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(54) **SUPPORT SYSTEM FOR SOLAR PANELS WITH MODIFIED JOISTS**

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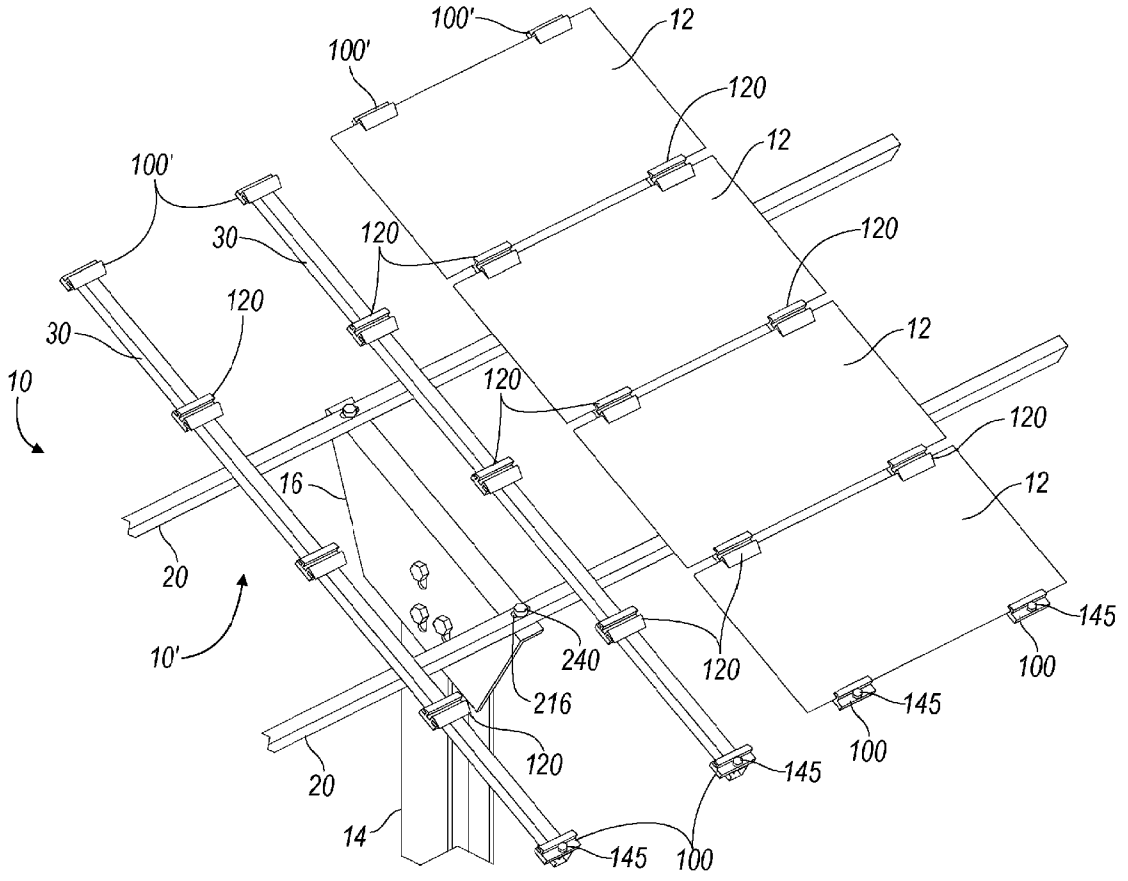
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(57) **ABSTRACT**

A foldable, bi-directional, two-tier panel support system includes a wide variety of different configurations both for the lower support joists and the upper panel rails. The overall array is provided with additional strength through the use of various diagonal and lateral supports running between adjacent upper panel rails. Additional panel loads can be accommodated by extended longitudinal beams on tilt brackets, and additional bracing attached thereto.



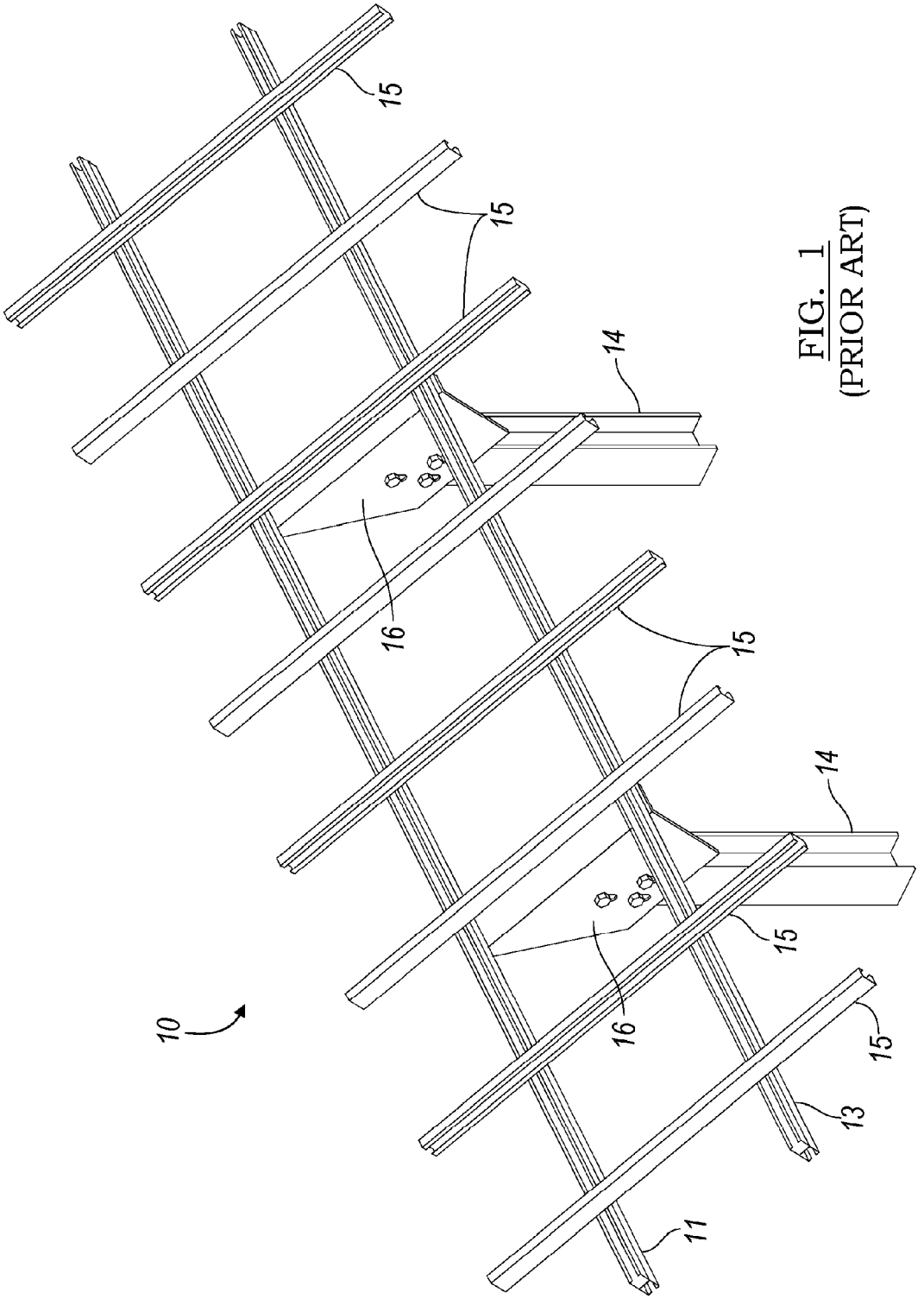



FIG. 1
(PRIOR ART)

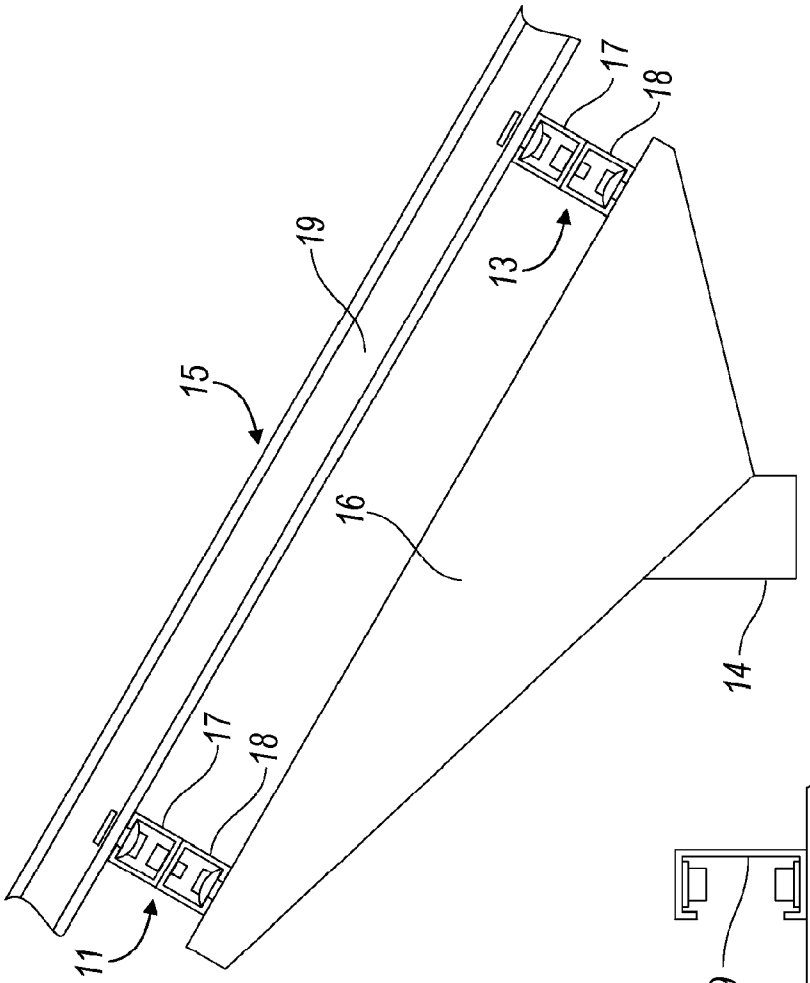



FIG. 2A
(PRIOR ART)

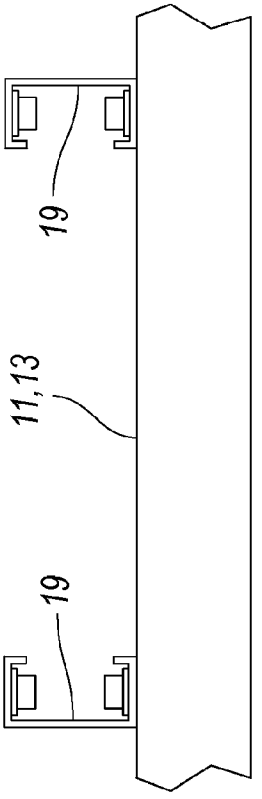



FIG. 2B
(PRIOR ART)

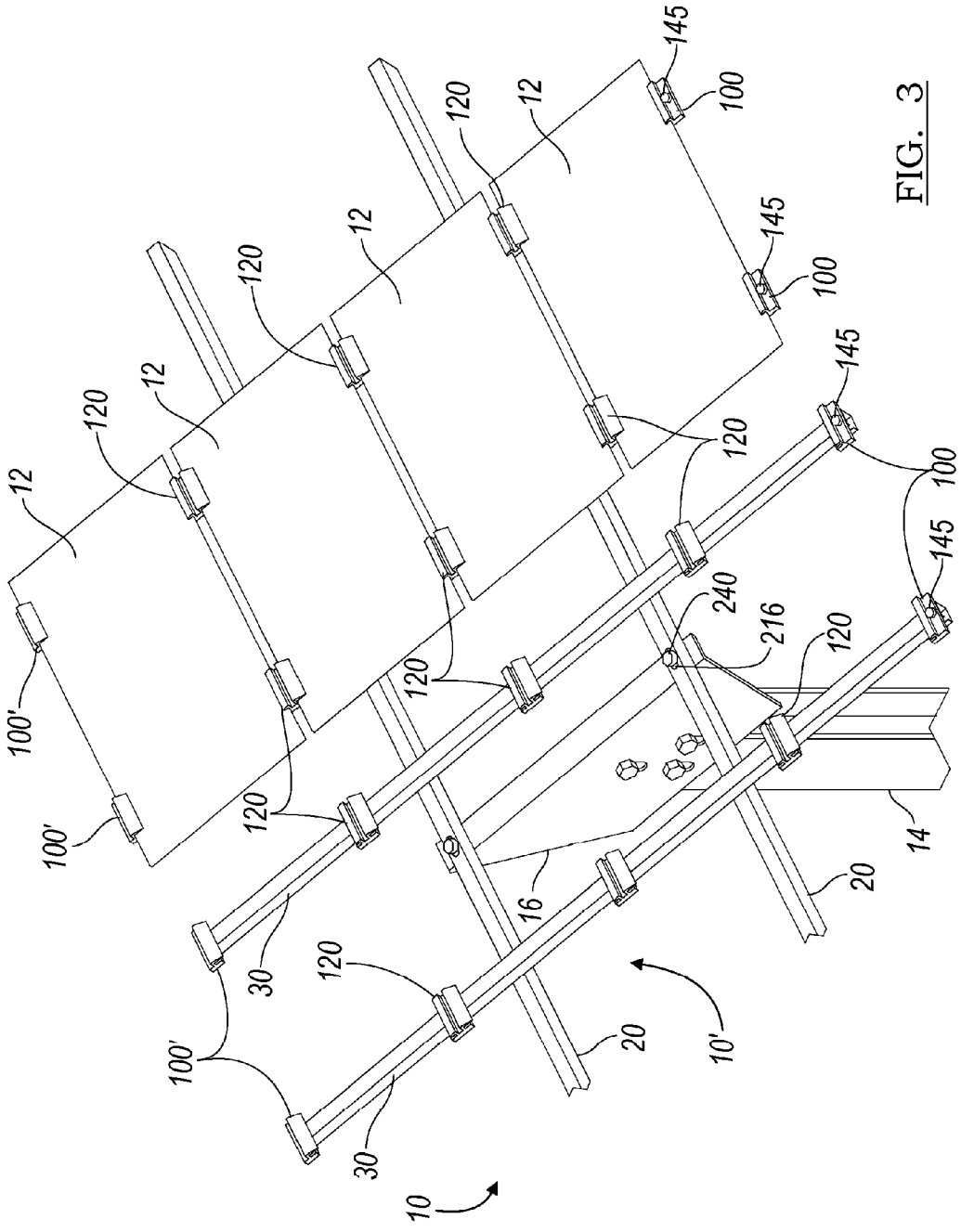

145
100
120
12
145
100
120
12
120
12
145
120
12
100
100'
120
240
216
120
120
100'
120
14
16
20
30
120
100'
20
10'
30
10

FIG. 3

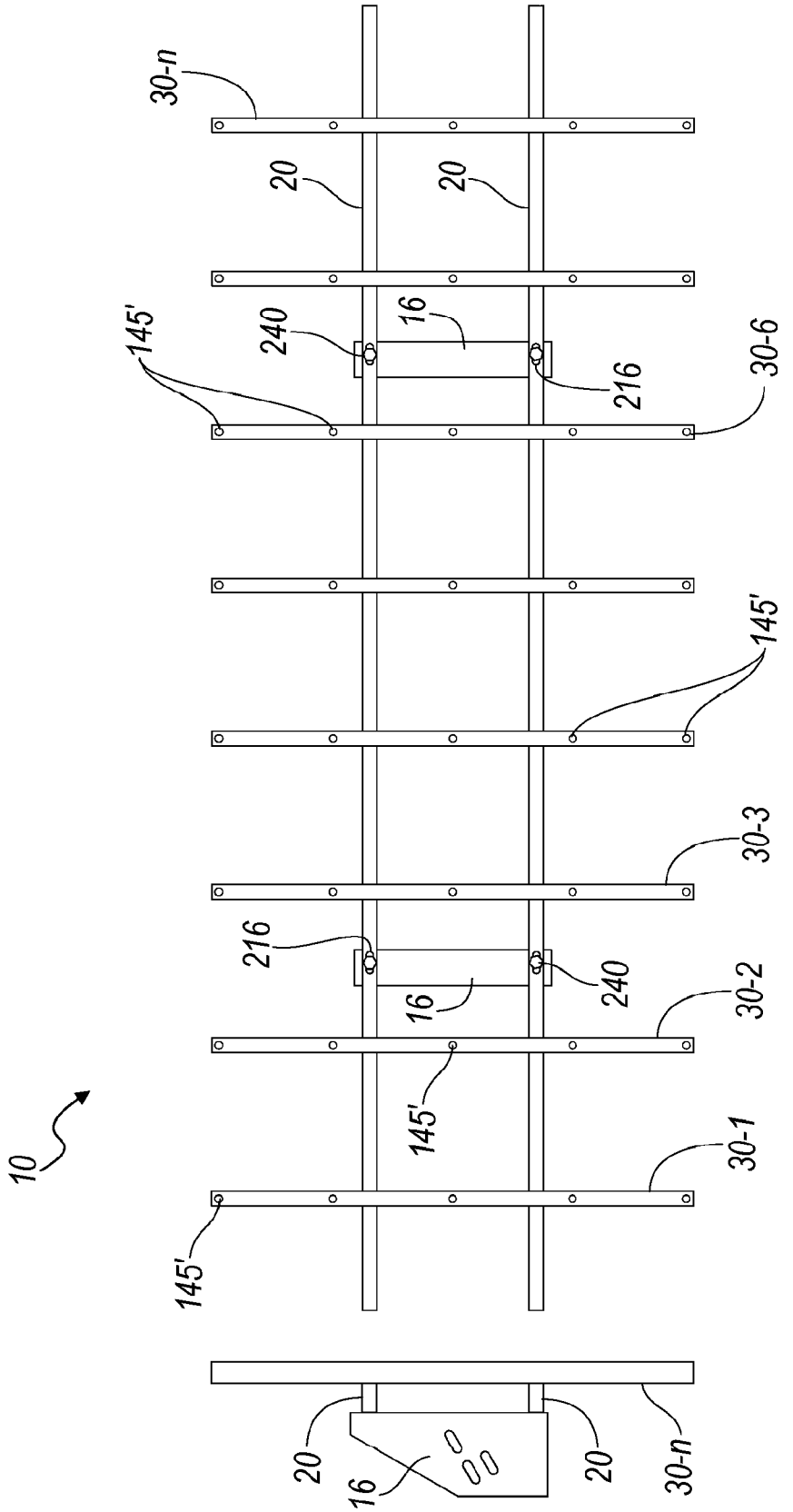

10
30-n
20
20
145'
240
16
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30-6
145'
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20
16
20
30-n

FIG. 4A

FIG. 4B

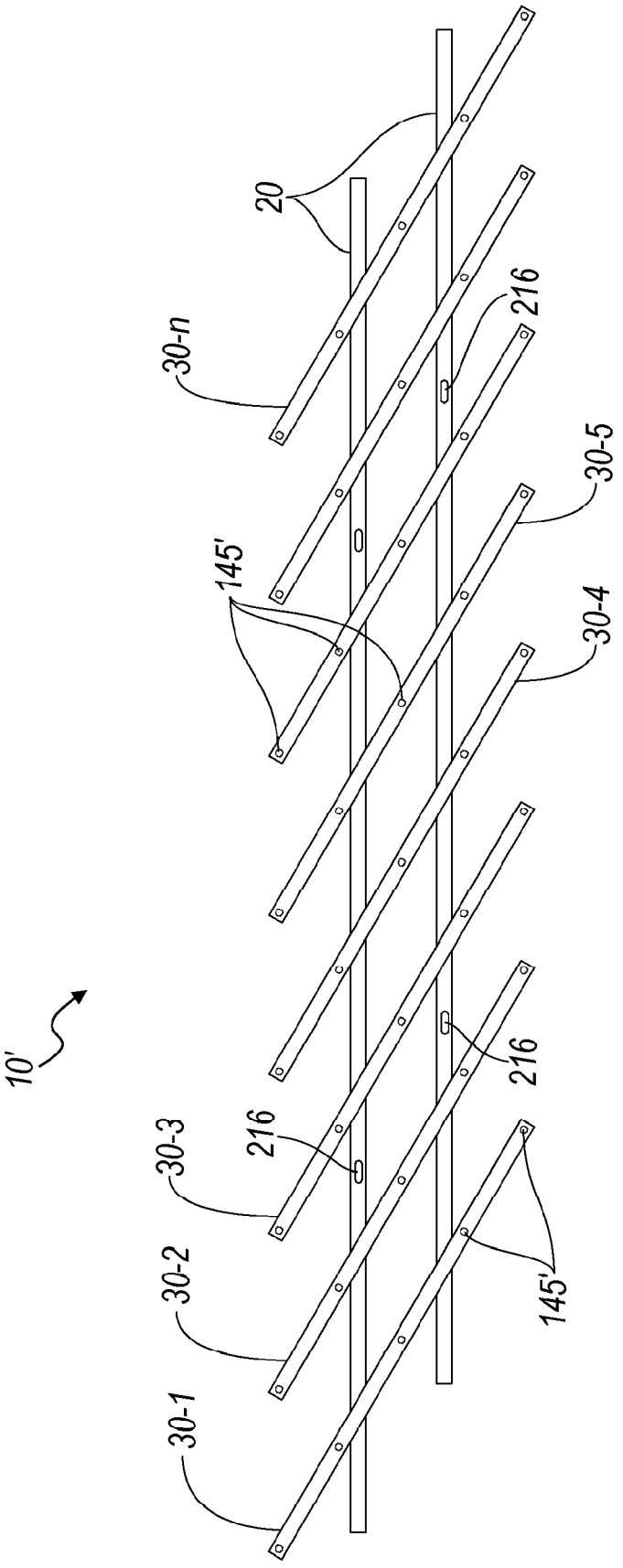



FIG. 5A

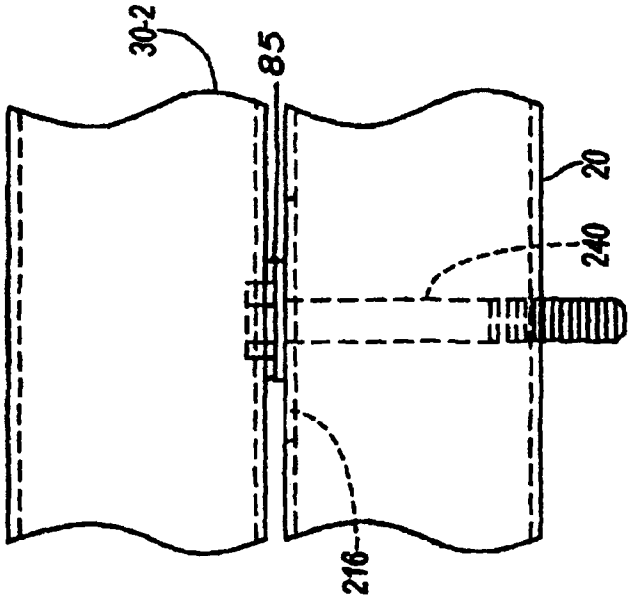



FIG. 5C

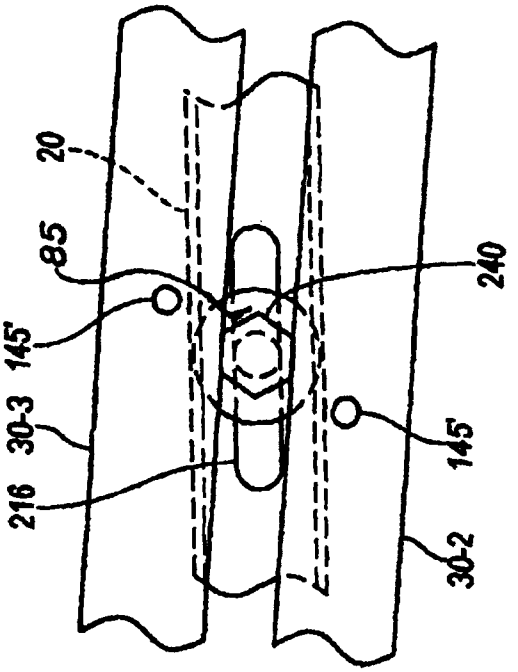



FIG. 5B

FIG. 7a

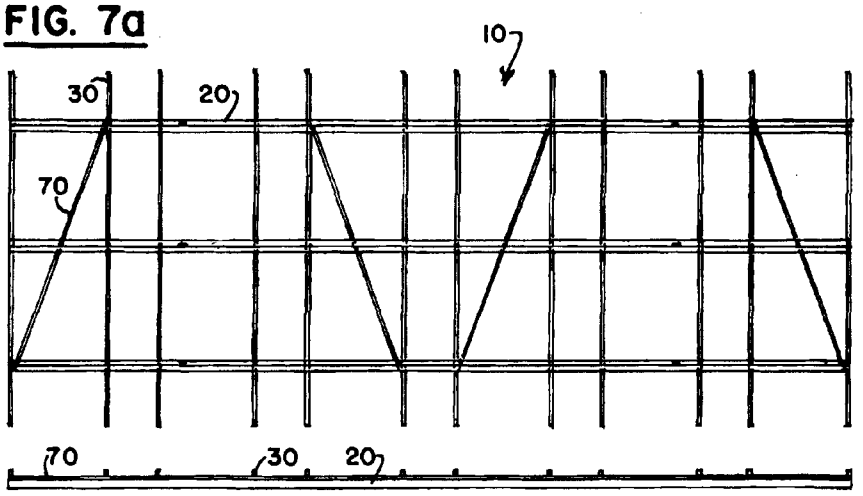
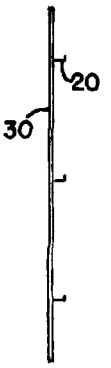



FIG. 7c

FIG. 7b



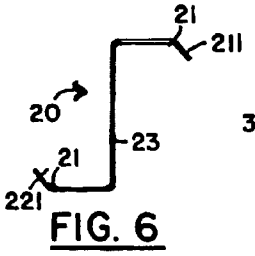




FIG. 6

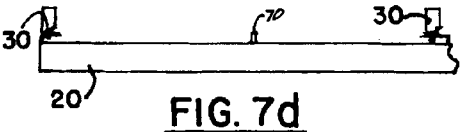



FIG. 7d

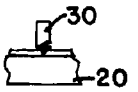



FIG. 7e

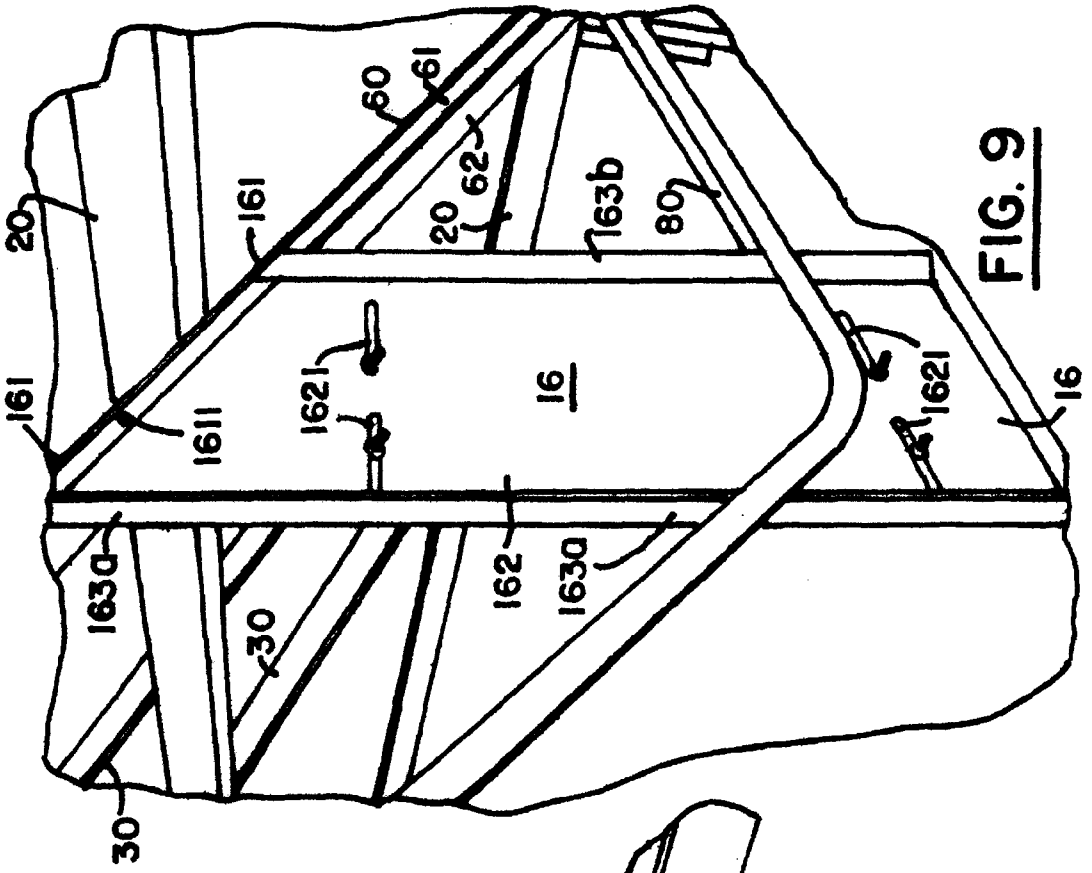

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FIG. 9

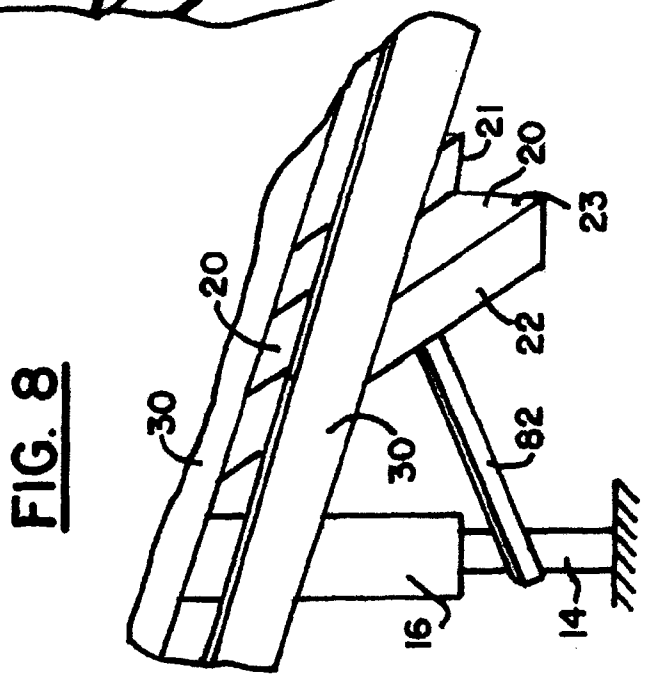

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FIG. 8

FIG. 11

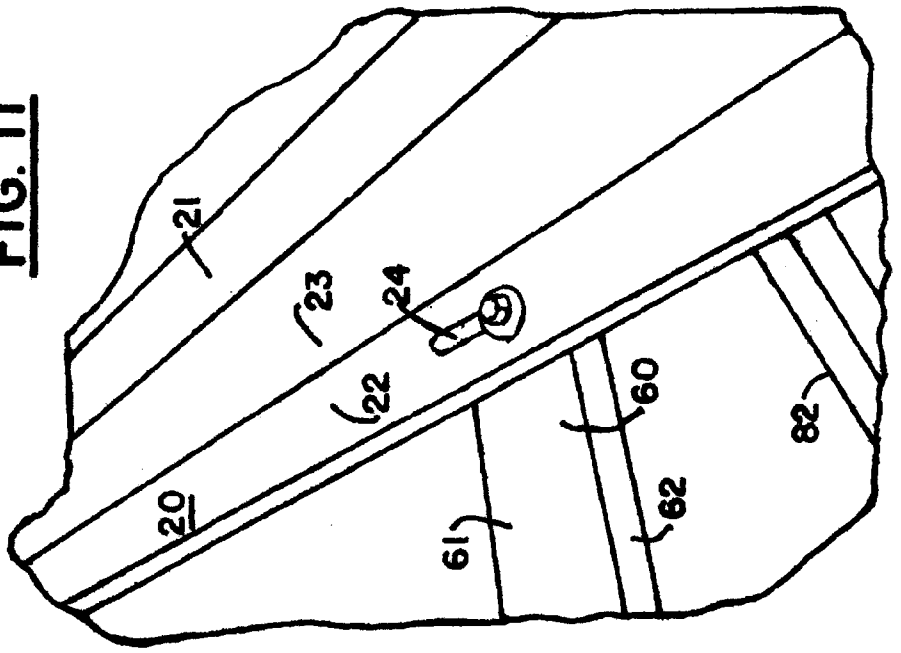

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FIG. 10

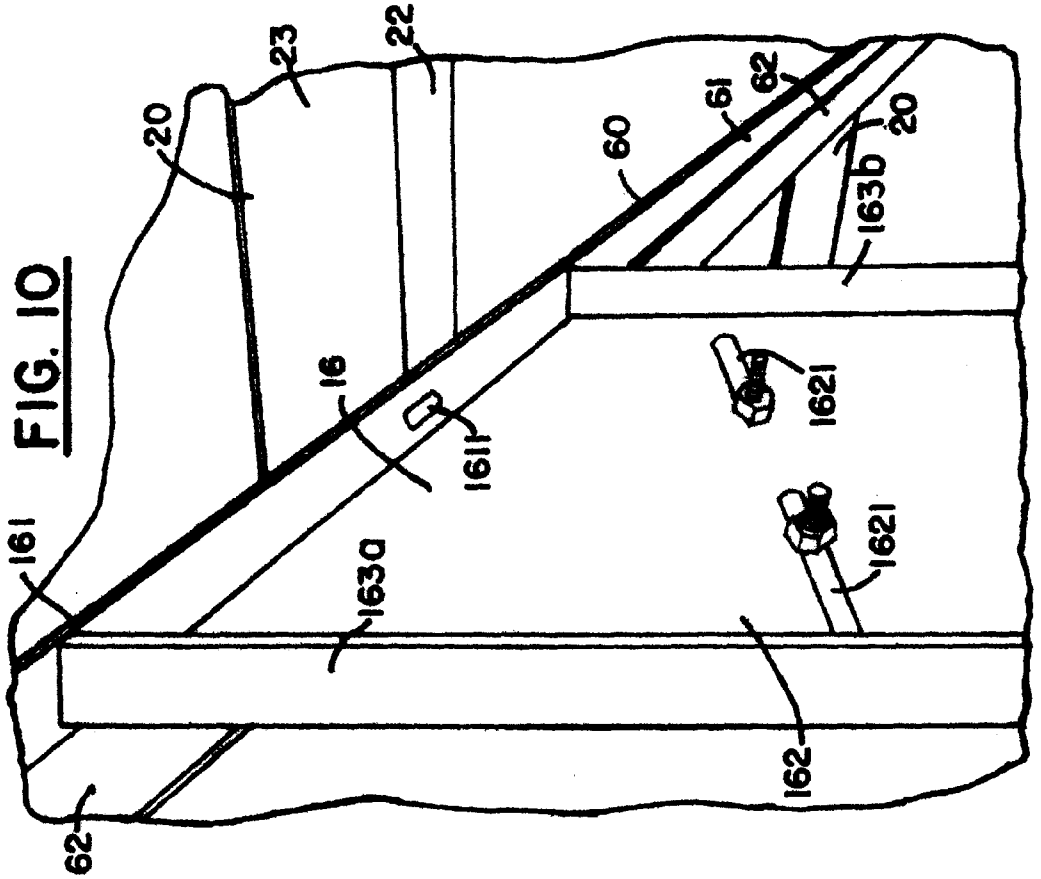
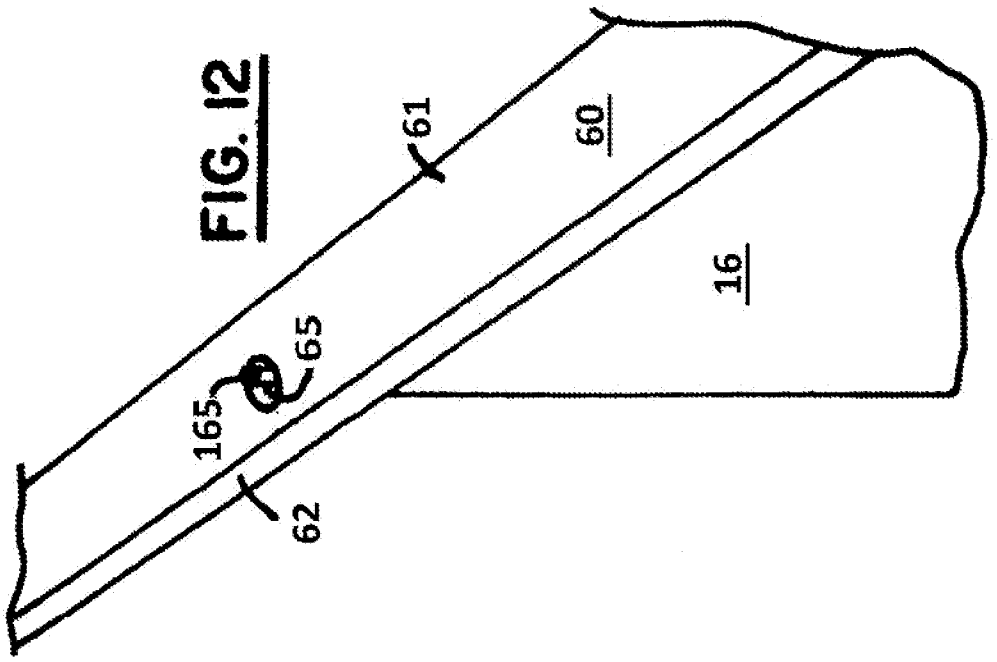

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163b
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1611
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163a
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FIG. 12



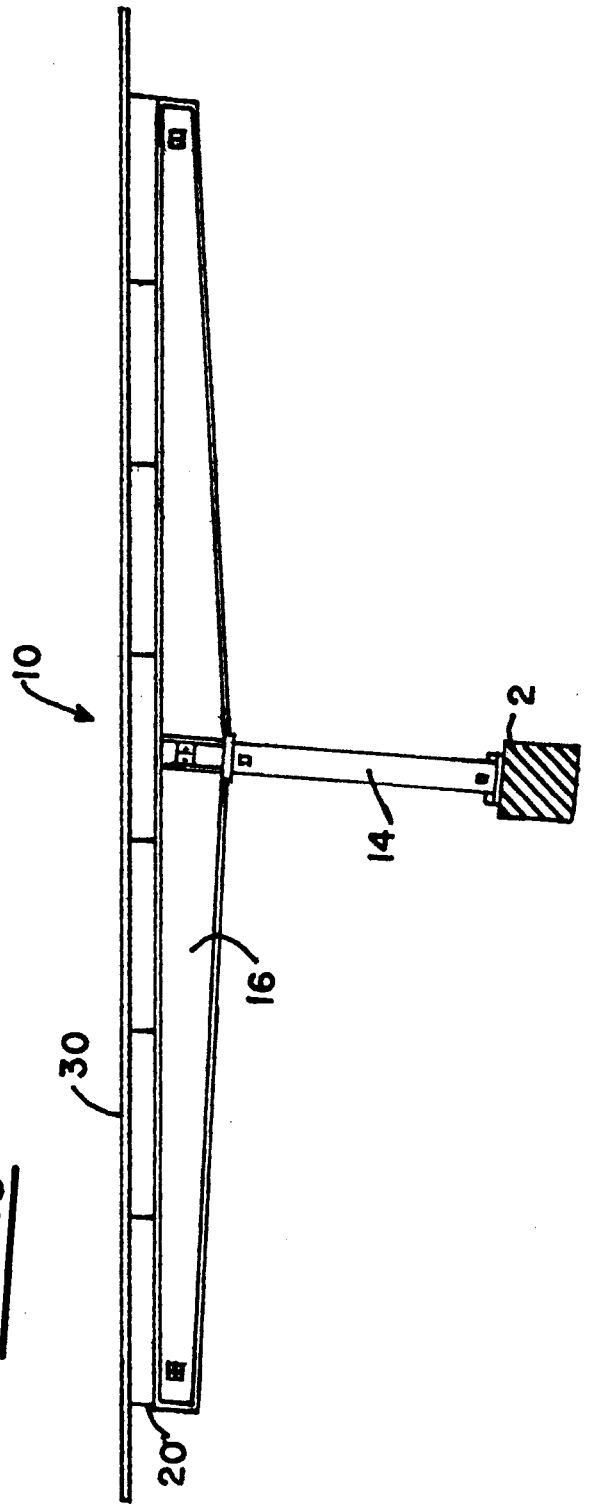



FIG. 13

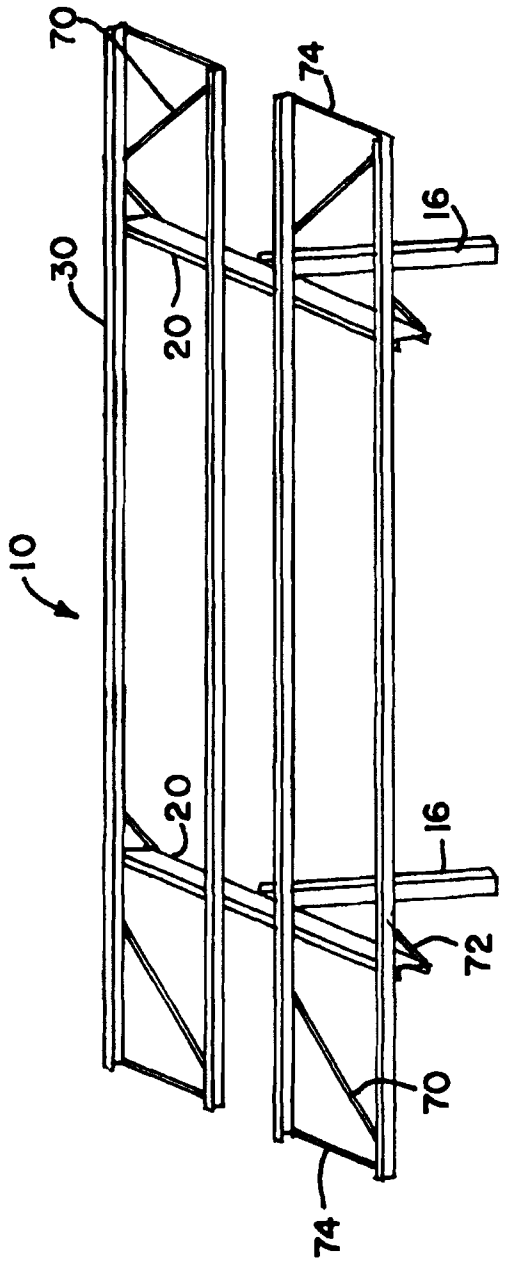



FIG. 14

# SUPPORT SYSTEM FOR SOLAR PANELS WITH MODIFIED JOISTS

## PRIORITY INFORMATION

**[0001]** The present Utility application claims priority as a continuation-in-part application from U.S. Provisional Patent Application Ser. No. 61/539,653, filed Sep. 27, 2011 (now abandoned); and priority as a continuation-in-part of U.S. patent application Ser. No. 13/115,506, filed May 25, 2011 (currently pending), which is a continuation-in-part of U.S. patent application Ser. No. 12/686,598, filed Jan. 13, 2010 (now issued as U.S. Pat. No. 8,256,169), which is a continuation-in-part of U.S. patent application Ser. No. 12/567,908, filed Sep. 28, 2009 (now issued as U.S. Pat. No. 8,240,109), which is a continuation-in-part of U.S. patent application Ser. No. 12/383,240, filed Mar. 20, 2009 (now issued as U.S. Pat. No. 8,316,590). References made to all listed applications, and their contents, are incorporated herein by reference in their entirety.

## FIELD OF THE INVENTION

**[0002]** This invention relates in general to support systems for panels and panel-like structures, such as solar energy collection systems. More particularly, the present invention is directed to a ground-supported mounting system for an array of photovoltaic panels, and a method of assembling the same for activation. The panel support system can include a bi-directional, two-tier matrix having specifically configured support, and bracing elements arranged for attachment to a tilting ground substrate supported system.

## BACKGROUND OF THE INVENTION

**[0003]** A standard photovoltaic (solar) panel array includes a plurality of substantially parallel solar panels **12** (FIG. **3**), optimally arranged for converting light incident upon the panels to electricity. Various panel support systems are used for attachment to roofs, free-field ground (supported by a ground substrate, such as a concrete pad) racks (**14**, **15** in FIG. **1**) or tracking units. Typically, these support systems are costly, labor-intensive to install, heavy, structurally inferior, and mechanically complicated.

**[0004]** Placing the photovoltaic or solar panels **12** on the support structure **10** can be very difficult, as can wiring of the solar panels for array activation. Further, some large solar panels tend to sag and flex, thereby rendering the panel mounting unstable. Unstable panel arrangements also jeopardize the integrity of the wiring arrangement, which is necessary for the photovoltaic panels to be useful.

**[0005]** All of these difficulties are exacerbated when the solar panel array is mounted at an angle, such as 45° from horizontal. Tilting support systems (**16**, **14** in FIGS. **1** and **3**), whether they are free-field ground racks or variable tilt racks mounted on buildings, are examples of installations that can be particularly difficult when mounting solar panel arrays. Examples of conventional tilt-mounted configurations are depicted in FIGS. **1-3**, **4***a*, **4***b*. Most structural, bi-directional arrays used for mounting panels are designed so that optimum stress characteristics occur when the support array is in a horizontal position. Placing such an array at an angle to horizontal introduces an additional set of stresses that can degrade the structural integrity of the array under any number of conditions. Even if the tilt support for the array is adjustable so that the array can be mounted to the tilt support in a horizontal position, the stresses are still introduced once the tilt support is moved so that the array is at an angle to the original horizontal position. Also, in many cases, the tilt support (such as tilt bracket **16**) is not adjustable after it is originally installed. Consequently, the panel array must be mounted under the additional stresses created by placing the panel array in a non-horizontal position. Very often, this is difficult, time-consuming, and even dangerous.

**[0006]** With advanced rigging techniques, it is possible to effect safe installation of support matrices or arrays **10** at non-horizontal angles. However, this is normally done using special rigging or installation equipment. Once this equipment is removed, the stresses encountered when at the non-horizontal mounting angles begin to take effect. These stresses are increased by environmental conditions, such as the wind, rain or snow, may ultimately serve to degrade certain structural numbers of the support matrix. The amount of degradation depends upon the overall external force and weight of the panel support matrix and the angle at which the support matrix is ultimately placed in reference to those external environmental forces. It has been discovered that tubular structures (**17** and **18** in FIG. **2***a*) especially those forming the lower support joists (**11**, **13** in FIGS. **2***a*, **2***b*), can be especially vulnerable to destructive stresses developed by a non-horizontal mounting of the panel support matrix.

**[0007]** One traditional panel support system includes off-the-shelf metal framing channels (upper members **19** constituting panel rails **15** in FIGS. **2***a*, **2***b*) having a C-shaped cross-section, such as those sold under the trademarks UNISTRUT™ or BLIME™, improvised for use as upper and lower support members forming the bi-directional support matrix. The photovoltaic (solar) panels **12** or other panel-like structures are directly secured to the support members and held in place by panel clips or panel holders in a wide range of sizes and shapes. The panel clips serve as hold-down and grounding devices to secure the panel against the corresponding top support member in a spaced relationship. The panel clips are positioned and attached about the panel edges once each panel is arranged in place on the bi-directional support matrix.

**[0008]** For a conventional free-field ground rack system (for mounting solar panels) as shown in FIGS. **1-3**, vertical support elements, such as I-beams **14**, are spaced and securely embedded vertically in the ground or substrate. Tilt-mounting brackets **16** are installed at the top of each I-beam, and each tilt-mounting bracket is secured to the I-beam such that a tilt bracket flange or top section extends above the I-beam at a 90° angle to the side of the tilt-mounting bracket as best seen in FIGS. **1** and **3**. As shown in this case, two UNISTRUT™ joists **13** span the tilt-mounting brackets **16** and are secured thereto. As seen in FIG. **2***b*, UNISTRUT™ upper panel rails **15** are positioned across and fastened to the lower support joists **13**. To secure each upper panel rail **15** to the corresponding lower support joists **13**, a bolt (through a bolt hole made in the rail sidewall) attaches to a threaded opening in a transverse nut-like plate slideably mounted inside the channel of the UNISTRUT™ rail, so that the nut-like plate engages and tightly secures against the upper flange of the joist's C-channel **11** as seen in FIG. **2***a*. Importantly, the width of the plate is slightly less than the width of the channel, so that the plate can be slideably adjusted in the channel, without the plate rotating therein.

**[0009]** Once the bi-directional, two-tier support system **10** is assembled, each solar panel **12** is mounted on a lower

portion of conventional panel holding clips which are secured to the upper panel rails about the perimeter of each panel. The other portion of the panel clips is put in place and tightened. This installation process is usually inaccurate and time-consuming, even with expensive, skilled installers.

**[0010]** Another conventional example of a panel support system is shown in U.S. Pat. No. 5,762,720, issued to Hanoka et al., which describes various mounting brackets used with a UNISTRUT™ channel. Notably, the Hanoka et al. patent uses a solar cell module having an integral mounting structure, i.e. a mounting bracket bonded directly to a surface of the backskin layer of a laminated solar cell module, which is then secured to the channel bracket by a bolt or slideably engaging C-shaped members. Other examples are shown in U.S. Pat. No. 6,617,507 issued to Mapes et al., U.S. Pat. No. 6,370,828 issued to Genschorek, U.S. Pat. No. 4,966,631 issued to Matlin et al., and U.S. Pat. No. 7,012,188 issued to Erling. All of these examples of conventional systems are incorporated herein by reference as background.

**[0011]** Notably, existing conventional support systems require meticulous on-site assembly of multiple parts performed by expensive, dedicated field labor. Assembly is often performed in unfavorable working conditions, i.e. in harsh weather and over difficult terrain, without the benefit of quality control safeguards and precision tooling. Misalignment of the overall support assembly often occurs. This can jeopardize the supported solar panels **12**, or other supported devices. Further, wiring of the solar panels, once electrically connected, is also problematic in conventional systems.

**[0012]** Proper spacing of the photovoltaic (solar) panels **12** is important to accommodate expansion and contraction due to the change in weather. It is also important that the panels are properly spaced for maximum use of the bi-directional area of the span. Different spacing may be required on account of different temperature swings within various geographical areas. It is difficult, however, to precisely space the panels on-site using existing support structures without advanced (and expensive) technical assistance.

**[0013]** For example, with one of the existing designs described above (with reference to FIGS. **2***a* and **2***b*), until the upper panel rails are tightly secured to the lower support joist, each rail is free to slide along the lower support joists and, therefore, will need to be properly spaced and secured once mounted on-site. Further yet, since the distance between the two support joists is fixed on account of the drilled bolt holes through the rails, it is preferred to drill the holes on-site, so that the lower support joists can be aligned to attach through the pre-drilled attachment holes of the tilt bracket. Consequently, the operation of drilling the holes on-site requires skilled workers, and even with skilled installation, might still result in misalignment of the support structure and/or the solar panels supported by that structure.

**[0014]** One major advantage of free-field ground racks, such as the tilt brackets (**14**, **16**) depicted in FIGS. **1**, **2***a* and **3**, is that very large solar panel arrays can be supported. The space that permits the elaborate support structure of a free field support, such as those depicted, usually means that a very large solar array can be accommodated, at least in the space available. Unfortunately, there are limitations other than the available ground space.

**[0015]** In particular, the tilt bracket **16** in conventional arrangements can accommodate only two lower support joists **20**. This substantially limits the size of the solar array that can be accommodated. Conventionally, larger arrays require additional ground or substrate installations to support additional tilt brackets. This can be an expensive, an often intolerably awkward option for creating substrate or ground support for large solar panel arrays.

**[0016]** Even if arrangements can be made to support larger solar panel arrays with expanded tilt bracket capacity, new problems arise. For example, new sets of stresses are introduced by the larger array when secured to its non-horizontal position provided by the tilt brackets. These stresses have been examined, and results indicate increased array warping or deflection, especially over time. This can lead to a very unstable arrangement for holding panels.

**[0017]** It is important to note that misalignment difficulties are exacerbated by the flexing of the support array **10**, and the sagging permitted by the flexibility of the panels. The sagging of the panels can cause the panels to work out of their clips or holders, whether they are secured by separate holding clips or part of the overall structure of the upper support rail. Improper installation, which occurs frequently in conventional systems, can lead to dislocation of the panels due to sagging and/or changing environmental conditions and stresses. A wide variety of different mounting positions and array arrangements also exacerbate the stability problems caused by panel sagging and deflection. Further, certain mounting positions will make the panels more vulnerable to environmental disruptions created by wind and precipitation. Freeze-thaw cycles can also be a major factor. All of these variables are further complicated by non-horizontal mounting of the panel support array.

**[0018]** Existing panel clips or holders are generally configured to avoid damage to the solar panel framework and to facilitate easy installation, often at the cost of panel security. Once panels loosen, the integrity of the electrical connections (in particular ground connections) between the panel and the supporting panel rail **30** is compromised. While a break of the electrical circuit is not necessarily the immediate result, resistance will increase at the loosened connections, thereby degrading electrical efficiency. If such a condition persists, degradation of the metal at the electrical contact points can also occur, thereby even further degrading the electrical system.

**[0019]** Conventional panel clips or holders can be problematical for a number of reasons. Firstly, installation for use of the clips is very time-consuming, even for skilled installers. If the clips are not sufficiently tight, loosening of the panels will certainly occur. If the clips are overly tight, the panels can be deformed or otherwise degraded. Further, the cost of numerous panel clips, as well as the gaskets that are used therein, can substantially increase the overall equipment costs, as well as add adding to the installation costs.

**[0020]** The arrangements depicted in FIGS. **1**, **3**, **4***a*, **4***b*, and **5***a* are limited to rather constrained configurations. In particular, only two support joists **20** can be mounted on the ground support and tilt bracket configuration (**14**, **16**). This severely limits the size and shape of the solar panel arrays that can be used with this type of ground support. If sufficient space exists and the ground support and tilt bracket configuration (**14**, **16**) are sufficiently strong, then larger panel arrays with more than two support joists **20** would be highly desirable.

**[0021]** Therefore, a need exists for a low-cost, uncomplicated, structurally strong support system and assembly method, so as to optimally position and easily attach a plurality of photovoltaic panels while meeting architectural and engineering requirements, especially with regard to durabil-

ity. Likewise, there is an urgent need for a non-horizontal mounted solar panel system that will maintain the security of the mechanical connections of the solar panels to panel rails despite the flexing of the panels (and support structure) caused by gravity, vibration, and the other environmental factors previously discussed.

**[0022]** At present, none of the conventional systems has these capabilities. With this invention, an improved panel support system is achieved having a more precise configuration in the field, without requiring extensive and extra work at the installation site. The use of such an improved system would facilitate easy placement of solar panels onto the support structure. Further, a simple panel holding arrangement could be used within the overall concept of the system, while providing secure mechanical and electrical connections. The shipping configuration of the improved support system would be such so as to be easily handled in transit while still facilitating rapid deployment. With this invention, rapid deployment on a ground support and tilt-mounting bracket would not sacrifice stable support for the panels. Rapid deployment includes rapid mechanical and electrical connections of the panels to panel support rails in a manner that keeps the panels electrically and mechanically secure, despite panel flexing caused by the several factors discussed.

## SUMMARY OF THE INVENTION

**[0023]** It is a primary object of the present invention to improve upon conventional photovoltaic solar panel systems, especially with regard to assembly, wiring, and overall installation durability.

**[0024]** It is another object of the present invention to provide a support and installation system for solar panels in which the panels and installation site are less likely to be damaged during installation.

**[0025]** It is a further object of the present invention to provide a support system for solar panels that is easily installed on-site while still resulting in a precise configuration for purposes of mounting the solar panels.

**[0026]** It is an additional object of the present invention to provide a solar panel support system that can be assembled very quickly on-site.

**[0027]** It is still another object of the present invention to provide a solar panel support system that can achieve close tolerances during field installation without the necessity of skilled labor at the installation site.

**[0028]** It is still an additional object of the present invention to provide a solar panel support system which can be easily adapted to a wide variety of solar panel array sizes and shapes.

**[0029]** It is yet another object of the present invention to provide a solar panel support system which minimizes the necessity for precise measurements at the installation site during installation.

**[0030]** It is still an additional object of the present invention to provide a solar panel support system that can be precisely configured to a specific ground environment.

**[0031]** It is another object of the present invention to provide a support system for solar panels and other panel-like structures in which degradation caused by metal-to-metal contact is substantially reduced.

**[0032]** It is again another object of the present invention to provide a support system for panel-like structures in which accommodation is made for movement caused by wind, changes in temperatures, or other environmental conditions.

**[0033]** It is again another object of the present invention to provide a flexible arrangement for adapting a solar panel support system to accommodate a wide variety of different panel configurations.

**[0034]** It is still an additional object of the present invention to provide a solar panel mounting system that can accommodate easy installation and removal of panels on adjacent frameworks.

**[0035]** It is still a further object of the present invention to provide a folding solar panel support system in which rotation of structural members with respect to each other can be advantageously controlled.

**[0036]** It is yet another object of the present invention to provide panel clips for a solar panel support structure which allow easy installation without interfering with adjacent panels.

**[0037]** It is still an additional object of the present invention to provide a collapsible panel support system wherein deployment of the support system using rotating connection members can be precisely adjusted.

**[0038]** It is again a further object of the present invention to provide a panel support structure which integrates easily in a wide range of mounting sites, and needs minimal mounting or deployment time.

**[0039]** It is still another object of the present invention to provide a support system for panels or panel-like structures for a wide range of uses, positions and structures.

**[0040]** It is again an additional object of the present invention to provide a panel support system in which the relative rotation of the structural members to each other, when deploying the support system, is carefully calibrated and controlled without adjusting or tightening of the rotating joints at the installation site.

**[0041]** It is still another object of the present invention to provide a panel support system which can be easily fixed to a "hard" mounting ground support using bolts, without causing damage to the panel support system.

**[0042]** It is yet another object of the present invention to provide a panel support system that can be easily deployed or removed by rotating intersecting structural members, without fouling, jamming or binding at the intersections of the structural members.

**[0043]** It is again an additional object of the present invention to provide a panel mounting system which facilitates quick, secure mounting of the panels once the support system is deployed, without complex panel-holding devices.

**[0044]** It is yet another object of the present invention to provide a panel support system that can accommodate flexing, sagging and other deformation of the panels while maintaining a secure connection thereto.

**[0045]** It is yet a further object of the present invention to provide a panel mounting system which facilitates easy electrical connections to the panels.

**[0046]** It is again an additional object of the present invention to provide a panel support system that facilitates secure and easy connection and disconnection of electrical wires running throughout the system.

**[0047]** It is still another object of the present invention to provide a panel support system that facilitates secure electrical connections between the panels and the supporting panel rails under a wide variety of conditions and circumstances.

**[0048]** It is again a further object of the present invention to provide a panel support system that accommodates secure support when positioned in a non-horizontal position.

**[0049]** It is yet another object of the present invention to provide a panel support system that reduces degradation due to metal fatigue, even when the support system is exposed to extreme weather conditions when mounted in a non-horizontal position.

**[0050]** It is again a further object of the present invention to provide a panel support system that aligns and installs easily to substrate support installations.

**[0051]** It is still an additional object of the present invention to provide a panel support system that holds up to the accumulation of snow and/or water, as well as shifting forces and torque caused by wind, particularly when the support system is mounted in a non-horizontal (i.e. inclined) position.

**[0052]** It is still another object of the present invention to provide a panel support system that is particularly effective with ground supported, tilt bracket installations.

**[0053]** It is the overall goal of the present invention to provide a comprehensive panel mounting system that facilitates rapid, secure installation, including deployment of the panel support structure, placement of the panels on that support structure, and wiring of the panels for activation.

**[0054]** These and other goals and objects of the present invention are achieved with a support system for an array of parallel panels, wherein the support system includes vertical tilt brackets supported by an underlying substrate. This support system also has a foldable support array which includes a connection interface for each vertical tilt bracket supporting at least two upper panel rails at connection points, and at least two diagonal supports arranged between adjacent upper panel rails. The foldable support array is arranged so that the upper panel rails are parallel to each other in a deployed position and is collapsible so that the upper panel rails, and at least one of the diagonal supports are substantially longitudinally aligned with each other in a package suitable for motor road transport.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0055]** Having generally described the nature of the invention, reference will now be made to the accompanying drawings used to illustrate and describe the preferred embodiments thereof. Further, the aforementioned advantages, and others, will become apparent to those skilled in this art from the following detailed description of the preferred embodiments when considered in light of these drawings, in which:

**[0056]** FIG. **1** is a perspective view of an assembled conventional field ground rack support system for securing a plurality of solar panels;

**[0057]** FIG. **2***a* is a side view of a conventional tilt bracket mount with prior art C-shaped sectional channels secured back-to-back to form support joists to which upper panel rails, also shown in FIGS. **2***b*, are secured;

**[0058]** FIG. **2***b* shows an end view of prior art upper panel rails, each with a C-shaped sectional channel;

**[0059]** FIG. **3** is a perspective view of a previously-disclosed, inventive support system in a configuration as used with the instant invention showing solar panels arranged in a column and in a spaced relationship thereon, wherein the support system has horizontally-aligned lower support joists and (relative thereto) vertically-aligned upper panel rails;

**[0060]** FIG. **4***a* is a top plan view of the bi-directional span of the assembly as used in the instant invention, in the open position showing vertically-aligned upper panel rails attached atop horizontally-aligned lower support joists;

**[0061]** FIG. **4***b* is an end elevational view of the bi-directional span of the assembly shown in FIG. **4***a;*

**[0062]** FIG. **5***a* is a top view illustrating the bi-directional support frame of the assembly shown in FIG. **4***a* collapsed to an intermediate semi-folded position;

**[0063]** FIG. **5***b* is a top view depicting, in enlarged detail, the support system in a collapsed or folded position, and in particular, a steel bearing washer between the upper panel rail and the lower support joists, as well as a connector for holding the lower support joist to a support and/or tilt bracket or similar structure, i.e. held between adjacent, folded panel rails;

**[0064]** FIG. **5***c* is a side view of FIG. **5***b* depicting the steel bearing washer and the connector for holding the lower support joist to a support and/or tilt bracket or similar structure;

**[0065]** FIG. **6** is an end view of a lower support joist used as part of the present invention;

**[0066]** FIG. **7***a* is a top view of a support system configured with diagonal cross supports according to the present invention;

**[0067]** FIG. **7***b* is an end view of the support system of FIG. **7***a;*

**[0068]** FIG. **7***c* is a side view of the support system of FIG. **7***a;*

**[0069]** FIG. **7***d* is a front view of a portion of the support system of FIG. **7***c;*

**[0070]** FIG. **7***e* is yet another view of a portion of the support system of FIG. **7***d;*

**[0071]** FIG. **8** is an end perspective view of the lower support joist of the present invention with a plurality of upper panel rails attached thereto;

**[0072]** FIG. **9** is a side perspective view of a tilt mounting bracket used as part of the present invention;

**[0073]** FIG. **10** is an end perspective view of the tilt mounting bracket of FIG. **9**;

**[0074]** FIG. **11** is a front perspective view of a lower support joist of the present invention;

**[0075]** FIG. **12** depicts a top perspective view of an alternative longitudinal beam used in the configuration of the present invention;

**[0076]** FIG. **13** is a side view of an alternative arrangement for a ground-mounted tilt structure; and

**[0077]** FIG. **14** is a front perspective view of an additional embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0078]** The present invention is used in the conventional environment depicted in FIGS. **1**-**2**(*b*), and is an improvement upon the previously disclosed inventions depicted in FIGS. **3**-**5**(*a*-*c*). The previously disclosed inventions by some of the same inventors are found in U.S. patent application Ser. No. 12/383,240 (filed Mar. 20, 2009); U.S. patent Ser. No. 12/567,908 (filed Sep. 28, 2009); and, U.S. patent application Ser. No. 12/686,598 (filed Jan. 13, 2010). All of these patent applications describe the referenced support systems. The present patent application relies on all three for priority and incorporates all by reference for purposes of providing a more complete background for the instant invention.

**[0079]** FIGS. **3**-**5**(*a*-*c*) are relied upon as disclosing the bi-directional, two-tier panel support matrix environment in which the improvements of the present application operate. Only a summary of the structures depicted in FIGS. **3**-**5**(*a*-*c*) is provided herein, sufficient for an understanding of the background of the present invention. Full, detailed descrip-

tions of the structures depicted in FIGS. **3-5**(*a-c*) are found in the aforementioned, incorporated applications.

**[0080]** A summary of certain aspects of the previous inventions incorporated herein by reference is provided below. In accordance with one previously described inventive embodiment constituting the background of which the present invention is an improvement, FIG. **3** depicts a support system **10** for an array or photovoltaic array of solar panels **12**, attached to a conventional, free-field vertical support arrangement (**14**, **16**). The support system **10** is constituted by a bi-directional, two-tier support frame of horizontally-aligned lower support joists **20** and vertically-aligned upper panel rails **30** (identified as **30-1** through **30-***n*), as also seen in FIGS. **4***a* and **4***b*.

**[0081]** For purposes of convenience when describing the new embodiments of the present invention, the orientation description of "upper" and "lower" will be used. While the array of support system **10** can be placed in any orientation with respect to longitudinal or latitudinal descriptors, for the sake of clarity the present invention always has lower support joists **20** and upper panel rails **30**. The designation of "upper" and "lower" appears to be the most straight-forward for dealing with the two-tier aspects of the new invention considered herein.

**[0082]** The terminology "support joist" has been used previously with regard to the prior art structural members **11**, **13**. The same functional type of lower structural member is designated here as "lower support joist" **20** for the descriptions of both past and present inventive embodiments. The upper structural member, previously denoted as an upper support rail **15** is more accurately described by the designation "upper panel rail" **30** in the present embodiments. This is appropriate since the structural element **30**, denoted as an upper panel rail **30**, is always located above lower support joist **20** and constitutes the elements to which the external solar panels **12** are held to the support system **10**.

**[0083]** In one alternative to the first support system **10** described above, the bi-directional, two-tier support system **10** can have the lower support joists **20** aligned along the length of tilt-mounting brackets **16**. As a result, upper panel rails **30** extend longitudinally, as described and depicted in the subject previous applications. It should be understood that within the context of the present invention any orientation of the substantially perpendicular structural elements (lower support joists **20** and upper support rails **30**) can be used.

**[0084]** Further, a wide variety of different shapes, sizes and configurations are encompassed by the concept of the present invention, which is not to be limited by the examples provided herein. The present array of support members (**20**, **30**) can be adjusted to conform to any support structure or any "footprint" available for the deployment of solar panels **12**, or any other panel-like structure to be supported by the present invention. Further, as described infra, both the upper panel rails **30** and lower support joists can be modified.

**[0085]** The present invention is directed in particular to the use of a folding support system **10** mounted on a tilt bracket ground support substructure, in particular, vertical ground supports **14** depicted in FIGS. **1**, **2***a* and **3**. The various embodiments of the present invention include modifications to the tilt-mounting brackets **16** and the lower support joists **20**, as well as improvements to the interface between the two. These improvements are meant to address the different stresses caused by non-horizontal mounting in conjunction with increased panel array sizes, and various and ever changing environmental forces caused by wind, snow and rain. This increased capability is provided without degrading the convenience of off-site pre-assembly, compact transport configuration or rapid deployment of earlier versions of the folding support system **10**.

**[0086]** One variation of the present invention is the increased size of the tilt-mounting bracket **16** as depicted in FIG. **13**. In distinct contrast to the earlier versions depicted in FIGS. **1**, **2***a* and **3**, the tilt-mounting bracket **16** is sized to accommodate more than two lower support joists **20**. As a result, longer panel rails **30** can be supported, and much larger solar panel arrays **12** can be accommodated. A major advantage is that only one ground support, such as concrete pier **2** shown on FIG. **13**, is required for each tilt bracket **16**. While a stronger vertical support **14** is needed for the increased weight, an increase in expense for such support structures is relatively minor compared to the economic benefit of the increased size of the panel array **10** being supported.

**[0087]** While the cost of the increased size of vertical support **14** (and its substrate interface **2**) is not necessarily significant, the cost of the enlarged tilt-mounting bracket **16** can be. For example, tilt-mounting bracket **16** in FIG. **13** can be constituted by a structural truss, depending upon the size of panel array **10** that is to be supported, as well as the use to which the overall structure is to be put. For example, the overall structure can be used as a shelter, carport, or the like. Consequently, the overall size of the structure and the panel array **10** can be virtually any value that can be accommodated for the size of the installation site. Accordingly, additional variations are appropriate.

**[0088]** Different variations are found in the different designs depicted in FIGS. **9** and **10**, as well as that depicted in FIG. **12**. In both cases, a longitudinal beam **60** is located atop (or as part of) the tilt-mounting bracket **16**.

**[0089]** In FIGS. **5** and **10** the longitudinal beam **60** forms the extended length of the top of the tilt-mounting bracket **16**, being welded thereto. In contrast, longitudinal beam **60** in FIG. **12** is not welded to tilt-mounting bracket **16**. Rather, longitudinal beam **60** is configured to interface with certain structural aspects of the tilt-mounting bracket **16**, and can be connected thereto in a wide variety of different techniques, such as bolting. This arrangement admits to greater flexibility, and can accommodate a wider range of longitudinal beam **60** sizes and configurations. As a result, the selection of longitudinal beam **60** size and configuration can be made based upon the load to be placed upon the overall structure so that a more stable structure can be obtained.

**[0090]** In FIGS. **9** and **10**, an L-shaped channel as beam **60** is depicted. It should be noted that the tilt-mounting bracket **16** can be formed with a substantial top surface **161** or only a top edge welded so that the longitudinal beam **60** forms the top surface of the tilt-mounting bracket **16**. Either variation is entirely acceptable within the concept of the present invention. While the longitudinal beam **60** is depicted as an L-shaped structure, other shapes are permissible within the concept of the present invention.

**[0091]** Tilt-mounting bracket **16**, as depicted in FIGS. **9** and **10**, has a sidewall **162** and two end walls **163**(*a*), **163**(*b*). As depicted, the top wall **161** is constituted by one side (top side **61**) of the angle iron constituting longitudinal beam **60**. The top side **61** of longitudinal beam **60** (constituted by an L-channel with sides **61**, **62**) includes a slotted aperture **1611** for alignment of the lower support joists **20** of support matrix **10**. This is used to receive connecting bolts that hold a lower support joist **20** to the combined longitudinal beam **60** and

tilt-mounting bracket **16**, which helps to align the support matrix **10** during the unfolding step. Preferably, the combined tilt-mounting bracket structure (**16**, **60**) is made of steel, as is the lower support joist **20**. The bolts can be any type currently used to hold the support matrix **10** to the tilt-mounting bracket **16**. As stated, the slotted opening **1611** provides a level of adjustability that helps facilitate easy alignment and connection of the support matrix **10** to the tilt-mounting bracket **16** (as supported by substrate support structures **14**, **2**).

**[0092]** It has already been noted that the ground support or substrate support structure **2** and vertical beam **14** must be larger to accommodate the weight of an increased panel array **12**. Likewise, the tilt-mounting bracket **16** is preferably modified to accommodate the greater weight and dimensions of the larger support system **10** and the panels **12** that are ultimately contained therein. The tilt-mounting bracket **16** is not part of vertical support **14** in these embodiments. Consequently, it must be attached thereto. To accommodate the greater weight, a more elaborate and robust connection scheme is needed. Consequently, the sidewall **162** of the tilt-mounting bracket **16** contains slotted openings **1621** (for bolts) to more easily mount it to the vertical support **14** and to provide greater structural stability. Also, increased connectivity to the longitudinal beam **60** must be facilitated to maintain the necessary structural stability. One such method is to use the L-shaped channel as the longitudinal beam **60** formed as part of the tilt-mount bracket **16** as discussed.

**[0093]** In the embodiment depicted in FIG. **12**, the longitudinal beam **60** is separate from the tilt-mounting bracket **16**. It must be fitted to the top of the tilt-mounting bracket **16** before support system **10** is deployed. In this embodiment, because longitudinal beam **60** is longer than that in FIGS. **9** and **10**, mounting the longitudinal beam **60** on the tilt-mounting bracket **16** can be somewhat awkward. To facilitate easy mounting, the tilt bracket **16** of either or both of end walls **163**(*a*) or **163**(*b*) is provided with an alignment finger **165**. A slotted guide opening **65** on the upper surface **61** of longitudinal beam **60** allows an easy fit of the longitudinal beam onto the tilt-mounting bracket **16**. The looseness of the interface between slotted guide opening **65** and the alignment finger **165** permits easy adjustment of beam **60** on tilt-mounting bracket **16** before the final connectors are tightened, holding the longitudinal beam **60** to the tilt-mounting bracket **16**.

**[0094]** Because the present invention allows for longer longitudinal beams **60**, a drawback occurs when increasing the size of the supported panel array. In particular, as longitudinal beam **60** becomes longer, more support is needed to support longitudinal beam **60** and the overlying extended support matrix **10**. This is especially true at the ends of the longitudinal beam **60**, which tends to sag under the extra weight of panel support system **10**, and its load of panels **12**.

**[0095]** To address this situation, arcuate vertical bracing **80** is applied to the tilt-mounting brackets **16**, as depicted in FIG. **9**. The arcuate vertical brace **80** is connected to the sidewall **162** of tilt-mounting bracket **16**. The end surfaces **163**(*a*), **163**(*b*) of the tilt-mounting bracket **16** are cut so that the arcuate vertical brace **80** fits into the resulting openings and is welded to the end surfaces **163**(*a*), **163**(*b*). These help support the arcuate vertical brace **80**. However, other support is needed and is preferably provided by welding the arcuate vertical brace **80** to the sidewall **162** of tilt-mounting bracket **16**. While welding is preferred, other connection methods, such as bolts, can also be used. Further, any combination of welding and bolting is also appropriate. With regard to the design shown in FIGS. **12***a* and **12***b*, an angled support member **82** (best seen in FIG. **8**) is used for added structural support.

**[0096]** The use of larger panel arrays **10** on ground supported tilt-mounting brackets **16** of this invention leads to additional weight and stresses on the lower support joists **20**, especially the tubular structures relied upon in the aforementioned patent applications, incorporated herein by reference. These stresses are substantially increased by environmental factors such as wind, precipitation, and freeze cycles. Over long periods, tubular structures which are entirely adequate for smaller support arrays, begin to experience metal fatigue when arrayed in larger area configurations. Even if this metal fatigue does not result in immediate failure, additional deformation and panel loosening can result.

**[0097]** The inventive solution to this difficulty is a new design for the lower support joist **20**, depicted in FIGS. **6** and **8**. This type of lower support joist **20** includes an upper member **21** and a lower member **22**, each substantially parallel to the other member. A median connecting member **23** extends between the two parallel upper and lower members **21**, **22**. While the median connecting member **23** is depicted in FIGS. **6** and **8** as being perpendicular to the parallel upper and lower members **21**, **22**, the support joist **20** of the present invention is not limited thereto. Rather, the median connecting member **23** can be diagonal, extending between opposite rear edges of the parallel upper and lower members **21**, **22**. Further, the median connecting member **23** could be a curve such as an S-shaped structure, or any other structurally appropriate configuration.

**[0098]** The outer, opposite edges of the upper and lower members **21**, **22** have angled end portions **211**, **221**, respectively. The end portions can be straight, as depicted in FIG. **6**, or they can be curved. These end portions **211**, **221** help strengthen the overall support joist **20**. However, additional functionality can be obtained when the end portions **211**, **221** are curved to serve as wiring troughs, or even drainage structures.

**[0099]** The lower support joists **20** are connected to the supporting longitudinal beams **60** using bolts **240** as depicted in FIG. **11**. Slotted openings **24** are formed in the lower member **22** to facilitate easy connection between the panel support system **10** and the tilt-mounting bracket with longitudinal beam assembly (**16**, **60**). As previously described with respect to the cited folding panel support system **10** design, only connection to one longitudinal beam need be made in order to allow the entire panel support system **10** to be unfolded and then be fully deployed for complete connection.

**[0100]** Besides easy connection, the slotted openings **24** also provide a means for draining precipitation. It is important to note that if the slotted openings **24** prove to be inadequate for precipitation drainage, then additional openings (not shown) can be formed in the lower member **22** of support joist **20**.

**[0101]** An additional expedient for strengthening the lower support joist **20** and the overall panel support system **10** is the use of diagonal braces **70** as depicted in FIGS. **7***a*-**7***d*. The key aspect of the cross-bracing arrangement is constituted by cross-braces **70** arranged in a substantially A-shaped configuration. Preferably, diagonal braces **70** are U-shaped channels which rest upon lower support joists **20**. More specifically, these diagonal braces **70** rest on the upper members **21** of lower support joists **20**, on the same surfaces as upper panel rails **30**. The diagonal braces **70** are arranged between panel

rails **30** to form the A-shaped configuration depicted in FIG. **7***a*. While a U-shape for the diagonal brace **70** is preferred, any number of other shapes can be used to affect the necessary bracing on the lower support joist **20** of the panel support system **10**.

**[0102]** As depicted in FIG. **7***a*, the diagonal braces **70** are connected to the lower support joists **20** at three separate points. The diagonal braces **70** need to be pre-connected to the folding panel support system **10** only at the middle portion in order to permit folding of the entire structure **10** as previously described with respect to the earlier folding array configurations. The ends of each diagonal brace **70** are then bolted to one of the upper members **21** of the lower support joist **20** once the entire panel support system **10** has been unfolded for deployment.

**[0103]** The diagonal bracing configuration of FIG. **7***a* results in less deflection than a support matrix **10** having only parallel bracing. It was discovered that in one test case the difference in deflection was 0.2 of an inch less with the cross-bracing of FIG. **7***a*. A matter of 0.2 of an inch can be crucial when compounded with environmental factors such as wind, accumulated precipitation, freeze cycles and the like. It can be the difference between maintaining a grip on the panels **12** (with standard panel clips or holders) and losing that grip, thereby undermining the entire purpose of the panel support system **10**.

**[0104]** Encompassing the aforementioned improvements, the panel support system **10** of this invention still allows for off-site assembly (at a convenient staging site) to precise engineering specifications. Once the support members (**30**, **20**) are assembled, the bi-directional span of panel support system **10** can be folded or collapsed on itself, as shown with reference to FIG. **5***a*. The panel support system **10** is easily transported (by motor road vehicle) to the installation site.

**[0105]** In one method of installation, the panel support system **10** is positioned and secured to at least one tilt-mounting bracket **16**, via one of the longitudinal beams **60**, while still in the folded position. After attaching one lower support joist **20** to one of the tilt-mounting brackets **16**, using a pair of tilt-mounting bracket attachment bolts **240** (as shown in FIGS. **5***b* and **5***c*) the bi-directional support system **10** is unfolded to the position of FIG. **4***a*, and the other lower support joist(s) **20** is/are attached to second and/or third tilt-mounting bracket **16**, via second and/or third paired bolts **240** being connected to either of the longitudinal beam(s) **60** described above with reference to FIGS. **9**, **10** **12***a* and **12***b*. This arrangement of panel support system **10** provides the capability of rapid, accurate deployment, requiring little skilled labor. Other installation methods, such as unfolding the support system **10** first, and then attaching it to the tilt-mounting brackets **16**, can also be used.

**[0106]** Another method of strengthening the overall support system **10** is to use steel elements for both the lower support joists **20** and the upper panel rails **30**. This can be especially critical when the size of the support system (and the panel configuration supported) becomes even larger. The enhanced strength of all-steel construction is also very important when environmental conditions (heavy winds, snow, hail, icing, or the like) lead to increased stresses of all types. Steel elements can be used with virtually any of the element shapes, sizes, and configurations previously described herein, as well as any number of shapes and configurations known in the structural steel arts.

**[0107]** While the steel-to-steel connections between upper panel rails **30** and lower support joists **20** permit the omission of insulation between these two structural members, there is still the possibility of binding if either of the structural elements (**20**, **30**) deforms. To address this, stainless steel bearing washer **85**, as depicted in FIGS. **5***a* and **5***b*, are placed between the upper panel rails **30** and the lower support joists **20** at each intersection. The stainless steel bearing washers **85** facilitate easy, controlled rotation of the upper panel rails **30** and the lower support joists **20** with respect to each other. This is important for easy installation, especially when only a single lower support joist is attached to a tilt bracket while the rest of array **10** is unfolded to continue the installation. Steel bearing washer **85** is sized to easily span adjustment slot **216** in lower support joist **20**, with bolt **240** passing therethrough.

**[0108]** Another variation of the present invention eliminates the use of panel clips or holders (**120** in FIG. **3**). Since framed photovoltaic panels are expected for use with the inventive support structure **10**, they can be held to the upper panel rails **30** by means of screws (not shown) suitable for metal connections. Most framed photovoltaic panels come with pre-drilled holes for screws, in standard configurations. These can be used with pre-drilled holes (not shown) in the upper panel rails **30** to facilitate rapid installation of the framed solar panels **12** once the support array **10** is fully unfolded and attached to the underlying supports (tilt brackets **16**). By using the pre-drilled holes in the framed solar panels **12**, the expensive panel clips or holders **120** can be entirely eliminated, along with the additional steps of installing the panel clip bottoms **100** using bolts **145** through pre-drilled holes **145'**, and then placing the solar panels **12** within those clips. The top portions **100**, of the clips are then tightened to hold panel **12** in place. These steps are now eliminated.

**[0109]** The result is a faster and more secure installation than can be achieved with conventional panel clips **120**. The elimination of the panel clips **120** also removes the requirement for expertise with panel clips on the part of the installers. Virtually no skill is required to run screws through the standard holes in the framed solar panels **12** into predrilled holes (not shown) in the upper panel rails **30**.

**[0110]** FIG. **14** depicts another embodiment of the present invention. In this configuration, lower support joists **20** are constituted by C-channels, which also serve as tilt brackets **16**. These support joists (i.e, tilt brackets) **20** are connected to upright supports **16**. In this particular configuration, the C-channel **20** constitutes both the tilt bracket and support joists found in previous embodiments.

**[0111]** The upper panel rails **30** are constituted by the type of structural elements previously described with respect to FIG. **6**. However, other configurations can be used for the upper panel rails **30** in this particular arrangement. The attachment between the upper panel rails **30** and the lower support joists **20** can be accomplished using bolts, as previously described. The upper panel rails **30** and the lower support joists **20** are separated by steel bearing washers **85** in order to prevent binding between the two structural elements when they rotate with respect to each other.

**[0112]** As with earlier embodiments of the present invention, diagonal braces **70** are used between adjacent upper panel rails **30**. As in previous embodiments, the diagonal braces **70** are slanted opposite each other so as to suggest a roughly A-shaped configuration. Because the diagonal braces **70** are slanted opposite each other, at least one end of one of

the diagonal braces must be disconnected so that the overall support array **10** can be folded as previously described. Usually one end of one of the diagonal braces **70** is left connected to one of the upper panel rails **30**, and the other end left loose for the folding process necessary for transport. Accordingly, the other diagonal braces **70** can be rotatably connected to panel rails **30**. The diagonal braces **70** are aligned with the upper panel rails **30** when the support array **10** is folded for transport on a motor road vehicle such as a truck.

**[0113]** Upon reaching the installation site, the folded support array **10** of FIG. **14** will preferably be placed on a pre-existing tilt bracket **20** attached to an existing vertical support **16**. Then the entire support array **10** can be unfolded and panel rails **30** attached to the other tilt bracket **20**. The loose ends of the diagonal braces **70** are then attached to panel rails **30** as appropriate to form the configuration depicted in FIG. **14**.

**[0114]** The diagonal braces **70**, in the opposing slanted configuration as previously described, provide a much higher level of stiffness to the overall support array **10** than is found in previous designs. Additional stiffening of the overall support array **10** can be provided by auxiliary diagonal braces **72** connected between tilt bracket **20** and upper panel rail **30**. As depicted in FIG. **14**, auxiliary diagonal brace **72** is connected between the median connecting member **23** of upper panel rail **30** and a lower portion of the C-channel constituting the tilt bracket **20**. Auxiliary diagonal brace **72** can be configured with a surface and a drilling hole configuration to accommodate the connection between perpendicular pieces. Further stiffening can also be provided by lateral braces **74**, which are mounted at the ends of the upper panel rails **30**. While lateral braces **74** are depicted as being attached to the lower edge of the upper panel rail structure, other connection arrangements are also possible. The result of the FIG. **14** configuration is a panel support system **10** that can withstand a wide range of stresses that might be caused by both extensive panel loading and environmental occurrences.

**[0115]** While a number of embodiments have been described as examples of the present invention, the present invention is not limited thereto. Rather, the present invention should be construed to include every and all modifications, permutations, variations, adaptations, derivations, evolutions and embodiments that would occur to one having skill in this technology and being in possession of the teachings of the present application. Accordingly, the present invention should be construed as being limited only by the following claims.

We claim:

**1**. A support system for an array of parallel panels, said support system including a vertical tilt brackets supported by an underlying substrate, and a foldable support array, said foldable support array comprising:

a) a connection interface for each said vertical tilt bracket supporting at least two upper panel rails at connection points; and,

b) at least two diagonal supports arranged between adjacent said upper panel rails, wherein said upper panel rails are parallel to each other in a deployed position, and said foldable array is collapsible so that said upper panel rails and at least one of said diagonal supports are substantially aligned in a package suitable for motor road transport.

**2-9**. (canceled)

**10**. A method of installing a foldable support array of upper panel rails and diagonal supports to support an array of parallel panels using on-site vertical tilt brackets, where said bi-level support array is folded so that all elements are substantially aligned in a package suitable for motor road transport, said method comprising the steps of:

a) unfolding said support array and attaching to said on-site vertical tilt brackets; and,

b) attaching diagonal supports between adjacent upper support rails.

**11**. The method of claim **10**, further comprising the steps of:

c) attaching panels to said upper panel rails by screws passing through panel frames and into said upper panel rails.

**12**. The method of claim **11**, further comprising the step of:

d) attaching auxiliary diagonal braces between at least one said vertical tilt bracket and at least one said upper panel rail.

**13**. The method of claim **12**, further comprising the step of:

e) attaching perpendicular lateral supports between two adjacent upper panel rails.

**14-15**. (canceled)

**16**. The method of claim **10**, wherein said foldable support array further comprises lower support joists, said lower support joists are rotatably connected to said upper panel rails to be unitarily foldable so that said upper panel rails and said lower support joists are substantially aligned with each other in a folded position in a package suitable for motor road transport, and said upper panel rails and said lower support joists are substantially perpendicular to each other in a bi-level deployed position when mounted on said vertical tilt brackets.

**17**. The method of claim **10**, wherein adjacent said diagonal supports are slanted in opposite directions when connected between adjacent upper panel rails.

**18**. The method of claim **10**, wherein at least two pairs of panel rails are connected to each said vertical tilt bracket.

**19**. The support system of claim **1**, further comprising steel bearing washers at intersections between said diagonal supports and said upper panel rails.

**20**. The support system of claim **1**, wherein said at least two diagonal supports are aligned opposite each other.

**21**. The support system of claim **20**, further comprising:

c) at least one auxiliary diagonal support arranged from at least one said upper panel rail to at least one said vertical tilt bracket.

**22**. The support system of claim **21**, wherein said foldable support array comprises two sets of two interconnected panel rails.

**23**. The support system of claim **20**, wherein said vertical tilt bracket comprises a C-channel, and at least one of said upper panel rails comprises two substantially parallel members connected by a median connecting member.

**24**. The support system of claim **20**, wherein said foldable support array further comprises lower support joists rotatably connected to said upper panel rails and said foldable support array is collapsible, so that said upper panel rails, said lower support joists and at least one of said diagonal supports are substantially aligned in a package suitable for motor road transport, and further wherein said upper panel rails and said lower support joists are substantially perpendicular to each other in a bi-level deployed position mounted on said vertical tilt brackets.

**25**. The support system of claim **24**, further comprising steel bearing washers between said upper panel rails and said lower support joists at intersections therebetween.

**26**. The support system of claim **25**, wherein said connection interface comprises an elongated longitudinal beam extending along an upper portion of said vertical tilt bracket.

**27**. The support system of claim **26**, further comprising an arcuate support extending from said vertical tilt bracket to said extended longitudinal beam.

**28**. The support system of claim **25**, wherein said upper panel rails, said lower support joists, and said diagonal supports are steel.

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