



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.06.2010 Bulletin 2010/22

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

(21) Application number: **08170117.9**

(22) Date of filing: **27.11.2008**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

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(54) **An improved tumble dryer**

(57) The present invention relates to a household tumble dryer, which comprises a rotatable drum (2) and heating means (5) for heating an airflow passing through said interior drying volume (200).

The household tumble dryer comprises sensor means (6A,6B) and a control system (7), which comprises at least a first control loop (51) and a second control loop (52) that can cooperate for controlling the operation of said heating means (5).

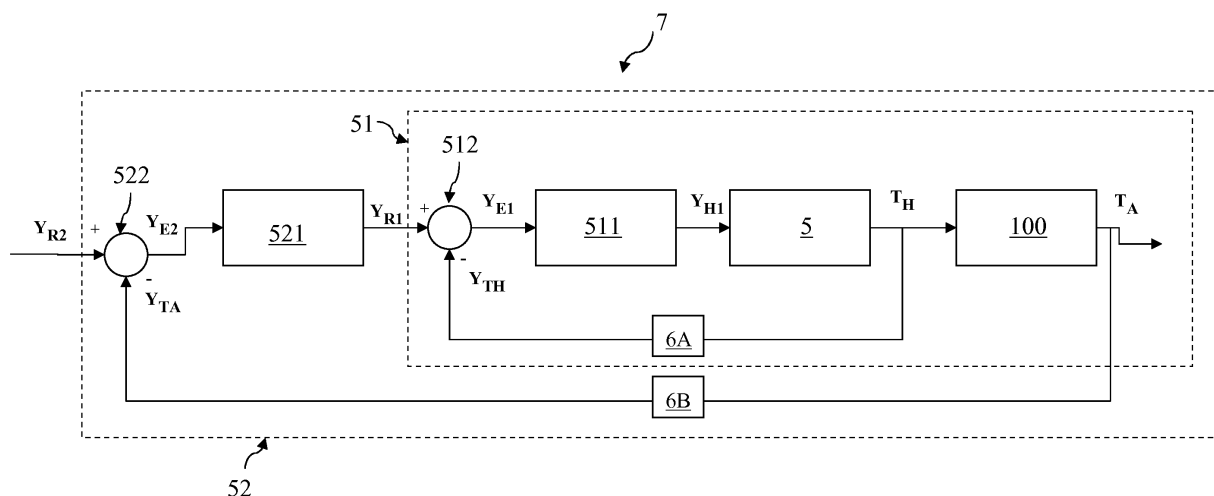


FIG. 3

Description

[0001] The present invention relates to a household tumble dryer having improved performances in terms of drying cycle efficiency, energy consumption and safety.

[0002] Household tumble dryers are quite popular nowadays.

[0003] As widely known, these appliances generally comprise a rotatable drum that defines an interior drying volume for receiving a wash load to be dried.

[0004] The rotatable drum is actuated by an electric motor to tumble the wash load during the drying cycle.

[0005] Dryers may be of the vented type, in which an airflow is taken from the outside of the appliance during the drying cycle. The airflow is heated by a heating element and it is forced to pass through the drying volume to remove humidity from the wash load. The humid exhaust air is then blown outside.

[0006] In dryers of the condensing type, instead, the airflow follows a closed path that is fully inside the appliance. After being heated, the airflow passes through the drying volume and it is circulated to a condenser for dehumidification. Then, the airflow is conveyed to the heating element for being heated again.

[0007] In both the described cases, the circulation of the mentioned airflow is ensured by a fan.

[0008] Available dryers generally comprise a control system, which regulates the dryer operation and manages the drying cycle.

[0009] Typically, the control system regulates the flow rate of the airflow passing through the drying volume and the temperature of the heating means to achieve desired temperature levels and ensure safety.

[0010] An example of these known control systems is disclosed in US4231166.

[0011] Unfortunately, traditional control systems provide relatively poor performances in terms of drying and energy consumption efficiency, since they are mainly focused on the achievement of certain predefined levels of heating power or flow rate, which are established on the base of the user's settings.

[0012] Important environmental factors that influence the drying cycle efficiency, such as the actual conditions of the wash load, the operating conditions of the tumble dryer (e.g. the possible presence of lint obstructions) et cetera, are not properly taken into account.

[0013] Other known simpler control methods make use of the hysteresis control, for which the heater is placed in the air channel and therein controlled by means of a temperature sensing element and it is switched on when the feedback temperature is below a predefined threshold and switched on when it is above a second predefined threshold in order to not exceed the safety temperature limit for the air channel. According to this control strategy, the temperature within the air channel varies with a "saw-teeth" profile. As a consequence, the average temperature within the air channel is higher than the average temperature in the drying chamber and this last is further

pushed down during the drying cycle by continuous energy interruptions of the heater.

[0014] This behaviour is particularly critical in the final drying phase whenever the maximum power should be provided to the laundry for obtaining high quality drying performances.

[0015] It follows that the average temperature of the drying chamber is not optimized because it is relatively low and stays below a value that could be reached when controlling the heater, in a more stable manner, near the highest temperature limit allowed in the air channel (preferably below a temperature safety threshold). Therefore, this hysteresis control strategy results in inefficient energy consumption, which derives from a longer drying (time) process executed at lower temperature, compared to a drying cycle whenever the temperature of the heater is kept closer the predetermined upper temperature limit temperature (preferably below a temperature safety threshold), without being controlled in an (predominant) oscillating manner, as it happens with the on-off or hysteresis control.

[0016] Therefore, the main aim of the present invention is to provide a household tumble dryer, which allows the overcoming of the drawbacks mentioned above.

[0017] Within this aim, it is an object of the present invention to provide a household tumble dryer, in which the control system is capable of offering improved performances in terms of drying cycle efficiency, drying time reduction, energy consumption reduction and control robustness.

[0018] 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.

[0019] Thus, the present invention provides a household tumble dryer according to the following claim 1.

[0020] In its more general definition, the household tumble dryer according to the present invention comprises a control system that is provided at least with a first control loop and a second control loop, which are capable of cooperating in order to control the operation of said heating means.

[0021] This dual loop control of the heating means of the dryer guarantees the obtaining of adequate heating power and safety levels and, at the same time, the achievement of high drying cycle efficiency and remarkable savings in terms of energy consumption.

[0022] Another object of the present invention is to provide a tumble dryer wherein the heater is controlled by means of a PI control, causing the difference between the average temperature of the air channel and the average temperature of the drying chamber (with or without laundry inside) to be minimized.

[0023] 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;
- Fig. 2 represents a schematic diagram of the household tumble dryer according to the present invention, in a configuration of the condensing type;
- Fig. 3 represents a schematic diagram of a control system in the household tumble dryer according to the present invention, in a first embodiment; and
- Fig. 4 represents a schematic diagram of a control system in the household tumble dryer, according to the present invention, in a second embodiment.

[0024] Referring now to the drawings, the present invention relates to a household tumble dryer 1, which comprises a rotatable drum 2 that is preferably actuated by an electric motor 3.

[0025] The rotatable drum 2 defines an interior drying volume 200 for receiving a wash load 100 for drying.

[0026] The drying volume 200 comprises an air inlet portion 201, through which an airflow 20 can enter 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.

[0027] 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 in the external environment, after having passed through the drying volume 200. Before entering the drying volume 200, the airflow 20 is heated by heating means 5, such as an electric heater.

[0028] As an alternative (figure 2), the dryer 1 may be configured as a condensing dryer. In this case, the airflow 20 follows a substantially closed loop, which is interior the dryer. After having passed through the drying volume 200, the airflow 20 is directed through condensing means 9 for dehumidification and then again to the heating means 5.

[0029] The correct circulation of the airflow 20 is ensured by properly positioned air ducts (not shown) and by a fan 8.

[0030] The dryer 1 comprises first sensor means 6A and second sensor means 6B for detecting respectively the temperature T_H of the airflow 20 at the air inlet portion 201 and the temperature T_A at the air outlet portion 202.

[0031] It should be noticed that the temperature T_H substantially coincides with the temperature of the heating means 5 while the temperature T_A is substantially the actual temperature of the wash load 100.

[0032] Preferably, the sensor means 6A-6B comprise temperature sensors that are able to provide signals indicative of the detected temperatures, e.g. thermocouples. Of course, temperature sensors of different kind may be used.

[0033] The dryer 1 comprises a control system 7, which in general terms may be defined as the entire set of control arrangements used for controlling the dryer 1, in particular for managing the drying cycle of the dryer 1.

[0034] In this respect, the term "drying cycle" means the sequence of steps needed for performing drying operations of the wash load 100.

[0035] The control system 7 preferably comprises a control unit 70, which controls the operating drying cycle of the dryer 1 by sending proper command signals 71 to the heating means 5, the motor 3 and the fan 8 and which 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.

[0036] The control system 7 comprises also a plurality of control loops, which preferably involve the control unit 70 in their physical implementation, as it will be more apparent in the following.

[0037] In particular, the control system 7 comprises a first control loop 51 (figures 3,4) for regulating the temperature T_H of the airflow 20 at the air inlet portion 201 and a second control loop 52 for regulating the temperature T_A of the airflow 20 at the air outlet portion 202.

[0038] The control loops 51 and 52 are configured, so as to be capable of cooperating for controlling the operation of the heating means 5.

[0039] Preferably, the first control loop 51 receives in input a first feedback signal Y_{TH} from the first sensor means 6A, the signal Y_{TH} being indicative of the temperature T_H .

[0040] The second control loop 52 instead preferably receives in input a second feedback signal Y_{TL} from the second sensor means 6B, the signal Y_{TL} being indicative of the temperature T_A .

[0041] In practice, the control system 7 controls the operation of the heating means 5 by means of two concurrent loops 51 and 52, which work on the base of different feedback signals.

[0042] The control loop 51 works on the base of a first feedback signal Y_{TH} that is indicative of the temperature T_H substantially coincident with the temperature of the heating means 5. In its control action, the first control loop 51 thus takes into account control parameters that substantially depend on the operating conditions of the heating means 5 and/or on related safety requirements.

[0043] The control loop 52 instead works on the base of a second feedback signal Y_{TA} indicative of the temperature T_A that substantially coincides with the actual temperature of the wash load 100. Its control action, the second control loop 52 is therefore influenced by different control parameters that substantially depend on the actual status of the wash load 100 or other environmental conditions, such as for example the actual level of lint obstruction at the outlet portion 202.

[0044] The control loops 51 and 52 may be arranged according to different configurations and may comprise one or more logic blocks such as adders, controllers, switches and the like.

[0045] Said logic blocks may be hardware implemented as self standing devices or as circuits/boards of the control unit 70.

[0046] As an alternative, these logic blocks may be

implemented as software programmes, modules or routines that are executed by a suitable processing unit, for example by a microprocessor (not shown) of the control unit 70.

[0047] According to a first embodiment of the present invention, which is shown in figure 3, the control loops 51 and 52 may be arranged according to a cascade configuration, in which the control loop 51 is positioned downstream with respect to the control loop 52.

[0048] In this case, the control loops 51 and 52 are mutually nested and they can mutually interact to control the heating means 5.

[0049] According to this embodiment of the present invention, the first control loop 51 receives in input a first reference signal Y_{R1} that is provided by the second control loop 52.

[0050] The reference signal Y_{R1} may be indicative of the desired temperature for the heating means 5. For example, the reference signal Y_{R1} may express the temperature profile to be followed by the heating means 5 during a certain interval of the drying cycle.

[0051] The first loop 51 advantageously works as a retroactive loop and it thus comprises a first controller 511 that receives in input a first error signal Y_{E1} obtained from a first adder 512 that calculates the difference between the first reference signal Y_{R1} and the first feedback signal Y_{TH} .

[0052] The controller 511 provides in output a first control signal Y_{H1} for regulating the operation of the heating means 5, which (from a logic point of view) may be represented as a logic block receiving in input the control signal Y_{H1} and providing in output a temperature value T_H , which is detected by the first sensor means 6A that provide the feedback signal Y_{TH} .

[0053] The wash load 100 may in turn be modelled as a logic block that receives in input a temperature value T_H and provides in output a temperature value T_A , which is detected by the first sensor means 6B that provide the feedback signal Y_{TA} .

[0054] The second control loop 52 receives in input a second reference signal Y_{R2} that may be indicative of a desired temperature for the wash load 100. As an example, the signal Y_{R2} may be represented by a predefined temperature profile for the wash load 100 that is selected by the control unit 7 on the base of a manual selection operated by the user or depending from other environmental conditions, such as the presence of lint obstructions at the outlet portion 202.

[0055] The second control loop 52 preferably comprises a second controller 521 that receives in input a second error signal Y_{E2} that is obtained from the difference between the second reference signal Y_{R2} and the second feedback signal Y_{TA} , which difference is advantageously calculated by means of an adder 522.

[0056] The second controller 521 generates in output the first reference signal Y_{R1} for the first control loop 51.

[0057] It has to be noted how the entire first control loop 51 can be modelled as a logic block that receives

in input the first reference signal Y_{R1} and provides in output a temperature value T_A for the wash load 100.

[0058] Thanks to the described cascade configuration, the first control loop 51 retroactively regulates the operation of the heating means 5 on the base of the first reference signal Y_{R1} that is in turn generated by the second control loop 52 on the base of a second reference signal Y_{R2} that may be generated on the base of the wash load conditions and/or environmental conditions.

[0059] In this manner, the regulation of the heating means 5 can easily take into account additional external factors that are not strictly linked to the functioning of the heating means themselves or to safety reasons.

[0060] According to a further embodiment of the present invention, which is shown in figure 4, the control loops 51 and 52 may be arranged according to a parallel configuration. In this case, each control loop 51 and 52 works in a substantially independent manner and it is selectively activated on the base of signals that are indicative of the operative status of the dryer 1.

[0061] For example, during the start-up of the drying cycle the first control loop 51 may be activated in order to rapidly bring the heating means to a full functioning and quickly reach a certain temperature level T_H at the inlet portion 201.

[0062] Then, the second control loop 52 may be enabled and the first control loop 51 may be excluded, so to as to control the operation of the heating means 5 on the base of the temperature T_A of the wash load 100, i.e. on the base of different factors such as the wash load conditions and/or environmental conditions.

[0063] The first control loop 51 may be again enabled if the operating conditions of the dryer 1 so requires, for example in case the temperature T_H overcomes predefined safety levels.

[0064] According to this further embodiment of the present invention, the first control loop 51 receives in input a third reference signal Y_{R3} , which may be advantageously indicative of the desired profile temperature for the heating means 5, when the first control loop 51 is active.

[0065] The first control loop 51 comprises also a third controller 513 that receives in input a third error signal Y_{E3} , which is obtained from an adder 514 that calculates the difference between the third reference signal Y_{R3} and the first feedback signal Y_{TH} coming from the first sensor means 6A.

[0066] The controller 513 generates in output a second control signal Y_{H2} for regulating the operation of the heating means 5.

[0067] The second control loop 52 receives in input a fourth reference signal Y_{R4} , which may instead be indicative of the desired temperature for the wash load 100.

[0068] The second control loop 52 comprises advantageously a fourth controller 523 that receives in input a fourth error signal Y_{E4} , which is obtained from the adder 524 that calculates the difference between the reference signal Y_{R4} and the second feedback signal Y_{TA} coming

from the second sensor means 6B.

[0069] Also, the controller 523 generates in output a third control signal Y_{H3} for regulating the operation of the heating means 5.

[0070] For the activation/exclusion of the control loops 51 and 52, switching means 555 are provided, which receive in input the control signals Y_{H2} and Y_{H3} and select which control signal has to be enabled for controlling the heating means 5.

[0071] As mentioned above, such a selection is advantageously operated on the base of signals I_s that are indicative of the operative status of the dryer 1. For example, said signals I_s may be alarm signals coming from additional sensors (not shown) or from the sensor means 6A and/or 6B. Alternatively, the signals I_s may be command signals generated by the control unit 70.

[0072] According to a preferred control method, when the temperature at the inlet portion 201 (the air channel) raises above a first predefined temperature threshold T_{HR1} , which is above a temperature safety limit T_S , the heater 5 is energized only if the fan 8 is energized (rotated), in a synchronized manner.

[0073] On some drier constructions the fan 8 is mounted on the shaft of the rotating drum, and is rotated together with drum motor 3. With these constructions and under the described conditions, the heater is energized in synchronism with the drum and with the fan 8.

[0074] In another case the heater 5 can be activated also only when the airflow measurable (by means of known measurement tools) at inlet portion 201 is above a predetermined airflow threshold A_{TH} . For instance, this airflow threshold A_{TH} corresponds to the reduced airflow achieved when the rotational direction of the drum is reversed.

[0075] This control method avoids that the temperature in the air channel 201, especially around the heater 5, to rise above to the safety thresholds T_S , but it still maintains the temperature at an acceptable level, without sudden drops.

[0076] In other cases, when the temperature of the air channel is above a first predefined temperature threshold T_{HR1} , the power delivered by the heater can be controlled in order to be reduced or temporarily discontinued, with the aim to reduce the magnitude of the temperature oscillation in the air channel 20 and in order to reduce the drying time, (by maintaining an higher temperature in the air channel 20) and, as a consequence, to reduce the energy consumption.

[0077] When the temperature is below the first predetermined temperature threshold, the synchronized activation is not required because the temperature of the air channel is far enough from the temperature safety limit and the safety of the machine is not at risk.

[0078] The tumble dryer 1 according to the present invention fully allows the achievement of the intended aims and objects.

[0079] Thanks to the presence of two concurrent control loops 51, the drying cycle can be managed taking

into account also the actual wash load conditions and other additional environmental conditions. The possibility of incurring in wash load over-drying or under-drying conditions is thus dramatically reduced and the dryer 1 can work in a more efficient manner, with a lower energy consumption and a reduce drying time.

[0080] The adoption of retroactive control loops ensures noticeable control robustness, with high level of safety.

[0081] Additionally, it has been shown how the control loops 51 and 52 can work with the dryer 1 in a vented or condensing configuration, without the need of additional hardware/software resources.

[0082] 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 or relatively simple software procedures may be adopted.

Claims

1. A household tumble dryer (1) comprising:

- a rotatable drum (2) having an interior drying volume (200) for receiving a wash load (100) for drying, said interior drying volume having an air inlet portion (201), through which an airflow (20) enters said internal drying volume, and an air outlet portion (202), through which said airflow exits from said internal drying volume;
- heating means (5) for heating said airflow before said airflow passes through said air inlet portion;
- first sensor means (6A) for detecting the temperature (T_H) of said airflow at said air inlet portion; and
- second sensor means (6B) for detecting the temperature (T_A) of said airflow at said air outlet portion; and
- a control system (7) for controlling the operation of the dryer (1);

characterised in that said control system comprises at least a first control loop (51) for regulating the temperature (T_H) of said airflow at said air inlet portion (201) and a second control loop (52) for regulating the temperature (T_A) of said airflow at said air outlet portion (202), said first control loop and said second control loop cooperating for controlling said heating means (5).

2. A household tumble dryer, according to claim 1, **characterised in that** said first control loop receives in input a first feedback signal (Y_{TH}) indicative of the temperature (T_H) of said airflow at said air inlet portion, said first feedback signal being provided by said first sensor means.

3. A household tumble dryer, according to claims 1 or 2, **characterised in that** said second control loop receives in input a second feedback signal (Y_{TA}) indicative of the temperature (T_A) of said airflow at said air outlet portion, said second feedback signal being provided by said second sensor means. 5
4. A household tumble dryer, according to one or more of the previous claims, **characterised in that** said first control loop and said second control loop are arranged according to a cascade configuration, said first control loop being positioned downstream with respect to said second control loop. 10
5. A household tumble dryer, according to claim 4, **characterised in that** said first control loop receives in input a first reference signal (Y_{R1}), said first control loop comprising a first controller (511) that receives in input a first error signal (Y_{E1}), which is obtained from the difference between said first reference signal (Y_{R1}) and said first feedback signal (Y_{TH}), said first controller generating in output a first control signal (Y_{H1}) for controlling said heating means. 15
6. A household tumble dryer, according to claim 5, **characterised in that** said second control loop receives in input a second reference signal (Y_{R2}), said second control loop comprising a second controller (521) that receives in input a second error signal (Y_{E2}), which is obtained from the difference between said second reference signal (Y_{R2}) and said second feedback signal (Y_{TA}), said second controller generating in output said first reference signal (Y_{R1}). 20
7. A household tumble dryer, according to one or more of the claims from 1 to 3, **characterised in that** said first control loop and said second control loop are arranged according to a parallel configuration. 25
8. A household tumble dryer, according to claim 7, **characterised in that** said first control loop or said second control loop is selectively activated on the base of signals (I_s) that are indicative of the operative status of said dryer. 30
9. A household tumble dryer, according to claim 8, **characterised in that** said first control loop receives in input a third reference signal (Y_{R3}), said first control loop comprising a third controller (513) that receives in input a third error signal (Y_{E3}), which is obtained from the difference between said third reference signal (Y_{R3}) and said first feedback signal (Y_{TH}), said third controller generating in output a second control signal (Y_{H2}) for controlling said heating means. 35
10. A household tumble dryer, according to claims 8 or 9, **characterised in that** said second control loop receives in input a fourth reference signal (Y_{R4}), said second control loop comprising a fourth controller (523) that receives in input a fourth error signal (Y_{E4}), which is obtained from the difference between said fourth reference signal (Y_{R4}) and said second feedback signal (Y_{TA}), said second controller generating in output a third control signal (Y_{H3}) for controlling said heating means. 40
11. A household tumble dryer, according to claims 9 and 10, **characterised in that** switching means (555) receive in input said second control signal (Y_{H2}) and said third control signal (Y_{H3}), said switching means selecting said first control signal (Y_{H1}) or said second control signal (Y_{H2}) for regulating the operation of said heating means. 45
12. A household tumble dryer, according to claims 11, **characterised in that** said switching means select said second control signal (Y_{H2}) or said third control signal (Y_{H3}) on the base of signals (I_s) that are indicative of the operative status of said dryer. 50
13. A household tumble dryer, according to one or more of the claims from 1 to 12, **characterised in that** it is of the condensing type or of the vented type. 55
14. Method for controlling a household dryer according to any of the preceding claims further comprising a fan (8) wherein the heating means (5) are energized only when the temperature at inlet portion (201) rises above a first predefined temperature threshold (T_{HR1}).
15. Method for controlling a household dryer according to any of the preceding claims further comprising a fan (8) wherein the heater (5) is energized only when an airflow at the inlet portion (201) is above a predetermined airflow threshold (A_{TH}).

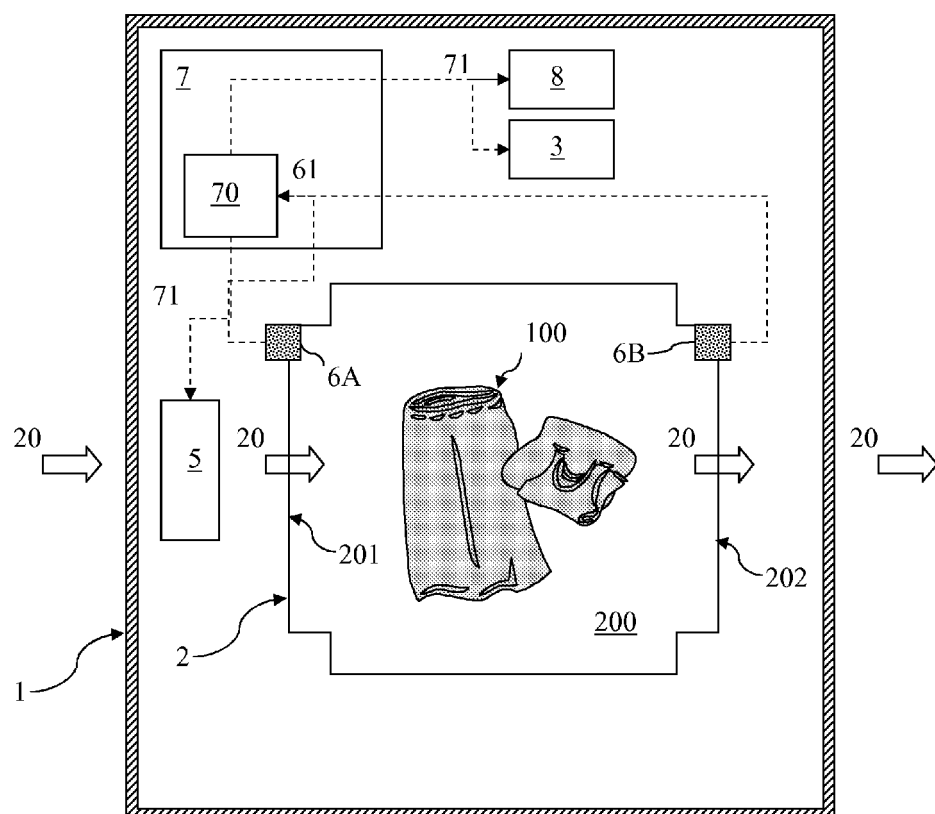


FIG. 1

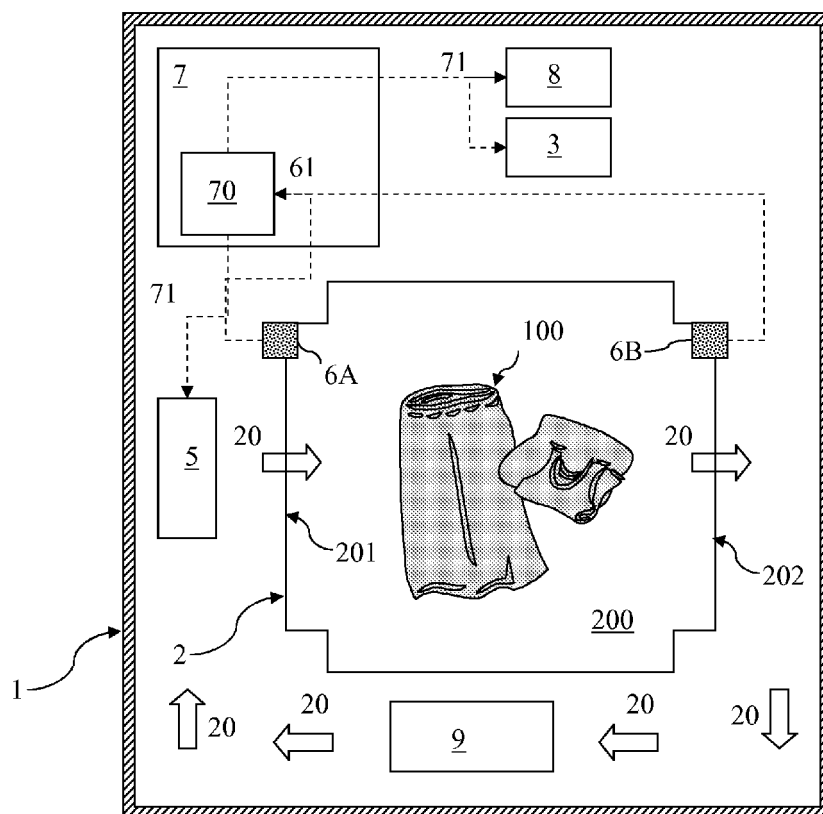


FIG. 2

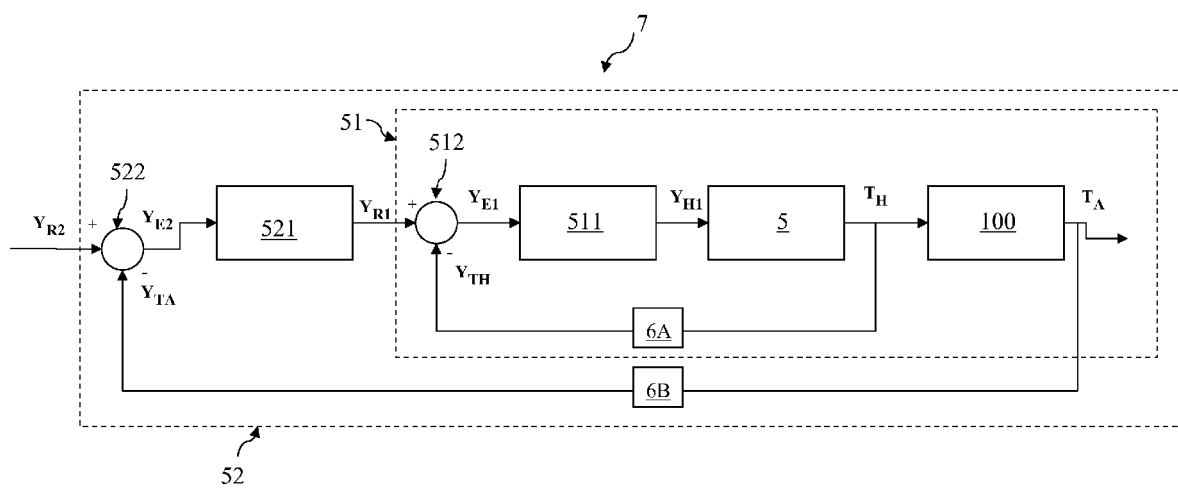


FIG. 3

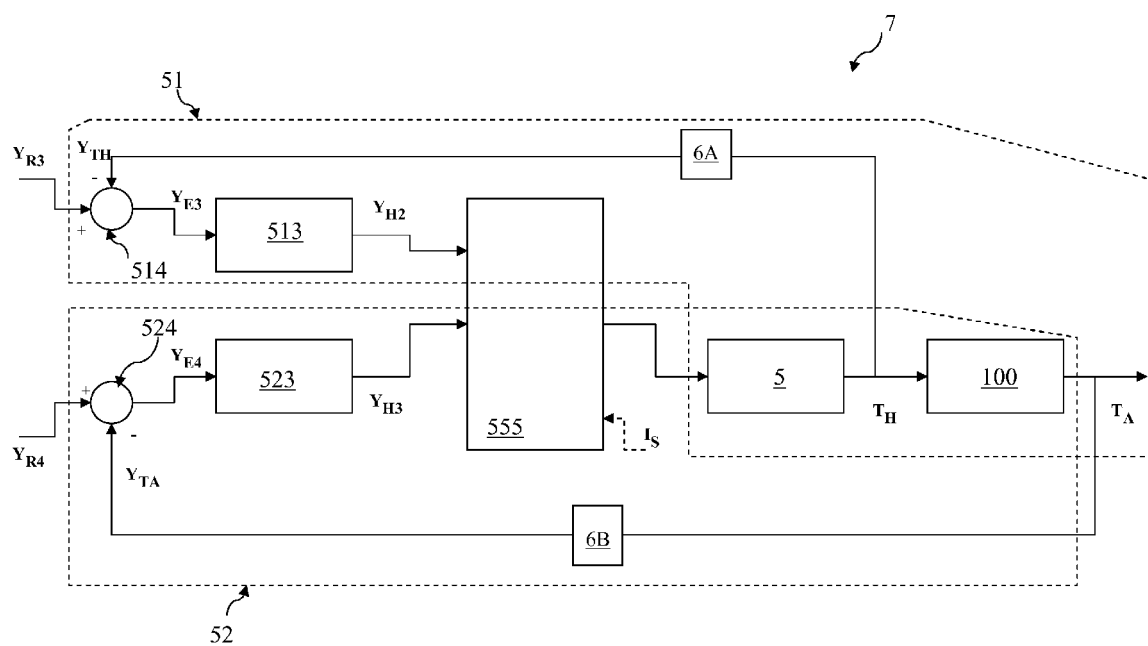


FIG. 4



EUROPEAN SEARCH REPORT

Application Number
EP 08 17 0117

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
1 D,A	US 4 231 166 A (MCMILLAN STEPHEN L) 4 November 1980 (1980-11-04) * column 1, line 50 - line 68 *	1-15	INV. D06F58/28
2 A	EP 1 712 672 A (WHIRLPOOL CO [US]) 18 October 2006 (2006-10-18) * paragraph [0009] - paragraph [0010] * * paragraph [0013] - paragraph [0014] *	1-15	
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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			D06F
1	Place of search Munich	Date of completion of the search 18 June 2009	Examiner Hannam, Martin
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03 82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 17 0117

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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18-06-2009

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

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