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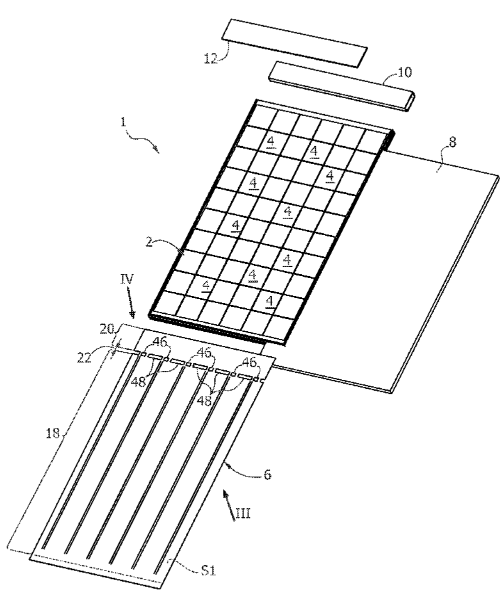
(54) **Title**: HYBRID SOLAR PANEL

FIG. 2



(57) Abstract: A hybrid solar panel is described (1) comprising a layer of photovoltaic cells (4) cooled by a cooling system comprising one or more heat pipe devices (16) each including an evaporation side (18) and a condensation side (20) for a thermovector fluid circulating within them. More precisely, the photovoltaic cells (4) are preferably arranged only in correspondence of the evaporation side (18) of the heat pipe devices (16) in such a way that they supply heat flow to the aforesaid evaporation side (18) such that their temperature can be lowered and such as to cause evaporation of the thermovector fluid inside the heat pipe devices (16), which is then carried in the vapour phase toward the condensation side (20). A manifold member (10) is installed next to the condensation side (20), arranged to convey a fluid, particularly water, in a heat exchange relationship with the thermovector fluid within the thermal exchange layer (6). The fluid flowing in the manifold member (10) is heated by the thermovector fluid in the vapour phase which condenses inside the condensation side (20) of each heat pipe device. The layer (2) of photovoltaic cells (4) and the thermal exchange layer (6) are clamped into a back panel (2) by means of a framework preferably made of metal profiled bars. The thermal exchange layer (6) is a metal component wherein the heat pipe devices (16) are made by soldering two sheets of metallic material using roll-bond technology.

WO 2012/176136 A2

"Hybrid solar panel"

TEXT OF THE DESCRIPTION

Field of invention

The present invention relates to a hybrid solar panel, of the type comprising a plurality of photovoltaic cells and cooling means for said photovoltaic cells arranged for transfer of heat flow to a fluid, e.g. water, conveyed to the outside for other uses.

In particular, the invention relates to a hybrid photovoltaic panel comprising:

- a photovoltaic layer including a plurality of photovoltaic cells,
- a thermal exchange layer including cooling means for said photovoltaic cells,
- a manifold member arranged to convey a fluid, particularly a liquid, in thermal exchange relationship with said thermal exchange layer,

wherein

said thermal exchange layer comprises one or more heat pipe devices adapted to contain a thermovector fluid, each heat pipe device comprising:

- an evaporation side of the thermo vector fluid arranged for absorbing a heat flow from the photovoltaic cells and defining said cooling means,
- a condensation side of the thermovector fluid, in correspondence of which said manifold member is applied,

Wherein the photovoltaic cells of the photovoltaic layer are applied in correspondence of the evaporation side of said one or more heat pipe devices and are in thermal exchange relationship therewith.

Prior Art

The solar panels of the hybrid type are well known in the technical field of reference and therefore offer the possibility of transforming the energy associated with solar radiation into electrical energy by photovoltaic cells, as well as the possibility for heating a fluid, in particular a liquid, by means of a cooling circuit of the photovoltaic cells themselves.

Several known solutions involve the use of heat exchangers manufactured with roll-bond technology and arranged at the back of the photovoltaic cells. However, in view of the undoubted benefits typical of the solutions made with roll-bond technology, which include, for example, the very competitive cost, good performance and the relative simplicity of production, there are a number of technical problems that cannot be considered as being solved.

In particular, the use of a heat exchanger manufactured using roll-bond technology implies having to tolerate considerable pressure losses of the fluid within the heat exchanger, due to the relatively small dimensions of the passage areas of the channels of the exchanger with a consequent increase in the power required for the rotational driving of a pump arranged to circulate a cooling fluid, in particular a liquid, inside the aforesaid heat exchanger.

The above-mentioned problems are further aggravated by the fact that the cooling fluid used is water in almost all cases, which creates many problems in the use of aluminium alloys of which the heat exchangers produced with roll-bond technology are made.

In fact, in the presence of aqueous solutions, pure aluminium, or its alloys have amphoteric behaviour, making it subject to destructive corrosion phenomena. In the known solutions, the problem is solved by additives which are periodically placed in the cooling circuit, but which can, however, cause deposits and have a far from negligible cost.

Moreover, hybrid solar panels of the known type manufactured, with heat exchangers produced with roll-bond technology, sometimes have marked thermal non-uniformities between different areas of the panel that are accentuated during operational transients. These thermal non-uniformities notably reduce the efficiency of photovoltaic cells, especially if they are connected in series.

It should not be forgotten that the efficiency of the photovoltaic cells tends to increase with the decreasing of their temperature, so that their cooling is beneficial, not only because it allows the obtaining of resulting additional useful energy, but also because it increases the conversion efficiency of the photovoltaic cells.

Another known solution is illustrated in WO-A-2011/032164, wherein a hybrid solar panel is illustrated, comprising a layer of photovoltaic cells arranged in arrays on fins of respective heat pipe devices. As known to those skilled in the art, the heat pipe devices contain within them a thermovector fluid, which undergoes two phase changes, one within an evaporation side (liquid-gas) the other within a condensation side (gas-liquid) and they essentially operate as a thermal diode, i.e. there is a single direction of circulation of thermovector fluid within them and a single direction of heat transfer.

The photovoltaic cells are arranged on fins applied next to the evaporation side of the heat pipe devices while the condensation sides of each heat pipe device are inserted into a head where thermal exchange takes place with a fluid flowing within it.

The solution illustrated in the document WO-A-2011/032164 above all presents a considerable complication from a constructive point of view. Moreover, the heat pipe devices used have a tubular structure with a single internal volume within which the phase changes of the thermovector fluid occur, and are severely limited in their operation by problems of entrainment, or rather migration of particles of thermovector fluid in the liquid phase in the gas stream of the same thermovector fluid that travels upwards to the condensation side.

The structure of the hybrid solar panel presented in the aforesaid document is also decidedly non-compact and is therefore not suitable for the application in contexts that require the smallest bulk possible or easy camouflage of the solar panel.

Object of the invention

The object of the present invention is that of solving the previously described technical problems.

In particular, the object of the invention is to provide a hybrid solar panel with a compact structure, with a simple construction, low cost and high efficiency.

Summary of the invention

The object of the invention is achieved by a hybrid solar panel having the features forming the subject of one or more of the following claims, which form an integral part of the technical disclosure herein provided in relation to the invention.

In particular, the object is achieved by a hybrid solar panel having all the features listed at the beginning of the present description and further characterized in that each heat pipe device comprises a closed circuit arranged for the circulation of the thermovector fluid and including a first channel adapted to receive the thermovector fluid from the condensation side in liquid phase and adapted to convey the thermovector fluid towards at least one second channel, which in turn is adapted to convey the thermo vector fluid in vapour phase towards the condensation side, wherein each heat pipe device is made by joining a first and a second sheet made of metal material in correspondence of areas delimiting the closed circuit of each heat pipe device.

Brief description of the figures

The invention will now be described with reference to the attached drawings, provided purely by way of non-limiting example, wherein:

- Figure 1 is a perspective view of a hybrid solar panel according to a preferred embodiment of the invention,
- Figure 2 is an exploded perspective view of the solar panel of Figure 1,
- Figures 3 and 4 are plan views according to, respectively, the arrows III and IV of Figure 2, of a component of the panel according to the invention,
- Figures 5 and 6 are enlarged views of details indicated by the arrows V and VI in Figure 3,
- Figures 7 and 8 are views according to the arrows VII and VIII of Figure 1,
- Figures 9 and 10 are sectional views along the tracks IX - IX and X – X, respectively, of Figure 7.
- Figure 11 shows a further embodiment of a component of the panel according to the invention, and
- Figures 12, 13 are enlarged views of details indicated with arrows XII, XIII, respectively, in Figure 11.

Detailed description

In Figure 1 the reference number 1 indicates a hybrid solar panel according to a preferred embodiment of the present invention.

Also with reference to Figure 2, the hybrid solar panel 1 comprises a photovoltaic layer 2 including a plurality of photovoltaic cells 4, a thermal exchange layer 6 and a back panel 8, wherein the thermal exchange layer 6 is arranged between the photovoltaic layer 2 and the back panel 8. The solar panel 1 further comprises a manifold member 10, within which a duct 11 is formed, and a flat member 12 arranged on opposite sides of the thermal exchange element 6 externally with respect to the photovoltaic layer 2 at the back panel 8.

With reference to Figure 1, the photovoltaic layer 2, the thermal exchange layer 6 and the back panel 8 are clamped together by means of a framework 14, preferably comprised of metal profiled bars.

With reference to Figures 3, 4, the thermal exchange layer 6 comprises a plurality of heat pipe devices indicated with the reference number 16 containing a thermovector fluid and manufactured using roll-bond technology by soldering of a first and a second sheet S1, S2 of metallic material, preferably aluminium.

As known to the skilled person, roll-bond technology involves the creation of cavities and/or channels, of any particular path, between two sheets of metallic material by applying a serigraphy reproducing, substantially in plan view, the path of the cavities and/or channels, followed by the subsequent pressing and hot rolling of the metal sheets. The latter operation creates the soldering of the material only in correspondence of areas where the serigraphy was not applied, i.e. at the areas delimiting the channels and/or the cavities.

Subsequently, the volumes of the cavities and/or channels are formed by means of pneumatic inflation, which envisages the injection of pressurized air (typically between 90 and 130 bar) between the metal sheets. The air pressure is however dependent on the thickness, the nature of the joined sheets and on the conformation of the cavities and/or channels.

Each heat pipe device 16 comprises a closed circuit arranged for the circulation of thermovector fluid, and comprising an evaporation side 18 and a condensation side 20 of the thermovector fluid, separated by adiabatic zone 22.

In addition, named L_C, L_E and L_A, the lengths, respectively, of the condensation side 18, the evaporation side 20 of each single heat pipe device 16 and of the adiabatic zone, and named L_{TOT} the sum thereof, typical values are:

- between 0.03 and 0.4 for L_C/L_{TOT}
- between 0.5 and 0.97 mm for L_E/L_{TOT}, and
- between 0.001 and 0.4 for L_A/L_{TOT}

The evaporation side 18 comprises a first channel 24 in fluid communication with a second channel 26 by means of a connecting portion 28, having an essentially “U”-shaped geometry and arranged at the opposite end with respect to the condensation side 20.

The latter comprises a reservoir 30 in fluid communication with the first channel 24 by means of an outflow port 32 and in fluid communication with the second channel 26 by means of an inflow port 34.

The term “reservoir” used in the present description is intended to indicate a portion of the closed circuit within which the thermovector fluid flows (and is temporarily accumulated), having passage areas appreciably greater with respect to those of the channels 24, 26 (and the rest of the circuit in general) in such a way as to introduce a localized hydraulic capacity in the closed circuit.

With reference to Figures 5, 6, in a preferred embodiment the first channel 24 is in fluid communication with the outflow port 32 by means of a siphon duct generally indicated by the reference numeral 36. The siphon duct 36 comprises a first and a second bend 38, 40 fluid dynamically arranged in series, wherein - in this embodiment - the bend 38 is located at a distance D_{38} from the reservoir 30 which is greater than a distance D_{40} of the second bend 40 from the reservoir 30 itself. In addition, the bends 38, 40 define a curved path essentially with an "S"-shaped geometry comprising an outflow stretch 38a that connects the outflow port 32 to the first bend 38, creating a first curve of magnitude preferably equal to 180° which enters an upflow stretch 40a. The upflow stretch 40a flows directly into the second bend 40, which in turn creates a second curve, of magnitude preferably equal to 180°, in order to then directly flow into the first channel 24.

It should be noted that the magnitude of the curves of the bends 38, 40 can be chosen at will, within the limits imposed by the function of the siphon duct 36, as will become clear below. In addition, using the reservoir 30 as a reference, the bend 40 has a greater geometric height than the bend 38. Using the same logic, the outflow port 32 has a smaller geometric height than the inflow port 34. The meaning of the term "geometric height" will also be made clearer below, with particular reference to the functional description of the solar panel 1.

With reference to Figures 3 to 6, it should also be noted that the siphon duct 36 and the inflow and outflow ports 34, 32 are preferably created in the condensation side 20.

Each first channel 24 is preferably bordered, along the evaporation side 18, by a first and a second thermal interruption 42, 44. The term “thermal interruption” means a physical interruption of the material of the sheets S1, S2 or an insert of thermally insulating material or indeed, a combination of both, and any provision in general designed to minimize the conductive thermal exchange between the channel 24 and the metallic material of the surrounding sheets S1, S2 - which essentially functions as a fin and is therefore potentially capable of conveying a massive heat flow.

Thermal interruptions 42 and 44 essentially extend from a border area with the adiabatic zone 22 up to the connecting portion 28.

Furthermore, the thermal interruptions 42, 44 may comprise, for example, interruptions of the material of the sheets S1, S2 made by laser cutting, inserts of thermally insulating material or a combination thereof.

The adiabatic zone 22 comprises a plurality of openings essentially with a transverse orientation to the first and second channels 24, 26 and comprising first openings 46 arranged between the channels 24, 26 of each heat pipe device 16, and a plurality of second openings 48 arranged between the channels 26 and 24 of adjacent heat pipe devices 16.

At the ends of the array of devices 16 recesses 50 are also provided. The openings 46, 48 and the recesses 50 have the function of limiting the structural continuity between the condensation side 20 and the evaporation side 18 to areas only where it is strictly necessary, thus limiting the heat flow transmitted by conduction between the evaporation side 18 and the condensation side 20 (in this sense they can also be defined as thermal interruptions).

Again, with reference to Figures 3, 4, according to an advantageous aspect of the invention, the path of the channels 24, 26, the connecting portion 28, the siphon duct 36 and the reservoir 16 are manufactured by means of outwards bulging of just one of the sheets S1, S2, in particular the sheet S1.

This is because, with reference to Figure 4, for the application considered here it is preferable to have a substantially planar surface, corresponding to the sheet S2, for coupling with the photovoltaic layer 2.

It is preferable to have planar geometry for the sheet S2, at least corresponding to the evaporation side 18 of each heat pipe device 16, and still preferably along the entire length of each heat pipe device 16.

As also shown in Figure 4, the thermal interruptions 42, 44 are preferably through-holes and pass through both sheets S1, S2. This also applies in the case wherein the thermal interruptions are created, for example, by means of inserts of thermally insulating material.

With reference to Figure 2 and Figures 7 to 10, the manner in which the components of the panel 1 are assembled together will be briefly described.

The thermal exchange layer 6 is arranged between the photovoltaic layer 2 and the back panel 8 in such a way that the latter two are located on opposite sides with respect to the thermal exchange layer 6 and are preferably only arranged next to the evaporation side of the heat pipe devices 16 and possibly also next to the adiabatic zone 22.

In this way, once the layers 2, 6 and the back panel 8 are blocked and clamped by means of the framework 14, the condensation side 20 of each of the heat pipe devices 16 remains exposed to the outside. It should also be noted that the planar surface of the sheet S2 is well suited for coupling with the surface of the photovoltaic cells 4. This coupling, as will be described below, can either be direct, or with an interposed element (indirect).

The parts in relief on the surface of the sheet S1 are instead in contact with the back panel 8. Regarding the condensation side 20, it is closed between a flat member 12, arranged on the sheet S2 and having the function of shielding against solar radiation, and the manifold member 10, which is fixed on the opposite part of the condensation side 20 in contact and in thermal exchange relationship with the reservoirs 30.

The operation of the solar panel 1 is as follows. The solar panel 1 is adapted for installation on a support structure such as, for example, the roof of a building, so that the condensation side 20 of the thermal exchange layer 6 has a geometric height greater than the evaporation side 18. This is because each heat pipe device 16 is arranged for operation by gravity, or rather, the thermovector fluid contained in the closed circuit of each device primarily circulates under the action of the gravitational force. This further clarifies the meaning of the term "geometric height" previously used with reference to the reservoir 30.

The panel 1 is installed so that the photovoltaic layer 2 is directly exposed to solar radiation, so that the back panel 8 is in the shade. When the solar radiation hits the photovoltaic layer 2, the photovoltaic cells 4 transform the energy associated with the solar radiation (at least in part) into electrical energy which is drained by known collector devices. Contextually, the photovoltaic cells 4 are subjected to heating both due to the incidence of solar radiation, as well as the transformation of the energy received into electrical energy. According to the preferential mode with which the components of the panel 1 are dimensioned and coupled together (previously described), the photovoltaic cells 4 are coupled to the sheet S2 of the thermal exchange layer 6 and they are only applied at the evaporation side 18 of each device 16. The cells 4 may be applied so they are in direct contact with the sheet S2 or can be coupled thereto by means of a thin layer of coupling material, which performs an anchoring function and prevents the creation of hot spots on the photovoltaic cells 4

In this way, the photovoltaic cells 4 transfer heat flow to the thermal exchange layer 6 - in particular to the evaporation side 18 of each device 16 - supplying the operation of the heat pipe devices 16 themselves, creating a temperature difference between the evaporation side 18 and the condensation side 20, and providing the necessary heat for the thermovector fluid to evaporate in the channel 26, as will now be described.

The first channel 24 of each device 16 is adapted to receive the thermovector fluid in the liquid phase (by gravity) from the reservoir 30 through the siphon duct 36, and is adapted to convey the thermovector fluid towards the second channel 26. In particular, when the thermovector fluid flows from the reservoir 30 through the outflow port 32, it enters the siphon duct 36 undergoing a rapprochement to the reservoir 30, after covering the path of the outflow stretch 38a, the first bend 38 and the upflow stretch 40a, and a subsequent distancing as a result of covering the path of the bend 40, after which the fluid is directed towards the channel 24

Thanks to the presence of the thermal interruptions 42, 44 the conductive thermal exchange between the channel 24 of each device 16 and the surrounding material of the sheets S1, S2 is greatly limited. It should be noted that this is very important as the absence of a sufficient barrier against the conductive thermal exchange between the channel 24 and the surrounding metallic material, would result in the major risk of premature evaporation of thermovector fluid within the channel 24, which is in fact designed to accommodate the thermovector fluid in the liquid phase and convey it, preferably always maintained in the liquid phase, towards the channel 26.

The thermovector fluid then enters the second channel 26 in which, thanks to the heat flow coming from the photovoltaic cells 4, evaporates and is transported in the vapour phase from the channel 26 to the reservoir 30. It should be noted that the evaporation is favoured, among other factors, by the absence of thermal interruptions around the channel 26.

The condensation side 20 is in a thermal exchange relationship with a fluid, particularly water, which is conveyed within the duct 11 of the manifold member 10.

The water flowing within the duct 11 absorbs heat flow from the thermovector fluid in the vapour phase as it moves towards and enters each reservoir 30, causing its condensation and subsequent return to the liquid phase towards the bottom of the reservoir 30 itself, whereupon it enters the corresponding siphon duct 36.

In this way, water flowing within the duct 11 increases in temperature and can be conveyed to the outside of the manifold member 10 for use, for example, as domestic hot water.

The thermovector fluid within each of the heat pipe devices 16 therefore travels along a cycle which comprises two phase changes, one in the evaporation side 18, and the other in the condensation side 20. This process proceeds spontaneously and is repeated in a cyclic way as long as an appreciable difference in temperature remains between the condensation side 20 and the evaporation side 18; in particular the temperature of the latter must be higher.

In this way, in addition to obtaining hot water that can be used elsewhere, cooling of the photovoltaic cells 4 is also obtained thanks to the thermovector fluid flowing in the closed circuit of each heat pipe device 16, in particular in the evaporation side 18.

It should also be noted that the thermovector fluid can be, and preferentially is, different from water, which eliminates the previously cited problems of corrosion of aluminium.

Also thanks to the gravitational operation and to the essentially spontaneous procedure of the thermovector fluid cycle, a pump for supplying fluid to the cooling system of the cells 4 is not necessary, which is in fact defined by the evaporation side of each device 16.

In this way, the power requirement necessary for the operation of the system is reduced, by saving on the power share allocated for driving a pump for cooling liquid. The photovoltaic cells 4, moreover, can work with higher efficiency because their operating temperature is reduced by the thermal exchange layer 6.

The essentially doubled circuit structure of each heat pipe device 16, or rather comprising a channel for the thermovector fluid in the liquid phase as well as a channel for the thermovector fluid in the vapour phase, also ensures the absence of problems of entrainment of thermovector fluid in the liquid phase in the gas stream of the same thermovector fluid, in that essentially there are no longitudinally developed interfacing zones between thermovector fluid in the liquid phase and thermovector fluid in the vapour phase in any of the channels 24, 26. The only interfacing zone is that where the phase change in the evaporation side takes place, which has a predominantly transversally-developed face with respect to the development of the channels 24, 26

The presence of the siphon ducts 36 is also very important from the perspective of maintaining the controllability of the heat flow transmitted to the outside through the condensation side 20 of each heat pipe device 16. In particular, one of the most frequent problems of the heat pipe devices of the known type is the total (or near-total) evaporation of the thermovector fluid due to an excessive heat flow entering the system.

Thanks to the siphon duct 36 a certain amount of thermovector fluid in the liquid phase is guaranteed, trapped between the outflow port 32 and possibly part of the reservoir 30 - typically near the bottom of it - and the first bend 38. In this way there can still be a certain amount of fluid trapped in part in the reservoir 30, in part in the outflow stretch 38a, in part in the first bend 38 and in part, possibly, in the upflow stretch 40a.

It should be noted in fact that the operation of the siphon duct 36 is comparable to that of a siphon drain for a kitchen sink, wherein there is the presence of a certain amount of liquid in a section of the siphon which is located at a lower level with respect to the outflow port, in this case the port 32. In this way, even in conditions of massive heat transfer from the photovoltaic cells 4 it is possible to maintain the controllability of the system and prevent the complete evaporation of the thermovector fluid, while maintaining a good performance even under particularly harsh conditions of use.

Further assistance regarding the maintenance of the controllability of the heat flow transferred to the outside is also offered by the flat members 12, preferably made of thermally insulating material, which offer a shielding action on the condensation side 20, substantially limiting the heat flow transferred by radiation to the reservoirs 30.

In the embodiments described the photovoltaic cells 4 are preferably only arranged next to the evaporation side of the heat pipe devices 16, as it is in the evaporation side 6 that the thermal exchange layer should receive heat flow ensuring that the heat pipe 16 devices are able to function at their best. It should be noted in fact that in the case of the arrangement of the photovoltaic layer 2, for example astride of the condensation side 18 and the evaporation side, 20 or in such a way as to cover them both, as is the case of several different known types of devices, numerous non-uniformities would be created in the temperature field on the back of the cells 4, leading to malfunction of the system.

Numerous variations and modifications are possible without losing the advantages described herein. It is possible for example to create the thermal exchange layer with doubled heat pipe devices without siphon duct 36, thus closer to a traditional known solution. It is also possible to manufacture the heat pipe devices 16 without the reservoir 30, thus creating a system wherein the hydraulic capacity is essentially of the distributed type.

It is also possible to vary the path of the channels 24, 26 according to requirements. In the preferred embodiment described here the channels 24, 26 have a rectilinear development but embodiments are possible wherein, for example, the channel 26 has a serpentine development or wherein more than one channel

26 is provided for conveying the thermovector fluid in the vapour phase towards the condensation side. It is in fact possible to envisage solutions wherein the channel 24 bifurcates into a pair (or a triplet, and so on) of channels 26 which flow into two (or more) separate inflow ports of each reservoir 30. In this case, the siphon duct between the single channel 24 and the reservoir 30 can also be created in the "multiple" form with a greater number of outflow ports 16 directly connected to respective outflow stretches, and then to respective first bends, respective upflow stretches then having two (or more) second bends that flow into the channel 24. In this way, there would essentially be a siphon duct for each channel 26.

In figure 11 a further embodiment of the thermal exchange layer 6 is shown with the reference numeral 106. In the example illustrated here the thermal exchange layer 106 comprises two heat pipe devices 116, but it is of course possible to envisage a different number of devices 116, from a minimum of one to a maximum depending on the size of the layer 106.

Each heat pipe device 116 comprises a closed circuit arranged for the circulation of a thermovector fluid and including an evaporation side and a condensation side of the thermovector fluid indicated, respectively, with reference numbers 118, 120.

Analogously to the embodiment previously described, the thermal exchange layer 106 and each device 116 are created by joining a first and a second sheet of metallic material S1, S2 using roll-bond technology, or rather joining sheets S1, S2 at areas delimiting the closed circuit of each device 116, in order to inject pressurized air in the regions that define the path of the closed circuit to form the internal volumes of the circuit itself.

Next to an area of interface between the evaporation side 118 and the condensation side 120, an adiabatic zone is provided, functionally analogous to the adiabatic zone of the absorber devices described above, designated by the reference numeral 125 and comprising a first and a second thermal interruption 125A, 125B, the first with a rectilinear structure, the second with a "V-shaped" geometry. In this way the condensation side essentially has a "step" plan, wherein the step is defined by the thermal interruption with a "V-shaped" geometry. It is therefore possible to identify a maximum (longitudinal) extension and a minimum (longitudinal) extension for the condensation side 120, respectively, L_C, L_C'.

Typical values may be:

- comprised between 1.1 and 3 for L_C/L_C'

Thermal interruptions are preferably made by laser cutting, but it is also possible to create them by means of inserts of thermally insulating material (preferably through with respect to sheets S1, S2) or it is possible to provide a combination of both.

The evaporation side 118 comprises a first channel 124 in fluid communication with a plurality of second channels 126 which depart from a first manifold branch 128. In greater detail, the channel 124 is in fluid communication with the manifold branch 128 and the channels 126 by means of a first siphon duct 129. The channels 124 and 126 preferably have a rectilinear and parallel development, but other solutions are possible,

With reference to Figure 13, the siphon duct 129 comprises a first and a second bend 129A, 129B arranged fluid dynamically in series, wherein the first bend 129A has a lower geometric height with respect to the second bend 129B. Preferably, the first bend 129A creates a curve at an angle of 180°, while the second bend 129B preferably creates a curve at an angle of 90°.

In other words, still with reference to Figure 13, channel 124 flows directly into the bend 129A, which essentially creates an inversion of the path of the thermovector fluid compared to channel 124. The bend 129A then flows into the bend 129B, which creates a partial "straightening" of the path of the thermovector fluid by leading into the manifold branch 128, which is preferably transversely orientated with respect to channel 124.

The channels 126 flow into a reservoir 130 through a second manifold branch 131. The second manifold branch 131 is (preferably) transversely orientated with respect to the channels 126 (and 124) and in this embodiment it has an increasing passage area proceeding from the furthest channel 126 to the nearest channel 126 with respect to a common outflow 131A.

Now, the connections between the condensation side 120 and the evaporation side 118 will be described in greater detail, in particular the connections between the reservoir 130 and channels 124, 126. With reference to Figure 12, the first channel 124 and the second channels 126 are in fluid communication with the reservoir 130 by means of, respectively, an outflow port 132 and an inflow port 134, having a greater geometric height than the outflow port 132. It should also be noted that the reservoir 130 has a bottom 130A inclined towards the outflow port 132, i.e. the bottom 130A has a profile which slopes from the inflow port 134 towards the port 132 in order to facilitate the outflow of the thermovector fluid.

In greater detail, the channel 124 is in fluid communication with the port 132 by means of a second siphon duct 136, functionally analogous to the siphon ducts previously described, comprising a first and a second bend 138, 140 arranged fluid dynamically in series. The first and second bends 138, 140 define a double-curved path (essentially "S"-shaped), wherein each bend defines a curve preferably of magnitude 180°.

Analogously to the siphon ducts previously described, the duct 138 includes an outflow stretch 138a that departs from the outflow duct 132 and leads into the first bend 138, and an upflow stretch 140a into which the first bend 138 flows, which in turn leads into the second bend 140, which leads directly into the channel 124.

It should also be noted that in this embodiment the first bend 138 and the second bend 140 are arranged on opposite sides with respect to the outflow port 132, in particular the bend 140 is located above the port 132.

Analogously to the embodiments described, named D_{138} and D_{140}, the distances, respectively, between the reservoir 130 and the bends 138, 140, the distance D_{138} is preferably greater than the distance D_{140}, but in this embodiment, owing to the arrangement of the bends, the opposite can also be envisaged. Finally, each channel 124 is bordered by a thermal interruption 144, preferably having an "L"-shape so as to also be bordered by the siphon duct 313, which can be manufactured for example, by laser cutting or by means of an insert of thermally insulating material.

Only one of the sheets S1, S2 (in particular the sheet S1) bulges outwards at the path of the closed circuit of each device 116, for reasons of optimal coupling with the photovoltaic cells 4.

Regarding the operation, there are a few variations with respect to the embodiments previously described.

In the closed circuit defined by the channels 124, 126, the reservoir 130 and all the connection channels between the above elements, a thermovector fluid circulates which undergoes a first phase change at the evaporation side (liquid-vapour) and a second phase change in the condensation side (vapour-liquid). The hybrid solar panel 1 is installed so that each device 116 is arranged with the reservoir 130 at a higher geometric height than the rest of the circuit so that the operation is essentially gravitational.

Furthermore, the manifold member 10 is applied next to the condensation side 118, as previously described, specifically on the sheet S1 (and the flat member 12 is placed on the opposite side)

The thermovector fluid leaves the reservoir 130 in the liquid phase (helped in part by the profile of the bottom 130A) through the outflow port 132 and runs through the siphon duct 138, then the first channel 124. The latter is adapted to convey the thermovector fluid towards the first manifold branch 128 and to each of the channels 126. It should be noted that the evaporation of thermovector fluid within the channel 124 is prevented or at least hindered by the thermal interruption 144, which limits the conductive thermal exchange with the surrounding portions of the sheets S1, S2.

When the thermovector fluid enters the channels 126, the heat flow dispersed by the photovoltaic cells 4 is transferred to the thermovector fluid which evaporates and goes back towards the manifold branch 131 and towards the inflow port 134, through which it enters the reservoir 130. When passing through the condensation side 120 the thermovector fluid condenses, transferring heat to the liquid in the manifold member 10, that can then be used elsewhere, for example in domestic hot water.

It should be noted that the variable passage area of the branch 131 allows drainage of the thermovector fluid flow in an optimal way, because it gradually increases as the branch 131 intercepts a channel 126 closer to the outflow 131A.

In this way, the non-uniformities of the field of motion of the thermovector fluid within the circuit are limited.

The cycle then repeats itself during the operation of each device 116, which is interrupted when the temperature difference between the condensation side and the evaporation side is close to zero.

The presence of the siphon ducts 129 and 136 is also very important from the perspective of maintaining the controllability of the heat flow exchanged even under harsh operating conditions (i.e. strong incident solar radiation on the photovoltaic cells 4). Analogously to the siphon ducts previously described, the siphon duct 136 guarantees, thanks to its geometry, the presence of thermovector fluid in the liquid phase in a stretch between the reservoir 130 and the second bend 140.

The siphon duct 129 provides a further contribution from the view of maintaining a certain amount of thermovector fluid in the liquid phase also downstream of channel 124, and immediately upstream of channels 126. In particular, thanks to the siphon duct 129 it is possible to maintain thermovector fluid in the liquid phase at least in the first bend 129A and upstream thereof, i.e. in the channel 124.

In alternative embodiments, it is possible to envisage the presence of the sole siphon duct 129. The same can also be applied to the closed circuit layouts previously described, with which it is also possible to implement a solution with two distinct siphons of the type described in Figure 11.

Essentially, in the various embodiments presented herein, each solar absorber device comprises a reservoir which is in communication with one or more channels adapted to convey the thermovector fluid in the vapour phase ("vapour channel(s)") thereto by means of one or more siphon ducts. The one or more vapour channels also lead into the reservoir itself via one or more inflow ports with respect to which the one or more siphon ducts are fluid dynamically arranged upstream.

The aforesaid siphon ducts are arranged upstream of said one or more vapour channels and may be provided at the outflow of the reservoir upstream of the channel adapted to receive the thermovector fluid in the liquid phase (“liquid channel”) or downstream of it (and downstream of the vapour channel(s)) or in both places. In the first case the siphon duct is connected to the outflow port of the reservoir and flows into the liquid channel, connecting and setting in fluid communication the liquid channel and the reservoir (notwithstanding of course the fluid communication that is established between the reservoir and the vapour channel(s)).

In the second case the siphon duct connects and establishes fluid communication between the liquid channel and the vapour channel(s) (possibly through the manifold branch 128, if present), since it is arranged at an interface zone between them.

Naturally, the details of construction and the embodiments may be widely varied with respect to what is described and illustrated purely by way of example, without thereby departing from the scope of the present invention, as defined by the attached claims

CLAIMS

1. A hybrid solar panel (1), comprising:

- a photovoltaic layer (2) including a plurality of photovoltaic cells (4),

- a thermal exchange layer (6; 106) including cooling means for said photovoltaic cells (4),

- a manifold member (10) arranged to convey a fluid, particularly a liquid, in thermal exchange relationship with said thermal exchange layer (6; 106),

wherein

said thermal exchange layer (6; 106) comprises one or more heat pipe devices (16; 116) adapted to contain a thermovector fluid, each heat pipe device (16; 116) comprising:

- an evaporation side (18; 118) of said thermo vector fluid arranged for absorbing a heat flow from said photovoltaic cells (4) and defining said cooling means,

- a condensation side (20; 120) of said thermovector fluid, in correspondence of which said manifold member (10) is applied,

said photovoltaic cells (4) of said photovoltaic layer (2) being applied in correspondence of the evaporation side (18; 118) of said one or more heat pipe devices (16; 116) and being in thermal exchange relationship therewith,

the solar panel (1) being characterized in that each heat pipe device (16; 116) comprises a closed circuit (24, 26, 28, 30, 36; 124, 126, 128, 130, 136) arranged for the circulation of said thermovector fluid and including a first channel (24; 124) adapted to receive the thermovector fluid from said condensation side (20; 120) in liquid phase and adapted to convey the thermovector fluid towards at least one second channel (26; 126), said at least one second channel (26; 126) being in turn adapted to convey the thermo vector fluid in vapour phase towards said condensation side (20; 120), and

in that said thermal exchange layer (6; 106) is made by joining a first and a second sheet (S1, S2) made of metal material in correspondence of areas delimiting the closed circuit (24, 26, 28, 30, 36; 124, 126, 128, 130, 136) of each heat pipe device (16; 116).

2. The solar panel (1) according to Claim 1, characterized in that only the first sheet (S1) made of metal material of said thermal exchange layer (6; 106) is bulging outwards in correspondence of the path of the closed circuit (24, 26, 28, 30, 36; 124, 126, 128, 130, 136) of said one or more heat pipe devices (16; 116), said second sheet (S2) made of metal material having a flat surface extending at least in correspondence of the evaporation side (18; 118) of said one or more heat pipe devices (16; 116), preferably along the entire extension thereof, said flat surface being coupled to said photovoltaic cells (4).

3. A solar panel (1) according to Claim 1 or 2, characterized in that the condensation side (20; 120) of each heat pipe device (16; 116) comprises:

- a reservoir (30; 130) in fluid communication with said at least one second channel (26; 126) by means of an inflow port (32; 132), and

- at least one siphon duct (36; 136) by which said reservoir (30; 130) is in fluid communication with said at least one second channel (26; 126).

4. The solar panel (1) according to Claim 3, characterized in that the condensation side (20; 120) of each heat pipe device (16; 116) comprises a siphon duct (36; 136) arranged upstream of said first channel

(24; 124) and connecting said first channel to said outflow port (32; 132), said siphon duct (36; 136) comprising a first and a second bend (38, 40; 138, 140) arranged fluid dynamically in series.

5. The solar panel (1) according to Claim 4, characterized in that each siphon duct (36; 136) furthermore comprises:

an outflow stretch (38a; 138a) connected to said outflow port (32; 132) and leading into said first bend (38; 138), and

- an upflow stretch (40a; 140a) into which said first bend (38; 138) leads said upflow stretch (40a; 140a) in turn leading into said second bend (40; 140) which leads into said first channel (24; 124).

6. The solar panel (1) according to Claim 4, characterized in that the evaporation side (118) of each heat pipe device (116) comprises a further siphon duct (129) arranged downstream of said first channel (124) in correspondence of an interface between said first and at least one second channels (124, 126).

7. The solar panel (1) according to Claim 3, characterized in that said condensation side (20; 120) is coupled to said manifold member (10) in correspondence of the reservoir (30; 130) of each of said one or more heat pipe devices (16; 116).

8. The solar panel (1) according to any of the preceding Claims, characterized in that said thermal exchange layer (6; 106) comprises an adiabatic area (22; 125) in correspondence of an interface between said evaporation side (18; 118) and said condensation side (20; 120) of each of said one or more heat pipe devices (16; 116), wherein said adiabatic area (22; 125) comprises a plurality of thermal interruptions.

9. The solar panel (1) according to any of the preceding Claims, characterized in that it furthermore comprises a back panel (8) arranged in contact with said first sheet (S1) made of metal material on an opposite side with respect to said photovoltaic layer (2), wherein said solar panel (1) furthermore comprises a framework (14) arranged for clamping together said photovoltaic layer (2), said thermal exchange layer (6; 106) and said back panel (8).

10. The solar panel (1) according to any of the preceding Claims, characterized in that the first channel (24; 124) of each heat pipe device (16; 116) is bordered by a first and a second thermal interruption (42, 44; 144) comprising:

- interruptions provided by means of laser cut,
- inserts made of thermally insulating material or
- a combination thereof.

FIG. 1

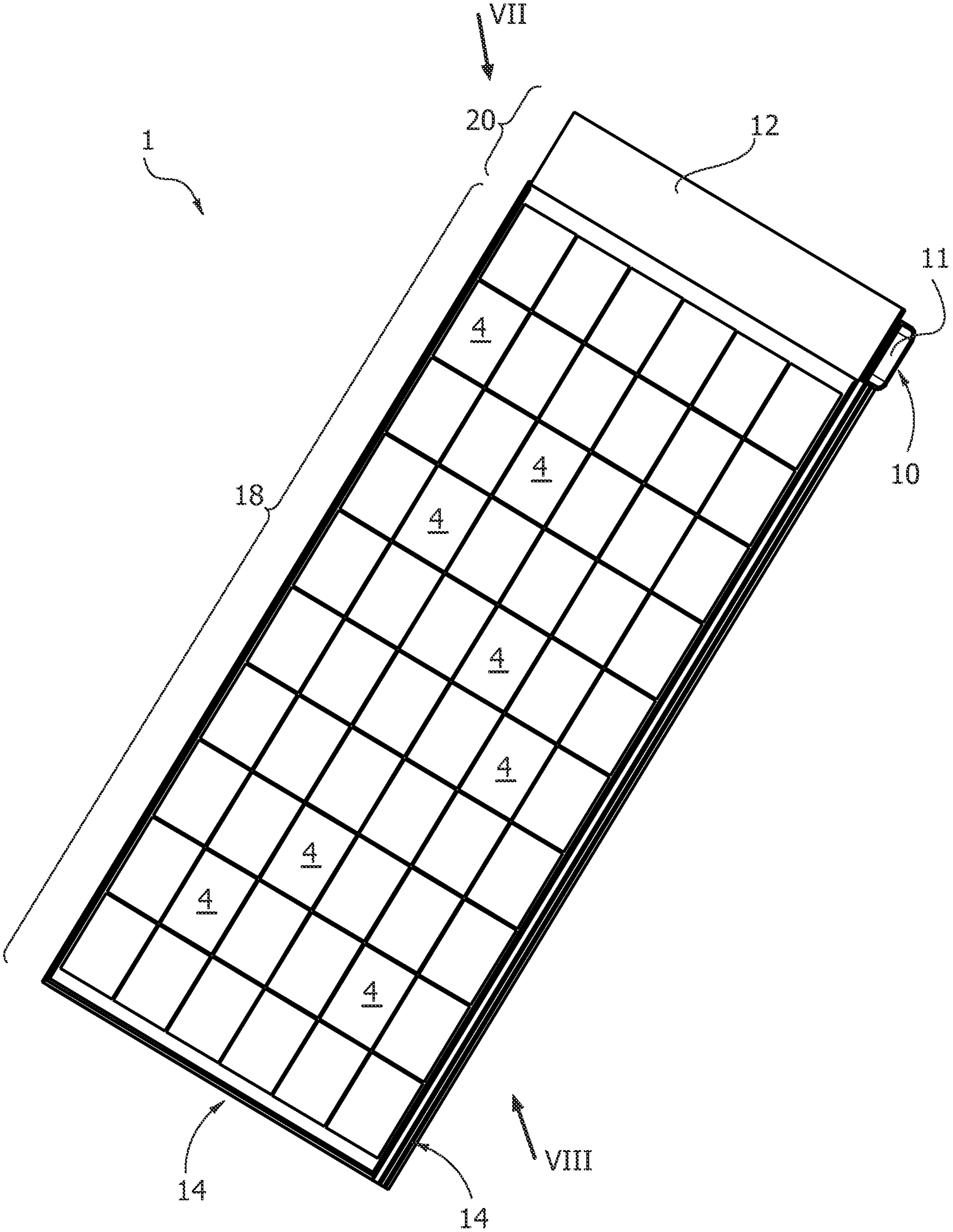


FIG. 2

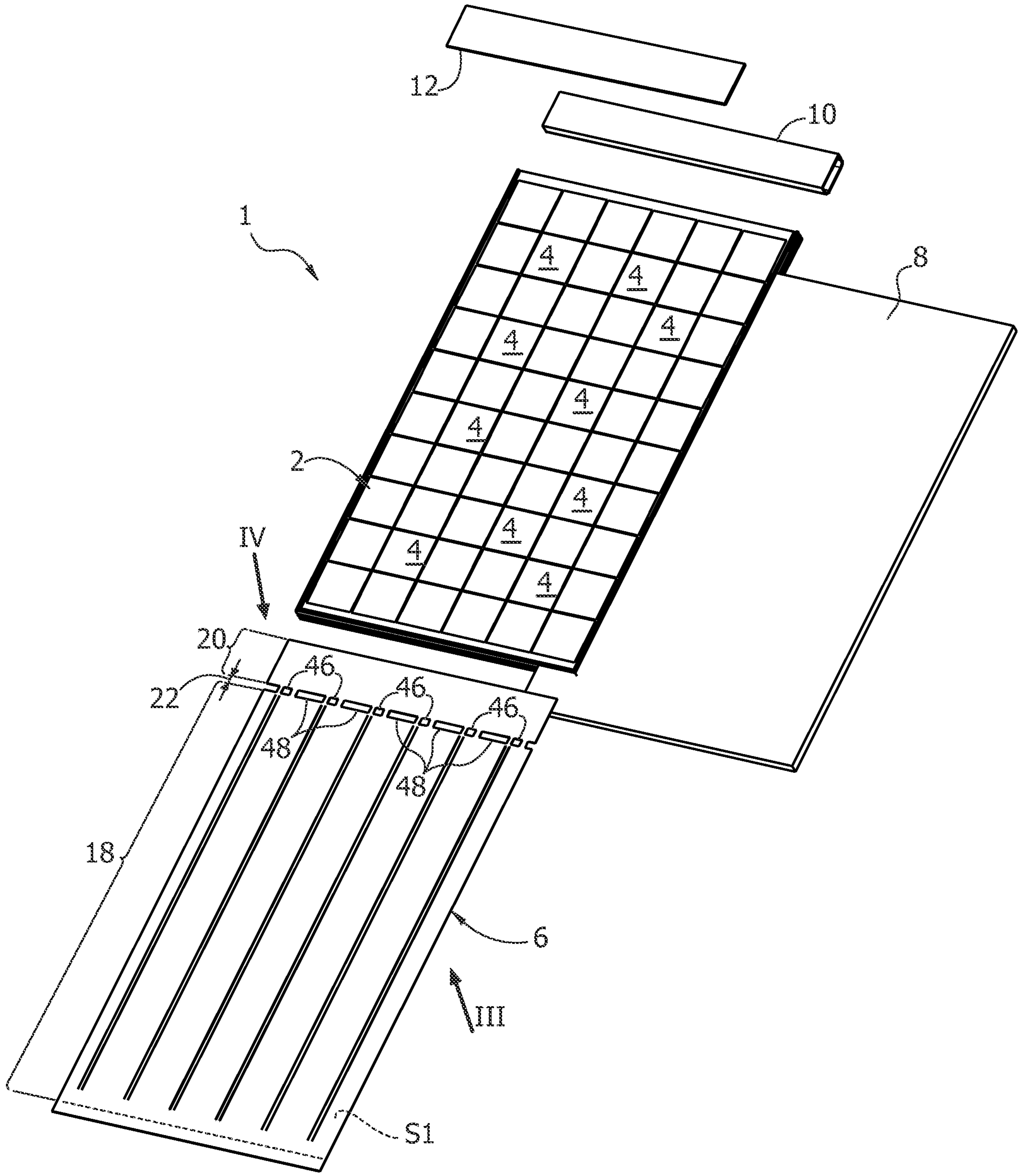


FIG. 3

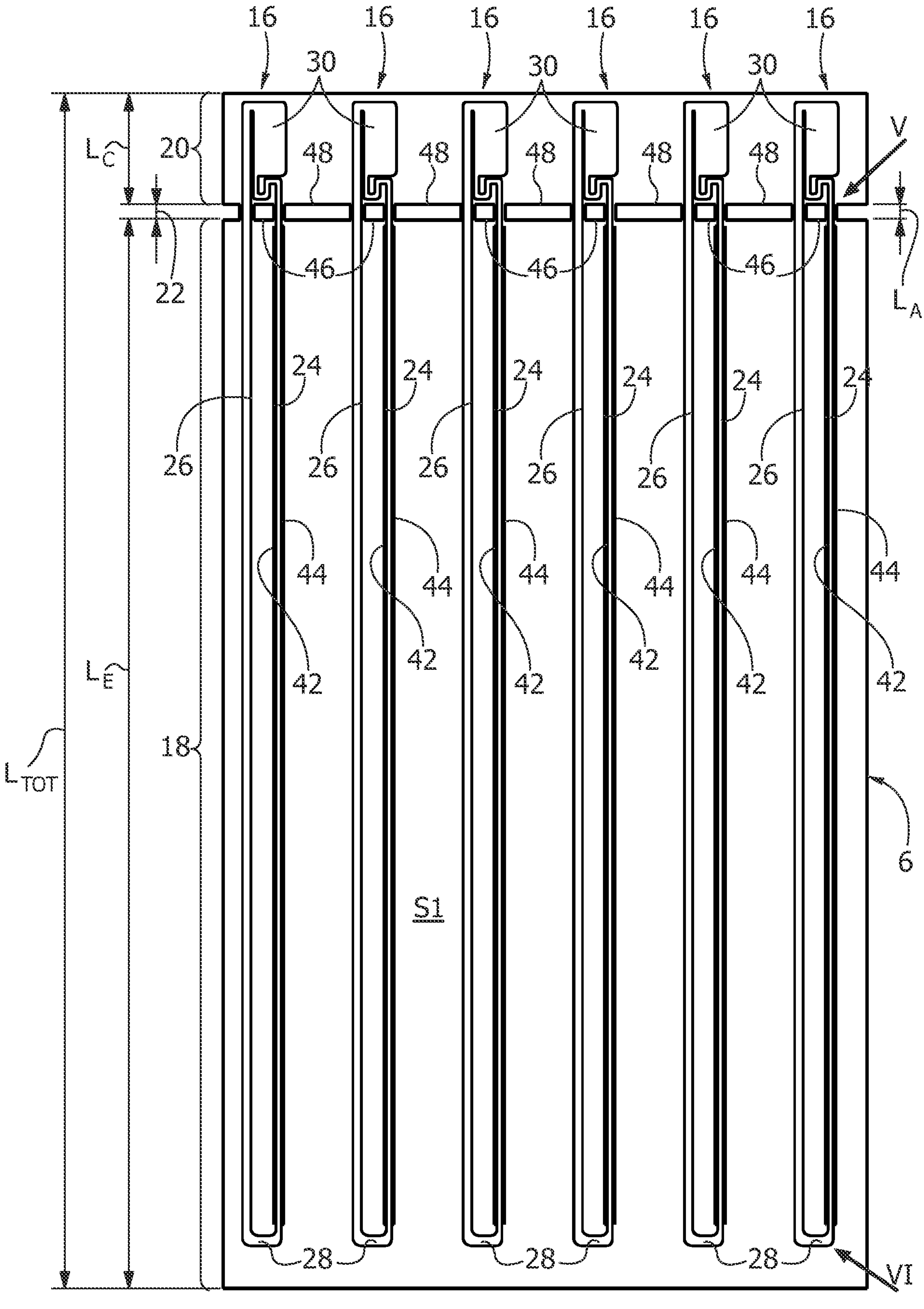


FIG. 4

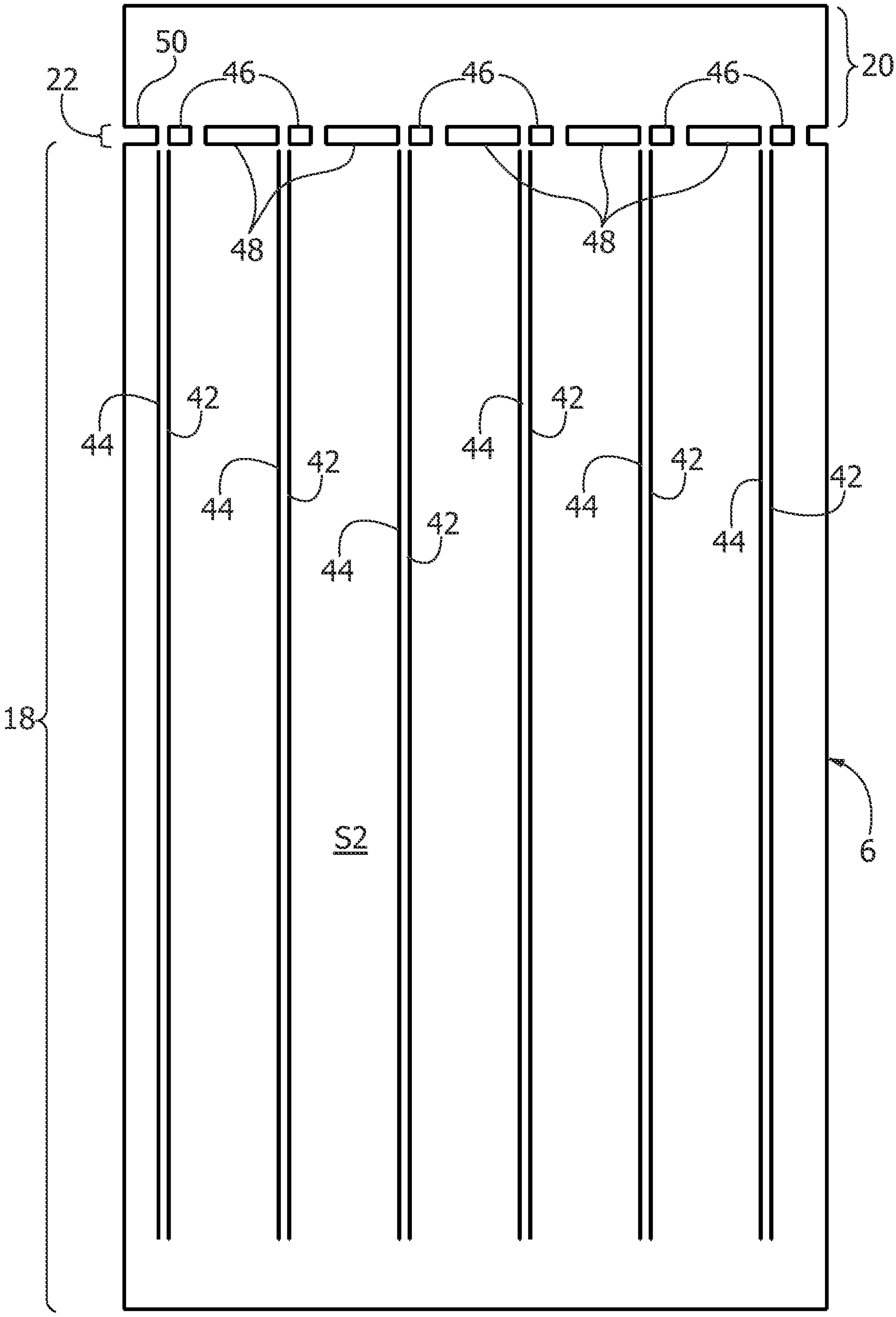


FIG. 5

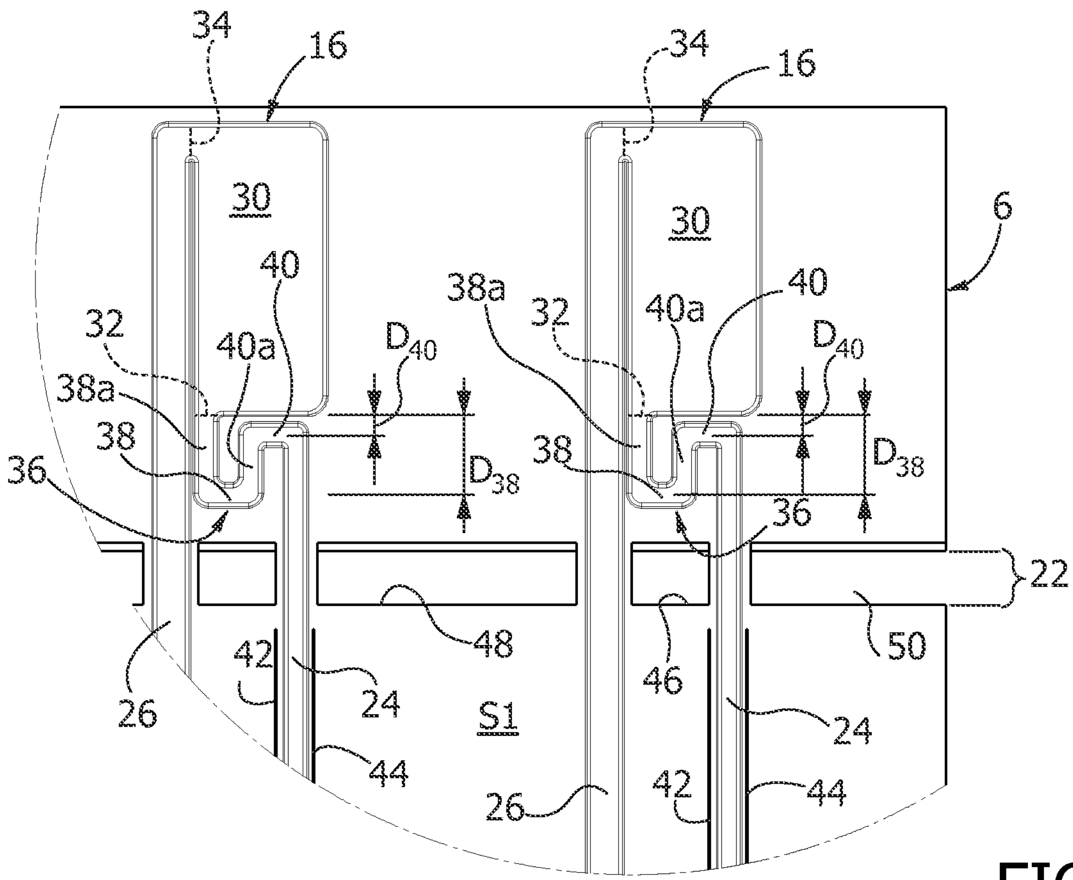

34
16
30
6
40
38a
32
40a
D40
D38
38
36
22
48
50
46
42
24
26
S1
44

FIG. 6

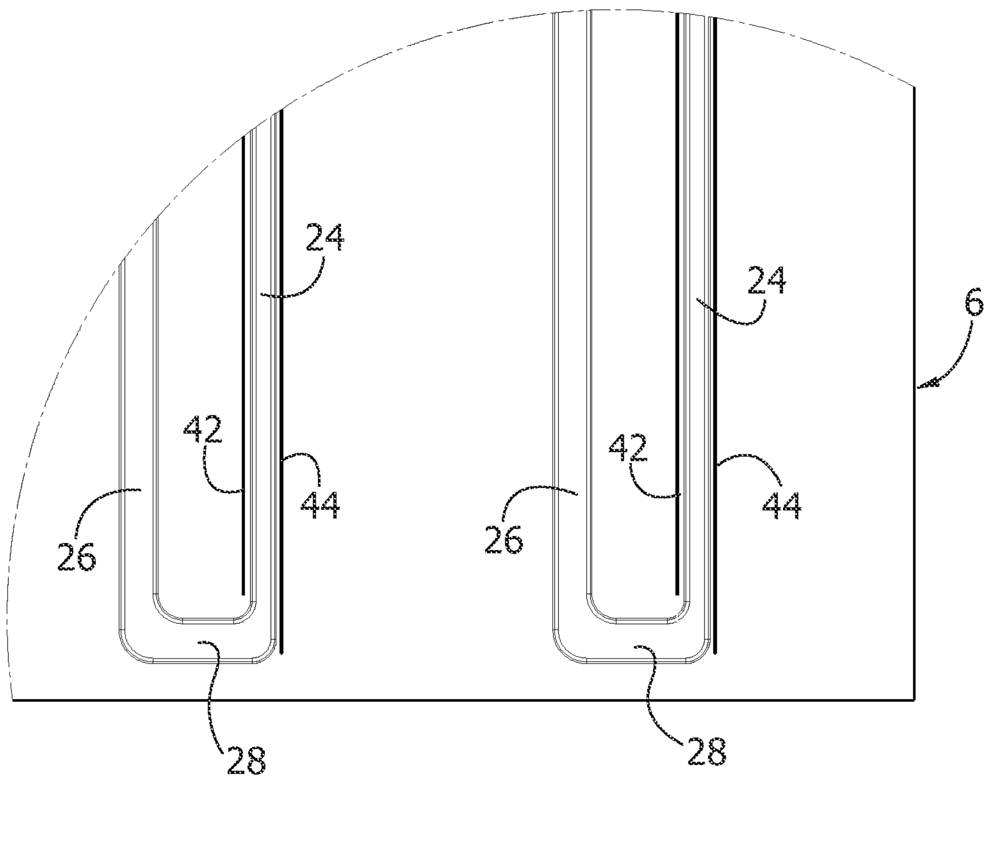

24
6
42
44
26
28

FIG. 7

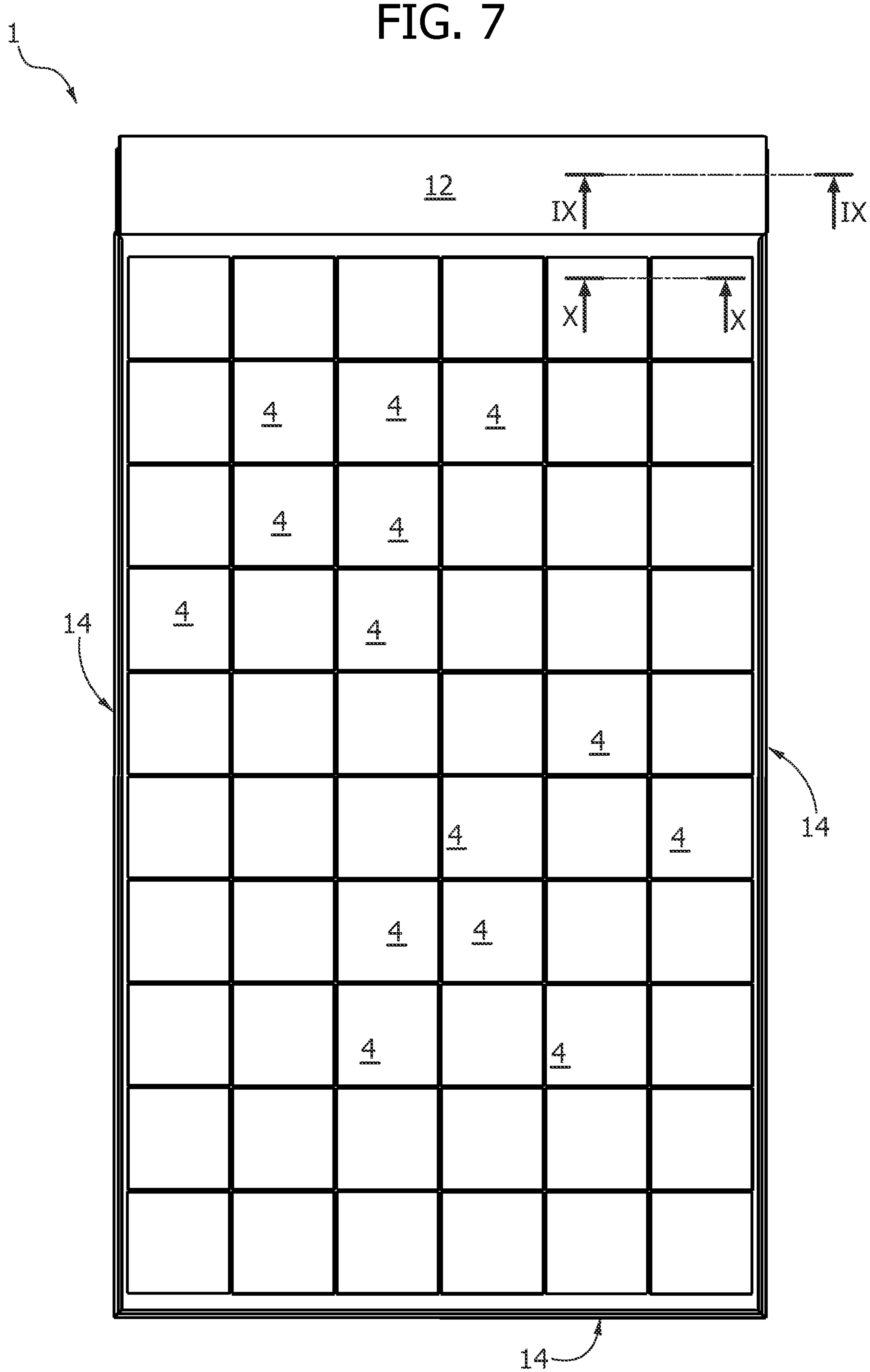


FIG. 8

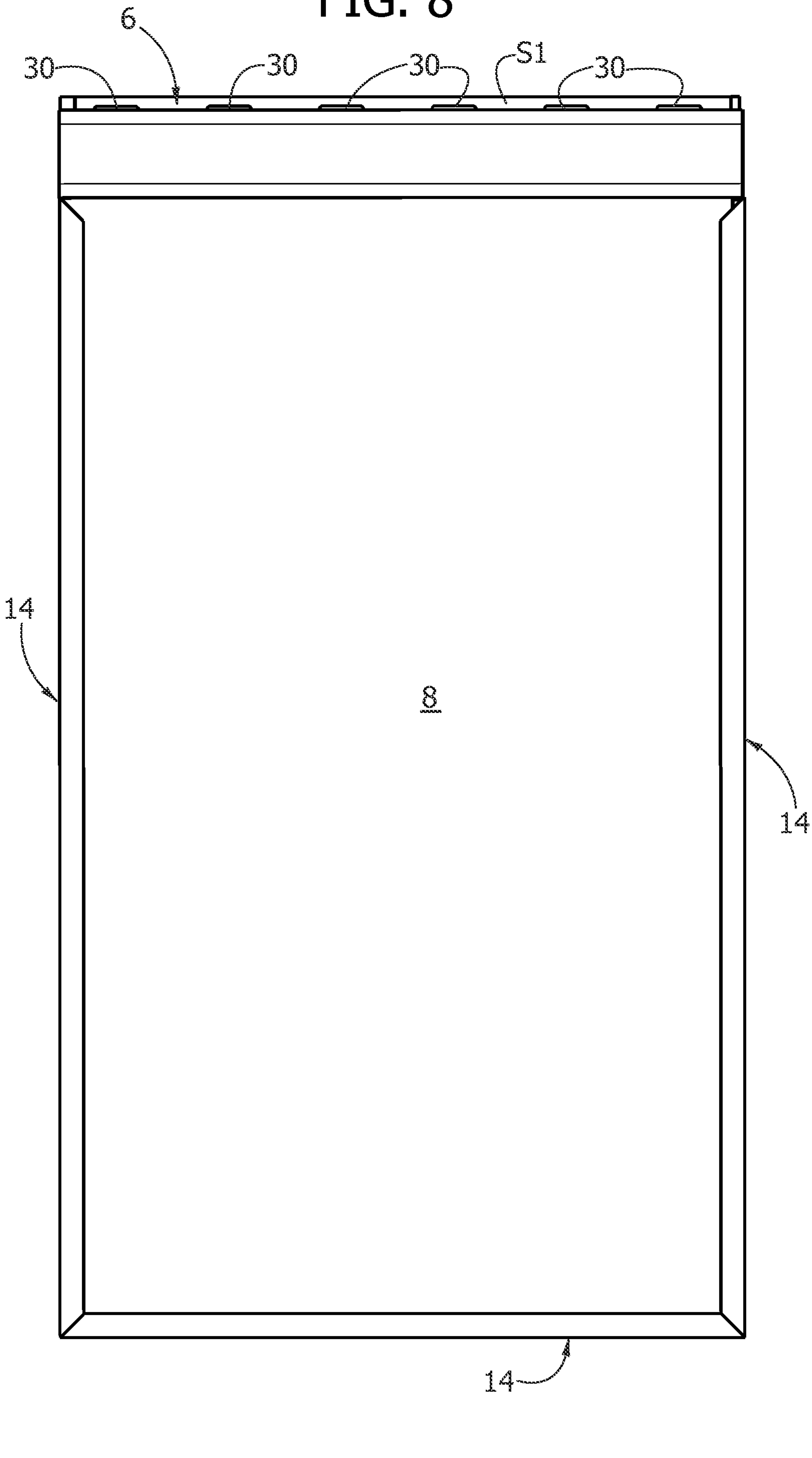


FIG. 9

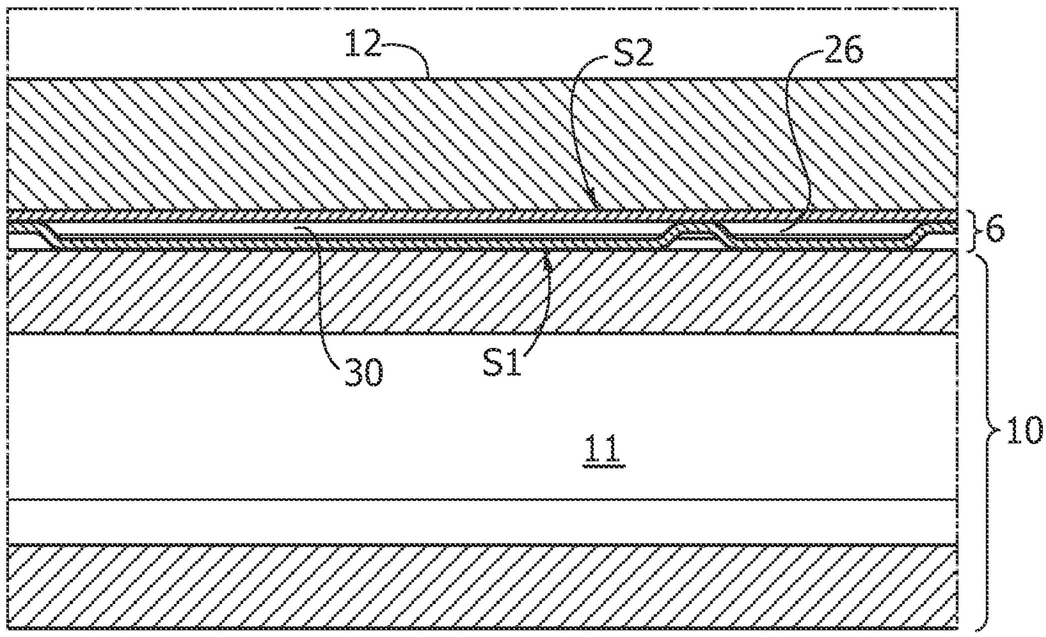


FIG. 10

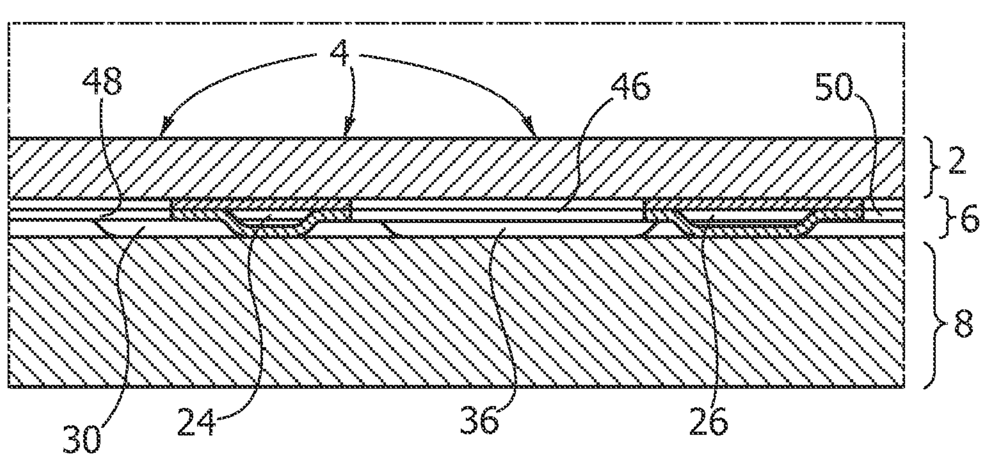
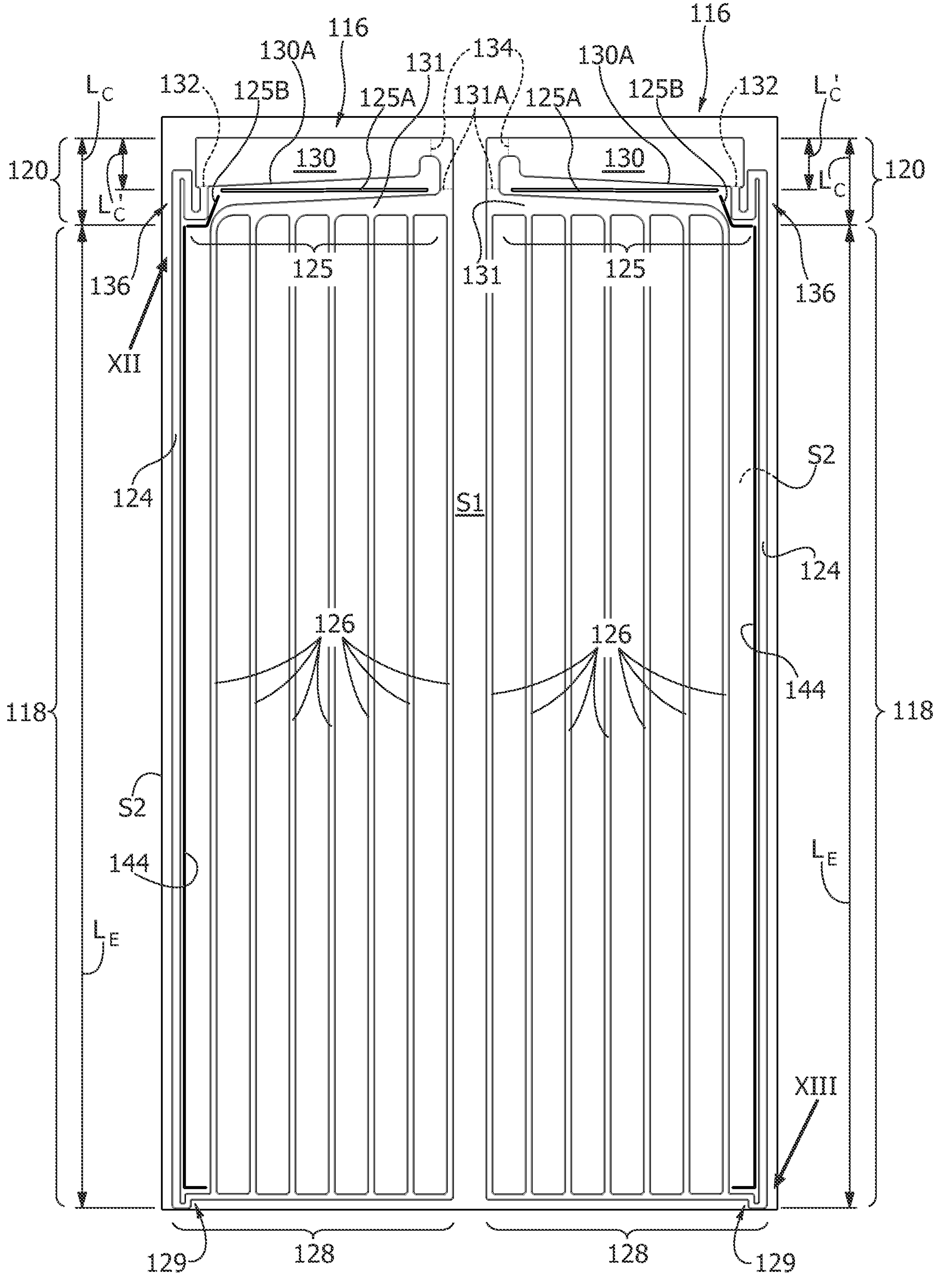


FIG. 11


116
116
130A
130A
134
131
131A
132
132
125B
125B
125A
125A
Lc
Lc'
120
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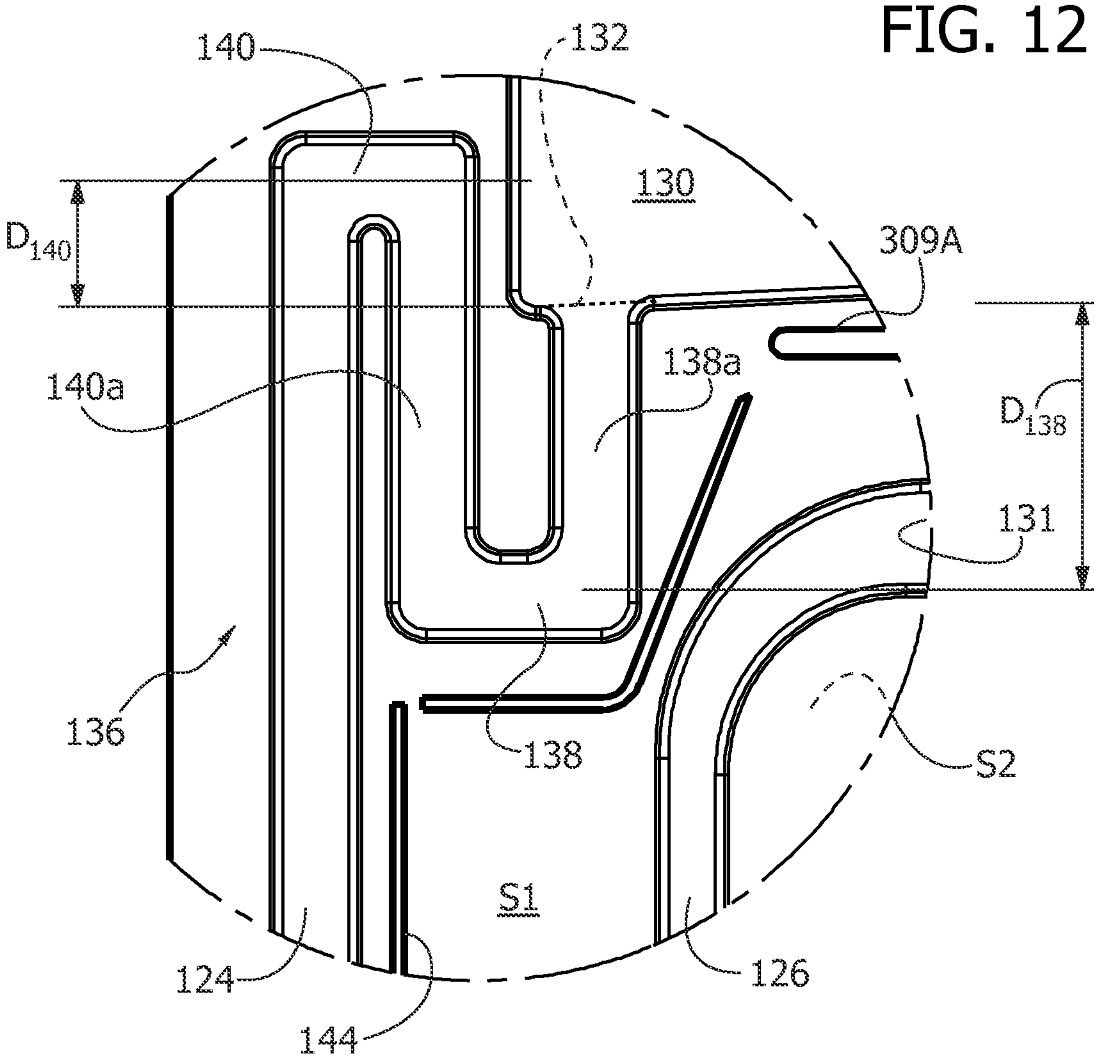
130
125
125
131
136
136
XII
124
124
S1
S2
S2
126
126
144
144
118
118
LE
LE
XIII
129
129
128
128

FIG. 12


140
132
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D_{140}
309A
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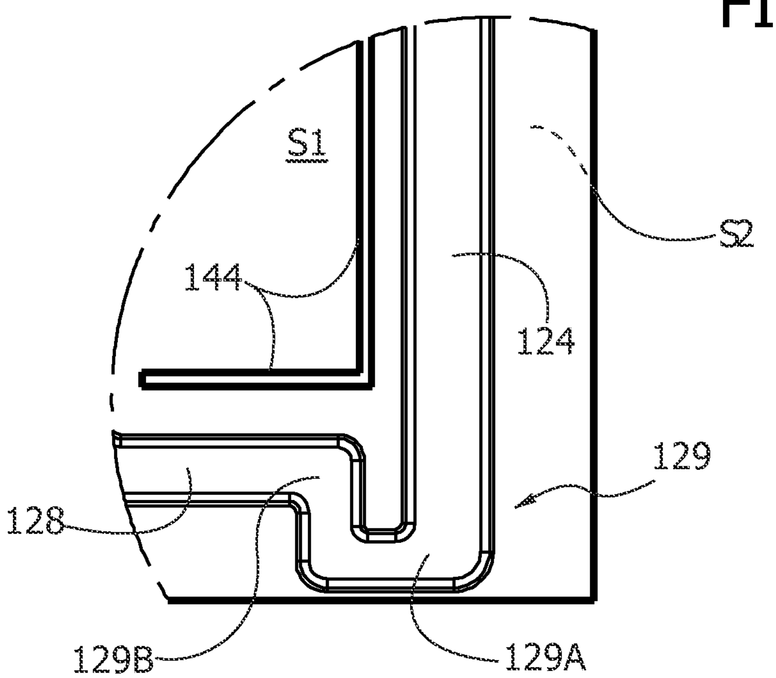
138a
D_{138}
131
136
138
S2
S1
124
126
144

FIG. 13


S1
S2
144
124
129
128
129B
129A