second heat exchanger (10, 12),
- an electronic board or inverter position of an electronic board or inverter controlling a component of the heat pump system (4),
- an electronic board or inverter position of an electronic board or inverter controlling a motor (32) for driving the laundry treatment chamber (18) being a drum,
- a refrigerant fluid outlet position at the compressor (14),
- the compressor (14),
- the expansion device (16), or
- a position in the air flow (A) of the process air.

13. Laundry treatment apparatus, in particular heat pump tumble dryer or washing machine having a drying function, wherein the apparatus comprises a heat pump system (4), a control unit (30) adapted to control the operation of the heat pump system and a laundry treatment chamber (18) for treating laundry using process air, and wherein the heat pump system (4) comprises:

a first heat exchanger (10) for cooling a refrigerant fluid (R),
a second heat exchanger (12) for heating the refrigerant fluid (R),
an expansion device (16),
a refrigerant loop (6), in which the refrigerant fluid is circulated through the first and second heat exchangers and the expansion device, and
a compressor (14) for circulating the refrigerant fluid through the refrigerant loop (6), wherein the compressor (14) is adapted to be operated at different compressor speeds and/or different compressor powers under the control of the control unit (30);
wherein the control unit (30) is adapted to implement a method according to any of the previous claims.

14. Laundry treatment apparatus, in particular heat pump tumble dryer or washing machine having a drying function, wherein the apparatus comprises a heat pump system (4), a control unit (30) adapted to control the operation of the heat pump system (4) and a laundry treatment chamber (18) for treating laundry using process air,
wherein the heat pump system (4) comprises:

a first heat exchanger (10) for cooling a refrigerant fluid (R),
a second heat exchanger (12) for heating the refrigerant fluid (R),
an expansion device (16),
a refrigerant loop (6), in which the refrigerant fluid is circulated through the first and second heat exchangers (10, 12) and the expansion device (16), and
a compressor (14) for circulating the refrigerant fluid through the refrigerant loop (6), wherein the compressor (14) is adapted to be operated at different compressor speeds and/or different compressor powers under the control of the control unit (30),
wherein the apparatus further comprises:
a cooling air blower (24) for conveying cooling air to the compressor (14),
a first temperature sensor (28) for detecting a first temperature at a first position in the cabinet of the laundry treatment apparatus and for providing a first temperature signal (T1), and
optionally a second temperature sensor (29) for detecting a second temperature at a second position in the cabinet of the laundry treatment apparatus and for providing a second temperature signal (T2), wherein the second position is different of the first position,
wherein the control unit (30) is adapted to operate the cooling air blower (24) in dependency of the first temperature signal (T1),

wherein the control unit (30) is adapted to control the speed and/or the power of the compressor (14) in dependency of the first temperature signal (T1) or the second temperature signal (T2), and

wherein, if the compressor (14) is operated in dependency of the first temperature signal (T1), the control unit (30) starts to change or changes the speed and/or power of the compressor (14) at a level (TL2) of the first temperature signal (T1) which is higher than a level (TL1) of the first temperature signal (T1) at which the control unit starts or activates the cooling air blower (24).

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15. Apparatus according to claim 14, wherein the control unit (30) is adapted to activate the blower (24) if the first temperature signal (T1) exceeds a first temperature level (TL1).

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16. Apparatus according to claim 14 or 15, wherein the control unit (30) is adapted to operate the compressor (14) at maximum speed and/or power, if the first temperature signal (T1) or the second temperature signal (T2) or a combination of the first and second temperature signal (T1, T2) is below a second temperature level (TL2), or
- wherein the control unit (30) is adapted to control the reduction of the compressor speed and/or power, if the first temperature signal (T1) or the second temperature signal (T2) or a combination of the first and second temperature signal (T1, T2) exceeds a second temperature level (TL2).

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17. Apparatus according to claim 14, 15 or 16, wherein the control unit (30) is adapted to control the apparatus according to any of the previous method claims 1 to 12.

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18. Method according to any of the previous claims 1 to 12 or laundry treatment apparatus according to any of the previous claims 13 to 17,
- wherein the laundry treatment apparatus comprises a first temperature sensor (28) for providing the first temperature signal (T1), or
- a first temperature sensor (28) for providing the first temperature signal (T1) and a second temperature sensor (29) for providing the second temperature signal (T2), wherein the first and second temperature sensors are arranged at different positions within the cabinet of the apparatus, and
- wherein the first temperature sensor (28) and, if applicable the second temperature sensor (29), is arranged at one of the following laundry treatment components or one of the following laundry treatment positions:

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the heat pump system (4),
the refrigerant loop (6),

the first heat exchanger (10),
the second heat exchanger (12),
the expansion device (16),
the compressor (14),
an electronic board for powering the motor of the compressor (14),
an electronic board for powering the motor (32) for driving the drum being the laundry treatment compartment (18) and/or process air blower (8), and
a position within a process air channel (20) for detecting the process air temperature.

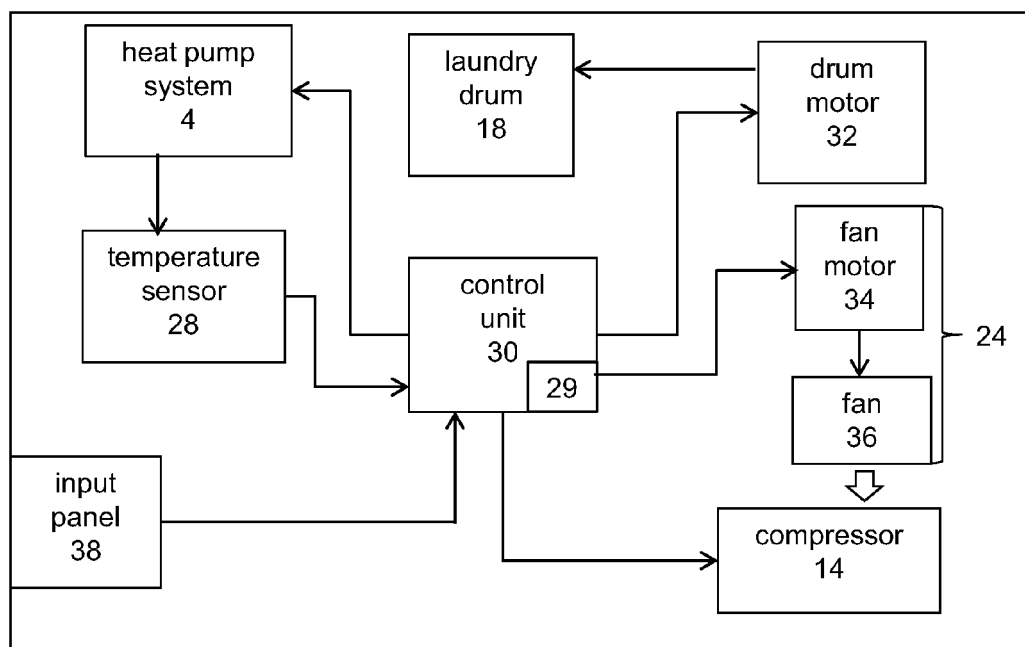
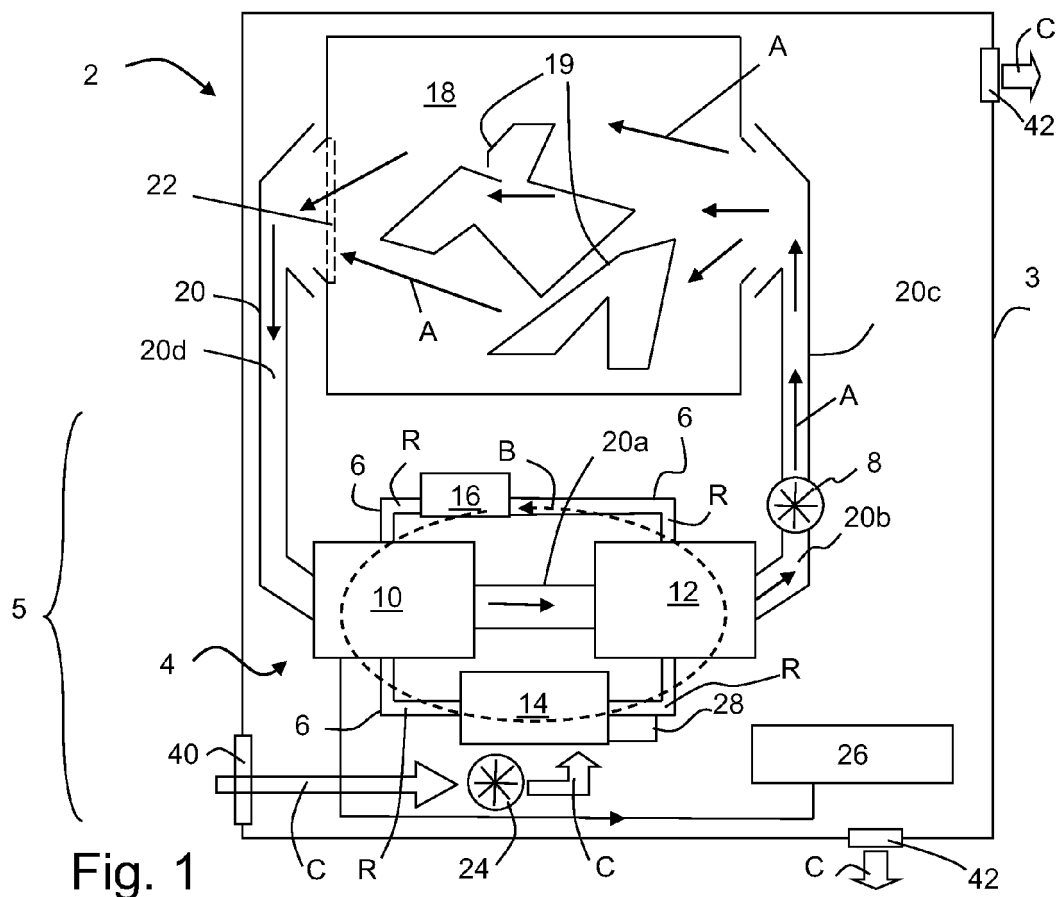


Fig. 2

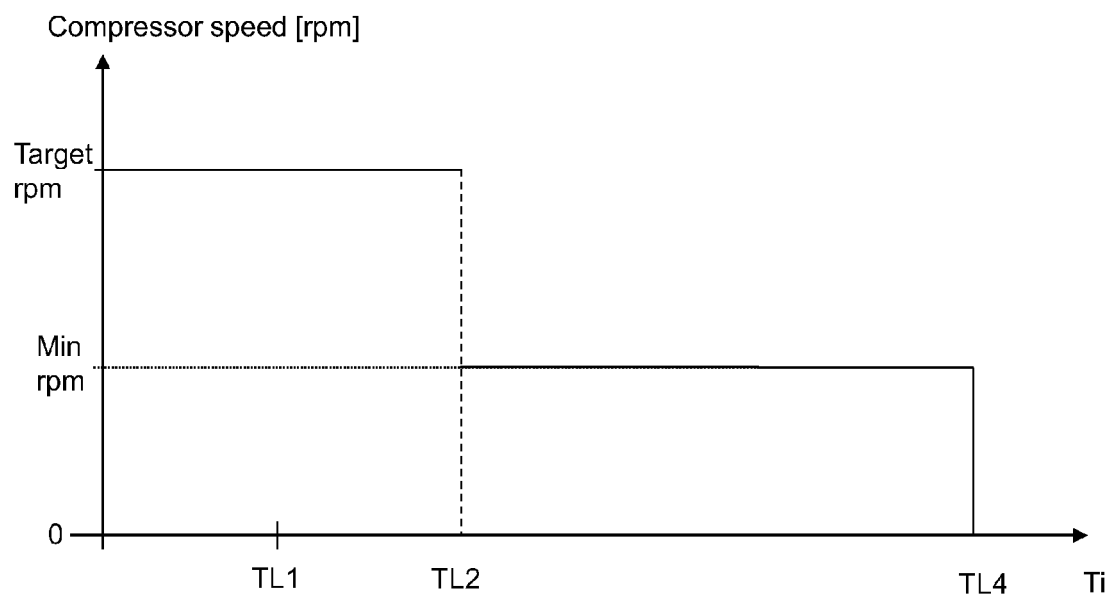


Fig. 3

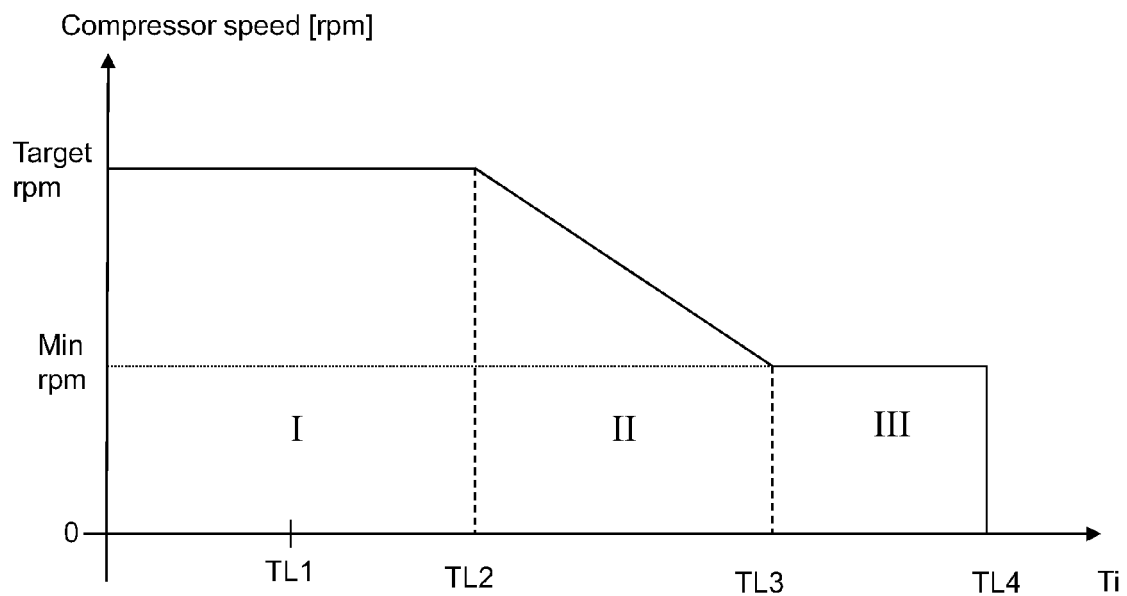


Fig. 4

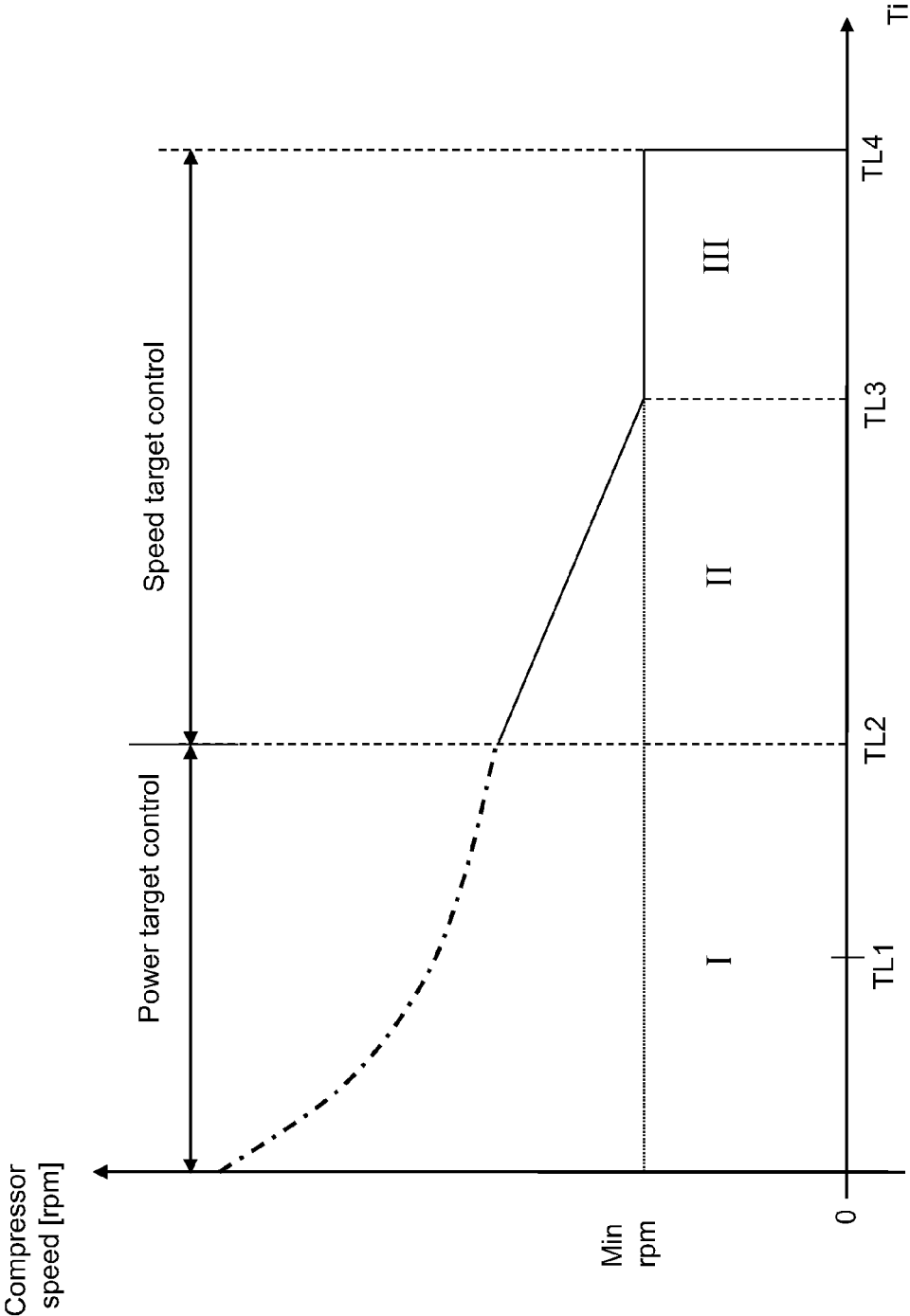


Fig. 5

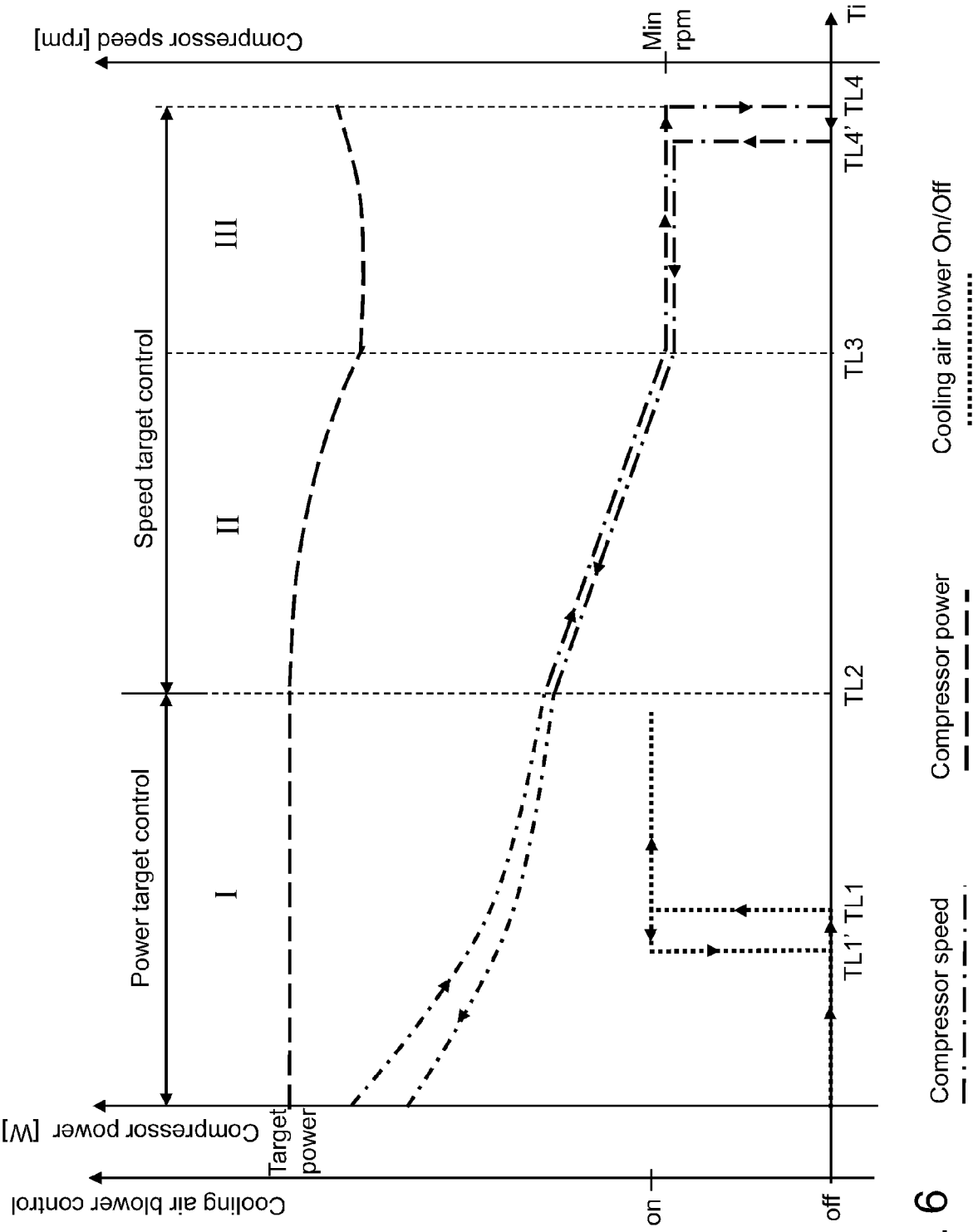


Fig. 6



EUROPEAN SEARCH REPORT

Application Number
EP 12 19 2958

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