



(43) International Publication Date
27 November 2014 (27.11.2014)

(51) International Patent Classification:
D06F 58/20 (2006.01) *D06F 58/28* (2006.01)

(21) International Application Number:
PCT/EP2013/060646

(22) International Filing Date:
23 May 2013 (23.05.2013)

(25) Filing Language: English

(26) Publication Language: English

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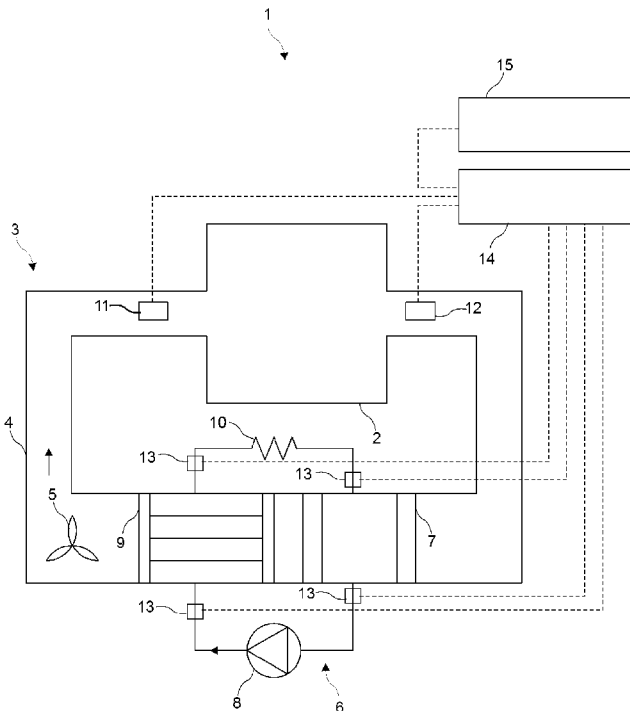
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

[Continued on next page]

(54) Title: HEAT PUMP TYPE LAUNDRY DRYER AND METHOD OF DRYING LAUNDRY USING THE SAME

Fig. 1



(57) Abstract: The present invention relates to a heat pump type laundry dryer (1) and a method of drying laundry with such a dryer. The heat pump type laundry dryer comprises a process air circuit (3) having a duct (4) for circulating process air (5) through a laundry drum (2), a refrigerant circuit (6) having an evaporator (7), a compressor (8), a condenser (9), and an expansion valve (10) in serial connection for circulating a refrigerant, wherein the evaporator (7) and condenser (9) are arranged in heat exchange with the process air in the duct (4) for dehumidifying and subsequently heating the same, a first temperature sensor (11) arranged to measure a temperature (T1) of the process air to be discharged into a drum (2) and a second temperature sensor (12) arranged to measure a temperature (T2) of the process air drawn out of the drum (2). The heat pump type laundry dryer is further provided with at least one additional temperature sensor (13), located at the refrigerant circuit (6), arranged to measure the temperature of the refrigerant (T3) and a control unit (14) adapted to dry the laundry to a target dryness by operating the process air circuit (3) and the refrigerant circuit (6) on the basis of the predetermined correlation between the temperatures (T1, T2, T3) and any abnormality of the temperatures (T1, T2, T3) measured by the first temperature sensor (11), the second temperature sensor (12), and the additional temperature sensor (13).

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Description**HEAT PUMP TYPE LAUNDRY DRYER AND METHOD OF DRYING LAUNDRY
USING THE SAME**

- [0001] The present invention relates to a heat pump type laundry dryer and a method of drying laundry using the same.
- [0002] The heat pump technology constitutes a relatively energy-efficient method of drying laundry. A heat pump type laundry dryer typically consists of a closed process air circuit and a refrigerant circuit which are arranged to exchange heat. The process air circuit includes a duct for circulating process air through a laundry drum, by means of a fan. The refrigerant circuit includes an evaporator, a compressor, a condenser, and an expansion valve in serial connection for circulating a refrigerant. The evaporator and the condenser are arranged in heat exchange with the process air in the circulation duct for dehumidifying and subsequently heating the process air. The heat absorbed by the evaporator is partly transferred back to the process air by means of the condenser. Thereby, a drying performance of the dryer is increased.
- [0003] In general, the drying process depends on several factors. For instance, the rate of heat transferred to the clothes and the amount of moisture in the clothes will affect the total duration as well as the overall progress of the drying process. The drying process is generally continued until the clothes achieve a standard level of dryness. During the drying process the humidity of the clothes progressively decreases. If the drying process is terminated too early the clothes may remain wet. If the drying process is terminated too late the clothes may be damaged. In either case, a customer will not be satisfied with the drying result. Therefore, it is important to conduct the drying process in an accurate and reliable way.
- [0004] Several techniques for sensing dryness have been devised. A commonly known method is to sense the dryness with a humidity sensor. Humidity sensors, generally measure a capacitance or a resistance of a probe exposed to the drying environment.
- [0005] Humidity sensors have several drawbacks such as contamination and aging. Another commonly applied technique is to sense dryness by

measuring temperature changes in the process air drying the clothes.

Temperature sensors are less vulnerable to the drying environment.

[0006] US 2009/0064531 A1 discloses a cloth treating apparatus for drying clothes with a heat pump. The cloth treating apparatus includes a cabinet for receiving the clothes and a circulation duct for supplying hot air to the cabinet. The heat pump is provided along the circulation duct. The cloth treating apparatus has a control unit which determines dryness of the clothes based on a temperature of the air drawn into the cabinet and a temperature of the air discharged from the cabinet.

[0007] The drying process may also be affected by unpredictable factors. Customers do not essentially operate a dryer or a washer/dryer in a way complying with the user-instructions supplied by the manufacturer. There may be instances where the customer additionally puts wet clothes into the drum or takes part of the clothes out of the drum. Hence, a change in drying conditions affects the progress of the drying process and compromises accurate operation of the dryer. Consequently, the dryer may malfunction and/or fail to achieve the target dryness level resulting in over dried or under dried laundry.

[0008] An objective of the present invention is to provide a heat pump type laundry dryer and a method of drying laundry which overcome the drawbacks of the above mentioned prior art and enable a reliable, accurate and an energy-efficient method of drying and sensing dryness of laundry.

[0009] This objective has been achieved by the heat pump type laundry dryer according to claim 1, and the method of drying laundry according to claim 9. The dependent claims define preferred embodiments of the present invention.

[0010] The heat pump type laundry dryer of the present invention comprises a first temperature sensor arranged to measure a temperature of the process air to be discharged into the drum, a second temperature sensor arranged to measure a temperature of the process air drawn out of the drum, and at least one additional temperature sensor arranged to measure a temperature of the refrigerant. The control unit of the heat pump type

laundry dryer of the present invention is adapted to dry the laundry to a target dryness by operating the process air circuit and the refrigerant circuit on the basis of a predetermined and recorded correlation between the measured temperatures, and any abnormality of the measured temperatures. Thereby, the drying process can be conducted in a reliable and an energy-efficient way and the target dryness of laundry can be sensed accurately.

- [0011] In an embodiment of the invention, operation of the process air circuit and operation of the refrigerant circuit are halted if a temperature of the refrigerant changes abnormally. Thereby, any abnormal operation of the refrigeration circuit can be avoided at an early stage and the clothes can be protected from damages.
- [0012] In another embodiment of the invention, the dryness of the laundry is sensed based on a temperature drop across the process air discharged into and drawn out of the drum. In this preferred embodiment, sensing dryness of the laundry is initiated when the refrigerant temperature starts strictly decreasing. Thereby, an incorrect sensing of the dryness, in particular an under drying of the clothes are avoided.
- [0013] In another embodiment of the invention, sensing dryness of the laundry is alternatively initiated when said temperature drop across the process air discharged into and drawn out of the drum starts strictly decreasing.
- [0014] In another embodiment of the invention, it is judged that the laundry has reached a target dryness when said temperature drop across the first temperature sensor and the second temperature sensors falls within a predetermined temperature range defining the target dryness. Thereby, an incorrect sensing of the dryness, in particular an excessive or insufficient drying of the clothes are avoided.
- [0015] In another embodiment of the invention, the user can specify a target dryness for the laundry by selecting out of a plurality of target dryness levels. Thereby, customer satisfaction can be improved.
- [0016] In another embodiment of the invention, each of the plurality of target dryness levels selectable by the user is respectively defined by one of a plurality of cascaded temperature ranges which are graded between damp

dry to extra dry.

[0017] In another embodiment of the invention the temperature of the refrigerant is measured with a sensor arranged between an upstream side of the condenser and a downstream side of the compressor. The refrigerant temperature is highest prior to entering the condenser. Thus, with the preferred configuration any abnormality in the refrigeration cycle can be immediately monitored.

[0018] Additional advantages of the heat pump type laundry dryer and the method of drying laundry of the present invention will now become apparent with the detailed description of the preferred embodiments with reference to the accompanying drawings in which:

[0019] Figure 1 - is a schematic view of a heat pump type laundry dryer according to a preferred embodiment of the present invention. The solid arrows respectively show a circulation direction of the process air and the refrigerant;

[0020] Figure 2 - is a graphic showing both a temperature of the refrigerant and a temperature drop across the process air entering and exiting a laundry drum during a drying process according to a preferred embodiment of the present invention;

[0021] Figure 3 - is a flowchart showing the steps of a method of drying laundry according to a preferred embodiment of the present invention.

[0022] The reference signs appearing on the drawings relate to the following technical features.

1. Heat pump type laundry dryer
2. Drum
3. Process air circuit
4. Duct
5. Fan
6. Refrigerant circuit
7. Evaporator
8. Compressor
9. Condenser
10. Expansion valve (capillary)

11. 1st temperature sensor
12. 2nd temperature sensor
13. Additional temperature sensor
14. Control unit
15. Input means

[0023] The heat pump type laundry dryer (1) comprises a drum (2) for receiving laundry, a process air circuit (3) including a duct (4) arranged to discharge process air into the drum (2) and to draw process air out of the drum (2), and a fan (5) arranged to circulate the process air in the duct (4) through the drum (2), a refrigerant circuit (6) including an evaporator (7), a compressor (8), a condenser (9), and an expansion valve (10) connected in series to circulate a refrigerant, wherein the evaporator (7) is arranged to dehumidify the process air in the duct (4), and the condenser (9) is arranged to heat the dehumidified process air in the duct (4), a first temperature sensor (11) arranged to measure a temperature (T1) of the process air to be discharged into the drum (2) and a second temperature sensor (12) arranged to measure a temperature (T2) of the process air drawn out of the drum (2).

[0024] As shown in Figure 1, the heat pump type laundry dryer (1) according to the present invention further comprises at least one additional temperature sensor (13), located at the refrigerant circuit (6), arranged to measure a temperature of the refrigerant (T3) and a control unit (14) adapted to dry the laundry to a target dryness by operating the process air circuit (3) and the refrigerant circuit (6) on the basis of the predetermined correlation between the temperatures (T1, T2, T3) and any abnormality of the temperatures (T1, T2, T3) respectively measured by the first temperature sensor (11), the second temperature sensor (12) and the additional temperature sensor (13).

[0025] The additional temperature sensor (13) is preferably arranged so as to specifically measure the temperature of the refrigerant between an upstream side of the condenser (9) and a downstream side of the compressor (8). More than one additional temperature sensor (13) can be used.

- [0026] At least one additional temperature sensor (13) can be alternatively located at the downstream side of the condenser (9) and/or at the downstream side of the expansion valve (10) and/or at the downstream side of the evaporator (7).
- [0027] The control unit (14) is preferably further adapted to keep track of changes in the refrigerant temperature (T3), and to halt the operation of the process air circuit (3) by stopping the fan (5) and to halt the operation of the refrigerant circuit (6) by stopping the compressor (8) if the refrigerant temperature (T3) changes abnormally.
- [0028] Figure 2 shows how the temperature of the refrigerant changes during the drying process. At an initial stage of the drying process the refrigerant temperature increases whereas at a final stage of the drying process the refrigerant temperature decreases. The refrigerant temperature may abruptly change in case of malfunctioning as exemplified in Figure 2. However, an abnormal change in the refrigerant temperature may also be conceived as a deviation beyond the maximal and minimal operation ranges set for a standard operation of the refrigeration circuit (6). These ranges are stored in a memory (not shown) provided in the heat pump type laundry dryer (1) and can be retrieved by the control unit (14). The numerical values in Figure 2 are only exemplary and may vary depending on the ambient temperature and specific design parameters of the heat pump type laundry dryer (1) of the present invention.
- [0029] The control unit (14) is preferably further adapted to initiate, when the refrigerant temperature (T3) starts strictly decreasing, sensing dryness of the laundry based on a temperature drop (ΔT) across the first temperature sensor (11) and the second temperature sensor (12).
- [0030] In an alternative embodiment, the control unit (14) is preferably further adapted to keep track of changes in a temperature drop (ΔT) across the first temperature sensor (11) and the second temperature sensor (12), and to initiate, when said temperature drop (ΔT) starts strictly decreasing, sensing dryness of the laundry based on said temperature drop (ΔT).
- [0031] As shown in Figure 2, the refrigerant temperature (T3) and the temperature drop (ΔT) starts to strictly decrease almost simultaneously.

- [0032] The control unit (14) is preferably further adapted to judge that the laundry has reached the target dryness when said temperature drop (ΔT) across the first temperature sensor (11) and the second temperature sensor (12) falls within a predetermined temperature range defining the target dryness and to halt operation of the process air circuit (3) and operation of the refrigerant circuit (6) if the judgment is affirmative.
- [0033] As shown in Figure 1, the heat pump type laundry dryer (1) further comprises an input means (15) allowing a user to specify a target dryness of the laundry by selecting out of a plurality of target dryness levels. In this embodiment, the control unit (14) is adapted to judge that the laundry has reached the selected target dryness when the temperature drop (ΔT) across the first temperature sensor (11) and the second temperature sensor (12) falls within a corresponding predetermined temperature range defining the target dryness specified by the user. The predetermined temperature ranges are stored in a memory (not shown) provided in the heat pump type laundry dryer (1) and can be retrieved by the control unit (14).
- [0034] In another embodiment, each of the plurality of target dryness levels is respectively defined by one of a plurality of cascaded temperature ranges which are graded between damp dry to extra dry. The heat pump type laundry dryer (1) has preferably three dryness levels including a damp dry level, a dry level and an extra dry level. These dryness levels occupy the far right hand side of the temperature drop (ΔT) curve shown in Figure 2.
- [0035] Next, a method of drying laundry using a heat pump type laundry dryer (1) will be explained with reference to Figure 3.
- [0036] As shown in Figure 3, in step 101, the user may select a target dryness level out of a plurality of target dryness levels using the input means (15) shown in Figure 1. In step 101, the control unit (14) starts to circulate process air in the duct (4) through the drum (2) and to circulate the refrigerant through the evaporator (7) and the condenser (8) in order to dry the laundry to the selected target dryness level. In steps 102a to 102c, a temperature (T_1) of the process air to be discharged into the drum (2), a temperature (T_2) of the process air drawn out of the drum (2), and a

temperature of the refrigerant (T3) are simultaneously measured. These measurements are repeatedly performed until the selected target dryness level is reached.

- [0037] As shown in Figure 3, in step 102e, the control unit (14) calculates the changes in the refrigerant temperature (T3). In step 103, the control unit (14) determines whether the refrigerant temperature (T3) changes abnormally on the basis of the calculation. In step 112, the control unit (14) halts the circulation of the process air and the refrigerant if it is determined that the refrigerant temperature (T3) changes abnormally. The drying process may be resumed. This abnormality determination is repeatedly performed until the selected target dryness level is reached.
- [0038] As shown in Figure 3, in step 102d, the control unit (14) calculates the temperature drop (ΔT) across the process air entering and exiting the drum (2). In step 104a, the control unit (14) determines whether the refrigerant temperature (T3) has started to strictly decrease on the basis of the changes in refrigerant temperature (T3). In step 105, the control unit (14) initiates, if it is determined that the refrigerant temperature has started strictly decreasing, to sense dryness of the laundry based on said temperature drop (ΔT). In step 102f, the control unit (14) calculates changes in said temperature drop (ΔT). In step 104b, the control unit (14) determines whether said temperature drop (ΔT) has started to strictly decrease. Alternatively, in step 105, the control unit (14) initiates sensing dryness if it is determined that said temperature drop (ΔT) has started strictly decreasing. The dryness is sensed based on said temperature drop (ΔT).
- [0039] As shown in Figure 3, in steps 106 to 108, the control unit (14), acquires a target dryness level selected by the user. In steps 109 to 111, the control unit (14), judges that the laundry has reached a selected target dryness when a temperature drop (ΔT) of the process air entering and exiting the drum (2), falls within a corresponding predetermined temperature range defining the target dryness specified by the user in step 101. If the judgment is negative, the drying process is continued until the temperature drop (ΔT) falls into the predetermined temperature range corresponding to

the selected target dryness. The predetermined temperature ranges are preferably defined by four threshold values Th1 to Th4. The predetermined temperature ranges are cascaded and respectively correspond to “damp dry”, “dry” and “extra dry”.

Claims

1. A heat pump type laundry dryer (1), comprising:
 - a drum (2) for receiving laundry,
 - a process air circuit (3) including a duct (4) arranged to discharge process air into the drum (2) and to draw process air out of the drum (2) and a fan (5) arranged to circulate the process air in the duct (4) through the drum (2),
 - a refrigerant circuit (6) including an evaporator (7), a compressor (8), a condenser (9), and an expansion valve (10) connected in series to circulate a refrigerant, wherein the evaporator (7) is arranged to dehumidify the process air in the duct (4), and the condenser (9) is arranged to heat the dehumidified process air in the duct (4),
 - a first temperature sensor (11) arranged to measure a temperature (T1) of the process air to be discharged into the drum (2) and
 - a second temperature sensor (12) arranged to measure a temperature (T2) of the process air drawn out of the drum (2);

characterized in that

 - at least one additional temperature sensor (13), located at the refrigerant circuit (6), arranged to measure the temperature of the refrigerant (T3) and
 - a control unit (14) adapted to dry the laundry to a target dryness by operating the process air circuit (3) and the refrigerant circuit (6) on the basis of the predetermined correlation between the temperatures (T1, T2, T3) and any abnormality of the temperatures (T1, T2, T3) measured by the first temperature sensor (11), the second temperature sensor (12), and the additional temperature sensor (13).
2. The heat pump type laundry dryer (1) according to claim 1, **characterized in that** the control unit (14) is further adapted to keep track of changes in the refrigerant temperature (T3) and to halt operation of the process air circuit (3) by stopping the fan (5) and operation of the refrigerant circuit (6) by stopping the compressor (8) if the refrigerant temperature (T3) changes abnormally.
3. The heat pump type laundry dryer (1) according to claim 2, **characterized in that** the control unit (14) is further adapted to initiate, when the refrigerant temperature (T3) starts strictly decreasing, sensing dryness of the laundry based on a temperature drop (ΔT) across the first temperature sensor (11) and

- the second temperature sensor (12).
4. The heat pump type laundry dryer (1) according to claim 2, **characterized in that** the control unit (14) is further adapted to keep track of changes in a temperature drop (ΔT) across the first temperature sensor (11) and the second temperature sensor (12), and to initiate, when said temperature drop (ΔT) starts strictly decreasing, sensing dryness of the laundry based on said temperature drop (ΔT).
 5. The heat pump type laundry dryer (1) according to any one of claims 2 to 4, **characterized in that** the control unit (14) is further adapted to judge that the laundry has reached the target dryness when said temperature drop (ΔT) across the first temperature sensor (11) and the second temperature sensor (12) falls within a predetermined temperature range defining the target dryness, and to halt operation of the process air circuit (3) and operation of the refrigerant circuit (6) if the judgment is affirmative.
 6. The heat pump type laundry dryer (1) according to claim 5, **characterized in that** an input means (15) allowing a user to specify a target dryness of the laundry by selecting out of a plurality of target dryness levels and **in that** the control unit (14) is adapted to judge that the laundry has reached the selected target dryness when the temperature drop (ΔT) across the first temperature sensor (11) and the second temperature sensor (12) falls within a corresponding predetermined temperature range defining the target dryness specified by the user.
 7. The heat pump type laundry dryer according to any one claims 1 to 6, **characterized in that** said at least one additional temperature sensor (13) is arranged to measure the temperature of the refrigerant between an upstream side of the condenser (9) and a downstream side of the compressor (8).
 8. The heat pump type laundry dryer according to any one claims 1 to 6, **characterized in that** at least one additional temperature sensor (13) is arranged to measure the temperature of the refrigerant, located at the downstream side of the condenser (9) and/or the expansion valve (10) and/or the evaporator (7).
 9. A method of drying laundry for a heat pump type laundry dryer (1) comprising the steps of:
 - selecting of drying level and starting of the drying operation (101)

- measuring the temperature (T1) of the process air to be discharged into the drum (2) (102a)
 - measuring the temperature (T2) of the process air drawn out of the drum (2) (102b)
 - measuring (102c) the temperature of the refrigerant (T3) (102c)
 - detecting the predetermined correlation between the temperatures (T1, T2, T3) and any abnormality of the temperatures (T1, T2, T3) respectively measured in the first measuring step (102a), the second measuring step (102b) and the additional measuring step (102c).
10. The method of drying laundry according to claim 9, comprising the steps of:
- calculating the changes in the refrigerant temperature (T3) (102e)
 - determining (103) whether the refrigerant temperature (T3) changes abnormally on the basis of the calculation (103) and
 - halting (112) the circulation of the process air and the refrigerant if it is determined that the refrigerant temperature (T3) changes abnormally (112).
11. The method of drying laundry according to claim 10, comprising the steps of:
- calculating the temperature drop (ΔT) across the process air entering and exiting the drum (2) (102d)
 - determining whether the refrigerant temperature (T3) has started to strictly decrease on the basis of the changes in refrigerant temperature (T3) (104a) and,
 - initiating, if it is determined that the refrigerant temperature has started strictly decreasing, to sense dryness of the laundry based on said temperature drop (ΔT) (105).
12. The method of drying laundry according to claim 10, comprising the steps of:
- calculating the temperature drop (ΔT) across the process air entering and exiting the drum (2) (102d),
 - calculating the changes in said temperature drop (ΔT) (102f),
 - determining whether said temperature drop (ΔT) has started to strictly decrease (104b) and
 - initiating, if it is determined that said temperature drop (ΔT) has started strictly decreasing, to sense dryness of the laundry based on said temperature drop (ΔT) (105).

13. The method of drying laundry according to claim 11 or 12, comprising the steps of:
- judging that the laundry has reached the target dryness when said temperature drop (ΔT) falls within a predetermined temperature range defining the target dryness (109, 110, 111) and
 - halting the circulation of the process air and the refrigerant if the judgment is affirmative (112).
14. The method of drying laundry according to claim 13, comprising the steps of:
- selecting a target dryness level out of a plurality of target dryness levels through a user specification (101),
 - acquiring the target dryness specified by the user through selecting out of a plurality of target dryness levels (106, 107, 108) and
 - judging that the laundry has reached a selected target dryness when a temperature drop (ΔT) of the process air entering and exiting the drum (2), falls within a corresponding predetermined temperature range defining the target dryness specified by the user (109, 110, 111).
15. The method of drying laundry according to any one of claims 9 to 14, comprising the step of,
- measuring the temperature of the refrigerant between the upstream side of the condenser (9) and a downstream side of the compressor (8) (102c).

Fig. 1

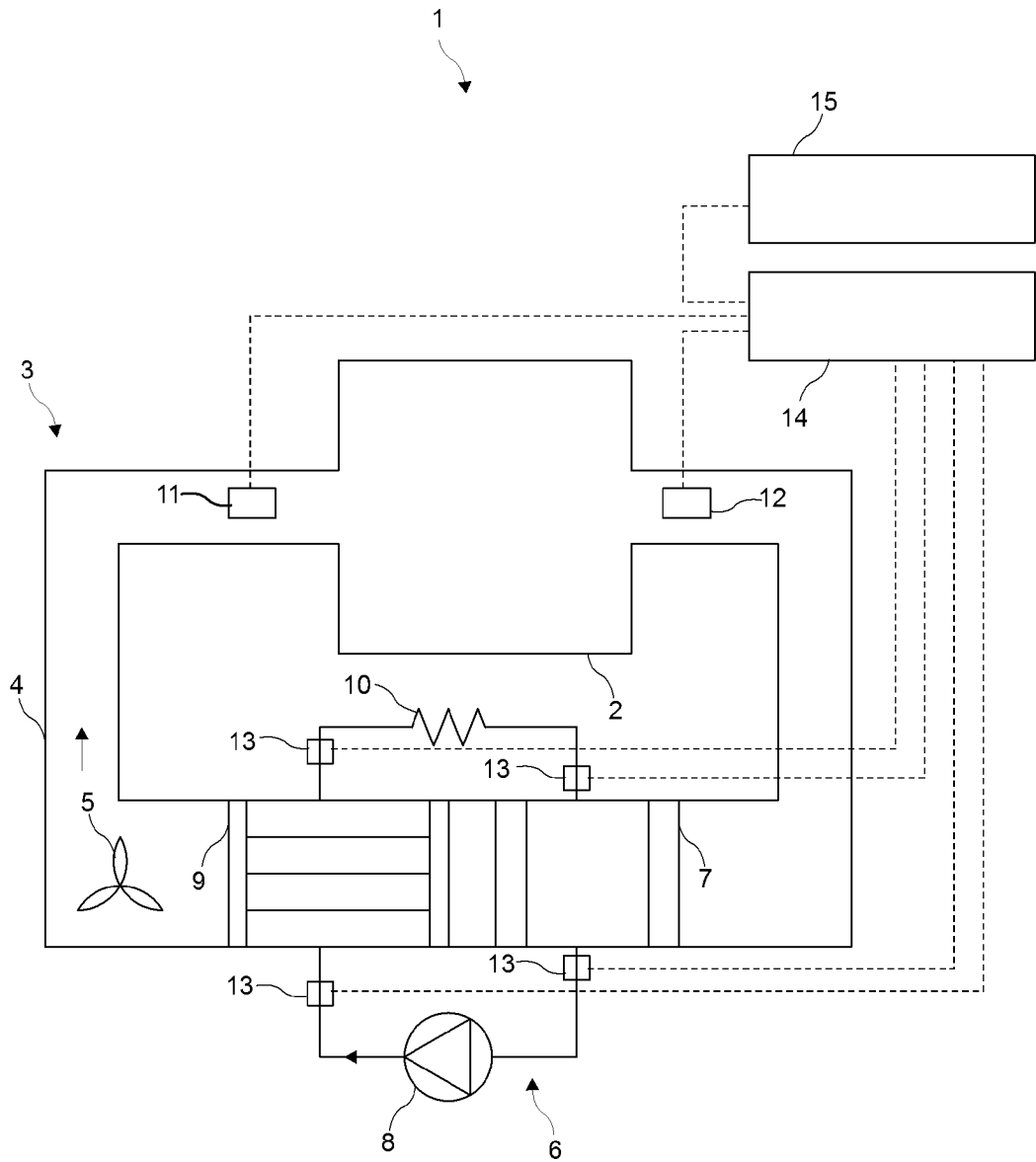


Fig. 2

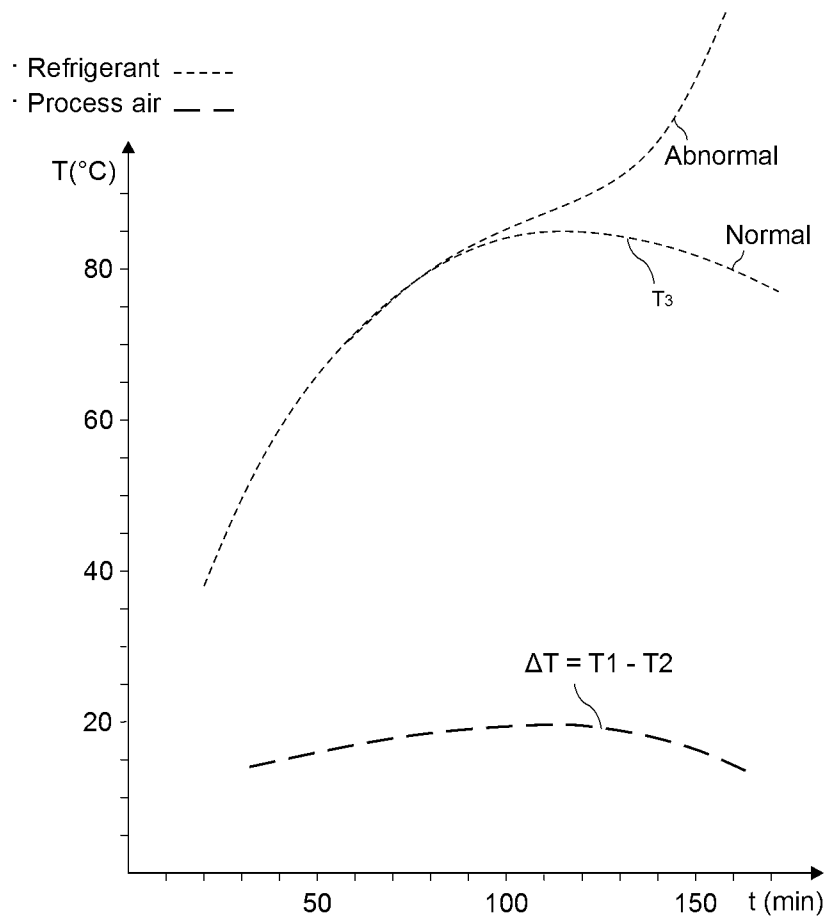
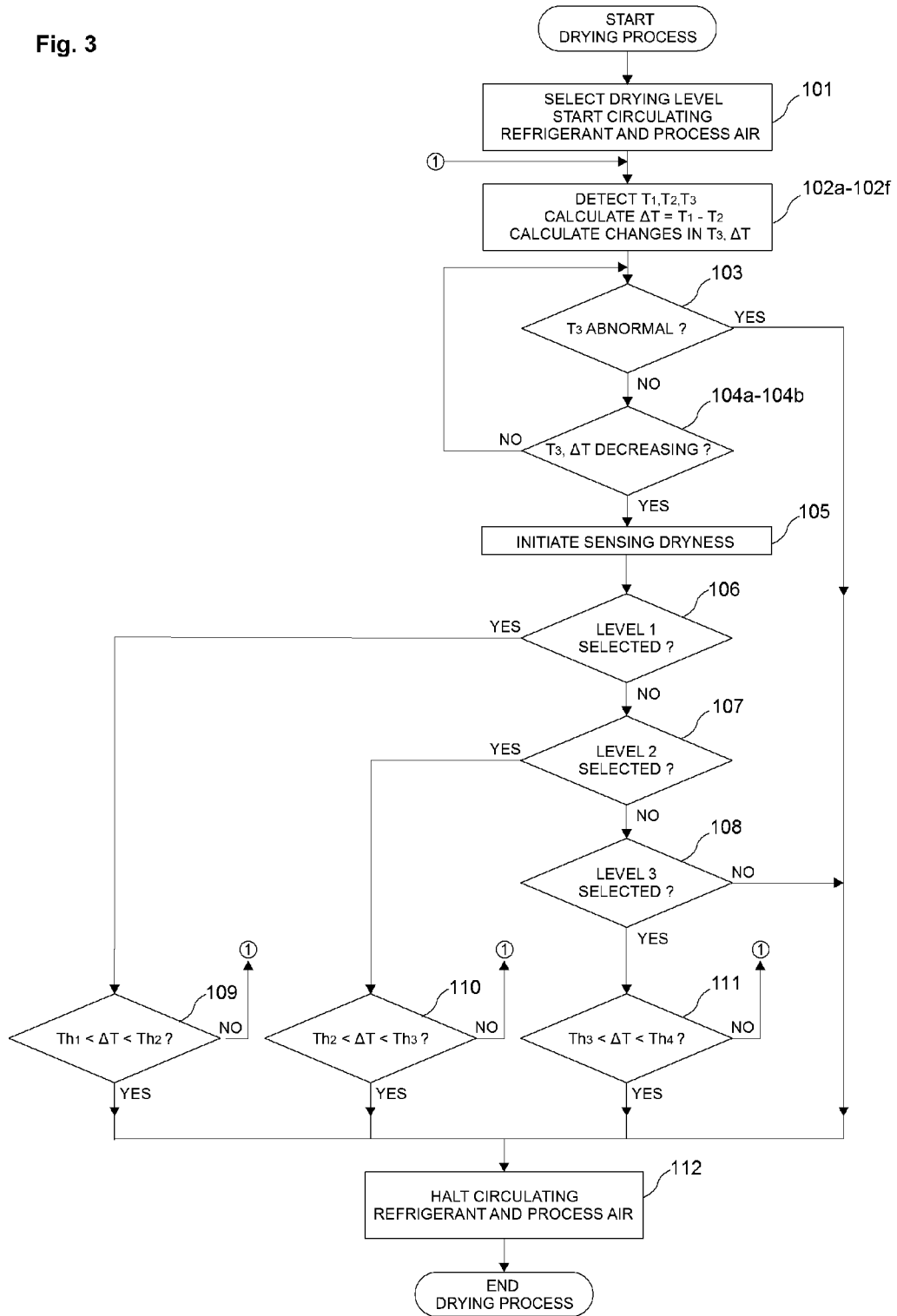


Fig. 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/060646

A. CLASSIFICATION OF SUBJECT MATTER
INV. D06F58/20 D06F58/28
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
D06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 284 310 A1 (ELECTROLUX HOME PROD CORP [BE]) 16 February 2011 (2011-02-16)	1,9
Y	the whole document	2-8, 10-15
Y	----- US 2009/248206 A1 (YOO HEA KYUNG [KR] ET AL) 1 October 2009 (2009-10-01) abstract paragraphs [0048] - [0091]; figures	2-8, 10-15
X	----- WO 2012/134148 A2 (LG ELECTRONICS INC [KR]; JUNG KIWOOK [KR]; LEE JUNSEOK [KR]; CHOI YOUN) 4 October 2012 (2012-10-04) the whole document	1,2, 7-10,15
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Further documents are listed in the continuation of Box C.

See patent family annex.

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- "A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search 24 September 2013	Date of mailing of the international search report 02/10/2013
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Prosig, Christina

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/060646

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2011 079449 A1 (BSH BOSCH SIEMENS HAUSGERAETE [DE]) 24 January 2013 (2013-01-24) the whole document	1,2, 7-10,15
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