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(54) **Clothes dryer and method for operating a clothes dryer**

(57) A clothes dryer 31 comprises a closed loop L for process air P, the loop L comprising a drum 2, a first heat exchanger 8, a second heat exchanger 4, and a third heat exchanger 5, wherein the first heat exchanger 8 has a first air channel 9 and a second air channel 11 for transferring heat between them, an air outlet 9b of the first air channel 9 being connected to an air inlet 4a of the second heat exchanger 4, an air outlet 4b of the second heat exchanger 4 being connected to an air inlet 11a of the second channel 11 of the first heat exchanger 8, and an air outlet 11 b of the second channel 11 being connected to an air inlet 5a of the third heat exchanger 5. A method for operating a clothes dryer 21;31 is also disclosed. The invention is particularly useful for closed-loop heat pump clothes dryers.

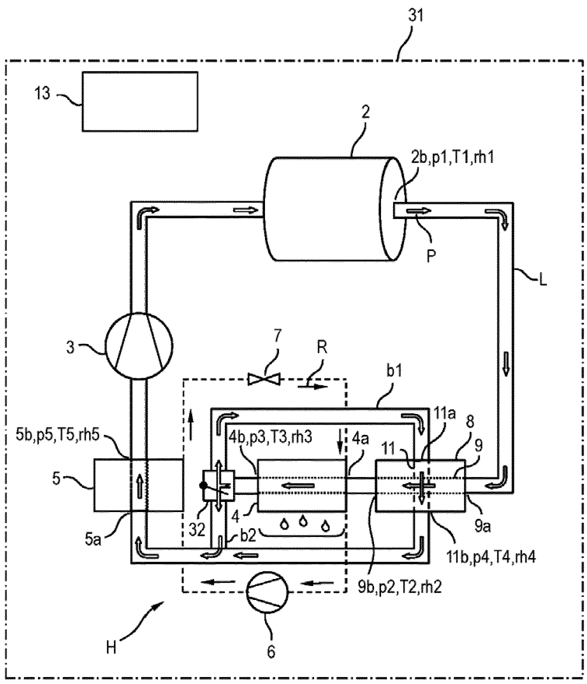

Fig.5

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Description

[0001] The invention relates to a clothes dryer, comprising a closed loop for process air, the closed loop comprising a drum for storing clothes, a first heat exchanger, a second heat exchanger, and a third heat exchanger, wherein the first heat exchanger is an air-air heat exchanger having a first air channel and a second air channel for transferring heat between these air channels, an air inlet of the first air channel is connected to an air outlet of the drum, an air outlet of the first air channel is connected to an air inlet of the second heat exchanger, and an air outlet of the third heat exchanger is connected to an air inlet of the drum. The invention also relates to a method for operating a clothes dryer, wherein process air flows from a drum through a first channel of a first heat exchanger where it is cooled down, then through a second heat exchanger where it is cooled down further, then through a third heat exchanger where it is warmed up, and then back into the drum. The invention is particularly useful for a closed-loop heat pump clothes dryer.

[0002] As sketched in **fig.1,** a known heat pump clothes dryer 1 comprises a closed cycle or closed loop L for circulating process air P. One component of this closed loop L is a drum 2 for receiving wet clothes or laundry that is to be dried. The process air P is circulated using a fan 3. As an example, during a drying cycle, the process air P is discharged from an air outlet 2b (working point p1) of the drum 2. There, the process air P has an intermediate temperature T1 of about 40 °C, a high absolute humidity, and a relative humidity rh1 of about 85% or 0.85. The process air P then enters an air inlet 4a of a heat exchanger that is also an evaporator 4 of a compressor-type heat pump H. There, the process air P is cooled down below its dew point such that condensate C is generated, in particular by getting the process air P in contact with surfaces of the evaporator 4. The process air P discharged by an air outlet 4b of the evaporator 4 (at working point p3) thus has a relatively low temperature level T3 of about 32 °C, has a significant lower absolute humidity, and a relative humidity rh3 close to its saturation point or being saturated, i.e. having a rh3 of about 100% or 1. The process air P then enters an air inlet 5a of a further heat exchanger that is also a condenser 5 of the heat pump H. When being discharged through an air outlet 5b (working point p5), its temperature has been increased to a high temperature level T5 of about 73 °C while keeping the absolute humidity constant. The relative humidity rh5, however, drops to about 13%. This enables the process air P to absorb water from the wet clothes after re-entering the drum 2. By taking up water from the wet clothes, the relative humidity of the process air P is increased again to rh1 of about 85%, and its temperature drops to the intermediate level T1. Since the process air P circulates in a closed loop, this process is repeated until the clothes reach a certain target humidity or target humidity rate.

[0003] If adjacent air outlets 2b, 4b, 5b and air inlets 4a, 5a, and 2a are close together and/or if air ducts between adjacent air inlets and air outlets have a negligible effect on the process air P, the condition of the process air P and the working points, resp., are the same for these air inlets and air outlets.

[0004] Operation of the heat pump clothes dryer 1 may be controlled by a control means, e.g. a central control circuitry 13.

[0005] A temperature difference between the heat exchangers (i.e., the evaporator 4 and the condenser 5) is generated due to the compressor-type heat pump H in which a fluid (or refrigerant R) is compressed by a compressor 6 from a superheated gas status at a low pressure/low temperature regime to a superheated gas status at high pressure/high temperature regime. At that high pressure, the refrigerant is condensed to a sub-cooled liquid in the condenser 5 (which thus acts as a refrigerant-air heat exchanger) at a temperature equal or close to a saturation temperature at a bubble point of the refrigerant R for that pressure. Then reaching an expansion valve 7, the refrigerant R expands to a low pressure level reaching a bi-phase state at a temperature equal or close to the saturation temperature at a dew point of the refrigerant R for that pressure and then evaporates in the evaporator 4 (which thus acts as an air-refrigerant heat exchanger) to reach the superheated gas status again.

[0006] A theoretical calculation of such a process for the specific working points p1, p3, and p5 as defined in table 1:

i	h_i	$m_{air;i}$ [kg/s]	$m_{water;i}$ [kg/h]	rh_i	T_i [°C]	v_i [m^3/kg]	Vol_i [m^3/h]	w_i
1	146	0.057	8.39	0.85	40	0.946	193	0.041
2	---	---	---	---	---	---	---	---
3	109	0.057	6.16	1	32	0.906	185	0.030
4	---	---	---	---	---	---	---	---
5	153	0.057	6.16	0.13	73	1.029	210	0.030

is shown in **fig.2.** There, h_i denotes an enthalpy at working point pi, $m_{air;i}$ a mass flow rate of the dry air component of the process air P, $m_{water;i}$ a mass flow rate of the water contained in the process air P, v_i a volume flow rate of the wet air / process air P, and w_i a ratio ("humidity ratio") of the mass of water (in kg) per mass of dry air (in kg) of the process air P. In the configuration of fig.2, the clothes dryer 1 achieves a dehumidification rate or condensate C generation rate at the evaporator 4 of 2.22 kg/h of water.

[0007] To achieve an even higher efficiency of the drying process, it is known from DE 10 2007 010 272 A1, from CH 705 546 A2, from DE 10 2007 018 787 A1, from DE10 2007 038 192 A1, from DE10 2008 007 971 A1, or from DE 10 2009 002 482 A1 to place an additional air/air heat exchanger between the drum and the evaporator into the closed loop L to effect an stronger cooling of the process air P prior to entering the condenser. This is shown in fig.1 by the heat exchanger 8. While the process air P flows through a first air channel 9 of the air/air heat exchanger 8, cool ambient air A is drawn through a ambient air duct 10 into a second air channel 11 of the air/air heat exchanger 8 and afterwards discharged out of the clothes dryer 1. To create an air flow of the ambient air A, a separate fan 12 may be used.

[0008] WO 2013/124163 A2 discloses a household appliance, more particularly a tumble dryer, comprising a working chamber and at least one latent heat store having a respective storage medium, wherein the respective storage medium is thermally coupled via a respective associated heat exchanger to a working medium circulating through the working chamber, wherein the working medium first moves from the working chamber to a heat sink, from said heat sink to the heat exchanger, from said heat exchanger to a heat source, and from said heat source back to the working chamber, and wherein the respective storage medium forms a substance mixture together with a respective carrier fluid, wherein said substance mixture can be conducted in a respective closed circuit through the associated heat exchanger for an exchange of heat with the working medium. The respective substance mixture circulates between the associated heat exchanger and at least one reservoir in the respective closed circuit, and the reservoir can be refilled layer-by-layer with the substance mixture conducted through the respective associated heat exchanger. Document WO 2013/124163 A2 further relates to a method for operating such a household appliance.

[0009] WO 2012/123914 A1 discloses a treatment device for treating hot and humid air from at least one drying installation, notably a dryer (I 0), comprising: an inlet to receive the air for treating coming from the outlet of the drying installation, an air/air exchanger through which the air for treating circulates - at least one air/fluid exchanger for dehumidifying the air for treating, the air/air exchanger and said at least one air/fluid exchanger being placed in series in such a way as to allow air from said at least one air/fluid exchanger and/or air from outside to be heated up using the air for treating, at least one outlet for air after treatment connected to the inlet of the drying installation, at least one bypass bypassing said at least one air/fluid exchanger.

[0010] WO 2008/155263 A1 discloses a condensation tumble dryer having a drying chamber for the objects to be dried, a process air channel, in which a heater is located for heating the process air and by means of which the heated process air can be guided to the objects to be dried via a fan, an air-to-air heat exchanger, a heat pump circuit having an evaporator, a compressor, and a condenser, at least one condensate collection vessel, a condensate pump, a condensate drain, and a first line leading from the condensate pump to the condensate drain, wherein a second line branches off the first line, the second line opening in the process air channel between the drying chamber and the air-to-air heat exchanger. WO 2008/155263 A1 further relates to a method for the operation of the said condensation tumble dryer.

[0011] However, the placement of the additional air/air heat exchanger according to the prior art causes a considerably higher construction effort (including a significantly higher construction volume) and considerably higher costs.

[0012] It is the **object** of the present invention to at least partially overcome the disadvantages of the prior art and in particular to provide a clothes dryer that has a significantly increased efficiency while showing an only moderately increased complexity.

[0013] The object is achieved according to the features of the independent claims. Advantageous embodiments are in particular disclosed in the dependent claims, the description following and the drawing attached.

[0014] The object is achieved by a clothes dryer, comprising a closed loop or air channel for process air, the closed loop comprising a drum for storing clothes, a first heat exchanger, a second heat exchanger, and a third heat exchanger, wherein: the first heat exchanger is an air-air heat exchanger having a first air channel and a second air channel for transferring heat between these air channels, an air inlet of the first air channel is connected to an air outlet of the drum, an air outlet of the first air channel is connected to an air inlet of the second heat exchanger, an air outlet of the second heat exchanger is connected to an air inlet of the second air channel of the first heat exchanger, an air outlet of the second air channel of the first heat exchanger is connected to an air inlet of the third heat exchanger, and an air outlet of the third heat exchanger is connected to an air inlet of the drum.

[0015] This clothes dryer gives the advantage that, with the same energy input, a considerable increase of the dehumidification rate of over 10 % can be achieved. Also, with the same energy input, an increase of the temperature of the process air at the air outlet of the condenser and thus at the air inlet of the drum of over 5 °C can be achieved. Therefore, by the improved ability to condense the process air and to generate higher temperatures of the process air at the drum inlet, a considerably faster drying cycle (over 10% faster) with consequent energy savings can be provided as compared to the prior art.

[0016] This clothes dryer takes advantage of the lower process air temperature at the outlet of the evaporator to saturate the wet process air coming from the drum and to pre-heat it before entering the condenser.

[0017] The clothes dryer may be a household appliance. The clothes dryer may be a tumble dryer having a rotatable drum. The drum may be rotatable around a horizontal or a vertical axis. The clothes dryer may be a stand-alone dryer or a washing/drying appliance.

[0018] The first heat exchanger may also be called a "cross flow air-to-air heat exchanger ".

[0019] The second heat exchanger is provided to cool down the process air, in particular below its dew point to generate condensate and thus to reduce the absolute humidity of the process air.

[0020] The third heat exchanger is provided to heat up the dried process air, in particular before it enters the drum. This decreases a relative humidity of the process air.

[0021] During a drying cycle, the process air within the process air loop therefore flows from the drum through the first channel of the first heat exchanger where it is cooled down, then through the second heat exchanger where it is cooled down further, then at least partially through the second channel of the first heat exchanger where it is warmed up, then through the third heat exchanger where it is warmed up further, and then back into the drum.

[0022] It is an advantageous embodiment that the air outlet of the second heat exchanger is only connected to the air inlet of the second channel of the first heat exchanger. Thus, a flow of the process air by-passing the second air channel is prevented. Such an embodiment can be realized in a particularly simple set-up.

[0023] It is another advantageous embodiment that the air outlet of the second heat exchanger is connected to the air inlet of the second air channel of the first heat exchanger and to the air inlet of the third heat exchanger. Thus, process air being discharged from the air outlet of the second heat exchanger may partially flow to the air inlet of the second air channel of the first heat exchanger (representing a first branch of the process air loop) and partially directly to the air inlet of the third heat exchanger (representing a second branch or by pass branch of the process air loop). This at least partial diversion or by-passing of the second air channel of the first heat exchanger allows an adaptation to operating conditions of the heat exchangers and therefore a particularly flexible adaption to varying drying conditions.

[0024] It is an advantageous embodiment that a controllable air guidance device is connected to the air outlet of the second heat exchanger to control a relative flow volume of the process air to the air inlet of the second air channel of the first heat exchanger (i.e., the first branch) and directly to the air inlet of the third heat exchanger (i.e., the second branch), resp. Thus, a particularly flexible adaptation to the operating conditions of the heat exchangers is achievable. The controllable air guidance device may be driven by a motor. It may comprise one or more flaps, valves, shutters etc. to widen or narrow a flow cross-section of one path or of both paths. The air guidance device may also be called an "air path splitter".

[0025] The controllable air guidance device may be controlled such that it may be set to two or more pre-defined positions (e.g. flap positions) corresponding to respective flow volume ratios. Alternatively or additionally, the controllable air guidance device may set the flow volume ratio in a continuous or quasi-continuous manner. The controllable air guidance device may completely block or shut off the air path from the air outlet of the second heat exchanger to the air inlet of the second air channel of the first heat exchanger and/or to the air inlet of the third heat exchanger.

[0026] It is an alternative embodiment that the air guidance device is a non-controllable or fixed device splitting the process air loop L and process air paths, resp., in a fixed manner, esp. in a fixed ratio of flow volumes.

[0027] It is an advantageous embodiment that the second heat exchanger and the third heat exchanger are components of a heat pump of the clothes dryer. Such a clothes dryer can be operated in a particularly efficient manner. Such a clothes dryer may also be called a "closed cycle heat pump clothes dryer".

[0028] In general, the any suitable type of heat pump may be used, e.g. a Stirling-type heat pump or a Vuilleumier-type heat pump. It is a particularly advantageous embodiment that the second heat exchanger is an evaporator and the third heat exchanger is a condenser of a compressor-type heat pump. A compressor-type heat pump additionally comprises a compressor and an expansion valve in generally well-known manner.

[0029] It is an advantageous embodiment that the clothes dryer is operable such that the process air that is discharged from the first air channel of the first heat exchanger is nearly or just saturated. Thus, a precipitation of condensate from the first heat exchanger can be avoided. Alternatively, the first heat exchanger can be used to cool down the incoming process air below its dew point and to thus create the conditions for condensation.

[0030] It is an advantageous embodiment to prevent condensation of the process air at the first heat exchanger that the temperature of the process air that flows through the first channel of the first heat exchanger is lowered by not more than 5 °C, in particular by not more than 4 °C, especially by not more than 3 °C.

[0031] Alternatively, the clothes dryer is operable such that (in particular including the first heat exchanger being designed such that) it can cause precipitation of condensate at the first heat exchanger during a drying cycle.

[0032] In particular a mass flow rate of the dry air component of the process air m_{air} may be between 0.02 and 0.10 kg/s, in particular between 0.05 and 0.06 kg/s, in particular for the case in which the process air in the evaporator inlet has a relative humidity of about 0.85 and a temperature of about 40 °C.

[0033] Also, a mass flow rate of the water contained in the process air m_{water} before the second heat exchanger may in particular be between 2.5 and 18.62 kg/h, in particular between 5 and 15 kg/h, in particular between 8 and 9 kg/h, in particular between 8.2 and 8.5 kg/h, in particular between 8.35 and 8.45 kg/h, in particular at about 8.4 kg/h, in particular for the case in which the process air in the evaporator inlet has a relative humidity of about 0.85 and a temperature of about 40 °C.

[0034] A mass flow rate of the water contained in the process air m_{water} after the second heat exchanger may be between 0,8 and 16 kg/h, in particular between 2 and 10 kg/h, in particular between 5.5 and 6.5 kg/h, in particular between 5.7 and 6.1 kg/h, in particular between 5.8 and 6.0 kg/h, in particular between 5.9 and 6.0 kg/h, in particular for the case in which the process air in the evaporator inlet has a relative humidity of about 0.85 and a temperature of about 40 °C

[0035] Furthermore, a relative humidity rh of the process air may be in the range between 0.75 and 0.95, in particular between 0.8 and 0.9, in particular about 0.85, after the drum and before the first air channel of the first heat exchanger (i.e., at working point 1).

[0036] The relative humidity rh may in particular be approx. 1 after the first air channel of the first heat exchanger and before the second heat exchanger (i.e., working point 2) and also after the second heat exchanger and before the second air channel of the first heat exchanger (i.e., working point 3).

[0037] The relative humidity rh may be in the range from 0.70 to 0.95, in particular between 0.8 and 0.9, in particular about 0.85, after second air channel of the first heat exchanger and before the third heat exchanger (i.e., at working point 4).

[0038] The relative humidity rh may be in the range between 0.04 and 0.26 (in particular in the range between 0.08 between 0.15, especially at about 0.11, after the third heat exchanger and before the drum (i.e., at working point 5).

[0039] A temperature T of the process air may e.g. be in the range from 25 °C to 45 °C (in particular about 40 °C) at working point 1. The temperature T may e.g. be in the range from 35 °C to 40 °C (in particular about 37 °C) at working point 2, but lower than the temperature T at working point 1, in particular between 2 °C and 5 °c lower, in particular 3 °C to 4 °C lower.

[0040] The temperature T may be e.g. in the range from 3,9 °C to 41,4 °C, in particular in the range from 25 °C to 35 °C, in particular, in the range from 29 °C to 33 °C, in particular at about 31 °C, at working point 3.

[0041] The temperature T may be in the range from 8,8 °C to 43 °C, in particular in the range from 32 °C to 36 °C, but higher then working point 3 (in particular approx. 34 °C) at working point 4 and in the range from 59 to 80 °C (in particular approx. 75 °C) at working point 5.

[0042] A volume flow rate v of the process air may e.g. be in the range from 0.865 to 0,991 m^3/kg (in particular in the range from 0.94 to 0.95 m^3/kg) at working point 1, in the range from 0.8514 to 0.9875 m^3/kg (in particular in the range from 0.93 to 0.94 m^3/kg) at working point 2, and in the range from 0.807 to 0.956 (in the range from 0.88 to 0.92, in particular at about 0.90) m^3/kg at working point 3. The volume flow rate v may be in the range from 0.821 to 0.959 (in particular in the range from 0.90 to 0.93, in particular at about 0.91) m^3/kg at working point 4 and in the range from 0.934 to 1.087 (in particular in the range from 1.00 to 1.05, in particular at about 1.03 or 1.04) m^3/kg at working point 5.

[0043] A humidity ratio w of the process air may e.g. be in the range from 0.0149 to 0.0615 (in particular in the range from 0.035 to 0.045, in particular at about 0.0411) at working point 1 and at working point 2, and in the range from 0.00687 to 0.0482 (in particular in the range from 0.025 to 0.035, in particular at about 0.0292) at working points 3, 4, and 5.

[0044] The object is also achieved by a method for operating a clothes dryer, wherein process air flows from a drum through a first channel of a first heat exchanger where it is cooled down, then through a second heat exchanger where it is cooled down further, then at least partially through a second channel of the first heat exchanger where it is warmed up, then through a third heat exchanger where it is warmed up further, and then back into the drum. The method may be implemented in analogy to the clothes dryer as described above and achieves the same advantages.

[0045] For example, in one embodiment, none of the process air directly flows from the second heat exchanger to the third heat exchanger. This is equivalent to a design in which the second channel of the first heat exchanger is not bypassed and practically all of the process air flows from the second heat exchanger to the second channel of the first heat exchanger.

[0046] Alternatively, part of the process air discharged from the second heat exchanger flows directly to the third heat exchanger and the other part flows to the second channel of the first heat exchanger and only then to the third heat exchanger.

[0047] The above described features and advantageous embodiments of the present invention are now described in greater detail by means of schematic descriptions of several embodiments in combination with respective figures of the drawing attached. In the drawing,

Fig.1 shows a sketch of a clothes dryer according to the prior art;
Fig.2 shows a w-T-diagram for the clothes dryer according to the prior art;
Fig.3 shows a sketch of a first novel clothes dryer;
Fig.4 shows a w-T-diagram for the first novel clothes dryer; and
Fig.5 shows a sketch of a second novel clothes dryer.

[0048] **Fig.3** shows a sketch of a first novel closed loop heat pump clothes dryer 21. The clothes dryer 21 differs from the clothes dryer 1 according of the art in that the second air channel 11 of the first heat exchanger 8 is not connected to the ambiance or the outside of the process air loop L but to the process air loop L itself. In other words, process air P flows through both air channels 9 and 11. The first air channel 9 and the second air channel 11 are functionally separated by the evaporator 4.

[0049] In detail, the process air P flows from the drum 2 through the first channel 9 of the first heat exchanger 8 where it is cooled down, then through the evaporator 4 where it is cooled down further, then through the second channel 11 of the first heat exchanger 8 where it is warmed up, then through the condenser 5 where it is warmed up further, and then back into the drum 2. A section of the process air loop L between and including the air outlet 9b of the first air channel 9 and the air inlet 4a of the evaporator 4 defines a working point p2 for the process air P. The working point p3 corresponds to a section of the process air loop L between and including the air outlet 4b of the evaporator 4 and the air inlet 11a of the second air channel 11 of the first heat exchanger 8. A working point p4 corresponds to a section of the process air loop L between and including the air outlet 11 b of the second air channel 11 and the air inlet 5a of the condenser 5.

[0050] A theoretical calculation of such a process for the specific working points p1 to p5 as defined in table 2:

i	h_i	$m_{air;i}$ [kg/s]	$m_{water;i}$ [kg/h]	rh_i	T_i [°C]	v_i [m^3/kg]	Vol_i [m^3/h]	w_i
1	146	0.057	8.39	0.85	40	0.946	193	0.041
2	143	0.057	8.39	1	37	0.937	191	0.041
3	106	0.057	5.96	1	31	0.903	184	0.029
4	109	0.057	5.96	0.84	34	0.911	186	0.029
5	153	0.057	5.96	0.11	76	1.035	211	0.029

is shown in **fig.4.** By means of the first channel 9 of the heat exchanger 8, the temperature T of the process air P is thus decreased by an amount ΔT = 3 °C (i.e. between working point p1 an working point p2), and increased by approximately the same amount ΔT = 3 °C by means of the second channel 11 (i.e. between working point 3 the working point 4). The calculations have been carried out assuming an atmospheric pressure at all the points of 1,013 bar.

[0051] In this configuration, the clothes dryer 21 achieves a dehumidification rate or condensate C (see fig.1) generation rate at the evaporator 4 of 2.43 kg/h of water which is over 10% higher than what the clothes dryer 1 achieves.

[0052] **Fig.5** shows a sketch of a second novel clothes dryer 31. That clothes dryer 31 is similar to the clothes dryer 1 but additionally comprises a controllable air guidance device 32 that is connected to the air outlet 4b of the evaporator 4 to control a relative flow of a volume of the process air P through a first branch b1 to the air inlet 11a of the second air channel 11 of the first heat exchanger 8 and through a second branch b2 to the air inlet 5a of the condenser 5. In other words, the controllable air guidance device 32 introduces a bypass or branch line from the air outlet 4b of the evaporator 4 directly to the air inlet 5a of the condenser 5. It is controllable e.g. by an electrical motor or an actor (not shown), e.g. by the central control circuitry 13. The relative flow volume can e.g. be controlled by setting a flow cross-section of one or both branches b1 and b2.

[0053] The air guidance device 32 may also be set such that the process air P flows through the first branch b1 (thus completely passing the second channel 11 of the first heat exchanger 8) and/or only through the second branch b2.

[0054] Of course, the present invention is not limited to the described or shown embodiments.

[0055] For example, the clothes dryer may comprise a non-controllable or fixed air guidance device to give a fixed flow ratio through both branches.

List of Reference Numerals

[0056]

1	clothes dryer
2	drum
2a	air inlet of the drum
2b	air outlet of the drum
3	fan
4	evaporator
4a	air inlet of the evaporator
4b	air outlet of the evaporator
5	condenser
5a	air inlet of the condenser
5b	air outlet of the condenser

6	compressor
7	expansion valve
8	first heat exchanger
9	first air channel
9a	air inlet of the first air channel
9b	air outlet of the first air channel
10	ambient air duct
11	second air channel
11a	air inlet of the second air channel
11b	air outlet of the second air channel
12	fan
13	central control circuitry
21	clothes dryer
31	clothes dryer
32	air guidance device
b1	first branch
b2	second branch
C	condensate
H	heat pump
L	process air loop
P	process air
pi	working point i
rhi	relative humidity of the process air at working point i
Ti	temperature of the process air at working point i

Claims

1. A clothes dryer (21; 31), comprising a closed loop (L) for process air (P), the closed loop (L) comprising a drum (2) for storing clothes, a first heat exchanger (8), a second heat exchanger (4), and a third heat exchanger (5), wherein

- the first heat exchanger (8) is an air-air heat exchanger having a first air channel (9) and a second air channel (11) for transferring heat between these air channels (9, 11),
- an air inlet (9a) of the first air channel (9) is connected to an air outlet (2b) of the drum (2),
- an air outlet (9b) of the first air channel (9) is connected to an air inlet (4a) of the second heat exchanger (4),
- an air outlet (4b) of the second heat exchanger (4) is connected to an air inlet (11 a) of the second channel (11) of the first heat exchanger (8),
- an air outlet (11b) of the second channel (11) of the first heat exchanger (8) is connected to an air inlet (5a) of the third heat exchanger (5), and
- an air outlet (5b) of the third heat exchanger (5) is connected to an air inlet (2a) of the drum (2).

2. The clothes dryer (21; 31) according to claim 1, wherein the air outlet (4b) of the second heat exchanger (4) is only connected to the air inlet (11 a) of the second channel (11) of the first heat exchanger (8).

3. The clothes dryer (21; 31) according to claim 1, wherein the air outlet (4b) of the second heat exchanger (4) is connected to the air inlet (11 a) of the second air channel (11) of the first heat exchanger (8) and to the air inlet (5a) of the third heat exchanger (5).

4. The clothes dryer (31) according to claim 3, wherein a controllable air guidance device (32) is connected to the air outlet (4b) of the second heat exchanger (4) to control a relative flow of the process air (P) to the air inlet (11 a) of the second air channel (11) of the first heat exchanger (8) and to the air inlet (5a) of the third heat exchanger (5).

5. The clothes dryer (31) according to claim 3, wherein a fixed air guidance device (32) is connected to the air outlet (4b) of the second heat exchanger (4) to set a relative flow of the process air (P) to the air inlet (11 a) of the second air channel (11) of the first heat exchanger (8) and to the air inlet (5a) of the third heat exchanger (5).

6. The clothes dryer (21; 31) according to any of the preceding claims, wherein the second heat exchanger (4) and the third heat exchanger (5) are components of a heat pump (H) of the clothes dryer (21; 31).

7. The clothes dryer (21; 31) according to any of the preceding claims, wherein the second heat exchanger (4) is an evaporator and the third heat exchanger (5) is a condenser of a compressor-type heat pump (21; 31).

8. The clothes dryer (21; 31) according to any of the preceding claims, wherein the clothes dryer (21; 31) is operable such that the process air (P) being discharged from the first air channel (9) of the first heat exchanger (8) is just saturated.

9. The clothes dryer (21; 31) according to any of the preceding claims, wherein a temperature (T) of the process air (P) flowing through the first channel (9) of the first heat exchanger (8) is lowered by not more than 5 °C.

10. The clothes dryer (21; 31) according to any of the preceding claims, wherein the second heat exchanger (4) is provided to cool down the process air (P) entering through the air inlet (4a) of the second heat exchanger (4).

11. A method for operating a clothes dryer (21; 31), wherein process air (P)

- flows from a drum (2) through a first channel (9) of a first heat exchanger (8) where it is cooled down,
- then through a second heat exchanger (4) where it is cooled down further,
- then at least partially through a second channel (11) of the first heat exchanger (8) where it is warmed up,
- then through a third heat exchanger (5) where it is warmed up further, and
- then back into the drum (2).

12. The method according to claim 11 wherein a part of the process air (P) directly flows from the second heat exchanger (4) to the third heat exchanger (5).

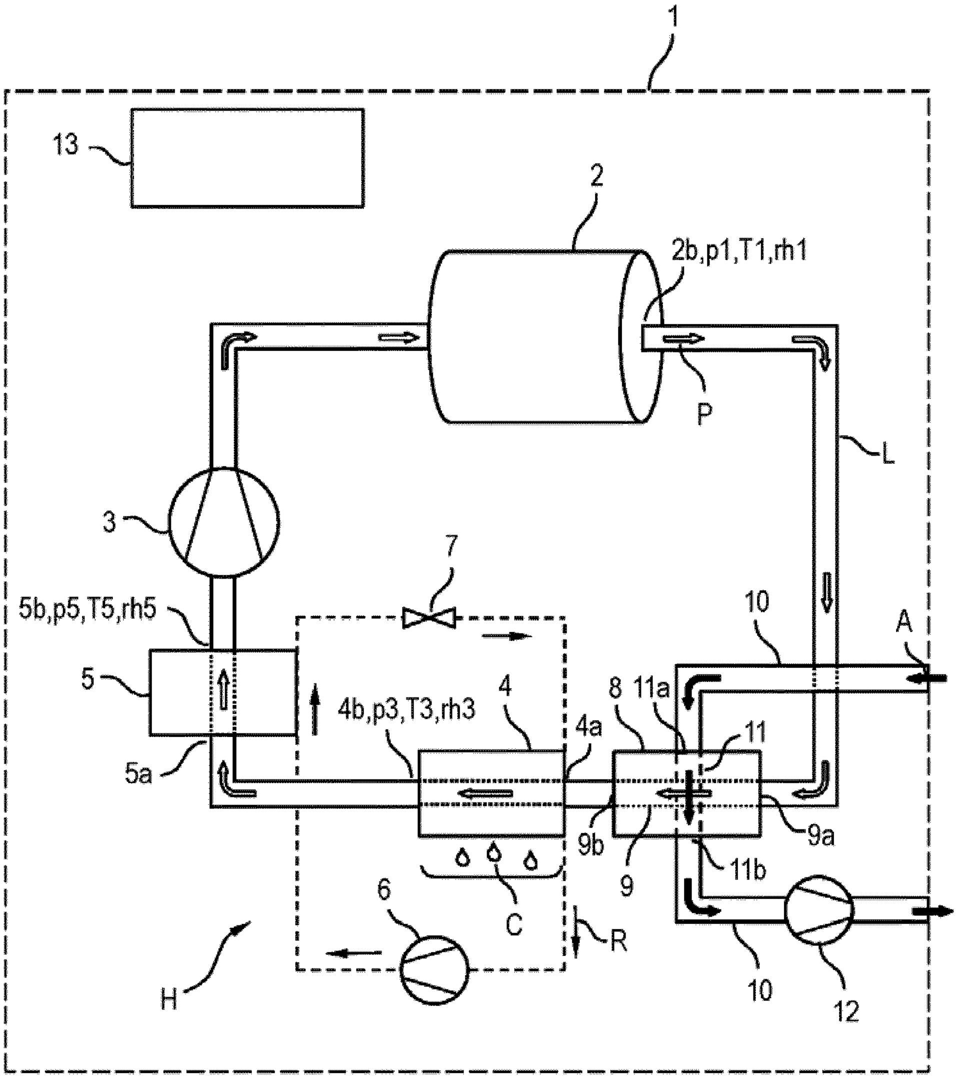
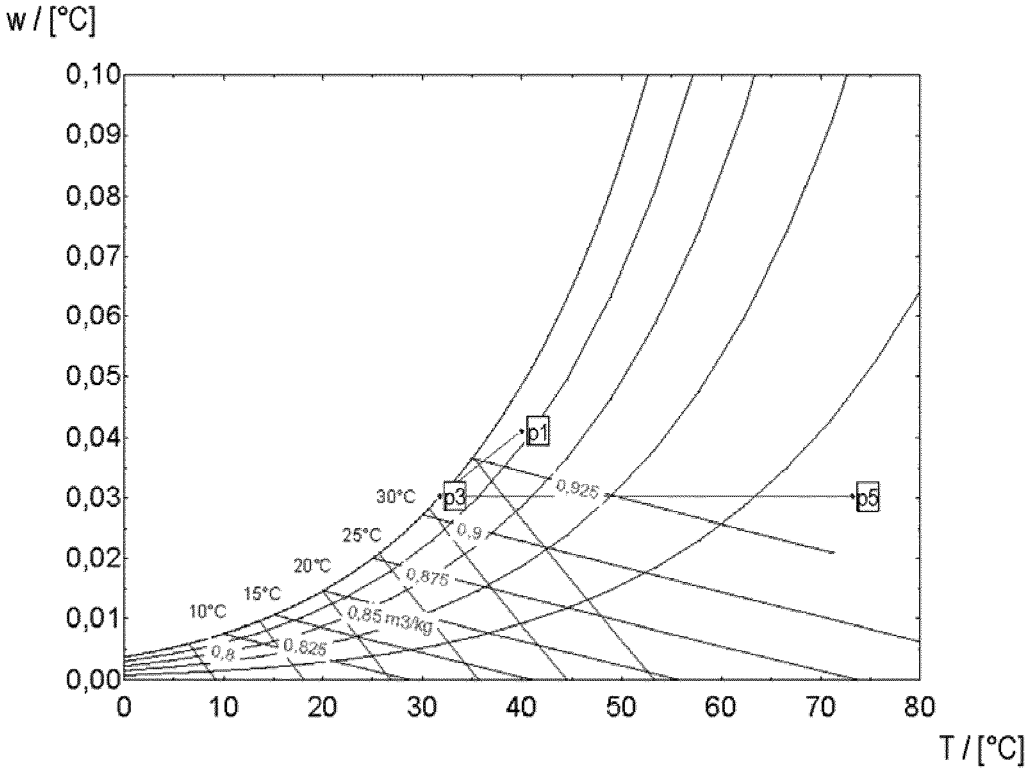

1
13
2
2b,p1,T1,rh1
P
L
3
7
5b,p5,T5,rh5
10
A
5
4
4b,p3,T3,rh3
8
11a
4a
11
5a
9b
9a
9
11b
6
C
R
H
10
12

Fig.1


w / [°C]
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0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0
10
20
30
40
50
60
70
80
T / [°C]
p1
p3
p5
30°C
25°C
20°C
15°C
10°C
0,925
0,9
0,875
0,85 m3/kg
0,825
0,8

Fig.2

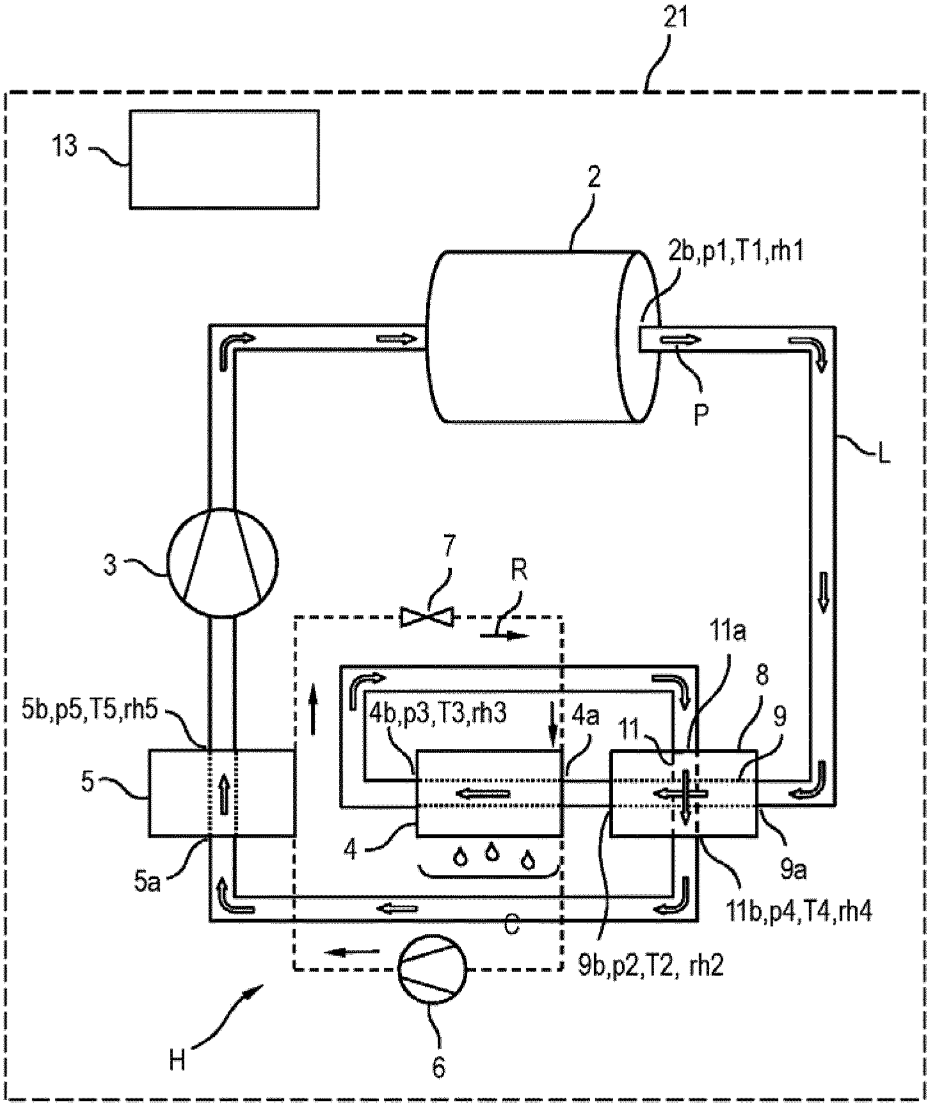
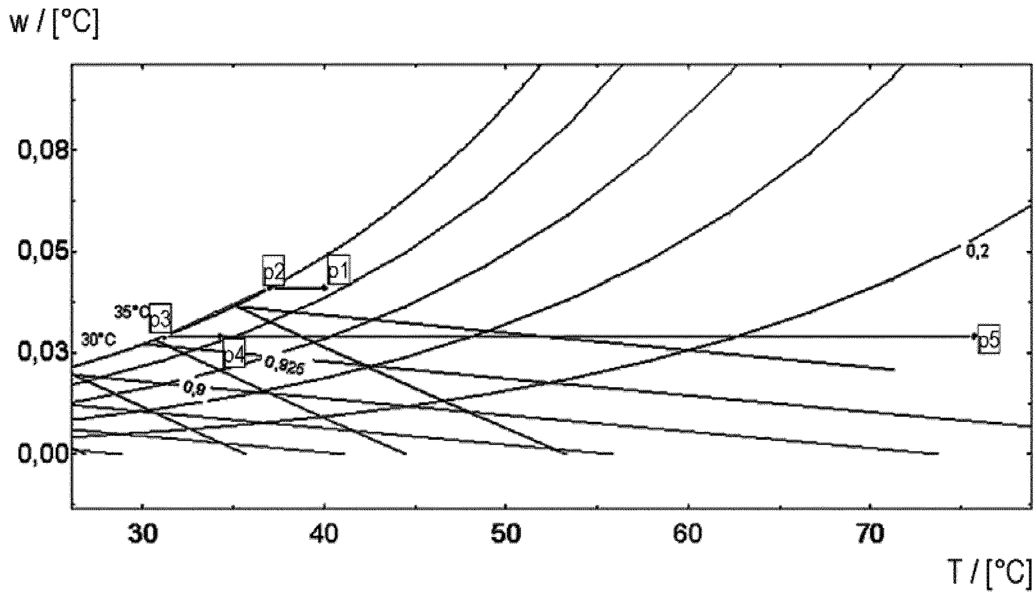

21
13
2
2b,p1,T1,rh1
P
L
3
7
R
11a
8
5b,p5,T5,rh5
4b,p3,T3,rh3
4a
11
9
5
4
5a
9a
11b,p4,T4,rh4
C
9b,p2,T2, rh2
H
6

Fig.3


w / [°C]
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0,05
0,03
0,00
30
40
50
60
70
T / [°C]
p1
p2
p3
p4
p5
35°C
30°C
0,9
0,925
0,2

Fig.4

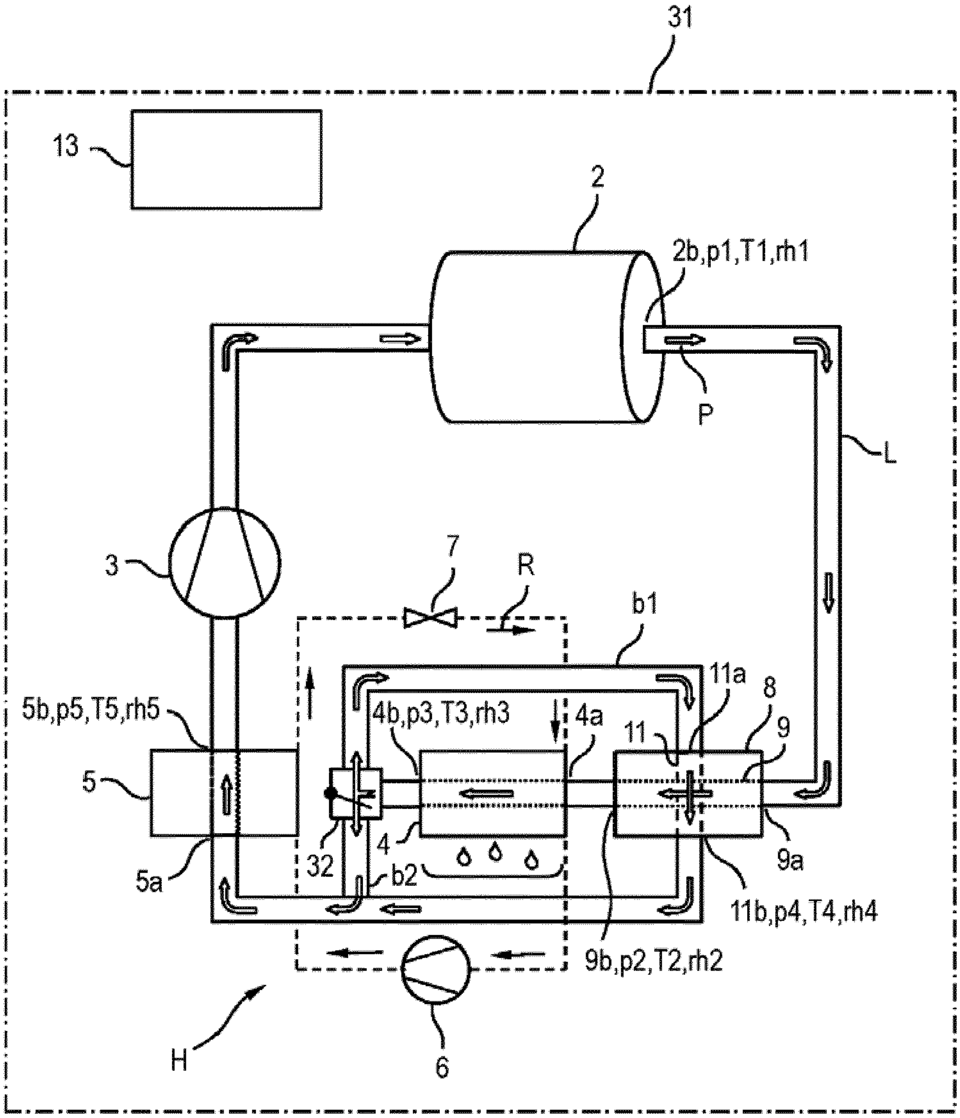
31
13
2
2b,p1,T1,rh1
P
L
3
7
R
b1
5b,p5,T5,rh5
4b,p3,T3,rh3
4a
11a
8
11
9
5
32
4
9a
5a
b2
11b,p4,T4,rh4
9b,p2,T2,rh2
H
6

Fig.5

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EUROPEAN SEARCH REPORT

Application Number
EP 15 38 2052

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 A	DE 43 06 215 A1 (LICENTIA GMBH [DE]) 1 September 1994 (1994-09-01) * column 1, line 22 - column 2, line 16 * * figure 1 * -----	1,2,6,7,10,11 3-5,8,9,12	INV. D06F58/20
A	DE 197 38 735 A1 (BOSCH SIEMENS HAUSGERAETE [DE]) 11 March 1999 (1999-03-11) * column 1, line 29 - column 1, line 52 * * column 2, line 59 - column 3, line 11 * * figure 1 * -----	1-12	

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D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	16 July 2015	Bermejo, Marco

2

CATEGORY OF CITED DOCUMENTS

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16-07-2015

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