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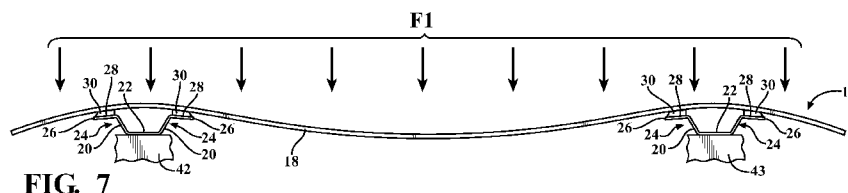
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(54) **Title:** PHOTOVOLTAIC MODULE ASSEMBLY AND METHOD OF ASSEMBLING THE SAME



(57) **Abstract:** A photovoltaic module assembly includes a photovoltaic module having at least one crystalline silicon photovoltaic cell. A rail is fixed relative to the module and extends along a width of the module to support the photovoltaic module in a landscape orientation on a racking system of an installation site. Adhesive is disposed between and contacts the photovoltaic module and the rail to adhere the rail to the photovoltaic module. The adhesive is formed from a silicone composition. The rail includes a base for abutting the racking system and a pair of legs extending from the base. The legs each present an adhesive receiving surface with the adhesive extending from the adhesive receiving surfaces to the photovoltaic module. The adhesive receiving surfaces are spaced from each other so that the legs move relative to each other when a load is applied to the module in excess of a predetermined level.

PHOTOVOLTAIC MODULE ASSEMBLY AND METHOD OF ASSEMBLING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention includes photovoltaic module assembly for mounting on a racking system of a photovoltaic module installation site.

2. Description of the Related Art

[0002] A photovoltaic module includes a photovoltaic cell that converts sunlight into electricity. Each of a plurality of photovoltaic modules are typically connected at a photovoltaic module installation site such as a solar field, e.g., for large-scale commercial energy production, a roof top of building, a side of a building, etc. The photovoltaic module installation site includes a racking system for supporting the plurality of photovoltaic modules. For packaging reasons, it is often advantageous to mount the photovoltaic module on the racking system in a landscape orientation.

[0003] The photovoltaic module is assembled into a photovoltaic module assembly for mounting to the racking system. Specifically, the photovoltaic module is combined with a rail that is suitable to engage the racking system to mount the photovoltaic module assembly on the racking system.

[0004] In many situations, it is often advantageous to use “short” rails to mount the photovoltaic module assembly to the racking system. Specifically, the photovoltaic module is typically rectangular in shape and has a width and a length longer than the width. The “short” rails extend along the width of the photovoltaic module. The use of “short” rails that extend along the width of the photovoltaic module, as opposed to longer rails that would extend along the length of the photovoltaic module, advantageously reduces the amount of material required to form the rail and the amount of material required to attach the rail to the module, thereby reducing cost.

[0005] The photovoltaic module referred to as “crystalline silicon modules” typically includes a back sheet, at least one crystalline silicon photovoltaic cell supported on the back sheet, a first encapsulant layer supported on the photovoltaic cell, and a cover sheet supported on the first encapsulant layer. The crystalline silicon photovoltaic cell is relatively fragile and can crack when bent, which ruins the photovoltaic module. The other components of the photovoltaic module are relatively

flexible and thus, in the absence of proper support, are subject to bending, which can ultimately lead to the cracking the crystalline silicon photovoltaic cell.

[0006] The “short” rails provide less rigidity and support to the photovoltaic module, thus allowing the photovoltaic module to bend more than typically associated with longer rails. When assembled to the racking system at the photovoltaic module installation site, the photovoltaic module is subject to loads such as, for example, those associated with wind and snow and/or ice on the photovoltaic module.

[0007] Due to the advantages associated with mounting the photovoltaic modules in a landscape orientation and the advantages associated with the use of “short” rails, it would be advantageous to develop a photovoltaic module assembly including “short” rails and capable of being mounted to a racking system in a landscape orientation while reducing breakage of the crystalline silicon photovoltaic cell, back sheet, and/or cover sheet due to loads applied to the photovoltaic module assembly while mounted on the racking system.

SUMMARY OF THE INVENTION AND ADVANTAGES

[0008] The present invention includes a photovoltaic module assembly for mounting on a racking system of a photovoltaic module installation site. The photovoltaic module assembly comprising at least one photovoltaic module including a back sheet, at least one crystalline silicon photovoltaic cell supported on the back sheet, a first encapsulant layer supported on the photovoltaic cell, and a cover sheet supported on the first encapsulant layer. At least one rail is fixed relative to the back sheet and is configured to support the at least one photovoltaic module on the racking system of the photovoltaic module installation site. The photovoltaic module defines a width and a length greater than the width. The rail extends along the width for mounting the photovoltaic module to the racking system. Adhesive is disposed between and contacts the back sheet of the photovoltaic module and the rail to adhere the rail to the photovoltaic module. The adhesive is formed from a silicone composition. The rail includes a base for abutting the racking system and a pair of legs extending from the base. The legs each present an adhesive receiving surface with the adhesive extending from the adhesive receiving surfaces to the photovoltaic module. The adhesive receiving surfaces are spaced from each other so that the legs move relative to each other when a load is applied to the module in excess of a predetermined level.

[0009]

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0011] Figure 1 is a perspective view of a photovoltaic module assembly;

[0012] Figure 2 is a perspective view of a rail of the photovoltaic module assembly;

[0013] Figure 3 is a perspective view of a photovoltaic module installation site including a plurality of solar module assemblies on a racking system;

[0014] Figure 4 is a perspective view of the photovoltaic module assemblies of Figure 1 when subjected to a load;

[0015] Figure 5 is a perspective view of the photovoltaic module assemblies of Figure 1 when subjected to another load;

[0016] Figure 6 is a rear view of the photovoltaic module assembly of Figure 3;

[0017] Figure 7 is a rear view of the photovoltaic module assembly of Figure 4;

[0018] Figure 8 is a rear view of the photovoltaic module assembly of Figure 5;

[0019] Figure 9 is an enlarged view of a portion of Figure 6;

[0020] Figure 10 is an enlarged view of a portion of Figure 7;

[0021] Figure 11 is an enlarged view of a portion of Figure 8;

[0022] Figure 12 is a cross-sectional view of along line 12 of Figure 1;

[0023] Figure 13 is a perspective view of another embodiment of the rail;

[0024] Figure 14 is a side view of the rail of Figure 13;

[0025] Figure 15 is a side view of the rail of Figure 13 assembled to a photovoltaic module;

[0026] Figure 16 is a perspective view of another embodiment of the rail including an opening for receiving a nut and a fastener;

[0027] Figure 17 is a side view of the rail of Figure 16 assembled to the racking system of the photovoltaic module installation site;

[0028] Figure 18 is a top view of the rail of Figure 16 assembled to the racking system of the photovoltaic module installation site;

[0029] Figure 19 is another embodiment of the photovoltaic module assembly including rails connecting two photovoltaic modules in a landscape orientation; and

[0030] Figure 20 is another embodiment of the photovoltaic module assembly including rails connecting two photovoltaic modules in a portrait orientation.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Referring to the Figures, wherein like numerals indicate like parts throughout the several views, a photovoltaic module assembly 10 is generally shown in Figure 1. With reference to Figure 3, the photovoltaic module assembly 10 is supported on a frame 12 of a racking system 14 of a photovoltaic module installation site 16. Specifically, the photovoltaic module assembly 10 includes at least one photovoltaic module 18 and at least one rail 20 mounted to the photovoltaic module 18 for engaging the frame 12. The photovoltaic module assembly 10, also referred to in industry as a solar cell module assembly, converts sunlight into electricity. Typically various components such as inverters, batteries, wiring, etc., are connected to the photovoltaic module assembly 10 and are not shown in the Figures for the sake of drawing clarity. The photovoltaic module 18 installation site 16 can, for example, be a solar field, e.g., for large-scale commercial energy production, a roof top of building, a side of a building, etc.

[0032] The at least one rail 20 can be further defined as a plurality of rails 20. For example, as shown in Figures 1 and 6-8, the photovoltaic module assembly 10 includes two rails 20. However, it should be appreciated that the photovoltaic module assembly 10 can include any number of rails 20 without departing from the nature of the present invention. The rail 20 can be formed of any type of material such as, for example, galvanized steel, aluminum, etc. The rail 20 can be, for example, 0.9m to 1m long.

[0033] The rail 20 is generally hat-shaped. In other words, the rail 20 includes a base 22 for abutting the frame 12 of the racking system 14 and a pair of legs 24 extend from the base 22. Specifically, the legs 24 each include a member 25 and a wing 26 that extend transversely and outwardly from the member 25. The base 22 extends along a lateral axis AL between the legs 24 and the legs 24 each typically extend from the base 22 at between 55 and 90 degrees relative to the lateral axis AL.

[0034] In one embodiment of the rail 20 shown in Figures 1-2 and 6-11, the wings 26 extend generally in parallel with the base 22. Alternatively, in the embodiment of the rail 20, the wings 26 extend transversely to the base 22, i.e., the wings 26 lie in a plane that intersects a plane in which the base 22 lies.

[0035] The rail 20 is configured to support the photovoltaic module assembly 18 on the frame 12 of the racking system 14 of the photovoltaic module installation site 16, as shown in Figures 3-5. Specifically, for example, a fastener 44 and nut 46 can be used to attach the rail 20 to the frame 12, as shown in Figures 16-18. The nut 46 can be referred to in industry as a “blind panel nut.” In such a configuration, the rail 20 defines an opening 48 that includes an enlarged portion 50 and a neck 52. The nut 46 and the opening 48 are sized and shaped such that the nut 46 can be inserted into the enlarged portion 50 and is retained by the neck 52, i.e., does not fit through the neck 52. The nut 46 is typically in the shape of a parallelogram. The neck 52 is sized to receive the fastener 44.

[0036] As shown in Figure 17, the frame 12 defines a hole 54 sized and shaped to receive the fastener 44. The fastener 44 is threaded and the nut 46 defines a threaded hole 56 configured to threadedly engage the fastener 44.

[0037] As best shown in Figures 17 and 18, the nut 46 has a length LN and the base 22 has a length LB. The length LN of the nut 46 and the length LB of the base 22 are sized such that the base 22 prevents rotation of the nut 46 relative to the base 22 about the threaded hole 56 when the nut 46 abuts the base 22. The length LN of the nut 46 is also sized such that the nut 46 can rotate relative to the base 22 about the threaded hole 56 when the nut 46 is spaced from the base 22 between the legs 24.

[0038] In use, the fastener 44 is inserted into the hole 54 and is subsequently threadedly engaged with the nut 46 such that the nut 46 can be spaced from the frame 12, i.e., such that the nut 46 is loose relative to the frame 12. The nut 46 is then inserted into the enlarged portion 50 of the opening 48. The rail 20 is then moved relative to the fastener 44 such that the neck 52 receives the fastener 44.

[0039] With the nut 46 spaced from the base 22, the nut 46 is rotated such that the length LN of the nut 46 is parallel to the length LB of the base 22, as shown in Figures 17 and 18. At this point, the nut 46 is moved to abut the base 22 such that the base 22 prevents further rotation of the nut 46 relative to the base 22. The fastener 44 is then rotated relative to the nut 46 to tighten the nut 46 against the base 22.

[0040] In an alternative embodiment, the nut 46 can be shaped to include surfaces that allow a predetermined amount of rotation of the nut 46 relative to the rail 20. After the predetermined amount of rotation, these surfaces engage the legs 24 and prevent further rotation of the nut 46 relative to the rail 20, thereby allowing relative rotation

between the fastener 44 and the nut 46 such that the fastener 44 and nut 46 allow can be tightened to the rail 20 frame 12.

[0041] In an alternative embodiment, the nut 46 can be fixed to the rail 20, e.g., by welding, adhesive, etc., such that the fastener 44 is inserted through the hole 54 and aligned with and threadedly engaged with the threaded hole 56. In addition to or in the alternative to the fastener 44 and the nut 46, the rail 20 can, for example, include a hook (not shown) sized and shaped to engage the racking system 14. In addition to or in the alternative to the hook, other types of fasteners (not shown) typically can secure the rail 20 to the racking system 14. However, it should be appreciated that the rail 20 can be engaged with the racking system 14 in any suitable fashion without departing from the nature of the present invention.

[0042] The at least one photovoltaic module 18 can be further defined as a plurality of photovoltaic modules 18, as shown in Figures 19 and 20, for example. In other words, the photovoltaic module assembly 10 can include a plurality of photovoltaic modules 18, i.e., typically referred to in industry as a multi-module panel. The photovoltaic module assemblies 18 shown in Figures 1-8 include two rails 20 and one photovoltaic module 18 and the photovoltaic module assemblies 18 shown in Figures 19 and 20 include two rails and two photovoltaic modules 18. It should be appreciated that the rails 20 are shown schematically in Figures 19a and 20 and the rails 20 in Figures 19 and 20 can be hat-shaped such as in Figures 2 or 13. The photovoltaic module assembly 10 can include any number of rails 20, i.e., one or more rails 20, and any number of photovoltaic modules 18, i.e., one or more photovoltaic modules 18, without departing from the nature of the present invention. When the photovoltaic module assembly 10 includes a plurality of photovoltaic modules 18, each of the photovoltaic modules 18 of the assembly 10 are physically connected to each other via the rail 20 and are also typically electrically connected to each other.

[0043] Typically, the rail 20 is connected to the photovoltaic modules 18 only with adhesive 30, as set forth further below, i.e., the photovoltaic module assembly 10 is frameless. A frameless embodiment of photovoltaic module assembly 10 is one that lacks a support structure around the periphery (edge) of the photovoltaic module 18. The rail 20 is adhesively secured to the photovoltaic module 18 and the adhesive 30 acts as a structural adhesive that supports the at least one photovoltaic module 18 on the at least one rail 20. The attachment of the rail 20 to the photovoltaic module 18 is

typically free of any type of mechanical hardware such as fasteners and clamps that clamp the rail 20 onto the photovoltaic module 18, i.e., the rail 20 typically is not mechanically fastened to the photovoltaic module 18. As such, the material and assembly costs associated with such mechanical hardware or fasteners are eliminated and the handling of the fragile photovoltaic modules 18 by workers associated with assembling mechanical hardware or fasteners is eliminated. In addition, damage to the photovoltaic modules 18 caused by over-tightening of the mechanical hardware is eliminated. Also, the adhesive 30 is a theft deterrent because it is relatively difficult to break the adhesive 30 between the rail 20 and the photovoltaic module 18 without proper tools.

[0044] The photovoltaic module 18 defines a width W and a length L greater than the width W . In the embodiment shown in Figures 1-19. The length L of the photovoltaic modules 18 is, for example, typically 2m and the width W is typically 1m-2m, however, the photovoltaic modules 18 can be of any size. For example, the length L and the width W can correspond to the dimensions of a module 18 having 72 photovoltaic cells 34 or a module 18 having 96 photovoltaic cells 34. In the configuration shown in Figures 1-19, the rail 20 extends continuously from one end to another end of the module 18 along the width W of the module 18. In the configuration shown in Figure 20, the rail 20 extends continuously from one end to another end of the module 18 along the length L of the module 18.

[0045] The photovoltaic modules 18 can be mounted to the racking system 14 in a landscape orientation, as shown in Figures 1-19, or in a portrait orientation, as shown in Figure 20. In the configuration shown in Figures 1-19, the rail 20 extends along the width W for mounting the photovoltaic module 18 to the racking system 14 in a landscape orientation. As shown in Figures 3-5, the frame 12 of the racking system 14 includes a plurality of upper mounting bars 42 and lower mounting bars 43. The rails 20 typically extend longitudinally across the upper 42 and lower 43 mounting bars of the racking system 14 in a perpendicular direction to the upper 42 and lower 43 mounting bars. As such, the photovoltaic module assemblies 10 shown in Figures 1-19, for example, are configured to be mounted to the racking system 14 in the landscape orientation. The photovoltaic module assembly 10 shown in Figure 20, for example, is configured to be mounted to the racking system 14 in a portrait orientation. Alternatively, the photovoltaic module 18 can be mounted to the racking

system 14 in any orientation without departing from the nature of the present invention.

[0046] As set forth above, the photovoltaic module assembly 10 includes at least one rail 20 mounted to the photovoltaic module 18. Specifically, as set forth further below, the rail 20 is fixed relative to the back sheet 32 of the photovoltaic module 18. The rail 20 is adhered to the back sheet 32 with the adhesive 30, as set forth further below.

[0047] The legs 24 each present an adhesive receiving surface 28 with the adhesive 30 extending from the adhesive receiving surfaces 28 to the photovoltaic module 18. Specifically, the wings 26 of the legs 24 present the adhesive receiving surfaces 28.

[0048] The adhesive receiving surfaces 28 are spaced from each other so that the legs 24 move relative to each other when a load is applied to the module in excess of a predetermined level. The load can, for example, be a result of forces associated with wind or snow and/or ice on the module 18. The rail 20 is more specifically configured such that when the load exceeds the predetermined level the legs 24 move relative to the base 22 before the crystalline silicone photovoltaic cell 34, the back sheet 32, and/or the cover sheet 38 break. The crystalline silicon photovoltaic cell 34, the back sheet 32, and/or the cover sheet 38 remain unbroken when the photovoltaic module 18 is subjected to a load of up to 2,400Pa. For example, The crystalline silicon photovoltaic cell 34, the back sheet 32, and/or the cover sheet 38 remain unbroken when the photovoltaic module is subjected to a load of 4,900Pa. As such, the module 18 passes the mechanical load test under the International Electrotechnical Commission (IEC) standards.

[0049] Figure 3 shows the module 18 at rest, i.e., with no extraneous forces applied to the module 18. Figure 6 shows a partial side view of the module of Figure 3 and Figure 9 shows an enlarged view of the interaction between the module 18, rail 20, and adhesive 30. A load F1, which exceeds the predetermined level, is applied to the module 18 in Figures 4, 7, and 10. A load F2, which exceeds the predetermined level, is applied to the module 18 in a different direction than load F1 in Figures 5, 8, and 11. The directions of loads F1 and F2 are shown merely for exemplary purposes and the module 18 reacts similarly to forces in different directions.

[0050] As shown in Figures 7 and 10, the module 18 crowns relative to the rail 20 under the application of load F1. The legs 24, and specifically, the members 25, bend

downwardly (relatively in Figures 7 and 10) relative to the base 22 to provide a more gradual deformation of the module 18 at the rail 20. This relatively gradual deformation about the rail 20 reduces the likelihood of breakage of the cell 34.

[0051] As shown in Figures 8 and 11, the module 18 bows relative to the rail 20 under the application of load F2. The legs 24, and specifically, the members 25, bend upwardly (relatively in Figures 8 and 11) relative to the base 22 to provide a more gradual deformation of the module 18 at the rail 20. This relatively gradual deformation about the rail 20 reduces the likelihood of breakage of the cell 34.

[0052] The adhesive 30 is configured to maintain adhesion between the module 18 and the rail 20 as the legs 24 move relative to the base 22 under the application of loads F1 and F2. The adhesive 30 advantageously deforms under compression and/or tension under the application of loads F1 and F2. This deformation allows for relative movement between the module 18 and the legs 24 when the legs 24 move relative to the base 22.

[0053] As set forth above, Figures 13-15 show another embodiment of the rail 20 in which the wings 26 extend transversely to the base 22. In such a configuration, as shown in Figure 15, the adhesive is trapezoidal in shape. Specifically, the rail 20 extends along an axis A, as shown in Figure 13, and the adhesive 30 is trapezoidal in shape in a plane perpendicular to the longitudinal axis A. The rail 20 shown in Figures 13-15 perform in a similar fashion as in Figures 9-11. Specifically, the legs 24 deform relative to the base 22 when the module 18 is subjected to forces F1 and F2. The trapezoidal shape of the adhesive 30 results in better stress distribution within the adhesive 30. Specifically, the entire adhesive 30 can be subject to the same stress and the thicker portion of the trapezoidal shape is capable of more stretching than that of the thinner portion of the trapezoidal shape.

[0054] The adhesive 30 has a thickness T from the adhesive receiving surface 28 of the rail 20 to the back sheet 32 and a width W between the adhesive receiving surface 28 of the rail 20 and the back sheet 32. With reference to Figure 1, the thickness T is measured along a first line L1 extending from the at least one rail 20 to the back sheet 32. The width W is measured along a second line L2 perpendicular to the first line L1. Specifically, the rail 20 and the back sheet 32 define planar surfaces 48 and the first line L1 extends perpendicularly to the planar surfaces 48 of the rail 20 and the back sheet 32 as shown in Figure 5. The thickness T, for example, can be between 2mm

and 8mm and the width W, for example, can be between 8mm and 20mm. As one example the thickness T can be between 3mm and 5mm and the width W can be between 8mm and 10mm. However, it should be appreciated that the thickness T and width W can have any magnitude without departing from the nature of the present invention.

[0055] With reference to Figure 12, the photovoltaic module 18 includes a back sheet 32, at least one photovoltaic cell 34 supported on the back sheet 32, a first encapsulant layer 36 formed from an organic polymer or a silicone composition supported on the photovoltaic cell 34, and a cover sheet 38 supported on the first encapsulant layer 36. The rail 20 is adhered to the back sheet 32 of the photovoltaic module 18 with the adhesive 30. The adhesive 30 is disposed between and contacts the photovoltaic module 18 and the rail 20. The adhesive 30 fixes the photovoltaic module 18 and the rail 20 together as a unit.

[0056] The at least one photovoltaic cell 34 is disposed between the back sheet 32 and the cover sheet 38. The photovoltaic module 18 may include one photovoltaic cell 34 or a plurality of photovoltaic cells 34. Typically, the photovoltaic module 18 includes a plurality of photovoltaic cells 34. When the photovoltaic module 18 includes the plurality of the photovoltaic cells 34, the photovoltaic cells 34 may be substantially coplanar with one another. Alternatively, the photovoltaic cells 34 may be offset from one another, such as in non-planar module configurations. Regardless of whether the photovoltaic cells 34 are planar or non-planar with one another, the photovoltaic cells 34 may be arranged in various patterns, such as in a grid-like pattern.

[0057] The photovoltaic cells 34 may independently have various dimensions, be of various types, and be formed from various materials. The photovoltaic cells 34 may have various thicknesses, such as from about 50 to about 250, alternatively from about 100 to about 225, alternatively from about 175 to about 225, alternatively about 180, micrometers (μm) on average. The photovoltaic cells 34 may have various widths and lengths. In one embodiment, the photovoltaic cells 34 are crystalline silicon photovoltaic cells 34 and independently comprise monocrystalline silicon, polycrystalline silicon, or combinations thereof.

[0058] When the photovoltaic module 18 includes more than one photovoltaic cell 34, a tabbing ribbon is typically disposed between adjacent photovoltaic cells 34 for establishing a circuit in the photovoltaic module 18.

[0059] The back sheet 32 can be formed from various materials. Examples of suitable materials include glass, polymeric materials, composite materials, etc. For example, the back sheet 32 can be formed from glass, polyethylene terephthalate (PET), thermoplastic elastomer (TPE), polyvinyl fluoride (PVF), silicone, etc. The back sheet 32 may be formed from a combination of different materials, e.g. a polymeric material and a fibrous material. The back sheet 32 may have portions formed from one material, e.g. glass, and other portions formed from another material, e.g. a polymeric material. The back sheet 32 can be of various thicknesses, such as from about 0.05 to about 5, about 0.1 to about 4, or about 0.125 to about 3.2, millimeters (mm) on average. Thickness of the back sheet 32 may be uniform or may vary.

[0060] Further examples of suitable back sheets 32 include those described in U.S. App. Pub. Nos. 2008/0276983, 2011/0005066, and 2011/0061724, and in WO Pub. Nos. 2010/051355 and 2010/141697, the disclosures of which are incorporated herein by reference in their entirety to the extent they do not conflict with the general scope of the disclosure. The aforementioned disclosures are hereinafter referred to as the “incorporated references.”

[0061] The cover sheet 38 may be substantially planar or non-planar. The cover sheet 38 is useful for protecting the module 18 from environmental conditions such as rain, snow, dirt, heat, etc. Typically, the cover sheet 38 is optically transparent. The cover sheet 38 is generally the sun side or front side of the module.

[0062] The cover sheet 38 can be formed from various materials. Examples of suitable materials include those described above with description of the back sheet 32. Further examples of suitable cover sheets 38 include those described in the references incorporated above. In certain embodiments, the cover sheet 38 is formed from glass. Various types of glass can be utilized such as silica glass, polymeric glass, etc. The cover sheet 38 may be formed from a combination of different materials. The cover sheet 38 may have portions formed from one material, e.g. glass, and other portions formed from another material, e.g. a polymeric material. The cover sheet 38 may be the same as or different from the back sheet 32. For example, both the cover sheet 38 and the back sheet 32 may be formed from glass with equal or differing thicknesses.

[0063] The cover sheet 38 can be of various thicknesses, such as from about 0.5 to about 10, about 1 to about 7.5, about 2.5 to about 5, or about 3, millimeters (mm), on average. Thickness of the cover sheet 38 may be uniform or may vary.

[0064] The first encapsulant layer 36 is disposed on the photovoltaic cells 34 and serves to protect the photovoltaic cells 34. Further, the first encapsulant layer 36 is utilized to bond the photovoltaic module 18 together by being sandwiched between the back sheet 32 (along with the photovoltaic cells 34) and the cover sheet 38. In particular, the first encapsulant layer 36 is generally utilized for coupling the cover sheet 38 to the back sheet 32.

[0065] The silicone composition is typically disposed on the back sheet 32 (along with the photovoltaic cells 34) to form a first layer. The cover sheet 38 is then disposed on the first layer, and the first layer is cured to form the first encapsulant layer 36.

[0066] In various embodiments, the photovoltaic module 18 further includes a second encapsulant layer 40 disposed between the back sheet 32 and the photovoltaic cells 34. In particular, the second encapsulant layer 40 is for coupling the photovoltaic cells 34 to the back sheet 32. The second encapsulant layer 40 generally protects the photovoltaic cells 34 from the back sheet 32 because the second encapsulant layer 40 is sandwiched between the photovoltaic cells 34 and the back sheet 32. The second encapsulant layer 40 may be uniformly disposed across the back sheet 32, or merely disposed between the photovoltaic cells 34 and the back sheet 32, in which case the second encapsulant layer 40 is not a continuous layer across the back sheet 32, but rather is a patterned layer.

[0067] The second encapsulant layer 40 may be the same as or different from the first encapsulant layer 36. When the first and second encapsulant layers 36, 40 are the same, the first and second encapsulant layers 40 typically form a continuous encapsulant layer that encapsulates the photovoltaic cells 34 between the back sheet 32 and the cover sheet 38. When the second encapsulant layer 40 is different from the first encapsulant layer 36, the second encapsulant layer 40 may only be present between the photovoltaic cells 34 and the back sheet 32, in which case the second encapsulant layer 40 is not a continuous layer across the back sheet 32, as noted above. In such embodiments, the first encapsulant layer 36 generally contacts both the back sheet 32 and the cover sheet 38 in locations in the photovoltaic module 18 other than where the photovoltaic cells 34 are disposed.

[0068] Most typically, both the first and the second encapsulant layers 36, 40 are independently formed from organic polymer or silicone compositions. In such

embodiments, the organic polymer or silicone composition utilized to form the second encapsulant layer 40 is uniformly applied on the back sheet 32 to form a second layer, which may optionally be partially or fully cured prior to disposing the photovoltaic cells 34 on the second layer. The organic polymer or silicone composition utilized to form the first encapsulant layer 36 is then applied on the second layer and the photovoltaic cells 34 to form the first layer. The cover sheet 38 is applied on the first layer to form a package, and the first and second layers of the package are cured to form the first and second encapsulant layers 40 and the module.

[0069] Alternatively, the cover sheet 38, the organic polymer or silicone composition utilized to form the first encapsulant layer 36 is uniformly applied on the cover sheet 38 to form a first layer, which may optionally be partially or fully cured prior to disposing the photovoltaic cells 34 on the first layer. The organic polymer or silicone composition utilized to form the second encapsulant layer 40 is then applied on the first layer and the photovoltaic cells 34 to form the second layer. The back sheet 32 is applied on the second layer to form a package, and the first and second layers of the package are cured to form the first and second encapsulant layers 40 and the module.

[0070] Although the first encapsulant layer 36 is typically sandwiched between the back sheet 32 (along with the photovoltaic cells 34) and the cover sheet 38, there may be at least one intervening layer (e.g., a tie layer) between the first encapsulant layer 36 and the cover sheet 38 and/or between the first encapsulant layer 36 and the photovoltaic cells 34.

[0071] The first encapsulant layer 36 is formed from an organic polymer or a silicone composition. Examples of organic polymer compositions suitable for forming the first encapsulant layer 36 are organic ionomers, thermoplastic polyurethanes, poly(vinyl-*co*-butyral), and poly(ethylene-*co*-vinyl acetate) (EVA). Examples of silicone compositions suitable for forming the first encapsulant layer 36 include hydrosilylation-reaction curable silicone compositions, condensation-reaction curable silicone compositions, and hydrosilylation/condensation-reaction curable silicone compositions. As noted above, in certain embodiments, the second encapsulant layer 40, when present in the photovoltaic module 18, also is formed from an organic polymer or a silicone composition. The organic polymer or silicone composition utilized to form the second encapsulant layer 40 may independently be selected from any of these compositions. In some embodiments each of the first encapsulant layer

and the second encapsulant layer, when present, independently is EVA. In other embodiments, each of the first encapsulant layer and the second encapsulant layer, when present, independently is a silicone composition.

[0072] The adhesive 30 can be any type of adhesive. For example, in certain embodiments, the adhesive 30 is formed from a silicone composition such that, once cured (or even prior to curing), the adhesive 30 comprises a silicone. The adhesive 30 advantageously has excellent adhesion to glass and metals, as well as a variety of other materials and substrates. The adhesive 30 is also flexible so as to absorb mismatches caused by differences in coefficient of thermal expansion of different material and to reduce stress on the photovoltaic module 18. The adhesive 30 can also withstand wind load and snow load and adequately resists deterioration.

[0073] The silicone composition utilized to form the adhesive 30 may comprise any type of silicone composition suitable for forming the adhesive 30. For example, in various embodiments, the silicone composition is selected from the group of a hydrosilylation-reaction curable silicone composition, a peroxide-curable silicone composition, a condensation-curable silicone composition, an epoxy-curable silicone composition, an ultraviolet radiation-curable silicone composition, and a high-energy radiation-curable silicone composition.

[0074] In one specific embodiment, the silicone composition used to form the adhesive 30 comprises a room-temperature vulcanizing silicone composition, which typically is either a hydrosilylation-reaction curable silicone composition or a condensation-curable silicone composition. Such room-temperature vulcanizing silicone composition are desirable because the adhesive 30 may be formed from these room-temperature vulcanizing silicone compositions without necessitating certain curing conditions associated with many silicone compositions, e.g. the application of heat. Accordingly, room-temperature vulcanizing silicone compositions may be utilized to form the adhesive 30 in a variety of locations, e.g. outdoors, in a variety of conditions. For example, the room-temperature vulcanizing silicone compositions may be utilized where assembly of the mounting rails 20 to the photovoltaic module 18 often takes place without necessitating, for example, a curing oven or other heat source for curing the silicone composition. While room-temperature vulcanizing silicone compositions may cure at ambient conditions, curing of such room-

temperature vulcanizing silicone compositions may be accelerated via the application of heat, if desired.

[0075] When the silicone composition comprises the room-temperature vulcanizing silicone composition that is hydrosilylation-reaction curable, the silicone composition typically comprises an organopolysiloxane having at least two silicon-bonded alkenyl groups and an organosilicon compound having at least two silicon-bonded hydrogen atoms. The organopolysiloxane and the organosilicon compound may independently be monomeric, oligomeric, polymeric, or resinous, and may independently comprise any combination of M, D, T, and/or Q units depending upon the desired physical properties of the adhesive 30. The silicon-bonded alkenyl groups of the organopolysiloxane and the silicon-bonded hydrogen atoms of the organosilicon compound may independently be pendent, terminal, or both. Further, additional non-reactive compounds, such as a non-reactive polyorganosiloxane, may be present in the silicone composition. The reaction between the organopolysiloxane and the organosilicon compound is typically catalyzed by a hydrosilylation-reaction catalyst. The hydrosilylation-reaction catalyst can be any of the well-known hydrosilylation catalysts comprising a platinum group metal (i.e., platinum, rhodium, ruthenium, palladium, osmium and iridium) or a compound containing a platinum group metal. Preferably, the platinum group metal is platinum, based on its high activity in hydrosilylation reactions.

[0076] Hydrosilylation-reaction catalysts include the complexes of chloroplatinic acid and certain vinyl-containing organosiloxanes disclosed in U.S. Pat. No. 3,419,593, which is hereby incorporated by reference in its entirety. A catalyst of this type is the reaction product of chloroplatinic acid and 1,3-diethenyl-1,1,3,3-tetramethyldisiloxane.

[0077] The hydrosilylation-reaction catalyst can also be a supported hydrosilylation-reaction catalyst comprising a solid support having a platinum group metal on the surface thereof. Examples of supported catalysts include, but are not limited to, platinum on carbon, palladium on carbon, ruthenium on carbon, rhodium on carbon, platinum on silica, palladium on silica, platinum on alumina, palladium on alumina, and ruthenium on alumina.

[0078] When the silicone composition comprises the room-temperature vulcanizing silicone composition that is hydrosilylation-reaction curable, the silicone composition

may be a one component composition or a two component composition. For example, the organopolysiloxane and the organosilicon compound may be kept separately from one another until combined to form the adhesive 30, in which case the silicone composition is the two component composition. In such embodiments, the hydrosilylation-reaction catalyst may be present in either component, although the hydrosilylation-reaction catalyst is typically present along with the organopolysiloxane. Alternatively, both the organopolysiloxane and the organosilicon compound may be present in a single component, in which case the silicone composition is the one component composition. However, such hydrosilylation-reaction curable silicone compositions are generally two component compositions to prevent premature reaction between and/or curing of the organopolysiloxane and the organosilicon compound.

[0079] As introduced above, in other embodiments, the silicone composition comprises the room-temperature vulcanizing silicone composition that is condensation-reaction curable. In these embodiments, the silicone composition may also be a one component composition or a two component composition. In particular, in the one component composition, the silicone composition generally begins to cure to form the adhesive 30 upon exposure to an ambient environment, e.g. moisture from ambient humidity, in which case a cure rate of the silicone composition can be controlled by influencing humidity. Alternatively, in the two component composition, the silicone composition begins to cure to form the adhesive 30 once the two components are mixed with one another.

[0080] Regardless of whether the silicone composition is the one component composition or the two component composition, when the silicone composition comprises the room-temperature vulcanizing silicone composition that is condensation-reaction curable, the silicone composition typically comprises an organopolysiloxane having at least one hydrolyzable group. The hydrolyzable group is typically silicon bonded and may be, for example, hydroxy, alkoxy, or other known hydrolyzable groups. Typically, the organopolysiloxane includes at least two silicon-bonded hydrolyzable groups, which are generally terminal. The organopolysiloxane may be monomeric, oligomeric, polymeric, or resinous, and may independently comprise any combination of M, D, T, and/or Q units depending upon the desired physical properties of the adhesive 30. If desired, the silicone composition may

further comprise additional components, such as cross-linking agents, e.g. an alkoxysilane, or additional organopolysiloxanes and/or organosilicon compounds, which may optionally have hydrolyzable functionality.

[0081] When the silicone composition comprises the room-temperature vulcanizing silicone composition that is condensation-reaction curable, the silicone composition typically further comprises a crosslinking agent and a catalyst. The crosslinking agent and the catalyst are typically present in the silicone composition regardless of whether the silicone composition is the one component composition or the two component composition. However, the particular crosslinking agent and the particular catalyst employed in the silicone composition is typically contingent on whether the silicone composition is the one component composition or the two component composition.

[0082] In particular, when the silicone composition is the two component composition (and when the silicone composition comprises the room-temperature vulcanizing silicone composition that is condensation-reaction curable), the crosslinking agent is typically an organosilicon compound having at least two silicon-bonded alkoxy groups. The alkoxy groups may be, for example, methoxy, ethoxy, propoxy, etc. The organosilicon compound may be a silane, in which case two, three, or four substituents of the silicon atom are independently selected alkoxy groups. If fewer than four substitutions of the silicon atom are alkoxy groups, the remaining substituents of the silicon atom are typically independently selected from hydrogen and substituted or unsubstituted hydrocarbyl groups. Alternatively, the organosilicon compound may be a siloxane.

[0083] Alternatively, when the silicone composition is the one component composition (and when the silicone composition comprises the room-temperature vulcanizing silicone composition that is condensation-reaction curable), the crosslinking agent typically comprises a functional silane. The functional silane is typically selected from amine functional silanes, acetate functional silanes, oxime functional silanes, alkoxy functional silanes, and combinations thereof. Generally, the functional silane includes at least three and optionally four substituents selected from those functionalities set forth above. The remaining substituent if the functional silane includes but three substituents selected from those functionalities set forth above is typically selected from hydrogen and substituted or unsubstituted hydrocarbyl groups.

[0084] When the silicone composition comprises the room-temperature vulcanizing silicone composition that is condensation-reaction curable, the catalyst is generally an organometallic compound. This is true regardless of whether the silicone composition is the one component composition or the two component composition. The organometallic compound may comprise titanium, zirconium, tin, and combinations thereof. In one embodiment, the catalyst comprises a tin compound. The tin compound may comprise dialkyltin (IV) salts of organic carboxylic acids, such as dibutyltin diacetate, dimethyl tin dilaurate, dibutyltin dilaurate, dibutyltin maleate and dioctyltin diacetate; tin carboxylates, such as tin octylate or tin naphthenate; reaction products of dialkyltin oxides and phthalic acid esters or alkane diones; dialkyltin diacetyl acetonates, such as dibutyltin diacetylacetonate (dibutyltin acetylacetonate); dialkyltin oxides, such as dibutyltin oxide, tin (II) salts of organic carboxylic acids, such as tin (II) diacetate, tin (II) dioctanoate, tin(II) diethylhexanoate, and tin(II) dilaurate; dialkyl tin (IV) dihalides, such as dimethyl tin dichloride; stannous salts of carboxylic acids, such as stannous octoate, stannous oleate, stannous acetate, and stannous laurate, and combinations thereof. Alternatively, the catalyst may comprise titanate acid esters, such as tetrabutyl titanate and tetrapropyl titanate; partially chelated organotitanium and organozirconium compounds, such as diisopropoxytitanium-di(ethylaceoacetate) and di(n-propoxy)zirconium-di(ethylaceoacetate); organoaluminum compounds, such as aluminum trisacetylacetonate, aluminum trisethylacetonate, diisopropoxyaluminum ethylacetonate; bismuth salts and organic carboxylic acids, such as bismuth tris(2-ethylhexoate) and bismuth tris(neodecanoate); chelate compounds, such as zirconium tetracetylacetonate and titanium tetraacetylacetonate; organolead compounds, such as lead octylate; organovanadium compounds; and combinations thereof. Generally, the one part composition utilizes an organometallic compound comprising tin as its catalyst, whereas the two part composition utilizes an organometallic compound comprising titanium as its catalyst.

[0085] Independent of the silicone composition utilized to form the adhesive 30, the silicone composition may further comprise an additive compound. The additive compound may comprise any additive compound known in the art and may be reactive or may be inert. The additive compound may be selected from, for example, an adhesion promoter; an extending polymer; a softening polymer; a reinforcing

polymer; a toughening polymer; a viscosity modifier; a volatility modifier; an extending filler, a reinforcing filler; a conductive filler; a spacer; a dye; a pigment; a co-monomer; an inorganic salt; an organometallic complex; a UV light absorber; a hindered amine light stabilizer; an aziridine stabilizer; a void reducing agent; a cure modifier; a free radical initiator; a diluent; a rheology modifier; an acid acceptor; an antioxidant; a heat stabilizer; a flame retardant; a silylating agent; a foam stabilizer; a gas generating agent; a surfactant; a wetting agent; a solvent; a plasticizer; a fluxing agent; a reactive chemical agent with functionality, such as a carboxylic acid, aldehyde, alcohol, or ketone; a desiccant; and combinations thereof.

[0086] Specific examples of silicone compositions that may be utilized to form the adhesive 30 are commercially available under the tradenames PV-8301 Fast Cure Sealant, PV-8303 Ultra Fast Cure Sealant, and PV-8030 Adhesive from Dow Corning Corporation, which is headquartered in Midland, MI, USA.

[0087] The invention has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation. Many modifications and variations of the present invention are possible in light of the above teachings, and the invention may be practiced otherwise than as specifically described.

CLAIMS

What is claimed is:

1. A photovoltaic module assembly for mounting on a racking system of a photovoltaic module installation site, said photovoltaic module assembly comprising:

at least one photovoltaic module including a back sheet, at least one crystalline silicon photovoltaic cell supported on said back sheet, a first encapsulant layer supported on the photovoltaic cell, and a cover sheet supported on the first encapsulant layer;

at least one rail fixed relative to said back sheet and being configured to support said at least one photovoltaic module on the racking system of the photovoltaic module installation site;

wherein said photovoltaic module defines a width and a length greater than said width, said rail extending along said width for mounting said photovoltaic module to the racking system; and

adhesive disposed between and contacting said back sheet of said photovoltaic module and said rail to adhere said rail to said photovoltaic module, said adhesive being formed from a silicone composition;

said rail including a base for abutting the racking system and a pair of legs extending from said base;

said legs each presenting an adhesive receiving surface with said adhesive extending from said adhesive receiving surfaces to said photovoltaic module, said adhesive receiving surfaces being spaced from each other so that said legs move relative to each other when a load is applied to said module in excess of a predetermined level.

2. The photovoltaic module assembly as set forth in claim 1 wherein said rail is configured such that when said load exceeds said predetermined level said legs move relative to said base before said crystalline silicon photovoltaic cell, the cover sheet, and the back sheet break.

3. The photovoltaic module assembly as set forth in claim 1 wherein said rail extends along a longitudinal axis and wherein said adhesive is trapezoidal in shape in a plane perpendicular to said longitudinal axis.

4. The photovoltaic module assembly as set forth in claim 1 wherein said adhesive receiving surfaces extend transversely to said back sheet such that said adhesive is trapezoidal in shape between each adhesive receiving surface and said back sheet.

5. The photovoltaic module assembly as set forth in claim 1 wherein said base of said rail defines at least one slot for receiving a fastener to fasten the rail to the racking system.

6. The photovoltaic module assembly as set forth in claim 1 wherein said crystalline silicon photovoltaic cell, the cover sheet, and the back sheet remain unbroken when said photovoltaic module is subjected to up to 2400Pa.

7. The photovoltaic module assembly as set forth in claim 6 wherein said adhesive has a thickness measured along a first line extending from said rail to said back sheet of said photovoltaic module and wherein said thickness is between 8mm and 20mm.

8. The photovoltaic module assembly as set forth in claim 6 wherein said adhesive has a thickness measured along a first line extending from said at least one rail to said back sheet of said at least one photovoltaic module said adhesive has a width between said at least one rail and said back sheet measured along a second line perpendicular to said first line, said width being between 8mm and 10 mm.

9. The photovoltaic module assembly as set forth in claim 1 wherein said base extends along an axis between said legs and wherein said legs each extend from said base at between 55 and 90 degrees relative to said axis.

10. The photovoltaic module assembly as set forth in one of claims 1 wherein said rail extends continuously from one end to another end of said module along said width of said module.

11. The photovoltaic module assembly as set forth in claim 1 wherein said silicone composition is a room temperature vulcanizing silicone composition.

12. The photovoltaic module assembly as set forth in one of claims 1 wherein said room temperature vulcanizing silicone composition is a condensation curable silicone composition.

13. The photovoltaic module assembly as set forth in claim 12 wherein said condensation curable silicone composition comprises:

an organopolysiloxane having at least one hydrolysable group;

a crosslinking agent; and
a catalyst.

14. The photovoltaic module assembly as set forth in any one of claims 1 to 13 wherein said photovoltaic cell module is frameless, said first encapsulant layer is formed from an organic polymer or silicone, and said cover sheet is formed of glass and said back sheet is formed of an organic polymer or silicone.

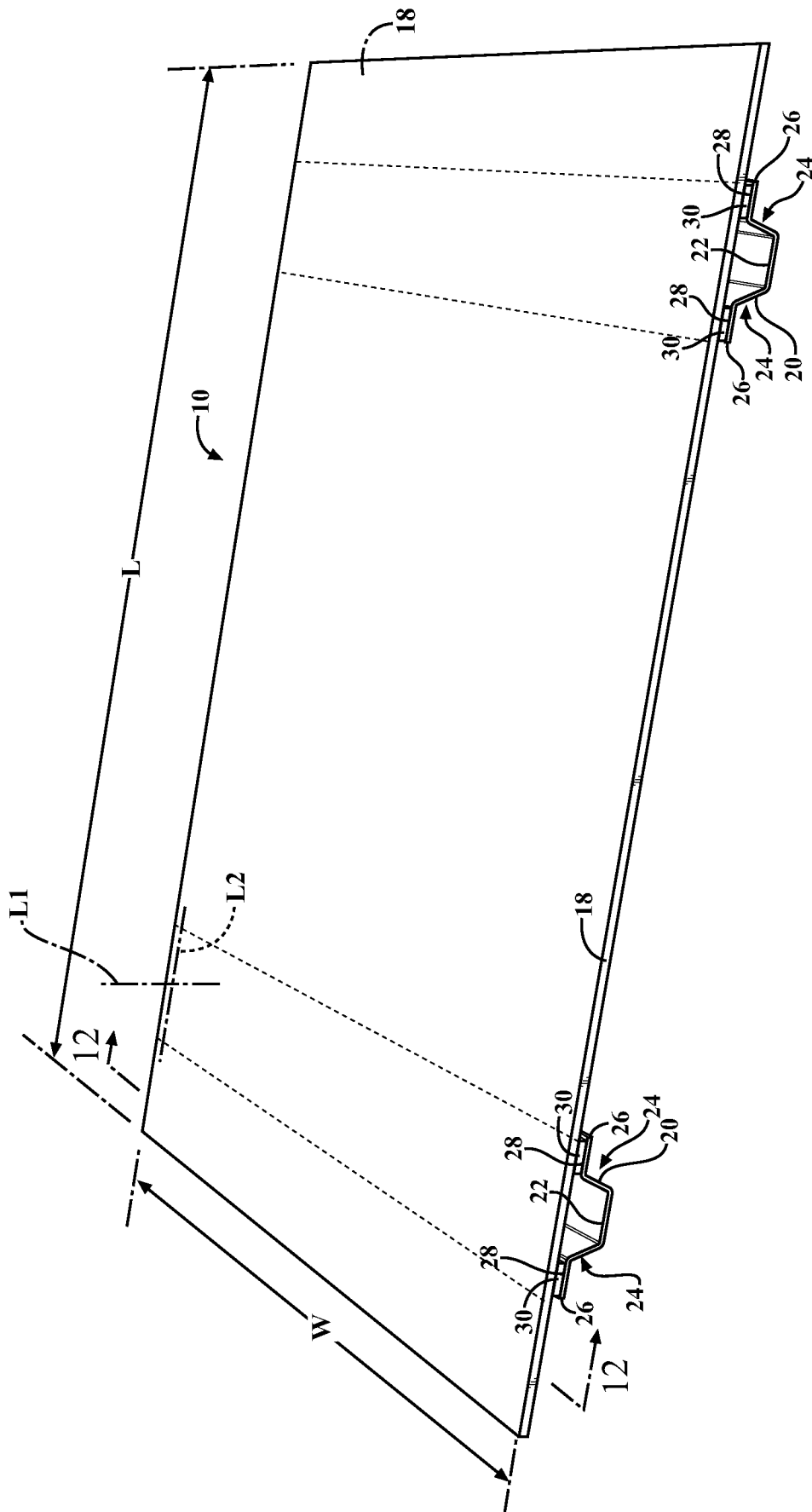


FIG. 1

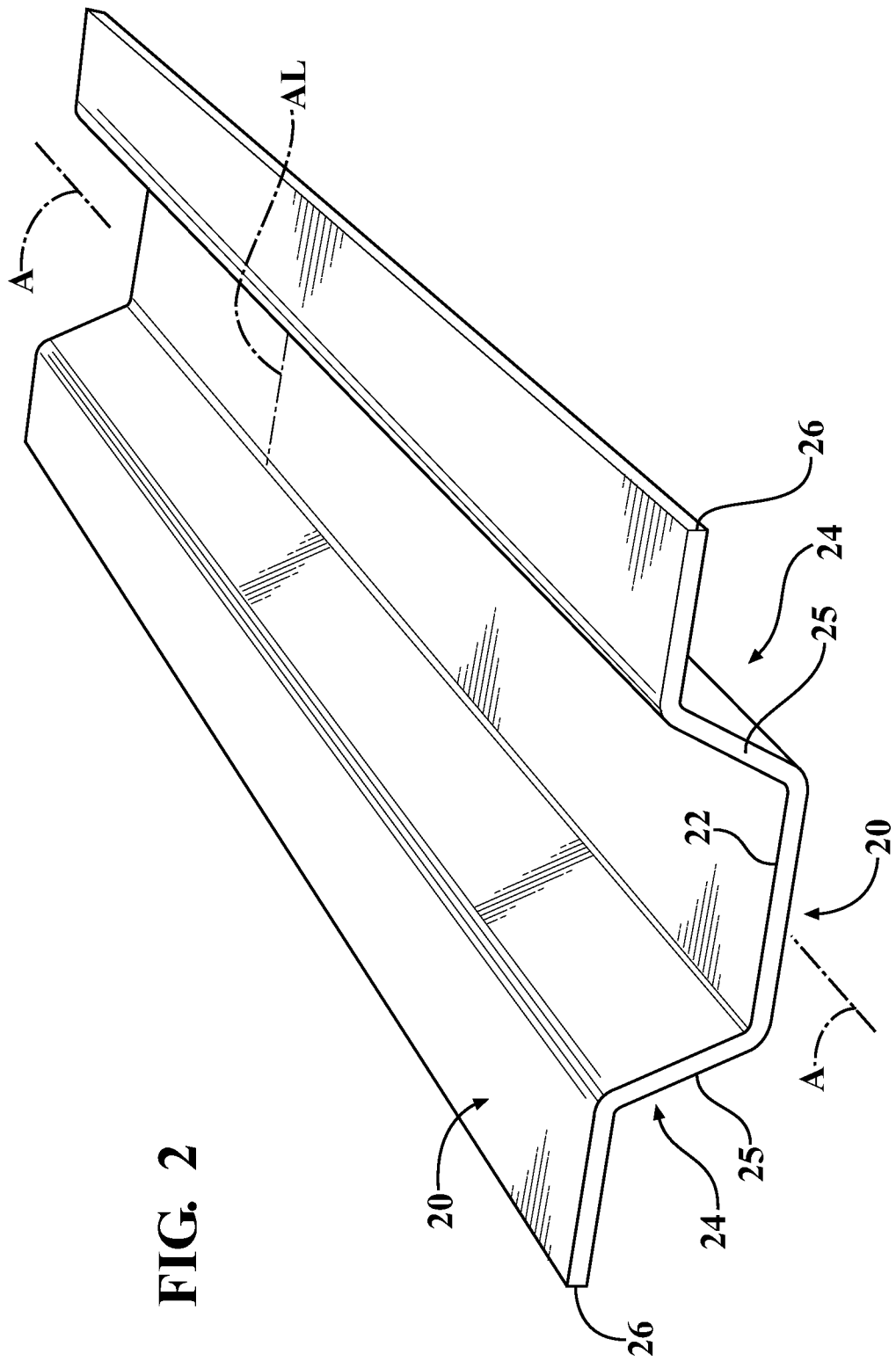


FIG. 2

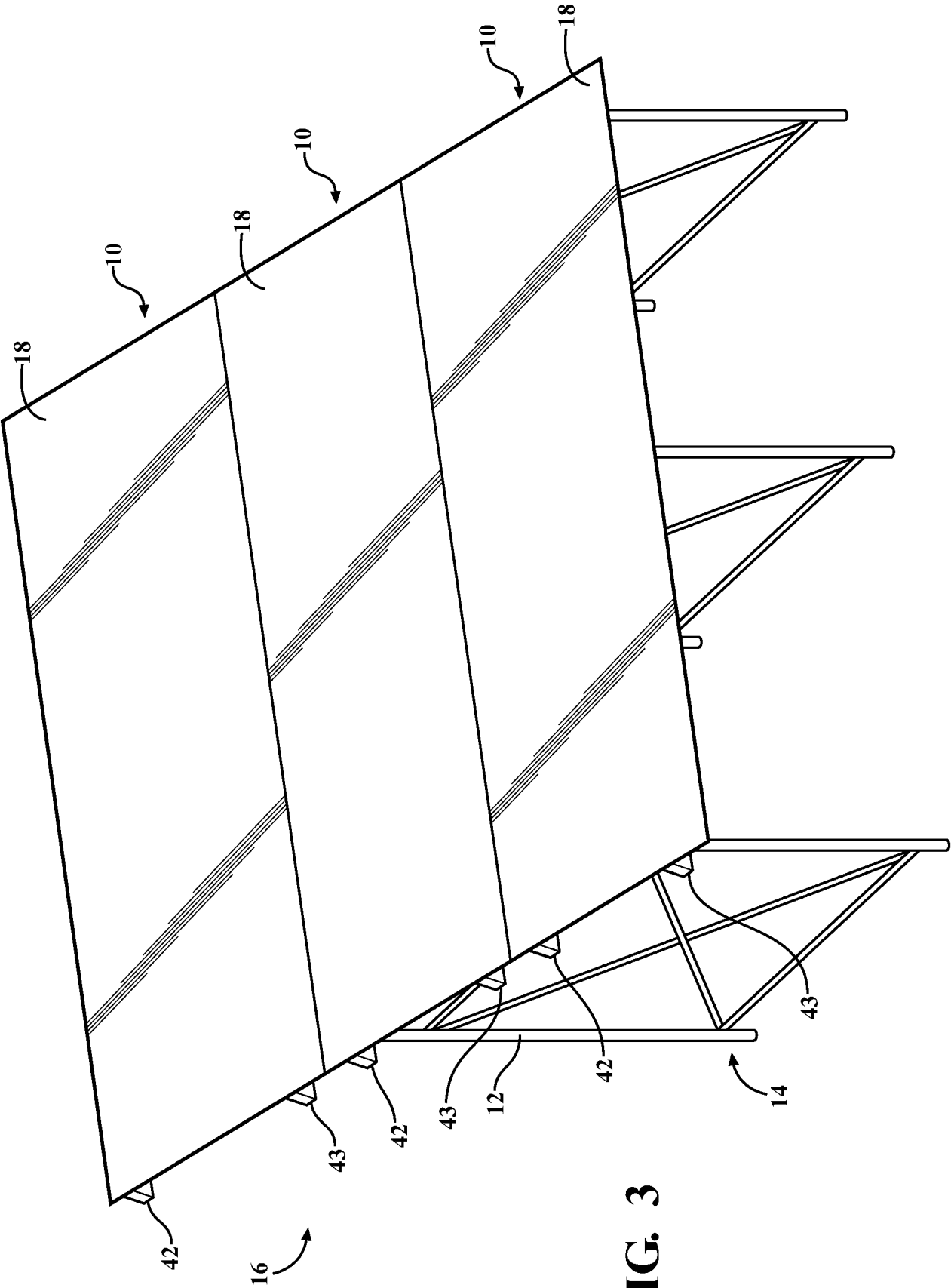


FIG. 3

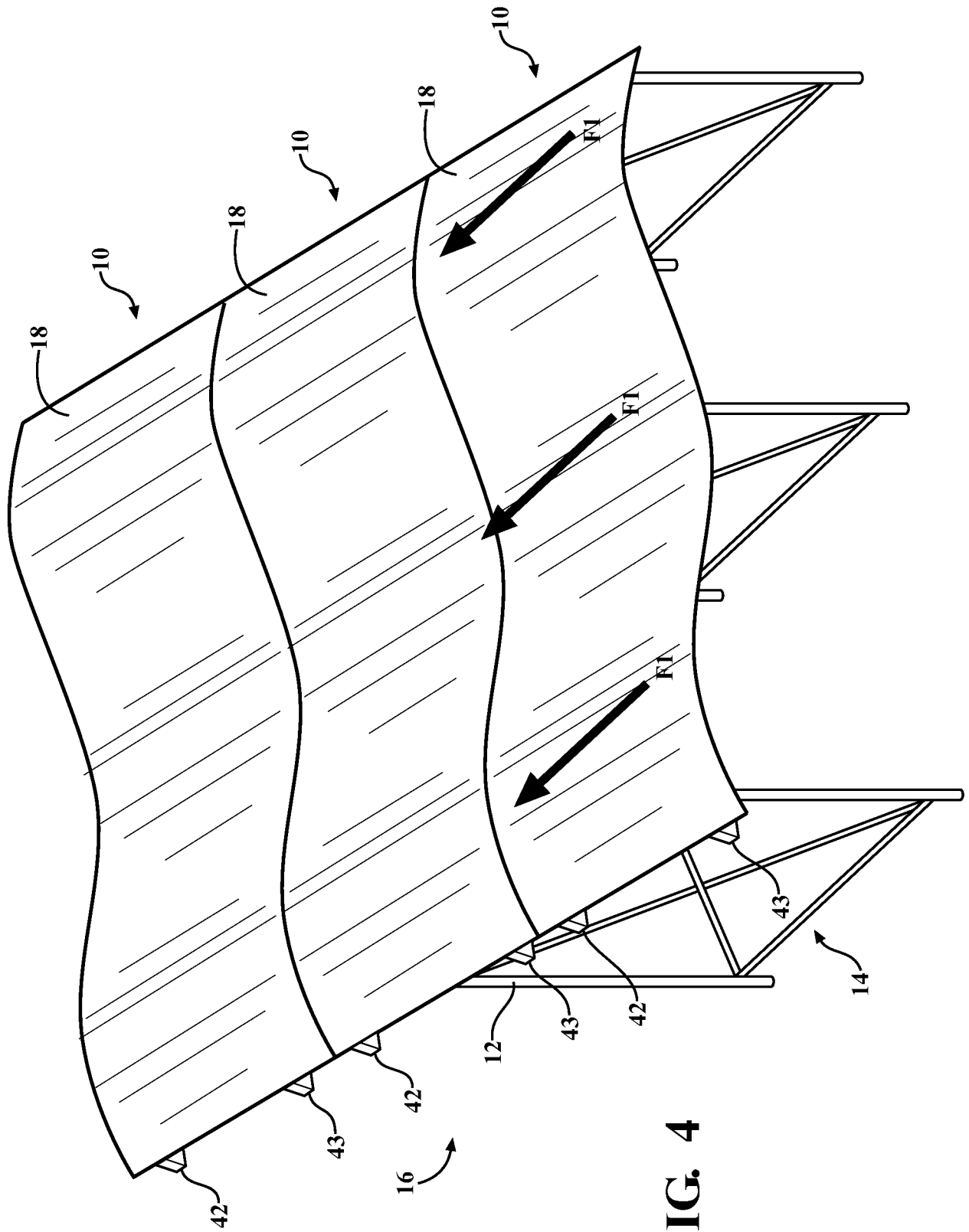


FIG. 4

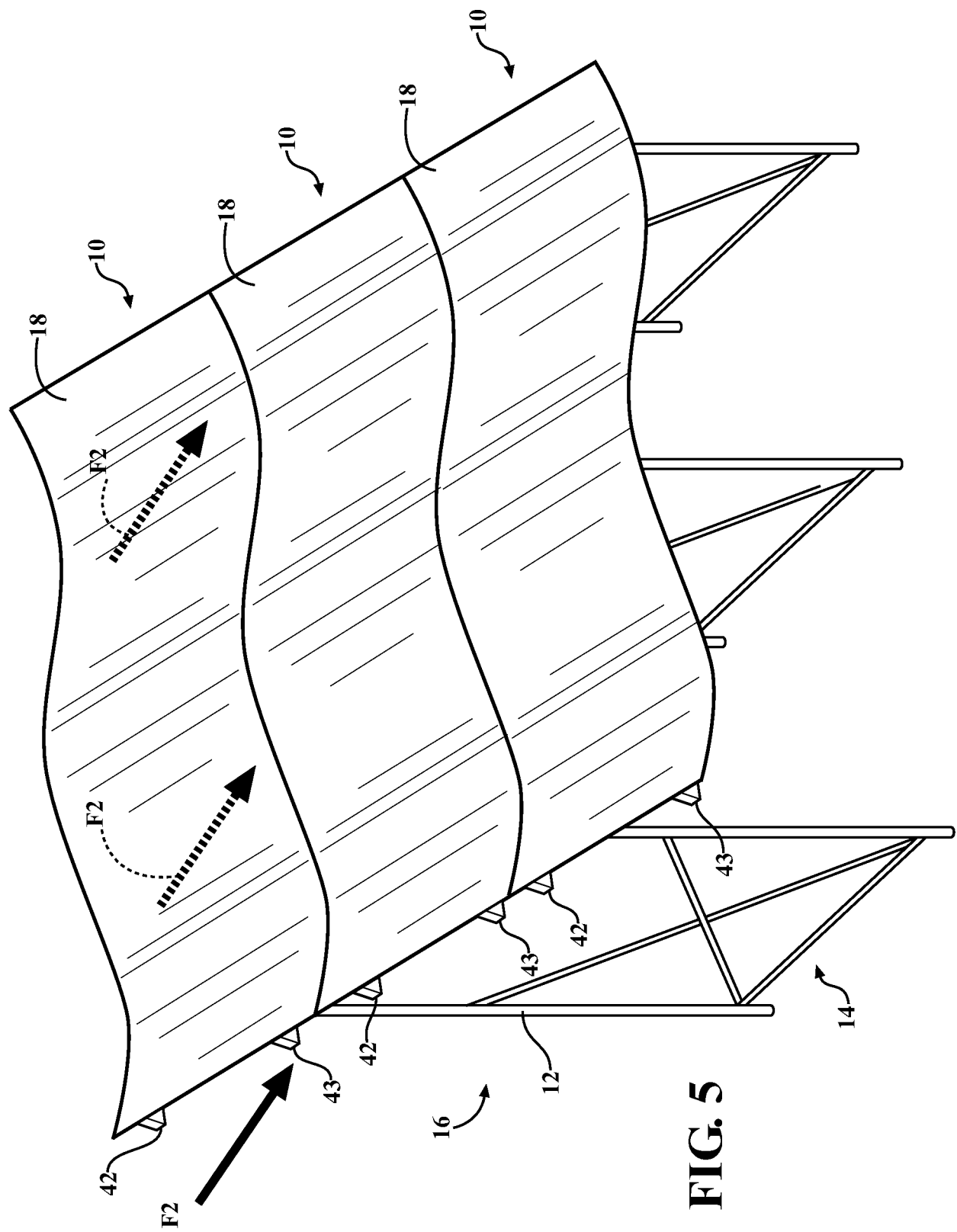


FIG. 6

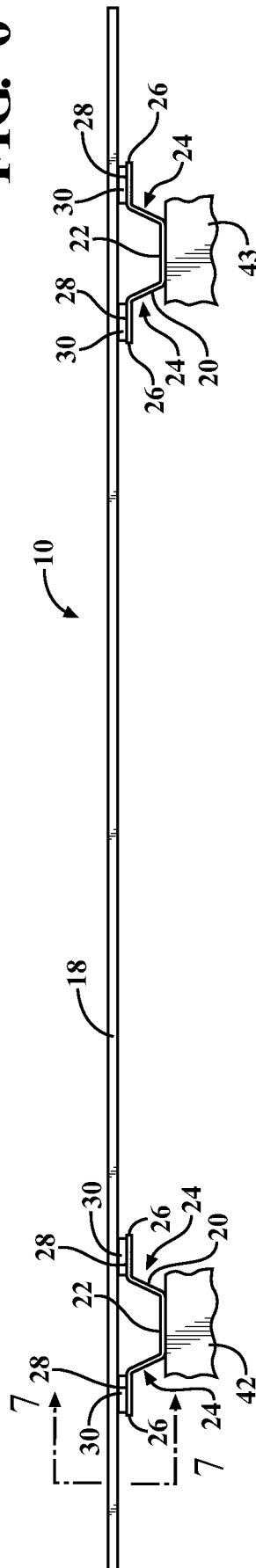


FIG. 7

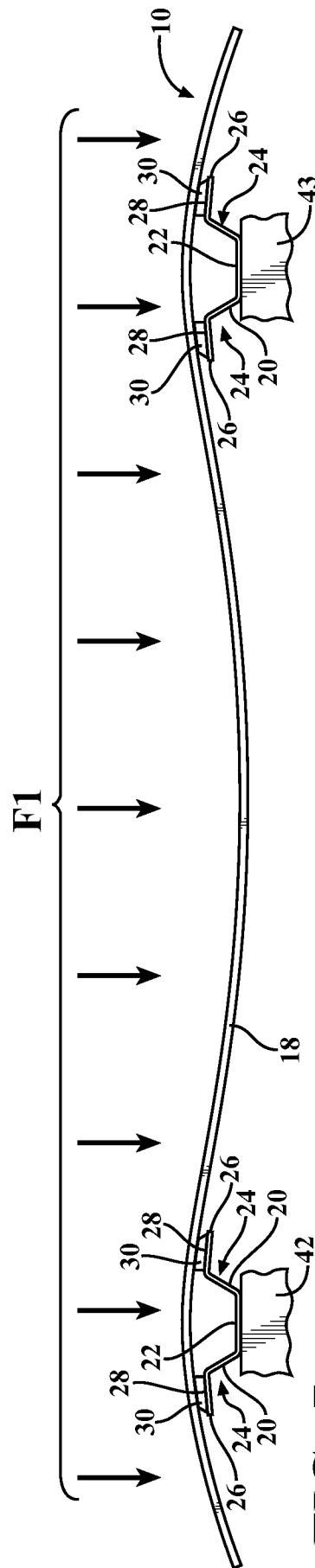


FIG. 8

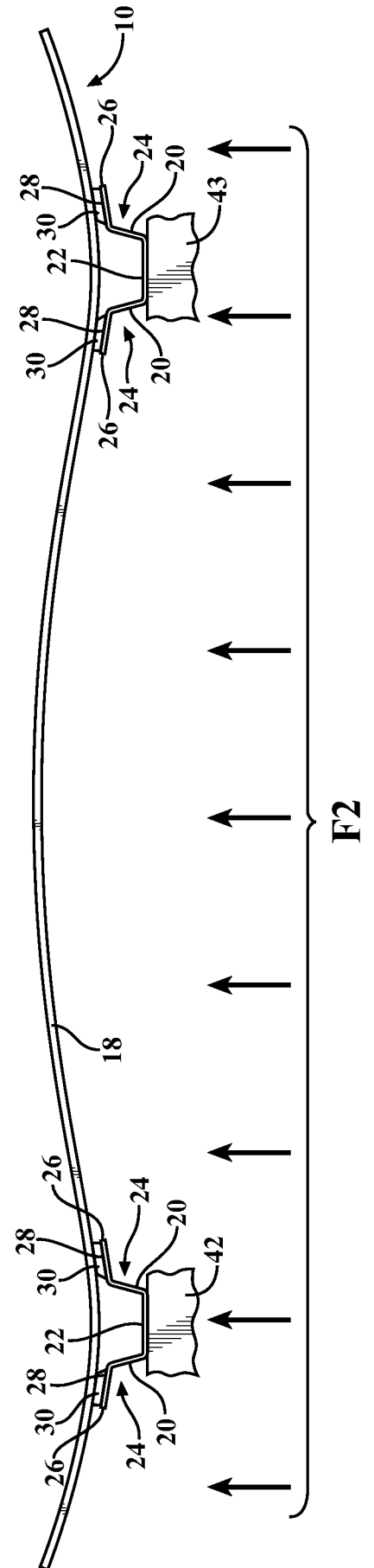
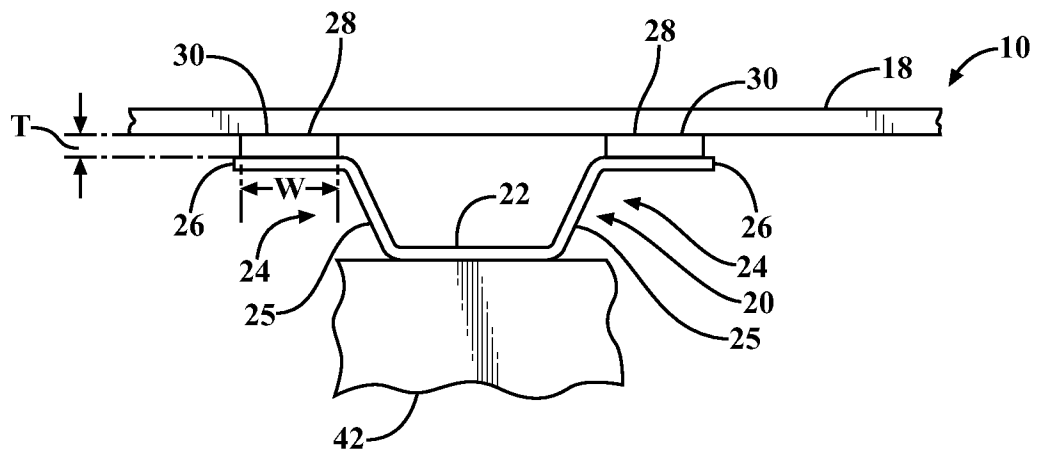
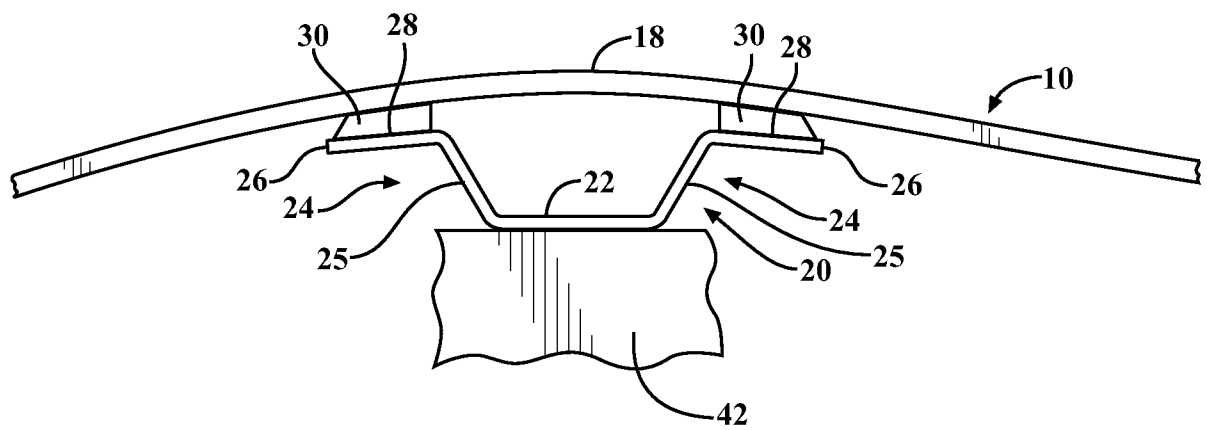
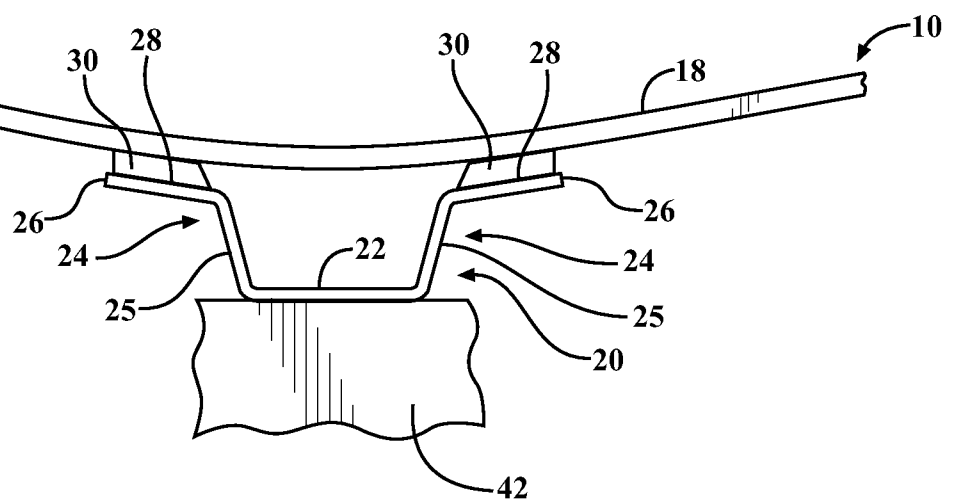


FIG. 9**FIG. 10****FIG. 11**

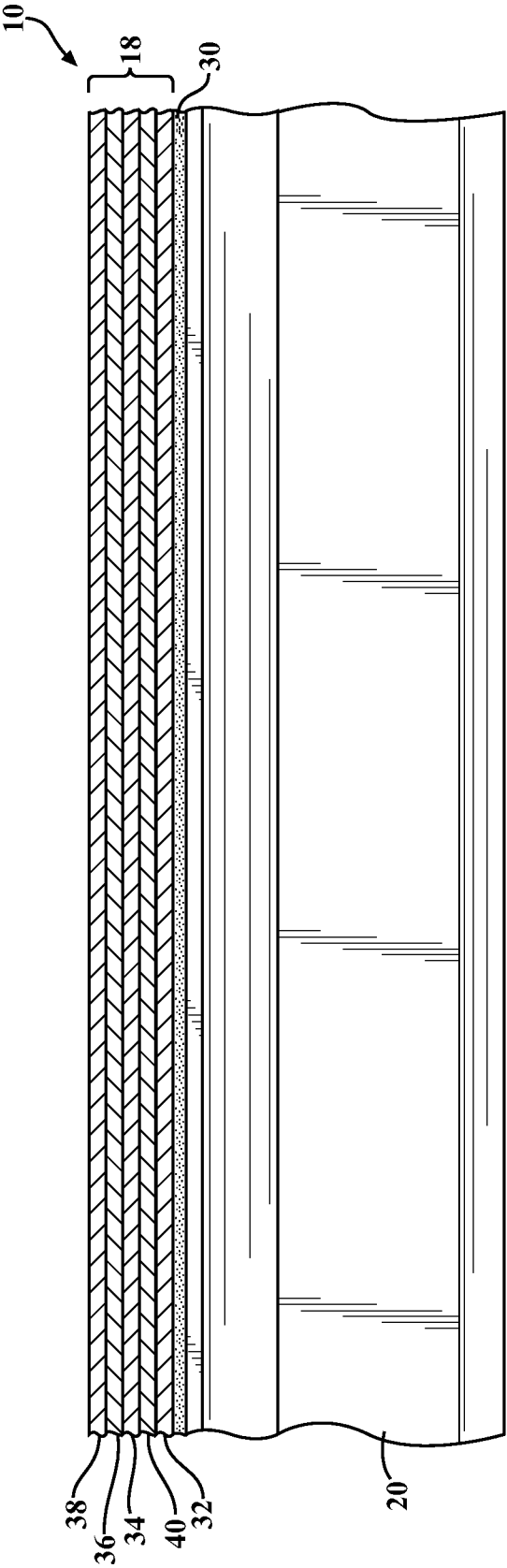
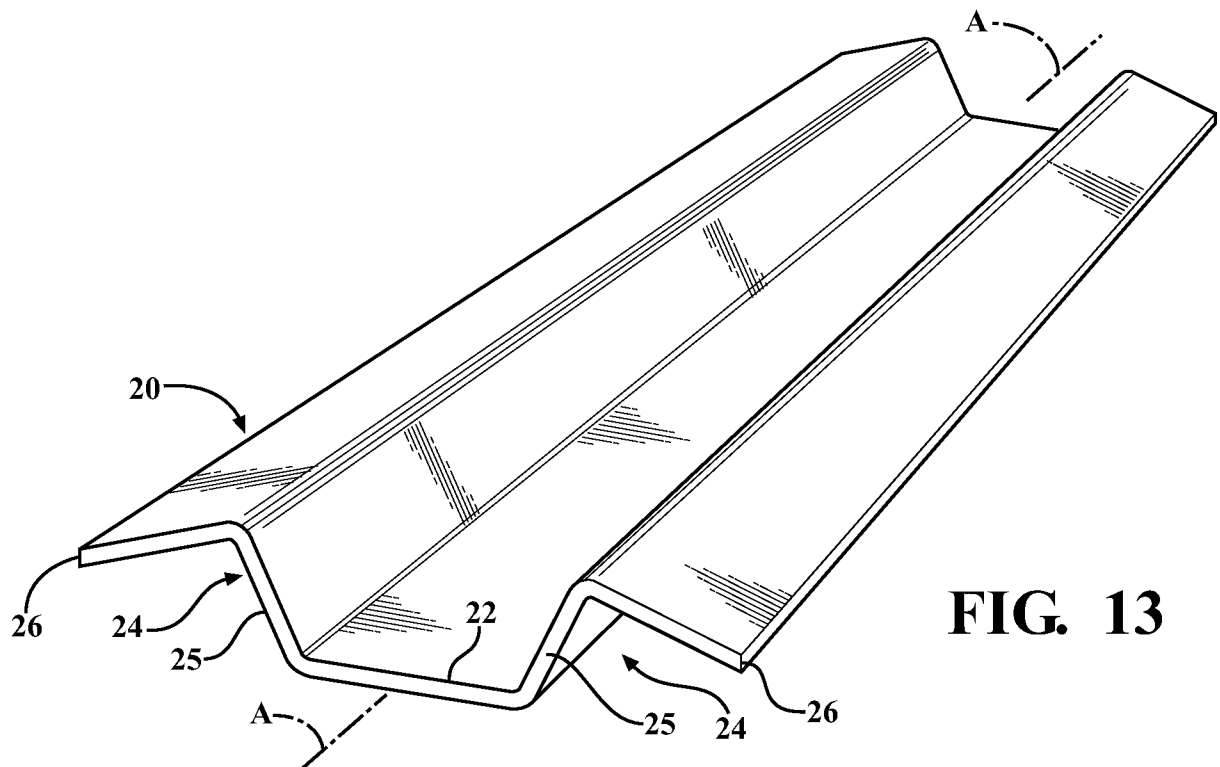
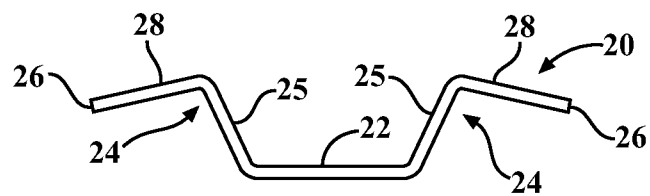
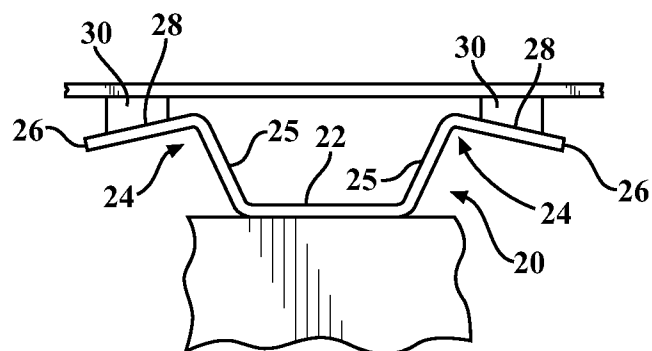


FIG. 12



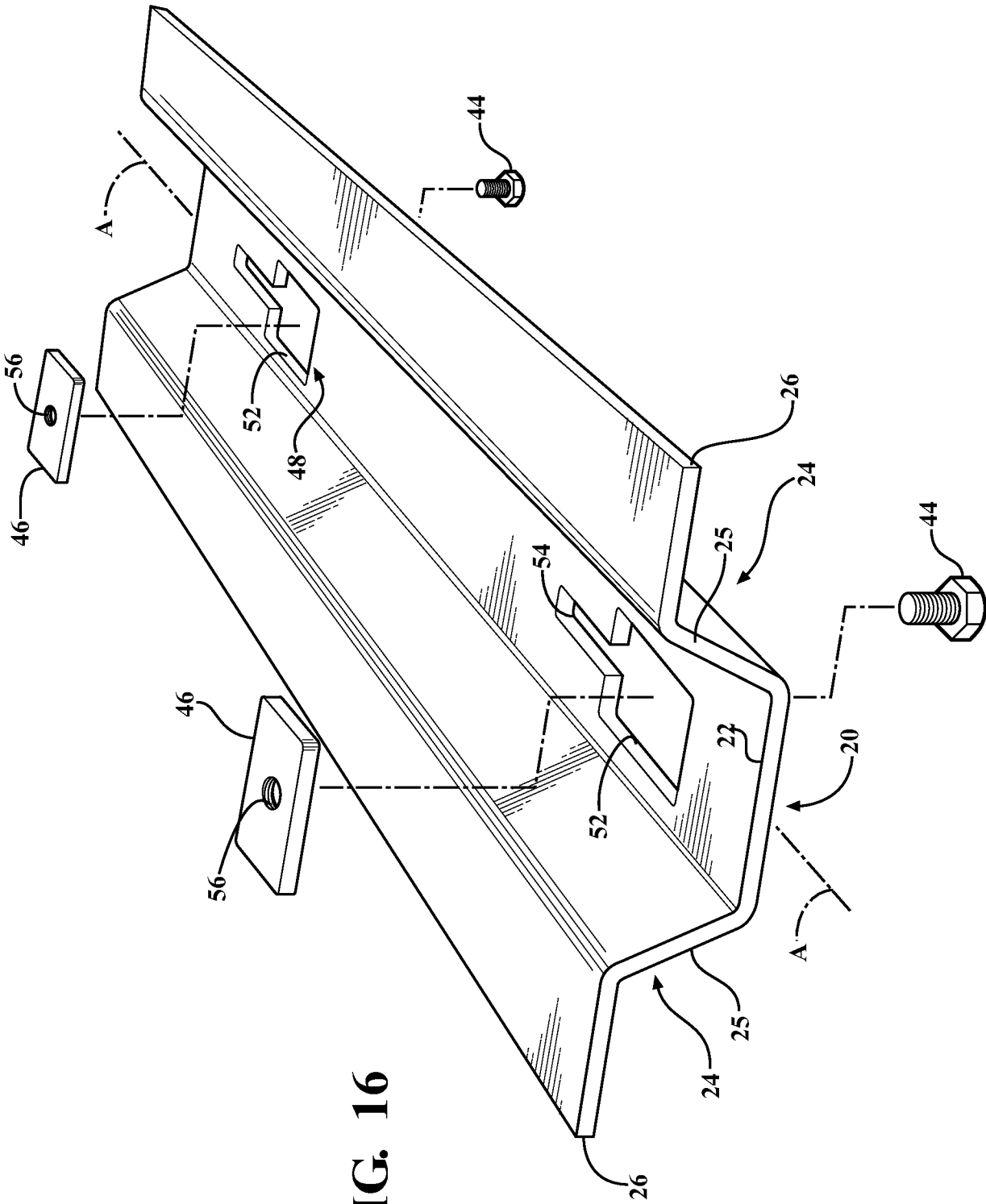


FIG. 16

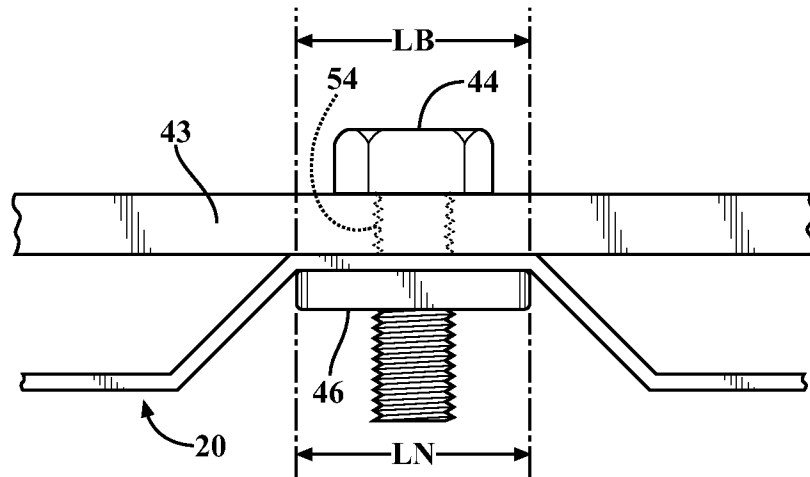
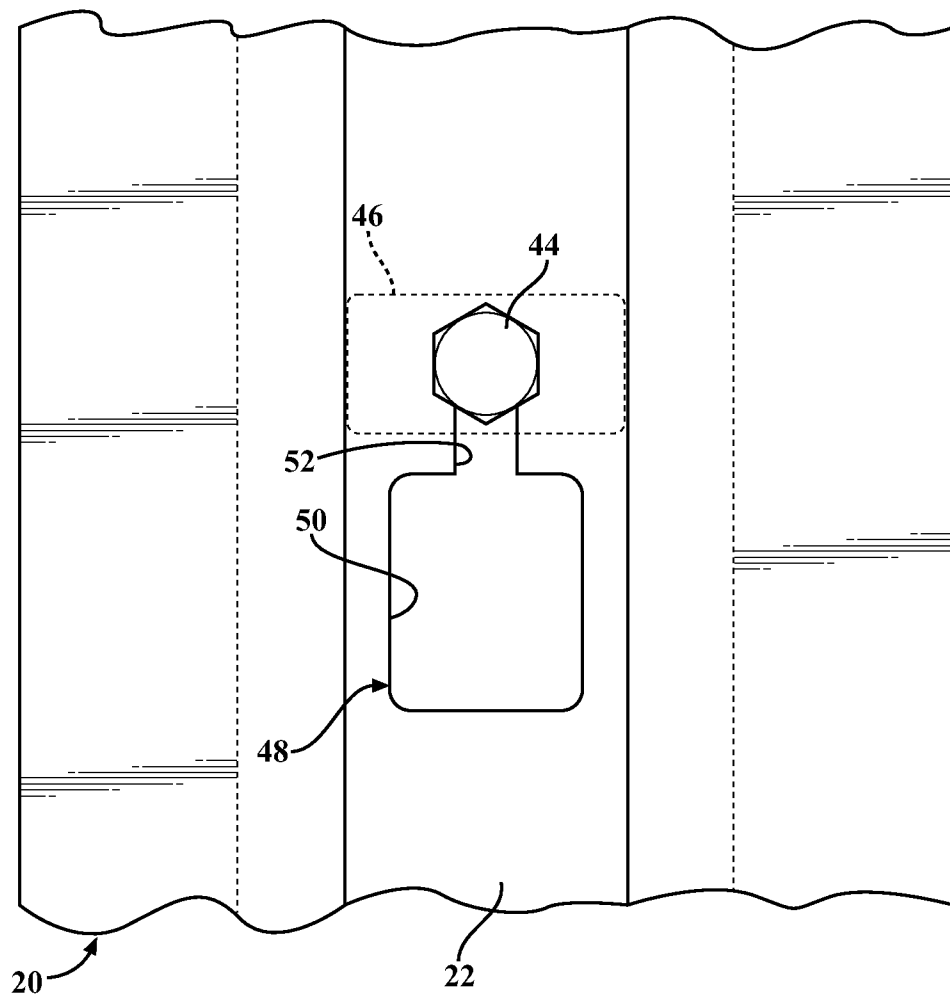
FIG. 17**FIG. 18**

FIG. 19

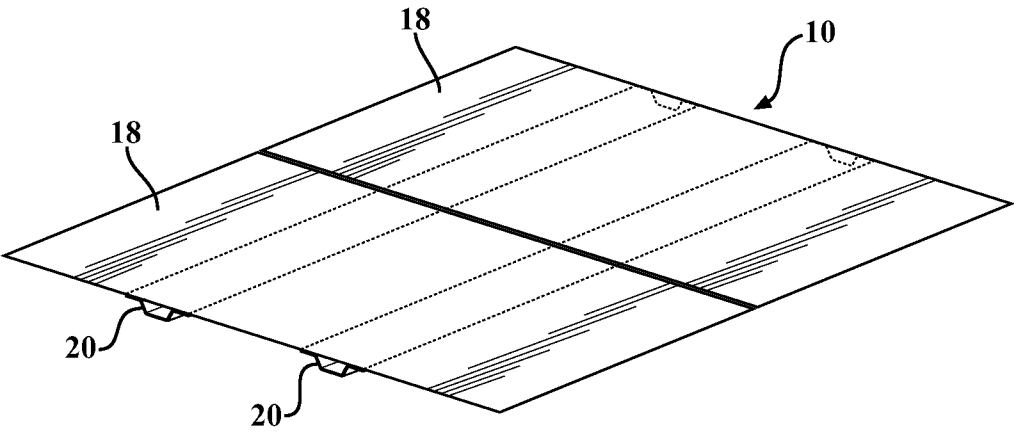
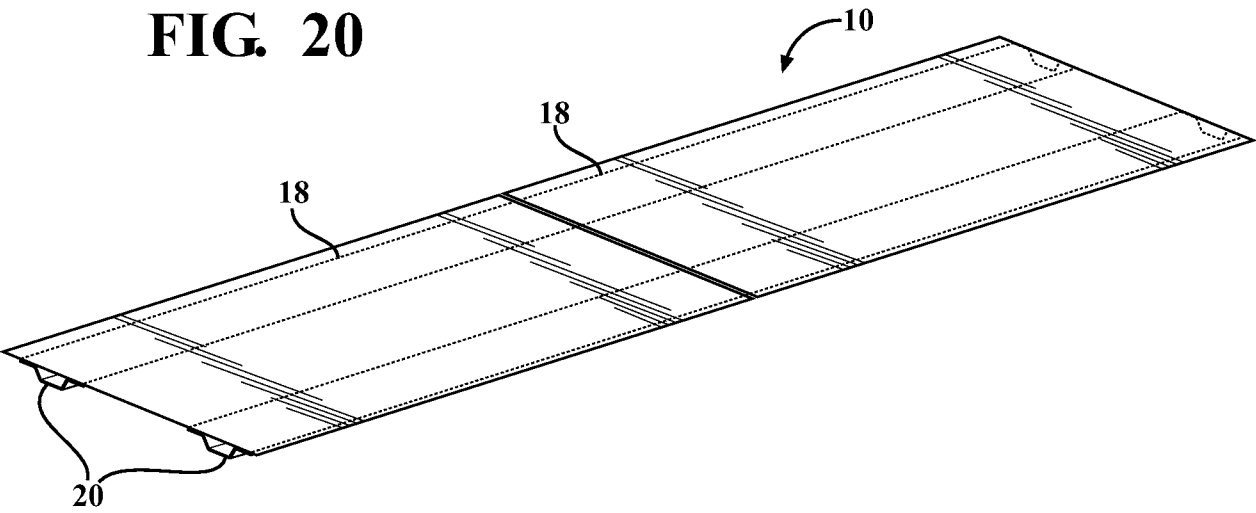


FIG. 20



INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/061433

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H01L31/042 F24J2/52
 ADD. F24J2/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 H01L F24J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	DE 20 2010 003295 U1 (FULLER H B CO [US]) 24 June 2010 (2010-06-24) figures	1
A		2-14
X	DE 10 2008 032985 A1 (GEHRLICHER SOLAR AG [DE]) 21 January 2010 (2010-01-21) figures	1
X	WO 2012/105494 A1 (KYOCERA CORP [JP]; YAMASHITA MITSUO [JP]; TODA KAZUhide [JP]; SUMIDA K) 9 August 2012 (2012-08-09) figures	1
A		2-14



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

18 February 2014

Date of mailing of the international search report

28/02/2014

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Authorized officer

Ferro Pozo, José

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/061433

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