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PHOTOVOLTAIC MODULES****Publication Classification**(51) **Int. Cl.**

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

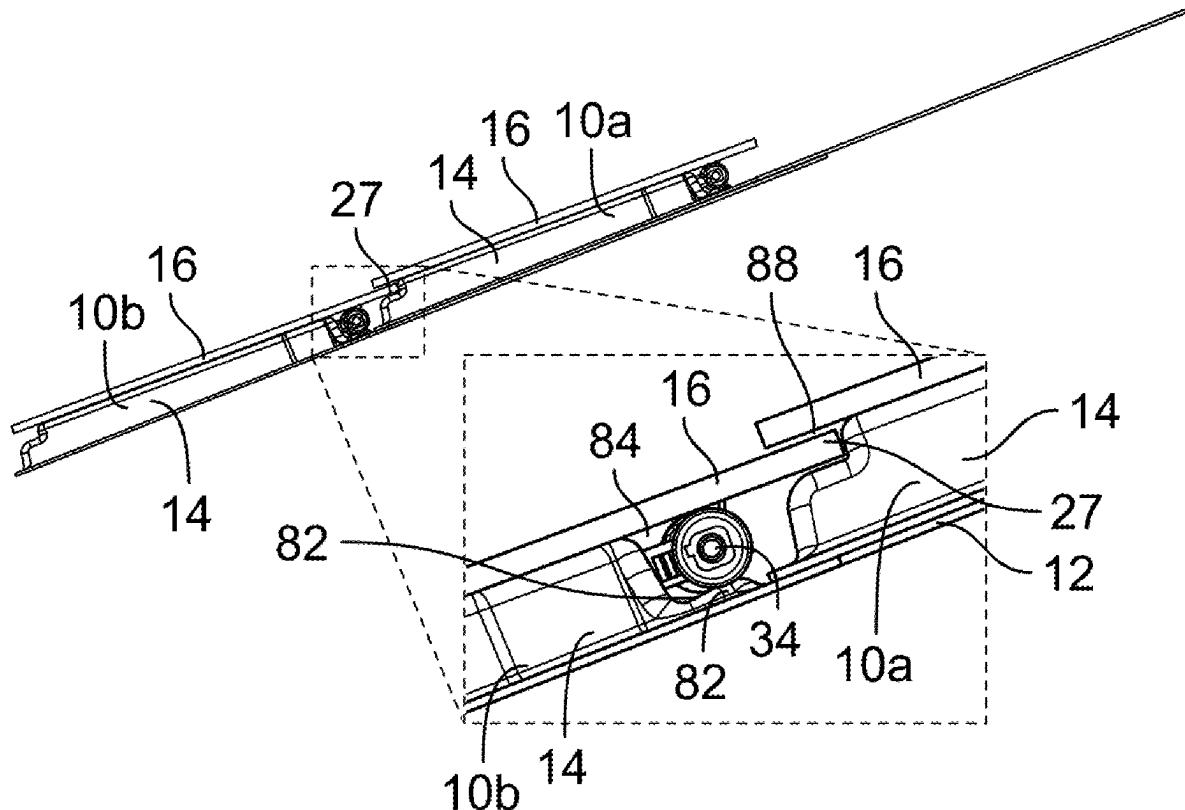
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continuation of application No. 17/941,934, filed on
Sep. 9, 2022, now Pat. No. 11,689,149, which is a
continuation of application No. 17/501,606, filed on
Oct. 14, 2021, now Pat. No. 11,444,569.(60) Provisional application No. 63/091,428, filed on Oct.
14, 2020.

(57)

ABSTRACT

A system includes a plurality of photovoltaic modules, each having a mat with an edge and a spacer with an edge, the edge of the mat being attached to the edge of the spacer. The spacer includes a plurality of support members and a solar module mounted to the support members. Each of the support members includes a ledge. The solar module and the ledge form a space therebetween. The space is sized and shaped to receive an edge of a solar module of another of the photovoltaic modules. The spacer of one of the photovoltaic modules overlays the mat of another of the photovoltaic modules.



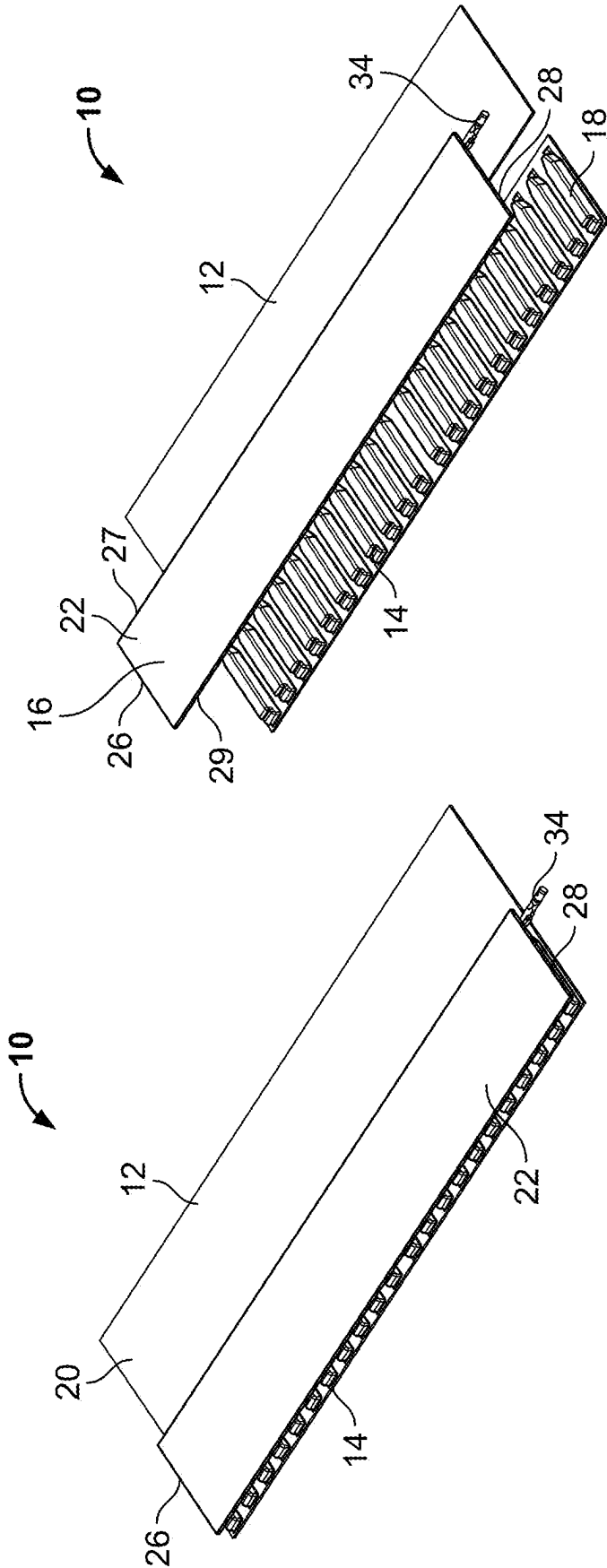


FIG. 2

FIG. 1

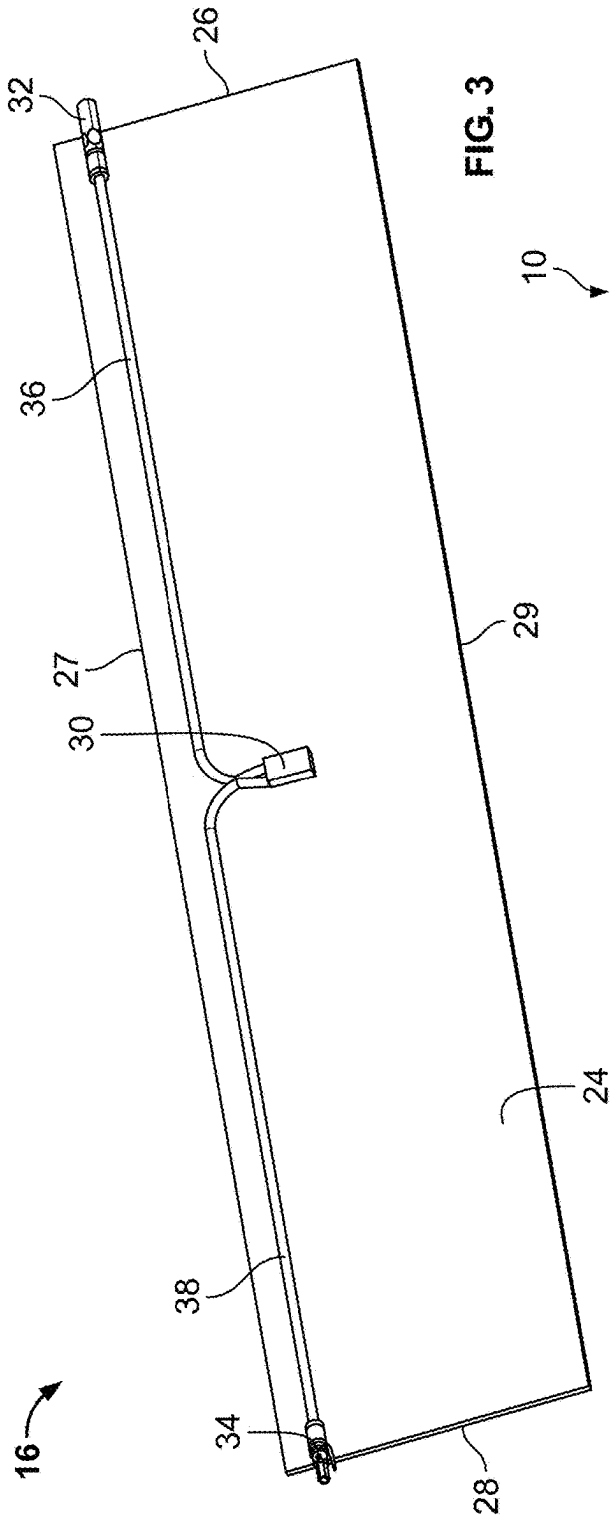


FIG. 3

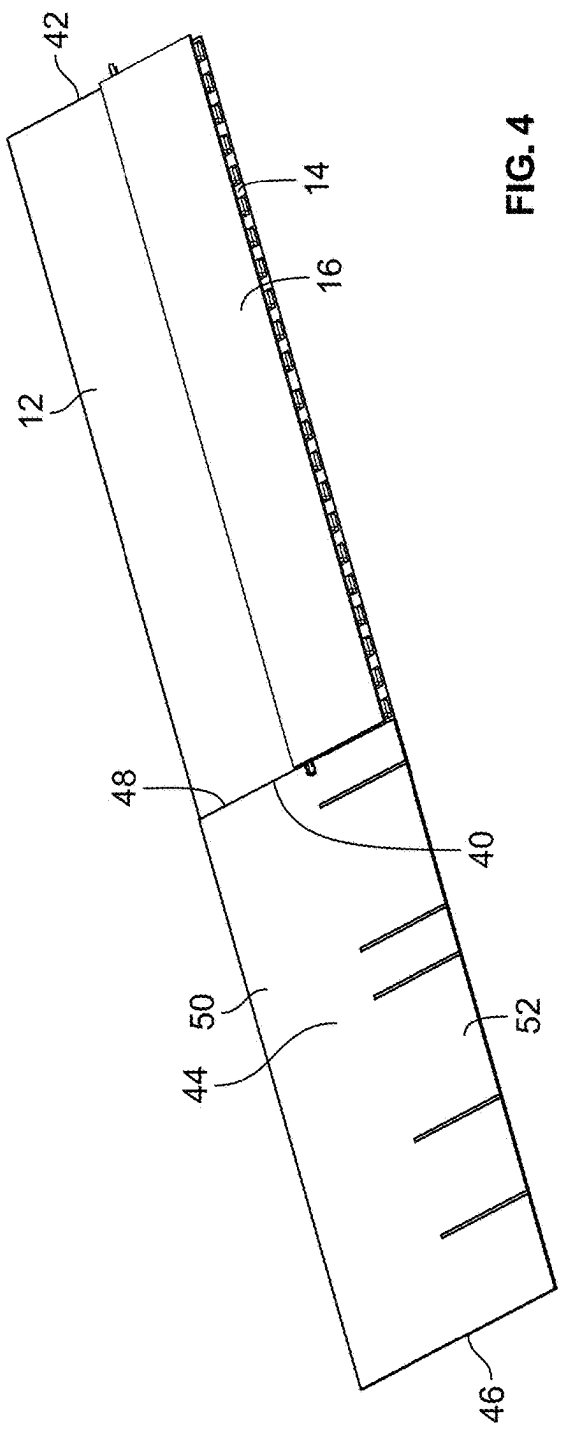


FIG. 4

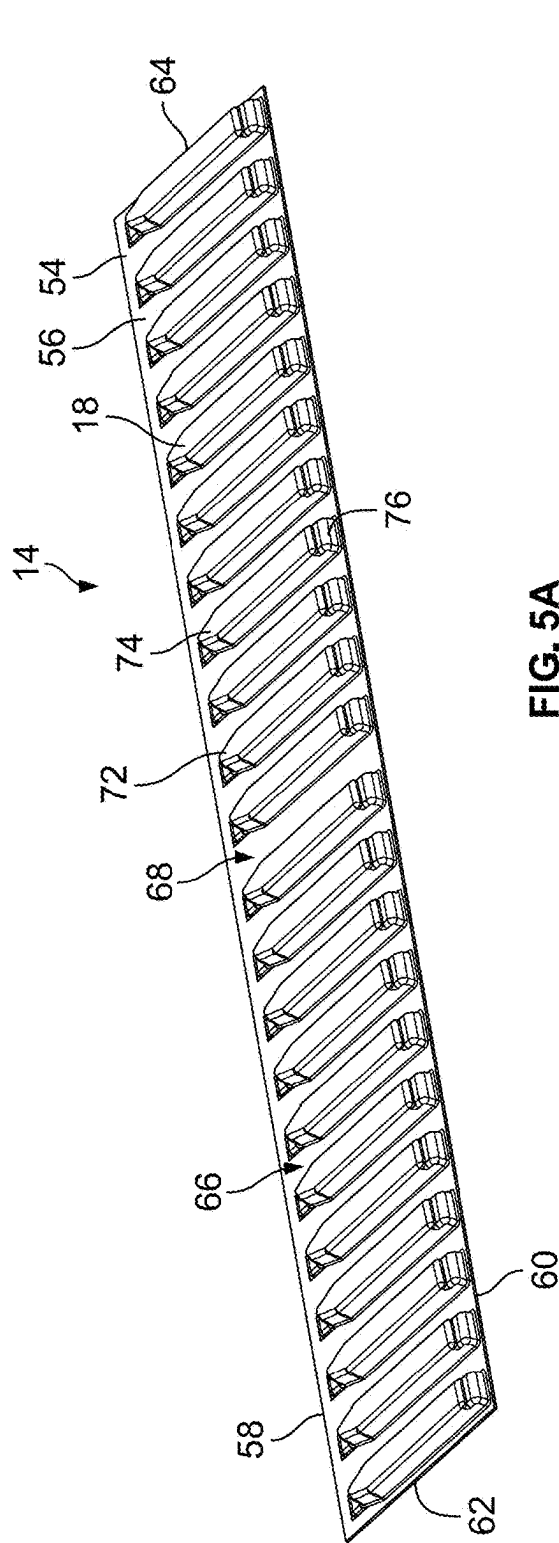


FIG. 5A

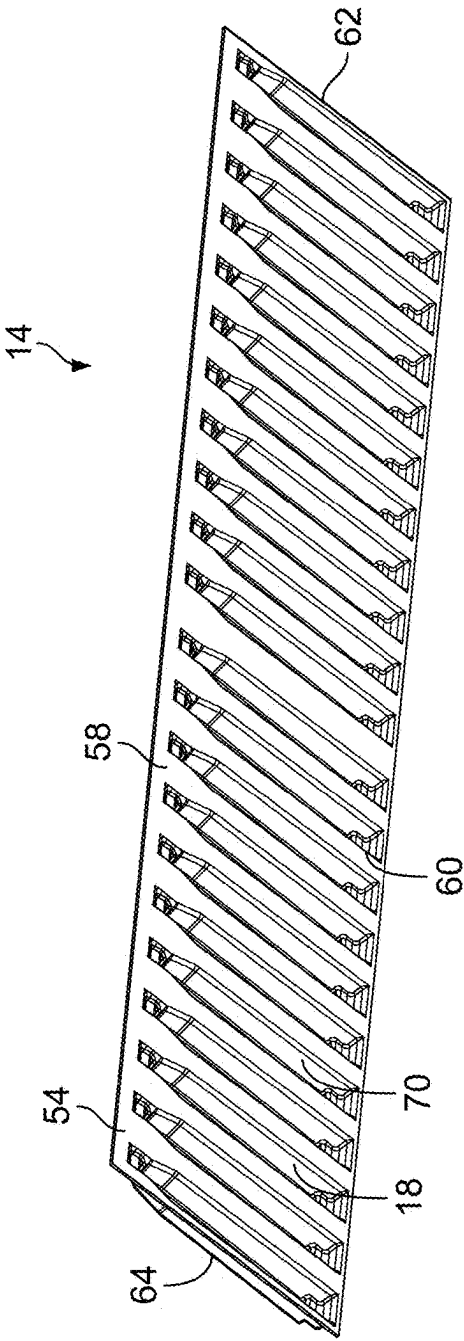
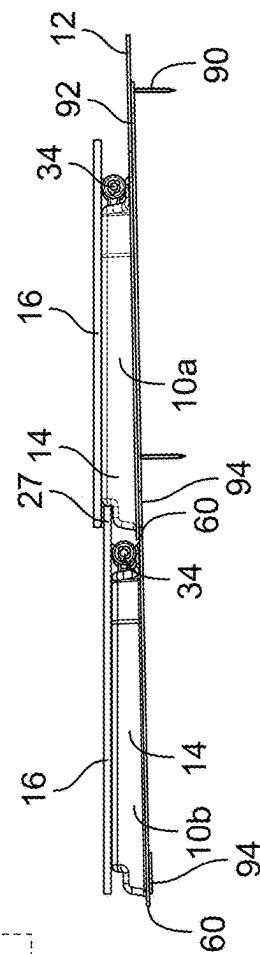
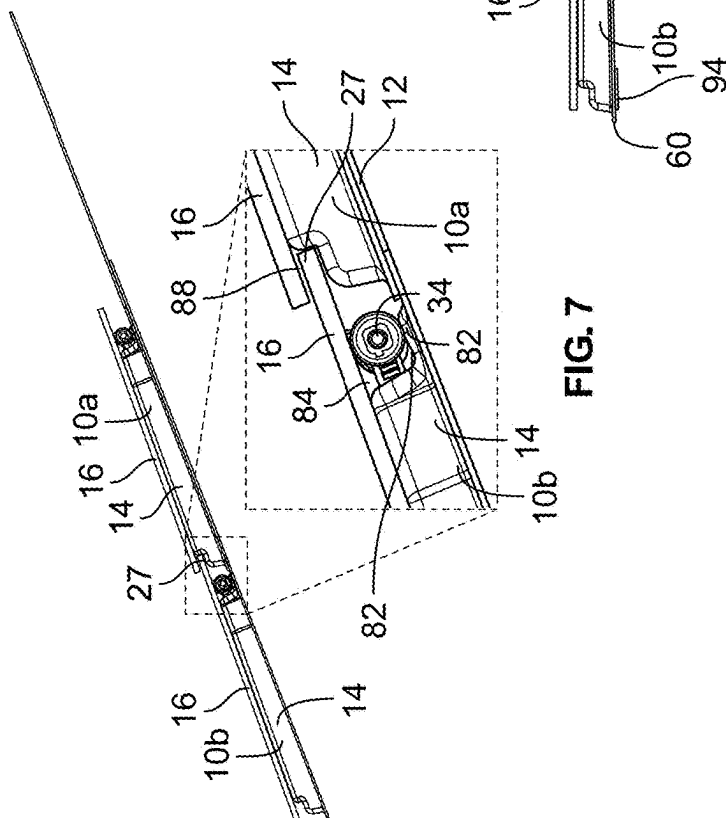
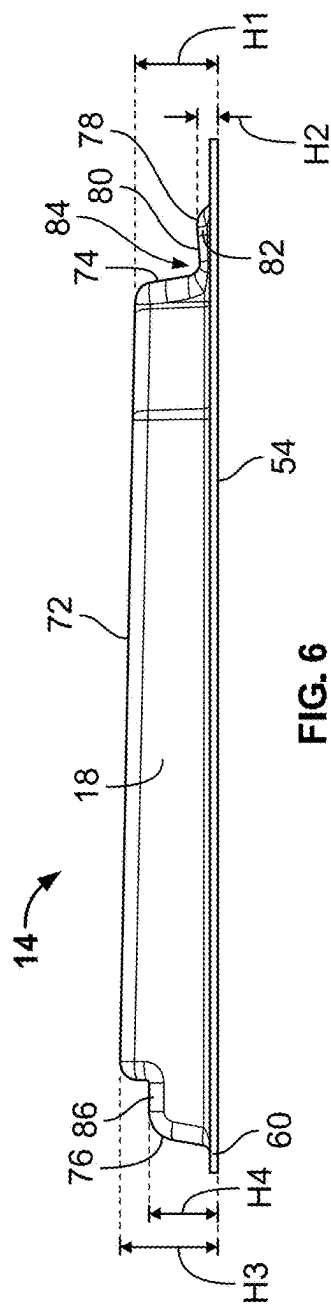


FIG. 5B



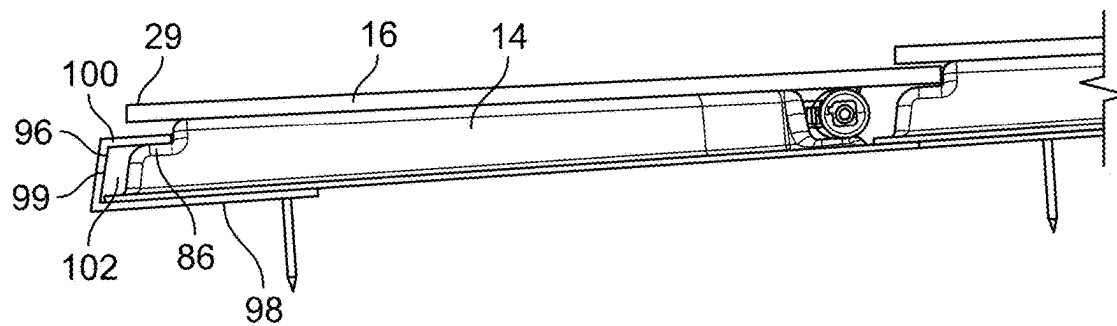


FIG. 9

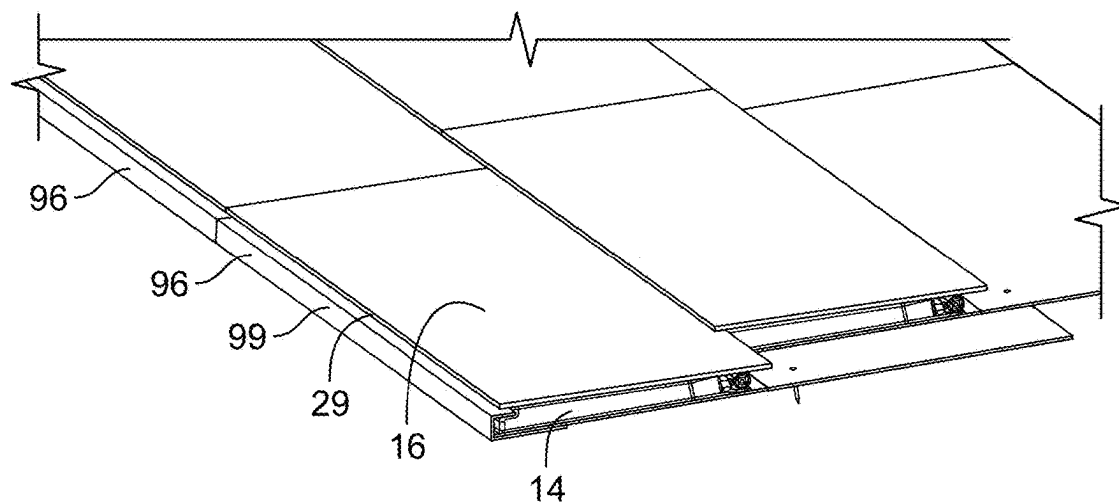


FIG. 10

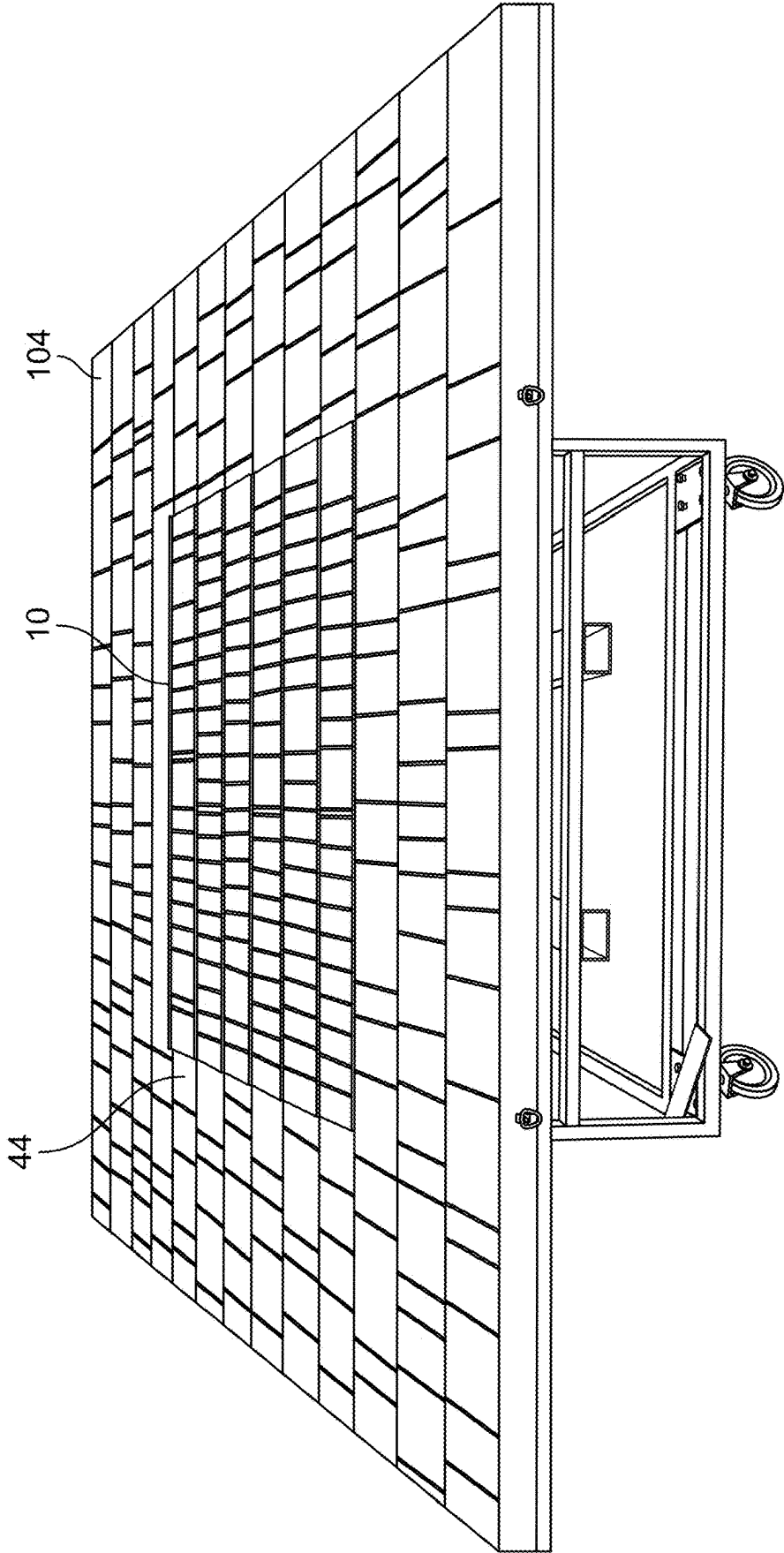
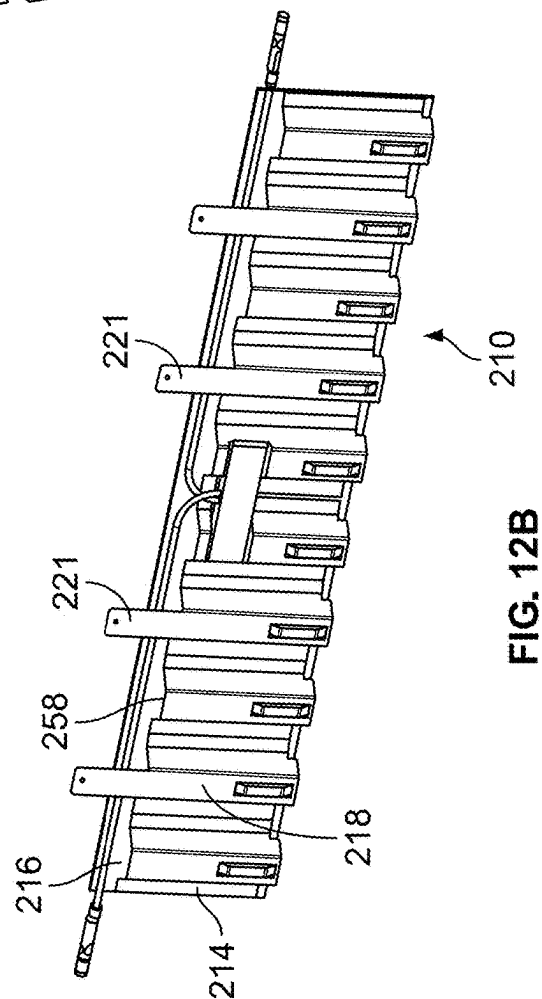
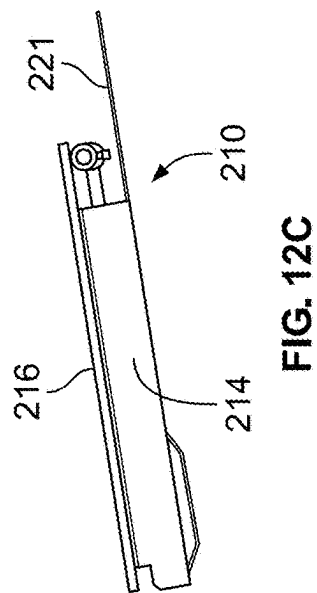
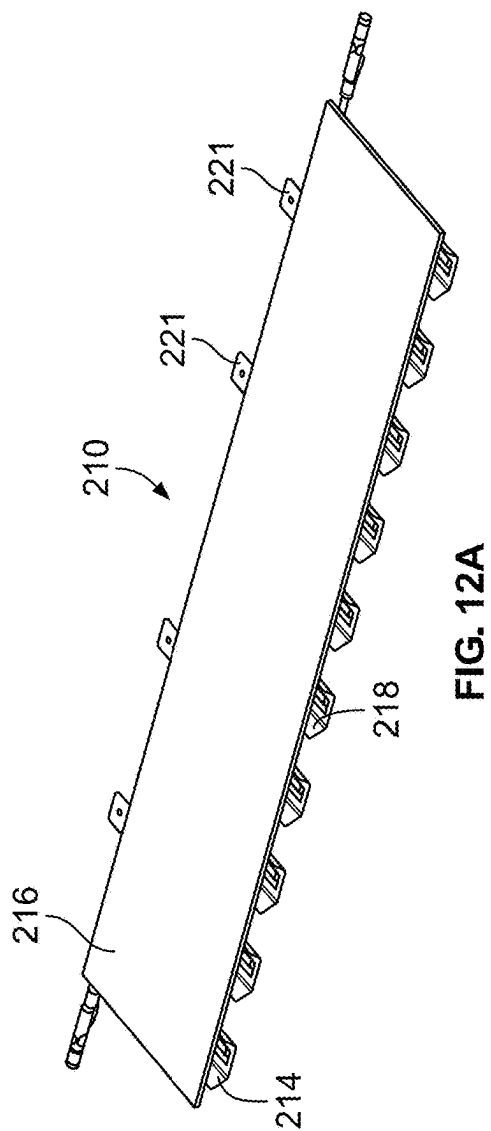
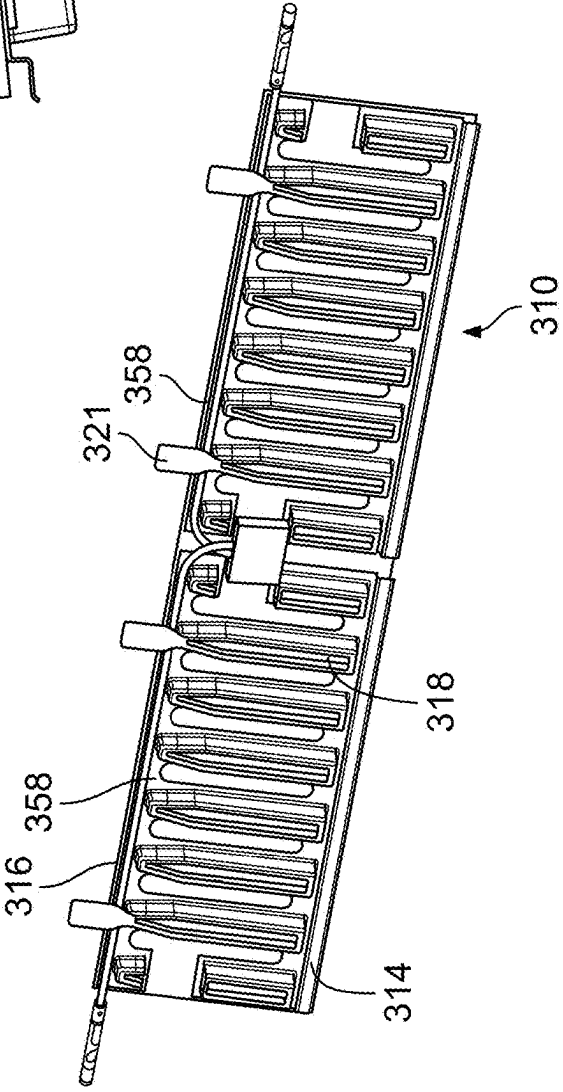
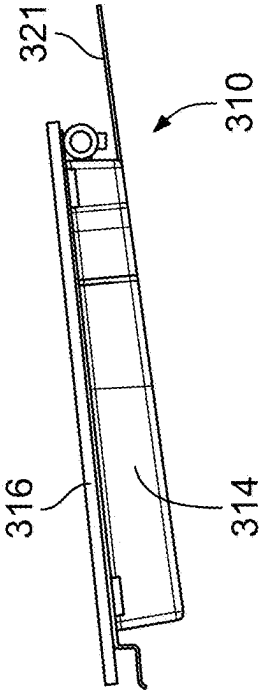
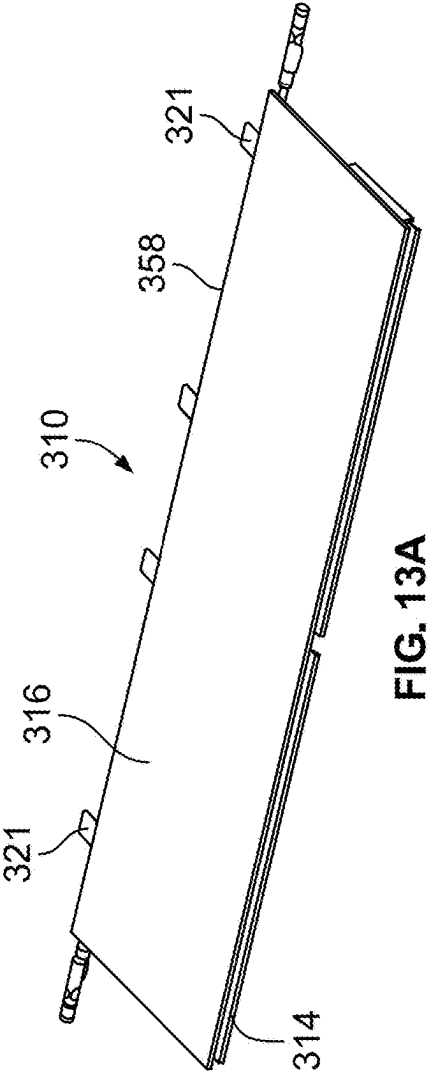


FIG. 11





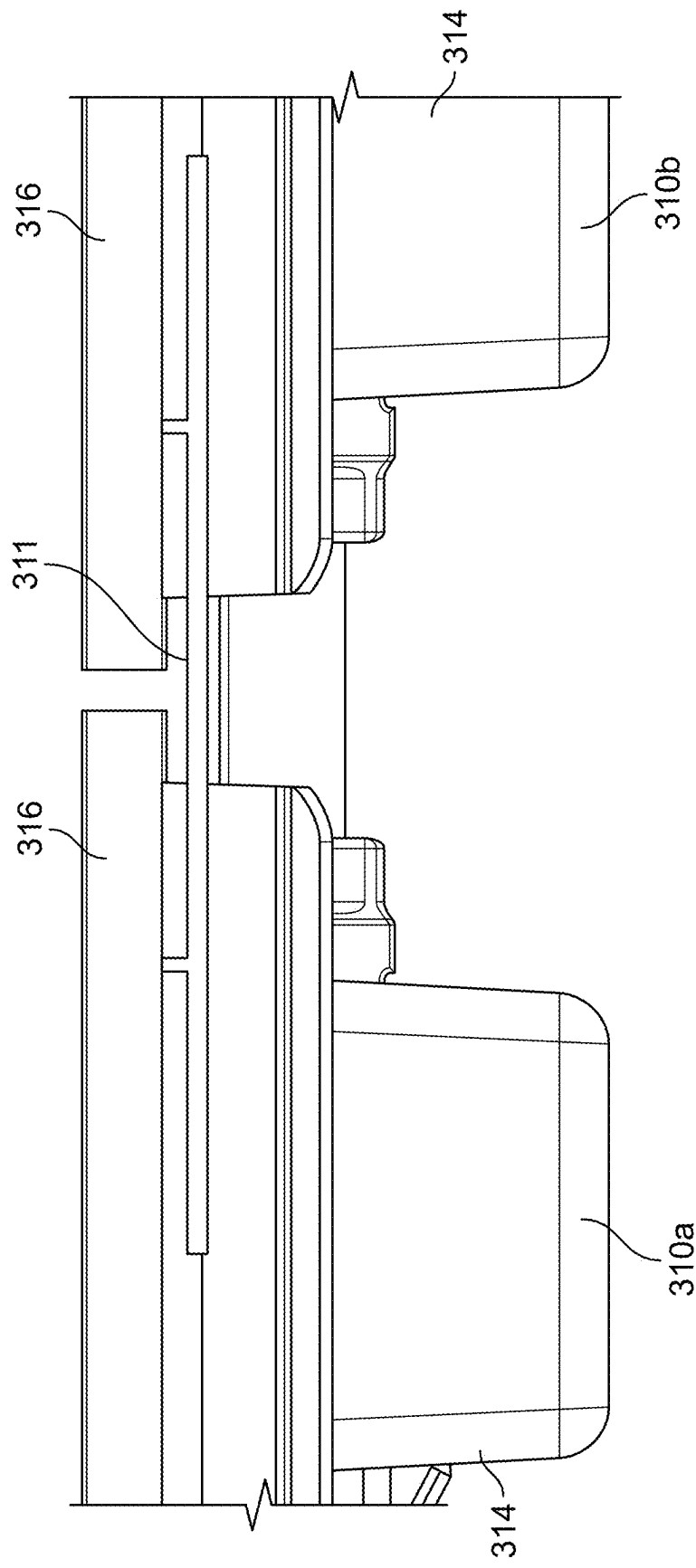


FIG. 14

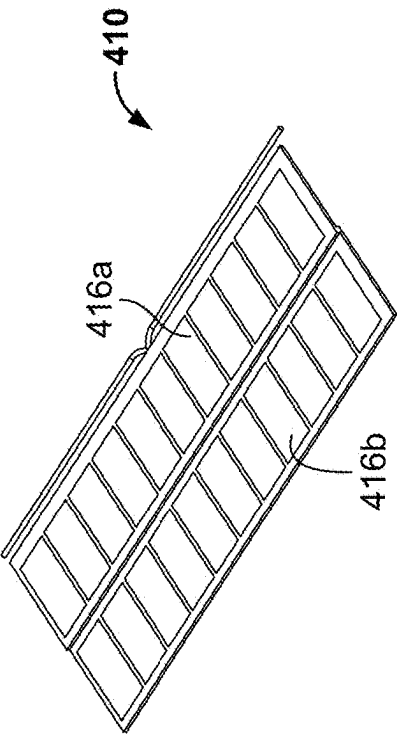


FIG. 15A

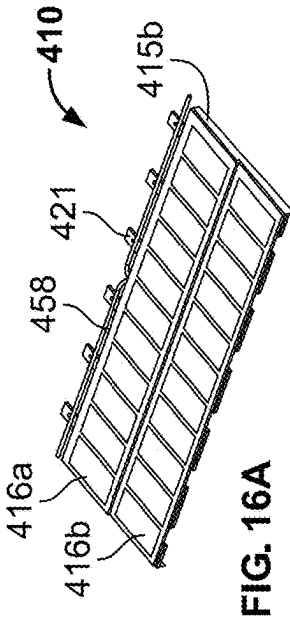


FIG. 16A

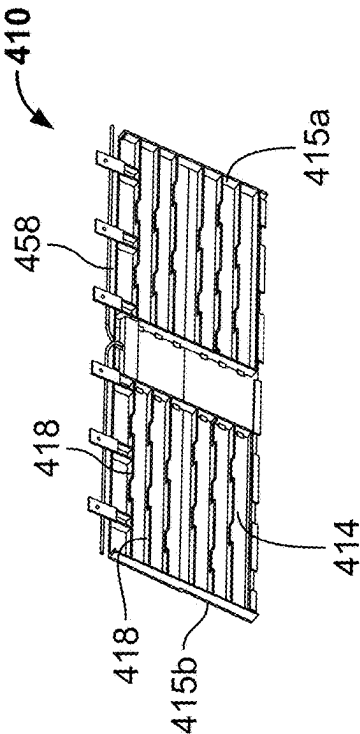


FIG. 16B

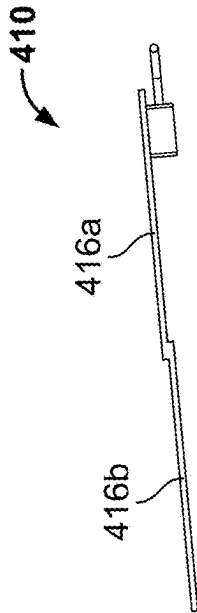


FIG. 15B

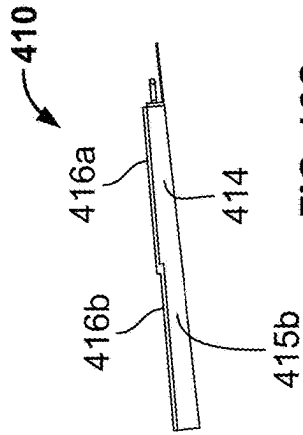


FIG. 16C

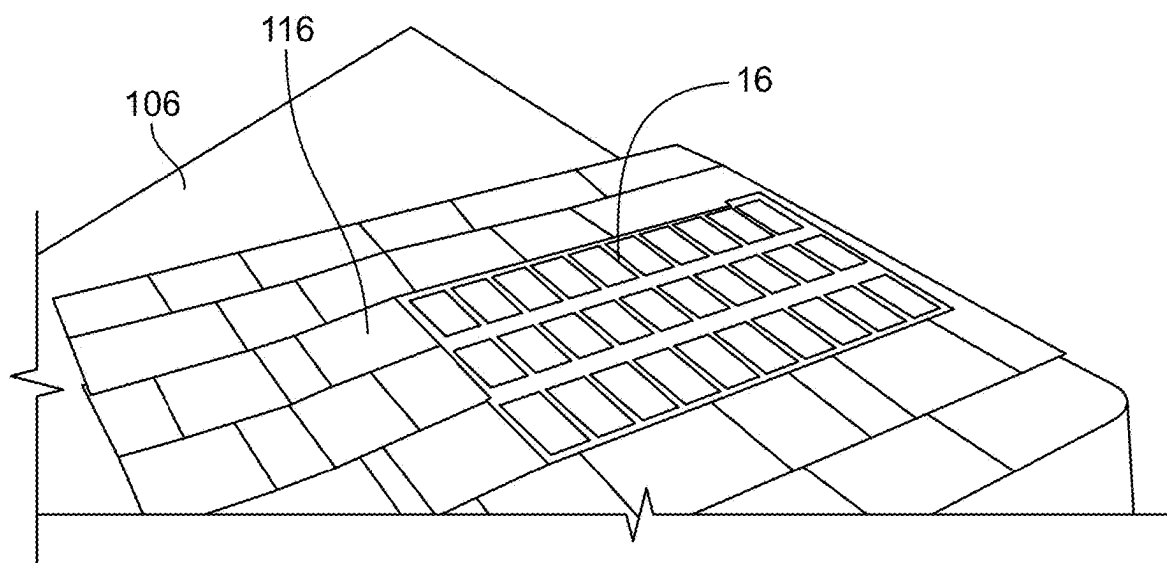
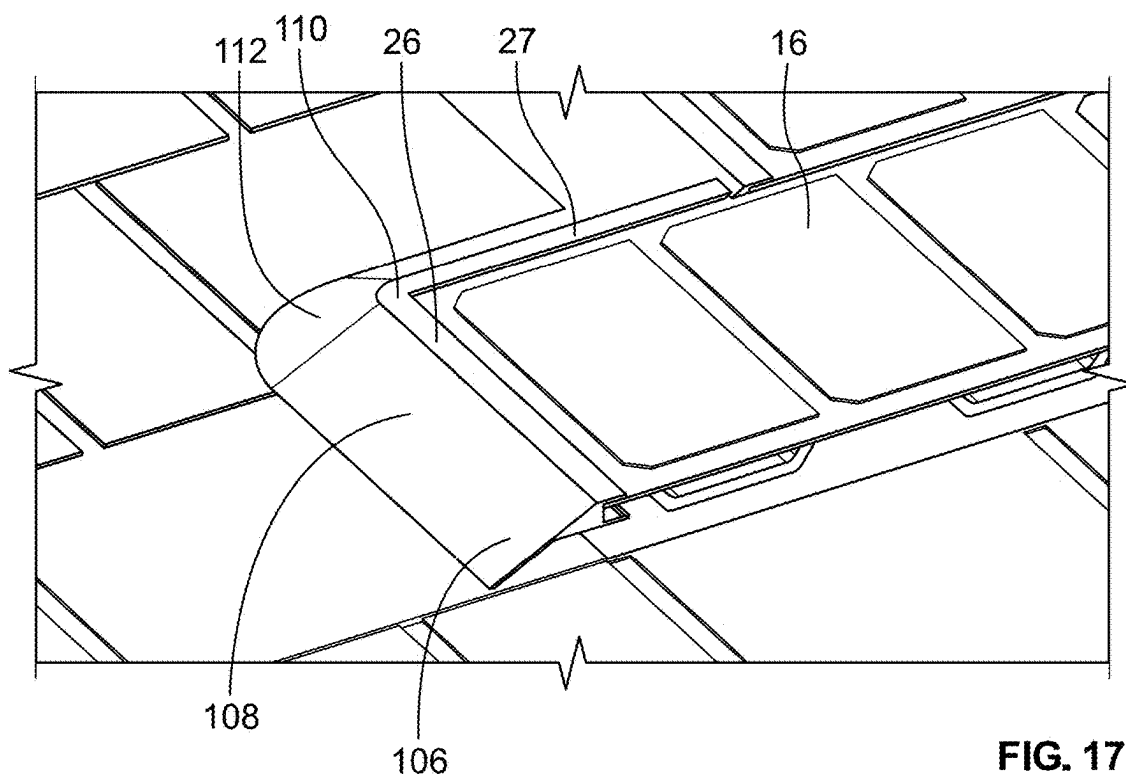


FIG. 18

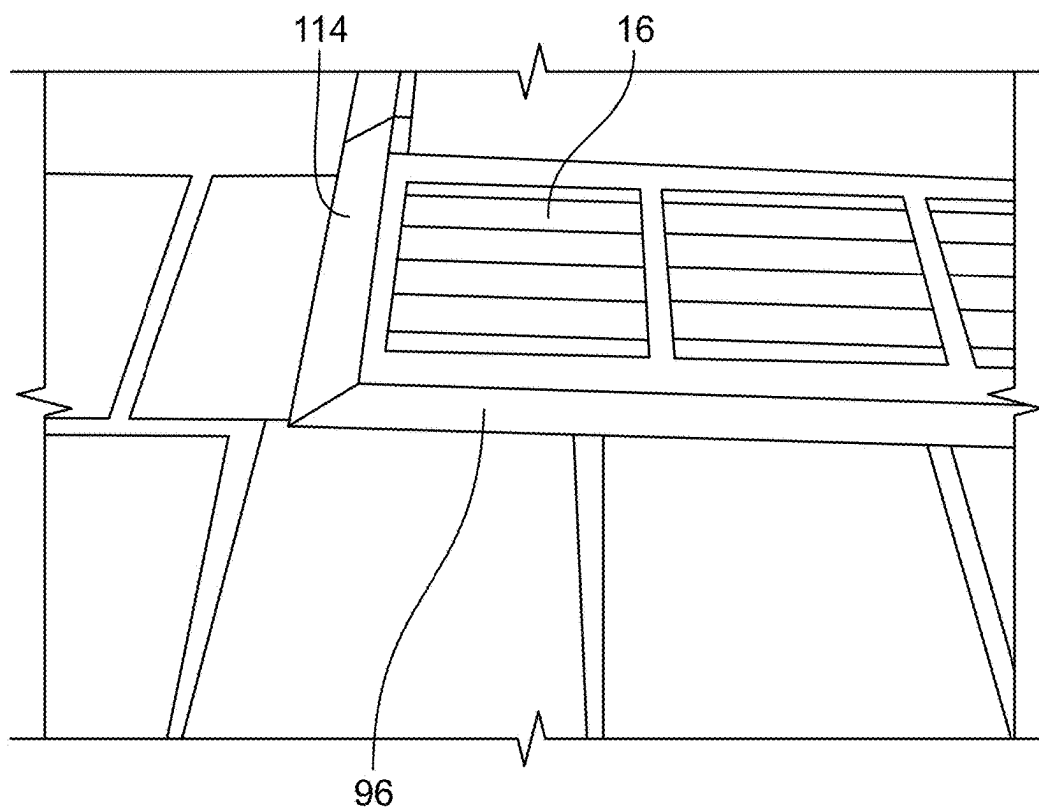


FIG. 19A

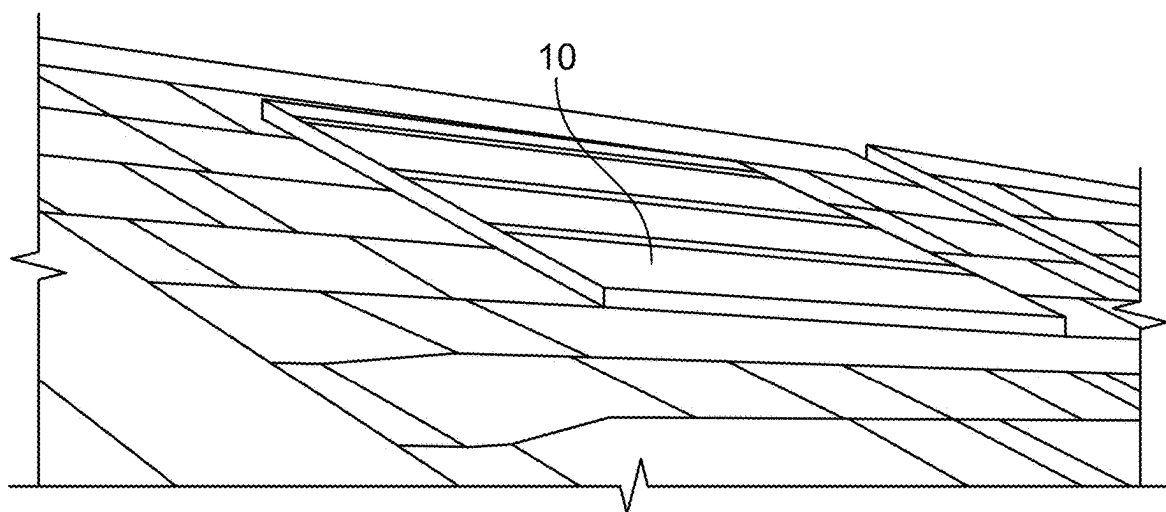


FIG. 19B

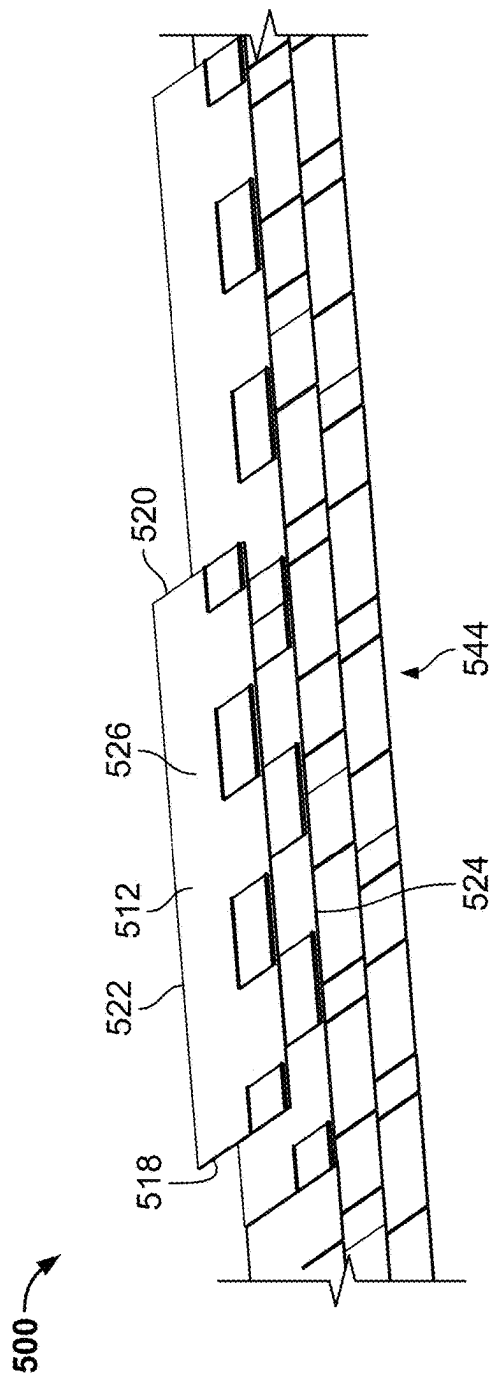


FIG. 20

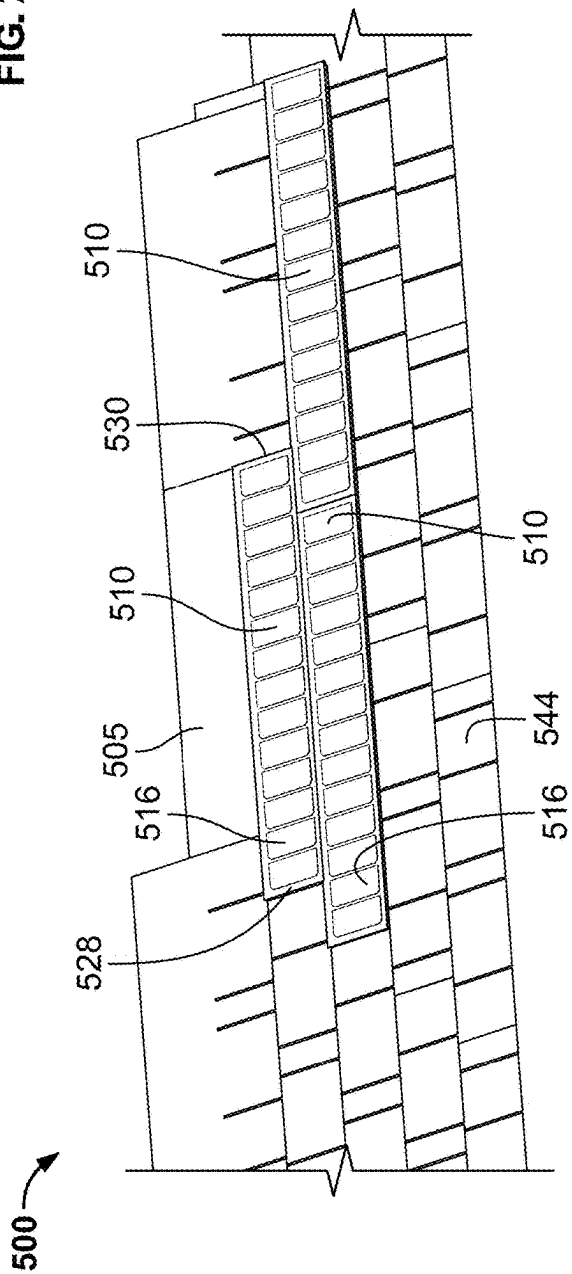


FIG. 21

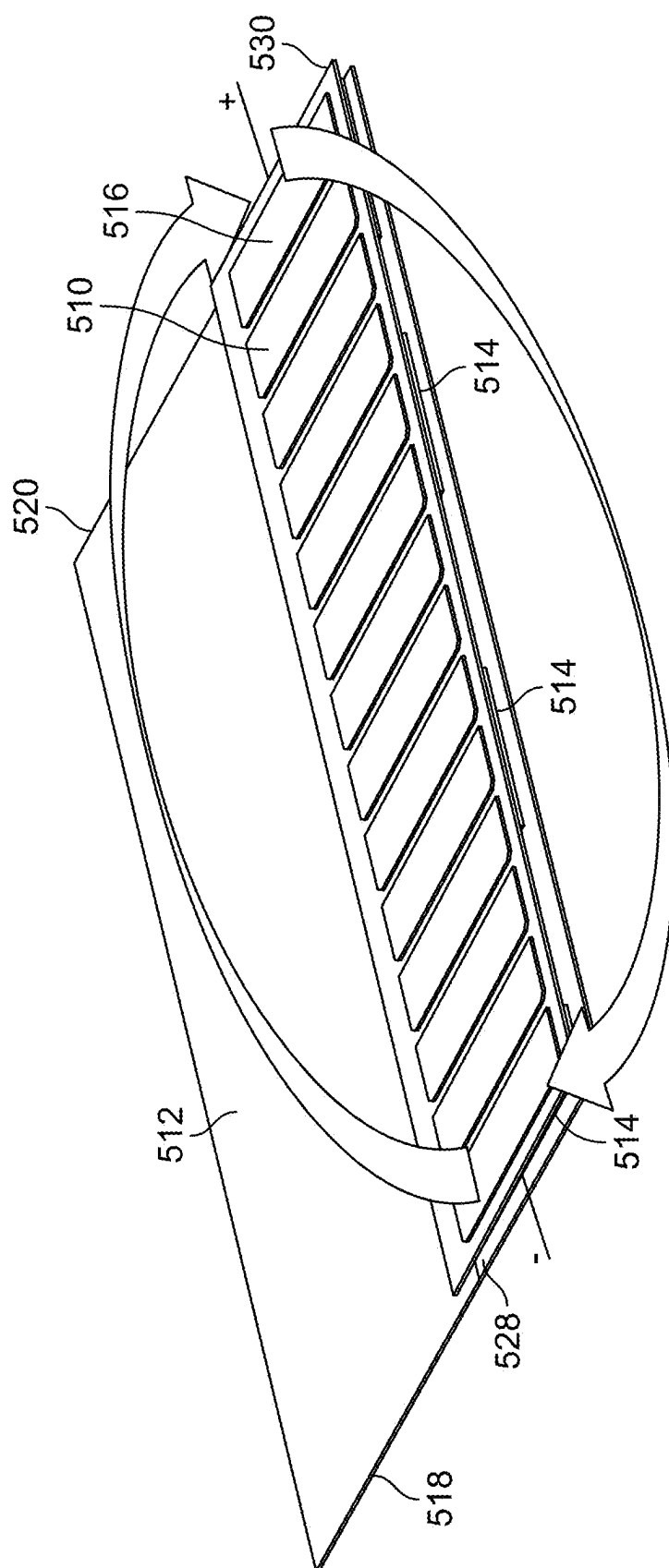


FIG. 22

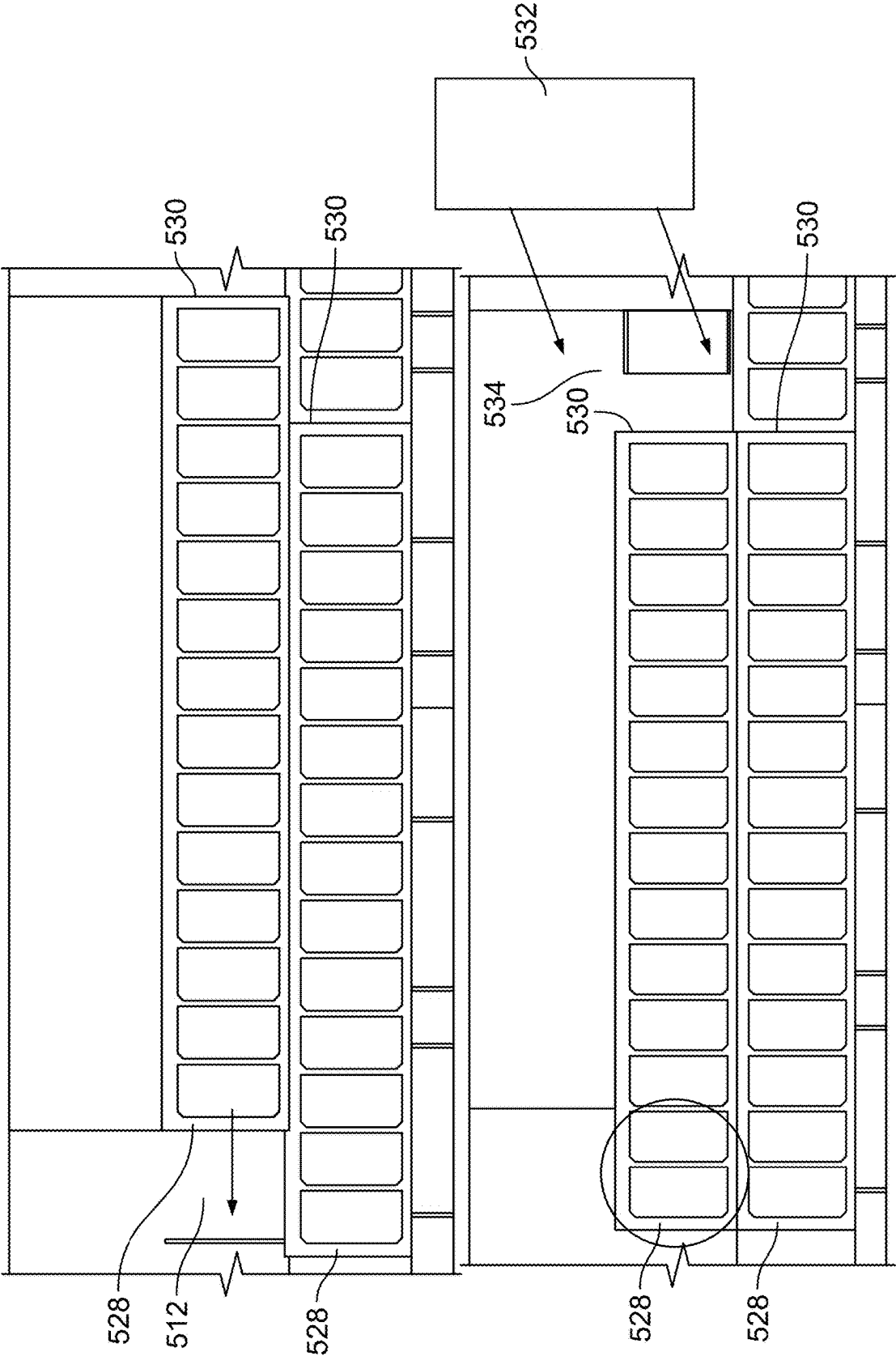


FIG. 23

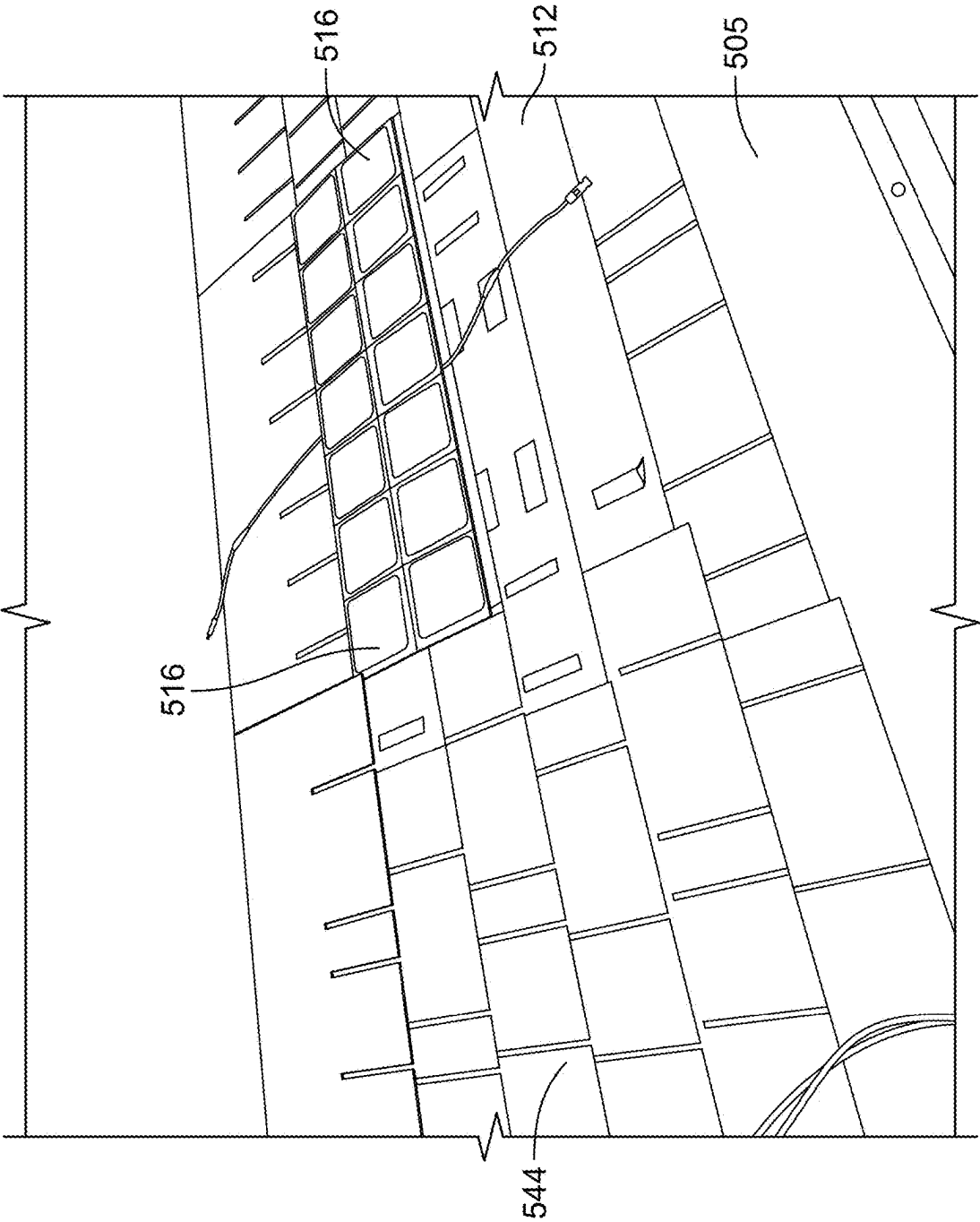
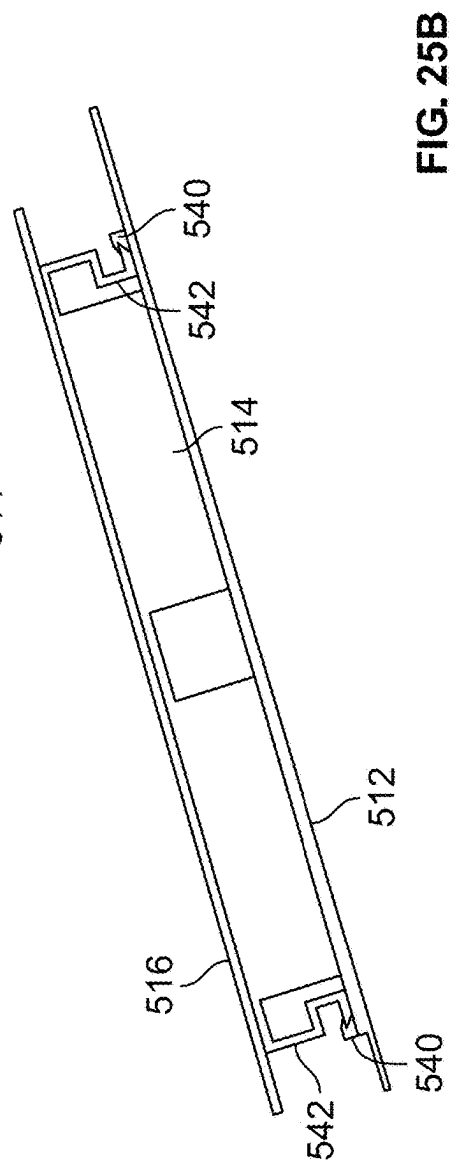
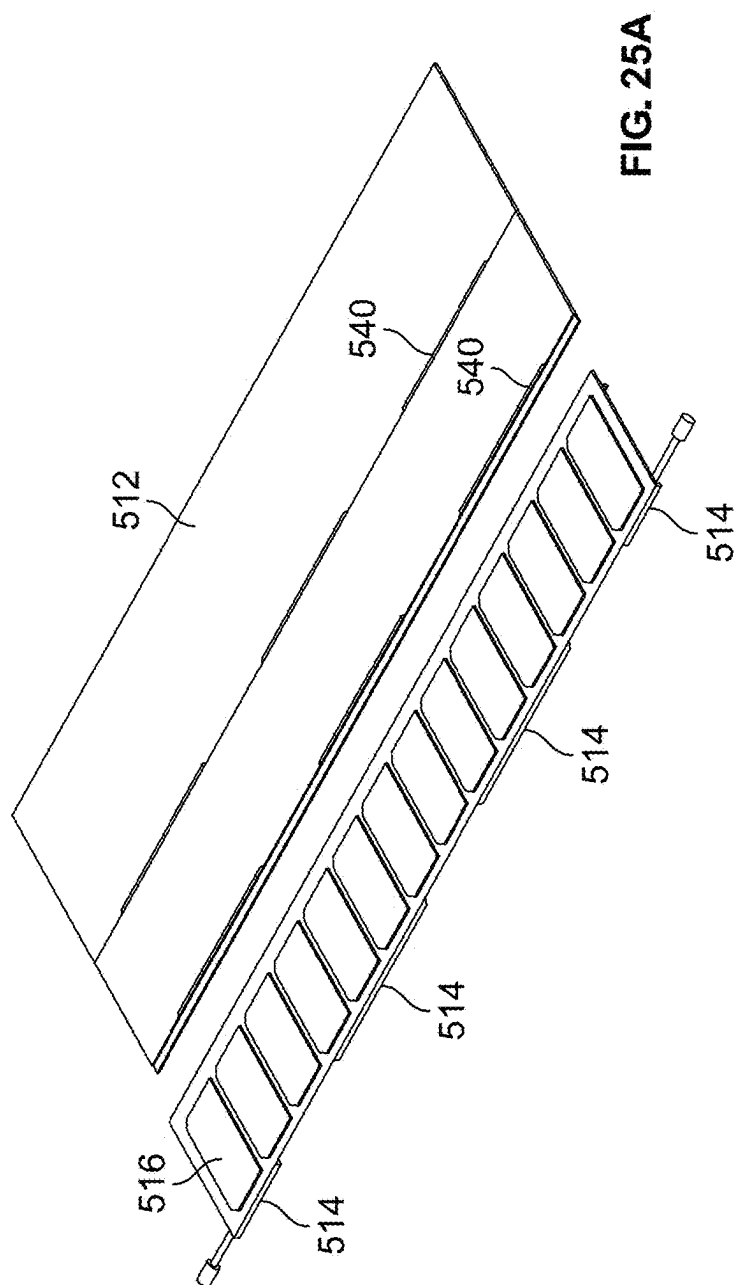
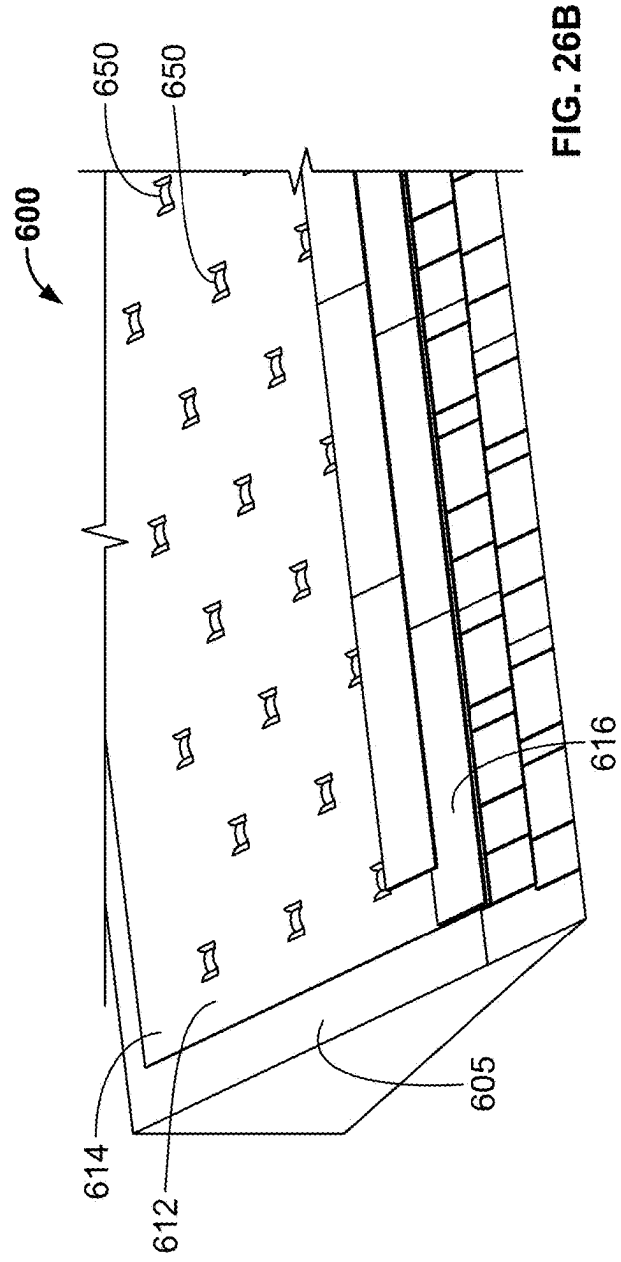
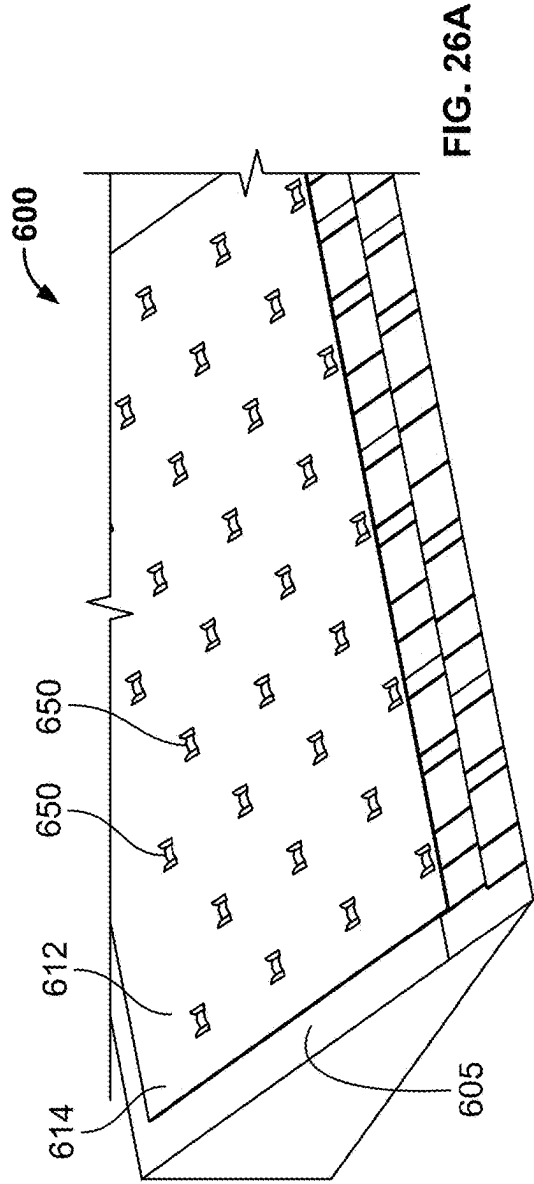


FIG. 24





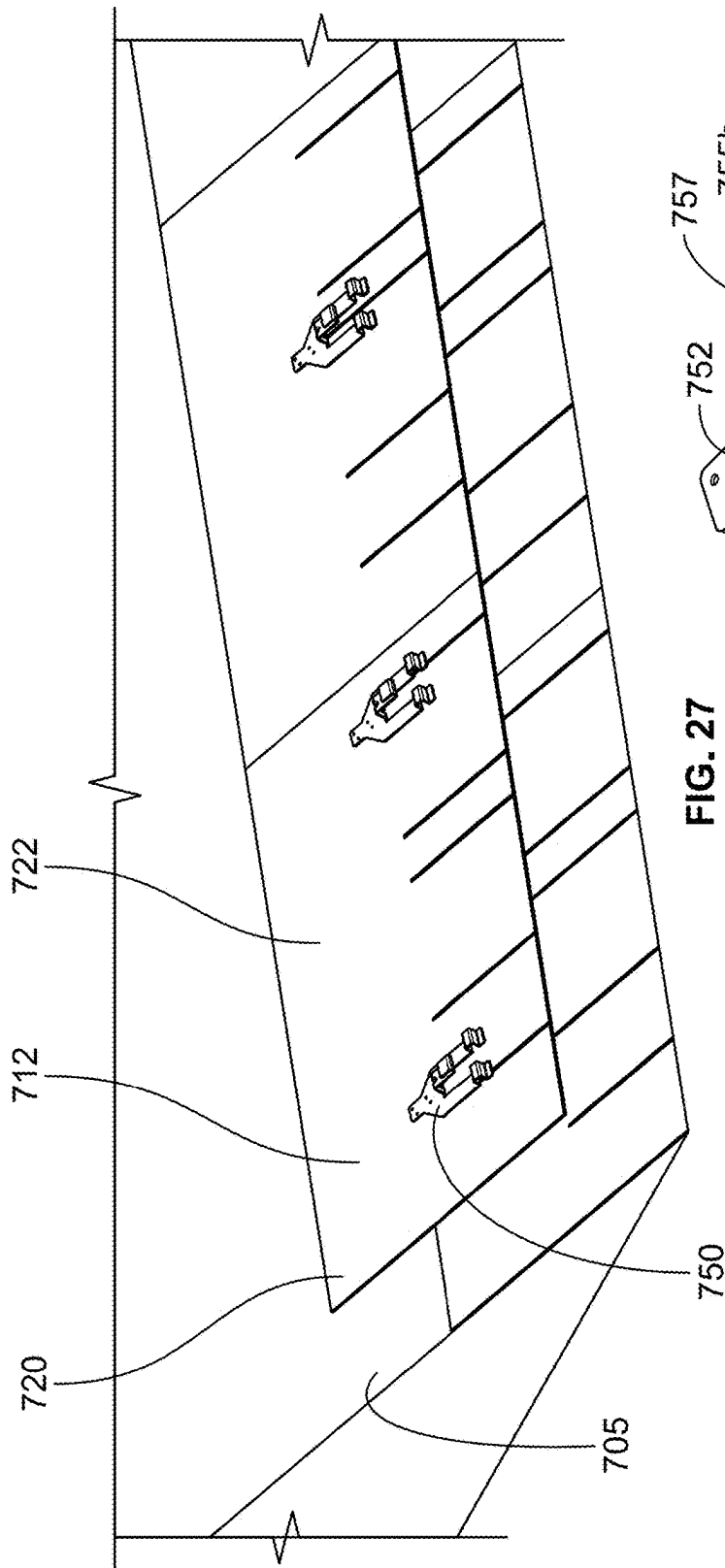


FIG. 27

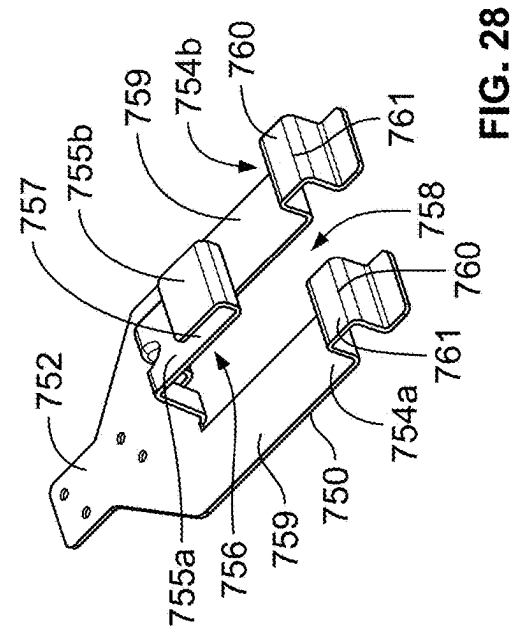
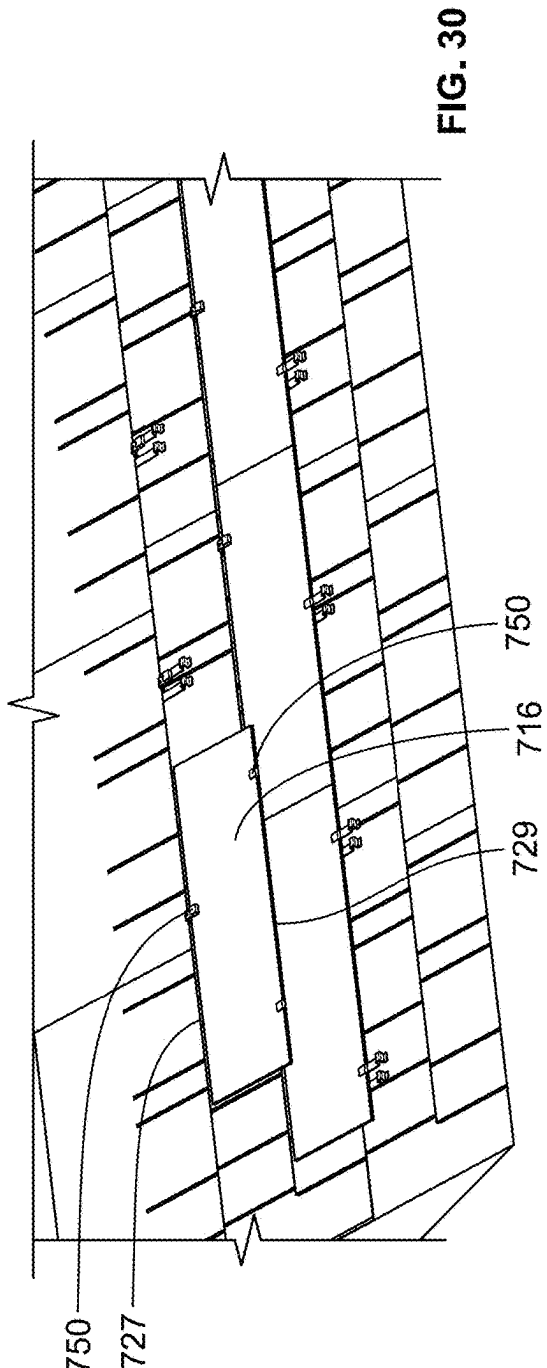
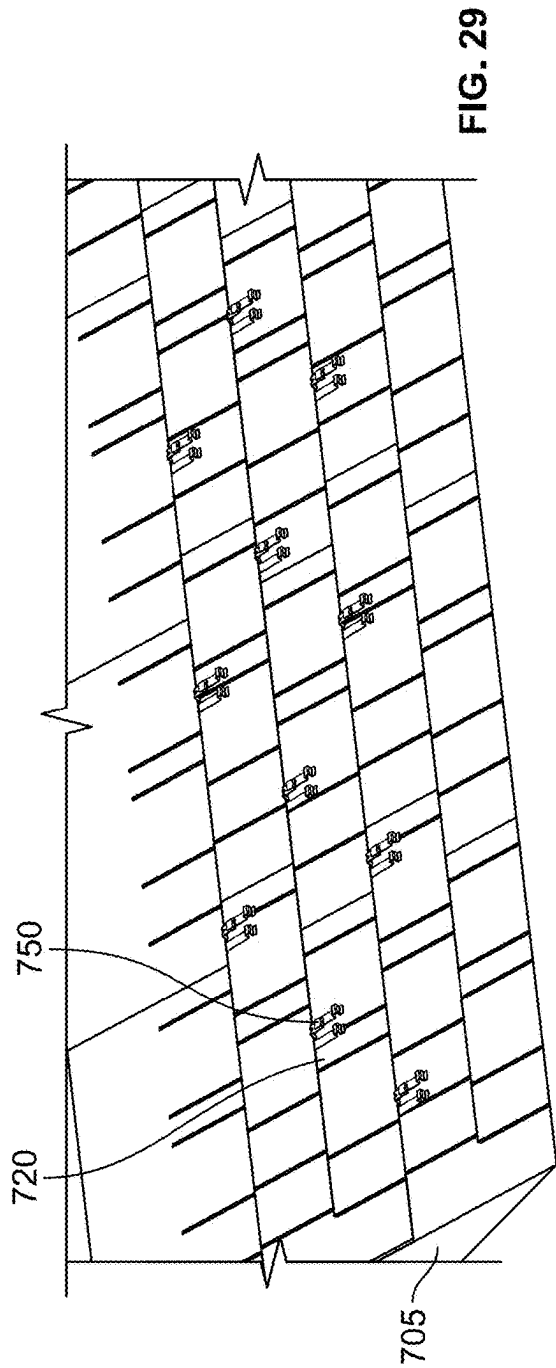


FIG. 28



MOUNTING APPARATUS FOR PHOTOVOLTAIC MODULES

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of U.S. patent application Ser. No. 18/315,975, filed May 11, 2023, entitled “MOUNTING APPARATUS FOR PHOTOVOLTAIC MODULES,” continuation of U.S. patent application Ser. No. 17/941,934, filed Sep. 9, 2022, now U.S. Pat. No. 11,689,149, entitled “MOUNTING APPARATUS FOR PHOTOVOLTAIC MODULES,” which is a continuation of U.S. patent application Ser. No. 17/501,606, filed Oct. 14, 2021, now U.S. Pat. No. 11,444,569, entitled “MOUNTING APPARATUS FOR PHOTOVOLTAIC MODULES,” which claims the benefit of U.S. Provisional Patent Application Ser. No. 63/091,428, filed Oct. 14, 2020, entitled “MOUNTING APPARATUS FOR PHOTOVOLTAIC MODULES,” the contents of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to photovoltaic modules and, more particularly, mounting apparatus for photovoltaic modules for roofing systems and methods for installing same.

BACKGROUND OF THE INVENTION

[0003] Photovoltaic systems having solar panels are commonly installed on roofing of structures. What is needed is mounting apparatus for photovoltaic modules having features for efficient installation thereof.

SUMMARY OF THE INVENTION

[0004] In some embodiments, a system includes a plurality of photovoltaic modules configured to be installed on a roof deck, each of the photovoltaic modules includes a mat having a first edge, a spacer having a first edge, wherein the first edge of the mat is attached to the first edge of the spacer wherein the spacer includes a plurality of support members, wherein each of the support members includes a first end, a second end opposite the first end, and a first ledge located at the first end, and at least one solar module mounted to the plurality of support members, wherein the at least one solar module of one of the plurality of photovoltaic modules and the first ledge of the one of the plurality of photovoltaic modules form a first space therebetween, wherein the first space is sized and shaped to receive an edge of a solar module of another of the plurality of photovoltaic modules, and wherein the spacer of one of the plurality of photovoltaic modules overlays the mat of another of the plurality of photovoltaic modules.

[0005] In some embodiments, the mat includes a first surface, and wherein the spacer overlays the first surface of the mat. In some embodiments, the spacer includes a base, and wherein the plurality of support members extends from the base. In some embodiments, the base of the spacer includes a first surface and the plurality of support members extends outwardly from the first surface of the base. In some embodiments, the spacer includes a first end and a second end opposite the first end, and wherein the plurality of support members extends from the first end to the second end. In some embodiments, each of the plurality of support

members is spaced apart from at least an adjacent one other of the plurality of support members. In some embodiments, the spacer includes a plurality of gaps, each of which is formed between a corresponding pair of the plurality of support members, and wherein each of the plurality of gaps is sized and shaped to receive electrical wiring. In some embodiments, at least one of the plurality of gaps is sized and shaped to receive an electrical component. In some embodiments, the spacer includes a third end extending from the first end to the second end, and a fourth end opposite the third end and extending from the first end to the second end, and wherein each of the plurality of support members extends from the third end to the fourth end.

[0006] In some embodiments, each of the plurality of support members includes an upper surface, and wherein the at least one solar module is mounted on the upper surface of each of the plurality of support members. In some embodiments, each of the plurality of support members includes a first height measured from the first surface of the base of the spacer to the upper surface of the support member, and the first ledge includes a second height measured from the first surface of the base of the spacer to an upper surface of the first ledge, and wherein the second height is less than the first height. In some embodiments, the at least one solar module and the first ledge form a first space therebetween, and wherein the first space is sized and shaped to receive at least one electrical component. In some embodiments, each of the plurality of support members includes a second ledge located at the second end thereof. In some embodiments, the second ledge includes a third height measured from the first surface of the base of the spacer to an upper surface of the second ledge, and wherein the third height is less than the first height, and wherein the third height is greater than the second height.

[0007] In some embodiments, a system includes a roofing layer configured to be installed directly on a roof deck, the roofing layer including a first surface, and a plurality of hooks installed on the first surface wherein the plurality of hooks is arranged in a pattern, wherein the pattern includes a plurality of rows and a plurality of columns; and a plurality of solar modules configured to be attached to the plurality of hooks. In some embodiments, the roofing layer includes a roofing membrane. In some embodiments, each of the plurality of hooks includes a double wing hook. In some embodiments, each of the plurality of hooks includes a mounting portion, a pair of feet extending from the mounting portion, and a hook portion extending from the mounting portion and offset from the pair of feet to form a slot therebetween, wherein a first edge of one of the plurality of solar modules engages the slot of one of the plurality of hooks, and a second edge of the one of the plurality of solar modules engages the hook portion of at least another one of the plurality of hooks. In some embodiments, the roofing layer includes at least one roofing shingle, wherein the roofing shingle includes a head lap, and wherein the mounting portion of at least one of the plurality of hooks is attached to the head lap of a corresponding one of the at least one roofing shingle. In some embodiments, the pattern is a long-staggered pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a top perspective view of an embodiment of a photovoltaic module;

[0009] FIG. 2 is an exploded, top perspective view of the photovoltaic module of FIG. 1;

[0010] FIG. 3 is a bottom perspective view of a solar module employed by the photovoltaic module of FIG. 1;

[0011] FIG. 4 is a top perspective view of the photovoltaic module of FIG. 1 juxtaposed with a shingle;

[0012] FIGS. 5A and 5B are top and bottom perspective views of a spacer employed by the photovoltaic module of FIG. 1;

[0013] FIG. 6 is a side elevational view of the spacer shown in FIGS. 5A and 5B;

[0014] FIGS. 7 through 9 are side elevational views of a plurality of photovoltaic modules shown in FIG. 1, the modules installed on a roof deck and interlocked with one another;

[0015] FIG. 10 is a top perspective view of a plurality of photovoltaic modules shown in FIG. 9;

[0016] FIG. 11 is a photo of a plurality of photovoltaic modules installed on a roof deck;

[0017] FIGS. 12A through 12C are top perspective, bottom perspective and side elevational views of an embodiment of a photovoltaic module;

[0018] FIGS. 13A through 13C are top perspective, bottom perspective and side elevational views of an embodiment of a photovoltaic module;

[0019] FIG. 14 is a side view of an embodiment of a plurality of photovoltaic modules;

[0020] FIGS. 15A and 15B are top perspective and side elevational views of an embodiment of a solar module;

[0021] FIGS. 16A through 16C are top perspective, bottom perspective and side elevational views of an embodiment of a photovoltaic module;

[0022] FIGS. 17 and 18 are photos of embodiments of photovoltaic modules with aesthetic trim installed on a roof deck;

[0023] FIGS. 19A and 19B are photos of embodiments of photovoltaic modules with side flashing installed on a roof deck;

[0024] FIGS. 20 through 22 are top perspective views of an embodiment of a system of mounting mats, roofing shingles and solar modules installed on a roof deck;

[0025] FIGS. 23 and 24 are a top plan view and a photo of an embodiment of the system shown in FIGS. 20 through 22;

[0026] FIGS. 25A and 25B are top perspective and side elevational views of an embodiment of a photovoltaic module;

[0027] FIGS. 26A and 26B are top perspective views of an embodiment of a system of solar modules installed on a roof deck; and

[0028] FIGS. 27 through 30 are top perspective views of an embodiment of a system of hook members for installing solar modules on a roof deck.

DETAILED DESCRIPTION

[0029] Referring to FIGS. 1 and 2, in some embodiments, a photovoltaic module 10 includes a mat 12, a spacer 14 juxtaposed with the mat 12, and a solar module 16 mounted to the spacer 14. In some embodiments, the solar module 16 is elevated relative to the mat 12. In some embodiments, the spacer 14 includes a plurality of support members 18. In some embodiments, the solar module 16 is mounted to the plurality of support members 18. In some embodiments, the mat 12 includes a first surface 20 and the spacer 14 overlays the first surface 20 of the mat 12. In some embodiments, the

photovoltaic module 10 is configured to be installed on a roof deck. In some embodiments, the roof deck is a component of a roofing system. In some embodiments, the roofing system includes a plurality of roofing shingles installed on the roof deck. In some embodiments, the roofing shingles include asphalt shingles. In some embodiments, the roofing system includes roof tiles. In some embodiments, the roofing system includes terracotta roof tiles.

[0030] Referring to FIGS. 1 through 3, in some embodiments, at least one solar module 16 includes a first surface 22, a second surface 24 opposite the first surface 22, a first end 26, a second end 28 opposite the first end 26, a first edge 27 extending from the first end 26 to the second end 28, and a second edge 29 opposite the first edge 27 and extending from the first end 26 to the second end 28. In some embodiments, a junction box 30 is mounted to the second surface 24. In some embodiments, the junction box 30 is mounted on the second surface 24 proximate to the first edge 27. In some embodiments, a first electrical connector 32 is mounted to the second surface 24. In some embodiments, a second electrical connector 34 is mounted to the second surface 24. In some embodiments, the first and second electrical connectors 32, 34 are mounted to the second surface 24 proximate to the first edge 27. In some embodiments, the first electrical connector 32 is a female connector. In some embodiments, the second electrical connector 34 is a male connector. In some embodiments, the first electrical connector 32 extends outwardly from the first end 26. In some embodiments, the second electrical connector 34 extends outwardly from the second end 28. In some embodiments, the first and second electrical connectors 32, 34 are electrically connected to the junction box 30 by electrical wires 36, 38, respectively.

[0031] Referring to FIG. 4, in some embodiments, the photovoltaic module 10 includes a first edge 40 and a second edge 42 opposite the first edge 40. In some embodiments, a roofing shingle 44 includes a first edge 46 and a second edge 48 opposite the first edge 46. In some embodiments, the second edge 48 of the roofing shingle 44 is juxtaposed with the first edge 40 of the photovoltaic module 10. In some embodiments, the first edge 46 of the roofing shingle 44 is juxtaposed with the second edge 42 of the photovoltaic module 10. In some embodiments, the roofing shingle 44 includes a head lap 50 and a reveal portion 52. In some embodiments, the head lap 50 is aligned with the mat 12 of the photovoltaic module 10, while the reveal portion 52 is aligned with the solar module 16.

[0032] Referring to FIGS. 5A and 5B, the spacer 14 includes a base 54 having a first surface 56. In some embodiments, the plurality of support members 18 extends outwardly from the first surface 56 of the base 54. In some embodiments, the spacer 14 includes a first edge 58 and a second edge 60 opposite the first edge 58. In some embodiments, the mat 12 is adjacent to the first edge 58 of the base 54 of the spacer 14. In some embodiments, the mat 12 is attached to the first edge 58 of the base 54 of the spacer 14.

[0033] In some embodiments, the mat 12 is composed of a polymer. In some embodiments, the mat 12 includes thermoplastic polyolefin (TPO). In other embodiments, the mat 12 is composed of polyethylene terephthalate (PET), polyethylene naphthalate (PEN), polyetheretherketone (PEEK), polyaryletherketone (PAEK), polyarylate (PAR), polyetherimide (PEI), polyarylsulfone (PAS), polyether-sulfone (PES), polyamideimide (PAI), or polyimide; poly-

vinyl chloride (PVC); ethylene propylene diene monomer (EPDM) rubber; silicone rubber; fluoropolymers-ethylene tetrafluoroethylene (ETFE), polyvinylidene fluoride (PVDF), tetrafluoroethylene-hexafluoropropylene copolymers (FEP), and tetrafluoroethylene-hexafluoropropylene-vinylidene fluoride copolymers (THV), or blends thereof.

[0034] Still referring to FIGS. 5A and 5B, in an embodiment, the spacer 14 includes a first end 62 and a second end 64 opposite the first end 62. In some embodiments, the plurality of support members 18 extends from the first end 62 to the second end 64. In some embodiments, each of the plurality of support members 18 is spaced apart from at least an adjacent one other of the plurality of support members 18. In some embodiments, the spacer 14 includes a plurality of gaps 66, each of which is formed between a corresponding pair of the plurality of support members 18. In some embodiments, each of the plurality of gaps 66 is sized and shaped to receive electrical wiring. In some embodiments, electrical wiring may be routed through at least one of the plurality of gaps 66. In some embodiments, each of the plurality of gaps 66 is configured to permit a flow water to travel and drain therethrough. In some embodiments, at least one gap 68 of the plurality of gaps 66 is sized and shaped to receive an electrical component. In some embodiments, the electrical component is the junction box 30. In some embodiments, the at least one gap 68 of the plurality of gaps 66 receives the junction box 30 when the solar module 16 is positioned on the spacer 14. In some embodiments, each of the plurality of support members 18 extends intermediate the first edge 58 and the second edge 60. In some embodiments, each of the plurality of support members 18 is substantially parallel to one another. In some embodiments, each of the plurality of support members 18 is hollow and includes an interior portion 70. In some embodiments, the interior portions 70 result in a weight reduction of the spacer 14.

[0035] Referring to FIGS. 6 through 8, each of the plurality of support members 18 includes an upper surface 72. In some embodiments, the solar module 16 is mounted on the upper surface 72 of each of the plurality of support members 18. In some embodiments, the solar module 16 is mounted on the upper surface 72 of at least one of the plurality of support members 18. In some embodiments, the upper surface 72 extends obliquely relative to the mat 12.

[0036] In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 4 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 3.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 3 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 2.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 2 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 1.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.1 degree to 1 degree relative to the base 54. In some embodiments, the upper

surface 72 extends obliquely in a range of 0.1 degree to 0.5 degree relative to the base 54.

[0037] In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 4 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 3.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 3 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 2.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 2 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 1.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 0.5 degree to 1 degree relative to the base 54.

[0038] In some embodiments, the upper surface 72 extends obliquely in a range of 1 degree to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1 degree to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1 degree to 4 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1 degree to 3.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1 degree to 3 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1 degree to 2.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1 degree to 2 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1 degree to 1.5 degrees relative to the base 54.

[0039] In some embodiments, the upper surface 72 extends obliquely in a range of 1.5 degrees to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1.5 degrees to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1.5 degrees to 4 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1.5 degrees to 3.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1.5 degrees to 3 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1.5 degrees to 2.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 1.5 degrees to 2 degrees relative to the base 54.

[0040] In some embodiments, the upper surface 72 extends obliquely in a range of 2 degrees to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 2 degrees to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 2 degrees to 4 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 2 degrees to 3.5 degrees relative to the base 54. In some

embodiments, the upper surface 72 extends obliquely in a range of 2 degrees to 3 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 2 degrees to 2.5 degrees relative to the base 54.

[0041] In some embodiments, the upper surface 72 extends obliquely in a range of 2.5 degrees to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 2.5 degrees to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 2.5 degrees to 4 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 2.5 degrees to 3.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 2.5 degrees to 3 degrees relative to the base 54.

[0042] In some embodiments, the upper surface 72 extends obliquely in a range of 3 degrees to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 3 degrees to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 3 degrees to 4 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 3 degrees to 3.5 degrees relative to the base 54.

[0043] In some embodiments, the upper surface 72 extends obliquely in a range of 3.5 degrees to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 3.5 degrees to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 3.5 degrees to 4 degrees relative to the base 54.

[0044] In some embodiments, the upper surface 72 extends obliquely in a range of 4 degrees to 5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 4 degrees to 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely in a range of 4.5 degrees to 5 degrees relative to the base 54.

[0045] In some embodiments, the upper surface 72 extends obliquely 0.1 degree relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 0.5 degree relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 1 degree relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 1.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 2 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 2.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 3 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 3.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 4 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 4.5 degrees relative to the base 54. In some embodiments, the upper surface 72 extends obliquely 5 degrees relative to the base 54.

[0046] Still referring to FIGS. 6 through 8, In some embodiments, each of the plurality of support members 18 includes a first end 74, a second end 76 opposite the first end 74, and a ledge 78 located at the first end 74 of the support member 18. In some embodiments, each of the plurality of support members 18 includes a first height H1 measured from the base 54 of the spacer 14 to the upper surface 72 of

the support member 18 proximate to the first end 74, and the ledge 78 includes a second height H2 measured from the base 54 of the spacer 14 to an upper surface 80 of the ledge 78. In some embodiments, the second height H2 is less than the first height H1. In some embodiments, the ledge 78 includes a raised bump 82. In some embodiments, the solar module 16 and the ledge 78 form a first space 84 therebetween. In some embodiments, the first space 84 is sized and shaped to receive at least one electrical component. In some embodiments, the at least one electrical component includes at least the junction box 30. In some embodiments, the at least one electrical component includes at least one of the first and second electrical connectors 32, 34. In some embodiments, the at least one electrical component includes at least one of the first and second electrical wiring 36, 38. In some embodiments, the raised bump 82 is configured to elevate the first and second electrical connectors 32, 34 relative to the roof deck to prevent water from reaching the connectors 32, 34.

[0047] Still referring to FIGS. 6 through 8, in an embodiment, each of the plurality of support members 18 includes a ledge 86 located at the second end 76 thereof. In some embodiments, each of the plurality of support members 18 includes a third height H3 measured from the base 54 of the spacer 14 to the upper surface 72 of the support member 18 proximate to the second end 76, and the ledge 86 includes a fourth height H4 measured from the base 54 of the spacer 14 to an upper surface 72 of the ledge 86. In some embodiments, the third height H3 is greater than the first height H1. In some embodiments, the third height H3 is greater than the second height H2. In some embodiments, the third height H3 is greater than the fourth height H4. In some embodiments, the fourth height H4 is less than the first height H1. In some embodiments, the fourth height H4 is greater than the second height H2.

[0048] In some embodiments, the first height H1 is in a range of 10 mm to 20 mm. In some embodiments, the first height H1 is in a range of 10 mm to 19 mm. In some embodiments, the first height H1 is in a range of 10 mm to 18 mm. In some embodiments, the first height H1 is in a range of 10 mm to 17 mm. In some embodiments, the first height H1 is in a range of 10 mm to 16 mm. In some embodiments, the first height H1 is in a range of 10 mm to 15 mm. In some embodiments, the first height H1 is in a range of 10 mm to 14 mm. In some embodiments, the first height H1 is in a range of 10 mm to 13 mm. In some embodiments, the first height H1 is in a range of 10 mm to 12 mm. In some embodiments, the first height H1 is in a range of 10 mm to 11 mm.

[0049] In some embodiments, the first height H1 is in a range of 11 mm to 20 mm. In some embodiments, the first height H1 is in a range of 11 mm to 19 mm. In some embodiments, the first height H1 is in a range of 11 mm to 18 mm. In some embodiments, the first height H1 is in a range of 11 mm to 17 mm. In some embodiments, the first height H1 is in a range of 11 mm to 16 mm. In some embodiments, the first height H1 is in a range of 11 mm to 15 mm. In some embodiments, the first height H1 is in a range of 11 mm to 14 mm. In some embodiments, the first height H1 is in a range of 11 mm to 13 mm. In some embodiments, the first height H1 is in a range of 11 mm to 12 mm.

[0050] In some embodiments, the first height H1 is in a range of 12 mm to 20 mm. In some embodiments, the first

embodiments, the fourth height H4 is 9 mm. In some embodiments, the fourth height H4 is 10 mm. In some embodiments, the fourth height H4 is 11 mm. In some embodiments, the fourth height H4 is 12 mm. In some embodiments, the fourth height H4 is 13 mm. In some embodiments, the fourth height H4 is 14 mm. In some embodiments, the fourth height H4 is 15 mm.

[0078] In some embodiments, the solar module 16 and the ledge 86 form a second space 88 therebetween. In some embodiments, the second space 88 of one 10a of the photovoltaic modules 10 is sized and shaped to receive the first edge 27 of the solar module 16 of another 10b photovoltaic module 10 and interlock the photovoltaic modules 10a, 10b. In some embodiments, the solar module 16 of the photovoltaic module 10a overlays and holds-down the first edge 27 of the solar module 16 of the photovoltaic module 10b. In some embodiments, the interlocked photovoltaic modules 10a, 10b promote watershedding.

[0079] In some embodiments, the photovoltaic modules 10a, 10b are installed on a roof deck by a plurality of fasteners 90. In some embodiments, the mat 12 is configured to receive the plurality of fasteners 90. In some embodiments, the plurality of fasteners 90 includes a plurality of nails. In some embodiments, the mat 12 includes a head lap 92. In some embodiments, the head lap 92 is configured to receive the plurality of nails. In some embodiments, the second edge 60 of the spacer 14 is attached to the roof deck by an adhesive 94. In certain embodiments, the adhesive 94 includes polyvinyl butyrate, acrylic, silicone, polycarbonate, or pressure sensitive adhesives.

[0080] In some embodiments, the spacer 14 of one of the photovoltaic modules 10 overlays the mat 12 of another of the photovoltaic modules 10. In some embodiments, the spacer 14 of one of the photovoltaic modules 10 overlays the head lap 92 of the mat 12 of another of the photovoltaic modules 10.

[0081] Referring to FIGS. 9 and 10, in an embodiment, a starter bar 96 is engaged with the ledge 86 of the spacer 14 of one of the photovoltaic modules 10. In some embodiments, the starter bar 96 includes a base 98, a front wall 99 extending from the base 98, an upper rail 100 extending from the front wall, and a channel 102 formed by the base 98, the front wall 99 and the upper rail 100. In some embodiments, the front wall 99 extends substantially perpendicular to the base 98. In some embodiments, the upper rail 100 extends substantially parallel to the base 98. In some embodiments, the starter bar 96 includes a C-shaped cross-section. In some embodiments, the channel 102 is sized and shaped to receive the second edge 60 of the spacer 14, such that the second edge 60 is positioned therein intermediate the base 98 and the upper rail 100. In some embodiments, the upper rail 100 is configured to be positioned intermediate the ledge 86 of the spacer 14 and the second edge 29 of the solar module 16. In some embodiments, the starter bar 96 is installed on the roof deck. In some embodiments, the base 98 of the starter bar 96 is attached to the roof deck. In some embodiments, the base 98 is attached to the roof deck by a plurality of the nails 90. In some embodiments, FIG. 11 shows a system of a plurality of photovoltaic modules 10 and a plurality of the roofing shingles 44 installed on a roof deck 104.

[0082] In some embodiments, the spacer 14 is composed of plastic. In some embodiments, the spacer 14 is composed of a polymer. In some embodiments, the polymer is a

thermoformed polymer. In some embodiments, the polymer is an injection molded polymer. In some embodiments, the spacer 14 is ultrasonically welded to the mat 12. In some embodiments, the spacer 14 is heat welded to the mat 12. In some embodiments, the spacer 14 is thermally bonded to the mat 12. In some embodiments, the spacer 14 is attached to the mat 12 by an adhesive. In some embodiments, the spacer 14 and the mat 12 are integral with one another. In some embodiments, the solar module 16 is ultrasonically welded to the spacer 14. In some embodiments, the solar module 16 is removably attached to the spacer 14. In some embodiments, the solar module 16 is heat welded to the spacer 14. In some embodiments, the solar module 16 is thermally bonded to the spacer 14. In some embodiments, the solar module 16 is attached to the spacer 14 by an adhesive. In some embodiments, the spacer 14 is composed of metal. In some embodiments, the spacer 14 is composed of aluminum.

[0083] Referring to FIGS. 12A through 12C, in another embodiment, a photovoltaic module 210 includes a spacer 214 and a solar module 216 attached to the spacer 214. In some embodiments, the spacer 214 includes a plurality of support members 218. In some embodiments, the spacer 214 includes at least one tab 221 extending outwardly from a first edge 258 thereof. In some embodiments, the at least one tab 221 extends from a corresponding one of the plurality of support members 218. In some embodiments, the at least one tab 221 includes a plurality of the tabs 221. In some embodiments, the at least one tab 221 is configured to receive a fastener. In some embodiments, the fastener includes a nail. In some embodiments, the spacer 214 is composed of metal. In some embodiments, the spacer 214 is composed of sheet metal.

[0084] Referring to FIGS. 13A through 13C, in another embodiment, a photovoltaic module 310 includes a spacer 314 and a solar module 316 attached to the spacer 314. In some embodiments, the spacer 314 includes a plurality of support members 318. In some embodiments, the spacer 314 includes at least one tab 321 extending outwardly from a first edge 358 thereof. In some embodiments, the at least one tab 321 extends from a corresponding one of the plurality of support members 318. In some embodiments, the at least one tab 321 includes a plurality of the tabs 321. In some embodiments, the at least one tab 321 is configured to receive a fastener. In some embodiments, the fastener includes a nail. In some embodiments, the spacer 314 is composed of plastic. In some embodiments, the spacer 314 is injection molded. Referring to FIG. 14, a side lap 311 extends between two of adjacent photovoltaic modules 310a, 310b. In some embodiments, the side lap 311 is located intermediate the spacer 314 and the solar module 316 of each of the photovoltaic modules 310a, 310b.

[0085] Referring to FIGS. 15A through 16C, in another embodiment, a photovoltaic module 410 includes a spacer 414 and at least two solar modules 416a, 416b attached to the spacer 414. In some embodiments, the solar modules 416a, 416b are aligned in rows. In some embodiments, the spacer 414 includes a plurality of support members 418. In some embodiments, the spacer 414 includes at least one tab 421 extending outwardly from a first edge 458 thereof. In some embodiments, the at least one tab 421 includes a plurality of the tabs 421. In some embodiments, the at least one tab 421 is configured to receive a fastener. In some embodiments, the fastener includes a nail. In some embodi-

ments, the spacer **414** includes sidewalls **415a**, **415b** that enclose the photovoltaic module **410** when it is installed on roof deck.

[0086] Referring to FIGS. 17 through 19B, in an embodiment, at least one trim element **106** is attached to at least one of the first and second ends **26**, **28** of the solar module **16**. In some embodiments, the trim element **106** is clipped to the at least one of the first and second ends **26**, **28**. In some embodiments, the trim element **106** includes an upper surface **108**. In some embodiments, the upper surface **108** is oblique relative to the first surface **22** of the solar module **16**. In some embodiments, the solar module **16** includes a corner **110** formed by the first end **26** and the first edge **27** and the trim element **106** is attached to the corner **110**. In other embodiments, the corner **110** may be formed by the first edge **27** and the second edge **29**, the second end **28** and the first edge **27**, or the second end **28** and the second edge **29**, one or more of which is configured to receive a corresponding trim element **106**. In some embodiments, the trim element **106** includes a curvilinear side surface **112**. In some embodiments, the trim element **106** includes flashing **114**. In some embodiments, at least one roofing shingle **116** overlays the upper surface **108** of the trim element **106**.

[0087] Referring to FIGS. 20 through 22, in an embodiment, a roofing system **500** includes a photovoltaic module **510** configured to be installed on a roof deck **505**. In some embodiments, the photovoltaic module **510** includes at least one mat **512** configured to be installed to the roof deck **505**, at least one spacer **514** installed on the mat **512**, and at least one solar module **516** mounted to a corresponding one of the at least one spacer **514**. In some embodiments, the at least one spacer **514** includes a plurality of spacers **514**. In some embodiments, the at least one solar module **516** includes a plurality of solar modules **516** mounted to a corresponding one of the plurality of spacers **514**.

[0088] In some embodiments, the at least one mat **512** includes a first end **518** and a second end **520** opposite the first end **518**, a first edge **522** extending from the first end **518** to the second end **520**, and a second edge **524** opposite the first edge **522** and extending from the first end **518** to the second end **520**. In some embodiments, the at least one mat **512** includes a head lap **526**. In some embodiments, the at least one solar module **516** includes a first end **528** and a second end **530** opposite the first end **528**. In some embodiments, the first end **528** of the at least one solar module **516** is substantially aligned with the first end **518** of the at least one mat **512**, and the second end **530** of the at least one solar module **516** is substantially aligned with the at least one second end **520** of the mat **512**. In some embodiments, the second end **530** of the at least one solar module **516** is substantially aligned with the first end **518** of the at least one mat **512**, and the first end **528** of the at least one solar module **516** is substantially aligned with the at least one second end **520** of the mat **512** (see FIG. 22). Referring to FIGS. 23 and 24, in an embodiment, the first end **528** of the at least one solar module **516** is offset from the first end **518** of the at least one mat **512**, and the second end **530** of the at least one solar module **516** is offset from the second end **520** of the at least one mat **512**. In some embodiments, at least one shingle section **532** overlays an exposed area **534** of the mat **512**.

[0089] In some embodiments, the at least one mat **512** includes a plurality of mats **512**. In some embodiments, the

roofing system **500** includes a plurality of roofing shingles **544** installed adjacent to the at least one mat **512**.

[0090] Referring to FIGS. 25A and 25B, in an embodiment, the at least one mat **512** includes at least one first hook member **540**. In some embodiments, the photovoltaic module **510** includes at least one second hook member **542** engaged with a corresponding one of the at least one first hook member **540**. In some embodiments, the at least one first hook member **540** includes at least one pair of first hook members **540** and the at least one second hook member **542** includes at least one pair of second hook members **542**. In some embodiments, each of the at least one pair of first hook members **540** engages a corresponding one of the at least one pair of second hook members **542**. In some embodiments, each of the at least one pair of first hook members **540** is spaced apart from one another. In some embodiments, the at least one pair of second hook members **542** is spaced apart from one another. In some embodiments, the at least one pair of first hook members **540** includes a plurality of pairs of first hook members **540**. In some embodiments, each of the plurality of pairs of first hook members **540** is spaced apart from one another. In some embodiments, the plurality of pairs of first hook members **540** are aligned in rows.

[0091] Referring to FIGS. 26A and 26B, in an embodiment, a roofing system **600** includes a roofing layer **612** configured to be installed directly on a roof deck **605**. In some embodiments, the roofing layer **612** includes a roofing membrane. In some embodiments, the roofing membrane is configured to be rolled. In some embodiments, the roofing membrane is composed of a polymer. In some embodiments, the roofing membrane includes thermoplastic polyolefin (TPO). In other embodiments, the roofing membrane is composed of polyethylene terephthalate (PET), polyethylene naphthalate (PEN), polyetheretherketone (PEEK), polyaryletherketone (PAEK), polyarylate (PAR), polyetherimide (PEI), polyarylsulfone (PAS), polyethersulfone (PES), polyamideimide (PAI), or polyimide; polyvinyl chloride (PVC); ethylene propylene dicn monomer (EPDM) rubber; silicone rubber; fluoropolymers-ethylene tetrafluoroethylene (ETFE), polyvinylidene fluoride (PVDF), tetrafluoroethylene-hexafluoropropylene copolymers (FEP), and tetrafluoroethylene-hexafluoropropylene-vinylidene fluoride copolymers (THV), or blends thereof. In some embodiments, the roofing layer **612** includes a first surface **614**.

[0092] In some embodiments, a plurality of hooks **650** is installed on the first surface **614** of the roofing layer **612**. In some embodiments, the system **600** includes a plurality of solar modules **616** configured to be attached to the plurality of hooks **650**. In some embodiments, each of the plurality of hooks **650** includes a double wing hook. In some embodiments, the plurality of hooks **650** is arranged in a defined pattern. In some embodiments, the pattern includes a plurality of rows and a plurality of columns. In some embodiments, the plurality of hooks **650** is arranged in a long-staggered pattern, as shown in FIGS. 26A and 26B. In some embodiments, the plurality of hooks **650** in each row of the long-staggered pattern are arranged and located in alternate columns. In some embodiments, the plurality of hooks **650** is arranged in a short-staggered pattern. In some embodiments, the plurality of hooks **650** in each column of the short-staggered pattern are arranged and located in alternate rows. In some embodiments, the plurality of hooks **650** is arranged in a square or rectangular pattern. In some embodiments, the plurality of hooks **650** in each row of the

long-staggered pattern are arranged and located in each column, and vice-versa. In some embodiments, the plurality of hooks **650** is arranged in a random pattern.

[0093] Referring to FIGS. **27** through **30**, in an embodiment, a roofing layer **712** includes at least one roofing shingle **720**. In some embodiments, the at least one roofing shingle **720** is installed on the roof deck **705** by a plurality of fasteners. In some embodiments, the at least one roofing shingle **720** includes a plurality of roofing shingles **720**. In some embodiments, the at least one shingle **720** includes a head lap **722**. In some embodiments, the head lap **722** is configured to receive the plurality of fasteners. In some embodiments, the plurality of fasteners includes a plurality of nails. In some embodiments, the at least one roofing shingle **720** is installed on the roof deck **705** by an adhesive. In some embodiments, one of the plurality of roofing shingles **720** overlays the head lap **722** of another of the plurality of roofing shingles **720**.

[0094] In some embodiments, a plurality of hooks **750** includes a mounting portion **752**, a pair of legs **754a**, **754b** extending from the mounting portion **752**, and a hook portion **756** extending from the mounting portion **752** and offset from the pair of legs **754a**, **754b** to form a slot **758** therebetween.

[0095] In some embodiments, the pair of legs **754a**, **754b** are spaced apart and substantially parallel to one another. In some embodiments, the hook portion **756** includes a first portion **755a** extending in a first direction and second portion **755b** extending in a second direction opposite the first direction. In some embodiments, a slot **757** is formed between the first and second portions **755a**, **755b**. In some embodiments, each of the legs **754a**, **754b** includes an extended portion **759** and a foot **760** having a raised portion **761** offset from the extended portion **759**. In some embodiments, a first edge **727** of one of the plurality of solar modules **716** engages the slot **758** of one of the plurality of hooks **750**, and a second edge **729** of one of the plurality of solar modules **716** engages the hook portion **756** of at least another one of the plurality of hooks **750**. In some embodiments, the hook portion **756** is resiliently biased. In some embodiments, the mounting portion **752** is attached to the head lap **722** of the corresponding one of the plurality of roofing shingles **720**. In some embodiments, the mounting portion **752** is configured to receive at least one fastener. In some embodiments, the at least one fastener includes at least one nail.

[0096] It should be understood that the embodiments described herein are merely exemplary and that a person skilled in the art may make many variations and modifications without departing from the spirit and scope of the invention. All such variations and modifications are intended to be included within the scope of the invention.

What is claimed is:

1. A system, comprising:

a roof deck;

a plurality of photovoltaic modules installed on the roof deck,

wherein the plurality of photovoltaic modules is arranged in an array,

wherein the array includes

an upper side extending along the roof deck,

a lower side extending along the roof deck,

at least a first side extending between the upper side and the lower side, and

an upper surface,

wherein the upper surface extends in a first plane;

at least one trim element installed on the roof deck,

wherein the at least one trim element includes a first trim element,

wherein the first trim element is proximate to the first side of the array; and

a plurality of roofing shingles installed on the roof deck, wherein each of the plurality of roofing shingles includes an upper surface,

wherein the plurality of roofing shingles includes a first roofing shingle,

wherein the first roofing shingle includes a first end,

wherein the first roofing shingle overlays the first trim element,

wherein at least a portion of the first roofing shingle extends in a second plane,

wherein the second plane is different from the first plane, and

wherein the upper surface of the array is above the upper surface of the first roofing shingle, and

wherein the first end of the first roofing shingle is adjacent to the upper surface of the array at the first plane.

2. The system of claim 1, wherein the first trim element includes an upper surface, and wherein the at least a portion of the first roofing shingle overlays the upper surface of the first trim element.

3. The system of claim 1, wherein each of the plurality of photovoltaic modules extends substantially in the first plane.

4. The system of claim 1, wherein the second plane is oblique to the first plane.

5. The system of claim 1, wherein the first roofing shingle is an asphalt shingle.

6. The system of claim 1, wherein the plurality of photovoltaic modules includes a first photovoltaic module, and wherein the first trim element is clipped to the first photovoltaic module.

7. The system of claim 1, wherein the array includes a second side extending between the upper side and the lower side, wherein the at least one trim element includes a second trim element, and wherein the second trim element is located proximate to the second side of the array.

8. The system of claim 7, wherein the plurality of roofing shingles includes a second roofing shingle, and wherein at least a portion of the second roofing shingle overlays the second trim element.

9. The system of claim 8, wherein the second trim element includes an upper surface, and wherein the at least a portion of the second roofing shingle overlays the upper surface of the second trim element.

10. The system of claim 8, wherein the second roofing shingle is an asphalt shingle.

11. The system of claim 7, wherein the plurality of photovoltaic modules includes a second photovoltaic module, wherein the second trim element is clipped to the second photovoltaic module.

12. A system, comprising:

a roof deck;

a plurality of photovoltaic modules installed on the roof deck,

wherein the plurality of photovoltaic modules is arranged in an array,

wherein the array includes

an upper side extending along the roof deck,
 a lower side extending along the roof deck,
 a first side extending between the upper side and the lower side,
 a second side extending between the upper side and the lower side, and
 an upper surface,
 wherein the upper surface extends in a first plane;
 a plurality of trim elements installed on the roof deck,
 wherein the plurality of trim elements includes a first trim element and a second trim element,
 wherein the first trim element is proximate to the first side of the array,
 wherein the second trim element is proximate to the second side of the array; and
 a plurality of roofing shingles installed on the roof deck,
 wherein each of the plurality of roofing shingles includes an upper surface and a first end,
 wherein the plurality of roofing shingles includes a first roofing shingle and a second roofing shingle,
 wherein the first roofing shingle overlays the first trim element,
 wherein at least a portion of the first roofing shingle extends in a second plane, and
 wherein the second plane is different from the first plane,
 wherein the second roofing shingle overlays the second trim element,
 wherein at least a portion of the second roofing shingle extends in a third plane,
 and wherein the third plane is different from the first plane,
 wherein the upper surface of the array is above the upper surface of the first roofing shingle and the upper surface of the second roofing shingle,
 wherein the first end of the first roofing shingle is adjacent to the upper surface of the array at the first plane, and
 wherein the first end of the second roofing shingle is adjacent to the upper surface of the array at the first plane.

13. The system of claim **12**, wherein each of the first trim element and the second trim element includes an upper surface, wherein the at least a portion of the first roofing shingle overlays the upper surface of the first trim element, and wherein the at least a portion of the second roofing shingle overlays the upper surface of the second trim element.

14. The system of claim **12**, wherein each of the plurality of photovoltaic modules extends substantially in the first plane.

15. The system of claim **12**, wherein the second plane is oblique to the first plane.

16. The system of claim **12**, wherein the third plane is oblique to the first plane.

17. The system of claim **12**, wherein each of the first roofing shingle and the second roofing shingle is an asphalt shingle.

18. The system of claim **12**, wherein the plurality of photovoltaic modules includes a first photovoltaic module and a second photovoltaic module, wherein the first trim element is clipped to the first photovoltaic module, and wherein the second trim element is clipped to the second photovoltaic module.

19. A system, comprising:

a roof deck;

a plurality of photovoltaic modules installed on the roof deck,

wherein the plurality of photovoltaic modules is arranged in an array,

wherein the array includes

an upper side extending along the roof deck,

a lower side extending along the roof deck,

at least a first side extending between the upper side and the lower side, and

an upper surface,

wherein the upper surface extends in a first plane;

at least one trim element installed on the roof deck,

wherein the at least one trim element includes a first trim element,

wherein the first trim element is proximate to the first side of the array; and

a plurality of roofing shingles installed on the roof deck,

wherein each of the plurality of roofing shingles includes an upper surface,

wherein the plurality of roofing shingles includes a first roofing shingle,

wherein the first roofing shingle includes a first end,

wherein the first roofing shingle overlays the first trim element,

wherein at least a portion of the first roofing shingle extends in a second plane,

wherein the second plane is different from the first plane, and

wherein the upper surface of the array is above the upper surface of the first roofing shingle, and

wherein the first end of the first roofing shingle intersects the upper surface of the array at the first plane.

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