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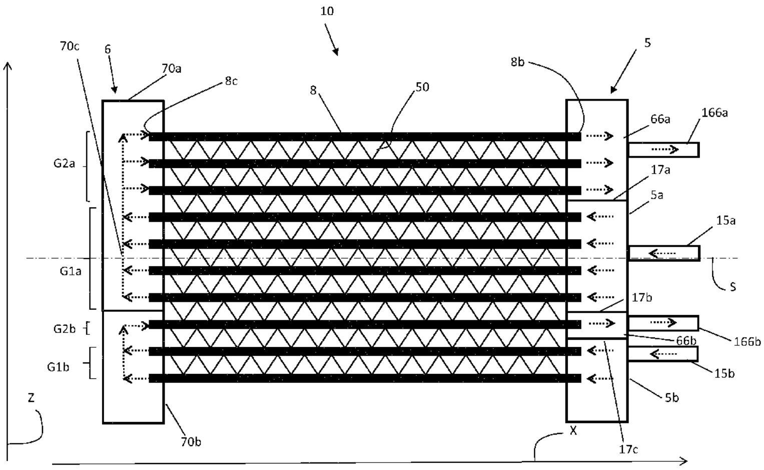

FIG. 8b

(57) Abstract: The present invention relates to a laundry dryer (1) comprising a casing (2) supporting a drying chamber (3) for receiving a load to be dried; a process air conduit (11) in communication with the drying chamber (3) where a process air stream is apt to flow and including an air duct (11a); a heat pump (30) having a heat pump circuit in which a refrigerant (R) can flow, said heat pump circuit including a first heat exchanger (31) where the refrigerant is cooled off and the process air stream is heated up, and a second heat exchanger (32) where the refrigerant is heated up and the process air is cooled off. The first and/or second heat exchanger are thermally coupled to the process air conduit (11) to perform heat exchange between said refrigerant flowing in said heat pump circuit and said process air stream; said first and/or second heat exchanger (31; 32) further comprising at least one heat exchanger module (10). The module includes an inlet header (5a; 5b) to direct a flow of said refrigerant into said module (10) and at least two outer headers (66a, 66b), fluidly separated from each other, each of which is apt to discharge a flow of said refrigerant from said module (10); or at least two inlet headers (5a, 5b), fluidly separated from each other, each of which is apt to direct a flow of said refrigerant into said module (10) and an outer header (66a; 66b) to discharge a flow of said refrigerant from said module; and a plurality of heat exchange layers (8) fluidly connecting said inlet(s) (5a; 5b) to said outlet header(s) (6a; 6b) to enable said refrigerant (R) to flow from said inlet(s) to said outlet header(s) and/or vice versa; said layers (8) being stacked one above the other(s) in a stacking direction (Z) and each heat exchange layer including a plurality of channels (7).

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Heat pump laundry dryer

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DESCRIPTION

FIELD OF THE INVENTION

The present invention relates to a laundry dryer including a heat pump, in particular to a laundry dryer which optimizes the energy consumption and/or the duration of the drying cycles.

BACKGROUND ART

Most dryers consist of a rotating drum called tumbler (thus the dryer is also called tumble dryer), through which heated air is circulated to evaporate the moisture from a load of laundry. The tumbler is rotated around its axis.

Known laundry dryers include two categories: condense laundry dryers and vented laundry dryers. Dryers of the first category circulate air, exhausted from the drum, through a heat exchanger/condenser in order to cool the air and condense the moisture; they subsequently re-circulate the air back through the drum, after having heated the same using a heater. Dryers of the second category draw air from the surrounding area, heat it, blow it into the drum during operation and then exhaust it through a vent into the outside.

Generally, dryers of the first category are the most common in the market, due to the fact that they do not require special means for proper installation such as an exhaust duct to exhaust the humid hot air coming from the drum. However, commonly, for the same power and the same amount of load, the drying cycle of a condensed dryer is longer than an equivalent cycle in a vented dryer.

Several solutions have been proposed according to the prior art in order to improve the efficiency of condense and vented dryers. In particular, heat pump technology has been applied to laundry dryer in order to enhance the efficiency in drying clothes. In traditional heat pump dryer, air flows in a close loop. The air, moved by a fan, passes through a drum removing water from wet clothes, and then it is cooled down and dehumidified in a heat pump evaporator and heated up in a heat pump condenser to be re-inserted into the drum. In order to function, the heat pump includes a refrigerant with which the air is in thermal exchange, and the refrigerant is compressed by a compressor, condensed in the condenser laminated in an expansion device and then vaporized in the evaporator.

EP 1209277 discloses a heat-pump clothes drying machine in which the motor used to drive the drum holding the clothes to be dried is also connected to a first fan, which circulates the drying air, as well as a second fan that cools the compressor.

US 2011/0280736 relates to a control method of a dryer. A control method of a dryer including a heat pump having a variable velocity type compressor, the control method includes steps of selecting at least one course supplying air or dried air; increasing an activation velocity of the compressor to a target velocity, as the selected course is implemented; and adjusting an open degree of an expansion valve provided in the heat pump.

SUMMARY OF THE INVENTION

The present invention is relative to a laundry dryer for drying clothes and other garments including a heat pump having a first and a second heat exchanger. The dryer of the invention may include either a vented or a condense dryer. The configuration and location of the heat exchangers in the laundry dryer of the invention is such that a high ratio between the heat transfer capacity and the heat exchanger volume is achieved. Therefore, in case the heat transfer capacity is kept constant with respect to prior art dryers, in the dryer of the invention more free space is available for the other dryer's components (e.g. compressor, motor, electronic board, etc.). For example, the amount of space occupied by the heat exchanger(s) in the casing of the dryer can be reduced without affecting the amount of exchanged heat. Alternatively, using the same space for the heat exchanger(s) as in the prior art, an improved heat transfer capacity is achieved in the dryer of the invention.

A heat pump dryer includes a drying chamber, such as a drum, in which the load of laundry, e.g., clothes, to be dried is placed. The drying chamber is part of a process air circuit, in particular a closed-loop circuit in case of a condensed dryer or an open circuit in case of a vented dryer, which in both cases includes an air duct for channeling a stream of air to dry the load. The process air circuit is connected with its two opposite ends to the drying chamber. More specifically, hot dehumidified air is fed into the drying chamber, flowing over the laundry, and the resulting humid cool air exits the same. The humid air stream rich in water vapor is then fed into an evaporator of a heat pump, where the moist warm process air is cooled and the humidity present therein condenses. The resulting cool dehumidified air is then either vented outside the dryer in the ambient where the latter is located or it continues in the closed-loop circuit. In this second case, the dehumidified air in the process air circuit is then heated up before entering again in the drying chamber by means of a condenser of the heat pump, and the whole loop is repeated till the end of the drying cycle. Alternatively, ambient air enters into the drum from the ambient via an inlet duct and it is heated up by the condenser of the heat pump before entering the drying chamber.

The heat pump of the apparatus includes a refrigerant circuit in which a refrigerant can flow and which connects via piping a first heat exchanger or condenser, a second heat exchanger or evaporator, a compressor and a pressure-lowering device. The refrigerant is pressurized and circulated through the system by the compressor. On the discharge side of the compressor, the hot and highly pressurized vapor is cooled in the first heat exchanger, called the condenser, until it condenses into a high pressure, moderate temperature liquid, heating up the process air before the latter is introduced into the drying chamber. The condensed refrigerant then passes through the pressure-lowering device such as an expansion device, e.g., a choke, a valve or a capillary tube. The low pressure liquid refrigerant then enters the second heat exchanger, the evaporator, in which the fluid absorbs heat and evaporates due to the heat exchange with the warm process air exiting the drying chamber. The refrigerant then returns to the compressor and the cycle is repeated.

In some embodiments, in the first and/or second heat exchanger, the refrigerant may not be subject to a phase transition.

In the following, with the terms “downstream” and/or “upstream”, a position with reference to the direction of the flow of a fluid inside a conduit is indicated. Additionally, in the present context, the terms “vertical” and “horizontal” are referred to the positions of elements with respect to the dryer in its normal installation or functioning. Indeed, a horizontal plane (X, Y) formed by two horizontal, perpendicular directions X, Y is defined, and a vertical direction Z, perpendicular to the horizontal plane, is defined as well in a 3-D space.

Applicants have considered a heat pump dryer wherein the first and/or the second heat exchanger of the heat pump includes one or more modules realized as follows. Each module includes two headers, which can be an inlet header to allow the inflow of refrigerant into the module and an outlet header to allow the refrigerant to discharge from the module. Further, the module includes a plurality of heat exchange layers stacked in a stacking direction (in other words, the layers are overlapped, i.e. are disposed one above – or on the top of - the other along a given direction). Each heat exchange layer includes more than one channel for the refrigerant flow, the channels being located one adjacent to the other(s) within the layer. The channels are in fluid communication with the inlet and/or the outlet header so that the refrigerant is allowed to flow from the inlet to the outlet header and/or vice versa. Preferably, the plurality of channels is parallel to each other within each heat exchanger layer. Each heat exchange layer defines two opposite ends, one of which is fixed to said either inlet or outlet header, the layers thus departing from the inlet and/or the outlet header.

As an example, each heat exchange layer includes an upper plate and a lower plate attached to each other, each of which is stamped or otherwise formed to partially define the lower or upper half of a plurality of internal channels, completely formed when the two plates are attached together.

Preferably, within each heat exchange layer, the plurality of channels is also substantially parallel to each other, however they can also be angled or they can have an irregular shape.

Preferably, the stacking direction is a vertical direction and the heat exchange layers are stacked one above the other.

The heat exchange layers have a given width which depends on the number of channels realizing the heat exchange layer, and a longitudinal extension, which corresponds to the longitudinal extensions of the channels forming the same. The width and the longitudinal extension direction preferably define a plane. This plane might be perpendicular to the vertical stacking direction of the layers, or it can form an angle with the same. Alternatively, the layers may be tilted one with respect to the other or may form arches one on top of the other; the arches could be parallel to each other, e.g., having a constant distance one with respect to the other(s), or tilted.

Preferably, channels of neighbouring heat exchange layers in the stacking direction are connected by finnings. The plurality of channels is subjected to, at least in part, the process air stream so that there is heat exchange between the refrigerant flowing within the channels and the process air. For this purpose, therefore, at least partially, preferably for their whole extension, the channels of the heat exchange layers of the modules of the first and/or second heat exchanger are located within the air duct, part of the process air circuit.

The headers have the function of holding the various heat exchange layers and as an inlet and/or outlet for the refrigerant into the module.

Applicants have realized that the process air stream is not uniformly distributed along the air duct. Therefore, the heat exchange between the refrigerant flowing within the channels of the heat exchange layers and the process air is not constant along the heat exchange layers of each module.

In view of the above, a main object of the present invention is to improve the heat exchange between the refrigerant flowing within the channels of the heat exchange layers and the process air.

In an aspect, the inventions relates to a laundry dryer comprising:

- a casing supporting a drying chamber for receiving a load to be dried;
- a process air conduit in communication with the drying chamber where a process air stream is apt to flow and including an air duct; and
- a heat pump having a heat pump circuit in which a refrigerant can flow, said heat pump circuit including a first heat exchanger where the refrigerant is cooled off and the process air stream is heated up, and a second heat exchanger where the refrigerant is heated up and the process air is cooled off; said first and/or second heat exchanger being thermally coupled to the process air conduit to perform heat exchange between said refrigerant flowing in said heat pump circuit and said process air stream; said first and/or second heat exchanger further comprising at least one heat exchanger module, said module including
    - o an inlet header (5a; 5b) to direct a flow of said refrigerant into said module (10) and at least two outer headers (66a, 66b), fluidly separated from each other, each of which is apt to discharge a flow of said refrigerant from said module (10); or at least two inlet headers (5a, 5b), fluidly separated from each other, each of which is apt to direct a flow of said refrigerant into said module (10) and an outer header (66a; 66b) to discharge a flow of said refrigerant from said module; and
    - o a plurality of heat exchange layers (8) fluidly connecting said inlet(s) (5a; 5b) to said outlet header(s) (6a; 6b) to enable said refrigerant (R) to flow from said inlet(s) to said outlet header(s) and/or vice versa; said layers (8) being stacked one above the other(s) in a stacking direction (Z) and each heat exchange layer including a plurality of channels (7).

Due to the fact that there is the presence of two inlet headers and/or two outlet headers , the heat exchange between the refrigerant flowing within the channels of the heat exchange layers and the process air can be advantageously optimized.

The module of the invention includes either two inlet and one outlet header or two outlet and one inlet header. This is the so-called “minimal” configuration. The module can include more inlet and outlet header(s) in addition to those defined in the minimal configuration, for example in can include two inlet and two outlet headers, three inlet and two outlet headers, three oulet and two inlet headers and so on.

Indeed, the at least two inlet and/or two outlet headers of the present invention allow to divide in groups the heat exchange layers, so that at least two respective groups of heat exchange layers are distunguished, wherein the flow rate of the refrigerant flowing within the respective channels of the at least two groups is different. In general, the higher the flow rate of the refrigerant, the higher is the heat exchange but also the higher is the refrigerant pressure drop.

In view of the above, the at least two header inlet and/or outlet headers of the present invention allow to define at least two respective groups of heat exchange layers wherein the refrigerant flowing within the respective channels has different flow rates which are suitable to reach the best compromise between a high heat exchange and a low pressure drop.

Furthermore, the at least two respective groups of heat exchange layers can be advantageously chosen according to the foreseen process air stream in the air duct, which process air stream is not uniform.

In other words, the at least two respective groups of heat exchange layers allows to distribute the flow of refrigerant in different ways, i.e. to have different layouts of groups of heat exchange layers (and therefore of paths for the refrigerant flow) with a same overall size of the module.

It is underlined that in the present application saying that a first component is "fluidly separated" from a second component means that a fluid can't flow from the first component to the second component or vice versa; on the contrary, saying that a first component is "fluidly connected" to a second component means that a fluid can flow from the first component to the second component and vice versa.

It is also to be understood that the inlet and outlet headers may be at a given distance from each other, so that the heat exchange layers are connected at their opposite ends to the inlet and outlet headers, respectively, i.e. the heat exchange layers are interposed between the inlet and the outlet headers, or the inlet and outlet headers can be located one in contact or adjacent to the other (for example overlapped one above the other along the stacking direction), so that the heat exchange layers are attached with one end to the inlet or to outlet header and with the opposite end to another header, which can be a inlet header or oulte header as well, or a return header, as better detailed below. In the first case, the refrigerant flows from the inlet to the outlet header bridging a single heat exchange layer, while in the second case from the inlet header the refrigerant has to flow through at least two heat exchange layers, one flowing in one direction and one flowing in substantially the opposite direction, in order to reach the outlet header.

According to the aforementioned aspect, the dryer of the invention may include, alternatively or in combination, any of the following characteristics.

Preferably, each of said inlet and/or outlet header directs and/or discharges a flow of said refrigerant to a respective group of said heat exchange layers of said module.
More preferably, said heat exchange layers of said group are adjacent in said stacking direction.
As mentioned, the plurality of inlet and/or outlet headers allow to divide the heat exchange layers in groups, in order to optimize the heat transfer.
The most advantageous way of dividing the layers in groups is to separate the layers in group of layers which are adjacent to each other in the stacking direction. So each groups is formed by adjacent layers.
In a preferred embodiment, one of said inlet and one of said outlet headers are positioned one above the other along said stacking direction, and each of said heat exchange layers includes a first and a second opposite ends, said first end being connected to one of said inlet or said outlet header(s).
In this embodiment, at least one inlet and at least one outlet header are located one on top of the other in the stacking direction. All layers have one of their ends connected to the inlet or the outlet header. The second end can be connected to an additional inlet or outlet header or to a return header, for example.
Advantageously, said module includes a first and a second tube and each of said heat exchange layers including a first end connected to said first tube and a second end connected to said second tube, said first and or second tube being divided in sections, said sections defining either said two inlet headers and said one outlet header or said two outlet headers and said inlet header.
In this preferred embodiment, all layers are connected, via their opposite ends, to two tubes which are spaced apart one from the other. These tubes allows the flow of refrigenrant from one layer to the other(s). The tubes are divided in sections, and these sections define the inlet and outlet headers. For example, a tube can be divided in three sections, which are the two inlet and the outlet headers or the two outlet and the inlet headers. Depending on the position of the connection between a specific layer and the

tube, the layer can be connected – via one of its ends - to an inlet header or to an outlet header or to a return header.

A return header is a header that is not connected directly to the outside of the module, on the contrary it is in fluid comunication to the outside only via an inlet or an outlet header. Therefore, the return header can only receive and direct the refrigerant from/to heat exchange layers.

More preferably, said first or said second tube is divided in at least three sections by separators defining either said two inlet headers and said one outlet header (66a; 66b) or said two outlet headers and said inlet header, said inlet and outlet header(s) being located alternately one after the other(s).

Preferably, two inlet or two outlet headers realized in the same tube are not in direct contact to each other, but are preferably separated by an outlet or inlet header, respectively.

More preferably, said first and or second tube includes one or more sections defining one or more return headers, and each of said return headers is connected to one of a first or second ends of said heat exchange layers whose other of said first or second ends is connected to said inlet or outlet headers.

Thus the tubes divided in sections define the inlet header(s), the outlet header(s) and the return header(s). Each layer is preferably connected to one inlet or outlet header by means of one end and, by means of its opposite end, to a return header.

Preferably, said inlet and outlet headers are stacked one above the other(s) in said stacking direction.

In an advantageous embodiment, one tube of the two includes sections defining inlet and outlet headers only and the other tube of the two includes sections defining return headers only.

In this case the two tubes are “specialized”, one including only inlet and outlet headers and the second one only return headers. Therefore the refrigerant, in order to exit the module, has to pass through at least two different heat exchange layers in order to flow from the inlet to the outlet header.

In an embodiment, said inlet and outlet headers are arranged symmetrically with respect to a middle plane of said module, said middle plane being perpendicular to said stacking direction.

In an alternative embodiment, said inlet and outlet headers are arranged asymmetrically with respect to a middle plane of said module, said middle plane being perpendicular to said stacking direction.

The realization of the module with a plurality of inlet and/or outlet headers is extremely flexible and either symmetric or asymmetric modules can be obtained according to the specific process air flow present in the conduit where the module is located.

Advantageously, said channels of each heat exchange layer are arranged one parallel to the others.

One heat exchange layer is thus including a plurality of parallel channels where the refrigerant can flow.

Preferably, said heat exchange layers of said module are arranged one parallel to the others and are spaced apart each others by finnings.

The presence of finning further widens the heat exchange area between the refrigerant and the process air, thus a more efficient module can be fabricated.

In a preferred embodiment, said first heat exchanger includes more heat exchanger modules than said second heat exchanger.

Preferably, said first and/or said second heat exchanger includes at least two of said heat exchanger modules.

More preferably, said first and/or second heat exchanger includes at least one first and at least one second heat exchanger module and one of the outlet header(s) of said at least one first heat exchanger module is connected to one of the inlet header(s) of said at least one second heat exchanger module.

The first and second heat exchangers of the dryer can both include the module according to the invention and in addition each of them can include a different amount of modules, depending on the specific need of heat exchange. In case more than one module is present, the various modules are connected one to the others connecting together the outlet header of one to the inlet header of the following one, located downstream to the first with reference to the direction of flow of the refrigerant.

Advantageously, the channels have a hydraulic diameter smaller or equal than 5 mm.

According to an embodiment of the invention, the hydraulic diameter of each channel, where the hydraulic diameter D_H is defined as $D_H = 4\ A / P$ (where A is the cross sectional area of the channel and P is the wetted perimeter of the cross-section of the channel), is smaller or equal than 5 mm, i.e. $D_H \leq 5$ mm, more preferably $D_H \leq 3$ mm, even more preferably $D_H \leq 1$ mm.

Due to the size of the hydraulic diameter, the module 8 of the invention may include many channels, therefore the refrigerant flow is divided in a plurality of smaller refrigerant streams, one per channel. In this way the pressure drop of the refrigerant within the channels is reduced compared to the refrigerant pressure drop in bigger channels.

Additionally, it is known that the maximum pressure that a pipe can withstand is inversely proportional to its hydraulic diameter. A small hydraulic diameter therefore means that the channels can withstand higher pressures than bigger pipes. For this reasons, high pressures refrigerants, such as carbon dioxide, can be used in the heat pump circuit of the dryer of the invention.

Moreover, still due to the smaller size, a smaller amount of refrigerant is needed for the proper functioning of the module than in standard heat pump dryers. Use of hydrocarbons, which are flammable, can be therefore also considered, due to the low amount required.

The shape of the cross section of the channels is not relevant for the present invention, and it can be squared, rectangular, circular (in this case the hydraulic diameter coincide with the diameter of the circle), elliptic, and so on. The cross section of the plurality of channels does not have to be the same for all channels in the plurality, but it can be different and the various channels can have a combination of the possible above listed cross sections. In addition, the cross section may vary both in hydraulic diameter and/or in shape along the extension of the channel.

Preferably, said heat exchange layer includes a plurality of channels one parallel to the others.

Preferably, the channels extend along a direction which is substantially parallel to the horizontal plane and also perpendicular to the flow of the process air stream when the dryer is functioning. In other words, the channels, which preferably have a diameter much smaller than their length, extend from one header to another header in such a way that their longitudinal extension results substantially parallel to the horizontal plane and perpendicular to the flow of process air with which the heat exchange takes place.

In case the channels are rectilinear, their longitudinal extension (and longitudinal direction) corresponds to their longitudinal axis. In case the channels are not rectilinear, i.e. for example they are forming arches, their longitudinal extension (and longitudinal direction) corresponds to the line joining the point from which they depart from the inlet/outlet header and the first point having the maximum distance from the inlet/outlet header longitudinal axis.

The channels may include rectilinear portions and/or bumps or other turbulence-inducing elements that may enhance the heat transfer between the refrigerant and the air process stream. Additionally, channels may include smooth or corrugated inner and/or outer surfaces and may comprise bends or curves.

In a preferred embodiment of the invention, the channels are rectilinear. In an additional embodiment of the invention, the channels include a plurality of rectilinear portions connected to each other via U-bends. In this latter embodiment, the rectilinear portions are preferably stacked one above the other in a vertical direction. According to a different embodiment of the invention, the rectilinear portions are coplanar, more preferably in a plane parallel to the horizontal plane. According to a further embodiment, the channels are bended forming an arch, their longitudinal extension being preferably still perpendicular to the process air flow. This latter embodiment is used in particular to place the module of the dryer of the invention in the most suitable location within the process air conduit. Indeed, it is known that there are portions of the process air conduit in which the process air flow is more uniform and less turbulent. Heat exchange between the process air flow and the refrigerant is therefore optimal in these locations. An arched channel allows the positioning of the module also in locations in which other objects are present or narrow thus in general to better exploit the available space and/or to reduce the limitations given by a not even distribution of the air flow.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features and advantages of the present invention shall become clearer from the following detailed description of preferred embodiments thereof, made with reference to the attached drawings and given as an indication and not for limiting purposes.

In particular, the attached drawings are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification. The drawings together with the description serve to explain the principles of the invention. In the drawings, corresponding characteristics and/or components are identified by the same reference numbers. In such drawings:

- Fig. 1 is a schematic view, where some elements have been removed for clarity, of a laundry dryer according to the invention;

- Fig. 2 is a perspective view of a portion of an embodiment of the dryer of the invention of Fig. 1 with the casing removed;

- Fig. 3 is a perspective view in section of an element of the dryer of Fig. 1;

- Figs. 4a and 4b are schematic views, front view and top view respectively, of a first embodiment of a heat exchanger module of a dryer out of the scope of the present invention;

- Figs. 5a and 5b are schematic views, front view and top view respectively, of a second embodiment of a heat exchanger module of a dryer out of the scope of the present invention;

- Figs. 6a and 6b are schematic views, front view and top view respectively, of an embodiment of connection between two heat exchanger modules of Figs. 4a, 4b;

- Figs. 7a, 8a, 7b, 8b are schematic front views of a first, second, third, fourth embodiments, respectively, of a heat exchanger module of a dryer according to the present invention; and

- Fig. 9 is a schematic lateral cross section of a heat exchanger module used in the laundry dryer of the invention of Fig. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

With initial reference to Fig. 1, a laundry dryer realized according to the present invention is globally indicated with 1.

Laundry dryer 1 comprises an outer box casing 2, preferably but not necessarily parallelepiped-shaped, and a drying chamber, such as a drum 3, for example having the shape of a hollow cylinder, for housing the laundry and in general the clothes and garments to be dried. The drum 3 is preferably rotatably fixed to the casing, so that it can rotates around a preferably horizontal axis (in alternative embodiments, rotation axis may be vertical or tilted). Access to the drum 3 is achieved for example via a door, preferably hinged to casing 2, which can open and close an opening realized on the casing 2 itself.

More in detail, the casing 2 generally includes a front panel 20, a rear wall panel 21 and two sidewall panel all mounted on a basement 24. Panels 20, 21 and basement 24 can be of any suitable material. Preferably, the basement 24 is realized in plastic material. Preferably, the basement 24 is molded.

Preferably, the basement 24 includes an upper and a lower shell (in Fig. 2 only the lower shell 24a is visible).

The dryer 1 defines an horizontal plane (X’, Y’) which is substantially the plane of the ground on which the dryer 1 is situated, and a vertical direction Z’ perpendicular to the plane (X’, Y’).

Laundry dryer 1 also comprises an electrical motor assembly (not shown in the figures) for rotating, on command, revolving drum 3 along its axis inside the casing 2. Casing 2, revolving drum 3, door and motor are common parts in the technical field and are considered to be known; therefore they will not be described in details.

Dryer 1 additionally includes a process air circuit 4 which comprises the drum 3 and an air process conduit 11, schematically depicted in Fig. 1 as a plurality of arrows showing the path flow of a process air stream through the dryer 1. In the basement 24, air process conduit 11 includes an air duct 11a which is formed by the connection of the two upper and lower shells 24a. Air process conduit 11 is preferably connected with its opposite ends to two opposite sides of drum 3. Process air circuit 4 may also include a fan or blower 12 (see Fig. 1) and an electrical heater (not shown in the figures).

The air duct 11a can be integral with the basement 24 as depicted in Fig. 2, or it can be a different element attached to the same. Moreover, the air duct 11a can be located not only in the basement 24, but also in correspondence of a top or lateral part within the casing 2 of the laundry dryer 1.

The dryer 1 of the invention additionally comprises a heat pump 30 including a first heat exchanger called also condenser 31 and a second heat exchanger called also evaporator 32. Heat pump 30 also includes a refrigerant closed circuit (schematically depicted in the picture with lines connecting the first to the second heat exchanger and vice versa, see in detail Fig. 1) in which a refrigerant fluid flows, when the dryer 1 is in operation, cools off and may condense in correspondence of the condenser 31, releasing heat, and warms up, potentially even evaporating, in correspondence of the second heat exchanger (evaporator) 32, absorbing heat. Alternatively, no phase transition takes place in the condenser and/or evaporator, which indicates in this case respectively a gas heater and gas cooler, the refrigerant cools off or it warms up, respectively, without condensation or evaporation. In the following the heat exchangers are named either condenser and evaporator or first and second heat exchanger, respectively.

More in detail, the heat pump circuit connects via piping 35 (visible in Fig. 2) the second heat exchanger 32 where the refrigerant warms up and may undergo a phase transition from the liquid to the vapor via a compressor 33 to the first heat exchanger 31, in which the refrigerant cools off and may condense again. The cooled or condensed refrigerant arrives via an expansion device 34 (visible in Fig. 1), such as a choke, a valve or a capillary tube, back at the evaporator 32.

The condenser 31 and the evaporator 32 of the heat pump 30 are located at the process air conduit 11. More preferably, they are located at, even more preferably in, the air duct 11a, for example of basement 24, at least partially.

In case of a condense dryer – as depicted in Fig. 1 – where the air process circuit 4 is a closed loop circuit, the condenser 31 is located downstream of the evaporator 32. The air exiting the drum 3 enters the conduit 11 and reaches the evaporator 32 which cools down and dehumidifies the process air. The dehumidified cool process air continues to flow through the conduit 11 till it enters the condenser 31, where it is warmed up by the heat pump 30 before re-entering the drum 3.

A lint filter 103 (visible in Fig. 1) to block the lint is preferably present in the dryer 1. The lint filter 103 is preferably located before the process air reaches the evaporator 32, e. g., when it exits the drum 3.

First and/or second heat exchanger 31, 32 further include – according to a characteristic of the invention - one or more heat exchanger modules 10 located along the process air conduit 11. In particular, the first and the second heat exchangers 31 and 32 are located in the air duct 11a. Thus the preferred location of the air duct 11a within the casing 2 is a volume of the same where enough space is available to host the modules 10.

With now reference to Fig. 2, the basement 24 of a dryer 1 showing a plurality of modules 10 included in the evaporator 32 and in the condenser 31 of the heat pump 30 according to the invention is depicted. In the mentioned figures, the casing 2 and the drum 3 of the dryer 1 have been removed in order to show the heat exchangers located along the process air conduit 11, more specifically in air duct 11a. As stated above, although in the appended drawings both evaporator 32 and condenser 31 of the dryer 1 includes heat exchanger modules 10, it is to be understood that the evaporator 32 only or the condenser 31 only might include such module(s) 10. In addition, a single module 10 can be included in either evaporator 32 or condenser 31. Moreover, in case both evaporator and condenser include more than one module 10 according to the invention, the evaporator can include a different number of modules from the condenser (as per the appended Fig. 2 where the evaporator 32 includes two modules 10 and the condenser four modules 10). Preferably, the condenser 31 includes more modules than the evaporator 32. In case more than one module is included, the modules can be identical or different.

The air duct 11a in which the modules 10 are present can be in any location of the laundry dryer 1, depending on the layout of the same, and it can have any configuration, e.g. it can be straight, curved, realized integral to another portion of the casing 2 of the laundry dryer 1 or separated from the same; it may include further elements in addition to the modules 10 of the heat exchangers 31, 32 or it may be empty otherwise, etc. The air duct 11a has the function of a housing for the first and/or second heat exchanger 31, 32 and to direct the flow through the same. Preferably, the air duct 11a is air tight.

The structure of a single module 10 will be now be described, with reference to the different embodiments depicted in Figs. 3, 4a-4b, 5a-5b, 7a-7b, 8a-8b. In this regard, the embodiments depicted in Figs. 4a-4b and 5a-5b are out of the scope of the present invention.

A heat exchanger module 10 includes a first tube or pipe 5 and a second tube or pipe 6. The tubes have a longitudinal extension along an axis, which corresponds to the main direction of flow of the refrigerant within the headers. The refrigerant is flowing into the module 10 via one of the tubes 5,6 and exiting the same via either the same tube or a different one 5,6. A plurality of channels, each indicated with 7, fluidly connects the first and second tube and vice versa, so that the refrigerant can enter and exit the module. The plurality of channels is subject to the flow of process air, i.e. channels 7 are located within the air duct 11a of the dryer 1. The channels 7, due to their configuration, allow a better heat exchange between the refrigerant and the process air than known dryers.

Channel 7 defines a longitudinal direction X along which it extends, which corresponds to the longitudinal extension of the heat exchange layer 8. Preferably, the channels 7 are mounted in the module 10 so that their longitudinal extension X is substantially perpendicular to a process air flow direction and substantially parallel to the horizontal plane. In other words preferably, when mounted, the longitudinal direction X lies on a plane parallel to the plane (X', Y') defined by the dryer 1.

Preferably, the refrigerant flow within channels 7 is substantially perpendicular to the process air flow. However, depending on the direction of the process air flow, the direction of the process air stream and the direction of the refrigerant flow can form an angle therebetween.

The channels 7 are grouped in heat exchange layers 8: each heat exchange layer includes a plurality of channels 7 which are preferably adjacent and parallel to each other. More preferably, each module 10 includes a plurality of heat exchange layers 8, more preferably all heat exchange layers 8 are stacked one above the other in a stacking direction Z and even more preferably parallel to each other, substantially forming a plurality of parallel rows. Preferably the stacking direction is the vertical direction, i.e. Z and Z' are parallel to each other.

According to an embodiment of the invention, heat exchange layer 8 includes a single tube, having for example an elongated cross section, including two substantially parallel flat surfaces 9a, 9b. Within the tube, separators 8a are realized in order to longitudinally divide the interior of the tube in the plurality of channels 7. Such a structure is schematically depicted in the cross section of a heat exchange layer 8 of Fig. 9. The cross section of the single channel 7 can be arbitrary. Each heat exchange layer 8 has a width W which depends on the number of channels which are located one adjacent to the other (see Fig. 4b and 5b).

Preferably, each couple of adjacent stacked heat exchange layers 8 is connected via finnings 50. Preferably the upper surface 9a of a heat exchange layer 8 is connected via the plurality of finnings 50 to the lower surface 9b of the adjacent heat exchange layer 8.

The width W of the layer 8 defines a direction Y which, together with the longitudinal direction X of channels 7 defines a heat exchange layer plane (X, Y). The heat exchange layer plane (X, Y) might be, when the module is mounted on the dryer, either parallel to the horizontal plane (X', Y') defined by the dryer 1 or tilted with respect to the same. Alternatively or in addition, the heat exchange layer plane (X, Y) can be perpendicular to the stacking direction Z or form an angle with the same. Moreover, each heat exchange layer 8 can also be not planar, but for example curved, e.g. having a concavity pointing either up or down along the stacking direction.

As an example, in Fig. 3 a section of a tube 5, 6 is represented. The tube 5, 6 includes a cylindrical envelope 107 in which a plurality of apertures 7a are realized, the plurality of channels 7 forming a heat exchange layer 8 being inserted therein. However different configurations are possible, as better detailed below.

The cross section of the tubes 5, 6 can be circular or preferably oblong. The cross section of the tubes 5, 6 refers to the cross section of the header along a plane perpendicular to the stacking direction Z. Preferably, the oblong cross section is such that its smallest diameter, i.e. the smallest cord passing through the geometrical center of the cross section, is smaller than the width W of the heat exchange layer 8. In this way, the cross section includes a “long side” on which the end of the heat exchange layer 8 can attach, and which has to have at least a width equal to (or wider than) W, and a “shorter side” realized in order to minimize space, and also in order to save some refrigerant (the refrigerant is indeed relatively expensive and it is preferred to minimize the same for a given heat exchange capacity). For example, the cross section of the tubes 5, 6 can be an oval or a rectangle. However, a single module 10 may also include a tube 5, 6 having a given cross section and the other tube 5, 6 having a different cross section.

The refrigerant enters the module 10 via an inlet header. The inlet header is part of tubes 5, 6. Additionally, the refrigerant exits the module 10 via an outlet header, which is also part of the tubes 5, 6. Inlet and outlet hader will be better detailed below. The refrigerant entering the module via the inlet header can come from the outlet header of another module 10, from the compressor 33 or from the expansion device 34. Additionally, the refrigerant exiting the outlet header may be directed towards the inlet header of another module 10, towards the expansion device 34 or towards the compressor 33. The connection between the compressor 33, modules 10 and expansion device 34 and between modules is made via piping 35, as it can be seen in Fig. 2. In the following figures, the flow of the refrigerant R will be indicated with a dotted line having a pointing arrow in the direction of the flow.

Each of the heat exchange layers 8 includes two opposite ends 8b, 8c. In some embodiments, one end 8b is connected to the inlet header and the opposite end 8c is connected to the outlet header (see Figs. 4a-4b and 6a-6b). Alternatively, an additional return header can be present (see Figs. 5a-5b, 7a-7b and 8a-8b), as detailed below.

According to the embodiment of the module 10 of the dryer 1 depicted in Figs. 4a and 4b (which is out of the scope of the present invention), the two tubes coincides with the inlet and outlet headers 5, 6. They are mounted vertically (i.e. their axis Z is the vertical axis Z' of the dryer 1) on the basement 24 of the dryer 1, parallel one to the other, and the channels 7 connecting the two headers 5, 6 are substantially straight along the longitudinal direction X. Channels 7 are divided in heat exchange layers 8, each of which includes a different tube defining upper and lower surfaces 9a, 9b (see Fig. 9) within which the channels 7 are realized. A plurality of heat exchange layers 8 connects the inlet header 5 to the outlet header 6, all layers 8 having a first end 8b and a second end 8c longitudinally opposite to each other, the first end 8b being connected to the inlet header 5 and the second end 8c being connected to the outlet header 6. Heat exchange layers are stacked one above the other along the vertical direction forming a plane (Z, X) defined by the longitudinal extension X of the channels 7 and the stacking direction Z. This plane is perpendicular to the horizontal plane (X', Y') and to direction of flow of process air as clear from Figs. 4a, 4b (the process air is depicted as an arrow in Figs. 4b and 5b). In addition, each heat exchange layer has a width direction Y perpendicular to the longitudinal extension X of the channels 7. In the present embodiment, this width direction Y is parallel to the horizontal plane (X', Y') and the air flow direction, i.e. the layer planes (X, Y) are horizontal (parallel to the horizontal plane (X', Y')). In other words, the module 10 is mounted so that the heat exchange layers 8 form parallel planes between which the process air flows. In each header 5, 6, at each end 8b, 8c of the heat exchange layers 8, a plurality of apertures 7a is realized, in each aperture 7a the heat exchange layer 8 with the respective plurality of channels 7 being inserted. The so-formed rows of apertures 7a (see Fig. 3) are parallel one to the other and perpendicular to the longitudinal extension Z of the header 5, 6.

The refrigerant enters the inlet header 5 of module 10 via an inlet aperture 5in along a flow direction parallel to the longitudinal extension Z of header 5 and branches off into the various channels 7 via apertures 7a (see Fig. 3). The heat exchange layers 8 are "parallel" to each other according to the refrigerant flow direction. In each channel 7, the flow of the refrigerant is substantially parallel to the flow direction of the refrigerant in the other channels 7 and has the same direction. The refrigerant then exits the module via an outlet aperture 6out of outlet header 6.

The direction of flow of refrigerant in the headers 5, 6 is perpendicular to the process air flow. In addition, the flow of the refrigerant in the inlet header 5 is parallel to the flow of the refrigerant in the outlet header 6, but with opposite direction.

In a different embodiment, not depicted, the refrigerant flow in the inlet header and in the outlet header can also be parallel and have the same direction.

According to the embodiment of the module 10 of the dryer 1 depicted in Figs. 5a and 5b (which is out of the scope of the present invention), the tubes 5,6 are vertically mounted as in the embodiment above, but one of the two tube, in this case the first tube 5, includes a transversal separator 17 which divides it in two separated portions or sections. In other words, there are still two parallel vertical tubes connected by parallel heat exchange layers 8, but one of the tubes is divided in two and the first portion represents the inlet header 5a, while the second portion is the outlet header 66a. The second tube has the function of ar return header for the refrigerant flow, as detailed below. The flow of refrigerant entering the first tube 5 via the the inlet header 5a is therefore prevented by separator 17 to go from the inlet to the outlet header directly. The flow of refrigerant has therefore to traverse a first group of heat exchange layers 8 in order to reach return header 6, which in this case corresponds to the second tube 6, The heat exchange layers 8 are thus divided in two groups G1, G2: the first group G1 connects the first section of first tube 5 (the inlet header 5a) to the return header or second tube 6 and the second group G2 connects the return header 6 to the second section of first tube or outlet header 66a.

The refrigerant flow which enters the first section (the inlet header 5a) in a vertical Z direction is distributed via apertures 7a into the first group G1 of heat exchange layers 8 and the refrigerant flows within the parallel channels 7 of the first group G1 towards the return header 6. Therefore, the heat exchange layers 8 within the first group G1 are parallel with respect to the refrigerant flow. The refrigerant streams exit the first group G1 of heat exchange layers 8 and enter the return header 6, where they merge. From the return header 6, the refrigerant flow then enters the second group G2 of heat exchange layers 8 reaching the outlet header 66a. Thus, also the heat exchange layers 8 within the second group G2 are parallel to each other with respect to the refrigerant flow. However the layers 8 of the two groups G1, G2 are in series with respect to the refrigerant flow. Indeed, the refrigerant flows in parallel in all layers belonging to the same group, while it has to flow through the layers of first and the second group in a given order – the layers of the two groups being thus in series.

The connection between modules can be made as follows. Referring to Figs. 6a and 6b, a first and a second module 10, 10' are connected to each other. The modules 10, 10' are realized according to the example of figs. 4a and 4b. These two modules can for example both belong to the condenser 31. The two modules are realized parallel one to the other and one in front of the other in the direction of flow of the process air (the process air is depicted as an arrow in Fig. 6b), both substantially perpendicular to the horizontal plane. Both modules have heat exchange layers 8, 8' which are parallel to the horizontal plane. The refrigerant flow enters the inlet header 5 of the first module 10, it divides within the plurality of channels 7 and the various streams merges in the outlet header 6. The refrigerant exits the first module 10 via the outlet header 6, thus entering the inlet header 5' of the second module 10'. In the second module 10', again the refrigerant flow travels through the plurality of channels 7' and exits the second module via the outlet header 6' of the second module 10'. In this case, therefore, the modules 10, 10' are in series with respect to the process air flow and in series with respect to the refrigerant flow.

Alternatively, many other different connections can be realized.

With now reference to Figs. 7a, 7b, 8a and 8b, a first, second, third and fourth embodiments, respectively, of a heat exchanger module 10 of the dryer 1 according to the present invention are described. In Figs. 8a and 8b, corresponding characteristics and/or components are identified by the same reference numbers. For the sake of conciseness, the Applicants refer to the above description for the components of Fig. 7a, 7b, 8a, 8b having the same reference numbers of those of preceding figures.

According to the first embodiment shown in Fig. 7a, the heat exchanger module 10 comprises the first tube 5 having two sections 5a and 5b which defines two inlet headers, wherein each of said header sections 5a and 5b directs a refrigerant flow to a respective group G1a, G1b of heat exchange layers 8 of the module 10. The inlet header sections 5a and 5b of the tube 5 are fed by respective inlet connection pipes 15a and 15b.

The exchange layers 8 are stacked one above the other in the stacking direction Z, and preferably they are parallel to each other, substantially forming a plurality of parallel rows.

Furthermore, the first tube 5 of the heat exchanger module 10 comprises an additional section which is the outlet header 66a. The outlet header 66a discharges the refrigerant flow by an outlet connection pipe 16.

The inlet and outlet headers 5a, 6, 5b are overlapped one above the other along the stacking direction Z. In particular, the two inlet header sections 5a and 5b are located at opposite sides of the single outlet header section 66a along the stacking direction Z. Preferably, the two inlet header sections 5a, 5b are separated from the outlet header section 66a by transversal walls 17a and 17b, at the opposite sides of the outlet header 66a.

Each of the heat exchange layers 8 includes a first and a second opposite ends 8b and 8c, the first end 8b being connected to the inlet or the outlet header sections 5a, 5b, 66a and the second end 8c being connected to the second tube 6.

The second tube 6 comprises two sections 70a and 70b, and each of said two sections 70a, 70b is connected to the second ends 8c of heat exchange layers 8 whose first ends belong to a respective one of the two inlet header sections 5a, 5b or to the single section of the outlet header 66a.

The two sections 70a, 70b of the second tube 6 are overlapped one above the other along the stacking direction Z. In particular, the two sections 70a, 70b are separated by a transversal wall 70c.

The two sections 70a, 70b of the second tube 6 respectively receives the refrigerant flows coming from the two inlet header sections 5a, 5b of the first tube 5, i.e. the refrigerant flows of the two groups G1a, G1b of heat exchange layers 8 of the module 10.

The sections 70a and 70b defines two return headers because the flow that is received from the inlet headers is “re-sent” to the first tube 5.

The single section of the outlet header 66a receives a refrigerant flow from a respective group G2a, G2b of heat exchange layers 8 of the module 10, wherein the group G2a of heat exchange layers 8 connects the section 70a of the second tube 6 the outlet header 66a, while the group G2b of heat exchange layers 8 connects the section 70b to the outlet header 66a.

In other words, the heat exchange layers 8 of the module 10 are thus divided in four groups G1a, G1b, G2a, G2b: the groups G1a, G1b respectively connect the two inlet header sections 5a, 5b of the first tube 5 to the two return header sections 70a, 70b of the second tube 6 , and the groups G2a, G2b respectively connect the two return header sections 70a, 70b of the second tube 6 to the outlet header 6.

The refrigerant flow which enters the two inlet header sections 5a, 5b of first tube 5 is respectively distributed into the groups G1a, G1b of heat exchange layers 8 and the refrigerant flows within the channels 7 of the heat exchange layers 8 of the groups G1a, G1b towards the two return header sections 70a, 70b of the second tube 6. The refrigerant flows exit the groups G1a, G1b of the heat exchange layers 8 and respectively enter the two return header sections 70a, 70b, where they merge. From the two return header sections 70a, 70b, the refrigerant flows then respectively enter the groups G2a, G2b of the heat exchange layers 8 reaching the outlet header 66a, part of the first tube 5. The heat exchange layers 8 of the groups G1a and G2a, as well as of the groups G1b and G2b, are in series with respect to the refrigerant flow. Indeed, the refrigerant flows in parallel in all layers 8 belonging to the same group, while it has to flow through the layers 8 of the groups G1a and G2a (as well as through the layers 8 of the groups G1b and G2b) in a given order – the layers 8 of the two groups G1a and G2a (as well as the two groups G1b and G2b) being thus in series.

In the first embodiment shown in Fig. 7a, the inlet and outlet headers 5a, 5b, 66a are arranged symmetrically with respect to a middle plane S of the module 10, wherein the middle plane S is perpendicular to the stacking direction Z. In particular, the two inlet header sections 5a, 5b are connected to two groups G1a, G1b having the same number of heat exchange layers 8 (three in the not-limiting example of Fig. 7a).

With now reference to Fig. 7b, a second embodiment of a heat exchanger module 10 of the dryer 1 according to the present invention is described. This second embodiment differs from the first embodiment shown in Fig. 7a substantially only in that the inlet and outlet headers 5a, 5b, 66a are arranged asymmetrically with respect to a middle plane S of the module 10, wherein the middle plane S is perpendicular to the stacking direction Z. In particular, the two inlet header sections 5a, 5b of first tube 5 are connected to two groups G1a, G1b having different numbers of heat exchange layers 8 (respectively three and two in the not-limiting example of Fig. 7b).

In Figs. 7a and 7b, corresponding characteristics and/or components are identified by the same reference numbers. For the sake of conciseness, the Applicants refer to the above description of Fig. 7a for the components of Fig. 7b having the same reference numbers of those of Fig. 7a.

With now reference to Fig. 8a, a third embodiment of a heat exchanger module 10 of the dryer 1 according to the present invention is described.

According to the third embodiment shown in Fig. 8a, the heat exchanger module 10 comprises the first tube 5 having two inlet header sections 5a and 5b, wherein each of said inlet header sections 5a and 5b directs a refrigerant flow to a respective group G1a, G1b of heat exchange layers 8 of the module 10. The inlet header sections 5a and 5b of the first tube 5 are fed by respective inlet connection pipes 15a and 15b.

The exchange layers 8 are stacked one above the other in the stacking direction Z, and preferably they are parallel to each other, substantially forming a plurality of parallel rows.

Furthermore, the first tube 5 of the heat exchanger module 10 comprises two outlet header sections 66a and 66b, wherein each of said outlet header sections 66a and 66b discharges a refrigerant flow from a respective group G2a, G2b of heat exchange layers 8 of the module 10. The outlet header sections 66a and 66b of the first tube 5 discharge the refrigerant flow by respective outlet connection pipes 166a and 166b.

The inlet and outlet headers 5a, 5b, 66a, 66b are overlapped one above the other along the stacking direction Z.

In particular, the two inlet header sections 5a, 5b and the two outlet header sections 66a, 66b are alternate each other along the stacking direction Z. In the not-limiting example of Fig. 8a, the series of outlet/inlet header sections is, starting from the top of Fig. 8a: 66a, 5a, 66b, 5b.

Of course, the outlet/inlet header sections 66a, 5a, 66b, 5b are adjacent each others in the stacking direction Z. Preferably, the two inlet header sections 5a, 5b are separated from the two outlet header sections 66a, 66b by transversal walls 17a, 17b and 17c. In the not-limiting example of Fig. 8a, the series of transversal walls is: 17a, 17b, 17c (respectively between the header sections 66a and 5a, 5a and 66b, 66b and 5b).

Each of the heat exchange layers 8 includes a first and a second opposite ends 8b and 8c, the first end 8b being connected to the inlet or the outlet header 5a, 5b, 66a, 66b and the second end 8c being connected to the second tube 6.

The second tube 6 comprises two sections 70a and 70b, and each of said two return header sections 70a, 70b is connected to the second ends 8c of heat exchange layers 8 whose first ends belong to a respective one of the two inlet header sections 5a, 5b or to a respective one of the two outlet header sections 66a, 66b.

The two sections 70a, 70b of the second tube 6 are overlapped one above the other along the stacking direction Z. In particular, the two sections 70a, 70b are separated by a transversal wall 70c. In the not-limiting example of Fig. 8a, the section 70a is arranged above the section 70b.

The two return header sections 70a, 70b respectively receives the refrigerant flows coming from the two inlet header sections 5a, 5b i.e. the refrigerant flows of the two groups G1a, G1b of heat exchange layers 8 of the module 10.

Each of the two outlet header sections 66a, 66b receives a refrigerant flow from a respective group G2a, G2b of heat exchange layers 8 of the module 10, wherein the group G2a of heat exchange layers 8 connects the return header section 70a to the outlet header section 66a of the firt tube 5, while the group G2b of heat exchange layers 8 connects the return header section 70b to the outlet header section 66b.

In other words, the heat exchange layers 8 of the module 10 are thus divided in four groups G1a, G1b, G2a, G2b: the groups G1a, G1b respectively connect the two inlet header sections 5a, 5b of the first tube 5 to the two return header sections 70a, 70b of the second tube 6, and the groups G2a, G2b respectively connect the two return header sections 70a, 70b of the second tube 6 to the two outlet header sections 66a, 66b of the first tube 5.

The refrigerant flow which enters the two inlet header sections 5a, 5b of first tube 5 is respectively distributed into the groups G1a, G1b of heat exchange layers 8 and the refrigerant flows within the channels 7 of the heat exchange layers 8 of the groups G1a, G1b towards the two return header sections 70a, 70b of the second tube 6. The refrigerant flows exit the groups G1a, G1b of the heat exchange layers 8 and respectively enter the two return header sections 70a, 70b, where they merge. From the two sections 70a, 70b of the intermediate header 70, the refrigerant flows then respectively enter the groups G2a, G2b of the heat exchange layers 8 reaching the two outlet header sections 66a, 66b of the first tube 5. The heat exchange layers 8 of the groups G1a and G2a, as well as of the groups G1b and G2b, are in series with respect to the refrigerant flow. Indeed, the refrigerant flows in parallel in all layers 8 belonging to the same group, while it has to flow through the layers 8 of the groups G1a and G2a (as well as through the layers 8 of the groups G1b and G2b) in a given order – the layers 8 of the two groups G1a and G2a (as well as the two groups G1b and G2b) being thus in series.

In the third embodiment shown in Fig. 8a, the inlet and outlet headers 5a, 5b 66a, 66b are arranged symmetrically with respect to a middle plane S of the module 10, wherein the middle plane S is perpendicular to the stacking direction Z. In particular, the inlet header section 5a and the outlet header section 66b are connected to two groups G1a, G2b having the same number of heat exchange layers 8 (two in the not-limiting example of Fig. 8a), and the outlet header section 66a and the inlet header section 5b are connected to two groups G2a, G1b having the same number of heat exchange layers 8 (three in the not-limiting example of Fig. 8a).

With now reference to Fig. 8b, a fourth embodiment of a heat exchanger module 10 of the dryer 1 according to the present invention is described. This fourth embodiment differs from the third embodiment shown in Fig. 8a substantially only in that the inlet and outlet headers 5a, 5b, 66a, 66b are arranged asymmetrically with respect to a middle plane S of the module 10, wherein the middle plane S is perpendicular to the stacking direction Z. In particular, the inlet header section 5a and the outlet header section 66b are connected to two groups G1a, G2b having different numbers of heat exchange layers 8 (respectively four and one in the not-limiting example of Fig. 8b), and the outlet header section 66a and the inlet header section 5b are connected to two groups G2a, G1b having different numbers of heat exchange layers 8 (respectively three and two in the not-limiting example of Fig. 8b).

The group G2b shown in the not-limiting example of Fig. 8b comprises one single heat exchange layer 8. Therefore, in the present detailed description, the word "group" includes the limit case wherein only one element (i.e. only one heat exchange layer) belongs to the group itself.

In Figs. 8a and 8b, corresponding characteristics and/or components are identified by the same reference numbers. For the sake of conciseness, the Applicants refer to the above description of Fig. 8a for the components of Fig. 8b having the same reference numbers of those of Fig. 8a.

Preferably, the heat exchange layers 8 of the module 10 of Figs. 7a, 7b, 8a, 8b are arranged one parallel to the others and are spaced apart each others by finnings 50.

Preferably, the first and/or second heat exchanger 31, 32 of the dryer 1 according to the invention includes at least one first and at least one second heat exchanger module 10 of Figs. 7a, 7b, 8a, 8b and the outlet header 66a,66b of the first heat exchanger module 10 is connected to the inlet header 5a,5b of the second heat exchanger module 10.

In other words, the connection between modules 10 of Figs. 7a, 7b, 8a, 8b can be made in an analogous manner of that depicted in Figs. 6a, 6b for the module 10 of Figs. 4a, 4b.

Indeed the connection between the modules of the invention can be made in an analogue manner as in figs. 6a and 6b, where an outlet of a first module is connected to an inlet of the subsequent module.

Although illustrative embodiments of the present invention have been described herein with reference to the attached drawings, it is to be understood that the present invention is not limited to the specific embodiment illustrated and described herein, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the following claims.

CLAIMS

1. A laundry dryer (1) comprising:

- a casing (2) supporting a drying chamber (3) for receiving a load to be dried;

- a process air conduit (11) in communication with the drying chamber (3) where a process air stream is apt to flow and including an air duct (11a); and

- a heat pump (30) having a heat pump circuit in which a refrigerant (R) can flow, said heat pump circuit including a first heat exchanger (31) where the refrigerant is cooled off and the process air stream is heated up, and a second heat exchanger (32) where the refrigerant is heated up and the process air is cooled off; said first and/or second heat exchanger being thermally coupled to the process air conduit (11) to perform heat exchange between said refrigerant flowing in said heat pump circuit and said process air stream; said first and/or second heat exchanger (31; 32) further comprising at least one heat exchanger module (10), said module including

- an inlet header (5a; 5b) to direct a flow of said refrigerant into said module (10) and at least two outlet headers (66a, 66b), fluidly separated from each other, each of which is apt to discharge a flow of said refrigerant from said module (10); or at least two inlet headers (5a, 5b), fluidly separated from each other, each of which is apt to direct a flow of said refrigerant into said module (10) and an outlet header (66a; 66b) to discharge a flow of said refrigerant from said module; and

- a plurality of heat exchange layers (8) fluidly connecting said inlet(s) (5a; 5b) to said outlet header(s) (6a; 6b) to enable said refrigerant (R) to flow from said inlet(s) to said outlet header(s) and/or vice versa; said layers (8) being stacked one above the other(s) in a stacking direction (Z) and each heat exchange layer including a plurality of channels (7).

2. Laundry dryer (1) according to claim 1, wherein each of said inlet and/or outlet header (5a, 5b; 66a, 66b) directs and/or discharges a flow of said refrigerant (R) to a respective group (G1a, G1b; G2a, G2b) of said heat exchange layers (8) of said module (10).

3. Laundry dryer (1) according to claim 2, wherein said heat exchange layers (8) of said group (G1a, G1b; G2a, G2b) are adjacent in said stacking direction (Z).

4. Laundry dryer (1) according to any of the preceding claims, wherein one of said inlet and one of said outlet headers (5a; 5b; 66a;66b) are positioned one above the other along said stacking direction (Z), and each of said heat exchange layers (8) includes a first and

a second opposite ends (8b, 8c), said first end (8b) being connected to one of said inlet or said outlet header(s) (5a; 5b; 66a; 66b).

5. Laundry dryer (1) according to any of the preceding claims, wherein said module (10) includes a first and a second tube (5, 6) and each of said heat exchange layers (8) including a first end (8b) connected to said first tube (5) and a second end (8c) connected to said second tube (6), said first and or second tube (5,6) being divided in sections, said sections defining either said two inlet headers (5a; 5b) and said one outlet header (66a; 66b) or said two outlet headers (66a; 66b) and said inlet header (5a; 5b).

6. Laundry dryer (1) according to claim 5, wherein said first or said second tube is divided in at least three sections (5a, 5b; 66a, 66b) by separators defining either said two inlet headers (5a; 5b) and said one outlet header (66a; 66b) or said two outlet headers (66a; 66b) and said inlet header (5a; 5b), said inlet and outlet header(s) being located alternately one after the other(s). 6. Laundry dryer (1) according to claim 4 or 5, wherein said first and or second tube includes one or more section defining one or more return headers (70a,70b), and each of said return headers (70a, 70b) is connected to one of a first or second ends (8b, 8c) of said heat exchange layers (8) whose other of said first or second ends (8b,8c) is connected to said inlet or outlet headers (5a, 5b; 66a, 66b) .

7. Laundry dryer (1) according to any of the preceding claims, wherein said inlet and outlet headers (5a, 5b; 66a, 66b) are stacked one above the other(s) in said stacking direction (Z).

8. Laundry dryer (1) according to any of claims from 4 to 7, wherein one tube (5) of the two includes sections (5a, 5b; 66a, 66b) defining inlet and outlet headers only and the other tube (6) of the two includes sections defining return headers only (70a,70b).

9. Laundry dryer (1) according to any of the preceding claims, wherein said inlet and outlet headers (5; 6) are arranged symmetrically with respect to a middle plane (S) of said module (10), said middle plane (S) being perpendicular to said stacking direction (Z).

10. Laundry dryer (1) according to any of claims 1 to 8, wherein said inlet and outlet headers (5; 6) are arranged asymmetrically with respect to a middle plane (S) of said module (10), said middle plane (S) being perpendicular to said stacking direction (Z).

11. Laundry dryer (1) according to any of the preceding claims, wherein said channels (7) of each heat exchange layer (8) are arranged one parallel to the others.

12. Laundry dryer (1) according to any of the preceding claims, wherein said heat

exchange layers (8) of said module (10) are arranged one parallel to the others and are spaced apart each others by finnings (50).

13. Laundry dryer (1) according to any of the preceding claims, wherein said first heat exchanger (31) includes more heat exchanger modules (10) than said second heat exchanger (32).

14. Laundry dryer (1) according to one or more of the preceding claims, wherein said first and/or said second heat exchanger (31; 32) includes at least two of said heat exchanger modules (10).

15. Laundry dryer (1) according to claim 13, wherein said first and/or second heat exchanger (31; 32) includes at least one first and at least one second heat exchanger module (10) and one of the outlet header(s) (66a; 66b) of said at least one first heat exchanger module (10) is connected to one of the inlet header(s) (5a; 5b) of said at least one second heat exchanger module (10).

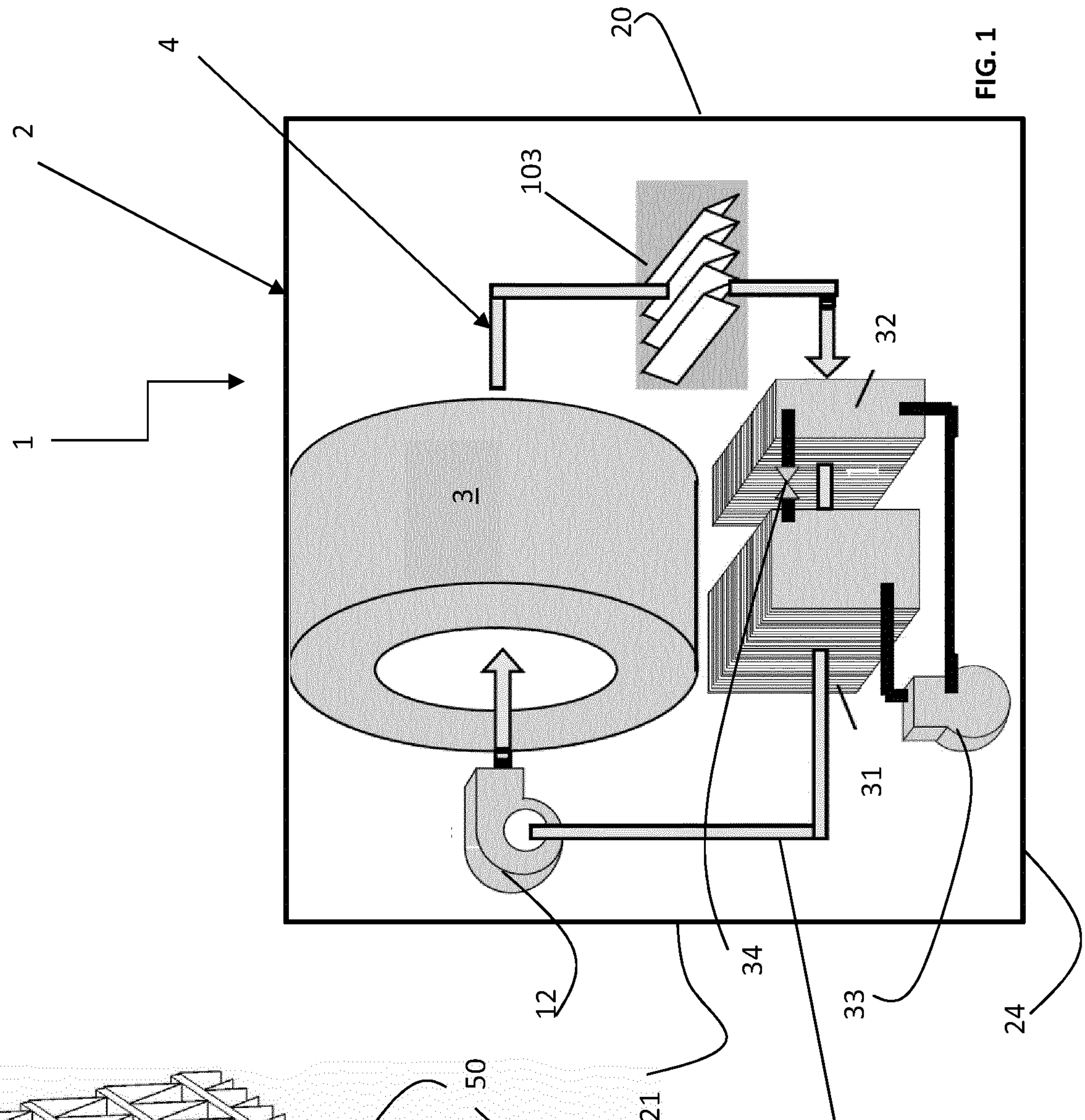


FIG. 1

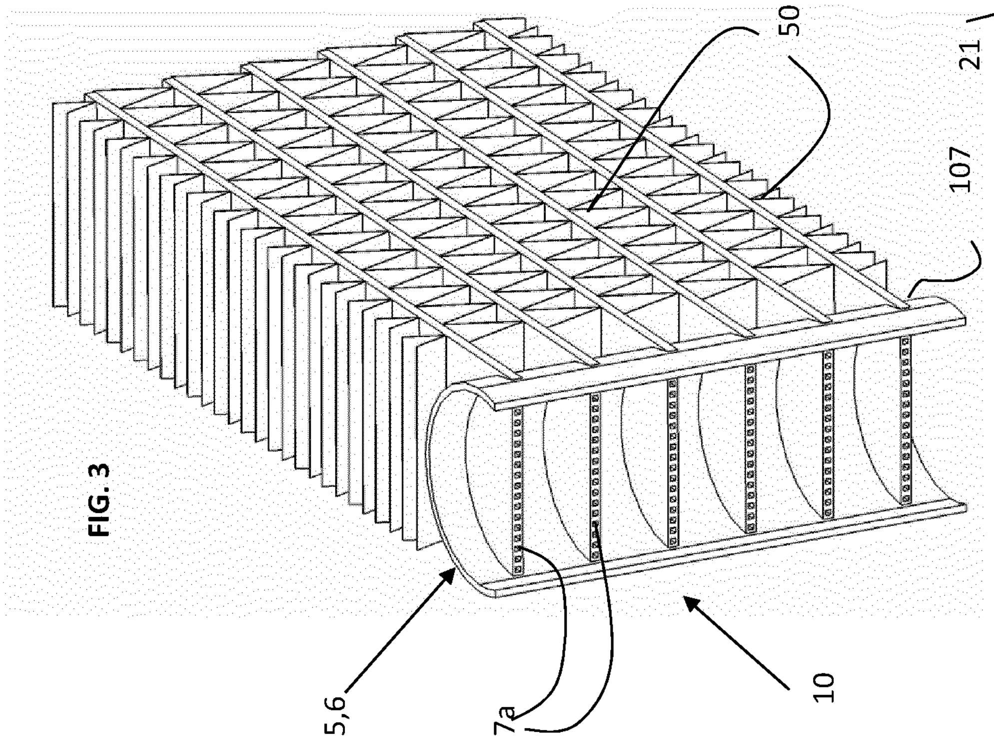


FIG. 3

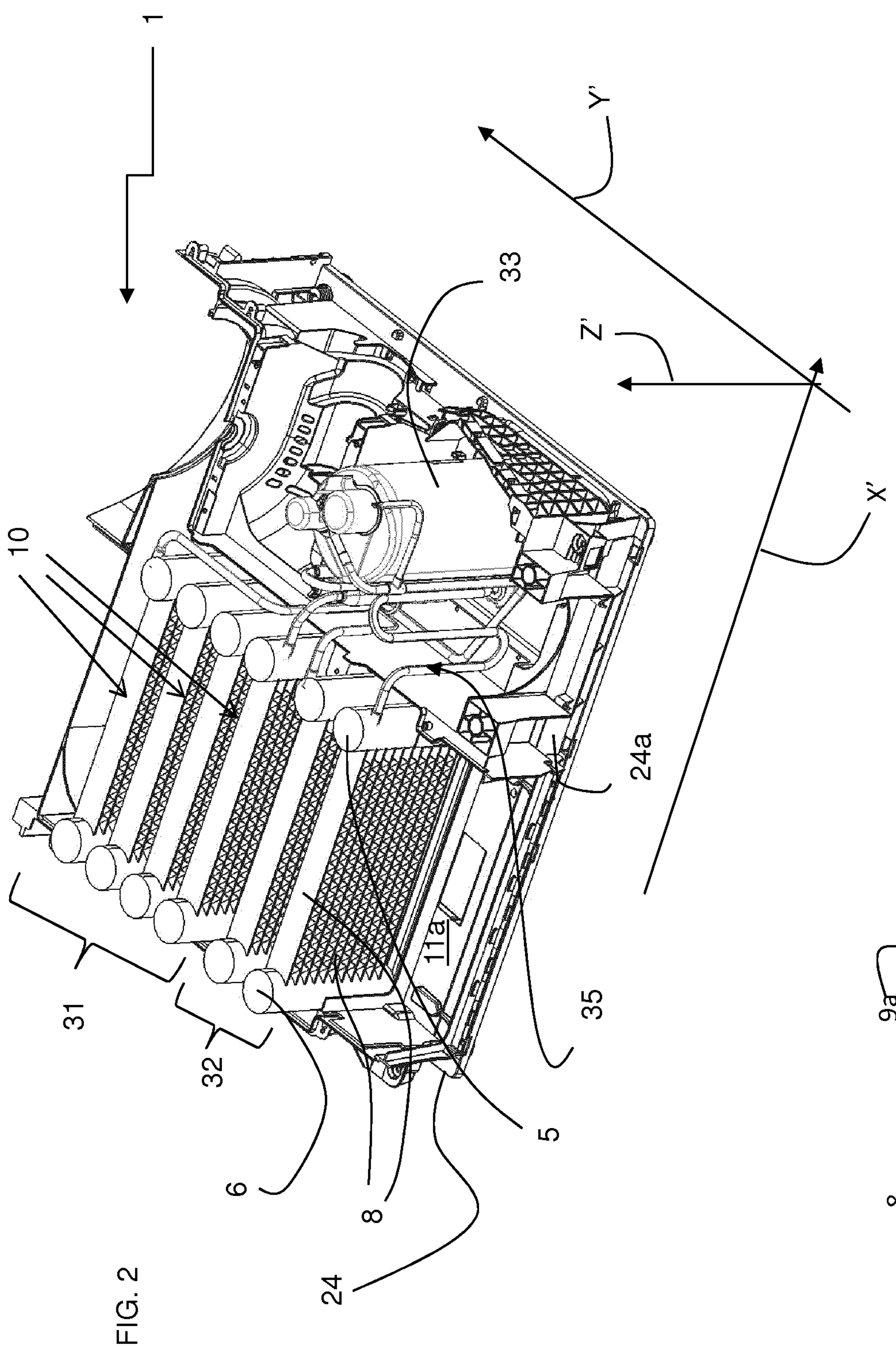


FIG. 2

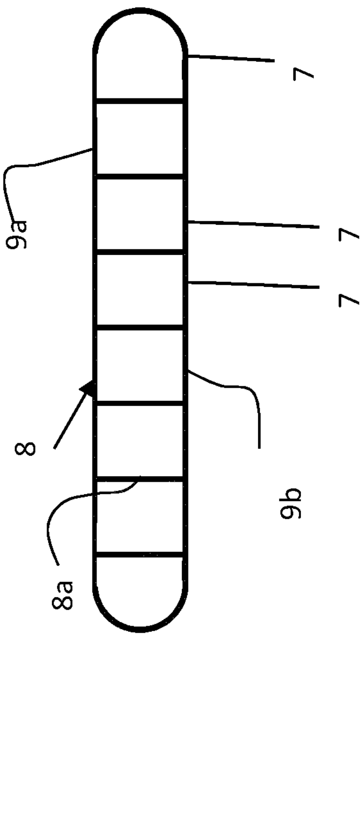


FIG. 9

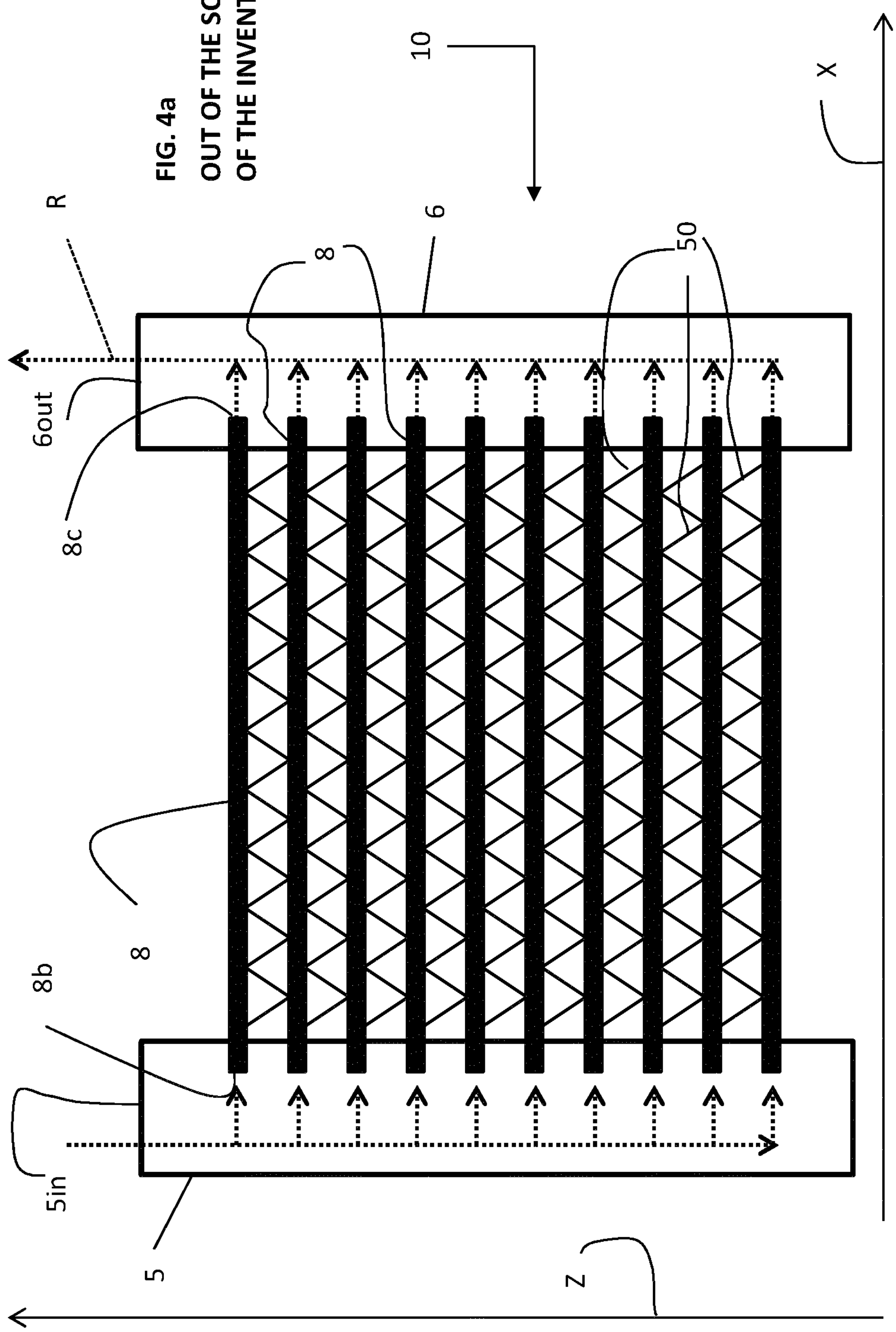


FIG. 4a

OUT OF THE SCOPE OF THE INVENTION

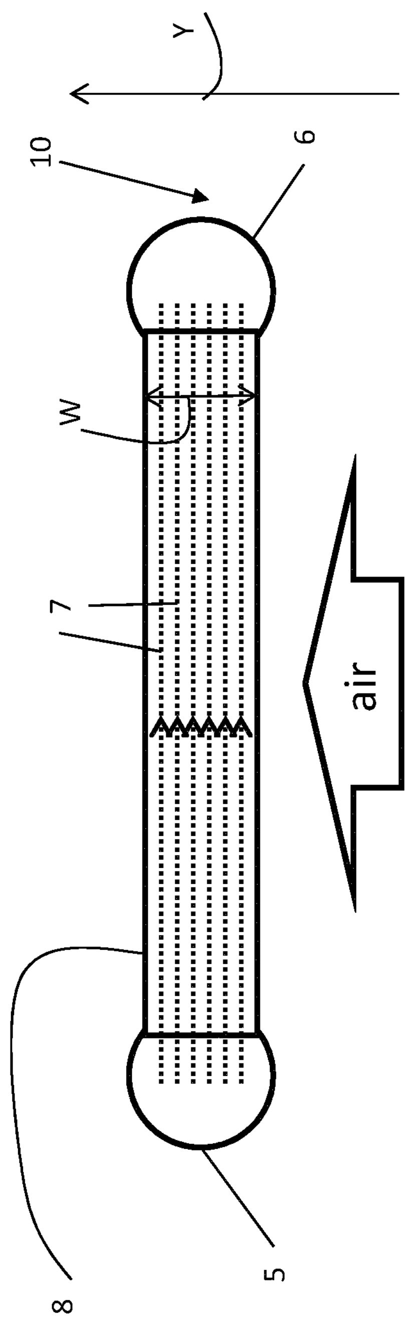


FIG. 4b

OUT OF THE SCOPE OF THE INVENTION

FIG. 5a

OUT OF THE SCOPE OF THE INVENTION

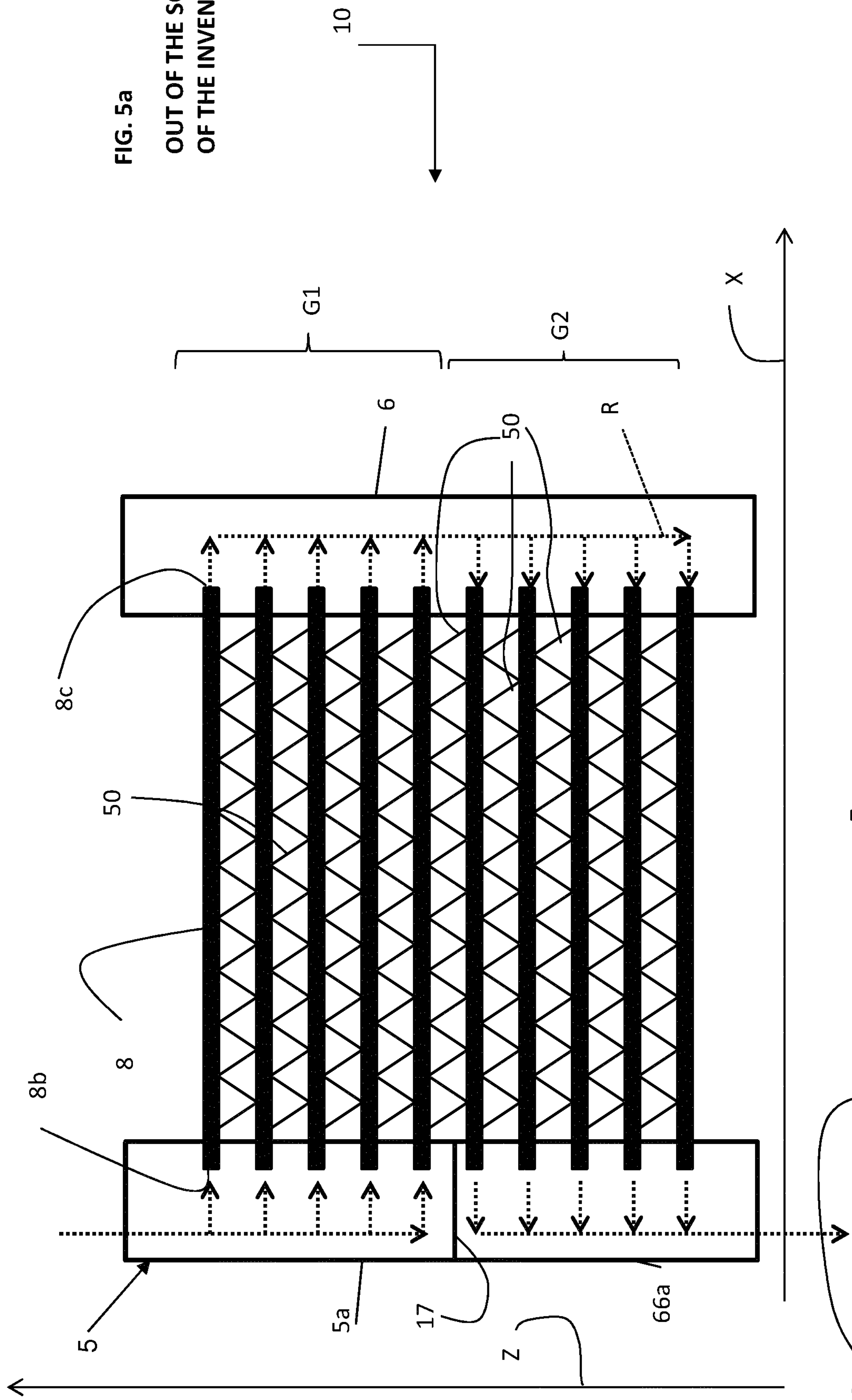
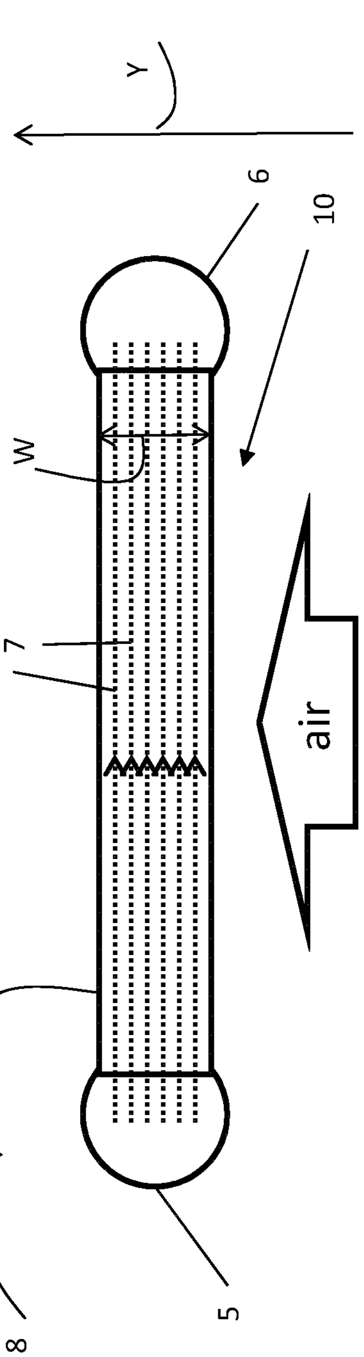


FIG. 5b

OUT OF THE SCOPE OF THE INVENTION



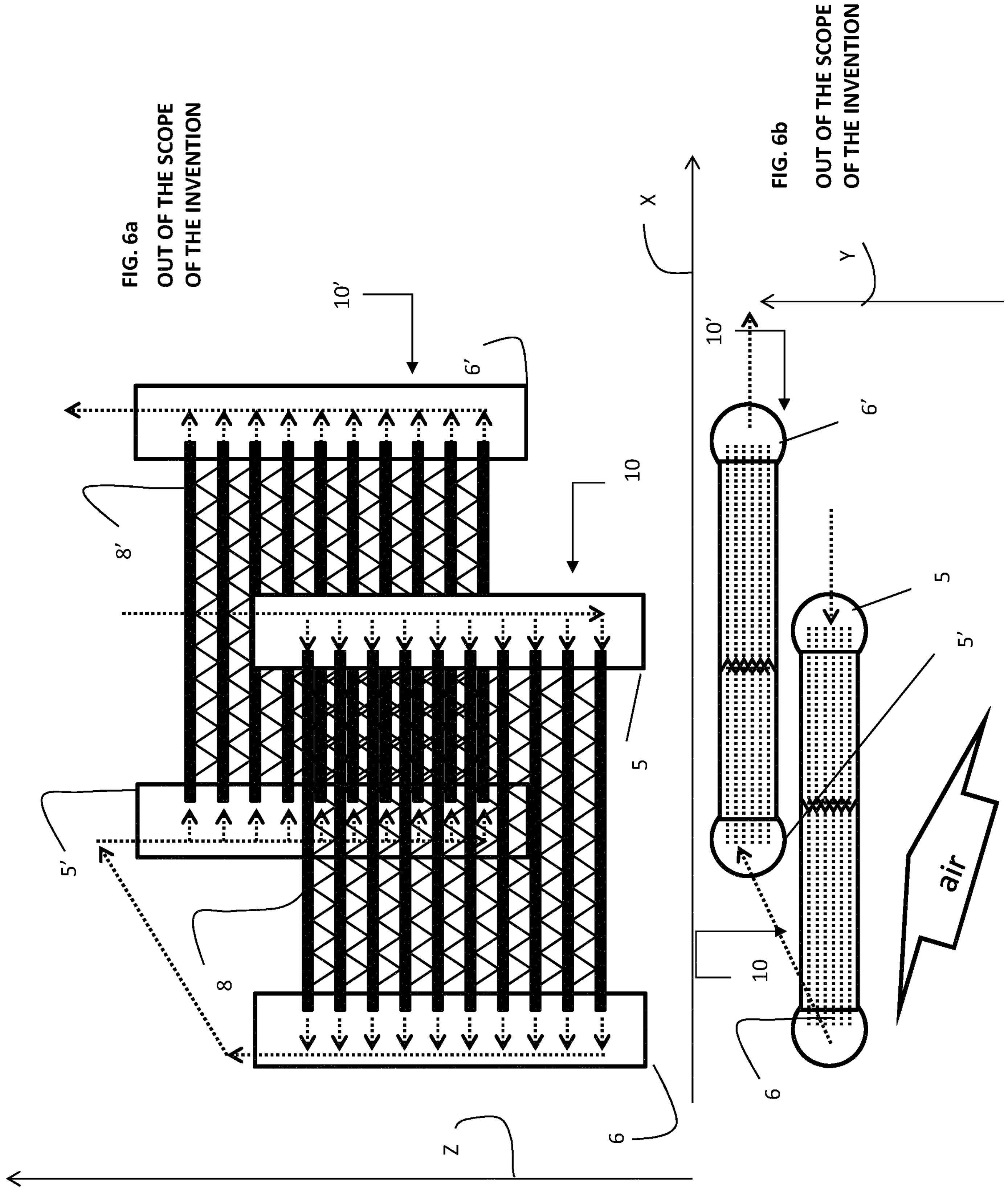


FIG. 6a
OUT OF THE SCOPE
OF THE INVENTION
FIG. 6b
OUT OF THE SCOPE
OF THE INVENTION
10'
6'
8'
10
5
5'
8
6
Z
X
Y
air

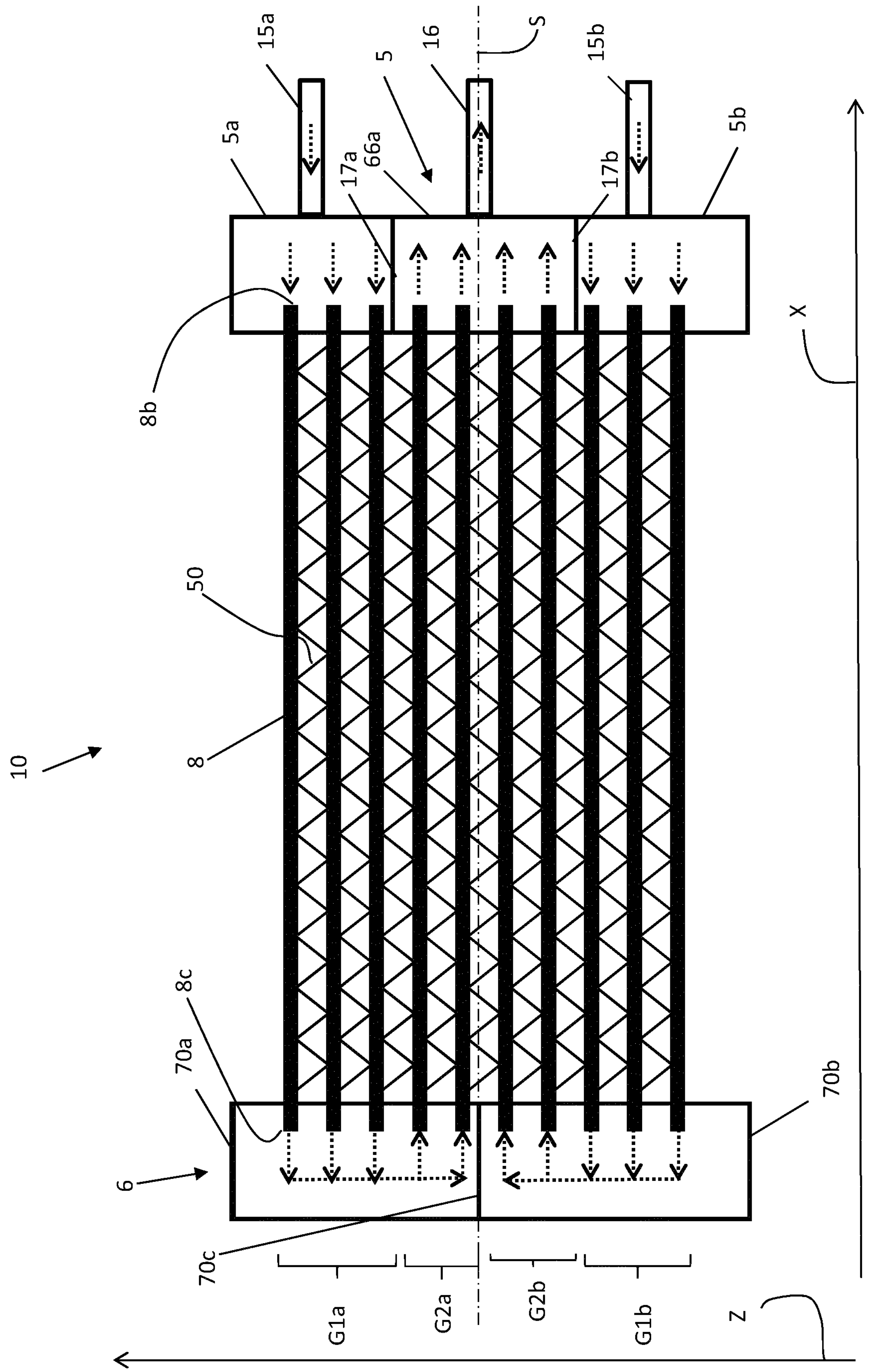

15a
16
5
S
15b
5a
5b
66a
17a
17b
X
8b
50
8
10
8c
70a
70b
6
70c
G1a
G2a
G2b
G1b
Z

FIG. 7a

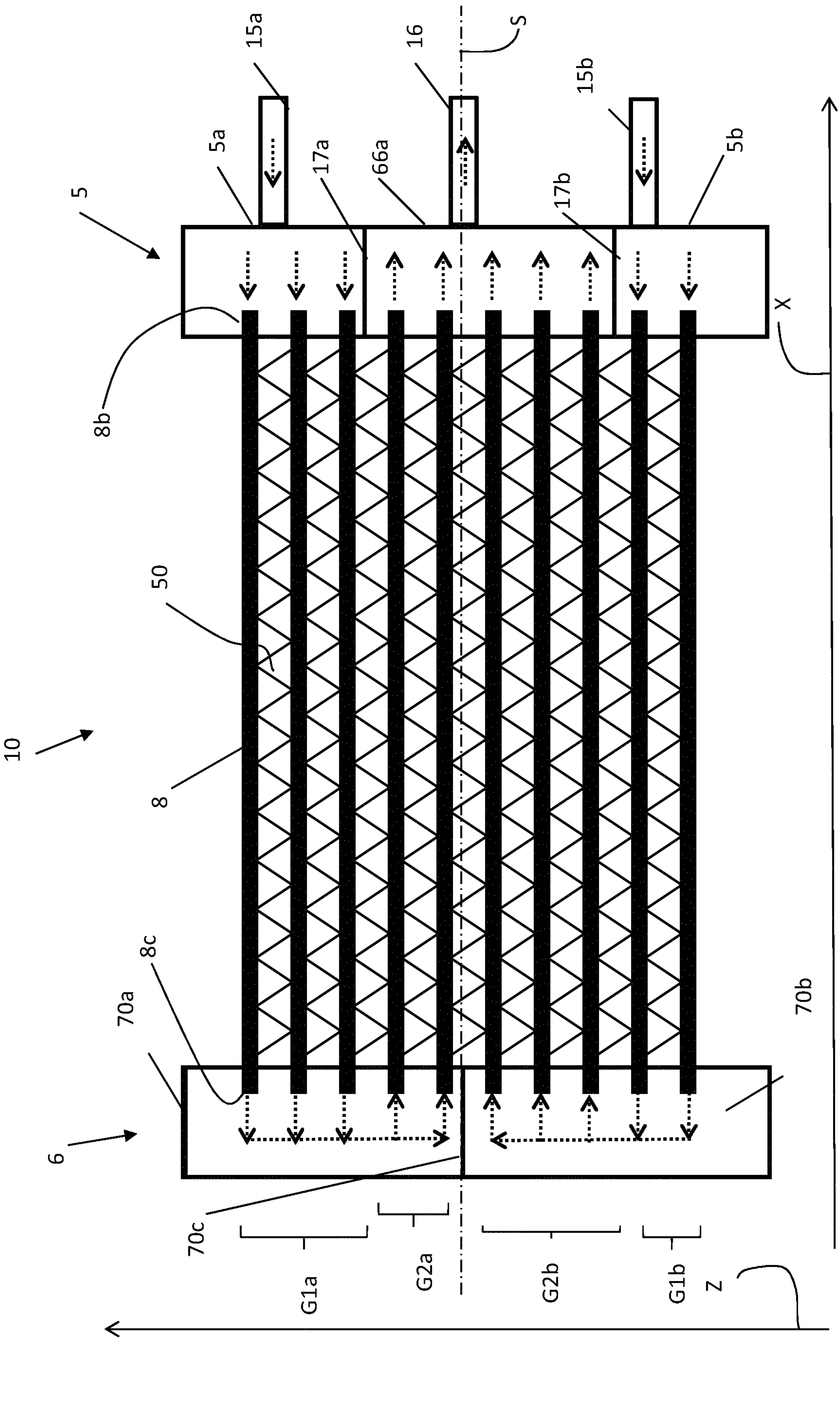

15a
16
S
15b
5a
17a
66a
17b
5b
5
X
8b
50
10
8
8c
70a
70b
6
70c
G1a
G2a
G2b
G1b
Z

FIG. 7b

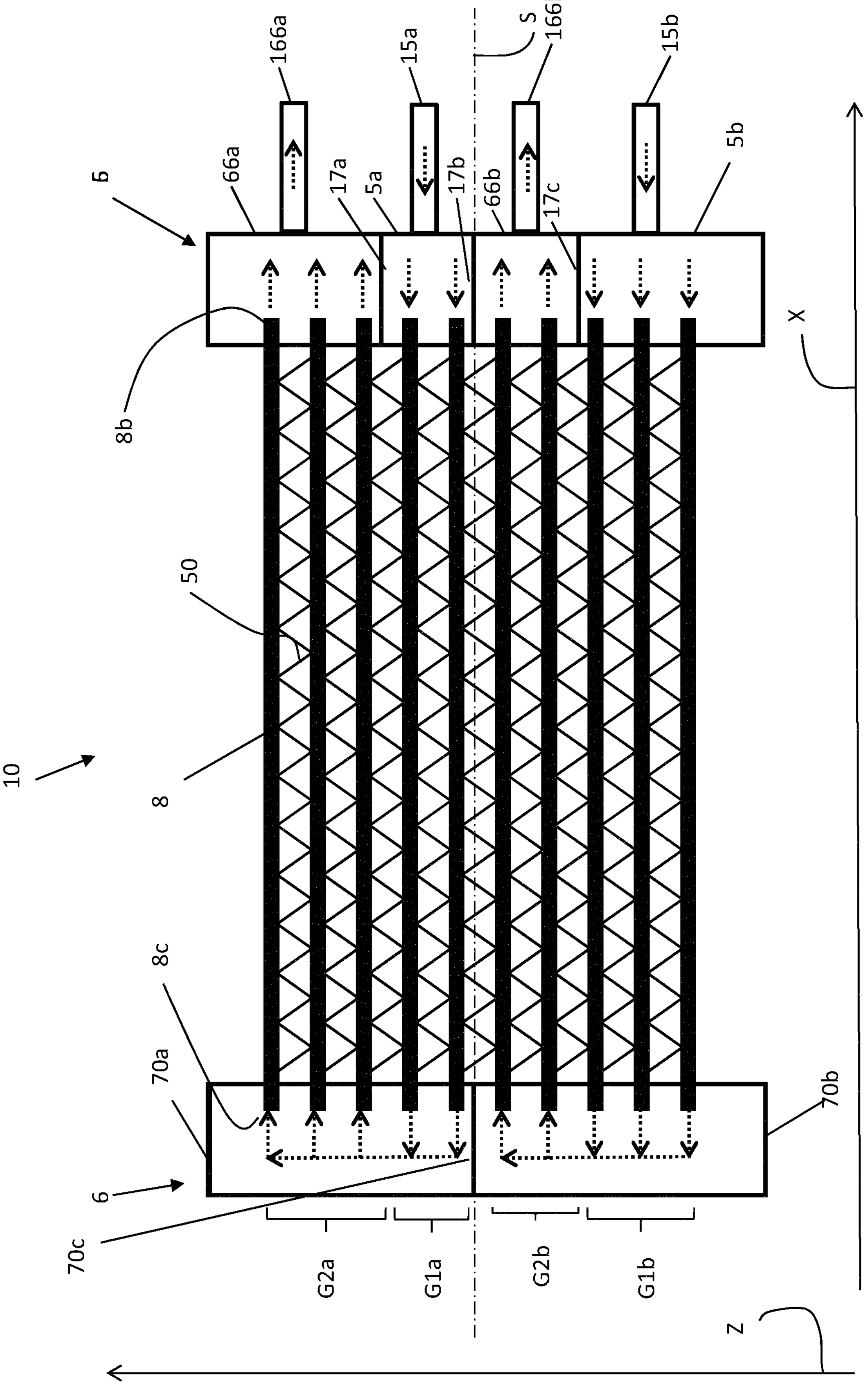

166a
15a
S
166b
15b
5b
66a
17a
5a
17b
66b
17c
6
X
8b
50
10
8
8c
70a
70b
6
70c
G2a
G1a
G2b
G1b
Z

FIG. 8a

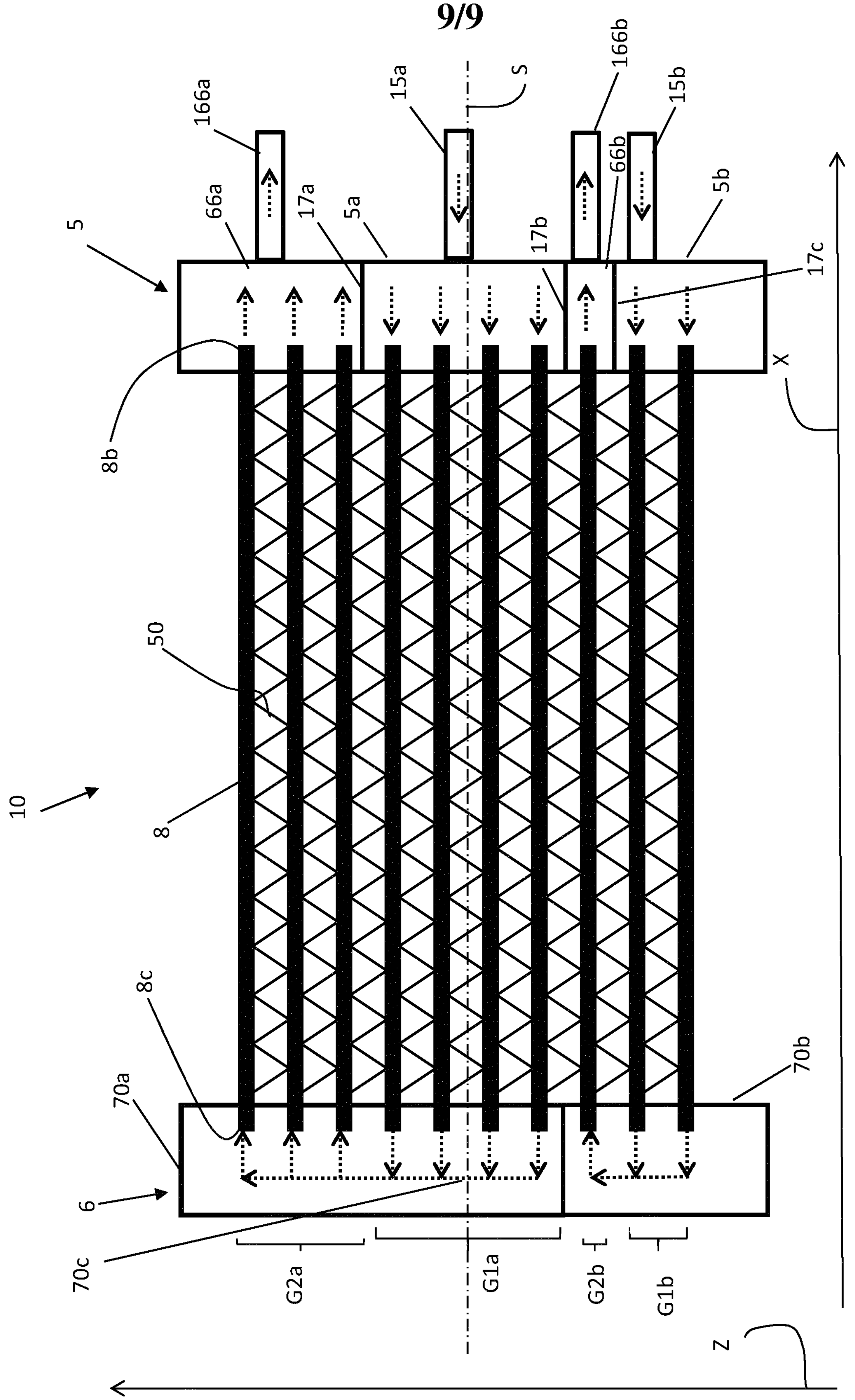

166a
15a
S
166b
15b
5
66a
17a
5a
17b
66b
5b
17c
X
8b
50
10
8
8c
70a
70b
6
70c
G2a
G1a
G2b
G1b
Z

FIG. 8b

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/073694

A. CLASSIFICATION OF SUBJECT MATTER
INV. A47L15/48 D06F58/20 F28F3/00
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)
A47L D06F F28F

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	DE 102 55 575 C1 (MIELE & CIE [DE]) 11 December 2003 (2003-12-11) the whole document -----	1-15
A	EP 1 209 277 A2 (ELECTROLUX ZANUSSI ELETTRODOME [IT]) 29 May 2002 (2002-05-29) cited in the application the whole document -----	1-15
A	US 2011/280736 A1 (LEE YONGJU [KR] ET AL) 17 November 2011 (2011-11-17) cited in the application the whole document -----	1-15
A	EP 1 452 815 A1 (LINDE AG [DE]) 1 September 2004 (2004-09-01) the whole document -----	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2014	23/04/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Spitzer, Bettina

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/073694

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 10255575 C1	11-12-2003	NONE	
EP 1209277 A2	29-05-2002	AT 256214 T	15-12-2003
		DE 60101445 D1	22-01-2004
		DE 60101445 T2	14-10-2004
		EP 1209277 A2	29-05-2002
		ES 2211711 T3	16-07-2004
US 2011280736 A1	17-11-2011	AU 2011245856 A1	06-09-2012
		CN 102762791 A	31-10-2012
		EP 2565323 A2	06-03-2013
		US 2011280736 A1	17-11-2011
		WO 2011136593 A2	03-11-2011
EP 1452815 A1	01-09-2004	DE 10316711 A1	02-09-2004
		DE 10316712 A1	02-09-2004
		EP 1452815 A1	01-09-2004