(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 May 2010 (20.05.2010)

PCT

(10) International Publication Number
WO 2010/054831 A2

(51) International Patent Classification:
F24J 2/54 (2006.01)

(21) International Application Number:
PCT/EP2009/008098

(22) International Filing Date:
13 November 2009 (13.11.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PCT/EP2008/009674
14 November 2008 (14.11.2008) EP
PCT/EP2008/011022
22 December 2008 (22.12.2008) EP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

WO 2010/054831 A2

(54) **Title**: A SOLAR PANEL SUPPORT APPARATUS

(57) **Abstract**: A solar panel support apparatus having first and second support stations arranged spaced apart in an axial direction of a solar panel or of an array of solar panels, each said support station being adapted to support said solar panel or array at respective first and second pivot points, said first and second pivot points being spaced apart in a direction transverse to said axial direction and each of said first and second pivot points cooperating with respective first and second guide members of the associated support station, at least one of said guide members permitting movement of the respective pivot point with at least a vertical component and a drive adapted to displace at least one of said pivot points and preferably at least one pivot point at each of said support stations.

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A Solar Panel Support Apparatus

The present invention relates to a solar panel support apparatus in accordance with claim 1.

In general solar panels or arrays of solar panels are placed at a fixed angle with respect to the sun. This angle is generally selected so that the solar panel or arrays of solar panels generate the maximum output when the suns radiation is most intense at the location of the earth's surface where the panel or the panels are placed, typically between midday and early afternoon. As the position of these solar panels is fixed, they only utilize the full incident energy for at best one to two hours per day. Fig. 1 shows such an assembly of solar cells.

The object of the invention is to provide a solar panel support apparatus for which a closer packing arrangement of the array of solar panels is possible on roofs which are not ideally positioned relative to the path of the sun and which enables a higher utilization of the energy incident on the solar panel or the array of solar panels to be obtained.

In accordance with the invention this object is satisfied by a solar panel support apparatus having first and second support stations arranged spaced apart in an axial direction of a solar panel or of an array of solar panels, each said support station being adapted to support said solar panel or array at respective first and second pivot points, said first and second pivot points being spaced apart in a direction transverse to said axial direction and each of said first and second pivot points cooperating with respective first and second guide members of the associated support station, at least one of said guide members permitting movement of the respective pivot point with at least a vertical component and a drive adapted to displace at least one of said pivot points, preferably at at least one pivot point at each of said support stations. In this way, the angle formed between the solar panel and the roof or the support surface can be varied using the drive, such that the solar panel can be moved during the day, to achieve an ideal angle of incidence for the respective time of the day, i.e. generally perpendicular to the solar radiation, at least in a plane transverse to said axial direction.

In other words the plane of the solar panels or array of solar panels can be ideally positioned relative to the sun in at least a direction transverse to the axial direction by rotation around the axial direction in that it always faces the sun and follows the sun from the position at which it rises to the position at which it sets. By supporting each panel or array of panels at two pivot points at each support station it is possible to ensure that the panel is always stably supported even with relatively high winds and to ensure that it does not twist significantly under such winds which could damage the panel.

Although it is necessary to provide a certain spacing between adjacent rows of panels (a row being defined by panels aligned in the axial direction) the support apparatus of the present invention still allows an at least approximately 50% higher electrical energy yield than a fixed installation because of the ability to track the sun from sunrise to sunset. Expressed differently this also enables a higher yield from less solar panel area, which makes the assembly less expensive despite any additional cost for the support apparatus.

Advantageously the first and second guide members of each of the support stations are connected to a single support post. In this way, the material requirement of the support station is reduced and the support stations can be manufactured more cost effectively.

Preferably, at least one of the first and second guide members at each of the first and second support stations has a respective guide slot associated with one of the first and second pivot points. In this way, the pivot points can be efficiently guided in the guide slots and add stability to the support apparatus while ensuring reliable guidance.

Advantageously a toothed rack is provided at one side of the at least one guide member having the guide slot at at least one of the support stations. The drive has a pinion gear cooperating with the rack to produce movement of the pinion gear along the rack and corresponding movement of the respective pivot point along the associated guide slot. This enables a stepping motor to be used to drive the pinion and allows a design where the motor is generally located beneath the panel and the rack and pinion can be protected against leaves and other debris. A further rack is preferably provided at an oppositely disposed guide member at the oppositely disposed support station, there being a further pinion cooperating with the further rack, the first pinion and the further pinion being connected by a driveshaft drivable from a common drive. In this embodiment relatively simple and inexpensive rack and pinion gearing can be installed on the support stations enabling a reliable and cost effective drive of the respective pivot points in the guide slots associated with the guide members, as well as mechanically synchronized movement of the opposite ends of the solar panel without the need for two drive motors and electrical synchronization thereof.

Thus, the common drive is advantageously a simple electric motor, preferably a stepping motor, disposed generally beneath the solar panel or array in a preferably protected position. Using an electric motor, one obtains a cost effective, highly efficient, readily controlled and easily installable drive.

In a preferred embodiment each of the first and second guide members at each of the first and second support stations has a respective guide slot, with the guide slots at each support station being generally inclined relative to each other and to an associated support post forming a generally Y-shaped structure, the respective guide slots being preferably concavely curved. The Y shaped structure permits a uniform generally synchronized displacement of the first and second pivot points in the respective support station adding greatly to the stability and durability of the solar panel support apparatus. The curved arrangement of the guide slots also means a direct relationship can be achieved between the stepping intervals of the motor and the change of angle of the solar panel. This would not be the case for straight guide slots although a direct relationship could be achieved by a suitable electronic control which reflects the precise geometry of the support apparatus and panel assembly.

In a preferred embodiment of the invention the first and second guide members at each of the support stations are pivotally connected to a respective support post and are lockable in a selected pivotal position relative to the support post. In this way, the generally Y shaped structure can be mounted in any desired position angular in relation to a support surface or a roof. Thus the axial direction of the solar panels can be selected to be parallel to, transverse to or skewed relative to the roof spars by suitable positioning of the rails.

Respective posts of the first and second support stations are preferably adapted for connection to respective rails. Using a rail system for the mounting of the support stations on a surface, the solar panel support apparatus can be installed quicker, more cost effectively and more precisely and irrespective of the spacing of the roof spars.

Preferably, the rails extend either parallel to a roof spar or transverse thereto beneath tiles provided on the roof but above the roof spars and are adapted to support a plurality of support stations supporting solar panels or an array of solar panel arrays, neighbouring ones of the solar panels or solar panel arrays being spaced apart in a direction perpendicular to their axial directions by a minimum amount selected to substantially avoid shading of one solar panel or solar panel array by its neighbour or neighbours. Avoiding shading of the solar panels or solar panel arrays increases the overall power output.

In a preferred embodiment the support post passes through a resilient element forming a roof tile or a support for a roof tile or a seal for a roof tile. Using a resilient element, the penetration of the roof skin by the posts can be sealed off to protect against the elements and any unwanted intrusion by insects, for example. For houses with a flat roof and/or not utilizing roof tiles, the lead throughs are adapted accordingly.

The solar panel support apparatus is adapted for use with solar panels of either the photovoltaic type adapted for the generation of electricity or for thermal panels adapted to generate heated fluids, in particular water or a heat transfer fluid. In this way, the solar panel support apparatus can improve the efficiency not only for the generation of electricity, but also for the generation of hot water for use in heating and/or bathing.

In a preferred embodiment sealed lead-throughs are provided for additionally leading electric cables or heat transfer fluid lines through a roof, preferably adjacent selected support posts of the support stations.An electric power cable for a drive passes through a respective lead-through in the roof to the drive, preferably adjacent a post. Again, using a resilient element, the underside of the outer layer of the roof can be sealed off to protect against the elements and any unwanted intrusions.

In a preferred embodiment the solar panel or the array of solar panels is/are mounted in a frame, with the pivot points being connected to the frame or the frame supporting said pivot points. In this way, the solar panel support apparatus can be built smaller and consequently more cost effectively.

In a preferred embodiment control means for parking the solar panels or the array of solar panels in a parked position is provided and the parked position is generally parallel to a roof or a support surface during wind and/or during the night. Utilizing the parked position, the solar panel or the array of solar panels can be protected against wind turbulence, by using a wind meter integrated into the solar panel support apparatus. The control means are adapted to initiate a displacement of the solar panel or the array, when the signal of the wind meter shows that the wind speed has reached or exceeds a preset threshold.

A further advantage of the solar panel support apparatus in accordance with the invention is that any commercially available solar panel or solar panel array can be adapted for connection to the solar panel support apparatus in accordance with the invention by providing suitable pivot points or attachment points. This means, that the solar panel support apparatus in accordance with the invention can be used to upgrade existing solar panel or solar panel array support stations increasing the output significantly at marginal costs.

In a particularly advantages embodiment the solar panel support apparatus is mounted to a track system so that the solar panel support apparatus can be rotated about an axis of rotation perpendicular to a surface of the roof (or installation surface), i.e. in a plane which is generally parallel to the surface of the roof. Using this track system the solar panels can not only be pivoted relative to the support stations to follow the daily varying east to west motion of the sun, but also the solar panel support apparatus, or groups of such apparatuses can also be moved around a circular track to reflect the daily change in elevation motion of the sun which changes with the seasons. This enables a further improvement on top of the 50% output gain of the system in accordance with the invention.

In an alternative advantageous embodiment the solar panel support apparatus in accordance with the invention has a lifting system attached to at least one of the support stations of the solar panel support apparatus so that the solar panel support apparatus can be displaced at at least one support station in a direction generally perpendicular to the surface of the roof. Using this lifting system, which can be a piston in cylinder arrangement, or a pinion gear and rack arrangement or a ball screw arrangement or a hoist system, the solar panel support apparatus can not only be displaced in accordance with the daily varying east to west motion of the sun, but also to reflect the daily change in elevation motion of the sun and the seasonal change in elevation, i.e. winter to spring to summer to autumn to winter etc.. This enables a further improvement on top of the 50% output gain of the system in accordance with the invention.

In the following the invention will be described in more detail with reference to embodiments and to the drawings; in which:

Fig. 1 shows a house with an array of solar panels fixed to the roof of the house known from the prior art,

Fig. 2 shows a rear view of the solar panel support apparatus in accordance with the invention,

Fig. 3 shows a front view of the solar panel support apparatus in accordance with the invention,

Fig. 4 shows a Y shaped support station in accordance with the invention,

Fig. 5 shows a flat roof with an array of solar panel support apparatus in accordance with the invention,

Fig. 6 shows a close up view of the array of solar panel support apparatus of Fig. 5,

Fig. 7 shows a side view of the array of solar panel support apparatus of Fig. 5,

Fig. 8 shows a detail of the array of solar panel support apparatus of Fig. 7, on the section A-A,

Fig. 9 shows a close up view of the detail B of the array of solar panel support apparatus of Fig. 8,

Fig. 10 shows a roof supporting an array of solar panel support apparatus in accordance with the invention,

Fig. 11 shows a roof supporting an array of solar panel support apparatus in accordance with the invention

Fig. 12 shows a side view of the array of solar panel support apparatus of Fig. 10,

Fig. 13 shows a side view of the array of solar panel support apparatus of Fig. 11,

Fig. 14 shows a typical arrangement of roof spars if roof tiles are used as the outer roof surface,

Fig. 15 shows a detailed view of the drive shaft in accordance with the invention,

Fig. 16 shows a detailed view of the drive mounting in accordance with the invention,

Fig. 17 shows a detailed view of the pinion gear in accordance with the invention,

Fig. 18 shows a further support station in accordance with the invention,

Fig. 19 shows another support station in accordance with the invention,

Fig. 20 shows a solar panel support apparatus in accordance with the invention mounted to a track system,

Fig. 21 shows a solar panel support apparatus with one of the support stations mounted to a lifting system in accordance with the invention,

Fig. 22 shows a side view of a practical embodiment of a solar panel support apparatus with two axis steering with the panels mounted for movement around a circular track,

Fig. 23 shows a view of the solar panel support apparatus of Fig. 22 from below.

Fig. 24 shows a detail view of the circulat track of Figs. 22 and 23,

Fig. 25 shows the detail of the drive system for driving the solar panels mounted on a frame around the circular track of Figs. 22 to 24, and

Fig. 26 shows a detail of how the frame carrying the solar panels is arranged to rotate around the circular track.

Fig. 1 shows a prior art arrangement of an array of solar panels 2 positioned on the roof 4 of a house 6. The solar panels 2 are fixedly connected to the roof 4 of the house 6, i.e. they are set to a certain angle. This angle is chosen such that the angle of incidence of the solar radiation incident on the solar panels is an optimum angle of incidence for the highest radiation intensity. This typically is between late morning and early afternoon for a flat roof, but varies depending on the geometry and/or the orientation of the roof 6 in question.

Fig. 2 shows a rear view of the solar panel support apparatus 10 of the present invention, in which a first support station 12 and second support station 14 are arranged spaced apart in an axial direction of a solar panel 16 or of an array 18 of solar panels 16. Each of the support stations 12, 14 (sometimes simply referred to as supports) is adapted to support the solar panel 16 or array 18 at respective first and second pivot points 20, 22, the first and second pivot points 20, 22 being spaced apart in a direction transverse to the axial direction. Each of the first and second pivot points 20, 22 cooperate with respective first and second guide members 24, 26 of the associated support station 12, 14. Expressed generally, at least one of the guide members 24, 26 permits movement of the respective pivot point 20, 22 with at least a vertical component. Although it is stated above that at least one of the guide members permits movement of the respective pivot point with a vertical component, in actual fact, in the embodiment of Fig.2, both of the guide members permit vertical movement of the associated pivot point 20, 22. However, this is not the case in all embodiments (see Fig. 18 for example).

A drive 28 is provided and is adapted to displace at least one of the pivot points 20, 22 and preferably at at least one pivot point 20, 22 at each of the support stations 12, 14 to change the orientation of the solar panel 16 or array 18 around the axial direction so that it faces the sun during the movement of the sun from sunrise to sunset.

Fig. 2 also shows that the first and second guide members 24, 26 of each support station 12, 14 are connected to a single support post 30 and thus form a generally Y –shaped support. This means that the two guide members 24, 26 can be attached to a common post or could be integrally formed therewith (as shown in Fig. 22), but they can also be two separate components adjacent to one another with their own respective post. The frame 32 to which the solar panel 16 or the array 18 of solar panels 16 is/are connected is shown, with the frame 32 being connected at each longitudinal end to the respective first and second pivot points 20, 22. The drive shaft 36 adapted for a connection to the drive 32 is also shown. Fig. 3 shows a perspective view of the solar panel support apparatus 10 from the front. In Fig. 3 the first and second guide members 24, 26 at each of the first and second support stations 12, 14, are visible with each of the first and second guide members 24, 26 having a respective guide slot 34 associated with one of the first and second pivot points 20, 22.

Fig. 4 shows the generally Y shaped support station 12, 14 for a solar panel support apparatus, each of the first and second guide members 24, 26 at each of the first and second support stations 12, 14 has a respective guide slot 34, the guide slots 34 at each support station 12, 14 being generally inclined relative to each other and to an associated support post 30. The guide slots 34 of the guide members 24, 26 of the generally Y shaped support station 12, 14 are preferably concavely curved. Also indicated in Fig. 4 is a toothed rack 42 provided at one side of the guide member 24, 26 having the guide slot 34 at each of the support stations 12, 14. The drive 28 has a pinion gear 44 (shielded by a housing) cooperating with the rack 42 to produce movement of the pinion gear 44 along the rack 42 and corresponding movement of the respective pivot point 20 along the associated guide slot 34, with the pivot point 22 moving in its respective guide slot in synchronization with the pivot point 20. In this way, the angle formed between the solar panel and the roof or the support surface can be varied using the drive 28, such that the solar panel can be moved during the day, ensuring an optimum angle of incidence for the respective time of day. This is achieved particularly efficiently in that a further rack 42 is provided at the oppositely disposed guide member 24, 26 at the oppositely disposed support station 12, 14. There a further pinion 44 cooperating with the further rack 42 is provided, with the first pinion 44 and the further pinion 44 being connected by a driveshaft 36 drivable from a common drive 28.

Also shown in Fig. 4 are the post connectors 48 which each engage with the support post 30 through an arcuate slot. Using the connector 48 the first and second guide members 24, 26 at each of the support stations 12, 14 are pivotally connected to the respective support post 30 and can be locked in a selected pivotal position relative to the support post 30. This means that, the solar panel 16 or array 18 of solar panels can be mounted at any desired angle, depending on the mounting angle of the guide members 24, 26 at the support post 30, to the plane of the mounting surface or roof and can, for example, be varied from approximately 30° to -30° relative to a horizontal plane.

Fig. 5 shows a flat roof 38 with a plurality of solar panels 16 or array of solar panels 18 connected to the roof 38 of a house 46 using the solar panel support apparatus 10 in accordance with the invention. In a series of experiments it has been shown that by using the solar panels supported in accordance with the invention an output gain is obtained of at least 50 % in comparison to a fixed installation.

This is achieved, due to the fact that the solar panels 16 are supported in accordance with the invention to track the movement of the sun from east to west.

To improve the angular acceptance of the solar radiation, this two dimensional apparatus can be adapted to be displaced in three dimensions, by mounting at least one of the support stations 12, 14 to respective lifting systems such as a piston. Using this lifting system the solar panel support apparatus 10 can not only be displaced in accordance with the daily varying east to west motion of the sun, but also to reflect the daily change in elevation motion of the sun and the seasonal change in elevation, i.e. winter to spring to summer to autumn to winter etc.. This enables a further improvement on top of the 50% output gain of the system in accordance with the invention.

Fig. 6 shows a detail view of the region C indicated in Fig. 5, it clearly shows an array of solar panels mounted to a support surface 46 via the support stations 12, 14 in accordance with the invention. This further illustrates the fact that the solar panel support apparatus 10 in accordance with the invention can be adapted for use with a plurality of solar panels or solar panel arrays in a modular manner. Thus, for example, n – support stations can be used to support n-1 solar panels 16 or solar panel arrays 18.

Fig. 7 shows a side view of a house 46 on whose roof 38 an array of solar panels 16 or an array of arrays of solar panels 18 is mounted. Fig. 8 shows a section A-A through the roof 38 of the house 46 as shown in Fig. 7. In this one can see how solar panels 16 or arrays of solar panels 18 are connected to the roof 38 via the support stations 12, 14, also indicated is a region B shown to an enlarged scale in Fig. 9.

Fig. 9 shows a close up view of region B of Fig. 8, assuming that the solar panels are arranged on a roof 38 in such a way that the solar panel 16 or the array of solar panels 18 are facing to the south (as the case would be for the northern hemisphere of the earth, or vice versa). In this example the solar radiation is incident on the solar panel 16 or array of solar panels 18 at an angle α of only 10°. For this particular positioning of the solar panels in each case only approximately half of the solar panel or the array of solar panels is irradiated by the solar radiation. Using the solar panel support apparatus in accordance with the invention, an adjustment of the angle of inclination of the solar panel 16 or the array of solar panels 18 to the angle β of here 30° is possible by use of the drive 28. Now the total surface area of the panels is irradiated by the solar radiation and the utilization of the energy of the solar radiation consequently increases. With fixed solar panel installations such as are usually used on roofs full exploitation of the solar panel area can only be achieved by spacing the panels or rows of panels far apart. In addition Fig. 9 shows sections of a rail 40 on which the support stations 12, 14 are mounted, e.g. by the use of brackets such as 31 in Fig. 3.

In the above Figures, the solar panel 16 or array of solar panels 18 are mounted on to a flat roof 38, of a house. The support stations can however also be mounted onto any roof surface at any angle of inclination and orientation as shown in Fig. 10 by use of suitable connectors or pots, e.g. using posts 30 of different length for the two support stations 12, 14. Also, the array of solar panels 16 or array 18 of solar panels 16 could be mounted in a field, for the generation of thermal energy and/or photovoltaic energy.

Fig. 10 shows a plurality of solar panel support apparatuses 10 with a total of 9 support stations 12, 14 each adjacent two support stations supports in the embodiment a solar panel 16 but could also support an array of solar panels 18. The support apparatus is arranged such that the axial direction of the solar panels (about which the panels can be rotated) is generally parallel to the apex of the roof 50. This arrangement is chosen typically when the outer surface of the roof 50 with the solar panels 16 or array of solar panels 18 is facing generally towards either the east or the west as the case may be (dependent on whether the roof is located in the northern or southern hemisphere). In this way, in this example, the solar panels 16 or array of solar panels 18 are inclined at an angle of approximately 35° to the surface of the roof 50 in the morning and are displaced in the course of day such that in the evening they are inclined at an angle of approximately -35° to the surface of the roof 50. Therefore the solar panels 16 or array of solar panels 18 have followed the path of the sun in dependence of the time of day and are orientated to receive the maximum intensity of the solar radiation for each point in time of the day.

Similarly Fig. 11 shows 6 solar panel support apparatuses 10 each with a solar panel 16 or an array 18 of solar panels 16 arranged such that the axial direction of the solar panels is generally perpendicular to the apex of the roof 50. This arrangement is chosen typically when the outer surface of the roof 50 with the solar panels 16 or arrays 18 of solar panels 16 is facing generally towards either the south or the north as the case may be (dependent on whether the roof is located on the northern or southern hemisphere). In this way, in this example the solar panels 16 or array 18 of solar panels 16 are inclined at an angle of approximately 34° to the surface of the roof 50 in the morning and are displaced in the course of day such that in the evening they are inclined at an angle of approximately -34° to the surface of the roof 50. Therefore the solar panels 16 or array of solar panels 18 have followed the course of the sun in dependence of the time of day and are orientated at the maximum intensity of the solar radiation for each point in time of the day.

If the roof 50 of a building is pointing in a direction which is not generally either north, east, south or west, then the angle at which the axial direction of the solar panel 16 or the array 18 of solar panels 16 is placed in relation to the apex of the roof is at an angle to the roof spars and this angle can be chosen using simple geometric relationships. Thus the axial direction of the solar panels 16 or the array 18 of solar panels 16 is selected such that, at the time of day where the sun is at its closest position towards that point on the earth's surface, the solar panel 16 or array 18 faces the sun i.e. receives the highest intensity of solar radiation.

Fig. 12 shows a section through the roof 50 of Fig. 10. Similarly Fig. 13 shows a section through the roof 50 illustrated in Fig. 11.

Typically the support stations 12, 14 of the solar panel support apparatus 10 are adapted for the connection to respective rails 40, preferably via the support posts 30.

Fig. 14 shows a top view of the surface of the roof 50 of Fig. 13. Illustrated in this are 3 rows of solar panels 16 or arrays 18 of solar panels mounted using the solar panel support apparatus 10 in accordance with the invention. The roof spars 54 of the roof surface not connected to the solar panel support apparatus 10 are shown, to run generally in parallel to the axial direction of the solar panel support apparatus 10. The spars 54 are boarded over on the outside and the boards, i.e. the boarded in roof surface are/is covered with roofing felt. Roof laths are mounted on the felt above and generally parallel to the spars and cross laths 56 are mounted transverse to these for supporting roof tiles 58, i.e. in this case the roof laths 56 are tile supports. The support stations 12, 14 of the solar panel support apparatus 10 are connected to rails 40 via support posts 30, in this case the rails run in parallel to the roof spars 54 of the roof 50. The rails 40 can either be mounted to the roof laths 56 or further laths are provided for the connection of the rails 40 to the roof spars 54. In the embodiment shown in Fig 12, the rails 40 are consequently arranged to run perpendicular to the roof spars 54, and therefore do not necessarily require a further lath for the connection to the roof spars 54.

The rails 40 extend either parallel to a roof spar 54 or transverse thereto or skewed relative thereto beneath the roof tiles provided on the roof 50 but above the roof spars 54. They are adapted to support a plurality of the aforementioned support stations 12, 14 supporting solar panels 16 or an array 18 of solar panels. Neighbouring rows of solar panels 16 or arrays 18 are spaced apart in a direction perpendicular to their axial directions by a minimum amount selected to substantially avoid shading of one solar panel 16 or solar panel array 18 by its immediate neighbour or neighbours.

Fig. 15 shows a detailed view of the drive shaft 36 in accordance with the invention; in this the drive shaft 36 is rotatably connected to the frame 32 of the solar panel support apparatus 10 via drive shaft mounting brackets 62. Furthermore, the drive shaft 36 is connected to the drive gear or pinion 44 positioned in the pinion housing 46 and also to the oppositely disposed further pinion (not shown). The drive shaft 36 and thus the two pinions 44 are driven by the drive motor 28, e.g. a stepping motor. While the pinion 44 and the drive shaft 36 are being driven by the drive 28, the pinion 44 displaces the solar panel support frame 10 by cooperation with and movement along the toothed rack 42 provided on the guide member 24, 26. Upon displacement of the pinion 44 on the toothed rack 42, the pivot points 22 are displaced in the guide slots 34 of the guide member 24, 26 to obtain the angular displacement of the solar panel 16 or the array of solar panels 18. The pivot points 20 are similarly moved in the guide slots

34 of the guide members via the thrusting force exerted by the panel frame. Also shown are the post connectors connecting the guide member 24, 26 to the support post 30 and the frame mounting brackets 60 which are adapted for a connection of the solar panel 16 or the array 18 of solar panels to the supporting frame 32.

Fig. 16 shows a view of the drive housing 68 in accordance with the invention, in which the drive 28 is connected to the drive shaft 36, via a suitable gear wheel arrangement consisting, for example, of at least two cog wheels 64, 66 protected in the cog wheel housing 70. Also shown are the pinion housing 46 and the pinion 44 cooperating with the toothed rack 42 of the guide member 24, 26.

Fig. 17 shows a detailed view of the pinion gear housing 46 in accordance with the invention. In the pinion housing 46 the pinion 44 is connected to the drive shaft 36. The drive shaft 36 is brought into rotation by a bevel gear 66 fixedly connected to the drive shaft 36 and communicating with a cog wheel 64 driven by the drive motor 28 with the bevel gear 66 being hidden from view in the housing 70. The pinion can then move along the rack 42 provided at the guide member 24, 26. This assembly is connected to the solar panel 16 or the array of solar panels 18 via the bracket 60.

The drive shown in Figs. 15 to 17 is an electric motor, preferably a stepping motor.

In the embodiments shown in Figs. 11 to 17 roof tiles are used for the waterproofing of the roof 50 of the building. Each of the support posts 30 passes through a resilient element forming a roof tile or a support for a roof tile (roof lath 56) or a seal for a roof tile. Similarly, the sealed lead-throughs are provided for leading electric cables or heat transfer fluid lines through a roof 50, preferably adjacent selected support posts 30 of the support stations 12, 14. An electric power cable for a drive 28 also passes through a respective lead-through in the roof 50 to the drive 28, preferably adjacent a support post 30.

There are many types of roofs on the market, the support stations 12, 14 of the solar panel support apparatus 10 can be adapted for connection to all of these roof types using mounting brackets and/or rails specifically adapted for their connection to the respective roof construction.

In all of the embodiments shown, the solar panels 16 or array of solar panels 18 can be either photovoltaic panels or thermal panels. The solar panel 16 or the array 18 of solar panels is/are mounted in a frame 32, with the pivot points 20, 22 being connected to the frame 32 or the frame 32 is adapted to support the pivot points 20, 22.

Furthermore, the solar panel support apparatus 10 in accordance with the invention can be adapted for the connection to all types of solar panels 16 and solar panel arrays 18 commercially available and suitable for this application. Also solar panels 16 or solar panel arrays 18 supported by apparatus known from the prior art can be adapted for the connection, thereby upgrading the system and increasing the efficiency, as tests have shown by at least 50%.

Control means for parking the solar panels 16 or the array of solar panels 18 in a parked position is provided, with the parked position being generally parallel to the roof 38, 50 or support surface during wind and/or during the night. To detect when a storm is about to affect the solar panels 16 or the array of solar panels 18, a wind meter can be connected to the solar panel support apparatus 10.

Furthermore, the control means are adapted for detecting the angle of displacement of the solar panels 16 or the array of solar panels 18 with respect to a roof 38, 50 for which the solar panels 16 or the array of solar panels 18 are at that moment in time obtaining the maximum angular efficiency, and for correcting this if need be. This can, for example, be a feedback control system adapted to sense the power output of the solar panels and to maximize this by appropriate incremental movement of the drive motor.

The detection of the angle best suited for the momentary detection of the highest efficiency can take place every minute, every 15 minutes, every 30 minutes or every hour or for any suitable time interval. The detection can take place either by measuring the temperature of the fluid in the thermal panels or by measuring the current output of the photovoltaic panels.

Fig. 18 shows an alternative design of a support station 12, 14 in accordance with the invention. In this the first and second support stations 12, 14 are again arranged spaced apart in an axial direction of a solar panel 16 or of an array 18 of solar panels. Each of the support stations 12, 14 is again adapted to support the solar panel 16 or array 18 at respective first and second pivot points 20, 22, the first and second pivot points 20, 22 being spaced apart in a direction transverse to said axial direction. Each of said first and second pivot points 20, 22 cooperates with respective first and second guide members 24, 26 of the associated support station 12, 14. In this arrangement the guide member 26 permits movement of the respective pivot point 20 with a vertical component whereas the guide member 24 guides the pivot point 22 in the horizontal direction in a horizontal slot. A drive 28 is again adapted to displace at least one of said pivot points 20, 22 namely the pivot point 22 at each of said support stations 12, 14 in the horizontal direction.

The difference in the design of the support station 12, 14 illustrated in Fig. 18 to the support station 12, 14 shown in Fig. 4 is, that rather than using a rack and gear pinion 44 to drive the solar panel 16 or solar panel array 18, a linear stepping motor 28 (or a hydraulic or pneumatic jack or a ball rack and spindle arrangement) is used. The linear drive 28 drives the second pivot point 22 in the longitudinal guide slot 34 and this automatically causes the displacement of the first pivot point 20 in the guide slot 34 of the second guide member 26. Again the support station 12, 14 is rotationally connected to the support post 30 via post connectors 48. Alternatively, a rotary stepping motor and rack arrangement could be used to move the pivot point 20 up and down the vertical slot guide (e.g. as shown in Fig. 19). A short length of such a rack 42 is shown schematically in Fig. 18.

Fig. 19 shows another design of the support station 12, 14 in accordance with the invention. In this the first and second support stations 12, 14 are again arranged spaced apart in an axial direction of a solar panel 16 or of an array 18 of solar panels. Each of the support stations 12, 14 is again adapted to support the solar panel 16 or array 18 at respective first and second pivot points 20, 22, the first and second pivot points 20, 22 are spaced apart in a direction transverse to said axial direction (which is directed perpendicular to the plane of the drawing as in Fig. 18). Each of said first and second pivot points 20, 22 cooperates with respective first and second guide members 24, 26 of the associated support station 12, 14. The guide members 26 permits movement of the respective pivot point 20, 22 with at least a vertical component in a slot guide 34. A drive 28 adapted to displace the pivot point 22 (and preferably the pivot point 22 at each of said support stations 12, 14) up and down the guide slot 34.

In Fig. 19 the first pivot point 20 at each end of the solar panel 16 or array 18 is connected to a link 24 which is respectively pin jointed at its ends to the cross member 25 and to the frame 32 of the solar panel 16. The pivot point 22 thereby pivots about the centre of the pin joint to the cross member 24 via the link 25. The drive 28 drives the pinion 44 along the toothed rack 42 for the displacement of the second pivot point 22 in the guide slot 34 of the guide member 26. In this embodiment the solar panel 16 or solar panel array 18 is displaced in the guide member 26. In contrast to the other embodiments, only one of the guide members here has a guide slot 34. Again the support station 12, 14 is rotationally connected to the support post 30 via post connectors 48.

Finally, it should be noted that the term pivot point 20, 22 has been selected to describe the connection between the frame 32 and the guide members 24, 26 because the angle of the solar panel 16 or array 18 changes relative to the axis of the respective pivot point. Alternatively, the pivot points 20, 22 could be called guide points or support points.

It will be appreciated that the motion of the solar panels 16 or arrays of solar panels 18 produced by the invention can be likened to the movement of a rocking cradle or swingboat, that is to say a plane defined by the open top surface of the cradle or of the swingboat, equivalent to the plane of a solar panel or array, swings from a positive angle through a middle position to a negative angle, essentially about a rotational axis spaced from the cradle or swingboat with simultaneous translational movement of the said top surface. The rotational axis is the centre of curvature of the cradle runners or the pivot point of the swingboat support.

Fig. 20 shows a plurality of solar panel support apparatuses 10 in this example with a total of 20 support stations 12, 14. Each adjacent pair of support stations supports one solar panel 16 in this embodiment, but could also support an array of solar panels 18. The support apparatuses 10 are arranged on a track system 80 such that the plurality of support apparatuses 10 may be jointly rotated in relation to the surface 86 (shaded area) which can be the surface of a roof 50. In other words, the plurality of solar panel support apparatuses 10 can be jointly rotated in a plane which is generally parallel to the surface 86 of the roof. Thus the rotation of the plurality of support apparatuses 10 takes place about an axis of rotation which is generally perpendicular to the surface 86 of the roof 50.

The solar panel support apparatuses 10 may be rotated from a starting position at -60° through a middle position at 0° up to a final position at +60° and vice versa, by means of track rollers 84 supported on the tracks 80. Using this track system 80 the solar panels 16, 18 can not only be pivoted to follow the daily east to west motion of the sun, but the solar panel support apparatuses can also be rotated on the track about an axis generally perpendicular to the support surface 86 to reflect the daily change in elevation motion of the sun and the seasonal change in elevation, i.e. winter to spring to summer to autumn to winter etc.. This enables a further improvement on top of the above referenced 50% output gain of the system in accordance with the invention. The surface 86 need not be a roof surface but it can be any installation surface 86 on which the solar panel apparatus 10 in accordance with the invention is installed. To obtain the ideal orientation of the solar panels 16 or array 18 of solar panels at all times of the day and year a computer can be used to control both the motor rotating the solar panels 16 relative to the support station 12, 14 and the motor driving the plurality of support apparatuses (10) around the track.

The rollers 84 can e.g. run on the insides of flanges of a circularly curved T-beam or I-beam forming the track 80, with the rollers rotating on axles supported by a yoke engaging over the upper side of the track, with a frame carrying the support structure being connected to the yokes. The motor for driving the group of support apparatuses 10 around the track 80 can, for example, comprise a motor driving a pinion gear adapted to engage with a toothed rack formed on or joined to the edge of one of the flanges of the I-beam or T-beam. Finally, it should be noted that it is also possible to mount each pair of support stations 12, 14 supporting a solar panel 16 or an array 18 of solar panels on a respective track 80 although it is considered more efficient to mount a plurality of solar panel support apparatuses 10 on a common frame rotatable around a track 80.

Fig. 21 shows a support apparatus 10 where at least one lifting system 88 has been connected to the foot of the support station 12 to improve the angular acceptance of the solar radiation, i.e. the apparatus 10 previously moveable in two dimensions has been adapted to be displaced in three dimensions, by mounting a lifting systems 90 such as a piston in cylinder arrangement, or a rack and pinion arrangement, or a ball screw arrangement, between a bracket 31 mounted at one of the support posts 30 connected to the support station 12 and the surface 86 of the roof 50. The lifting system could alternatively be provided at the support station 14 and indeed respective lifting stations 90 moveable in opposite senses could be provided at both support stations 12, 14. If only one of the support stations e.g. 12 is provided with a piston or a lifting system, then a hinge 92 could be provided at the other respective support station 14 about which the support station 14 can be pivoted. Alternatively the post 30 at the support station without a lifting system in this example the support station 14 could be made flexible. Using this lifting system the solar panel support apparatus 10 can not only be displaced in accordance with the daily varying east to west motion of the sun, but also to reflect the daily change in elevation motion of the sun and the seasonal change in elevation, i.e. winter to spring to summer to autumn to winter etc.. In this case at least one of the support stations 12, 14 of the solar panel support apparatus 10 can be displaced in a direction generally perpendicular to the surface 86 of the roof 50. This enables a further improvement on top of the 50% output gain referred to earlier. For a small number of solar panels 16 or array 18 of solar panels, the support stations 12, 14 may be mounted on a rail system which could then itself be lifted using one or more lifting systems of the type described in connection with Fig. 21.

Turning now to Figs, 22 to 26 there is shown a practically realised version of the system previously described with reference to Fig. 20. The system is intended for mounting on a flat roof or other horizontal surface or even on the ground but could also be mounted on an inclined roof. As seen in Fig. 23 there are a total of sixteen solar panels 16 mounted in four rows on a frame 100 comprising longitudinal tubes 102 parallel to the rows and cross tubes 104 perpendicular to and above the longitudinal tubes 102 to which they are attached. The dimensions entered in Fig. 22, which is a scale drawing, are in millimetres and give one example of suitable dimensions of the support apparatus which are not however intended to restrict the design in any way.

The solar panels are carried by the generally "Y-shaped supports 12 and 14 (only supports 12 are visible in Fig. 22) and the supports 12 and 14 are attached by their respective posts 30 to the cross tubes of the frame and the detail of the mounting of the solar panels 16 at the supports 12, 14 and the way their angle can be varied is precisely the same as was described in the preceding embodiments so that the previous description applies and will not be repeated here.

The longitudinal tubes 102 sit directly above a circular track 80 and carry plastic rollers 84 mounted on brackets 110 which run on the lower flange 112 of the circular track 80 which is formed from a U-section facing outwardly as shown in Fig. 24. That is to say the base 114 of the U-section is radially innermost and the flanges such as 112 are radially outwardly directed from the base. In this embodiment the rollers 84 have a small cone angle to match the usually inclined inner face of a commercially available U-section, however this is not essential. The rollers enable the frame 100 and with it all sixteen panels to rotate about the central axis 116 of the track 80.

The track is bolted via suitable brackets to paving stones 118 which are bedded on the roof or ground in a common generally horizontal plane. The lines 121 represent cables which go from the axis 116, from a fixing point at a central paving stone 118' to points on the circular track and stabilise it and keep it in shape. Further cables 123 go from the mounting point on the central paving stone 118' to the ends of the longitudinal beams 102 at the intersections with the cross beams 124 and triangulate and stiffen the frame 100 to hold it in form. As can be seen from Fig. 22 the cables 123 pass above the circular track 80 they can thus rotate with frame about the central mounting point. The rotary movement of the frame 100 around the track is generated by a drive motor 120 which in this embodiment is an elongate motor typically used for driving roller shutters but could be any other suitable motor. The motor 120 can be a stepping motor but can also be any other suitable controllable motor which can be switched on and off or regulated to move the frame in increments or continuously.

The axis of the motor is perpendicular to the plane of the circular track 80, i.e. vertical as can be appreciated from Fig. 23. The motor 120 drives a flanged roller 122 via a reduction gearbox 124. This is not only appropriate because of the relatively slow speed of rotation of the frame and solar panels around the circular track but also makes it impossible for say wind loads acting on the solar panels to drive the motor in an unwanted manner. In the illustrated embodiment a plurality of meshing spur gears are used to secure the required step down ratio for the motor 120 that is used. Any other form of self inhibiting step down gearing could be used such as a worm gear system.

The flanged roller 122 engages a flexible steel cable 128 which is best seen in Figs. 22 and 26 which makes one turn around the flanged roller 122 to ensure there is no slippage at the roller and also extends around the circular track 80 between the two flanges of the U-section. The cable can be anchored at one end and tensioned at the other. A synthetic rope could also be used instead of a steel cable.

When the motor 120 is driven it drives the flanged roller at a lower angular speed due to the reduction gearbox and the flanged roller grips the steel cable and drives the frame 100 around the circular track 80. As can be seen from Figs. 25 and 26 the mount 132 for the motor and the gearbox 124, whose output shaft 129 carries the flanged roller 122, is attached by bolts 134 which pass through holes 136 in the mount 132 to the frame member 102.

It is noted that the power cables for the motor 120 and for motors for changing the elevation of the solar panels 16 as well as the power output cables from the solar panels have flexible portions which are located within and guided by a plastic chain guide of the kind typically used in excavators for flexible hydraulic lines so that they can follow the movement of the frame 100 around the axis 116 without being kinked or damaged. The movement of the frame around the axis 116 permits steering of the solar panels about a second axis. The steering about the second axis, i.e. the axis 116 serves to adjust the array of panels to the seasonally dependent changes in the position of the sun.

The tracking of the sun during its daily movement from east to west, i.e. the movement about the first axis, is done in the same way as with one axis steering, i.e. by moving the solar panels in the Y-shaped supports 12 and 14, which are bolted to the cross members 104. As an example this steering can be done from 36 degrees plus to 36 degrees minus and this is normally sufficient. It is the angular range permitted by the current design of the Y-shaped supports 12, 14 as described in detail above. This angle can be increased if necessary by changing the length of the arms of the Y-shaped supports if this is deemed appropriate for some reason, such as the specific position of installation.

The steering about the second axis 116 is designed to cover a range of nought degrees to 200 degrees and back. This is not strictly necessary for any one installation but makes the system very flexible and easily adaptable to different locations worldwide.

As indicated earlier, in an arrangement with one axis steering the movement of the solar panels 16 around the axis defined by the Y-shaped supports, typically the longitudinal axis of the panels, is usually used to track the movement of the sun from east to west and the angle of the longitudinal axis of the panel relative to the horizontal is generally set to an optimum value for the elevation of the sun at the position of installation and having regard to circumstances such as the way the roof faces.

The spacing between the rows of solar panels is elected so that one row of panels does not shade the next, at least not to a significant degree, which would otherwise reduce the electrical output if one row of solar panels is in the shadow of another row. The spacing my reduce the electrical output compared to the peak output from a fixed array of solar panels but should give a higher yield in total and certainly a higher yield for the investment in solar panels.

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Patent Claims

1. A solar panel support apparatus (10) having first and second support stations (12, 14) arranged spaced apart in an axial direction of a solar panel (16) or of an array (18) of solar panels, each said support station (12, 14) being adapted to support said solar panel (16) or array (18) at respective first and second pivot points (20, 22), said first and second pivot points (20, 22) being spaced apart in a direction transverse to said axial direction and each of said first and second pivot points (20, 22) cooperating with respective first and second guide members (24, 26) of the associated support station (12, 14), at least one of said guide members (24, 26) permitting movement of the respective pivot point (20, 22) with at least a vertical component and a drive (28) adapted to displace at least one of said pivot points (20, 22) and preferably at at least one pivot point (20, 22) at each of said support stations (12, 14).

2. A solar panel support apparatus (10) in accordance with claim 1, wherein the first and second guide members (24, 26) of each said support station (12, 14) are connected to a single support post (30).

3. A solar panel support apparatus (10) in accordance with either of the preceding claims, wherein at least one of said first and second guide members (24, 26) at each of said first and second support stations (12, 14) has a respective guide slot (34) associated with one of said first and second pivot points (20, 22).

4. A solar panel support apparatus (10) in accordance with claim 3, wherein a toothed rack (42) is provided at one side of at least one said guide member (24, 26) having said guide slot (34) at at least one of said support stations (12, 14), said drive (28) having a pinion gear (44) cooperating with said rack (42) to produce movement of said pinion gear (44) along said rack (42) and corresponding movement of the respective pivot point (20, 22) along the associated guide slot (34).

5. A solar panel support apparatus (10) in accordance with claim 4, wherein a further rack (42) is provided at an oppositely disposed guide member (24, 26) at the oppositely disposed support station (12, 14), there being a further pinion (44) cooperating with said further rack (42), said first pinion (44) and said further pinion (44) being connected by a driveshaft (36) drivable from a common drive (28).

6. A solar panel support apparatus (10) in accordance with claim 5, wherein said common drive (28) is an electric motor, preferably a stepping motor disposed generally beneath said solar panel (16) or array (18) in a preferably protected position.

7. A solar panel support apparatus (10) wherein each of said first and second guide members (24, 26) at each of said first and second support stations (12, 14) has a respective guide slot (34), said guide slots (34) at each support station (12, 14) being generally inclined relative to each other and to an associated support post (30) forming a generally Y-shaped structure, the respective guide slots (34) being preferably concavely curved.

8. A solar panel support apparatus (10) in accordance with any one of the preceding claims, wherein said first and second guide members (24, 26) at each of said support stations (12, 14) are pivotally connected to a respective support post (30) and are lockable in a selected pivotal position relative to said support post (30).

9. A solar panel support apparatus (10) in accordance with any one of the preceding claims wherein respective posts (30) of said first and second support stations (12, 14) are adapted for connection to respective rails (40).

10. A solar panel support apparatus (10) in accordance with claim 9, wherein said rails (40) extend either parallel to a roof spar (54) or transverse thereto beneath tiles (58) provided on a roof (50) but above said roof spars (54) and are adapted to support a plurality of support stations (12, 14) supporting an array of solar panels (16) or arrays of solar panel arrays (18), neighbouring ones of said solar panels (16) or solar panel arrays (18) being spaced apart in a direction perpendicular to their axial directions by a minimum amount selected to substantially avoid shading of one solar panel (16) or solar panel array (18) by its neighbour or neighbours.

11. A solar panel support apparatus (10) in accordance with any one of the preceding claims wherein each said support post (30) passes through a resilient element forming a roof tile (58) or a support (56) for a roof tile (58) or a seal for a roof tile (58).

12. A solar panel support apparatus (10) in accordance with any one of the preceding claims, wherein said solar panels are photovoltaic panels or thermal panels.

13. A solar panel support apparatus (10) in accordance with any one of the preceding claims, wherein sealed lead-throughs are provided for leading electric cables or heat transfer fluid lines through a roof (38, 50), preferably adjacent selected support posts (30) of said support stations (12, 14) and wherein an electric power cable for a said drive (28) passes through a respective lead-through in said roof (38, 50) to said drive (28), preferably adjacent a support post (30).

14. A solar panel support apparatus (10) in accordance with any one of the preceding claims, wherein said solar panel (16) or said array (18) of solar panels is mounted in a frame (32), with said pivot points (20, 22) being connected to said frame (32) or said frame (32) supporting said pivot points (20, 22).

15. A solar panel support apparatus (10) in accordance with any one of the preceding claims, wherein control means for parking said solar panels (16) or said array (18) of solar panels in a parked position is provided and wherein the parked position is generally parallel to a roof (38, 50) or a support surface during wind and/or during the night.

16. A solar panel support apparatus (10) in accordance with any one of the preceding claims, wherein said solar panel support apparatus (10) or an array of such solar panel support apparatuses (10) can be rotated in a plane which is generally parallel to an installation sur-

face (86), e.g. a roof (50) or a surface of a field, i.e. about an axis generally perpendicular to said surface (86).

17. A solar panel support apparatus (10) in accordance with claim 16, wherein said solar panel support apparatus (10) or said array of solar panel support apparatuses (10) is mounted on a circular or part circular track (80) and moveable thereon to generate said rotation.

18. A solar panel support apparatus (10) in accordance with any one of the preceding claims, wherein at least one of the support stations (12, 14) of said solar panel support apparatus (10) can be displaced in a direction generally perpendicular to an installation surface (86).

19. A solar panel support apparatus, in particular but not exclusively in accordance with any one of the preceding claims, and adapted for one or two axis steering, wherein the solar panels which are of fixed or adjustable elevation are mounted on a frame (100) rotatable about a circular track (80), for example to adjust to the seasonally dependent changes in the position of the sun, and wherein a cable (128) is tensioned around the circular track and extends once or more around a roller (122) drivable by a motor (120) and located outside the track (80) to rotate the frame around the axis (116) of the circular track.

20. A solar panel support apparatus in accordance with claim 19, wherein the circular track is an outwardly facing U-section and the frame has a plurality of rollers (94) adapted to roll on said section for example on the lower flange (112) thereof.

Fig. 1

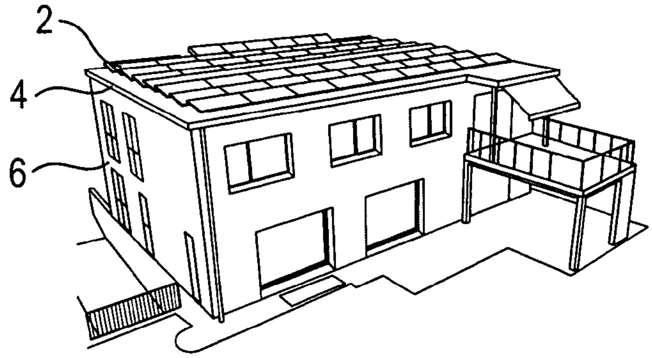


Fig. 2

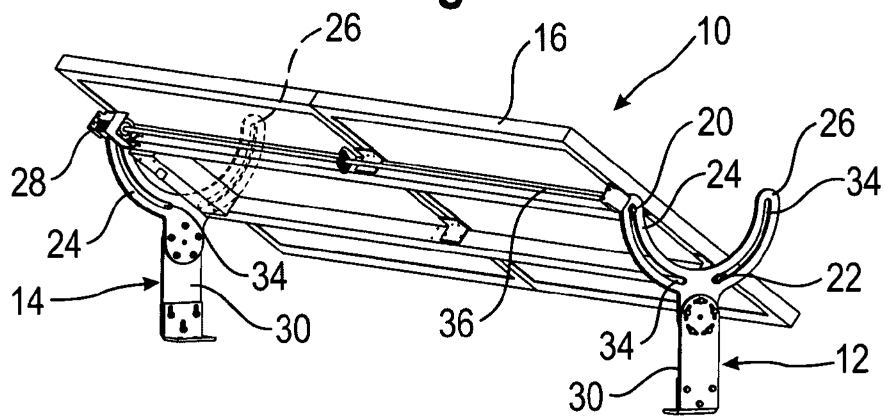


Fig. 3

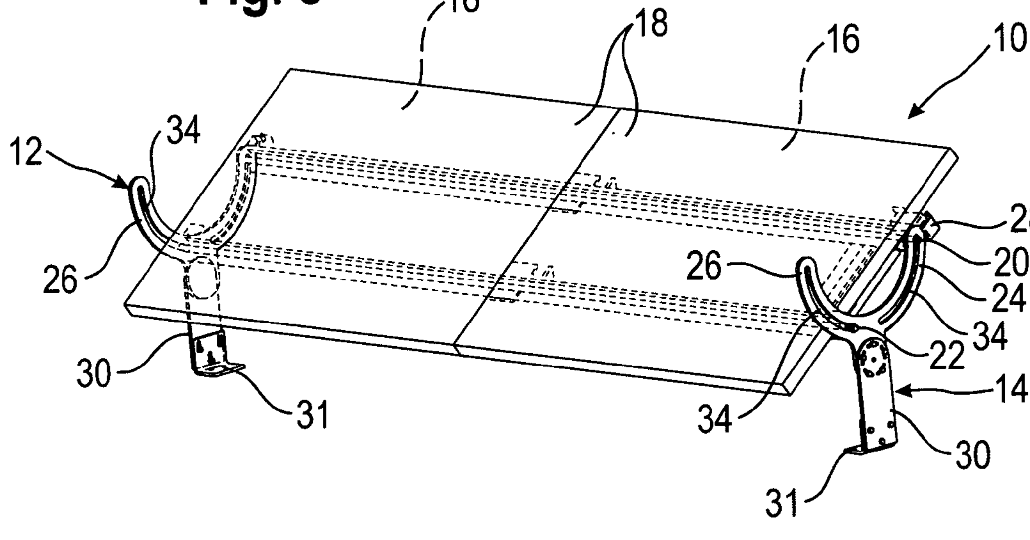


Fig. 4

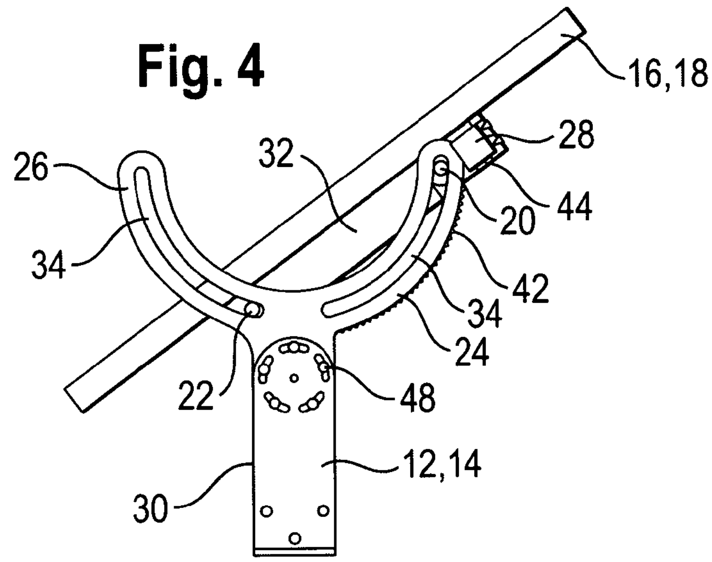


Fig. 5

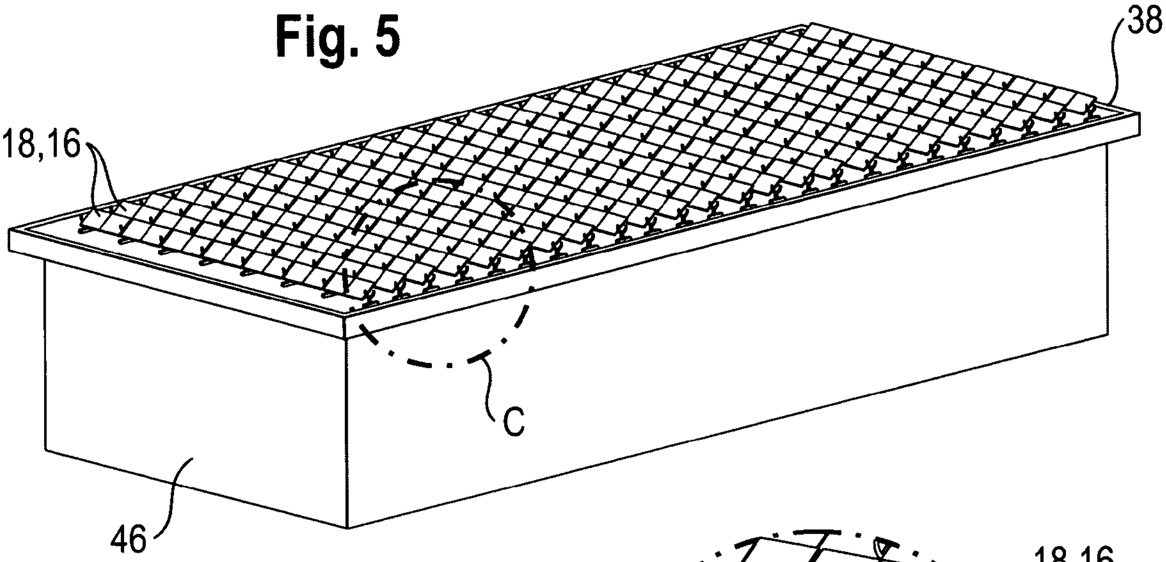


Fig. 6

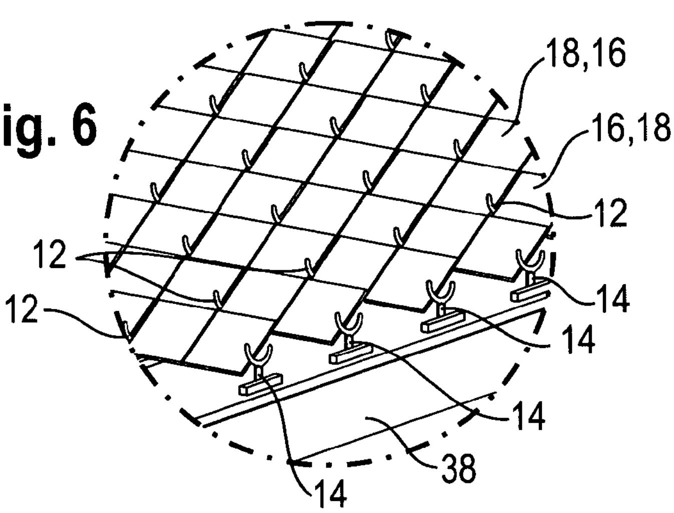


Fig. 7

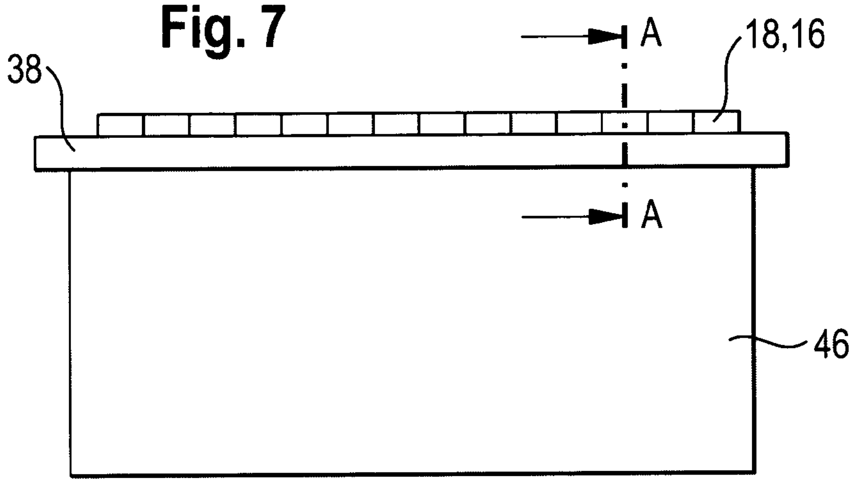


Fig. 8

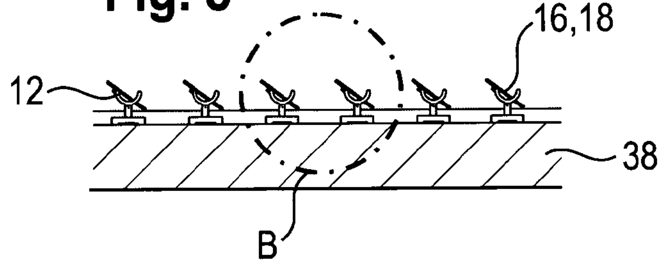
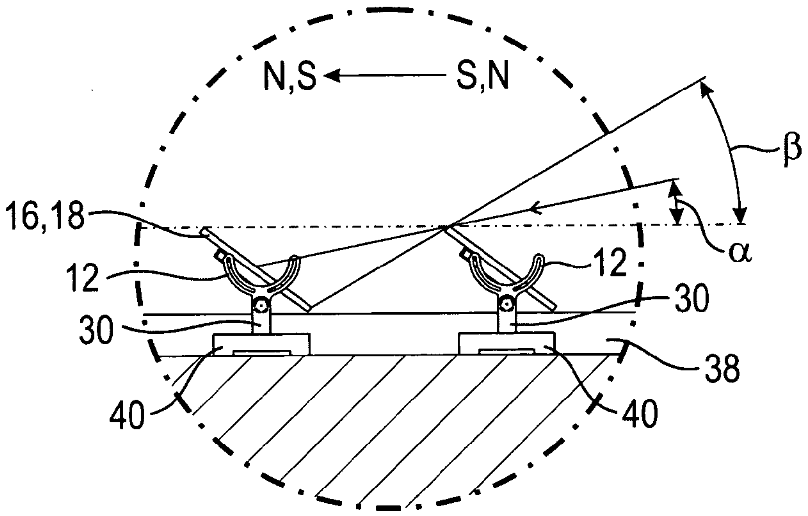


Fig. 9



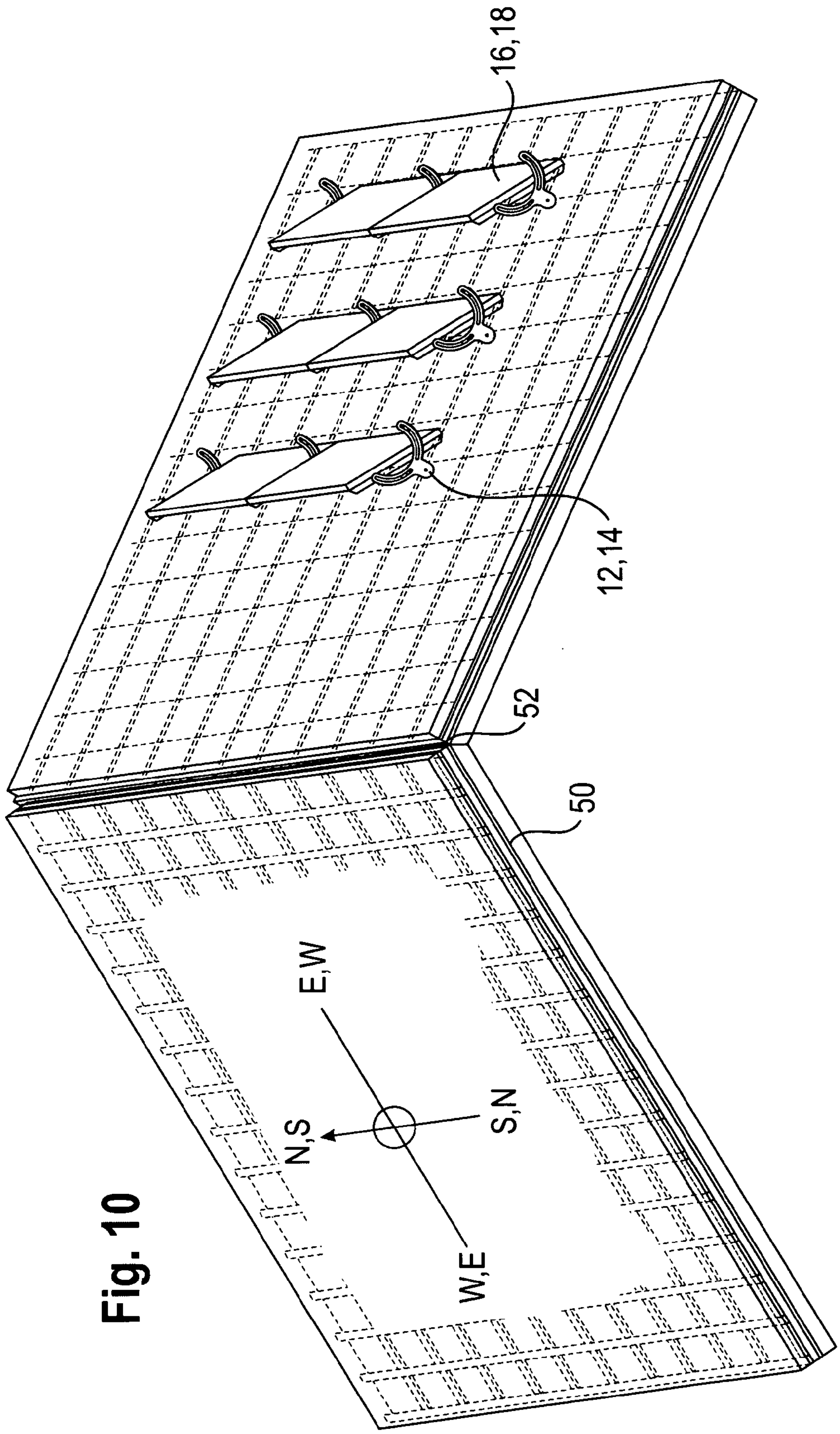


Fig. 10

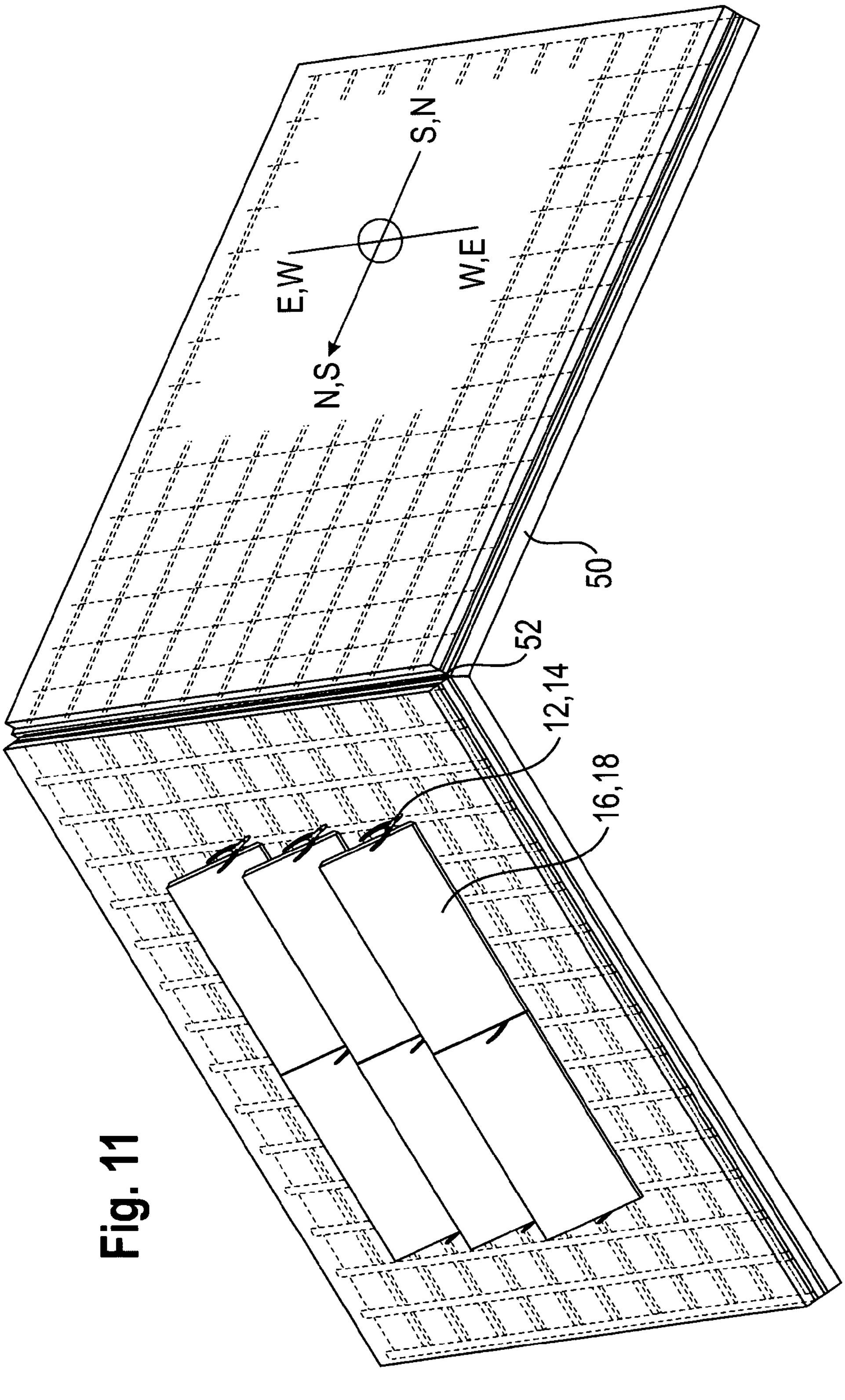


Fig. 11

Fig. 12

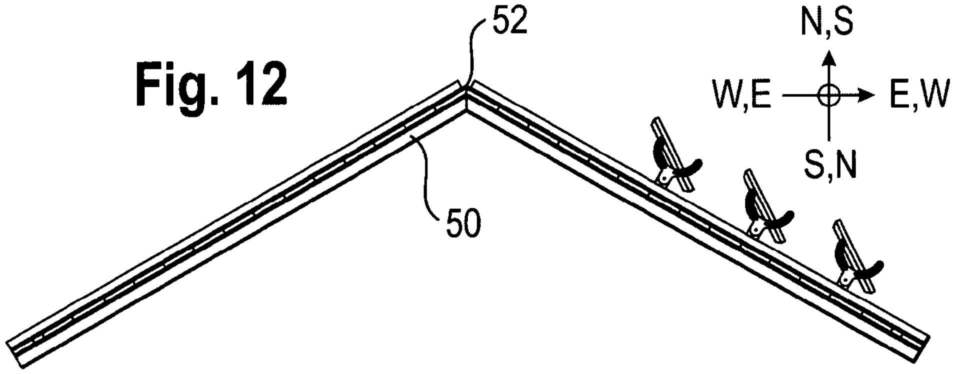


Fig. 13

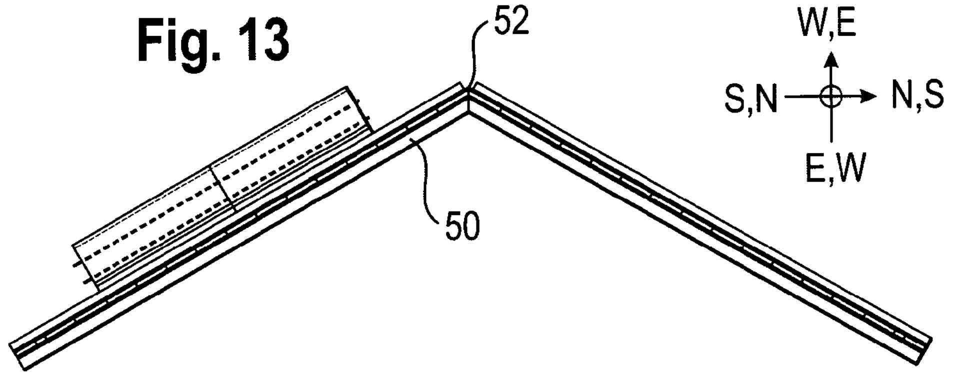


Fig. 14

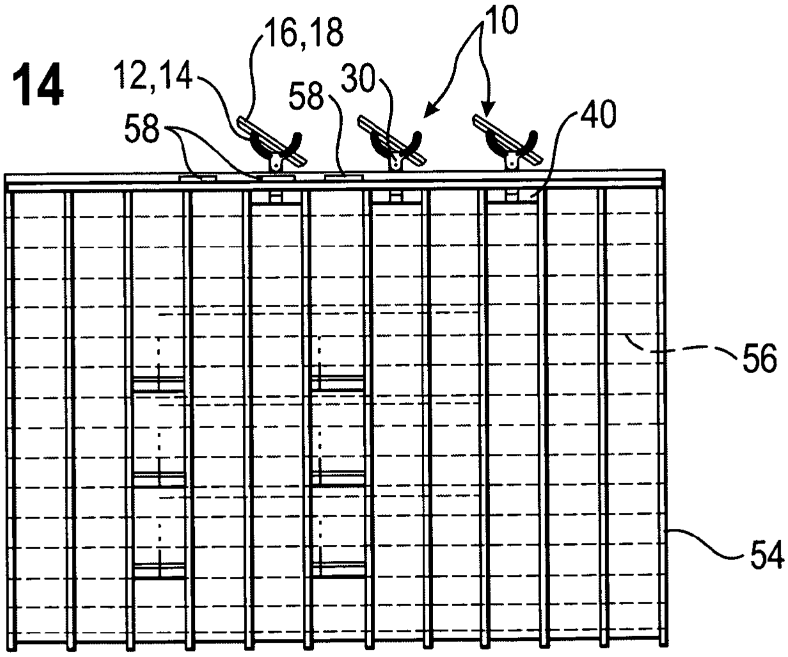


Fig. 15

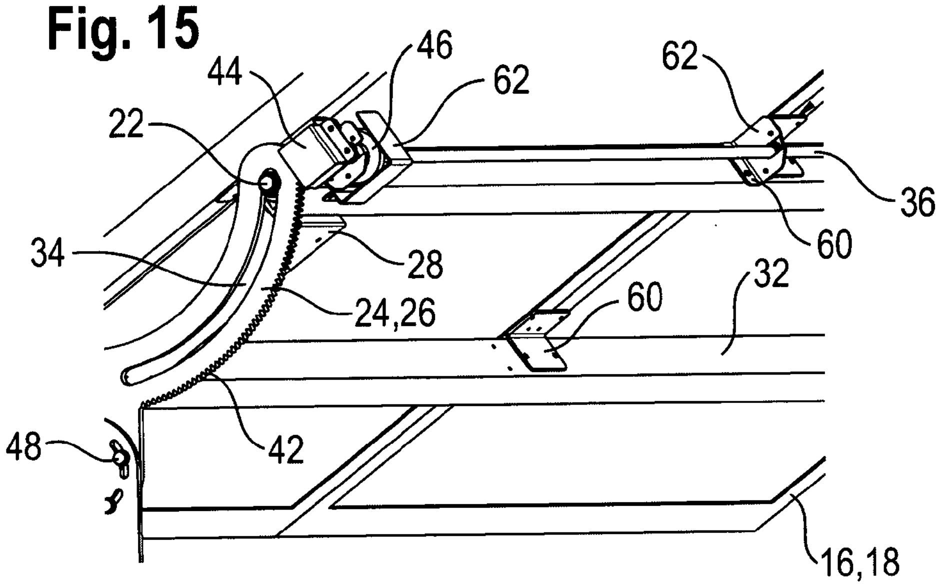


Fig. 16

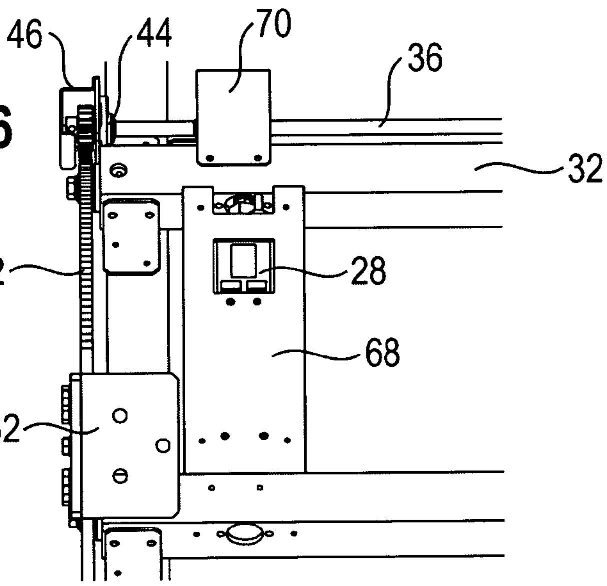


Fig. 17

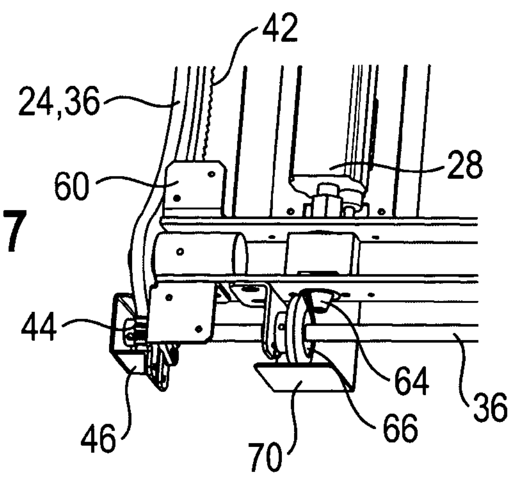


Fig. 18

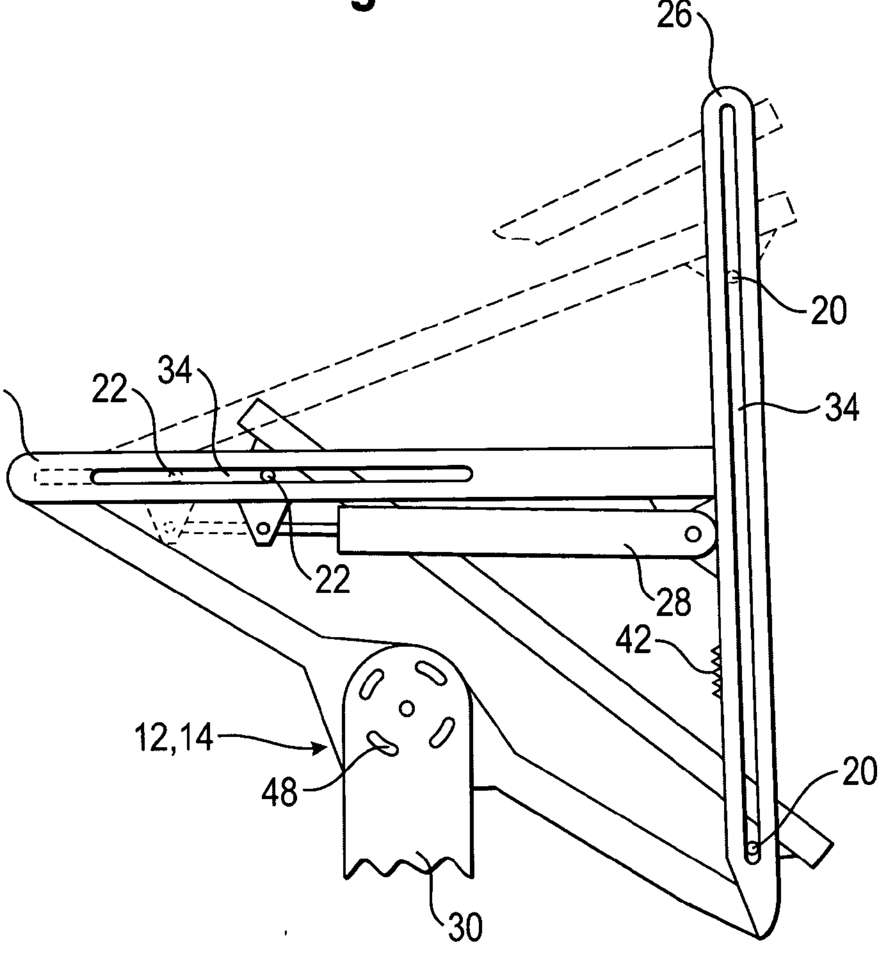


Fig. 19

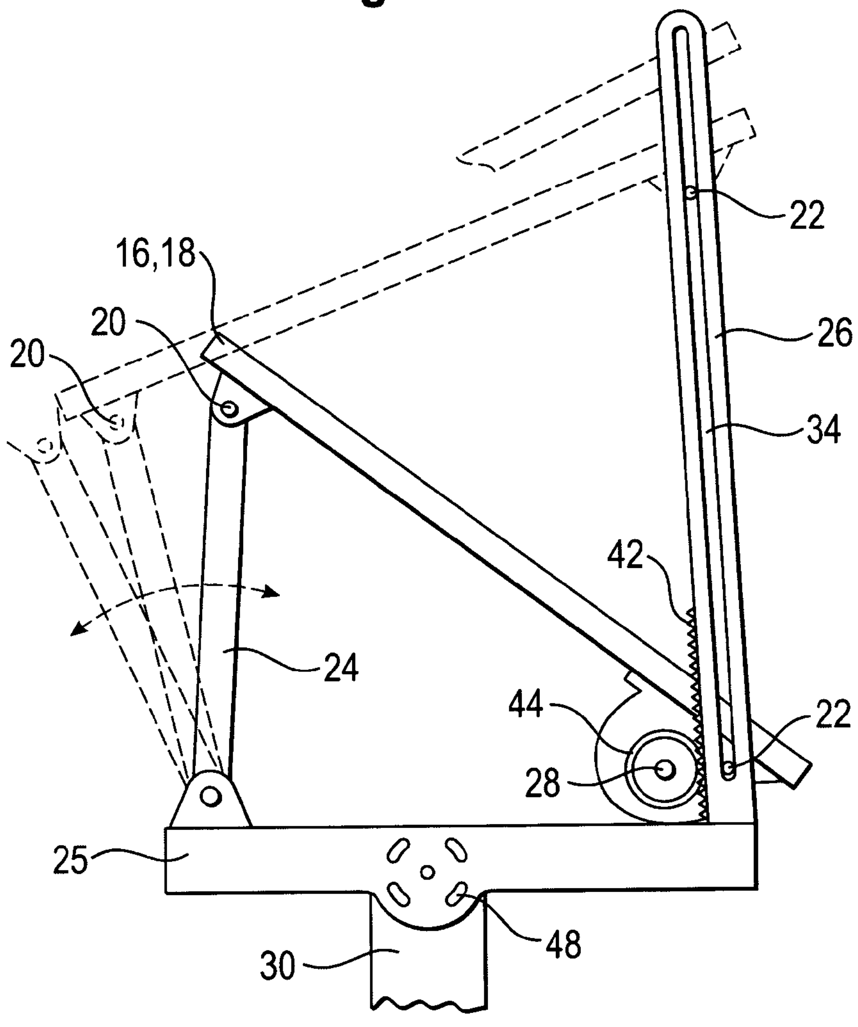
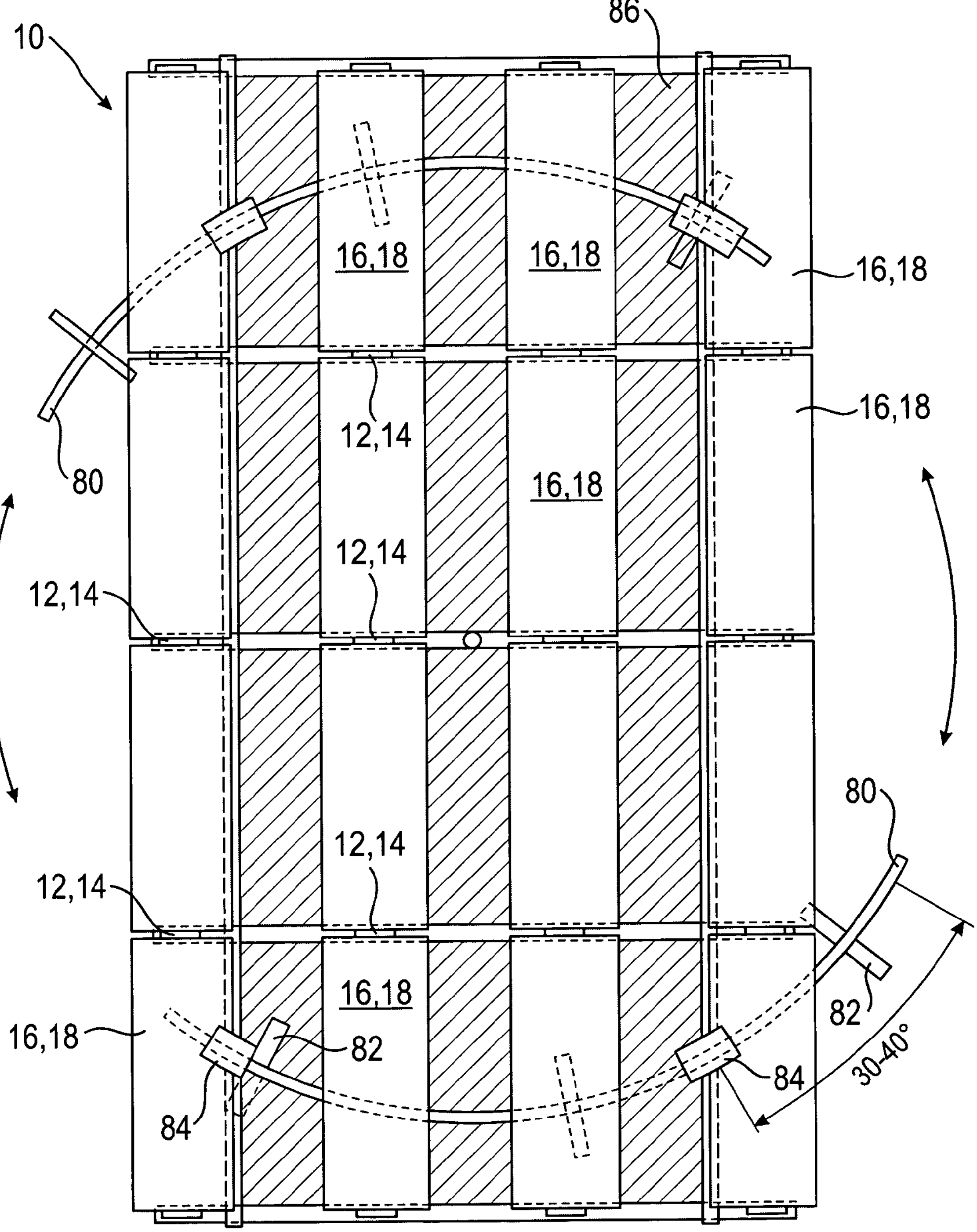


Fig. 20


86
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30-40°

Fig. 21

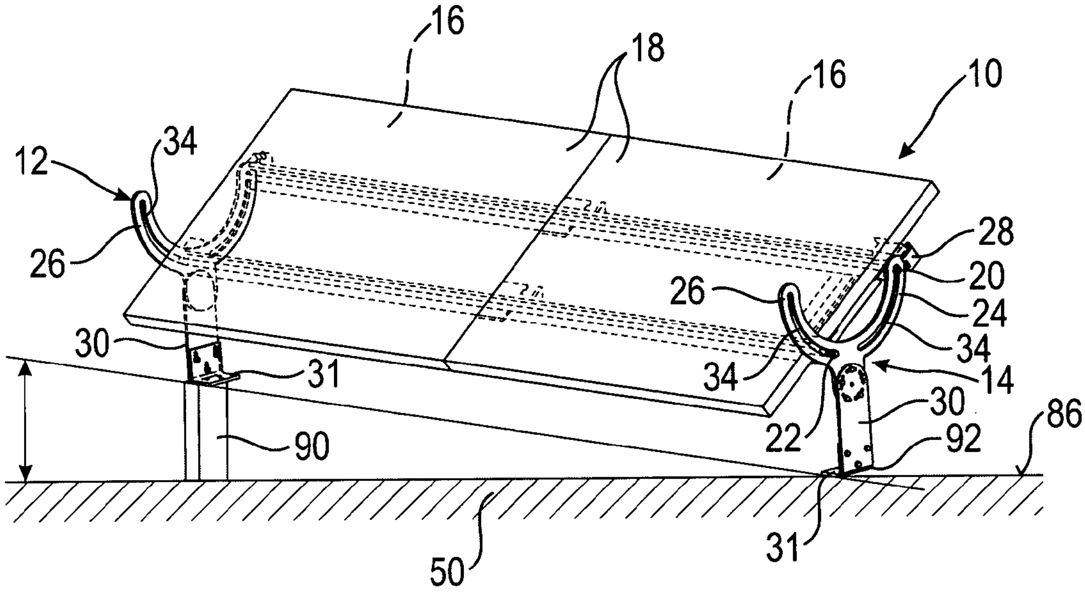


Fig. 22

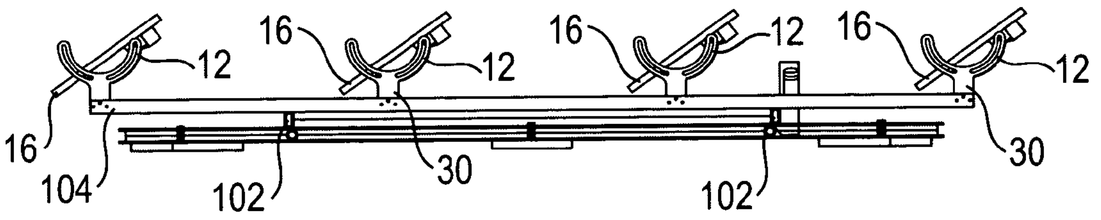
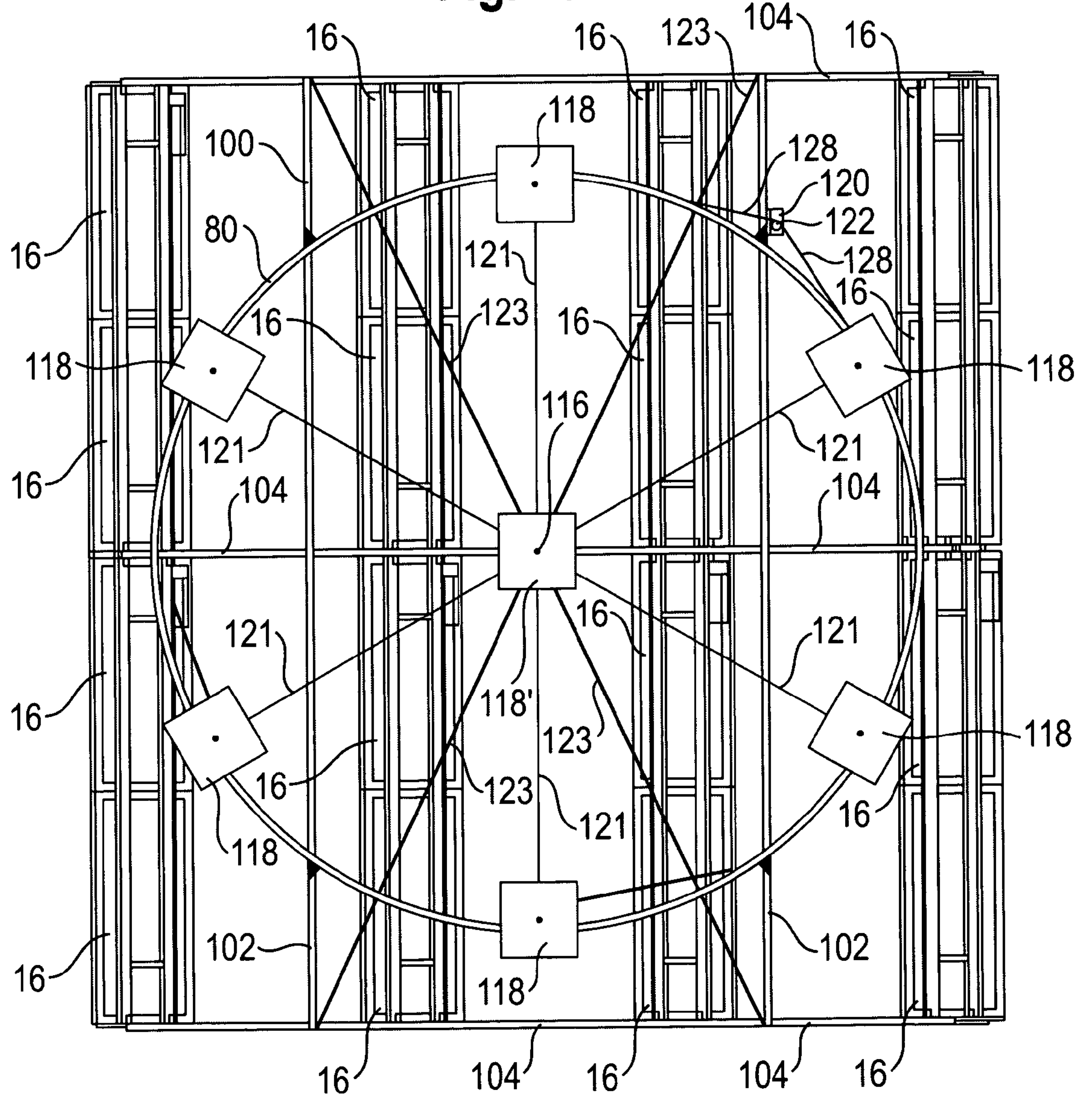


Fig. 23



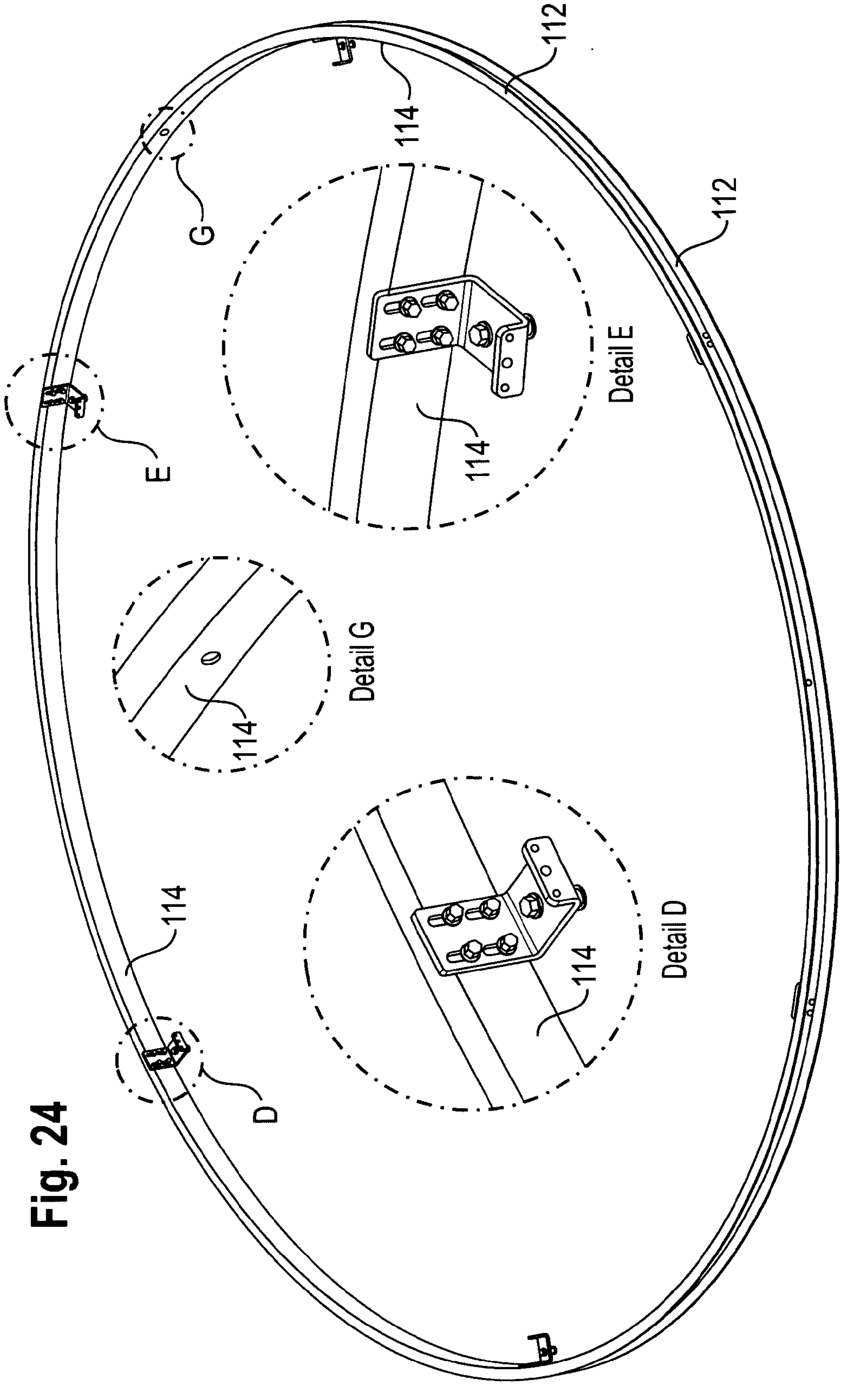


Fig. 24

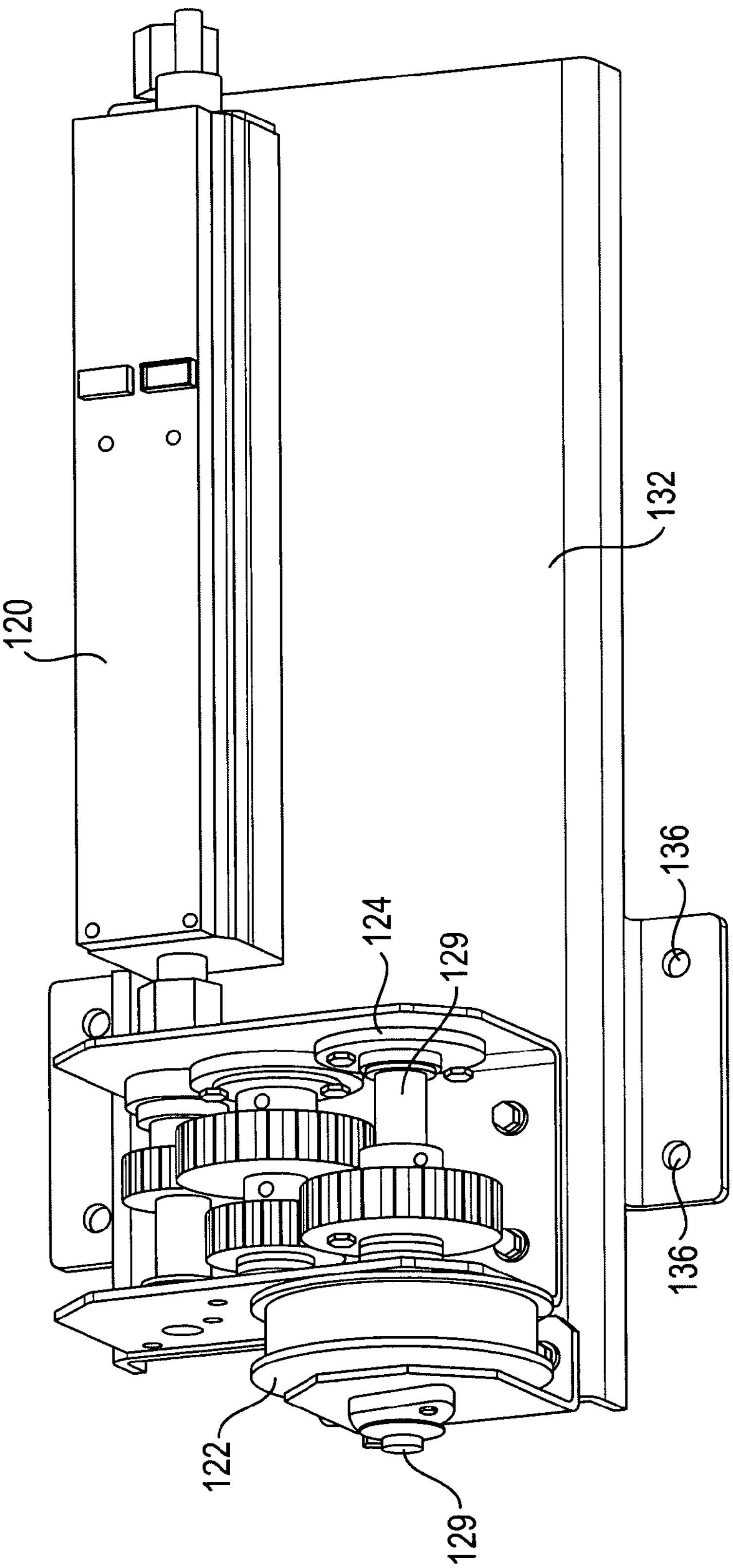


Fig. 25

Fig. 26