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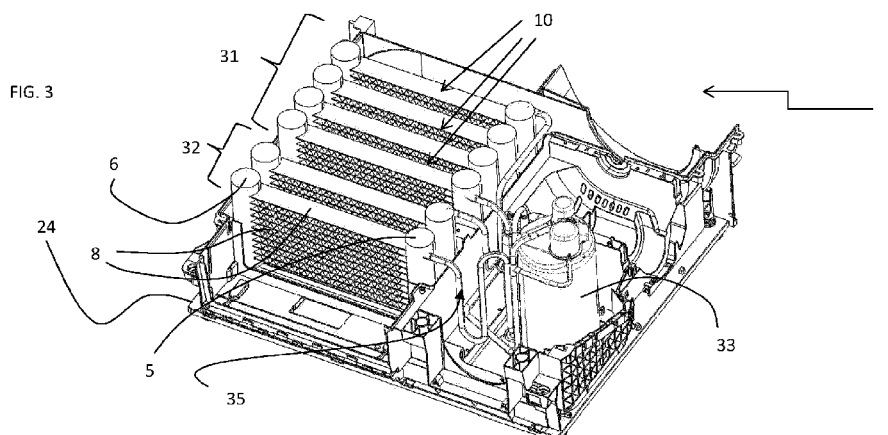
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(54) Title: LAUNDRY DRYER



(57) Abstract: A laundry dryer (1) is disclosed, which comprises a casing (2) supporting a drying chamber (3) for receiving a load to be dried and having a basement (24); a process air conduit (11) in communication with the drying chamber (3) where an air process stream is apt to flow; a heat pump (30) having a heat pump circuit in which a refrigerant (R) can flow, said heat pump circuit including a condenser (31) and an evaporator (32); said evaporator (32) and/or said condenser (31) being thermally coupled to the process air conduit (11) to perform heat exchange between said refrigerant (R) flowing in said heat pump circuit and said process air stream.

Laundry dryer

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 a tumbler, thus called tumble dryer, through which heated air is circulated to evaporate the moisture from the load. The tumbler is rotated around its axis.

Known laundry dryer includes 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 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, dryer 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 drier, 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.

European patent EP 0467188 discloses a laundry drier with a heat pump circuit for heating of the process air guided by means of an electric-motor-driven fan in a closed process air channel, and a heat pump circuit which is equipped for precipitation of the moisture contained in the process air from the laundry drying chamber and which consists of a condenser, evaporator, compressor and throttle, as well as in addition with a settable opening for exhaust air and an opening for feed air in the process channel.

German patent DE 4330456 relates to a tumble dryer with a drum, with a closed drying-air circuit by means of which drying air can be conducted through the drum and which is provided with a first blower as well as with a heating system and a condenser, with an open coolant circuit by means of which cooling air can be conducted by means of a second blower through the condenser, and with a refrigerant circuit comprising a compressor, a liquefier arranged downstream in the drying-air circuit, an expansion valve and an evaporator arranged in the cooling-air circuit.

Any reference herein to known prior art does not, unless the contrary indication appears, constitute an admission that such prior art is commonly known by those skilled in the art to which the invention relates, at the priority date of this application.

Summary of the invention

The present invention is relative to a laundry dryer for drying clothes and other garments including a heat pump. The dryer of the invention may include either a vented or a condense dryer. The configuration and construction of the heat pump in the dryer of the invention is realized in order to obtain a higher energy efficiency and optimization, at least in part, of the drying cycles' duration with respect to known heat pump dryers.

A traditional heat pump dryer includes a drying chamber, such as a drum, in which the load, e.g. clothes, to be dried is placed. The drying chamber is part of an air process 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 conduit 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 dry 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 dry 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 dry air in the process 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 such a dryer includes a heat pump circuit in which a refrigerant can flow and which connects via piping the evaporator where the refrigerant undergoes a phase transition from the liquid to the vapor phase due to the heat exchange with the warm process air exiting the drying chamber. The evaporated refrigerant is then supplied via a compressor to the condenser, which functions as seen above as a heat source for the dryer and in which the refrigerant condenses again, heating up the process air before the latter is introduced into the drying chamber. The condensed refrigerant arrives via an expansion device, such as a choke, a valve or a capillary tube back at the evaporator closing the circuit. The functioning of such a heat pump, which is the functioning of a heat pump according to the prior art and according to the invention, is schematically depicted in fig. 2. Due to their function, condenser and evaporator can also be called in the following "heat exchanger", in particular first and second heat exchanger.

20 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 X,Y perpendicular directions is defined, and a vertical direction Z, perpendicular to the horizontal plane, is defined as well in a
25 3-D space.

Applicants have realized that, in addition to the proper choice of refrigerant and compressor, also the design of the heat exchangers, i.e. namely of the evaporator and the condenser, can severely affect energy consumption and drying time performances. In particular, a proper configuration of the heat exchanger(s) allows achieving several benefits, such as maximizing the heat exchange between the refrigerant and the process air, reducing the pressure drop both in the refrigerant and in the process air circuit, and reducing the amount of refrigerant needed for a proper functioning of the heat pump. All these benefits allow saving energy, reduce the drying cycle duration and, in general, allow the realization of a more “ecofriendly” dryer.

The structure of the heat exchanger of the dryer of the present invention is the following: the heat exchanger includes one or more heat exchanger modules, each of which includes two headers, 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. Between the two headers, a plurality of channels is interposed, so that the refrigerant is allowed to flow from the inlet to the outlet header and/or vice versa.

More in details, in one of its aspects, the invention 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 an air process stream is apt to flow;
- A heat pump having a heat pump circuit in which a refrigerant can flow, said 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;

Characterized in that said first and/or second heat exchanger further comprises a heat exchanger module, said module including

- An inlet header to direct a flow of said refrigerant into said module;
- an outer header to discharge said refrigerant from said module; and
- a plurality of channels having a longitudinal direction connecting said inlet and said outlet header to enable said refrigerant to flow from said inlet to said outlet header and/or vice versa; said plurality of channels being at least in part subject to the flow of said air process stream.

Said heat exchanger module can be part of the first heat exchanger, of the second heat exchanger, or of both.

Due to the above mentioned configuration of the heat exchanger of the invention, a high ratio between the heat transfer capacity and the heat exchanger volume is achieved: a reduction of the overall dimensions of the heat exchanger is therefore possible, and thus the volume occupied by it within the casing can be also reduced. For example, the amount of space occupied by the heat exchanger(s) in the basement of the dryer can be much reduced without affecting the amount of exchanged heat, on the contrary the latter quantity is kept substantially constant. In addition, a significant reduction on the amount of refrigerant needed and of the pressure drops on both the air and refrigerant circuits is obtained, as detailed below.

Alternatively, the dryer of the invention may include a heat exchanger having the same dimensions as the one of the prior art, but with an increased cooling and heating capacity, due to the above mentioned reasons, and therefore improving the energy consumption and reducing the duration of a drying cycle.

In case an evaporator of the dryer of the invention includes a single heat exchanger module, the inlet header receives the refrigerant from a capillary tube and the refrigerant then leaves the outlet header leading to a compressor.

In case a condenser of the dryer of the invention includes a single heat exchanger module, the inlet header receives the refrigerant flow from a compressor, while the outlet header sends the refrigerant flow towards the capillary tube.

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

Preferably, the inlet and outlet headers each include a pipe, having a longitudinal extension, within which the refrigerant can flow. More preferably the header(s) is(are) realized in metal. Preferably, the inlet and the outlet header have substantially the same construction and both include an inlet and an outlet aperture. Preferably, the inlet and outlet header are parallel to each other.

Preferably, the channels of the plurality are substantially parallel to each other.

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 the first to the second 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 an arch, 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 on top of 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.

According to an embodiment of the invention, the hydraulic diameter of each of the channel, where the hydraulic diameter D_H is defined as

$$D_H = \frac{4A}{P}$$

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 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.

20 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, the channels are realized in metal, more preferably aluminum.

In a preferred realization, the plurality of channels forms a plurality of channels layers stacked in a stackwise direction, each layer including more than one channel, the channels being located one adjacent to the other(s). More preferably, the plurality of channels are parallel to each other within each channels layer and the plurality of channels layers are also substantially parallel to each other. Preferably, the stackwise direction is a vertical direction and the channels layers are stacked one on top of the other.

Said stackwise direction and the longitudinal direction of the channels define a first plane, which is preferably perpendicular to the horizontal plane and also perpendicular to air flow direction of the process air when the dryer is functioning.

Each channels layer defines a second plane which is formed by the longitudinal direction of the channel and by the width direction of the layer.

Preferably, fins are located between adjacent layers. Fins are preferably realized using a corrugated sheet of material which is formed of a material well-suited to heat transfer applications, such as metal. In particular, fins are preferably in contact with each two adjacent layers.

According to an embodiment, the second plane defined by the channels layer is parallel to the horizontal direction and also to the air flow direction. In this case, the air pressure drop in the process air circuit is minimized because this configuration minimizes the resistance to flow of the process air. However, in the evaporator, during the functioning of the dryer, water condenses on the surfaces of the module. The water flows down, for example to a canister, by its own weight. However, the velocity of the process air is not fast enough to avoid a temporary coverage of the channels layer outer surface by the condensed water. The fins can be covered by this water as well. The fact that the fins and/or the surfaces of the module is/are covered by water, reduces the heat exchange surface available for the heat exchange between the refrigerant and the process air, reducing the efficiency of the heat pump. For this reason, preferably the evaporator of the dryer of the invention includes a heat exchanger module having a layer defining a plane which is tilted with respect to the horizontal plane, in particular more preferably the angle α formed between the channels layer plane and the horizontal plane is comprised between $3^\circ \leq \alpha \leq 20^\circ$.

Preferably, the second plane formed by the layers and the longitudinal direction of the header are substantially perpendicular. Alternatively, the second plane and the longitudinal direction of the header are inclined forming an angle comprised between $70^\circ \leq 90^\circ - \alpha \leq 87^\circ$. According to a different embodiment, the plane and the longitudinal direction defined by the headers are parallel.

In all the above embodiments, however, preferably the longitudinal direction of flow of the refrigerant within the channels is substantially perpendicular to the process air direction.

According to a preferred embodiment of the invention, each channel layer includes one single pipe having an outer wall within which partition walls are realized in order to form the plurality of adjacent channels. The partition walls are preferably realized integral with the outer wall of the pipe, for example by stamping.

In case a plurality of channels layers is present, they can be in parallel or in series according to the refrigerant flow, as detailed below.

In case of multiple channels layers, each of them might include two opposite ends, the first end being in fluid communication with the inlet header and the second end being in fluid communication with the

second header. The refrigerant flowing in the inlet header is therefore distributed in parallel flows into the different channels layers, entering the same via their first ends and exiting the channels layers from their second ends, coming into the outlet header where the various streams merges. In each channels layer, in addition, the flow is further divided in a plurality of streams, one for each channel. In the following, it is said that a group of channels layers is parallel with respect to the refrigerant flow direction when the refrigerant flow can pass through all the channels layers of the group at the same time, i.e. there is a plurality of refrigerant streams which are running within the various channels at the same time.

In the following therefore, channels layers are named “parallel” with respect to the refrigerant flow when the refrigerant flow is distributed in the same in form of a plurality of groups of streams which run in all channels layers of the group at the same time.

Alternatively, channels layers might include two opposite ends, and the ends can be alternatively connected in fluid communication either with one or the headers or with another end of another layer. For example a single channel can belong to a plurality of channels layers: the channel can include a first rectilinear portion, included in the first channels layer, a second rectilinear portion belonging to the second channels layer stacked on top of the first portion, a U-bend connecting the first and second rectilinear portion, and so on. Therefore the first end of the first channels layer is connected to the inlet header, while the second end of the first channels layer is connected via the U-bend to the first end of the second channels layer and so on. In this case the channels layers are “in series”, because the streams of refrigerant flow have to pass the various channels layers in the order they are given, i.e. the flow has to go through first the first channels layer, then through the second channels layer, etc.

In the following therefore channels layers are named “in series” with respect to the refrigerant flow, when the flow of refrigerant have to traverse the channels layers in a given sequence and not all of them at the same time.

According to a preferred realization, the channels within a channels layer are directly connected to the inlet and outlet header, i.e. for each channel there is an aperture realized on the header in which the channel is

inserted, for each channels layer therefore a row of apertures is realized on the headers, preferably the various rows being parallel.

Alternatively, for each channels layer, a single aperture is realized in the header, to which the inlet of a connecting pipe is attached. The connecting pipe then includes a number of outlets equal to the number of channels in the channels layer.

Preferably, the flow of the refrigerant in the inlet header is substantially parallel to the flow of the refrigerant in the outlet header. In a first variant, the direction of flow in both headers is the same, in a second variant the two directions are opposite one to the other.

In an embodiment of the present invention, the inlet and outlet headers are mounted on the dryer perpendicularly to the horizontal plane and parallel to each other; in other words the longitudinal extension of the headers, which corresponds to the flow direction of the refrigerant therein, is perpendicular to the horizontal plane and to air flow in the air process conduit. In a different embodiment of the invention, the headers are still parallel one to the other, and also substantially parallel to the horizontal plane.

According to a first variant of this embodiment, in case channels layers are present, the channels layers are parallel with respect to the refrigerant flow, and substantially straight. The flow of the refrigerant within each channels layer is along a single longitudinal direction.

According to a different variant of the above mentioned embodiment of the invention, the inlet and outlet header are parallel to each other, the channels layers are in parallel, but the flow of refrigerant within each channels layer is along at least two directions, preferably one direction opposite to the other. For example, a module may include a channels layer which departs from the inlet header and extends for a given first length along a given direction, then form a U turn and extends in a direction substantially parallel to the first one for a second length equal to the first length till it meets the outlet header. The two portions of the channels layer are within the same plane. In this case the channels within a channels layer have an U

shaped form. The refrigerant therefore, internally to these channels, flows along a first direction in a first portion of the channels, and flows in the opposite direction for a second portion of the channels.

Moreover, a separator can be placed within one or both headers, in order to transversally divide the same in multiple portions. The refrigerant cannot flow through the separator. The channels therefore connecting the inlet and the outlet headers are divided in multiple groups, the number of which depending on the number of separator. The number of groups is equal to the number of separators plus one. For example, in case the inlet(outlet) header includes a single separator, the channels are divided in a first and a second group, the first group is connecting the first portion of the header (which is the inlet header) to an intermediate header, the second group is connecting the second portion of the header (outlet header) to the intermediate header. The channels layers within each group are in parallel with respect to the refrigerant flow, however the two groups are in series with respect to the refrigerant flow. Indeed, the refrigerant within each group flows at the same time in all channels layers belonging to the same group, while it has to flow through the channels layers of the first and the second group in a given order – the groups being thus in series (i.e. first it has to flow through the channels layers of the first group and then through the channels layers of the second group).

In case more modules are present, the connection among them can be configured according to different embodiment.

A first and a second module can be for example stacked one on top of the other in the same direction, being therefore in parallel with respect to the process air flow (the definition of parallel and in series with respect to the process air flow is analog to the definition given with respect to the refrigerant flow). A pipe can bring the refrigerant towards the inlet headers of the first and the second module, the pipe branches in two and the refrigerant enters both inlet headers. The two outlet headers are also connected via a piping which collects the flow of refrigerant coming from the two. The two modules are also in parallel with respect to the refrigerant flow.

Alternatively, the connection between the first and the second modules can be configured so as to be in series with respect to the air flow direction, i.e. the first module can be in front of the second module with respect to the process air flow. The inlet header of the first module receives the refrigerant flow coming from the capillary tube/compressor, while the outlet header of the first module is in fluid communication with the inlet header of the second module, the outer header of the second module leading then the refrigerant flow towards the compressor/capillary tube. In this case the modules are also in series with respect to the refrigerant flow.

The same configuration as above in which the modules are in series with respect to the air flow (i.e. the modules are one in front of the other in the direction of the air flow) can be also parallel with respect to the refrigerant flow. In this case, a pipe brings the refrigerant towards the inlet headers of both modules, the refrigerant entering both inlet headers. The two outlet headers are also connected via a piping which collects the flow of refrigerant coming from the two outlet headers.

In case of more than two modules, the modifications to be made to the overall configuration are clear to the man skilled in the art in view of the above.

According to a further characteristic of the invention, a cleaning system is provided in correspondence of the heat exchanger module.

It is known that the lint flowing through the process air conduit in a heat pump tumble dryer can be a cause of many inconveniences. If not properly filtered, the lint gets deposited and stuck on the fins between the layers of the heat exchanger, creating an additional pressure drop in the air conduit and/or a thermal resistance to the heat exchange with the process air. The addition of a filtering surface is not appreciated by most users, due to the need of a regular and constant cleaning operation of the same.

Due to the reduced size of the heat exchanger of the invention, a plurality of nozzles can be located according to the invention substantially facing the heat exchanger module. More preferably, the nozzles are disposed in a stack manner along the same stackwise direction in which the layers are stacked and facing the latter. Alternatively, the nozzles can be disposed horizontally still facing the channels of the

module. Preferably the nozzles spray air or water (preferably condensed water generated during the laundry drying cycle at the evaporator) or a combination of the two on the layers so as to clean the same from the lint. In addition, preferably the direction of the spray is opposite is in counterflow to the direction of the process air flow

According to another characteristic of the invention, due to the "small" dimensions of the fins, i.e. they have a thickness of 0.1 mm-0.3 mm, the fins themselves form a mesh filter blocking the lint flowing in the conduit.

Brief description of the drawings

These and other features and advantages of the invention will better appear from the following description of some exemplary and non-limitative embodiments, to be read with reference to the attached drawings, wherein:

- Fig. 1a and fig. 1b are schematic views, where some elements have been removed for clarity, of a laundry condense dryer and of a vented condensed dryer, respectively, according to the invention;
- Fig. 2 is a flow diagram of the principle of functioning of an element of the dryer of the invention of fig. 1a or fig. 1b;
- Fig. 3 is a perspective view of a portion of an embodiment of the dryer of the invention of fig. 1a or 1b with the casing removed;
- Fig. 4 is an enlarged view of a detail of fig. 3;
- Fig. 5 is a perspective view in section of an element of the dryer of fig. 1a or 1b;
- Fig. 6 is a cross-sectional view of an element of the detail of fig. 4;
- Figs. 7a and 7b are a schematic front view and top view, respectively, of an embodiment of the heat exchanger module of the dryer of the invention of fig. 1a or fig. 1b;

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- Figs. 8a and 8b are a schematic front view and top view, respectively, of an additional embodiment of the heat exchanger module of the dryer of the invention of fig. 1a or fig. 1b;
- Figs. 9a and 9b are a schematic front view and top view, respectively, of a further additional embodiment heat exchanger module of the dryer of the invention of fig. 1a or fig. 1b;
- Figs. 10a and 10b are a schematic front view and top view, respectively, of a further additional embodiment of the heat exchanger module of the dryer of the invention of fig. 1a or fig. 1b;
- Figs. 11a and 11b are a schematic front view and top view, respectively, of a further additional embodiment of the heat exchanger module of the dryer of the invention of fig. 1a or fig. 1b;
- Figs. 12a and 12b are a schematic front view and top view, respectively, of a further additional embodiment of the heat exchanger module of the dryer of the invention of fig. 1a or fig. 1b;
- Figs. 13a, 13b, 13c and 13d are three perspective views and a side view of a portion of a further embodiment of the dryer of the invention of fig. 1a or 1b with the casing removed;
- Fig. 14 is perspective view of a portion of a further embodiment of the dryer of the invention of fig. 1a or 1b with the casing removed;
- Figs. 15a, 15b and 15c are a schematic front view, top view and lateral view, respectively, of the embodiment of fig. 14;
- Figs. 16a and 16b are a schematic front view and top view, respectively, of an embodiment of connection between two heat exchanger modules of any of the examples of figs. 7a-7b to figs. 12a-12b and of figs. 15a-15c;
- Figs. 17a and 17b are a schematic front view and top view, respectively, of an embodiment of connection between two heat exchanger modules of any of the examples of figs. 7a-7b to figs. 12a-12b and of figs. 15a-15c;
- Fig. 18a and 18b are a schematic front view and top view, respectively, of an embodiment of connection between two heat exchanger modules of any of the examples of figs. 7a-7b to figs. 12a-12b and of figs. 15a-15c;

- Fig. 19 is a perspective view of an additional embodiment of a heat exchange module of the dryer of the invention of fig. 1a or fig. 1b;
- Fig. 20 is a schematic view of an additional element of the dryer of the invention of fig. 1a or fig. 1b.

Detailed description of the embodiment or embodiments

With initial reference to figs. 1a and 1b, 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 rotate 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, which can open and close an opening realized on the casing itself. .

More in detail, 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, basement 24 is molded.

Preferably, basement 24 includes an upper and a lower shell 24a, 24b (visible in the figures 13a and 13b detailed below).

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

Laundry dryer 1 also comprises an electrical motor assembly for rotating, on command, revolving drum 3 along its axis inside casing. 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 figs. 1a and 1b 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 is formed by the connection of the two upper and lower shells 24a, 24b. 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 (shown only in fig. 1a) and an electrical heater (not shown in the figures).

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. 2) 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 (see figs. 3 and 4 for example) the second heat exchanger 32 where the refrigerant warms up and may undergo a phase transition from the liquid to the vapour via a compressor 33 to the condenser 31, in which the refrigerant cools off and may condense again. The cooled or condensed refrigerant arrives via an expansion device 34, such as a choke, a valve or a capillary tube, back at the evaporator 32.

Preferably, in correspondence of evaporator 32, the dryer 1 of the invention may include a condensed-water canister 40 (shown only in fig. 1b) which collects the condensed water produced, when the dryer is in operation, inside evaporator 32 by condensation of the surplus moisture in the process air stream arriving from the drying chamber 3. The canister 40 is located at the bottom of the evaporator 32. Preferably,

through a connecting pipe and a pump (not shown in the drawings), the collected demineralized water is sent in a reservoir located in correspondence of the highest portion of the dryer 1 so as to facilitate manual discharge of the water by the user.

The condenser 31 and the evaporator 32 of the heat pump 30 are located in correspondence of the process air conduit 11.

In case of a condense dryer – as depicted in fig. 1a – 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 dry 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.

In case of a vented dryer – as depicted in fig. 1b – the process air circuit 4 includes an exhaust duct 104 connected to the drum 3 via an aperture 4a into which the process air enters after having passed the whole drum 3 to de-humidify the laundry. The process air travelling into the exhaust duct 104 is exhausted outside the dryer via an exhaust aperture 105 defining an opening in the casing 2. The evaporator 32 of the heat pump is located along the exhaust duct 104 in order again to cool the process air exiting the drum 3 and causing condensation of the moisture therein. Air enters into vented dryer 1 through one or more air vents 13 realized in the casing 2, more preferably in the rear panel 21 of same. The air travels through an inlet duct 101, part of the process air conduit 4, from intake vents 13 reaching the condenser 31, where it is heated as it passes through and it is then introduced in the rotatable drum 3. During operation, the heated process air dries the laundry present inside drum 3.

In both dryers 1 of figs. 1a and 1b, a lint filter 103 to block the lint is preferably present (only in fig. 1a it is shown). The lint filter 103 is preferably located before the process air reaches the evaporator 32, i.e. when it exits the drum 3.

It is to be understood that in the dryer 1 of the invention, the electrical heater can also be omitted, being the heat pump 30 sufficient to heat up the air process stream for the purpose of laundry drying. However,

heat pump 30 and heater can also work together to speed up the heating process (and thus reducing the drying cycle time). In the latter case, preferably condenser 31 of heat pump 30 is located upstream the heater.

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.

With now reference to figs. 3 and 4, 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. As stated above, although in the appended drawings both evaporator 32 and condenser 31 of the dryer 1 includes heat exchanger modules 10 realized according to the invention, 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 figures 3 and 4 where the evaporator 32 includes two modules 10 and the condenser four modules 10).

Preferably, modules 10 are located in correspondence of the basement 24 of dryer 1.

The structure of a single module 10 will be now be described, with reference to the different embodiments depicted in figs. From 7a-7b to 12a-12b, 15a-15b-15c and 19.

A heat exchanger module 10 includes an inlet header 5 and an outlet header 6. Inlet and outlet headers 5,6 have preferably the structure of a pipe and more preferably with a circular cross section. The headers 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 the inlet header 5 and exiting the same via the outlet header 6. A plurality of channels, each indicated with 7, is connecting the inlet to the outlet header and vice versa, so that the refrigerant can flow between the two headers, the plurality of

channels being subject to the flow of process air, i.e. channels 7 are located within the air process conduit 11 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. 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 Y and substantially parallel to the horizontal plane.

Preferably, the refrigerant flow within channels 7 is substantially perpendicular to the process air flow.

According to a preferred embodiment, the channels 7 are grouped in channels layers 8: each channels layer includes a plurality of channels 7 which are adjacent and parallel to each other. More preferably, each module 10 includes a plurality of channels layers 8, more preferably all layers 8 are stacked one on top of the other in a stackwise direction and even more preferably parallel to each other, substantially forming a plurality of parallel rows. Preferably the stackwise direction is the vertical direction. According to an embodiment of the invention, channels 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 channels layer 8 of fig. 6. The cross section of the single channels 7 can be arbitrary. Each channels layer 8 has a width which depends on the number of channels which are located one adjacent to the other.

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

A channels layer 8 has a width direction Y which, together with the longitudinal direction X of channels 7 defines a channels layer plane (X,Y).

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

The refrigerant entering the module 10 via the inlet header 5 can come from the outlet header 6 of another module 10, from the compressor 33 or from the expansion valve 34. Additionally, the refrigerant exiting the outlet may be directed towards the inlet header 6 of another module 10, towards the capillary tube 34 or towards the compressor 33. The connection between the compressor 33, modules 10 and capillary tube 34 (not depicted) and between modules is made via piping 35, as it can be seen in figures 3 and 4. 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.

According to a first embodiment of the module 10 of the dryer 1 of the invention depicted in figs. 7a and 7b, the two headers 5,6 are mounted vertically (i.e. their axis Z is the vertical axis) 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 channels layers 8, each of which includes a different tube defining upper and lower surfaces 9a,9b (see fig. 6) within which the channels 7 are realized. A plurality of channels layers 8 connects the inlet 5 to the outlet header 6, all layers having a first end 8b and a second end 8c longitudinally opposite to each other, the first end being connected to the inlet header and the second end being connected to the outer header. Channels layers are stacked one on the other along the vertical direction forming a plane (Z,X) defined by the longitudinal extension X of the channels 7 and the direction of stacking Z. This plane is perpendicular to the horizontal plane and to direction of flow Y of process air as clear from figs. 7a, 7b. In addition, each channels 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 and the air flow direction; i.e. the layer planes (X,Y) are horizontal. In other words, the module 10 is mounted so that the channels layers 8 forms parallel planes between which the process air flows. In each header 5,6 in correspondence of each channels layer's end 8b,8c, a plurality of apertures 7a is realized, in each aperture 7a a channel 7 being inserted. The so-formed

rows of apertures 7a (see fig. 5) 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. The channels 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 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 is parallel to the flow of the refrigerant in the outlet header, but with opposite direction.

According to a second embodiment of the module 10 depicted in figs. 8a and 8b, the module 10 is substantially analog to the module 10 described with reference to figs. 7a and 7b, with the exception of the refrigerant flow in the inlet and in the outlet header: in this second preferred embodiment, the two flows are parallel and have the same direction.

According to a third embodiment of the module 10 of the dryer of the invention depicted in figs. 9a and 9b, the inlet and the outlet header 5, 6 are disposed within the basement 24 substantially parallel to the process air flow direction Y (i.e. they horizontally lie on the basement), therefore also the resulting refrigerant flow within the headers is parallel to horizontal plane (X,Y). In addition, the module 10 includes

a plurality of channels layers 8, which are stacked one on top of the other in a stackwise direction which corresponds to the vertical direction Z and which are all formed by a single tube. Channels layers 8 are parallel to each other and their longitudinal extension X is perpendicular to the process air flow direction Y.

The single tube within which the various channels 7 are realized has a first rectilinear portion 8e defining the first channels layer, it then includes a U-shaped bend 8f and it extends for a second rectilinear portion 8g parallel to the first rectilinear portion 8e defining the second channels layer, and so on. In this way a

single row of apertures 7a is formed in each header 5, 6 and the flow of refrigerant in the various layers can be considered in series with respect to the refrigerant flow. The flows of refrigerant within the various channels 7 forming the channels layers are parallel to each other. Additionally, the channels layer planes (X,Y) are parallel to the horizontal plane (X,Y).

The flows of the refrigerant in the two headers 5,6 are preferably parallel to each other. The two flows can have the same direction, or opposite directions.

According to a fourth embodiment of the module 10 of the present invention, depicted in figs. 10a and 10b, the module's overall configuration is similar to that of the first or the second embodiment above described of figs. 7a,8a,7b,8b, but one of the two headers includes a transversal separator 17 which divides the header in two separated portions. In other words, there are still two parallel vertical headers connected by parallel layers 8, but one of the layers is divided in two and the first portion represents the inlet header 5, while the second portion is the outlet header 6. The second header 5a is an intermediate header for the refrigerant flow. The flow of refrigerant entering the header 5 is therefore prevented by separator 17 to go from the first to the second portion 5,6 of the header. The channels layers 8 are thus divided in two groups: the first group G1 connects the first portion 5 (the inlet header 5) to the intermediate header 5a and the second group G2 connects the intermediate header 5a to the outlet header 6.

The refrigerant flow which enters the first portion 5 (the inlet header 5) in a vertical Z direction is distributed via apertures 7a into the first group G1 of channels layers 8 and the refrigerant flows within the parallel channels in the first group G1 towards the intermediate header 5a. Therefore, the layers within the first group G1 are parallel with respect to the refrigerant flow. The refrigerant streams exit the first group G1 of channels layers 8 and enter the intermediate header 5a, where they merge. From the intermediate header 5a, the refrigerant flow then enters the second group G2 of channels layers 8 reaching the outlet header 6. Thus, also the channels layers within the second group G2 are parallel to each other with respect to the refrigerant flow. However the layers 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.

According to a fifth embodiment of the invention depicted in figs. 11a and 11b, the configuration of the module 10 is substantially analog to that of the first and second embodiment. However, instead of a single aperture 7a realized on the header 5,6 for each channel 7, a single aperture 80 for each channels layer 8 is realized, to which the inlet of a connecting pipe 19 is attached. The connecting pipe 19 then includes a number of outlets equal to the number of channels 7 in the channels layer 8.

Therefore, for each layer of the plurality belonging to the same module 10, two connecting pipes are present to connect, each via a single hole 80, the two opposite ends 8b,8c of the channels layer 8 to the two headers 5,6, respectively.

According to a sixth embodiment of the module 10 of the dryer 1 of the invention, depicted in figs. 12a and 12b, the module 10 includes two headers 5,6 which are mounted vertically (i.e. their axis Z is the vertical axis) on the basement 24 of the dryer 1 and the channels 7 connecting the two headers 5,6 have each a first and a second straight portion 7a,7b connected via a U-shaped bend 7c. The first and second straight portions 7a,7b are parallel to each other, having both the same length. the first and second straight portions 7a,7b of channel 7 extend along the longitudinal direction X, which is perpendicular to the longitudinal extension of the header Z and to the process air flow, but parallel to the horizontal plane.

Channels 7 are divided in channels layers 8, each of which includes a tube defining upper and lower surface 9a,9b (see fig. 6) within which the channels 7 are realized. A plurality of channels layers 8 connects the inlet

5 to the outlet header 6, each layer being realized by a different tube. Channels layers are connected to headers 5,6 via connecting pipes 19 as described in the fifth embodiment. Channels layers are stacked one on the other along the Z direction forming a plane (Z,X) defined by the longitudinal extension X of the channels 7 and the direction of stacking Z. This plane is perpendicular to the horizontal plane and to direction of flow Y of process air as clear from figs. 7a, 7b. In addition, each channels layer has a width

direction Y perpendicular to the longitudinal extension X of the channels 7. As in the first and in the second

embodiments, the module 10 is mounted so that the channels layers 8 form parallel planes (preferably parallel to the horizontal plane) between which the process air flows.

The refrigerant enters the inlet header 5 of module 10 via inlet aperture 5_{in} along a flow direction parallel to the longitudinal extension Z of header 5 and branches off into the various layers 8 via apertures 80. In each channel 7, in the first straight portion 7a, the refrigerant flows along the longitudinal extension X of the channel and it then bends along the U-shaped bends. The direction of the flow is then reversed along the same axis X. The channels layers 8 are “parallel” to each other according to the refrigerant flow direction. In the various channels 7, the flow direction of the refrigerant is substantially parallel to the flow direction of the refrigerant in the other channels. The refrigerant then exits the module via outlet aperture 6_{out} of outlet header 6.

The flow of refrigerant in the headers is perpendicular to the process air flow and it undergoes a 180° turn of direction. In addition, the flow of the refrigerant in the inlet header is parallel to the flow of the refrigerant in the outlet header, but with opposite direction.

According to a seventh embodiment of the invention depicted in figs. 13a, 13b 13c and 13d, the module 10 has substantially the same configuration of the module of the first or the second embodiment, with the following differences. As mentioned, channels layer 8 defines a plane formed by the longitudinal direction of channel X and the width direction of the layer. In the first and second embodiment, said plane is parallel to the longitudinal direction Z of headers 5,6 and it is parallel to the horizontal plane (X,Y). In the seventh embodiment, such a plane forms an angle with the horizontal plane, and correspondingly with the longitudinal extension of the headers. Preferably said angle is comprised between 3° and 20°. Preferably, the module of the seventh embodiment is part of an evaporator 32.

Alternatively, the angle above mentioned between the horizontal plane and the layer plane can be formed according to the eighth embodiment of module 10 depicted in figs. 14 and 15a-15c. In this embodiment, the module 10 is realized in an identical manner as the module of the first or the second embodiment,

however the headers 5,6 are mounted forming an angle with the vertical direction. The angle is chosen so that the angle formed by the channels layer plane and horizontal plane is comprised between 3° and 20°.

According to a ninth embodiment of the invention depicted in fig. 19, the module 10 has a configuration similar to that outlined with reference to the first and second embodiment, with the exception of the configuration of channels 7. Each channel 7 includes an arch portion 7d which connects the inlet to the outlet header. Consequently, also the channels layers 8 include a tube which has an arched top view. An extension direction X is still defined, which is the line connecting the two headers, and the channels layer planes are still parallel to horizontal plane.

It is to be understood that also different combinations of the characteristics of the modules 10 of the various embodiments above outlined are possible. For example, any of the module 10 of embodiments first-ninth may include a connecting pipe 19 connecting the headers 5,6 to the channels layers 8; any channel 7 of embodiments first-ninth may include two rectilinear portions connected by a U-shaped bend, or a curved arch, and so on; any module may include a channels layers plane which is tilted or parallel with respect to the horizontal plane.

The evaporator 32 and/or the condenser 31 may include one or more of modules 10, in case more than one module is included, the modules can be identical or different.

The connection between modules can be made according to the invention as follows. The description is made with reference to the module 10 realized according to the first and/or the second embodiment, however the same teaching applies to the connection between any two modules of any of the afore mentioned embodiments using modifications which are within the skills of the expert in the technical field.

With now reference to figs. 16a and 16b, a first and a second module 10, 10' are connected to each other. The two modules are stacked in the same vertical direction Z as the layers, i.e. the inlet and outlet headers of first and second module are mounted one on top of the other and the channels layers 8, 8' of the first and the second module 10, 10' are all stacked one on top of the other. The flow of refrigerant enters at the same time both first and second inlet headers 5,5' of the first and the second module 10,10' for example via

a piping located between the inlet header 5 of the first module 10 and the inlet header 5' of the second module 10'. The refrigerant flows then within the channels layers 8,8' reaching the corresponding outlet headers 6,6'. The flows of refrigerant exiting the two outlet headers 6,6' is then merged. The flows in the first and second inlet header 5,5' and in the first and second outlet header 6,6' are parallel to each other but have opposite directions. In this configuration, the channels layers 8,8' of the first and second module 10,10' are parallel with respect to the refrigerant flow, and the first and the second module are also parallel with respect to the process air flow.

Referring to figs. 17a and 17b, a first and a second module 10, 10' are connected to each other. 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, both substantially perpendicular to the horizontal plane. Both modules have channels 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. 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, as depicted in figs. 18a and 18b, a first and a second module 10, 10' are connected to each other. 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 and substantially perpendicular to the horizontal plane. Both modules have channels layers 8,8' which are parallel to the horizontal plane and to the process air flow. The flow of refrigerant enters at the same time both first and second inlet headers 5,5' of the first and the second module 10,10' for example via a piping located above the inlet header 5 of the first module 10 and the inlet header 5' of the second module 10'. The refrigerant flows then at the same time within the channels layers 8,8' reaching the corresponding outlet headers 6,6'. The flows of refrigerant exiting the two outlet headers 6,6' are then merged. The flows in the first and second inlet headers 5,5' and in the first and second outlet

header 6,6' are parallel to each other and have the same direction. In this configuration, the channels layers 8,8' within the first and within the second module 10,10' are parallel with respect to the refrigerant flow, and the channels layers 8,8' of the first and of the second module 10,10' are in series with respect to the process air flow.

According to a different aspect of the invention, the dryer 1 includes a cleaning system 50 in correspondence of the heat exchanger module 10, as schematically shown in fig. 20.

In front of the surface defined by the stack direction and the longitudinal direction of the channels, a plurality of nozzles 51 is disposed. As depicted, the nozzles are also disposed along a vertical direction parallel to the stack direction of the channels layers 8. Alternatively, horizontal rows of nozzles 51 can be realized, in front of the channels 7. Preferably, nozzles can spray air and/or water on the modules, more preferably the spraying direction is in counter flow to the process air flow.

Such a plurality of nozzles 51 can be located in front of all modules 10, or only in front of some of them.

Additionally, the cleaning system 50 may include a filtering mesh 52 to filter the lint flowing in the air conduit 11. Nozzles are located in conduit 11. Also the filtering mesh 52 can be sprayed by the nozzle to remove the lint.

Preferably, the geometrical shape of nozzles 51 is such that it offers the minimum possible resistance to the process air flow.

Where ever it is used, the word "comprising" is to be understood in its "open" sense, that is, in the sense of "including", and thus not limited to its "closed" sense, that is the sense of "consisting only of". A corresponding meaning is to be attributed to the corresponding words "comprise", "comprised" and "comprises" where they appear.

While particular embodiments of this invention have been described, it will be evident to those skilled in the art that the present invention may be embodied in other specific forms without departing from the essential characteristics thereof. The present embodiments and examples are therefore to be considered in

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all respects as illustrative and not restrictive, and all modifications which would be obvious to those skilled in the art are therefore intended to be embraced therein.

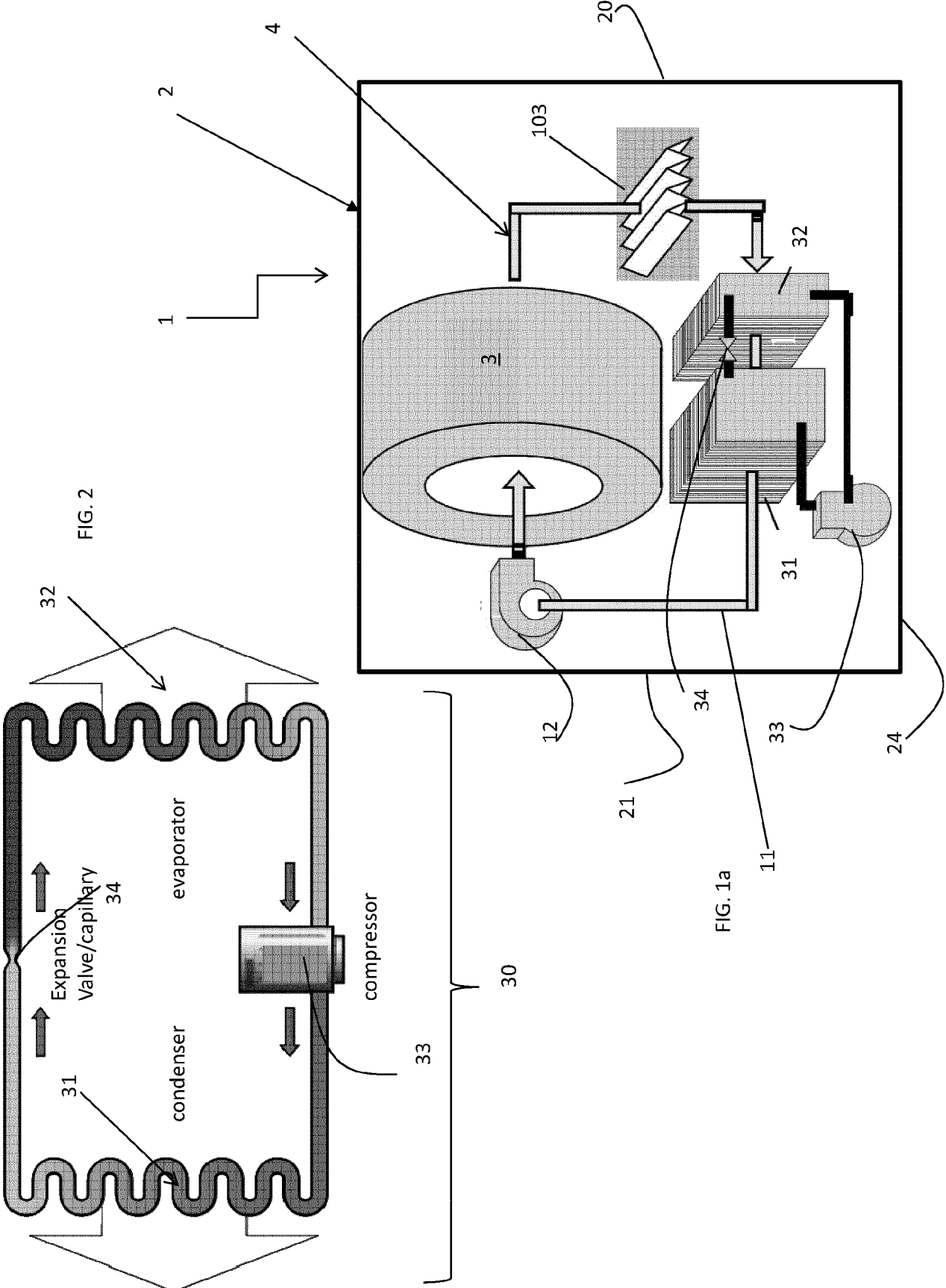
Claims

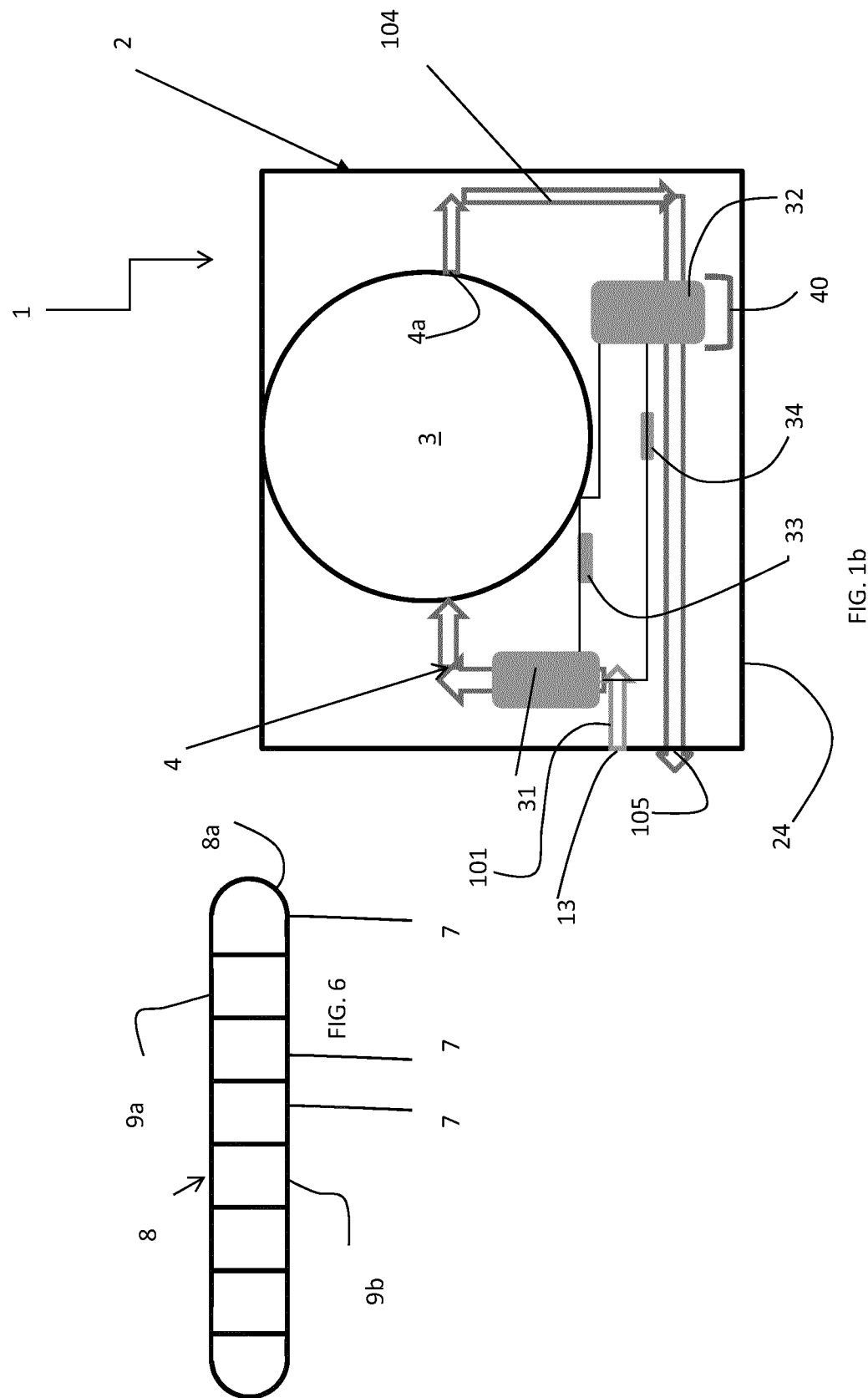
1. A laundry dryer comprising:
 - a casing supporting a drying chamber for receiving a load to be dried and having a basement;
 - a process air conduit in communication with the drying chamber where an air process stream is apt to flow;
 - a heat pump having a heat pump circuit in which a refrigerant 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 a heat exchanger module, said module including
 - an inlet header to direct a flow of said refrigerant into said module;
 - an outer header to discharge said refrigerant from said module; and
 - a plurality of channels extending along a longitudinal direction connecting said inlet to said outlet header to enable said refrigerant to flow from said inlet to said outlet header and/or vice versa; said plurality of channels being at least in part subject to the flow of said air process stream;
 - wherein said module includes a plurality of adjacent channels forming a channels layer, and said module includes a plurality of said layers, said channel layers being stacked in a stackwise direction one on top of the other(s), wherein fins are located between adjacent layers.
2. A laundry dryer as claimed in claim 1, wherein said channels of the plurality are substantially parallel one to the others.
3. A laundry dryer as claimed in any one of the preceding claims, wherein said inlet and said outlet header are substantially parallel to each other.

4. A laundry dryer as claimed in any one of the preceding claims, wherein said channels have a hydraulic diameter smaller or equal than 5 mm.
5. A laundry dryer as claimed in any one of the preceding claims, wherein said casing includes a basement which comprises an upper and a lower shell, and/or wherein said casing includes a basement and the basement is realized in plastic material.
6. A laundry dryer as claimed in any one of the preceding claims, wherein , said channels layers are substantially parallel one to the others.
7. A laundry dryer as claimed in claim 6, wherein said laundry dryer defines an horizontal plane and a vertical direction perpendicular to the horizontal plane, and wherein each channels layer defines a plane by said longitudinal direction and by a width direction, said plane being substantially parallel to the horizontal plane.
8. A laundry dryer as claimed in claim 6, wherein said laundry dryer defines a horizontal plane and a vertical direction perpendicular to the horizontal plane, and wherein each channels layer defines a plane by said longitudinal direction and by a width direction, said plane forming an angle comprised between 3° and 20° with the horizontal plane.
9. A laundry dryer as claimed in claim 8, wherein said module is part of an evaporator.
10. A laundry dryer as claimed in any one of the preceding claims, wherein said channels layers are in parallel with respect to the refrigerant flow direction, that is the refrigerant flow is distributed in form of a plurality of groups of streams which run in all channels layers at the same time.
11. A laundry dryer as claimed in any one of the preceding claims, wherein said layers are in series with respect to the refrigerant flow direction, that is the flow of refrigerant have to traverse the channels layers in a given sequence.
12. A laundry dryer as claimed in any one of the preceding claims, including a fist and a second module, the first and second module being connected in parallel with respect to the process air flow.

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13. A laundry dryer as claimed in any one of the preceding claims, including a first and a second module, the first and second module being connected in series with respect to the process air flow.
14. A laundry dryer as claimed in any one of the preceding claims, including a cleaning system having a plurality of nozzles substantially facing said channels for spraying water and/or air to said channels.





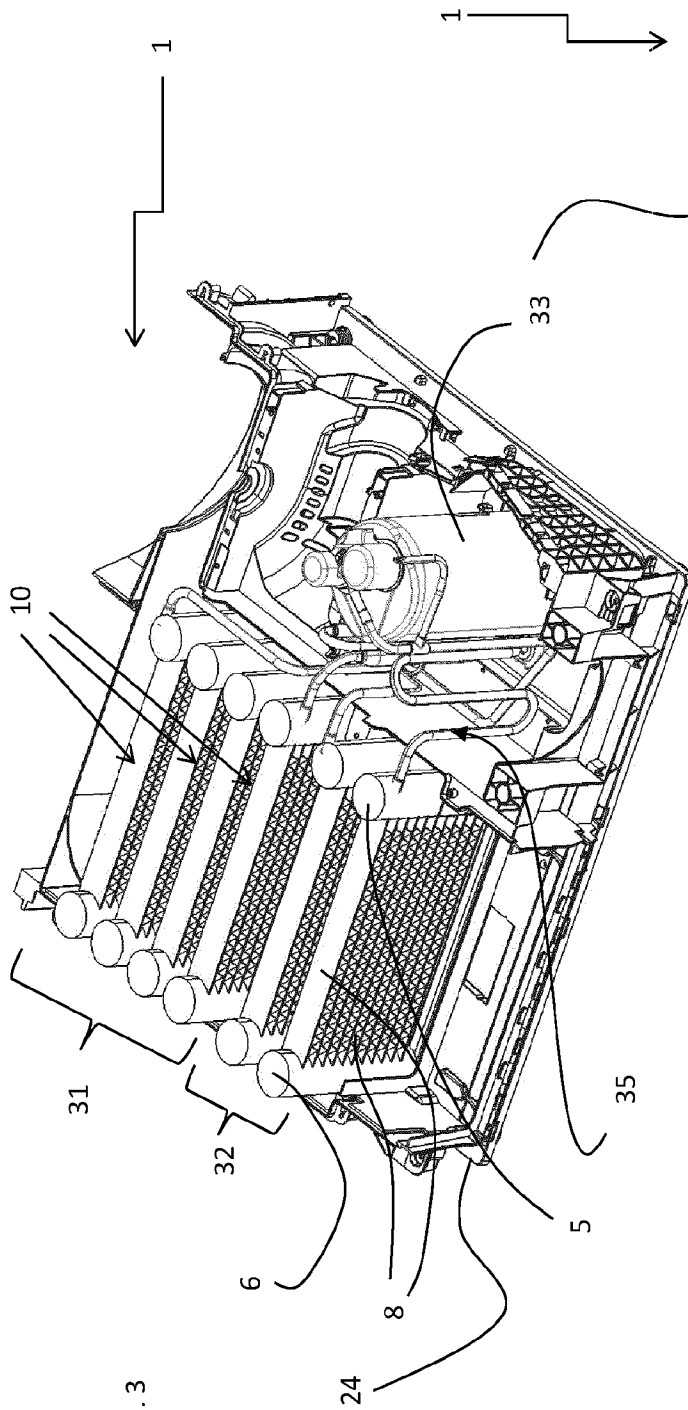


FIG. 3

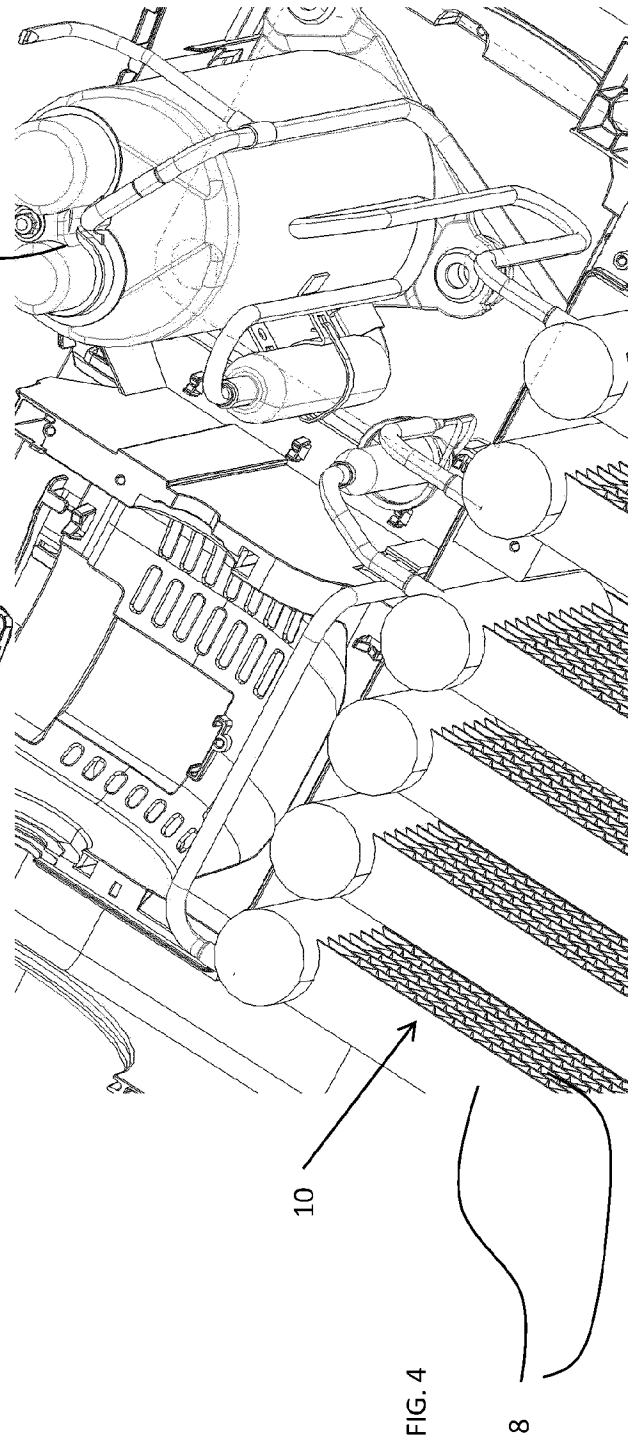
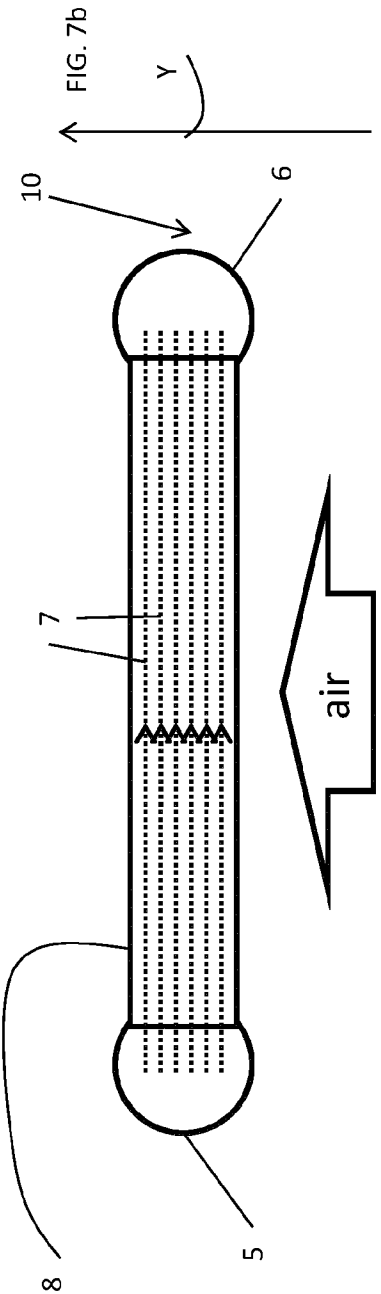
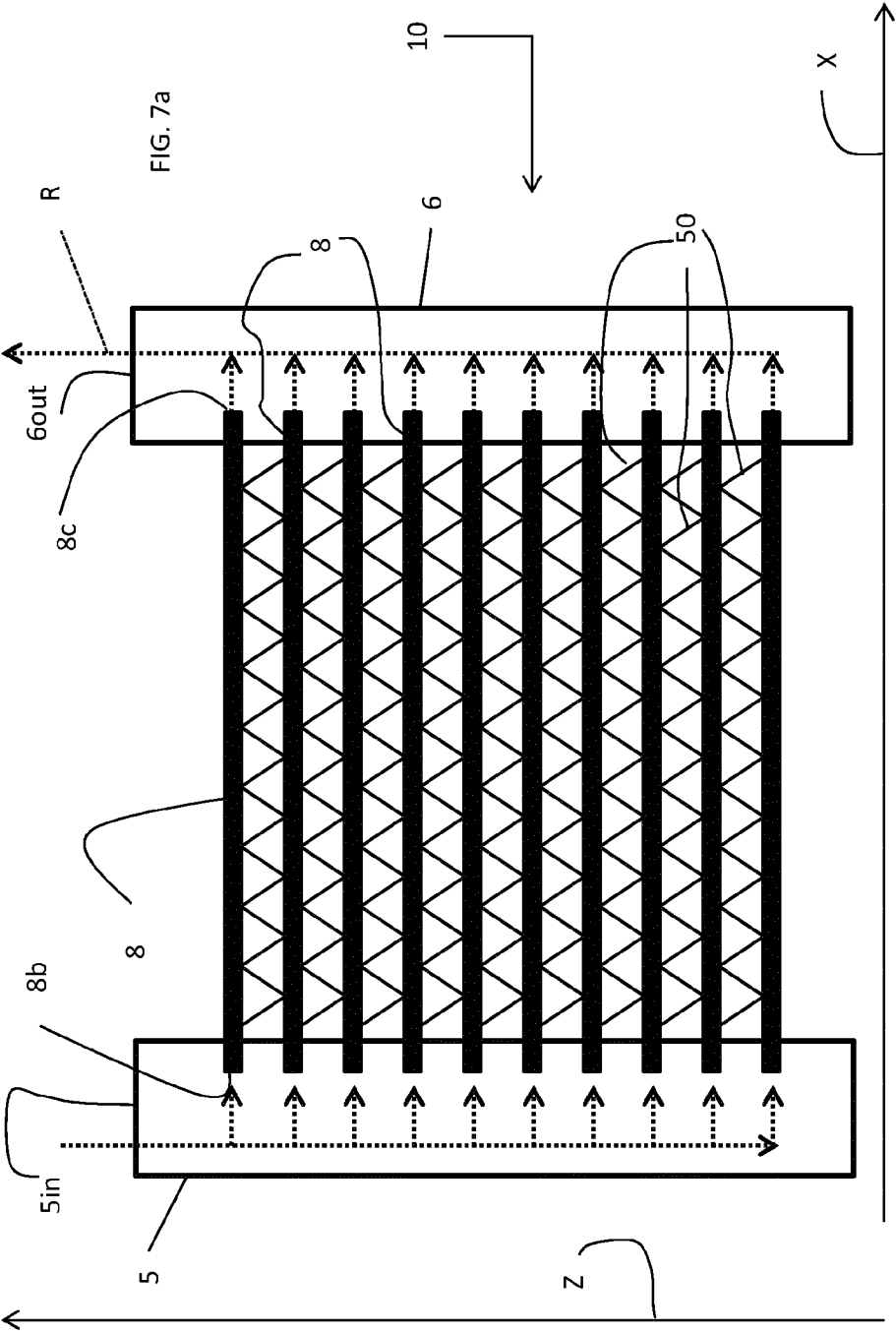
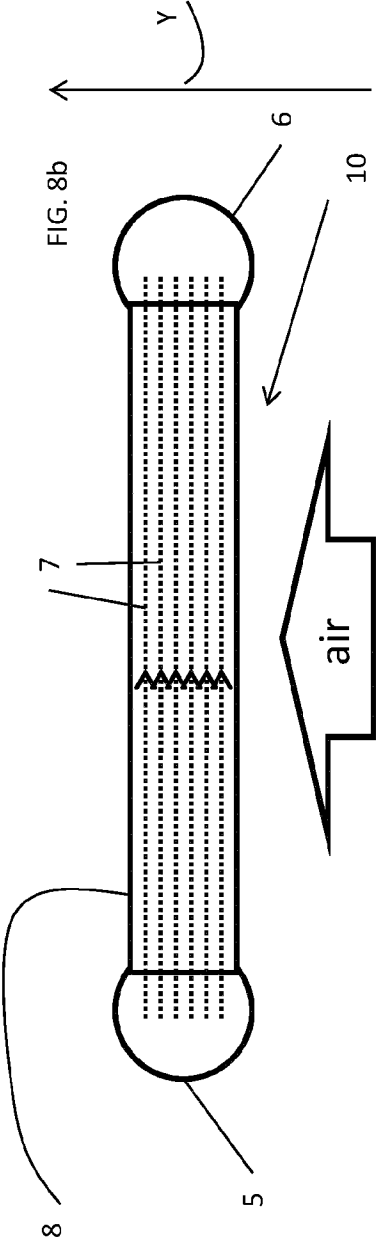
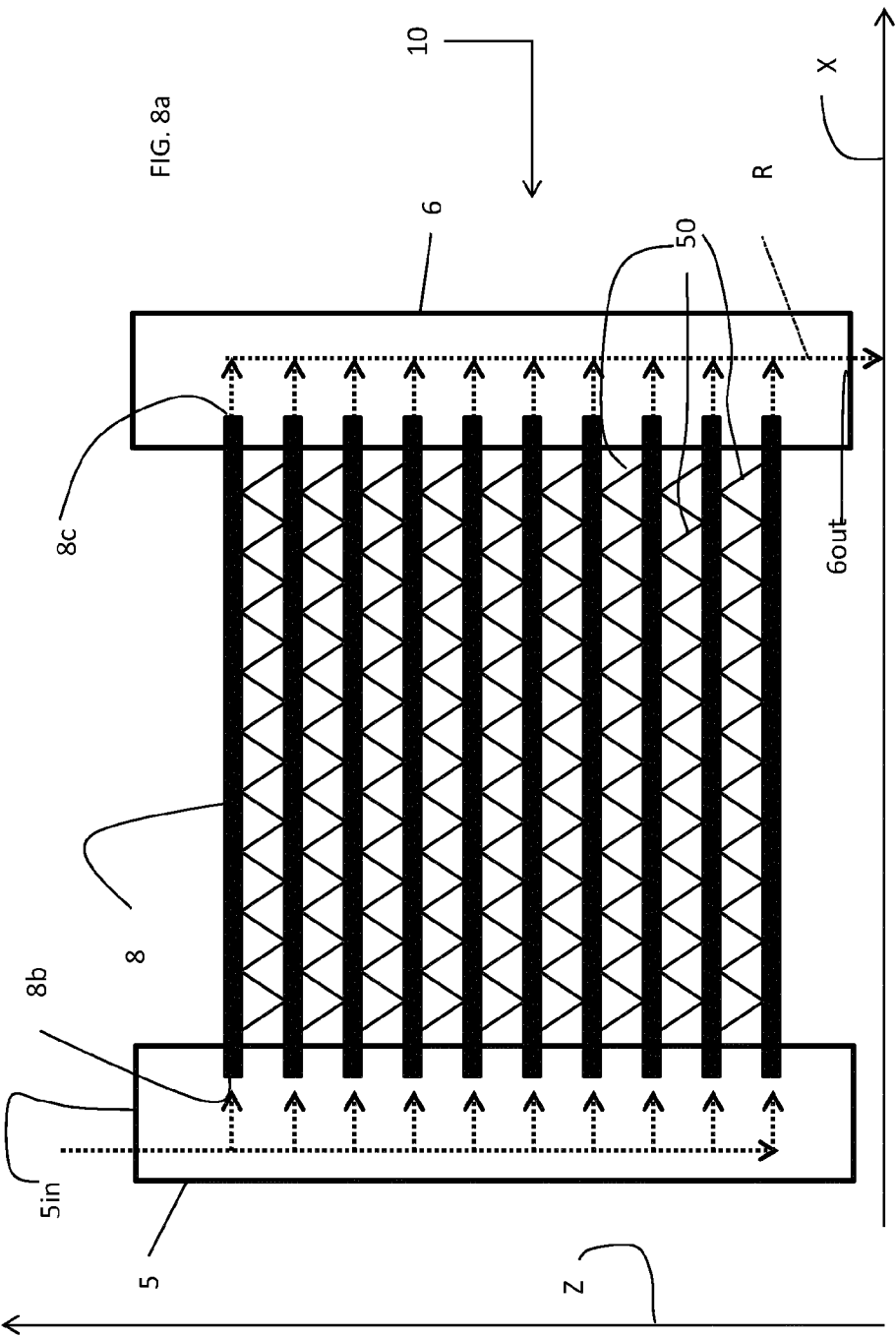
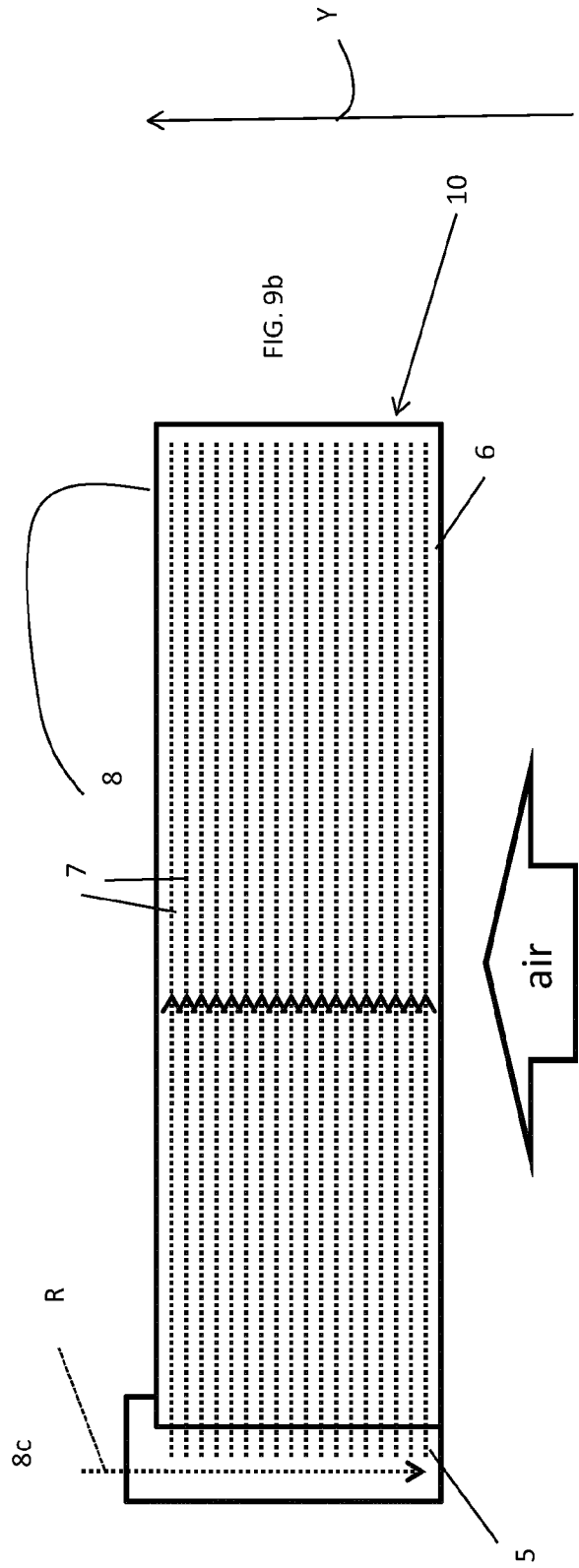
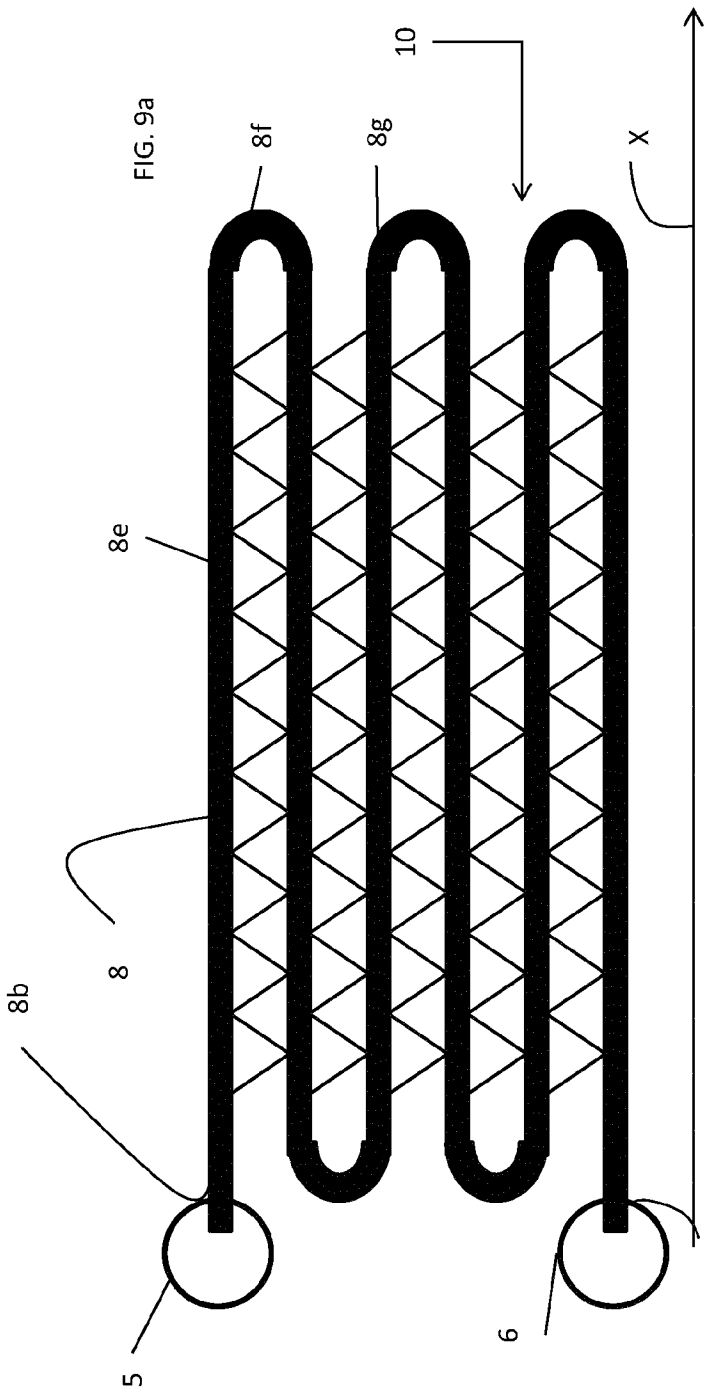
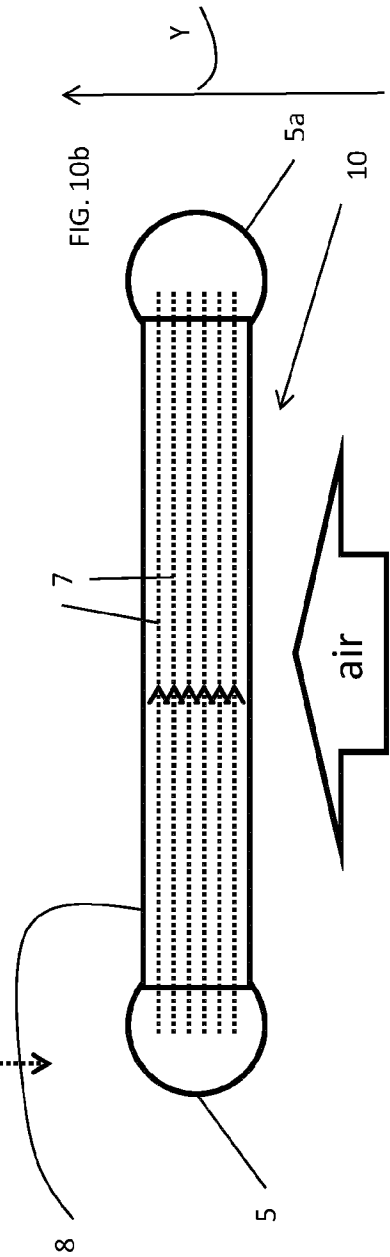
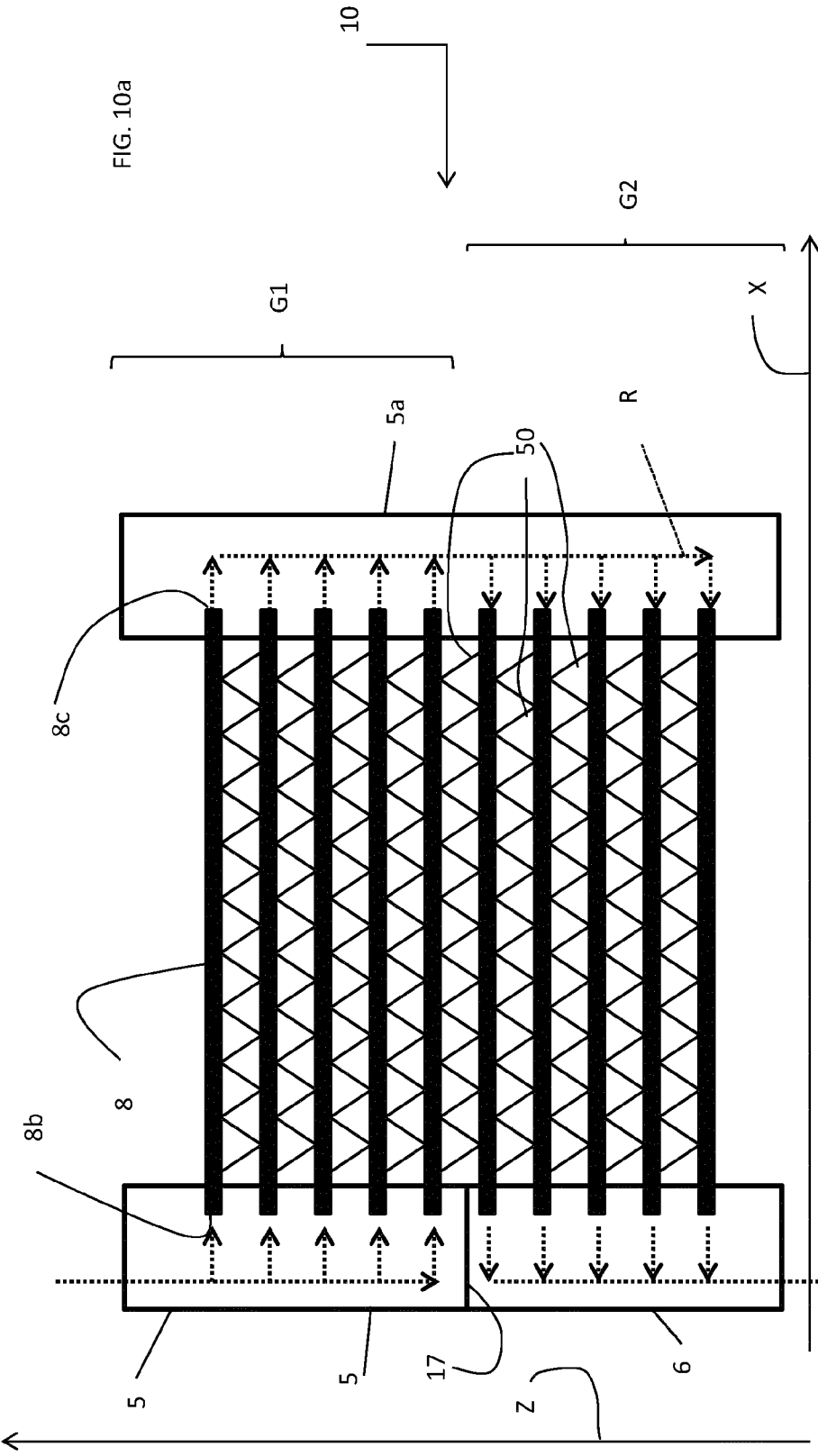


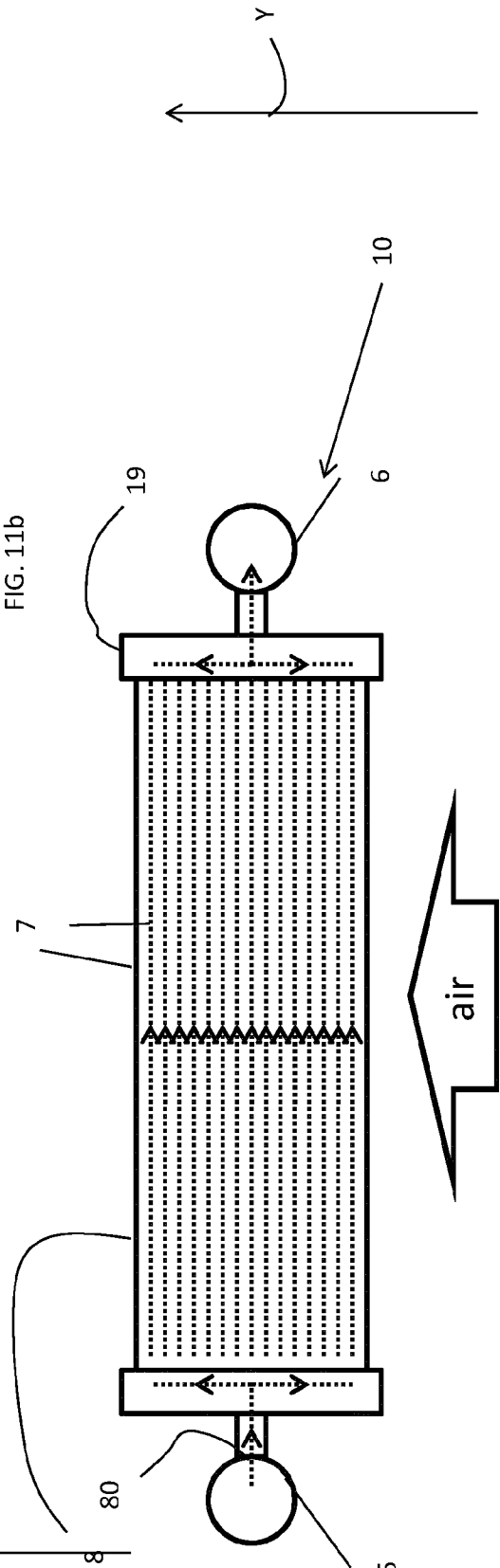
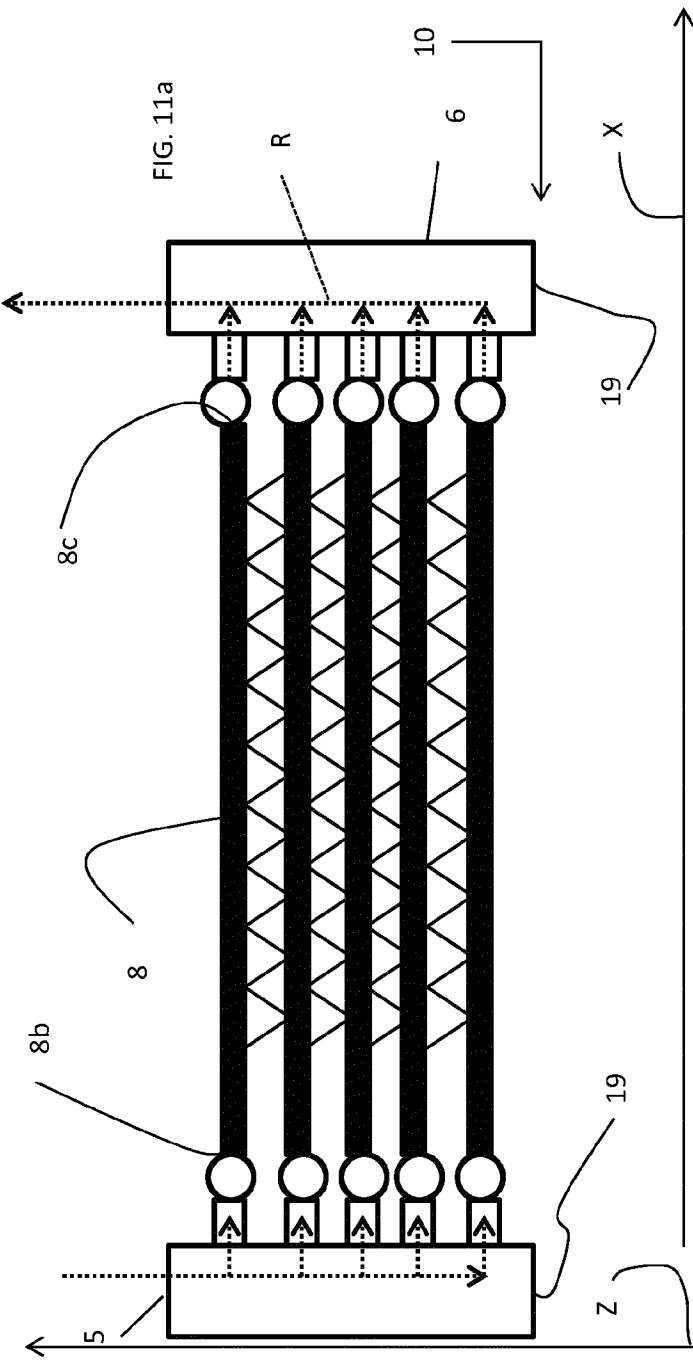
FIG. 4

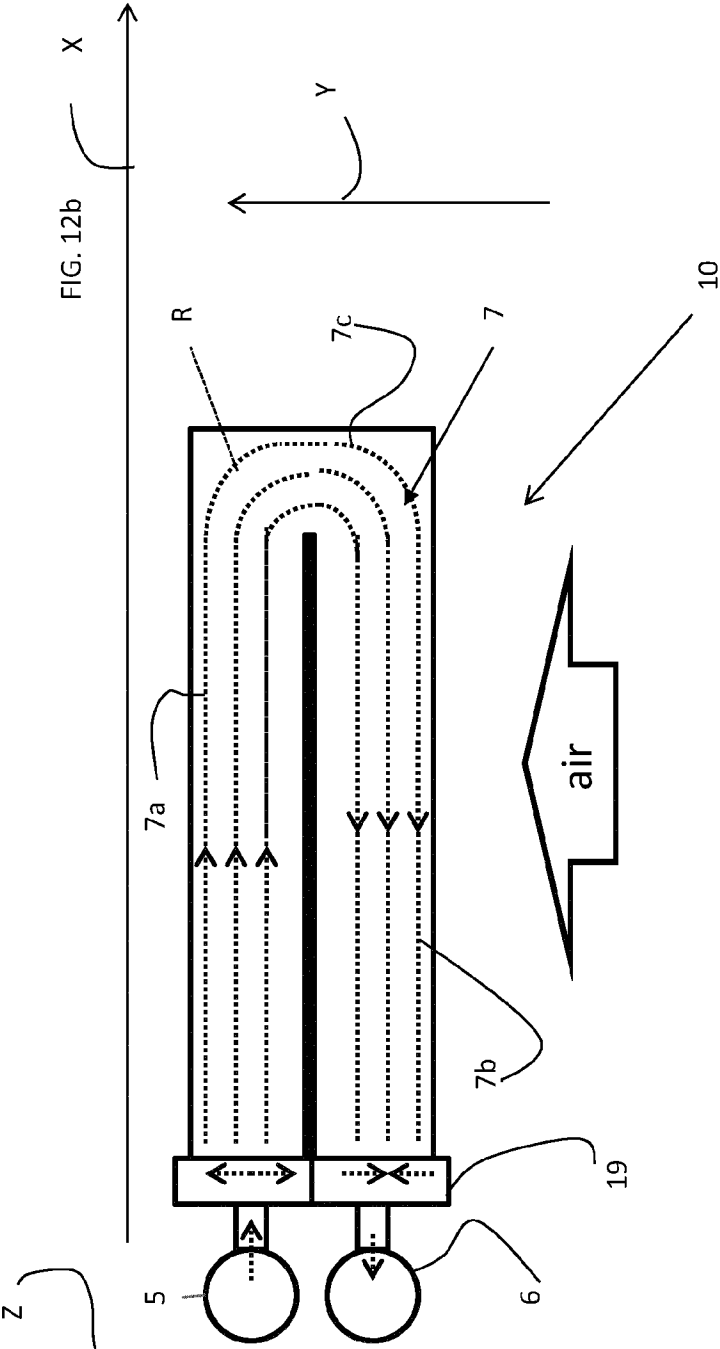
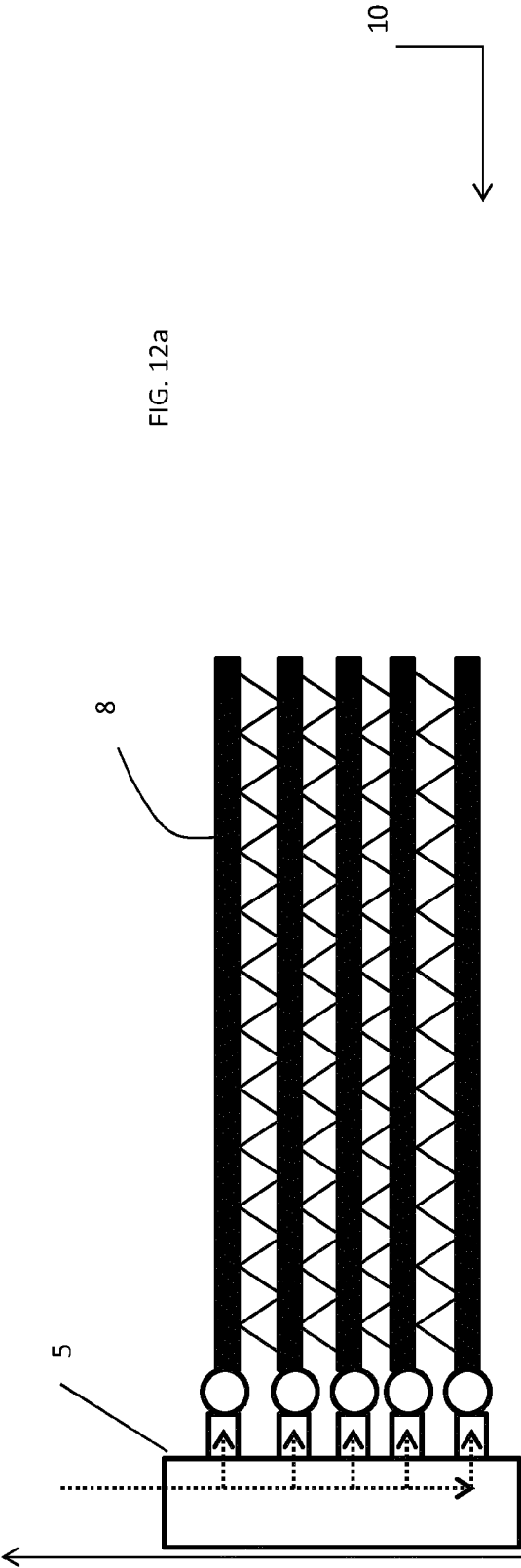












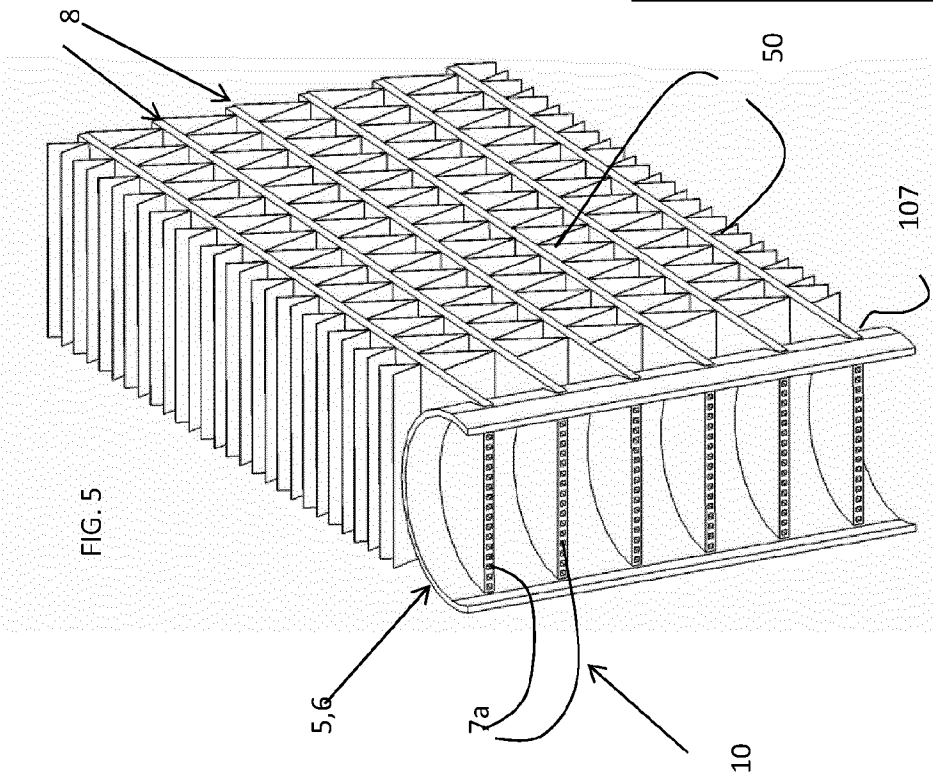
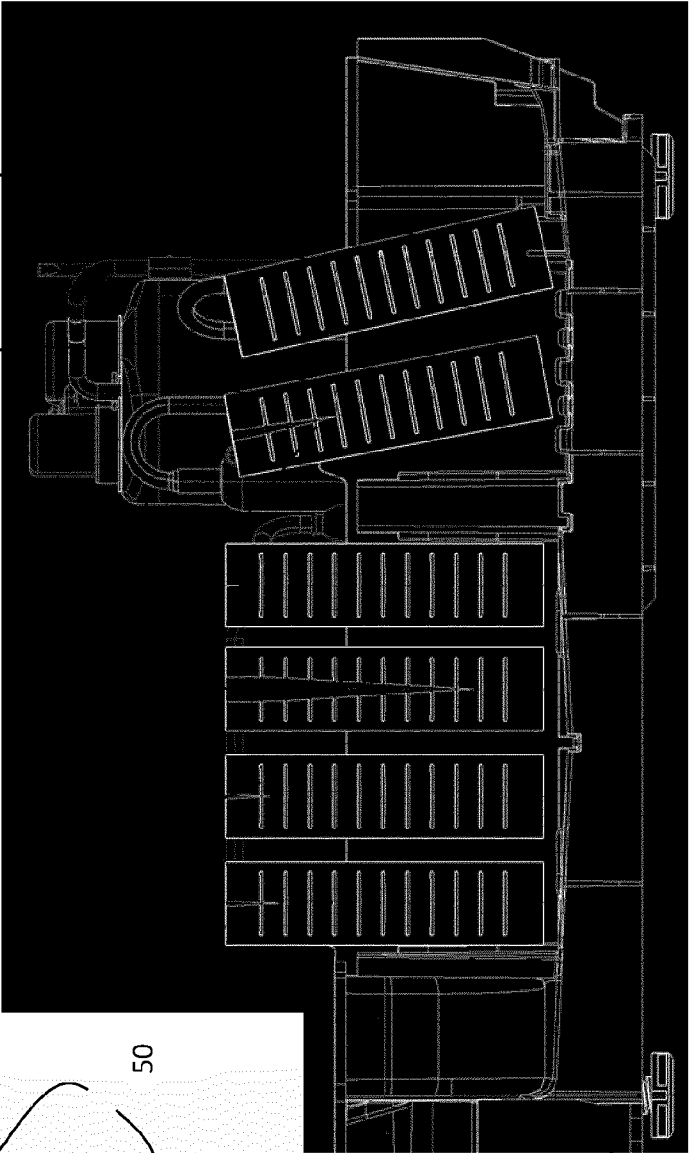


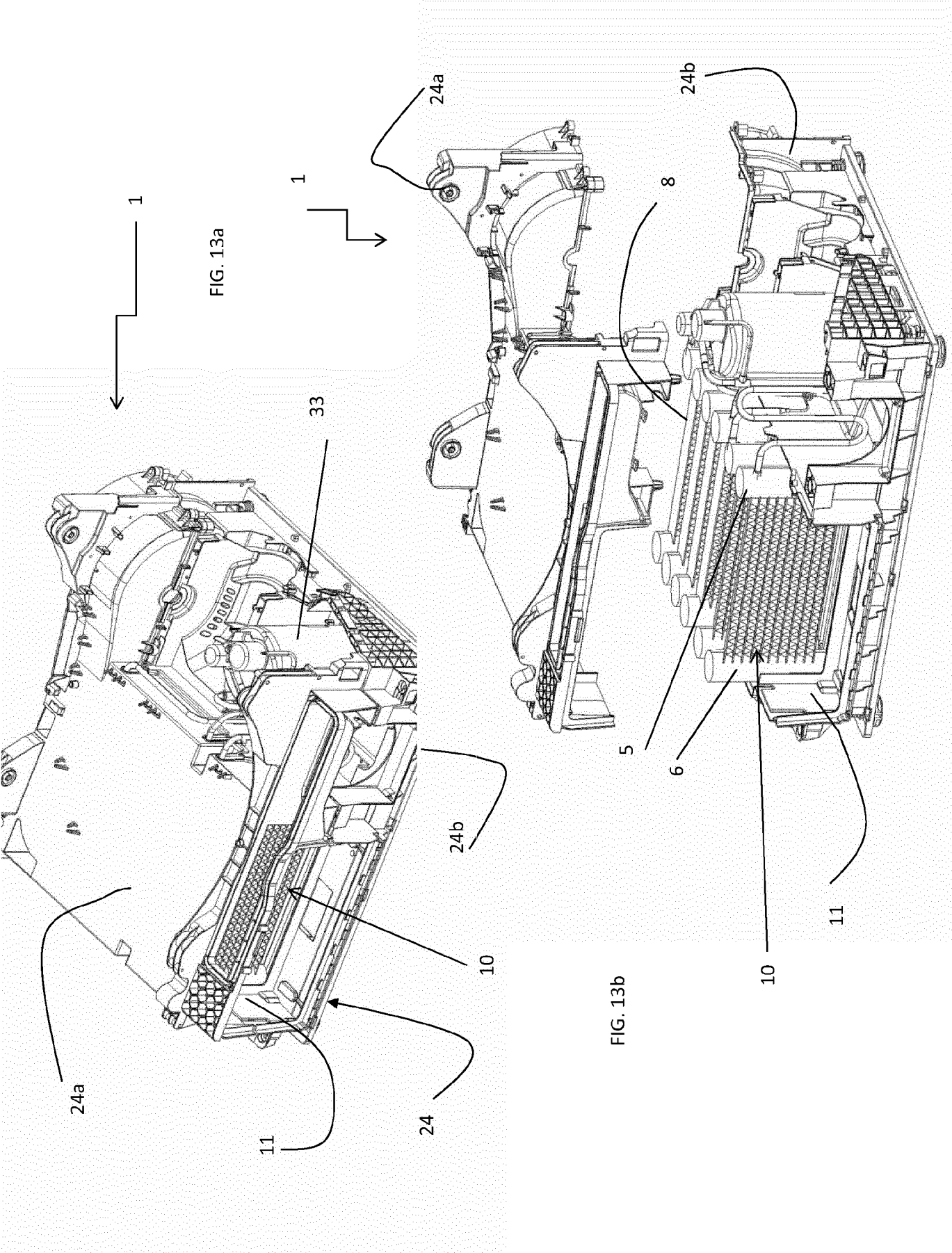
FIG. 14

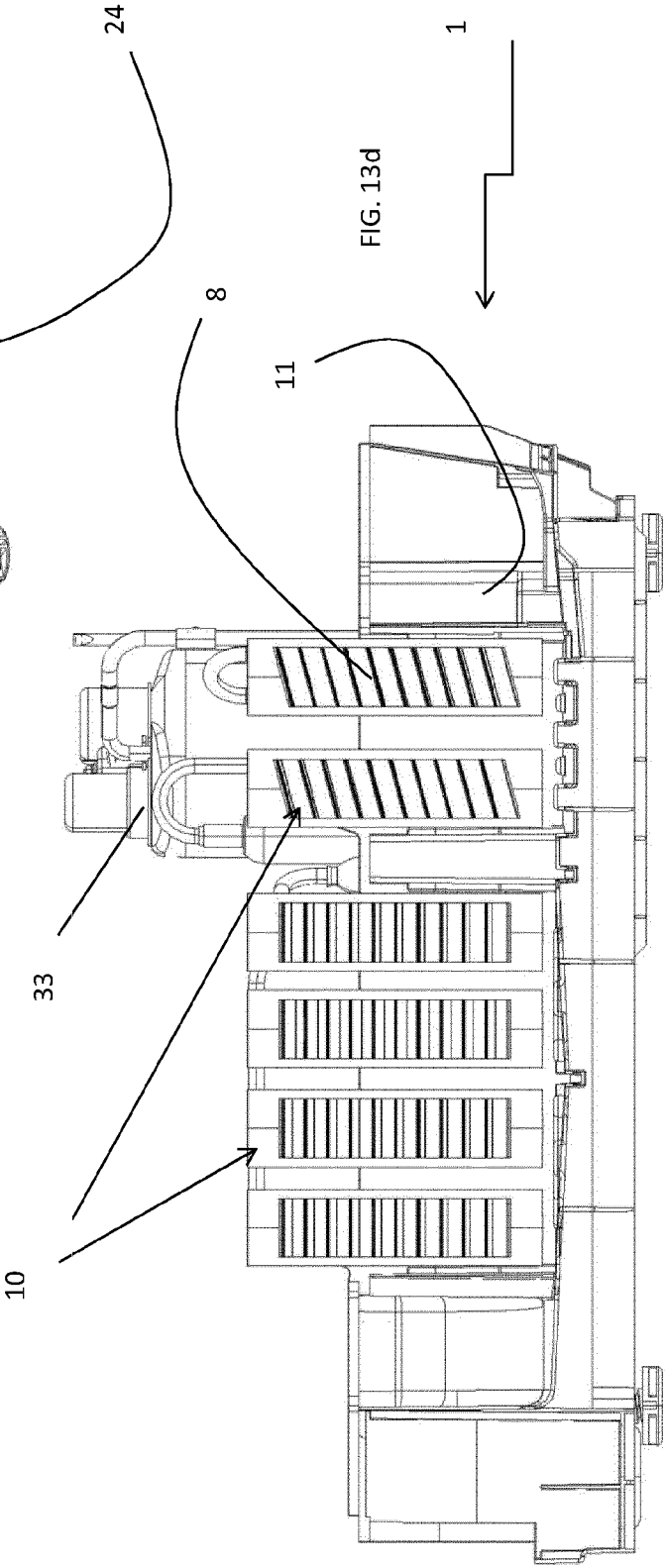
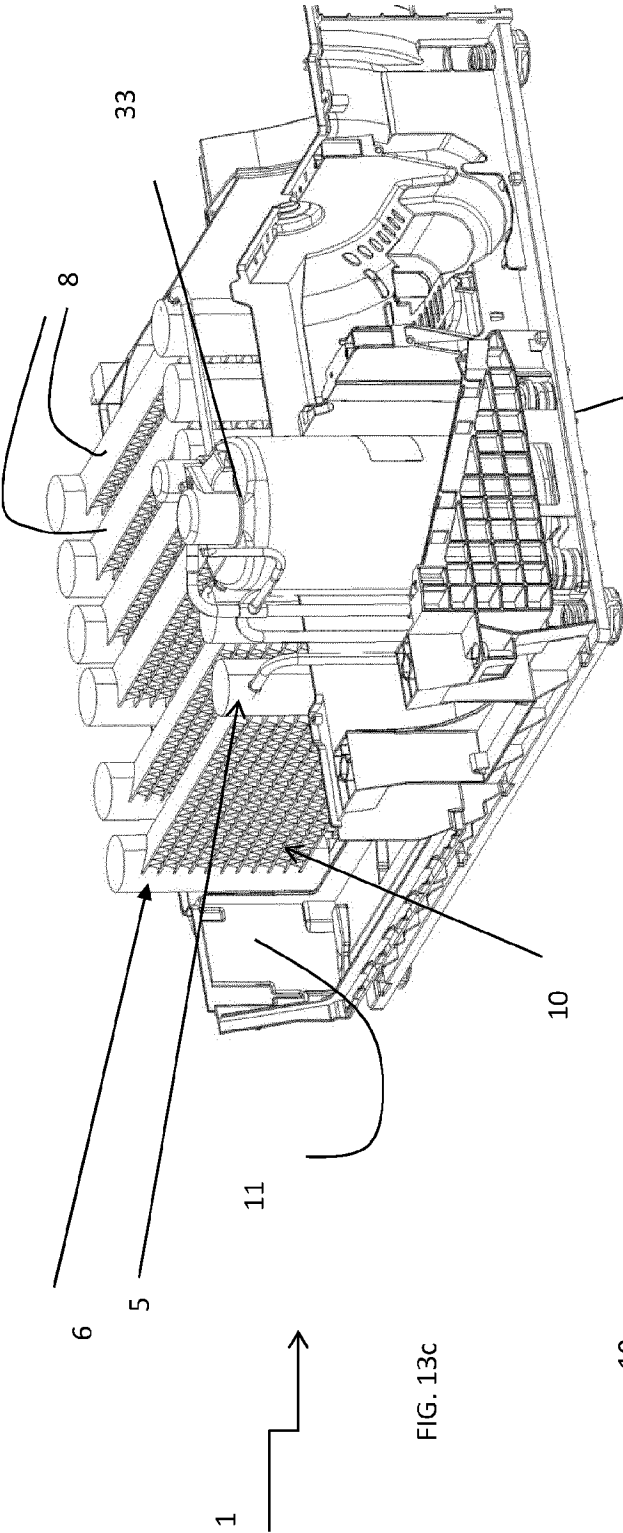
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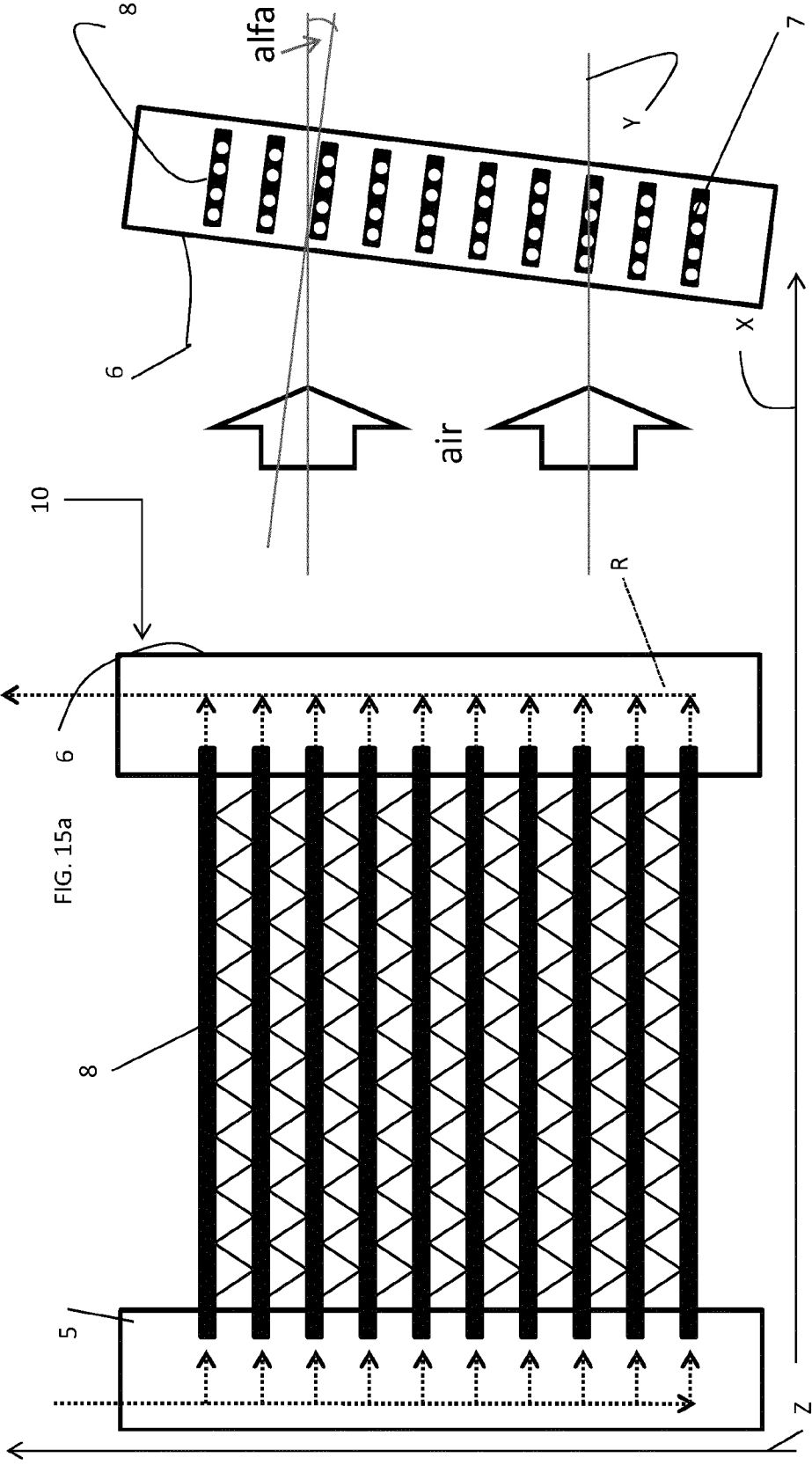


FIG. 15b

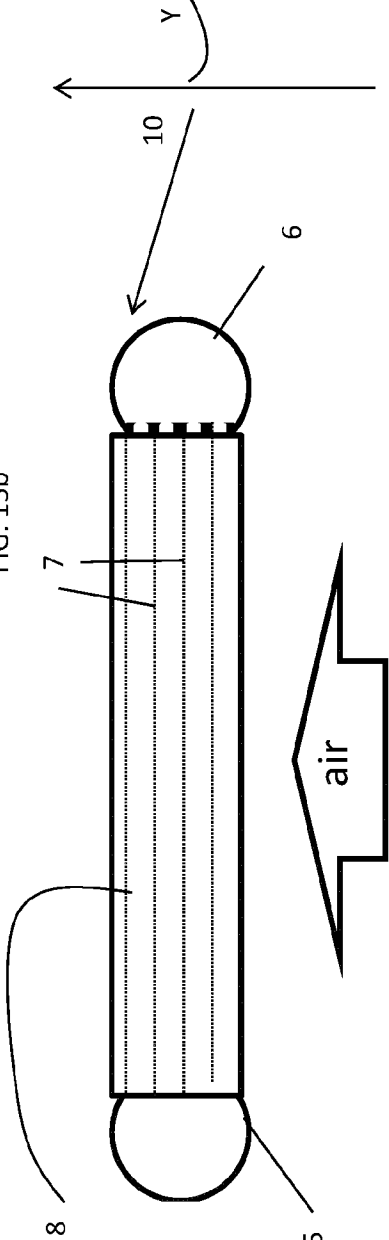
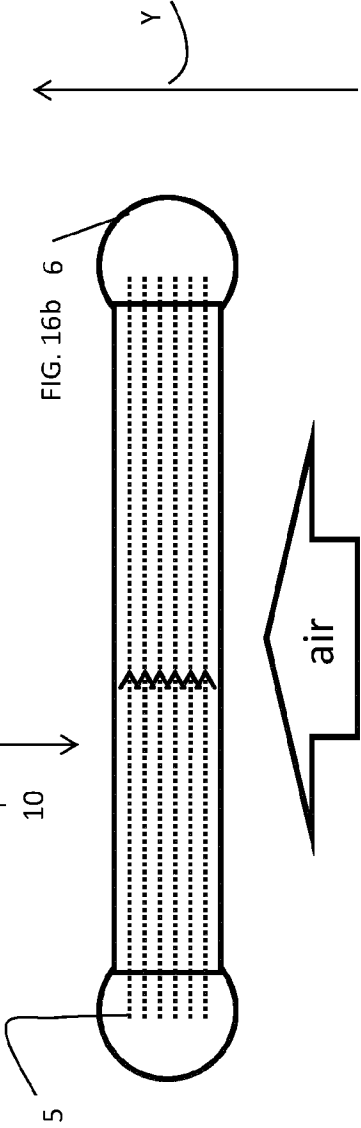
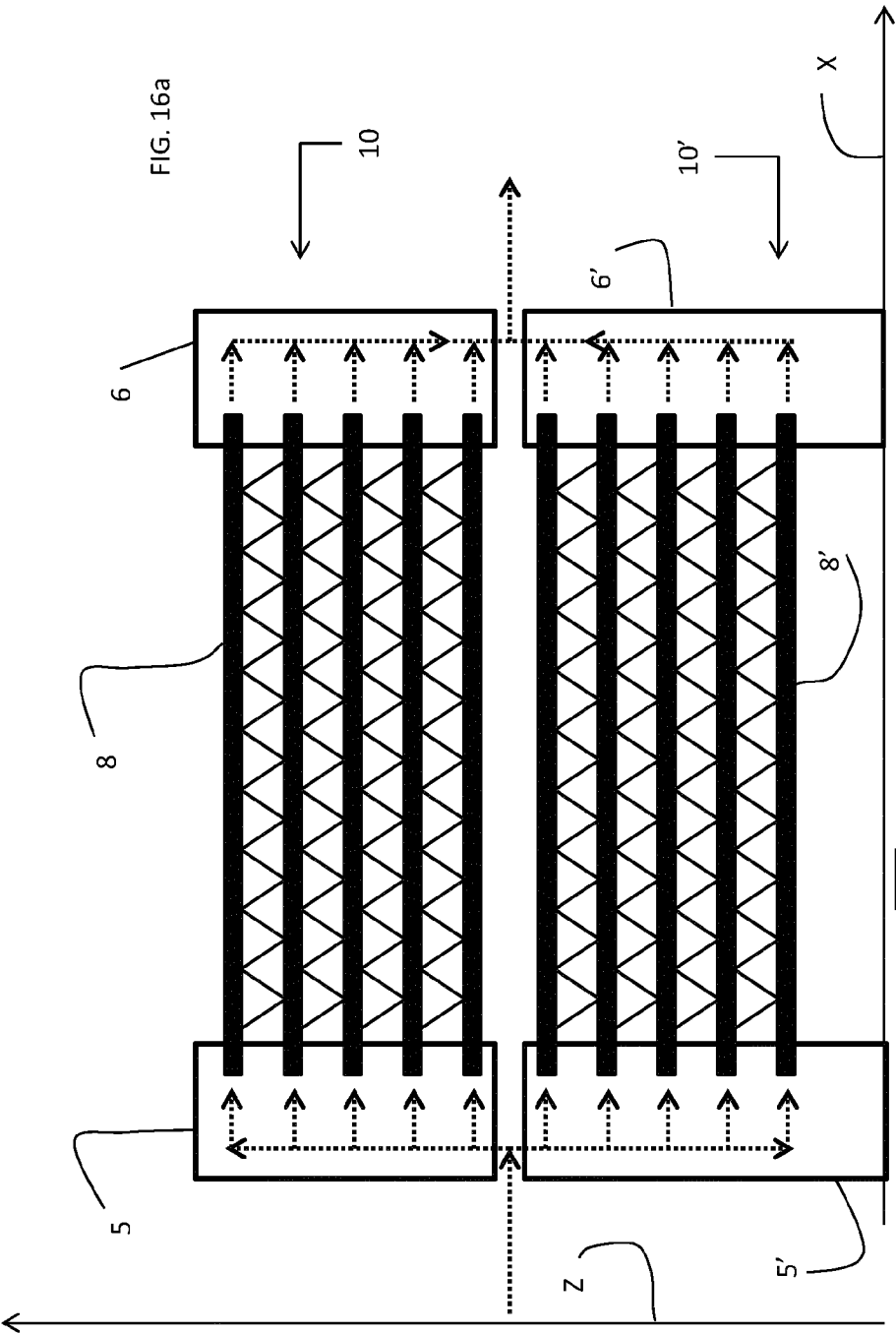
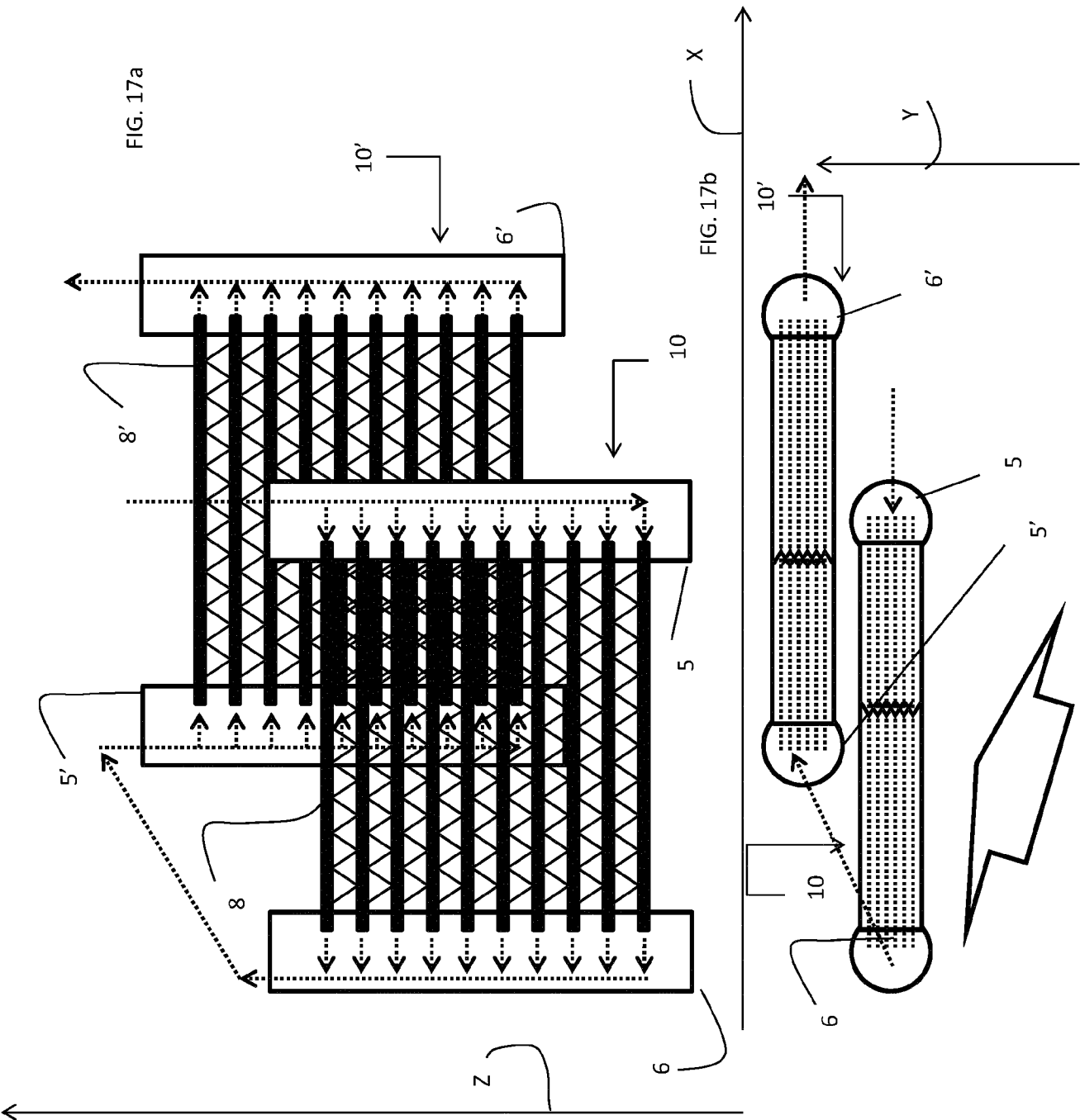
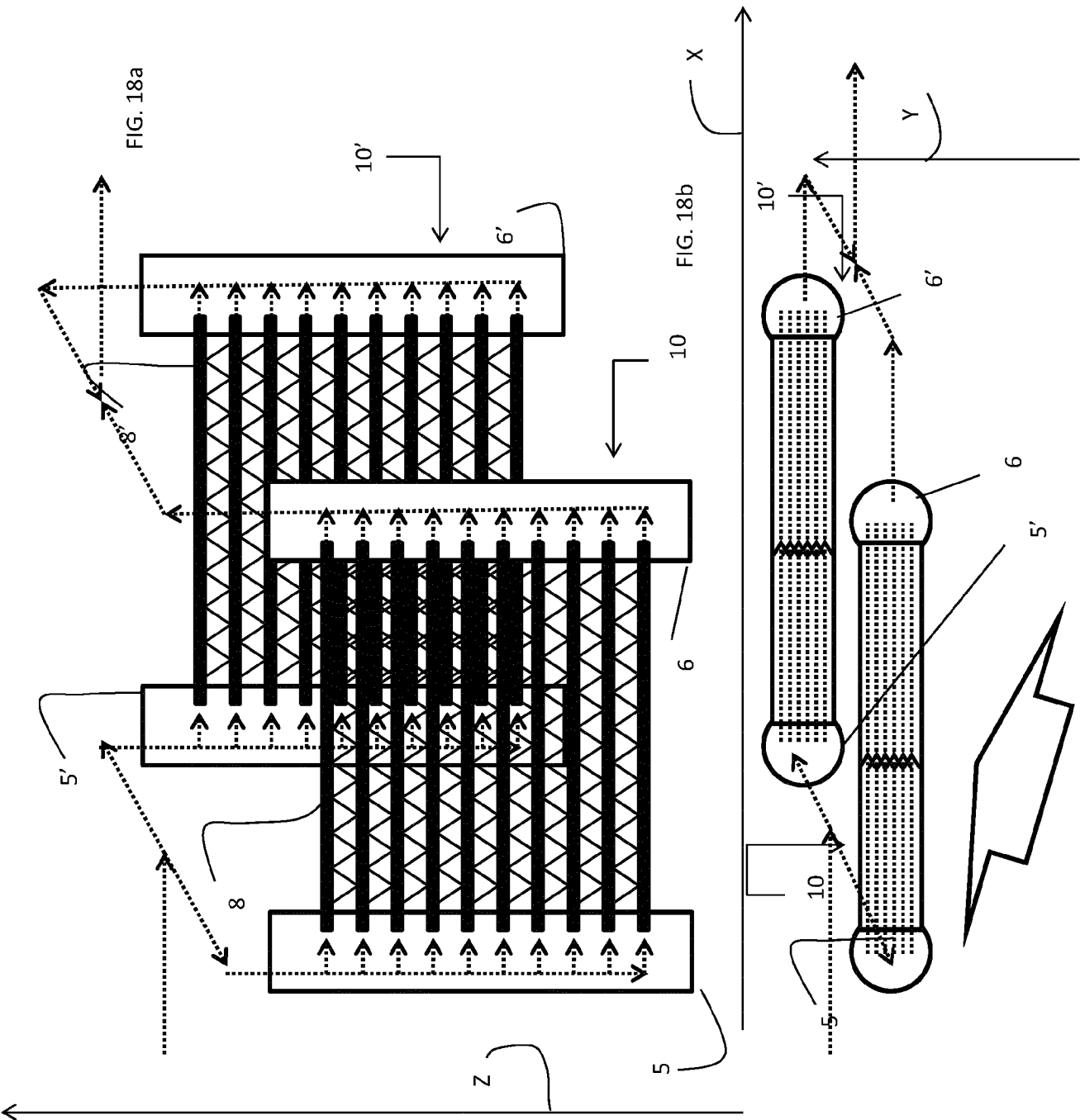


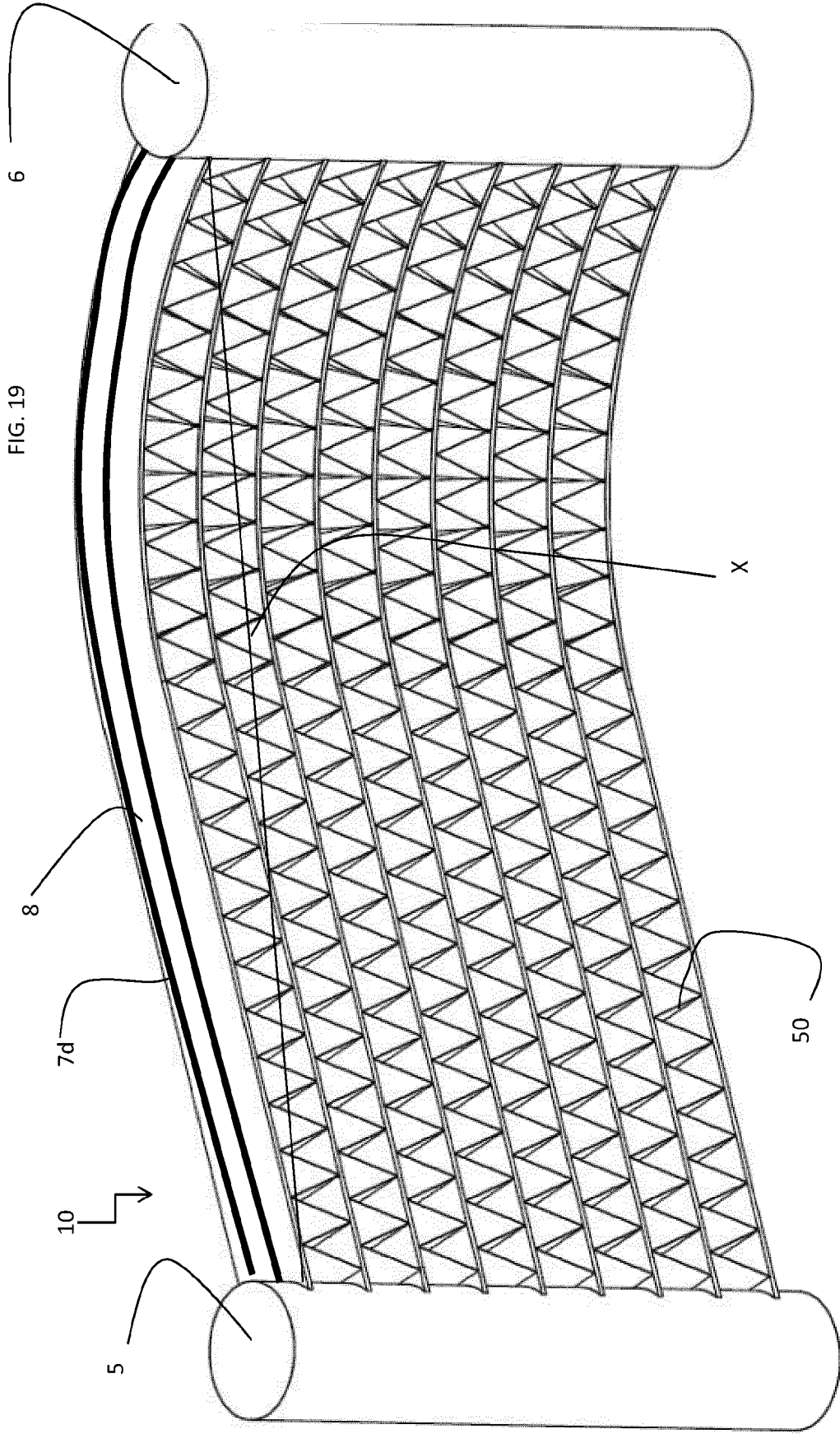
FIG. 15c











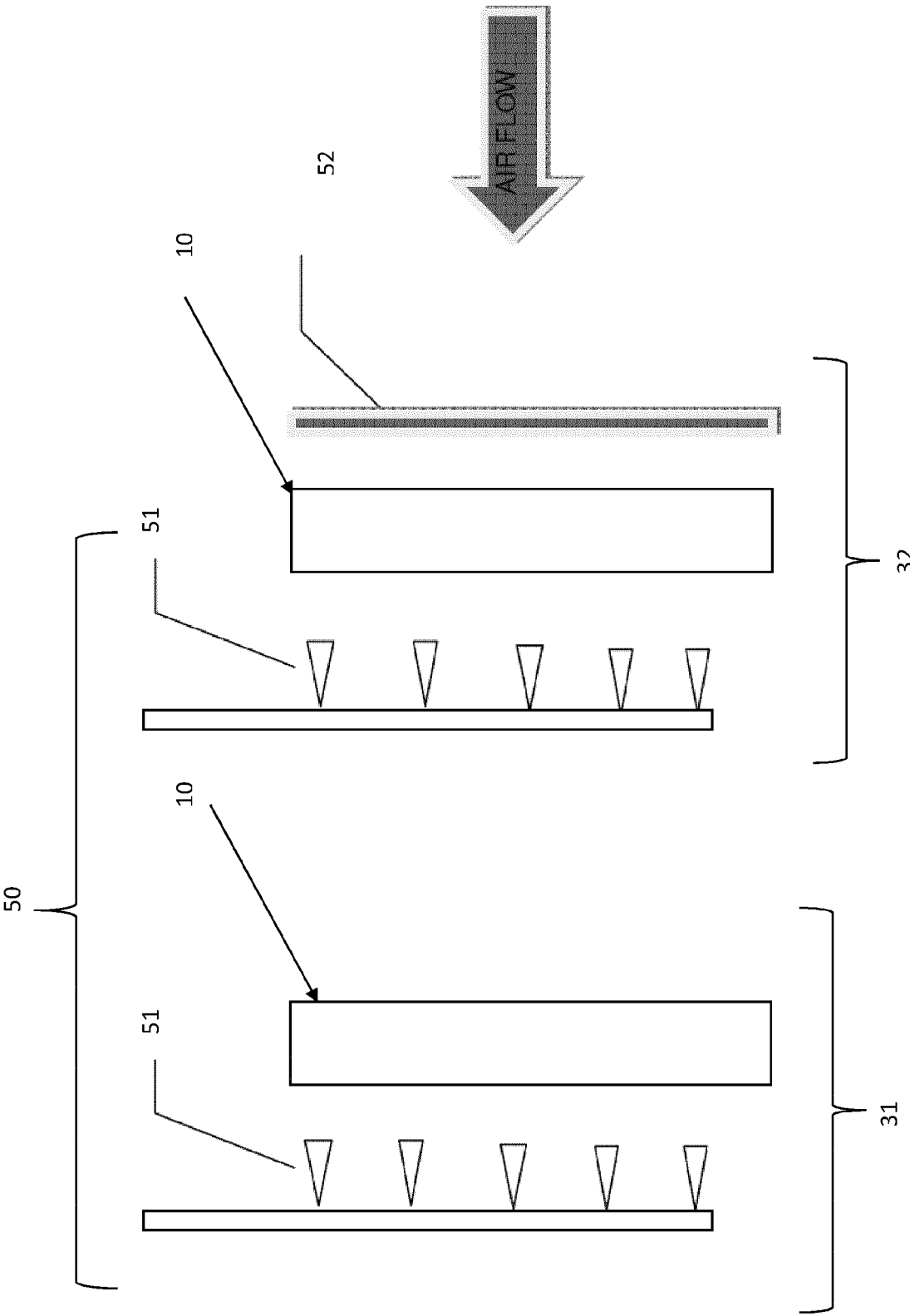


FIG. 20