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

(11) **EP 2 987 904 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
24.02.2016 Bulletin 2016/08

(51) Int Cl.:
D06F 58/02 *(2006.01)* ***D06F 58/20*** *(2006.01)*

(21) Application number: **14382322.7**

(22) Date of filing: **21.08.2014**

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

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(54) **Front-loading tumble dryer comprising a heat pump**

(57) A front-loading tumble dryer 31 comprises a housing 102 that accommodates a rotatable drum 103 and a heat pump 2, 22, the drum 103 comprising a rear wall 108 having an inlet opening 119 for process air PL, and the heat pump 2, 22 comprising a condenser 2, wherein the condenser 2 is at least partially positioned between the rear wall 108 of the drum 103 and a rear wall 3 of the housing 102.

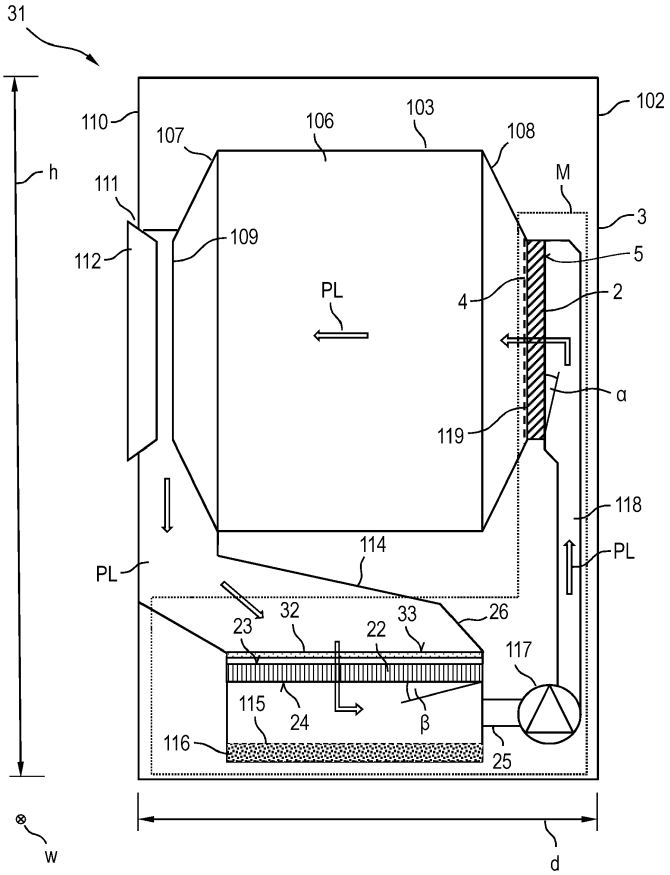

Fig.4

EP 2 987 904 A1

Description

[0001] The invention relates to a front-loading clothes drying device (without loss of generality also called a "tumble dryer"), comprising a housing that accommodates a rotatable drum and a heat pump, the drum comprising a rear wall having an inlet opening for process air, and the heat pump comprising a compressor, a condenser, an evaporator and an expansion valve. The invention is particularly applicable to ventless dryers.

[0002] Limited availability of space in tumble dryers with heat pumps caused by standardized dimensions of its outer housing (e.g. a width of 60 cm, a depth of 60 cm, and a height of 80 cm) and a large volume of the drum (of typically at least 112 liters) creates several problems, including ensuring a sufficient energy exchange with laundry loads inside the drum, restrictions concerning a size of heat pump components, and restrictions concerning a process airflow generation and distribution.

[0003] **Fig.5** shows a cross-sectional side view of a front-loading tumble dryer 101 according to the prior art. The tumble dryer 101 has an outer housing 102 of standardized dimensions, e.g. a width w of 60 cm, a depth d of 60 cm, and a height h of 80 cm. The housing 102 accommodates a drum 103 that is rotatable around a horizontal axis and a compressor heat pump. The compressor heat pump typically comprises a compressor (not shown), a condenser 104, an evaporator 105 and an expansion valve (not shown). The operation of a heat pump in a clothes dryer is well known in principle and is therefore not described in greater detail. The drum 103 has a basically cylindrical shape with a tubular side wall 106, a front wall 107 and a rear wall 108. The front wall 107 has a central opening 109 that acts as a loading port for loading and extracting clothes or laundry and as an outlet opening for process air PL. A front wall 110 of the housing 102 has an opening 111 for accessing the central opening 109 of the drum 103, which opening 111 can be closed by a front door 112.

[0004] When the door 112 is closed, the process air PL can flow out of the drum 103 via the central opening 109 and then downwards through a lint filter 113. The lint filter 113 filters lint, hairs, etc. that have been released from the clothes or laundry within the drum 103. The filtered process air PL then flows further downward into a floor assembly 114 or bottom group containing the evaporator 105 and the condenser 104. In the floor assembly 114, the filtered process air PL firstly flows horizontally through the evaporator 105. This causes the process air PL to cool down and to condense and rain out. The condensate drips through a partitioning floor 115 in form of lattice into a container tray 116. From there the condensate may be pumped out to a drain (not shown) or a condensate tank (not shown). The condensate tank may e.g. be used to release the condensate in a flush-like manner into a substantially vertical pipe to clean the evaporator 105 and/or the condenser 104. This flush-like self-cleaning process can be used to wash away particles like lint, hair, etc. sticking to the surface of the evaporator 105 and/or the condenser 104. The pipe may have a diffuser at its lower end to create a spray of condensate for better cleaning.

[0005] After the evaporator 105, the relatively dry and cool process air PL flows horizontally through the condenser 104 where it is warmed up. The warm process air PL is then sucked into a fan 117 or blower and then blown out upwards through an air guiding channel 118 to the rear wall 108 of the drum 103. The rear wall 108 has a central inlet opening 119, through which the warm process air PL enters the drum 103. Thus, there exists a closed-loop circuit for the process air PL that comprises the drum 103, the filter 113, the evaporator 105, the condenser 104, the fan 117, and the air guiding channel 118. The closed-loop circuit may also comprise e.g. other air guiding sections that are not explicitly described.

[0006] With this tumble dryer 101, a height, a depth and a width of the evaporator 105 and of the condenser 104 are factors restricting their efficiency. For example, the height of the evaporator 105 and of the condenser 104 is restricted on the top by a position of the side wall 106 of the drum 103 and the partitioning floor 115 on the bottom. The evaporator 105 may even be more restricted in its height due to the volume occupied by the substantially vertical pipe to self-clean the evaporator 105. Restrictions regarding the width are e.g. caused by mechanical constraints like ribs reinforcing the floor assembly 114, a position of a drum drive motor, a drum belt, a space occupied by the compressor, etc. Restrictions regarding the depth may be caused e.g. by air guiding channels in front and behind the evaporator 105 and the condenser 104 and a position of a fluid pump (not shown) for pumping out the container tray 116. Also, the deeper the evaporator 105 and the condenser 104 are the higher a pressure drop becomes and the worse a temperature gradient profile will be.

[0007] EP 2 321 456 B1 discloses a drying appliance comprising a drying chamber and a process air guide for guiding drying air through said drying chamber, said process air guide comprising a heat exchanger for cooling process air which comprises a charge of humidity and particulates, and disposed downstream of said drying chamber within said process air guide, wherein said heat exchanger is coated at least partially with a polymer coating on a part of a surface of the heat exchanger, and wherein the part of said surface below said coating has a passivating layer interposed between said coating and said surface, and said coating has a surface energy not exceeding 40 mN/m.

[0008] WO 2009/103785 A1 relates to a household device for drying laundry, in particular a laundry dryer or clothes dryer, said device comprising a component around which process air can flow, wherein the component comprises a metal or plastic substrate with a surface which faces the process air. This surface has a coating for preventing adhesion of foreign particles.

[0009] It is the object of the present invention to at least

partially overcome the disadvantages of the prior art.

[0010] The object is achieved according to the features of the independent claims. Advantageous embodiments can be derived, inter alia, from the description and the dependent claims.

[0011] The object is achieved by a front-loading tumble dryer, comprising a housing that accommodates a rotatable drum and a heat pump. The drum comprises a rear wall having an inlet opening for process air. The heat pump comprises a condenser. The condenser is at least partially positioned between the rear wall of the drum and a rear wall of the housing.

[0012] This give the advantage that the condenser is moved from the floor assembly to a position further at the back of the housing and may also be positioned higher up than before. This in turn allows for a more efficient design and/or placement of the condenser. In particular an entrance area of the condenser for the process air may be enlarged. Additionally, the design and/or placement of other components, in particular of the heat pump and/or the compressor, the evaporator can be improved since it is not or not as much restricted by the condenser anymore. In particular, an entrance area for the process air of the evaporator may be enlarged. Also, heat loss by the air guiding channel leading to the inlet opening of the drum is reduced since it can be made shorter.

[0013] The tumble dryer may be a dedicated or standalone tumble-dryer. The tumble dryer may alternatively be a washer/dryer combination.

[0014] The heat pump may also comprise a compressor, an evaporator, and an expansion valve that may be connected by refrigerant lines. Such a heat pump may also be called a 'compressor heat pump'.

[0015] It is an embodiment that the condenser is completely positioned between the rear wall of the drum and a rear wall of the housing. This removes restrictions on the design and/or placement of the evaporator and/or other components, in particular of the floor assembly, even further.

[0016] It is an embodiment that the condenser is at least partially positioned between the inlet opening of the drum and the rear wall of the housing. Thus, the condenser is at least partially positioned right in front or upstream of the inlet opening of the drum. This gives the advantage that the condenser may have an increased entrance for the process air. The condenser may also be thinner with respect to a flow-through of the process air which reduces the drop of air pressure along its depth. Also, the heat loss between the condenser and the drum is negligible. These effects significantly increase the efficiency of the tumble dryer. The increase in performance density of the condenser and/or evaporator can be used to build these components with less material and thus with reduced costs.

[0017] It is an embodiment that the condenser is completely positioned between the inlet opening of the drum and the rear wall of the housing, in particular at or near the inlet opening. This enables a particularly effective heat exchange from the condenser to the process air, as well as a compact design.

[0018] It is an embodiment that the condenser has a plate-like form. This enables a particularly large cross-section and small pressure drop. A plate-like condenser has the further advantage that - because of its compact depth dimension - it can easily be placed between the rear wall of the drum and the rear wall of the housing even if this space is small in depth. Also, a distribution of the process air at the inlet opening of the drum is improved.

[0019] It is an embodiment that the condenser is substantially vertically aligned. This includes an exact or nearly exact vertical alignment as well as an angular deviation / inclination / tilt from the vertical alignment of up to 45°. A tilted position of the (in particular plate-like) condenser gives the advantage of a larger air entrance area while using up the same cross-sectional area projected from the central inlet opening of the rear wall. Another advantage may be a further reduction of the airflow pressure drop at the condenser. The angular deviation may in particular comprise a deviation of less than 45°, in particular of up to 30°, in particular of up to 15°, in particular of up to 10°, in particular of up to 5°.

[0020] It is an embodiment that the condenser is separated from the drum interior by an air-permeable screen, e.g. a mesh. This enables protection of the condenser from direct contact with the laundry.

[0021] It is an embodiment that the tumble dryer comprises a closed-loop process airflow circuit, comprising the drum, an evaporator, the condenser, and a fan for circulating the process air within the circuit. The drum, the evaporator, and the condenser may be arranged in this order with respect to a flow direction of the process air. The fan may e.g. be arranged between the drum and the evaporator (i.e. downstream the drum and upstream the evaporator) or between the evaporator and the condenser (i.e. downstream the evaporator and upstream the condenser). The closed-loop process airflow channel may further comprise an additional heater and/or a lint filter.

[0022] It is an embodiment that the evaporator is positioned below the drum and arranged for the process air to flow through the evaporator in a substantially vertical manner, e.g. in a top-to-bottom direction. This enables a particularly large cross-section of the evaporator. In particular, most of the width and the depth of the housing can be used as entrance area, except e.g. for the space to be used by other existing components like a compressor, a drive motor for the drum, and a water pump. The condensed water can drop down from the evaporator and is collected in the container tray. The container tray or swamp can be integrated into the floor assembly or be a separate part.

[0023] A bend of the air path leading from the evaporator to the fan is convenient to ensure separation of the condensed water drops from the air flow.

[0024] That the evaporator is arranged for the process

air to flow through the evaporator in a substantially vertical manner may comprise that the evaporator is substantially horizontally aligned. This includes a horizontal alignment and an angular deviation or tilt from the horizontal alignment of up to 45°. A tilted position of the (in particular plate-like) evaporator gives the advantage of a larger surface or air entrance area while using up the same cross-sectional area if projected from above. Another advantage may be a further reduction of the airflow pressure drop at the evaporator. The angular deviation may in particular comprise a deviation of less than 45°, in particular of up to 30°, in particular of up to 15°, in particular of up to 10°, in particular of up to 5°.

[0025] It is an embodiment that the evaporator has a plate-like form. This enables a particularly small pressure drop across the evaporator. A plate-like evaporator has the further advantage that it can easily be placed below the drum and above the floor.

[0026] It is an embodiment that a lint filter has a plate-like form. Thus, a filter having a particularly large surface area and a small pressure drop is provided. Furthermore, a possible risk of a blockage of the filter because of lint accumulation is greatly reduced. It is a particular embodiment that the filter has the same air entrance area or surface area as the evaporator.

[0027] It is an embodiment that the lint filter is substantially horizontally aligned above the evaporator. This includes a horizontal alignment and an angular deviation or tilt from the horizontal alignment of up to 45°. A tilted position of the (in particular plate-like) lint filter gives the advantage of an even larger surface area while using up the same cross-sectional area if projected from above. The angular deviation may in particular comprise a deviation of less than 45°, in particular of up to 30°, in particular of up to 15°, in particular of up to 10°, in particular of up to 5°.

[0028] The lint filter may be removable for cleaning (e.g. through a service opening) or may be self-cleaning. If the lint filter has an angular deviation, wetting of the lint filter by the moist process air in combination with the process air flow may suffice to remove the lint.

[0029] It is an embodiment that the compressor is at least partially positioned in the process airflow channel downstream the evaporator and upstream the condenser. In this arrangement, waste heat of the compressor can be used to pre-heat the process air prior to entering the condenser. The pre-heated process air lets the condenser work in a higher energetic state, thus letting the compressor work more efficiently at lower temperatures. This re-using of the waste heat from the compressor may also generate higher process air temperatures at the inlet opening of the drum which in turn leads to higher water evaporation from the laundry or clothes.

[0030] It is an embodiment that the compressor is standing next to the evaporator, in particular as part of the floor assembly.

[0031] It is an embodiment that the heat pump (i.e. its components is like the compressor, the condenser, the evaporator, the expansion valve(s), interconnecting pipes, etc.) is arranged in one common structural part or 'module' of the tumble dryer. Because of the position of the condenser, this module may be substantially L-shaped. The use of a module is beneficial for assembly and testing aspects during the production of the tumble dryer. In particular, this embodiment enables the production of the heat pump as a separate functional set which is later integrated into the whole dryer assembly. Brazing processes, leak testing, vacuuming of a cooling/refrigerant circuit, refrigerant loading, functionality checks, storage, etc. related to the heat pump are some of the specific processes steps which benefit from such a modular construction.

[0032] Some of the features, characteristics, and advantages of the invention are now described in greater detail in conjunction with several figures. In the drawing,

- Fig.1 shows a cross-sectional side view of a tumble dryer according to a first embodiment;
- Fig.2 shows a cross-sectional side view of a tumble dryer according to a second embodiment;
- Fig.3 shows a cross-sectional side view of a tumble dryer according to a third embodiment;
- Fig.4 shows a cross-sectional side view of a tumble dryer according to a fourth embodiment; and
- Fig.5 shows a cross-sectional side view of a tumble dryer according to the prior art.

[0033] **Fig.1** shows a cross sectional side view of a tumble dryer 1 according to a first embodiment. The tumble dryer 1 has a set-up generally similar to the tumble dryer 101 except that the condenser 2 is now positioned between the rear wall 108 of the drum 103 and a rear wall 3 of the outer housing 102, namely between the inlet opening 119 of the drum 103 and the rear wall 3 of the housing 102, in particular at or near the inlet opening 119.

[0034] The condenser 2 has a plate-like form and is vertically aligned. Its form and planar size is similar to the form and planar size of the inlet opening 119, e.g. circular. In one alternative, the size (width and/or height) of the condenser 2 may be significantly larger. The condenser 2 is separated from the interior of the drum 103 that accommodates the laundry by an air-permeable screen 4. This leaves more flexibility to form and/or place the evaporator 105.

[0035] During operation of the tumble dryer 1, the dry but relatively cool process air PL sucked from the evaporator 105 by the fan 117 is blown through the air guiding channel 118 to the condenser 2. Since the process air PL is relatively cool, a heat loss at the air guiding channel 118 is small. On level with the condenser 2, the process air PL make a horizontal turn in the direction of the drum 103 and thus in the direction of the condenser 2.

[0036] The process air PL is then flowing through the condenser 2 in a substantially horizontal manner. An air entrance area 5 of the condenser 2 is large while its thickness or depth is small. It follows that there is a much

smaller pressure drop through the condenser 2 and a much larger air entrance area as compared to the tumble dryer 101. This greatly increases the efficiency of the condenser 2.

[0037] Alternatively, the condenser 2 can have an angular deviation (or tilt or angular inclination) α from the vertical alignment of up to 45° that is set by the maximum angle the condenser 2 can be inclined or tilted within the air guiding channel 118. The angular deviation α gives the advantage of an even larger air entrance area 5. Also, the drop of air pressure may be reduced even more and/or a particularly even pressure over the air entrance area 5 of the condenser 2 may be achieved.

[0038] **Fig.2** shows a cross-sectional side view of a tumble dryer 11 according to a second embodiment. The tumble dryer 11 differs from the tumble dryer 1 in that a compressor 12 is positioned in the process airflow channel downstream the evaporator 105 and upstream the condenser 2. In particular, the compressor 12 is standing next to the evaporator 105, in particular on the partitioning floor 115 as part of and in the floor assembly 114. Thus, waste heat produced by the compressor 12 is transferred to the process air PL surrounding it. Therefore, the compressor 12 can be used to pre-heat the process air PL prior to entering the condenser 2. The pre-heated process air PL enables the condenser 2 to work in a higher energetic state, thus letting the compressor 12 work more efficiently at lower temperatures. This re-using of the waste heat from the compressor 12 may also generate higher temperatures of the process air PL at the inlet opening 119 of the drum 103 which in turn leads to stronger water evaporation from the laundry within the drum 103.

[0039] This position of the compressor 12 is only possible because of the removal of the condenser from the floor assembly 114.

[0040] **Fig.3** shows a cross-sectional side view of a tumble dryer 21 according to a third embodiment. The tumble dryer 21 differs from the tumble dryer 1 in that the evaporator 22 is positioned and arranged for the process air PL to flow through the evaporator 22 in a substantially vertical manner, i.e. from top to bottom. To achieve this, the evaporator 22 has a plate-like form and is substantially horizontally aligned. This form and position of the evaporator 22 is enabled by the removal of the condenser 104 from a below-the-drum position to its behind-the drum position. By this, an entrance area 23 or planar surface of the evaporator 22 for the process air PL can be greatly enlarged, in particular in its depth, e.g. tenfold as compared to the tumble dryer 1 or 11.

[0041] During operation of the tumble dryer 1, the hot wet process air PL flowing in from the lint filter 113 enters the evaporator 22 through the (upper) entrance area 23 and exits the evaporator 22 through a (lower) exit area 24. Thus a flow direction of the process air PL through evaporator 22 from top to bottom is achieved. Nearly the full width w and depth d of the housing 102 can be used for the entrance area 23, except for some space required by the other existing components like the compressor 12, a drive motor (not shown) for rotating the drum 103, or a water pump for pumping the condensate from the container tray 116. The condensed water or condensate can drop down from the evaporator 22.

[0042] The entrance area 23 and the exit area 24 of the evaporator 22 are large while its thickness or depth (here measured in a vertical direction) is small. It follows that there is a smaller pressure drop through the evaporator 22 and a larger planar area that can be used for the heat exchange between the evaporator 22 and the process air PL. This increases the efficiency of the evaporator 22.

[0043] While the evaporator 22 is shown to be aligned in a horizontal direction, the evaporator 22 may alternatively have an angular deviation (or tilt or angular inclination) β from the horizontal position or alignment of up to 45°. The maximum angular deviation β is determined by the maximum angle the evaporator 22 can be inclined or tilted. The angular deviation β may have the advantage that the entrance area 23 and the exit area 24 may be further enlarged. Also, the drop of air pressure may be reduced even more and/or a particularly even pressure over the size (width and/or height) of the evaporator 22 may be achieved, e.g. because the process air PL may hit the entrance area 23 in a more perpendicular fashion.

[0044] Additionally, a self-cleaning effect of the evaporator 22 may be achieved without the need for pressurized water rinsing. This is due to equal or (when the evaporator 22 is inclined by the angle β) convergent directions of the flow direction of the process air PL through the evaporator 22 and a direction of the falling condensate water drops. To support the self-cleaning, the evaporator 22 may have a hydrophobic coating.

[0045] Also, the evaporator 22 is positioned higher than an air path 25 to an inlet side of the fan 117 to ensure separation of the condensate drops from the process air PL flowing into the fan 117. This can be achieved e.g. by providing a bend 26 in the air path from the evaporator 22 to the fan 117.

[0046] **Fig.4** shows a cross-sectional side view of a tumble dryer 31 according to a fourth embodiment. The tumble dryer 31 differs from the tumble dryer 21 in that a lint filter 32 now has a plate-like form and is positioned in parallel and upstream to the evaporator 22, i.e. substantially horizontally aligned above the evaporator 22. Thus, an entrance area 33 of the lint filter 32 is also greatly enlarged.

[0047] Additionally, a cross-section of the process air channel following the central opening 109 is greatly increased providing less airflow restriction during a drying cycle. This may enhance user comfort for laundry loading of the drum 103.

[0048] The heat pump, including the condenser 2 and the evaporator 22, is arranged in one common module M of the tumble dryer 31. The module M, if viewed from the side, has an L-shape to accommodate the condenser 2 and the floor arrangement 114 supporting the evapo-

rator 22 and the compressor 12. This modular concept can also be applied to the tumble dryers 1, 11, and 21.

[0049] Of course, the present invention is not restricted to the shown embodiments.

List of Reference Numerals

[0050]

1	tumble dryer
2	condenser
3	rear wall of the outer housing
4	air-permeable screen
5	air entrance area
11	tumble dryer
12	compressor
21	tumble dryer
22	evaporator
23	entrance area
24	exit area
31	tumble dryer
32	lint filter
33	entrance area
101	tumble dryer
102	housing
103	drum
104	condenser
105	evaporator
106	side wall
107	front wall
108	rear wall of the drum 103
109	central opening
110	front wall
111	opening
112	front door
113	filter
114	floor arrangement
115	partitioning floor
116	container tray
117	fan
118	air guiding channel
119	inlet opening
d	depth
h	height
M	module
PL	process air
w	width
α	angular deviation
β	angular deviation

Claims

1. A front-loading tumble dryer (1; 11; 21; 31), comprising

- a housing (102) that accommodates a rotatable drum (103) and a heat pump (2, 105; 2, 12, 105; 2, 22),
- the drum (103) comprising a rear wall (108) having an inlet opening (119) for process air (PL), and
- the heat pump (2, 105; 2, 12, 105; 2, 22) comprising a condenser (2), wherein
- the condenser (2) is at least partially positioned between the rear wall (108) of the drum (103) and a rear wall (3) of the housing (102).

2. The tumble dryer (1; 11; 21; 31) according to claim 1, wherein the condenser (2) is completely positioned between the rear wall (108) of the drum (103) and the rear wall (3) of the housing (102).

3. The tumble dryer (1; 11; 21; 31) according to claim 2, wherein the condenser (2) is at least partially positioned between the inlet opening (119) of the drum (103) and the rear wall (3) of the housing (102).

4. The tumble dryer (1; 11; 21; 31) according to claim 3, wherein the condenser (2) is completely positioned between the inlet opening (119) of the drum (103) and the rear wall (3) of the housing (102).

5. The tumble dryer (1; 11; 21; 31) according to any of the claims 3 or 4, wherein the condenser (2) is positioned at or near the inlet opening (119).

6. The tumble dryer (1; 11; 21; 31) according to any of the preceding claims, wherein the condenser (2) has a plate-like form and is substantially vertically aligned.

7. The tumble dryer (1; 11; 21; 31) according to any of the preceding claims, wherein the condenser (2) is separated from an interior of the drum (103) by an air-permeable screen (4).

8. The tumble dryer (1; 11; 21; 31) according to any of the preceding claims, wherein the tumble dryer (1; 11; 21; 31) comprises a closed-loop process airflow circuit, comprising the drum (103), an evaporator (105; 22), the condenser (2), and a fan (117) for circulating the process air (PL) within the circuit.

9. The tumble dryer (21; 31) according to any of the preceding claims, wherein the evaporator (22) is positioned below the drum (103) and arranged for the process air (PL) to flow through the evaporator (22) in a substantially vertical manner.

10. The tumble dryer (21; 31) according to claim 9, wherein the evaporator (22) has a plate-like form and is substantially horizontally aligned.

11. The tumble dryer (31) according to claim 10, wherein a lint filter (32) has a plate-like form and is substan-

tially horizontally aligned above the evaporator (22).

12. The tumble dryer (11) according to any of the preceding claims, wherein the compressor (12) is at least partially positioned in the process airflow channel (118) downstream the evaporator (22) and upstream the condenser (2).

13. The tumble dryer (1; 11; 21; 31) according to any of the preceding claims, wherein the heat pump is arranged in one common module (M) of the tumble dryer (1; 11; 21; 31).

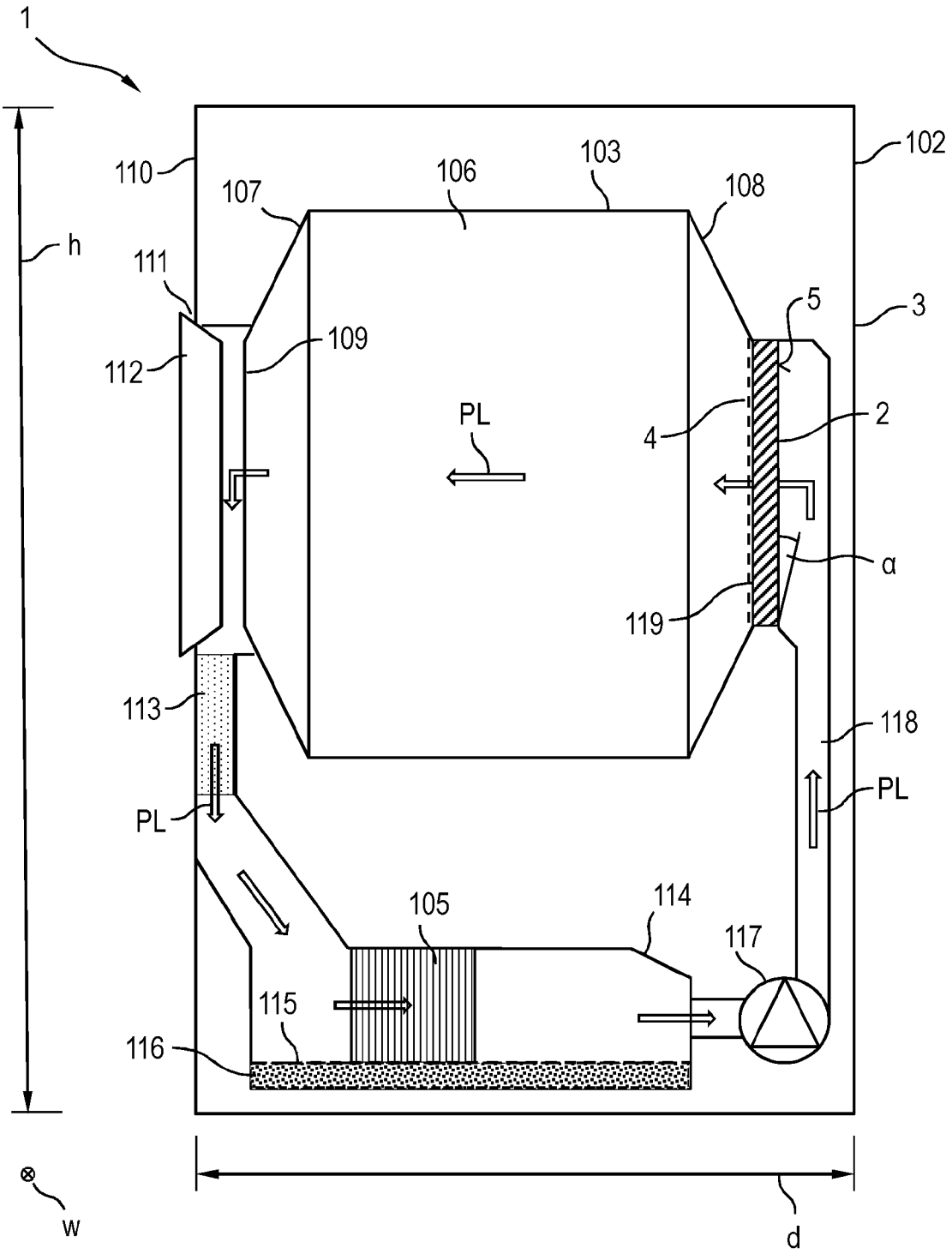
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Fig.1

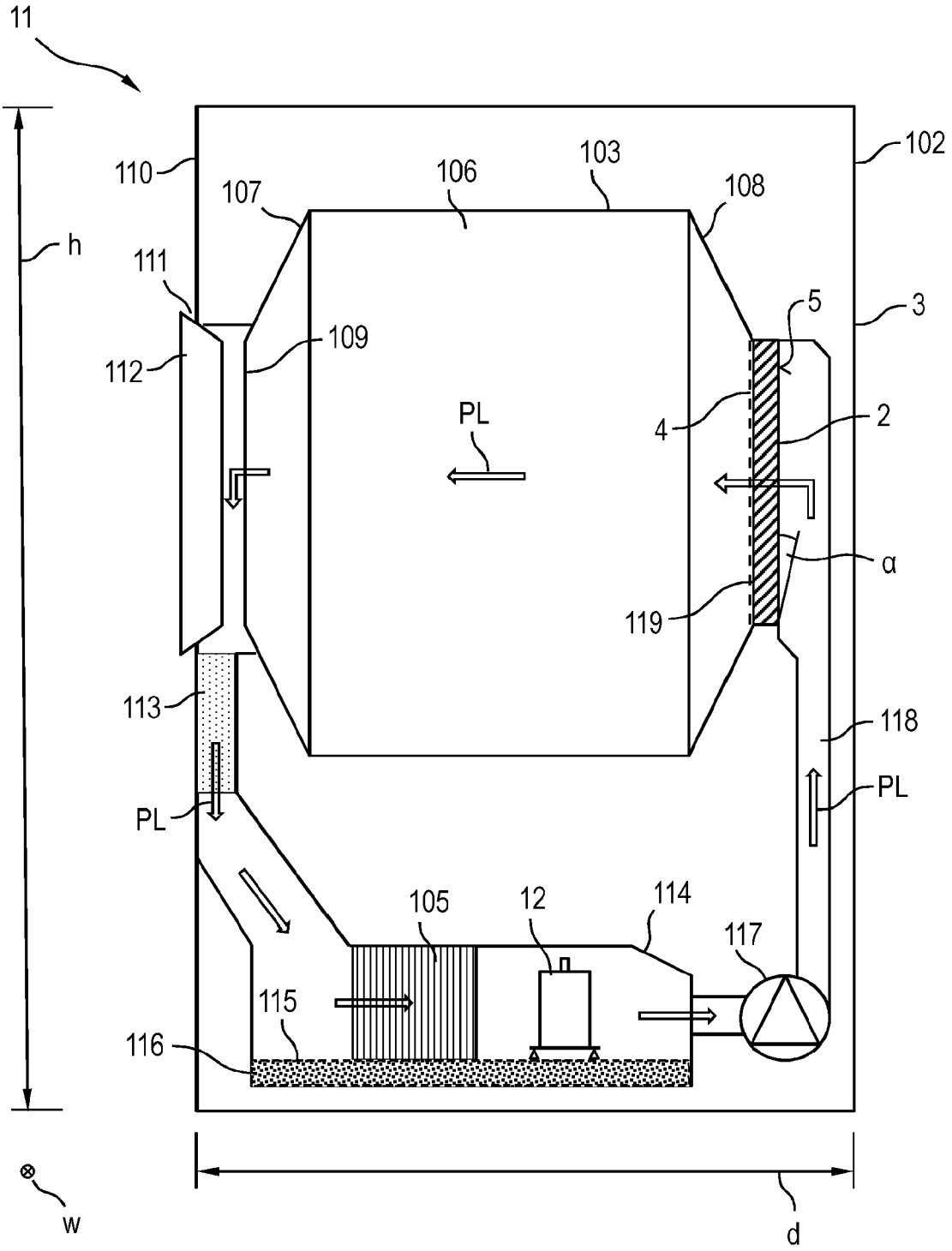
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Fig.2

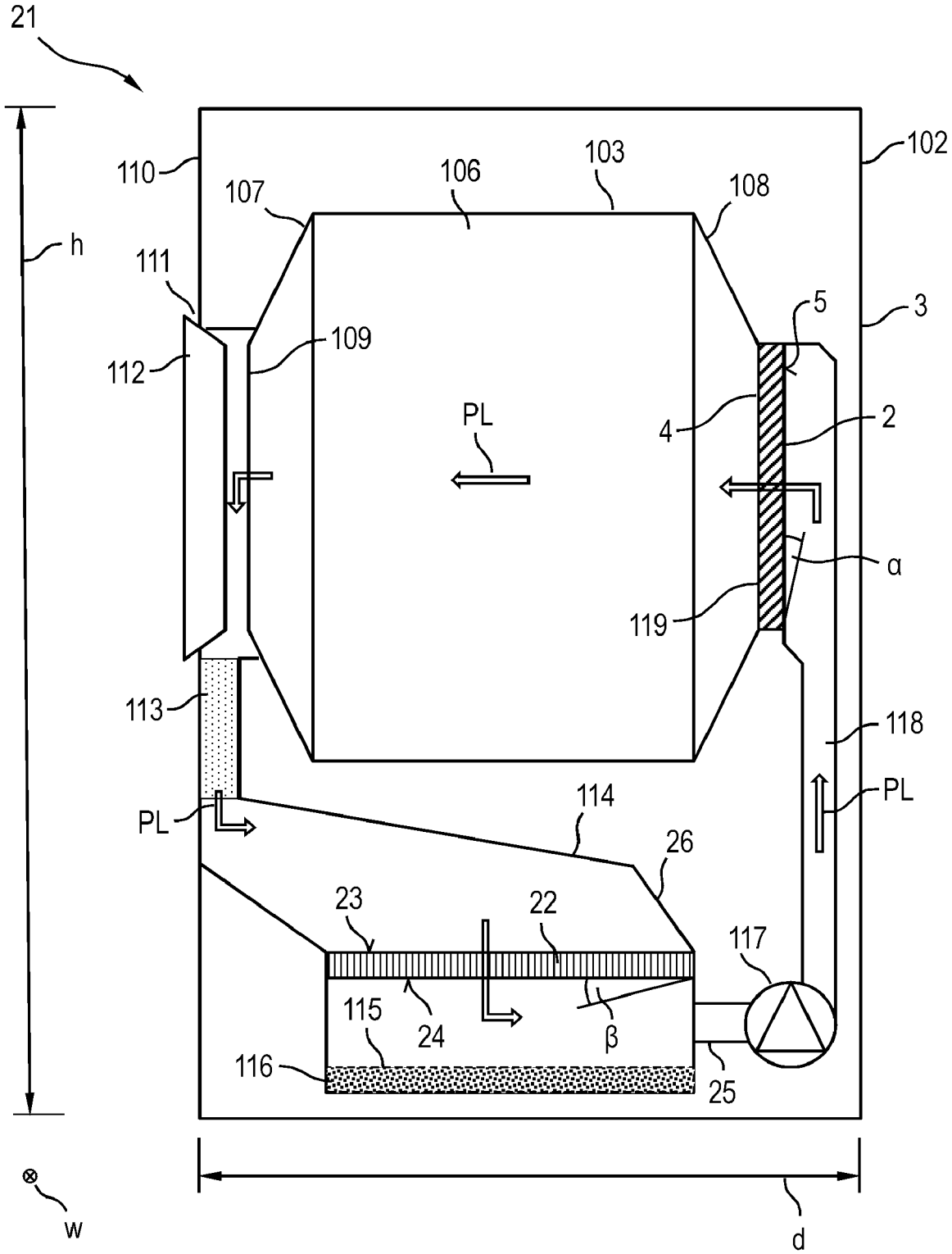
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Fig.3

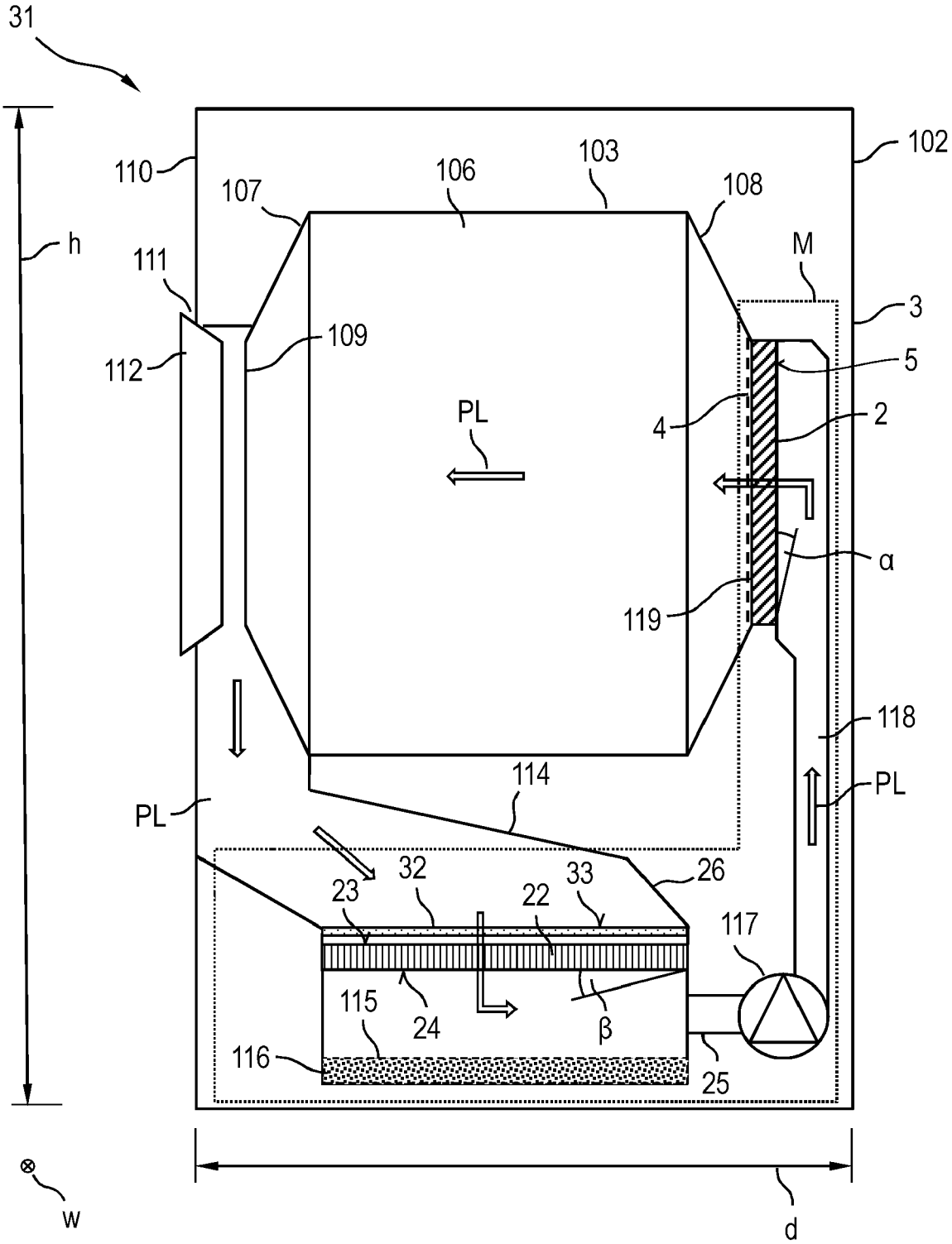
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Fig.4

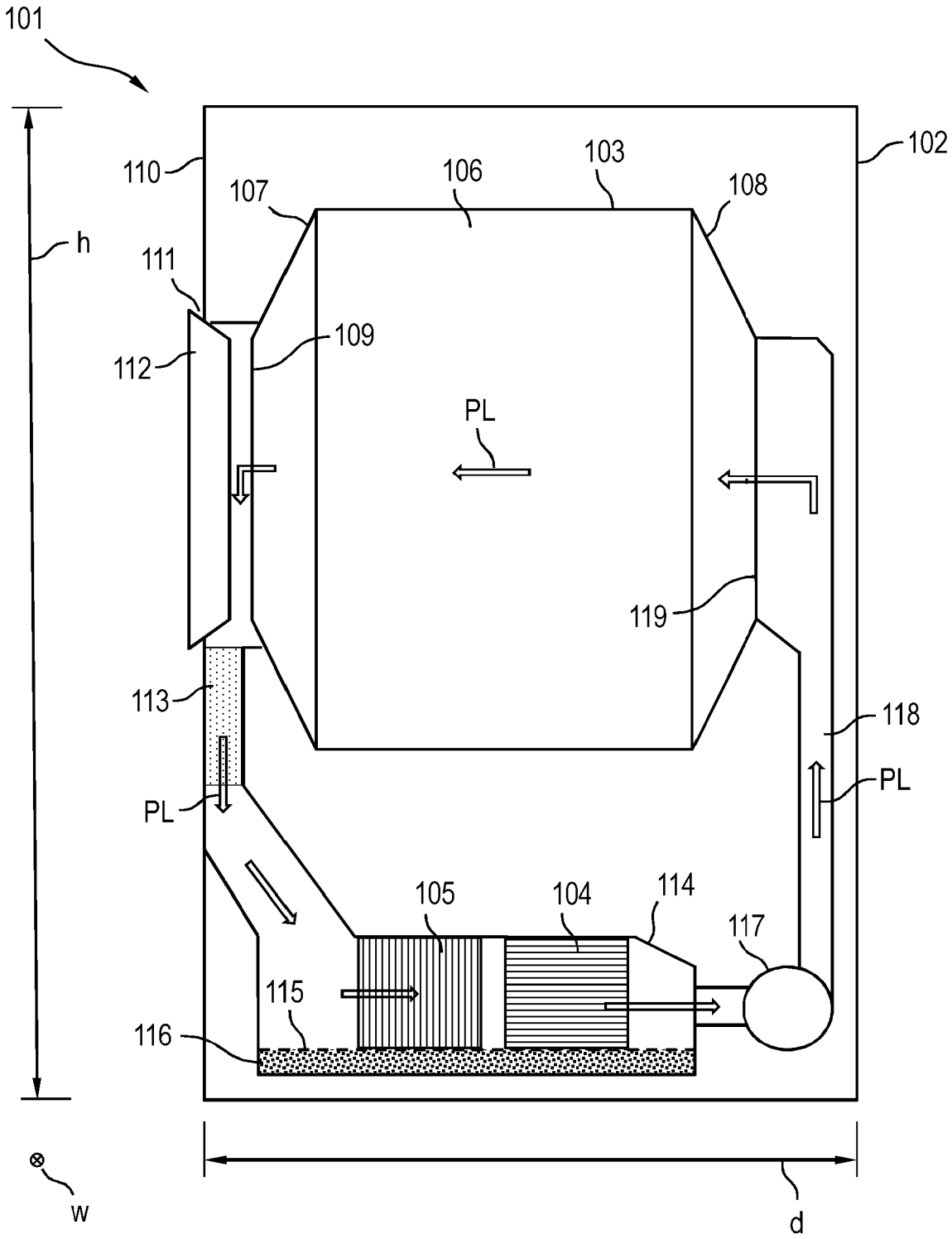
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Fig.5

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EUROPEAN SEARCH REPORT

Application Number
EP 14 38 2322

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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X : particularly relevant if taken alone
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