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Azoulay

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(54) **PHOTOVOLTAIC TILE FOR A ROOF**

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USPC 52/173.3; 126/621, 622, 623; 136/246, 136/251
See application file for complete search history.

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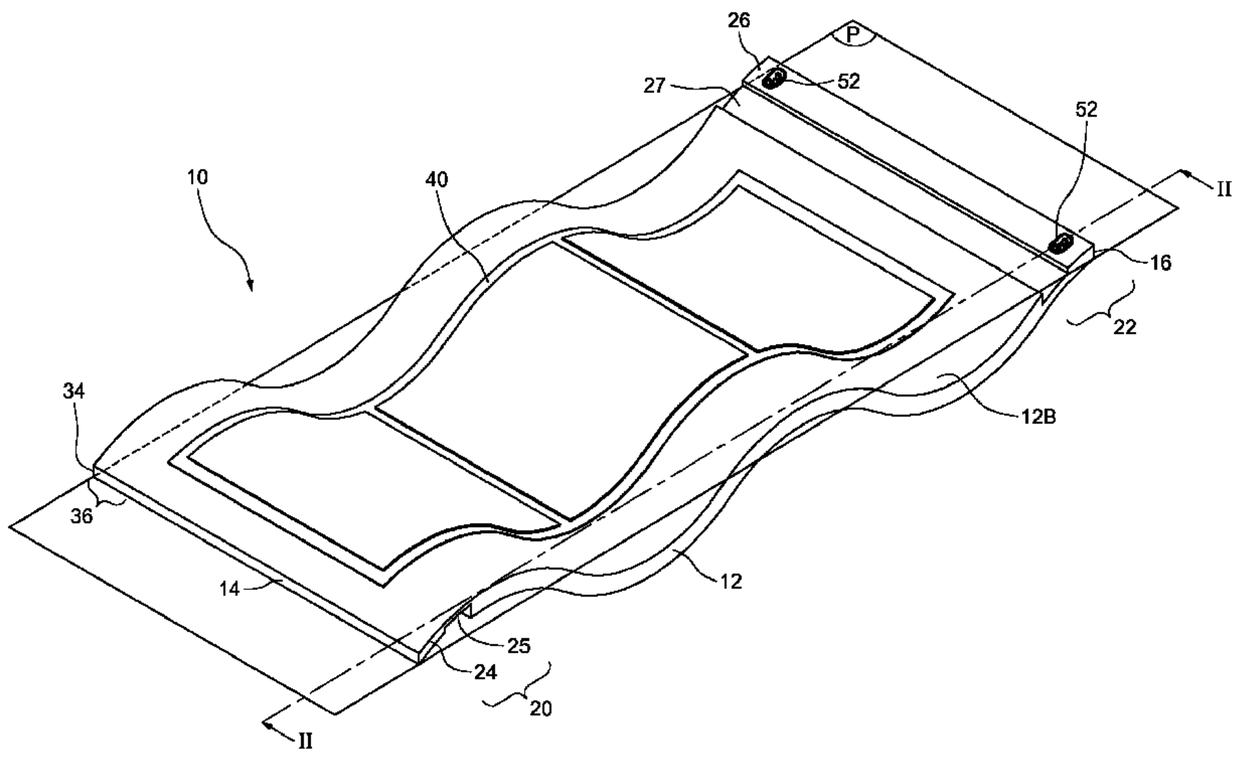
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(57) **ABSTRACT**

A photovoltaic tile for a roof includes a plurality of tiles, at least two adjacent tiles of which at least partially overlap each other, including a body (**12**) having overlapping edges constituting a top edge (**20**) and a bottom edge (**22**), the top edge (**20**) being formed so as to cover the bottom edge (**22**) of at least one of the adjacent tiles, a photovoltaic layer (**40**), and electrical connectors (**52**) which are connected to the photovoltaic layer (**40**) through electrical conductors (**54**). The electrical connectors (**52**) are provided in assembly elements (**57**, **58**) by nesting, the assembly elements being provided on the overlapping edges (**20**, **22**) to enable the overlapping edges to be mutually positioned during the placement of two of the adjacent tiles (**10**) and the electrical contact of the electrical connectors (**52**) with each other. The invention also relates a method for manufacturing such tile.

30 Claims, 14 Drawing Sheets



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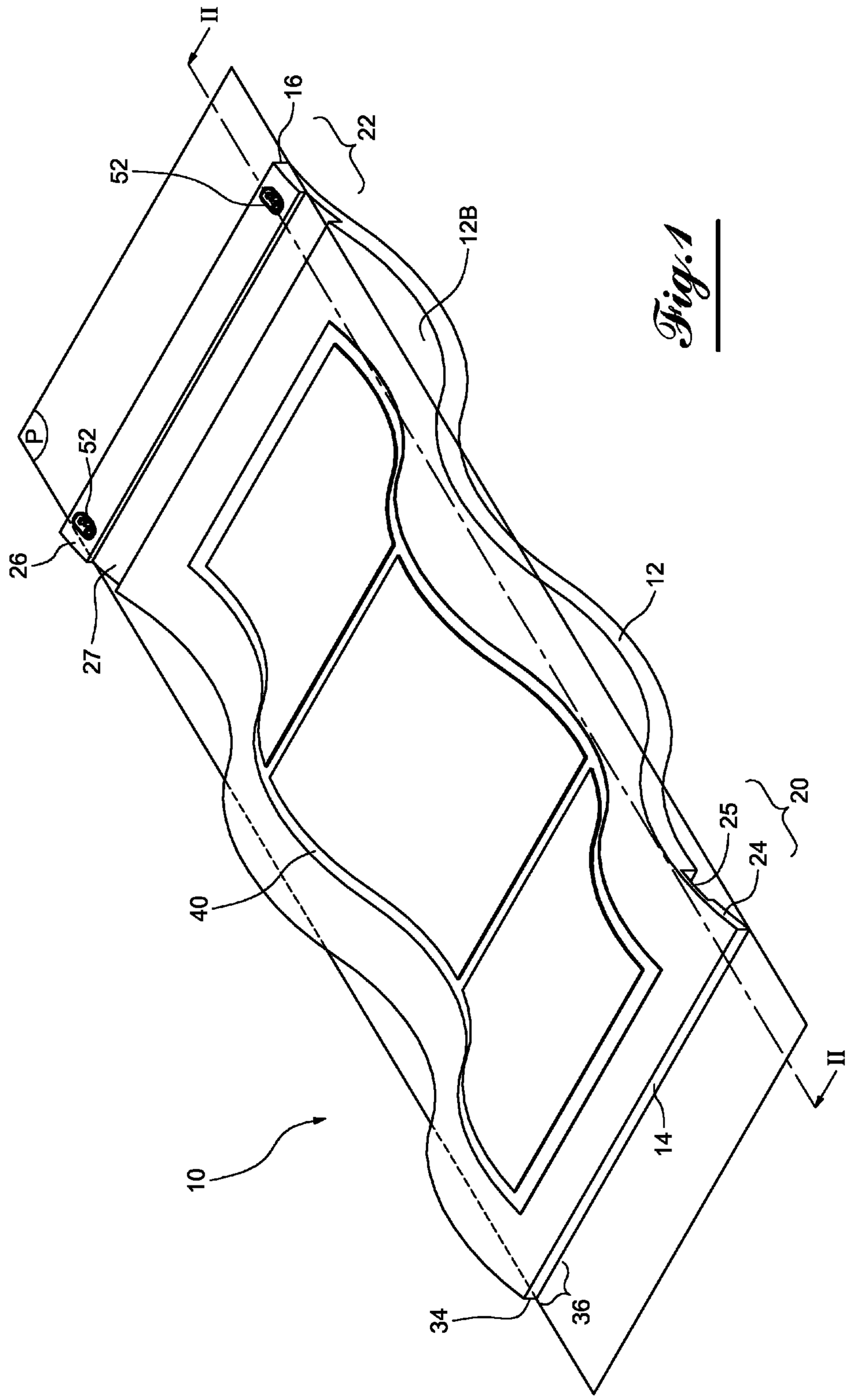


Fig. 1

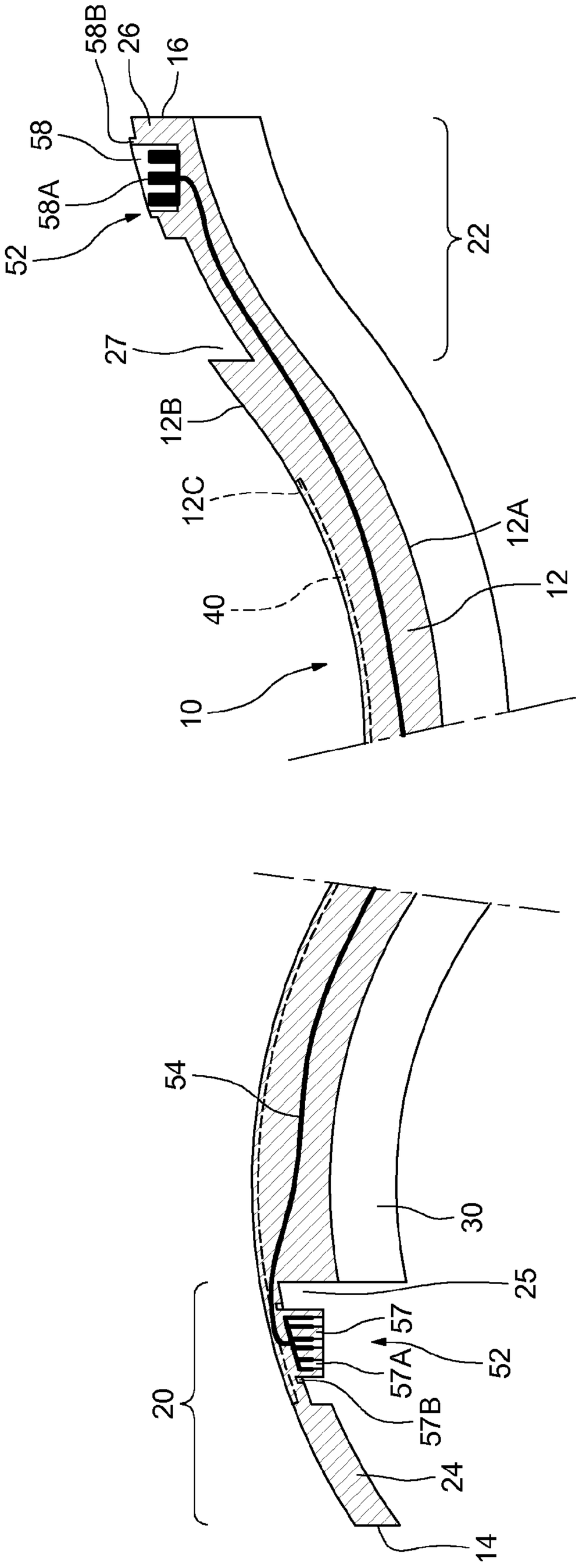

58B
26
16
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58A
52
22
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12C
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57A
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57B
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Fig. 2

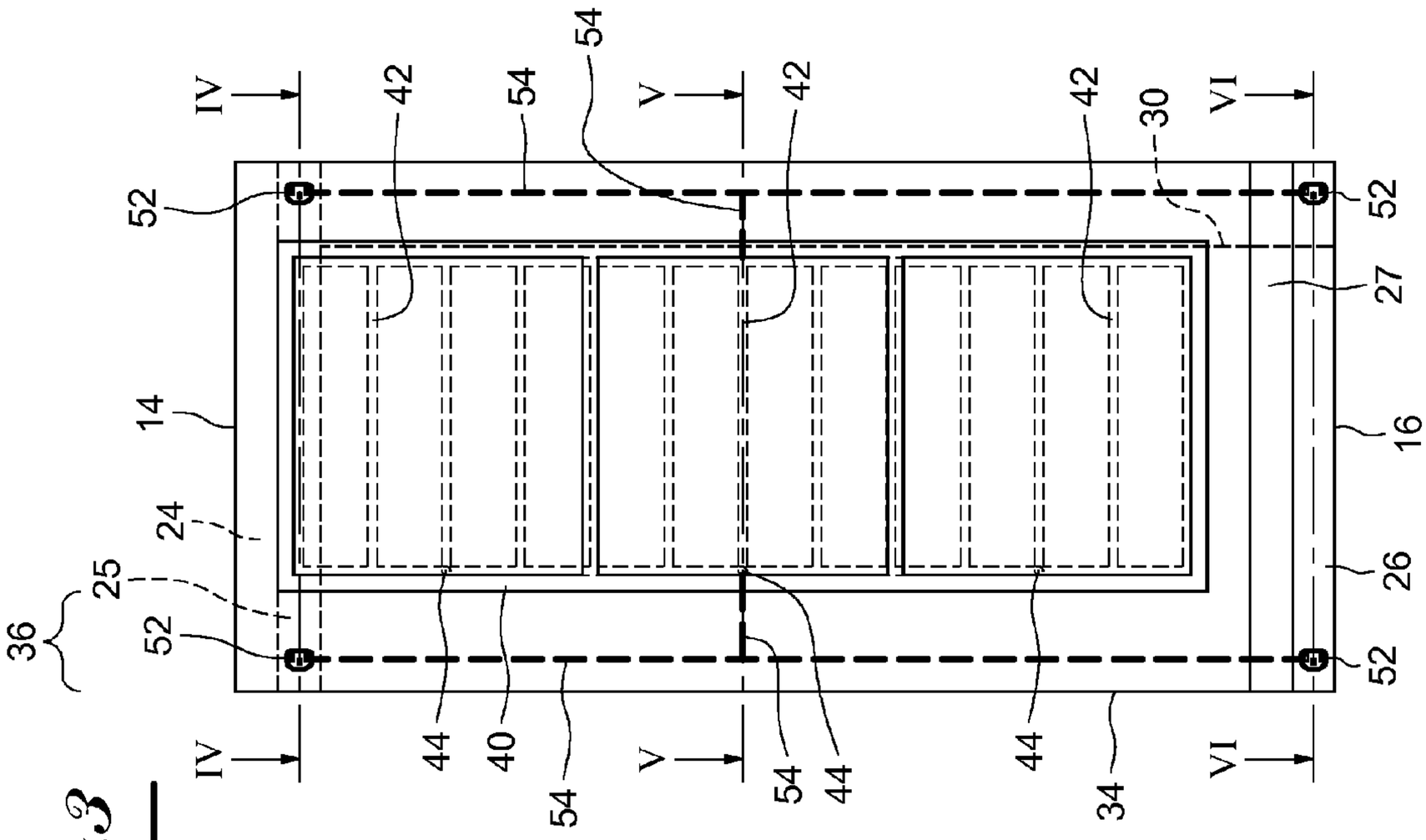


Fig.3

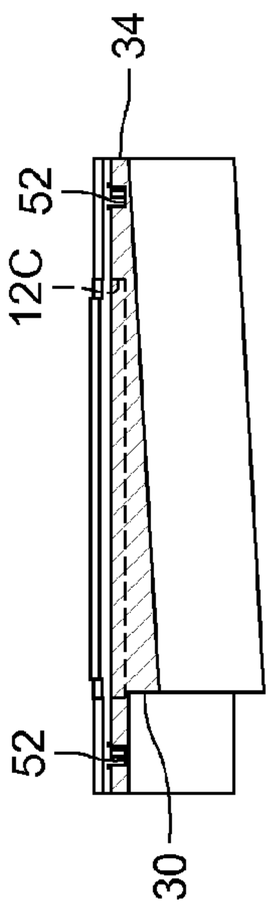


Fig.4

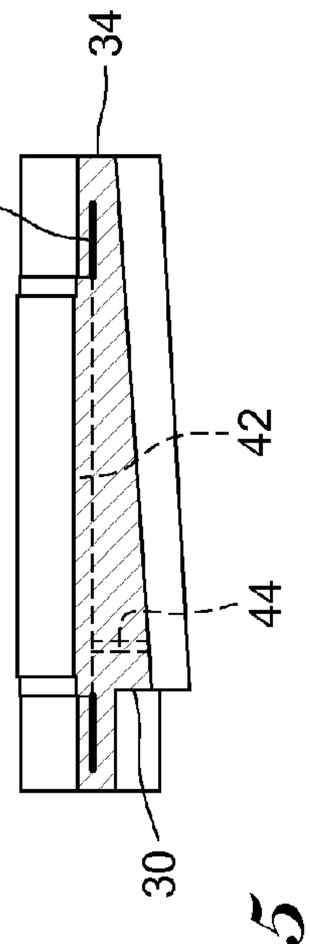


Fig.5

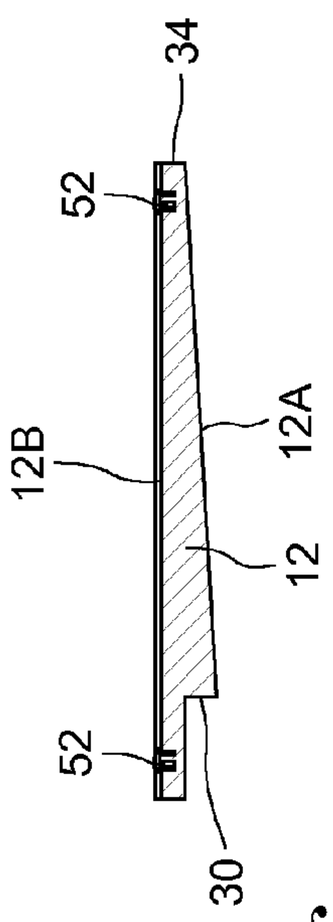


Fig.6

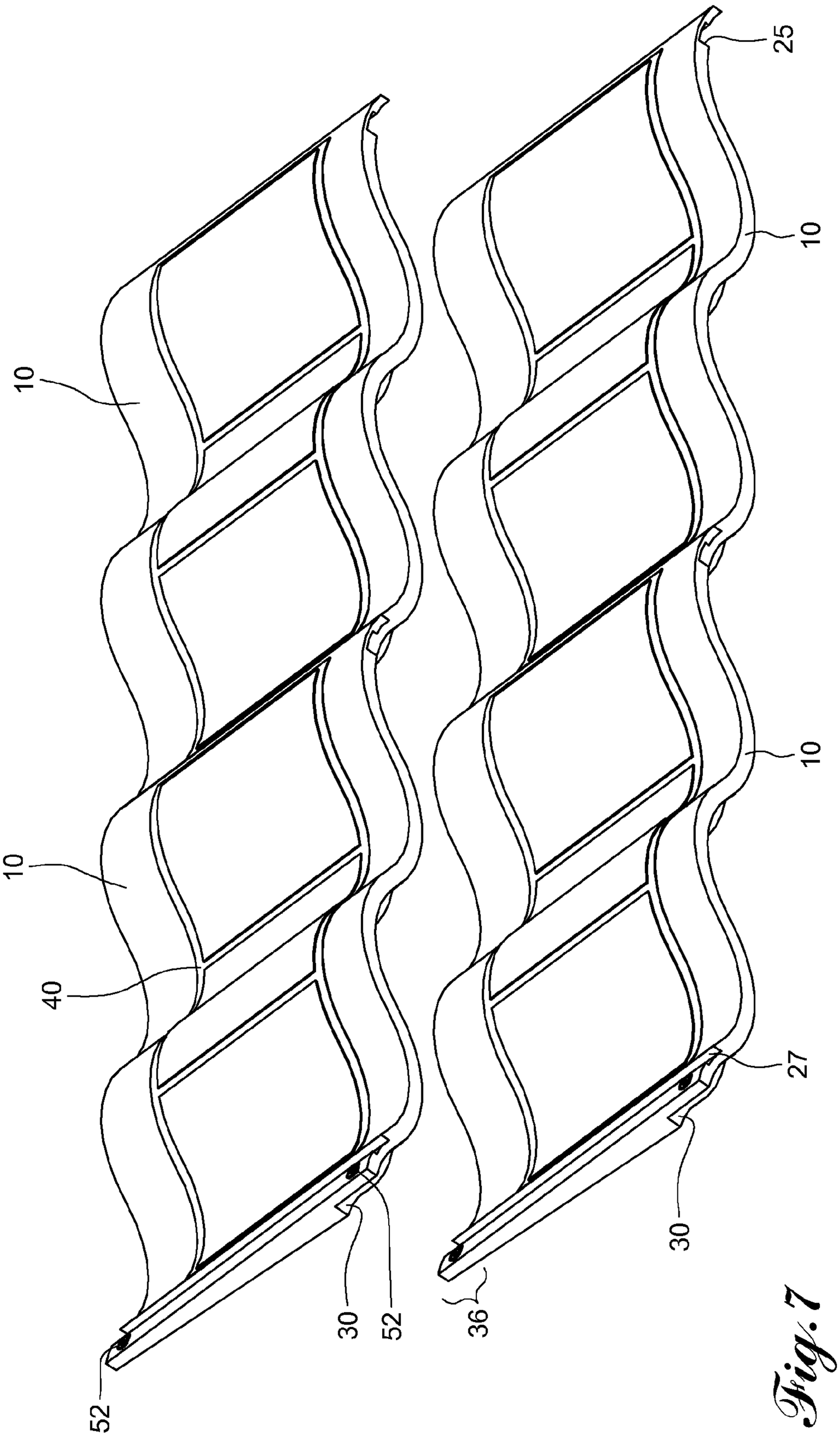


Fig. 7

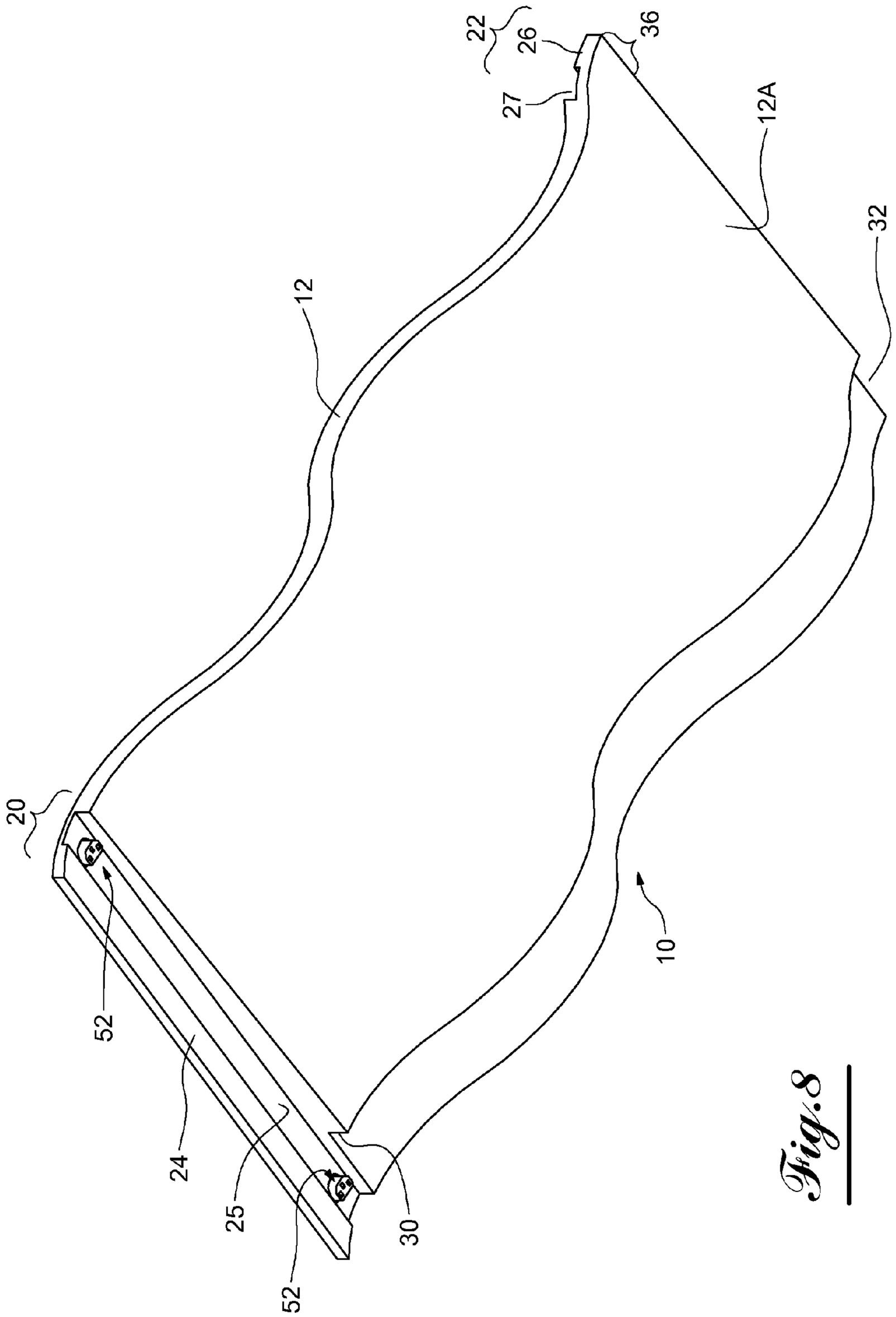


Fig. 8

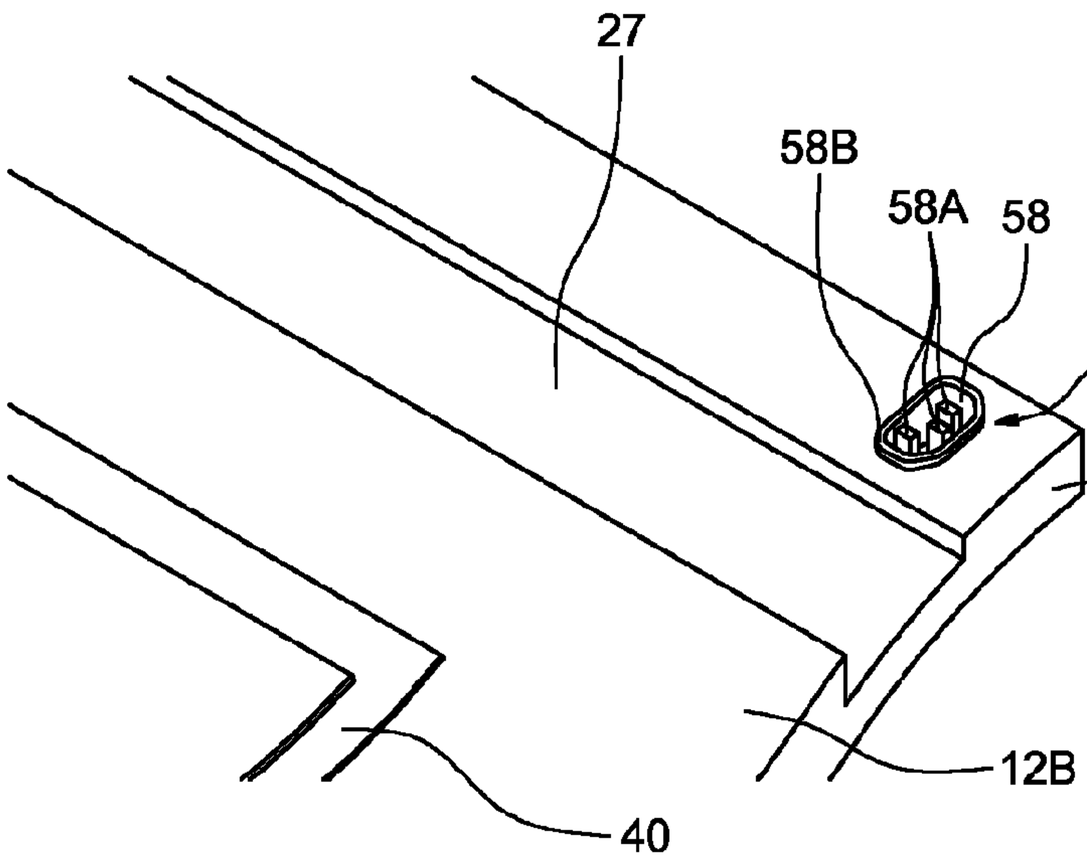
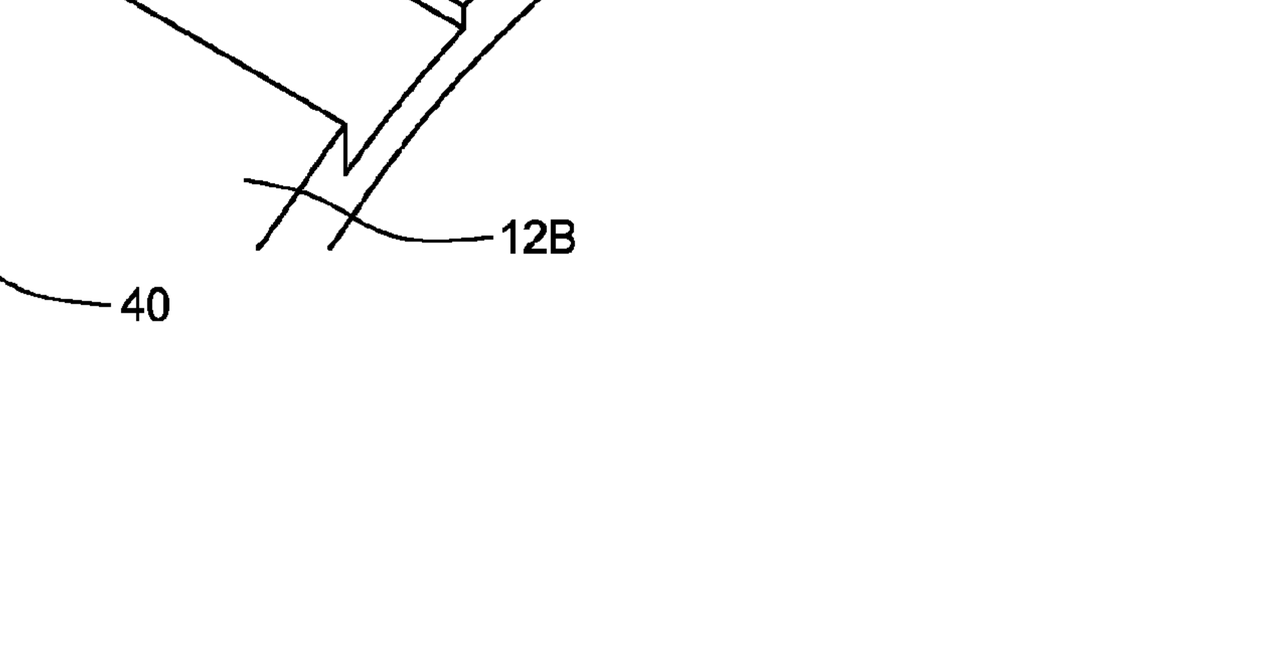


Fig.9

Fig.10



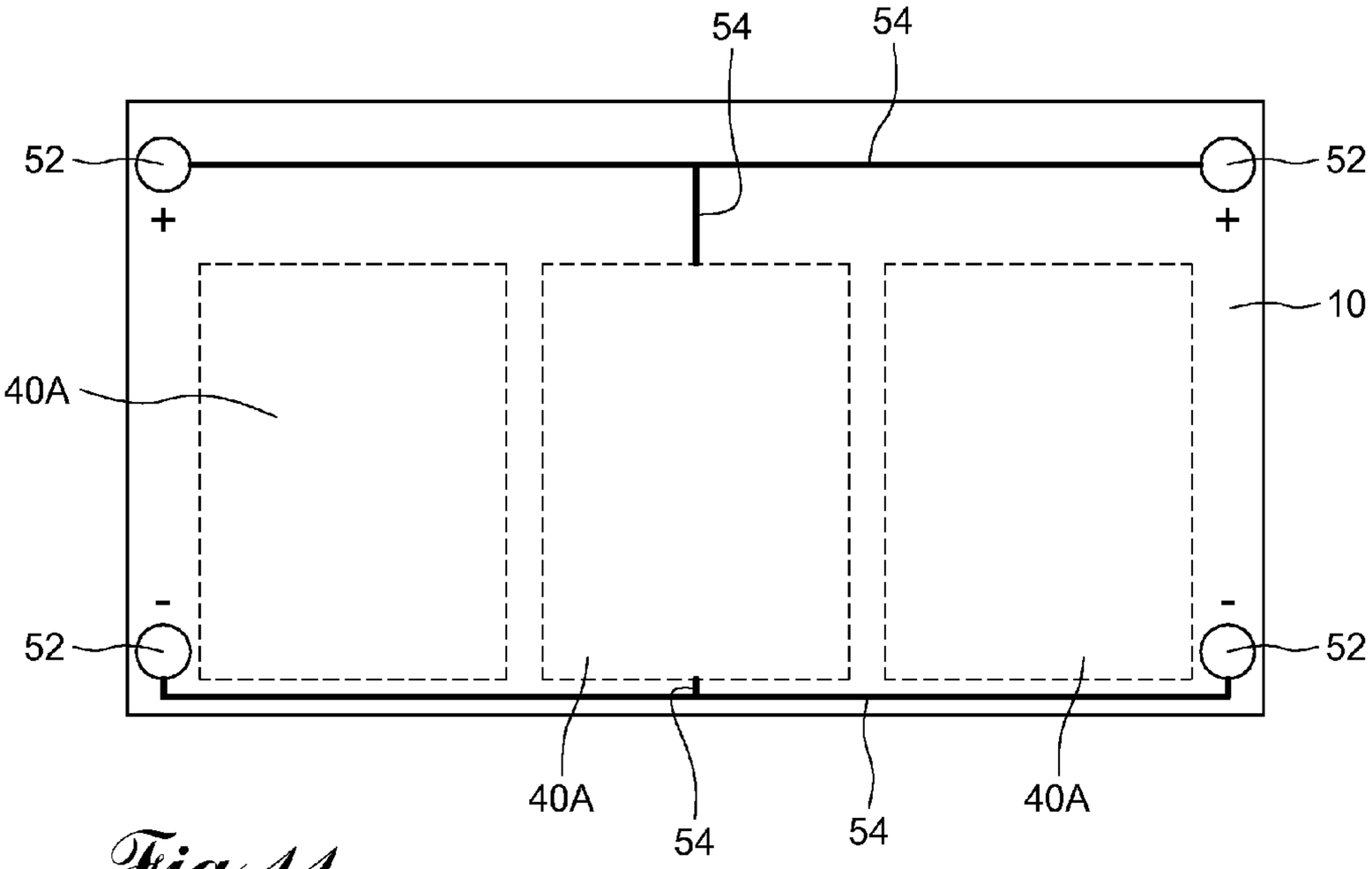

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40A

Fig. 11

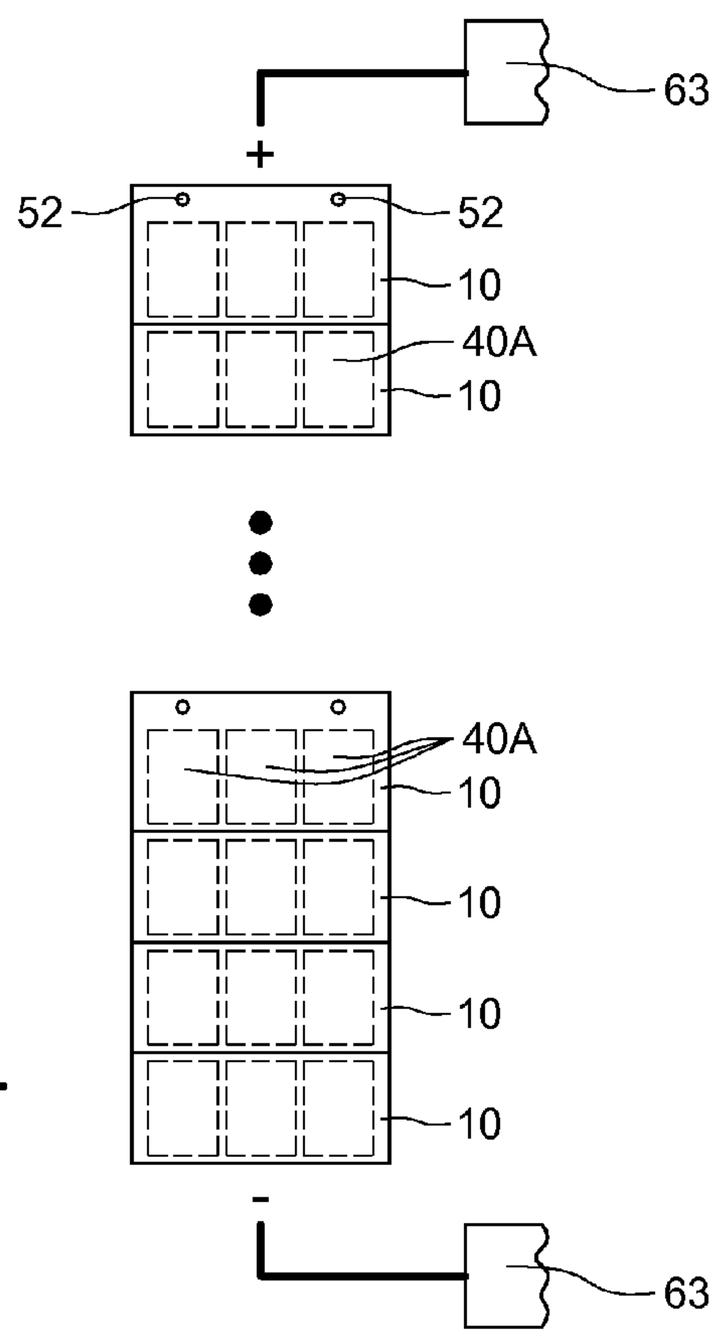

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Fig. 12

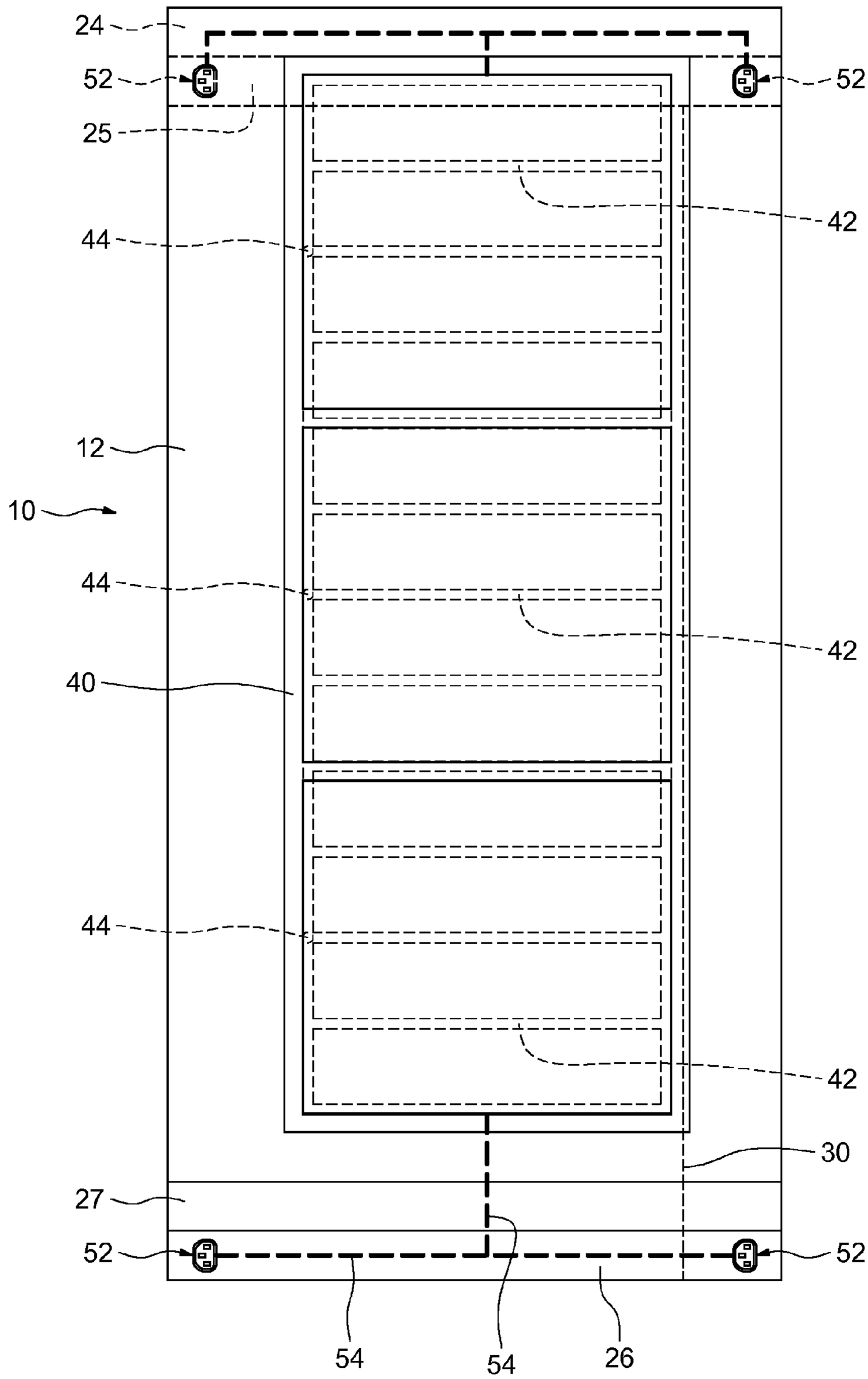


Fig. 13

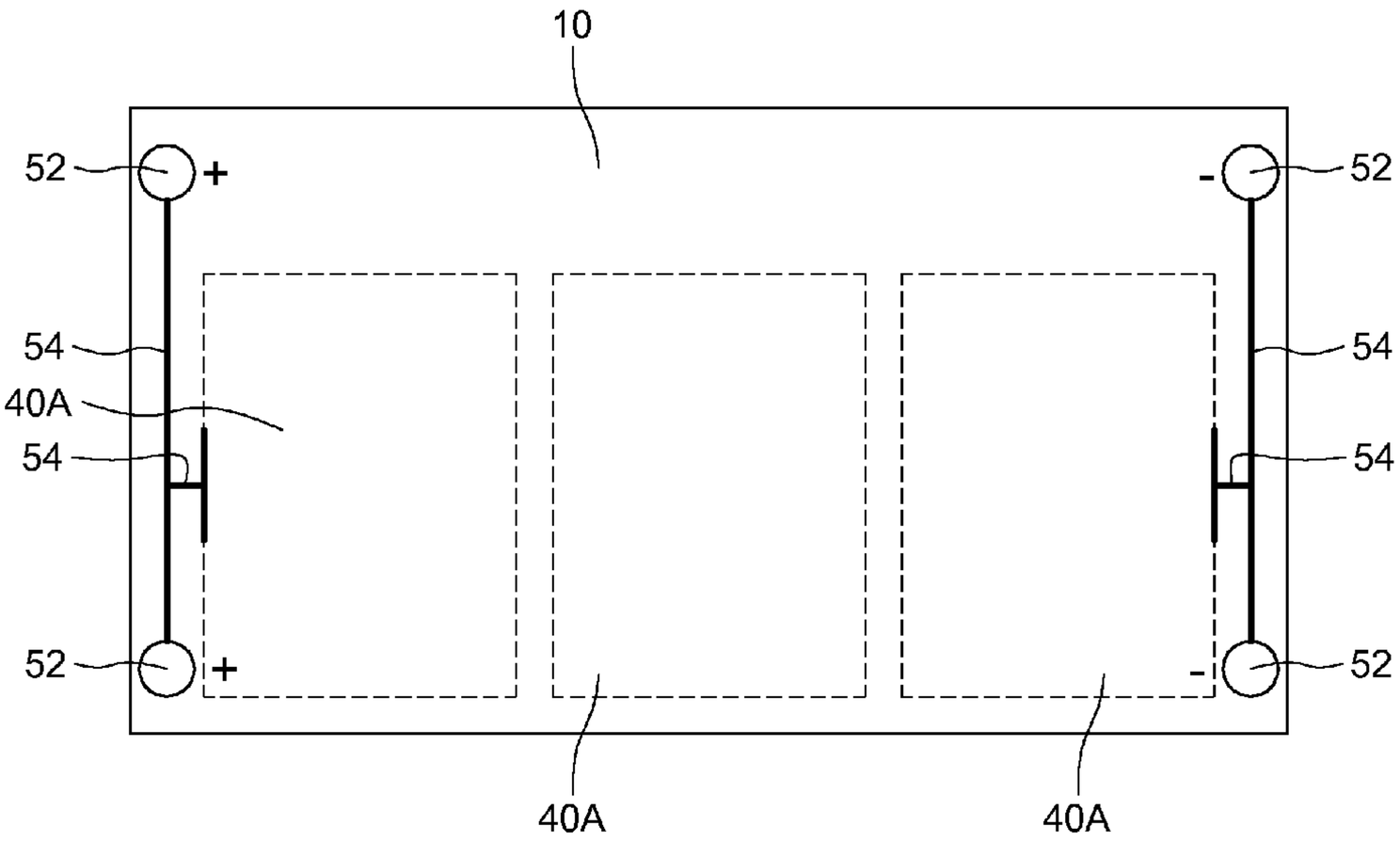

10
52
+
52
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54
40A
54
54
54
52
+
52
-
40A
40A

Fig. 14

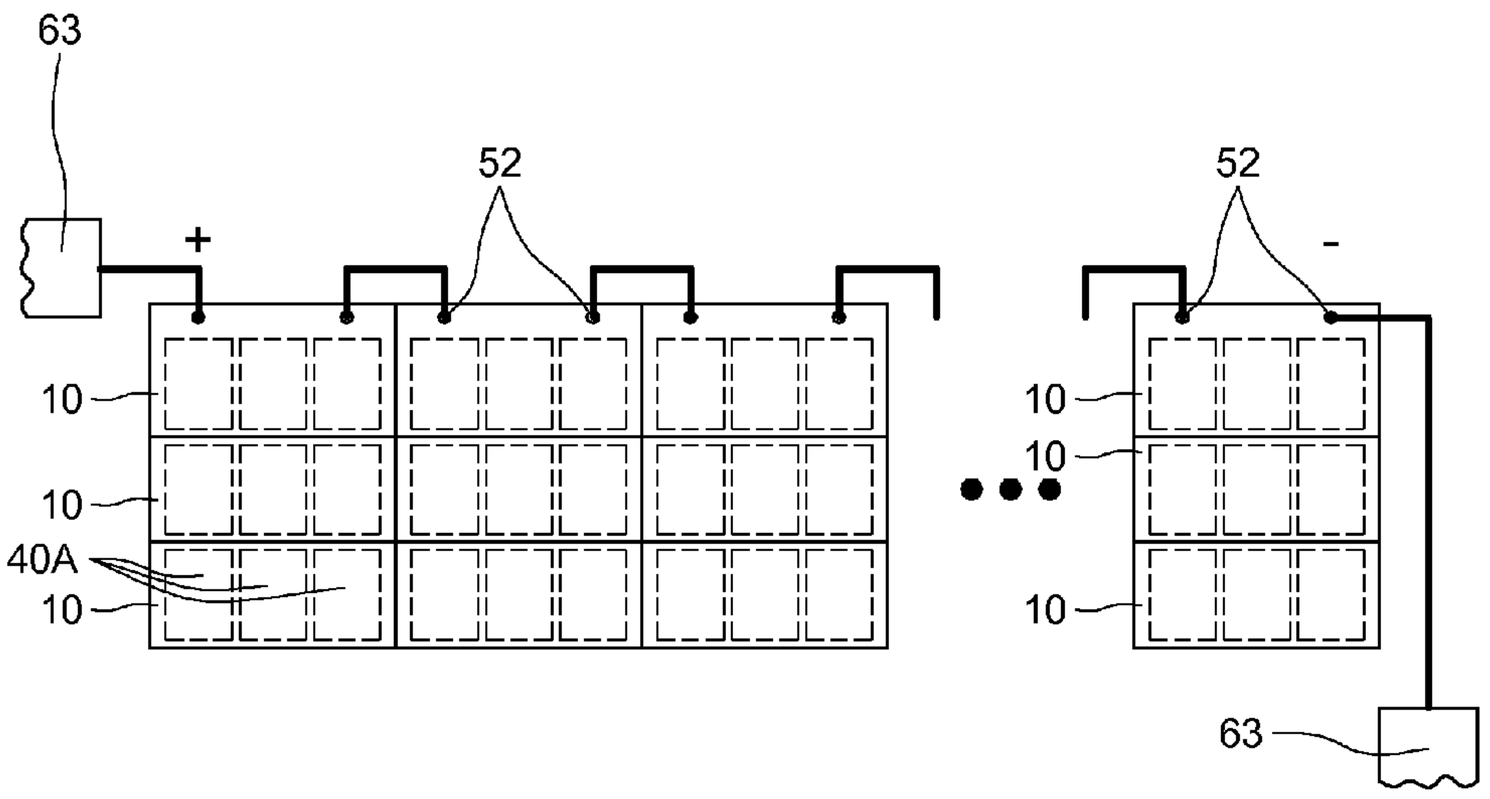

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10
10
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10
40A
10
10
10
63

Fig. 15

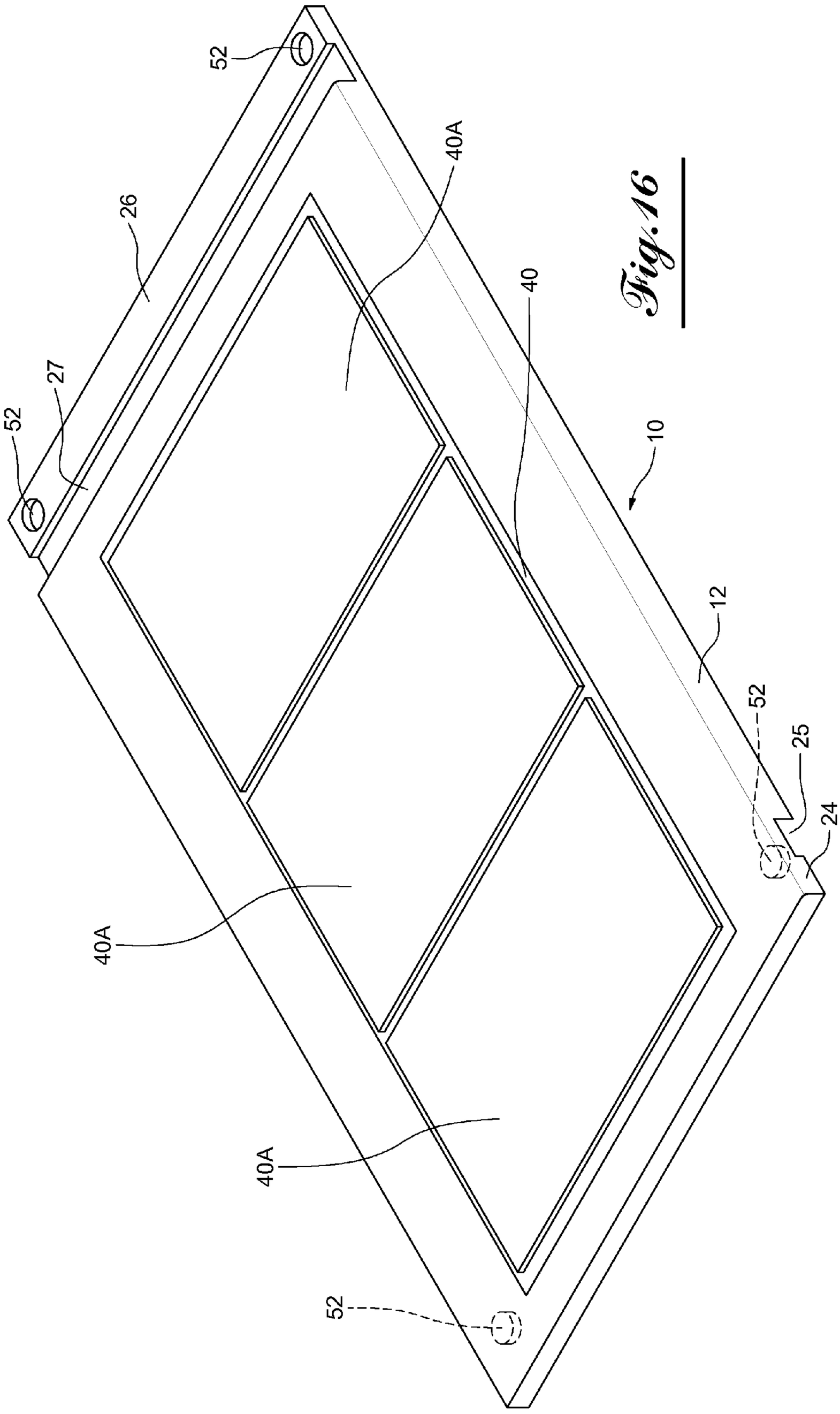


Fig. 16

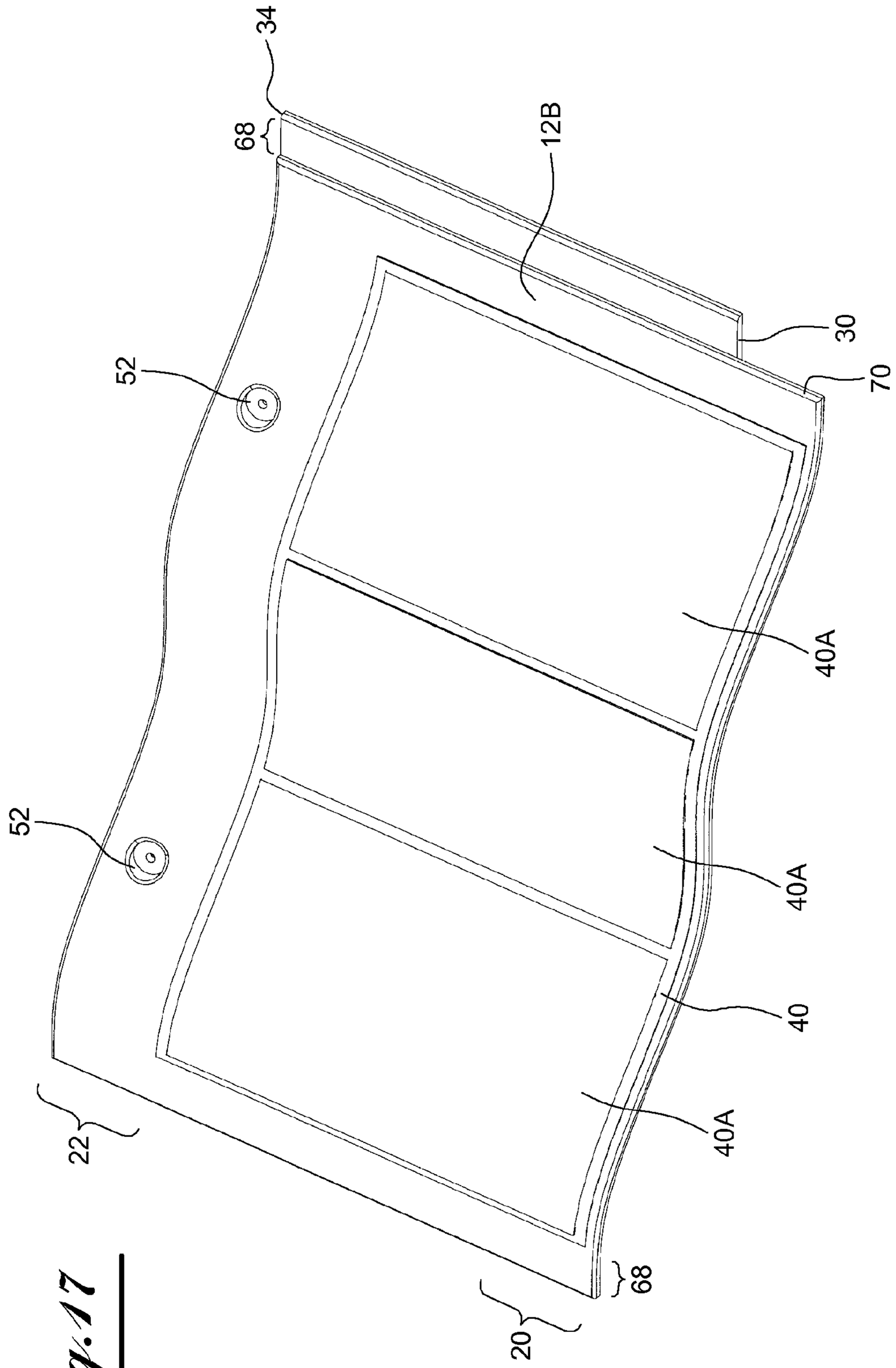


Fig. 17

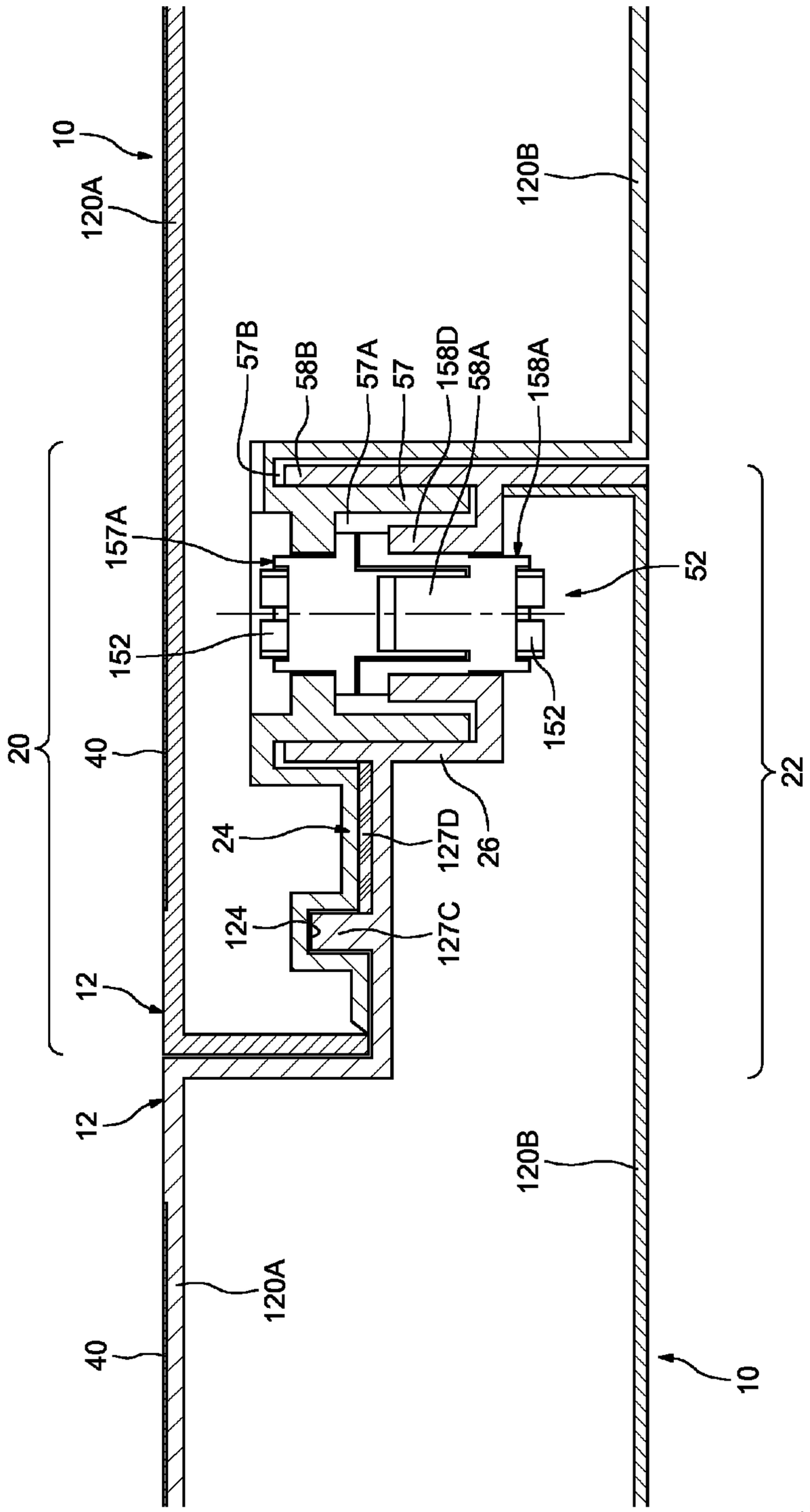

10
120A
40
12
12
20
24
124
127C
127D
26
152
152
157A
57B
58B
57A
57
158D
58A
158A
52
22
120B
120B
40
120A
10

Fig. 18

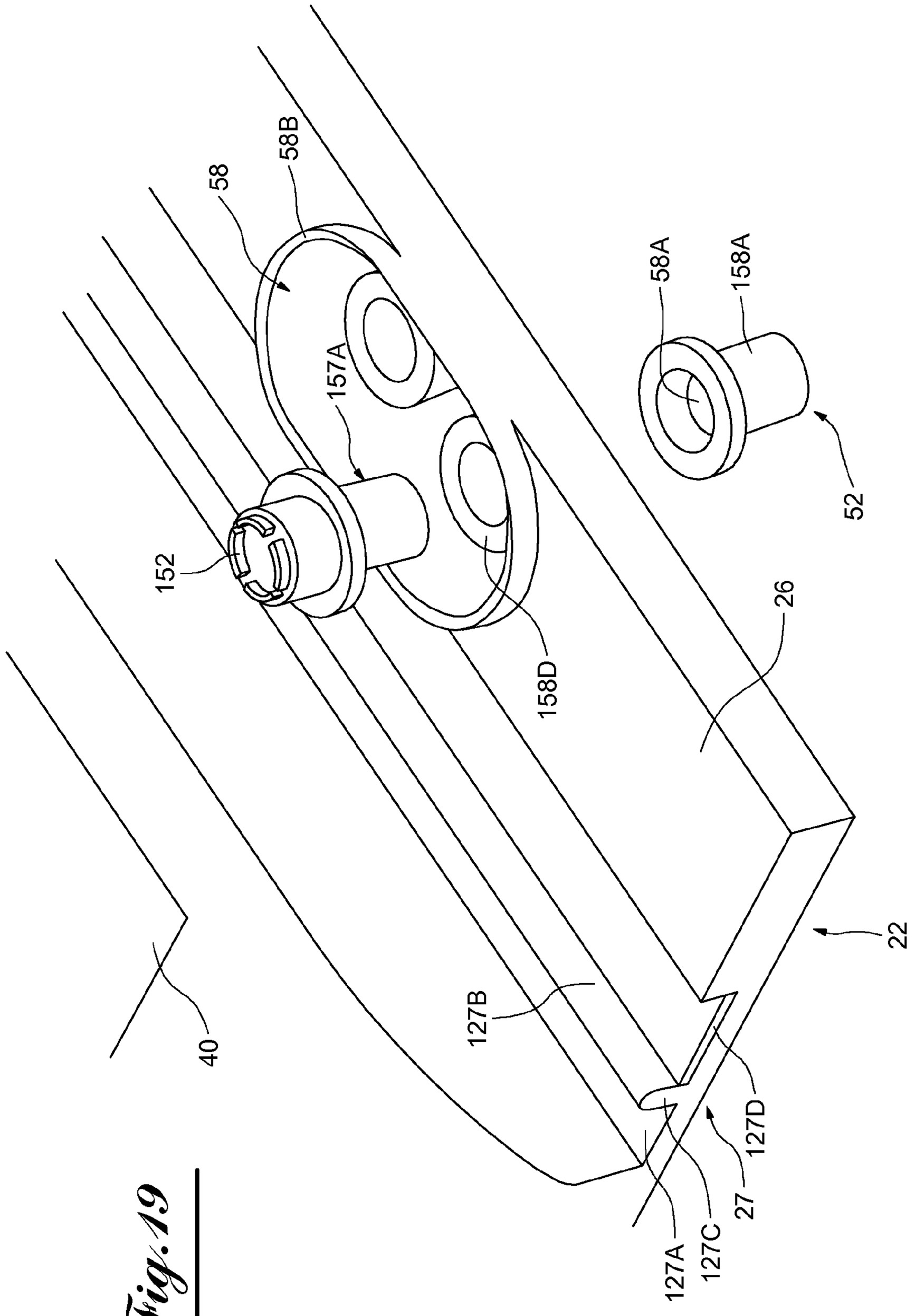


Fig. 19

Fig.20

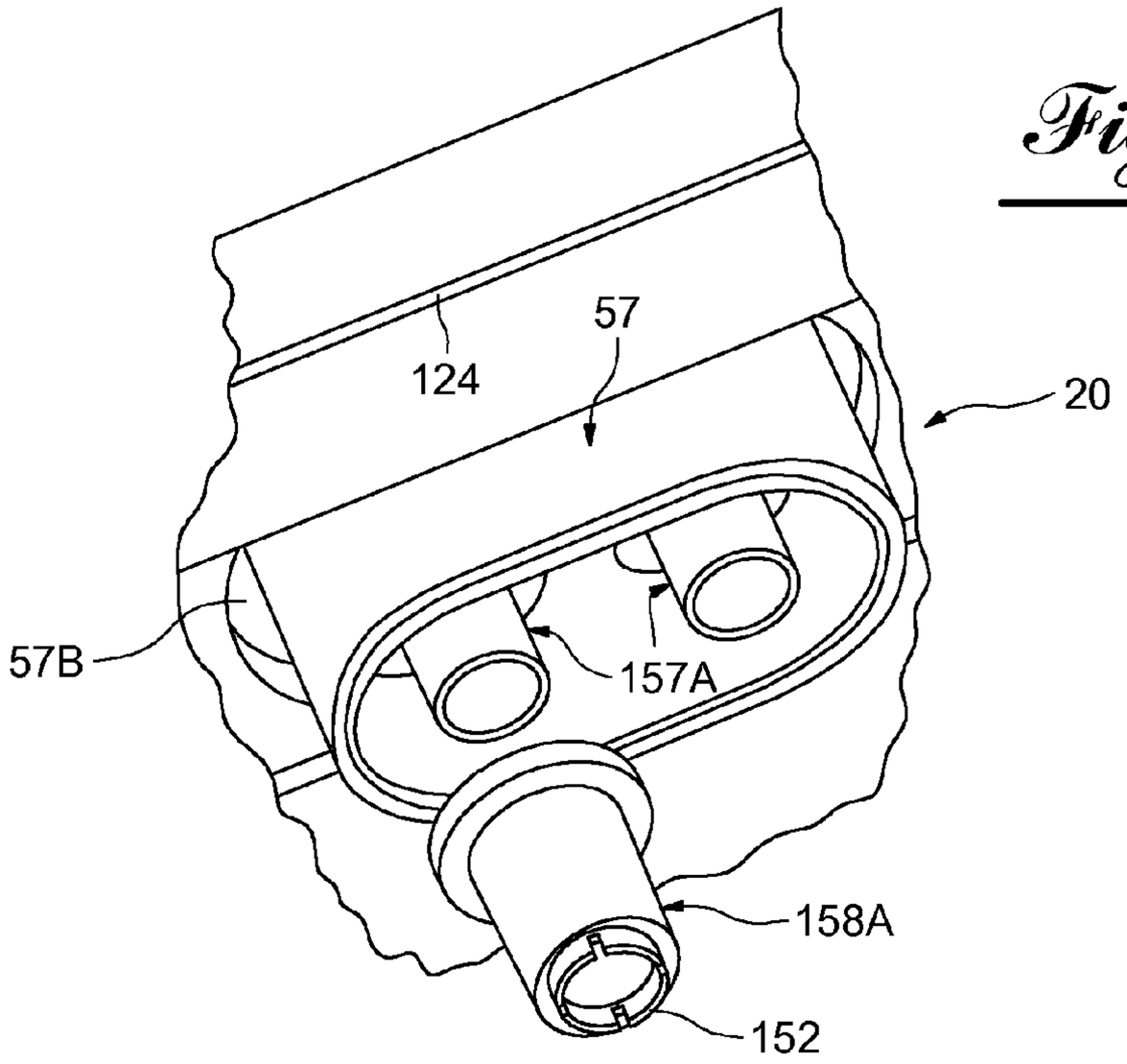


Fig.21

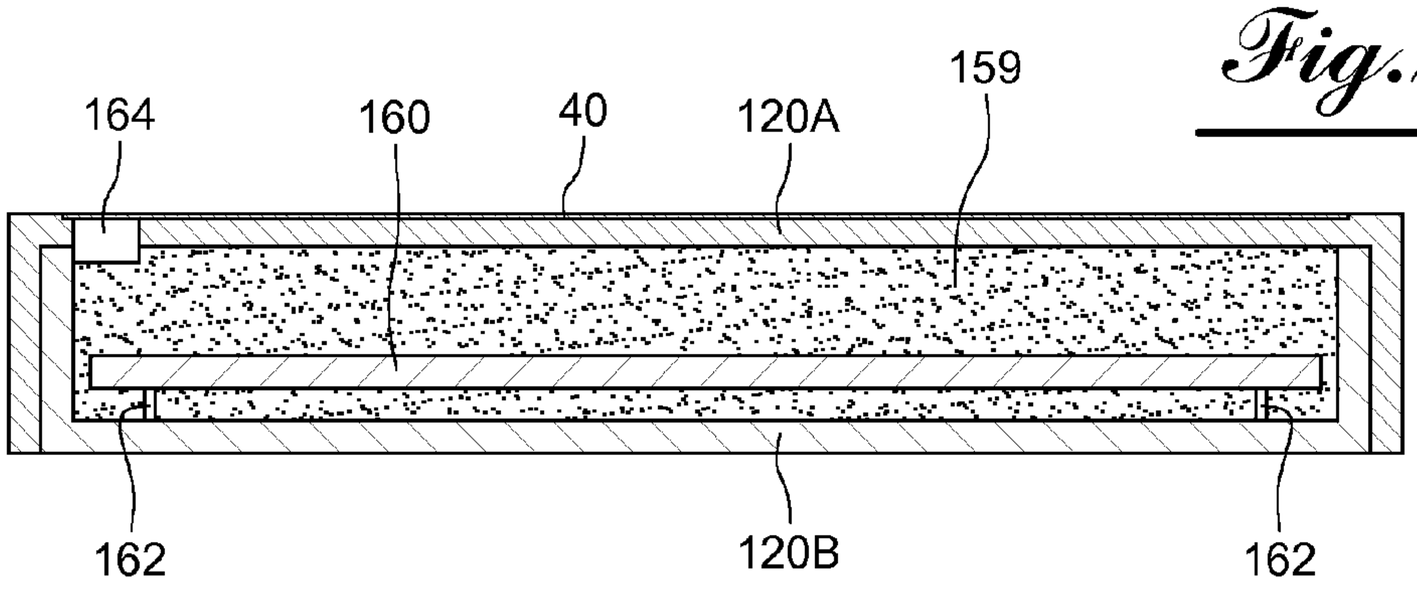
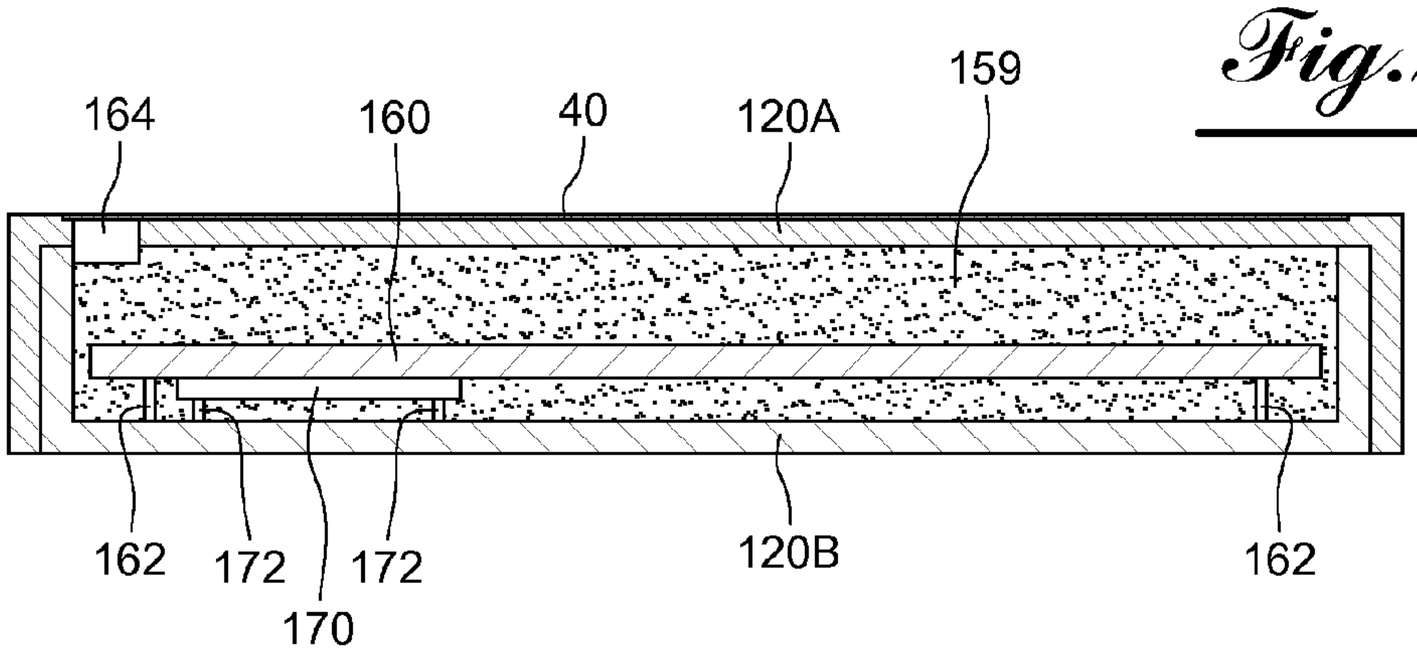


Fig.22



PHOTOVOLTAIC TILE FOR A ROOF

BACKGROUND OF THE INVENTION

The present invention relates to photovoltaic tiles for a roof.

More particularly, the invention relates to a photovoltaic tile for a roof comprising a plurality of said tiles, at least two adjacent tiles of which at least partially overlap each other, including:

- a body having overlapping edges constituting a top edge and a bottom edge, the top edge being formed so as to cover the bottom edge of at least one of the adjacent tiles,
- a photovoltaic layer placed on a free part of the upper surface of the body outside the bottom edge, and
- electrical connectors which are connected to the photovoltaic layer by means of electrical conductors to electrically connect one to another the photovoltaic layers of at least two adjacent tiles of the roof.

This type of tile is known from document NL1005287, in which the photovoltaic tile includes connectors, the connection of which requires precise manipulation of the tiles to prevent their deterioration.

SUMMARY OF THE INVENTION

The present invention in particular aims to resolve the drawbacks of the prior art.

To that end, the invention relates to a photovoltaic tile for a roof comprising a plurality of said tiles, at least two adjacent tiles of which at least partially overlap each other, including a body having overlapping edges constituting a top edge and a bottom edge, the top edge being formed so as to cover the bottom edge of at least one of the adjacent tiles, a photovoltaic layer placed on a free part of the upper surface of the body outside the bottom edge, and electrical connectors which are connected to the photovoltaic layer by means of electrical conductors to electrically connect one to another the photovoltaic layers of at least two adjacent tiles of the roof. In this tile, the electrical connectors are provided in assembly elements by nesting, said assembly elements being provided on the overlapping edges so as to enable said overlapping edges to be mutually positioned during the placement of two of the adjacent tiles so that, through the nesting of the assembly elements, the electrical connectors come into electrical contact with each other.

Owing to these arrangements, the same parts of the tile serve both the electrical connection function and the function for mutual maintenance in position of the adjacent tiles.

In various embodiments of the tile according to the invention, it is possible also to use one or more of the following provisions:

- the conductors are inside the body of the tile in their travel between the photovoltaic layer and their electrical connector;
- the nesting assembly elements comprise, on the one hand, at least one lug that protrudes from one of the top edge or the bottom edge, and on the other hand, at least one housing withdrawn in the other of the bottom edge or the top edge, the electrical connectors being withdrawn in their lug and their housing;
- the lug forms a plug protruding from its overlapping edge and the housing forms a tap formed withdrawn from its overlapping edge;

- the lug and the housing are substantially perpendicular to the median plane of the tile, that plane being provided to be parallel to the plane of a roof surface receiving the tile;
- the photovoltaic layer is in direct contact with the environment;
- the photovoltaic layer is a film adhered to the body of the tile using a flexible adhesive making it possible to absorb the differential expansions between the body and the film;
- the film making up the photovoltaic layer is housed in a cavity withdrawn from the upper surface of the body at the free portion thereof, the depth of the cavity being such that the upper surface of the film is flush with a peripheral part of the free edge of the upper surface of the body;
- the area of the upper surface of the body covered by the photovoltaic film is at least partially hollowed with cooling channels allowing a local passage of air between the body and the photovoltaic film;
- the cooling channels are grooves and the body defines air discharge conduits emerging on the one hand in one of the grooves and on the other hand at the lower surface of the tile;
- the photovoltaic layer is a layer of photovoltaic nanoparticles;
- the body of the tile is made from a polymer-based material, for example ceramic filler, or a wood-based material;
- the body has a base of a material adapted to polymerize upon cooling after molding or during press forming;
- the upper surface of the body of the tile is covered with a protective mineral layer, in particular protecting it from ultraviolet rays;
- the tile includes a thermally insulating layer on the lower surface of the body;
- the thermally insulating layer is covered with a lower finishing layer;
- the body includes an upper half-shell and a lower half-shell defining an inner space;
- the inner space between the upper half-shell and the lower half-shell is filled with a foam;
- the body contains at least one inner thermally insulating layer;
- the body contains an electronic unit for converting direct current into alternating current.

Furthermore, the invention also relates to a method for manufacturing a photovoltaic tile according to the invention, the method including a step for positioning, in a mold, conductors whereof at least one end is provided with an electrical connector, and a step for molding the body of the tile in the mold containing the conductors.

According to one embodiment, this method includes a step for positioning a photovoltaic layer in the mold before the step for molding the body.

According to another embodiment, this method includes a step for positioning a photovoltaic layer on the upper surface of the body after the molding step and after a step of removing the body from the mould.

According to other features, the method includes, after placing at least a first of said tiles on a frame face, a step for bringing a second tile closer so as to position its top edge opposite the bottom edge of the first tile and a step for placing the second tile adjacent to the first tile by bringing it substantially perpendicular to the plane of said frame face with, on the one hand the top edge of the second tile overlapping the bottom edge of the first tile, and on the other hand nesting of

the assembly elements substantially perpendicular to said frame face by nesting to mechanically maintain said tiles and connect them electrically.

Furthermore, the invention also relates to a covering assembly for a roof, comprising a plurality of photovoltaic tiles according to the invention placed adjacent to one another, the top edge of one of the tiles overlapping the bottom edge of at least one of the adjacent tiles while having their electrical connectors electrically connected.

BRIEF DESCRIPTION OF THE DRAWINGS

Other aims, features and advantages of the invention will appear during the following description of several embodiments, provided as non-limiting examples, in light of the appended drawings, in which:

FIG. **1** is a perspective view, of the high-angle view type, of a photovoltaic tile according to the invention;

FIG. **2** is a partial longitudinal cross-sectional view of the tile according to the invention, along line II-II of FIG. **1**, showing its nesting assembly elements and its electrical connector elements;

FIG. **3** is a top view of the tile of FIG. **1**;

FIGS. **4** to **6** are transverse cross-sections of the tile, respectively along lines IV-IV to VI-VI of FIG. **3**;

FIG. **7** is a perspective view showing an assembly of a plurality of tiles as shown in FIG. **1**;

FIG. **8** is a perspective view, of the low angle view type, of the tile shown in FIG. **1**;

FIG. **9** is a partial perspective view showing the details of an electrical connector of the tile as shown in FIG. **1**;

FIG. **10** is a partial perspective view showing the details of an electrical connector of the tile as shown in FIG. **8**;

FIGS. **11** and **12** are views showing the polarities and the cabling of tiles according to that shown in FIGS. **1** to **10**;

FIG. **13** is a view of the type of FIG. **3** for an alternative embodiment of the internal conductors of the tile according to the invention;

FIGS. **14** and **15** are views showing the polarities and cabling of tiles according to that shown in FIG. **13**;

FIG. **16** is a perspective view, of the high angle view type, of a flat alternative embodiment of a tile of the type of that in FIG. **1**;

FIG. **17** is a perspective view, of the high angle view type, of a thin alternative embodiment of a tile of the type of that in FIG. **1**;

FIG. **18** is a cross-sectional view along a longitudinal plane perpendicular to the photovoltaic surface of a tile according to the invention, showing an alternative embodiment of the body of the tile and its connectors;

FIG. **19** is a partial perspective view showing the details of an electrical connector of the tile as shown in FIG. **18**, in high angle view;

FIG. **20** is a partial perspective view showing the details of an electrical connector of the tile as shown in FIG. **18**, in low angle view;

FIGS. **21** and **22** are cross-sectional views in a longitudinal plane perpendicular to the photovoltaic surface of the tile, showing alternative embodiments of the body of the tile of FIG. **18**.

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

In the different figures, the same references designate identical or similar elements.

In the embodiments of the invention shown in the figures, the photovoltaic tile **10** includes a corrugated body **12**, the right **16** and left **14** lateral end surfaces of which intersect, halfway along their height, a median plane P at said body **12**. The corrugated tile is sinusoidal, with the result that the median plane P passes through the axis corresponding to the X axis of that sine curve, i.e. the plane P is at mid-height of the tile and parallel to the planes passing through the apices of the tile. In this way, the plane P is parallel to the plane of the face of the frame on which the tile is placed when it is incorporated into a roof.

At lateral end portions, the body **10** includes overlapping edges constituting a top edge **20** and a bottom edge **22**, the top edge being formed to overlap the bottom edge of at least one of the adjacent tiles of the roof. The top edge **20** is on the left in FIG. **1**, and the bottom edge **22** is on the right in FIG. **1**. The thickness of the tile **10** at its edges **20** and **22** is reduced relative to the thickness of the tile in its central portion between the overlapping edges.

The top edge **20** on the one hand has a lateral blocking rib **24** whereof the lateral end is the left lateral end surface **14**, and on the other hand, parallel to said surface **14** and toward the inside of the tile from the lateral blocking rib **24**, a lateral blocking slot **25** that emerges at the lower surface **12**A of the body **12**.

The bottom edge **22** has, on the one hand, a lateral blocking rib **26** whereof the lateral end is the right lateral end surface **16** and the shape of which is complementary to that of the lateral blocking slot **25**. The bottom edge **22**, on the other hand, has, parallel to said surface **16** and toward the inside of the tile from the lateral blocking rib **26**, a lateral blocking slot **27**, the shape of which is complementary to that of the lateral blocking rib **24** and which emerges at the upper surface **12**B of the body **12**.

The tile has, at the lower surface **12**A of the body **12**, a stop shoulder **30** (FIG. **2**) that defines a stop housing **32** (FIG. **8**) at a lower edge of the body. The thickness of the body **12** narrows regularly from the shoulder **30** toward the upper end surface **34** of the tile, the height of said surface **34** substantially corresponding to the height of the shoulder **30**. The shoulder **30** makes it possible on the one hand to shim the tiles of the lower horizontal row of the roof on a batten of the frame, the batten being housed in the stop housing **32**. The shoulder **30** on the other hand makes it possible to shim the tiles of the other horizontal rows while having their stop shoulder **30** bearing on the upper end surface **34** of the tile(s) of the next lowest row. An upper end edge **36** of the lower-row tiles is housed in the stop housing **32** of the higher-row tiles.

The tile **10** has a photovoltaic layer **40** directly in contact with the environment.

The photovoltaic layer **40** overlaps the upper surface **12**B of the body **12** except on a border strip that is at least at the bottom edge **22** and the upper end edge **36**, these two edges not being lit when the tiles are mounted on the roof. To maximize electrical energy production by maximizing the photovoltaic layer surface, the latter is on a free part of the upper surface of the body that is as large as possible so that it can be exposed to the light when the tile is incorporated into a roof.

In the illustrated embodiment, the photovoltaic layer **40** is a film adhered to the tile using a flexible adhesive making it possible to absorb differential expansions between the body **12** and the film **40**. The film is of the type available on the market under brand UNI-SOLAR and manufactured by the company United Solar Ovonic, subsidiary of the company Energy Conversion Devices (ECD). The film may also be of the type available from the company NANOSOLAR, Cali-

fornia or the company Ascent Solar, Colorado. Here, the photovoltaic film can withstand outdoor usage conditions, for example by incorporating a transparent protective layer.

As shown in FIGS. **3** to **6**, the film forming the photovoltaic layer **40** is housed in a cavity **12**C hollowed into the upper surface **12**B of the body and the bottom of which includes air passage grooves **42** and air discharge conduits **44** emerging on the one hand in one of the grooves **42** and on the other hand at the lower surface **12**A of the tile. The air passage grooves **42** and the air discharge conduits **44** make it possible to cool the photovoltaic layer **40** through the local circulation of air between the film and the body of the tile.

In one alternative not shown, the cooling cavity hollowed into the body to allow air to pass locally between the body and the photovoltaic film may be formed, replacing the grooves, by micro blades or micro perforations.

Aside from aesthetic aspects, the film housed in its cavity advantageously allows its upper surface not to protrude past the upper surface **12**B of the body **12** at the periphery of the tile, for example flush with said surfaces, which makes it possible to avoid deterioration of the film when the tiles are stacked for storage.

The top edge **20** and the bottom edge **22** are provided with electrical connectors **52** that are connected to the photovoltaic layer **40** through horizontal electrical conductors **54** and that make it possible to electrically connect one to another the photovoltaic layers **40** of tiles **10** placed adjacent on a roof.

The electrical connectors **52** are formed in nesting assembly elements so that, by nesting one tile **10** on another tile **10** by nesting, that's to say fitting together, the assembly elements of the body **12**, the electrical connectors **52** of the tiles **10** come into electrical contact with one another.

In the embodiment shown in FIGS. **1** to **10**, the electrical connectors **52** are part of the assembly elements made up on the one hand of a lug **57** forming a plug protruding into the lateral blocking slot **25**, and on the other hand, a housing **58** forming a tap arranged withdrawn into the lateral blocking rib **26**. The lugs **57** and the housings **58** extend substantially perpendicular to the median plane P at the body **12** of the tile **10**, or slightly inclined relative to the plane P, for example by 10 or 20 degrees.

In the embodiment as shown in FIGS. **9** and **10**, the lugs **57** and the housings **58** of the electrical connectors **52** are integral with the body **12** while having a hexagonal section having two opposite sides of different lengths, larger than the length of the other sides. The lugs **57** forming plugs and the housings **58** forming taps are of the type resembling the plugs and taps generally used to power CPUs and computer monitors. Three pins **58**A forming a male connector, for example made of copper, are in each housing **58**, extending parallel to the axes thereof, perpendicular to the median plane P at the body **12** of the tile **10**. Three wells **57**A made up of female connecting elements shaped into two half-shells, for example made from copper, are formed in the lugs **57**. The number of pins is not limited to three and may for example be less than three, a single pin being possible.

The mouth of each housing **58** and the root of each lug **57** respectively include a sealing gutter **57**B and a rubber weather strip **58**B.

The height of the pins **58**A and the wells **57**A is adapted to the corrugated profile of the tile and the available thickness in the body, the free end of the lugs **57** and the bottom of the housings **58** being parallel to the plane P of the tile.

The conductors **54** are electrically connected to the pins **58**A and the wells **57**A, as in computer power supply taps and plugs.

The body is made from a polymer material obtained by molding, for example by injection or compression, incorporating a filler, for example ceramic. The polymer is for example polypropylene (PP) or high density polyethylene (HDPE) or polymethyl methacrylate (PMMA) or polytetrafluoroethylene (PTFE) or any other equivalent material suitable to withstand atmospheric conditions outside the building and strong enough not to break in case of hail, for example.

For other materials, the body can be made from polymer as above, with a wood filler, or an injected or formed wood paste.

In the embodiment illustrated in FIGS. **1** to **8**, the electrical conductors **54** and their connection to the pins and wells are embedded in the body **12** made from a molded material, which advantageously serves as electrical insulation.

The dimensions of the tile illustrated in FIG. **1** are approximately 1 m long and 0.5 m wide, with a thickness varying between about 25 mm at the thinnest part of the tile and 50 mm at the shoulder **30**, but the invention can apply to smaller tiles, for example smaller by half in terms of length and width, or larger if necessary.

In one embodiment, the upper surface **12**B of the body **12** is covered with a protective mineral layer, less than one millimeter thick, for example an ultrafine layer of several microns, and aiming to protect the filled polymer from weather over time so that the latter does not age prematurely, for example due to ultraviolet rays from the sun. The protective mineral layer can be applied during production of the body or afterwards, during finishing. The curing of that optional mineral layer on the tile is done at a temperature compatible with the integrated electrical systems.

Advantageously, the tile **10** is provided with no outer transparent packaging enclosure of the photovoltaic layer **40** and the body **12** because the photovoltaic layer **40** is of a nature to withstand the environment naturally. Both the electrical connectors **42** and the electrical conductors **44** are protected by the body **12** of their tile or adjacent tiles.

The operation and use of the tile **10** already partially emerge from the preceding description and will now be explained in detail.

During placement of the tiles, typically on a frame provided with vertical rafters on which horizontal battens are fixed, a first, lower row of tiles is positioned with the stop shoulder **30** of the tiles against a vertical surface of the lower batten, which is housed in the stop housing **32**. These tiles are nailed and screwed on the second batten of the frame, for example by making the nail or screw pass through a piercing formed in the upper end edge **36** of the tiles.

Next, the upper rows are positioned one by one on the frame by placing, for example after vertical descent of the tiles, the median plane P of each tile **10** substantially parallel to the plane of the battens, then placing each tile in a downward movement in a direction perpendicular to said planes. During said downward movement, the shoulder **30** of the higher-row tile is placed bearing on the upper surface **34** of the upper end edge **36** of the lower-row tile(s) (FIG. **7**). During this downward movement, the top edges **20** are placed on the bottom edges **22**, with nesting of the lateral blocking ribs **24** or **26** in the corresponding lateral blocking slots **27** or **25** and nesting of the assembly elements to center the tiles relative to one another so that the electrical connectors **52** come correctly into electrical contact with one another. In fact, the centering allows good mutual positioning of the tiles to connect the electrical connectors **52** without deterioration thereof.

In the event the lugs **57** and the housings **58** extend at an incline relative to the plane P of the tile **10**, the incline is

chosen so that the latter downward movement occurs in a direction closer to the vertical than the perpendicular at the plane P, the incline angle being of the order of magnitude of the slope of the roof, for example slightly smaller than that angle.

Advantageously, the assembly elements and their connector enable an electrical connection at the same time as the mechanical assembly of the tiles, which has the benefit of reducing assembly time for the roof and eliminating delicate manipulations of the tiles. The assembly elements also make it possible to mechanically maintain said tiles relative to one another during placement thereof.

To complete the placement of each tile, one need only nail or screw the tile on its batten, without the need to perform any specific cabling operation of the adjacent photovoltaic tiles. The cabling of the tiles to the electrical network of the building is done upon placement of the tiles by simple connection on a corresponding connector installed on the frame, this connector being of the same type as that of the tiles and being integrated into an electrical circuit of the type illustrated in FIG. **12**.

The cabling form shown in FIG. **12** corresponds to electrical connection of adjacent tiles in vertical rows, for convenience called serial connection of the tiles. For this cabling mode, as shown in FIG. **11**, the electrical connectors **52** situated at the top of their tile **10** are for example connected to the positive pole of the photovoltaic layer **40**, which can include three modules **40**A. The electrical connectors **52** situated at the bottom of their tile **10** are connected to the negative pole of the photovoltaic layer **40**. A direct alternating converter **63** is connected to each tile row that typically extends from the top to bottom of a roof, the negative pole of the row for example being at the bottom and the positive pole at the top. For example, each converter **63**, of the standard type, is used for 16 to 18 tiles of 100 volts and 4 amperes.

As an alternative of the tile shown in FIG. **13**, the electrical conductors are vertical, without any other change for the rest of the tile.

The tiles like those shown in FIG. **13** are connected to one another by cabling as shown in FIG. **15**, which corresponds to an electrical connection of adjacent tiles in horizontal rows, for convenience called parallel connection of the tiles. In that case, the electrical connectors **52** situated to the left of their tile **10** are connected for example to the positive pole of the photovoltaic layer **40**, which can include three modules **40**A, as shown in the figures. The electrical connectors **52** situated to the right of their tile **10** are connected to the negative pole (FIG. **14**) of the photovoltaic layer **40**. A direct alternating converter is also connected to each row of a group of three tiles, the negative pole of the row for example being to the left of the row and the positive pole to the right.

As an alternative of the tile shown in FIG. **16**, the body is flat instead of being corrugated, without any other change for the rest of the tile relative to that described with regard to FIGS. **1** to **12**. The connectors **52** are the same as those shown for example in FIG. **9** and FIG. **10**, but here they are shown diagrammatically.

As an alternative of the tile shown in FIG. **17** based on the tile described relative to FIGS. **1** to **12**, the body of the tile is thin and has a substantially constant thickness, inasmuch as it does not include the lateral blocking slots and ribs. The latter parts are replaced by a system of flat lateral overlapping edges **68**, with a lateral shim shoulders **70** of the type described for vertically shimming the tiles in the embodiment described relative to FIGS. **1** to **12**.

Here, the top edge **20** and the bottom edge **22** including the electrical connectors **52** are the lower and upper edges of the tile, respectively. Corresponding lugs and housings, which are shown diagrammatically in FIG. **17**, serve to create a mechanical connection between the tiles so as to center them and prevent them from sliding relative to one another, while incorporating the connectors to which the conductors are connected. The connectors are for example as shown in FIGS. **2**, **9** and **10** or for example flat plates overlapping the free end of the lugs and the bottom of the housings.

Advantageously, the tiles as described above allow both an aligned assembly of the tiles and a staggered assembly.

In one embodiment not shown, the tile **10** includes a thermally insulating layer on the lower surface **12**A of the body **12**. The thermally insulating layer is for example fibrous or foam, or made from a foam and fibrous hybrid material, for example such as rock wool or polyurethane, respectively. The thermally insulating layer is covered with the lower finishing layer, for example a polymer plate or film making it possible to protect the thermally insulating layer from impacts during handling of the tile and, if applicable, moisture.

In one embodiment not shown, the photovoltaic layer is a layer of photovoltaic nanoparticles of the type used in inks and films known under the name "Nanosolar" indicated above.

The method for manufacturing such a tile **10** according to the invention will now be explained in detail.

First, the photovoltaic layer **40** in the form of a film, connected to the electrical conductors **54**, is pressed on the bottom of a mold cavity and the conductors **54** are positioned in the mold and maintained by guides such as lugs or inserts secured to the cavity and for example secured to electrical connectors **52** present at the free end of the conductors **54**.

After closing the mold, which maintains said conductors **54** and connectors **52**, the polymer material and its filler are injected into the mold to form the body **12** and bury the conductors **54** therein. The tile is then removed from the mould and is ready to use, without subsequent curing at a temperature above the melting temperature of the integrated connectors and conductors. In fact, the molding must make it possible for the material of the body **12** to be injected at a temperature at which the conductors and the connectors are not deteriorated.

In one alternative method, the material is not injection molded, but form molded using cold or hot compression, without changing the steps described above.

Advantageously, the polymerization of such a polymer material is done directly during molding and/or forming, upon cooling of the material to be stripped from the mould, without curing, as is the case for a traditional terracotta tile. Its material is adapted to polymerization upon cooling after molding or cold forming.

In one alternative method, the photovoltaic layer **40** in the form of a film is not present in the mold during molding, but is connected to the connectors **40** after the removal of the body from the mould, during its adhesion to the body provided with its conductors. Connecting members, for example such as thimbles, are provided at the interface of the conductors and the photovoltaic layer **40**.

In one alternative method, if the tile is provided with a protective mineral layer, the latter is for example applied around the photovoltaic layer. Alternatively, the protective mineral layer is applied on the body before adhering the photovoltaic layer on the body of the tile, overlapping the protective mineral layer if necessary.

In alternative methods, when the tile **10** has a thermally insulating layer, the latter is injected by over molding on the body or adhered on the body, the lower finishing layer then if applicable also being fastened by over molding or adhesion.

In one alternative method, nozzles are created in the body during molding, for example by providing drawers in the mold, and the conductors are inserted into the nozzles after the removal of the body from the mould and before connection to the photovoltaic layer. These channels can then be closed or remain open.

FIGS. **18** to **21** show one alternative embodiment of the tile **10** whereof the body **12** includes an upper half-shell **120**A and a lower half-shell **120**B defining an inner space. The half-shells are nested by their lateral walls, the lateral walls of the upper half-shell **120**A overlapping the lateral walls of the lower half-shell **120**B.

In this embodiment, in FIG. **19** and FIG. **18**, taking into consideration the tile **10** shown on the left, one can see that the bottom edge **22** has a lateral blocking slot **27** with two parallel recesses **127**A and **127**B separated by a rectilinear rib **1270**. The recess **127**B, closest to the lateral blocking rib **24**, receives a flat sealing device **127**D.

In this embodiment, each lug **57** and each housing **58** define a volume delimited by the oblong contoured walls and containing two coaxial connectors **52** provided with cylindrical elements.

The rubber weather strip **58**B, at the opening of the housing **58**, has an oblong contour protruding from the lateral blocking rib **26** of the bottom edge **22**. Inside the housing **58**, the upper half-shell **120**A defines two pillars **158**D each receiving a bush **158**A inside which a pin **58**A of the connector **52** extends. One of the bushes **158**A is shown disassembled from its tile in FIG. **19** and, in FIG. **20**, ready to be connected.

Each lug **57** here includes a well **57**A that contains a connecting bush **157**A in which the corresponding pin **58**A is housed. Each lug **57**, upon mechanical and electrical connection of the adjacent tiles, has the walls thereof defining its well **57**A cooperating by engagement with the wall defining the corresponding housing **58**. In this way, the weather strip **58**B of that wall engages in the corresponding sealing gutter **57**B. One of the bushes **157**A is shown ready to be connected in FIG. **20**. The bushes **157**A are shown assembled to their tile, mounted in its lug **57**, in FIG. **19**.

Each connector **52** includes quarter-circle pads **152** that are connected to the conductors extending between the half-shells **120**A and **120**B shown.

The top edge **20** includes, aside from its lugs **57**, a rectilinear slot **124** formed in its lateral blocking rib **24** to be opposite the rectilinear rib **127**C situated between the corresponding parallel recesses **127**A and **127**B. Part of this lateral blocking rib **24** bears on the flat seal **127**D.

In this embodiment, the inner space between the half-shells **120**A and **120**B is for example filled with polyurethane foam **159**, after assembly of the connectors. In this way, the foam for filling the inner space prevents condensation in the body of the tile and participates in the latter's thermal insulation properties.

To manufacture the tile, the method comprises injection or compression molding of the half-shells **120**A and **120**B, these shells for example having a base of ceramic or wood filled polymer as in the preceding embodiments. Next, the connectors are assembled to their half-shell, for example by crimping or screwing. The conductors are then connected to the connectors and photovoltaic layer. The half-shells **120**A and **120**B, electrically equipped and not attached, are then placed in a mold for injection of the polyurethane foam, then closing of the tile by bringing said half-shells together. The flat seal **127**D is then adhered in its slot.

In the alternative embodiment diagrammatically illustrated in FIG. **21**, an inner thermally insulating layer **160** is positioned between the half-shells **120**A and **120**B. This layer **160** is for example kept parallel to the bottom of the lower half-shell **120**B using slugs **162** molded with said half-shell, so as to leave a space between the half-shell and the inner thermally insulating layer space for filling the tile with the polyurethane foam **159**.

The thermally insulating layer, allowing the passage of the conductors and/or their maintenance, is for example a vacuum encapsulated insulator, typically of fibers, or a honeycomb. Its material is chosen to have a thermal insulating power several times greater than that of the polyurethane foam.

A junction box **164** is present in the upper half-shell **120**A, embedded in an opening thereof. The junction box makes it possible to recover the energy from the photovoltaic layer **40** to connect the latter to the connectors **52** via the conductors **54**.

For this alternative, before the injection of the polyurethane foam filler, the thermally insulating layer **160** is placed in the lower half-shell **120**B and the junction box **164** is placed in the upper half-shell **120**A.

In one alternative not shown of the embodiment diagrammatically illustrated in FIG. **21**, a plurality of inner thermally insulating layers are positioned parallel to one another and secured to one another.

In one alternative not shown, a thermally insulating layer inside the body of the tile is provided in a solid tile as shown for example in FIG. **2**. In that case, the tile body is molded around the thermally insulating layer, which can serve as a substrate for the electrical conductors and/or the connectors.

In one alternative embodiment diagrammatically illustrated in FIG. **22**, an electronic unit **170** is mounted between the inner thermally insulating layer **160** and the bottom of the lower half-shell **120**B. This electronic unit **170** is a direct current to alternating current converter, making the tile **10** electrically autonomous for its connection to the other tiles and/or to the electrical circuit of the building.

This electronic unit **170** is in the shape of a relatively flat rectangular rhomb. It is kept parallel to the bottom of the lower half-shell **120**B by slugs **172** molded with said half-shell, so as to leave a space between the half-shell and the inner thermally insulating layer for filling the tile with the polyurethane foam **159**.

For its electrical function, the unit **170** has, as input, two connectors for connection by conductor to the photovoltaic layer **40** via the junction box **164**, and as output, two connectors for the connection via the conductors to the connectors formed in the assembly elements of the tile. The expression "direct current to alternating current converter" also refers to an inverter making it possible to monitor and smooth the electrical energy coming out of the tile.

The invention claimed is:

1. A photovoltaic tile for a roof comprising a plurality of said tiles, at least two adjacent tiles of which at least partially overlap each other, said photovoltaic tile including

a body having overlapping edges constituting a top edge and a bottom edge, the top edge being formed so as to cover the bottom edge of at least one of the adjacent tiles,

a photovoltaic layer placed on a free part of an upper surface of the body outside the bottom edge,

respective male and female electrical connectors which are connected to the photovoltaic layer by electrical conductors in order to electrically connect one to another the photovoltaic layers of at least two adjacent tiles of the roof,

respective assembly elements provided on the respective overlapping edges so as to enable said overlapping edges to be mutually positioned during the placement of the

two adjacent tiles by nesting of said adjacent assembly elements of the two adjacent tiles,

wherein the assembly elements of the tile comprise:

respective blocking assembly elements provided on the respective overlapping edges, said blocking assembly elements comprising at least one shoulder forming a recess in one of the top edge and the bottom edge so as to enable said shoulder to be positioned against the other of the top edge and the bottom edge,

respective centering assembly elements provided on the respective blocking assembly elements, said centering assembly elements comprising (i) at least one lug that protrudes from one of the top edge and the bottom edge, and (ii) at least one housing recessed in the other of the top edge and the bottom edge,

so as to enable adjacent tiles to be centered relative to one another during the placement of two adjacent tiles by nesting of adjacent assembly elements of the two adjacent tiles,

wherein each of the male and female electrical connectors is provided in a respective entirely recessed position in a respective one of the lug and the housing of the tile, so that, through the nesting of the adjacent assembly elements of the two adjacent tiles, the electrical connectors contained in the adjacent assembly elements of the two adjacent tiles simultaneously come into electrical contact with each other.

2. The tile according to claim **1**, wherein the conductors are embedded inside the molded body of the tile in their travel between the photovoltaic layer and their electrical connector.

3. The tile according to claim **1**, wherein the lug forms a plug protruding from its overlapping edge and the housing forms a tap formed recessed from its overlapping edge, and the male and female electrical connectors in the assembly elements assemble by fitting.

4. The tile according to claim **3**, wherein the lug and the housing are substantially perpendicular to the median plane of the tile, that plane being provided to be parallel to the plane of a roof surface receiving the tile.

5. The tile according to claim **1**, wherein the photovoltaic layer is in direct contact with the environment.

6. The tile according to claim **1**, wherein the photovoltaic layer is a film adhered to the body of the tile using a flexible adhesive making it possible to absorb the differential expansions between the body and the film.

7. The tile according to claim **6**, wherein the film making up the photovoltaic layer is housed in a cavity recessed from the upper surface of the body at the free part thereof, the depth of the cavity being such that the upper surface of the film is flush with a peripheral part of the free edge of the upper surface of the body.

8. The tile according to claim **6**, wherein the area of the upper surface of the body covered by the photovoltaic film is at least partially hollowed with cooling channels allowing a local passage of air between the body and the photovoltaic film.

9. The tile according to claim **8**, wherein the cooling channels are grooves and the body defines air discharge conduits emerging on the one hand in one of the grooves and on the other hand at the lower surface of the tile.

10. The tile according to claim **1**, wherein the photovoltaic layer is a layer of photovoltaic nanoparticles.

11. The tile according to claim **1**, wherein the body of the tile is made from a polymer-based material.

12. The tile according to claim **11**, characterized in that the polymer-based material comprises a ceramic filler.

13. The tile according to claim **1**, wherein the body of the tile is made from a wood-based material.

14. The tile according to claim **1**, wherein the body has a base of a material adapted to polymerize upon cooling after molding or during press forming.

15. The tile according to claim **11**, wherein the upper surface of the body of the tile is covered with a protective mineral layer, in particular protecting it from ultraviolet rays.

16. The tile according to claim **1**, wherein the tile includes a thermally insulating layer on the lower surface of the body.

17. The tile according to claim **16**, wherein the thermally insulating layer is covered with a lower finishing layer.

18. The tile according to claim **1**, wherein the body includes an upper half-shell and a lower half-shell defining an inner space.

19. The tile according to claim **18**, wherein the inner space between the upper half-shell and the lower half-shell is filled with a foam.

20. The tile according to claim **1**, wherein the body thereof contains at least one inner thermally insulating layer.

21. The tile according to claim **1**, wherein the body contains an electronic unit for converting direct current into alternating current.

22. A method for manufacturing a photovoltaic tile according to claim **2**, the method including:

positioning conductors in a mold, wherein at least one end of the conductors is provided with an electrical connector, and

molding the body of the tile in the mold containing the conductors.

23. The method according to claim **22**, including positioning a photovoltaic layer in the mold before molding the body.

24. The method according to claim **22**, including positioning a photovoltaic layer on the upper surface of the body after the molding and after removing the body from the mold.

25. A method for covering a frame with photovoltaic tiles according to claim **1**, the method including:

after placing at least a first of said tiles on a frame face, bringing a second tile closer so as to position its top edge opposite the bottom edge of the first tile, and

placing the second tile adjacent to the first tile by bringing it substantially perpendicular to the plane of said frame face with (i) the top edge of the second tile overlapping the bottom edge of the first tile, and (ii) nesting of the assembly elements substantially perpendicular to said frame face by nesting to mechanically maintain said tiles and connect them electrically.

26. A covering assembly for a roof, comprising a plurality of photovoltaic tiles according to claim **1**, the top edge of one of the tiles overlapping the bottom edge of at least one of the adjacent tiles while having their electrical connectors electrically connected.

27. A tile according to claim **1**, wherein the blocking assembly elements of the tile comprise (i) a lateral blocking rib that protrudes from one of the top edge and the bottom edge, and (ii) a lateral blocking slot recessed in the other of the top edge and the bottom edge.

28. A tile according to claim **27**, wherein the male connectors are recessed in the housing and the female connectors are recessed in the lug.

29. The tile according to claim **27**, wherein the lug forms a plug protruding from its overlapping edge and the housing forms a tap formed withdrawn from its overlapping edge, and the male and female connection elements in the assembly elements assemble by fitting.

30. A tile according to claim **1**, wherein the lug is located in the recess.

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