(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 034 086 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.03.2009 Bulletin 2009/11

(51) Int Cl.:
D06F 58/28 *(2006.01)*

(21) Application number: **07115705.1**

(22) Date of filing: **05.09.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

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(54) Household tumble dryer with an improved cycle termination

(57) The present invention relates to an household tumble dryer, which comprises a rotatable drum, which defines an interior drying volume and air inlet and outlet portions, which operatively communicate with said interior drying volume.

The household tumble dryer comprises sensor means and a control unit, which receives from said sensor means signals indicative of the air temperature values at said air inlet portion and/or said air outlet portion.

Said control unit comprises processing means for executing at least a termination control procedure for managing the termination of said drying cycle. Said termination control procedure comprises an evaluation procedure for estimating the level of moisture of said wash load, basing on the information acquired from said sensor means.

In a further aspect the present invention relates to a method for controlling the operating drying cycle of a household tumble dryer.

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Description

[0001] The present invention relates to the field of household tumble dryers of the vented type or the condensing type. More particularly, the present invention concerns a household tumble dryer comprising improved features for managing the drying cycle. Household tumble dryers are quite popular nowadays.

[0002] As widely known, these appliances generally comprise a rotatable drum, which defines an interior drying volume for receiving a wash load to be dried.

[0003] The rotatable drum is actuated by an electric motor, so as to tumble the wash load during the drying operation of the dryer.

[0004] In dryers of the vented type, during the drying cycle, an airflow is taken from outside the appliance. The airflow is heated by a heating element and it is forced to pass through the drying volume, so as to remove humidity from the wash load. The humid exhaust air is then blown outside the appliance.

[0005] In dryers of the condensing type, the airflow follows a closed path that is fully inside the appliance. After being heated, the airflow passes through the drying volume. The humid exhaust air is then circulated to a condenser for de-humidification and it is again conveyed to the heating element for being heated again.

[0006] In both the cases above, the circulation of the mentioned airflow is ensured by a fan. Traditional dryers generally comprise a control unit, which executes a drying cycle control procedure for properly managing the drying cycle, i.e. the sequence of operations needed for drying the wash load.

[0007] Said control procedure may comprise some non-critical steps, such those of sending appropriate command signals to the heating element and the actuating elements of the dryer.

[0008] Instead, a notoriously critical aspect is represented by the control strategy that is chosen for terminating the drying cycle, in other words, by the information and the criteria that are used to decide the termination of the drying cycle.

[0009] As it will be more apparent in the following discussion of the state of the art, these factors may have remarkable influence on the overall performances of dryer, particularly on the wash load drying quality.

[0010] In some dryers of the prior art, the control unit merely terminates the operating drying cycle as soon as a predetermined and selectable drying interval elapses.

[0011] These dryers generally provide poor performances, since their drying cycle control procedure does not take into account the actual quantity and quality of the wash load. The user can merely select the predetermined drying interval that seems more appropriate for the wash load to be dried. This often determines the occurrence of over-drying or under-drying conditions of the wash load.

[0012] Other known dryers comprise strips of moisture or resistive sensors, which may be placed at the drum internal surface to detect the level of humidity of the wash load. The control unit stops the operating drying cycle as soon as the humidity level is lower than a predefined threshold.

[0013] Also these solutions have drawbacks. The mentioned sensors can only detect the superficial humidity of the wash load. Thus, the control unit is often provided with partial or wrong information related to the actual moisture content of the wash load. This fact may of course bring to unsatisfactory drying conditions of the wash load, especially when drying bulky items. In fact in such loads, as like for instance sleeping bags or heavy blankets, water is maintained for a longer time in the interior of the load without being sensed by the strips sensor, while the external portion, that becomes dried more quickly being in contact with the sensor, generates a wrong "dryness-signal" condition. In addition the mentioned strips of sensors are relatively expensive, particularly with respect to the cost reduction needs of an industrial mass-production for the dryer.

[0014] Japanese patent application nr. 58-173599 discloses a condenser dryer, in which temperature sensors detect the temperature difference between two predefined locations of the interior drying volume, specifically the water of the condenser and the air after the heater. The control unit stops the operating drying cycle as soon as the drying operation passes from a constant-rate drying period, in which said temperature difference is maintained substantially constant after an initial rise, to a falling-rate drying period, in which said temperature difference increases again.

[0015] This kind of solution is defective in that it still does not provide a precise control of the duration of the operating drying cycle, since the quantity and kind of the wash load is again not considered. For example, when the wash load is light the mentioned constant-rate drying period may not be present or it may quite short. Thus, the timing for the termination of the operating drying cycle cannot be precisely determined in certain operative conditions. In this cases, over-drying or under-drying conditions of the wash load still tend to occur. This solution cannot be applied to an air vented dryer.

[0016] US patent nr. 4,640,022 discloses a condensing dryer, in which a first sensor is placed upstream the heater and a second sensor is placed upstream the condenser. After a predefined period of drying, the difference between the detected temperatures is evaluated. The drying cycle is terminated after another predefined period of time from when said difference overcomes a threshold value A+B, where A is a predefined reference value and B is a selected value, which may vary in accordance with the time elapsed from the starting of the drying cycle and which takes into account certain operating variables such as the quantity and kind of wash load to be dried.

[0017] In this solution predefined drying intervals are still adopted. Once these drying intervals are selected, they

cannot be changed anymore according to the actual drying conditions of the wash load. This fact introduces some restrictions to the drying cycle control procedure, which might bring to unsatisfactory drying performances. Said control procedure is apparently influenced by the locations chosen for the sensor means and it is therefore not suitable for vented dryers. More specifically, one temperature sensor is located prior than the heating element dryer, In such position it would measure the temperature of the external air drawn into the drying chamber.

[0018] Therefore, the main aim of the present invention is to provide a household tumble dryer, which allows the overcoming of the above mentioned drawbacks.

[0019] Within this aim, it is an object of the present invention to provide a household tumble dryer, which adopts an improved drying cycle control procedure, particularly in terms of control strategy for managing the termination of the drying cycle.

[0020] It is an object of the present invention to provide a household tumble dryer, in which said improved drying cycle control procedure is not influenced by the dryer vented or condensing configuration and that is particularly efficient in determining the duration of the drying cycle when drying "bulky" loads.

[0021] It is also an object of the present invention to provide a household tumble dryer, which is easy to manufacture at industrial level, at competitive costs.

[0022] Thus, the present invention provides a household tumble dryer, according to the claim 1 proposed in the following claim 1 and the claims depending therefrom.

[0023] In a further aspect, the present invention relates also to a drying cycle control procedure, according to the following claim 11.

[0024] In the household tumble dryer, according to the present invention, a control unit comprises processing means for executing at least a termination control procedure for managing the termination the drying cycle. Said termination control procedure comprises a cyclic estimation of the actual level of moisture of the wash load, basing on the information acquired from temperature sensor means, which are positioned at inlet and outlet portions of the dryer rotatable drum.

[0025] The actual residual mass of water, which is actually present in the wash load, is thus continuously monitored. This allows an easy and precise determination of the timing for terminating the drying cycle, in order to ensure a high quality drying level for the wash load.

[0026] Further features and advantages of the household tumble dryer, according to the present invention, will become apparent from the following description of preferred embodiments, taken in conjunction with the drawings, in which:

- Fig. 1 represents a schematic diagram of the household tumble dryer, according to the present invention, in a configuration of the vented type; and
- Fig. 2 represents a schematic diagram of the household tumble dryer, according to the present invention, in a configuration of the condensing type; and
- Fig. 3A represents a schematic diagram of an improved drying cycle control procedure adopted by the household tumble dryer, according to the present invention;
- Fig. 3B represents a schematic diagram of a termination control procedure included in the drying cycle control procedure of figure 3A; and
- Fig. 4 represents a schematic diagram related to the behaviour over time of some relevant quantities in the household tumble dryer, according to the present invention. Referring now to the cited figures, the present invention related to a household tumble dryer 1, which comprises a rotatable drum 2 that is preferable actuated by an electric motor 3.

[0027] The rotatable drum 2 defines an interior drying volume 200 for receiving a wash load 100 for drying. The drying volume 200 comprises an air inlet portion 201, through which an airflow 20 enters the drying volume 200, and an air outlet portion 202, through which the airflow 20 exits from the drying volume 200 after having passed through it.

[0028] In the embodiment of figure 1, the dryer 1 is structured as a vented dryer. The airflow 20 is thus taken directly from outside the dryer 1 and it is blown again into the external environment, after having passed through the drying volume 200. Before entering the drying volume 200, the airflow 20 is heated by a heating element 5.

[0029] In the embodiment of figure 2, the dryer 1 is configured as a condensing dryer. In this case, the airflow 20 follows a closed loop, which is interior the dryer 1. After having been heated by the heating element 5, the airflow enters the drying volume 200 through the air inlet portion 201. After having passed through the drying volume 200, the airflow exits from the air outlet portion 202 and is directed towards a condenser 4 for dehumidification. Then, the airflow 20 is directed again to the heating element 5 for being re-heated.

[0030] In both the illustrated embodiments, the correct circulation of the airflow 20 is ensured by properly positioned air ducts (not shown) and by a fan 8.

[0031] The dryer 1 comprises sensor means 6A-6B for detecting the temperature of the airflow 20 at the air inlet portion 201 and at the air outlet portion 202. Preferably, said sensor means comprise a first temperature sensor 6A, which is positioned at the air inlet portion 201, and a second temperature sensor 6B that is located at the air outlet portion 202. The temperature sensors 6A-6B may advantageously comprise properly arranged thermocouples. Of course, temper-

ature sensors of different kind may be used.

[0032] A control unit 70 is also provided in the dryer 1. The control unit 70 controls the operating drying cycle of the dryer 1 by sending proper command signals 71 to the heating element 5, the motor 3 and the fan 8. The control unit 70 receives from the sensor means 6A-6B signals 61 that are indicative of the temperature of the airflow 20 respectively at the air inlet and outlet portions 201, 202.

[0033] The control unit 70 manages the drying cycle of the dryer 1 by means of a drying cycle control procedure 500. As mentioned above, the term "drying cycle" intends the sequence of steps, which is needed for performing drying operations of the wash load 100.

[0034] The control procedure 500 may include some traditional steps (globally indicated by the reference 501), which may comprise the steps of enabling/disabling the user's access to the drying volume 100, the steps of sending command signals 71 to the electric motor 3, to the fan 8 and/or to the heating element 5, and so on.

[0035] The control procedure 500 includes a termination control procedure 502, which is aimed ad managing the termination of the drying cycle.

[0036] The termination control procedure 502, as well as the other mentioned traditional steps 501 of the control procedure 500, may be executed by processing means 7 of the control unit 70.

[0037] The termination control procedure 502 comprises an evaluation procedure 50 for estimating the actual level of moisture of the wash load 100, basing on the information provided by the sensor means 6A-6B.

[0038] Preferably, the evaluation procedure 50 is cyclically executed as soon as the drying cycle starts running. Anyway, a time delay may be introduced according to the needs. Referring now to the figure 3B, the evaluation procedure 50 comprises a first step i) and a second step ii) of acquiring an inlet air temperature value T_{IN} and an outlet air temperature value T_{OUT}, which are indicative of the temperature of the airflow 20 respectively at the air inlet portion 201 and at the air outlet portion 202. The values T_{IN} and T_{OUT} may be advantageously obtained by properly filtering the signals 61 provided by the sensor means 6A-6B, so as to improve the signal to noise ratio.

[0039] When the evaluation procedure 50 starts running, it may adopt a reference value A_0, which may have been already stored by the control unit 70, or that can be calculated in a preliminary step (10), over a predefined initial period of time ΔT according to the following relation (a):

$$A_0 = \frac{1}{\Delta T}\int_0^{\Delta T}(T_{IN} - T_{OUT})dt \qquad (a)$$

[0040] The evaluation procedure 50 then comprises a third step iii) of calculating a first value A_i, which is indicative of the mean difference between temperature value T_{IN} and the temperature value T_{OUT} over a predefined period of time ΔT

[0041] The following values A_i may be advantageously calculated by means of the following relation (b):

$$Ai = \frac{1}{\Delta T}\int_{t_i-\Delta T}^{t_i}(T_{IN} - T_{OUT})dt \qquad (b)$$

where t_I is the evaluation time and ΔT is the temperature sampling time, which may be of 10s, for example.

[0042] Then, it is provided the subsequent step iv) of comparing the first value (Ai) with the reference value A_0.

[0043] At any cycle of the evaluation procedure 50, the reference value A_0 is automatically updated. The reference value A_0 basically represents a reference difference between the temperatures of the airflow at the inlet and outlet portions 201 and 202.

[0044] The evaluation procedure 50 comprises a further step v) of calculating a second value A_{max}, which is the maximum between the calculated first value A_i and the reference value A_0. A_{max} can be calculated according to the following relation (b):

$$A_{\max} = \max(Ai, Ao)\,. \qquad (b)$$

[0045] Once A_{max} is calculated, the evaluation procedure 50 foresees the step vi) of calculating a third value (D_i), which is obtained from the ratio between the first value A; and the second value A_{max}, according to the following relation (c):

$$Di(\%) = \frac{Ai}{A\max} * 100 . \qquad (c)$$

[0046] The third value D_i well represents the moisture content in the wash load. D_i is calculated from the difference between the temperature T_{IN} of the heated airflow 20A, which has just been heated to enter the drying volume 200, and the temperature T_{OUT} of the wet airflow 20B, which exits from the drying volume 200, said temperature T_{OUT} being mainly correlated to the actual temperature of the wash load 100.

[0047] The temperature difference T_{IN}-T_{OUT} is mainly correlated to the actual level of humidity of the wash load 100, as clearly shown by the following relation (d):

$$T_{IN}(t) - T_{OUT}(t) = k_1 \frac{dM_R(t)}{dt} + k_2 (\frac{T_{IN}(t) + T_{OUT}(t)}{2} - T_e(t)) \qquad (d)$$

where $M_R(t)$ is the moisture retention value and T_e is the temperature of the environment external to the dryer 1.

[0048] $M_R(t)$ is correlated to the ratio between the actual mass of water in the wash load 100 and the mass of the wash load in dry conditions, as shown in the following relation (e):

$$\frac{dM_R(t)}{dt} = \frac{W(t) - W_O}{W_O} * 100 \qquad (e)$$

where W(t) is the instantaneous weight of the wet wash load 100 (i.e. not having been dried yet) and Wo is the weight of the wash load 100 in dry conditions.

[0049] It is apparent how the above relation (d) is basically determined by two factors that are the actual evaporation rate $dM_R(t)/dt$ and possible heat losses of the dryer 1. Since D_i is expressed as a normalized ratio, a robust compensation against possible airflow and heat loss variations is provided for this control quantity.

[0050] On the other hand, the strict relation existing between D_i and the moisture retention level M_R can also be appreciated from figure 4, in which the temperatures T_{IN} and T_{OUT} and the quantities M_R and D; over time are shown.

[0051] The results of the evaluation procedure 50 are used by the control unit 70 in the termination control procedure 502 to decide whether terminate or not the drying cycle.

[0052] According to the step vii) of the termination control procedure 502, the control unit 70 terminates the drying cycle if the third value D_i is lower than a predefined threshold value D_T, which is indicative of a desired moisture retention threshold M_{RD}. Preferably, a value of 60% if chosen for D_T. As it can be observed from figure 4, this value corresponds to a M_{RD} of about 3%.

[0053] If the drying cycle is terminated, the control unit 70 sends command signals 71 for switching off the heating element 5 and the electric motor 3. The user can preferably access the drying volume 200 to remove the wash load 100, after a predefined time interval, so as to allow the wash load 100 to cool down.

[0054] If the third value D_i is higher than the threshold D_T, it means that a certain level of humidity is still present in the wash load 100. Thus, the alternative step viii) of the termination control procedure 502 foresees for the drying cycle to be continued. In this case, the processing means 7 repeat the evaluation procedure 50 by considering the calculated second value A_{max} as new reference value A_0.

[0055] The household tumble dryer 1, according to the present invention, has proven to fulfil the intended aims and objects.

[0056] The drying cycle control procedure 500 adopts a simple and effective control strategy for terminating the drying cycle, since the evaluation procedure 50 provides all the needed information for precisely determining the termination timing for the drying cycle, depending on the actual drying conditions of the wash load. That means that the possibilities of incurring in wash load over-drying or under-drying conditions are dramatically reduced.

[0057] The termination control procedure 502 is quite simple to carry out and it is provided also with a certain level of flexibility, since the termination of the drying cycle can be delayed or anticipated depending on the desired drying conditions of the wash load. To this aim, different threshold values D_T can be made available.

[0058] Additionally, it has been shown how the drying cycle control procedure 500 works with the dryer 1 in vented or condensing configuration, without the need of additional hardware/software resources.

[0059] The dryer 1 has a simple structure, which has been proven to be easy to manufacture at industrial level, at

competitive costs, since standard hardware components may be used, particularly for what concerning the temperature sensors. On the other hand, the termination control procedure 502, the evaluation procedure 50 and, more in general, the whole drying cycle control procedure 500 may be easily carried out by properly arranged computer programs. To this aim, the processing means 70 may comprises one or more microprocessor units.

Claims

1. A household tumble dryer (1) **characterised in that** it comprises:

- a rotatable drum (2), which defines an interior drying volume (200) for receiving a wash load (100) for drying, said interior drying volume comprising an air inlet portion (201), through which an airflow (20, 20A) enters said internal drying volume, and an air outlet portion (202), through which said airflow (20, 20B) exits from said internal drying volume after having passed through said internal drying volume; and
- a heating element (5) for heating said airflow before said airflow reaches said air inlet portion; and
- sensor means (6A, 6B) for detecting the temperature of said airflow at said air inlet portion and at said air outlet portion; and
- a control unit (70) for controlling the drying cycle of said household tumble dryer, said control unit receiving from said sensor means (61) signals indicative of the temperature of said airflow at said air inlet portion and said air outlet portion, said control unit comprising processing means (7) for executing at least a termination control procedure (502) for managing the termination of said drying cycle, said termination control procedure comprising an evaluation procedure (50) for estimating the actual level of moisture of said wash load, basing on the information received from said sensor means.

2. A household tumble dryer, according to claim 1, **characterised in that** said sensor means comprises a first temperature sensor (6A) at said air inlet portion and a second temperature sensor (6B) at said air outlet portion.

3. A household tumble dryer, according to one or more of the previous claims, **characterised in that** said evaluation procedure comprises the following steps:

i) acquiring an inlet air temperature value (T_{IN}), which is indicative of the temperature of said airflow at said air inlet portion; and
ii) acquiring an outlet air temperature value (T_{OUT}), which is indicative of the temperature of said airflow at said air outlet portion; and
iii) calculating a first value (A_i), which is indicative of the mean difference between said inlet air temperature value (T_{IN}) and said outlet air temperature value (T_{OUT}) over a predefined period of time (ΔT); and
iv) comparing said first value (Ai) with a reference value (A_0); and
v) calculating a second value (A_{max}), which is the maximum between said first value (A_i) and said reference value (A_0); and
vi) calculating a third value (D_i) from the ratio between first value (A_i) and said second value (A_{max}), said third value being indicating of the moisture retention value (M_R) of said wash load.

4. A household tumble dryer, according claim 3, **characterised in that** said termination control procedure comprises a step vii) of terminating said drying cycle, if said third value (D_i) is lower than a predefined threshold value (D_T).

5. A household tumble dryer, according claim 3, **characterised in that** said termination control procedure comprises a step viii) of repeating said evaluation procedure by considering said second value (A_{max}) as new reference value (A_0), if said third value (D_i) is higher than a predefined threshold value (D_T),.

6. A household tumble dryer, according to one or more of the claims from 4 to 5, **characterised in that** said predefined threshold value (D_T) is 60%.

7. A household tumble dryer, according to one or more of the claims from 4 to 6, **characterised in that** said predefined threshold value (D_T) is indicative of a desired moisture retention value (M_{RD})

8. A household tumble dryer, according to claim 7, **characterised in that** said desired moisture retention value (M_{RD}) is 3%.

9. A household tumble dryer, according to one or more of the previous claims, **characterised in that** it is of the vented type.

10. A household tumble dryer, according to one or more of the claims from 1 to 8, **characterised in that** it is of the condensing type.

11. A drying cycle control procedure (500) for managing the drying cycle of a household tumble dryer (1), said household tumble dryer comprising at least a rotatable drum (2), which defines an interior drying volume (200) for receiving a wash load (100) for drying, said interior drying volume comprising an air inlet portion (201), through which an airflow (20, 20A) enters said internal drying volume, and an air outlet portion (202), through which said airflow (20, 20B) exits from said internal drying volume after having passed through said internal drying volume, said household tumble dryer further comprising a heating element (5) for heating said airflow before said airflow reaches said air inlet portion, and sensor means (6A, 6B) for detecting the temperature of said airflow at said air inlet portion and at said air outlet portion, said drying cycle control procedure comprising a termination control procedure (502) for managing the termination of said drying cycle,
characterised in that said termination control procedure comprises the following steps:

i) acquiring an inlet air temperature value (T_{IN}), which is indicative of the temperature of said airflow at said air inlet portion; and
ii) acquiring an outlet air temperature value (T_{OUT}), which is indicative of the temperature of said exhaust air at said air outlet portion; and
iii) calculating a first value (A_i), which is indicative of the mean difference between said inlet air temperature value (T_{IN}) and said outlet air temperature value (T_{OUT}) over a predefined period of time (ΔT); and
iv) comparing said first value (Ai) with an reference value (A_0), which is indicative of the mean difference between said inlet air temperature value (T_{IN}) and said outlet air temperature value (T_{OUT}); and
v) calculating a second value (A_{max}), which is the maximum between said first value (A_i) and said reference value (A_0); and
vi) calculating a third value (D_i) from the ratio between first value (A_i) and said second value (A_{max}), said third value being indicative of the moisture retention value (M_R) of said wash load; and
vii) if said third value (D_i) is lower than a predefined threshold value (D_T), terminating said drying cycle; or
viii) if said third value (D_i) is higher than a predefined threshold value (D_T), repeating at least said steps i)-vi) by considering said second value (A_{max}) as new reference value (A_0).

12. A computer program comprising instructions for executing a drying cycle control procedure, according to claim 11.

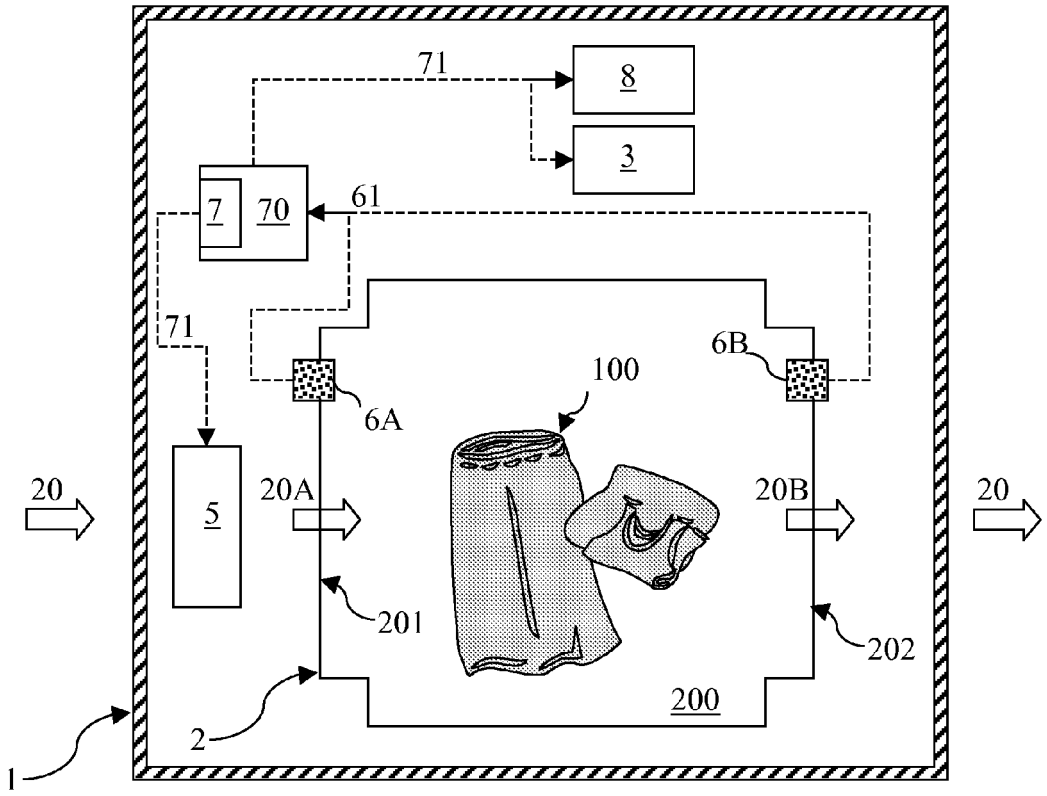

FIG. 1

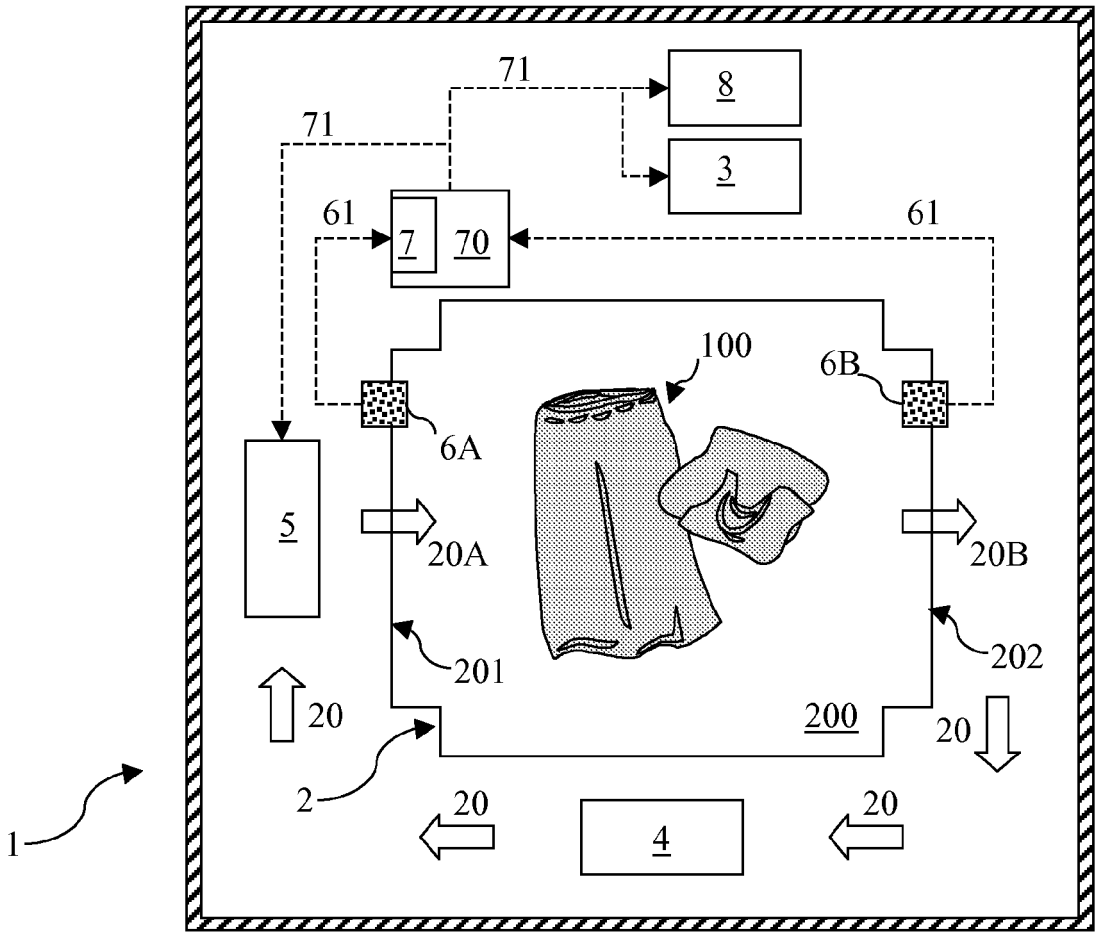

FIG. 2

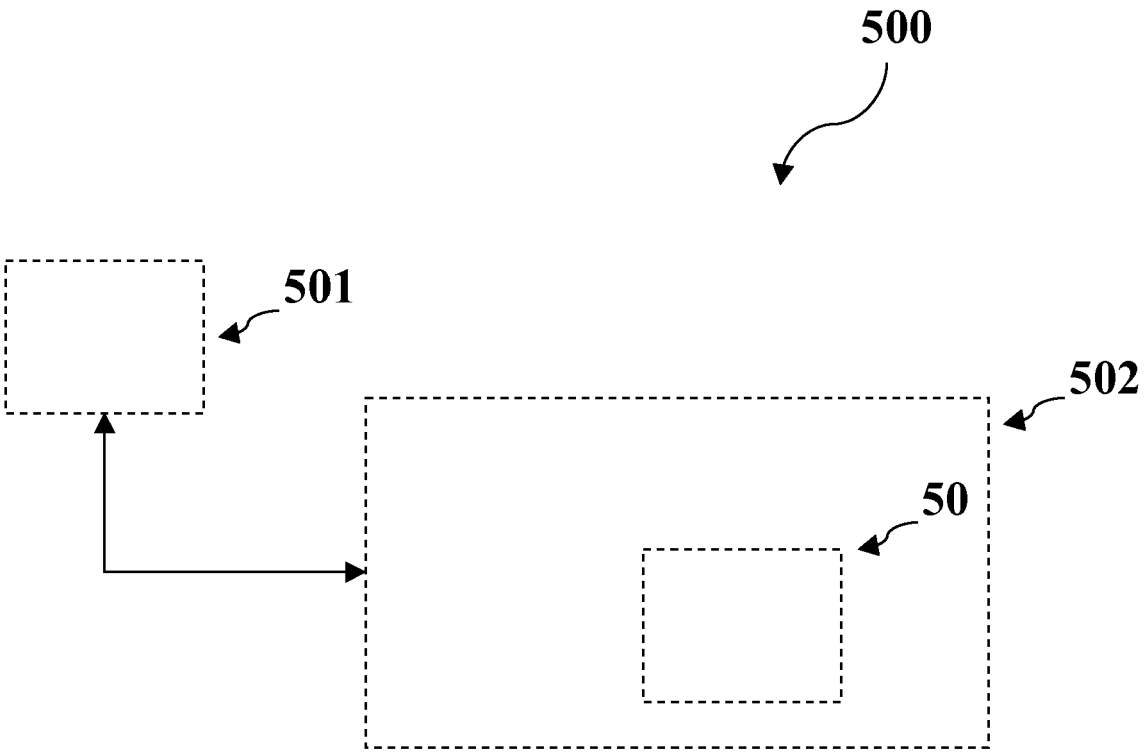

FIG. 3A

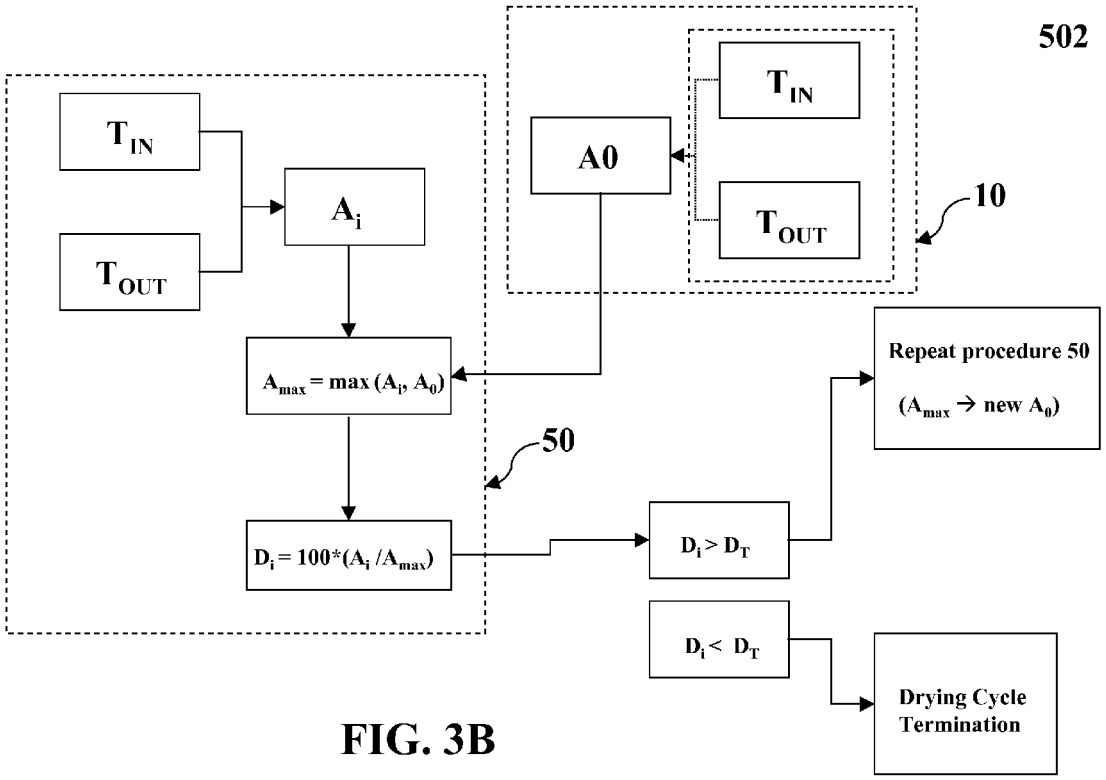
502
T_{IN}
A0
T_{OUT}
10
T_{IN}
A_i
T_{OUT}
$A_{max} = max (A_i, A_0)$
50
$D_i = 100*(A_i / A_{max})$
$D_i > D_T$
Repeat procedure 50
(A_{max} → new A_0)
$D_i < D_T$
Drying Cycle Termination

FIG. 3B

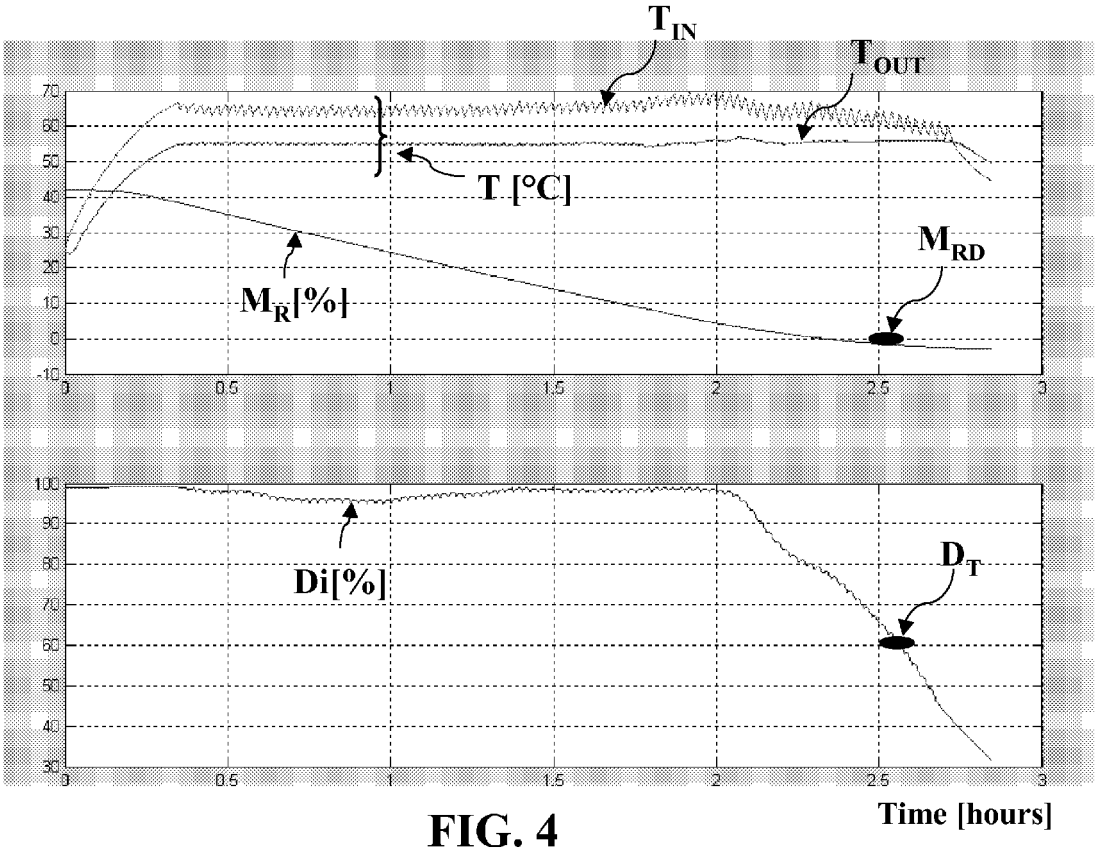

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 07 11 5705

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 420 104 A (CANDY SPA [IT]) 19 May 2004 (2004-05-19) * paragraphs [0027], [0028], [0030] - [0032]; claims 1,8,9,12-16,18; figures 5,6 *	1-12	INV. D06F58/28
X	US 4 206 552 A (GOLDSTEIN SANDERS [US] ET AL) 10 June 1980 (1980-06-10) * column 5, line 52 - line 55 * * column 6, line 30 - line 56 * * claims 1,4,6,10,11,14,18-28,31; figures 1,4 *	1-12	

TECHNICAL FIELDS SEARCHED (IPC)

D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	7 February 2008	Courrier, Gilles

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 11 5705

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07-02-2008

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

REFERENCES CITED IN THE DESCRIPTION

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- US 4640022 A **[0016]**