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(54) **Clothes tumble dryer and method for controlling the same**

Wäschetrommeltrockner und Verfahren zur Steuerung desselben

Sèche-linge à tambour et procédé pour contrôler celui-ci

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EP 1 790 769 B1

Description

[0001] The present invention refers to a clothes tumble dryer and a method for controlling the same.

[0002] An important feature in tumble driers is the ability of the drying process to be stopped as soon as the moisture content of the washload has been brought down to the desired value. In fact, if the drying process be interrupted too early, the resulting moisture content in the washload would be too high and this would again entail a number of obvious disadvantages. On the other hand, interrupting a drying process too late practically means an unnecessarily high energy usage, while the resulting too low a moisture content of the washload causes it to be subject to increased creasing, reduced ironability, increased likelihood for the washload items to suffer shrinking or undergo such other adverse effects as becoming statically charged.

[0003] Condenser-type tumble dryers are known in the art to comprise a closed-loop drying air circuit adapted to cause heated drying air to circulate through a perforated rotating drum, and a condenser adapted to remove the moisture from the hot moisture-laden drying air exiting the drum upon having flown through the drying load contained therein, as well as moisture sensors adapted to detect the moisture content of the air exiting the drum. Thus, the drying process is stopped when the moisture content of the drying air leaving the drum is sensed to have reached down to a pre-established value. However, this method has been unable to provide really satisfactory results, since it has been practically found that the actual moisture content of the drying load upon interruption of the drying process is greatly affected also by such variables as the amount of drying load items in the drum and the type and nature of the fabrics being handled.

[0004] Also known in the art are condenser-type tumble dryers, in which electrodes are arranged in the drum for measuring the electrical resistance of the load, based on the fact that such electrical resistance is a parameter that is in direct relation with, i.e. dependent on the moisture content of the drying load items. Other prior-art solutions call for the use of a drum that is comprised of two halves, wherein the conductivity between such halves is then measured to control the drying process. This method, however, is unable to ensure any reliable measurement of the moisture content of the drying load items, mainly owing to conductivity values being affected by such factors as water hardness.

[0005] US 4,640,022 discloses a clothes dryer of the dehumidifying type in which exhaust air from a drying space containing a load being dried is subjected to heat exchange with external air for removing moisture from the exhaust and, after being re-heated by a heater, the exhaust air is returned to the drying space again by a fan so as to dry the load with heated air. The clothes dryer includes a first heat-sensitive device for measuring the temperature of exhaust air at an outlet of the drying space, and a second heat-sensitive device for measuring the temperature of the exhaust air after having been subjected to the heat exchange with external air or the temperature of the external air after having been subjected to the heat exchange with the exhaust air. The difference between the temperatures measured by the first and second heat-sensitive device at a predetermined time after the starting of the drying operation is stored in a memory as a reference value A, and the later relation between the measured temperature difference and the reference value A, is checked to control the termination of the heat drying operation.

[0006] EP 1 4-20 104 discloses a process for drying laundry placed in a laundry enclosure or drum of a drying device such as a drying machine, washer-drier or drying cabinet, comprises one or more phases of drying the laundry in an airflow heated by heating means and conveyed into the laundry enclosure by ventilation means and a phase of ventilating the laundry in an airflow at ambient temperature conveyed into the laundry enclosure by the said ventilation means, in which the drying process begins with the ventilation phase, reducing the initial peak moisture content of the laundry by means of the airflow at ambient temperature. A first thermal sensor is placed in the airflow downstream of the laundry enclosure to detect the temperature of the air immediately after its passage through the laundry. A second thermal sensor is placed in the section between the heating means and the laundry enclosure to detect the temperature of the air before it goes through the laundry. The data relating to the temperature readings are transmitted to a control unit, which estimates the moisture content of the laundry on the basis of the difference between the temperatures of the air upstream and downstream of the laundry enclosure and determines the duration of the ventilation phase on the basis of the measured values and of the target values for the reduction of the moisture content of the laundry.

[0007] EP 0 978 778 discloses a clothes dryer provided with a humidity-modulated dual-setpoint temperature controller in which the two temperature setpoints are adjusted as a function of measured humidity for controlling the heater element in order to improve the energy efficiency of the dryer. These setpoints are adjusted based upon the RH detected by a humidity sensor coupled to the dual-setpoint temperature controller by means of a voltage signal that is proportional to the measured RH level in the exhaust of the drier. As the RH in the dryer exhaust decreases, the voltage signal will drop, which in turn reduces the temperature switching setpoints.

[0008] It therefore is a main object of the present invention to provide a clothes tumble drier of the above-mentioned kind, in which a desired moisture content of the drying load can be automatically attained to a high degree of accuracy at the interruption of the drying process, and this in a manner that is highly independent of factors such as the amount of drying load, the type of fabrics being handles, the initial moisture content of the drying load, as well as water hardness.

[0009] According to the present invention, this aim is reached in a clothes tumble dryer having the characteristics as recited and defined in the appended claims 1 to 14.

[0010] According to the present invention, the above-mentioned aim is also reached in a method for controlling a clothes tumble dryer as defined and recited in the appended claims 15 to 26.

[0011] Anyway, features and advantages of the present invention may be more readily understood from the description that is given below by way of a non-limiting example with reference to the accompanying drawings, in which:

- Figure 1 is a schematic view of a clothes tumble dryer according to the present invention;
- Figure 2 a flow chart describing a method for controlling a clothes tumble dryer according to the present invention;
- Figure 3 is a diagrammatical view of the course followed versus time by the relative humidity of the drying air entering the condenser during a drying process, along with the threshold values of relative humidity corresponding to a pre-established drying degree;
- Figure 4 is a diagrammatical view of the course followed versus time by the temperature of the drying air entering the condenser and the temperature of the drying air exiting the condenser during a drying process;
- Figure 5 is a diagrammatical view versus time of the temperature difference pattern between the drying air entering the condenser and the drying air exiting the condenser during a drying process, along with the threshold values of such temperature difference corresponding to a pre-established drying degree;
- Figure 6 is a diagrammatical view versus time of the pattern of the end-of-cycle coefficients dH and dT , as well as the control quantity D in the case of an "Extra Dry" drying cycle;
- Figure 7 is a diagrammatical view versus time of the pattern of the end-of-cycle coefficients dH and dT , as well as the control quantity D in the case of a "Dry Cottons" drying cycle;
- Figure 8 is a diagrammatical view versus time of the pattern of the end-of-cycle coefficients dH and dT , as well as the control quantity D in the case of a "Slightly Damp" drying cycle;
- Figure 9 is a diagrammatical view versus time of the pattern of the end-of-cycle coefficients dH and dT , as well as the control quantity D in the case of an "Iron Dry" drying cycle;
- Figure 10 is a diagrammatical view versus time of the pattern of the end-of-cycle coefficients dH and dT , as well as the control quantity D in the case of an "Mangle Dry" drying cycle.

[0012] The clothes tumble dryer according to the present invention - as generally indicated by the reference numeral 1 in the Figures - comprises a closed-loop drying air circuit adapted to cause heated drying air to be circulated through a perforated rotating drum 2 holding the washload to be dried, heating means 3 adapted to heat up said drying air, an air-cooled condenser 4 adapted to remove the moisture from the hot moisture-laden drying air exiting the drum after having flown through the washload to be dried, an open-loop cooling air circuit adapted to cause a stream of cooling air taken in from outside to circulate through and over the condenser 4 to cool it, and be eventually exhausted again into the outside atmosphere.

[0013] The above-mentioned tumble dryer also calls for temperature sensor means 5, 6 to be provided in correspondence to a drying-air condenser inlet 7, as well as in correspondence to a drying-air condenser outlet 8, in order to detect a temperature difference value ΔT between the drying air entering the condenser 4 and the drying air exiting the same condenser 4; it further calls for humidity sensor means 5 to be provided in correspondence to the drying-air condenser inlet 7, in order to detect a relative humidity value RH_{in} of the drying air entering the condenser.

[0014] In addition, the above-mentioned tumble dryer comprises control means coupled to both the humidity sensor means 5, so as to be able to receive the humidity values RH_{in} , and the temperature sensor means 5, 6 to also receive the temperature difference values ΔT during the operation of the tumble drier.

[0015] The tumble dryer is further provided with memory means for storing a threshold temperature-difference value ΔT_{TH} between the drying air entering the condenser 4 and the drying air exiting the same condenser 4, and a threshold humidity value RH_{inTH} for the drying air entering the condenser, which are indicative of a pre-established dryness level, i.e. degree of drying of the items loaded in the drum in accordance with the particular drying cycle selected by the user, wherein said threshold temperature-difference value ΔT_{TH} and said threshold humidity value RH_{inTH} are initialized in response to said tumble dryer being started to operate according to the particular drying cycle selected by the user.

[0016] The control means are adapted to compare the actual humidity value RH_{in} with the threshold humidity value RH_{inTH} , and are also adapted to compare the temperature difference value ΔT with the threshold temperature difference

value ΔT_{TH} , for automatically turning off said heating means 3 when at least the temperature difference value ΔT reaches up to or beyond the threshold temperature difference value ΔT_{TH} or at least the humidity value RH_{in} reaches down to or below the humidity threshold value RH_{inTH} .

[0017] Through the closed-loop drying air circuit, the hot and moisture-laden drying air is caused to leave the perforated rotating drum 2 and is conveyed towards the air-cooled condenser 4; then, the dehydrated drying air exiting the condenser 4 is sent back into the drum 3, upon having been duly heated up again, so as to remove additional moisture from the clothes being tumbled in the drum 2.

[0018] The tumble dryer comprises first blower means 11 adapted to cause the drying air to circulate inside and through the closed-loop drying air circuit. A first manifold arrangement 12 is provided to convey the drying air exiting the drum 2 into the drying-air condenser inlet 7, and a second manifold arrangement 13 is provided to convey the drying air exiting the drying-air condenser outlet 8 again into the drum 2.

[0019] Heating means 3 are provided downstream of the drying-air condenser outlet 8 to heat up the dehydrated drying air due to be sent again into the drum 2.

[0020] The condenser 4 comprises a plurality of fluid passageways, along which the drying air is able to flow in view of having the moisture condensed and removed therefrom, and these fluid passageways are capable of being invested by, i.e. are exposed to the flow of cooling air flowing through the open-loop cooling air circuit. In particular, the condenser 4 comprises a first array of spaced-apart fluid passageways 14 for the drying air, which are fluidly connected with the first manifold arrangement 12 at the drying-air condenser inlet 7, as well as fluidly connected with the second manifold arrangement 13 at the drying-air condenser outlet 8.

[0021] The condenser 4 further comprises a second array of spaced-apart fluid passageways 15 for the cooling air, which are arranged in an alternating relationship relative to said first array of fluid passageways 14, so that between two such adjacent fluid passageways 14 for the drying air there is provided a fluid passageway 15 for the cooling air.

[0022] The cooling air that flows along the second array of fluid passageways 15 is adapted to brush, i.e. move in contact with the fluid passageways 14 of the drying air, thereby cooling it down by convection so as to cause water vapour in the hot moisture-laden drying air to precipitate by condensation.

[0023] The open-loop cooling air circuit comprises second blower means 16 adapted to cause the cooling air to circulate, an air intake aperture 17 and an air exhaust aperture 18 fluidly connected with the second array of fluid passageways 15, through which the cooling air is taken in from the outside ambient, conveyed to and through the condenser, to be eventually sent back into the outside ambient again.

[0024] The drying-air condenser inlet 7 substantially represents the zone of the condenser at which the drying air to be dehydrated, and flowing in from the first manifold arrangement, enters the first array of fluid passageways 14, whereas the drying-air condenser outlet 8 represents the zone of the condenser at which the dehydrated drying air exits the first array of fluid passageways 14 to flow into the second manifold arrangement 13.

[0025] Most obviously, these zones are not fluidly connected with the cooling air passageways, since both the inlet and the outlet of such second array of fluid passageways 15 are suitably separated from the drying-air condenser inlet 7 and the drying-air condenser outlet 8, respectively.

[0026] In the particular embodiment, in fact, the inlet and the outlet of the second array of fluid passageways 15 are provided in a perpendicular arrangement relative to the drying-air condenser inlet 7 and the drying-air condenser outlet 8, respectively, so that the flows of drying air and the flows of cooling air practically cross each other.

[0027] The temperature and humidity sensor means 5, 6 comprise a relative humidity sensor, which is also capable of delivering accompanying temperature measurement values, and which is arranged in the vicinity of the drying-air condenser inlet 7, and a temperature sensor, such as for instance a thermocouple, which is situated in the vicinity of the drying-air condenser outlet 8. Both sensors are connected to the control means, which are adapted to receive - during the operation of the dryer - the signals being output by the sensors so as to monitor the pattern of the temperature T_{in} of the drying air entering the condenser, as well as the pattern of the temperature T_{out} of the drying air exiting the same condenser, along with the relative humidity RH_{in} of the drying air entering the condenser.

[0028] This data acquisition process by said control means may occur either continuously or at discrete intervals, by setting in this case a proper time interval to separate successive data acquisition events during which said control means are able to acquire the temperature values T_{in} , T_{out} , and the relative humidity values RH_{in} being detected and output by the sensors.

[0029] Extensive experimental tests have emphasized the fact that both the relative humidity values RH_{in} and the temperature values T_{in} , T_{out} of the drying air being detected as the clothes undergo gradual drying in the machine, fully correlate, i.e. can be brought into mutual relation with different final drying degrees of the clothes themselves.

[0030] It has in this way been possible to work out appropriate threshold temperature and relative humidity values of the drying air, which correspond to the various degrees of final drying that are usually required for clothes handled in such tumble dryers, in such a way as to ensure that reaching any of these threshold values causes the air heating means to be de-energized and, possibly, the operation of the dryer itself to be stopped by the control means.

In detail, in view of judging the final drying degree of the clothes, reference has been made - according to existing

standards - to residual moisture MR (moisture regain), as assessed in terms of difference in weight of a load of clothes subjected to a drying cycle, to a same load of clothes under standard conditions, i.e. left for 24 hours in a controlled atmosphere at a temperature of 20°C and 60% of relative humidity.

[0031] Some among the most used drying cycles commonly available in tumble dryers have then been selected, i.e.:

Drying Cycle	Final MR
Extra Dry (ED)	-6% → 0%
Dry Cottons (DC)	-3% → 3%
Slightly Damp (SD)	4% → 8%
Iron Dry (ID)	8% → 16%
Mangle Dry (MD)	18% → 24%

[0032] For example, in the case of the Extra Dry cycle, the drying load - as removed from the drum at the end of the cycle, has a weight ranging from about 6% less than the weight of the above-specified standard load to almost the same weight as the standard load. On the contrary, in the case of the Iron Dry cycle, the drying load - as removed from the drum at the end of the cycle - has a weight ranging from 8% to 16% more than the weight of said standard load.

[0033] The tests performed in this connection have given rise to the graph appearing in Figure 3 illustrating the trend versus time of the relative humidity value RH_{in} of the drying air as detected by the moisture sensor means 5 at the drying-air condenser inlet 7, with the heating means 3 operating, i.e. energized. As emphasized by the graph, the relative humidity RH_{in} tends to decrease as the drying degree of the clothes increases. Further indicated in Figure 3 are the threshold values for the relative humidity $RH_{inTH}[ED,DC,SD,ID,M]$ of the drying air entering the condenser, which have been found as corresponding to the different degrees of drying of the clothes in the above-noted cycles ED,DC,SD,ID,M.

[0034] In the description following hereinbelow, the term "relative humidity value RH_{in} " will be used to univocally mean the value of relative humidity of the drying air as detected by the moisture sensor means 5 at the drying-air condenser inlet 7, whereas the term "threshold relative-humidity value $RH_{inTH}[ED,DC,SD,ID,M]$ " will be used to univocally mean the threshold value of relative humidity of the drying air, which - as detected again by the moisture sensor means 5 at the drying-air condenser inlet 7 - has been found to correspond to the different degrees of drying of the clothes in the cycles ED,DC,SD,ID,M as indicated above.

[0035] RH_o is used to indicate the initial value of the relative humidity of the drying air flowing into, i.e. entering the condenser 4 as detected by the moisture sensor means 5 upon starting of the drying cycle selected by the user and, therefore, upon the heating means having been switched on.

[0036] Immediately after energization of the heating means 3, the value of RH_o can be noticed to be extremely variable to eventually go steadier at a relative-humidity value of approx. 96 to 97% after a first stabilization transient. It has been found that the initial value RH_o is the same for all drying cycles.

[0037] During this first transient phase, the control means of the machine do not acquire any of the relative-humidity readings RH_{in} that they receive from the moisture sensor means 5, since the related data are not representative of the real initial relative-humidity condition RH_o .

[0038] Thus, the control means are programmed to set themselves in a kind of observation state, in which they practically determine whether successive readings flowing in from the moisture sensor means 5 reveal a substantially constant value. In this connection, it will be readily appreciated that the control means may also be programmed to simply wait until a certain time interval of a duration corresponding to the aforementioned transient phase elapses, before they start acquiring the data being output by the sensor means. It has been experimentally found that such transient phase has a duration of approx. two minutes.

[0039] As this most clearly appears from the graph in Figure 3, the relative humidity RH_{in} decreases as the clothes in the drum becomes increasingly dry, until it eventually reaches a respective threshold value corresponding to a certain final drying degree or state reached by the clothes themselves. For example, when the value of relative humidity RH_{in} reaches down to at least approx. 68%, it has been found that degree of drying reached by the clothes being handled corresponds to a degree of drying that is typical of the Extra Dry (ED) cycle.

[0040] As a result, this relative humidity value of 68% turns out as being the threshold relative-humidity value $RH_{inTH}[ED]$ that can be associated to said Extra Dry cycle ED, and - as such - is therefore stored in the memory means for due reference. When the user then selects an Extra Dry cycle ED via the proper controls on the control panel of the tumble dryer, the control means automatically retrieve the threshold relative-humidity value $RH_{inTH}[ED]$ associated to such drying cycle from the memory means and, at the same time, enable the dryer to start operation by energizing the heating means 3, switching on the blower means 11, 16 and enabling the drum 2 to be driven rotatably.

[0041] Then, the control means - upon waiting for the initial transient observation phase to elapse - are enabled to start comparing the relative humidity value RH_{in} with the threshold relative-humidity value $RH_{inTH}[ED]$ for the Extra Dry [ED] cycle. When the relative humidity value RH_{in} is eventually found to have reached down to or below said threshold

value $RH_{inTH}[ED]$, the control means will then consider the selected drying cycle as being concluded and, as a result, cause the operation of the tumble dryer to stop by de-energizing the heating means 3, switching off the blower means 11, 16 and stopping the rotation of the drum 2. Since a cold air circulation phase may also be contemplated to take place at the end of the actual drying process in order to cool down the clothes before removing them from the drum 2, when the relative humidity value RH_{in} is found to have reached down to or below said threshold value $RH_{inTH}[ED]$, the control means would in this case simply de-energize the heating means 3, while waiting for this cool air circulation phase to be concluded before stopping the operation of the tumble dryer.

[0042] A degree of drying of the clothes corresponding to the one that may be considered typical for the Dry Cottons (DC) cycle, has on the contrary been found to exist when the relative humidity value RH_{in} reaches down to at least approx. 87%. This value is therefore stored in the memory means as the threshold relative-humidity value $RH_{inTH}[DC]$ associated to said Dry Cottons [DC] drying cycle.

[0043] Summarized in the table below are the threshold relative-humidity values $RH_{inTH}[ED,DC,SD,ID,M]$ for the different drying cycles:

Cycle	Final MR	RH_{in} Threshold
Extra Dry	-6% → 0%	68%
Dry Cottons	-3% → 3%	87%
Slightly Damp	4% → 8%	93%
Iron Dry	8% → 16%	93.5%
Mangle Dry	18% → 24%	94%

[0044] The tests that have been carried out to this effect have furthermore produced the graph represented in Figure 4, which illustrates the trend versus time of the drying air temperature T_{in} as detected by the temperature sensor means 5 at the drying-air condenser inlet 7, as well as the trend versus time of the drying air temperature T_{out} as detected by the temperature sensor means 6 at the drying-air condenser outlet 8, during the operation of the heating means 3.

[0045] Emphasized in this graph is the fact that the drying cycle is basically comprised of three distinct phases, actually. A first initial transient phase, which comes immediately after the energization of the heating means 3, and in which both temperatures T_{in} , T_{out} and also the evaporation rate increase.

[0046] The second phase is a saturation one, in which the temperatures T_{in} , T_{out} remain almost constant, since the thermal heating energy causes the water contained in the clothes being handled to evaporate, while the condenser is capable of dissipating most of the latent condensation heat.

[0047] There follows a third, final phase, in which the temperature of the drying air at the condenser inlet T_{in} tends to increase, owing to the clothes becoming increasingly dry, i.e. less and less damp, and the temperature of the drying air at the condenser outlet T_{out} tends on the contrary to decrease, since the evaporation rate is decreasing and the condenser is able to dissipate also the heat in the drying air, thereby cooling it down.

[0048] It clearly appears that the temperature difference ΔT between the drying air temperature at the condenser inlet T_{in} and the drying air temperature at the condenser outlet T_{out} is fully capable of being correlated to the actual residual moisture content in the clothes to be dried, i.e. the greater the value of $\Delta T = T_{in} - T_{out}$, the higher the degree of drying of the clothes.

[0049] Even in this case, the temperature values detected by the temperature sensor means 5, 6 following the energization of the heating means 3, are extremely variable and are by no means indicative of the actual trend of the temperatures. Therefore, the control means wait for this initial observation or transient phase to be concluded before starting with the acquisition of said values.

[0050] The graph in Figure 5 illustrates the trend versus time of the value of the temperature difference $\Delta T = T_{in} - T_{out}$, as well as the threshold values of this temperature difference $\Delta T_{TH}[ED,DC,SD,ID,M]$ of the drying air between condenser inlet and condenser outlet, which have been found as corresponding to the various degrees of drying due to be reached by the clothes in the respective drying cycles ED, DC, SD, ID, M.

[0051] For example, it has been found that, when the temperature difference ΔT reaches a value of at least 15°C, the degree of drying reached by the clothes in the drum corresponds to the degree of drying due to be reached in the Extra Dry cycle ED.

[0052] A temperature difference value of 15°C turns therefore out as being the threshold temperature-difference value $\Delta T_{TH}[ED]$ associable to the Extra Dry cycle ED and, as such, it is stored in the memory means.

[0053] In the description following hereinbelow, the term "temperature difference value ΔT " will be used to univocally mean the value of the difference between the temperature of the drying air as detected by the temperature sensor means 5 at the drying-air condenser inlet 7 and the temperature of the drying air as detected by the temperature sensor means 6 at the drying-air condenser outlet 8, whereas the term "threshold temperature-difference value ΔT_{TH} " will be used to univocally mean the threshold value of the difference between the temperature of the drying air as detected by the

temperature sensor means 5 at the drying-air condenser inlet 7 and the temperature of the drying air as detected by the temperature sensor means 6 at the drying-air condenser outlet 8 that has been found to correspond to the different degrees of drying of the clothes in the cycles ED,DC,SD,ID,M in the experimental tests performed to this effect.

[0054] When a user selects an Extra Dry drying cycle ED via the proper control devices on the control panel of the tumble dryer, the control means of the machine start by automatically retrieving the threshold temperature-difference value ΔT_{TH} [ED] corresponding to that cycle from the memory means, and start dryer operation by energizing the heating elements 3, switching on the air blower means 11, 16, and enabling the drum 2 to be driven rotatably. Then, upon allowing the initial observation time to elapse, the control means are capable of comparing the value of the temperature difference ΔT , as detected by the temperature sensor means 5, 6 with the threshold temperature-difference value ΔT_{TH} [ED] of the Extra Dry cycle ED. As soon as the temperature difference value ΔT reaches at least said threshold value ΔT_{TH} [ED], the control means consider the selected drying cycle as being concluded and stop dryer operation by de-energizing the heating means 3, switching off the air blower means 11, 16, and stopping drum rotation. In the case that a further unheated air circulation phase is provided to take place after the conclusion of the actual drying process in order to allow the clothes to be cooled down before they are removed from the drum, the control means simply cause the heating means 3 to be de-energized when the temperature difference value ΔT reaches said threshold temperature-difference value ΔT_{TH} [ED], while waiting for said cold air circulation phase to be concluded to turn off the tumble dryer and fully stop its operation.

[0055] Summarized in the table below are the threshold temperature-difference values for the different drying cycles:

Cycle	Final MR	ΔT_{TH} Threshold
Extra Dry	-6% $\rightarrow$ 0%	15 °C
Dry Cottons	-3% $\rightarrow$ 3%	7.4 °C
Slightly Damp	4% $\rightarrow$ 8%	5.9 °C
Iron Dry	8% $\rightarrow$ 16%	5.4 °C
Mangle Dry	18% $\rightarrow$ 24%	4.9 °C

[0056] The threshold temperature-difference values ΔT_{TH} [ED,DC,SD,ID,M] are independent of the initial quantity of water contained in the clothes to be dried. In fact, the transition from the intermediate saturation phase to the final phase of the drying cycle occurs at a given value of residual moisture, i.e. moisture that is still in the clothes being dried, wherein this value solely depends on the design parameters of the condenser.

[0057] According to the present invention, the method for controlling the drying cycles in a tumble dryer calls for the drying cycle selected by the user to be first of all read and the threshold humidity value RH_{inTH} and the threshold temperature-difference value ΔT_{TH} to be then set accordingly, i.e. on the basis of the selected cycle. These threshold values are retrieved from the memory means, in which they are properly stored.

[0058] Such reading of the cycle being selected and such setting of the corresponding values are performed by the control means, which are connected to the control devices in a control panel provided on the tumble dryer. The selected drying cycle is then immediately started by these control means by starting the operation of the dryer in the way described hereinbefore.

[0059] The method according to the present invention then calls for the relative humidity value RH_{in} and the temperature value T_{in} of the drying air entering the condenser, as well as the temperature value T_{out} of the drying air exiting the condenser to be detected as the drying cycle goes on. The control means acquire the data delivered by the humidity and temperature sensor means 5, 6 so as to monitor the trend of the relative humidity RH_{in} and the temperature difference value ΔT as the drying cycle progresses.

The method provides for the so detected relative humidity value RH_{in} to be compared with the threshold humidity value RH_{inTH} that has been set in accordance with the drying cycle selected by the user, and for the temperature difference value ΔT to be compared with the threshold temperature difference value ΔT_{TH} that has again been set in accordance with the drying cycle selected by the user.

[0060] The method then provides for the heating means 3 to be switched off when at least the temperature difference value ΔT reaches up to or beyond the threshold temperature-difference value ΔT_{TH} or when at least said humidity value RH_{in} reached down to or below the threshold humidity value RH_{inTH} .

[0061] When one of these threshold values is reached, further to switching off the heating means 3, the method may also provide for the tumble dryer to be fully stopped from operating, under de-energization of the air-circulating blower means 11, 16 and the motor means used to rotatably drive the drum.

[0062] The method preferably also provides for a transient observation phase to be included immediately upon the heating means 3 having been so switched on, in which the control means just wait for the humidity and temperature data from the sensor means to become steadier before they start acquiring said data.

[0063] The provision of two distinct threshold values, i.e. RH_{inTH} and ΔT_{TH} , for each drying cycle that can be selected

by the user, ensures greater effectiveness and accuracy in detecting the actual end-of-cycle condition, particularly in the case of drying cycles, such as Slightly Damp, Iron Dry and Mangle Dry, requiring less drying, i.e. a lower degree of dryness in the clothes, and having threshold values that lie rather close by.

[0064] It has been found and demonstrated experimentally that the trend of both RH_{in} and ΔT does not depend on the weight of the drying load, i.e. the amount of clothes to be dried.

[0065] The method for controlling the drying cycles in a clothes tumble dryer according to the present invention is not limited by, i.e. does not necessarily require the use of a condenser that is made and designed as has been described above by way of example. In the case of a tumble dryer that makes use of a different type of condenser, or a different condenser design, the trend of both temperature difference ΔT and relative humidity RH_{in} will in fact be much the same as the trends that have been found in the course of the above-described experimental tests considered herein, since the thermodynamics at the basis of these trends is anyway the same, regardless of the condenser being actually used.

[0066] The curves describing the trend versus time of humidity RH_{in} and temperature difference ΔT will most obviously have a different steepness, and different will clearly be also the threshold values RH_{inTH} , ΔT_{TH} corresponding to the degrees of drying to be reached in the various drying cycles that can be selected by the user.

[0067] Also the drying cycles that are made available to the user may of course be set and fixed according to principles that differ from the aforescribed ones based on residual moisture as compared to a same drying load under standard conditions as a control parameter.

[0068] It can however be most readily appreciated that - even in the presence of a different condenser design - it is anyway possible for both the threshold relative-humidity values RH_{inTH} of the drying air entering the condenser and the threshold temperature-difference values ΔT_{TH} of the drying air entering and exiting the condenser attributable to the various user-selectable drying cycles to be derived experimentally.

[0069] Such threshold values will then be made available to the control means via the memory means as soon as the operation of the tumble dryer is started, in accordance with the particular drying cycle selected by the user.

[0070] In a preferred embodiment of the present invention, the control means are adapted to numerically filter the signals they receive from the moisture and temperature sensor means 5, 6 so as to eliminate all detected values that are found to significantly depart from the main trend versus time of both the relative humidity values RH_{in} and temperature difference values ΔT being monitored by said control means during the drying cycle, i.e. as the clothes in the drum undergo drying.

[0071] Basically, the control means are adapted to discard any distorted, altered or perturbed value as may be detected by the moisture and temperature sensors, in such manner as to solely retain the main dynamics of the evolution of relative humidity RH_{in} and temperature difference ΔT with time.

[0072] Such disturbances in detected values include perturbed measurements that do not correspond to the actual humidity and temperature values and can occur due to such measurements being affected by the dynamic, i.e. flow conditions of the drying air.

[0073] A further cause of disturbance in detected values may be due to the fact that, for an even and effective drying of the clothes being tumbled in the drum to be ensured, during the drying cycle there are provided reversal periods, in which the heating means 3 are switched off and the drum is rotated in the reverse direction, i.e. counter-rotated so as to allow the clothes held therein to be counter-tumbled and reshuffled. These reversal periods last just a few seconds and are separated from each other by pre-determined intervals of a few minutes each provided therebetween.

[0074] Most obviously, detections performed by the sensor means within these reversal periods tend to result in the measurement of humidity values RH_{in} and temperature difference values ΔT that deviate to a rather considerable extent from the trend of the corresponding values that are on the contrary detected when the heating means 3 are switched on. In fact, as this can clearly be noticed in the graphs appearing in Figures 3, 4 and 5, in correspondence to, i.e. during said reversal periods the temperature-difference curve ΔT shows minimum-value peaks, whereas the relative-humidity curve RH_{in} shows maximum-value peaks.

[0075] The control means filter these humidity values RH_{in} and temperature difference values ΔT with the aid of a numeric low-pass filter.

[0076] In particular, the control means associate a first numeric low-pass filter to the humidity values RH_{in} and a second numeric low-pass filter to the temperature difference values ΔT , while both filters preferably comprise a numeric unit-gain low-pass filter of the first order according to following formulas:

$$y_n = a \cdot y_{n-1} + (1-a) \cdot RH_{in}$$

$$u_n = a \cdot u_{n-1} + (1-a) \cdot \Delta T$$

in which the coefficient a represents the parameter of the filters, the detected relative-humidity values RH_{in} represent the input variables of the first filter at the different instants n , and y_n represents the current value of the first filter at the different instants n , whereas the detected temperature-difference values ΔT represent the input variables of the second filter at the different instants n and u_n represents the current value of the second filter at the different instants n .

[0077] It has been found experimentally that - for the application considered - the parameter a of the filters can take a value ranging from 0.9 to 0.99.

[0078] In the particular embodiment being described, it has been opted to use the same value of the parameter a for all drying cycles selectable by the user, and for both the numeric filters, in order to avoid weighing too heavily on the processing load of the control means.

[0079] However, in order to ensure a more specific filtering effect, the value of the parameter a may vary in accordance with the various drying cycles that can be selected by the user, while within a same cycle selected by the user, the value of the parameter a may again differ in the two numeric low-pass filters.

[0080] The values of the parameter a of the filters are stored in the memory means and are adapted to be retrieved by the control means when the drying cycle selected by the user is started.

[0081] The control means acquire the relative-humidity values RH_{in} and the temperature-difference values ΔT detected by the corresponding sensor means, and then calculate, i.e. work out the related numeric filters to obtain a corresponding filtered relative-humidity value $RH_{in,filtered}$ and a corresponding filtered temperature-difference value $\Delta T_{filtered}$ giving the curves indicated in Figures 3 and 5.

[0082] The control means are adapted to compare each such filtered relative-humidity value $RH_{in,filtered}$ with the respective threshold relative-humidity value $RH_{in,TH}[ED,DC,SD,ID,M]$ corresponding to the actual drying cycle selected by the user, and are furthermore adapted to compare each such filtered temperature-difference value $\Delta T_{filtered}$ with the respective threshold temperature-difference value $\Delta T_{TH}[ED,DC,SD,ID,M]$ that corresponds to the actual drying cycle selected by the user.

[0083] In particular, the control means are adapted to determine a first end-of-cycle coefficient dH and a second end-of-cycle coefficient dT , which represent how close the filtered relative-humidity value $RH_{in,filtered}$ has got to the respective threshold value $RH_{in,TH}[ED,DC,SD,ID,M]$, and how close the filtered temperature-difference value $\Delta T_{filtered}$ has got to the respective threshold value $\Delta T_{TH}[ED,DC,SD,ID,M]$, respectively. These coefficients are determined by comparing the filtered values with the respective threshold values, according to following formulas:

$$dH = \frac{RH_{in,TH}[ED;DC;LH,ID,M]}{RH_{in,filtered}}$$

$$dT = \frac{\Delta T_{filtered}}{\Delta T_{TH}[ED,DC,LH,ID,M]}$$

[0084] These end-of-cycle coefficients dH and dT turn therefore out as being pure numbers that tend to unit as the the filtered values $RH_{in,filtered}$ and $\Delta T_{filtered}$ get closer to the respective threshold values $RH_{in,TH}[ED,DC,SD,ID,M]$ and $\Delta T_{TH}[ED,DC,SD,ID,M]$.

[0085] Thus, the control means are adapted to compose the end-of-cycle coefficients dH and dT so as to obtain a single control quantity D , on the basis of which they therefore decide that the drying cycle is to be caused to stop. This control quantity D is obtained by calculating the weighted average of the end-of-cycle coefficients dH and dT through a weight factor δ that determines the specific contribution of the individual coefficients in accordance with the drying cycle selected, according to following formula:

$$D = \delta \cdot dT + (100 - \delta) \cdot dH ,$$

wherein the value of the weight factor δ depends on the selected cycle, so as to determine which quantity, between relative humidity RH_{in} and temperature difference ΔT , is more significant in view of identifying the end-of-cycle condition. The weight factor δ is variable between 0 and 100 and depends on the selected cycle.

[0086] This is of particular value in the case of drying cycles as the Iron Dry and Mangle Dry ones, in which it is the value of temperature difference ΔT that prevaingly determines said end-of-cycle condition, since the value of relative humidity RH_{in} is less reliable.

[0087] The value of the weight factor δ has been determined experimentally for the different drying cycles provided for selection in a clothes tumble dryer, and is stored in the memory means so as to be made available for retrieval by the control means when the selected drying cycle is started.

[0088] The end-of-cycle condition occurs when the thus calculated control quantity D turns out to be equal to or in excess of a stop parameter sD that is variable from 85 to 100 in accordance with the cycle selected by the user.

[0089] Even the value of this stop parameter sD has been determined experimentally for the different drying cycles provided for selection in a clothes tumble dryer, and is stored in the memory means so as to be made available for retrieval by the control means when the selected drying cycle is started.

[0090] Summarized in the following table are the threshold values $RH_{inTH}[ED,DC,SD,ID,M]$, $\Delta T_{TH}[ED,DC,SD,ID,M]$, the values of the end-of-cycle coefficients dH and dT , the values of the weight factor δ , and the values of the stop parameters sD for each one of a number of drying cycles:

Cycle	RH_{inTH}	ΔT_{TH}	δ	sD
Extra Dry	68%	15 °C	50	100
Dry Cottons	87%	7.4 °C	50	100
Slightly Damp	93%	5.9 °C	50	100
Iron Dry	93.5%	5.4 °C	60	95
Mangle Dry	94%	4.9 °C	60	85

[0091] When such end-of-cycle condition is found to exist by the control means, these cause the heating means 3 to be switched off and, if provided or required so, the air-circulating blower means to be de-energized along with the motor means used to rotatably drive the dryer's drum.

[0092] According to a preferred embodiment of the present invention, the method for controlling the operation of a clothes tumble dryer includes an initialization phase, in which the control means read the cycle that has been selected by the user and set the threshold relative-humidity values $RH_{inTH}[ED,DC,SD,ID,M]$, the threshold temperature-difference values $\Delta T_{TH}[ED,DC,SD,ID,M]$, the value of the parameter a of the filters, the values of weight factor δ and the value of the stop parameter sD , which correspond to the selected cycle, by retrieving the related values from the memory means.

[0093] The control means cause then the heating means 3 to be switched on and the air-circulating blower means 11, 16 to be energized along with the drum rotation driving means.

[0094] It is to be noted that in a further simplified embodiment of the present invention the end-of-cycle coefficients dH and dT can be determined by comparing the current values of temperature difference ΔT and relative humidity RH_{in} , non filtered, with the respective threshold values. The end-of-cycle coefficients dH and dT are then composed, in the manner above described, to obtain the single control quantity D on the basis of which the control means switch off the heating means 3.

[0095] The control means are adapted to check the heating means 3 for the on/off state thereof through a proper operation sensor.

[0096] The method further includes a so-called transient observation phase, in which the control means just wait for the values of relative humidity RH_{in} and the values of temperature difference ΔT to stabilize.

[0097] In a preferred manner, within this transient observation phase there may be provided at least a reversal period, in which the heating means 3 are switched off and the drum 2 driven to rotate in an opposite direction, i.e. counter-rotated.

[0098] When the detected values of relative humidity RH_{in} and the detected values of temperature difference ΔT are detected to have become steadier, the control means check the heating means 3 for the on/off state thereof.

[0099] In the case that the heating means 3 are in the off state, i.e. the tumble dryer is performing a reversal period, the control means do not acquire said values of relative humidity RH_{in} and said values of temperature difference ΔT , and wait for the heating means 3 to switch in the on state thereof.

[0100] In the case that the heating means 3 are found in the on state thereof, the method calls for an initialization phase to occur, in which the control means acquire the value of relative humidity RH_{in} and the value of temperature difference ΔT detected by the sensor means 5,6 to initialize the related numeric low-pass filters by calculating the corresponding filtered initial value of relative humidity $RH_{in,filtered}$ and the corresponding filtered initial value of temperature difference $\Delta T_{filtered}$.

[0101] As a selected drying cycle progresses, the control means are adapted to acquire the relative-humidity values RH_{in} and the temperature-difference values ΔT detected by the sensor means, and to filter these values with the aid of the numeric low-pass filters at pre-determined successive time intervals; in the described embodiment there is provided a waiting time interval between two successive acquisition events of approx. 5 seconds.

[0102] The control means wait for such waiting time interval to elapse and, when this runs out, check the heating means 3 to see whether they are on or off.

[0103] In the case that the heating means 3 are found to be in the off state thereof, i.e. the tumble dryer is going

through a reversal period, the control means - in a loop-like cyclic manner - wait again for the waiting time interval to elapse and, when this runs out, check again the heating means 3 for the on/off state thereof.

[0104] If the heating means 3 are on the contrary found to be in the on state thereof, the control means acquire the value of relative humidity RH_{in} and the value of temperature difference ΔT as detected by the respective sensor means, and calculate the related numeric low-pass filters to determine the corresponding filtered relative-humidity value $RH_{in-filtered}$ and the corresponding filtered temperature-difference value $\Delta T_{filtered}$, in the same manner as described hereinbefore.

[0105] Then, the control means check whether the end-of-cycle condition has eventually occurred by calculating the values of the end-of-cycle coefficients dH and dT , the value of the control quantity D , and comparing the resulting value of the latter with the value of the stop parameter sD .

[0106] If the value of the control quantity D turns out to be equal to or in excess of the value of the stop parameter sD , the control means switch off the heating means 3 and, if possibly provided or required so by the cycle, cause the operation of the dryer to stop.

[0107] If the value of the control quantity D is found to be lower than the value of the stop parameter sD , the control means - in a loop-like cyclic manner - wait again for the waiting time interval to elapse and, when this runs out, check the heating means 3 for the on/off state thereof in view of acquiring again the values of relative humidity RH_{in} and temperature difference ΔT , updating the related numeric low-pass filters and checking again whether the end-of-cycle condition has been reached.

Claims

1. Clothes tumble dryer comprising a closed-loop drying air circuit adapted to circulate heated drying air through a perforated rotating drum (2) holding a load to be dried, an air-cooled condenser (4) adapted to remove moisture from the hot moisture-laden drying air exiting said drum, heating means (3) provided downstream the air-cooled condenser (4) for heating up the drying air to be sent again into the drum (2), an open-loop cooling air circuit adapted to circulate over and through the condenser (4) a stream of cooling air taken in from the outside ambient to cool said condenser, and to let out said stream of cooling air again into the outside ambient, temperature sensor means (5, 6) arranged at a condenser drying-air inlet (7) and at a condenser drying-air outlet (8) in order to detect a temperature difference value between the drying air entering the condenser (4) and the drying air exiting the condenser (4), **characterized in that** it further comprises humidity sensor means (5) arranged at said condenser drying-air inlet (7) in order to detect a humidity value of the drying air entering the condenser, control means coupled to said humidity sensor means (5) to receive said humidity value (RH_{in}), and coupled to said temperature sensor means (5, 6) to receive said temperature difference value (ΔT) during the operation of said tumble drier, memory means for storing a threshold temperature-difference value (ΔT_{TH}) between the drying air entering the condenser (4) and the drying air exiting the condenser (4), and a threshold relative-humidity value (RH_{inTH}) of the drying air entering the condenser, which are representative of a pre-determined dryness degree of the load and depend on the particular drying cycle selected by the user, said control means are adapted to retrieve said threshold values (ΔT_{TH} , RH_{inTH}) from the memory means in response to a given drying cycle selected by the user, said control means being further adapted to compare said relative humidity value (RH_{in}) with said threshold relative-humidity value (RH_{inTH}) and said temperature difference value (ΔT) with said threshold temperature-difference value (ΔT_{TH}) for determining an end-of cycle condition and switching off said heating means (3) when at least said temperature difference value (ΔT) reaches said threshold temperature-difference value (ΔT_{TH}) or at least said relative humidity value (RH_{in}) reaches said threshold relative-humidity value (RH_{inTH}).
2. Clothes tumble dryer according to claim 1, wherein said control means comprise numeric filter means to numerically filter said relative humidity value (RH_{in}) acquired and said temperature difference value (ΔT) acquired, in order to eliminate all detected values deviating to a significant extent from the main trend versus time of said values of relative humidity (RH_{in}) and temperature difference (ΔT) being monitored by said control means as the drying process of the clothes goes on, and establish a corresponding filtered relative-humidity value ($RH_{in-filtered}$) and a corresponding filtered temperature-difference value ($\Delta T_{filtered}$).
3. Clothes tumble dryer according to claim 2, wherein said numeric filter means comprise a first numeric low-pass filter associated to the relative humidity values (RH_{in}) and a second numeric low-pass filter associated to the temperature difference values (ΔT).
4. Clothes tumble dryer according to claim 3, wherein said first numeric filter and said second numeric filter comprise a filtering parameter (α) that depends on the particular drying cycle selected by the user.

5. Clothes tumble dryer according to claim 4, wherein said memory means are adapted to store the values of said filtering parameter (α), said control means being in turn adapted to retrieve said values when the drying cycle selected by the user is started.
- 5 6. Clothes tumble dryer according to claim 2, wherein said control means are adapted to compare said filtered relative-humidity value ($RH_{in,filtered}$) with said threshold relative-humidity value ($RH_{in,TH}$) corresponding to the drying cycle selected by the user, and are further adapted to compare said filtered temperature-difference value ($\Delta T_{filtered}$) with said threshold temperature-difference value (ΔT_{TH}) corresponding to the drying cycle selected by the user.
- 10 7. Clothes tumble dryer according to any of the preceding claims, wherein said control means are adapted to determine a first end-of-cycle coefficient (dH) and a second end-of-cycle coefficient (dT) that represent how close the filtered relative-humidity value ($RH_{in,filtered}$) has got to the respective threshold value ($RH_{in,TH}$), and how close the filtered temperature-difference value ($\Delta T_{filtered}$) has got to the respective threshold value (ΔT_{TH}], respectively.
- 15 8. Clothes tumble dryer according to any of the preceding claims, wherein said control means are adapted to calculate a weighted average of said end-of-cycle coefficients (dH , dT) through a weight factor (δ) that depends on the drying cycle selected by the user.
- 20 9. Clothes tumble dryer according to any of the preceding claims, wherein said weight factor (δ) depends on the selected drying cycle and said control means are adapted to retrieve the value of said weight factor (δ) from said memory means when the selected drying cycle is started.
- 25 10. Clothes tumble dryer according to any of the preceding claims, wherein said control means are adapted to compare the value of said weighted average with a stop parameter (sD) that depends on the particular drying cycle being selected, in order to switch off the heating means (3) when the value of said weighted average reaches up to or beyond the value of said stop parameter (sD), said control means being adapted to retrieve the value of said stop parameter (sD) from said memory means when the selected drying cycle is started.
- 30 11. Clothes tumble dryer according to any of the preceding claims, wherein reversal periods are provided during the drying cycle, in which the heating means (3) are switched off and the drum (2) is driven to rotate in the opposite direction, said control means being adapted to solely acquire said humidity values (RH_{in}) and said temperature difference values (ΔT) when said heating means (3) are switched on.
- 35 12. Clothes tumble dryer according to any of the preceding claims, wherein said control means are adapted to acquire said relative humidity values (RH_{in}) and said temperature difference values (ΔT) in correspondence to acquisition events that are separated from each other by a pre-set waiting time interval.
- 40 13. Clothes tumble dryer according to any of the preceding claims, wherein said numeric filters comprise a numeric unit-gain low-pass filter of the first order.
- 45 14. Clothes tumble dryer according to any of the preceding claims, wherein the value of said filtering parameter (α) ranges from 0.9 and 0.99.
- 50 15. Method for controlling a clothes tumble dryer including a closed-loop drying air circuit adapted to circulate heated drying air through the clothes to be dried held in a perforated rotating drum (2), an air-cooled condenser (4) adapted to remove moisture from the hot moisture-laden drying air exiting said drum, heating means (3) provided downstream the air-cooled condenser (4) for heating up the drying air to be sent again into the drum (2), an open-loop cooling air circuit adapted to circulate over and through the condenser (4) a stream of cooling air taken in from the outside ambient to cool said condenser, and then let out again said stream of cooling air into the outside ambient, **characterized in that** it comprises the steps of:
 - retrieving, in response to a given drying cycle selected by the user, a stored threshold temperature-difference value (ΔT_{TH}) between the drying air entering the condenser (4) and the drying air exiting the condenser (4), and a stored threshold relative-humidity value ($RH_{in,TH}$) of the drying air entering the condenser, both values depending on the drying cycle selected by the user and being representative of a pre-determined dryness degree of the clothes being handled,
 - detecting a relative humidity value (RH_{in}) of the drying air entering the condenser (4), and
 - detecting a temperature difference value (ΔT) between the drying air entering the condenser (4) and the drying

exiting the condenser (4),

- acquiring, during the operation of said tumble dryer, said relative humidity value (RH_{in}) and said temperature difference value (ΔT) detected by the respective sensor means,
- comparing said relative humidity value (RH_{in}) with said threshold relative-humidity value (RH_{inTH}) and said temperature difference value (ΔT) with said threshold temperature-difference value (ΔT_{TH}) for determining an end-of-cycle condition and switching off said heating means (3) when at least said temperature difference value reaches said threshold temperature-difference value or at least said relative humidity value reaches said threshold relative-humidity value.

16. Method according to claim 15, further comprising the steps of:

- numerically filtering said acquired relative-humidity values (RH_{in}) and said acquired temperature-difference values (ΔT), in order to eliminate all detected values deviating to a significant extent from the main trend versus time of said values of relative humidity (RH_{in}) and temperature difference (ΔT) being monitored by said control means as the drying process of the clothes goes on, and establish a corresponding filtered relative-humidity value ($RH_{infiltered}$) and a corresponding filtered temperature-difference value ($\Delta T_{filtered}$).

17. Method according to claim 16, wherein said comparison step comprises the steps of:

- comparing said filtered relative-humidity value ($RH_{infiltered}$) with said threshold relative-humidity value (RH_{inTH}) corresponding to the drying cycle selected by the user, and
- comparing said filtered temperature-difference value ($\Delta T_{filtered}$) with said threshold temperature-difference value (ΔT_{TH}) corresponding to the drying cycle selected by the user.

18. Method according to any of the preceding claims, further comprising the steps of:

- providing reversal periods during the drying cycle, in which the heating means (3) are switched off and the drum is driven to rotate in the opposite direction,
- solely acquiring said relative humidity value (RH_{in}) and said temperature difference value (ΔT) if said heating means (3) are found to be switched on.

19. Method according to claim 16, wherein said numerical filtering step comprises the steps of:

- numerically filtering said acquired relative-humidity value (RH_{in}) through a first numeric low-pass filter, and
- numerically filtering said acquired temperature-difference value (ΔT) through a second numeric low-pass filter.

20. Method according to claim 16, wherein said numerical filtering step further comprises the steps of:

- retrieving, in response to said tumble dryer being started operating, a stored numerical filtering parameter (α) that depends on the drying cycle selected by the user,
- numerically filtering in a differentiated manner said relative humidity value (RH_{in}) and said temperature difference value (ΔT) on the basis of said numerical filtering parameter (α).

21. Method according to any of the preceding claims, wherein said comparison further comprises the steps of:

- determining a first end-of-cycle coefficient (dH) and a second end-of-cycle coefficient (dT) that are representative of how close the filtered relative-humidity value ($RH_{infiltered}$) has got to the respective threshold value (RH_{inTH}), and how close the filtered temperature-difference value ($\Delta T_{filtered}$) has got to the respective threshold value (ΔT_{TH}), respectively.

22. Method according to any of the preceding claims, wherein said comparison step further comprises the steps of:

- calculating a weighted average of the end-of-cycle coefficients (dH , dT) through a weight factor (δ) that depends on the selected drying cycle and determines the specific contribution of the individual coefficients in accordance with the selected cycle, so as to obtain a single control quantity (D),
- retrieving said weight factor (δ) in accordance with the selected drying cycle.

23. Method according to any of the preceding claims, wherein said comparison step further comprises the steps of:

- comparing the value of said control quantity (D) with a stop parameter (sD) that depends on the selected drying cycle,
- retrieving the value of said stop parameter (sD) in accordance with the selected drying cycle,
- switching off the heating means (3) in the case that the value of the thus calculated control quantity (D) is found to be equal to or in excess of the value of said stop parameter (sD).

24. Method according to any of the preceding claims, wherein said acquisition step comprises the steps of:

- acquiring said relative humidity value (RH_{in}) and said temperature difference value (ΔT) in correspondence to acquisition events that are separated from each other by a pre-set time interval.

25. Method according to claim 2, comprising the steps of:

- checking, after the tumble dryer has started operating, said relative humidity values (RH_{in}) and said temperature difference values (ΔT) for becoming steadier,
- starting to acquire said relative humidity values (RH_{in}) and said temperature difference values (ΔT) if these are found to have stabilized.

26. Method according to any of the preceding claims, wherein said numerical filtering step comprises the steps of:

- numerically filtering the so acquired relative humidity values (RH_{in}) through a first numeric unit-gain low-pass filter of the first order,
- numerically filtering the so acquired temperature difference values (ΔT) through a second numeric unit-gain low-pass filter of the first order.

Patentansprüche

1. Wäschetrockner, der einen geschlossenen Trocknungsluftkreis umfasst, welcher geeignet ist, erhitzte Trocknungsluft durch eine perforierte Rotationstrommel (2) zu zirkulieren, welche eine Trocknungsbeladung enthält; ferner einen luftgekühlten Kondensator (4), der geeignet ist, Feuchtigkeit aus der aus der Trommel austretenden, heißen, feuchtigkeitshaltigen Trocknungsluft zu entfernen; Heizmittel (3), die dem luftgekühlten Kondensator (4) nachgelagert sind und dazu dienen, die erneut in die Trommel (2) zu sendende Trocknungsluft zu erhitzen; einen offenen Kühlluftkreis, der geeignet ist, einen von der Außenumgebung aufgenommenen Kühlluftstrom über und durch den Kondensator (4) zu zirkulieren, um den Kondensator zu kühlen, und den Kühlluftstrom wieder in die Außenumgebung zu entlassen; Temperaturmessmittel (5, 6), die an einem Kondensator-Trockenlufteinlass (7) und an einem Kondensator-Trockenluftauslass (8) angeordnet sind, um eine Temperaturdifferenz zwischen der in den Kondensator (4) eintretenden Trocknungsluft und der den Kondensator (4) verlassenden Trocknungsluft festzustellen, **dadurch gekennzeichnet, dass** dieser ferner ein Feuchtigkeitsmessmittel (5) umfasst, das am Trocknungslufteinlass (7) des Kondensators angeordnet ist, um einen Feuchtigkeitswert der in den Kondensator eintretenden Trocknungsluft festzustellen; ferner Steuermittel, die mit dem Feuchtigkeitsmessmittel (5) verbunden sind, um den Feuchtigkeitswert (RH_{in}) aufzunehmen, und mit den Temperaturmessmitteln (5, 6) verbunden sind, um den Temperaturdifferenzwert (ΔT) während des Betriebs des Wäschetrockners aufzunehmen; ferner Speichermittel zum Speichern eines Schwellwerts der Temperaturdifferenz (ΔT_{TH}) zwischen der in den Kondensator (4) eintretenden und der den Kondensator (4) verlassenden Trocknungsluft und eines Schwellwerts der relativen Feuchtigkeit (RH_{inTH}) der in den Kondensator eintretenden Trocknungsluft, die repräsentativ für einen vorher festgelegten Trockenheitsgrad der Trocknungsbeladung sind und von dem vom Benutzer jeweils ausgewählten Trocknungszyklus abhängig sind, wobei die Steuermittel geeignet sind, die Schwellwerte (ΔT_{TH} , RH_{inTH}) vom Speichermittel als Reaktion auf einen bestimmten vom Benutzer ausgewählten Trocknungszyklus abzurufen, und wobei die Steuermittel ferner geeignet sind, den Wert der relativen Feuchtigkeit (RH_{in}) mit dem Schwellwert der relativen Feuchtigkeit (RH_{inTH}) und den Temperaturdifferenzwert (ΔT) mit dem Schwellwert der Temperaturdifferenz (ΔT_{TH}) zu vergleichen, um einen Zyklusendzustand zu bestimmen und das Heizmittel (3) auszuschalten, wenn zumindest der Temperaturdifferenzwert (ΔT) den Temperaturdifferenz-Schwellwert (ΔT_{TH}) erreicht oder zumindest der Wert der relativen Feuchtigkeit (RH_{in}) den Schwellwert der relativen Feuchtigkeit (RH_{inTH}) erreicht.
2. Wäschetrockner gemäß Anspruch 1, wobei die Steuermittel numerische Filtermittel umfassen, um den aufgenommenen Wert der relativen Feuchtigkeit (RH_{in}) und den aufgenommenen Temperaturdifferenzwert (ΔT) numerisch zu filtern, um alle festgestellten Werte zu eliminieren, die bei laufendem Trocknungsprozess der Wäsche in signi-

fikantem Ausmaß von der durch die Steuermittel kontrollierten Haupttendenz in Relation zur Zeit der Werte der relativen Feuchtigkeit (RH_{in}) und der Temperaturdifferenz (ΔT) abweichen, und um einen entsprechenden gefilterten Wert der relativen Feuchtigkeit ($RH_{in,filtered}$) und einen entsprechenden gefilterten Wert der Temperaturdifferenz ($\Delta T_{filtered}$) zu ermitteln.

3. Wäschetrockner gemäß Anspruch 2, wobei die numerischen Filtermittel einen ersten numerischen Tiefpassfilter umfassen, der den Werten für die relative Feuchtigkeit (RH_{in}) zugeordnet ist, und einen zweiten numerischen Tiefpassfilter, der den Temperaturdifferenzwerten (ΔT) zugeordnet ist.
4. Wäschetrockner gemäß Anspruch 3, wobei der erste numerische Filter und der zweite numerische Filter einen Filterungsparameter (α) umfassen, der von dem vom Benutzer ausgewählten spezifischen Trocknungszyklus abhängig ist.
5. Wäschetrockner gemäß Anspruch 4, wobei die Speichermittel geeignet sind, die Werte des Filterungsparameters (α) zu speichern, und wobei die Steuermittel wiederum geeignet sind, die Werte abzurufen, wenn der vom Benutzer gewählte Trocknungszyklus gestartet wird.
6. Wäschetrockner gemäß Anspruch 2, wobei die Steuermittel geeignet sind, den gefilterten Wert der relativen Feuchtigkeit ($RH_{in,filtered}$) mit dem Schwellwert für die relative Feuchtigkeit ($RH_{in,TH}$) in Entsprechung zu dem vom Benutzer gewählten Trocknungszyklus zu vergleichen, und ferner geeignet sind, den gefilterten Wert der Temperaturdifferenz ($\Delta T_{filtered}$) mit dem Schwellwert der Temperaturdifferenz (ΔT_{TH}) in Entsprechung zu dem vom Benutzer gewählten Trocknungszyklus zu vergleichen.
7. Wäschetrockner gemäß einem der vorangehenden Ansprüche, wobei die Steuermittel geeignet sind, einen ersten Zyklusendkoeffizienten (dH) und einen zweiten Zyklusendkoeffizienten (dT) zu bestimmen, die darstellen, wie weit der gefilterte Wert für die relative Feuchtigkeit ($RH_{in,filtered}$) sich dem entsprechenden Schwellwert ($RH_{in,TH}$) angenähert hat bzw. wie weit sich der gefilterte Wert für die Temperaturdifferenz ($\Delta T_{filtered}$) dem entsprechenden Schwellwert (ΔT_{TH}) angenähert hat.
8. Wäschetrockner gemäß einem der vorangehenden Ansprüche, wobei die Steuermittel geeignet sind, anhand eines Gewichtungsfaktors (δ), der von dem vom Benutzer gewählten Trocknungszyklus abhängt, einen gewichteten Durchschnitt der Zyklusendkoeffizienten (dH , dT) zu berechnen.
9. Wäschetrockner gemäß einem der vorangehenden Ansprüche, wobei der Gewichtungsfaktor (δ) von dem ausgewählten Trocknungszyklus abhängig ist und die Steuermittel geeignet sind, den Wert des Gewichtungsfaktors (δ) aus dem Speichermittel abzurufen, wenn der ausgewählte Trocknungszyklus gestartet wird.
10. Wäschetrockner gemäß einem der vorangehenden Ansprüche, wobei die Steuermittel geeignet sind, den Wert des gewichteten Durchschnitts mit einem Stopp-Parameter (sD) zu vergleichen, der von dem spezifischen gewählten Trocknungszyklus abhängt, um die Heizmittel (3) auszuschalten, wenn der Wert des gewichteten Durchschnitts den Wert des Stopp-Parameters (sD) erreicht oder übertrifft, wobei die Steuermittel geeignet sind, den Wert des Stopp-Parameters (sD) aus dem Speichermittel abzurufen, wenn der gewählte Trocknungszyklus gestartet wird.
11. Wäschetrockner gemäß einem der vorangehenden Ansprüche, wobei Umkehrperioden während des Trocknungszyklus vorgesehen sind, in denen die Heizmittel (3) ausgeschaltet werden und die Trommel (2) zur Rotation in die Gegenrichtung gebracht wird, wobei die Steuermittel geeignet sind, alleine die Feuchtigkeitswerte (RH_{in}) und die Temperaturdifferenz-Werte (ΔT) aufzunehmen, wenn die Heizmittel (3) eingeschaltet sind.
12. Wäschetrockner gemäß einem der vorangehenden Ansprüche, wobei die Steuermittel geeignet sind, die Werte der relativen Feuchtigkeit (RH_{in}) und der Temperaturdifferenz (ΔT) in Entsprechung zu Aufnahme-Ereignissen aufzunehmen, die voneinander durch ein voreingestelltes Wartezeitintervall getrennt sind.
13. Wäschetrockner gemäß einem der vorangehenden Ansprüche, wobei die numerischen Filter einen numerischen Einheitsverstärkungs-Tiefpassfilter erster Ordnung umfassen.
14. Wäschetrockner gemäß einem der vorangehenden Ansprüche, wobei der Wert des Filterungsparameters (α) von 0,9 bis 0,99 reicht.

15. Verfahren zur Steuerung eines Wäschetrockners, der einen geschlossenen Trocknungsluftkreis umfasst, welcher geeignet ist, erhitzte Trocknungsluft durch die in einer perforierten Rotationstrommel (2) enthaltene, zu trocknende Wäsche zu zirkulieren; ferner einen luftgekühlten Kondensator (4), der geeignet ist, Feuchtigkeit aus der aus der Trommel austretenden, heißen, feuchtigkeitshaltigen Trocknungsluft zu entfernen; Heizmittel (3), die dem luftgekühlten Kondensator (4) nachgelagert sind und dazu dienen, die erneut in die Trommel (2) zu sendende Trocknungsluft zu erhitzen; einen offenen Kühlluftkreis, der geeignet ist, einen von der Außenumgebung aufgenommenen Kühlluftstrom über und durch den Kondensator (4) zu zirkulieren, um den Kondensator zu kühlen, und den Kühlluftstrom wieder in die Außenumgebung zu entlassen; **dadurch gekennzeichnet, dass** das Verfahren folgende Schritte umfasst:

- als Reaktion auf einen gegebenen, vom Benutzer gewählten Trocknungszyklus das Abrufen eines gespeicherten Schwellwerts der Temperaturdifferenz (ΔT_{TH}) zwischen der in den Kondensator (4) eintretenden und der den Kondensator (4) verlassenden Trocknungsluft und eines gespeicherten Schwellwerts der relativen Feuchtigkeit (RH_{inTH}) der in den Kondensator eintretenden Trocknungsluft, wobei beide Werte von dem vom Benutzer gewählten Trocknungszyklus abhängig und repräsentativ für einen vorher festgelegten Trockenheitsgrad der zu bearbeitenden Wäsche sind,
- Feststellen eines Werts der relativen Feuchtigkeit (RH_{in}) der in den Kondensator (4) eintretenden Trocknungsluft, und
- Feststellen eines Temperaturdifferenzwerts (ΔT) zwischen der in den Kondensator (4) eintretenden und der den Kondensator (4) verlassenden Trocknungsluft,
- Aufnehmen des Werts für die relative Feuchtigkeit (RH_{in}) und des Temperaturdifferenzwerts (ΔT) durch die entsprechenden Messmittel während des Betriebs des Wäschetrockners,
- Vergleichen des Werts der relativen Feuchtigkeit (RH_{in}) mit dem Schwellwert der relativen Feuchtigkeit (RH_{inTH}) und des Temperaturdifferenzwerts (ΔT) mit dem Schwellwert der relativen Temperaturdifferenz (ΔT_{TH}), um einen Zyklusendzustand zu bestimmen, und Ausschalten der Heizmittel (3), wenn zumindest der Temperaturdifferenzwert den Temperaturdifferenz-Schwellwert erreicht oder zumindest der Wert der relativen Feuchtigkeit den Schwellwert der relativen Feuchtigkeit erreicht.

16. Verfahren gemäß Anspruch 15, das zusätzlich folgende Schritte umfasst:

- numerisches Filtern der aufgenommenen Werte der relativen Feuchtigkeit (RH_{in}) und der aufgenommenen Temperaturdifferenzwerte (ΔT), um alle festgestellten Werte zu eliminieren, die bei laufendem Trocknungsprozess der Wäsche in signifikantem Ausmaß von der durch die Steuermittel kontrollierten Haupttendenz in Relation zur Zeit der Werte der relativen Feuchtigkeit (RH_{in}) und der Temperaturdifferenz (ΔT) abweichen, und um einen entsprechenden gefilterten Wert der relativen Feuchtigkeit ($RH_{in,filtered}$) und einen entsprechenden gefilterten Wert der Temperaturdifferenz ($\Delta T_{filtered}$) zu ermitteln.

17. Verfahren gemäß Anspruch 16, wobei der Vergleichsschritt folgende Schritte umfasst:

- Vergleichen des gefilterten Werts der relativen Feuchtigkeit ($RH_{in,filtered}$) mit dem Schwellwert für die relative Feuchtigkeit (RH_{inTH}) in Entsprechung zu dem vom Benutzer gewählten Trocknungszyklus, und
- Vergleichen des gefilterten Werts der Temperaturdifferenz ($\Delta T_{filtered}$) mit dem Schwellwert der Temperaturdifferenz (ΔT_{TH}) in Entsprechung zu dem vom Benutzer gewählten Trocknungszyklus.

18. Verfahren gemäß einem der vorangehenden Ansprüche, das ferner folgende Schritte umfasst:

- Bereitstellen von Umkehrperioden während des Trocknungszyklus', in denen die Heizmittel (3) ausgeschaltet werden und die Trommel zur Rotation in die Gegenrichtung gebracht wird,
- Aufnehmen nur des relativen Feuchtigkeitswerts (RH_{in}) und des Temperaturdifferenzwerts (ΔT), wenn die Heizmittel (3) als eingeschaltet festgestellt werden.

19. Verfahren gemäß Anspruch 16, wobei der numerische Filterungsschritt folgende Schritte umfasst:

- numerisches Filtern des aufgenommenen Werts der relativen Feuchtigkeit (RH_{in}) durch einen ersten numerischen Tiefpassfilter, und
- numerisches Filtern des aufgenommenen Temperaturdifferenzwerts (ΔT) durch einen zweiten numerischen Tiefpassfilter.

20. Verfahren gemäß Anspruch 16, wobei der Schritt des numerischen Filterns zusätzlich folgende Schritte umfasst:

- Als Reaktion auf den Betriebsbeginn des Wäschetrockners das Abrufen eines gespeicherten numerischen Filterungsparameters (α), der von dem vom Benutzer gewählten Trocknungszyklus abhängig ist,
- auf differenzierte Weise numerisches Filtern des Werts der relativen Feuchtigkeit (RH_{in}) und des Temperaturdifferenzwerts (ΔT) auf Basis des numerischen Filterungsparameters (α).

21. Verfahren gemäß einem der vorangehenden Ansprüche, wobei der Vergleich ferner folgende Schritte umfasst:

- Bestimmen eines ersten Zyklusendkoeffizienten (dH) und eines zweiten Zyklusendkoeffizienten (dT), die darstellen, wie weit der gefilterte Wert für die relative Feuchtigkeit ($RH_{in,filtered}$) sich dem entsprechenden Schwellwert ($RH_{in,TH}$) angenähert hat bzw. wie weit sich der gefilterte Wert für die Temperaturdifferenz ($\Delta T_{filtered}$) dem entsprechenden Schwellwert (ΔT_{TH}) angenähert hat.

22. Verfahren gemäß einem der vorangehenden Ansprüche, wobei der Vergleichsschritt ferner folgende Schritte umfasst:

- Berechnen eines gewichteten Durchschnitts der Zyklusendkoeffizienten (dH , dT) durch einen Gewichtungsfaktor (δ), der von dem gewählten Trocknungszyklus abhängig ist und den spezifischen Beitrag der einzelnen Koeffizienten in Entsprechung zum gewählten Zyklus bestimmt, um eine einzelne Kontrollmenge (D) zu gewinnen,
- Abrufen des Gewichtungsfaktors (δ) in Entsprechung zu dem gewählten Trocknungszyklus.

23. Verfahren gemäß einem der vorangehenden Ansprüche, wobei der Vergleichsschritt ferner folgende Schritte umfasst:

- Vergleichen des Werts der Kontrollmenge (D) mit einem Stopp-Parameter (sD), der vom gewählten Trocknungszyklus abhängig ist,
- Abrufen des Werts des Stopp-Parameters (sD) in Entsprechung zu dem gewählten Trocknungszyklus,
- Ausschalten der Heizmittel (3) in dem Fall, dass der Wert der berechneten Kontrollmenge (D) sich als gleich oder höher als der Wert des Stopp-Parameters (sD) erweist.

24. Verfahren gemäß einem der vorangehenden Ansprüche, wobei der Aufnahmeschritt folgende Schritte umfasst:

- Aufnehmen des Werts der relativen Feuchtigkeit (RH_{in}) und des Temperaturdifferenzwerts (ΔT) in Entsprechung zu Aufnahmeereignissen, die voneinander durch ein voreingestelltes Zeitintervall getrennt sind.

25. Verfahren gemäß Anspruch 2, das folgende Schritte umfasst:

- Nach Beginn des Betriebs des Wäschetrockners das Prüfen der Werte der relativen Feuchtigkeit (RH_{in}) und der Temperaturdifferenzwerte (ΔT) auf eine zunehmende Beständigkeit,
- Beginnen, die Werte der relativen Feuchtigkeit (RH_{in}) und die Temperaturdifferenzwerte (ΔT) aufzunehmen, wenn sich diese als stabilisiert erwiesen haben.

26. Verfahren gemäß einem der vorangehenden Ansprüche, wobei der Schritt der numerischen Filterung folgende Schritte umfasst:

- numerisches Filtern der auf diese Weise aufgenommenen Werte der relativen Feuchtigkeit (RH_{in}) durch einen ersten numerischen Einheitsverstärkungs-Tiefpassfilter erster Ordnung,
- numerisches Filtern der auf diese Weise aufgenommenen Temperaturdifferenzwerte (ΔT) durch einen zweiten numerischen Einheitsverstärkungs-Tiefpassfilter erster Ordnung.

Revendications

1. Sèche-linge à tambour comprenant un circuit d'air de séchage en boucle fermée apte à faire circuler l'air de séchage chauffé à travers un tambour perforé tournant (2) retenant une charge à sécher, un condenseur refroidi à air (4) apte à éliminer l'humidité de l'air de séchage chaud chargé d'humidité sortant dudit tambour, un moyen de chauffage (3) réalisé en aval du condenseur refroidi à air (4) pour chauffer l'air de séchage à envoyer à nouveau dans le

tambour (2), un circuit d'air de refroidissement en boucle ouverte apte à faire circuler sur et à travers le condenseur (4) un flux d'air de refroidissement prélevé de l'air ambiant extérieur pour refroidir ledit condenseur, et pour évacuer ledit flux d'air de refroidissement à nouveau vers l'air ambiant extérieur, un moyen de capteur de température (5, 6) agencé à une entrée d'air de séchage (7) du condenseur et à une sortie d'air de séchage (8) du condenseur pour détecter une valeur de différence de température entre l'air de séchage entrant dans le condenseur (4) et l'air de séchage sortant du condenseur (4), **caractérisé en ce qu'il** comprend en outre un moyen de détection d'humidité (5) agencé à ladite entrée d'air de séchage de condenseur (7) pour détecter une valeur d'humidité de l'air de séchage entrant dans le condenseur, un moyen de commande couplé audit moyen de détection d'humidité (5) pour recevoir ladite valeur d'humidité (RH_{in}), et couplé audit moyen de détection de température (5, 6) pour recevoir ladite valeur de différence de température (ΔT) durant le fonctionnement dudit sèche-linge à tambour, un moyen de mémoire pour stocker une valeur de différence de température de seuil (ΔT_{TH}) entre l'air de séchage entrant dans le condenseur (4) et l'air de séchage sortant du condenseur (4), et une valeur d'humidité relative de seuil (RH_{inTH}) de l'air de séchage entrant dans le condenseur, qui sont représentatives d'un degré de sécheresse prédéterminé de la charge et dépendent du cycle de séchage particulier sélectionné par l'utilisateur, lesdits moyens de commande étant aptes à extraire lesdites valeurs de seuil (ΔT_{TH} , RH_{inTH}) du moyen de mémoire en réponse à un cycle de séchage donné sélectionné par l'utilisateur, lesdits moyens de commande étant conçus en outre pour comparer ladite valeur d'humidité relative (RH_{in}) avec ladite valeur d'humidité relative de seuil (RH_{inTH}) et ladite valeur de différence de température (ΔT) avec ladite valeur de différence de température de seuil (ΔT_{TH}) pour déterminer un état de fin de cycle et pour commuter hors service ledit moyen de chauffage (3) lorsqu'au moins ladite valeur de différence de température (ΔT) atteint ladite valeur de différence de température de seuil (ΔT_{TH}) ou au moins ladite valeur d'humidité relative (RH_{in}) atteint ladite valeur d'humidité relative de seuil (RH_{inTH}).

2. Sèche-linge à tambour selon la revendication 1, dans lequel lesdits moyens de commande comprennent un moyen de filtre numérique pour filtrer de manière numérique ladite valeur d'humidité relative (RH_{in}) acquise et ladite valeur de différence de température (ΔT) acquise, pour éliminer toutes les valeurs détectées s'écartant d'un degré important de la tendance principale contre le temps desdites valeurs de l'humidité relative (RH_{in}), et ladite différence de température (ΔT) étant surveillée par lesdits moyens de commande au fur et à mesure que le processus de séchage des vêtements continue, et établir une valeur d'humidité relative filtrée correspondante (RH_{in} filtrée) et une valeur de différence de température filtrée correspondante (ΔT filtrée).

3. Sèche-linge à tambour selon la revendication 2, dans lequel ledit moyen de filtre numérique comprend un premier filtre passe-bas numérique associé aux valeurs d'humidité relatives (RH_{in}) et un deuxième filtre passe-bas numérique associé aux valeurs de différence de température (ΔT).

4. Sèche-linge à tambour selon la revendication 3, dans lequel ledit premier filtre numérique et ledit deuxième filtre numérique comprennent un paramètre de filtration (α) qui dépend du cycle de séchage particulier sélectionné par l'utilisateur.

5. Sèche-linge à tambour selon la revendication 4, dans lequel lesdits moyens de mémoire sont conçus pour stocker les valeurs dudit paramètre de filtration (α), lesdits moyens de commande étant aptes à leur tour à extraire lesdites valeurs lorsque le cycle de séchage sélectionné par l'utilisateur est démarré.

6. Sèche-linge à tambour selon la revendication 2, dans lequel lesdits moyens de commande sont aptes à comparer ladite valeur d'humidité relative filtrée (RH_{in} filtrée) avec ladite valeur d'humidité relative de seuil (RH_{inTH}) correspondant au cycle de séchage sélectionné par l'utilisateur, et sont aptes en outre à comparer ladite valeur de différence de température filtrée (ΔT filtrée) avec ladite valeur de différence de température de seuil (ΔT_{TH}) correspondant au cycle de séchage sélectionné par l'utilisateur.

7. Sèche-linge à tambour selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens de commande sont aptes à déterminer un premier coefficient de fin de cycle (dH) et un deuxième coefficient de fin de cycle (dT) qui représente le degré de rapprochement de la valeur d'humidité relative filtrée (RH_{in} filtrée) à la valeur de seuil respective (RH_{inTH}), le degré de rapprochement de la valeur de différence de température filtrée (ΔT filtrée) de la valeur de seuil respective (ΔT_{TH}), respectivement.

8. Sèche-linge à tambour selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens de commande sont conçus pour calculer une moyenne pondérée desdits coefficients de fin de cycle (dH , dT) par un facteur de poids (δ) qui dépend du cycle de séchage sélectionné par l'utilisateur.

9. Sèche-linge à tambour selon l'une quelconque des revendications précédentes, dans lequel ledit facteur de poids (δ) dépend du cycle de séchage sélectionné, et lesdits moyens de commande sont aptes à extraire la valeur dudit facteur de poids (δ) dudit moyen de mémoire lorsque le cycle de séchage sélectionné est démarré.

10. Sèche-linge à tambour selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens de commande sont aptes à comparer la valeur de ladite moyenne pondérée avec un paramètre d'arrêt (sD) qui dépend du cycle de séchage particulier sélectionné, pour commuter hors service le moyen de chauffage (3) lorsque la valeur de ladite moyenne pondérée atteint ou dépasse la valeur dudit paramètre d'arrêt (sD), lesdits moyens de commande étant aptes à extraire la valeur dudit paramètre d'arrêt (sD) dudit moyen de mémoire lorsque le cycle de séchage sélectionné est démarré.

11. Sèche-linge à tambour selon l'une quelconque des revendications précédentes, dans lequel des périodes d'inversion sont réalisées durant le cycle de séchage, dans lesquels les moyens de chauffage (3) sont commutés hors service et le tambour (2) est entraîné pour tourner dans la direction opposée, lesdits moyens de commande étant aptes à acquérir uniquement lesdites valeurs d'humidité (RH_{in}) et lesdites valeurs de différence de température (ΔT) lorsque lesdits moyens de chauffage (3) sont commutés en service.

12. Sèche-linge à tambour selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens de commande sont aptes à acquérir lesdites valeurs d'humidité relatives (RH_{in}) et lesdites valeurs de différence de température (ΔT) en correspondance avec des événements d'acquisition qui sont séparés les uns des autres par un intervalle de temps d'attente pré-établi.

13. Sèche-linge à tambour selon l'une quelconque des revendications précédentes, dans lequel lesdits filtres numériques comprennent un filtre passe-bas numérique à gain d'unité du premier ordre.

14. Sèche-linge à tambour selon l'une quelconque des revendications précédentes, dans lequel la valeur dudit paramètre de filtration (α) s'étend de 0,9 à 0,99.

15. Procédé de commande d'un sèche-linge à tambour comportant un circuit d'air de séchage en boucle fermée apte à faire circuler de l'air de séchage chauffé à travers les vêtements à sécher retenus dans un tambour perforé tournant (2), un condenseur (4) refroidi à air apte à éliminer l'humidité de l'air de séchage chaud chargé d'humidité sortant dudit tambour, les moyens de chauffage (3) étant réalisés en aval du condenseur refroidi à air (4) pour chauffer l'air de séchage à envoyer à nouveau dans le tambour (2), un circuit d'air de refroidissement en boucle ouverte apte à faire circuler sur et à travers le condenseur (4) un flux d'air de refroidissement prélevé de l'air ambiant extérieur pour refroidir ledit condenseur, et pour évacuer ensuite ledit flux d'air de refroidissement dans l'air ambiant extérieur, **caractérisé en ce qu'il** comprend les étapes de:

- extraire, en réponse à un cycle de séchage donné sélectionné par l'utilisateur, une valeur de différence de température de seuil stockée (ΔT_{TH}) entre l'air de séchage entrant dans le condenseur (4) et l'air de séchage sortant du condenseur (4), et une valeur d'humidité relative de seuil stockée (RH_{inTH}) de l'air de séchage entrant dans le condenseur, les deux valeurs dépendant du cycle de séchage sélectionné par l'utilisateur et étant représentatives d'un degré de sécheresse prédéterminé des vêtements en train d'être manipulés,
- détecter une valeur d'humidité relative (RH_{in}) de l'air de séchage entrant dans le condenseur (4), et
- détecter une valeur de différence de température (ΔT) entre l'air de séchage entrant dans le condenseur (4) et l'air de séchage sortant du condenseur (4),
- acquérir, durant le fonctionnement dudit sèche-linge à tambour, ladite valeur d'humidité relative (RH_{in}) et ladite valeur de différence de température (ΔT) détectée par le moyen de détection respectif,
- comparer ladite valeur d'humidité relative (RH_{in}) avec ladite valeur d'humidité relative de seuil (RH_{inTH}) et ladite valeur de différence de température (ΔT) avec ladite valeur de différence de température de seuil (ΔT_{TH}) pour déterminer un état de fin de cycle et pour commuter hors service lesdits moyens de chauffage (3) lorsqu'au moins ladite valeur de différence de température atteint ladite valeur de différence de température de seuil ou au moins ladite valeur d'humidité relative atteint ladite valeur d'humidité relative de seuil.

16. Procédé selon la revendication 15, comprenant en outre les étapes de:

- filtrer de manière numérique lesdites valeurs d'humidité relative acquises (RH_{in}) et lesdites valeurs de différence de température acquises (ΔT) pour éliminer toutes les valeurs détectées s'écartant selon un degré significatif de la tendance principale contre le temps desdites valeurs de l'humidité relative (RH_{in}), et la différence de

température (ΔT) étant surveillée par lesdits moyens de commande au fur et à mesure que le processus de séchage des vêtements continue, et établir une valeur d'humidité relative filtrée correspondante (RH_{in} filtrée) et une valeur de différence de température filtrée correspondante (ΔT filtrée).

17. Procédé selon la revendication 16, dans lequel ladite étape de comparaison comprend les étapes de:

- comparer ladite valeur d'humidité relative filtrée (RH_{in} filtrée) avec ladite valeur d'humidité relative de seuil (RH_{inTH}) correspondant au cycle de séchage sélectionné par l'utilisateur, et
- comparer ladite valeur de différence de température filtrée (ΔT filtrée) avec ladite valeur de différence de température de seuil (ΔT_{TH}) correspondant au cycle de séchage sélectionné par l'utilisateur.

18. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre les étapes de:

- réaliser des périodes d'inversion durant le cycle de séchage, dans lesquelles les moyens de chauffage (3) sont commutés hors service, et le tambour est entraîné pour tourner dans la direction opposée,
- acquérir uniquement ladite valeur d'humidité relative (RH_{in}) et ladite valeur de différence de température (ΔT) s'il s'avère que lesdits moyens de chauffage (3) sont en service.

19. Procédé selon la revendication 16, dans lequel ladite étape de filtration numérique comprend les étapes de:

- filtrer de manière numérique ladite valeur d'humidité relative acquise (RH_{in}) par un premier filtre passe-bas numérique, et
- filtrer de manière numérique ladite valeur de différence de température acquise (ΔT) par un deuxième filtre passe-bas numérique.

20. Procédé selon la revendication 16, dans lequel ladite étape de filtration numérique comprend en outre les étapes de:

- extraire, en réponse au démarrage dudit sèche-linge à tambour, un paramètre de filtration numérique stocké (α) qui dépend du cycle de séchage sélectionné par l'utilisateur,
- filtrer de manière numérique d'une manière différenciée ladite valeur d'humidité relative (RH_{in}) et ladite valeur de différence de température (ΔT) sur la base dudit paramètre de filtration numérique (α).

21. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite comparaison comprend en outre les étapes de:

- déterminer un premier coefficient de fin de cycle (dH) et un deuxième coefficient de fin de cycle (dT) qui sont représentatifs du degré de proximité de la valeur d'humidité relative filtrée (RH_{in} filtrée) de la valeur de seuil respective (RH_{inTH}), et du degré de proximité de la valeur de différence de température filtrée (ΔT filtrée) de la valeur de seuil respective (ΔT_{TH}), respectivement.

22. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite étape de comparaison comprend en outre les étapes de:

- calculer une moyenne pondérée des coefficients de fin de cycle (dH , dT) par un facteur de poids (δ) qui dépend du cycle de séchage sélectionné et détermine la contribution spécifique des coefficients individuels en accord avec le cycle sélectionné, de manière à obtenir une quantité de commande unique (D),
- extraire ledit facteur de poids (δ) en accord avec le cycle de séchage sélectionné.

23. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite étape de comparaison comprend en outre les étapes de:

- comparer la valeur de ladite quantité de commande (D) avec un paramètre d'arrêt (sD) qui dépend du cycle de séchage sélectionné,
- extraire la valeur dudit paramètre d'arrêt (sD) en accord avec le cycle de séchage sélectionné,
- commuter hors service les moyens de chauffage (3) dans le cas où la valeur de la quantité de commande ainsi calculée (D) s'avère égale ou supérieure à la valeur dudit paramètre d'arrêt (sD).

24. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite étape d'acquisition comprend

les étapes de:

- acquérir ladite valeur d'humidité relative (RH_{in}) et ladite valeur de différence de température (ΔT) en correspondance avec des événements d'acquisition qui sont séparés les uns des autres par un intervalle de temps pré-établi.

25. Procédé selon la revendication 2, comprenant les étapes de:

- vérifier, après que le sèche-linge à tambour a commencé à fonctionner, lesdites valeurs d'humidité relatives (RH_{in}) et lesdites valeurs de différence de température (ΔT), pour devenir plus régulière,
- commencer à acquérir lesdites valeurs d'humidité relatives (RH_{in}) et lesdites valeurs de différence de température (ΔT) s'il s'avère qu'elles se sont stabilisées.

26. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite étape de filtration numérique comprend les étapes de:

- filtrer de manière numérique les valeurs d'humidité relatives ainsi acquises (RH_{in}) à travers un premier filtre numérique passe-bas à gain d'unité du premier ordre,
- filtrer de manière numérique les valeurs de différence de température ainsi acquises (ΔT) à travers un deuxième filtre numérique passe-bas à gain d'unité du premier ordre.

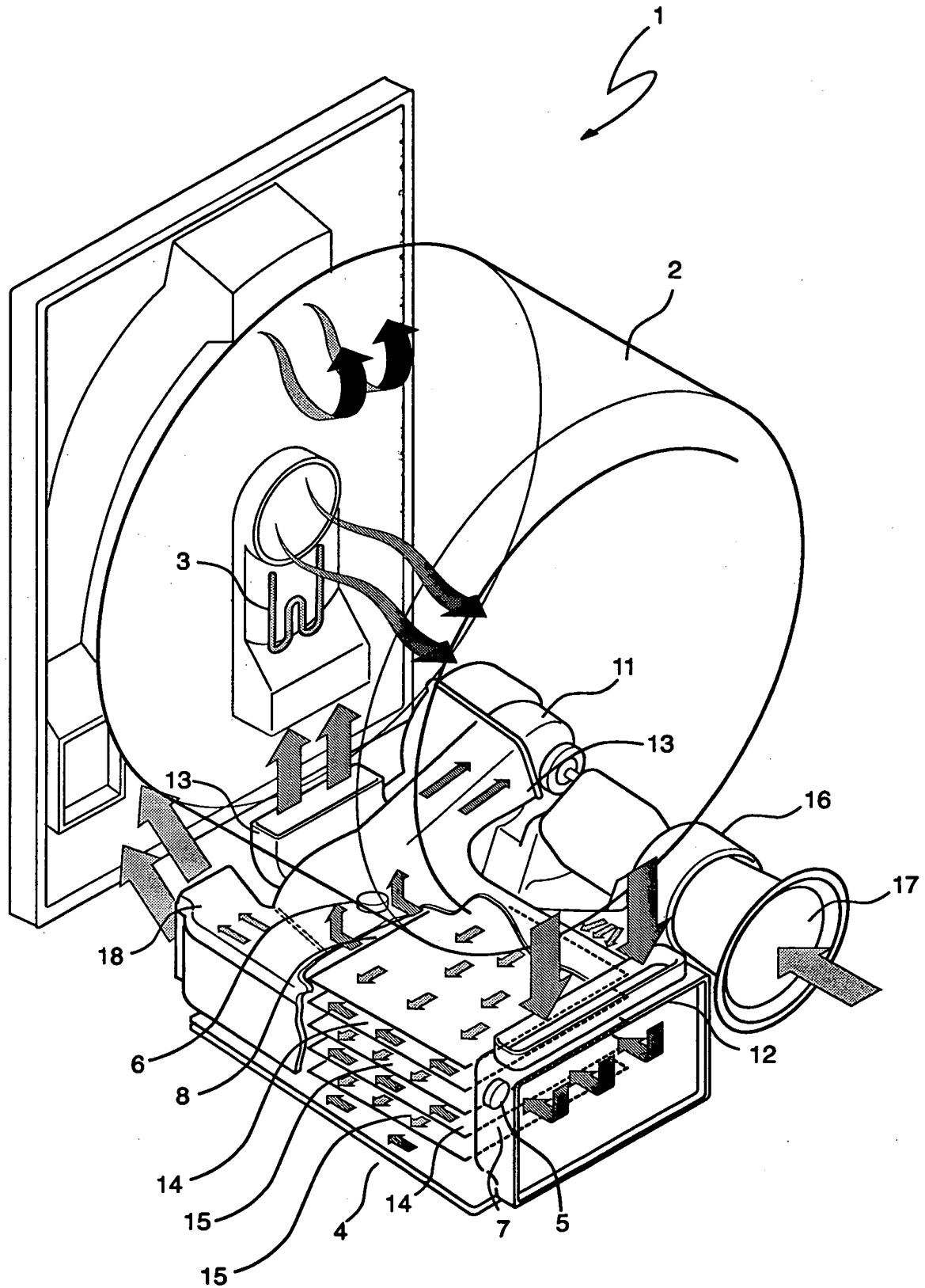


FIG. 1

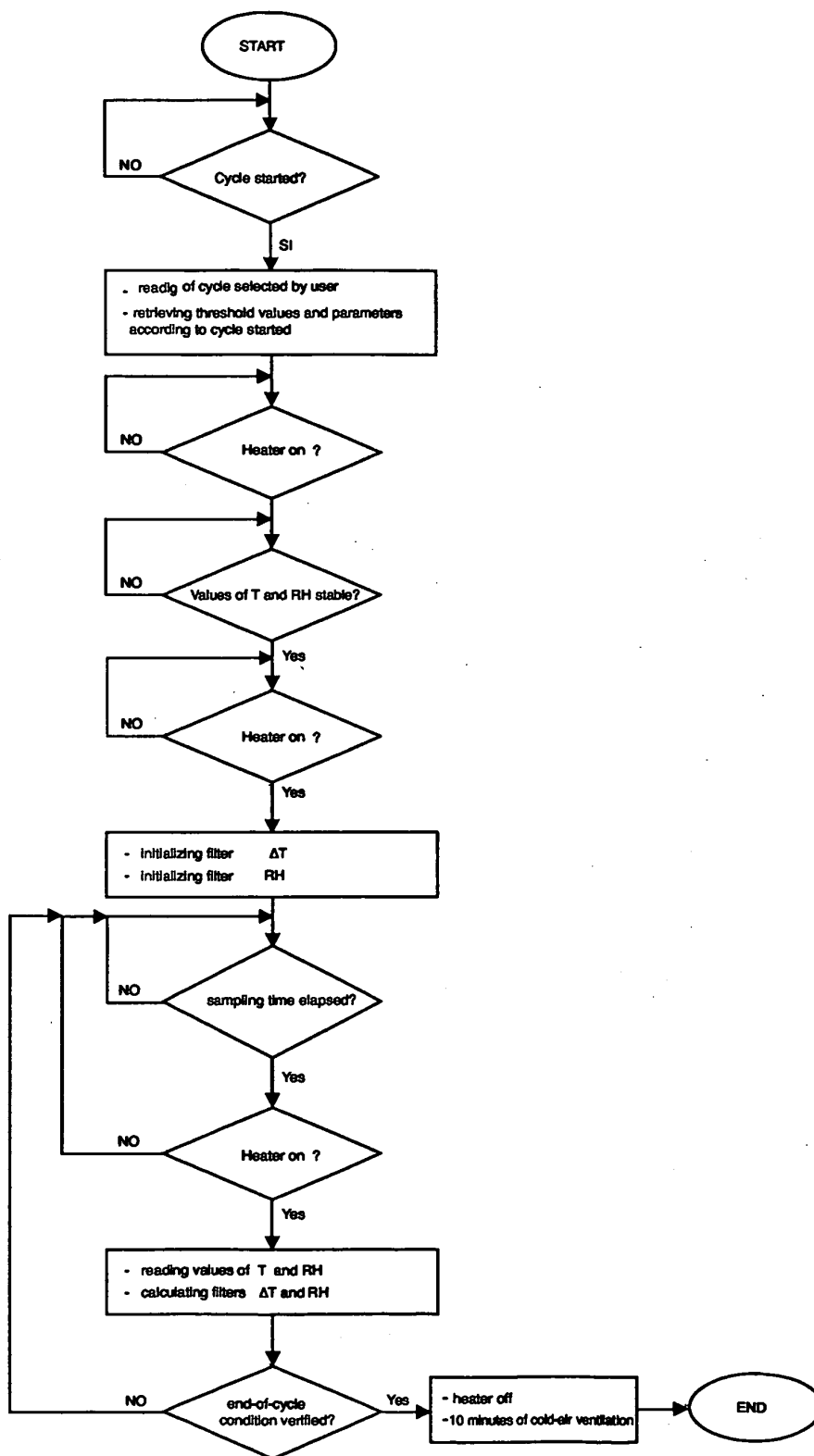


FIG 2

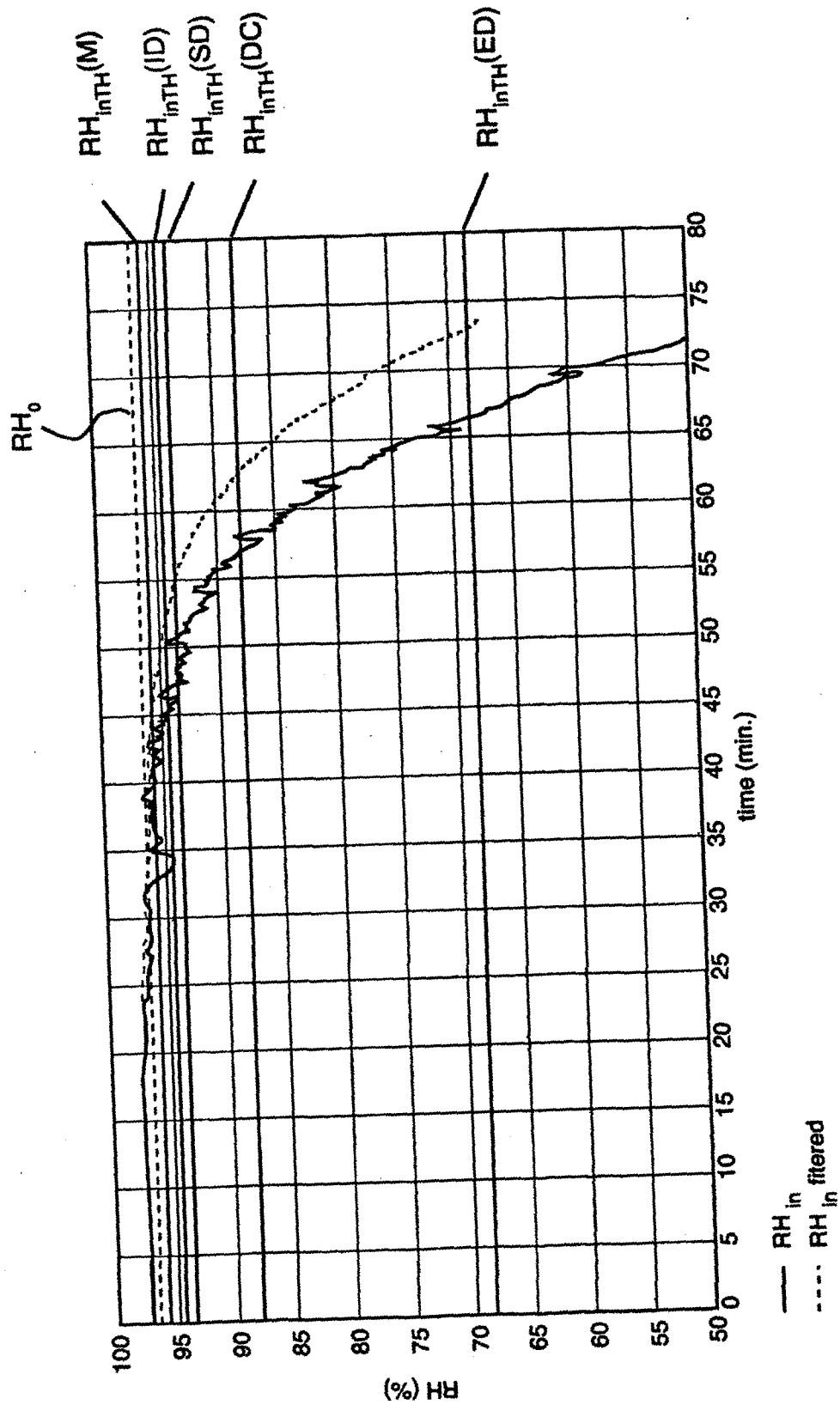


FIG.3

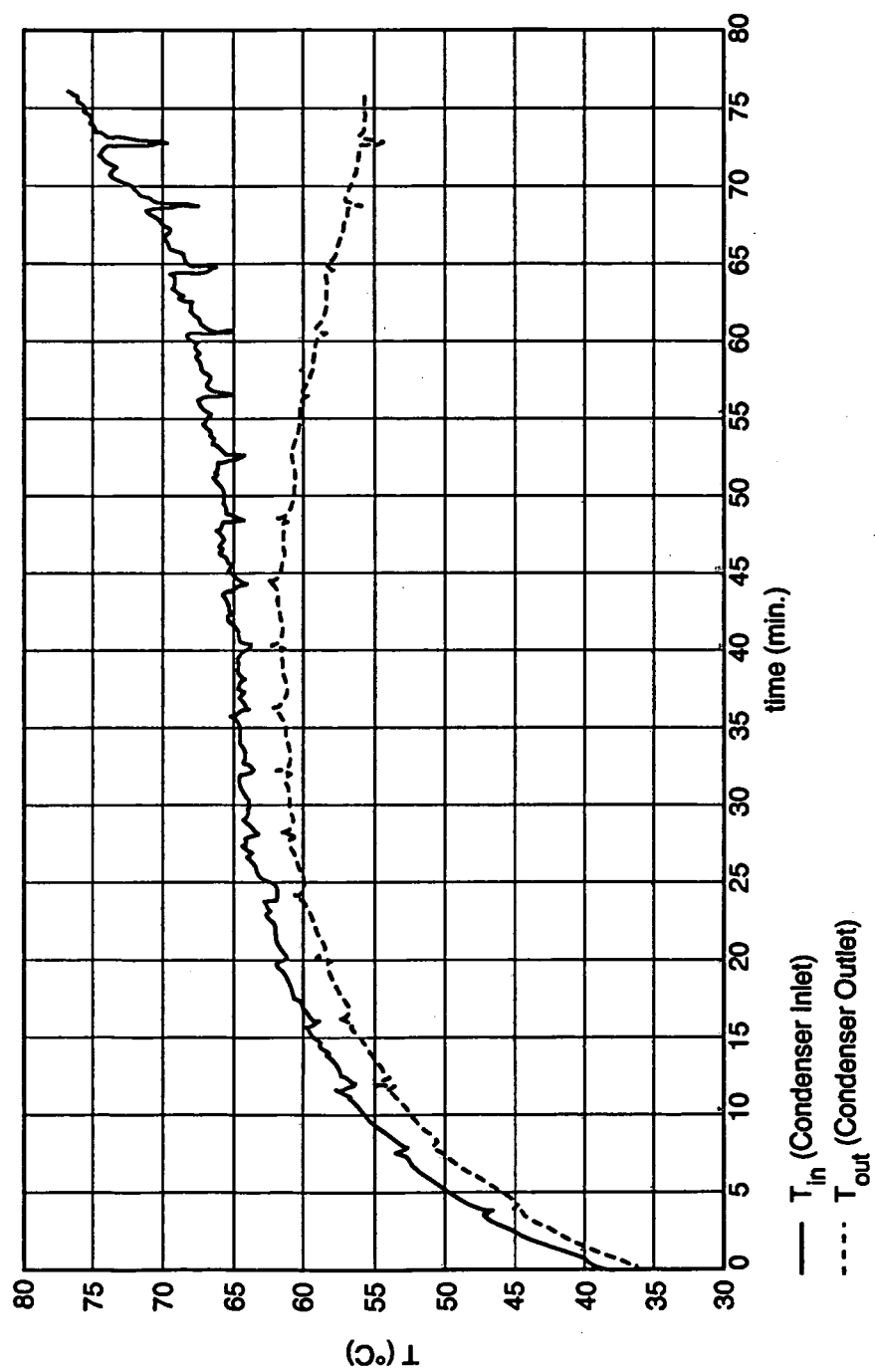


FIG.4

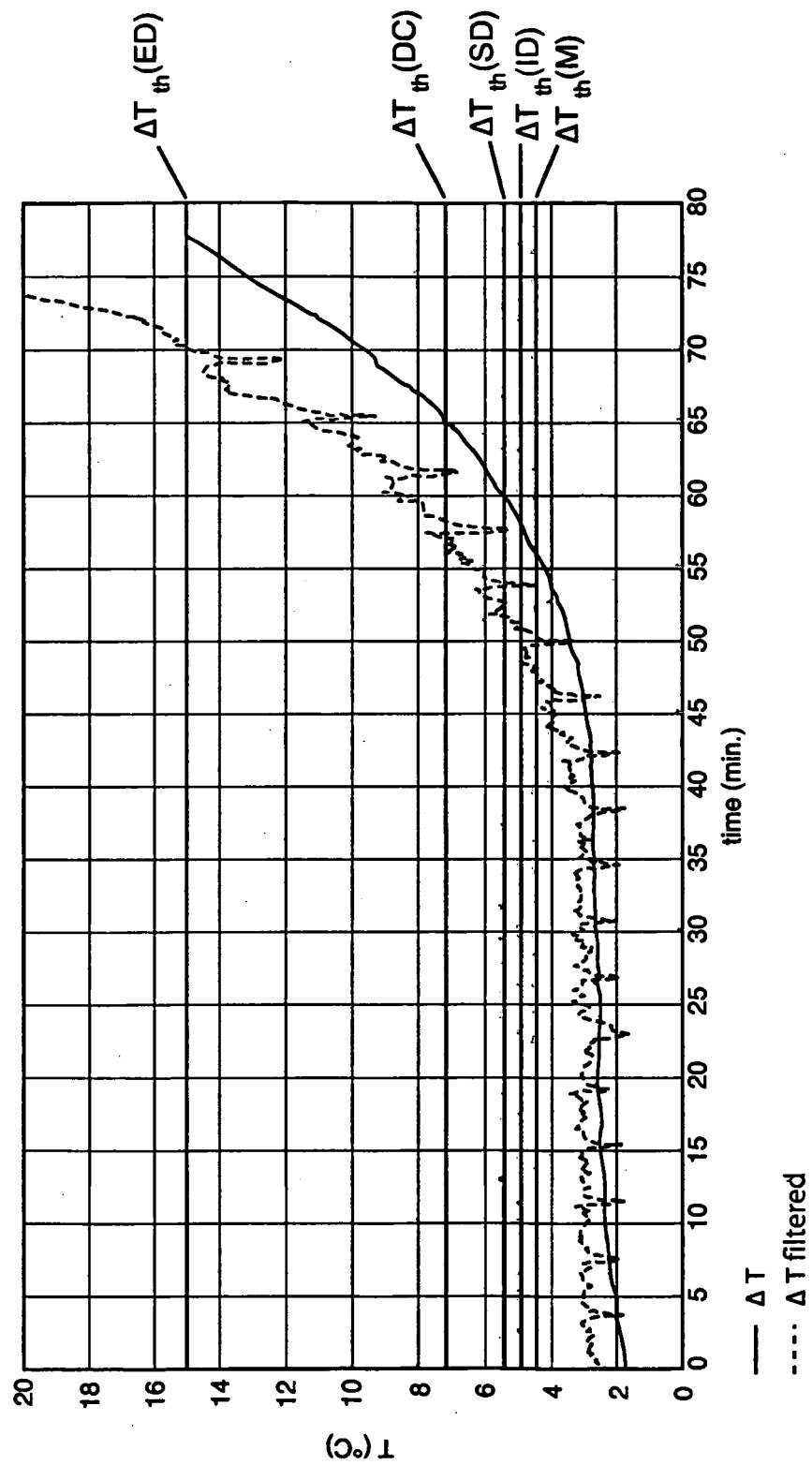


FIG. 5

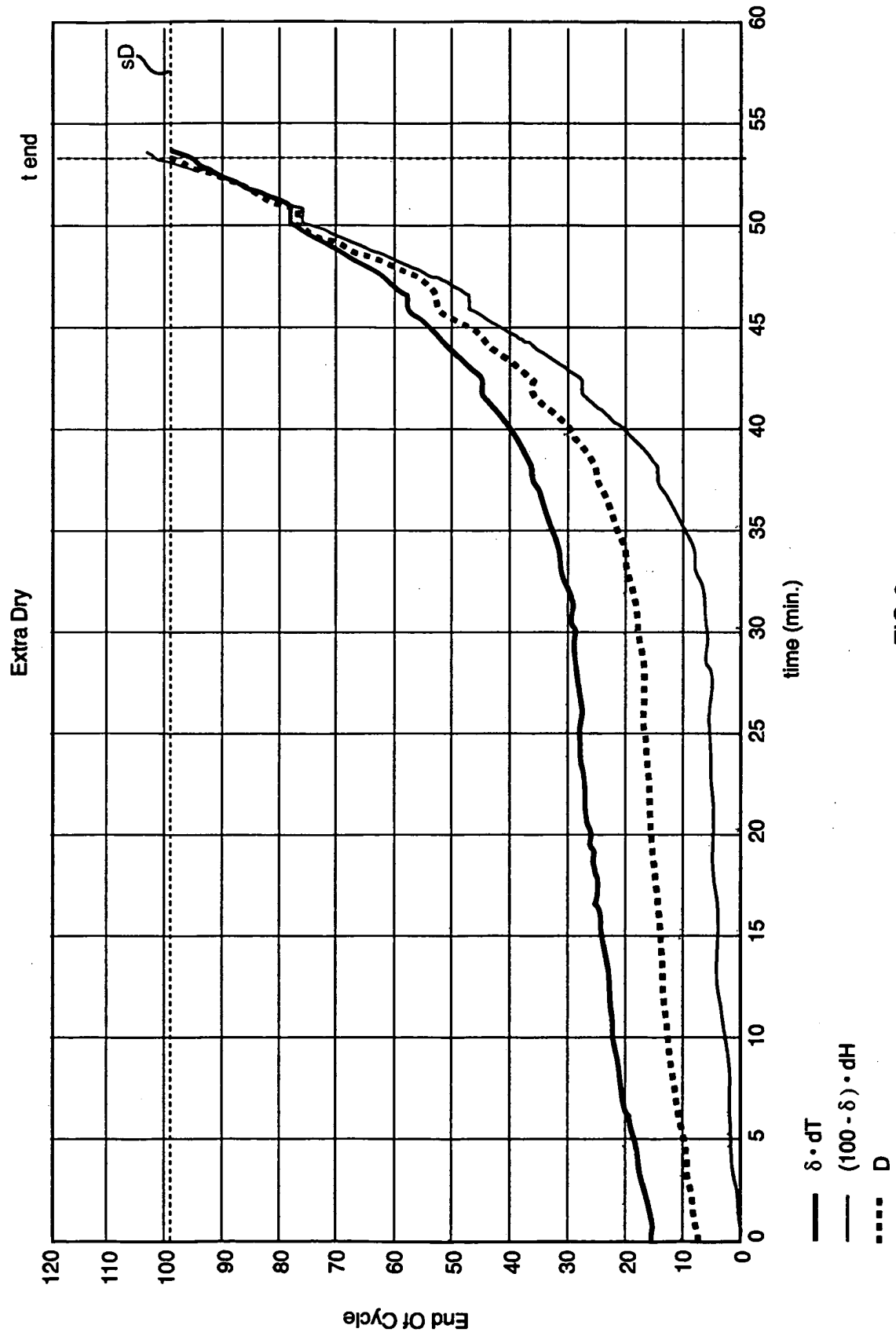


FIG.6

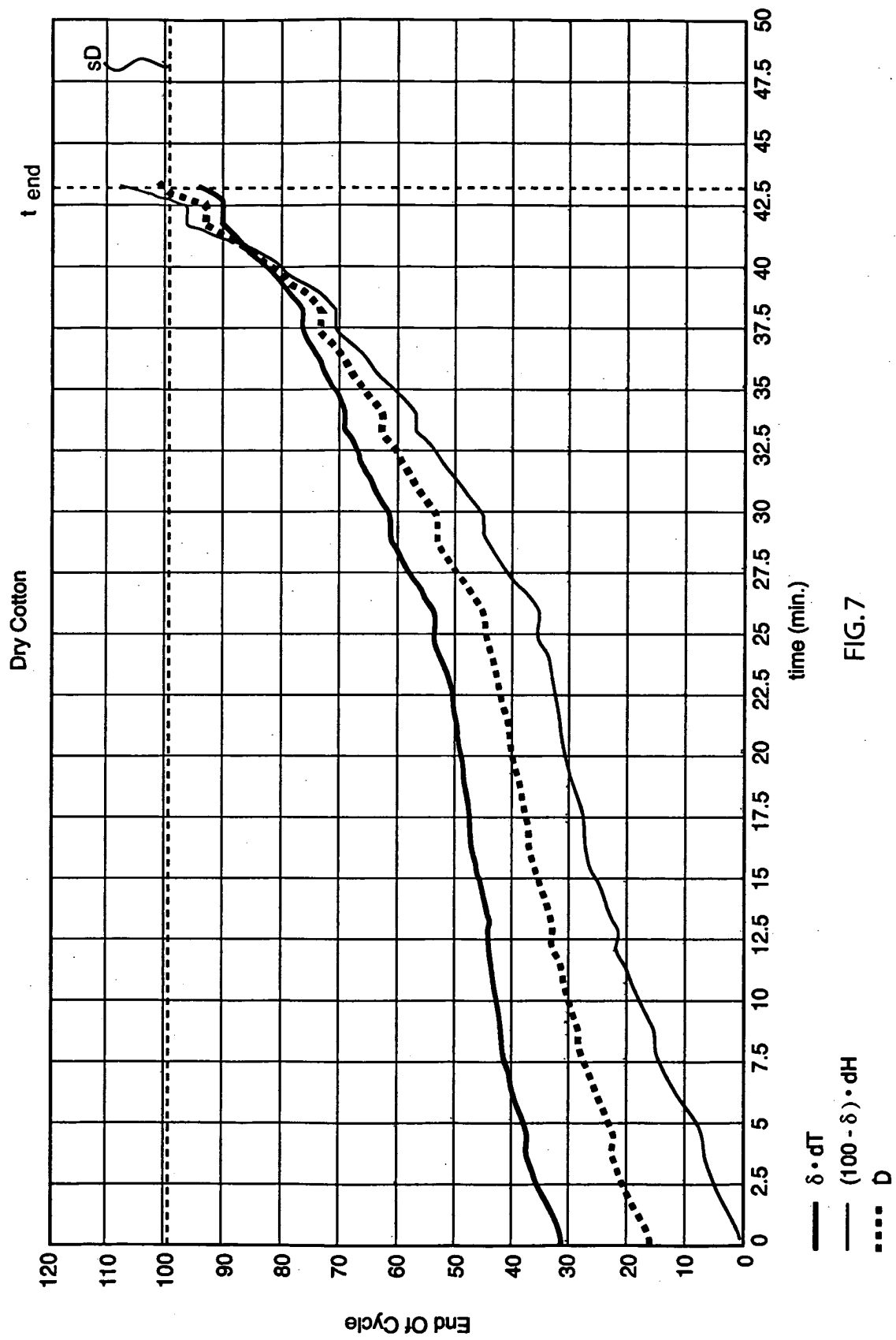


FIG. 7

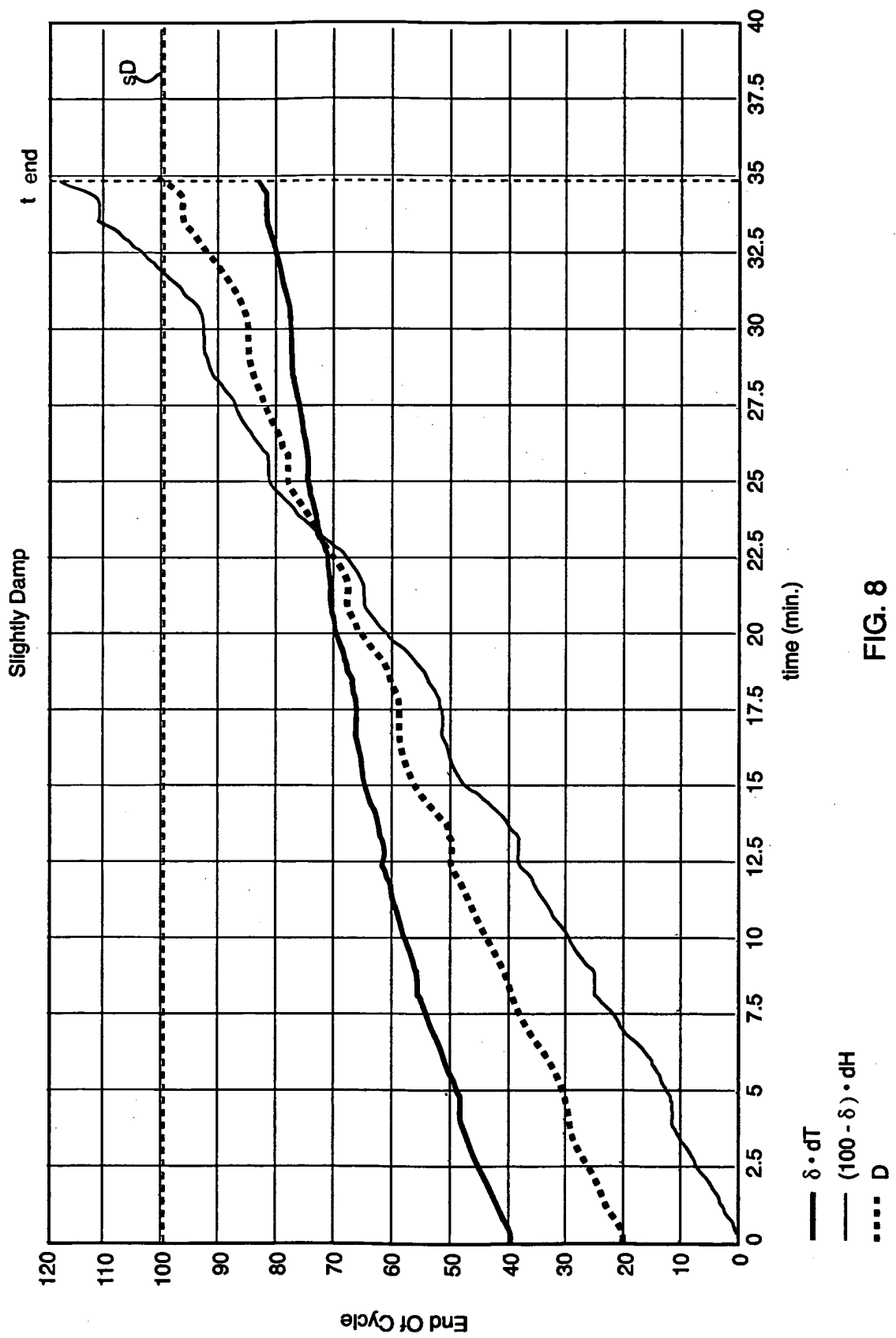


FIG. 8

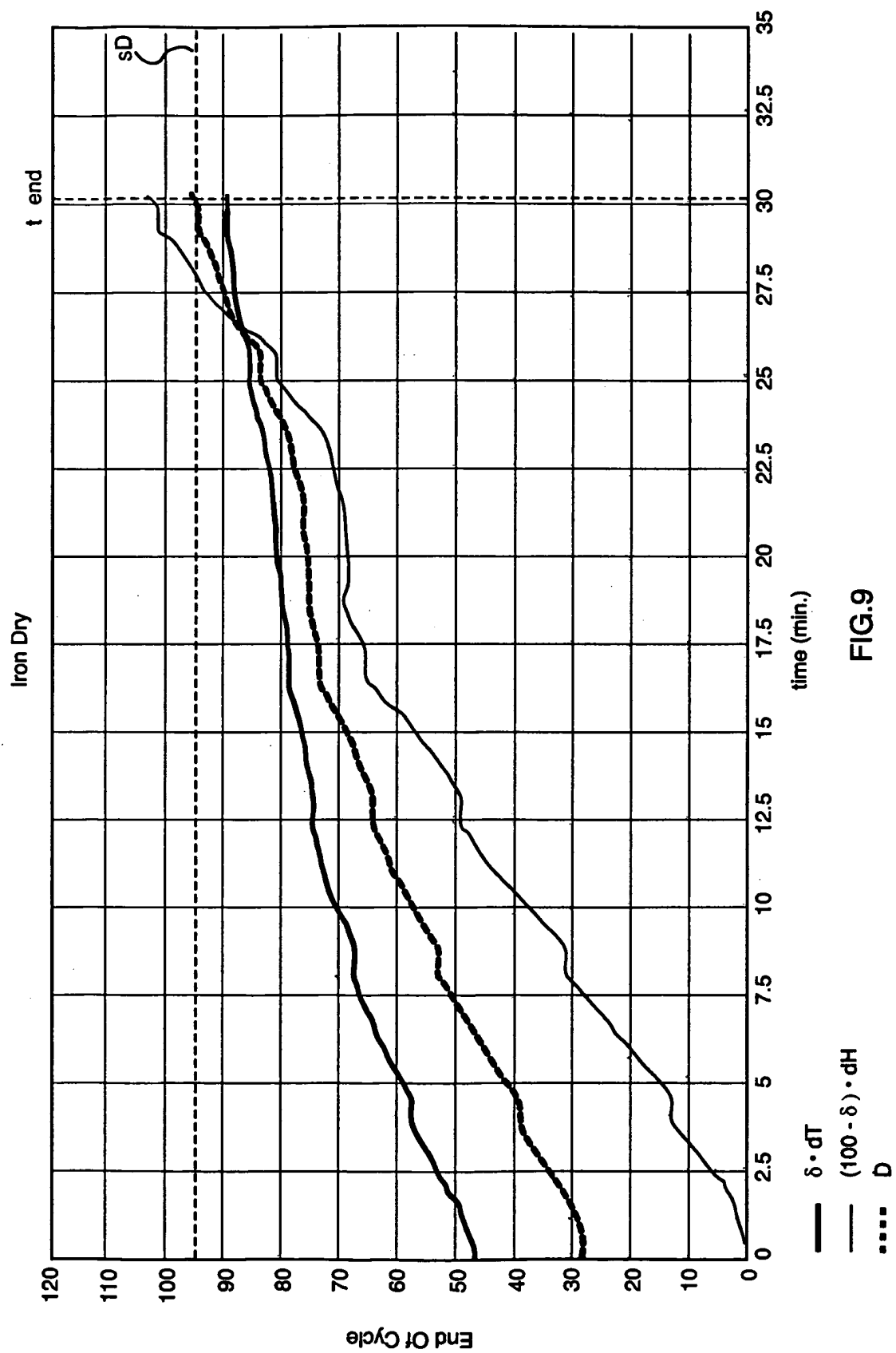


FIG.9

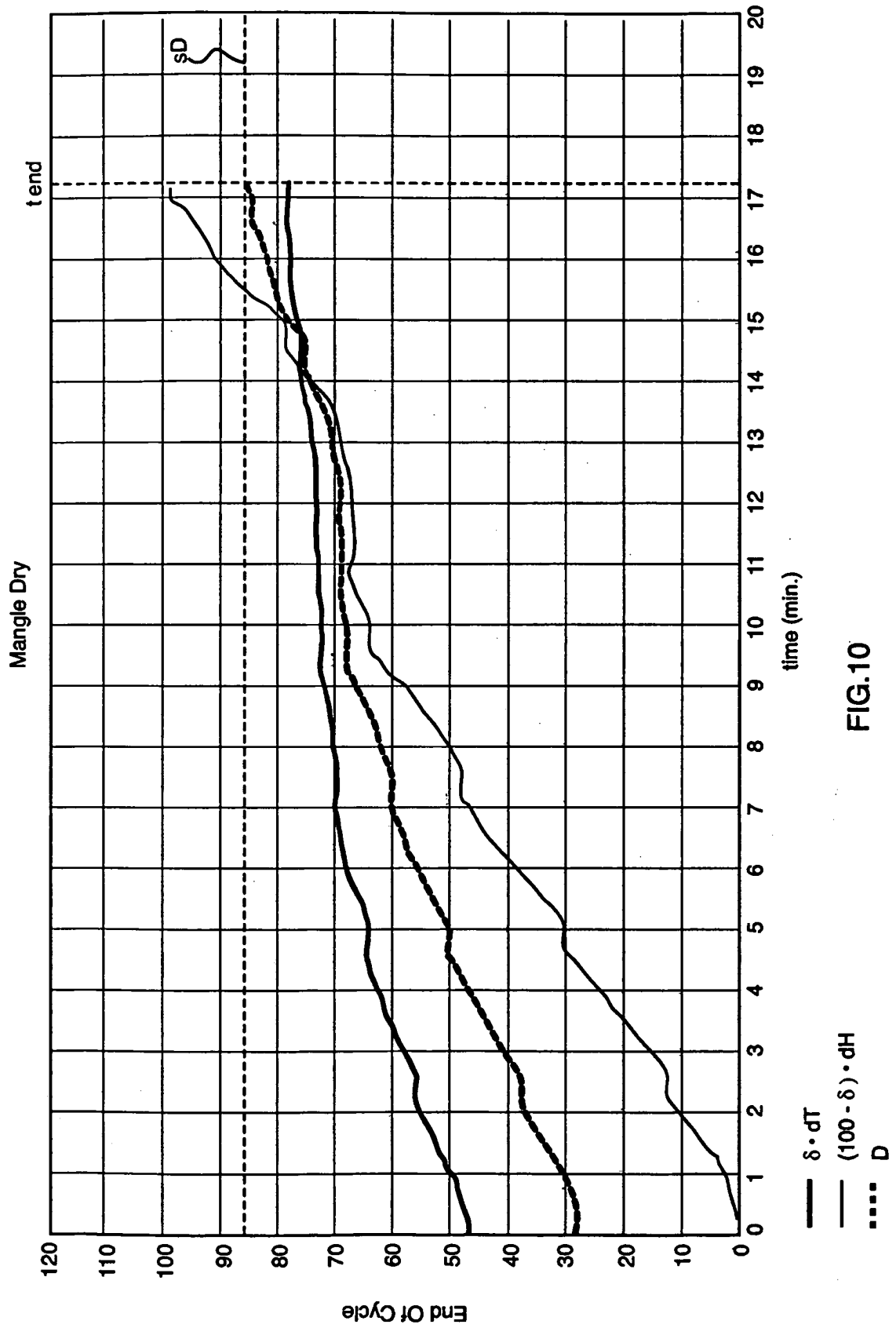


FIG.10

REFERENCES CITED IN THE DESCRIPTION

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