



(51) International Patent Classification:

F24J 2/38 (2014.01) *F16M 11/04* (2006.01)
F16M 11/10 (2006.01)

(21) International Application Number:

PCT/US2013/051733

(22) International Filing Date:

23 July 2013 (23.07.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/674,641 23 July 2012 (23.07.2012) US

(71) Applicant: MAGNA INTERNATIONAL INC.
[CA/CA]; 337 Magna Drive, Aurora, ON L4G 7K1 (CA).

(72) Inventors; and

(71) Applicants : WERNER, Mark, Francis [CA/CA]; 5985 Abbott Street, LaSalle, ON N9J 3L6 (CA). WOLETZ, Matthias, Peter [DE/US]; 851 Grant Avenue, Clawson, MI 48017 (US). ZUZELSKI, Michael, Gregory [US/US]; 21690 Meadow Lane, Beverly Hills, MI 48025 (US).

(74) Agents: HURLES, Steven, C. et al.; Dickinson Wright PLLC, 2600 West Big Beaver Road, Suite 300, Troy, MI 48084 (US).

(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, BN, 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, 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, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

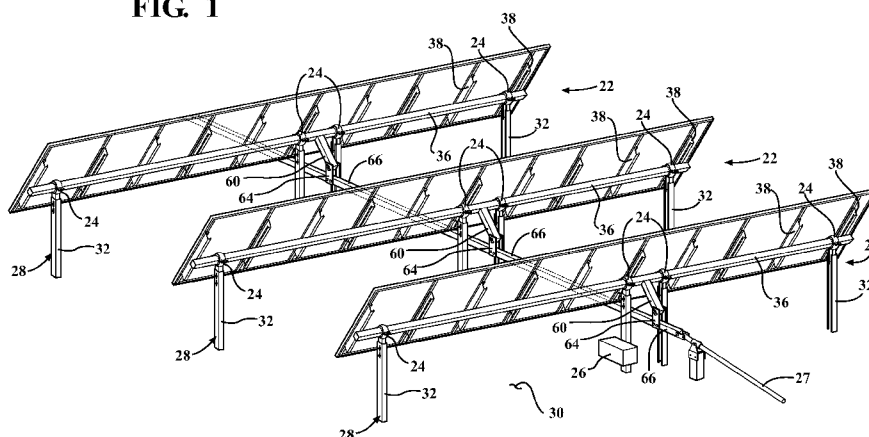
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE,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

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: SINGLE AXIS SOLAR TRACKER

FIG. 1



(57) Abstract: A single axis solar tracker assembly for supporting and controllably rotating a plurality of solar panels is provided. The solar tracker assembly includes a plurality of sub-assemblies which are spaced from one another in a first direction and are operably coupled with a driveshaft that is moveable in the first direction. Each sub-assembly includes at least one torque tube which extends in a second direction and torque arm which is operably coupled with the at least one torque tube. Each sub-assembly further includes a connector which operably connects the torque arm with the driveshaft for rotating the at least one torque tube in response to movement of the driveshaft in the first direction. The connector is pivotably coupled with the torque arm and non-pivotably coupled with the driveshaft and extends in a vertical direction to provide for an increased vertical distance between the torque arm and the driveshaft.



SINGLE AXIS SOLAR TRACKER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This PCT Patent Application claims the benefit of U.S. Provisional Patent Application Serial No. 61/674,641 filed July 23, 2012 entitled “Solar Photovoltaic Single Axis Tracker”, the entire disclosure of the application being considered part of the disclosure of this application, and hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates generally to support frame assemblies for solar related devices, and more particularly to support frame assemblies which are adjustable to controllably rotate a plurality of solar panels about a single axis.

2. Related Art

[0003] Solar trackers are devices which include a plurality of solar panels and (such as, for example, photovoltaic panels, reflectors, lenses or other optical devices) are operable to automatically adjust the orientations of those panels throughout each day to maximize the amount of solar rays captured or reflected by the solar panels. Solar trackers generally have a support frame assembly which engages and supports the solar panels. Typically, each support frame assembly has its own actuator for adjusting orientations of the solar panels.

[0004] Other types of solar trackers have a driveshaft which extends between and is operably connected to a plurality of sub-assemblies, each of which has a support frame assembly and a plurality of solar panels. Each sub-assembly includes a torque tube which supports the solar panels and a torque arm which interconnects the torque tube with the driveshaft. In operation, an actuator moves the driveshaft through a generally arcuate path, and this motion is translated through the torque arms into the torque tubes to rotate solar

panels. As such, the single actuator simultaneously adjusts the orientations of the solar panels of a plurality of sub-assemblies that are spaced from one another.

[0005] There remains a significant and continuing need for a more efficient and less costly solar tracker.

SUMMARY OF THE INVENTION AND ADVANTAGES

[0006] One aspect of the present invention provides for an improved solar tracker assembly for supporting and controllably rotating a plurality of solar panels. The solar tracker assembly includes a plurality of sub-assemblies which are spaced from one another in a first direction and are operably coupled together with a driveshaft that is moveable in the first direction. Each of the sub-assemblies includes at least one torque tube that extends in a second direction which is angled relative to the first direction. Each of the sub-assemblies further includes a torque arm which is operably coupled with at least one torque tube. Additionally, each of the sub-assemblies includes a connector which operably connects the torque arm with the driveshaft for rotating the torque tube in response to movement of the driveshaft in the first direction, and the connector is pivotably coupled with the torque arm and is non-pivotably coupled with the driveshaft. The connector extends in a vertical direction between the torque arm and the driveshaft to provide for an increased vertical distance between the torque arm and the driveshaft.

[0007] The improved solar tracker assembly offers a number of advantages as compared to other known solar tracker assemblies. For example, because of the increased vertical distance between the torque arm and the driveshaft, a gap is not required between solar panels immediately above the driveshaft, i.e. the solar panels may extend the entire length of the torque tube. As such, the improved solar tracker assembly may harness more solar rays and produce more electricity than other known solar trackers. This comes without having to increase the length of the torque arm, which would make actuation of the

driveshaft more difficult. The various components of the improved solar tracker assembly may also be fabricated at a low cost and may be assembled in the field very quickly and without any special equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] These and other features and advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0009] Figure 1 is a perspective and elevation view of an exemplary solar tracker assembly;

[0010] Figure 2 is an enlarged and perspective view of a support post and a bearing of the exemplary solar tracker assembly of Figure 1;

[0011] Figure 3 is an enlarged and fragmentary view of one of the support posts and bearings of the exemplary solar tracker assembly of Figure 1 and taken from a different vantage point than Figure 2;

[0012] Figure 4 is an enlarged and perspective view of one of the bearings of the exemplary solar tracker assembly of Figure 1;

[0013] Figure 5a is a perspective view of a subassembly of the exemplary solar tracker assembly of Figure 1;

[0014] Figure 5b is a fragmentary view of a torque arm of one of the subassemblies interconnected with a driveshaft of the exemplary solar tracker assembly of Figure 1;

[0015] Figure 6 is a perspective view of a frame assembly of one of the subassemblies of the exemplary solar tracker assembly of Figure 1 with the associated photovoltaic panels disposed in a zero degree orientation;

[0016] Figure 7 is a fragmentary view of a support post of the exemplary solar tracker assembly of Figure 1; and

[0017] Figure 8 is a cross-sectional view showing the movement of the photovoltaic panels in response to movement of the driveshaft of the solar tracker assembly of Figure 1.

DESCRIPTION OF THE ENABLING EMBODIMENT

[0018] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, an exemplary embodiment of a single axis solar tracker assembly **20** for harnessing potential energy from solar rays and generating electricity is generally shown in Figure 1. As shown, the solar tracker assembly **20** includes a plurality of sub-assemblies **22** (these being shown in the exemplary embodiment) which are spaced from one another in a longitudinal or first direction. The longitudinal direction could be a north-south direction, an east-west direction or any desirable direction. As shown, each of the exemplary sub-assemblies **22** has its own array of photovoltaic panels **24** which are configured to convert solar radiation into direct current (DC) electricity. The arrays of the different sub-assemblies **22** are all arranged to face in the same general direction, and as will be discussed in further detail below, the sub-assemblies **22** are all mechanically interconnected with one another so that a single driving unit or actuator **27** may simultaneously rotate the photovoltaic panels **24** of all of the sub-assemblies **22**. As such, the single actuator **27** is operative to adjust the sub-assemblies **22** such that the photovoltaic panels **24** simultaneously “follow the sun” across the sky during each day to increase the total amount of solar rays harnessed and the total amount of electricity generated by the photovoltaic panels **24** each day as compared to solar assemblies with stationary/non-moveable photovoltaic panels. It should be appreciated that the sub-assemblies **22** could include mirrors or any desirable type of solar panels in place of or in addition to the photovoltaic panels **24** of the exemplary embodiment. Additionally, it should be

appreciated that the actuator **27** may be any suitable type of actuator such as, for example, an electric motor, a pneumatic motor or a hydraulic motor.

[0019] Referring still to Figure 1, each of the sub-assemblies **22** includes a frame structure **28** which supports the photovoltaic panels **24** above a base **30**, such as the ground, a platform or a roof of a building. As discussed in further detail below, each of the frame structures **28** includes a plurality of support posts **32** which extend generally vertically upwardly from the base **30**; a plurality of bearings **34** (best shown in Figures 2-4) which are positioned at the upper ends of the support posts **32**; a torque tube **36** which extends between and is supported by the bearings **34**; and a plurality of rails **38** which support the photovoltaic panels **24**.

[0020] The support posts **32** of each frame structure **28** are anchored to the base **30** and are spaced apart from one another in a lateral (or second) direction, which is perpendicular to the aforementioned longitudinal direction. As shown in Figures 2-4 the support posts **32** of the exemplary embodiment have generally C-shaped cross-sections, and each support post **32** has a pair of spaced apart and vertically extending slots **40** adjacent their upper ends. It should be appreciated that the support posts **32** may have any suitable shape. The support posts **32** are preferably made of a metal, such as steel or aluminum, but may be of any suitable material and may be shaped through any suitable process or combination of processes including, for example, roll forming, extrusion, stamping, machining, etc.

[0021] Referring now to Figure 4, each of the bearings **34** includes lower (or first) and upper (or second) shells **42, 44**, each of which has a semi-spherical outer surface and a semi-spherical inner surface (not shown). In the exemplary embodiment, the lower and upper shells **44, 42** are of identical shape and construction, which provides for manufacturing advantages through economies of scale. Each of the lower shells **42** is

connected (for example, through welding) to the top of a bearing post **46** which has a pair of apertures that are spaced vertically from one another. The apertures are for connecting the bearing posts **46** with the aforementioned support posts **32** via fasteners **48**, e.g. bolts. The lower shells **42** may be attached to the bearing posts **46** in a factory setting before the various components are transferred to the field. The bearings **34** are interconnected with the support posts **32** by aligning the apertures of the bearing posts **46** with the slots **40** in the support posts **32** and inserting the fasteners **48** through the aligned apertures and slots **40**. This type of connection is particularly advantageous because it may be established in the field in a very quick manner and without any special equipment. Additionally, the slots **40** in the support posts **32** allow for the heights of the bearings **34** relative to the base **30** (shown in Figure 1) to be established in the field and to be easily adjusted if needed. For bases **30** having uneven terrain, this may be particularly advantageous. It should be appreciated that the bearing posts **46** may alternately be attached to the support posts **32** through a range of different connection means.

[0022] Each of the bearings **34** further includes a pair of races **50** which are configured to surround a portion of the torque tube **36**. The races **50** have generally smooth, continuous, and semi-spherical outer surfaces to provide for low-friction contact surfaces between the races **50** and the semi-spherical inner surfaces of the lower and upper shells **42**, **44**. The races **50** are preferably made of a self-lubricating and low-friction material, such as an acetyl co-polymer. In contrast to cylindrical bearings, which are found in many known solar tracker assemblies, the spherical bearings **34** of the exemplary embodiment compensate for some degree in the rotational variations of the support posts **32** and also may reduce stress at the bearings **34** from wind loading by providing for additional compliance in the joint due to the additional degrees of freedom allowed by the spherical design.

[0023] As best shown in Figure 4, in the exemplary embodiment, the torque tubes **36** are generally rectangularly shaped. However, it should be appreciated that the torque tubes **36** could have any suitable shape such as, for example, a circle. Referring now to Figure 5a, the rails **38** of the frame structures **28** are spaced in a lateral direction from one another and are interconnected with the torque tubes **36** at approximately their longitudinal mid-points. The photovoltaic panels **24** may be mounted on the rails **38** either in a landscape orientation or a portrait orientation (as shown in the exemplary embodiment). In the exemplary embodiment, each rail **38** is disposed between a pair of photovoltaic panels **24** and supports the adjacent lateral edges of those panels **24**.

[0024] Referring still to Figure 5a, each of the sub-assemblies **22** additionally includes a torque arm **60** which extends generally perpendicularly away from the torque tube **36** at an approximate lateral midpoint thereof. One end of each torque arm **60** is attached to the associated torque tube **36** through, for example, welding, adhesives, brazing, fasteners, etc. The other end of each torque arm **60** is attached via a connector **64** (such as, for example, one or more brackets) to an elongated driveshaft **66** which extends in the longitudinal direction between all of the sub-assemblies **22** (see Figure 1). As best shown in Figure 5b, the connector **64** of the exemplary embodiment is a generally U-shaped bracket **64**. The connector **64** is preferably attached to the torque arm **36** with a cleavis pin/cotter pin connection to establish a pivoting connection therebetween and is attached to the driveshaft **66** through a pair of fasteners that are spaced longitudinally from one another to establish a non-pivoting connection therebetween. The dispositions of the connectors **64** between the torque arms **60** and the driveshaft **66** is advantageous because it provides for a vertical offset between the bottoms of the torque arms **60** and the driveshaft **66**. This offset ensures a clearance between the lower edges of the photovoltaic panels **24** aligned laterally with and spaced vertically above the torque arm **60** and the driveshaft **66** during rotation of

the photovoltaic panels **24**. As shown in Figure 8, this also has the effect of reducing the amount of vertical movement of the driveshaft **66** when rotating the photovoltaic panels **24**, i.e. the radius of the arcuate path that the driveshaft **66** must move through to rotate the torque tube **36** and the photovoltaic panels **24** is reduced. Additionally, a “gap” is not required between photovoltaic panels **24** directly above the driveshaft **66** as is included in other known solar tracking systems. In other words, the exemplary sub-assemblies **22** include a constant row of photovoltaic panels **24** with increased electricity generation and improved aerodynamics, which results in a reduced wind turbulence on the sub-assemblies **22**. The additional photovoltaic panels **24** may be used, for example, to power battery backups or additional electrical equipment for the system.

[0025] As discussed above and shown in Figure 1, the driveshaft **66** extends longitudinally between and interconnects all of the sub-assemblies **22**. The driveshaft **66** is attached to an actuator **27** (such as an electric, hydraulic, or pneumatic motor) which is controlled by a control box **26** for controlling the movement of the driveshaft **66** through an arcuate path which extends in the longitudinal direction. Movement of the driveshaft **66** in the longitudinal direction causes the torque arms **60** to pivot about the torque tubes **36**, thereby rotating all of the torque tubes **36** of all of the sub-assemblies **22** simultaneously. This re-orientes all of the photovoltaic panels **24** relative to the base **30**. As such, a single actuator **27** is able to simultaneously re-orient the photovoltaic panels **24** of all of the sub-assemblies **22**, thus allowing the photovoltaic panels **24** to “follow the sun” through the sky to maximize the amount of solar rays harnessed by the solar tracker assembly **20** during each day. Although the exemplary solar tracker assembly **20** includes three sub-assemblies **22**, it should be appreciated that any desirable number of sub-assemblies **22** may be attached to one another through the driveshaft **66**.

[0026] As shown in Figures 1 and 5a, the torque arm **60** of each sub-assembly **22** extends generally perpendicularly relative to the photovoltaic panels **24**. During heavy winds, this orientation of the torque arm **60** allows it to provide support to the frame structure **28** for resisting wind forces acting on the photovoltaic panels **24**.

[0027] An exemplary process for assembling the sub-assemblies **22** of the exemplary embodiment in the field begins with anchoring the support posts **32** to the base **30** such that the support posts **32** extend generally vertically upwardly from the base **30**. Next, the bearing posts **46**, which are attached to the lower shells **42**, are joined to the support posts **32** with fasteners, such as bolts. Then, the races **50** are placed around the torque tubes **36** and set into the upwardly facing spherical inner surfaces of the lower shells **42**. To secure the torque tubes **36** with the bearings **34**, the flanges **58** on the upper shells **44** of the bearings **34** are then secured to the flanges **58** on the lower shells **42**. With this, the torque tubes **36** are supported above the support posts **32** by the bearings **34**, and the low friction contact between the races **50** and the shells **42, 44** allows the torque tube **36** to rotate relative to the base **30**. The rails **38** may then be secured to the torque tubes **36** through any suitable types of connections including, for example, brackets and fasteners. Next, with the rails **38** in place, the photovoltaic panels **24** may be installed onto the rails **38** thereby allowing the photovoltaic panels **24** to rotate relative to the base **30**.

[0028] Then, the driveshaft **66** may be attached to the sub-assemblies **22** by attaching the connectors **46** to the driveshaft **66** and to the ends of the torque arms **60** through, for example, fasteners. The actuator **27** may then be operably coupled with the driveshaft **66** to move the driveshaft in the longitudinal direction to simultaneously adjust the photovoltaic panels **24** of all of the sub-assemblies **22**.

[0029] Referring now to Figure 6, the torque arm **60** and the bearing posts **46** which are adjacent the torque arm **60** all include holes **68** which are aligned with one another when

the photovoltaic panels **24** of the corresponding sub-assembly **22** are in a zero degree position, i.e. parallel to the ground. A rod or bolt may then be inserted through these aligned holes to hold the sub-assembly **22** in this position. This may be advantageous during assembly and maintenance of the sub-assemblies **22**.

[0030] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims.

CLAIMS

Claim 1. A single axis solar tracker assembly for supporting and controllably rotating a plurality of solar panels, comprising:

a plurality of sub-assemblies spaced from one another in a first direction and operably coupled with a driveshaft that is moveable in said first direction, each of said sub-assemblies including:

at least one torque tube extending in a second direction which is angled relative to said first direction,

a torque arm operably coupled with said at least one torque tube,

a connector operably connecting said torque arm with said driveshaft for rotating said at least one torque tube in response to movement of said driveshaft in said first direction, and

said connector being pivotably coupled with said torque arm and non-pivotably coupled with said driveshaft and extending in a vertical direction between said torque arm and said driveshaft to provide for an increased vertical distance between said torque arm and said driveshaft.

Claim 2. The solar tracker assembly as set forth in claim 1 wherein said connector of each sub-assembly extends in a vertical direction between said torque arm and said driveshaft.

Claim 3. The solar tracker assembly as set forth in claim 1 wherein said connector of each sub-assembly is a bracket.

Claim 4. The solar tracker assembly as set forth in claim 3 wherein said bracket of each sub-assembly is generally U-shaped.

Claim 5. The solar tracker assembly as set forth in claim 4 wherein a clevis pin is used to establish said pivoting connection between said bracket and said torque arm.

Claim 6. The solar tracker assembly as set forth in claim 1 wherein each sub-assembly further includes a plurality of solar collectors operably coupled with said torque tube for harnessing potential energy from solar rays.

Claim 7. The solar tracker assembly as set forth in claim 6 wherein said plurality of solar collectors on each sub-assembly are photovoltaic panels.

Claim 8. The solar tracker assembly as set forth in claim 7 wherein said photovoltaic panels are coupled with said torque tube via a plurality of rails which are spaced from one another and extend in generally parallel relationship with one another.

Claim 9. The solar tracker assembly as set forth in claim 6 wherein said plurality of solar collectors on each sub-assembly includes at least one solar collector aligned in said second direction and spaced vertically above said torque arm.

Claim 10. The solar tracker assembly as set forth in claim 1 wherein said second direction is generally perpendicular to said first direction.

Claim 11. The solar tracker assembly as set forth in claim 1 wherein each of said sub-assemblies includes a plurality of support posts spaced in said second direction from one another and each having a bearing at its upper end which pivotably supports said torque tube.

Claim 12. The solar tracker assembly as set forth in claim 11 wherein each of said bearings has a first shell and a second shell and a pair of races which are rotatable within the confines of said first and second shells.

Claim 13. The solar tracker assembly as set forth in claim 11 wherein each of said support posts includes a pair of vertically extending slots and wherein said bearings are attached to said support posts with fasteners which extend through said slots.

Claim 14. The solar tracker assembly as set forth in claim 1 wherein said torque arm of each sub-assembly extends generally perpendicularly to said torque tube.

Claim 15. The solar tracker assembly as set forth in claim 1 wherein each of said torque tubes is generally rectangular in shape.

FIG. 1

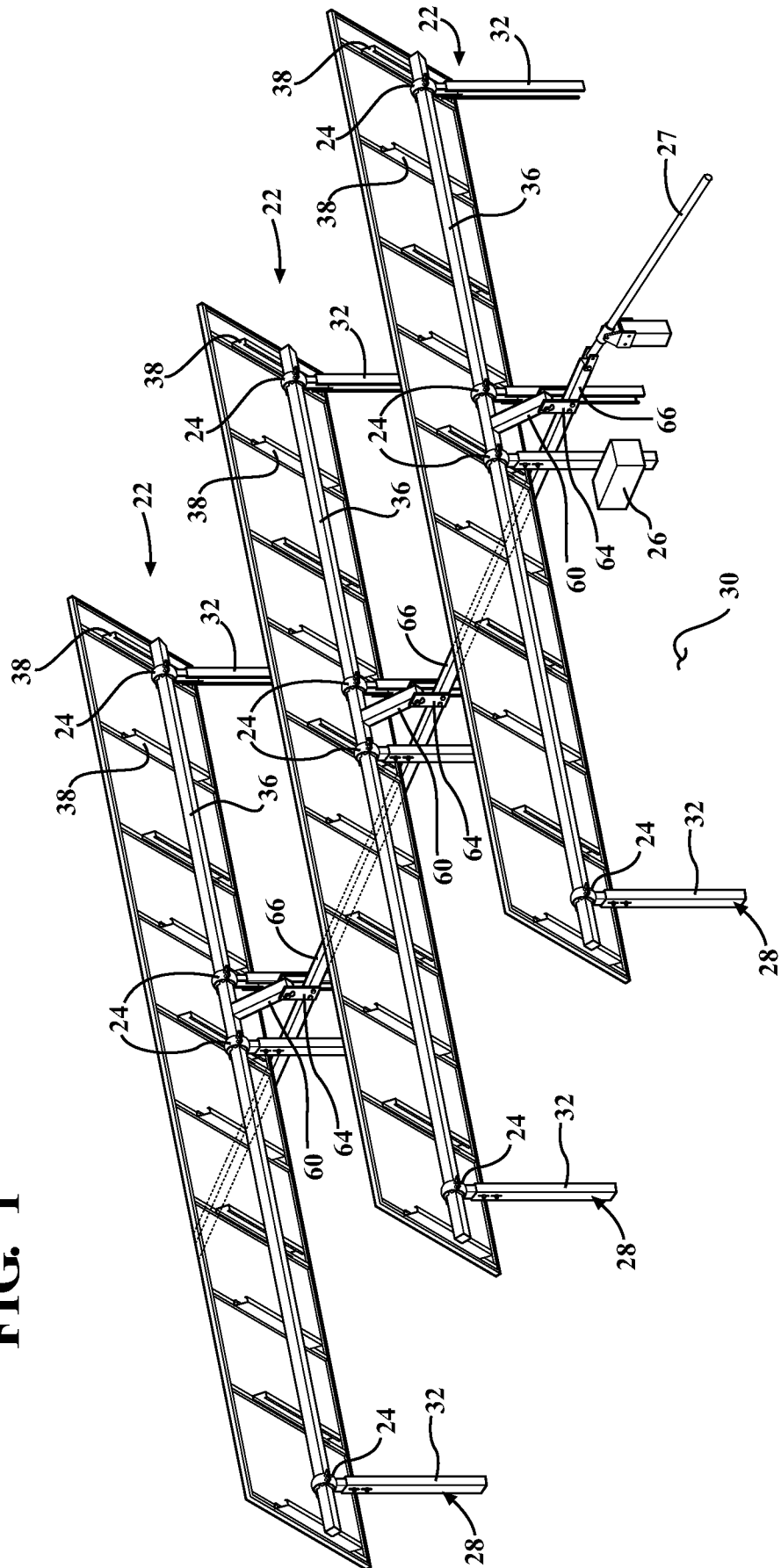


FIG. 2

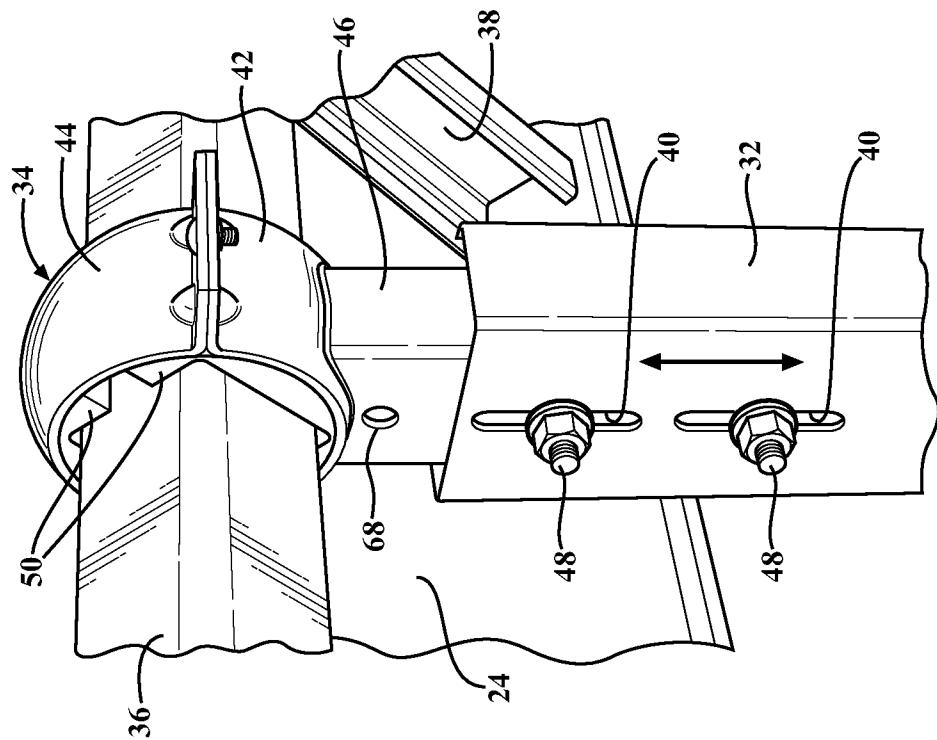
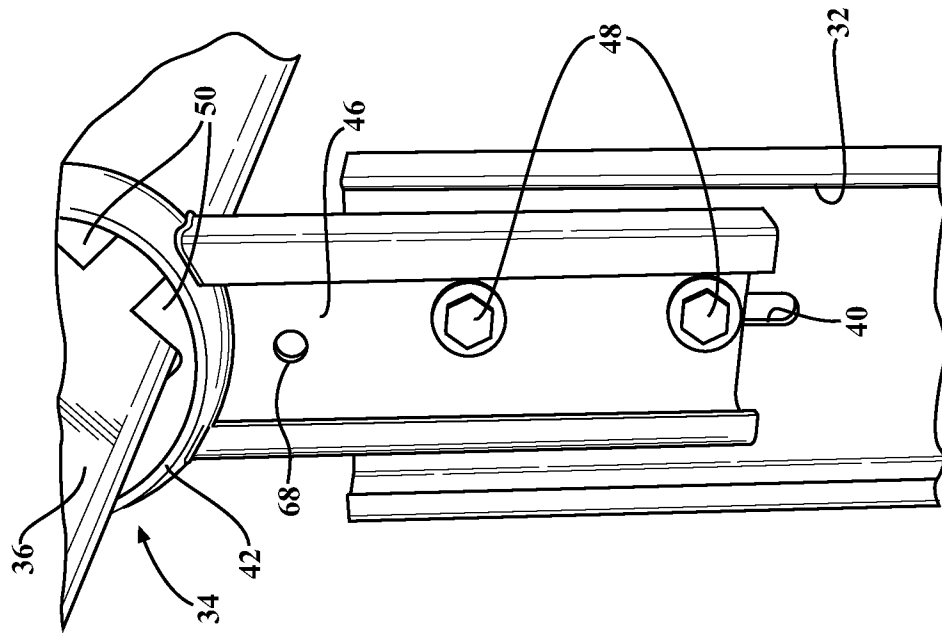


FIG. 3



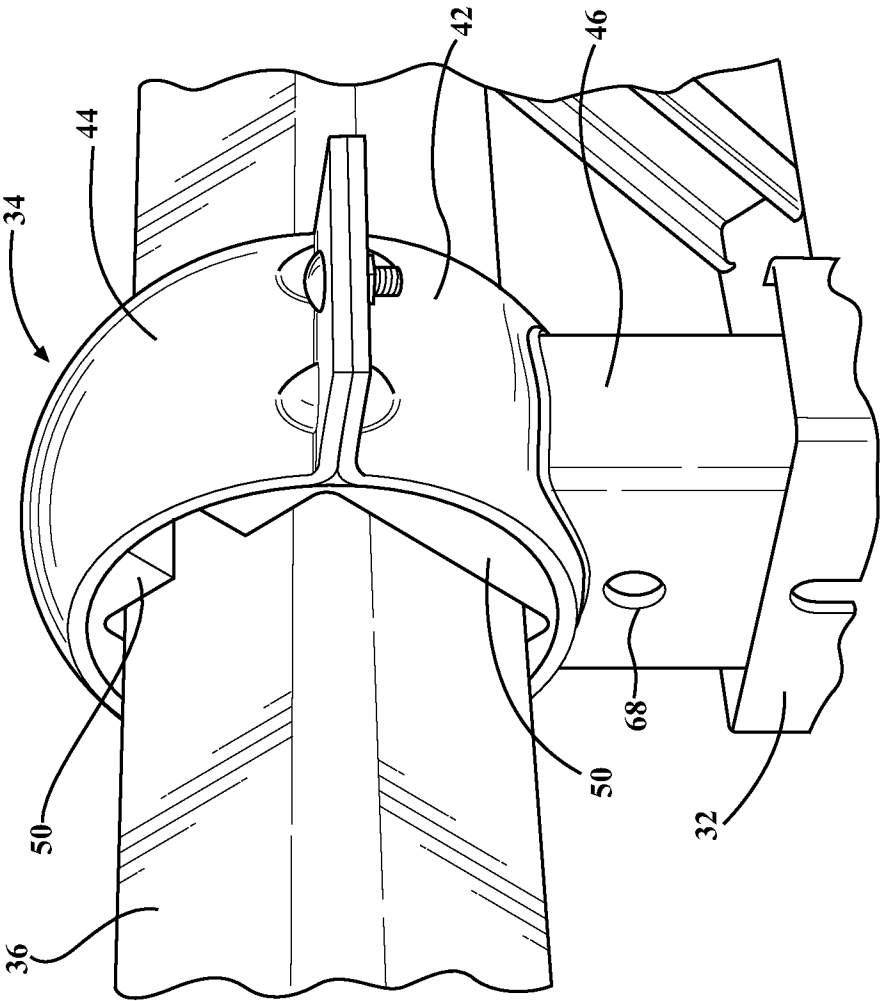


FIG. 4

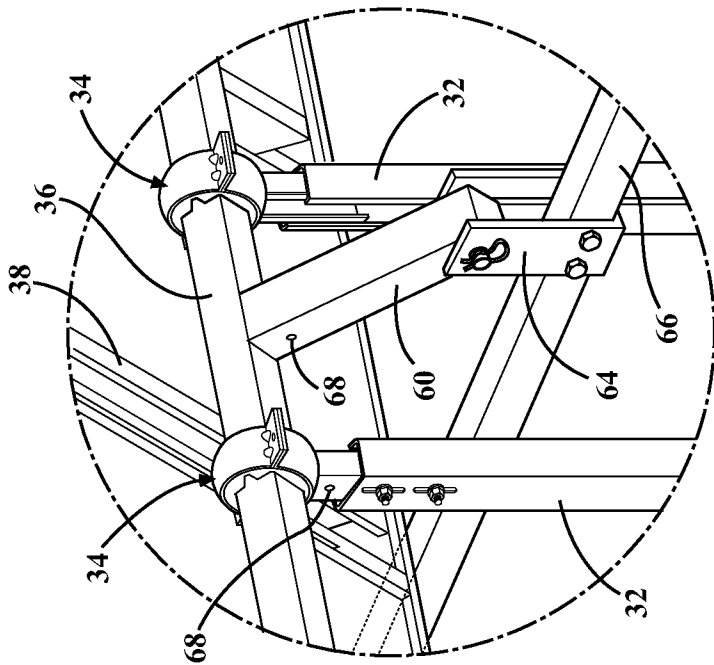
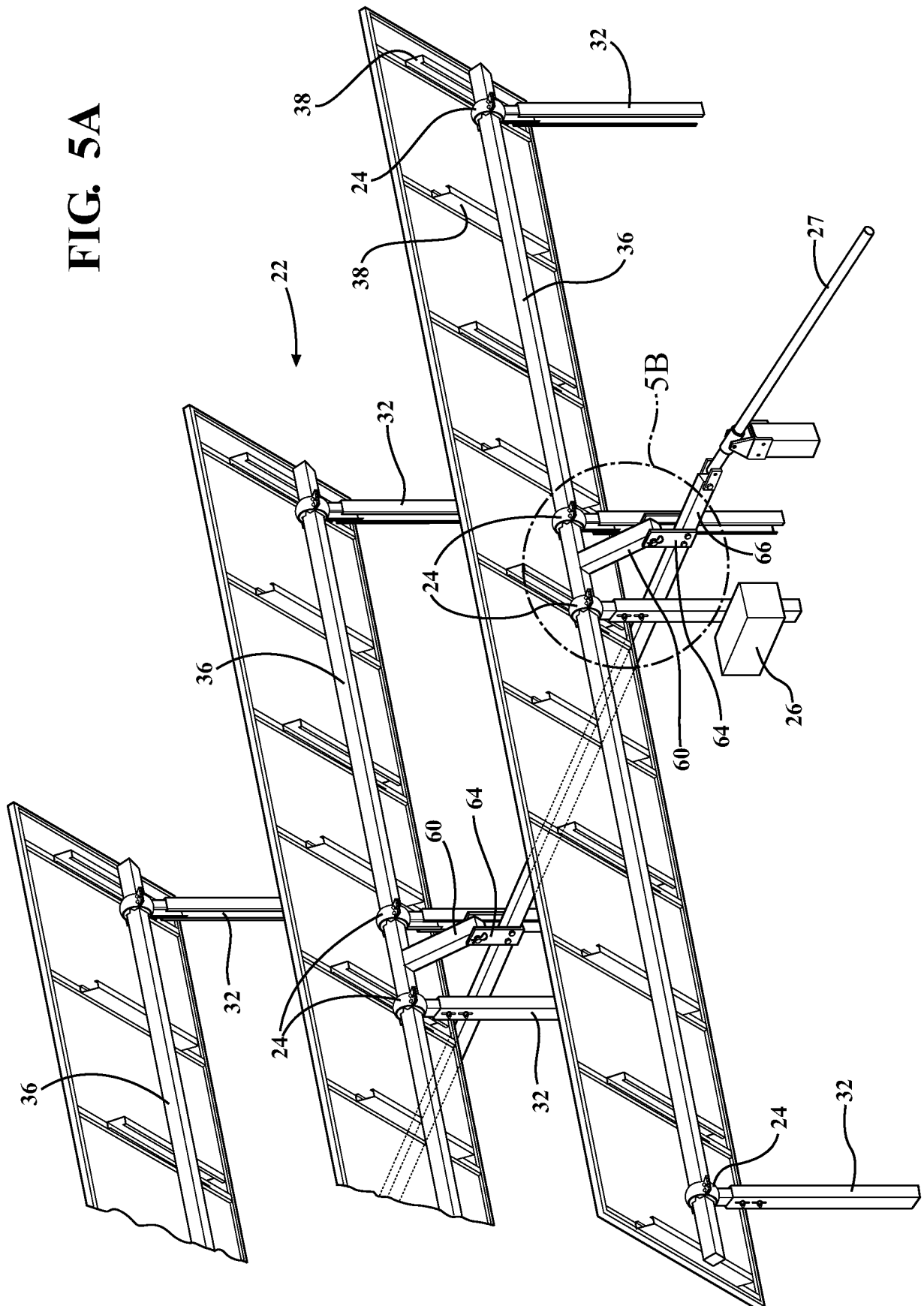


FIG. 5B

FIG. 5A



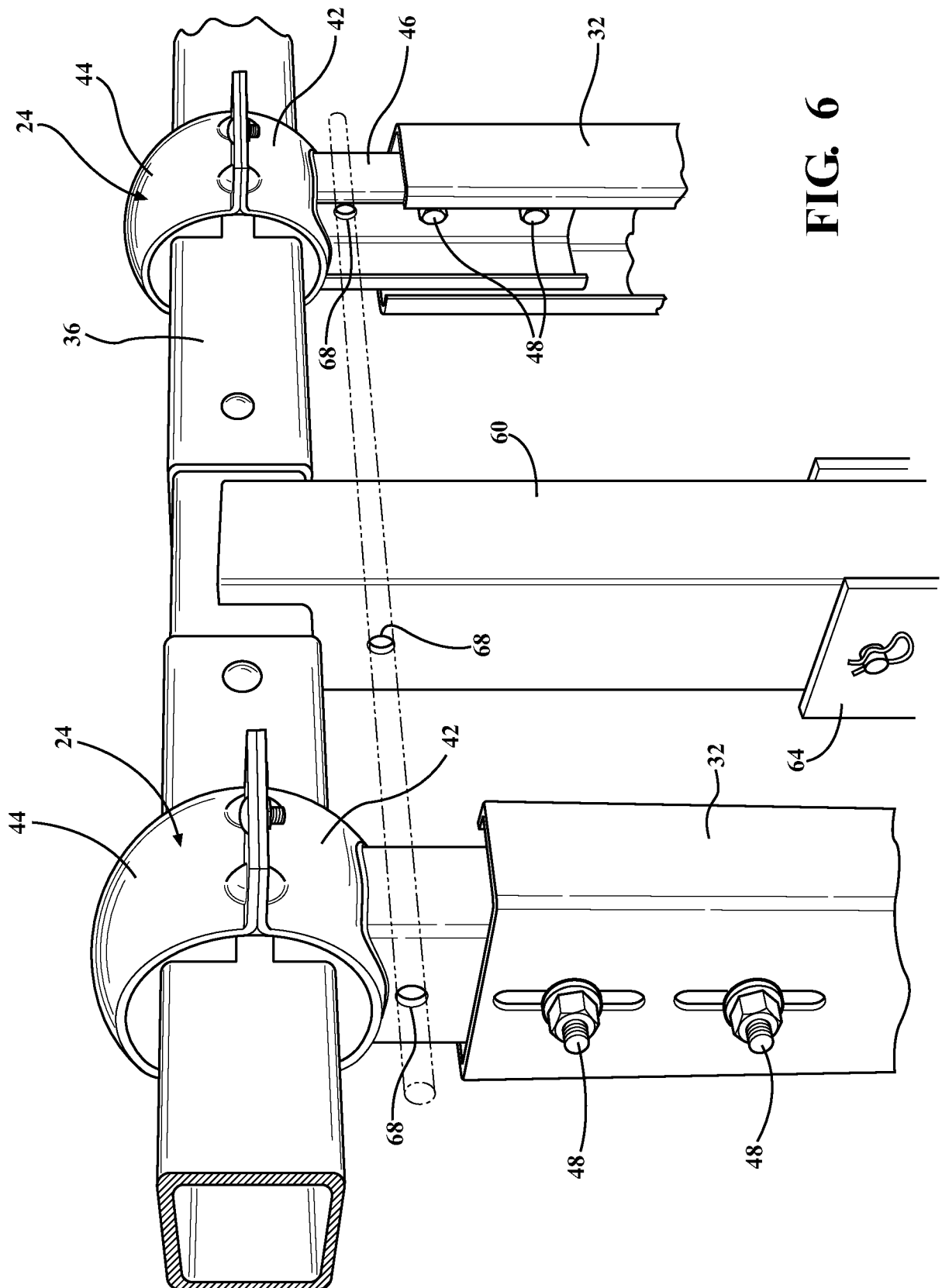
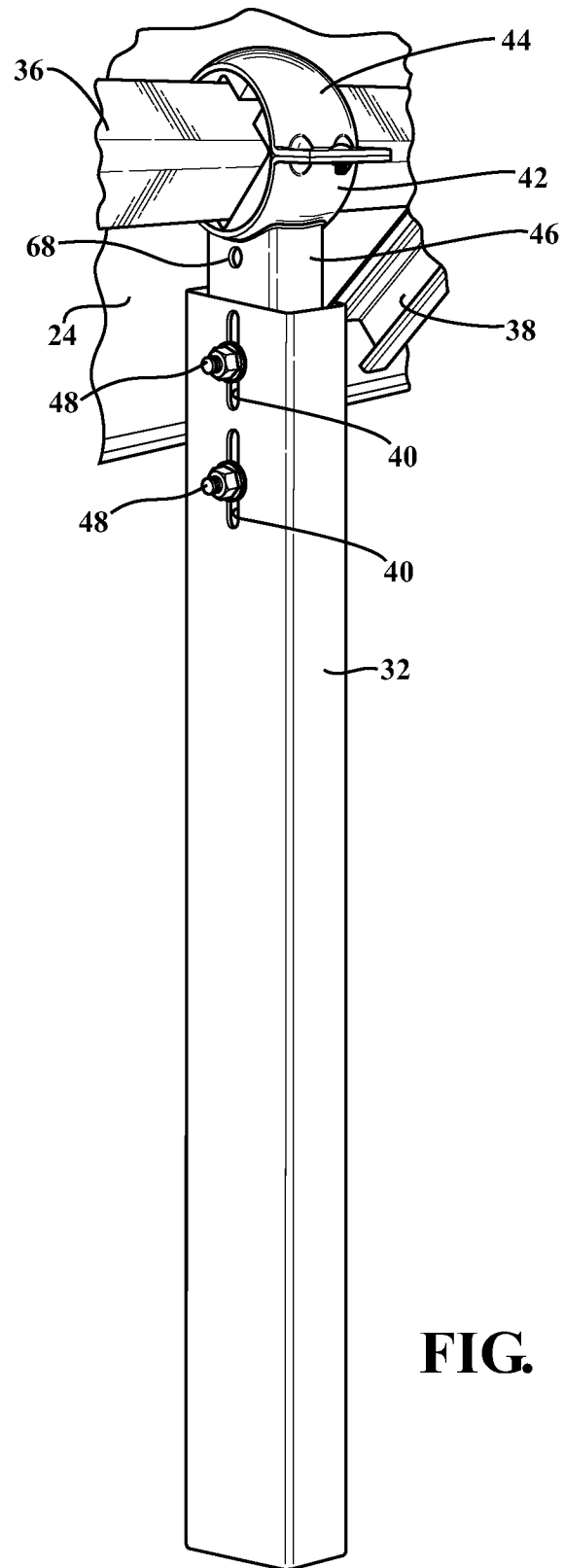
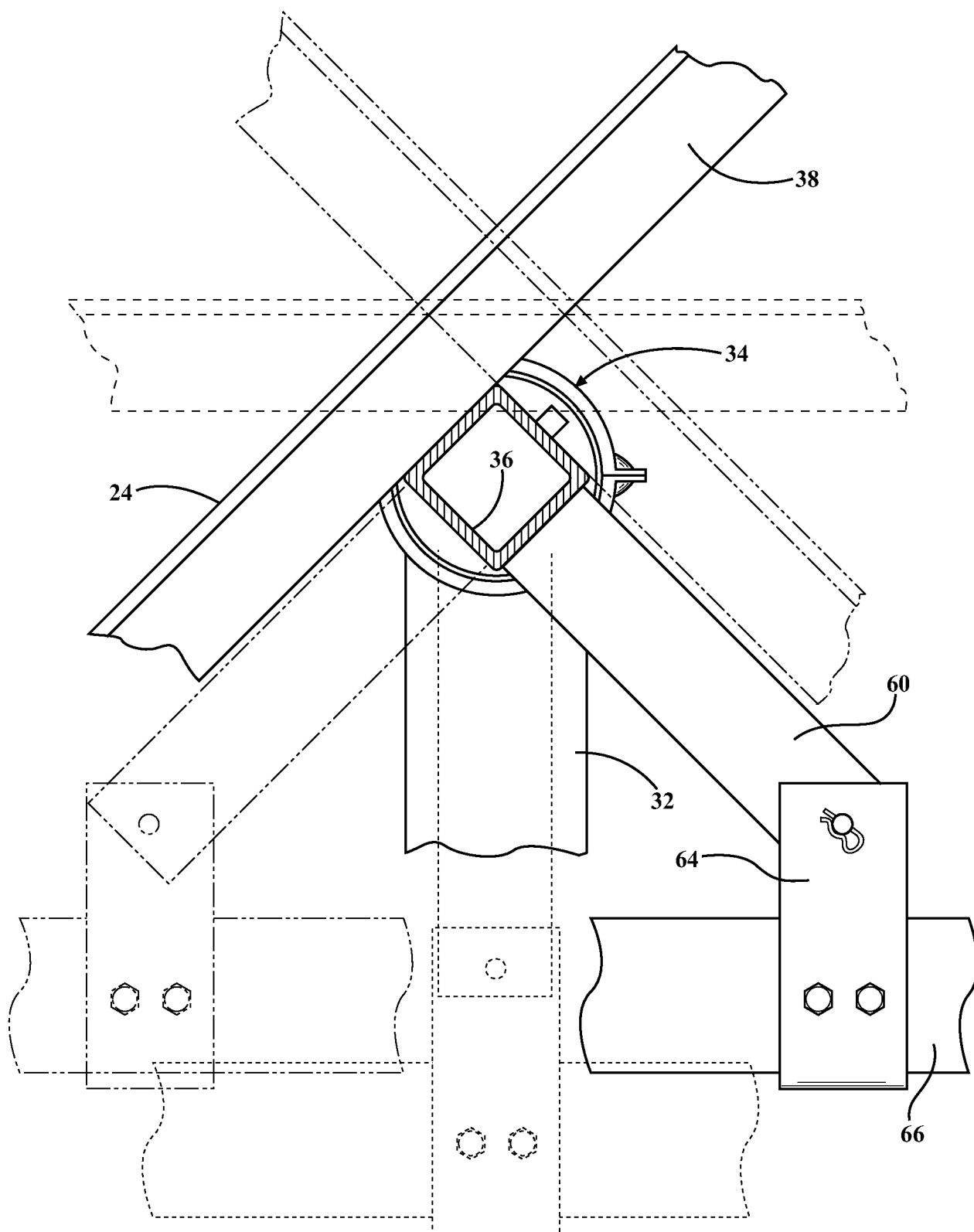


FIG. 6

**FIG. 7**

**FIG. 8**

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F24J 2/38; F16M 11/10; F16M 11/04 (2013.01)

USPC - 126/606; 248/185.1; 248/178.1

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC (8) - F24J 2/38; F16M 11/10; F16M 11/04 (2013.01)

USPC - 126/606; 248/185.1; 248/178.1

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

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

MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); ProQuest; IEEE; Google/Google Scholar;
KEYWORDS: Solar, Sun*1, PV, Photovoltaic*1, Cell*1, Panel*1, Collect*3, Track*3, Actuator*1, Control*4, Drive*, Motor***C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/0308091 A1 (CORIO, R) December 18, 2008; abstract; figures 1-2; paragraphs [0024, 0026, 0029, 0059]	1-15
A	US 2011/0121144 A1 (PASTOR, V et al.) May 26, 2011; entire document	1-15
A	US 2010/0101632 A1 (KATS, M et al.) April 29, 2010; entire document	1-15

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 December 2013 (10.12.2013)

Date of mailing of the international search report

20 DEC 2013

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-3201

Authorized officer:

Shane Thomas

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774