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(54) **FLAT ROOF TILE WITH INTEGRATED PHOTOVOLTAIC MODULE**

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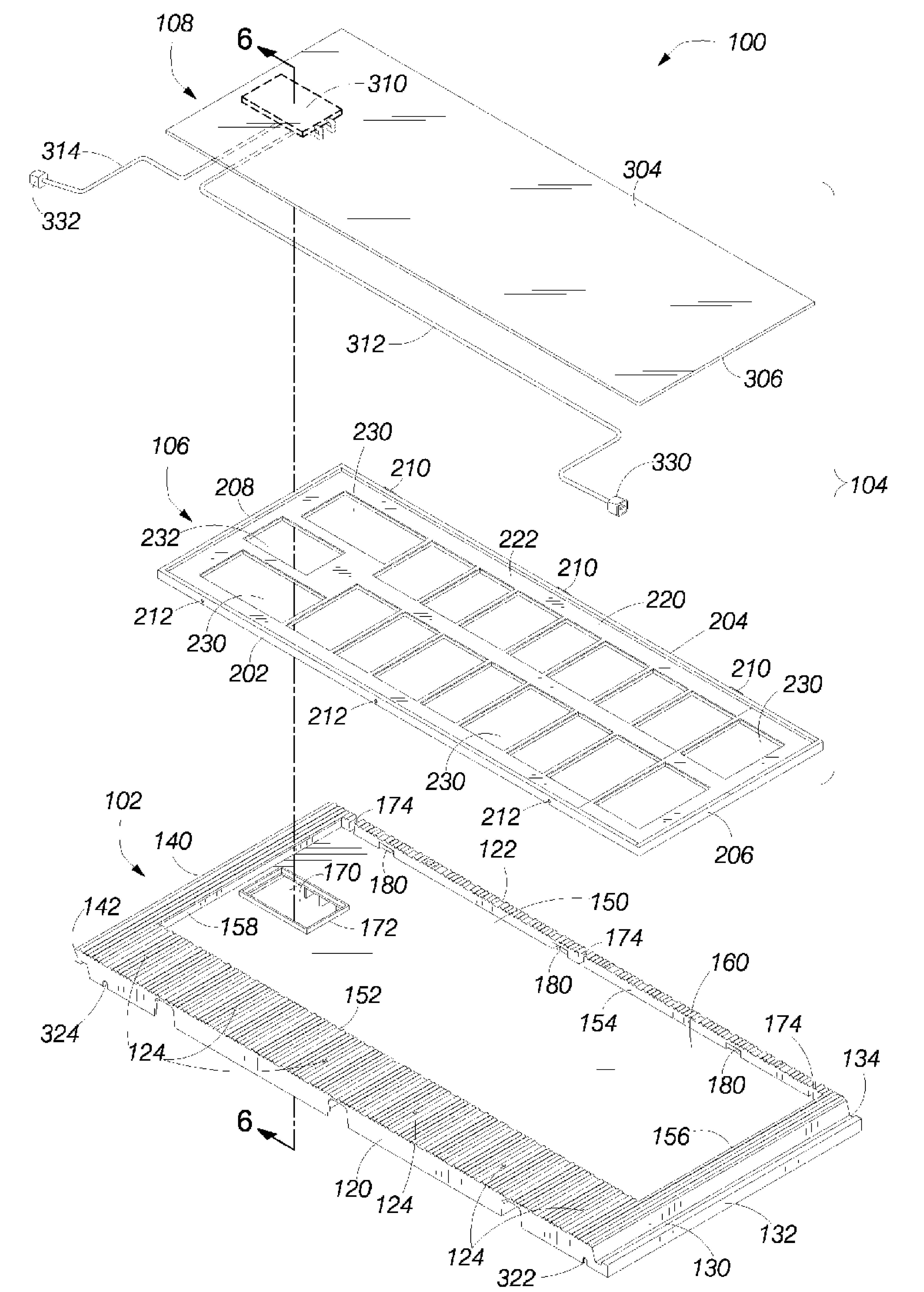
(52) **U.S. Cl.** **52/173.3**

(57) **ABSTRACT**

A roofing module provides weather protection generates electrical power. The module includes an injection molded base having a size, a shape and an appearance of a conventional flat concrete roofing tile with a top surface having a slate-like striated texture. The base is made from lightweight plastic material. The base includes a depressed portion in an upper surface. A photovoltaic panel assembly is positioned in the depressed portion with electrical conductors from the photovoltaic panel passing through an opening in the depressed portion.



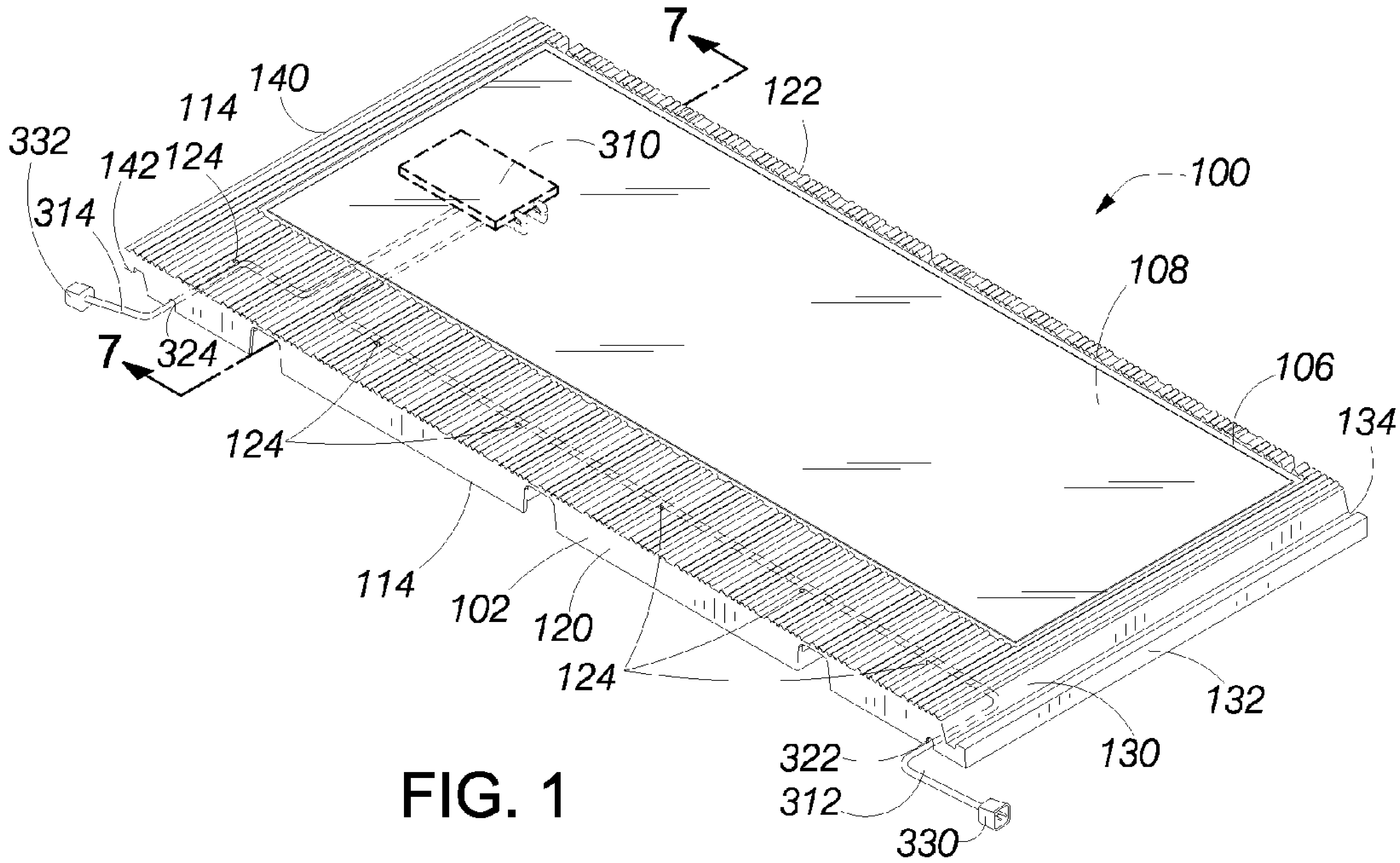

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FIG. 1

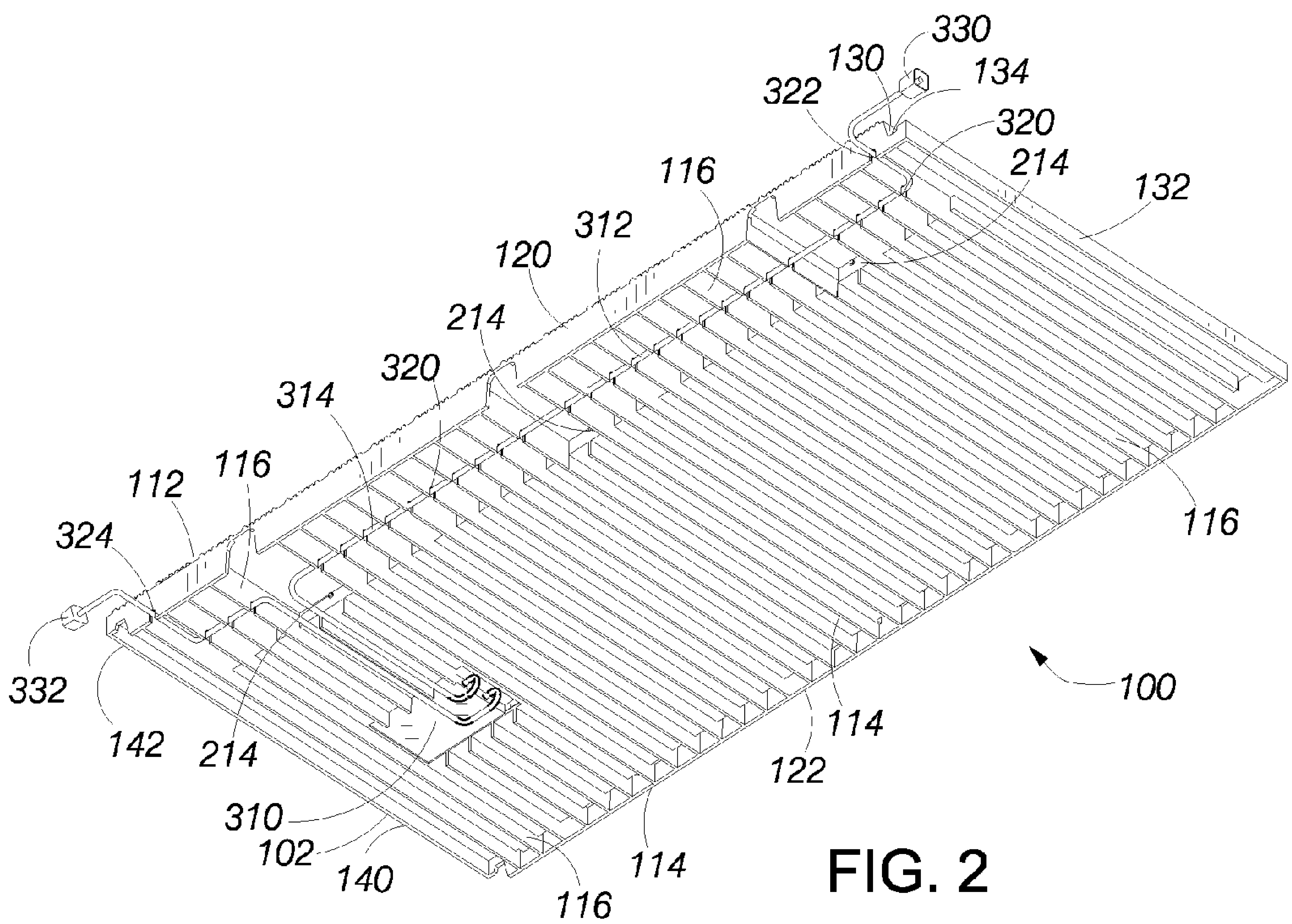
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FIG. 2

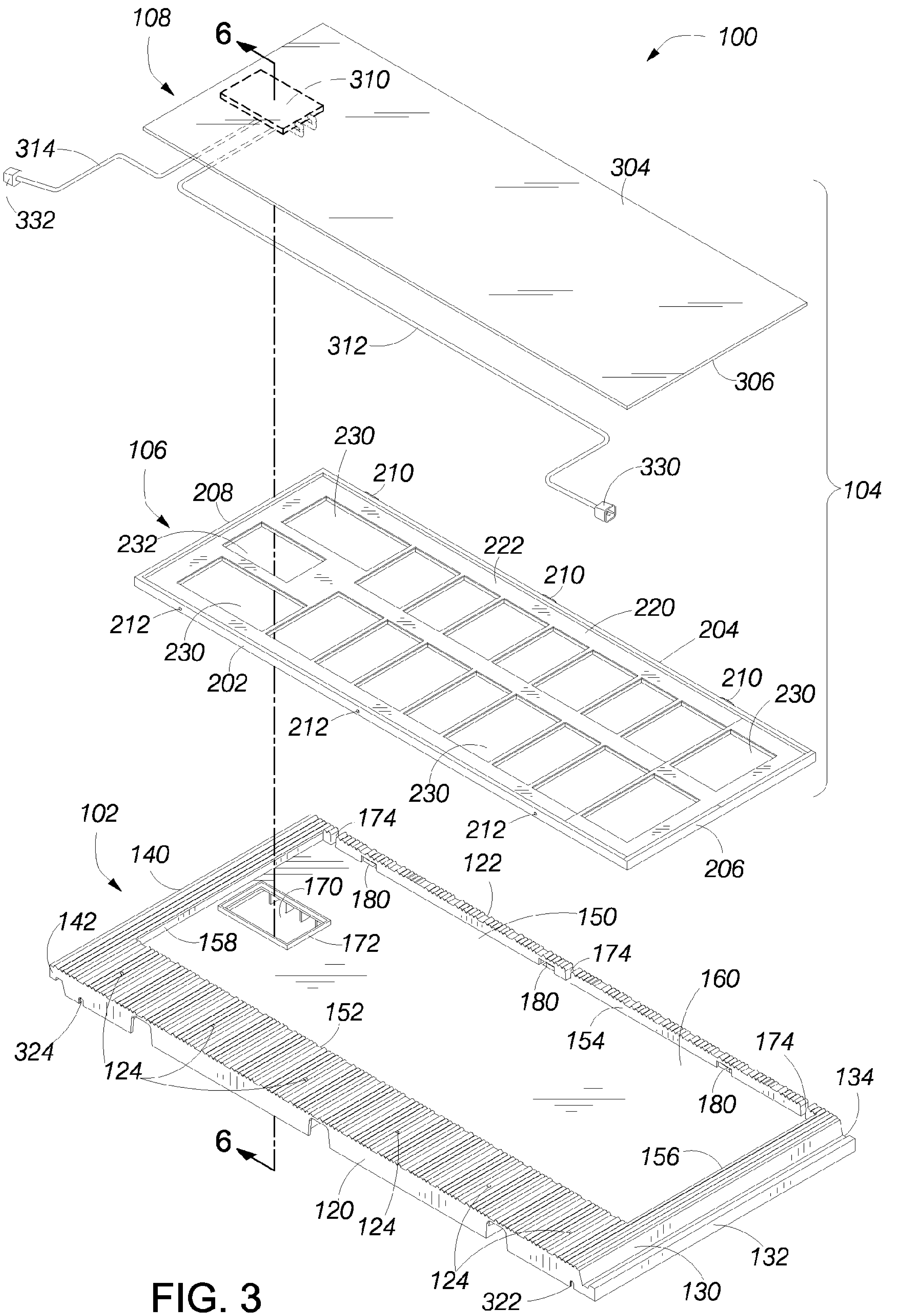
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FIG. 3

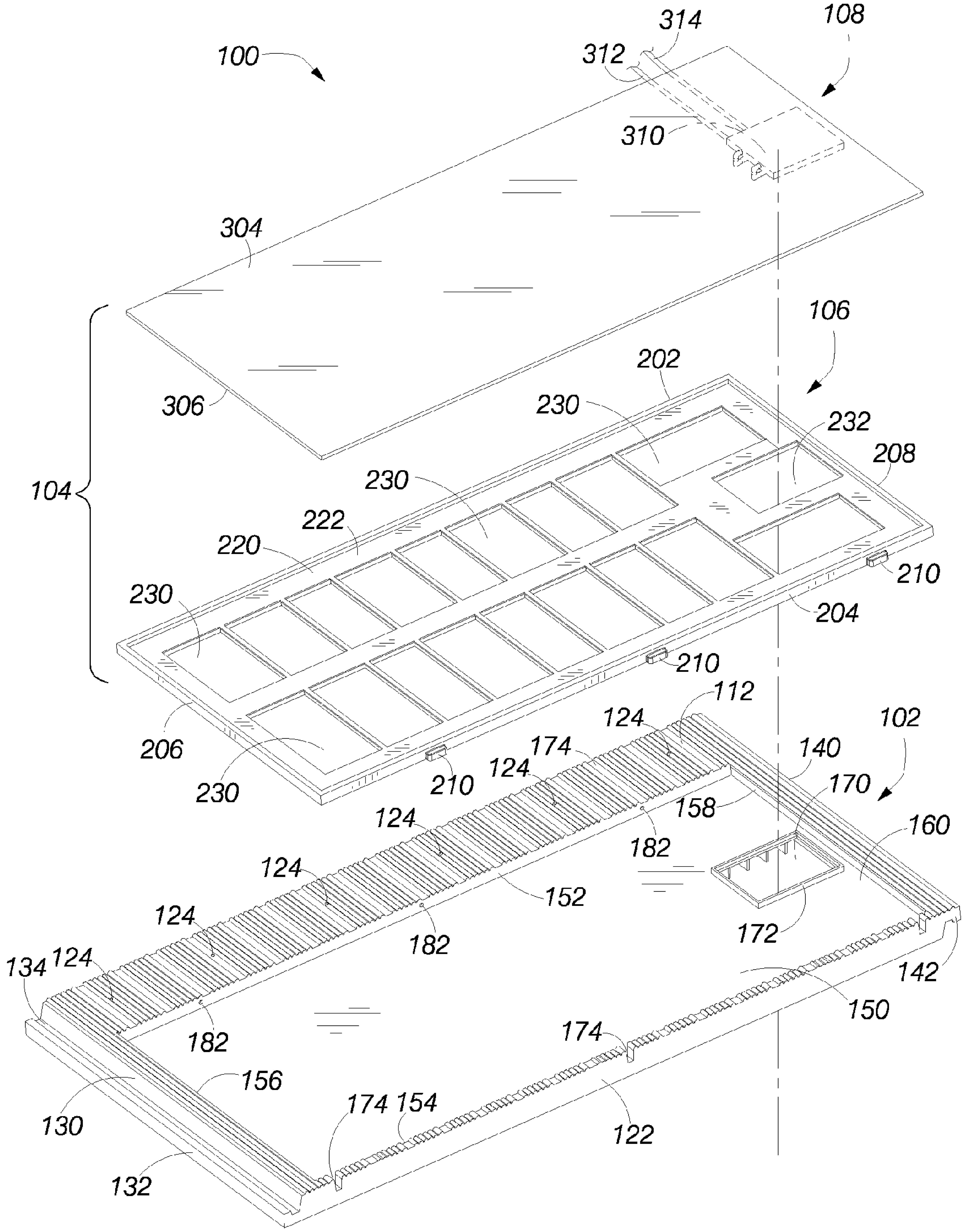
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FIG. 4

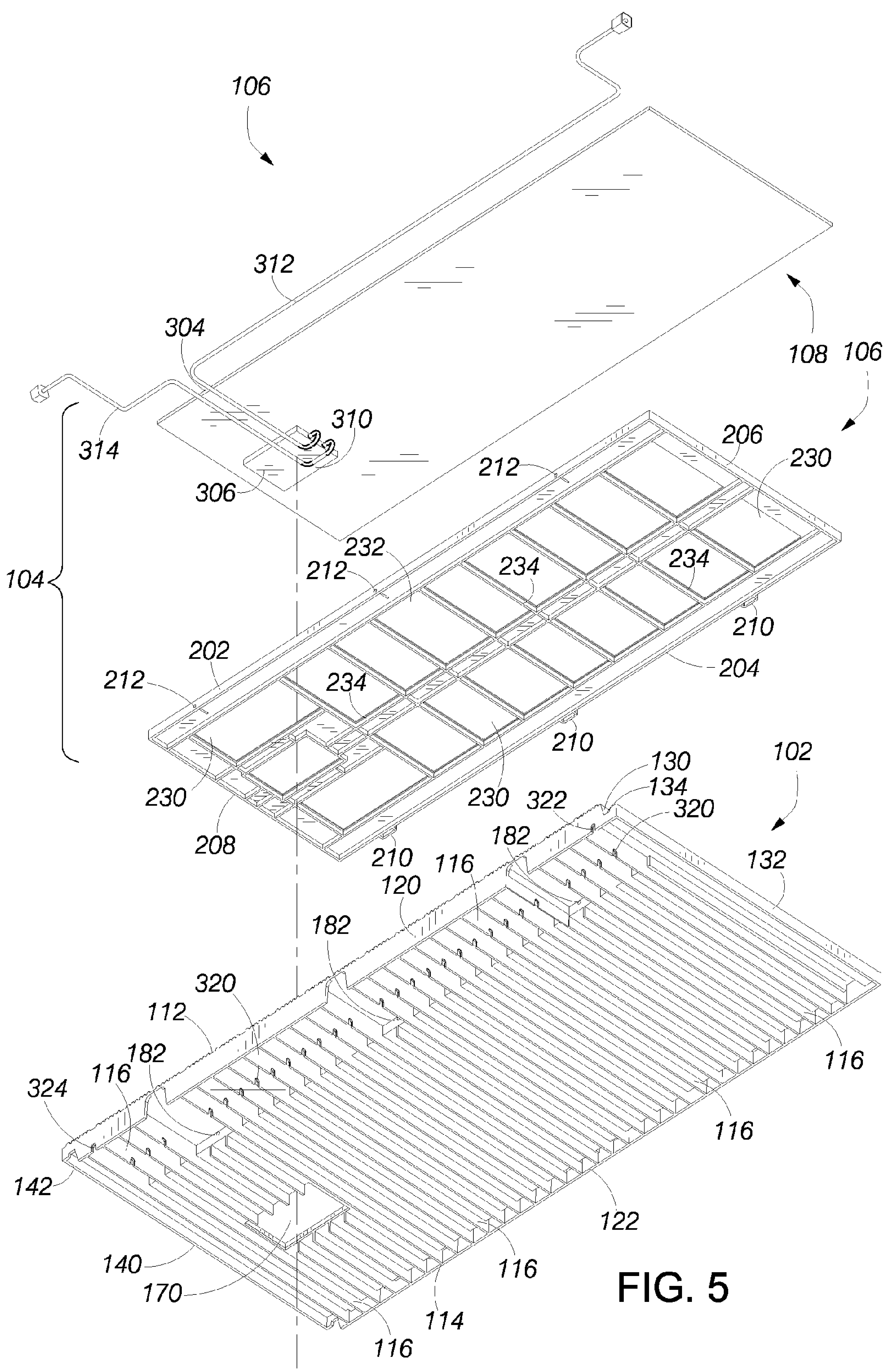
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FIG. 5

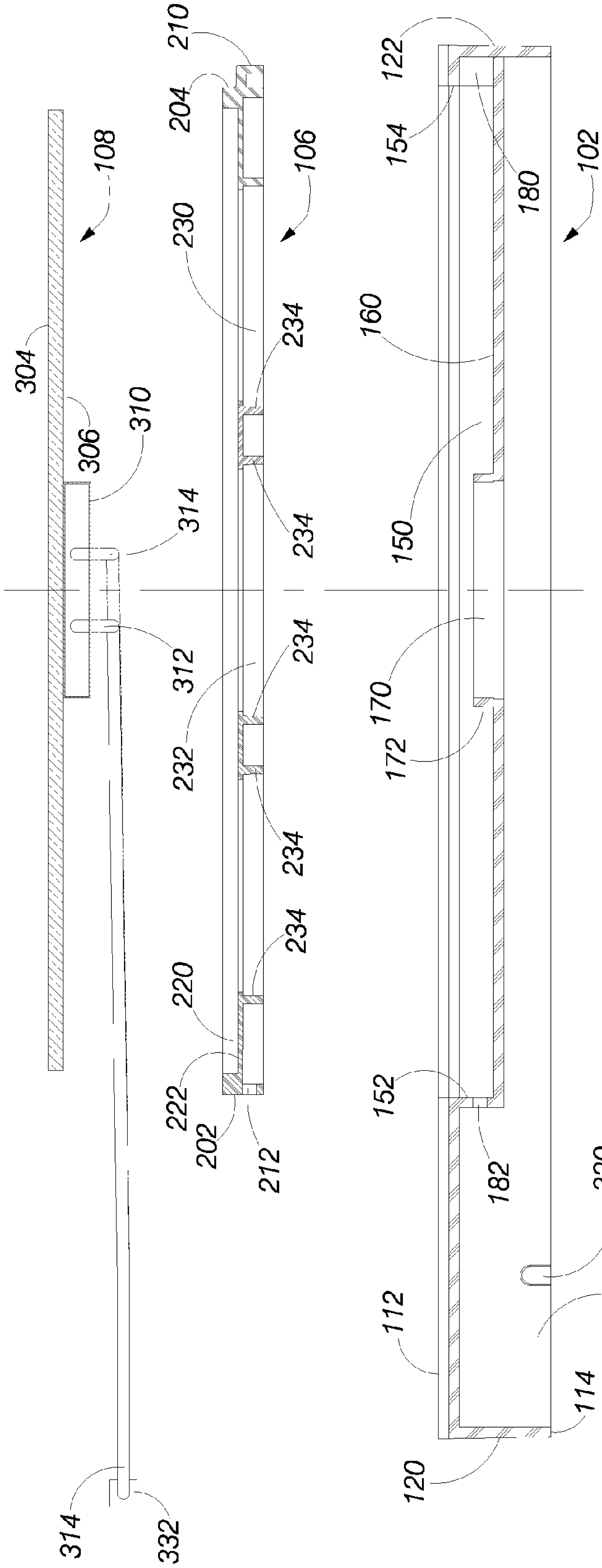
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FIG. 6

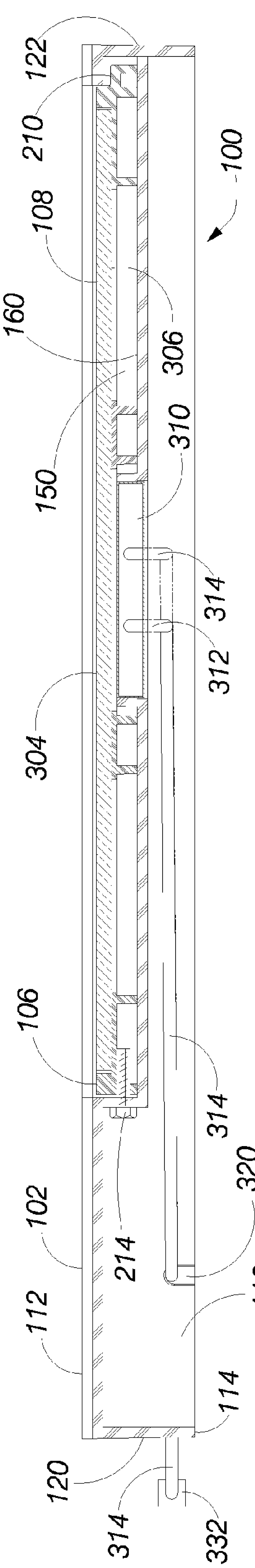
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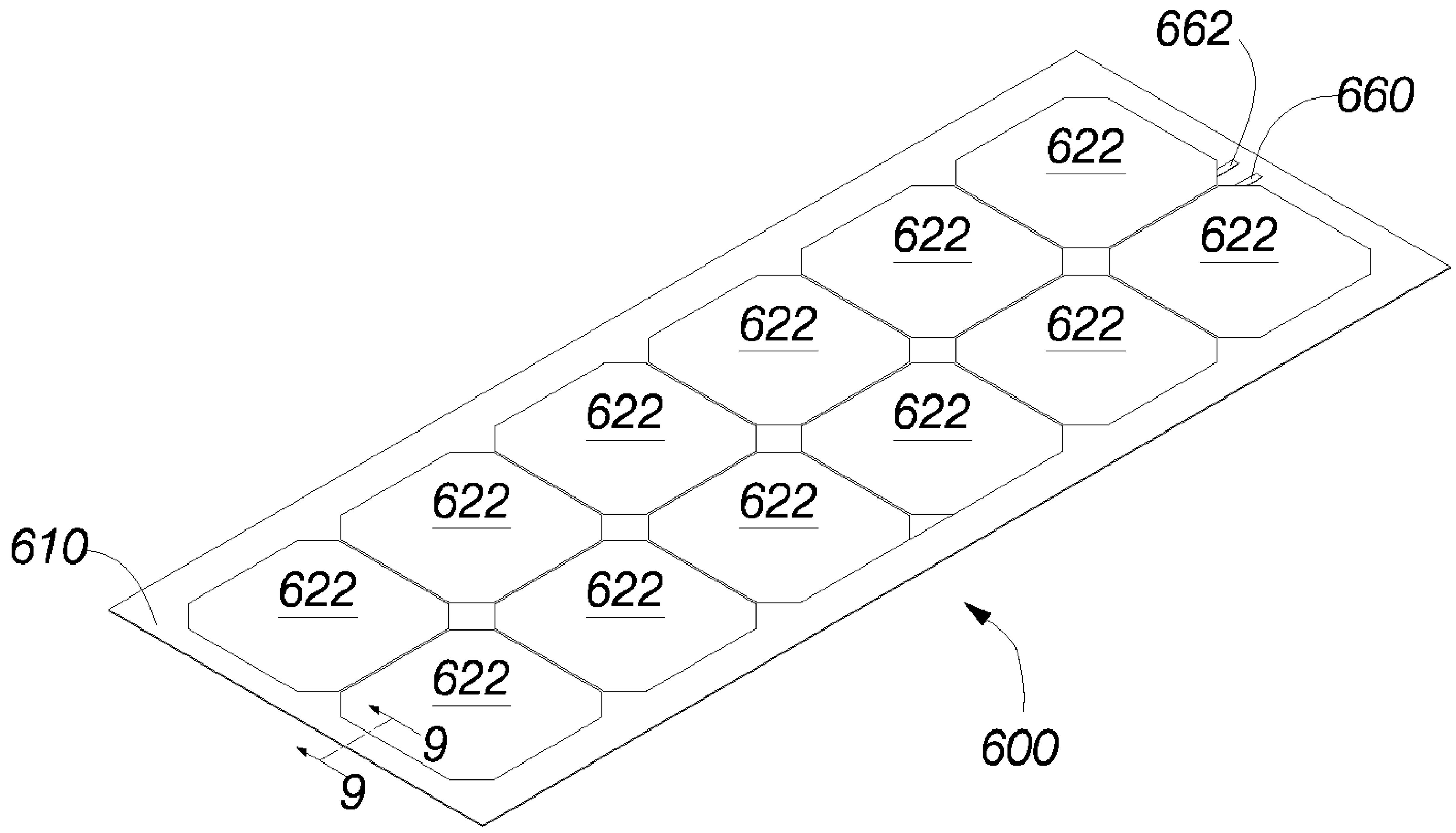
FIG. 7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9
9
600

FIG. 8

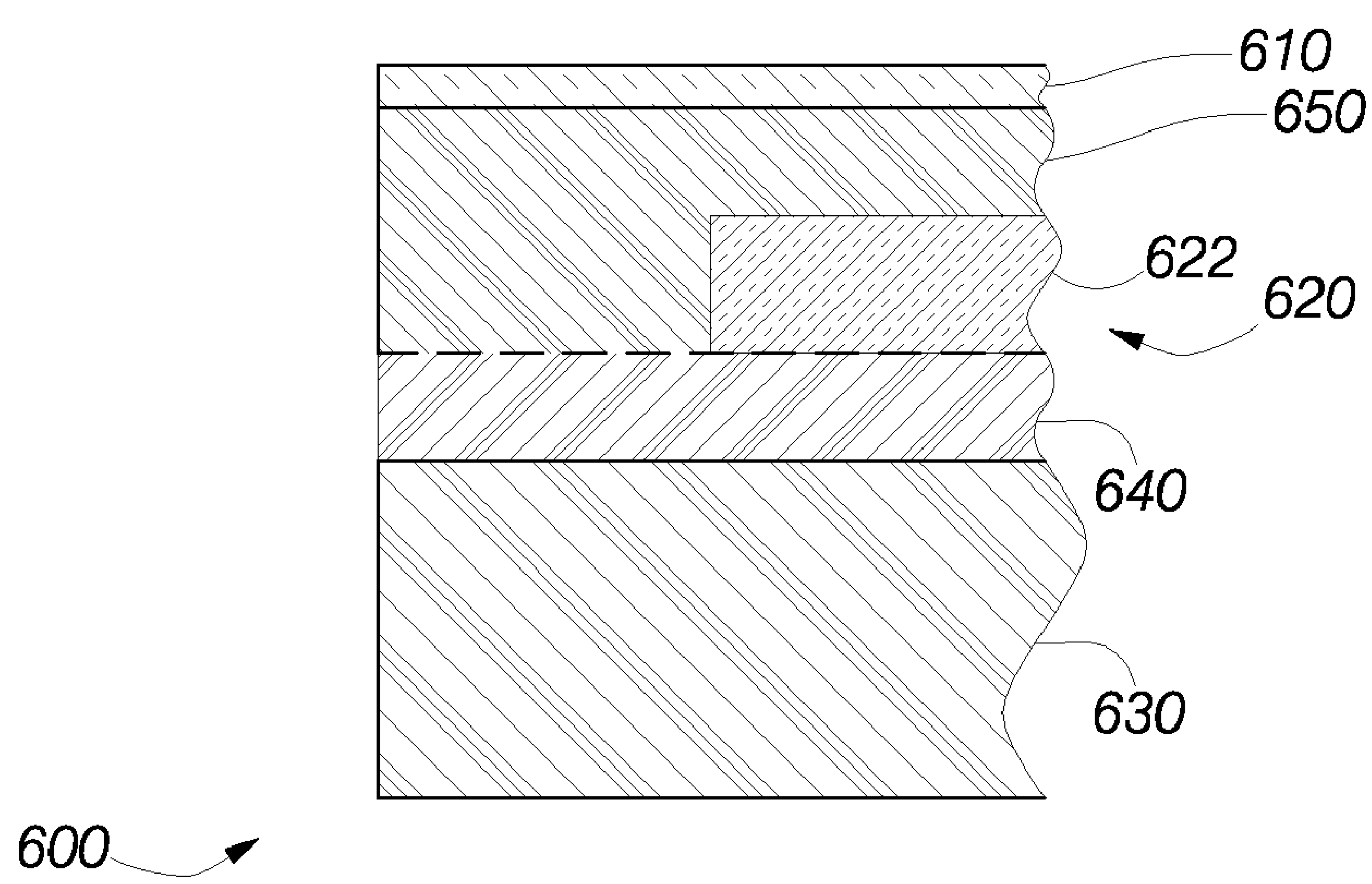
610
650
622
620
640
630
600

FIG. 9

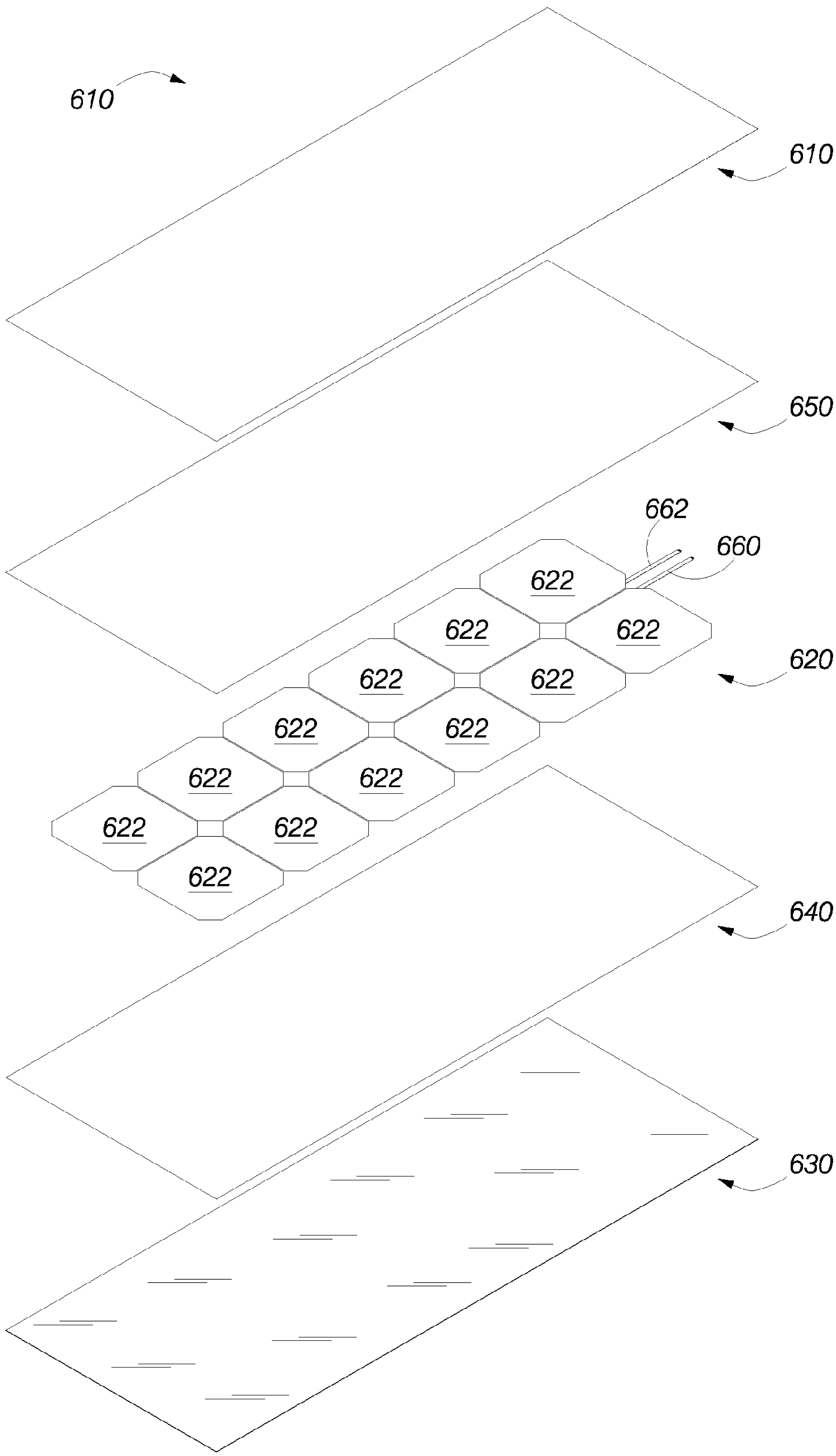

FIG. 10

FLAT ROOF TILE WITH INTEGRATED PHOTOVOLTAIC MODULE

RELATED APPLICATIONS

[0001] The present application claims the benefit of priority under 35 U.S.C. §119(e) to U.S. Provisional Application No. 60/940,408, filed on May 26, 2007.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to solar panels for generating electrical energy and more particularly relates to solar modules integrated into a flat roof tile.

[0004] 2. Description of the Related Art

[0005] Conventional solar panels for generating electrical power for residences are flat and are placed on a portion of the roof that faces the sun during midday. Originally, the solar panels were mounted over existing roofing materials (e.g., shingles) and formed a generally unaesthetic addition to a home. In some areas, the solar panels were not permitted because of the unattractive appearance. Recently developed solar panels are constructed in sizes and shapes that can be mounted directly to the underlying roof structure as replacements for flat roofing materials (e.g., flat concrete tiles) such that the solar panels provide the dual purpose of generating electrical power in response to sunlight and of providing protection from moisture intrusion while integrating in an aesthetically pleasing way with the roof system.

SUMMARY OF THE INVENTION

[0006] The roofing tile with integrated modular solar panel described herein and illustrated in the attached drawings enables the electricity-generating solar panel to be included in a seamless application with a conventional roofing tile because the solar panel is advantageously embodied in a shape and size of a conventional flat tile. As discussed herein, the size and shape of the solar panel tile may be adapted to the size and shape of tiles from a number of different manufacturers. The size and shape of the solar panel tile enables the same roofing mechanic who installs the conventional roofing tiles to install the solar panel tile without any special tools or fasteners. In particular, the solar panel tiles interlock with or overlap with adjacent conventional tiles when installed in the same course. The adjacent tiles may be solar panel tiles or conventional roofing tiles. The solar panel tiles have aesthetic features that match the aesthetic features of the conventional tiles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Certain aspects in accordance with embodiments of the present invention are described below in connection with the accompanying drawing figures in which:

[0008] FIG. **1** illustrates a top perspective view of a first embodiment of a solar panel tile;

[0009] FIG. **2** illustrates a bottom perspective view of the solar panel tile of FIG. **1**;

[0010] FIG. **3** illustrates an exploded perspective view of the solar panel tile of FIG. **1** looking at the top in the direction of FIG. **1** showing the base tile, the panel frame and the solar panel;

[0011] FIG. **4** illustrates an exploded perspective view of the solar panel tile of FIG. **1** similar to the view of FIG. **3** but with the solar panel tile rotated to show the lower edge;

[0012] FIG. **5** illustrates an exploded perspective view of the solar panel tile of FIG. **1** looking at the bottom in the direction of FIG. **2**;

[0013] FIG. **6** illustrates a cross-sectional elevation view of the solar panel taken along the line **6-6** in the exploded view of FIG. **3**;

[0014] FIG. **7** illustrates a cross-sectional elevation view taken along the lines **7-7** in FIG. **1**;

[0015] FIG. **8** illustrates a perspective view of an embodiment of a photovoltaic panel advantageously incorporated into the solar panel tile of FIGS. **1-7**;

[0016] FIG. **9** illustrates an enlarged cross-sectional view of the photovoltaic panel of FIG. **8** taken along the lines **9-9** in FIG. **8**; and

[0017] FIG. **10** illustrates an exploded perspective view of the photovoltaic panel of FIG. **8**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] FIGS. **1-7** illustrate an embodiment of a flat solar panel tile **100** suitable for mass production using injection molding techniques. The solar panel tile **100** comprises a tile base **102** and a solar panel assembly **104**. The solar panel assembly comprises a solar panel support frame **106** and a photovoltaic panel (solar cell array) **108**.

[0019] The tile base **102** is sized and shaped to conform to the size and shape of a conventional flat concrete tile configured to simulate the aesthetic appearance of a slate tile. In particular, the tile base has a plurality of striations (e.g., closely spaced grooves and ridges) formed on an exposed top surface **112** that are similar to the grooves on a concrete tile so that the top surface provides a “slate-like” appearance when viewed from a distance. An opposing bottom surface **114** (FIG. **2**) of the tile base is formed as a plurality of strengthening ribs **116**. Preferably, the tile base comprises injected molded plastic.

[0020] In the following description, “top” and “bottom” are used to designate the two opposing surfaces **112**, **114** with respect to the “thickness” of the solar panel tile **100**; “upper” and “lower” and “height” refer to the aspects of the tile with respect to a vertical direction along the slope of a roof (not shown) when a solar panel tile is oriented in a typical roof installation; and “left” and “right” and “width” refer to aspects of the tile with respect to a horizontal direction across the roof.

[0021] The top surface **112** of the tile base **102** has a horizontal width of approximately 34.6 inches and has a height of approximately 17 inches. In the illustrated embodiment, the tile base has an overall thickness from the top surface to the bottom surface **114** of approximately 1.25 inches. In general, the plastic is molded to have a structural thickness of approximately 0.125 inches in most locations; however, the plastic may be thicker in some portions of the structure and thinner in other portions of the structure in accordance with the mold characteristics.

[0022] The solar panel tile **100** is positioned in FIG. **1** with an upper edge **120** of the tile base **102** located toward the lower left in the drawing and with a lower edge **122** located toward the upper right in the drawing. The tile base is configured to be positioned on a roof in a horizontal rank with the upper edge of the tile base positioned beneath a lower edge of a tile in a next higher rank such that the tiles in higher ranks overlap tiles in the next lower rank in a conventional manner. The top surface of the tile base includes a plurality of holes

124 (e.g., 6 holes) formed approximately 1.8 inches from upper edge and extending through the thickness of the tile base. Each hole has a diameter of approximately 0.078 inch. When the solar panel tile is installed on a roof, a fastener may be driven through the holes to secure the tile to the roof. The holes are covered by an overlapping portion of a tile in a higher rank on the roof.

[0023] The top surface **112** of the tile base **102** has a left edge **130** shown at the lower right for the orientation of the tile base in FIG. **1**. The tile base includes a lower interlocking tab **132** that extends outwardly from the left edge by approximately 1 inch. An interlocking groove **134** is formed in the tab parallel to the left edge.

[0024] The top surface **112** of the tile base **102** has a right edge **140** shown at the upper left in the orientation of the tile base in FIG. **1**. An interlocking tongue **142** extends downwardly below the top surface proximate to the right edge. The tongue is sized and positioned so that the tongue engages the interlocking groove **134** when the right edge of the tile base is placed adjacent to the left edge of a tile in the same horizontal rank. Thus, two horizontally adjacent tiles are interlocked. In addition, any water draining into the space between the left and right edges of adjacent tiles is drained by the groove to the top surface of a tile in the next lower rank.

[0025] As shown in FIGS. **3** and **4**, the top surface **112** of the tile base **102** has a recessed portion **150**. The recessed portion has a generally rectangular shape having a width from left to right of approximately 32.3 inches. The recessed portion has a height in the direction from the upper edge of the tile base toward the lower edge of the base tile of approximately 12.4 inches. The boundaries of the recessed portion are defined by four perimeter walls. An upper boundary wall **152** is offset from the upper edge **120** of the tile base by approximately 4.2 inches. A lower boundary wall **154** is offset from the lower edge **122** of the tile base by approximately 0.5 inch. A left boundary wall **156** is offset from the left edge **130** of the base tile by approximately 1 inch. A right boundary wall **158** is offset from the right edge **140** of the tile base by approximately 1.3 inches. The recessed portion has bottom surface **160** at a depth from the top surface of approximately 0.55 inch.

[0026] As further shown in FIGS. **2**, **3** and **4**, the recessed portion **150** includes a generally rectangular cutout **170**. The cutout passes through the tile base **102** from the bottom surface **160** of the recessed portion to the bottom surface **114** of the tile base. The ribs **116** of on the bottom surface of the tile base are removed in the area encompassed by the cutout. In the illustrated embodiment, the cutout has a width in the direction from the left boundary towards the right boundary of approximately 4-4.25 inches, and has a length in the direction from the upper boundary of the recess to the lower boundary of the recess of approximately 2.5-2.75 inches. The cutout is offset from the right boundary wall **158** of the recess by approximately 0.5-0.75 inch. The cutout is positioned approximately midway between the upper boundary wall **152** and the lower boundary wall **154**. The cutout may also be located elsewhere in the recess in accordance with the positioning of electrical connectors (discussed below) on the photovoltaic panel **108**.

[0027] As further illustrated in FIGS. **3** and **4**, the cutout **170** is surrounded by a perimeter ridge **172** that has a thickness of approximately 0.1 inch and that is raised above the bottom surface **160** of the recessed portion **150** by approximately 0.25 inch. Any water that may collect on the bottom surface of the recessed portion is blocked from flowing into the cutout by the perimeter ridge. The lower boundary wall **154** of the recessed portion includes a plurality (e.g., 3) of slots **174** that pass through the upper surface **112** of the tile base **102** to permit any such water to drain onto the top surface of a tile in the next lower rank of tiles or to drain from the roof if the tile is in the lowest rank.

[0028] As shown in FIG. **3**, the lower boundary wall **154** of the recessed portion **150** further includes a plurality of rectangular openings **180** (e.g., 3 openings) having widths of approximately 1 inch and having heights of approximately 0.375 inch. As shown in FIG. **4**, the upper boundary **152** includes a plurality (e.g., 3) of generally circular openings **182** having diameters of approximately 0.156 inch.

[0029] The recessed portion **150** of the tile base **102** is sized and shaped to receive the solar panel support frame **106**. The support frame comprises an injection molded plastic material with an upper outer wall **202**, a lower outer wall **204**, a left outer wall **206** and a right outer wall **208** that conform to the upper boundary wall **152**, the lower boundary wall **154**, the left boundary wall **156** and the right boundary wall **158** of the recessed portion. Each outer wall of the support frame has a height of approximately 0.5 inch, which is slightly less than the depth of the recessed portion so that when the support frame is positioned within the recessed portion, the top of each outer wall is generally flush with or slightly below the upper surface **112** of the tile base **102**. The rectangular outer dimensions of the support frame are slightly smaller than the rectangular dimensions of the recessed portion of the tile base so that the support frame fits easily in the recessed portion with little room for movement in any direction.

[0030] The support frame **106** includes a plurality of generally rectangular protrusions **210** (e.g., 3 protrusions) extending from the lower outer wall **204**. The protrusions are positioned to be aligned with and inserted into the rectangular openings **180** in the lower boundary wall **154** of the recessed portion **150** of the tile base **102**. The support frame further includes a plurality of circular openings **212** (e.g., 3 openings) extending partially through the upper outer wall **202** below the level of the recessed portion. When the support frame is inserted into the recessed portion of the tile base, the circular openings in the support frame are aligned with the circular openings **182** in the upper boundary wall **152** of the recessed portion. As shown in FIG. **2** and in FIG. **6**, a fastener (e.g., a screw) **214** is inserted through the aligned holes to secure the support frame to the tile base.

[0031] The support frame **106** has a recessed middle portion **220** that has a depth of approximately 0.1875 inch to a lower surface **222** of the recessed middle portion. Each outer wall of the support frame **106** has a thickness of approximately 0.25 inch. The recessed middle portion of the support frame has a vertical length in the direction from the inside of the lower outer wall **204** to the inside of the upper outer wall **202** of approximately 12.31 inches and has a horizontal width in the direction from the inside of the left outer wall **206** to the inside of the right outer wall **208** of approximately 31.7 inches.

[0032] In the illustrated embodiment, the lower surface **222** of the recessed middle portion **220** of the support frame **106** has a plurality of openings **230** (e.g., 19 openings) formed therein to reduce the mass of the support frame, which also reduces the quantity of plastic needed to manufacture the support frame. Sixteen of the openings are formed in a pattern of rectangular openings with the sides having longer lengths parallel to the left outer wall **206** and the right outer wall **208** and with sides having shorter lengths parallel to the upper outer wall **202** and the lower outer wall **204**. Although illustrated as rectangular openings, the openings may be configured in other shapes. Three of the openings proximate the right outer wall are positioned with the respective longer sides parallel to the upper outer wall and the lower outer wall. One of the three openings is designated as a connector module opening **232**. The connector module opening aligned with and has approximately the same dimensions as the outer dimensions of the perimeter ridge **172** surrounding the cutout **170** in the recessed portion **150** of the tile base **102**. The size and position of the connector module opening are also selected to match the position of the positioning of electrical connectors (discussed below) on the photovoltaic panel **108**. As illustrated in the bottom view in FIG. **5**, the rectangular openings are surrounded by a plurality of ribs **234** extending horizontally and vertically across the support frame to provide a structurally stable frame.

[0033] The recessed middle portion **220** of the support frame **106** is sized to receive the photovoltaic (solar cell array) panel **108**. The photovoltaic panel has a generally rectangular surface having a horizontal width of approximately 31.65 inches, a vertical height of approximately 11.75 inches and a thickness of approximately 0.1875 inch between an upper surface **304** and a lower surface **306**. The photovoltaic panel may have a conventional construction comprising a plurality of cells connected in a selected series-parallel combination to produce a desired output voltage when solar energy is incident on the upper surface of the photovoltaic panel. In a particularly preferred embodiment, the photovoltaic panel is constructed in the manner described in FIGS. **8**, **9** and **10**, described below. The photovoltaic panel is secured in the support frame by a suitable weather-resistant adhesive, such as, for example, silicon adhesive.

[0034] The lower surface **306** of the photovoltaic panel **108** includes an output module (junction box) **310**, which is adhered to the lower surface after the photovoltaic panel is constructed in the manner described in FIGS. **8**, **9** and **10**. In particular, first and second sturdy weather-resistant, external electrical conductors **312**, **314** are electrically connected to the relatively fragile electrical conductors (not shown) that provide the electrical output of the cells in the photovoltaic panel.

[0035] After the electrical interconnections are completed and tested, the output module (junction box) **310** is adhered to the lower surface **306** of the photovoltaic panel **108** in a conventional manner using epoxy sealant (see FIG. **6**). The output module provides electrical insulation over the electrical connections and that also provides strain relief so that handling of the external electrical conductors **312**, **314** during installation of the flat solar tile **100** does not break the electrical connections or break the fragile electrical conductors of the photovoltaic panel **108**. Preferably, the output module is formed using a mold (not shown) so that the output module has predetermined dimensions (e.g., rectangular) that fit within the cutout **170** in the tile base **102** and that pass through the opening **232** in the support frame **106**. For example, in the illustrated embodiment, the output module has a horizontal length of approximately 4.2-4.4 inches, a vertical width of approximately 2.6-2.7 inches and a thickness of approximately 0.3 inch.

[0036] When the photovoltaic panel **108** is inserted in the support frame **106** and the support panel is inserted in the tile base **102**, the output module fits within the aligned opening **232** in the support frame and the cutout **170** in the tile base. The external conductors **312**, **314** extend below the tile base. As illustrated in FIG. **5**, the tile base includes a plurality of rib notches **320** formed in selected ones of the ribs **116** proximate the upper edge **120**. The rib notches are sized to receive the external conductors. One of the external conductors (e.g., the first conductor **312**) is routed through a first set of the rib notches and through a first edge notch **322** in the upper edge **120** of the tile base proximate the left edge **130**. The other external conductor (e.g., the second conductor **314**) is routed through a second set of the rib notches and through a second edge notch **324** in the upper edge proximate the right edge **140**.

[0037] A selected length of the first conductor **312** extends beyond the first edge notch **322** and is terminated in a first weather resistant connector **330** having a first mating polarity (e.g., female). A selected length of the second conductor **314** extends beyond the second edge notch **324** and is terminated in a second weather resistant connector **332** having a second mating polarity (e.g., male). When a plurality of the solar tiles **100** are positioned in a horizontal rank on a roof, the photovoltaic panels **108** in adjacent solar tiles are electrically connected in series by plugging the male connector from one tile into the female connector of the adjacent tile. The tile at each end of a horizontal rank of tiles is connected to a respective cable connected to a control system (not shown) in a central location that receives the electrical outputs from the strings and provides a system power output in a conventional manner.

[0038] As discussed above, the photovoltaic panel **108** may be a conventional photovoltaic panel configured to have the dimensions described above. In preferred embodiments, the photovoltaic panel is constructed in accordance with a laminated photovoltaic panel **600** illustrated in FIGS. **8**, **9** and **10**. The photovoltaic panel **600** is configured as a generally rectangular panel, which is sized and shaped to fit in the depressed central portion **220** of the support frame **106**.

[0039] As illustrated in FIGS. **8**, **9** and **10**, a laminated photovoltaic panel **600** is configured as a generally rectangular panel, which is sized and shaped to fit in the depressed central portion **220** of the support frame **106**. In the illustrated embodiment, the panel **600** has dimensions of approximately and has a thickness of less than approximately 0.2 inch to fit within the depth of the depressed central portion.

[0040] The panel **600** has a transparent upper protective layer **610** that faces upward and is exposed to the sun. A middle layer **620** is positioned beneath the upper protective layer **610**. The middle layer **620** comprises a plurality of photovoltaic cells **622** that are electrically interconnected. The middle layer **620** rests on a rigid lower layer **630**. The middle layer **620** is secured to the rigid lower layer **630** by a lower adhesive layer **640**. The middle layer **620** is secured to the upper protective layer **610** by an upper adhesive layer **650**.

[0041] The upper protective layer **610** provides impact protection as well as weather protection to the panel **600**. The upper protective layer **610** advantageously comprises DuPont™ Teflon® fluorinated ethylene propylene (FEP) resin, which is formed into a film layer of suitable thickness (e.g., approximately 0.1 inch). Thus, the photovoltaic cells **622** in the middle layer **620** are exposed to direct sunlight without being exposed to moisture and other climatic conditions and without being exposed to direct impact by feet, falling objects, and debris.

[0042] In the illustrated embodiment, the rigid lower layer **630** comprises fiber reinforced plastic (FRP). For example, the FRP layer advantageously comprises a polyester resin with embedded stranded glass fibers. In one advantageous embodiment, the FRP layer has a thickness of approximately 0.079 inch. The rigid lower layer of FRP provides an advantageous combination of light weight, rigidity, very low permeability and flatness

[0043] Preferably, the lower adhesive layer **640** is provided as a thin film that is positioned on the upper surface of the rigid lower layer **630**. The array of photovoltaic cells **622** in the middle layer **620** is then positioned on the lower adhesive layer **640**. In the illustrated embodiment, the lower adhesive layer **640** advantageously comprises a transparent adhesive, such as, for example, ethylene-vinyl-acetate (EVA). EVA is a transparent, heat-activated adhesive that is particularly suitable for securing the cells. Other suitable adhesives, such as, for example, polyvinylbuterol (PVB), or other pottant materials, can be substituted for the EVA. before positioning the photovoltaic cells **640** on the lower adhesive layer **640**.

[0044] After positioning the array of photovoltaic cells **622** on the lower adhesive layer **640**, the upper transparent adhesive layer **650** is placed over the middle layer **620** so that the photovoltaic cells **622** are sandwiched between the two transparent adhesive layers. The upper adhesive layer **650** should match the physical characteristics of the lower adhesive layer **640**. In the illustrated embodiment, both the upper adhesive layer **650** and the lower adhesive layer **640** comprise EVA, but other suitable transparent adhesives can be substituted for the EVA. The transparent upper protective layer **610** is then positioned over the upper transparent adhesive layer **650** to complete the laminated structure shown in an enlarged partial cross section in FIG. **9**.

[0045] The EVA material and the use of the EVA material to bind the layers of a laminated photovoltaic cell are described, for example, in U.S. Pat. No. 4,499,658 to Lewis. In addition to acting as a binder to secure the photovoltaic cells **622** between the upper protective layer **610** and the lower rigid layer **630**, the upper EVA layer **650** and the lower EVA layer **640** also act as a cushion between the two outer layers.

[0046] The photovoltaic cells **622** are electrically interconnected in a series-parallel configuration in a conventional manner to provide a suitable output voltage. For example, in the illustrated embodiment, **12** photovoltaic cells **622** are arranged in 2 rows of 6 cells each. The photovoltaic panel **600** is illustrated with two flat ribbon electrical conductors **660**, **662** extending from right side of the middle layer **620**. The two conductors **660**, **662** are electrically connected to the external conductors **312**, **314** within the connector module **310** shown in FIGS. **1-7**. In the illustrated embodiment, the two electrical conductors **660**, **662** are bent and are passed through openings (not shown) in the rigid lower layer **630**. Thus, the free ends of the two conductors **660**, **662** are exposed beneath the rigid lower layer **630** for interconnection to the external conductors **312**, **314** within the connector module **310**, as described above.

[0047] The upper protective layer **610**, the middle layer **620**, the lower layer **660**, and the two adhesive layers **640** and **650** are stacked in the order shown in FIGS. **9** and **10** and are aligned to form the sandwich structure shown in FIGS. **8** and **9**. The free end of each of the two panel output conductors **660**, **662** are covered with a temporary covering (e.g., a cloth tube, or the like) during the lamination process. The structure is permanently laminated in a known manner using heat and pressure. In one advantageous embodiment, the structure is laminated in a vacuum laminator in the manner described, for example, in US Patent Application Publication No. 2005/0178248 A1 to Laaly et al. In particular, the structure is first subjected to a vacuum to remove any trapped gas bubbles in the EVA adhesives. The structure is then subjected to high pressure to force the layers together as tightly as practical. The structure is then heated to a suitable temperature (e.g., approximately 160° C.) to cure the adhesives in the layers **640** and **650** and thereby permanently bond the adjacent layers. During the high temperature portion of the process, a portion of the upper layer **610** softens sufficiently to form a coating that surrounds the outer edges of the other layers, thus forming a moisture-resistant coating around the entire structure. In the illustrated embodiment, the upper layer **610** and the two transparent adhesive layers **640**, **650** secure the panel output conductors **660**, **662** to the top of the middle layer **620**. Preferably, the panel output conductors **660**, **662** extend from the bottom of the middle layer **620** and pass through one or more openings (not shown) in the rigid lower layer **630**. The opening through the bottom layer **630** is sealed during the lamination process. In an alternative embodiment, the panel output conductors **660**, **662** are connected to the photovoltaic cells **622** on the middle layer **620** after the lamination process is completed using known interconnection techniques.

[0048] The laminated structure is held at the high temperature for a sufficient time to cure the upper transparent adhesive layer **650** and the lower transparent adhesive layer **640** and to cause the two transparent adhesive layers to adhere together to become a combined layer that completely encapsulates the photovoltaic cells **622**. The high temperature also causes the upper transparent layer **610** to soften and flow to provide the protective upper coating described above. The laminated structure is then allowed to cool to ambient temperature.

[0049] After the lamination process is completed, the two panel ribbon conductors **660**, **662** are connected to the two external conductors **312**, **314**, as discussed above. The connections between the conductors and a portion of the conductors are connected within the output module **310**, as further discussed above. The panel is secured to the panel support frame **106**, and the panel support frame is secured to the tile base **102** to complete the assembly of the complete flat solar tile **100**.

[0050] In accordance with the embodiments disclosed herein, an aesthetically flat solar tile **100** combines the weather protection features and appearance of a conventional flat concrete “slate” tile with the electrical energy generating capabilities of a solar cell sandwich. The flat solar tile is easily installed with flat concrete tiles to include electrical energy generation capability on newly constructed roofs and can replace concrete tiles to add electrical energy generation capability to existing roofs.

[0051] The present invention is disclosed herein in terms of a preferred embodiment thereof, which provides a photovoltaic panel integrated into a flat solar tile having the appearance of a concrete “slate” tile, as defined in the appended claims. Various changes, modifications, and alterations in the teachings of the present invention may be contemplated by those skilled in the art without departing from the intended spirit and scope of the appended claims. It is intended that the present invention encompass such changes and modifications.

We claim:

1. A roofing module that provides weather protection and that generates electrical power, comprising:

a base comprising a generally rectangular injected molded plastic structure having the size and appearance of a conventional concrete roofing tile, including a striated upper surface; and

a photovoltaic panel assembly positioned in a depressed portion of the grooved upper surface of the base, the photovoltaic panel assembly comprising a photovoltaic panel installed in a panel support frame, the panel support frame being removably installable in the depressed portion of the base with at least a pair of electrical output conductors that pass through the upper surface of the base.

2. The roofing module as defined in claim **1**, wherein:

the photovoltaic panel includes an output module extending from a lower surface, the output module enclosing electrical connections between electrical output conductors on the photovoltaic panel and weather-resistant electrical conductors, the that provides weather protection and that generates electrical power;

the panel support frame includes at least one opening aligned with the output module to receive the output module when the photovoltaic panel is installed in the panel support frame; and

the base includes an opening aligned with the opening in the panel support frame to receive an extended portion of the output module when the panel support frame with the photovoltaic module is installed in the base.

3. The roofing module as defined in claim **1**, wherein the base includes a plurality of notches formed along one boundary of the depressed portion to allow water to drain from the depressed portion.

4. The roofing module as defined in claim **1**, wherein the base includes a first interlocking groove at one edge and an interlocking tab at an opposite edge, the interlocking tab configured to engage the interlocking groove of an adjacent module and also to engage an interlocking groove of a conventional concrete roofing tile.

5. A method of constructing a roofing tile having an integrated photovoltaic array, comprising:

constructing a photovoltaic assembly, comprising:

installing a photovoltaic array in a frame having a central depressed portion sized to receive the photovoltaic array, the photovoltaic array including at least a pair of electrical conductors; and

securing the photovoltaic array to the frame; and

installing the photovoltaic assembly in a injection molded base having a size, a shape and an appearance selected to correspond to a size, a shape and an appearance of a conventional concrete roofing tile with a slate-like striated upper surface such that the base is interchangeable with the conventional concrete roofing tile, comprising:

positioning the photovoltaic assembly in a depressed portion of an upper surface of the injection molded base;

passing the at least a pair of electrical conductors through an opening in the upper surface of the injection molded base; and

securing the photovoltaic assembly to the injection molded base.

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